

Hirtshals new west breakwater and working areas

Port of Hirtshals

FORCE 125-27160

A 1

Project No. and Title of Report:

FORCE 125-27160
Simulation study of new layout of Port of Hirtshals
**Evaluation of approach/departure in new
layout and during construction**

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|--|------------------------------|---|----------------|---|-------------|
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0. Executive summary

This report comprises a qualitative study evaluating the accessibility for the ferries into Port of Hirtshals (One layout with new west breakwater and buoys marking the 10.5 m curve, one layout with working area around the old breakwater and with new west breakwater established and one layout with the new west breakwater and shortened east breakwater and 12.0 m in the entrance) under different environmental conditions.

The study was carried out at FORCE Technology Simulation Centre, Kgs. Lyngby, Denmark in one of the full-mission simulators for the ferries "Color Superspeed", "Stavangerfjord" and "Norrøna" with the participation of captains from Color Line, Fjord Line and Smyril Line. A FORCE captain acted as instructor.

The pilot from Port of Hirtshals did some runs with other ships, but these runs are not part of the evaluation in this report.

The outcome of the study is solely based on the sailing captain's opinion of the different layouts and do not include evaluation by FORCE Technology.

It was decided to stop each simulation when the ships were at a position inside the port at the basin in front of the quay area as it was anticipated that at this position the situation was as today.

The simulations were conducted with the most critical environmental conditions for arriving to Port of Hirtshals.

Prevailing weather conditions in this document refer to the characteristics depicted under chapter 5.3.

The objectives of the study were to:

- Get the opinion from the captains of the new layout and the work area situation compared to today.

The simulations were carried out at FORCE simulator bridge D.

The following persons participated in the simulations:

| Name | Company |
|----------------------|-------------------|
| Helge Ås | Color Line |
| Stein Roger | Color Line |
| Jan Richter | Fjord Line |
| Petur av Vollaum | Smyril Line |
| Niels Kiersgaard | Port of Hirtshals |
| Andreas Christiansen | Port of Hirtshals |
| Frederik Knudsen | Niras |
| Morten Luther | Niras |

Figure 0-1 Participants

The following ships were used and accepted by the client:

| Ship No. | Name | Ship Type | Description | Load Con. | LOA m | Lpp m | Bmld m | Tf m | Ta m | Displacem cbm | Prop. | Rudd. | Bow thrst. | Stern thrst. |
|----------|------------------|-----------|-------------|-----------|-------|-------|--------|-------|-------|---------------|-------|-------|------------|--------------|
| 3293 | Color Superspeed | Ferry | 211m RoPax | S | 211.3 | 193.7 | 25.8 | 6.5 | 6.6 | 19117 | 2C | 2 | 2 | 1 |
| 3686 | StavangerFjord | RoPax | 170 m | L | 170 | 148 | 27.5 | 6.367 | 6.367 | 15325.3 | 2C | 2 | 2 | 0 |
| 3237 | Norrøna | Ferry | 164.6m | S | 164.6 | 152.4 | 30 | 6 | 6 | 17165 | 2C | 2 | 2 | 0 |

Figure 0-2 Ferries used in the simulations

The ships were manoeuvred by the participating captains during the three days of simulation.

The results, described in the form of conclusions and recommendations, are provided in chapters 0.1, 0.2 and 3.1, 3.2.

The results are based on the actual simulation runs and the tested environmental conditions as well as the evaluations carried out by participating captains. For a detailed description of the conclusions and recommendations, please see section 3.

0.1. Conclusions

0.1.1. General

The captains said that they experienced a lee effect from current and waves when entering at the new western breakwater i.e. before than they do today, which give a little more time to prepare for the port turn.

0.1.2. Color Line captains' opinion of the layouts

The captains from Color Line had the following opinions:

Layout 1, western breakwater in place and the 10.5 curve marked with buoys:

- Captains said that this layout felt as it is today, although they felt that they were more protected in the first part before the turn into the port

Layout 2, western breakwater in place and the work area marked with buoys:

- Captains said that this layout was very challenging especially the two buoys positioned near the turn into the port.
- Captains said that it would be beneficial if the two buoys could be moved more to the west.
- Captains said that the wind speed should be max 15 m/s.

Layout 3, western breakwater in place and eastern breakwater shortened with 12.0 m in the entrance:

- Captains said that this layout was a big improvement compared to the existing entrance as there is more space for turning into the port.

0.1.3. Fjord Line captain opinion of the layouts

The captain from Fjord Line had the following opinions:

Layout 1, western breakwater in place and the 10.5 curve marked with buoys:

- Captain said that this layout felt as it is today with the same environmental limits.

Layout 2, western breakwater in place and the work area marked with buoys:

- Captain said that this layout was very challenging especially the two buoys positioned near the turn into the port.
- Captain said that it would be beneficial if the two buoys could be moved more to the west.
- Captain said that the wind speed limits would probably have to be 5 m/s less than it is today and max 15 m/s.

Layout 3, western breakwater in place and eastern breakwater shortened with 12.0 m in the entrance:

- Captain said that this layout was a big improvement compared to the existing entrance and it would be a major improvement, which would cause no problems.

0.1.4. Smyril Line captain opinion of the layouts

The captain from Smyril Line had the following opinions:

Layout 1, western breakwater in place and the 10.5 curve marked with buoys:

- Captain said that this layout felt as it is today with the same environmental limits.

Layout 2, western breakwater in place and the work area marked with buoys:

- Captain said that this layout was very challenging especially the two buoys positioned near the turn into the port.
- Captain said that it would be beneficial if the two buoys could be moved more to the west.
- Captain said that the wind speed limits would probably have to be 5 m/s less than it is today.

Layout 3, western breakwater in place and eastern breakwater shortened with 12.0 m in the entrance:

- Captain said that this layout was a big improvement compared to the existing entrance and it would be a major improvement, which would cause no problems.

0.2. Recommendations

Based on observations made during the simulation with the ferries, the following are recommended.

- It is recommended to look at the markings for the work area, especially around the old western breakwater at this show, the most problematic. It is recommended to see if the buoys can be moved further to the west.

1. Introduction

FORCE Technology was contacted by Niras on behalf of Port of Hirtshals to conduct a simulation study to evaluate the approach/departure of new layouts of the port.

One layout with new west breakwater and buoys marking the 10.5 m curve, one layout with working area around the old breakwater and with new west breakwater established and one layout with the new west breakwater and shortened east breakwater and 12.0 m in the entrance.

The three ferry companies were invited to do the simulations (one day each) to give their opinion of the three suggested layouts.

This report presents a qualitative study where the conclusions are solely based on the captain's perception of the three layouts.

The pilot from Port of Hirtshals did some runs with other ships, but these runs are not part of the evaluation in this report.

The ships to be used should be the ones calling the port today (ferries from Color Line, Fjord Line and Smyril Line).

The environmental conditions to be simulated were chosen in cooperation with the client and data were delivered by Niras.

Prevailing weather conditions in this document refer to the characteristics depicted under chapter 5.3.

The objectives of the study were to:

- Get the opinion from the captains from the three shipowners of the feasibility to call the port in the new suggested layouts, one with the new western breakwater in place (layout 1) and one with the suggested work area in place (layout 2) and one with the western breakwater in place along with a shortened eastern breakwater (layout 3).

It was decided that the simulation runs should be stopped when the ferries were well inside the port, as it was anticipated that at this position would be as it is today.

