“CHANNELING THE GREEN DEAL FOR VENICE”
Action n. 2019-IT-TM-0096-S
CEF Connecting Europe Facility

MALAMOCCO
OPTIMIZATION OF CHANNEL LAYOUT
FULL-MISSION SIMULATIONS

AROUND WATER
di Andrea Zamariolo, Ph.D. Geol.

Activity		Phase 3
Task		Optimization of MM Channel layout
Authors		Mr. Jens Tommerup, Captain/Simulator Instructor, FORCE Technology Mr. Bugge T. Jensen, Senior Project Manager, FORCE Technology Miss Clara Giarrusso, Maritime Specialist, FORCE Technology
Dissemination Level		Final not for dissemination
Status		Final
Due date		
Document Date		18/04/2023
Version Number		7.0

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CHANNELING THE GREEN DEAL FOR VENICE is co-funded by the European Commission, Connecting Europe Facility (CEF) programme under grant agreement No. INEA/CEF/TRAN/M2019/2112366 - Action No: 2019-IT-TM-0096-S. The information and views set out in this document are those of the author(s) and do not necessarily reflect the official opinion of the European Union.

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APPENDICES

1. EXECUTIVE SUMMARY

This report comprises a qualitative full-mission ship simulator study for evaluating the optimized layout of the Malamocco-Marghera Channel in Port of Venice, Italy, tested during the full-mission simulations conducted in November 2022 and in March 2023.

Objectives

The purpose of the study is to identify the best solutions for infrastructure, safe navigation and environment protection. For this reason, a combination of scenarios must be tested on a full-mission ship simulator.
Hence it was agreed to conduct the simulations with the following objectives:

- Identify how the changes in the infrastructure of the channel optimized the safety of the navigation.
- Evaluate the safety limits and how those must be handled when a ship enters the channel.
- Evaluate in which areas of the optimized layout of the channel and for which of the design ship types (cruise, container, bulk, tanker, roro), it is possible to reduce the speed, but maintain a safe navigation.

The simulations were conducted at FORCE Technology's DANSIM facilities in Denmark with the use of two full-mission simulation bridges named A and D from where the captains/pilots maneuvered the ships and a 3'rd bridge named H where the tug master maneuvered the tug.

Scenarios for optimized layout

Scenarios 1 and 2 show the layouts of the preliminary optimized channel based on full mission simulations conducted in May 2022 in the existing channel, as well as results from fast-time simulations conducted in different channel layouts (July/August 2022). The proposed channel changes are illustrated below in Figure 1-1, Figure 1-2, and Figure 1-3.
In fact, during these simulations, the navigation shows some issues with large vessels in extreme weather conditions, as the ships showed the tendency to set and drift, due to various factors such

as the intensity of the wind, currents and bank effects. Therefore, the relatively narrow dimension of the canal makes the navigation difficult or impossible for large ships in case of bad weather conditions, hence the decision to dredge some specific areas of the canal where this problem was more recurrent was done. These improvements of the channels will increase the dimension of the ships allowed to call the port of Venice and will allow to increase the operational limits.

Scenario 3 was implemented and tested during the full mission simulations conducted in March 2023 and comprises a general improvement of the channel based on the past studies conducted on scenarios 1 and 2, and involves a general widening of the actual channel, straightening some other parts and increasing the water depth in the entire channel, in order to improve the viability and the safety of the entire channel. Scenario 3 represents the final version of the optimized layout of the channel, the combination of scenarios 1 and 2, and as a consequence the best possible improvement.

Regarding the shape of the banks, there is basically very little difference between the actual bathymetry of the channel and the suggested new layout. In fact, the slope of the banks along the channel varies of few degrees (approx. 5 degrees) in both cases, as it is specified later below in section 2.2, about the bank slope.

Scenario 1

Figure 1-1 shows the first problematic area of the channel, north of San Leonardo bend. The scope is to widen the channel by dredging the area highlighted in red, from 60 m (current width of the channel) to 90 m.

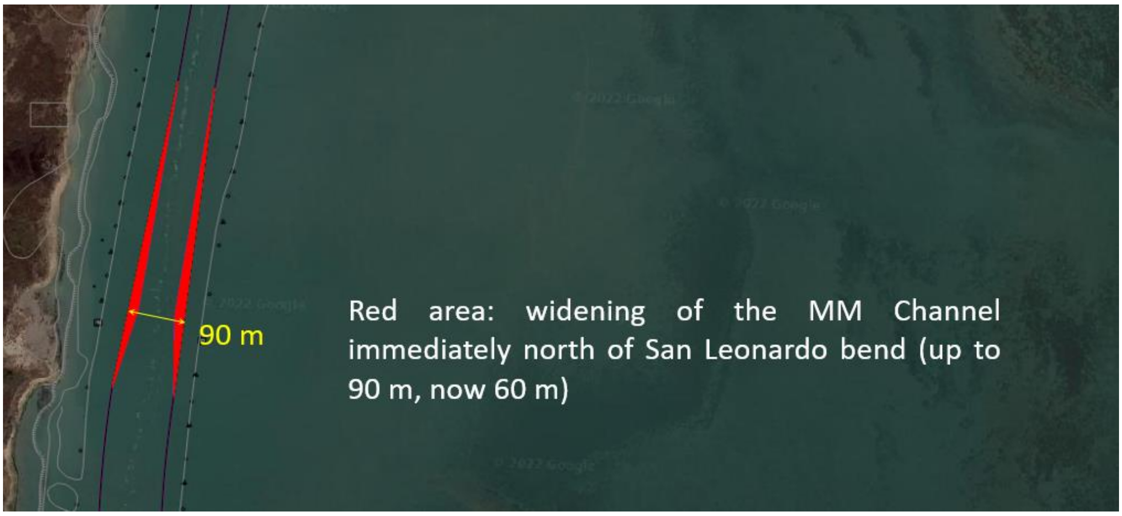


Figure 1-1 Area of dredging north of San Leonardo.

Then, Figure 1-2 shows the second problematic area of the channel, the bend of the channel at 2 NM south of Fusina basin. In this case, the rectification and widening of this part of the channel, consist of dredging a further 50 m in the width at the largest section, for a total width of the channel of 110 m.

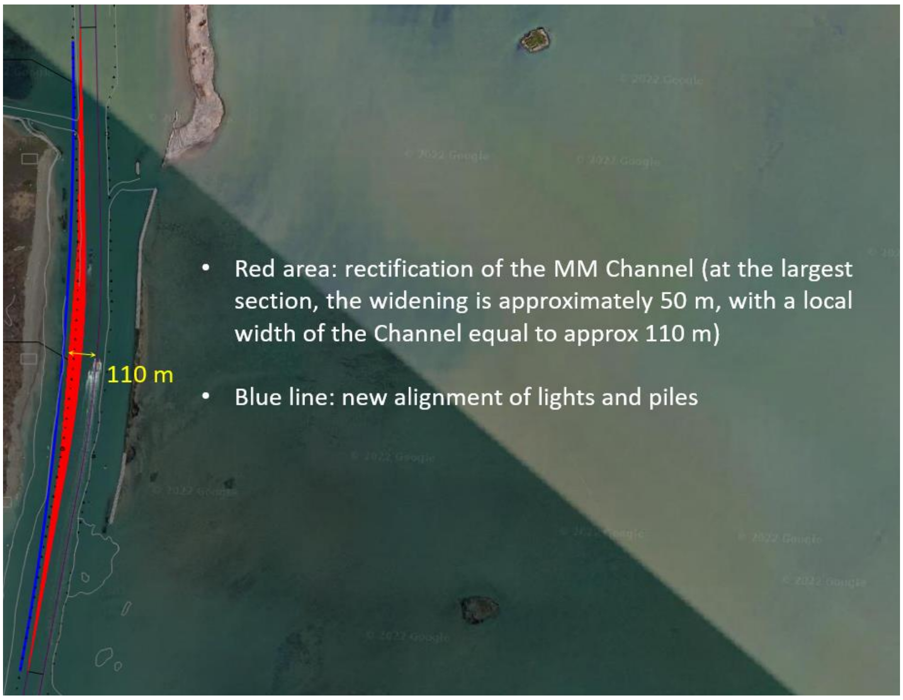


Figure 1-2 Area to dredge, about 2 NM south of Fusina.

Scenario 2

Moreover, the changes described in Figures 1-1 and 1-2 are merged with the changes showed in Figures 1-3, becoming part of the new scenario. In this case, the yellow areas in the figure show other improvements of the channel which mostly consist of widening by dredging these areas.

Figure 1-3 Improved areas in the channel north of Fusina.

The study was carried out at FORCE Technology, Lyngby, Denmark (from 2022-10-10 to 2022-10-14) using two coupled simulators, one for the cruise vessel, 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, and the Coast Guard. FORCE Technology captains also participated as instructors/captains.

For the simulation study a new database of Port of Venice with the new optimized layout of the channel, including new bathymetry, moved marks, and banks based on data from DHI srl was produced and used.

The metocean conditions used for the simulations are based on the simulations conducted in May 2022 with a new ship and speed parameter as an important element to investigate.

Scenario 3

The scenario analyzed during the full-mission simulations is illustrated in the following Figure 1-4 and Figure 1-5. This third version of the optimized layout of the channel is based on scenarios 1 and 2 but with more improvements according to the results of the simulations conducted on these last two scenarios.

The areas of the channel that characterize the scenario 3 of the channel are highlighted in yellow and red. The changes involve widening, smoothing, and rectifying some parts of the MM channel, as well as dredging intervention and general deepening of the entire channel.

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

Figure 1-4 Optimized layout, version 2, improvements of the actual bathymetry: south part of the channel.

Figure 1-5 Optimized layout, version 2, improvements of the actual bathymetry: north part of the channel.

1.1. Conclusions

The following conclusions are based on the conducted runs in the optimized layout of the MM channel:

In Scenario 1, navigation within the channel appears to be improved for bulk carriers and container vessels, allowing speed to be reduced to 7/8 knots for wind speeds up to 15/20 knots; however, the actual wind limits of 15 m/s (30 knots) should be maintained, while cruise ships may have increased wind limits by 10 m/s (20 knots). All vessels can sail safely in wind speeds up to 10 m/s, using a tugboat to assist if needed. However, for simulated cruise ships up to 300 m LOA with traditional propulsion, this improvement is insufficient to increase safety margins due to critical areas in the northern part of the channel.

In Scenario 2, navigation is improved for all ship designs, although maneuvering remains challenging, but in general this scenario increases the safety margins.

Scenario 3, the optimized final layout of the channel, overall represents the best possible scenario. In fact, it includes not only all the improvements seen in Scenario 1 and 2, but also further improvements deriving from a careful study of the results extrapolated after the simulations carried out on the two scenarios mentioned above.

Indeed, not only the navigation does appear to have generally improved, but according to the actual safety limitations, it appears to be safer under these conditions than under the conditions observed in Scenario 1 and 2 separately.

2. SUMMARY AND OBSERVATIONS

2.1. Summary

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.

In total 26 simulation runs were completed for Scenario 1 and 2, while 10 simulations were conducted in Scenario 3.

Only the conventional rudder/propeller driven cruise ship was tested, as the simulations in May 2022 showed that the POD driven cruise ships have better maneuverability.

Regarding Scenario 1 and 2, both the bulk and container ships were tested in two loading conditions: 11 m and 9 m draft to investigate more wind effect and less bank effect from the lighter loaded version:

- 11 runs with the conventional rudder-propeller driven cruise ship.
- 5 runs with the container ship 11 m draft.
- 4 runs with the container ship 9.5 m draft.
- 4 runs with bulk carrier 11 m draft.
- 2 runs with bulk carrier 9 m draft.

Regarding scenario 3, several ships were tested simulating arrivals and departures maneuvers from some of the quays. Two of those ships are also characterized by high draft, a container of 11.4 m and a bulk carrier of 10.7 m. The aim is to investigate the viability within the channel of bigger vessels compared to those allowed in the actual layout of the channel. More details about the list of ship used and the list of simulations conducted are illustrated respectively in Chapter 5 and Section 7.1.

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 container/bulk carrier.

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 safety of the conducted run. These comments together with the replays formed the basis for the conclusions and recommendations.

2.2. Observations

General

The optimized layout is a clear improvement for the navigation as the narrowing of the channel north of the San Leonardo bend is now smooth, and the turn happens gradually.

Also, the straightening of the channel 2 NM south of Fusina is a clear improvement, as only a small change of heading is needed during passage, making it is easier to stay in the center of the channel.

The suggested improvements in the basins north of Fusina improve safety but could be even better with as soft as possible narrowing's after the turning basins (intersection between channel and turning basin). In scenario 3, this improvement was implemented, making the navigation even more safe, as described in Chapter 1, under the section "Scenario optimized layout".

Reduced visibility did not influence the maneuvering significantly.

Bank slope

In the existing channel, banks are helping the pilots to stay in the center of the channel.
In the new suggested optimized layout of the channel, the bank effect is reduced due to the widening of the channel. However, the difference between the new suggested bathymetry and the existing one, is very small, since in both cases, the slopes are very gentle and vary by approximately 5 degrees.
Even in these conditions, the pilots managed to navigate safely within the channel.

Container ship and bulk carrier with medium-high draft (9 to 11 m)

The ship types were tested up to 15 m/s (30 knots), and especially with wind on stern quarter, it was difficult to control the ships when the speed was below 8 knots.

To handle the vessels in high winds (above 10 m/s - 20 knots) it was necessary to increase the speed to above 8 knots to maintain control.

Cruise ship

Only the conventional rudder/propeller driven cruise ship was tested, as the simulations in May 2022 showed that the POD driven cruise ships have better maneuverability.
In Scenario 1, the cruise ship was handled safely at 6 knots in up to 10 m/s - 20 knots wind approaching the Fusina terminal. After the Fusina terminal, the safety margin is on the limit, while as above, in Scenario 2 and 3 the safety margin is increased, and it is largely safe to navigate in winds up to 10 m/s or more.

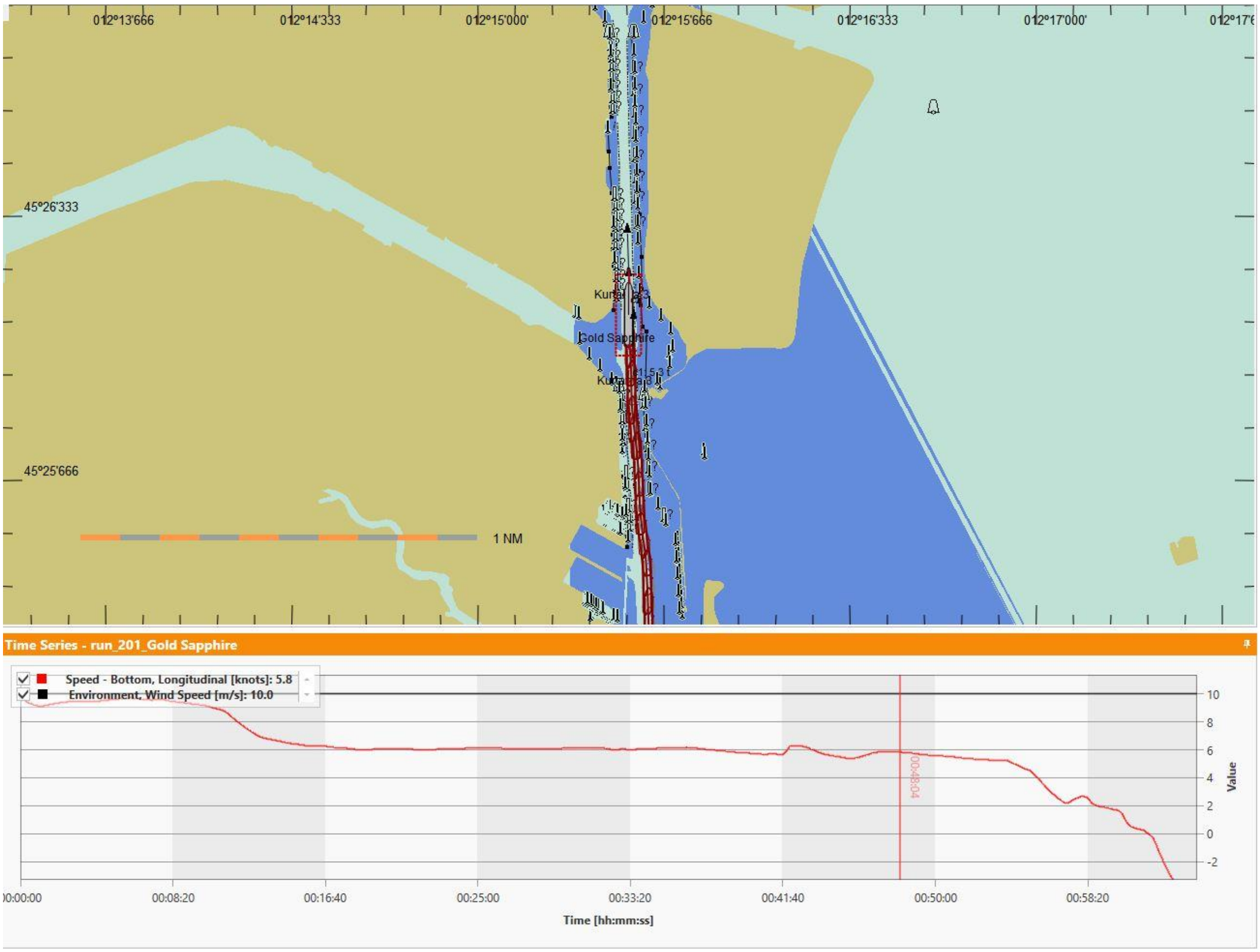


Figure 2-2-1 Run 201. Cruise ship, wind speed 10 m/s. The speed of the ship slowly decreases during the navigation approaching Fusina and right after it.

3. METHOD

3.1. General

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

The method used consists of the following:

- Update the database of Port of Venice with optimized layout of the Malamocco-Marghera Channel
- Develop list of runs.
- Conduct simulations and adapt list of runs continually.
- Debriefing.
- Evaluation of runs.
- Report outcome.

The following participated in the simulations conducted on scenarios 1 and 2:

- Capt Matteo La Sorte, Venice Coast Guard
- Capt. Paolo Amato, Venice Coast Guard
- Mr Gino Calderan, Tugboat (only till Tuesday 11)
- Capt Massimiliano Gambato, Tugboat Master
- Pilot Salvatori Papandrea, Port of Venice.
- Mr Paolo Menegazzo, North Adricatic Sea Port Authority
- Capt. Thue Rabjerg, FORCE Technology
- Capt. Jens Tommerup, FORCE Technology
- Senior PM Niels Arndal, FORCE Technology
- Senior PM Bugge T Jensen, FORCE Technology

The following participated in the simulations conducted on scenario 3:

- Daniele Ferrari, Venice Coast Guard
- Luigi Mennella, Pilot
- Paolo Fabris, Pilot
- Emanuele Banchieri, Panfido Tug Company
- Gianpaolo Guarinoni, Panfido Tug Company
- Federico Zoccarato, Port Authority
- Paolo Menegazzo, Port Authority
- Vincenzo Incandela, Cetena
- Daniele Milazzo, Cetena
- Carl Thue Rabjerg, Captain, FORCE Technology
- Guillermo Gomez Garay, Captain, FORCE Technology
- Niels Arndal, Senior PM, FORCE Technology
- Clara Giarrusso, Maritime Specialist, FORCE Technology

3.2. Simulations

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


Figure 3-1 Picture from the own ship bridge A


Figure 3-2 Picture from the tug bridge H

3.3. Debriefing

Short debriefing sessions were 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.

3.4. 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 information (run number, name, bridge)
- Realism
- Safety
- Navigation
- Communication
- General remarks

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

3.5. 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 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 SimFlex4 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

4. 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 are the green lights and red lights along the channel
- Faro fanale simbolo and Mede are pier lighthouses
- Palo di ancoraggio are the wooden poles for anchoring
- Bathymetry
- Waves
- Current
- Tide
- Visual database

4.1. 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.

- It was decided to simulate maximum ebb and flood tides without any time variation.
- It was decided to specify tide as a fixed value relative to MSL. The tide did not change during the simulation.

4.2. Bathymetry

The bathymetry of the optimized layout of the channel was delivered by DHI srl.

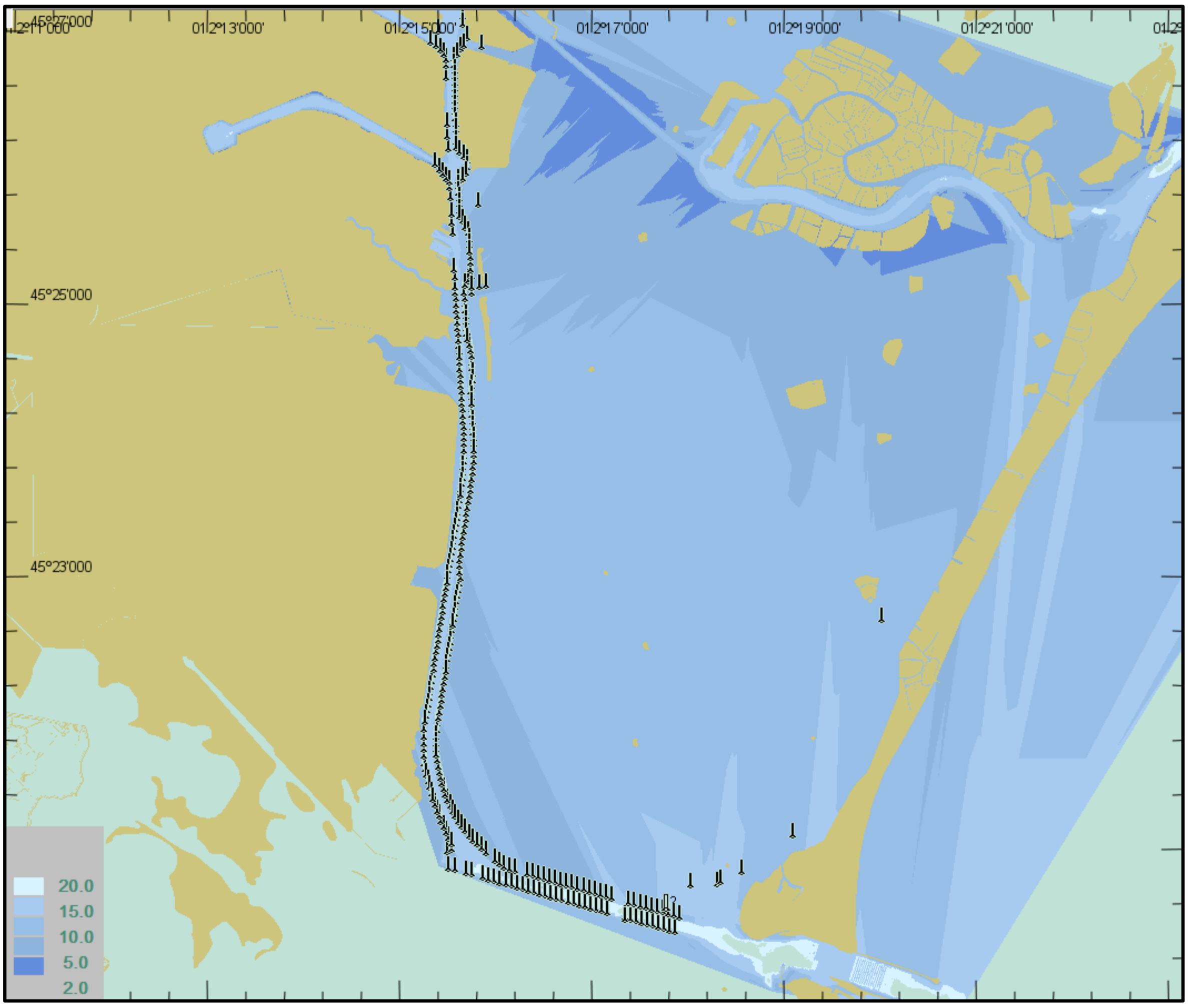


Figure 4-4-1 Bathymetry

4.3. Wind

The magnitude of the wind was chosen based on findings from simulations in May 2022 and lessons learned during the simulations.

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.

4.4. Current

Currents were delivered by DHI srl.

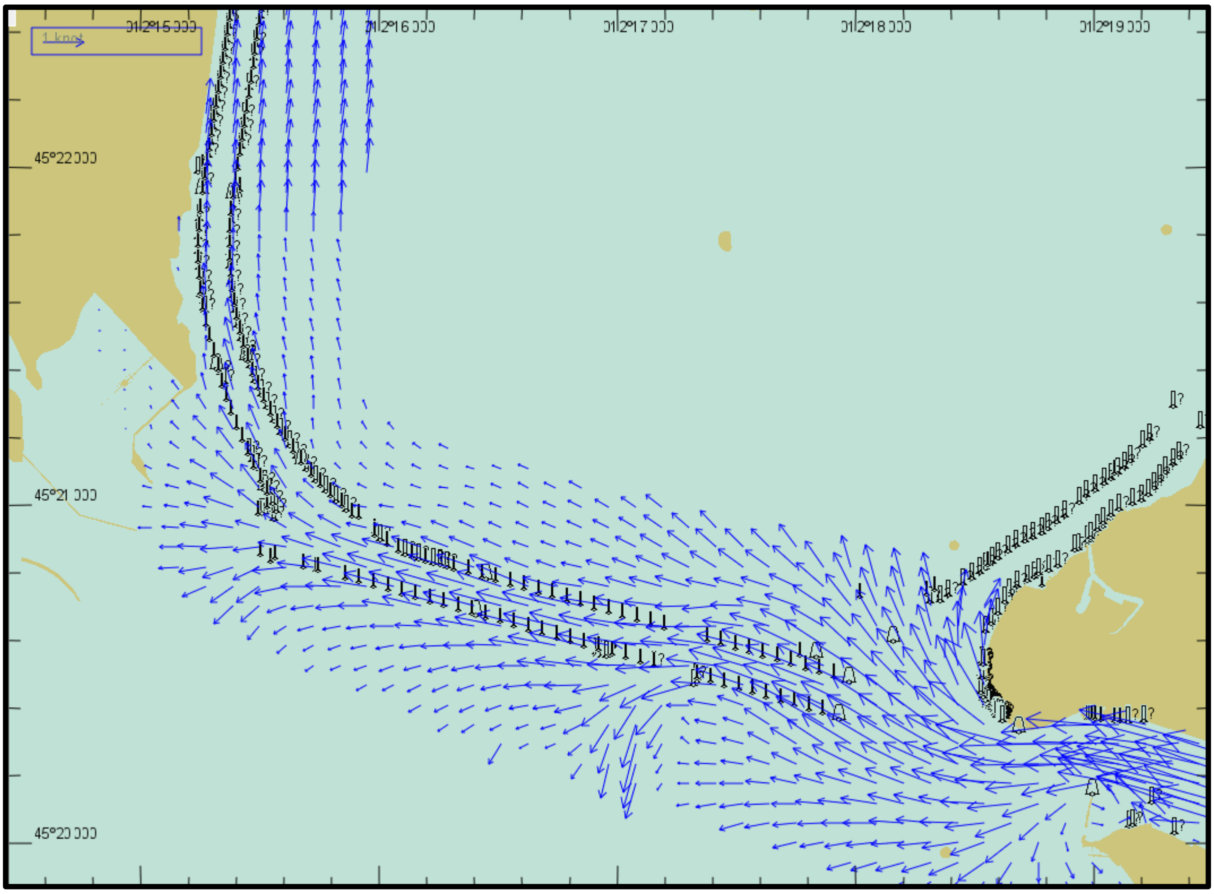


Figure 4-1 North-going current

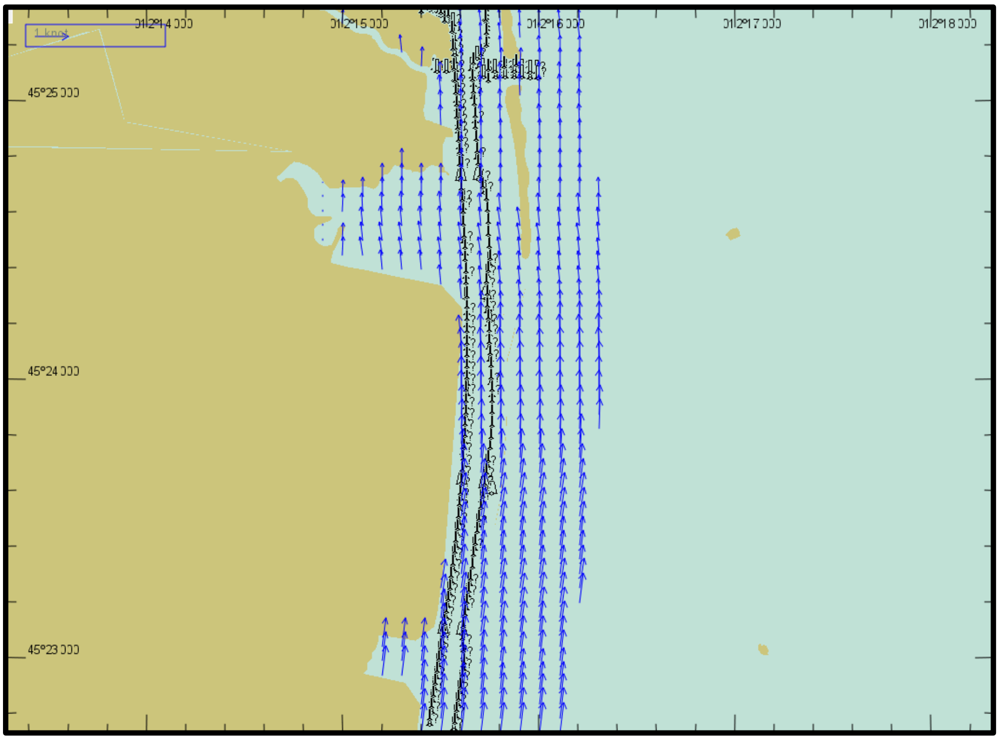


Figure 4-2 North-going current

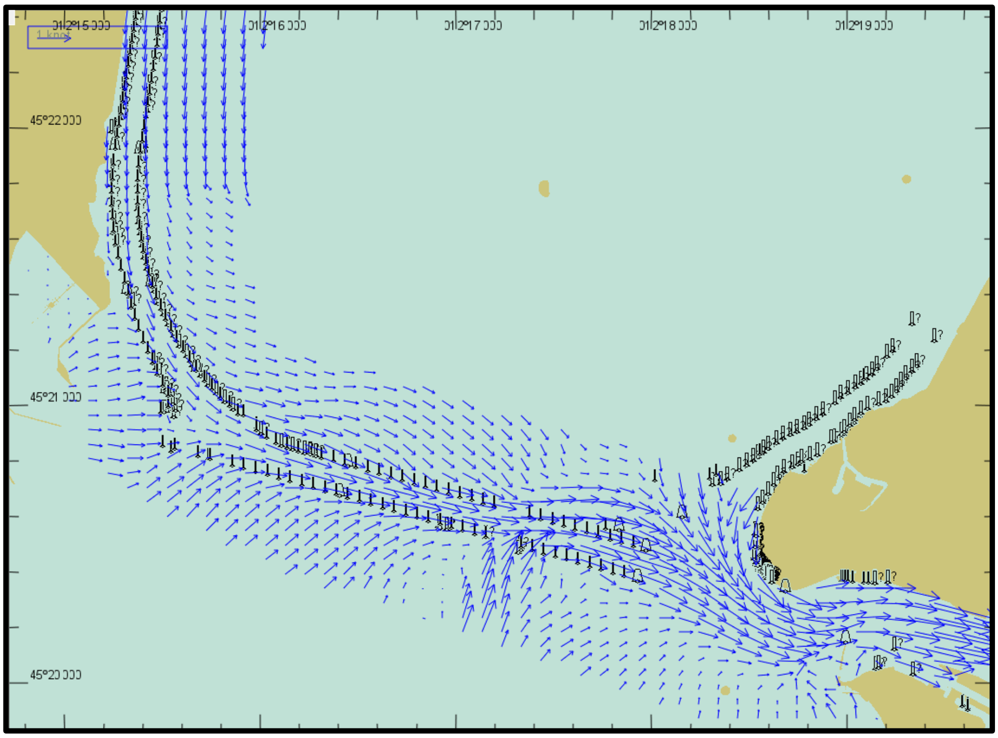


Figure 4-3 South-going current

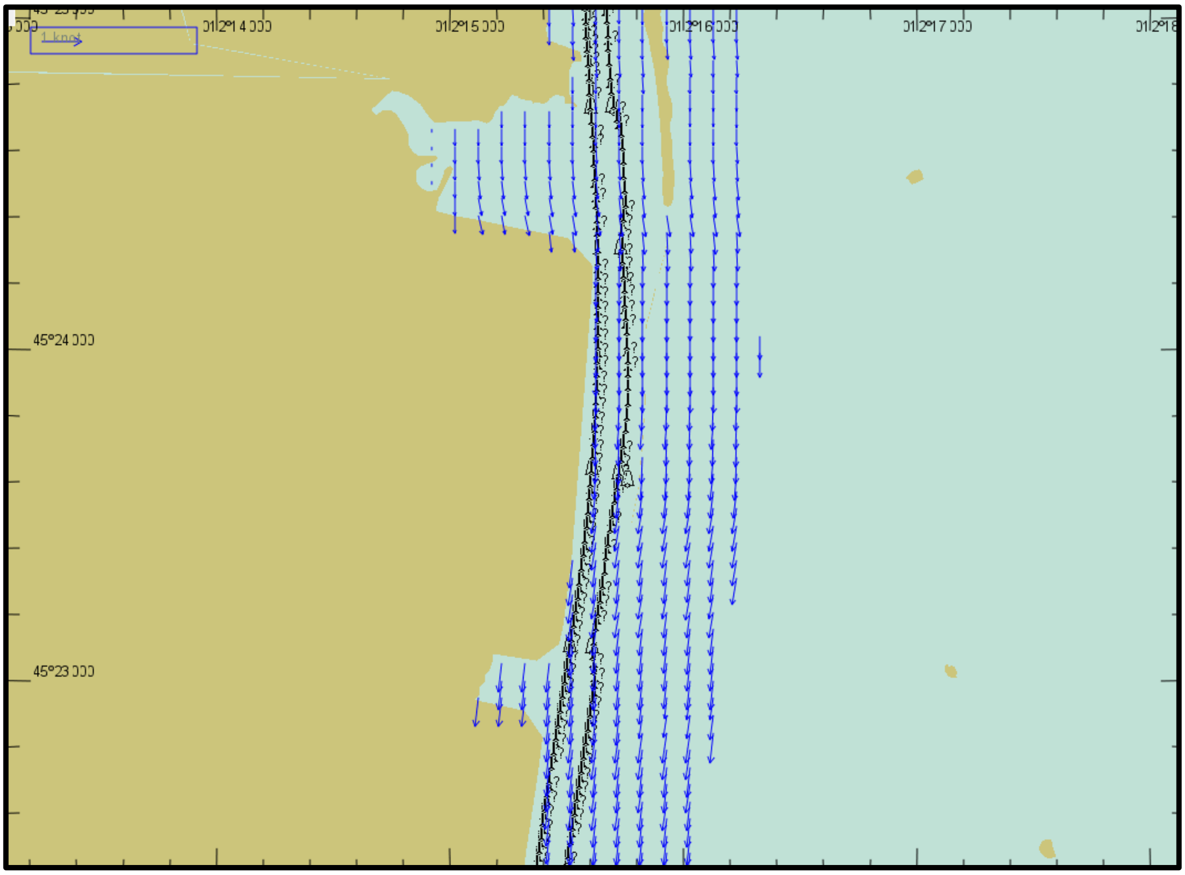


Figure 4-4 South-going current

4.5. Tide

Tide was set to a specific constant level when relevant

4.6. Waves

The channel is exposed to waves, but the waves are not significant as they are very low. For the simulations, waves were 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 4-5 below for an example of a wave map (15 m/s wind).

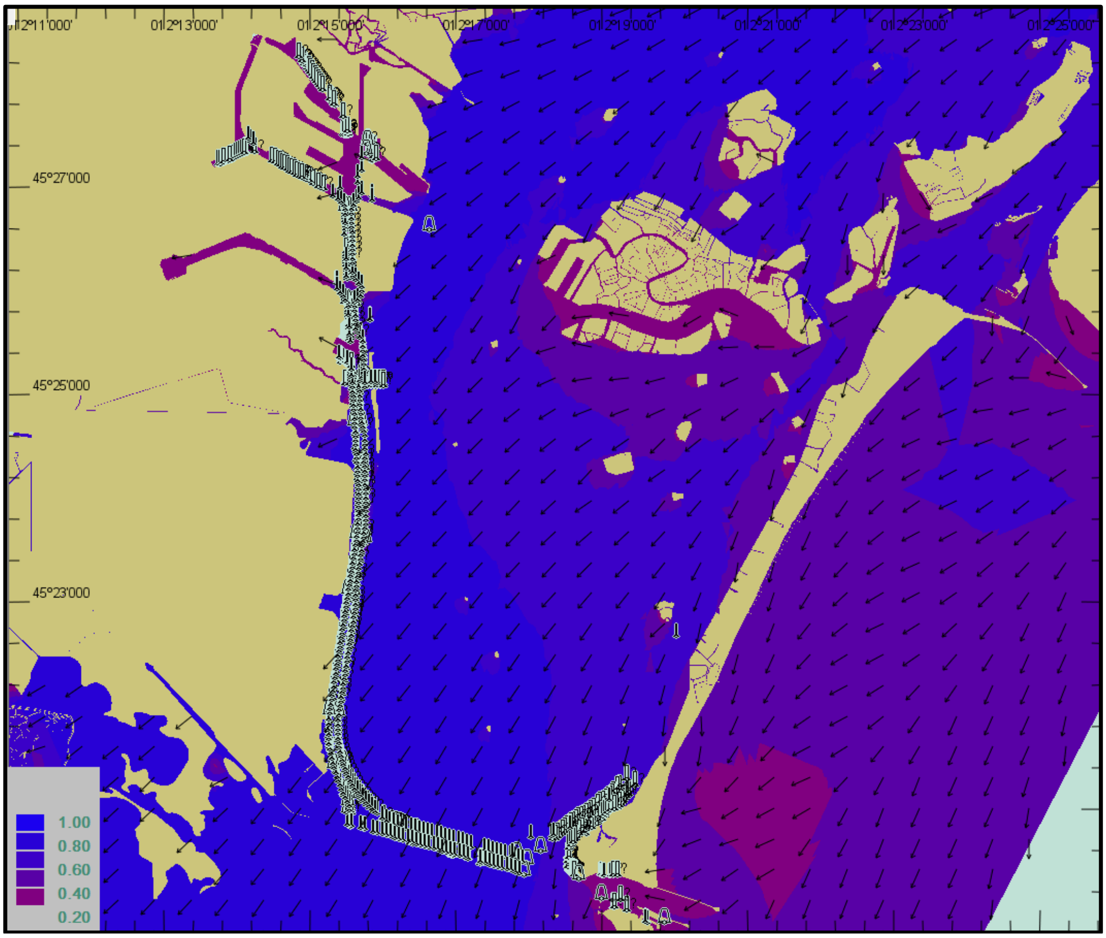


Figure 4-5 Example of a wave map (15 m/s wind)

The significant wave height is defined as the average height of the highest one-third in a wave spectrum. However, 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.

4.7. Visual

The visual part of the database is based on Google and photos received. See example in Figure 4-6 below.

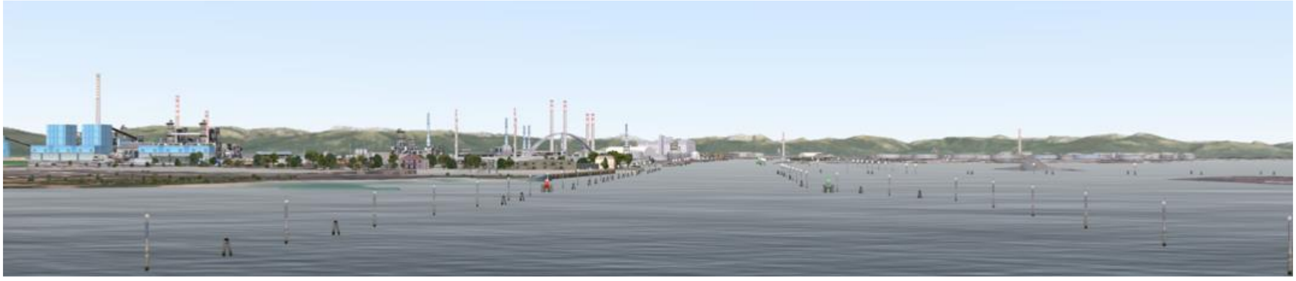


Figure 4-6 Example of visual database

5. SHIPS

The ships used in the simulations were six degree-of-freedom mathematical ship models of real ships. The ships used for these simulations are listed in the following tables (Table 5-1 and Table 5-2), while a full description of the ships' mathematical models can be found in Appendix B.

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	
3483	Coraline	Container Ship	2680 TEU	l	215.6	206.2	32.2	9.5	9.5	39740	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	
3324	Kurtama 3	Tug VSP	72 t BP		36.0	34.0	12.5	5.7	5.7	855	2VS	0	0	0	
3312	Molly	Bulker	2680 TEU		218.0	200.0	32.2	9.0	9.0	43470	1F	1	1	1	
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 5-1 Ship used in the simulations.

Ship Code	FT Ship Number	Ship Name	Ship Type	Displacement (T)	Gross Tonnage (GT)	LOA (m)	BEAM (m)	DRAFT (m)	PROP	BOW THR	STERN THR
Ship 2	3644	*Gold Sapphire*	CRUISE	50453	n. a.	294	32.2	8.3	2	3	3
Ship 4	3545	*MSC Fantasia*	CRUISE	63326	137936	333	37.9	8.4	2	3	2
Ship 6	3754	*Indigo Moon*	CONTAINER	59860	n. a.	280	40	9.5	1	1	2
Ship 9	3676	*Key Calla*	BULK	83353	44428	229	32.2	9.3	1	0	0
Ship 12	3763	Avior	BULK	99934	n.a.	285	43	10.7	1	0	0
Ship 13	3725	Atria	CONTAINER	109476	n.a.	345	43	11.4	1	1	2
Ship 14	3041	Baffin	TANKER	27251	n.a.	170	23.11	9.13	1	1	1

Table 5-2 Ship used during the full mission simulations in the optimized Layout of the channel.

Furthermore, tugs used were one manned OS 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 OS tug was maneuvered by a local Port of Venice tug master.

Tugs available for these simulations were:

- Manned OS tug of 72 t bollard pull.
- Vector tugs of 72 t bollard pull.

6. SIMULATION DESCRIPTION

During the full-mission simulations, the FORCE Technology bridges A and D (360 degrees outlook) were used as 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 bridges A and D, 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 ship’s 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 illustrated in Appendix A.

Figure 6-6-1 Simulator bridge A set-up, cruise ship bridge.

Figure 6-6-2 Simulator bridge H set-up, tug bridge.

7. DOCUMENTATION OF SIMULATIONS

7.1. List of simulations runs

The lists of conducted runs were adapted during simulations to confirm and explore different environmental settings on and above existing environmental limits, while at the same time keeping navigational speed as low as possible to minimize erosion. The simulations conducted are illustrated in Table 7-1 and Table 7-2.

The following list of runs illustrates the environmental conditions, the number of runs (divided per day), the areas of the channel in which the ships were sailing, the duration of the navigation, bridges, ships and tugs used during the days of the full-mission simulations.

