

Intended for
Nord Stream 2 AG

Date
October, 2016

Document number
W-PE-EIA-POF-REP-805-060400EN-01

NORD STREAM 2 STUDY ON COMMERCIAL SHIPS PASSING THE LAY BARGE IN THE FINNISH EEZ

NORD STREAM 2

Study on commercial ships passing the Lay barge in the Finnish EEZ

Revision **01**
Date **2016-10-31**

Document ID W-PE-EIA-POF-REP-805-060400EN-01
Ref 1100019533 / PO16-5068

Ramboll
Hannemanns Allé 53
DK-2300 Copenhagen S
Denmark
T +45 5161 1000
F +45 5161 1001
www.ramboll.com

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APPENDICES

Appendix 1

Movie showing the traffic around the lay barge

1. INTRODUCTION

Nord Stream 2 is a pipeline through the Baltic Sea planned to deliver natural gas from vast reserves in Russia directly to the EU gas market to fill the growing gas import demand. The twin 1,200 kilometre subsea pipelines will have the capacity to supply 55 billion cubic metres of gas per year in an economic, environmentally safe and reliable way, compensating for the drop in the EU's domestic production. The privately funded €8 billion infrastructure project will ensure long-term access to an important, low-emissions energy source, thereby contributing to the EU's climate protection efforts. Additional supplies will boost competition in the market and support the EU's global industrial competitiveness. Nord Stream 2 follows in the footsteps of the successful experience of construction and operation of the existing Nord Stream Pipeline, which has been recognised for its high environmental and safety standards, green logistics, open dialogue and public consultation.

Nord Stream 2 AG is an international consortium established for the planning, construction and subsequent operation of the Nord Stream 2 pipeline. Signatories to the shareholders agreement are PJSC Gazprom, the German companies Uniper SE and BASF SE/Wintershall Holding GmbH, the Anglo-Dutch group Royal Dutch Shell plc, the Austrian OMV AG and the French group ENGIE S.A. The envisaged shareholder structure of equal EU and Russian interests in the project reflects the significance of this new infrastructure for Europe's future energy supply needs. Nord Stream 2 AG is based in Zug, Switzerland.

1.1 Scope

Construction of the Nord Stream 2 pipeline system (NSP2) will to some degree disturb shipping traffic on some of the main navigational routes in the Baltic Sea. Dangerous situations may occur as a result of the presence of a safety area with a lay barge and numerous support vessels.

To minimize the level of disturbance and the number of dangerous situations, it is important to gather experience and learn from the construction of the Nord Stream pipeline system (NSP).

This report presents two detailed analyses, for the Finnish EEZ, of how ship traffic reacts to a lay barge surrounded by a safety area:

1. Ship tracks near lay barge (methodology given in section 3.1)
2. Lay barge passing through TSS (methodology given in section 3.2)

The analyses are based on Automatic Information System (AIS) data collected during the construction of NSP. The AIS data include data on the construction vessels and on commercial ship traffic in the Baltic Sea.

The present report only includes analyses for the Finnish EEZ. For similar analyses, of areas along the rest of the pipeline route, reference is made to the report "Study on commercial ships passing the lay barge", W-PE-EIA-POF-REP-805-060300EN-04, September 2016.

2. NORD STREAM PIPELINE SYSTEM

The offshore part of NSP was constructed between 2010 and 2012. It follows the route indicated in Figure 2-1.