The following persons participated in the simulations:

| Name | Company |
|----------------------|-------------------|
| Helge Ås | Color Line |
| Stein Roger | Color Line |
| Jan Richter | Fjord Line |
| Petur av Vollarum | Smyril Line |
| Niels Kiersgaard | Port of Hirtshals |
| Andreas Christiansen | Port of Hirtshals |
| Frederik Knudsen | Niras |
| Morten Luther | Niras |

Figure 1-1 Participants

The following ships were used:

| Ship No. | Name | Ship Type | Description | Load Con. | LOA m | Lpp m | Bmld m | Tf m | Ta m | Displacem cbm | Prop. | Rudd. | Bow thrst. | Stern thrst. |
|----------|------------------|-----------|-------------|-----------|-------|-------|--------|-------|-------|---------------|-------|-------|------------|--------------|
| 3293 | Color Superspeed | Ferry | 211m RoPax | S | 211.3 | 193.7 | 25.8 | 6.5 | 6.6 | 19117 | 2C | 2 | 2 | 1 |
| 3686 | StavangerFjord | RoPax | 170 m | L | 170 | 148 | 27.5 | 6.367 | 6.367 | 15325.3 | 2C | 2 | 2 | 0 |
| 3237 | Norrøna | Ferry | 164.6m | S | 164.6 | 152.4 | 30 | 6 | 6 | 17165 | 2C | 2 | 2 | 0 |

Figure 1-2 Own ships used in the simulations

The ships were manoeuvred by the participating captains during the three days of simulation.

The results, described in the form of conclusions and recommendations, are provided in chapters 0.1 and 0.2 and in section 3.

The results are based on the actual simulation runs and the tested environmental conditions as well as the evaluations carried out by participating captains for each run. For a detailed description of the conclusions and recommendations, please see section 3, for individual runs see appendix A (scenario, comments and track plots).

All environmental data used was developed based on data received from Niras.

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

- One FORCE Technology full-mission bridge simulator, Bridge D.
- Two databases of Port of Hirtshals.
- Three ferries from the FORCE ship database

The databases used for the simulations were

- Layout 1 with the western breakwater in place and a 10.5 m curve marked with yellow buoys.
- Layout 2 similar to layout 1, but with a work area marked by yellow buoys.
- Layout 3 with the new western breakwater in place and the eastern breakwater shortened, with 12 m depths in the entrance.

Description of the layouts can be found in appendix C.

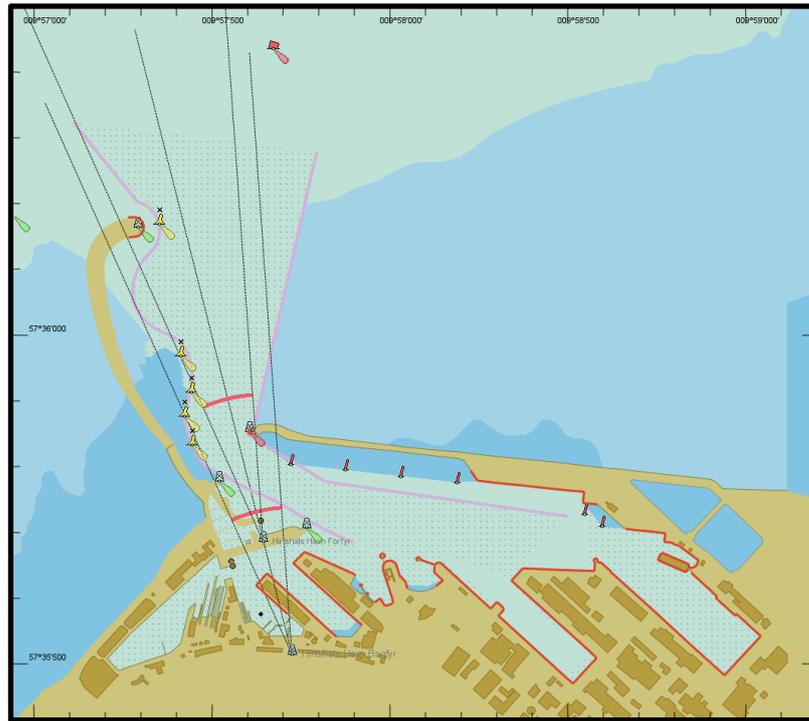


Figure 1-3 Layout 1 with western breakwater in place

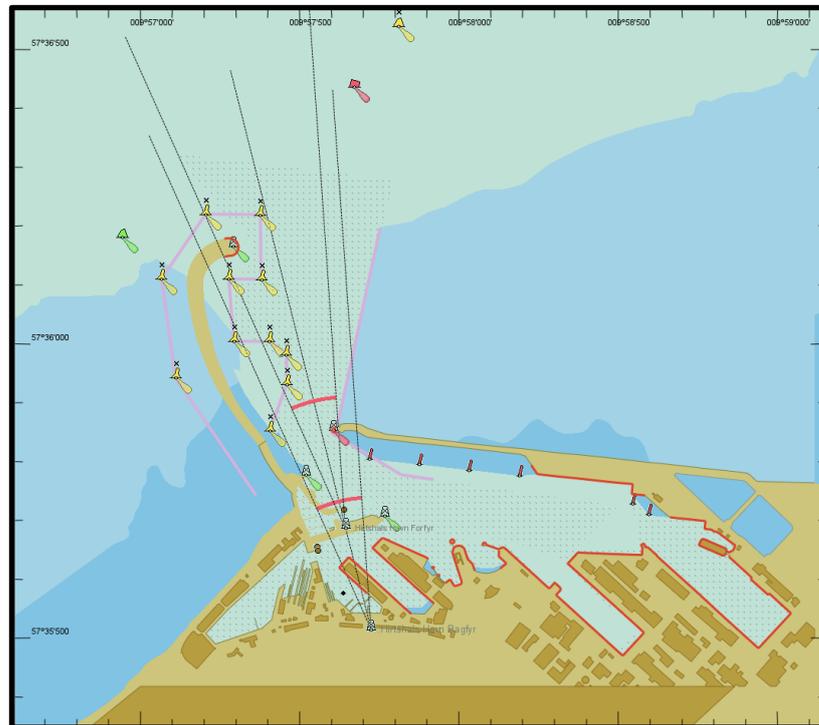


Figure 1-4 Layout 2 with work area in place

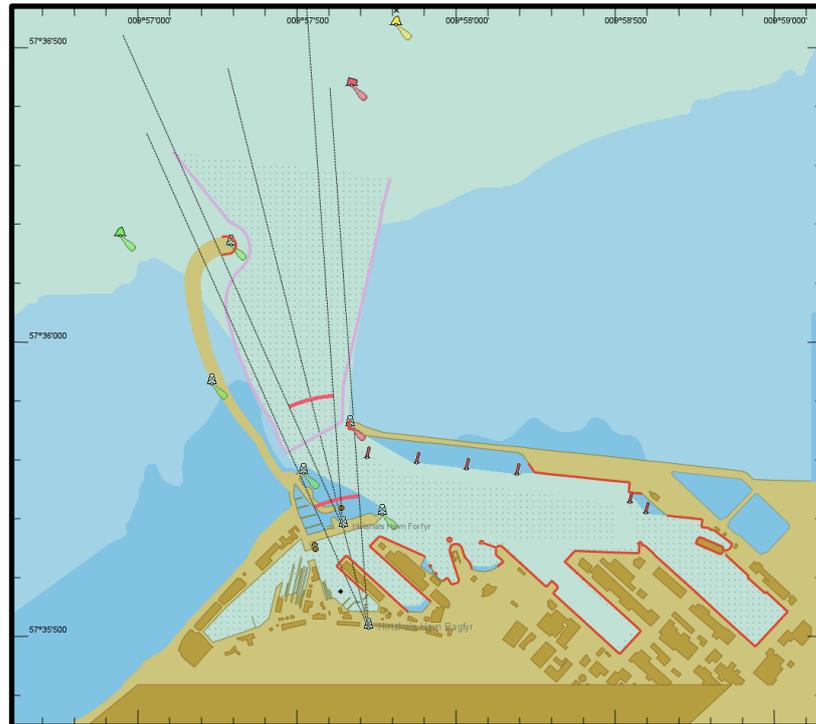


Figure 1-5 Layout 3 with western breakwater in place and eastern breakwater shortened

2. Summary and observations

2.1. Summary

Prior to the simulations the layouts and the ferries were tested by a FORCE Technology captain.

Three new databases of the Port of Hirtshals were used. It contained all necessary visual and bathymetric information based on the data from Danish Geodata Agency and Niras.