Run number	Day	Area	Ship FMB1	Ship PTB1	Ship Tug / Ownship or Vector	Senario	Sailing Direction	Tide	Visibilty		Wind speed	Wind dir	Current Speed	Current dir	Wave height	Wave dir from	Wave period	Max speed
									Type	Distance	m/s		kn		m		s	kn
101		MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP		Arrival	inbound				5	NE	0.5	S	0.5	NE	3.9	11
102		MM	Cruise Vsl 3645	tug1 VSP 3324 / 72 tBP	3324 VSP Vector	Arrival	inbound				5	NE	0.5	S	0.5	NE	3.9	11
103	Monday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Infinity	-	5	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9
104	Monday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Rain	3 nm	7.5	NE	Max Ebb Tide	180	0.3	NE	3.7	8/9
105	Monday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Rain	1 nm	10	ENE	Max Flood Tide	360	0.3	NE	3.7	

Run number	Day	Area	Ship FMB1	Ship PTB1	Ship Tug	Senario	Sailing Direction	Tide	Visibilty		Wind speed	Wind dir	Current Speed	Current dir	Wave height	Wave dir	Wave period	Max speed
									Type	Distance	m/s		kn		m		s	kn
201	Tuesday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Infinity		10	E	Max Ebb Tide	180	0.3	NE	3.7	
202	Tuesday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		outbound	Tide map	Infinity	-	7.5	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9
203	Tuesday	MM	Bulk Carrier 3481	tug1 VSP 3324 / 72 tBP			inbound	Tide map +0.20 m	Infinity		5	NE	0.5	S	0.5	NE	3.9	
204	Tuesday	MM	Bulk Carrier 3481	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map +0.20 m	Infinity	-	7.5	NNE	Max Ebb Tide	180	0.3	NE	3.7	
205	Tuesday	MM	Bulk Carrier 3481	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map +0.20 m	Infinity	-	7.5	NNE	Max Ebb Tide	180	0.3	NE	3.7	
206	Tuesday	MM	Bulk Carrier 3481	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map +0.20 m	Rain	3 nm	10	NE	Max Flood Tide	360	0.3	NE	3.7	
207	Tuesday	MM	Bulk Carrier 3481	tug1 VSP 3324 / 72 tBP			inbound	Tide map +0.20 m	Infinity		5	NE	0.5	S	0.5	NE	3.9	
208	Tuesday	MM	Bulk Carrier 3481	tug1 VSP 3324 / 72 tBP			inbound	Tide map +0.20 m	Infinity		5	NE	0.5	S	0.5	NE	3.9	

Run number	Day	Area	Ship FMB1	Ship PTB1	Ship Tug	Senario	Sailing Direction	Tide	Visibilty		Wind speed	Wind dir	Current Speed	Current dir	Wave height	Wave dir	Wave period	Max speed
301	Wedensday	MM	Container vsl 3601	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map	Infinity	-	7.5	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9
302	Wedensday	MM	Container vsl 3601	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map	Rain	3 nm	7.5	NE	Max Ebb Tide	180	0.3	NE	3.7	6
303	Wedensday	MM	Container vsl 3601	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map	Rain	2 nm	10	E	Max Ebb Tide	180	0.3	NE	3.7	6
304	Wedensday	MM	Container vsl 3483	tug1 VSP 3324 / 72 tBP	tug2 - Optional		outbound	Tide map	Infinity	-	10	E	Max Ebb Tide	180	0.3	NE	3.7	6
305	Wedensday	MM	Container vsl 3483	tug1 VSP 3324 / 72 tBP	tug2 - Optional		outbound	Tide map	Infinity	-	15	E	Max Ebb Tide	180	0.3	NE	3.7	6
306	Wedensday	MM	Container vsl 3483	tug1 VSP 3324 / 72 tBP	tug2 - Optional		outbound	Tide map	Infinity	-	15	E	Max Ebb Tide	180	0.3	NE	3.7	6
307	Wedensday	MM	Container vsl 3483	tug1 VSP 3324 / 72 tBP	tug2 - Optional	Emergency	outbound	Tide map	Infinity	-	5	NE	Max Ebb Tide	180	0.3	NE	3.7	6

Run number	Day	Area	Ship FMB1	Ship PTB1	Ship Tug	Senario	Sailing Direction	Tide	Visibilty		Wind speed	Wind dir	Current Speed	Current dir	Wave height	Wave dir	Wave period	Max speed
401	Thursday	MM	Bulk Carrier 3312	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map	Infinity	-	10	NE	Max Flood Tide	360	0.3	NE	3.7	
402	Thursday	MM	Bulk Carrier 3481	tug1 VSP 3324 / 72 tBP	tug2 - Optional		inbound	Tide map	Infinity	-	15	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9
403	Thursday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Infinity		10	E	Max Ebb Tide	180	0.3	NE	3.7	
404	Thursday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Infinity		10	NE	Max Ebb Tide	180	0.3	NE	3.7	
405	Thursday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Infinity		10	NE	Max Ebb Tide	180	0.3	NE	3.7	
406	Thursday	MM	Cruise Vsl 3644	tug1 VSP 3324 / 72 tBP	3324 VSP Vector		inbound	Tide map	Infinity		10	NE	Max Ebb Tide	180	0.3	NE	3.7	

Table 7-1 List of executed runs for Scenario 1 and 2.

Run #	Day	Bridge / Pilot	Layout (current / current+light / future) Nel futuro l'illuminazione è inclusa e va mantenuta una velocità max di 8 kn da dopo il curvone	Ship Code	FT Ship Number	Type	Tugs Config.	Tugs Bridge (Tug Master)	Vector Tug 1	Vector Tug 2	Route	Estimated time for simulation	Tide	Fog / Rain	Visibility (fog)	Wind speed	Wind dir	Night
19	3,4	D	F	Ship 12	3763	BULK	2 from Fusina	-	70	70	MALAMOCCO / B0018 Piemonte	120	0	-	-	10	NE	-
20	4	D	F	Ship 13	3725	CONTAINER	2	-	70	70	MALAMOCCO / LIGURIA (End of simulation 150 m after basin 3)	120	0	-	-	10	NE	-
21	4	D	F	Ship 13	3725	CONTAINER	2	70	70	-	B022 / 2 miles after FUSINA	40	0	-	-	10	NE	-
22	3	D	F	Ship 6	3754	CONTAINER	2	-	70	70	before CURVONE / LIGURIA (End of simulation 150 m after basin 3)	90	0	-	-	15	NE	-
23	2	D	F	Ship 2	3644	CRUISE	2 from Fusina	-	70	70	before CURVONE / BOLZANO (excluding berthing)	90	0	-	-	10	E	-
24	2	D	F	Ship 2	3644	CRUISE	2 from Fusina	-	70	70	2 miles before FUSINA / 2 miles after FUSINA	40	0	-	-	10	NE	-
25	2	D	F	Ship 2	3644	CRUISE	2 from Fusina	-	70	70	2 miles after FUSINA / 2 miles before FUSINA	40	0	-	-	10	NE	-
26	3	D	F	Ship 4	3545	CRUISE	2 from Fusina	-	70	70	MALAMOCCO / BOLZANO	120	0	-	-	9	NE	-
27	3	D	F	Ship 4	3545	CRUISE	2 from Fusina	-	70	70	BOLZANO / 2 miles after FUSINA	60	0	-	-	9	NE	-
28	4	A	F	Ship 14	3041	TANKER	2	70	70	-	2 miles before Fusina/Canale industriale Sud	60	0	-	-	5	NE	Night
29	4	A	F	Ship 9	3676	BULK	2	70	70	-	A0004 (PORTSIDE) / BACINO EVOLUZIONE 3	30	0	-	-	5	NE	Night

Table 7-2 Run list executed for Scenario 3.

7.2. Geographical plots of maneuvers

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

8. 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]

9. REFERENCES

[1] IALA Guidelines

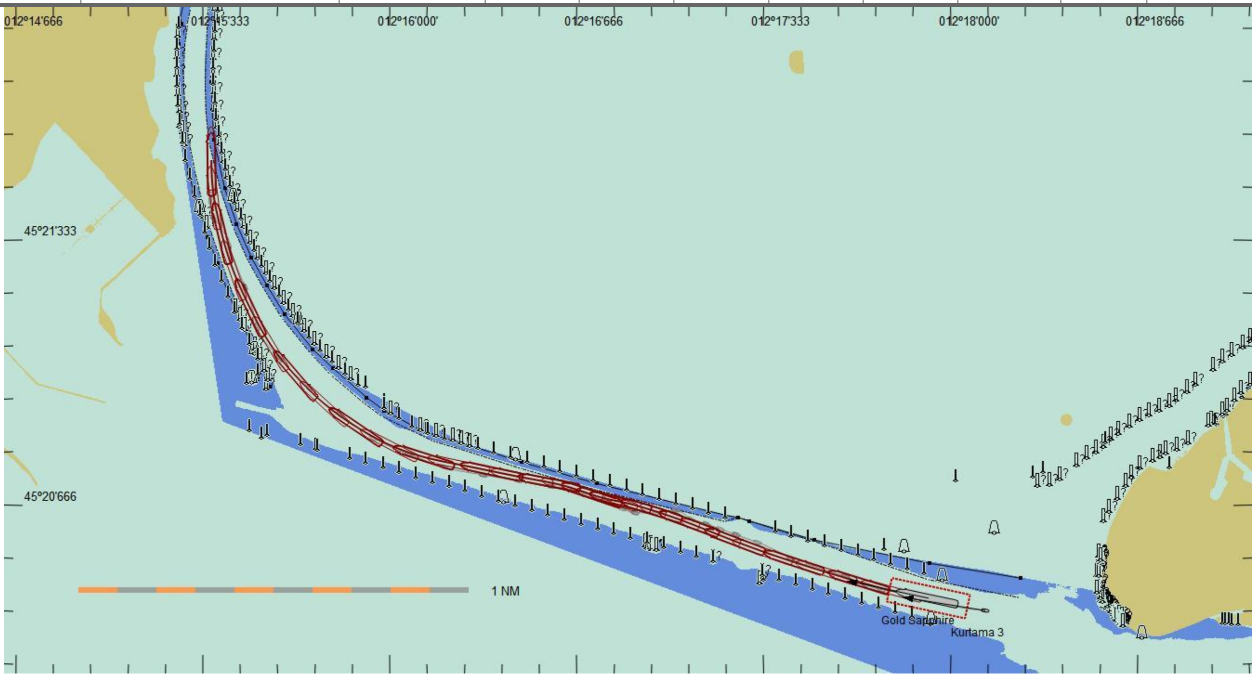
APPENDICES

APPENDIX A

TRACK PLOTS

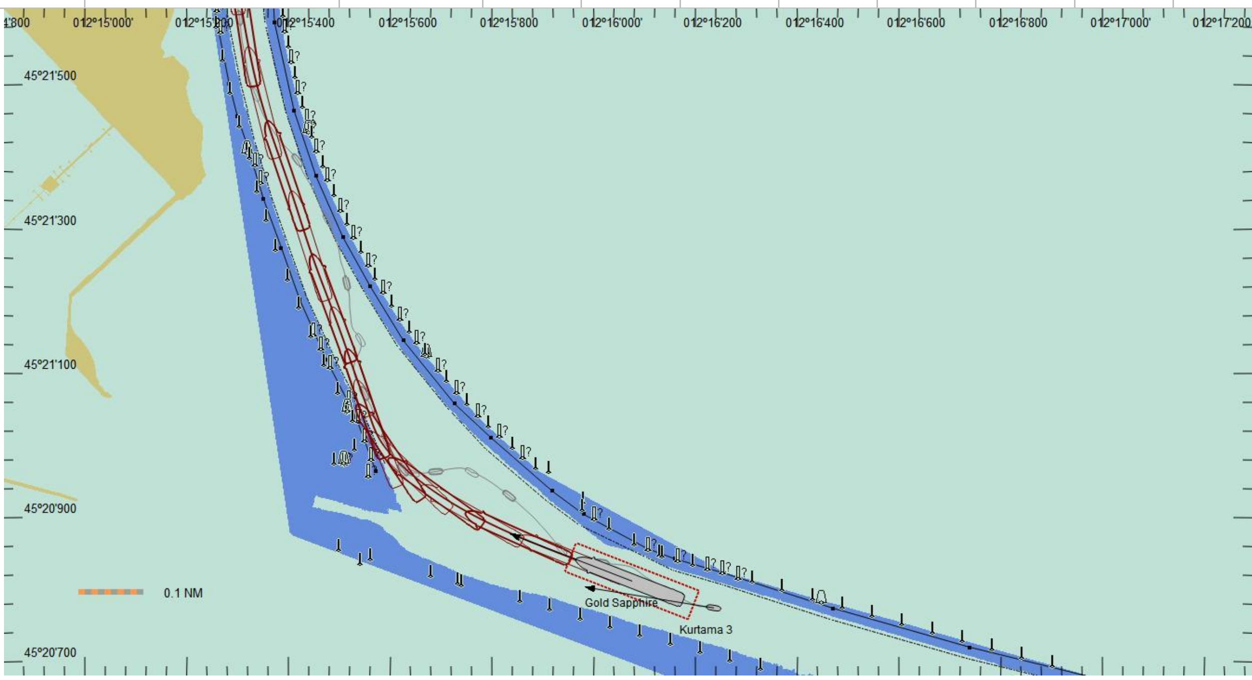
Run	Ship	Sailing Dir.	WS	WD	CS	CD	WH	WD from	WP	Max speed
			m/s		kn		m		s	kn

101	Cruise Vsl 3644	inbound	5	NE	0.5	S	0.5	NE	3.9	11

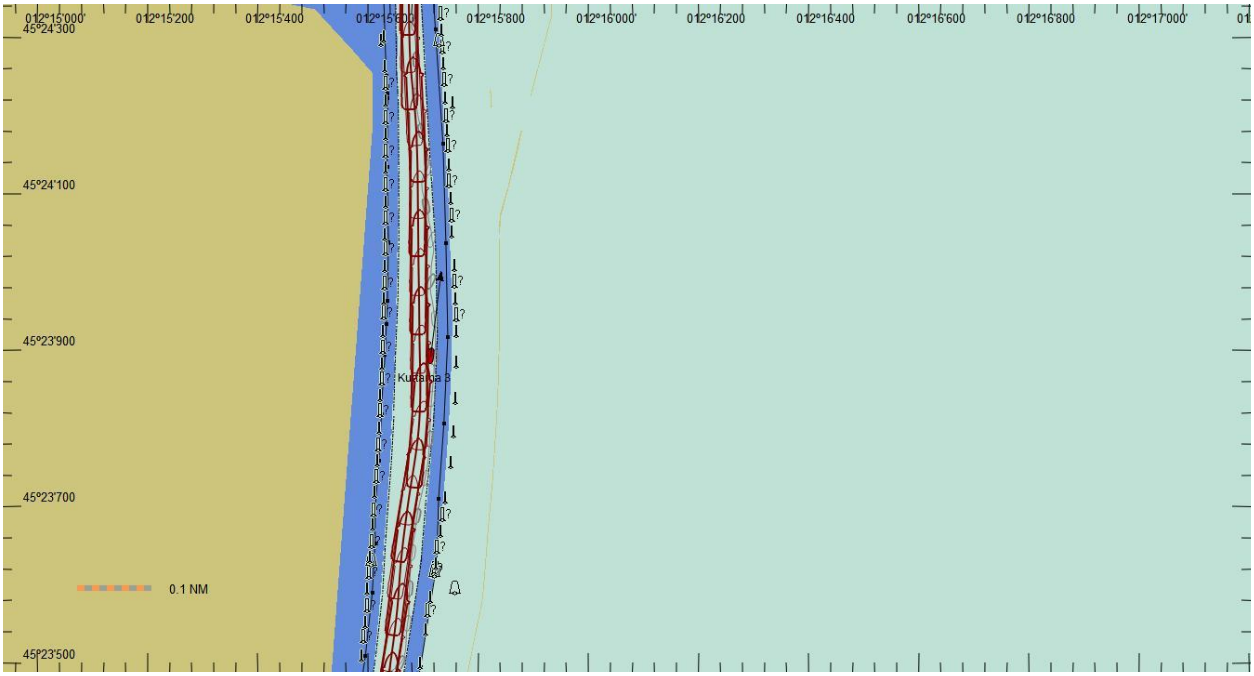


Run 101. *Beginning of the channel and San Leonardo bend. Duration 00:16:00.*

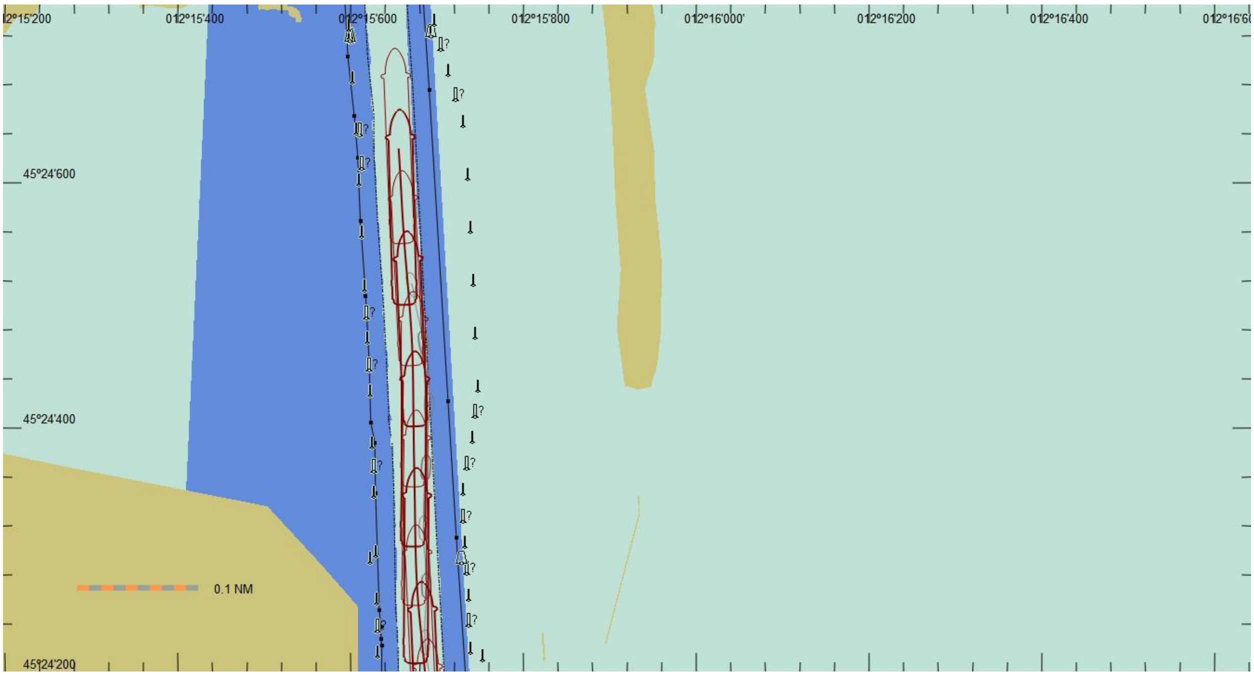
102	Cruise Vsl 3645	inbound	5	NE	0.5	S	0.5	NE	3.9	11



Run 102. *Arrival, inbound, San Leonardo bend. Duration 00:33:33.*

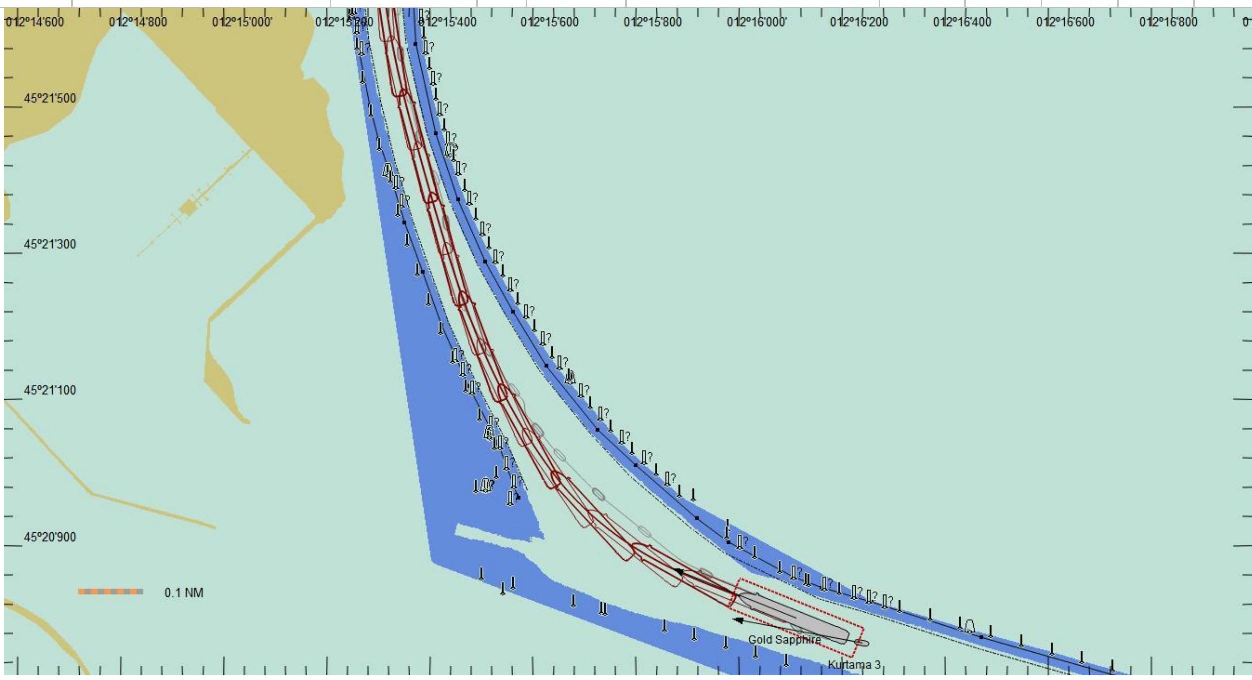


Run 102. *Bend at 2 NM south of Fusina.*

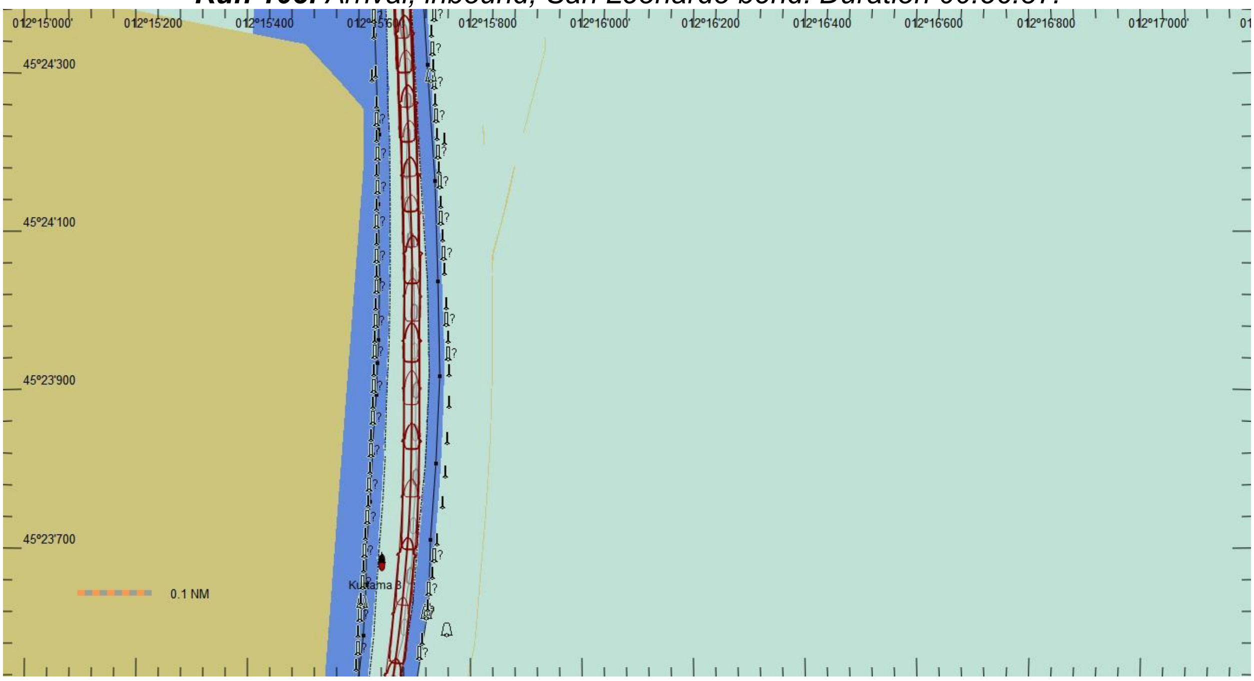


Run 102. *End of the navigation, in proximity of the Bend at 2 NM south of Fusina*

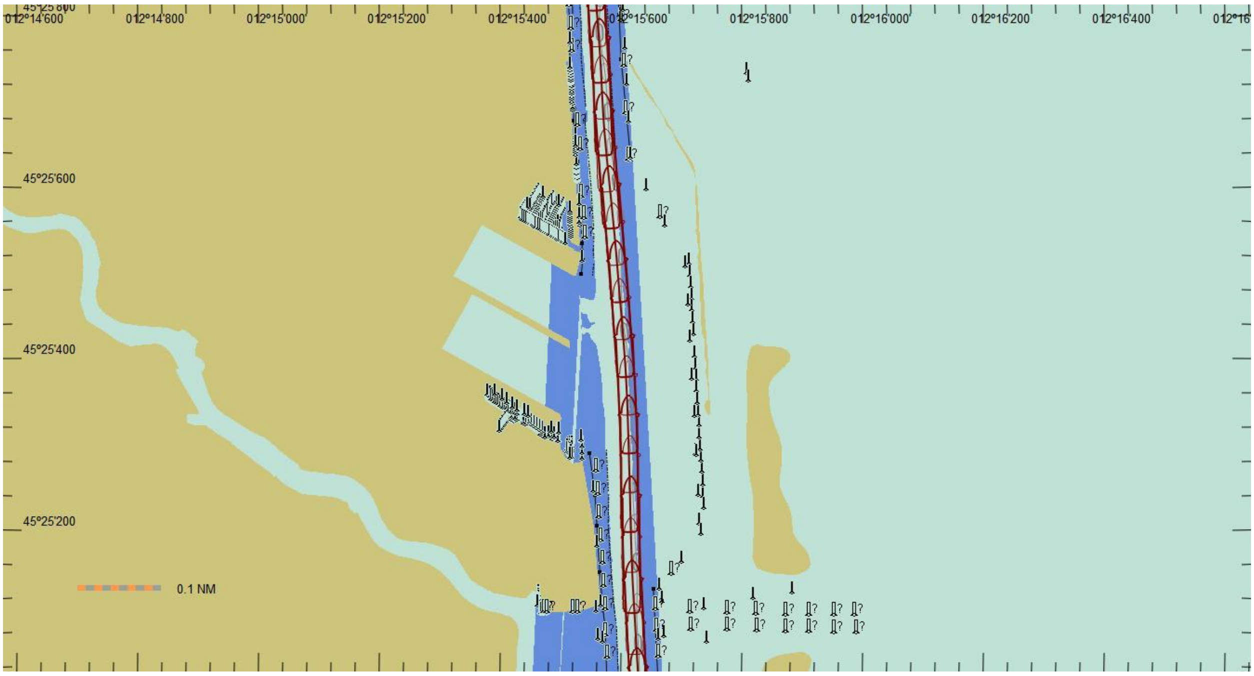
103	Cruise Vsl 3644	inbound	5	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9



Run 103. *Arrival, inbound, San Leonardo bend. Duration 00:56:37.*

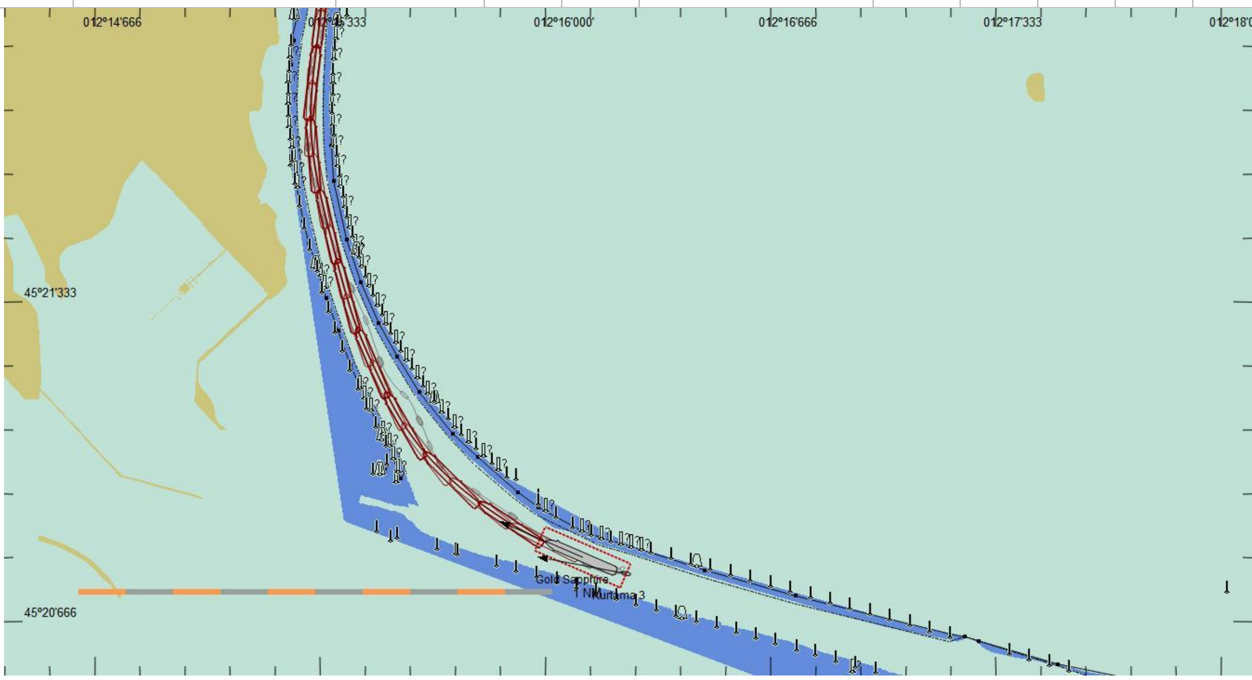


Run 103. *Bend at 2 NM south of Fusina.*

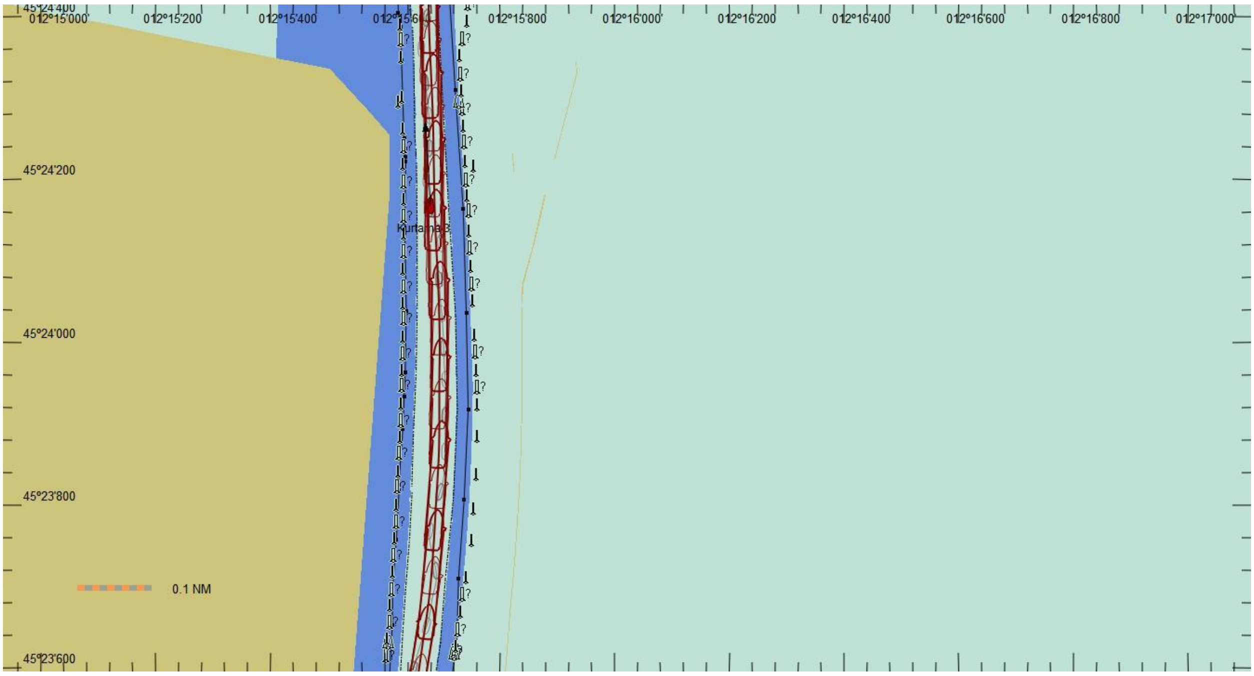


Run 103. *Cruise vessel is navigating nearby Fusina quay, approaching the end of the navigation.*

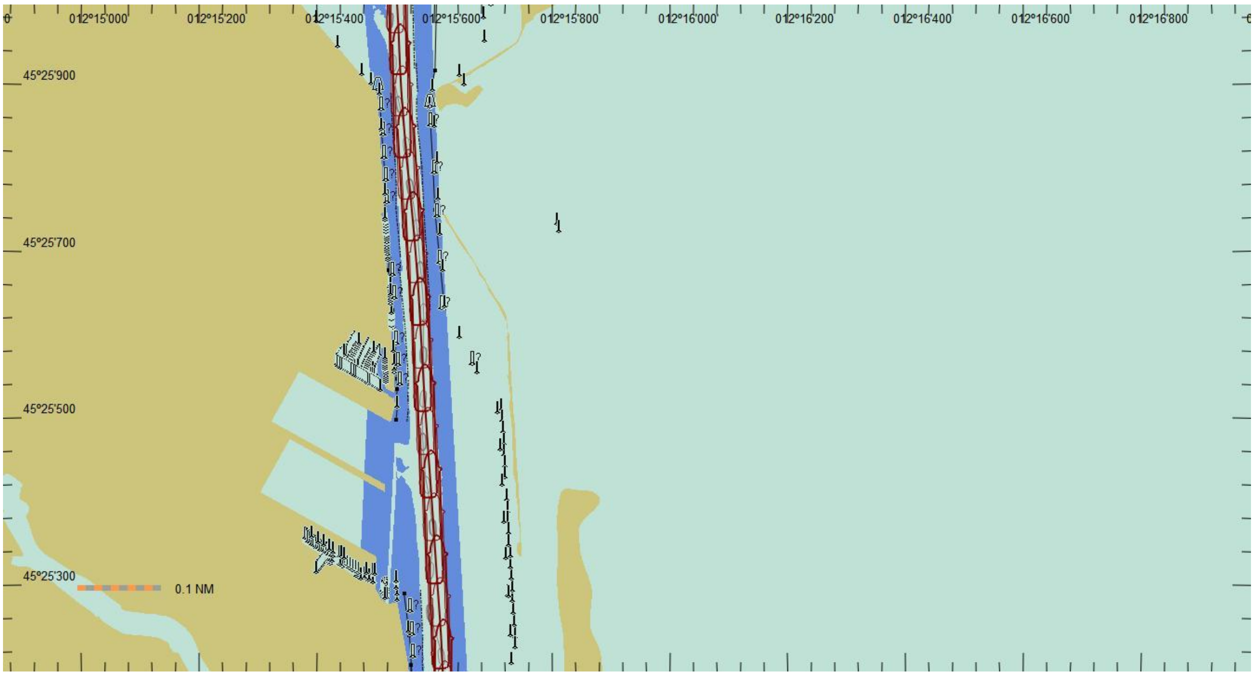
104	Cruise Vsl 3644	inbound	7.5	NE	Max Ebb Tide	180	0.3	NE	3.7	8/9



Run 104. *Arrival, inbound, San Leonardo bend. Duration 00:52:34. Rain, visibility distance 3 nm.*

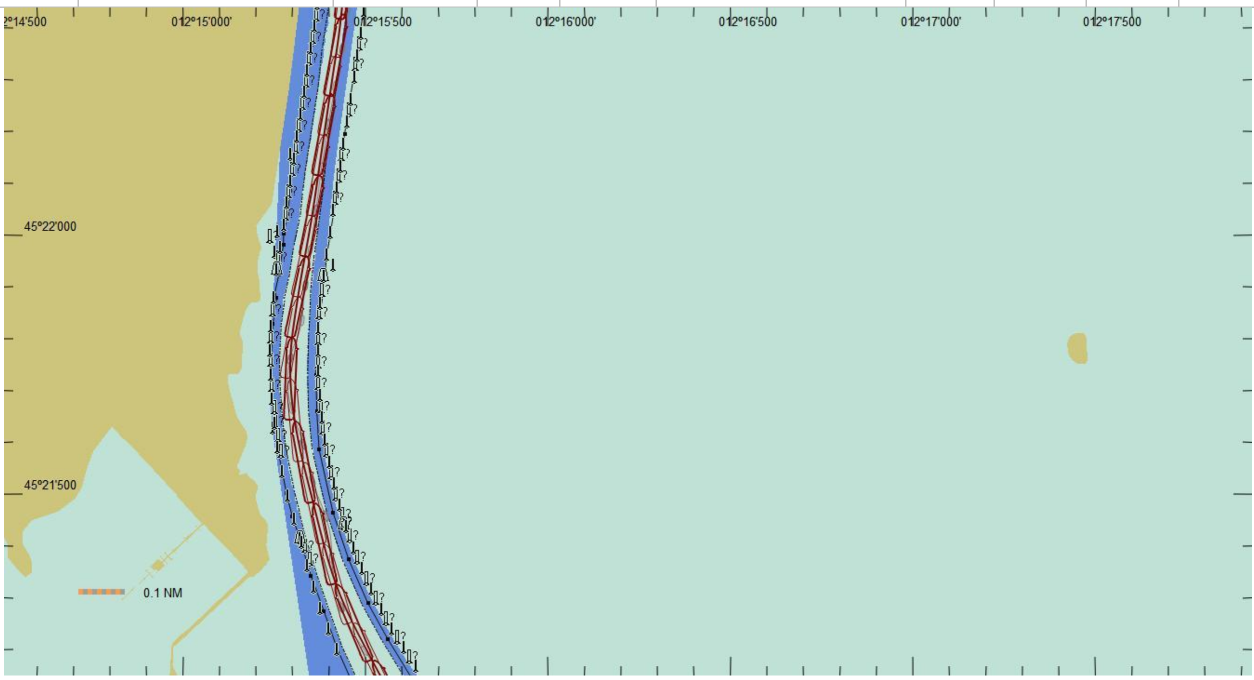


Run 104. *Bend at 2 NM south of Fusina*

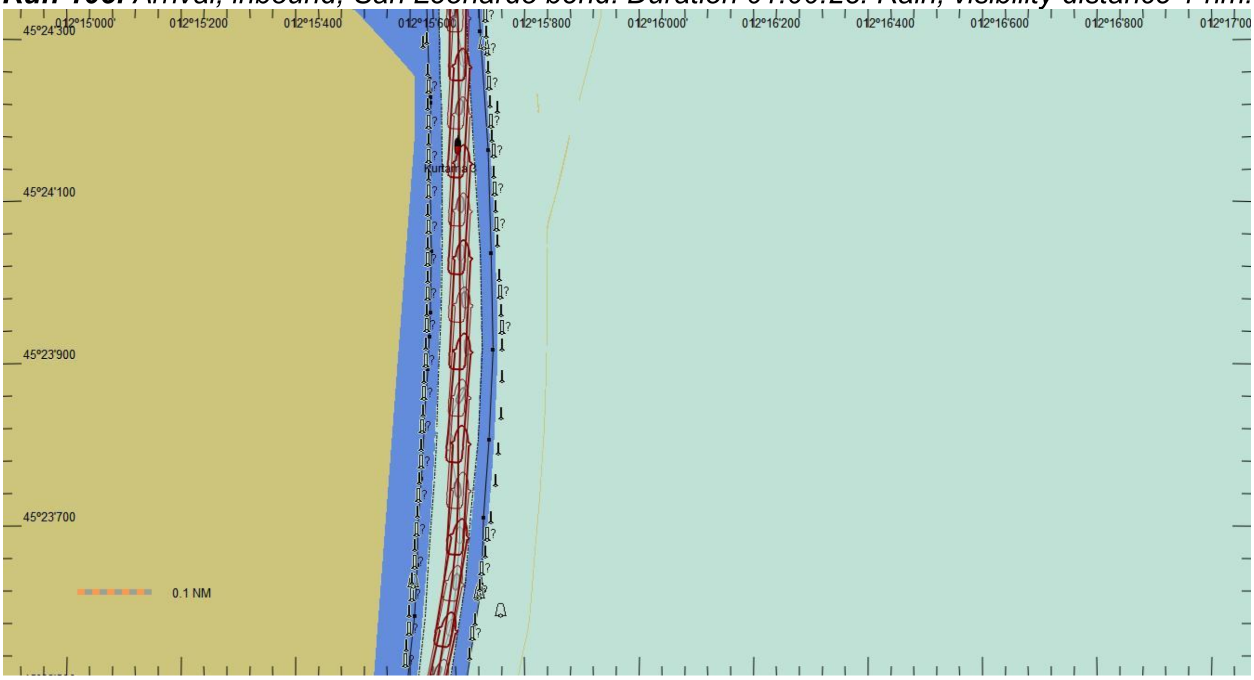


Run 104. *The vessel is navigating nearby Fusina quay, approaching the end of the navigation, in the north part of the channel.*

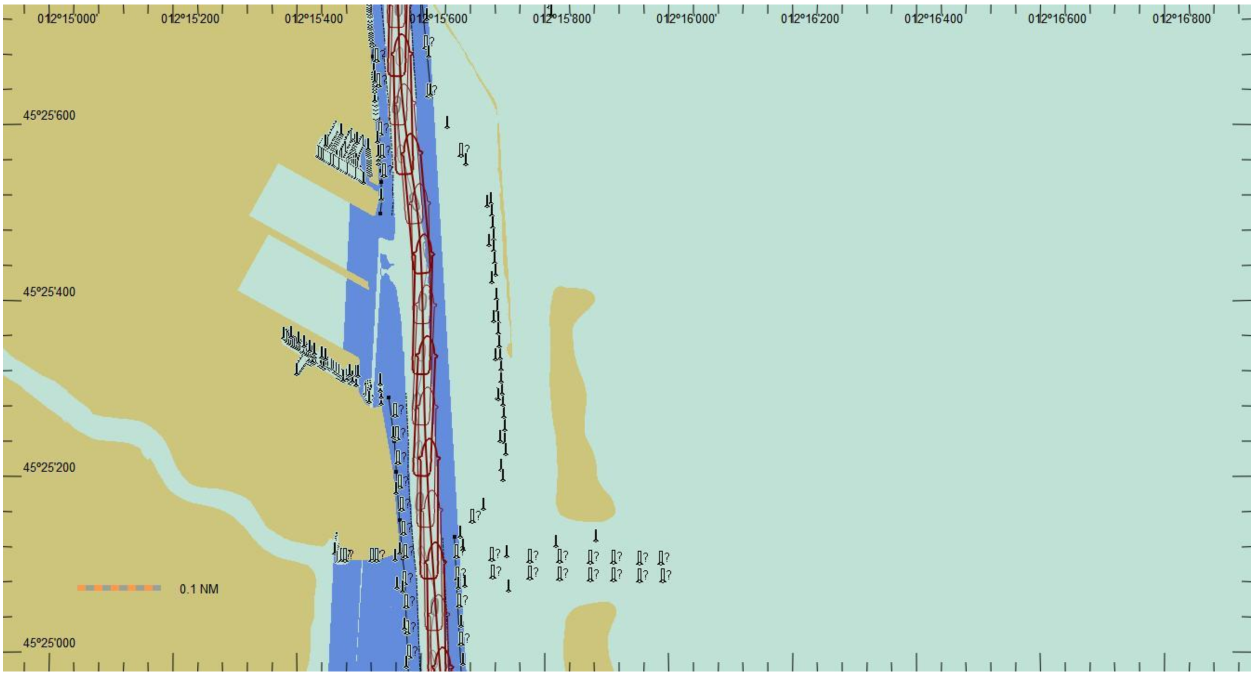
105	Cruise Vsl 3644	inbound	10	ENE	Max Flood Tide	360	0.3	NE	3.7