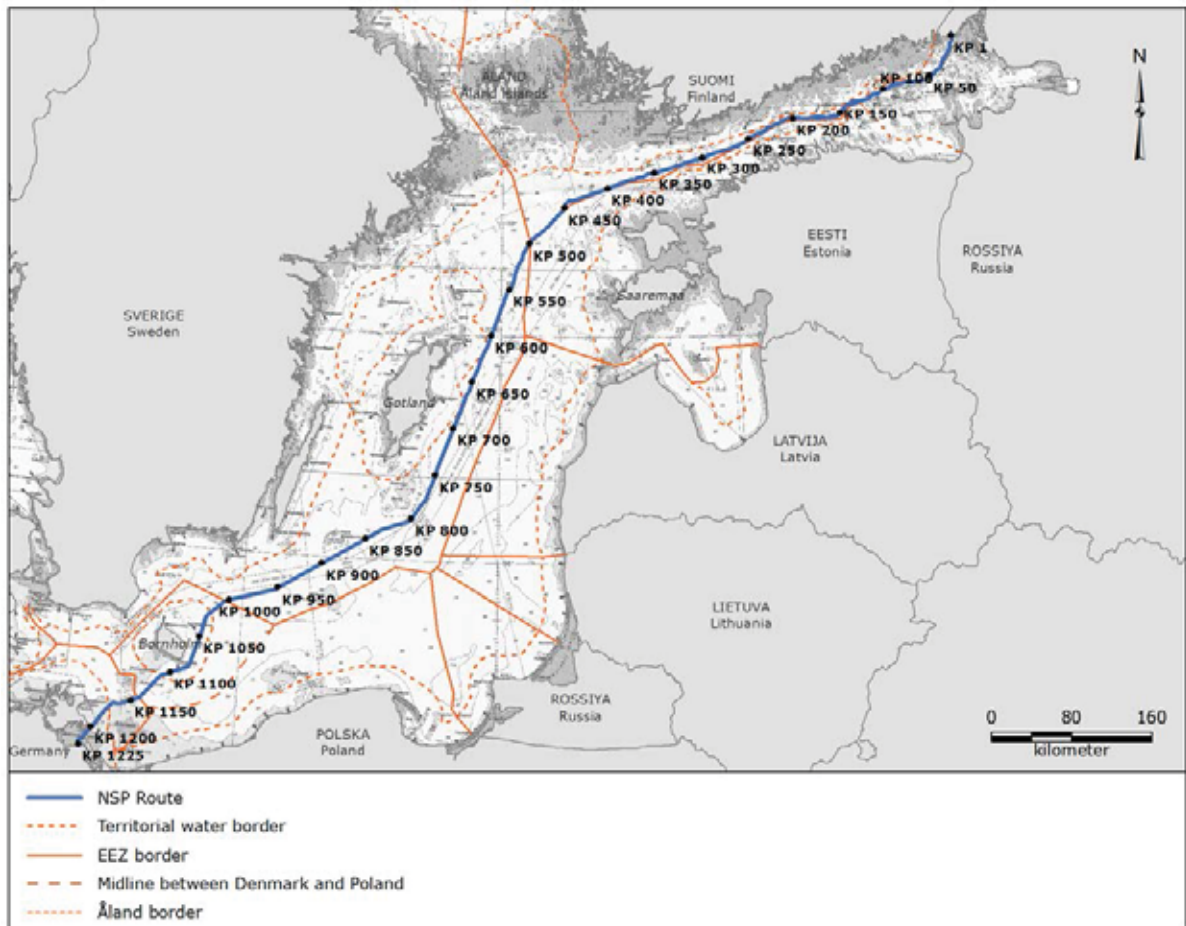


Figure 2-1 The NSP route with kilometre points (KPs).

Pipe-laying was carried out primarily by two different types of lay barges. In the Gulf of Finland (from KP 7.5 to KP 350), the dynamically positioned lay barge *Solitaire* was used (Figure 2-2). This vessel uses a dynamic positioning system to keep its position. The vessel is 300 m long and has a lay speed of approximately 3 km per day. The safety zone around the vessel is 2 km.



Figure 2-2 The lay barge *Solitaire* used in the Gulf of Finland.

Outside the Gulf of Finland (from KP 350 to KP 1196) the lay barge *Castoro Sei* was used (Figure 2-3). This vessel uses anchors to keep its position. The vessel is 143 m long and has a lay speed of approximately 3 km per day. The safety zone around the vessel is 3 km in Finnish waters.



Figure 2-3 The lay barge *Castoro Sei* used outside the Gulf of Finland.

The sizes of the safety zones are listed in Table 2-1.

Table 2-1 Size of the safety zones for the two different types of lay barges used.

Area	Safety zone of Anchor-positioned lay barge <i>Castoro Sei</i>	Safety zone of dynamically positioned lay barge <i>Solitaire</i>
Finland	3 km	2 km

3. ANALYSES

The intensity of the commercial ship traffic passing the lay barge is shown in Figure 3-1. As only the interaction between the commercial traffic and the lay barge is of interest, the ship traffic associated with construction activities has been removed from the analysis. At some of the locations it has proven difficult to obtain a complete overview of the construction traffic. Therefore, some ships that have been included in the analysis may actually be part of the construction traffic.