Observation, conclusions and recommendations are based on simulations limited to passing breakwaters and lining up the ferries in the port, maneuvering in the port and berthing the ferries was not a part of this study.

After each run, the captain completed an electronic evaluation form with all relevant observations and comments dealing with the current run. These comments from the captain have formed the basis for conclusions and recommendations.

The layouts and the surrounding area are described in section 5 and in Appendix C.

2.2. Observations

2.2.1. Day one with "Color Superspeed"

Twentytwo (22) runs were made with the ferry "Color Superspeed" on the first day.

Layout 1:

- The captains felt that it was comfortable to arrive and depart in this layout as they could feel that they the lee for current and waves further out than today.
- The margins were small at the highest wind speeds 18 m/s and up.
- No problems with departures were seen.
- The captains said that they felt a better protection from current and waves due to the new western breakwater, which also gave them more time for planning.

Layout 2:

- The buoys at the entrance are problematic as they give less space for the port turn into the port.
- The work area does not provide much margin for errors, and it must be carefully evaluated and planned when approaching this layout.
- The captains said that 15 m/s is absolutely maximum wind speed for this layout.

Layout 3:

- The captains said there is plenty of space for the port turn.
- There is plenty of space to drift

- The entrance is good and spacious; the challenge will be in the port for turning in strong wind.

2.2.2. Day two with "Stavangerfjord"

Seventeen (17) runs were made with the ferry "Stavangerfjord" on day two.

Layout 1:

- It is an advantage that the lee for current and waves come earlier than today.
- The captain said that this layout is more or less as today.
- The captain felt safe and secure.

Layout 2:

- The captain noted that there is much less space than today for the port turn.
- The captain said that limits would probably be lowered by 5 m/s compared to today.
- The captain did not feel that there was a bigger challenge for departure than he feels today.

Layout 3:

- Captain said it is a very fine layout with no limitations.
- Captain said the entrance does not set the limit; it is more the manoeuvring in the port in high wind speeds.

2.2.3. Day three with "Norrøna"

Sixteen (16) runs were made with the ferry "Norrøna" on day three.

Layout 1:

- Captain said it was easy to sail in the entrance.
- The captain said it was safe.

Layout 2:

- Very challenging entrance with much less space for drift.
- Very little space when departing.
- This layout can cause problems, especially the two buoys at the turn.
- The captain did not feel safe.

Layout 3:

- Good and safe with plenty of space for turn port into the port.

3. Conclusions and recommendations

3.1. Conclusions

The study's conclusions are based on 55 simulation runs with the captains from the three shipowners and their own ferry.

The summary presents the main findings and recommendations from these sessions, based on daily debriefings with the participants.

It's important to note that the observations, conclusions, and recommendations are limited to simulations involving passing the breakwaters and controlling the ferry inside the port. Maneuvering inside the port and docking the ferries were not part of this study.

3.1.1. General

The captains said that they experienced a lee effect from current and waves when entering at the new western breakwater i.e. before than they do today, which give a little more time to prepare for the port turn.

3.1.2. Color Line captains' opinion of the layouts

The captains from Color Line had the following opinions:

Layout 1, western breakwater in place and the 10.5m curve marked with buoys:

- Captains said that this layout felt as it is today, although they felt that they were more protected in the first part before the turn into the port

Layout 2, western breakwater in place and the work area marked with buoys:

- Captains said that this layout was very challenging especially the two buoys positioned near the turn into the port.
- Captains said that it would be beneficial if the two buoys could be moved more to the west.
- Captains said that the wind speed should be max 15 m/s.

Layout 3, western breakwater in place and eastern breakwater shortened with 12.0 m in the entrance:

- Captains said that this layout was a big improvement compared to the existing entrance as there is more space for turning into the port.

3.1.3. Fjord Line captain opinion of the layouts

The captain from Fjord Line had the following opinions:

Layout 1, western breakwater in place and the 10.5 curve marked with buoys:

- Captain said that this layout felt as it is today with the same environmental limits.

Layout 2, western breakwater in place and the work area marked with buoys:

- Captain said that this layout was very challenging especially the two buoys positioned near the turn into the port.
- Captain said that it would be beneficial if the two buoys could be moved more to the west.
- Captain said that the wind speed limits would probably have to be 5 m/s less than it is today and max 15 m/s.

Layout 3, western breakwater in place and eastern breakwater shortened with 12.0 m in the entrance:

- Captain said that this layout was a big improvement compared to the existing entrance and it would be a major improvement, which would cause no problems.

3.1.4. Smyril Line captain opinion of the layouts

The captain from Smyril Line had the following opinions:

Layout 1, western breakwater in place and the 10.5 curve marked with buoys:

- Captain said that this layout felt as it is today with the same environmental limits.

Layout 2, western breakwater in place and the work area marked with buoys:

- Captain said that this layout was very challenging especially the two buoys positioned near the turn into the port.
- Captain said that it would be beneficial if the two buoys could be moved more to the west.
- Captain said that the wind speed limits would probably have to be 5 m/s less than it is today.

Layout 3, western breakwater in place and eastern breakwater shortened with 12.0 m in the entrance:

- Captain said that this layout was a big improvement compared to the existing entrance and it would be a major improvement, which would cause no problems.

3.2. Recommendations

Based on observations made during the simulation with the ferries, the following are recommended.

- It is recommended to look at the markings for the work area, especially around the old western breakwater at this show, the most problematic. It is recommended to see if it is possible to move the buoys further to the west.

4. Method

4.1. General

The background of the present study is a request from Port of Hirtshals via Niras to evaluate the approach/departure to Port of Hirtshals in three layouts, one with the new western breakwater in place (layout 1), one with the work area during construction in place (layout 2) and if possible a layout with both the western breakwater in place along with a shortened eastern breakwater (layout 3).

The aim was to evaluate if the ferries could call the port under the existing limiting environmental conditions and get the captains' opinion. The main purpose was to evaluate if these environmental conditions still was safe.

The method is composed of the following:

- Use the two new layouts of the port
- Develop a list of runs
- Use the ferries from the three shipowners:
 - Color Line
 - Fjord Line
 - Smyril Line
- Environment settings
- Scenario development
- Simulations
- Debriefing
- Evaluation of runs

4.2. List of runs

A list of runs for the evaluation was created by Port of Hirtshals and FORCE Technology in collaboration. The list of runs was preliminary and subject to change during the simulations based on new findings. See list of conducted runs in Table 8-1.

4.3. Ships

Given the task of evaluating if the three specific ferries could enter the Port of Hirtshals the models were chosen from the FORCE Technology library of ships. See the description of the ships in section 6.

4.4. Scenario development

The scenarios were selected by FORCE and the client with respect to prevailing and critical wind speeds for different directions. Three directions were chosen wind from W, NW and NE along with the corresponding currents and waves. The ship's initial positioning was chosen by the participating captains to ensure that the captains had full control before beginning any manoeuvre.

The following aspects were considered when developing the simulation scenarios:

- Ship
- Starting position
- Environmental conditions (wind, current and waves)

4.5. Simulations

The simulations were carried out at one of FORCE Technology's bridges, bridge D (360 deg field of view) based on the list of runs developed.



Figure 4-1 Picture from bridge D Color Line



Figure 4-2 Picture from bridge D Fjord Line



Figure 4-3 Picture from bridge D Smyril Line

4.6. Debriefing

After each simulation day, a short debriefing session was conducted to sum up the findings of the day. The participants could elaborate on the runs and provide feedback on their experiences, sharing their observations and conclusions based on what they had witnessed.

Further, they filled in an evaluation sheet, commenting on each run.

4.7. Evaluation of runs

The evaluation of the feasibility of the ferries to arrive to the Port of Hirtshals is based on the participants' perceptions of the runs as seen during the simulations.

After each run, the participants (pilots/captains) and the FORCE Technology instructor each filled out an evaluation form with their experience of the newly finished run.

Further, the in-house developed evaluation program "Analyser" was used to replay each run, which enables showing tracks. See appendix A.