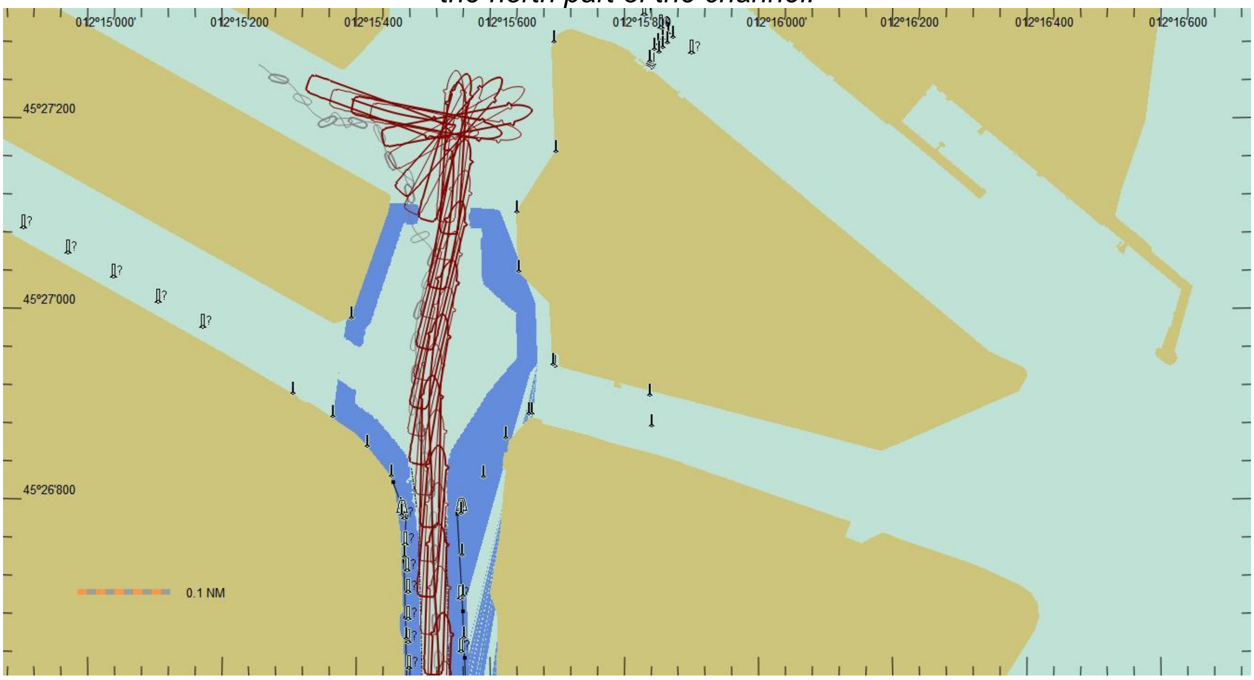
Run 105. *Arrival, inbound, San Leonardo bend. Duration 01:00:28. Rain, visibility distance 1 nm.*



Run 105. *Bend at 2 NM south of Fusina*

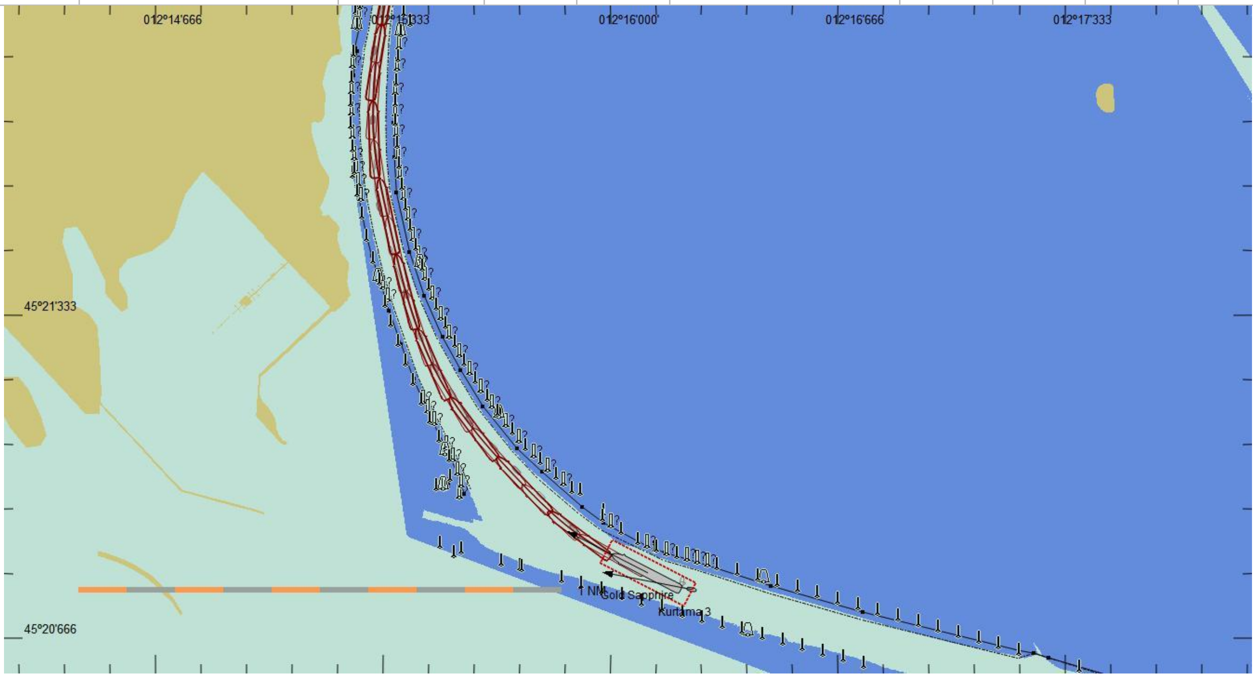


Run 105. *The vessel is navigating nearby Fusina quay, approaching the end of the navigation, in the north part of the channel.*

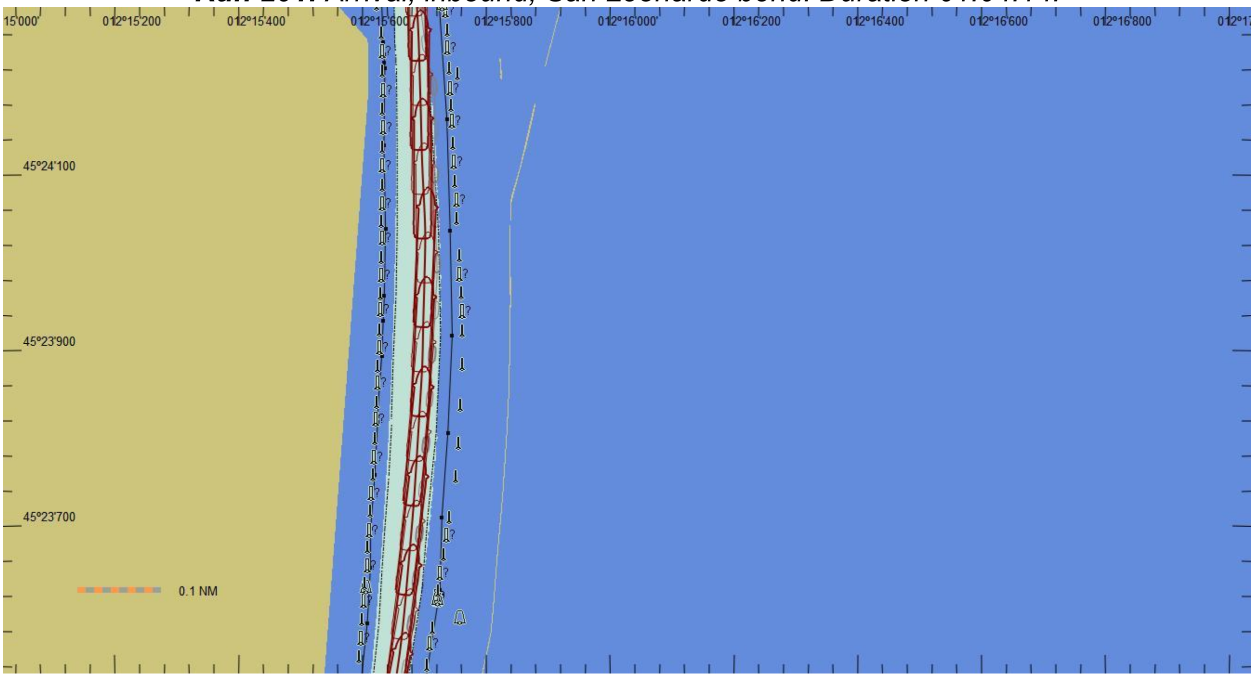


Run 105. *End of the navigation, the north part of the channel*

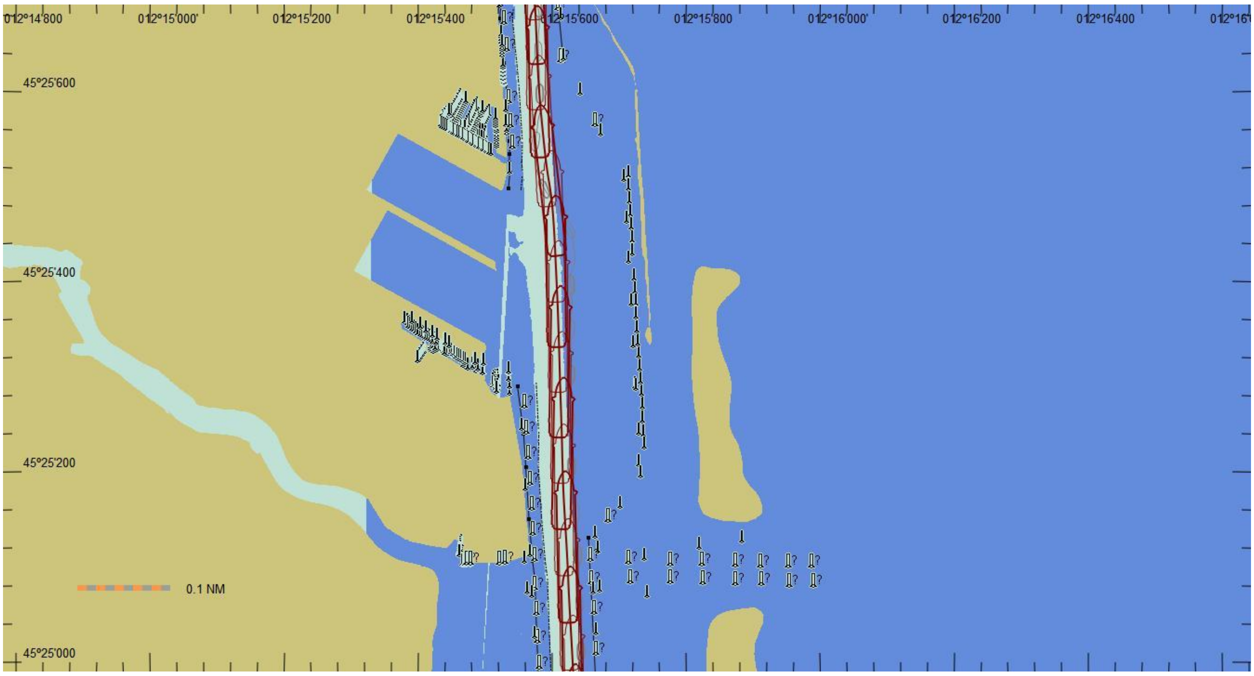
201	Cruise Vsl 3644	inbound	10	E	Max Ebb Tide	180	0.3	NE	3.7



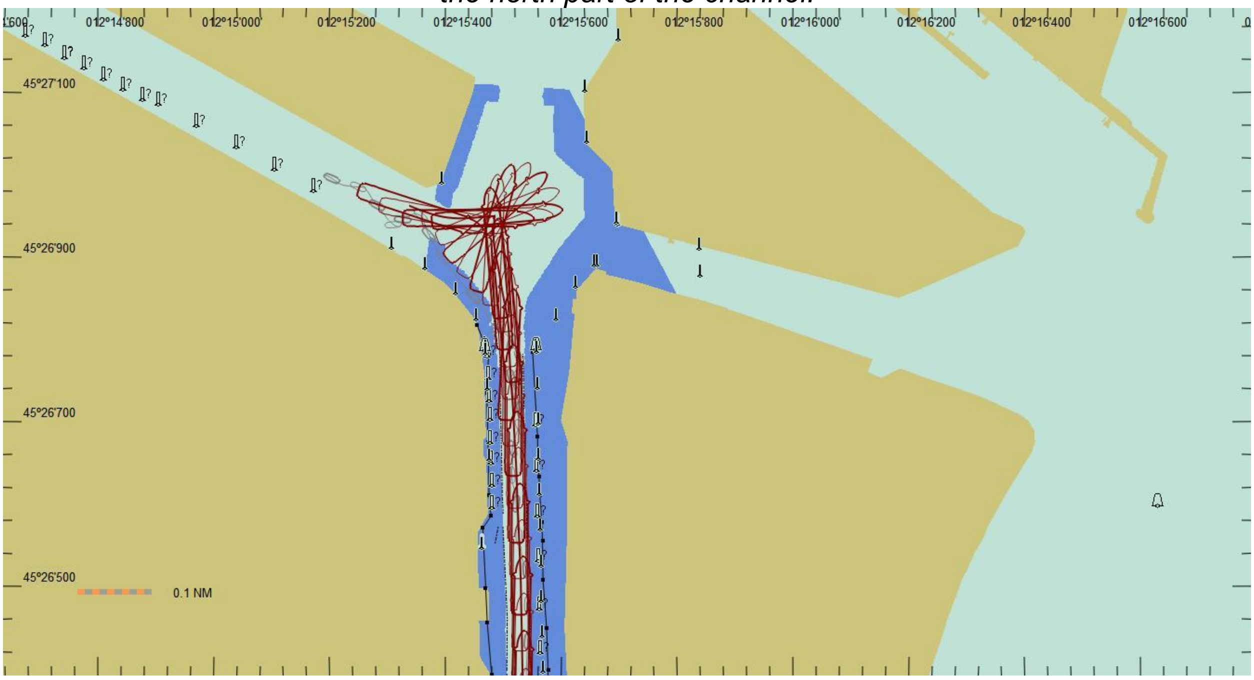
Run 201. *Arrival, inbound, San Leonardo bend. Duration 01:04:14.*



Run 201. *Bend at 2 NM south of Fusina*

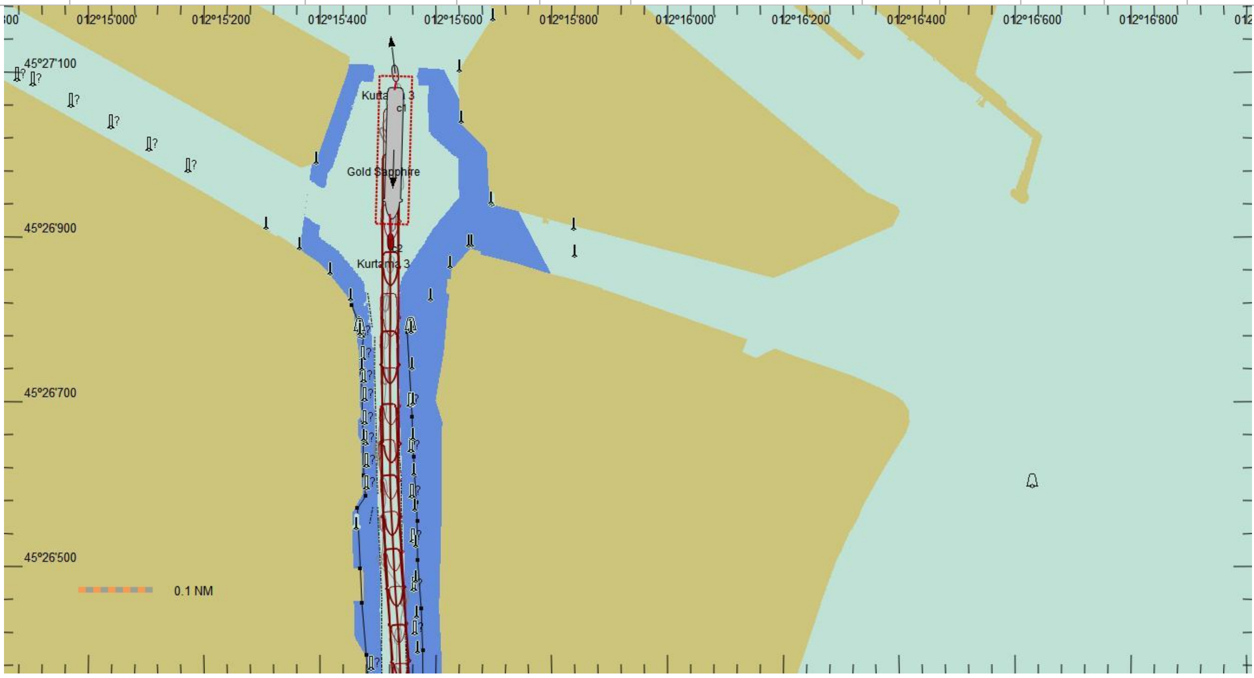


Run 201. *The vessel is navigating nearby Fusina quay, approaching the end of the navigation, in the north part of the channel.*

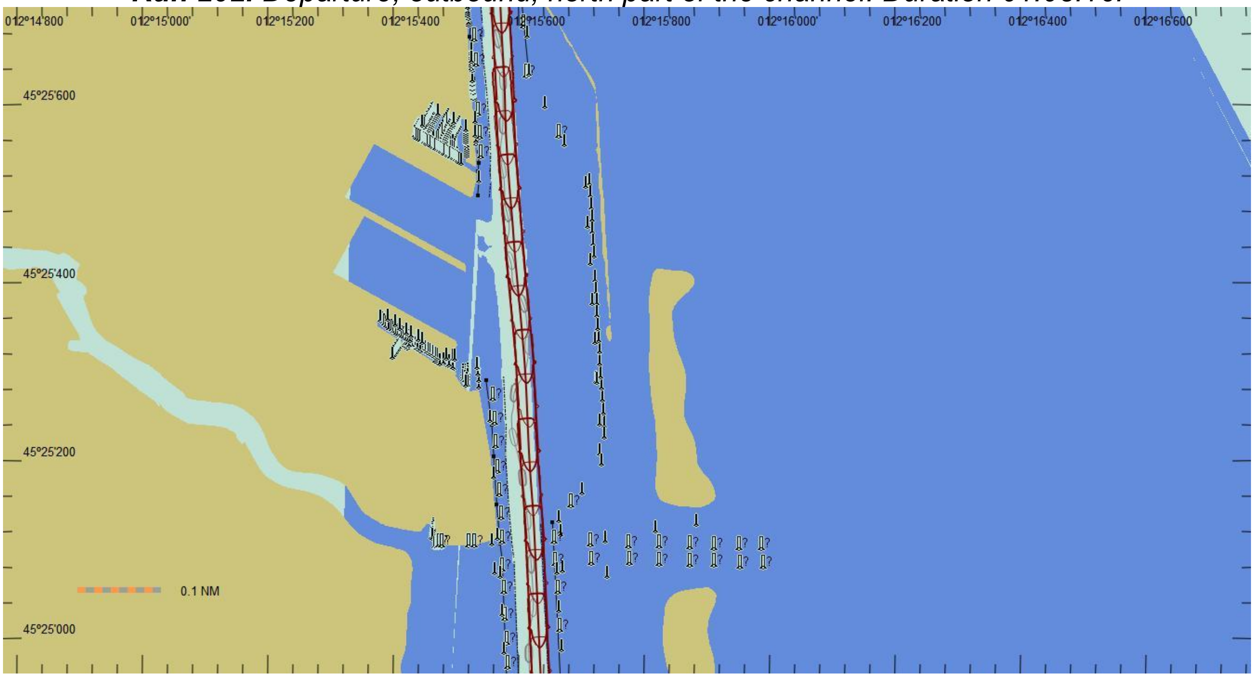


Run 201. *End of the navigation, north part of the channel.*

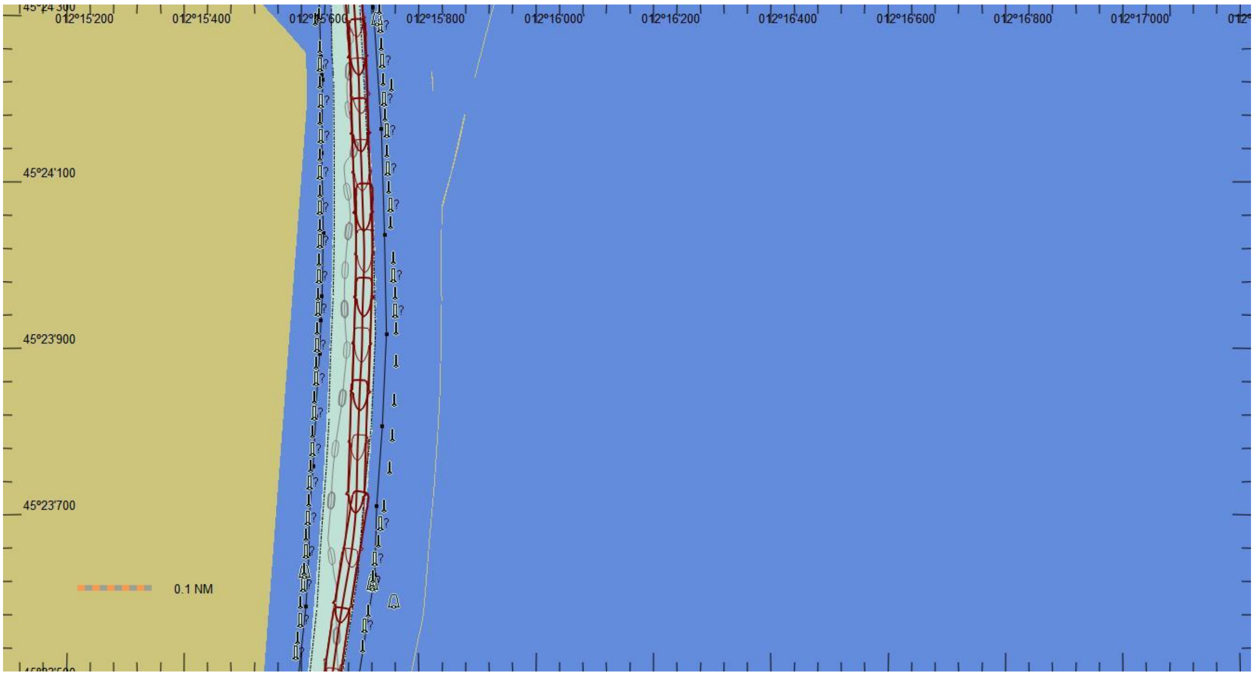
202	Cruise Vsl 3644	outbound	7.5	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9



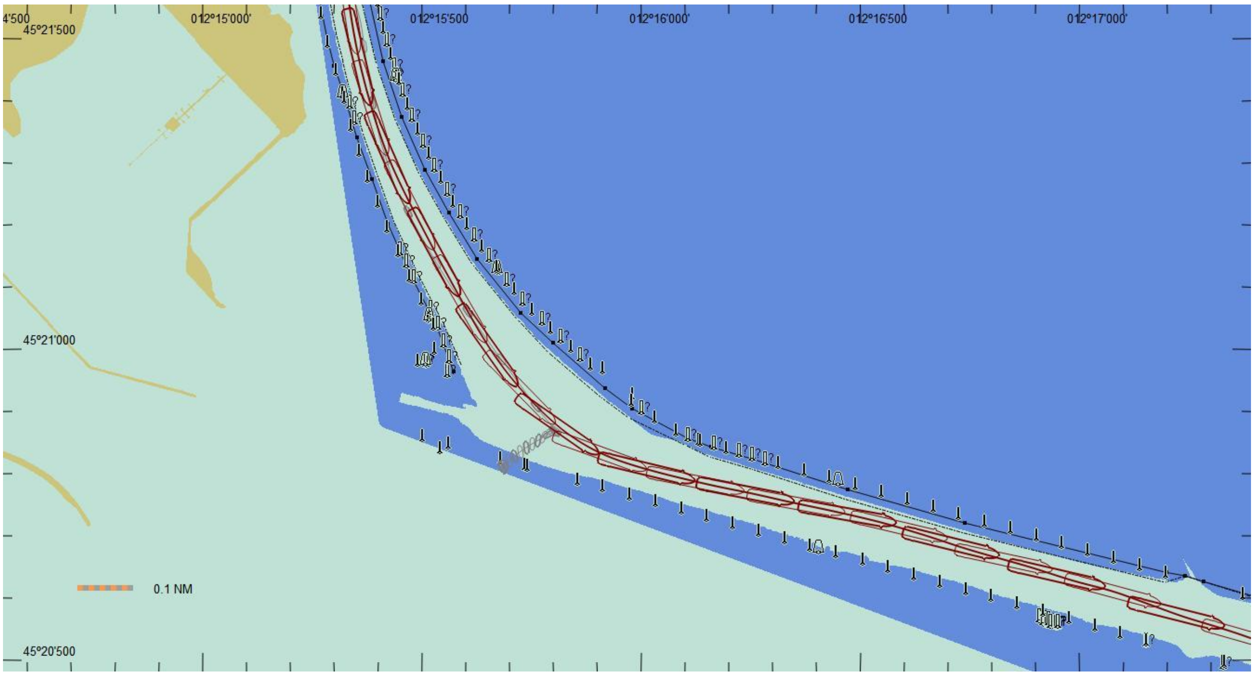
Run 202. *Departure, outbound, north part of the channel. Duration 01:08:16.*



Run 202. *Navigation in proximity of Fusina quay.*

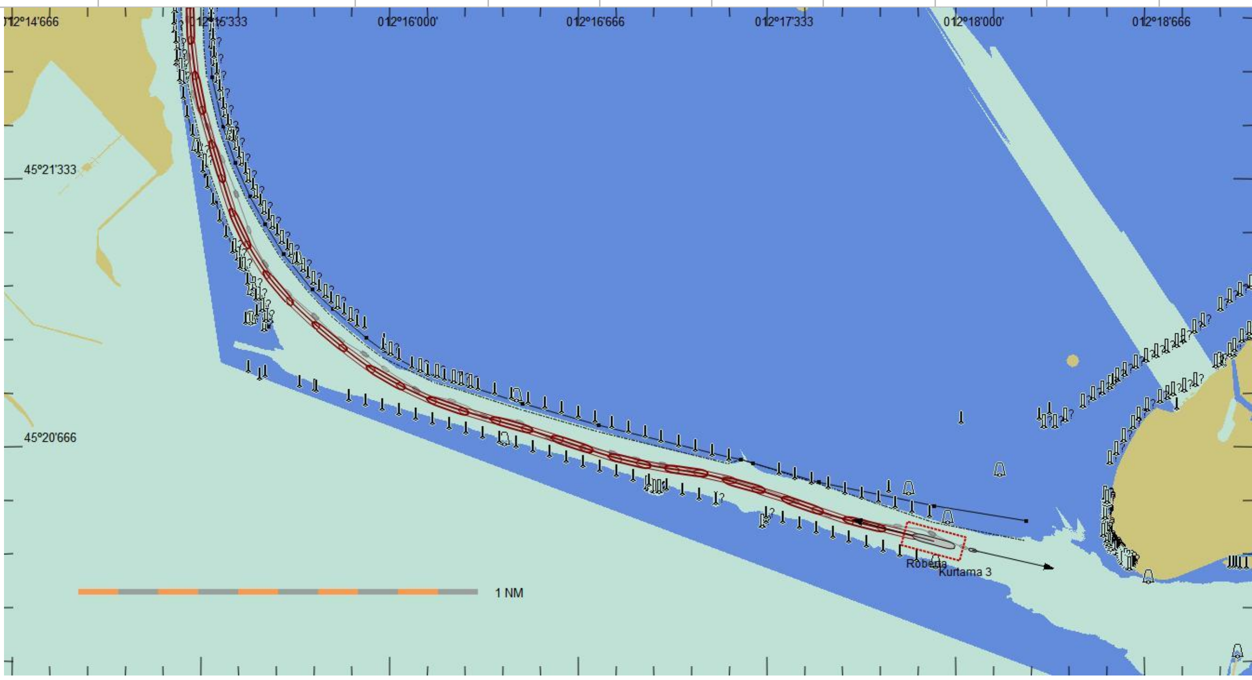


Run 202. *Bend at 2 NM south of Fusina*

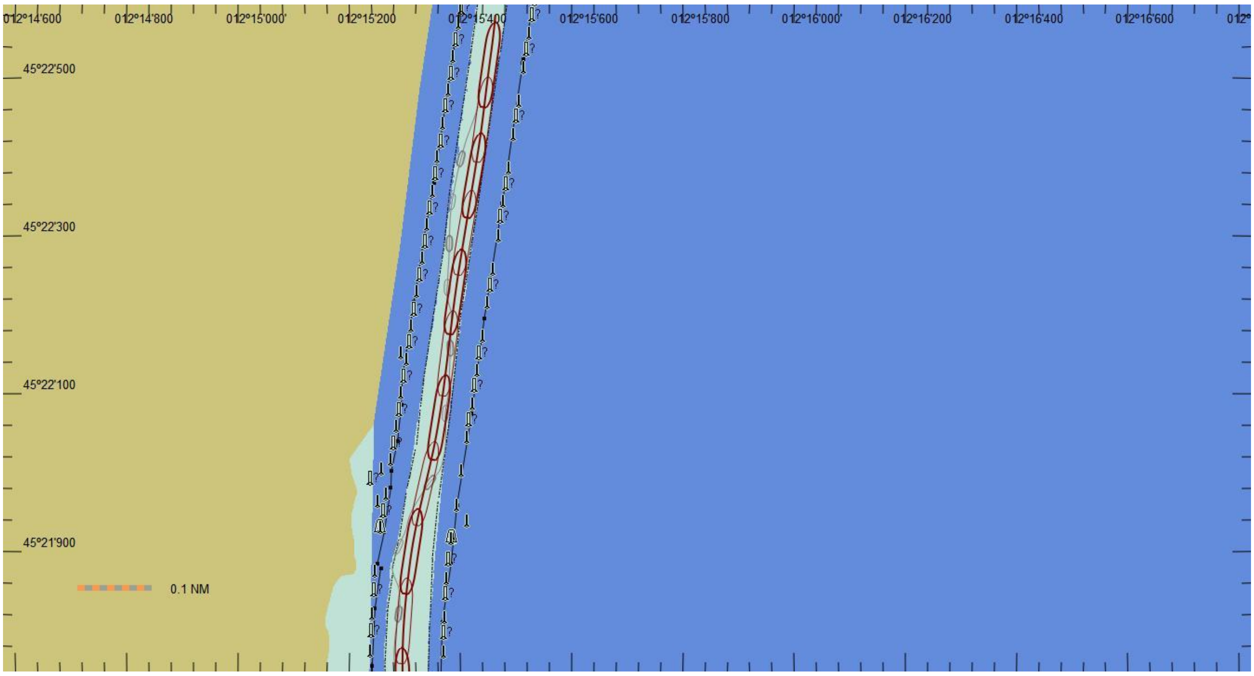


Run 202. *San Leonardo bend, south part of the channel, approaching the end of the navigation after that.*

203	Bulk Carrier 3481	inbound	5	NE	0.5	S	0.5	NE	3.9

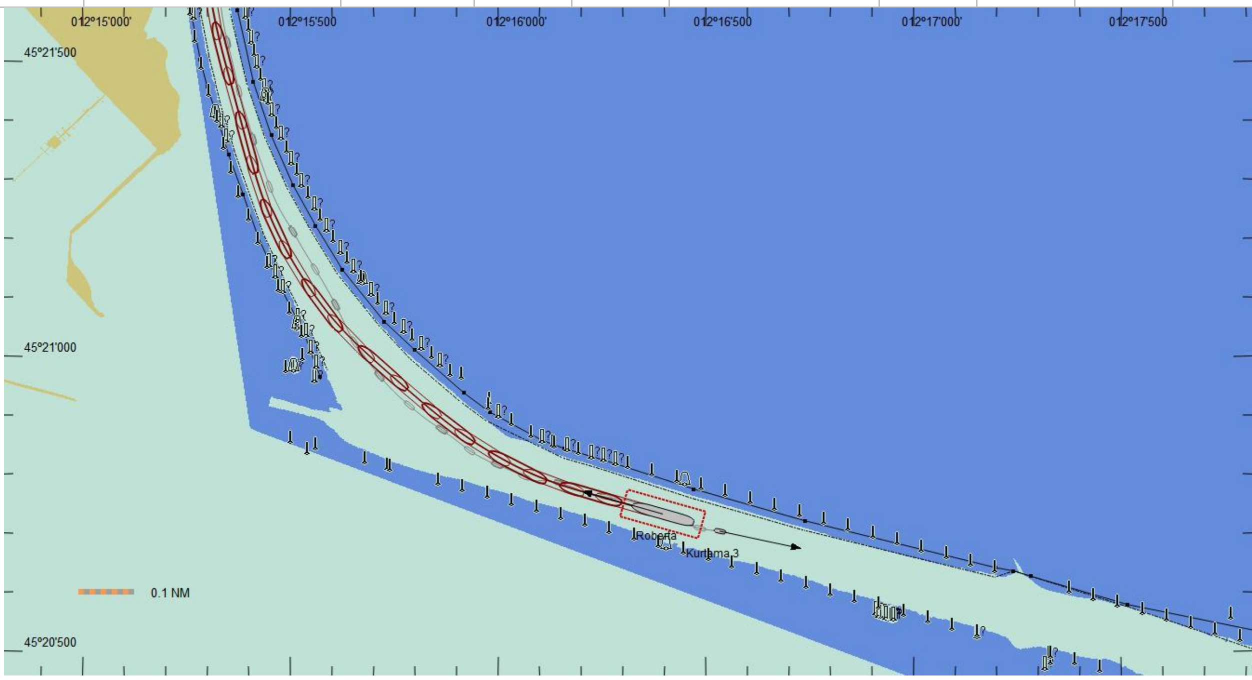


Run 203. *Beginning of the navigation in proximity of San Leonardo bend. Arrival, inbound. Duration 00:20:00.*

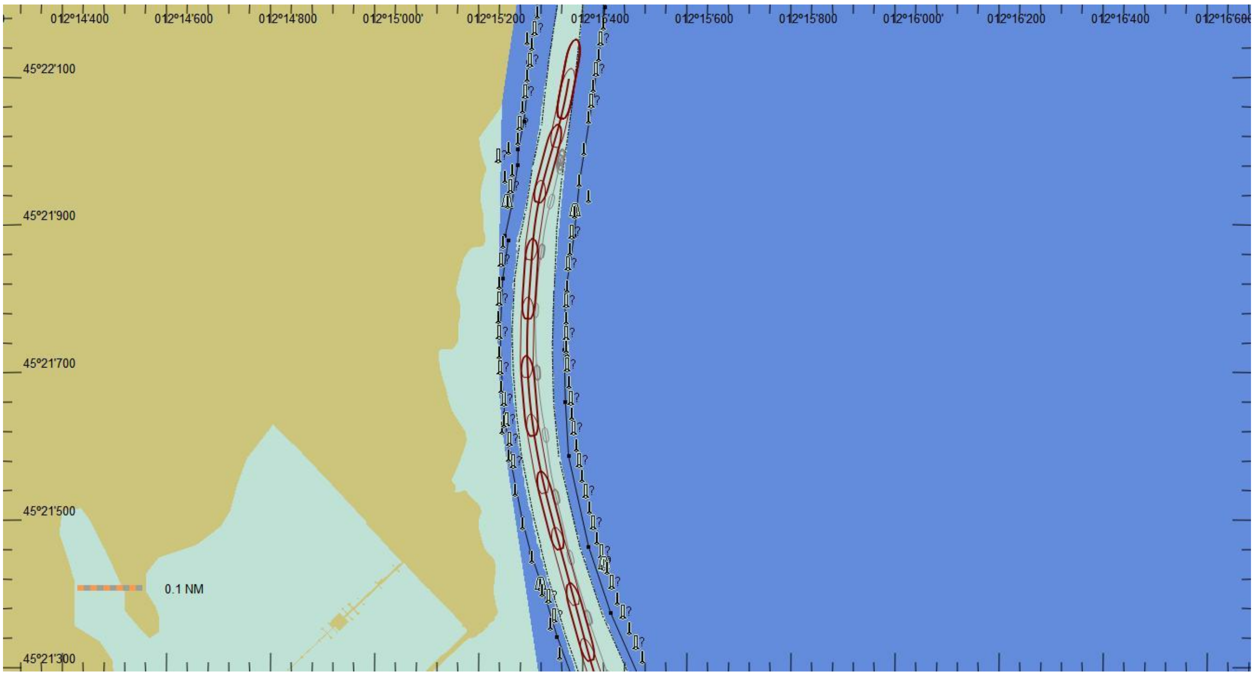


Run 203. *End of the navigation just after San Leonardo bend.*

204	Bulk Carrier 3481	inbound	7.5	NNE	Max Ebb Tide	180	0.3	NE	3.7

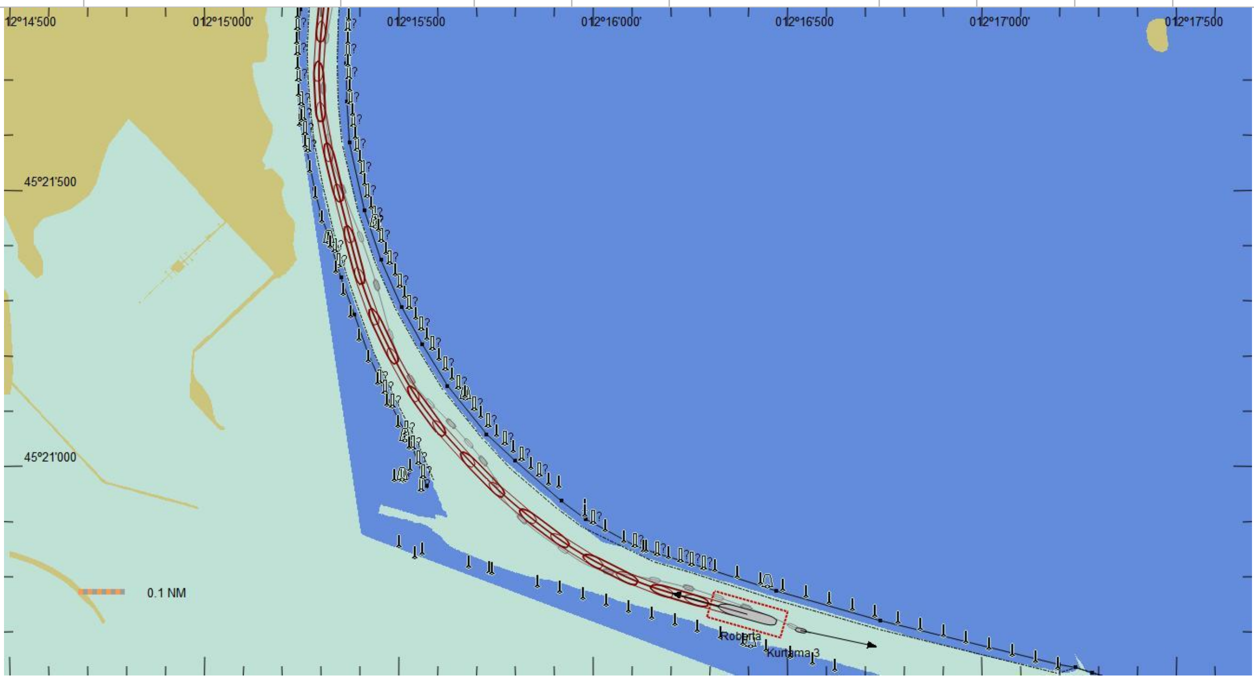


Run 204. *Beginning of the navigation in proximity of San Leonardo bend. Arrival, inbound. Duration 00:13:47.*

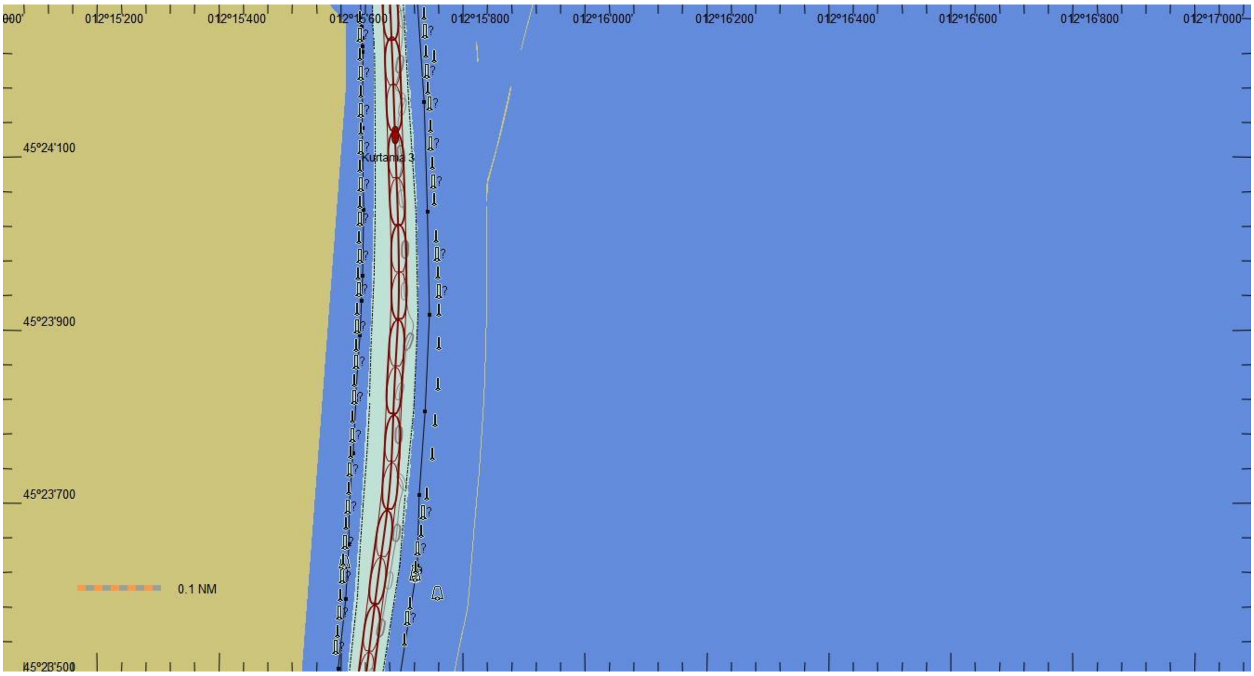


Run 204. *End of the navigation just after San Leonardo bend.*

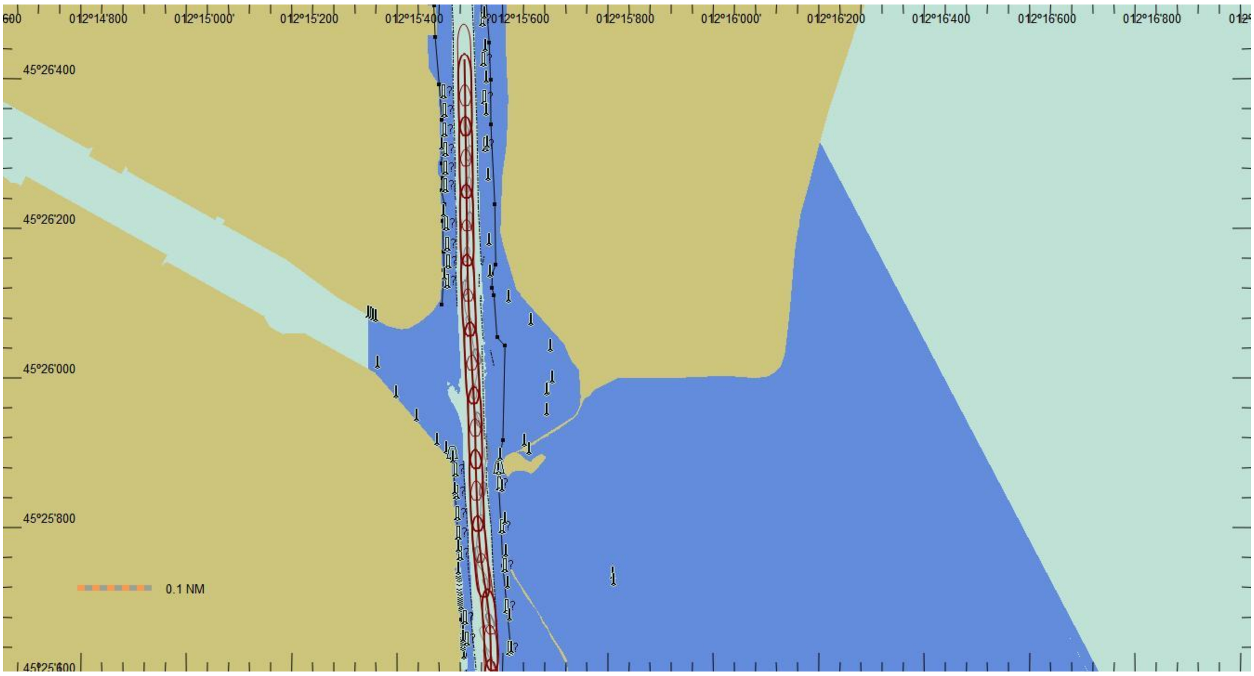
205	Bulk Carrier 3481	inbound	7.5	NNE	Max Ebb Tide	180	0.3	NE	3.7