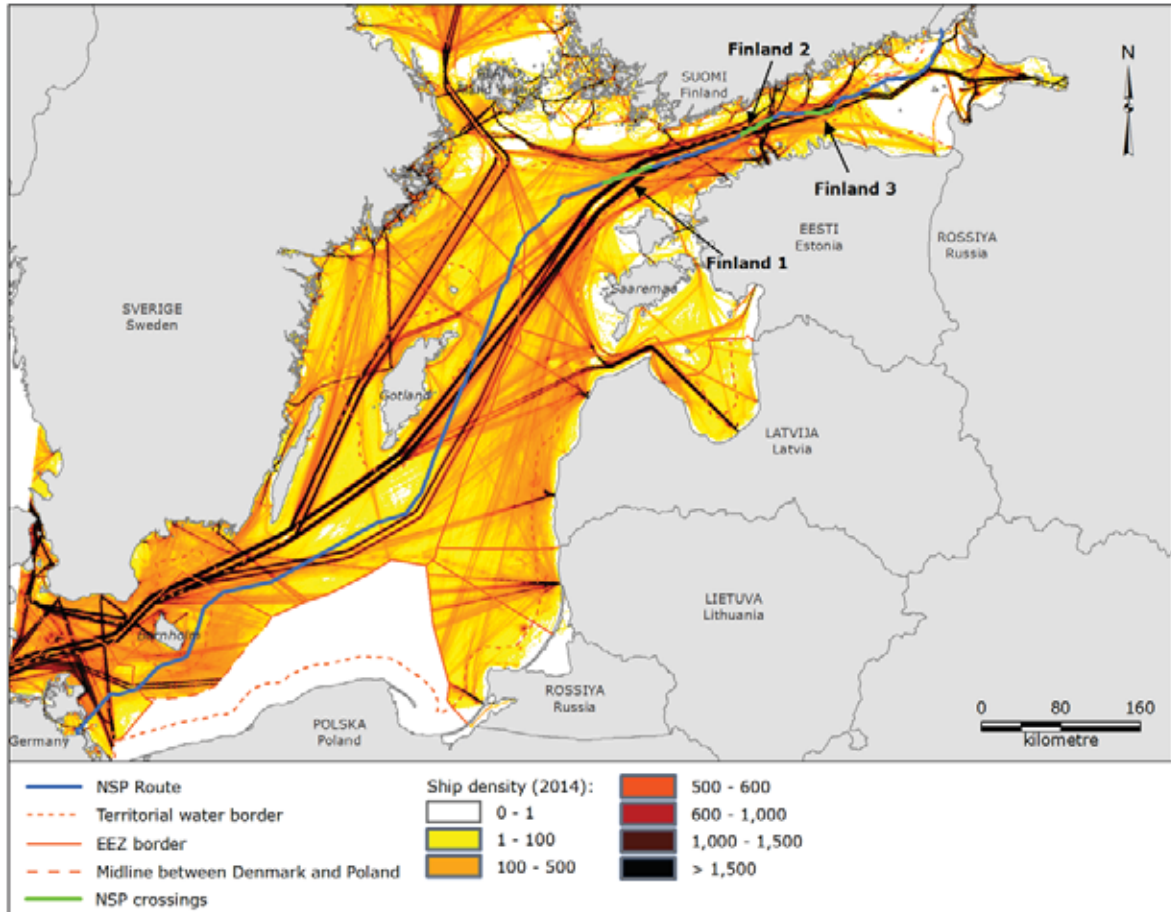


Figure 3-1 Ship traffic intensity plot showing the ship traffic in the Baltic Sea. The blue line indicates the route of NSP. The green lines marked by Finland 1, Finland 2 and Finland 3 indicate areas where the commercial ship traffic passing the lay barge has been analyzed in the Finnish EEZ.

AIS data are used to study the impact on commercial ship traffic caused by the construction of NSP. AIS is mandatory for all ships of 300 gross tonnage (GT) and upwards engaged in international voyages, cargo ships of 500 GT and upwards not engaged in international voyages, and all passenger ships irrespective of size. On average, a ship of 300 GT will have a length of approximately 36 m.

According to the scope (see section 1.1) two different analyses are performed and described below. The results are given in the following sections 4 and 5.

3.1 Ship tracks near lay barge

To understand how ships react to a lay barge, the tracks of commercial ships have been drawn relative to different lay barge positions. The number of tracks around the lay barge at one specific location is limited owing to the continuous movement of the lay barge. Therefore, the tracks from different lay barge positions have been superimposed around the lay barge. This is

done by drawing the tracks of all ships passing the lay barge in a coordinate system that moves with the lay barge so that coordinate system follows the position of the lay barge, see Figure 3-2.

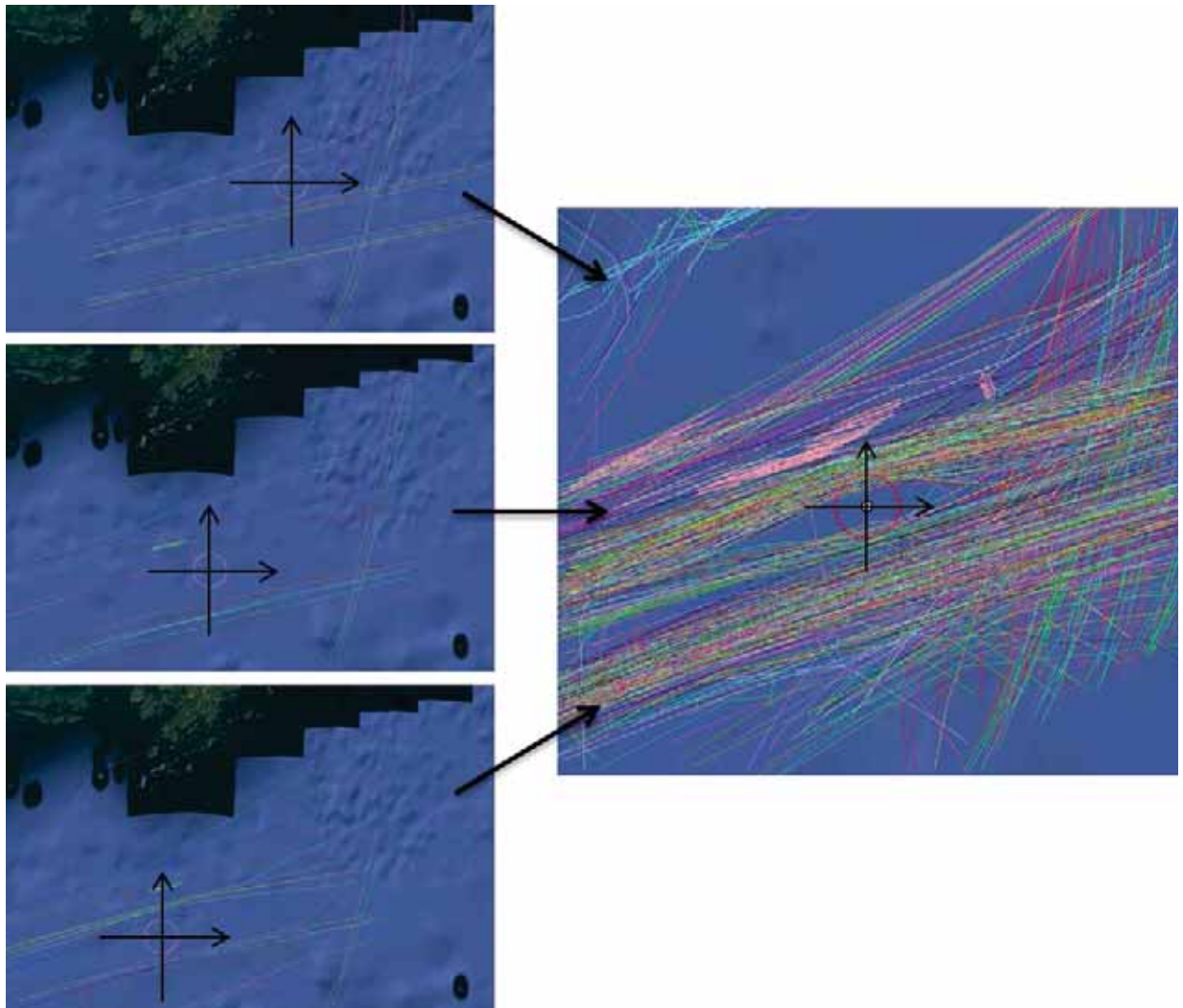


Figure 3-2 The three figures on the left show the tracks around the lay barge for different lay barge positions. The figure on the right shows the all of the tracks superimposed on the same picture with origin in the lay barge.