5. Description of area layouts

5.1. General

Two layouts of the area were developed for the simulations:

- Layout 1 with western breakwater in place and 10.5 m curve marked with yellow buoys.
- Layout 2 with western breakwater in place and with the work area around existing western breakwater area marked with yellow buoys. Depth in entrance 10.5 m.
- Layout 3 with western breakwater in place and eastern breakwater shortened, with 12.0 m depth in the entrance.

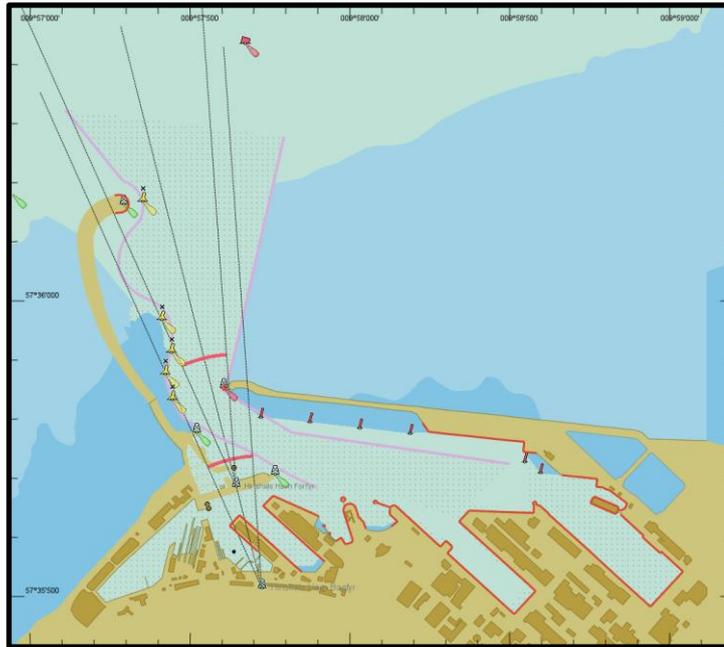


Figure 5-1 Hirtshals layout 1 area overview

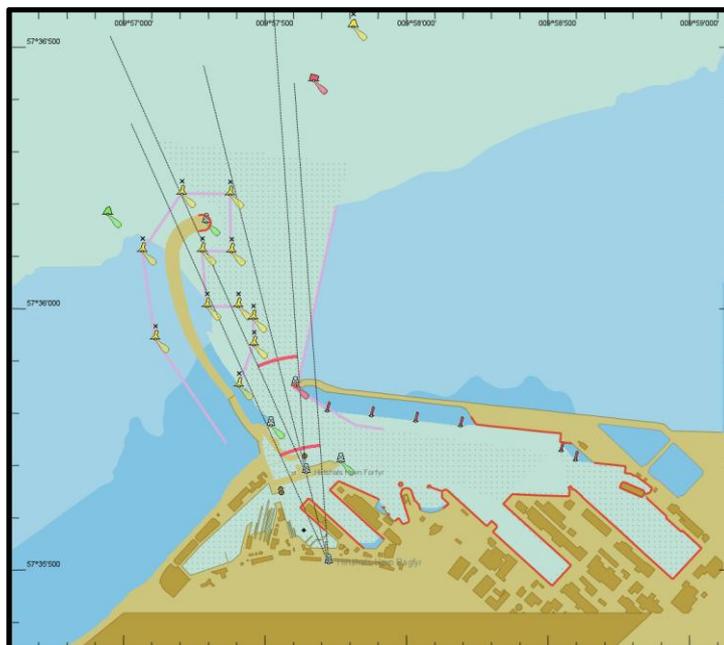


Figure 5-2 Hirtshals layout 2 area overview

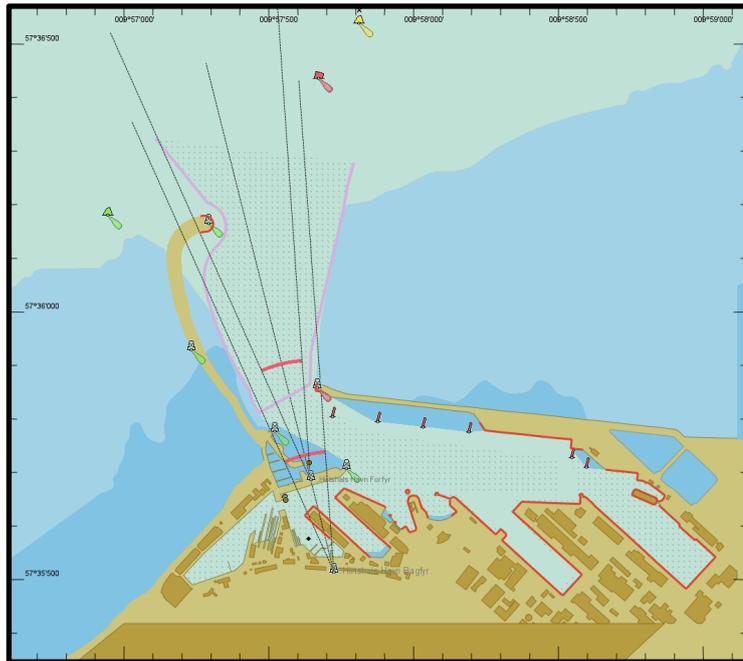


Figure 5-3 Hirtshals layout 3 area overview

5.2. Water depths

Water depth information in the area was taken from sea chart, surveys of the area and suggested dredging for the layouts (10.5 m in the entrance for layout 1 and 2 and 12.0 m for layout 3).

Water depths in the simulator are given as soundings (derived from depth contours, dredged areas and spot soundings) in the mathematical model, and the simulator program will interpolate between these soundings.

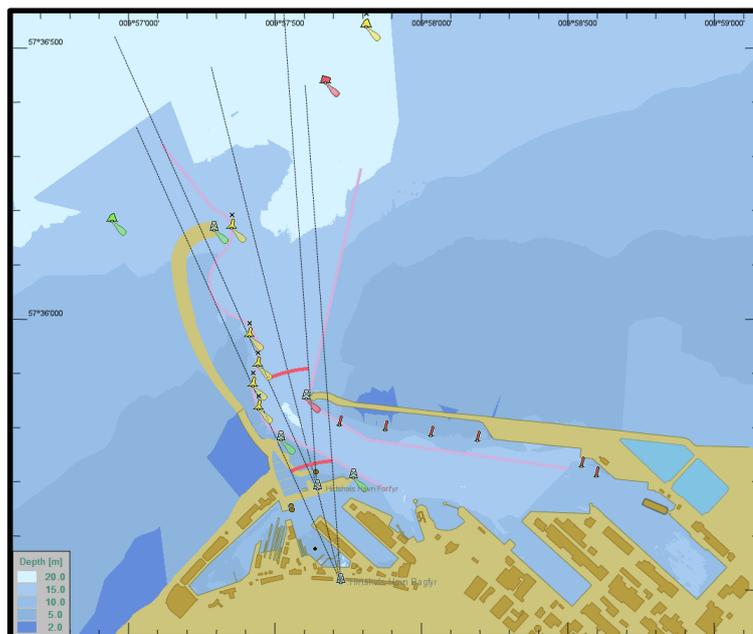


Figure 5-4 Depth as provided for previous study for layout 1 and 2 (2m, 5m, 10m, 15m and 20m shown)