Run 205. *Beginning of the navigation in proximity of San Leonardo bend. Arrival, inbound. Duration 00:54:39.*

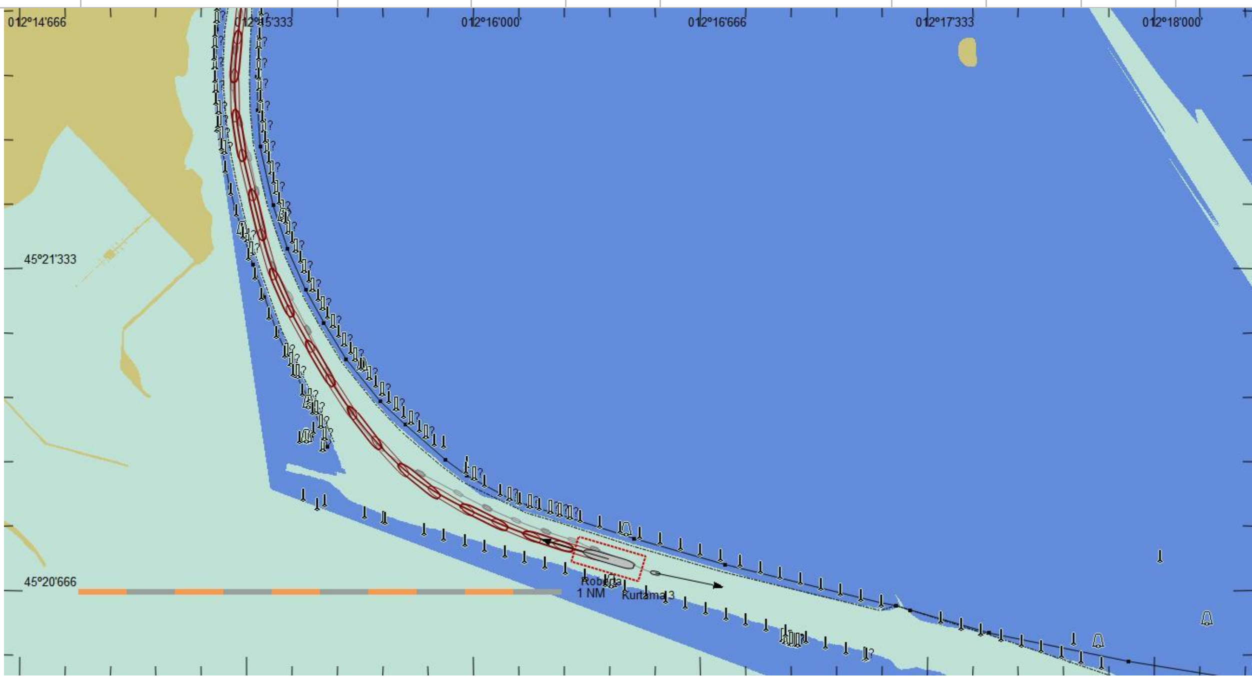


Run 205. *Bend at 2 NM south of Fusina.*

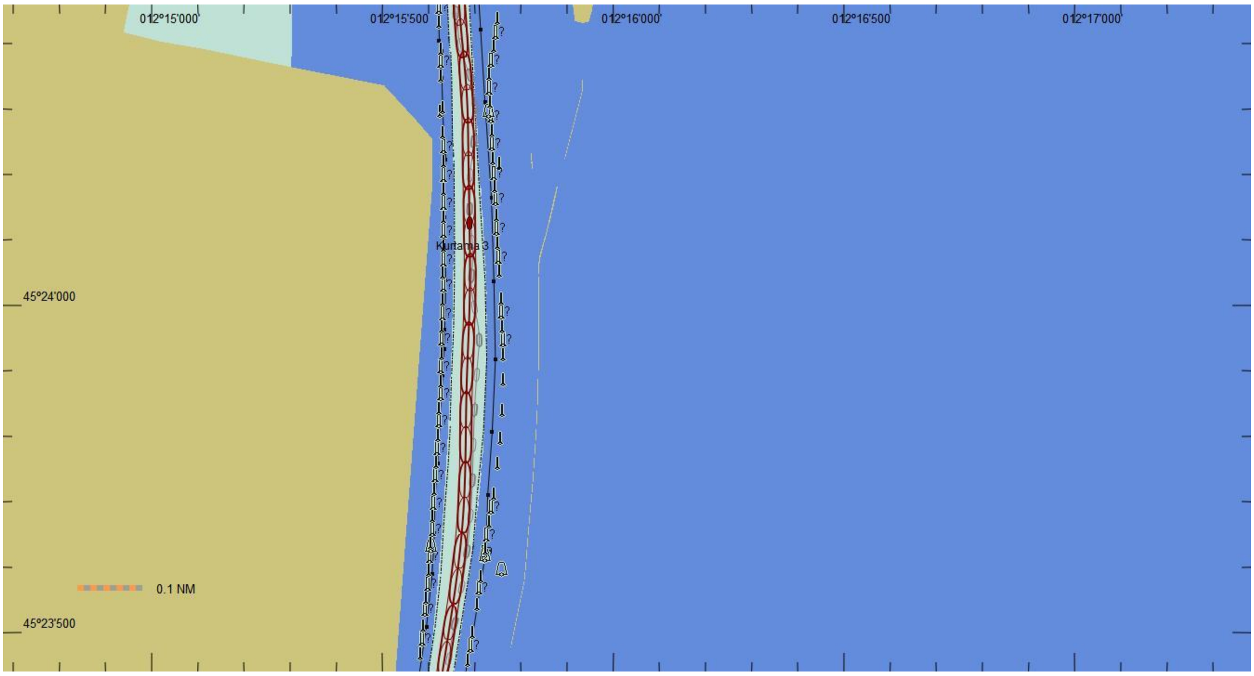


Run 205. *End of the navigation.*

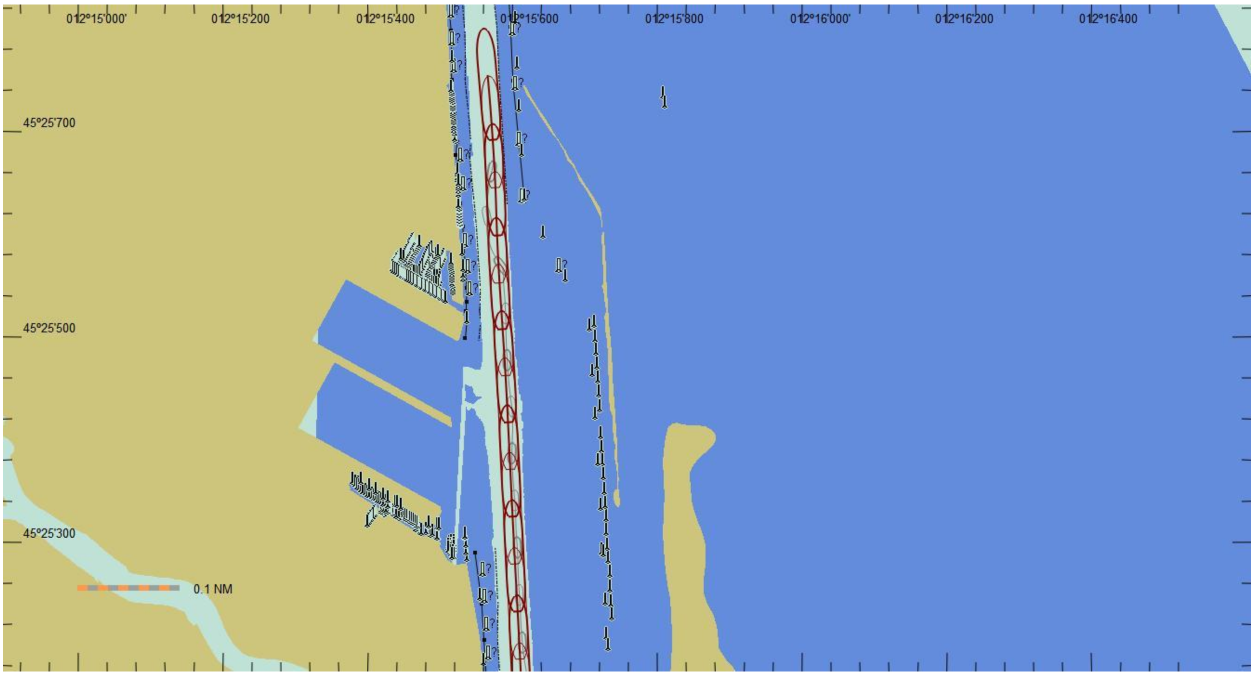
206	Bulk Carrier 3481	inbound	10	NE	Max Flood Tide	360	0.3	NE	3.7



Run 206. *Beginning of the navigation in proximity of San Leonardo bend. Arrival. Duration 00:45:08. Rain, visibility 3 nm.*

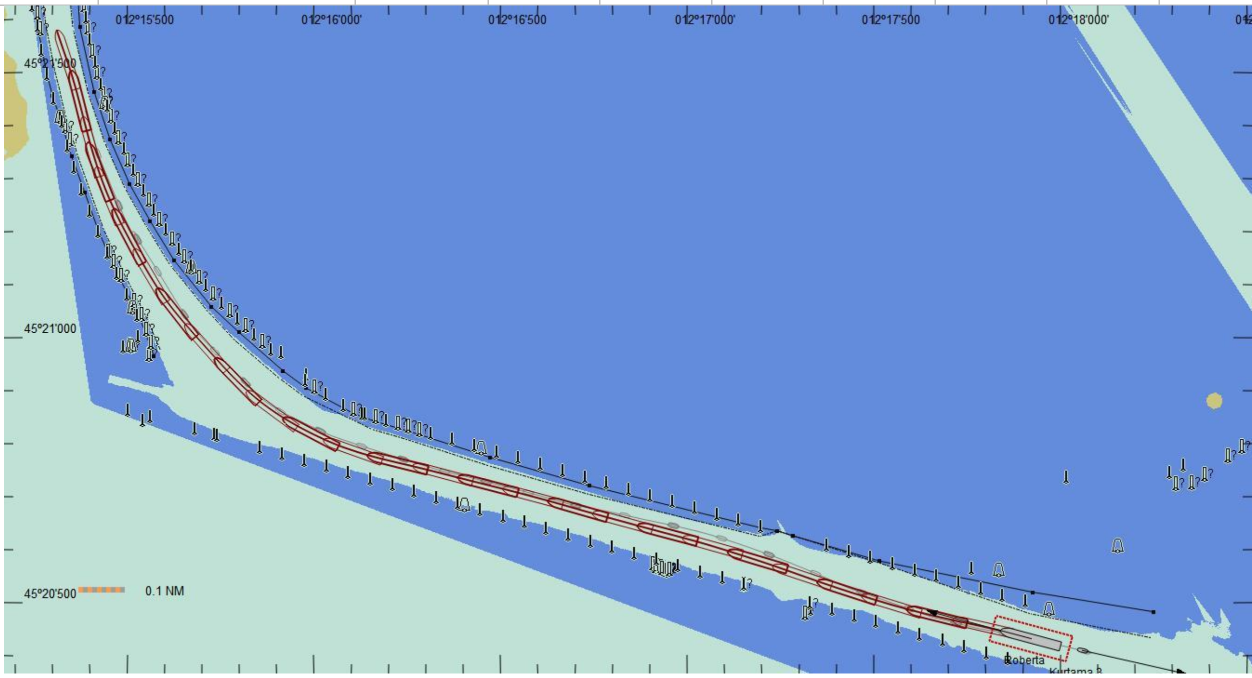


Run 206. *Bend at 2 NM south of Fusina*



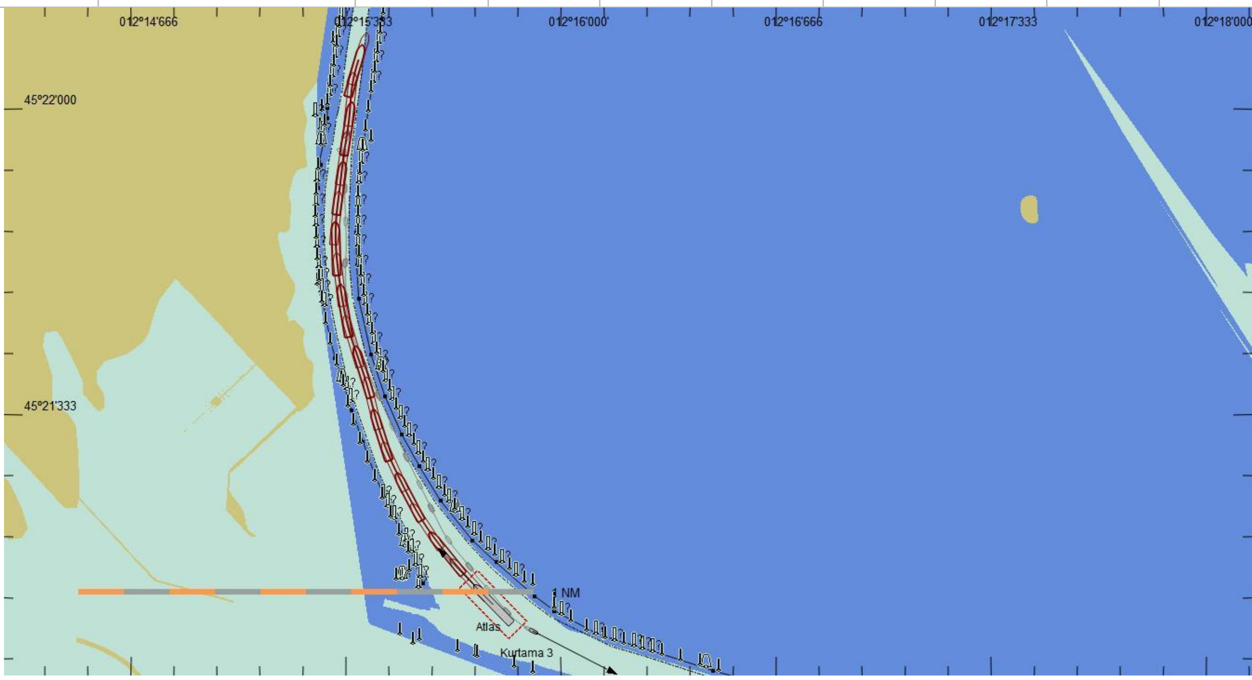
Run 206. *End of the navigation, north of Fusina quay.*

207	Bulk Carrier 3481	inbound	5	NE	0.5	S	0.5	NE	3.9



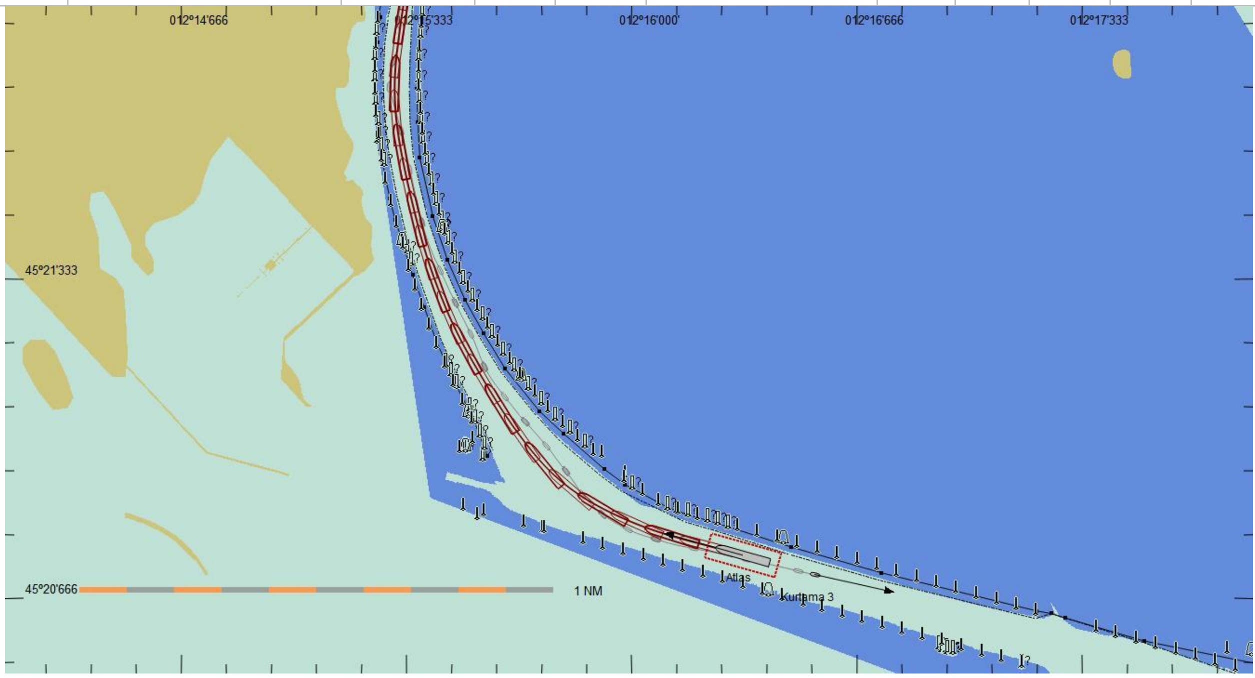
Run 207. *Begin and end of the navigation in proximity of San Leonardo bend. Arrival. Duration 00:13:56.*

208	Bulk Carrier 3481	inbound	5	NE	0.5	S	0.5	NE	3.9

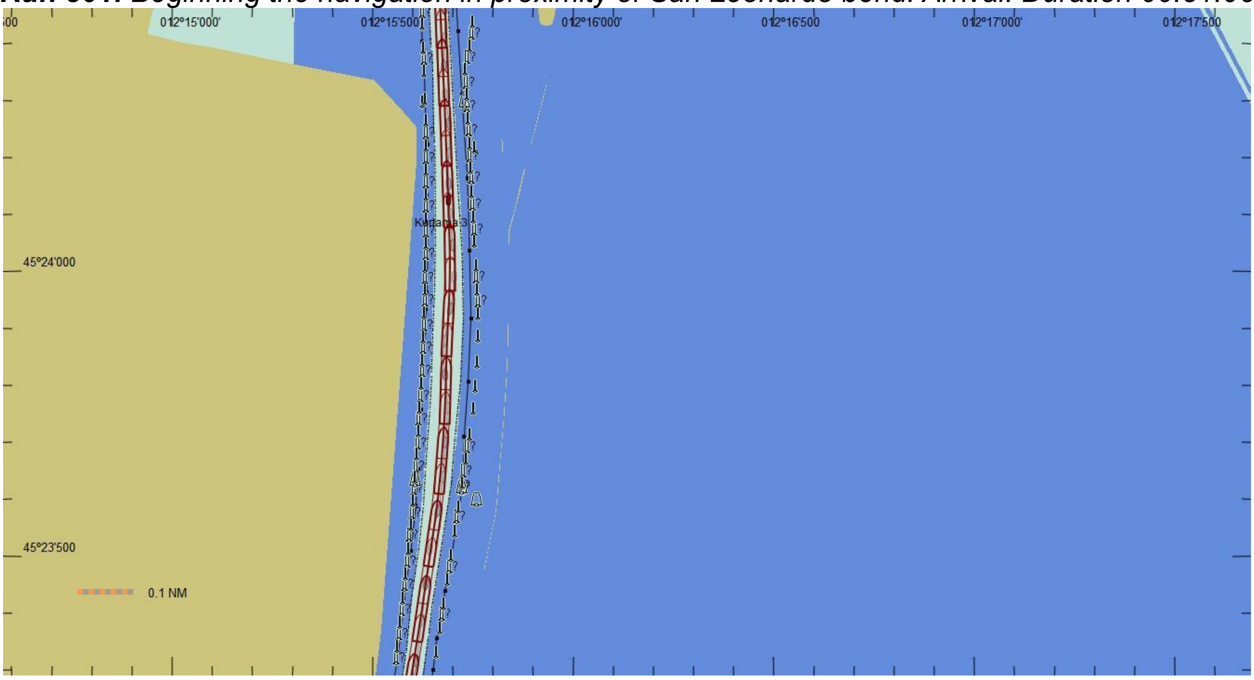


Run 208. *Begin and end of the navigation in proximity of San Leonardo bend. Arrival. Duration 00:19:50.*

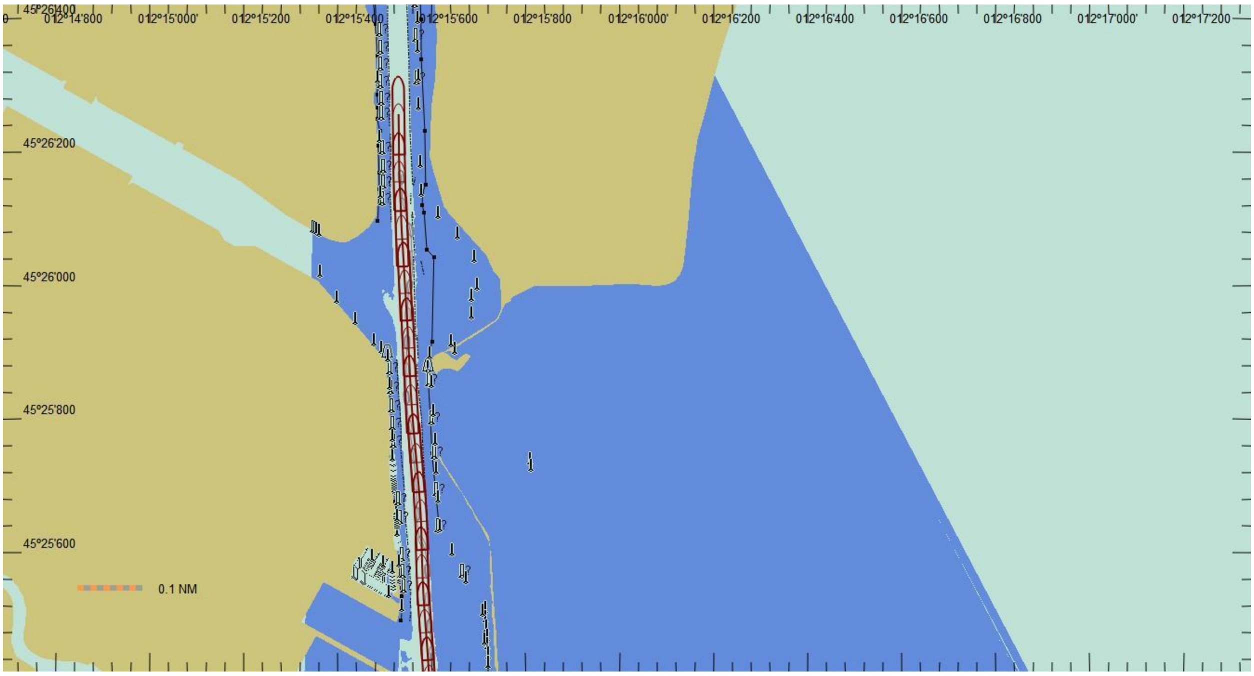
301	Container vsl 3601	inbound	7.5	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9



Run 301. *Beginning the navigation in proximity of San Leonardo bend. Arrival. Duration 00:51:06*

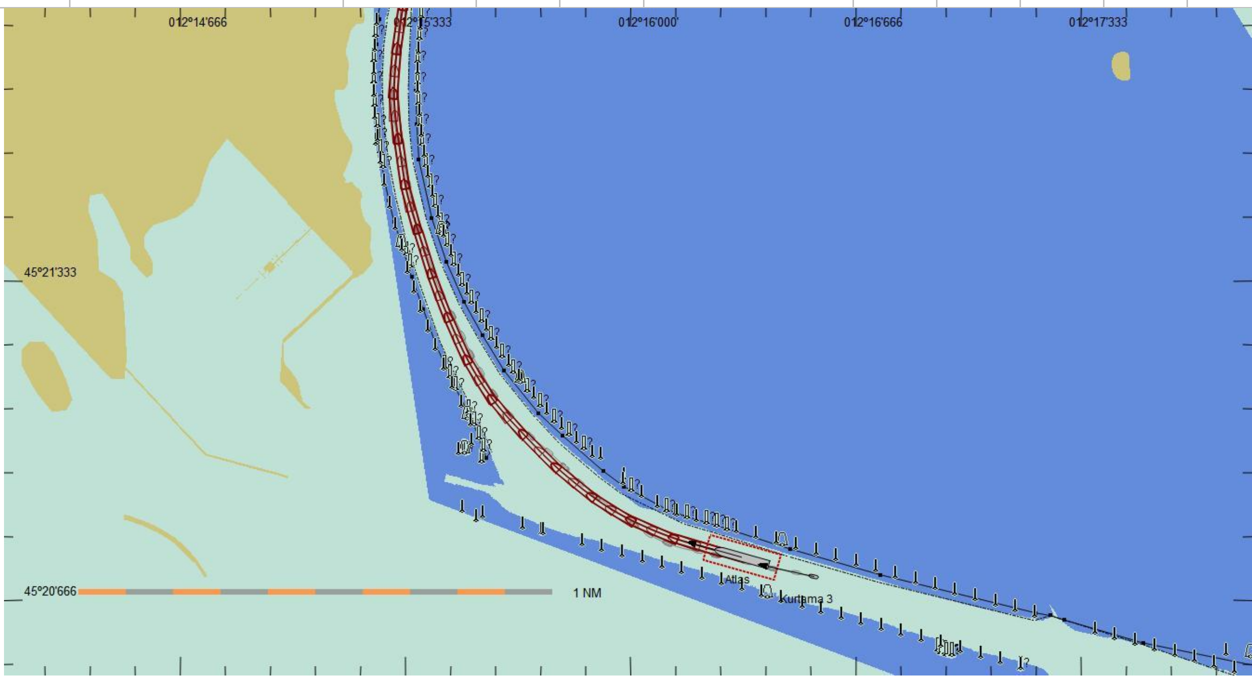


Run 301. *Bend at 2 NM south of Fusina*

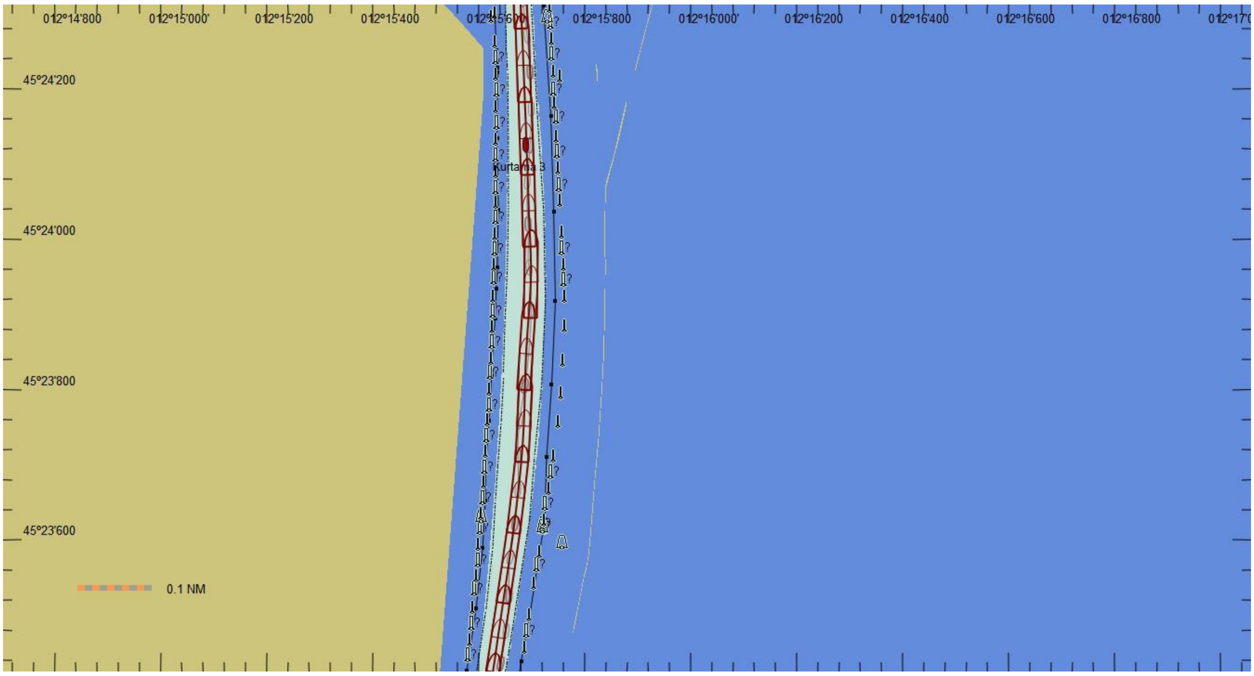


Run 301. *Approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

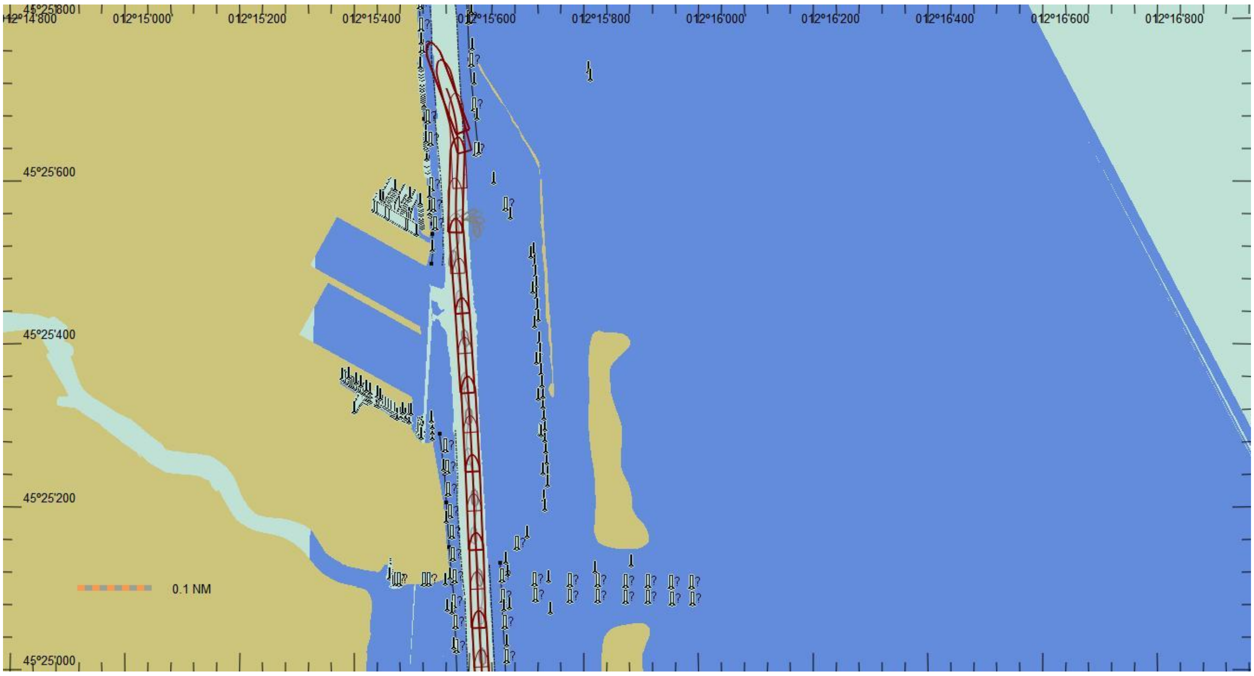
302	Container vsl 3601	inbound	7.5	NE	Max Ebb Tide	180	0.3	NE	3.7	6



Run 302. *Beginning the navigation in proximity of San Leonardo bend. Arrival. Duration 00:58:51. Rain, visibility 2 nm.*

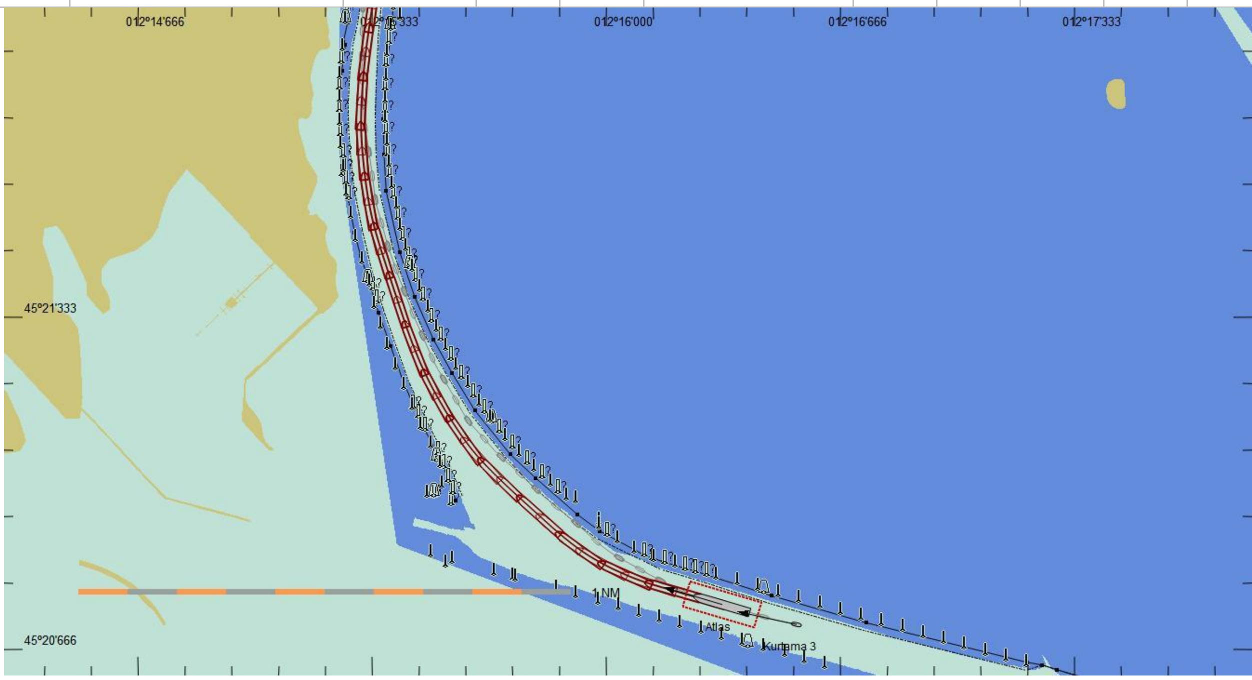


Run 302. *Bend at 2 NM south of Fusina*

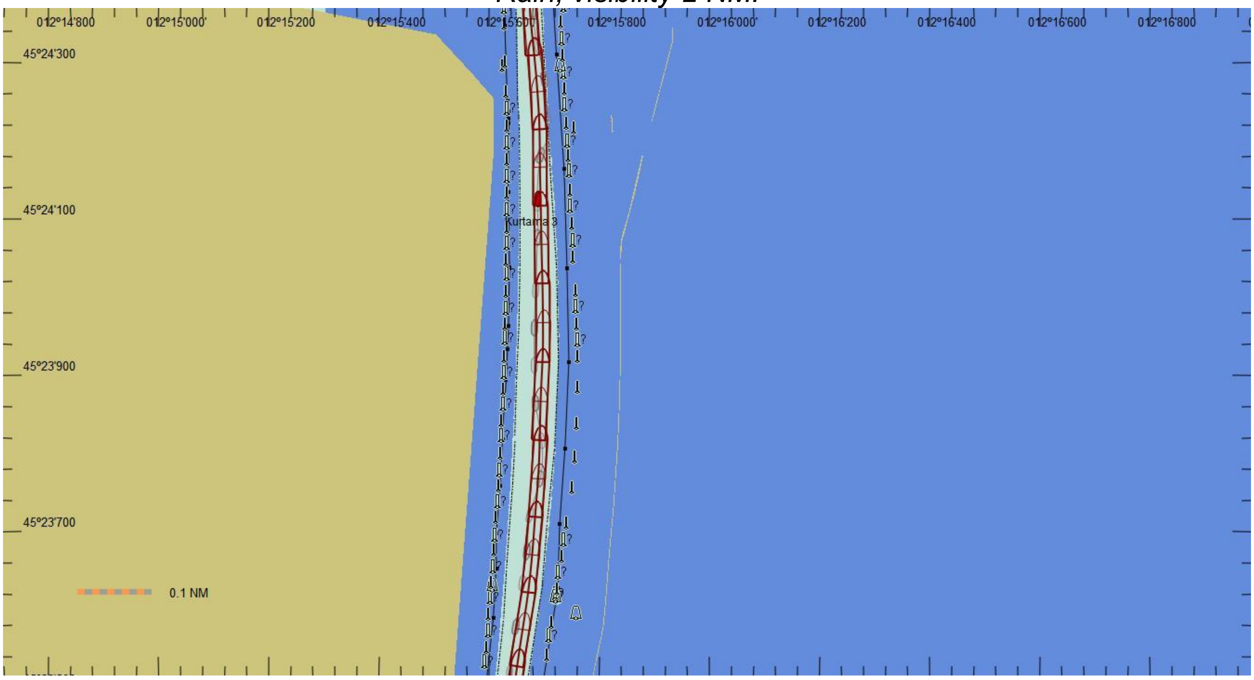


Run 302. *Approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

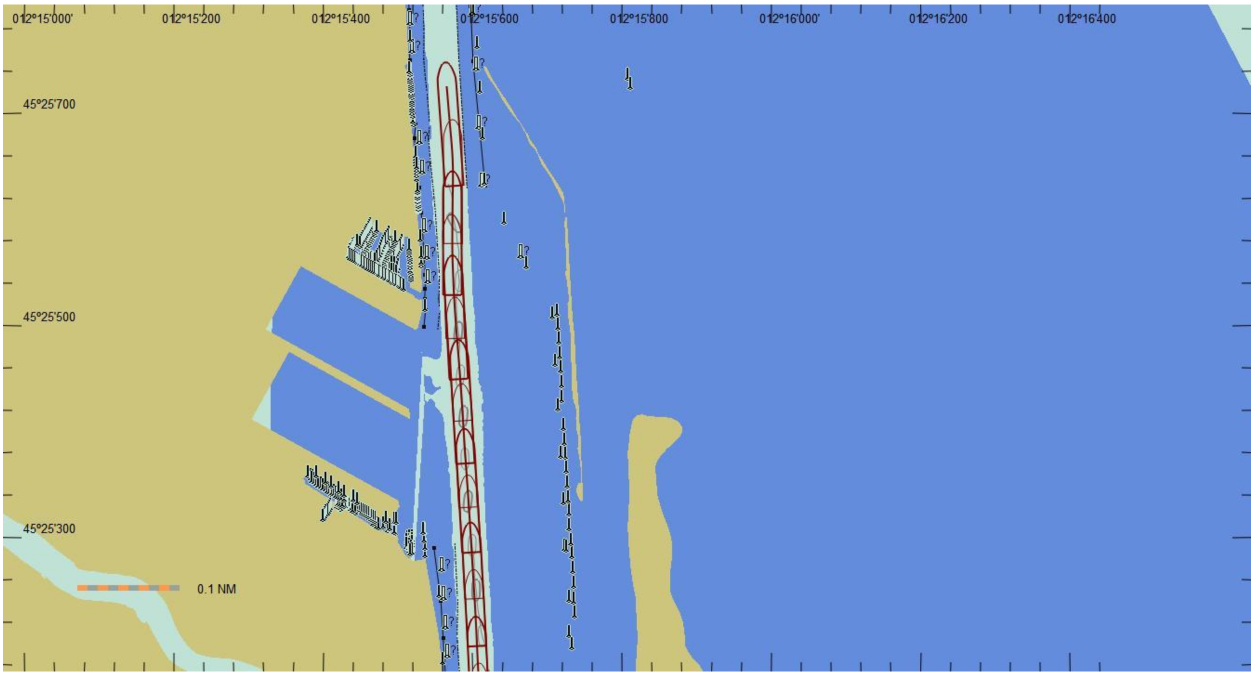
303	Container vsl 3601	inbound	10	E	Max Ebb Tide	180	0.3	NE	3.7	6



Run 303. *Beginning the navigation in proximity of San Leonardo bend. Arrival. Duration 00:56:54. Rain, visibility 2 NM.*