The analyzed areas are shown in Figure 3-1, and Section 4 presents the analyses of each selected area in the Finnish EEZ.

3.2 Lay barge passing through TSS

The three analyzed areas correspond to TSS areas in the Finnish EEZ. The analyzed areas are shown in Figure 3-3 with TSS area names, and they correspond to the areas "Finland 1", "Finland 2" and "Finland 3" in Figure 3-1. In these areas, the commercial vessels shall sail according to the general direction of the defined traffic lanes, and crossing of the TSS areas shall be done at an angle as close as possible to 90°. When the lay barge is located within the TSS, and especially within one of the traffic lanes, then the commercial vessels need to alter course in order to stay clear of the lay barge.

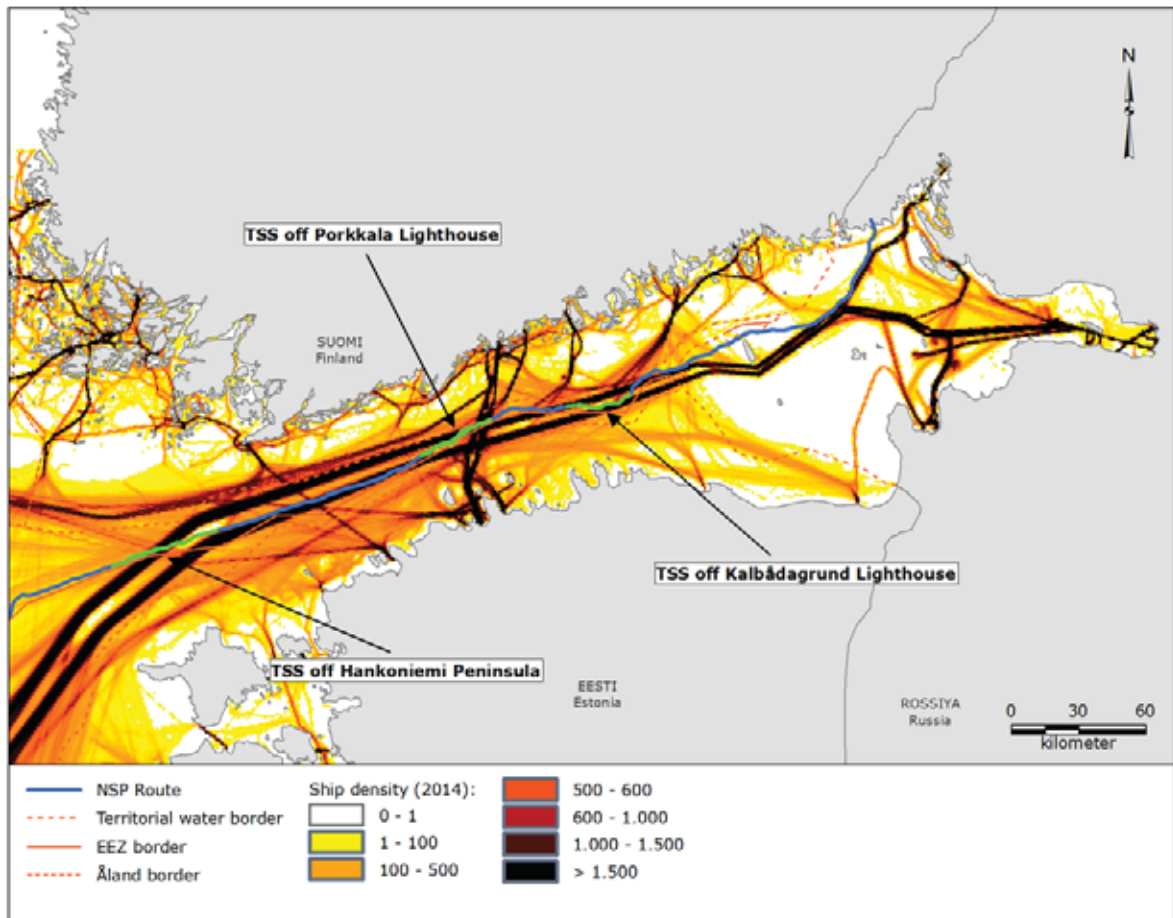


Figure 3-3. Areas analysed when lay barge passes TSS.

To analyze how commercial ships behave in the TSS areas, the ship traffic in the TSS areas is plotted for two periods in time; one with the lay barge passing through, and one with no lay barge present in the area. The ship traffic is shown on top of sea charts indicating the layout of the TSS areas as illustrated in Figure 3-4 (example). Commercial ship tracks are shown as semitransparent blue lines such that the sea chart is visible behind the tracks. Green tracks show the lay barge.