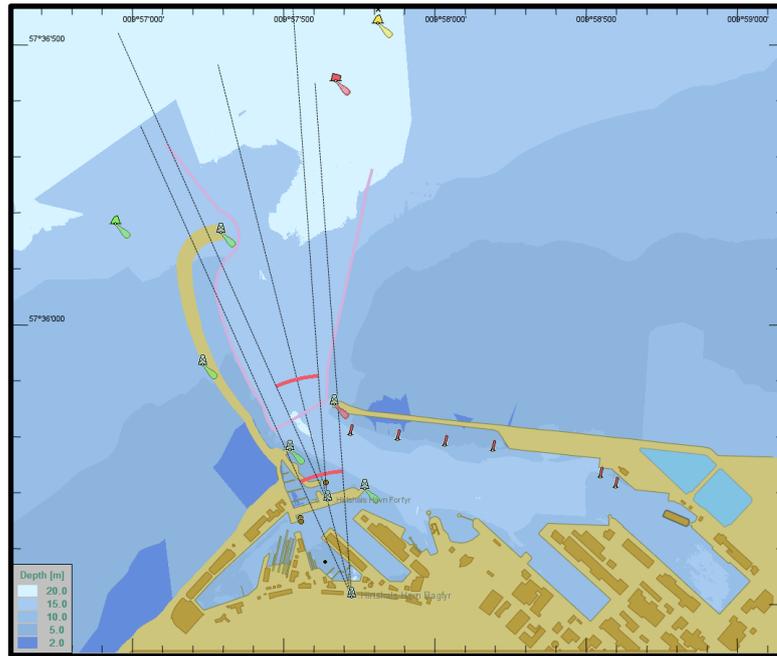


Figure 5-4 Depth as provided for previous study for layout 3 (2m, 5m, 10m, 15m and 20m shown)

5.3. Wind, current and waves

In the simulator, the wind speed is given as “meteorological wind speed” which is an average wind measured at 10 m height over a period of 10 minutes. This wind speed is not representative of the wind speed read from a wind indicator on a ship.

The predominant wind directions in the Hirtshals area are westerly winds originating from SSW and W. See wind rose below:

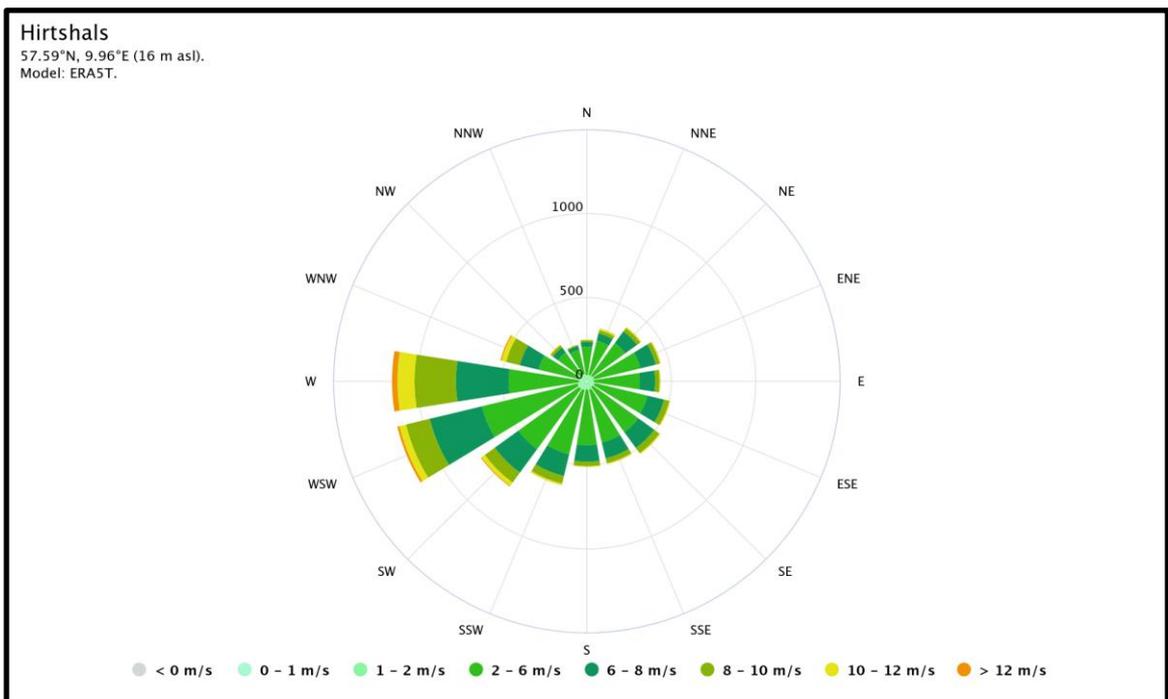


Figure 5-5 Windrose for Hirtshals

Wind used were:

- From W, NE and NW between 15m/s and 23 m/s

The currents were:

- E-going or W-going and corresponding to the wind direction and speed.

Waves were:

- From W, NE and NW and corresponding to the wind direction and speed

The correlation between wind, current and waves se below table:

| Wind speed [m/s] | Wind direction [deg.N] | Hs [m] | Tp [s] | MWD [deg.N] | Current speed [m/s] | Current direction [deg.N] |
|------------------|------------------------|--------|--------|-------------|---------------------|---------------------------|
| 19 | 278 | 3.4 | 8.3 | 292 | 1.18 | 62 |
| 18 | 273 | 3.2 | 8.2 | 290 | 1.12 | 62 |
| 16 | 272 | 2.6 | 7.2 | 286 | 0.87 | 62 |
| 14 | 270 | 2.2 | 7.1 | 285 | 0.64 | 60 |
| 12 | 274 | 1.9 | 6.8 | 285 | 0.62 | 61 |
| 10 | 281 | 1.6 | 6.6 | 286 | 0.52 | 60 |
| 18 | 288 | 3.2 | 7.9 | 291 | 1.18 | 62 |
| 16 | 301 | 2.6 | 7.3 | 297 | 0.79 | 63 |
| 14 | 317 | 2.4 | 7.4 | 300 | 0.69 | 62 |
| 12 | 317 | 1.9 | 6.9 | 298 | 0.32 | 61 |
| 10 | 310 | 1.5 | 6.7 | 293 | 0.65 | 61 |
| 18 | 60 | 1.8 | 5.6 | 40 | 0.83 | 267 |
| 16 | 39 | 2.2 | 6.3 | 24 | 0.79 | 268 |
| 14 | 36 | 2.4 | 7 | 6 | 0.69 | 269 |
| 12 | 51 | 1.7 | 6.1 | 17 | 0.55 | 265 |
| 10 | 59 | 1.4 | 5.8 | 31 | 0.37 | 272 |

Table 5-1 Correlation between wind, current and waves

For actual speeds and heights se list of runs in section 8.