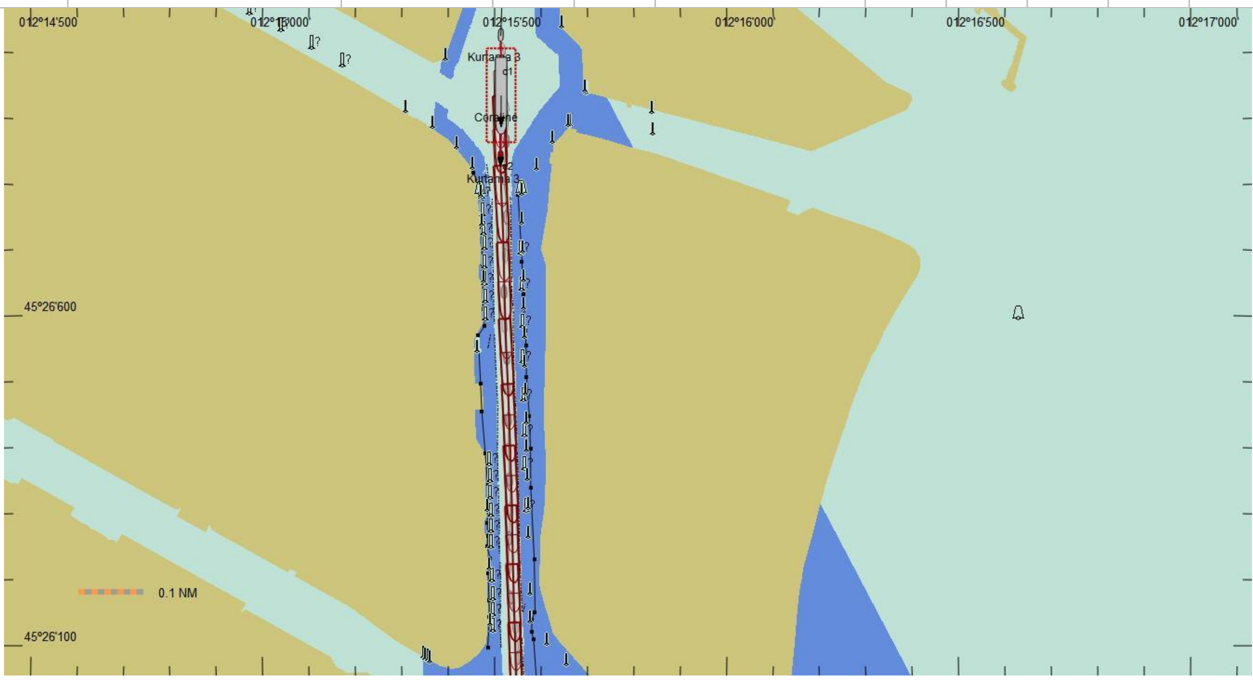


Run 303. *Bend at 2 NM south of Fusina*

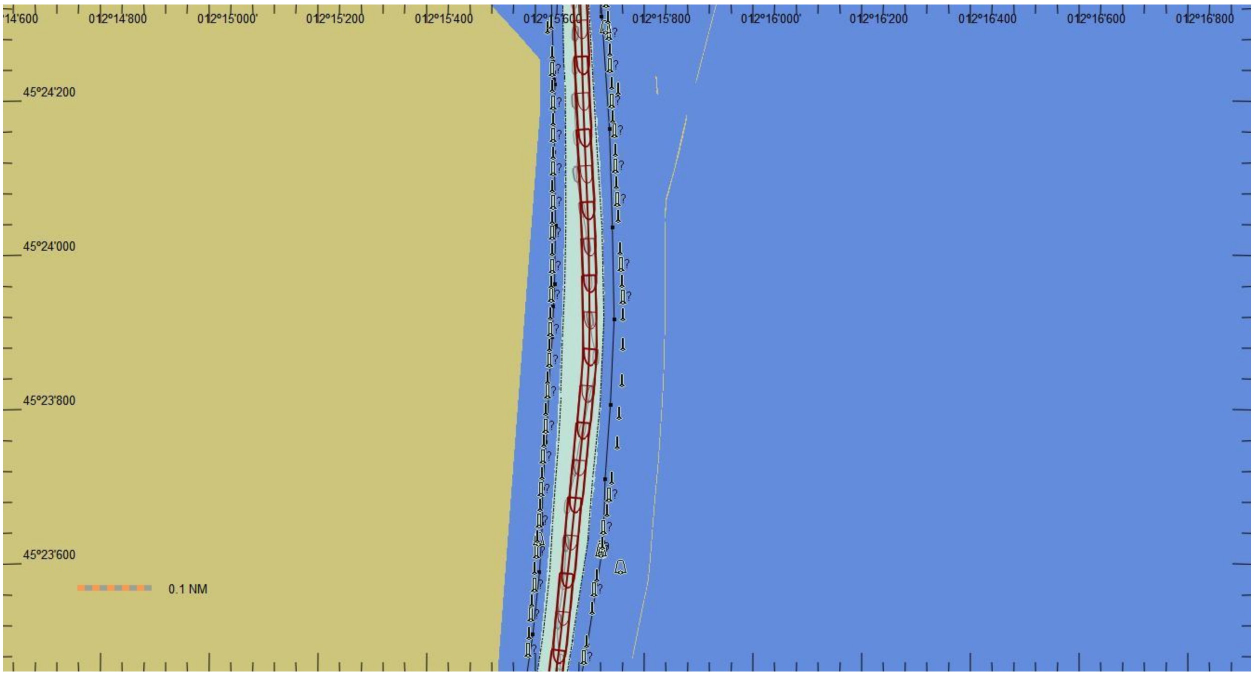


Run 303. *Approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

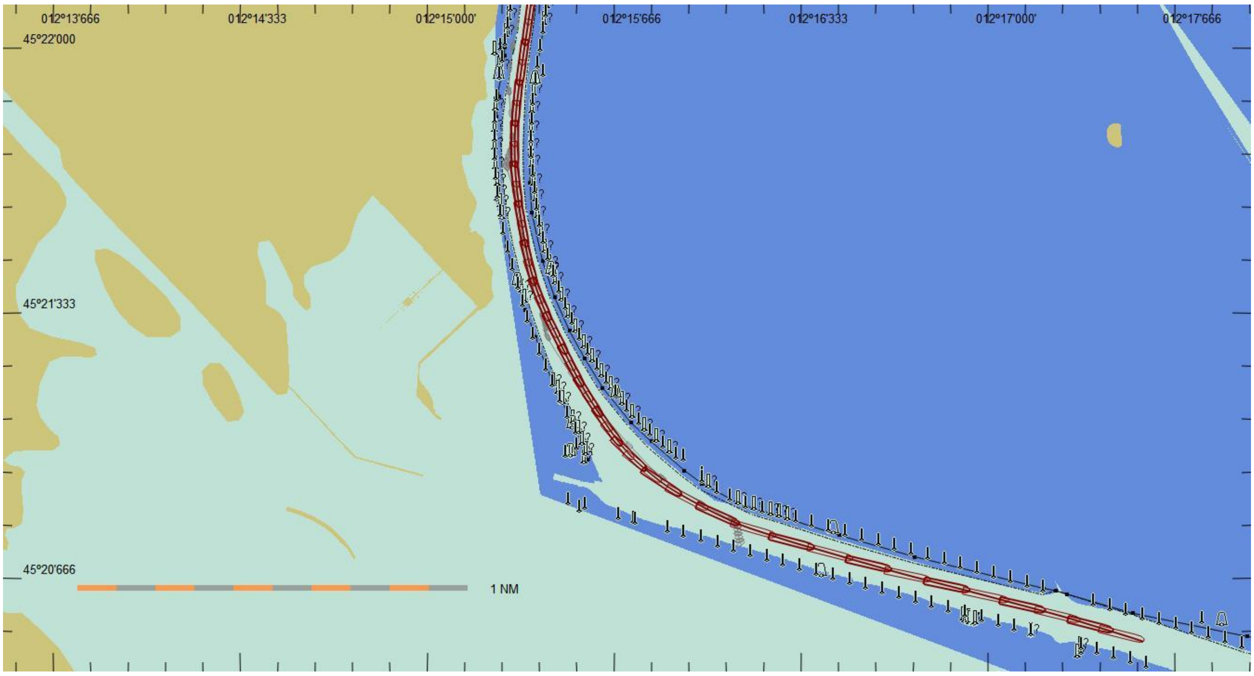
304	Container vsl 3483	outbound	10	E	Max Ebb Tide	180	0.3	NE	3.7	6



Run 304. *Beginning the navigation in the north part of the channel (north of Fusina quay). Departure. Duration 01:08:54.*

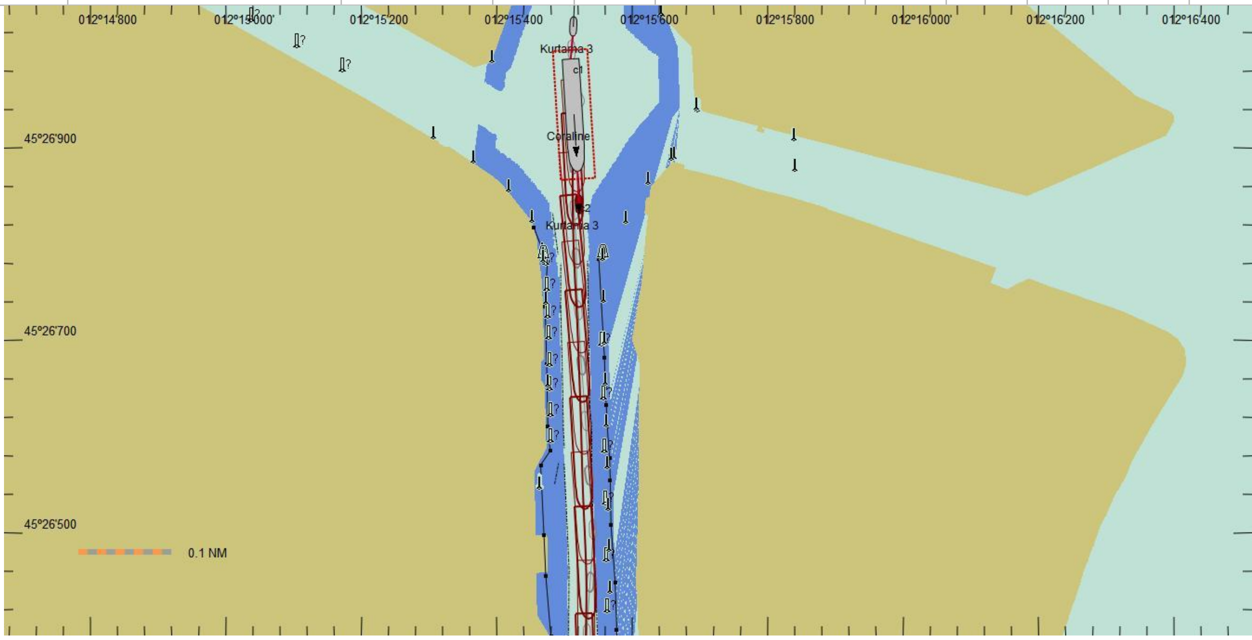


Run 304. *Bend at 2 NM south of Fusina*

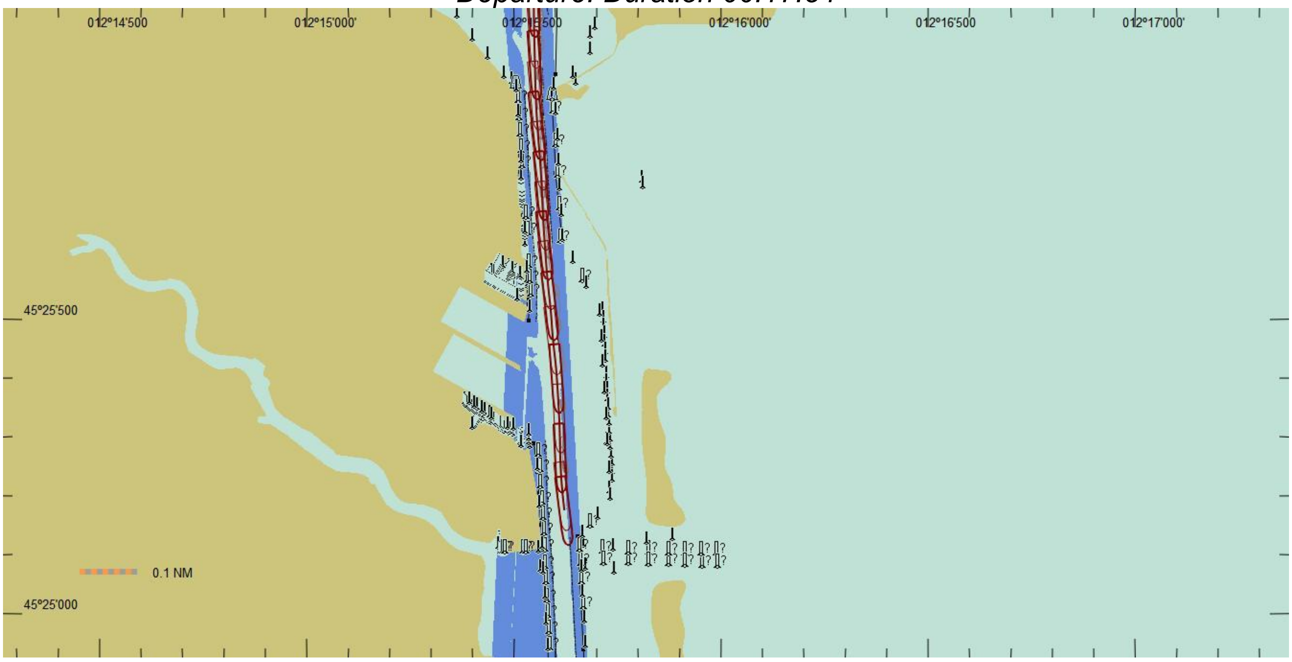


Run 304. *Approaching the end of the navigation, south part of the channel, after San Leonardo bend.*

305	Container vsl 3483	outbound	15	E	Max Ebb Tide	180	0.3	NE	3.7	6

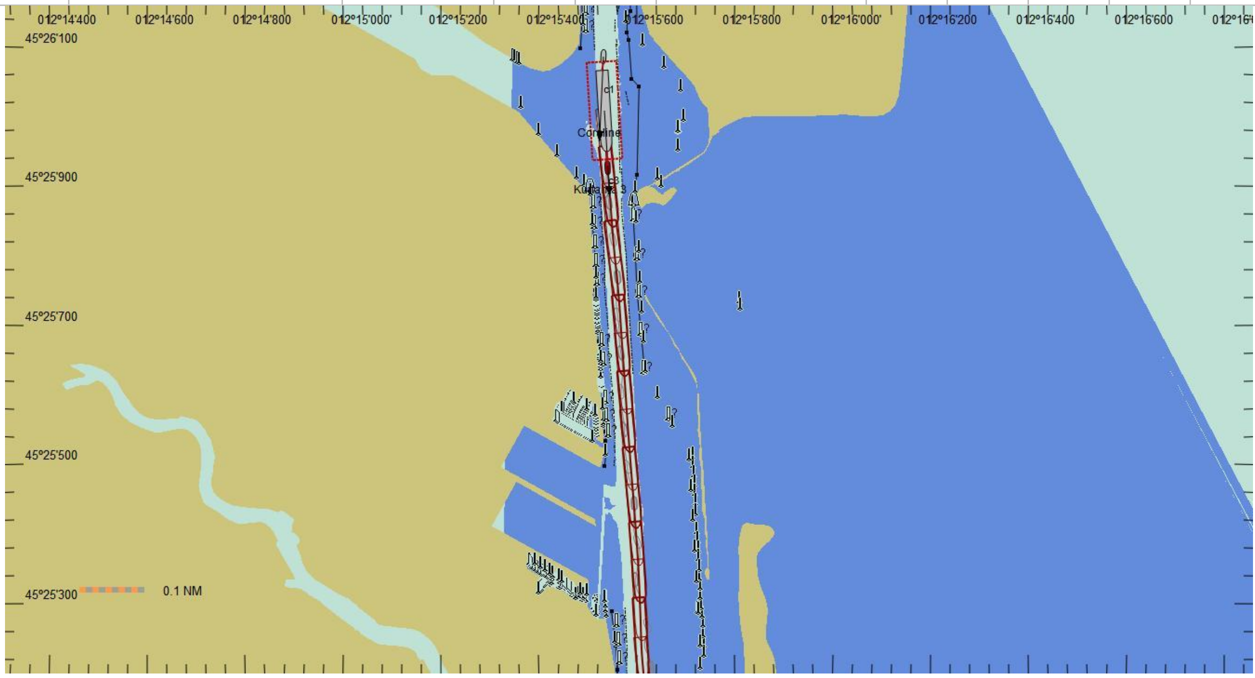


Run 305. *Beginning the navigation in the north part of the channel (north of Fusina quay). Departure. Duration 00:17:54*

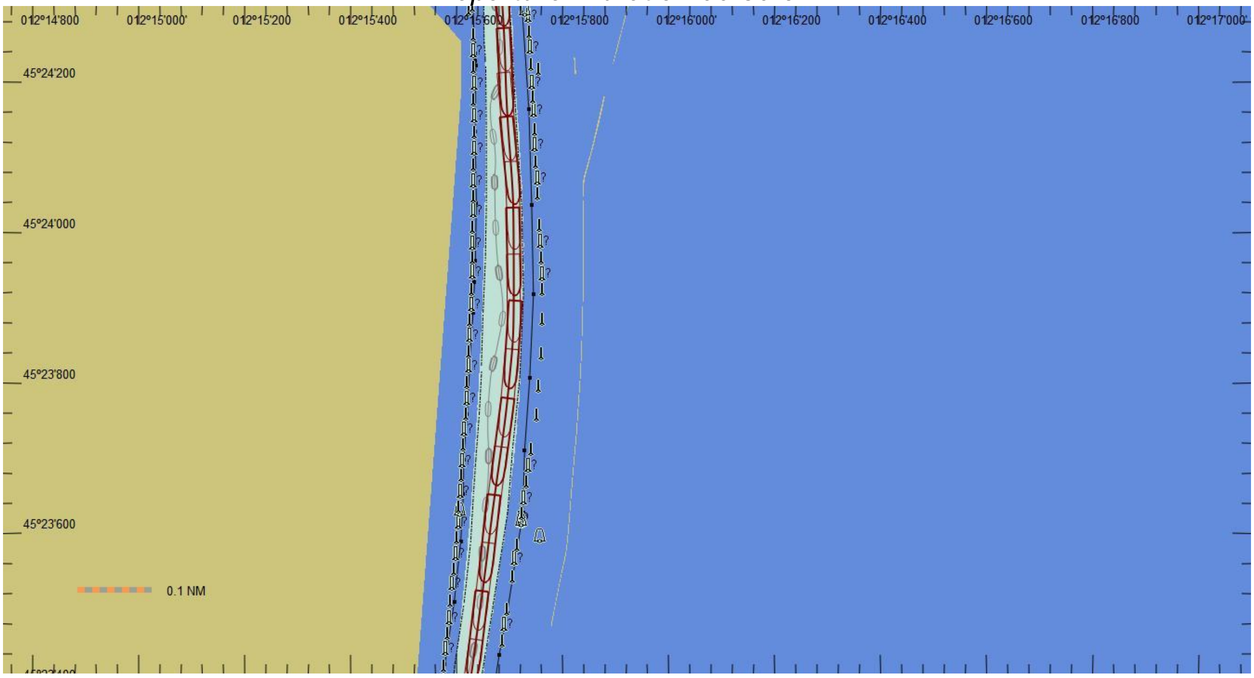


Run 305. *The ship is approaching the end of the navigation, in proximity of Fusina basin.*

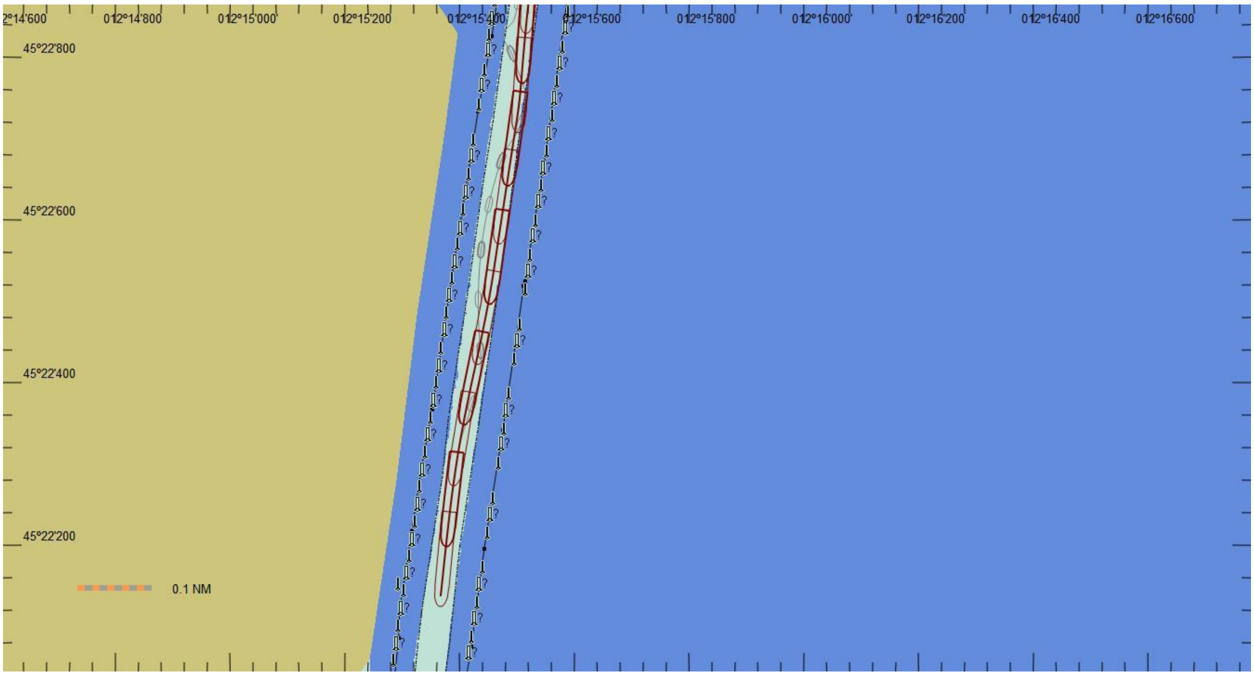
306	Container vsl 3483	outbound	15	E	Max Ebb Tide	180	0.3	NE	3.7	6



Run 306. *Beginning the navigation in the north part of the channel (north of Fusina quay). Departure. Duration 00:30:51.*

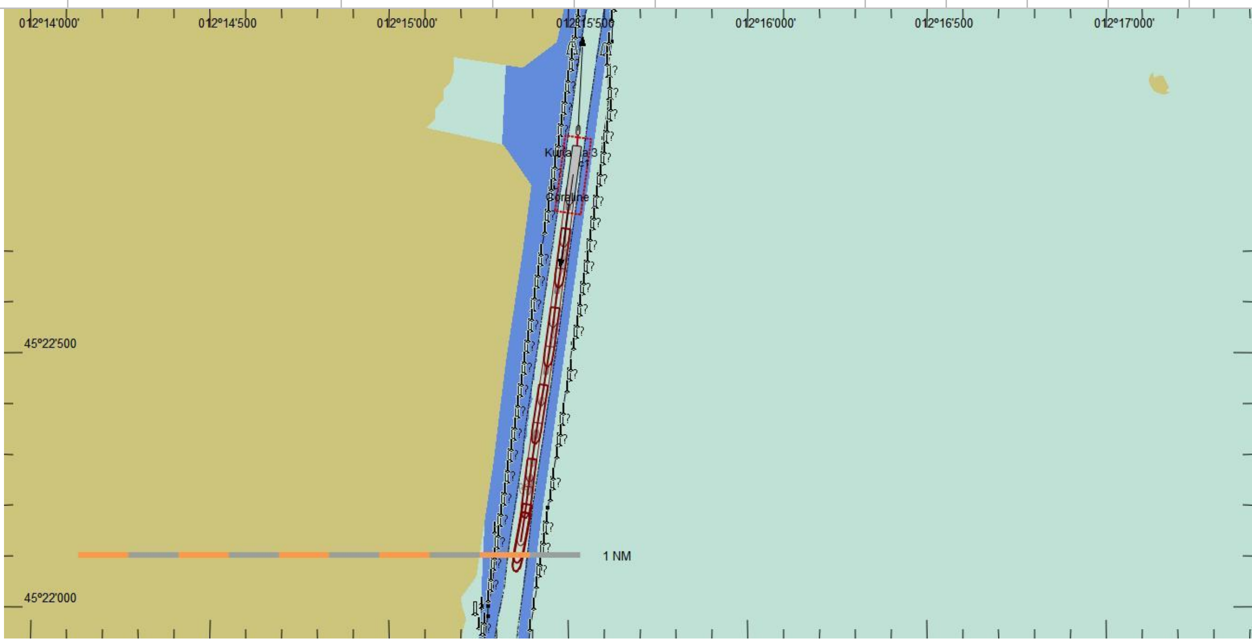


Run 306. *Bend at 2 NM south of Fusina*



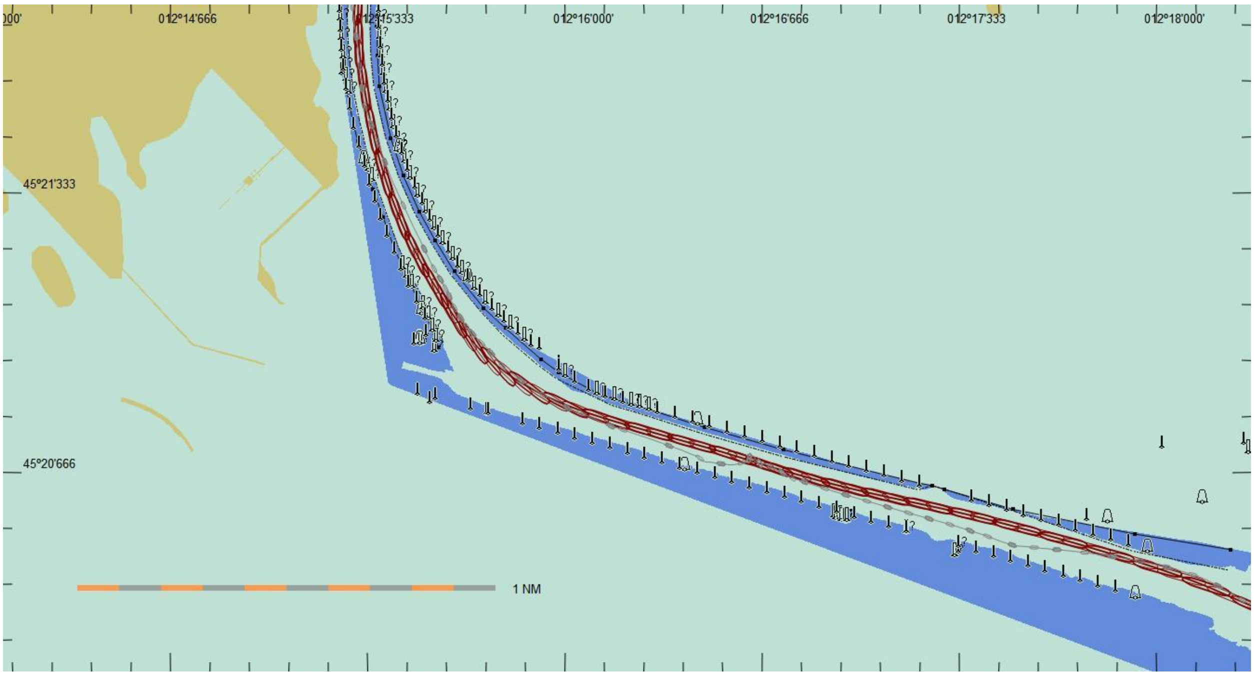
Run 306. *Approaching the end of the navigation, south of the channel, between Fusina quay and San Leonardo bend.*

307	Container vsl 3483	outbound	5	NE	Max Ebb Tide	180	0.3	NE	3.7	6

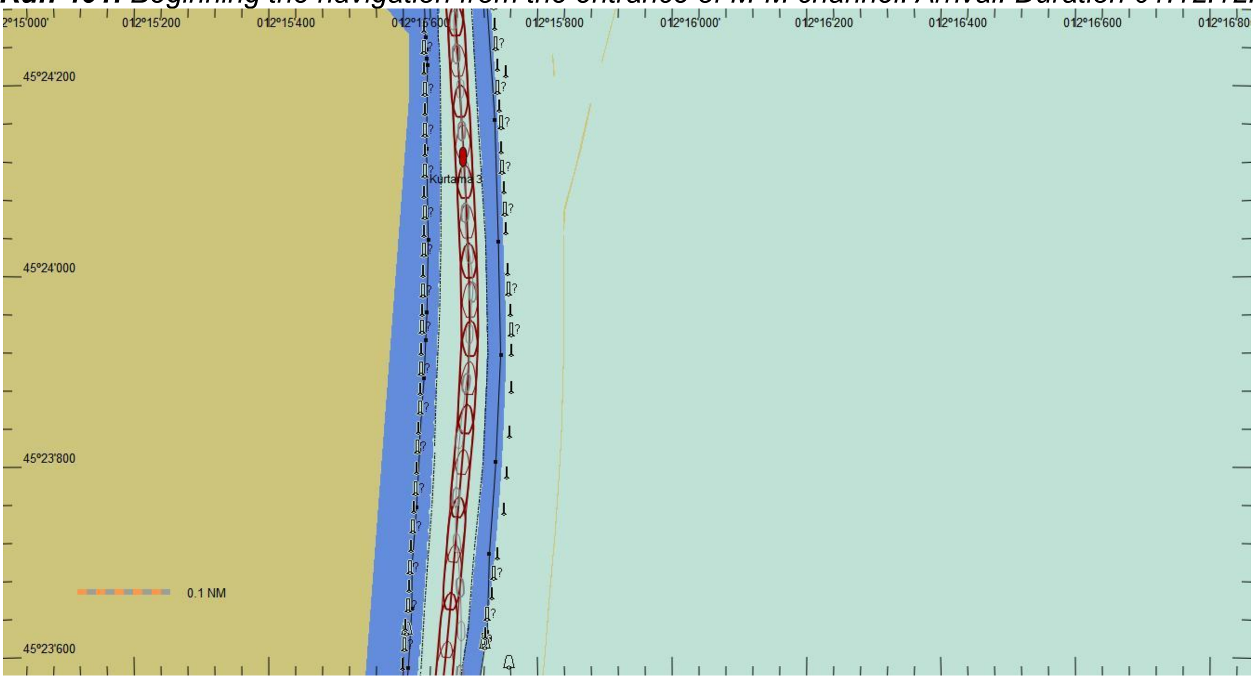


Run 307. *Begin and of the navigation Between Fusina and San Leonardo bend. Departure. Duration 00:06:04. Emergency situation.*

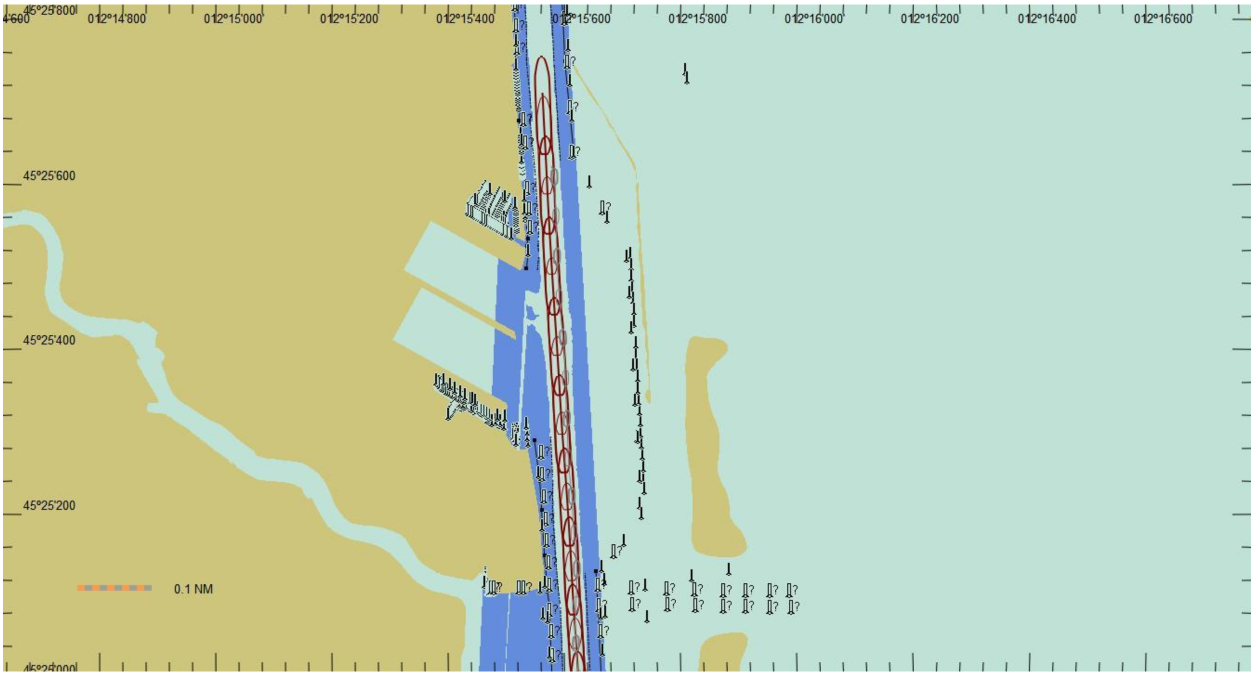
401	Bulk Carrier 3312	inbound	10	NE	Max Flood Tide	360	0.3	NE	3.7



Run 401. *Beginning the navigation from the entrance of M-M channel. Arrival. Duration 01:12:12.*

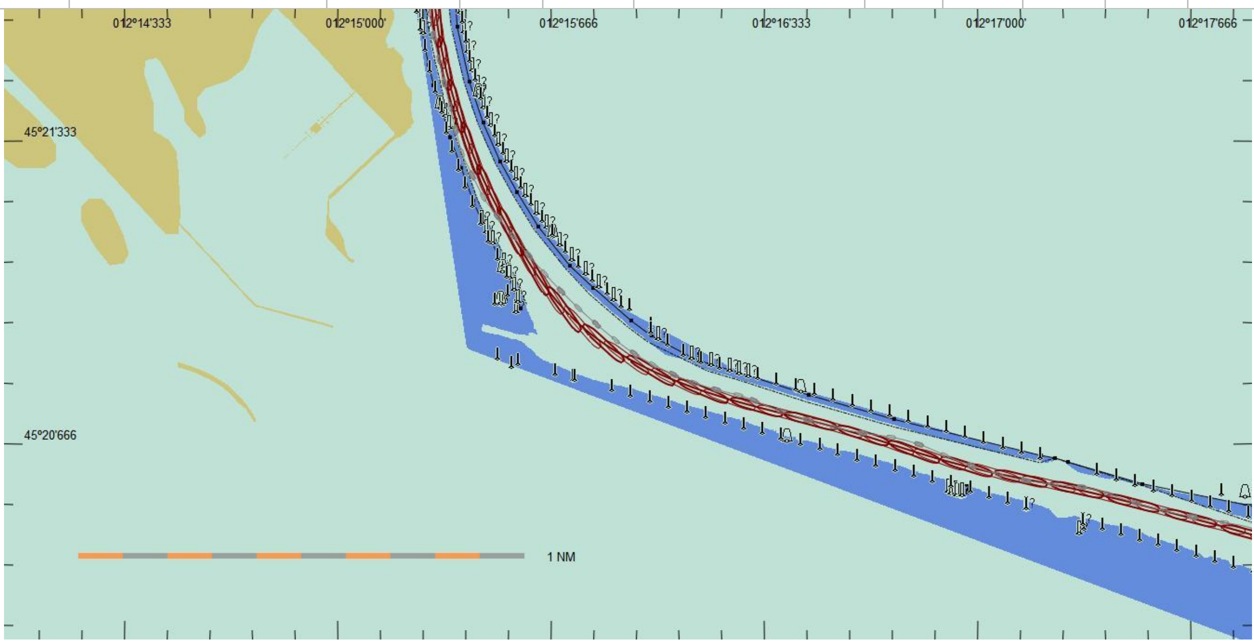


Run 401. *Bend at 2 NM south of Fusina*

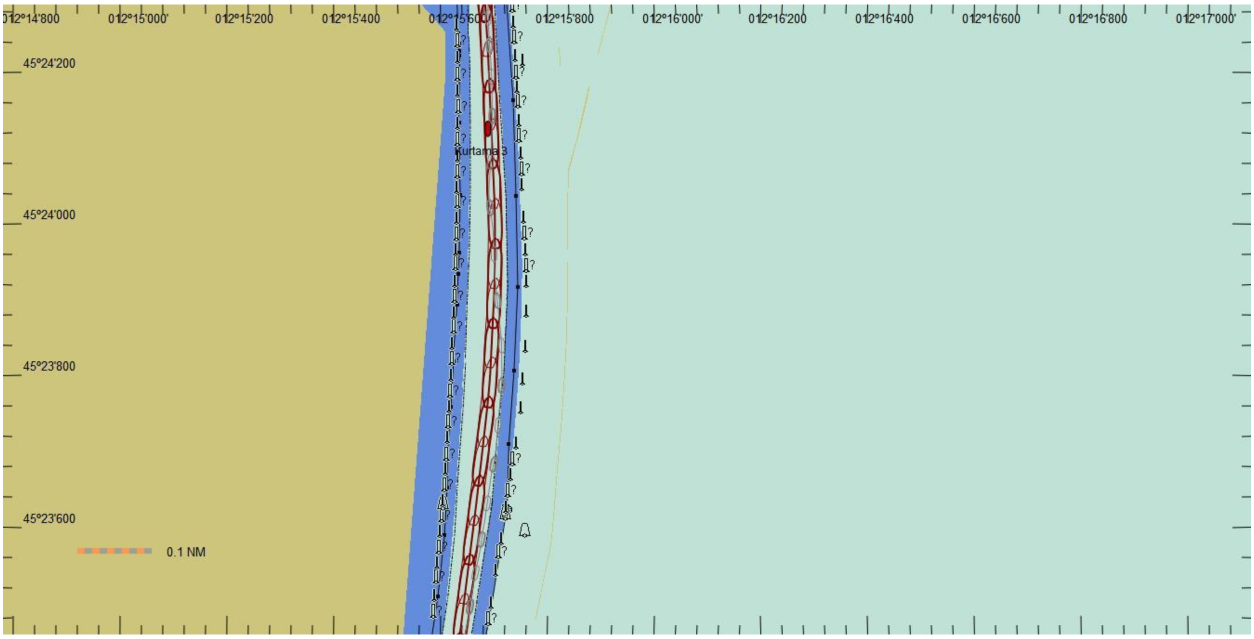


Run 401. *Approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

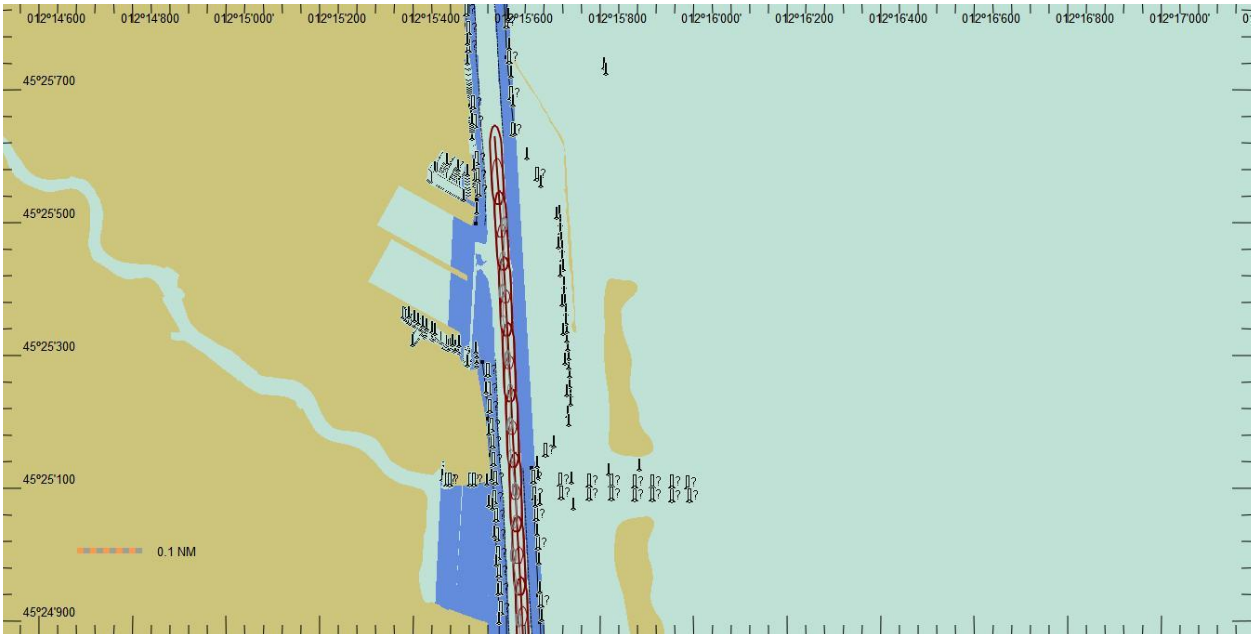
402	Bulk Carrier 3481	inbound	15	NNE	Max Flood Tide	360	0.3	NE	3.7	8/9



Run 402. *Beginning the navigation from the south entrance of the M-M channel. Arrival. Duration 01:06:28.*

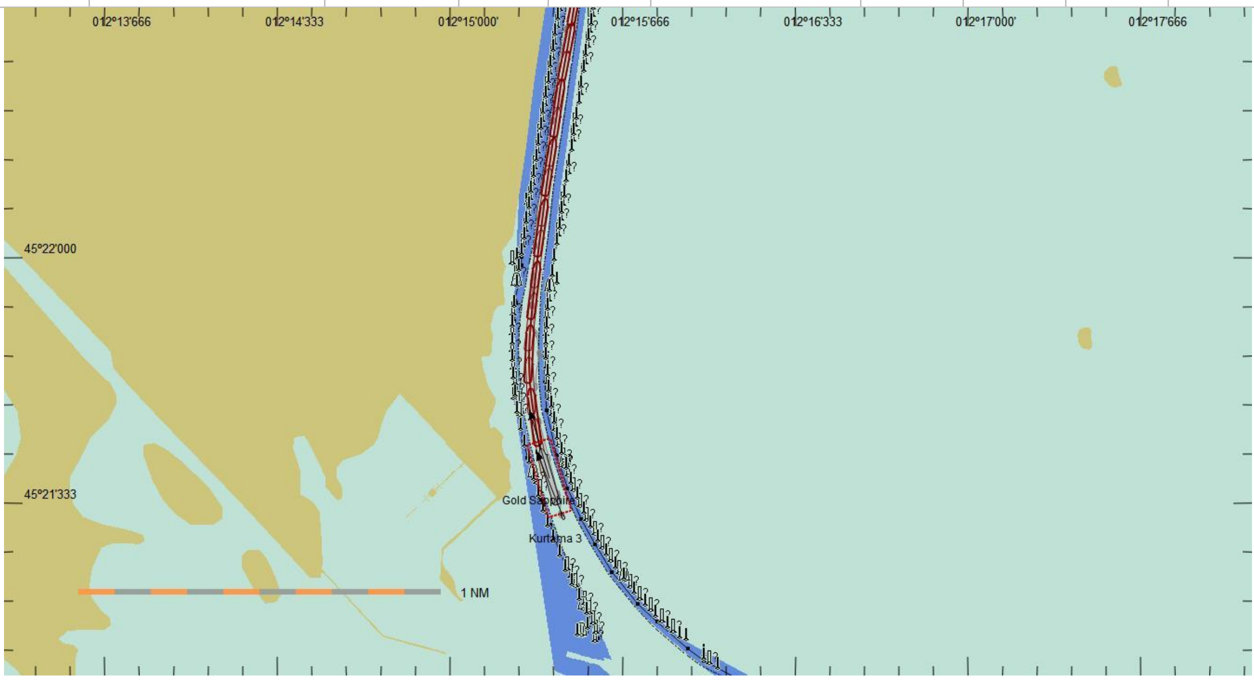


Run 402. *Bend at 2 NM south of Fusina*

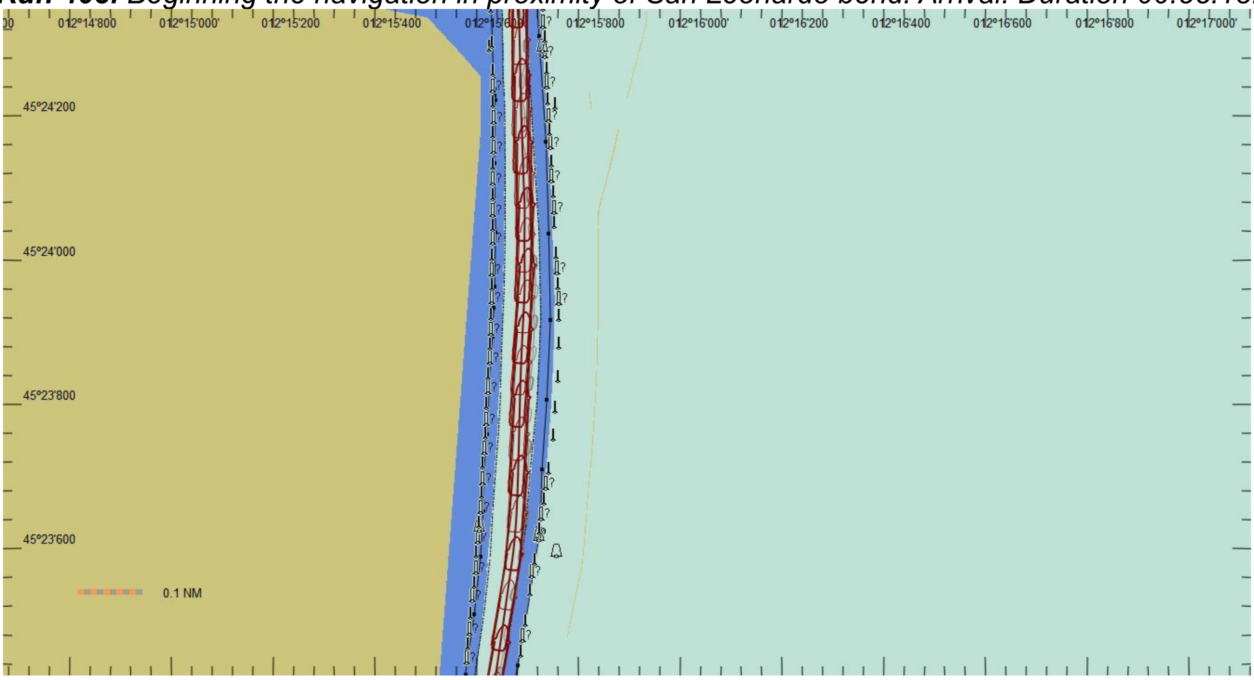


Run 402. *The ship is approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

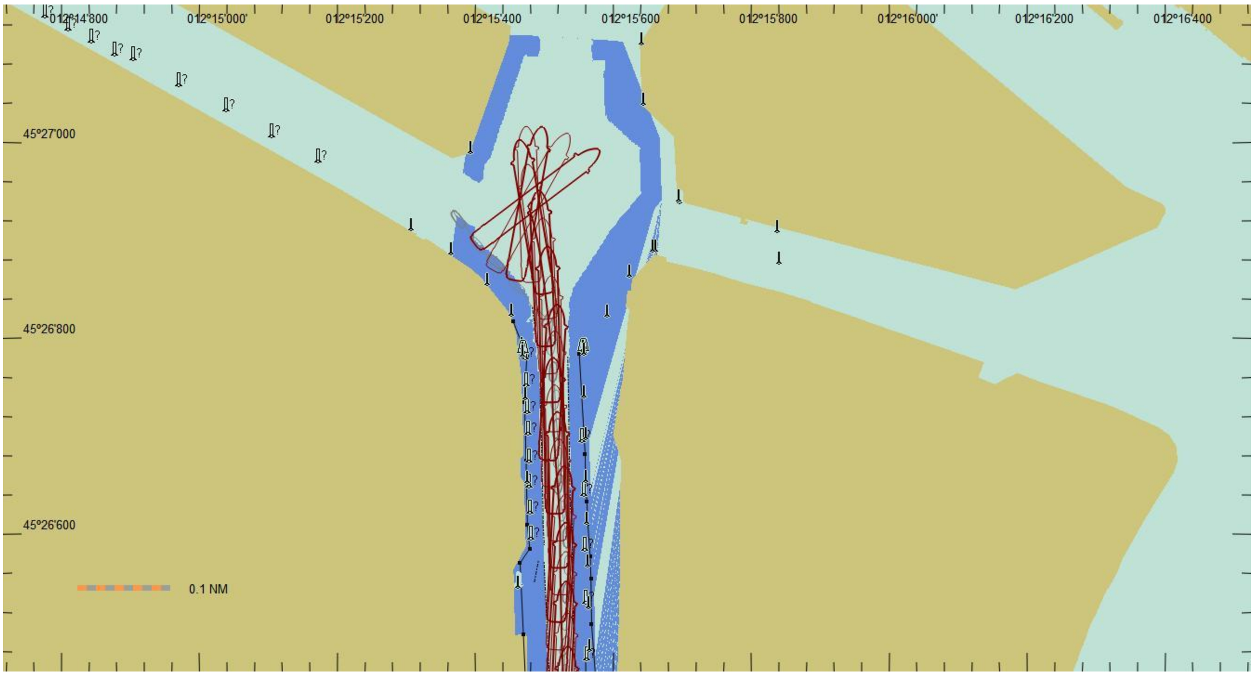
403	Cruise Vsl 3644	inbound	10	E	Max Ebb Tide	180	0.3	NE	3.7