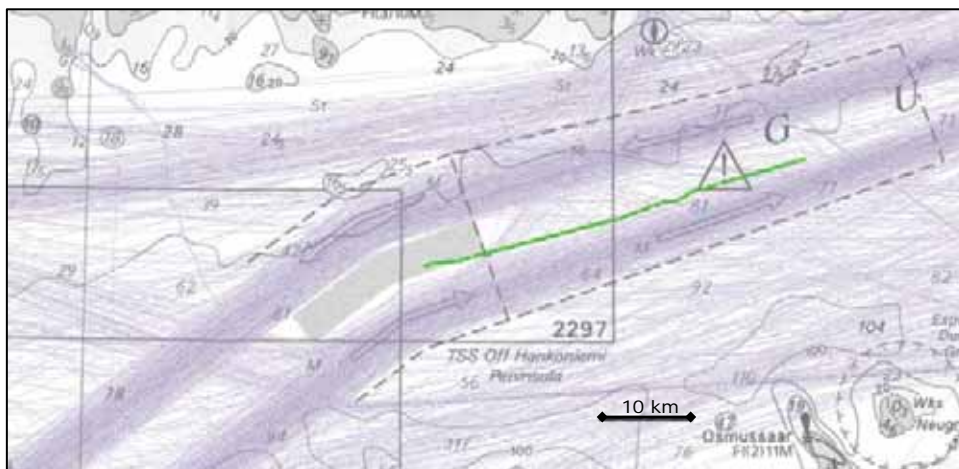


Figure 3-4. Illustration of ship tracks at the TSS off Hankoniemi Peninsula (example for illustration of methodology).

The results of the analyses are presented in Section 5.

4. SHIP TRACKS NEAR LAY BARGE

This section contains results of the analysis of ship tracks near the lay barge in the areas in the Finnish EEZ as indicated in Figure 3-1. The indicated areas are addressed in subsections in the following.

4.1 Finnish waters near Kalbådagrund

The ship traffic has been analyzed at three different locations in the Finnish waters. The first location is near Kalbådagrund (see Figure 4-1 and 'Finland 3' arrow in Figure 3-1). The analysis covers 14 days from October 31 to November 13, 2010. The area covers a traffic separation scheme (TSS) which the lay barge passes through. Moreover, a more shallow area, Kalbådagrund, is located north of the main traffic routes. However, it is noted that the depth near the main traffic routes is still sufficiently large to accommodate even larger commercial ships. An assisting vessel was located immediately north of the TSS area at about 13 – 15 m water depth during the lay barge operations.

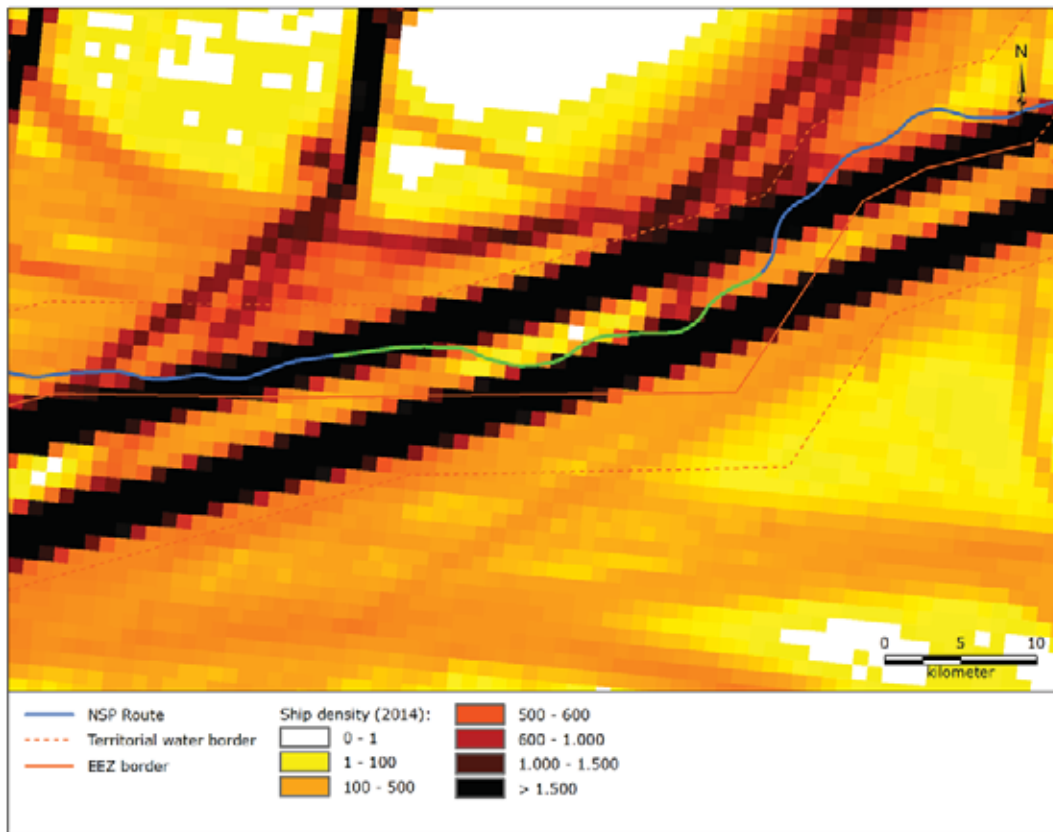


Figure 4-1. The analyzed area in Finnish waters near Kalbådagrund is indicated in green.

In this area the dynamically positioned lay barge *Solitaire* was used. The safety zone around this vessel was 2 km. The result of the analysis is shown in Figure 4-2.