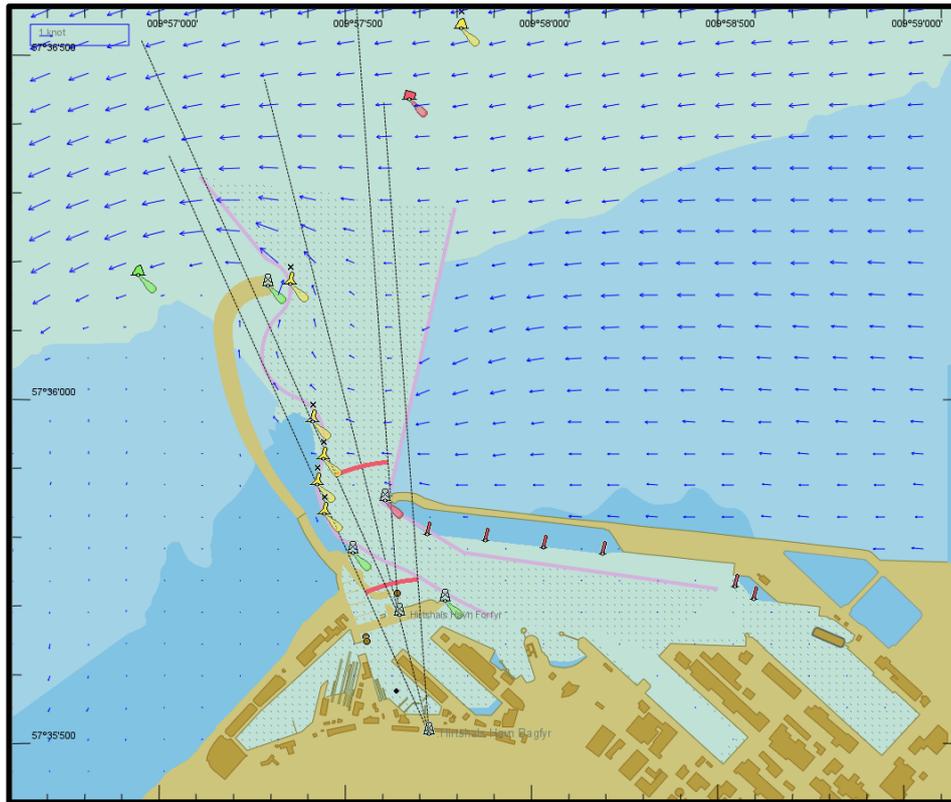


Figure 5-6 Example of a current field

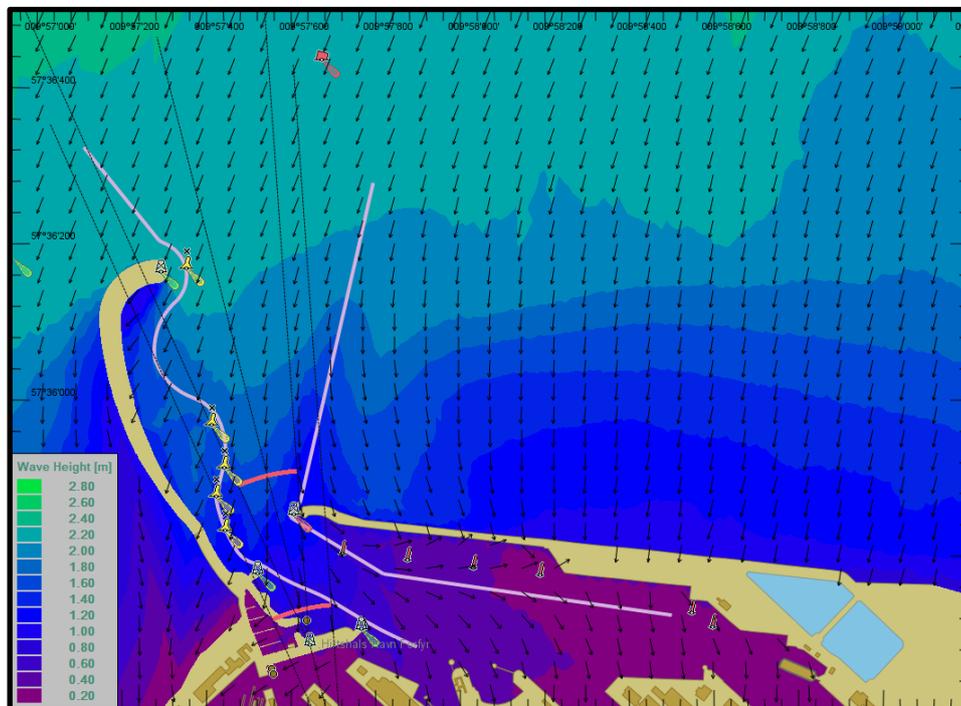


Figure 5-7 Example of a wave field

5.4. Visual database photos



6. Ships

6.1. General

The ships used in the simulations were six degree-of-freedom mathematical ship models of ferries "Color Superspeed", "Stavangerfjord" and "Norrøna".

Table 6-1 below shows the main dimensions of the three ferries.

| Ship No. | Name | Ship Type | Description | Load Con. | LOA m | Lpp m | Bmld m | Tf m | Ta m | Displacem cbm | Prop. | Rudd. | Bow thrst. | Stern thrst. |
|----------|------------------|-----------|-------------|-----------|-------|-------|--------|-------|-------|---------------|-------|-------|------------|--------------|
| 3293 | Color Superspeed | Ferry | 211m RoPax | S | 211.3 | 193.7 | 25.8 | 6.5 | 6.6 | 19117 | 2C | 2 | 2 | 1 |
| 3686 | StavangerFjord | RoPax | 170 m | L | 170 | 148 | 27.5 | 6.367 | 6.367 | 15325.3 | 2C | 2 | 2 | 0 |
| 3237 | Norrøna | Ferry | 164.6m | S | 164.6 | 152.4 | 30 | 6 | 6 | 17165 | 2C | 2 | 2 | 0 |

Figure 6-1Ships used in the simulations

Particulars for each ship is shown below in figures 6-1, 6-2 and 6-3.

6.2. Ship 3293 “Color Superspeed”

| Type of ship Condition Ship No. | | Ferry Design 3293 |
|---|----------------|-------------------------|
| Length between Perpendiculars | m | 193.7 |
| Length overall | m | 211.3 |
| Breadth moulded | m | 25.8 |
| Depth moulded | m | 9.4 |
| Draught fore/aft | m | 6.49/6.62 |
| Displacement | m ³ | 19117 |
| Wetted Surface | m ² | 5201 |
| Frontal wind Area | m ² | 680 |
| Lateral wind Area | m ² | 4330 |
| Block Coefficient based on L _{pp} | - | 0.584 |
| Trim by the Stern | % | 0.067 |
| Metacentric Height | m | 2.86 |
| LCB, % of L _{pp} forw. of L _{pp} /2 | % | -3.65 |
| Radius of Inertia, % of L _{pp} | % | 25.0 |
| Type of Engine | | Diesel |
| Number of Propellers | | 2 |
| Type of Propellers | | CP |
| Direction of Rotation | | Inwards |
| Number of Blades | | 4 |
| Propeller Diameter | m | 5.25 |
| Pitch Ratio at 0.7-R | | 1.40 |
| Area Ratio | | 0.74 |
| Shaft Power (ahead) total | kW | 2 x 18900 |
| Number of Rudders | | 2 |
| Type of Rudders | | Semi-spade |
| Distance from center line | m | 5.3 |
| Area of Rudder (movable part) | m ² | 18.2 |
| Total rudder Area/(L _{pp} x T) | % | 2.87 |
| Turning Velocity of Rudder (two Pumps) | deg/s | 4.6 |
| Max. rudder Angle | deg | 35 |
| Anchor Weight | kg | 2 x 6450 |
| Chain Weight | kg/m | 113 |
| Number of bow Thrusters | | 2 |
| Nominal bow thruster Power | kW | 2 x 2400 ~ 2 x 32.6 t |
| Number of stern Thrusters | | 1 |
| Nominal stern thruster Power | kW | 1 x 1200 ~ 1 x 16.3 t |

Figure 6-2 Ship 3293 “Color Superspeed” particulars

6.3. Ship 3686 "Stavangerfjord"

| Type of ship Condition Ship No. | | RoPax Fully Loaded Departure 3686 |
|---|----------------|--|
| Length between Perpendiculars | m | 148 |
| Length overall | m | 170 |
| Breadth moulded | m | 27.5 |
| Depth moulded | m | 20.45 |
| Draught fore/aft | m | 6.367 / 6.367 |
| Displacement | m ³ | 15325.3 |
| Wetted Surface | m ² | 4716 |
| Frontal wind Area | m ² | 700 |
| Lateral wind Area | m ² | 3800 |
| Block Coefficient based on L _{pp} | - | 0.591 |
| Trim by the Stern | % | 0.0 |
| Metacentric Height | m | 16.02 |
| LCB, % of L _{pp} forw. of L _{pp} /2 | % | -4.01 |
| Radius of Gyration, /L _{pp} | - | 0.25 |
| Radius of Gyration, /B | - | 0.35 |
| Type of Engine | | LNG gen sets |
| Number of Propellers | | 4 |
| Type of Propellers | | CP |
| Direction of Rotation | | Outward |
| Number of Blades | | 4 |
| Propeller Diameter | m | 4.7 |
| Pitch Ratio at 0.7·R | | 1.714 |
| Area Ratio | | 0.651 |
| Shaft Power (ahead) total | kW | 4 x 5400 |
| Number of Rudders | | 2 |
| Type of Rudders | | Promas flap |
| Position from center line | m | 5.0 |
| Area of Rudder (movable part) | m ² | 2 x 16.6 |
| Total rudder Area/(L _{pp} x T) | % | 3.52 |
| Turning Velocity of Rudder (two Pumps) | deg/s | 2.6 |
| Max. rudder Angle | deg | +/- 45 |
| Anchor Weight | kg | 2 x 5575 |
| Chain Weight | kg/m | 96.3 |
| Number of bow Thrusters | | 2 |
| Nominal bow thruster Power (tunnel/retractable) | kW | 2 x 1600 ~ 43 t. |
| Number of stern Thrusters | | 0 |
| Nominal stern thruster Power | kW | - |