Run 403. *Beginning the navigation in proximity of San Leonardo bend. Arrival. Duration 00:55:13.*

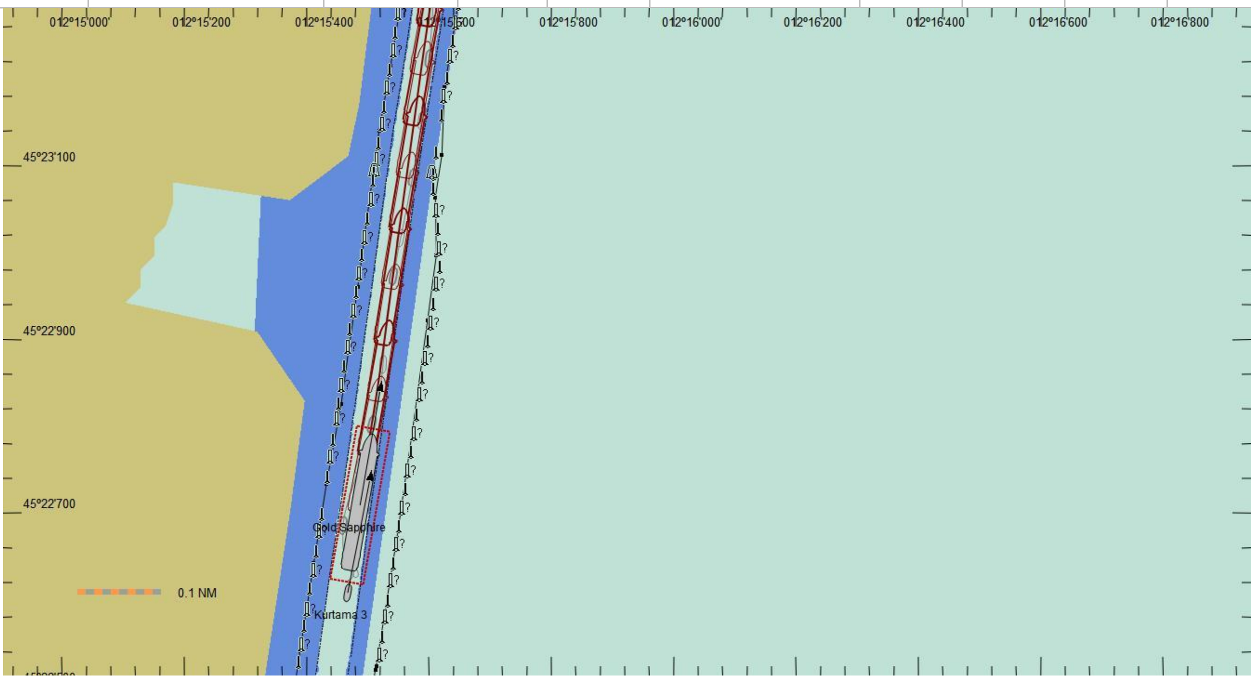


Run 403. *Bend at 2 NM south of Fusina*

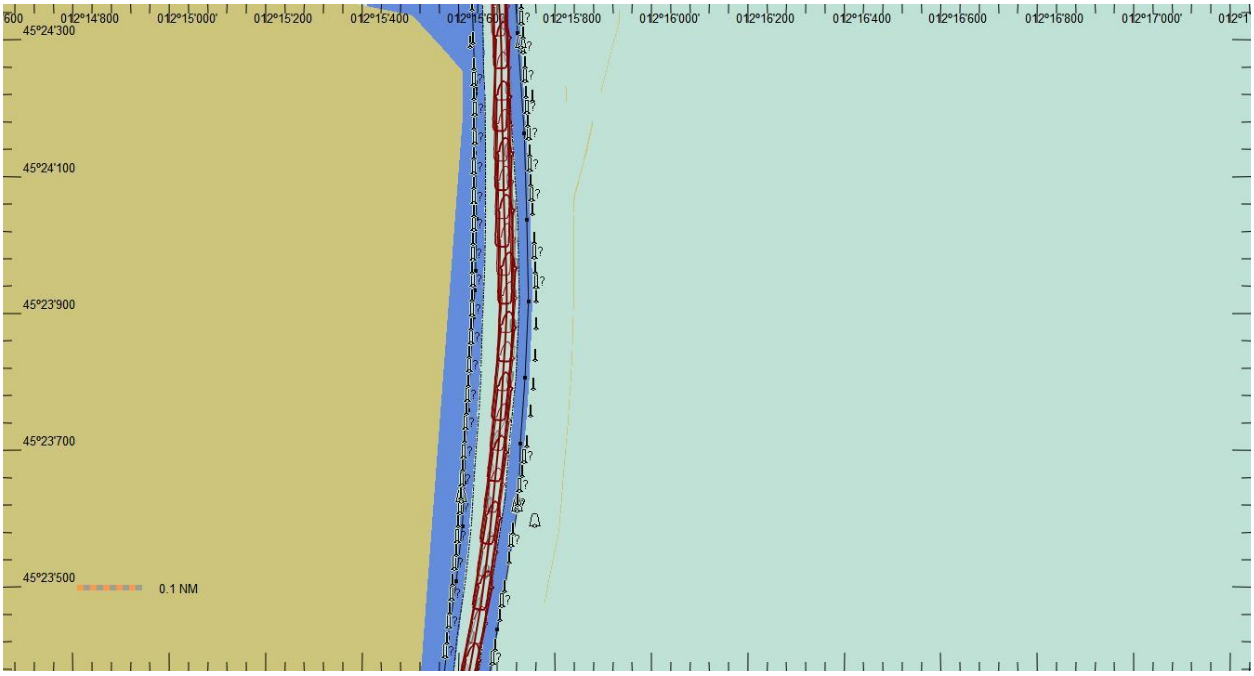


Run 403. *Approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

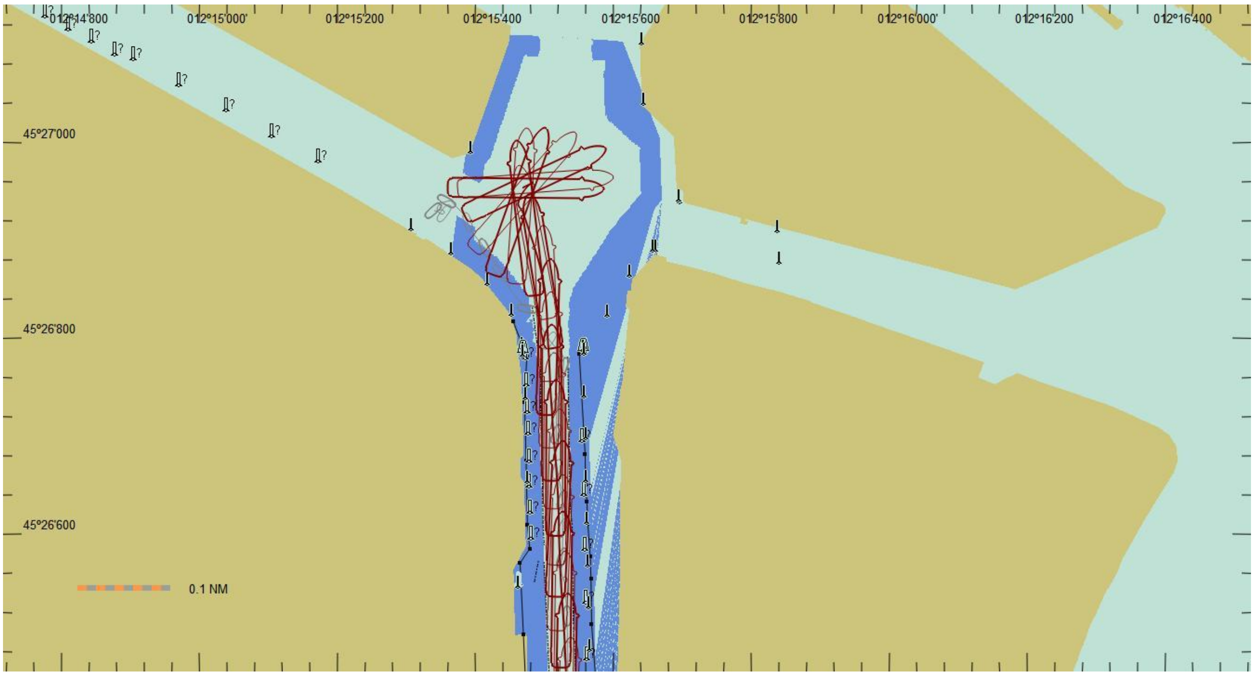
404	Cruise Vsl 3644	inbound	10	NE	Max Ebb Tide	180	0.3	NE	3.7



Run 404. *Beginning the navigation between Fusina basin and San Leonardo bend. Arrival. Duration 00:50:02.*

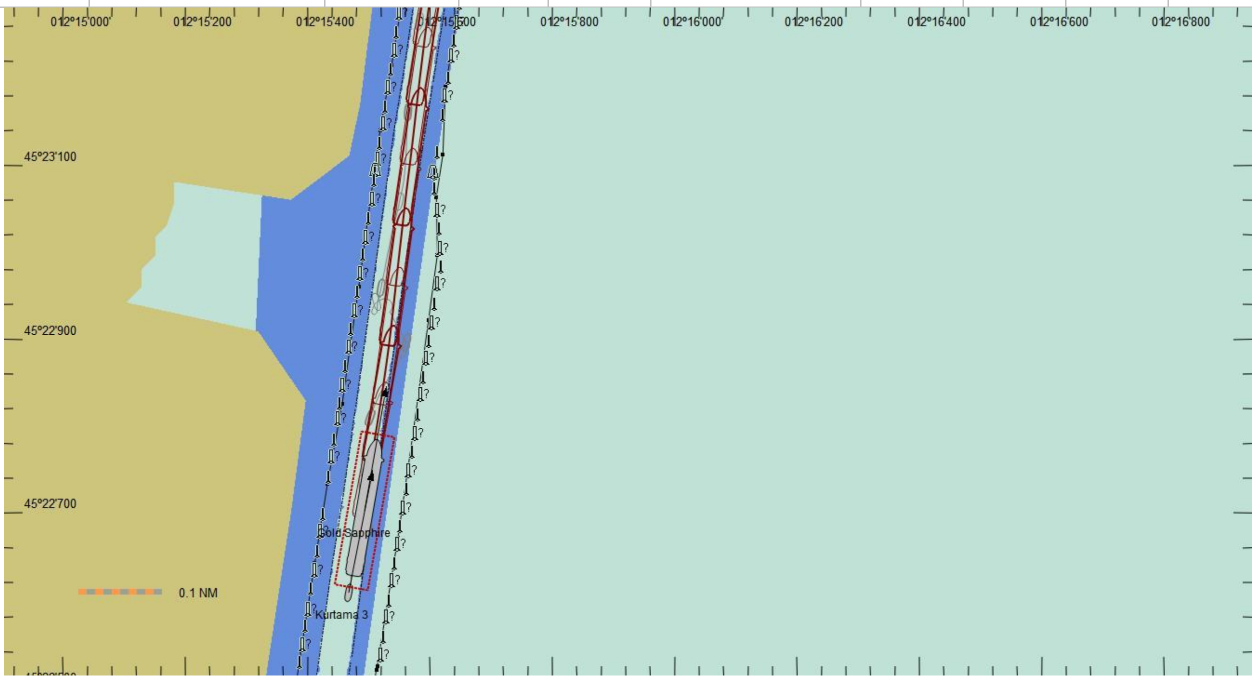


Run 404. *Bend at 2 NM south of Fusina*

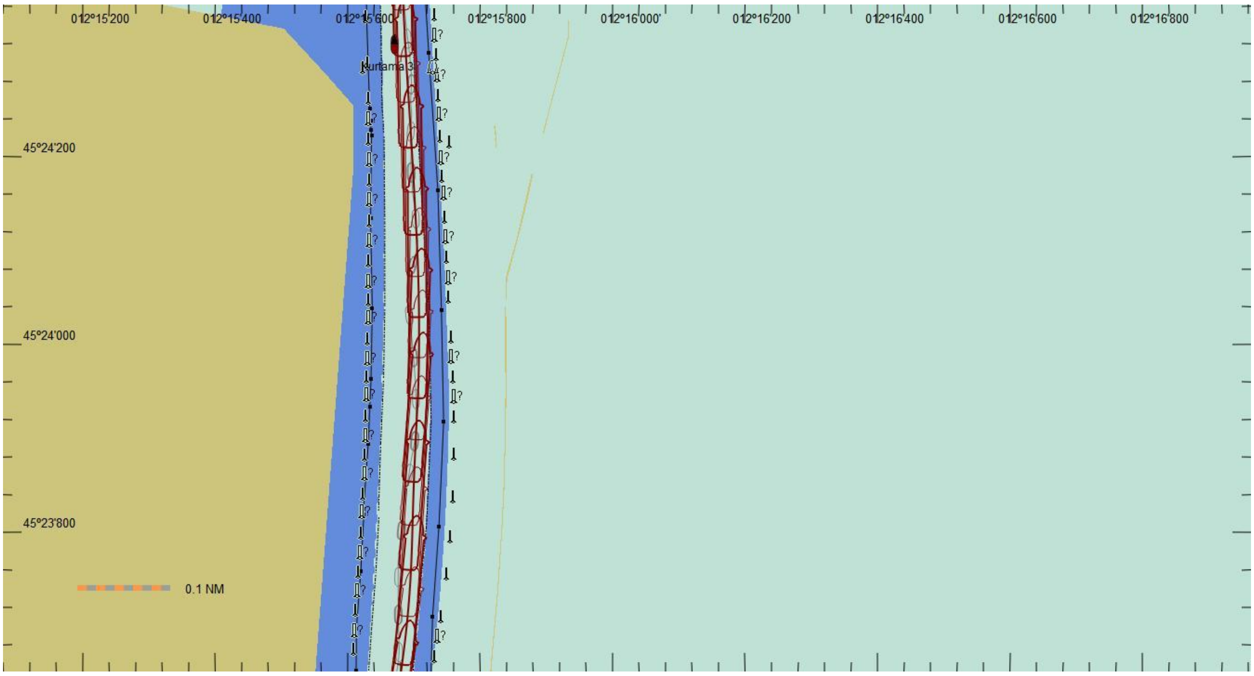


Run 404. *Approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

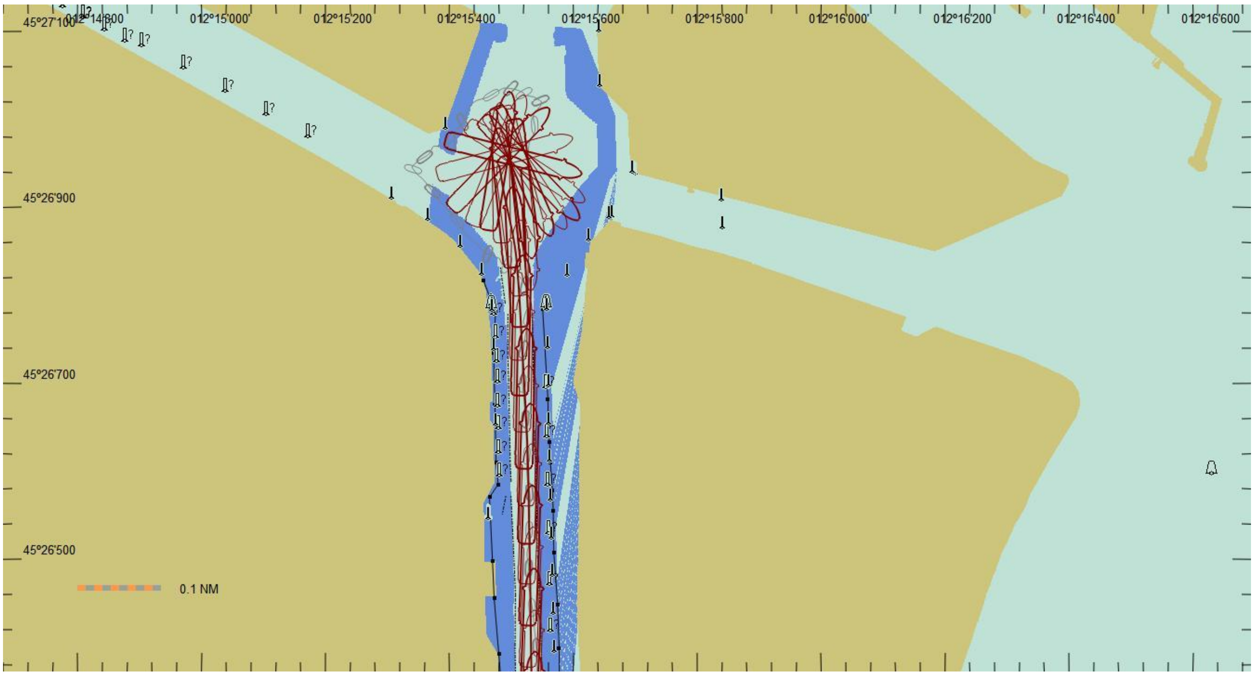
405	Cruise Vsl 3644	inbound	10	NE	Max Ebb Tide	180	0.3	NE	3.7



Run 405. *Beginning of the navigation between Fusina basin and San Leonardo bend. Arrival. Duration 00:49:00.*

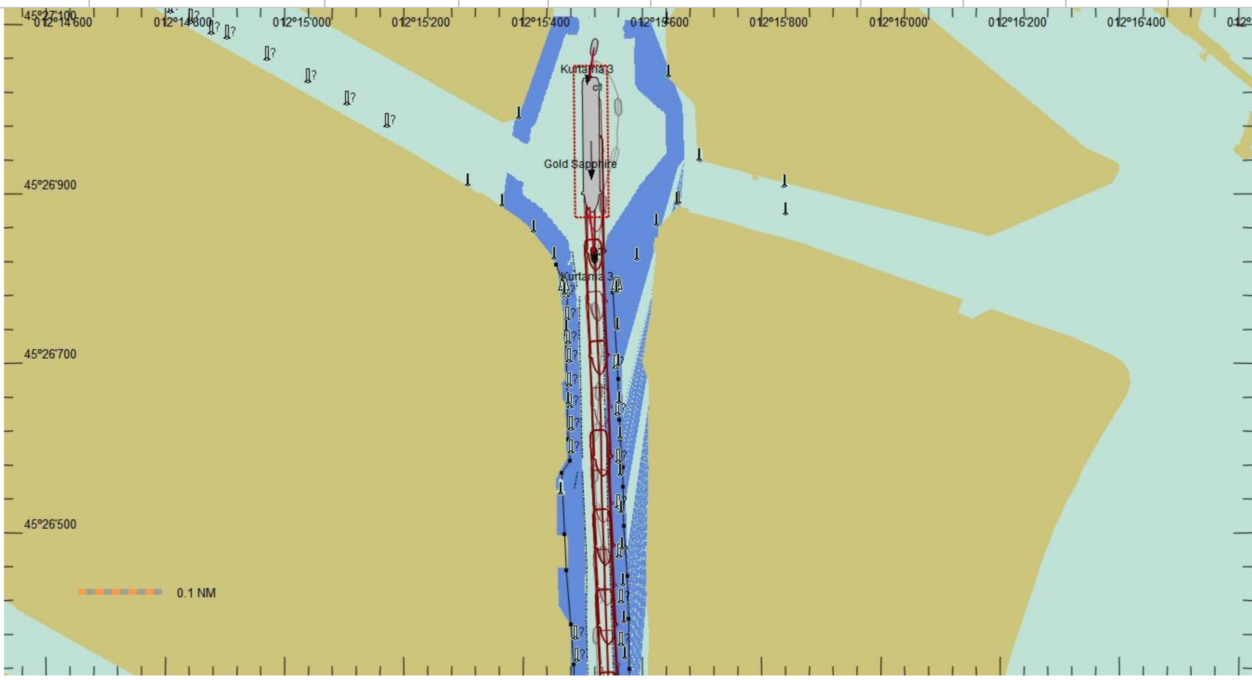


Run 405. *Bend at 2 NM south of Fusina*

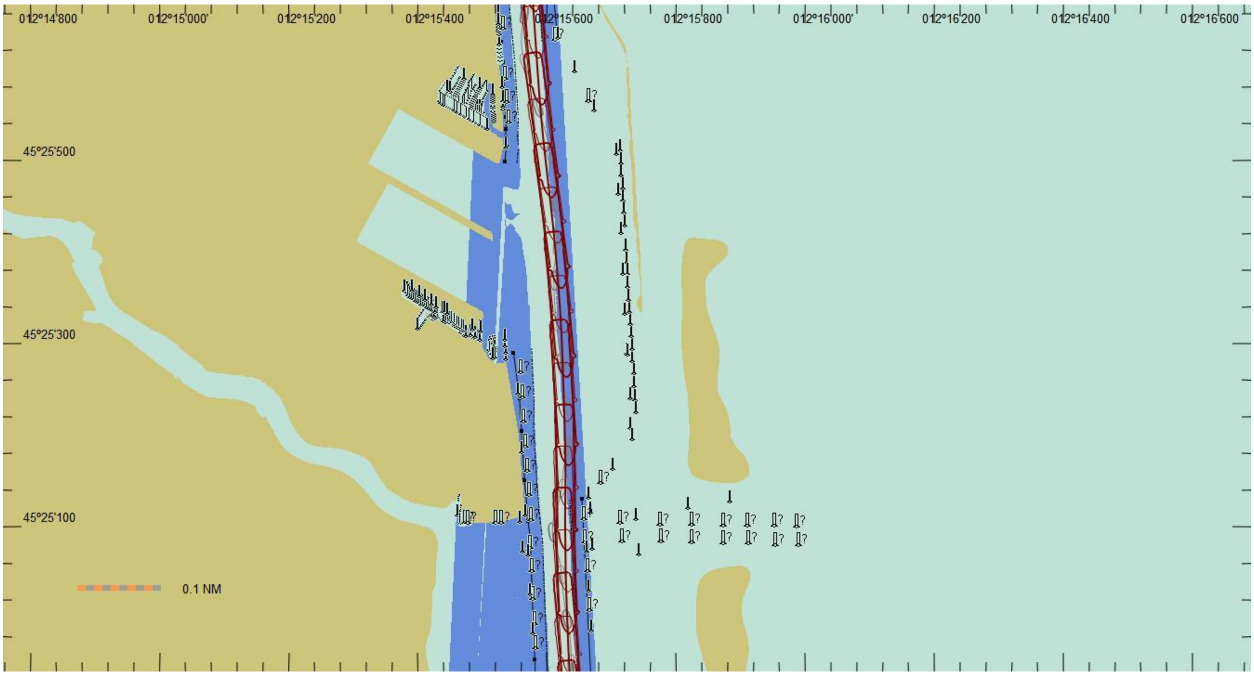


Run 405. *Approaching the end of the navigation, in the north part of the channel, after Fusina quay.*

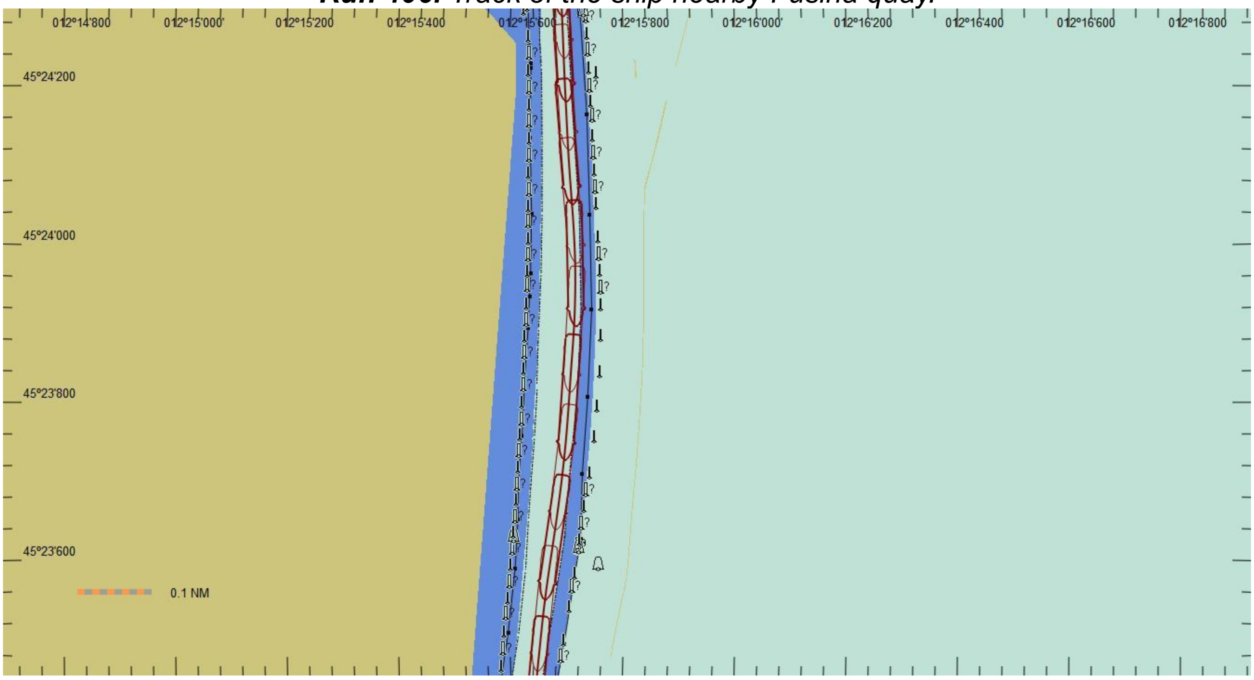
406	Cruise Vsl 3644	inbound	10	NE	Max Ebb Tide	180	0.3	NE	3.7



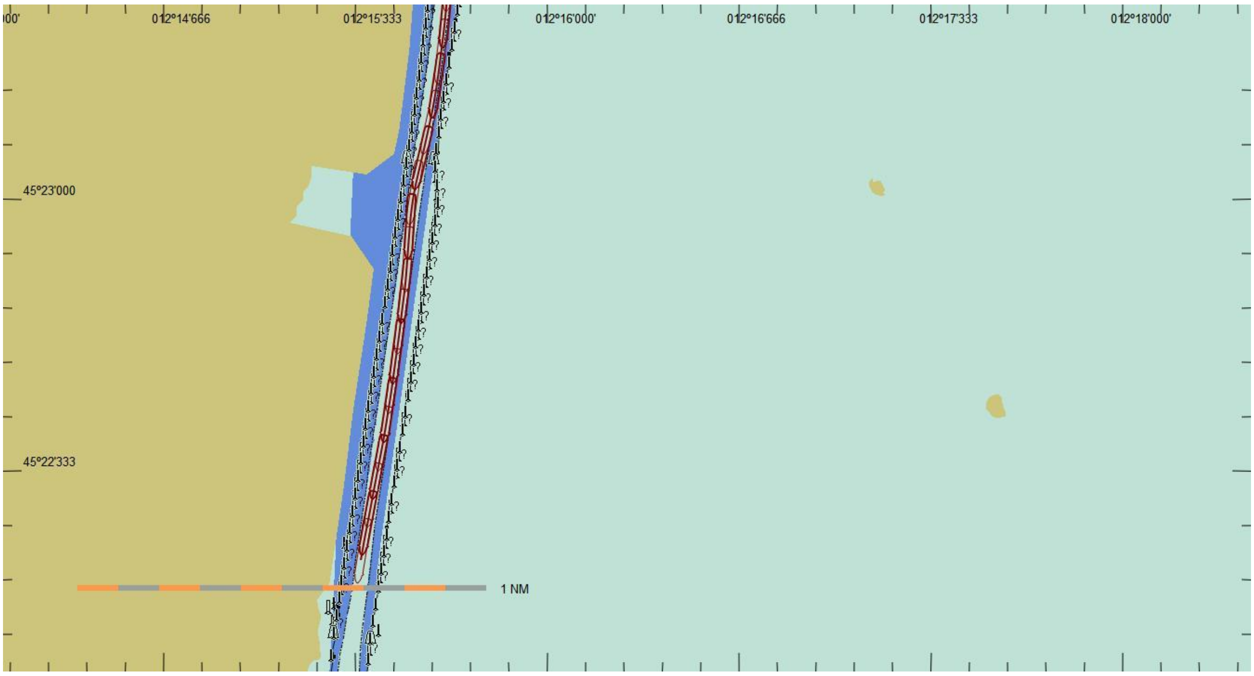
Run 406. *Beginning the navigation in the north part of the channel (north of Fusina quay). Departure. Duration 00:40:44.*



Run 406. *Track of the ship nearby Fusina quay.*



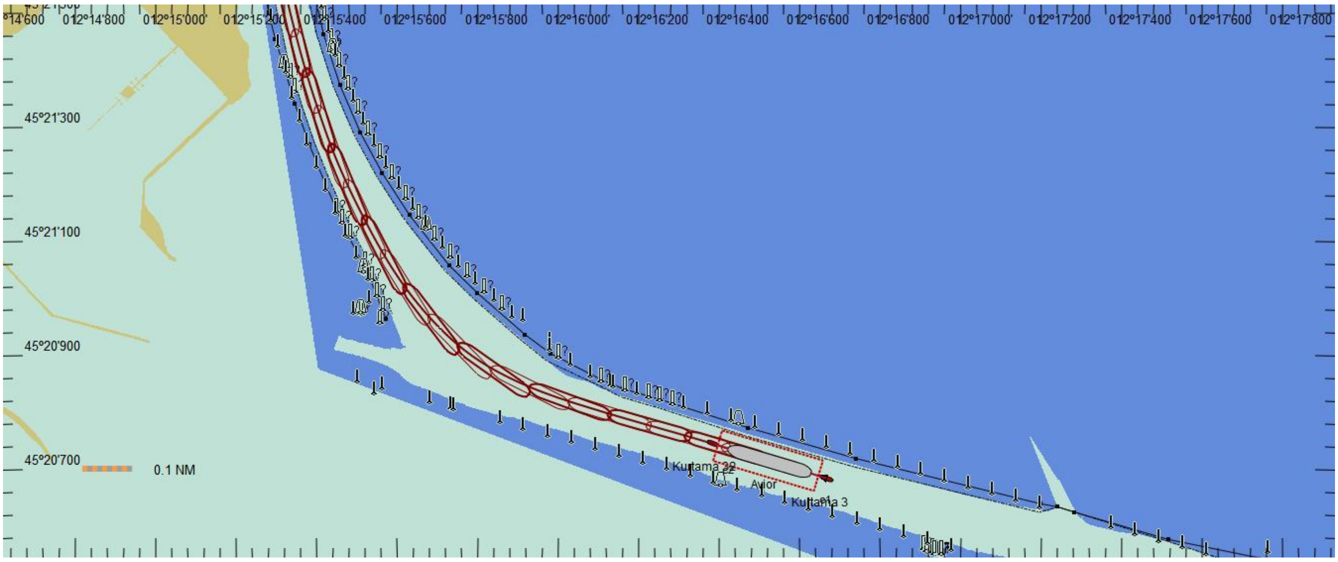
Run 406. *Bend at 2 NM south of Fusina*



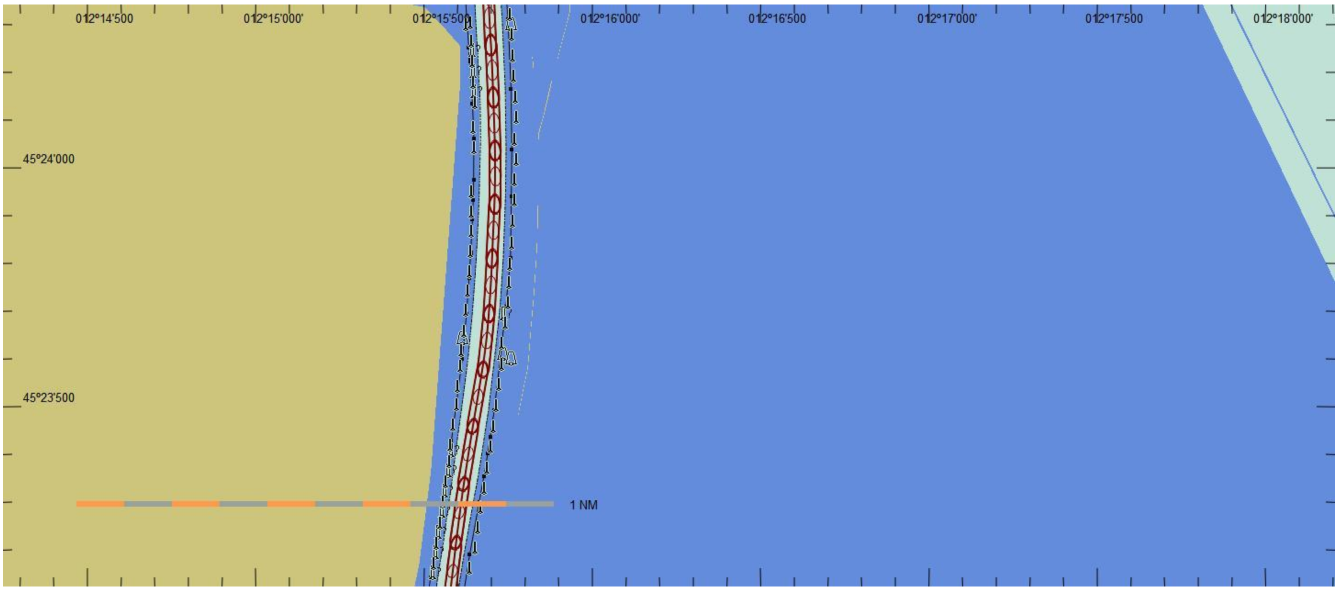
Run 406. *Approaching the end of the navigation, south of the channel, between Fusina quay and San Leonardo bend.*

SCENARIO 3 LAYOUT

Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
19	Ship 12	3763	Bulk	2	10	NE	D

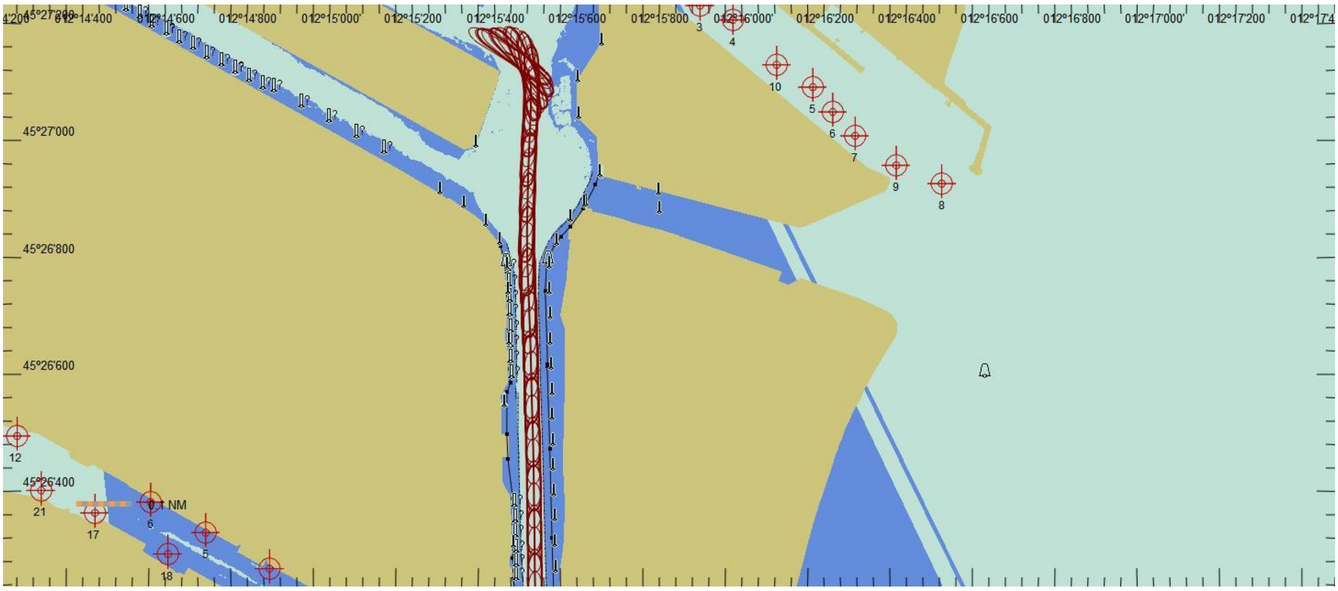


Run 19. From San Leonardo bend to B0018 Piemonte.



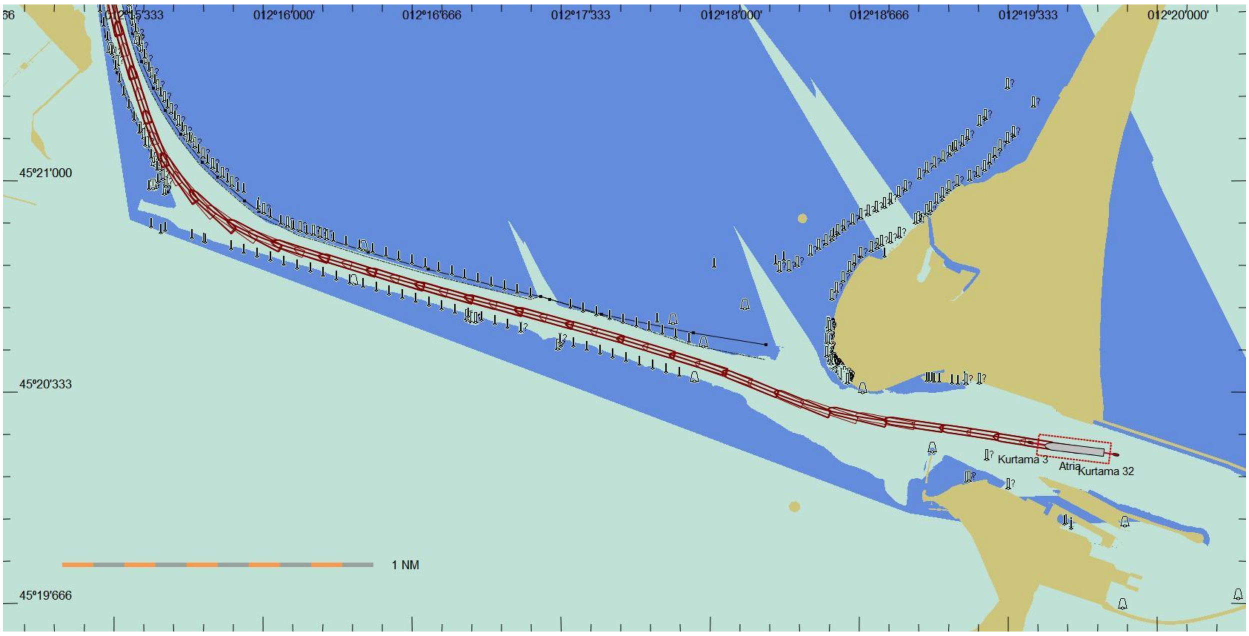
Run 19. From San Leonardo bend to B0018 Piemonte.

Run 19. From San Leonardo bend to B0018 Piemonte.

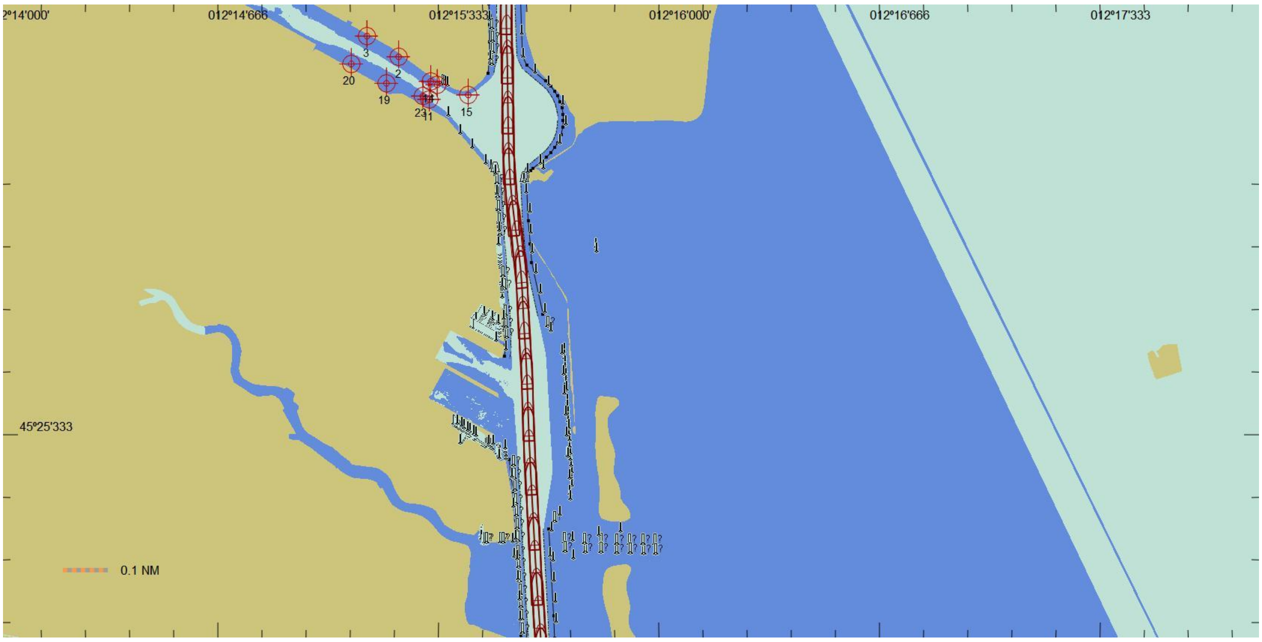


Run 19. From San Leonardo bend to B0018 Piemonte.