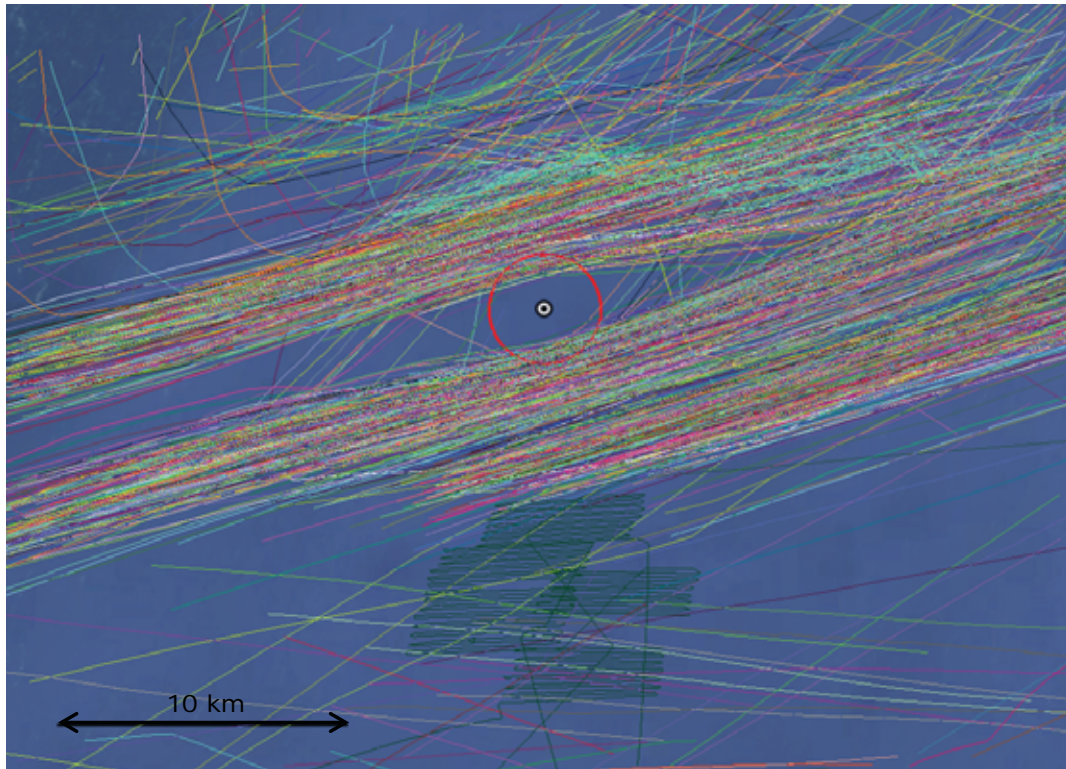


Figure 4-2. Ship tracks around the lay barge in Finnish waters near Kalbådagrund. The radius of the red circle is 2 km and equal to the safety zone around the lay barge.

Several commercial vessels are seen to pass through the lay barge safety zone. South of the lay barge, the closest passing occurs at a distance of about 825 m, and the closest passing north of the lay barge is observed at a distance of about 1,000 m.

Part of the explanation for the close passing may be that the lay barge passes through a TSS area where the ship traffic is restricted to follow the main east and west going ship traffic lanes. The commercial ships therefore both have to stay within the appropriate lane and avoid the lay barge. Analyses of the commercial ship traffic in TSS areas are seen in Section 5; including analyses of the area near Kalbådagrund.

4.2 Finnish waters between Helsinki and Tallinn

This section analyses the location between Helsinki and Tallinn (see Figure 4-3, and 'Finland 2' arrow on Figure 3-1). The analysis covers 13 days from November 27 to December 9, 2010. In this area there is heavy commercial ship traffic, as the lay barge passes the commercial ship traffic towards Helsinki (much of which is ferry traffic between Helsinki and Tallinn) and the main westbound ship traffic route in the Gulf of Finland.

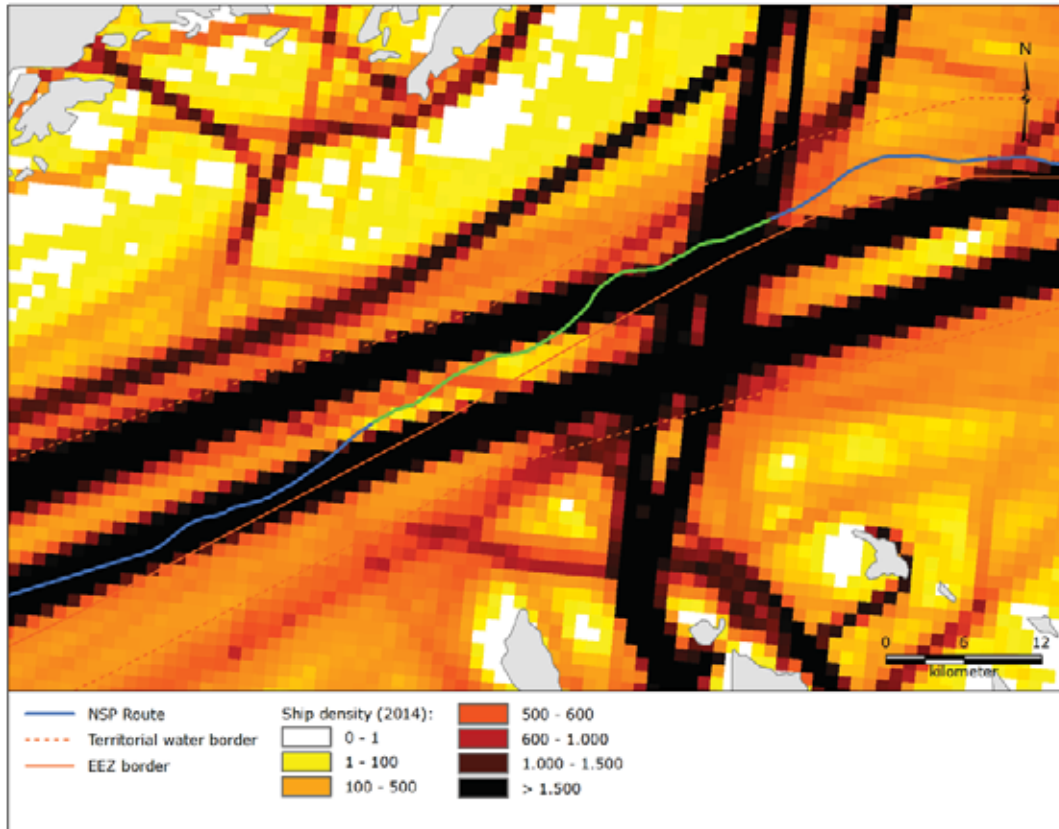


Figure 4-3 The analyzed area in Finnish waters between Helsinki and Tallinn is indicated in green.