Figure 6-3 Ship 3686 "Stavangerfjord" particulars

6.4. Ship 3237 "Norrøna"

| Type of ship Condition Ship No. | | Ferry Service, even keel 3237 |
|--|----------------|-------------------------------------|
| Displacement | m ³ | 17165 |
| Length between Perpendiculars | m | 152.4 |
| Length overall | m | 164.6 |
| Breadth moulded | m | 30.0 |
| Depth moulded | m | 9.50 |
| Draught fore/aft | m | 6.00/6.00 |
| Wetted Surface | m ² | 4526 |
| Frontal wind Area | m ² | 851 |
| Lateral wind Area | m ² | 4340 |
| Block Coefficient based on Lpp | - | 0.626 |
| Trim by the Stern | % | 0 |
| Metacentric Height | m | -4.91 |
| LCB, % of LPP forw. of LPP/2 | % | 3.0 |
| Radius of Inertia, % of LPP | % | 25.0 |
| Type of Engine | | Diesel |
| Number of Propellers | | 2 |
| Type of Propellers | | CP |
| Direction of Rotation | | Inwards |
| Number of Blades | | 4 |
| Propeller Diameter | m | 5.2 |
| Pitch Ratio at 0.7R | | 1.27 |
| Area Ratio | | 0.513 |
| Shaft Power (ahead) total | kW | 2 x 10800 |
| Number of Rudders | | 2 |
| Type of Rudders | | Twisted Spade |
| Position | | 6.3 m from CL |
| Area of Rudder | m ² | 15.00 |
| 100 x total rudder Area/LBP x T | | 3.28 |
| Turning Velocity of Rudder (two Pumps) | deg/s | 4.6 |
| Max. rudder Angle | deg | 45 |
| Anchor Weight | kg | 6225 |
| Chain Weight | kg/m | 56.5 |
| Number of bow Thrusters | | 2 |
| Nominal bow thruster Power | kW | 2 x 1750 ~ 2 x 25 t |
| Number of stern Thrusters | | 0 |
| Nominal stern thruster Power | kW | - |

Figure 6-4 Ship 3237 "Norrøna" particulars

7. Simulation description

During the simulations the FORCE bridge D was used for the simulations with the three ferries.

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

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

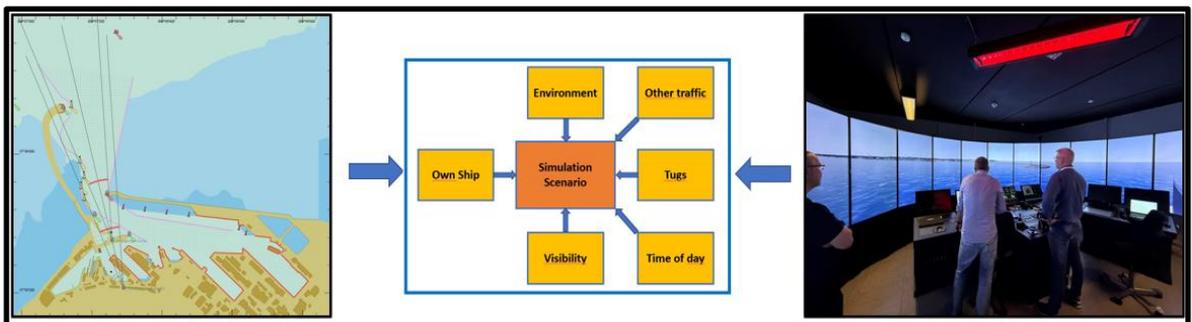


Figure7-1 Simulator bridge D set-up

8. Documentation of simulations

8.1. List of simulation runs

The final scenarios seen below were established during the simulations.

| Run | Layout | Wind | | Current | | Waves | | | Arrival | | Ship |
|-----|-----------------------|-----------|-----------|-----------|---------------|-----------|-----------|--------|-----------|------------------|------|
| | | Direction | Speed m/s | Direction | Speed (knots) | Direction | Hight (m) | Tp (s) | Departure | | |
| 101 | Layout 1, 10.5 m | W | 16 | ENE-going | 1.7 | WNW | 2.6 | 7.2 | Arrival | Color Superspeed | |
| 102 | Layout 1, 10.5 m | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Arrival | Color Superspeed | |
| 103 | Layout 1, 10.5 m | NW | 18 | E-going | 2.3 | WNW | 3.2 | 7.9 | Arrival | Color Superspeed | |
| 104 | Layout 1, 10.5 m | NE | 16 | W-going | 1.5 | NE | 2.2 | 6.3 | Arrival | Color Superspeed | |
| 105 | Layout 1, 10.5 m | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Color Superspeed | |
| 106 | Layout 1, 10.5 m | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Departure | Color Superspeed | |
| 107 | Layout 1, 10.5 m | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Departure | Color Superspeed | |
| 108 | Layout 1, 10.5 m | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Arrival | Color Superspeed | |
| 109 | Layout 1, 10.5 m | NW | 18 | E-going | 2.3 | WNW | 3.2 | 7.9 | Arrival | Color Superspeed | |
| 110 | Layout 2 Working Area | W | 18 | ENE-going | 2.2 | WNW | 3.2 | 8.2 | Arrival | Color Superspeed | |
| 111 | Layout 2 Working Area | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Arrival | Color Superspeed | |
| 112 | Layout 2 Working Area | NW | 18 | E-going | 2.3 | WNW | 3.2 | 7.9 | Arrival | Color Superspeed | |
| 113 | Layout 2 Working Area | NE | 16 | W-going | 1.5 | NE | 2.2 | 6.3 | Arrival | Color Superspeed | |
| 114 | Layout 2 Working Area | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Color Superspeed | |
| 115 | Layout 2 Working Area | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Color Superspeed | |
| 116 | Layout 2 Working Area | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Departure | Color Superspeed | |
| 117 | Layout 2 Working Area | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Departure | Color Superspeed | |
| 118 | Layout 3, 12.0 m | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Arrival | Color Superspeed | |
| 119 | Layout 3, 12.0 m | NW | 18 | E-going | 2.3 | WNW | 3.2 | 7.9 | Arrival | Color Superspeed | |
| 120 | Layout 3, 12.0 m | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Color Superspeed | |
| 123 | Layout 3, 12.0 m | W | 23 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Arrival | Color Superspeed | |
| 124 | Layout 3, 12.0 m | NE | 23 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Color Superspeed | |

Figure 8-1 List of executed runs "Color Superspeed"