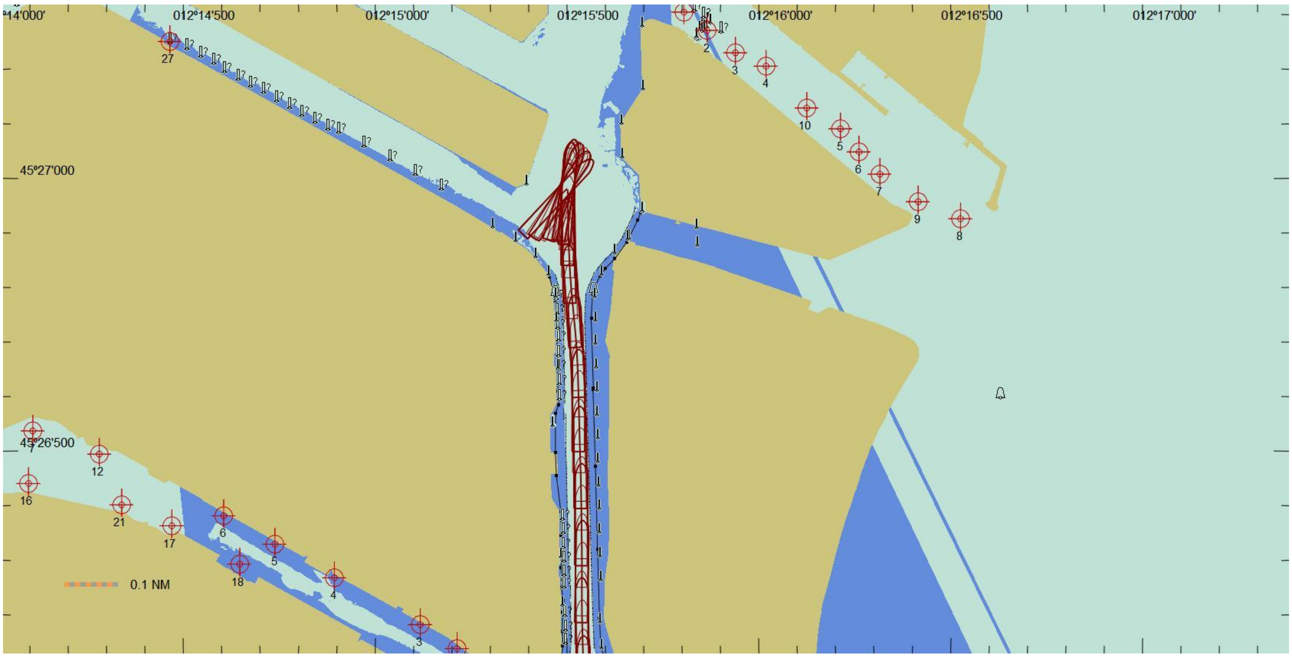
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
20	Ship 13	3725	Container	2	10	NE	D



Run 20. From the entrance of Malamocco to LIGURIA (End of simulation 150 m after basin 3).

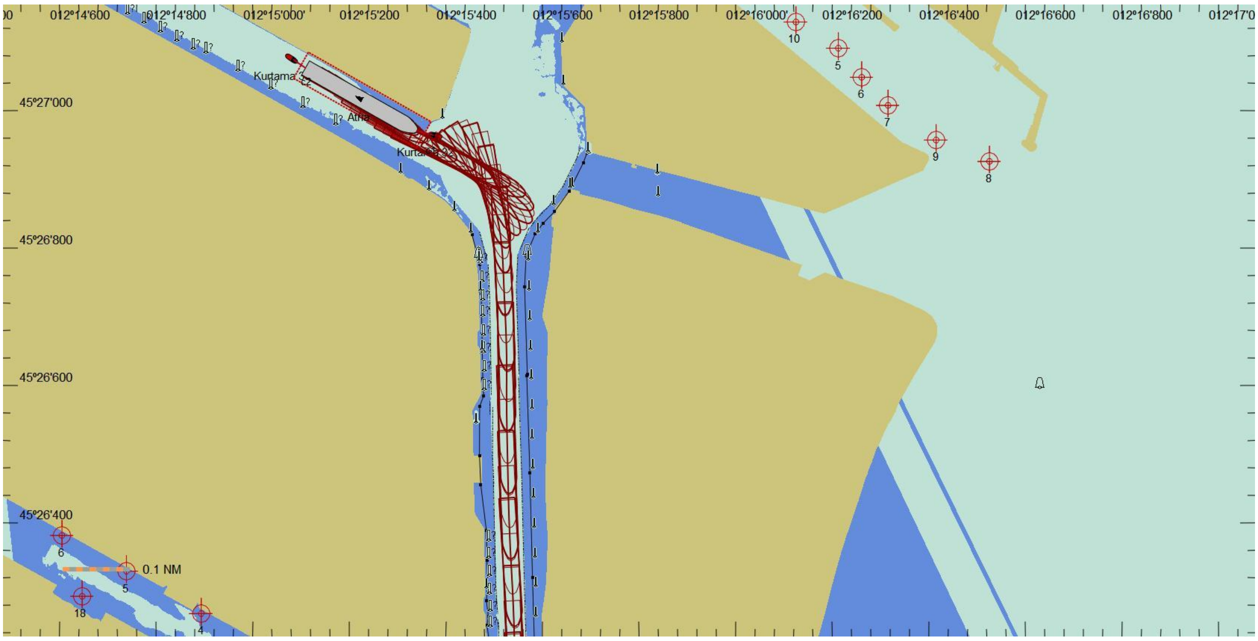


Run 20. From the entrance of Malamocco to LIGURIA (End of simulation 150 m after basin 3).



Run 20. From the entrance of Malamocco to LIGURIA (End of simulation 150 m after basin 3).

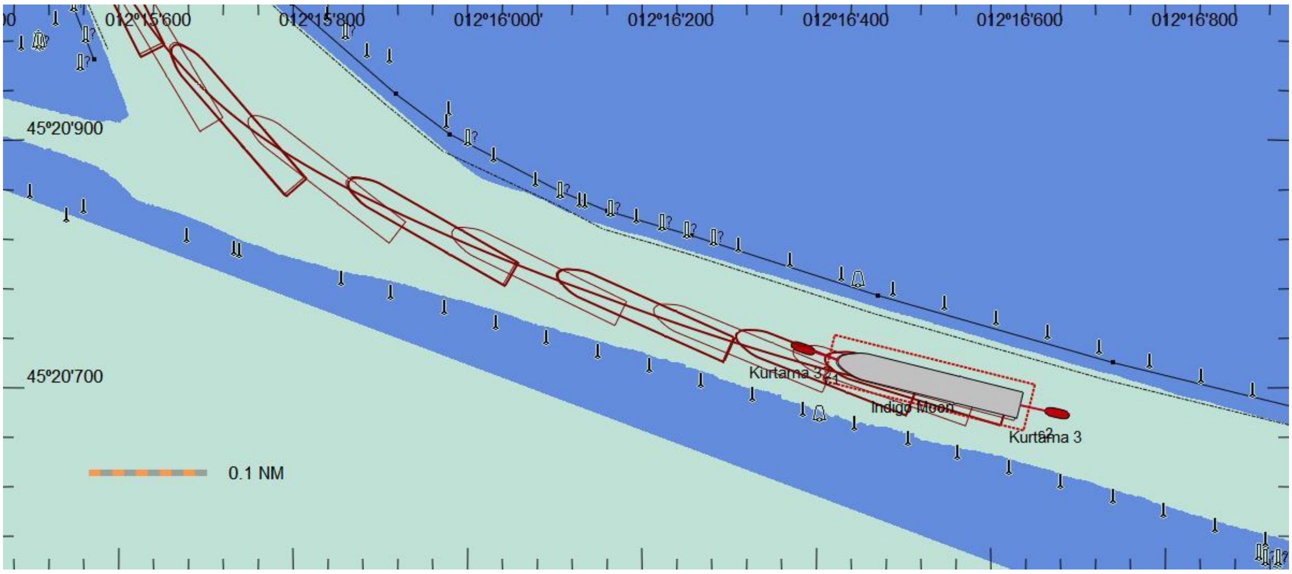
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
21	Ship 13	3725	Container	2	10	NE	D



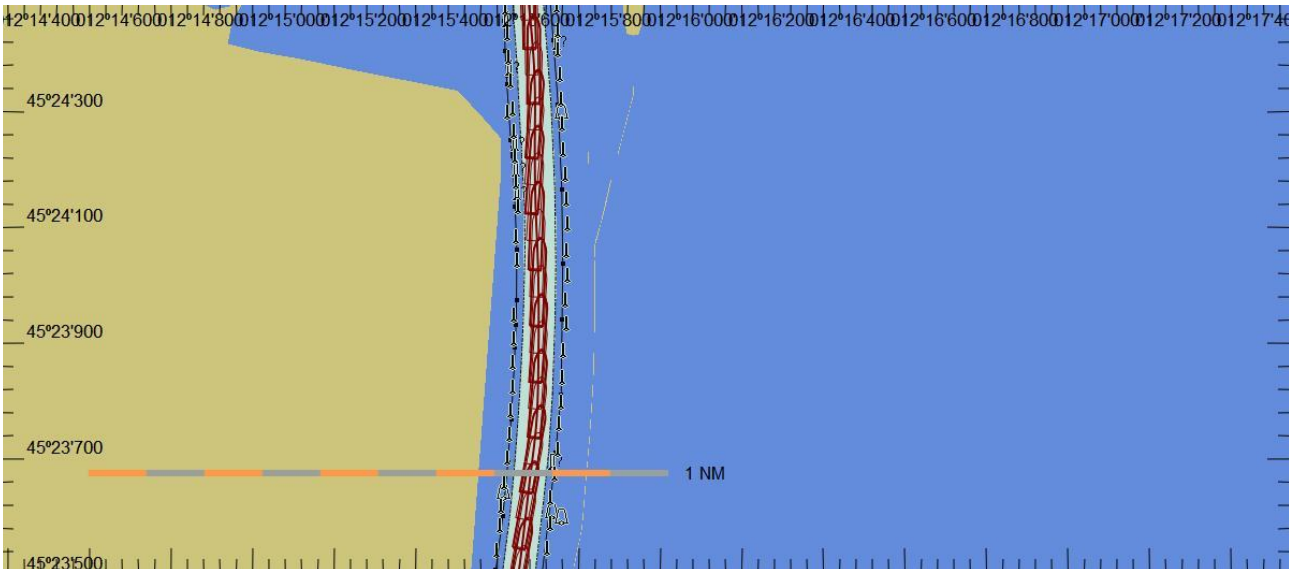
Run 21. From B022 to 2 (two) miles after FUSINA.

Run 21. From B022 to 2 (two) miles after FUSINA.

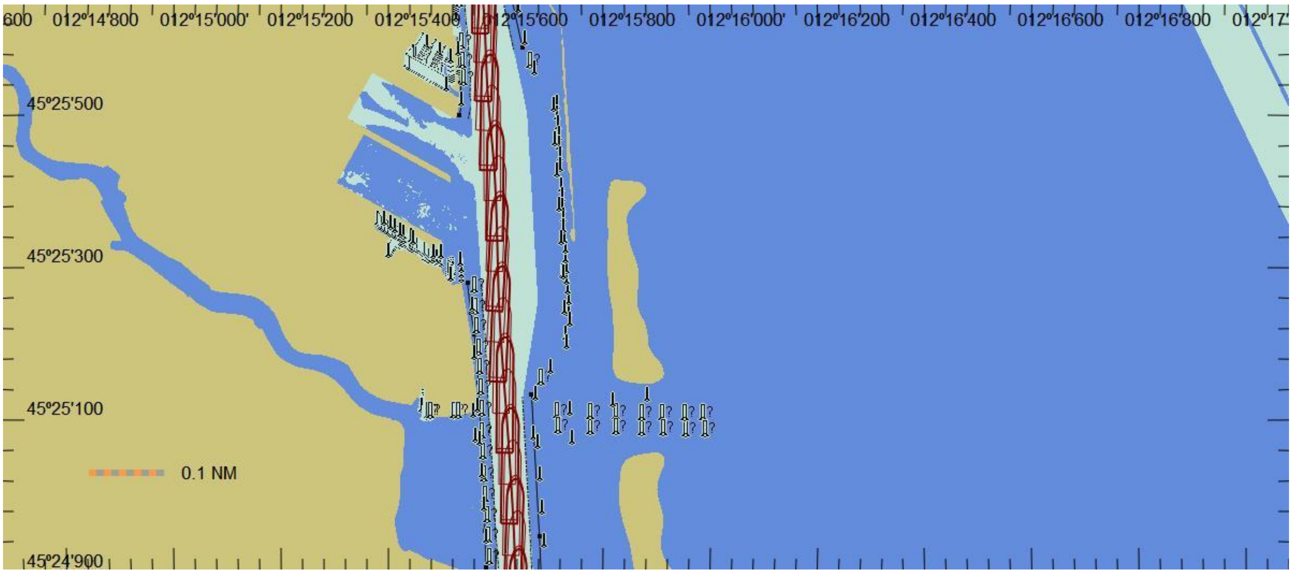
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
22	Ship 6	3754	Container	2	15	NE	D



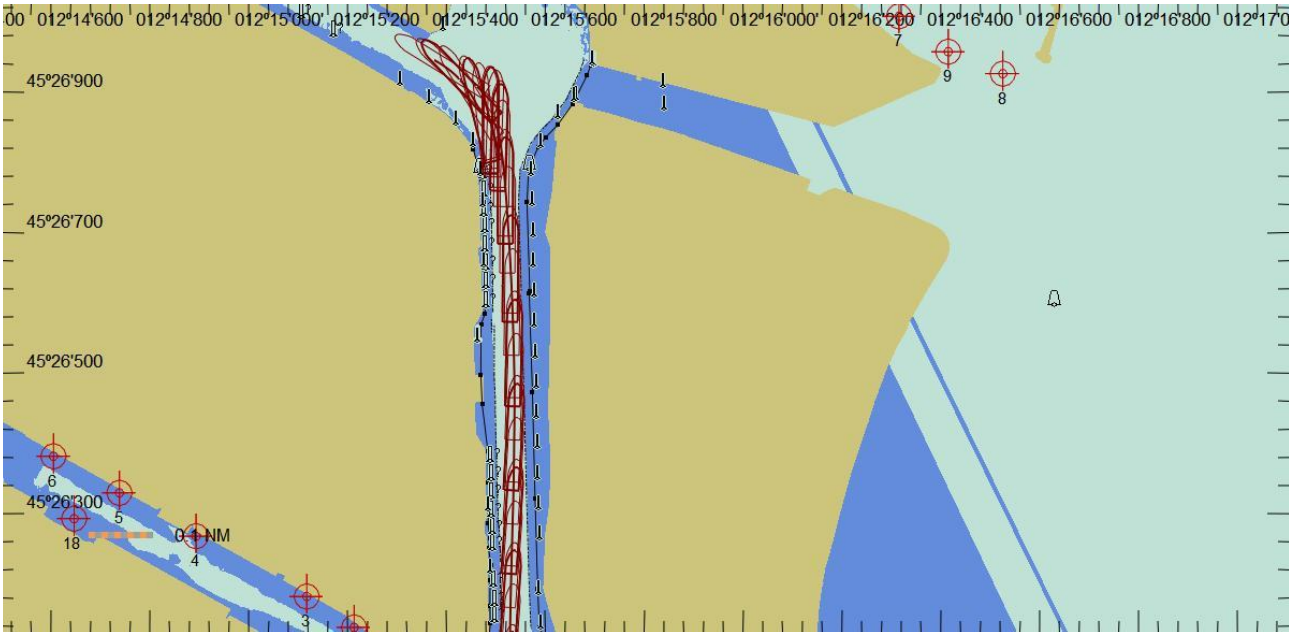
Run 22. Before San Leonardo curve to LIGURIA (End of simulation 150 m after basin 3).



Run 22. Before San Leonardo curve to LIGURIA (End of simulation 150 m after basin 3).

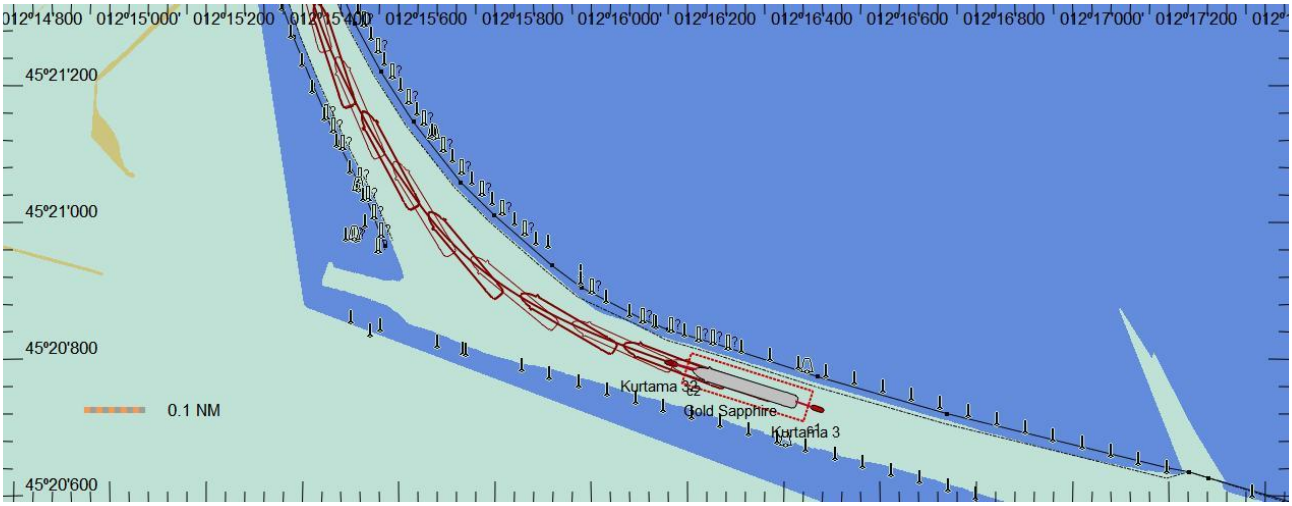


Run 22. Before San Leonardo curve to LIGURIA (End of simulation 150 m after basin 3).

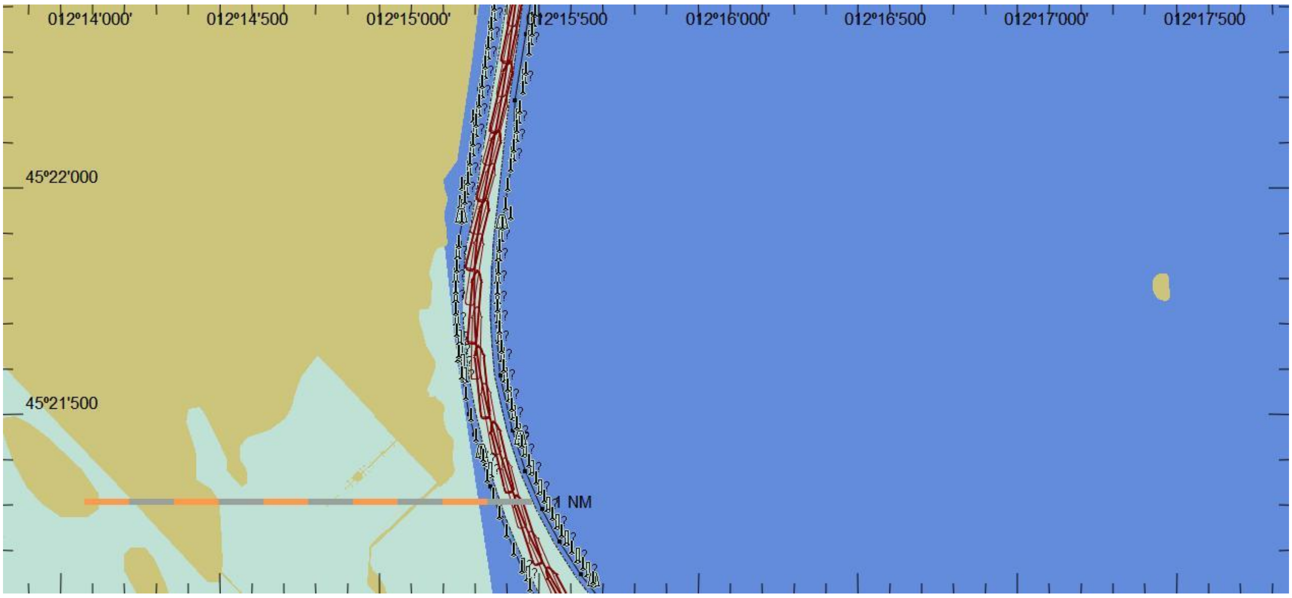


Run 22. Before San Leonardo curve to LIGURIA (End of simulation 150 m after basin 3).

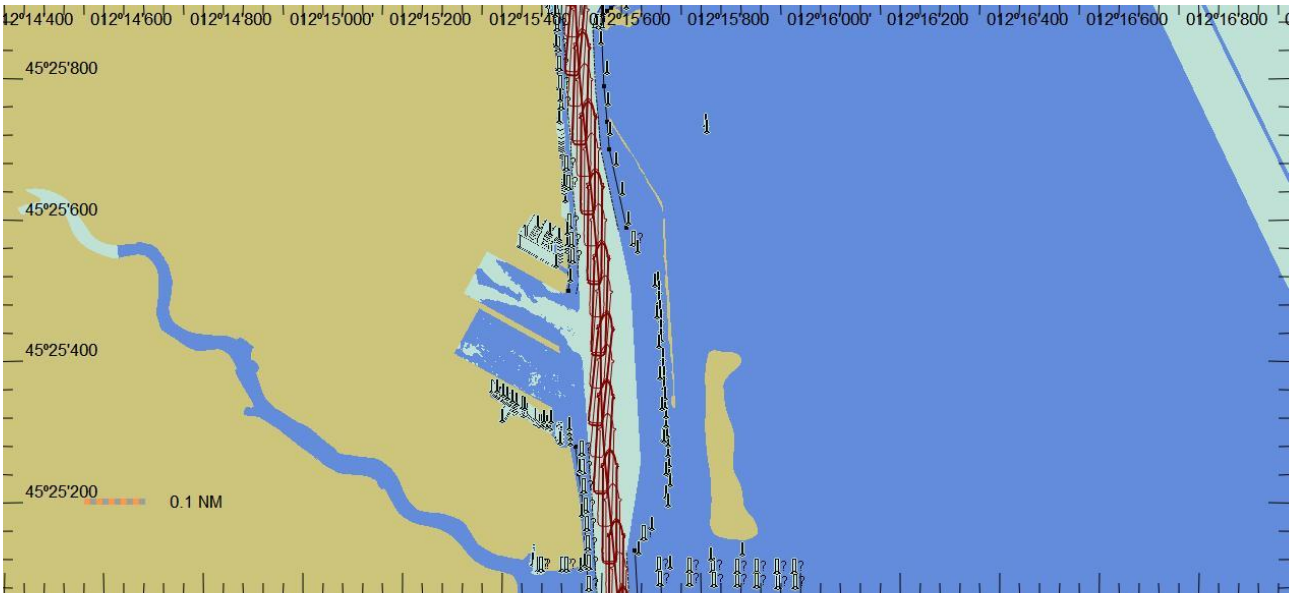
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
23	Ship 2	3644	Cruise	2	10	E	D



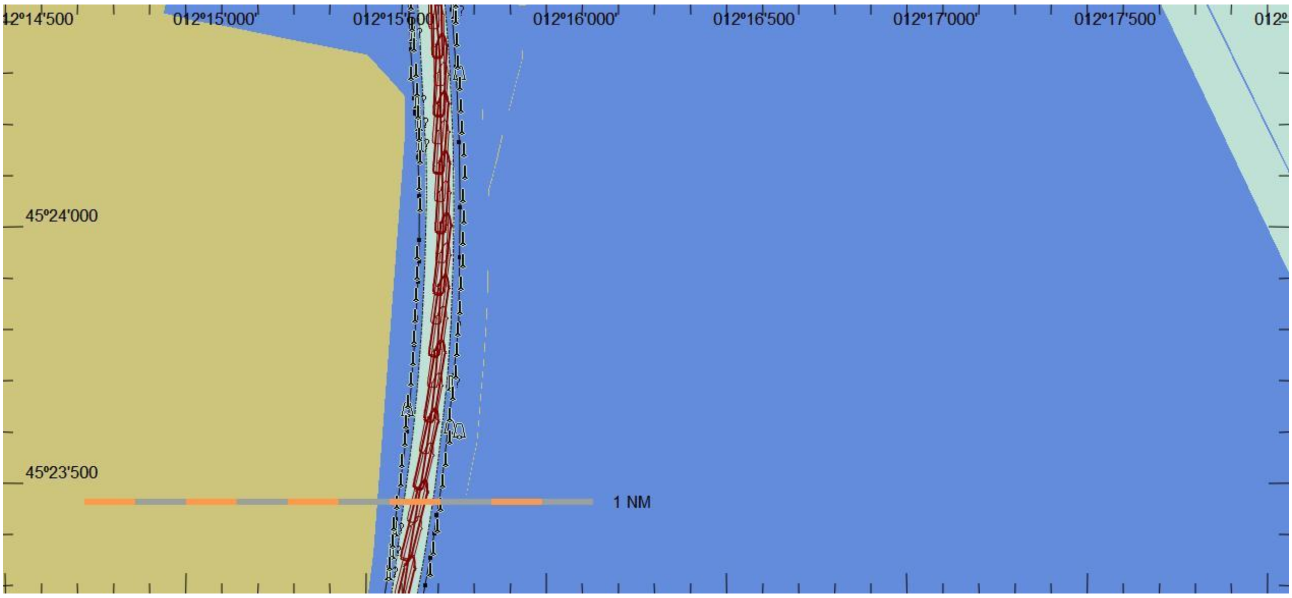
Run 23. Before San Leonardo curve to BOLZANO (excluding berthing).



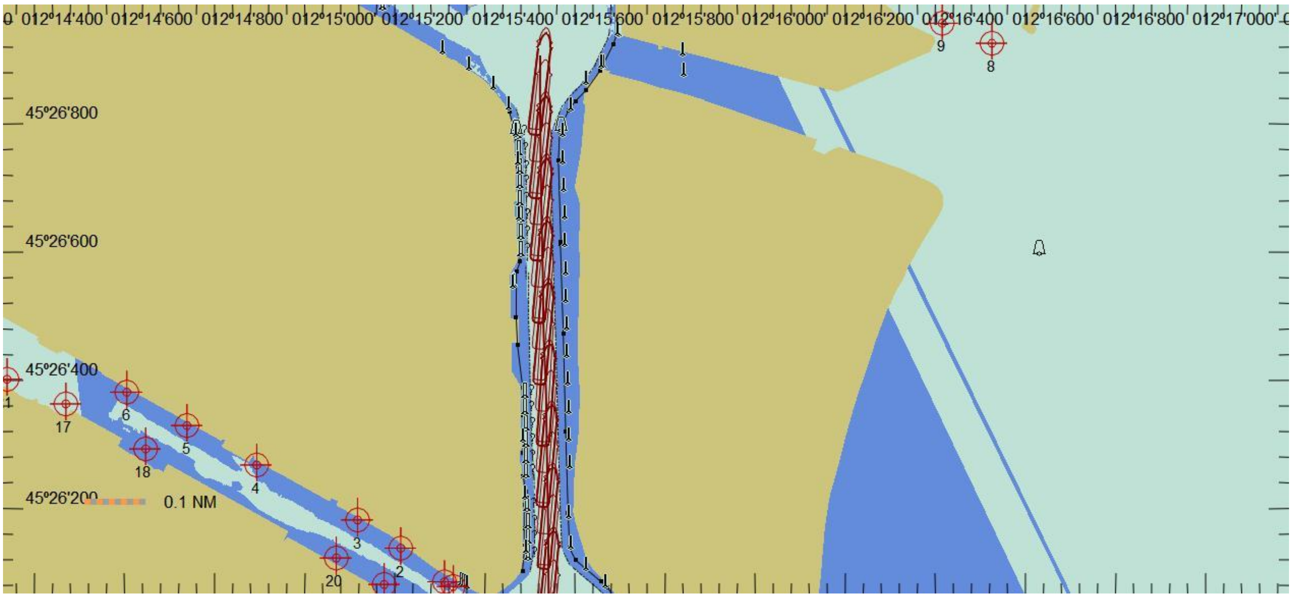
Run 23. Before San Leonardo curve to BOLZANO (excluding berthing).



Run 23. Before San Leonardo curve to BOLZANO (excluding berthing).

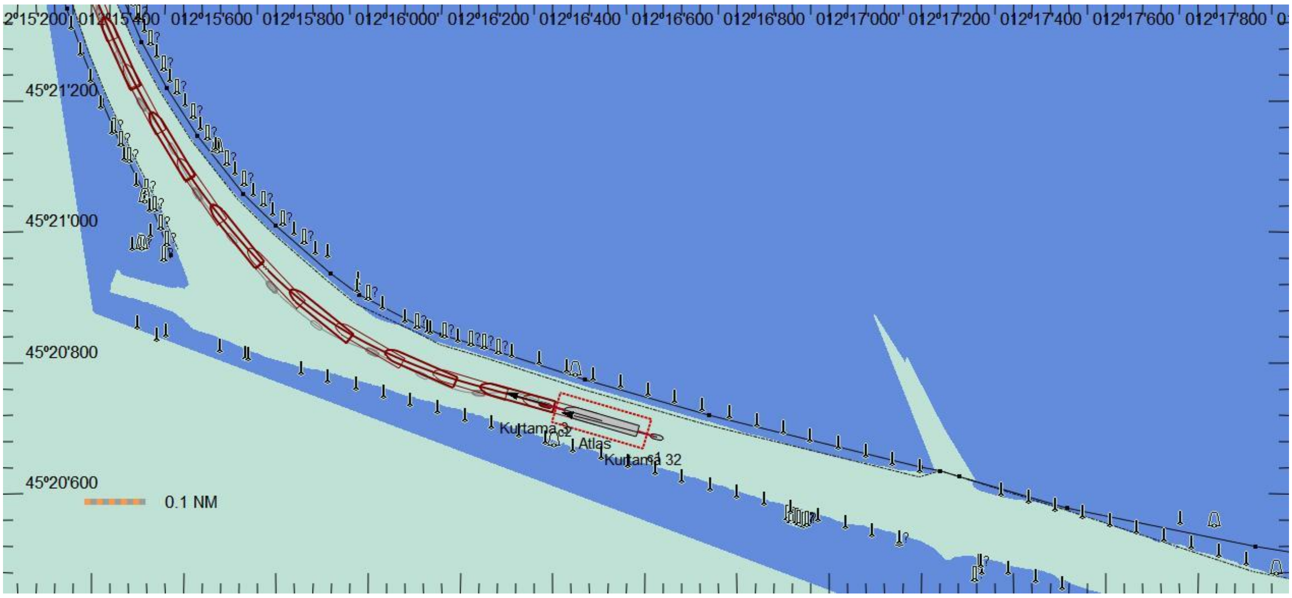


Run 23. Before San Leonardo curve to BOLZANO (excluding berthing).

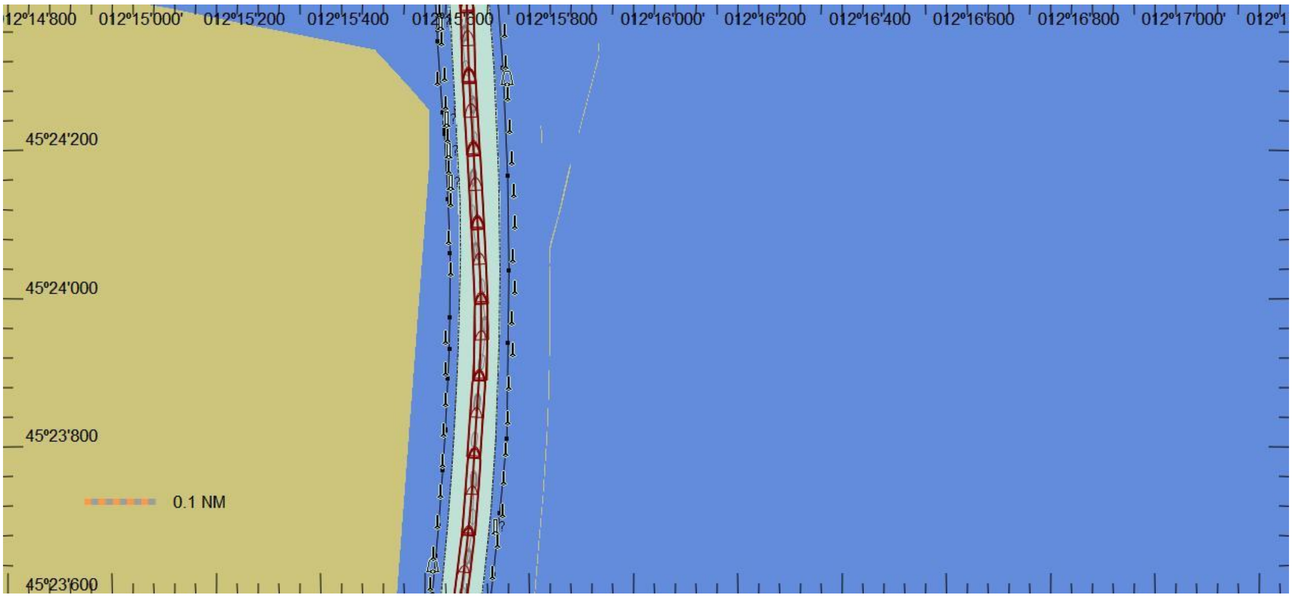


Run 23. Before San Leonardo curve to BOLZANO (excluding berthing).

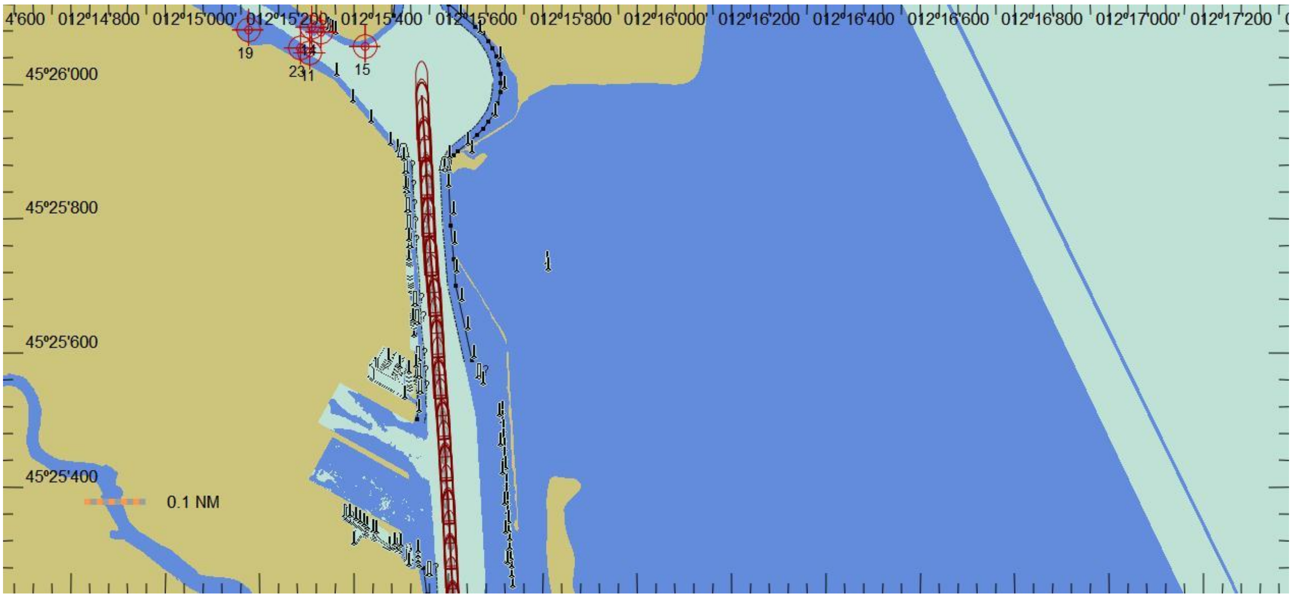
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
24	Ship 2	3644	Cruise	2	10	E	D



Run 24. From 2 (two) miles before FUSINA to 2 (two) miles after FUSINA.

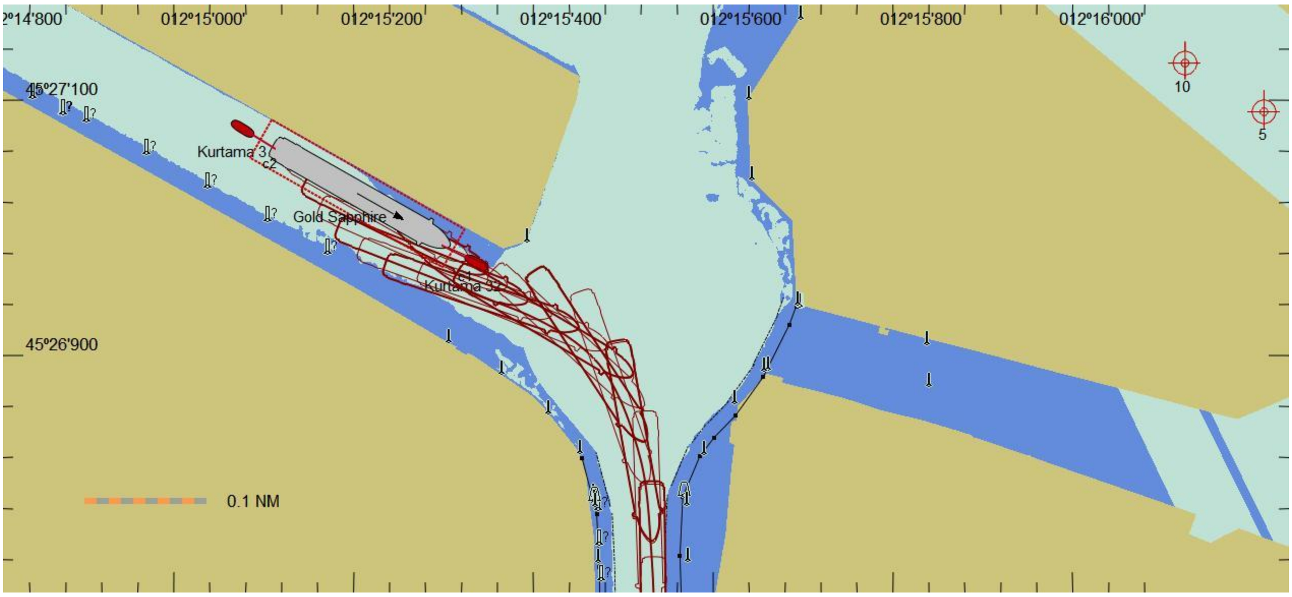


Run 24. From 2 (two) miles before FUSINA to 2 (two) miles after FUSINA

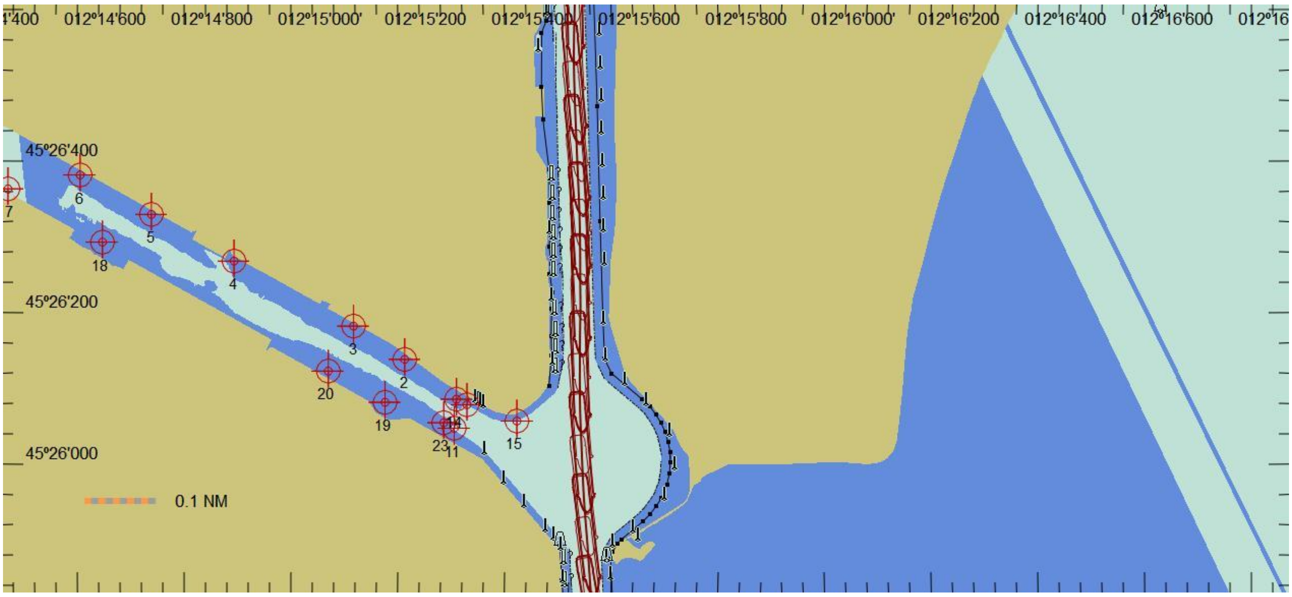


Run 24. From 2 (two) miles before FUSINA to 2 (two) miles after FUSINA.

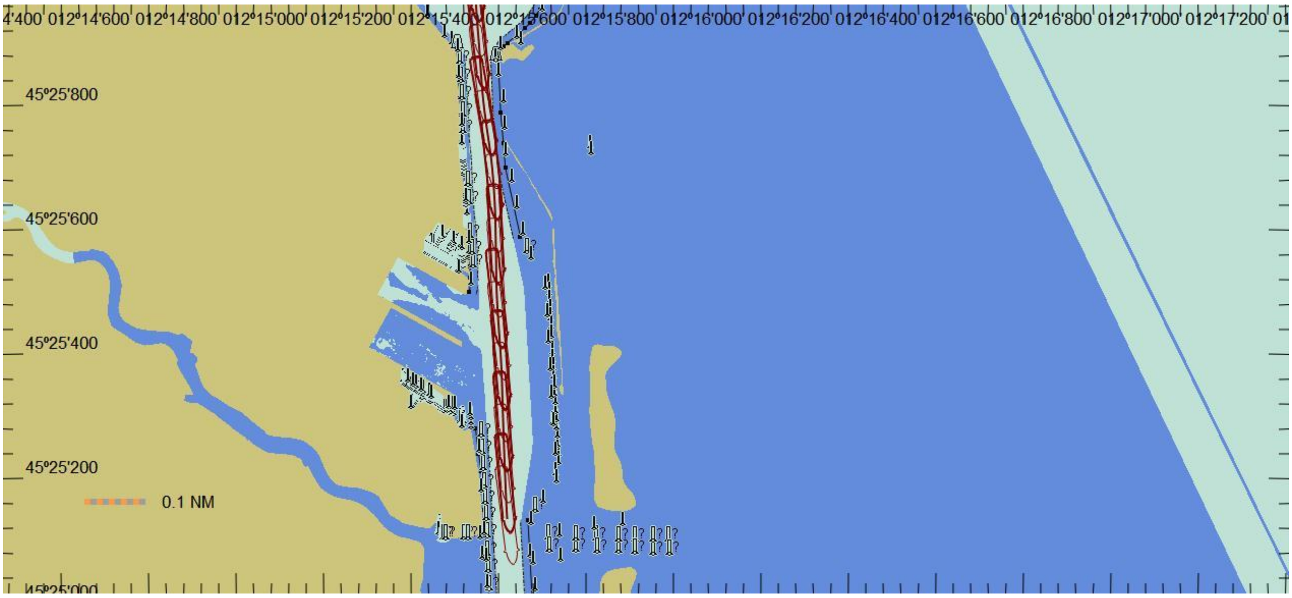
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
25	Ship 2	3644	Cruise	2	10	NE	D



Run 25. From 2 (two) miles after FUSINA to 2 (two) miles before FUSINA.