In this area the dynamically positioned lay barge *Solitaire* was used. The safety zone around this vessel was 2 km. The result of the analysis is shown in Figure 4-4.

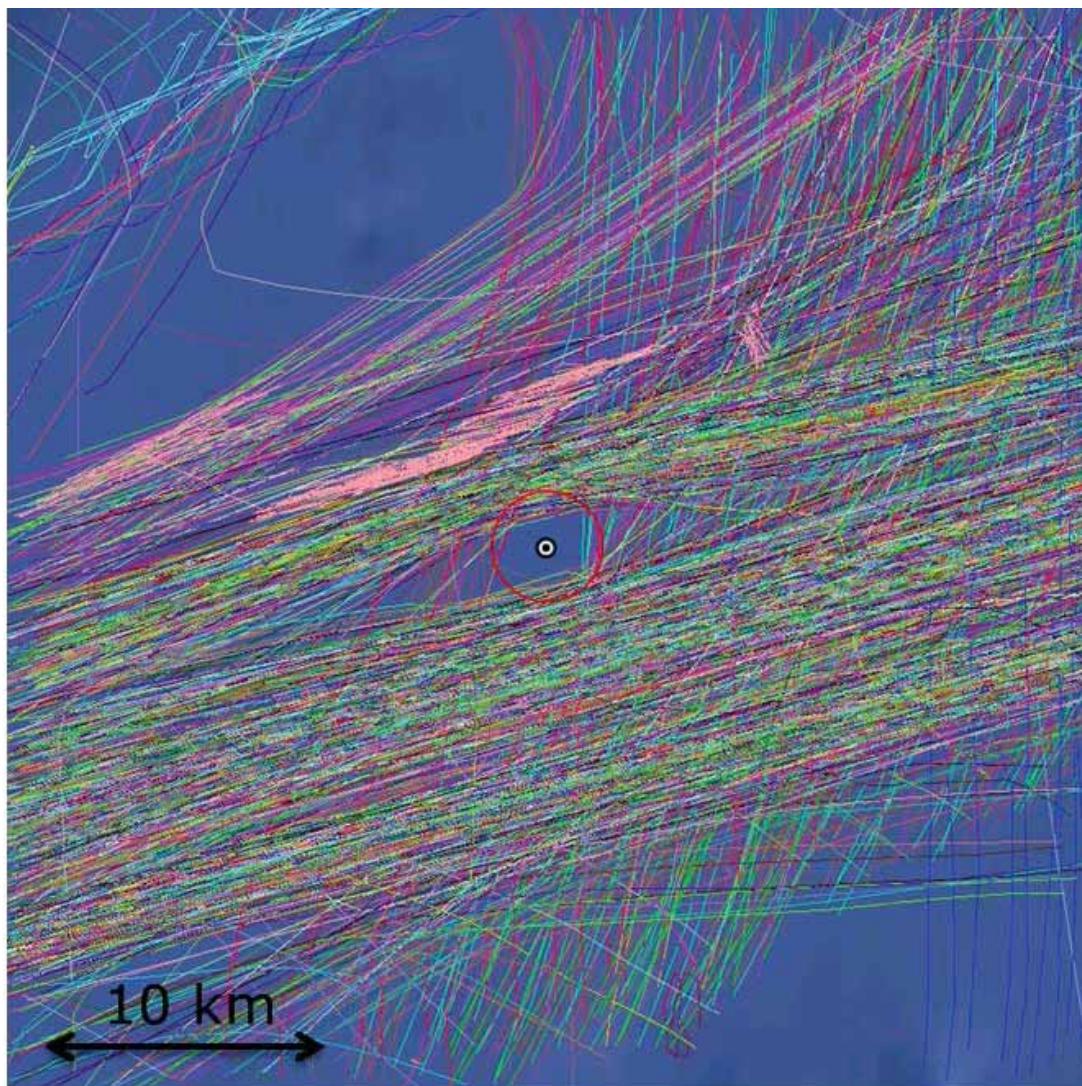


Figure 4-4 Ship tracks around the lay barge in Finnish waters between Helsinki and Tallinn (as seen in Figure 4-3). The radius of the red circle is 2 km and equal to the safety zone around the lay barge.

The ship traffic passing the lay barge in this part of the Gulf of Finland is relatively close; the closest vessel is just over 1,000 m away. As for the area near Kalbådagrund, part of the reason is that the lay barge passes through a TSS area. This is analyzed further in Section 5. However, the reason for the tracks closest to the lay barge is the presence of a 139 m rock placement vessel (post-lay) (see Figure 4-5), located 9 km behind the lay barge in a position which forced the commercial traffic to pass between the lay barge and the rock placement vessel. This is illustrated in Figure 4-6. Afterwards, the rock placement vessel moved closer to the lay barge, to a position which allowed the commercial traffic to pass north of both the lay barge and the rock placement vessel (see Figure 4-7).



Figure 4-5 Left: the rock placement vessel *Tideway Rollystone*. Right: the lay barge *Solitaire* used in the Gulf of Finland.