| Run | Layout | Wind | | Current | | Waves | | | Arrival | | Ship |
|-----|-----------------------|-----------|-----------|-----------|---------------|-----------|-----------|--------|-----------|----------------|------|
| | | Direction | Speed m/s | Direction | Speed (knots) | Direction | Hight (m) | Tp (s) | Departure | | |
| 201 | Layout 1, 10.5 m | W | 16 | ENE-going | 1.7 | WNW | 2.6 | 7.2 | Arrival | StavangerFjord | |
| 202 | Layout 1, 10.5 m | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Arrival | StavangerFjord | |
| 203 | Layout 1, 10.5 m | NW | 18 | E-going | 2.3 | WNW | 3.2 | 7.9 | Arrival | StavangerFjord | |
| 204 | Layout 1, 10.5 m | NE | 16 | W-going | 1.5 | NE | 2.2 | 6.3 | Arrival | StavangerFjord | |
| 205 | Layout 1, 10.5 m | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | StavangerFjord | |
| 206 | Layout 1, 10.5 m | W | 18 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Departure | StavangerFjord | |
| 207 | Layout 1, 10.5 m | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Departure | StavangerFjord | |
| 208 | Layout 2 Working Area | W | 18 | ENE-going | 2.2 | WNW | 3.2 | 8.2 | Arrival | StavangerFjord | |
| 209 | Layout 2 Working Area | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Arrival | StavangerFjord | |
| 210 | Layout 2 Working Area | NW | 18 | E-going | 2.3 | WNW | 3.2 | 7.9 | Arrival | StavangerFjord | |
| 211 | Layout 2 Working Area | NE | 16 | W-going | 1.5 | NE | 2.2 | 6.3 | Arrival | StavangerFjord | |
| 212 | Layout 2 Working Area | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | StavangerFjord | |
| 213 | Layout 2 Working Area | W | 19 | ENE-going | 2.3 | WNW | 3.4 | 8.3 | Departure | StavangerFjord | |
| 214 | Layout 2 Working Area | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Departure | StavangerFjord | |
| 215 | Layout 3, 12.0 m | NW | 20 | E-going | 2.5 | WNW | 3.2 | 7.9 | Arrival | StavangerFjord | |
| 216 | Layout 3, 12.0 m | NE | 20 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | StavangerFjord | |
| 217 | Layout 3, 12.0 m | NW | 23 | E-going | 2.5 | WNW | 3.2 | 7.9 | Arrival | StavangerFjord | |

Figure 8-2 List of executed runs "Stavangerfjord"

| Run | Layout | Wind | | Current | | Waves | | | Arrival | Ship |
|-----|-----------------------|-----------|-----------|-----------|---------------|-----------|-----------|--------|-----------|---------|
| | | Direction | Speed m/s | Direction | Speed (knots) | Direction | Hight (m) | Tp (s) | Departure | |
| 301 | Layout 1 10.5 m | W | 16 | ENE-going | 1.7 | WNW | 2.6 | 7.2 | Arrival | Norrøna |
| 302 | Layout 1 10.5 m | W | 18 | ENE-going | 2.2 | WNW | 3.2 | 8.2 | Arrival | Norrøna |
| 303 | Layout 1 10.5 m | NW | 16 | E-going | 1.5 | WNW | 2.6 | 7.3 | Arrival | Norrøna |
| 304 | Layout 1 10.5 m | NE | 16 | W-going | 1.5 | NE | 2.2 | 6.3 | Arrival | Norrøna |
| 305 | Layout 1 10.5 m | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Norrøna |
| 306 | Layout 1 10.5 m | W | 18 | ENE-going | 2.2 | WNW | 3.2 | 8.2 | Departure | Norrøna |
| 307 | Layout 1 10.5 m | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Departure | Norrøna |
| 308 | Layout 2 Working Area | W | 16 | ENE-going | 1.7 | WNW | 2.6 | 7.2 | Arrival | Norrøna |
| 309 | Layout 2 Working Area | W | 18 | ENE-going | 2.2 | WNW | 3.2 | 8.2 | Arrival | Norrøna |
| 310 | Layout 2 Working Area | NW | 16 | E-going | 1.5 | WNW | 2.6 | 7.3 | Arrival | Norrøna |
| 311 | Layout 2 Working Area | NE | 16 | W-going | 1.5 | NE | 2.2 | 6.3 | Arrival | Norrøna |
| 312 | Layout 2 Working Area | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Norrøna |
| 313 | Layout 2 Working Area | W | 18 | ENE-going | 2.2 | WNW | 3.2 | 8.2 | Departure | Norrøna |
| 314 | Layout 2 Working Area | NE | 18 | W-going | 1.6 | NE | 1.8 | 5.6 | Departure | Norrøna |
| 315 | Layout 3, 12.0 m | NW | 23 | E-going | 2.5 | WNW | 3.2 | 7.9 | Arrival | Norrøna |
| 316 | Layout 3, 12.0 m | NE | 23 | W-going | 1.6 | NE | 1.8 | 5.6 | Arrival | Norrøna |

Figure 8-3 List of executed runs "Norrøna"

8.2. Geographical plots of manoeuvres

The simulated manoeuvres are shown as sweep plots in Appendix A.

9. 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] |

10. References

- [1] IALA Guidelines

Appendix A

Track Plots and Comments

Appendix B

Ship Descriptions

Appendix C

Environment Descriptions

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 m height.

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

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

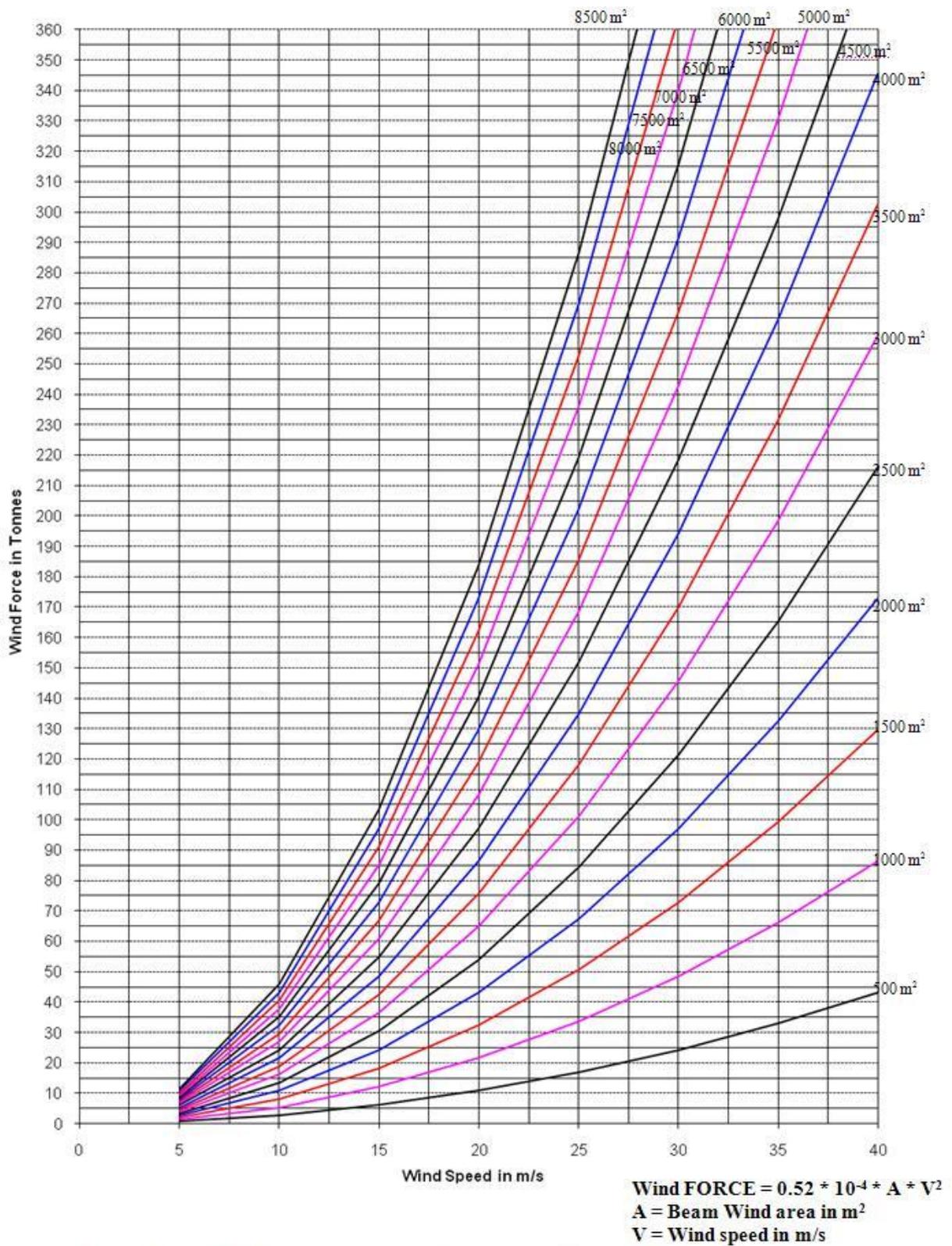
Example:

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.



Approximate wind forces; standard formula used by navigators.