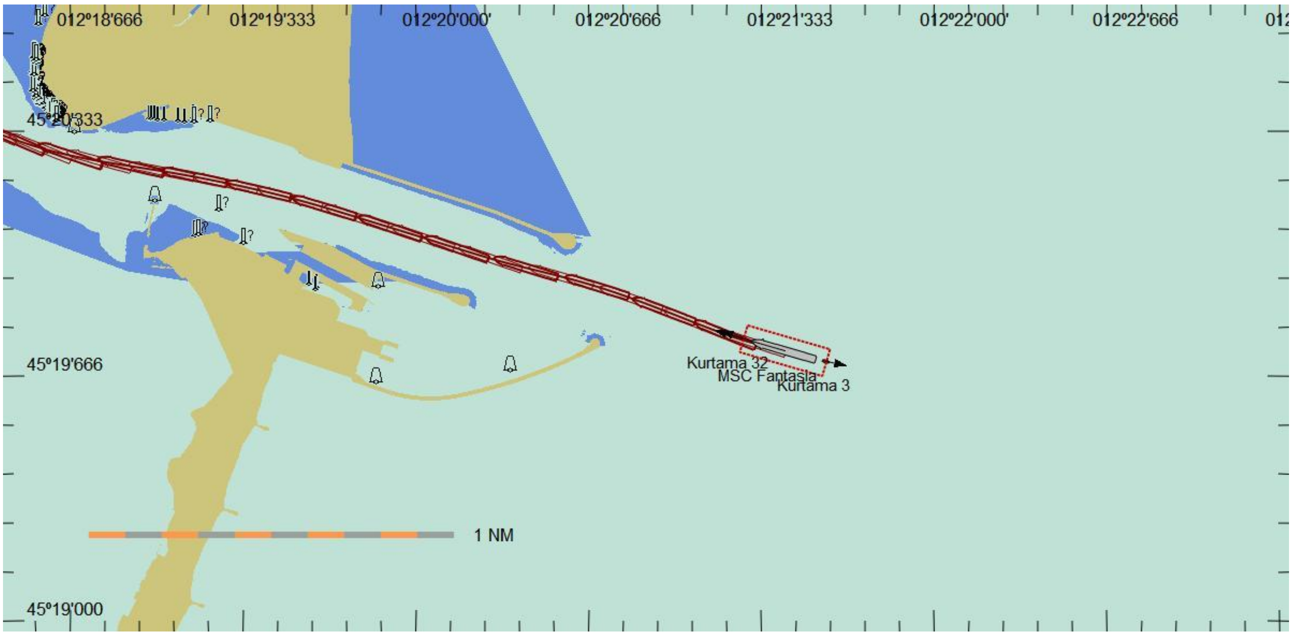


Run 25. From 2 (two) miles after FUSINA to 2 (two) miles before FUSINA.

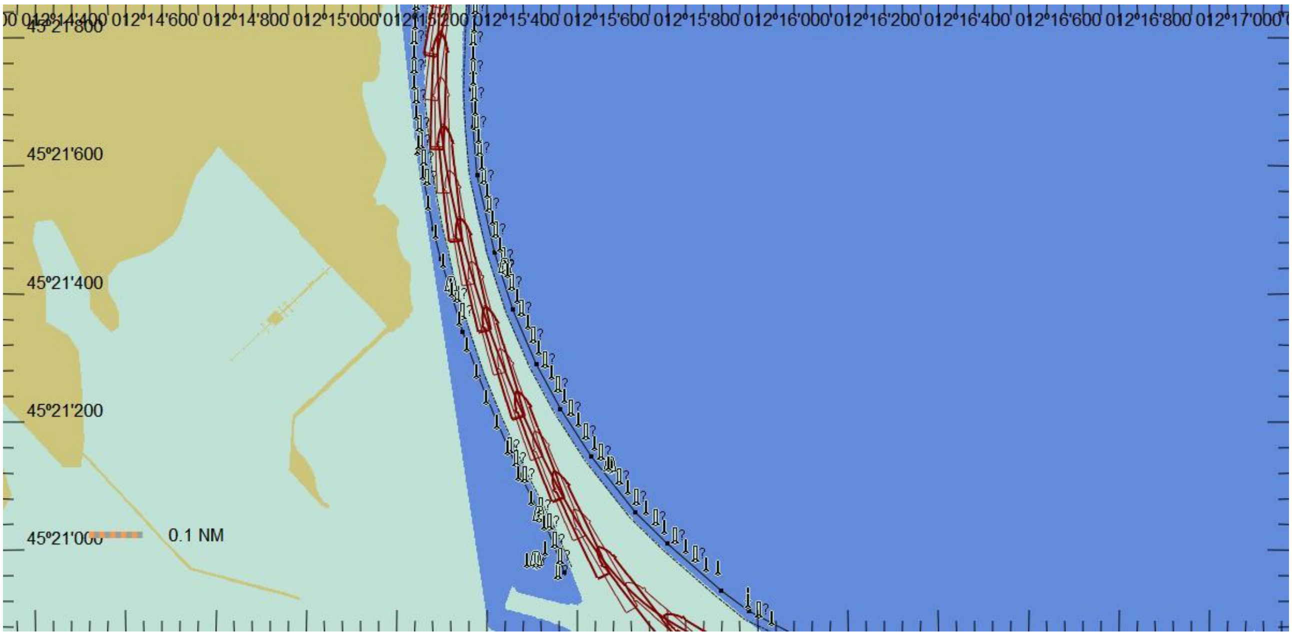


Run 25. From 2 (two) miles after FUSINA to 2 (two) miles before FUSINA.

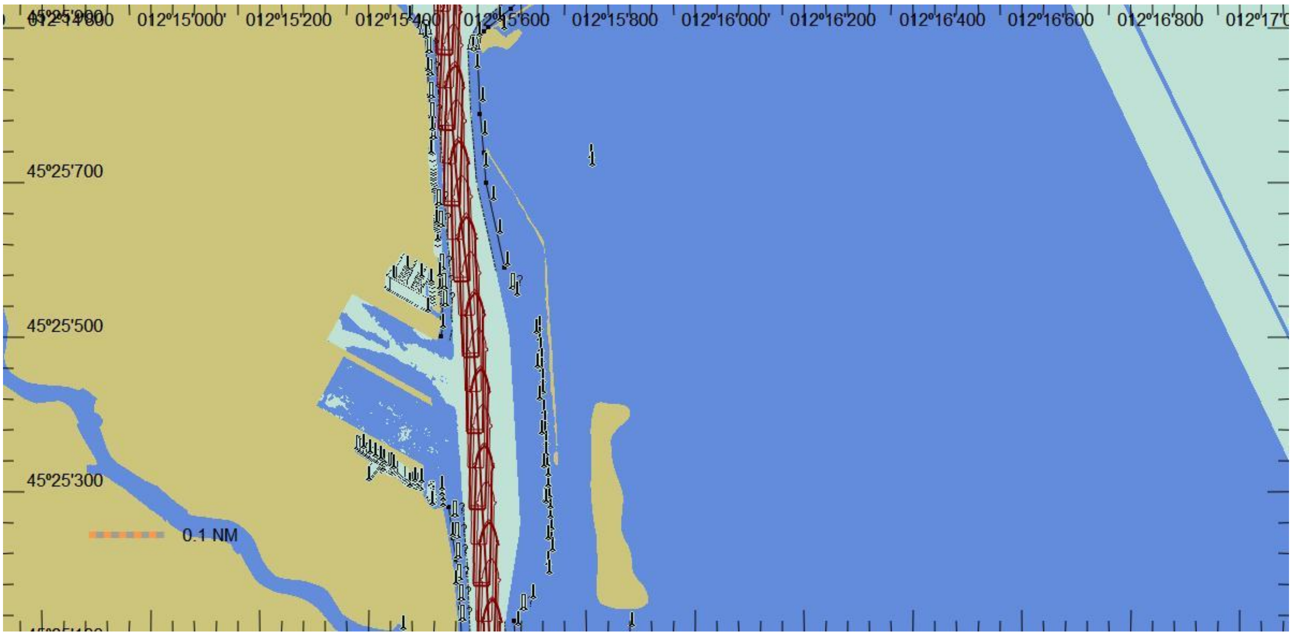
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
26	Ship 4	3545	Cruise	2	9	NE	D



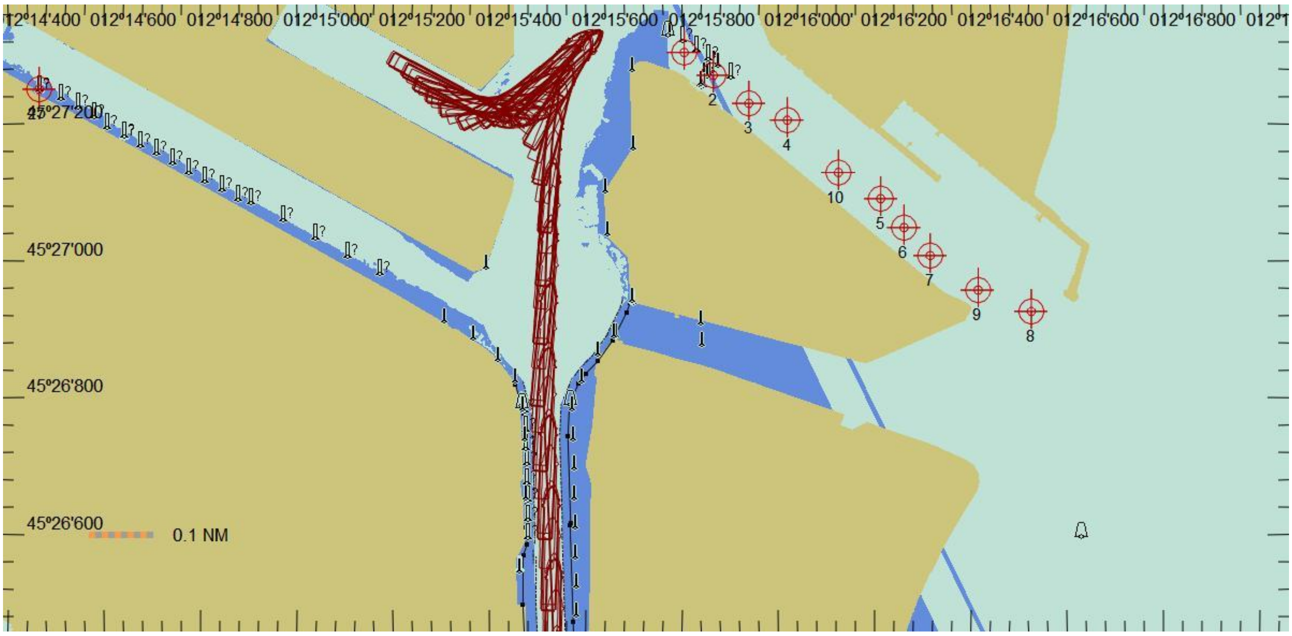
Run 26. From Malamocco entrance to Bolzano quay.



Run 26. From Malamocco entrance to Bolzano quay.

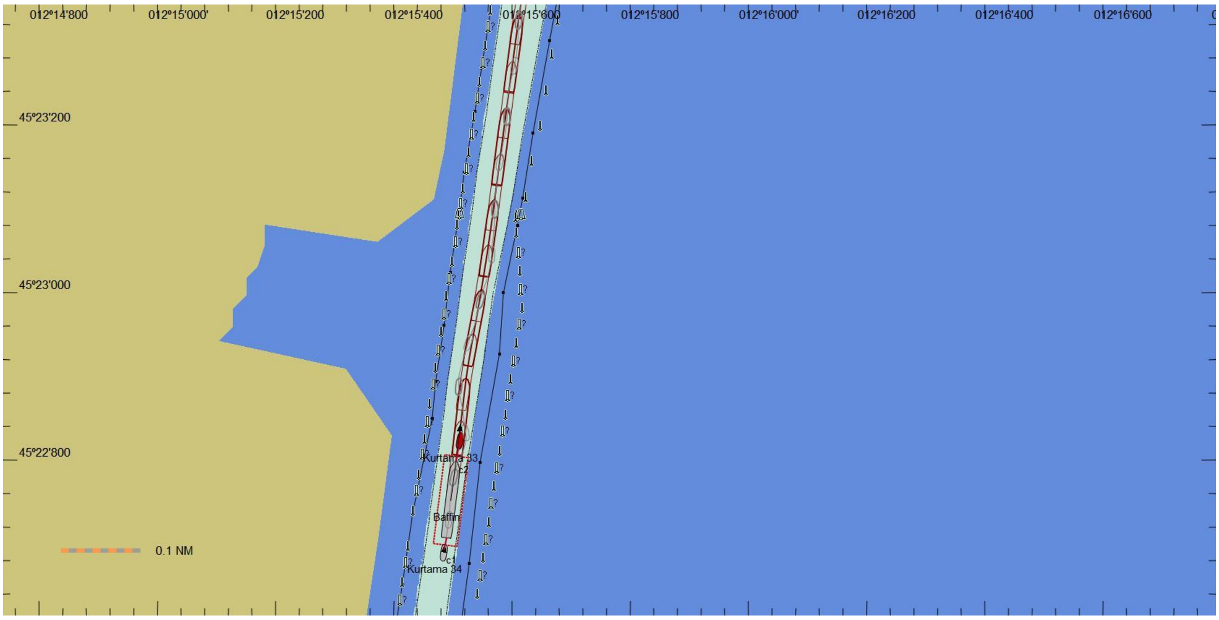


Run 26. From Malamocco entrance to Bolzano quay.

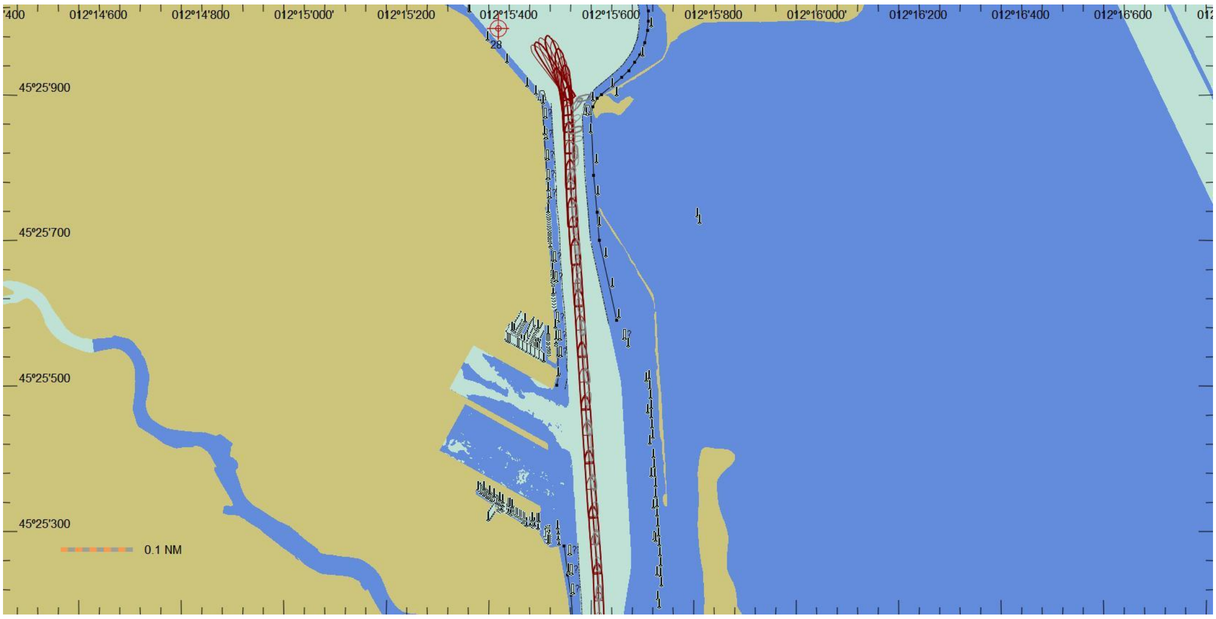


Run 26. From Malamocco entrance to Bolzano quay.

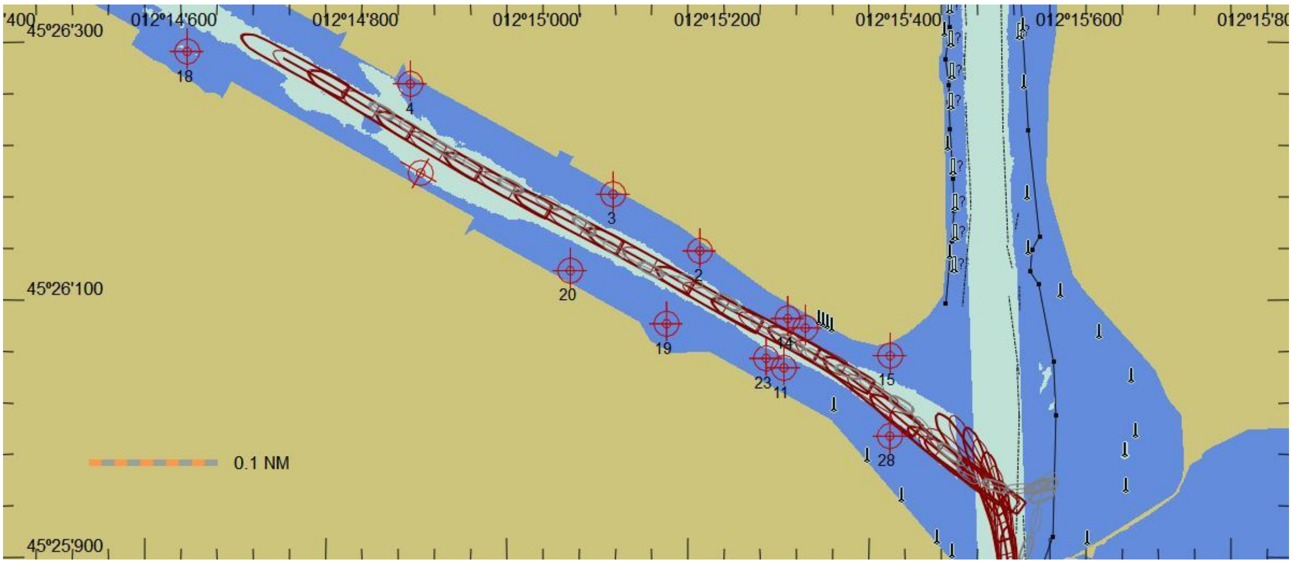
Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
28	Ship 14	3041	Cruise	2	5	NE	D



Run 28. From 2 miles before Fusina to Canale industriale Sud.

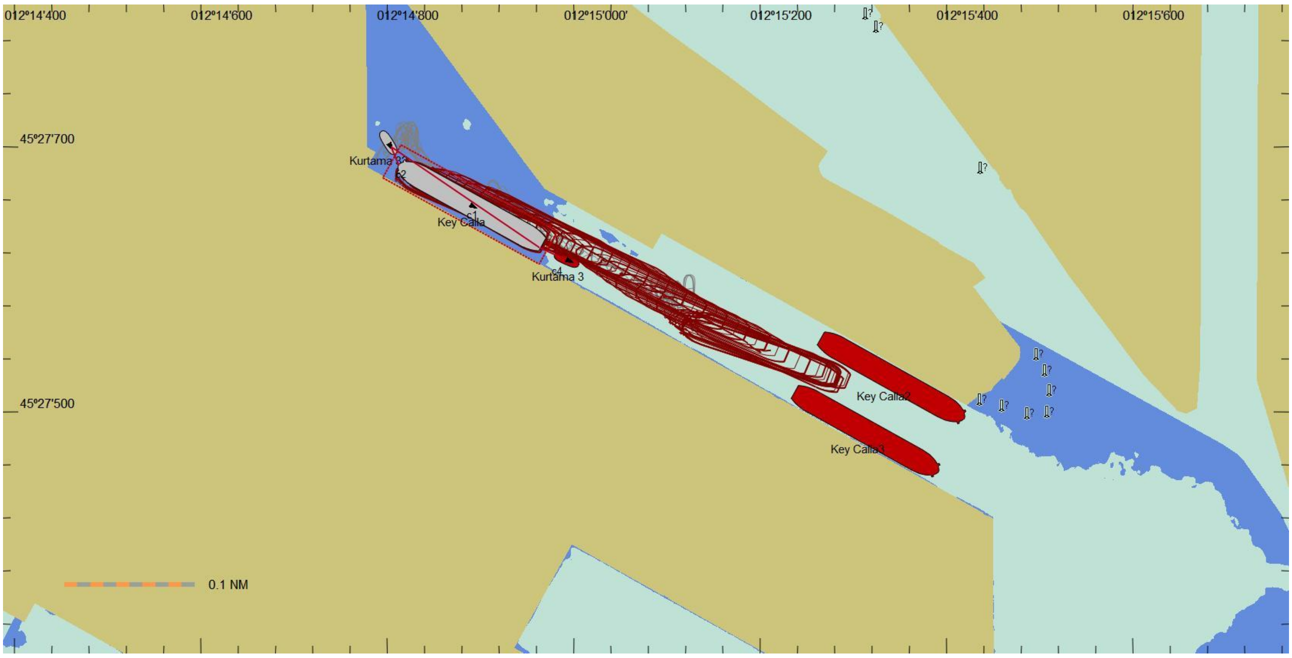


Run 28. From 2 miles before Fusina to Canale industriale Sud.



Run 28. From 2 miles before Fusina to Canale industriale Sud.

Run	Ship code	Ship number	Type	Tugs	WS (m/s)	WD	Bridge
29	Ship 9	3676	Bulk	2	5	NE	D



Run 29. From A0004 (Portside) to turning basin (bacino di evoluzione) 3.

APPENDIX B

Bridge posters

Gold Sapphire #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

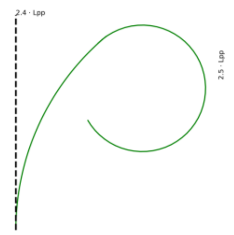
Rudder details

Parameter	
Number of rudders	2
Type of rudder	standard
Area of Rudder (movable part) [m^2]	22.00
Total rudder Area/(Lpp x T) [%]	2.03
Rudder speed (two Pumps) [deg/s]	4.6
Max. rudder Angle [deg]	45.0

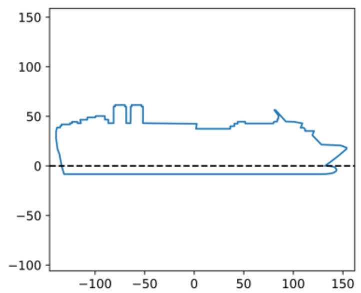
Speed Table

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	294.0 [m]
Beam	32.20 [m]
TF/TA	8.30 / 8.30 [m]
Disp	51714 [Tons]
Lateral wind area	13008 [m^2]
Propeller FP dir	Outward
# Blades	6
Diameter	5.6 [m]
Engine Diesel kW	42000 [kW]
Bow Thruster kW	9185 [kW]
Stern Thruster kW	9185 [kW]
Air draft	61.41 [m]

Bridge poster Gold Sapphire

#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

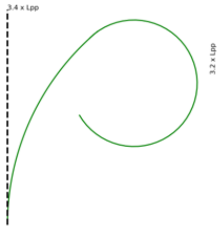
Rudder details

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

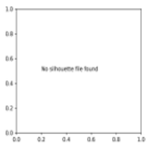
Speed Table

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]

Bridge poster Roberta

Atlas Ship 3601

Manoevering Characteristics

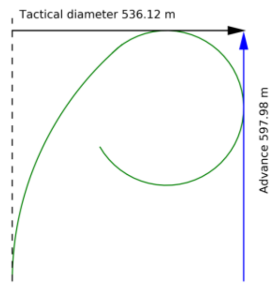
Parameter	Tanker	IMO limit
Turning circle, Advance	2.9 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.6 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	11.2 deg	14.8 deg
10/10 zig-zag, 2nd overshoot angle	34.7 deg	32.2 deg
20/20 zig-zag, 1st overshoot angle	21.4 deg	25.0 deg
Crash stop, Track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

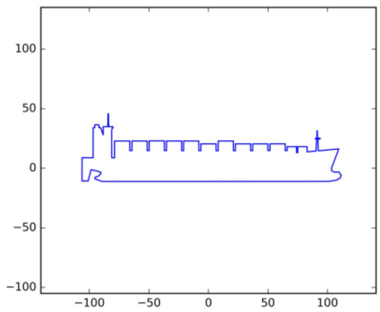
Rudder details

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]

Bridge poster Atlas

Coraline #3483

Manoevering Characteristics

Parameter	CONTAINER	IMO limit
Turning circle, Advance	632	Unknown
Turning circle, Tactical diameter	620	Unknown
10/10 zig-zag, 1st overshoot angle	Unknown	Unknown
10/10 zig-zag, 2nd overshoot angle	Unknown	Unknown
20/20 zig-zag, 1st overshoot angle	Unknown	Unknown
Crash stop, Track reach	Unknown	Unknown

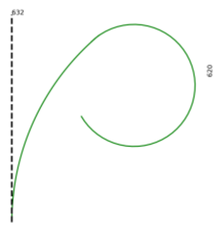
Rudder details

Parameter	
Number of rudders	1
Type of rudder	standard
Area of Rudder (movable part) [m^2]	39.84
Total rudder Area/(Lpp x T) [%]	2.03
Rudder speed (two Pumps) [deg/s]	4.6
Max. rudder Angle [deg]	35.0

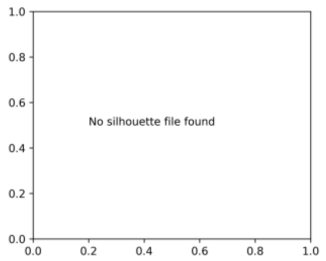
Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Sea	102	20.9	Grounded
Full Ahead	70	15.3	13.5
Half Ahead	54	11.8	11.0
Slow Ahead	38	8.2	7.9
Dead Slow Ahead	27	5.3	3.9
Dead Slow Astern	-27	-2.4	-1.7
Slow Astern	-38	-4.4	-2.7
Half Astern	-54	-8.0	-6.8
Full Astern	-71	-10.7	-9.6

Turning Circle



Outline



Particulars

LPP	206.2 [m]
LOA	215.6 [m]
Beam	32.20 [m]
TF/TA	9.50 / 9.50 [m]
Disp	40731 [Tons]
Lateral wind area	4108 [m^2]
Propeller FP dir	CLOCKWISE
# Blades	5
Diameter	7.0 [m]
Engine Diesel kW	20250 [kW]
Bow Thruster kW	736 [kW]
Stern Thruster kW	- [kW]
Air draft	1.00 [m]

Bridge poster Coraline

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

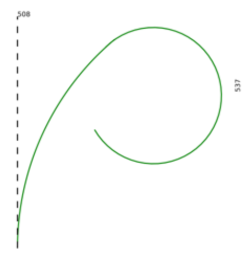
Rudder details

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



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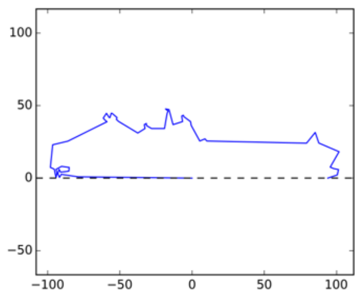


Particulars

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]

Bridge poster Tor Magnolia

M/V Melusina Loaded Ship 3583

Manoevering Characteristics

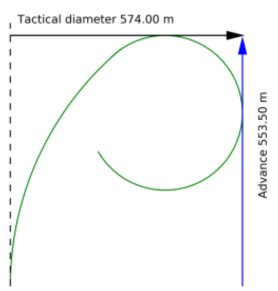
Parameter	Tanker	IMO limit
Turning circle, Advance	2.7 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.8 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	9.6 deg	13.3 deg
10/10 zig-zag, 2nd overshoot angle	17.5 deg	30.0 deg
20/20 zig-zag, 1st overshoot angle	16.6 deg	25.0 deg
Crash stop, Track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

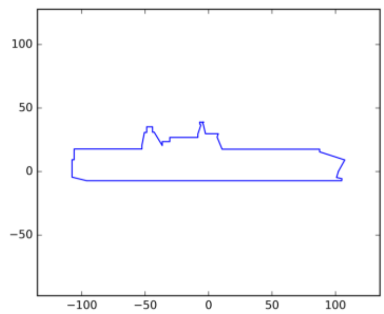
Rudder details

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]

Bridge poster Melusina

MSC Fantasia

Manoevering Characteristics

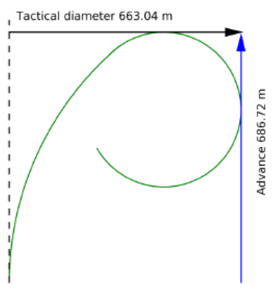
Parameter	Tanker	IMO limit
Turning circle, Advance	2.32 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.24 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	6.3 deg	20.0 deg
10/10 zig-zag, 2nd overshoot angle	10.2 deg	40.0 deg
20/20 zig-zag, 1st overshoot angle	12.8 deg	25.0 deg
Crash stop, Track reach	7.2 · Lpp	15 · Lpp

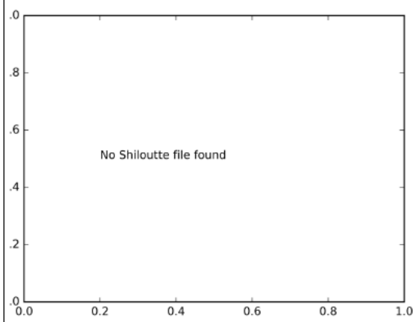
Rudder details

Parameter	
Number of rudders	2
Type of rudder	Twisted flap
Area of Rudder (movable part) [m^2]	27.00
Total rudder Area/(Lpp x T) [%]	1.10
Rudder speed (two Pumps) [deg/s]	1.25
Max. rudder Angle [deg]	45

Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Full Ahead	136	23.4	-
Sea	135	23.2	-
Half Ahead	119	20.6	13.2
Slow Ahead	105	18.2	13.2
Dead Slow Ahead	89	15.4	12.4
Dead Slow Astern	73	12.5	9.9
Slow Astern	59	10.2	8.1
Half Astern	46	7.5	6.3
Full Astern	33	4.9	4.0





LPP	296.0 [m]
LOA	333.3 [m]
Beam	37.92 [m]
TA/TF	8.16 / 8.42 [m]
Disp	63326 [m^3]
WSA	14600 [m^2]
1 Propeller FP	Inward
# Blades	5
Diameter	6.00 [m]
Engine Diesel kW	2 x 20200[kW]
Bow THruster kW	3 x 3100 [kW]
Stern THruster kW	2 x 3100 [kW]
Air draft	1.00 [m]

Bridge poster MSC Fantasia

Indigo Moon Ship 3754

Manoevering Characteristics

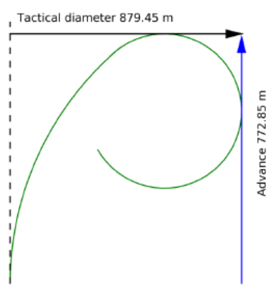
Parameter	Tanker	IMO limit
Turning circle, Advance	2.9 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	3.3 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	5.8 deg	14.9 deg
10/10 zig-zag, 2nd overshoot angle	7.8 deg	32.4 deg
20/20 zig-zag, 1st overshoot angle	11.0 deg	25.0 deg
Crash stop, Track reach	9.1 · Lpp	15 · Lpp

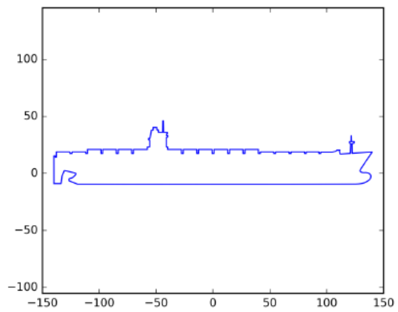
Rudder details

Parameter	
Number of rudders	1
Type of rudder	Semi spade
Area of Rudder (movable part) [m^2]	89.5
Total rudder Area/(Lpp x T) [%]	2.41
Rudder speed (two Pumps) [deg/s]	4.6
Max. rudder Angle [deg]	35

Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Full Ahead	98	26.1	grounded
Sea	68	19.2	grounded
Half Ahead	52	14.9	12.1
Slow Ahead	36	10.3	9.1
Dead Slow Ahead	26	7.3	6.7
Dead Slow Astern	-26	-3.5	-2.4
Slow Astern	-36	-5.5	-3.9
Half Astern	-52	-8.7	-6.3
Full Astern	-68	-11.2	-9.1





LPP	266.5 [m]
LOA	280.0 [m]
Beam	40.00 [m]
TA/TF	9.50 / 9.50 [m]
Disp	59860 [m^3]
WSA	11778 [m^2]
1 Propeller Fixed Pitch	Clockwise
# Blades	4
Diameter	9.00 [m]
Engine Diesel kW	49000[kW]
Bow THruster kW	3000 [kW]
Stern THruster kW	2 x 1220 [kW]
Air draft	46.20 [m]

Bridge poster Indigo Moon

Key Calla Ballast Ship 3676

Manoevering Characteristics

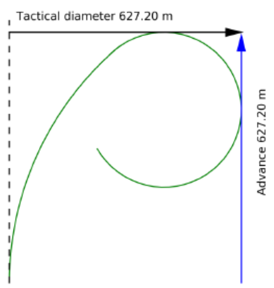
Parameter	Tanker	IMO limit
Turning circle, Advance	2.8 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.8 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	3.0 deg	19.0 deg
10/10 zig-zag, 2nd overshoot angle	3.5 deg	38.4 deg
20/20 zig-zag, 1st overshoot angle	7.5 deg	25.0 deg
Crash stop, Track reach	8.2 · Lpp	15 · Lpp

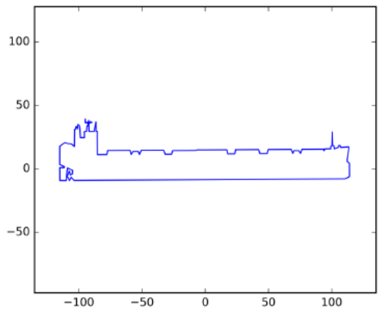
Rudder details

Parameter	
Number of rudders	1
Type of rudder	Semi Spade
Area of Rudder (movable part) [m^2]	53.0
Total rudder Area/(Lpp x T) [%]	2.76
Rudder speed (two Pumps) [deg/s]	2.8
Max. rudder Angle [deg]	37

Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Full Ahead	90	15.6	grounded
Sea	60	11.3	9.5
Half Ahead	44	8.3	7.0
Slow Ahead	38	6.9	6.2
Dead Slow Ahead	30	5.5	4.8
Dead Slow Astern	-30	-2.8	-1.8
Slow Astern	-38	-3.6	-2.3
Half Astern	-44	-4.4	-2.8
Full Astern	-67	-6.8	-4.8





LPP	224.0 [m]
LOA	229.0 [m]
Beam	32.24 [m]
TA/TF	9.26 / 7.91 [m]
Disp	53103 [m^3]
WSA	9691 [m^2]
1 Propeller FP	Clockwise
# Blades	4
Diameter	7.0 [m]
Engine Diesel kW	9130[kW]
Bow THruster kW	-1 [kW]
Stern THruster kW	-1 [kW]
Air draft	39.19 [m]

Bridge poster Key Calla Ballast

Avior #3763

Manoevering Characteristics

Parameter	BULK	IMO limit
Turning circle, Advance	2.9 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	2.8 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	6.8 deg	20.0 deg
10/10 zig-zag, 2nd overshoot angle	9.9 deg	40.0 deg
20/20 zig-zag, 1st overshoot angle	12.9 deg	25.0 deg
Crash stop, Track reach	17.1 · Lpp	15 · Lpp

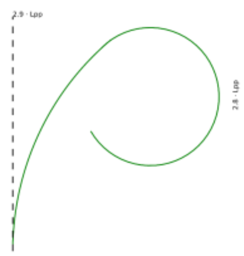
Rudder details

Parameter	
Number of rudders	1
Type of rudder	standard
Area of Rudder (movable part) [m^2]	84.0
Total rudder Area/(Lpp x T) [%]	2.96
Rudder speed (two Pumps) [deg/s]	2.9
Max. rudder Angle [deg]	35.0

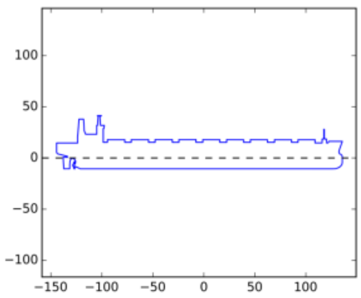
Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Sea	84	15.7	Grounded
Full Ahead	72	13.7	Grounded
Half Ahead	57	10.8	9.0
Slow Ahead	41	7.7	2.4
Dead Slow Ahead	30	5.2	1.7
Dead Slow Astern	-30	-2.8	-1.7
Slow Astern	-41	-5.0	-3.0
Half Astern	-57	-7.2	-5.5
Full Astern	-72	-9.2	-7.2

Turning Circle



Outline



Particulars

LPP	265.0 [m]
LOA	285.0 [m]
Beam	43.00 [m]
TA/TF	10.70 / 10.70 [m]
Disp	99934 [Tons]
WSA	14279 [m^2]
Propeller FP	CLOCKWISE
# Blades	4
Diameter	8.0 [m]
Engine Diesel kW	13579 [kW]
Bow THruster kW	0 [kW]
Stern THruster kW	0 [kW]
Air draft	41.44 [m]

Bridge poster Avior

M/V Baffin Loaded Ship 3041

Manoevering Characteristics

Parameter	TANKER	IMO limit
Turning circle, Advance	3.45 · Lpp	4.5 · Lpp
Turning circle, Tactical diameter	3.84 · Lpp	5.0 · Lpp
10/10 zig-zag, 1st overshoot angle	9.2 deg	14.8 deg
10/10 zig-zag, 2nd overshoot angle	15.0 deg	32.3 deg
20/20 zig-zag, 1st overshoot angle	12.5 deg	25.0 deg
Crash stop, Track reach	~16 · Lpp	15 · Lpp

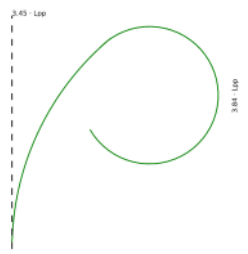
Rudder details

Parameter	
Number of rudders	1
Type of rudder	standard
Area of Rudder (movable part) [m^2]	36.8
Total rudder Area/(Lpp x T) [%]	2.45
Rudder speed (two Pumps) [deg/s]	4.5
Max. rudder Angle [deg]	35.0

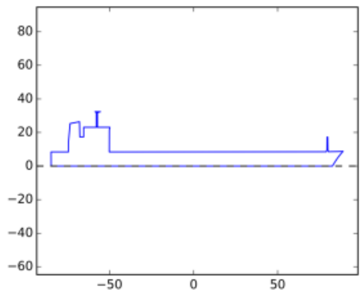
Speed Table

Handle	RPM	Deep [kn]	Shallow [kn]
Sea	111	16.2	Grounded
Full Ahead	101	14.6	Grounded
Half Ahead	83	12.0	8.7
Slow Ahead	57	8.1	6.1
Dead Slow Ahead	30	4.2	3.0
Dead Slow Astern	-30	-3.0	-1.2
Slow Astern	-57	-6.0	-4.3
Half Astern	-83	-9.0	-6.3
Full Astern	-111	-11.6	-8.1

Turning Circle



Outline



Particulars

LPP	164.0 [m]
LOA	170.0 [m]
Beam	23.11 [m]
TA/TF	9.13 / 9.13 [m]
Disp	27251 [Tons]
WSA	5580 [m^2]
Propeller FP	CLOCKWISE
# Blades	4
Diameter	5.665 [m]
Engine Diesel kW	5299 [kW]
Bow THruster kW	624 [kW]
Stern THruster kW	624 [kW]
Air draft	23.25 [m]

Bridge poster Baffin

APPENDIX C

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 meters height.

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

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

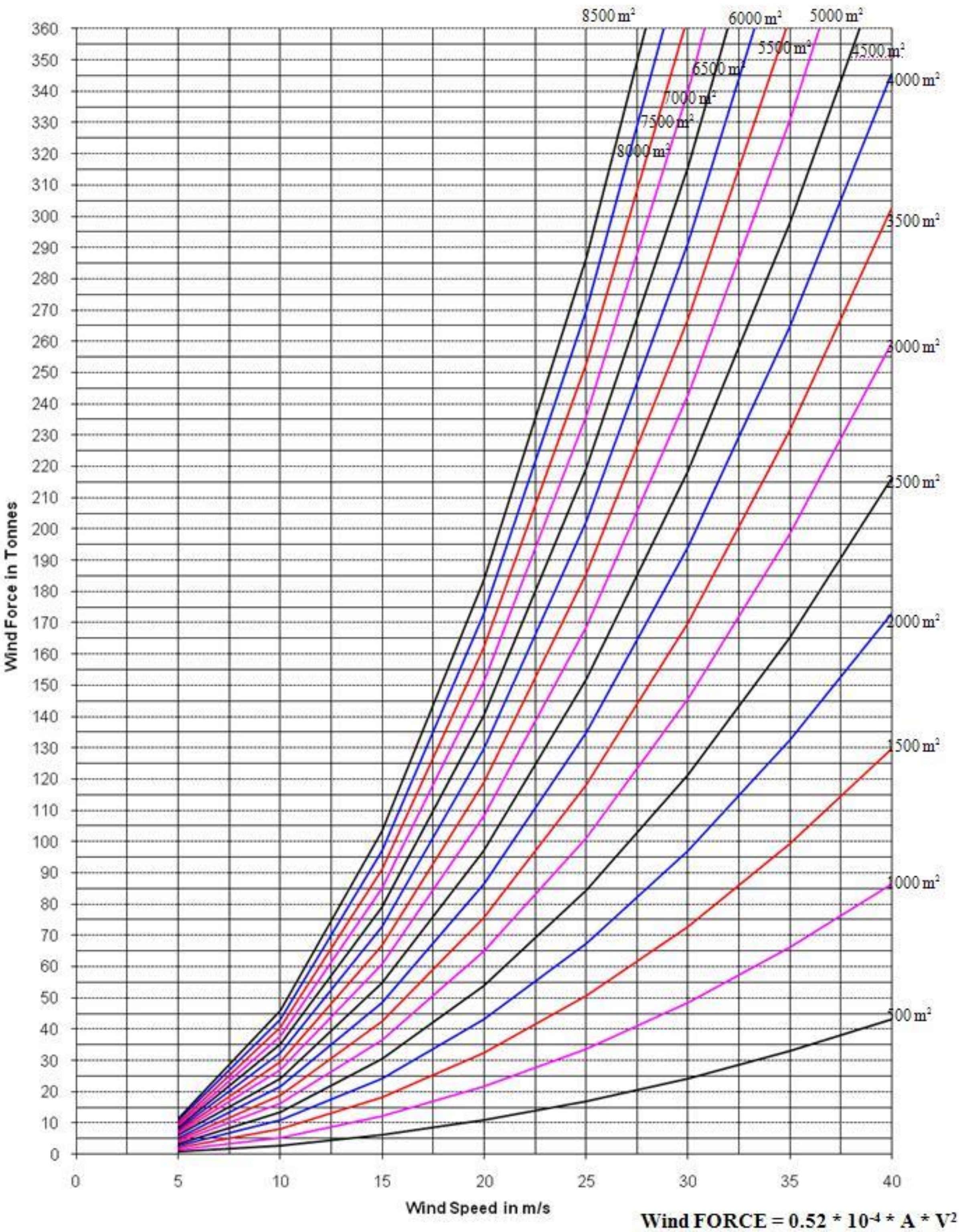
Example:

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 m/s

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.