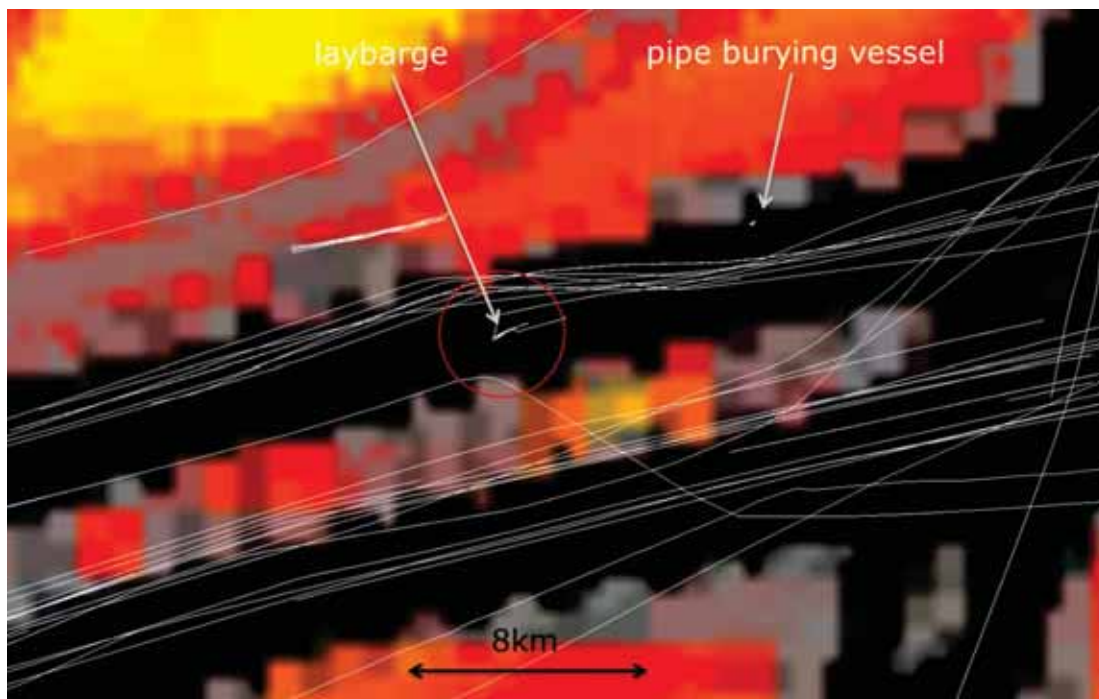


Figure 4-6 Tracks from all ships in the area while the rock placement vessel was situated in a position which forced the commercial traffic to pass between the lay barge and the rock placement vessel. The tracks are from 7 December, 2010 and cover a period of 6.5 hours.

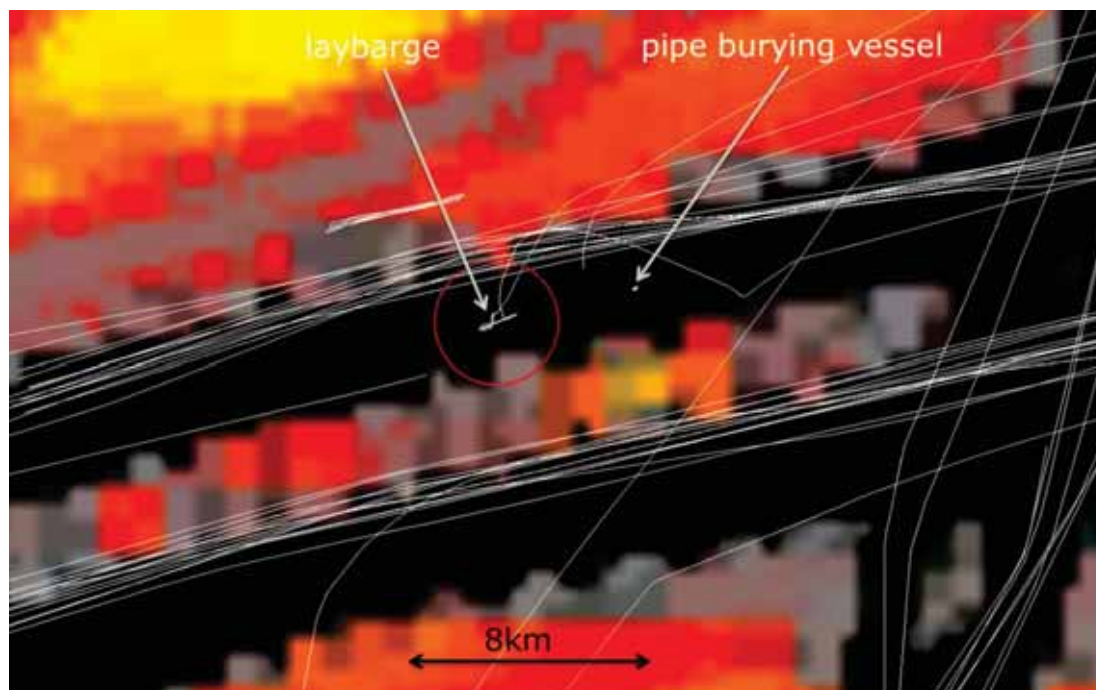


Figure 4-7 Tracks from all ships in the area while the rock placement vessel was situated in a position which allowed the commercial traffic to pass north of the lay barge and the rock placement vessel. The tracks are from 7 December, 2010 and cover a period of 8 hours.

The position of the rock placement vessel in Figure 4-7 does not seem to cause any problems for the commercial traffic, whereas its position in Figure 4-6 is potentially dangerous. Situations such as the one shown in Figure 4-6 should be avoided during the construction of NSP2.

In general, commercial ships adjust their course 15 km or more before passing the lay barge; see Figure 4-2, Figure 4-4 and Figure 4-10. Sketches illustrating a commercial vessel passing the lay barge and other nearby stationary equipment are seen in Figure 4-8.

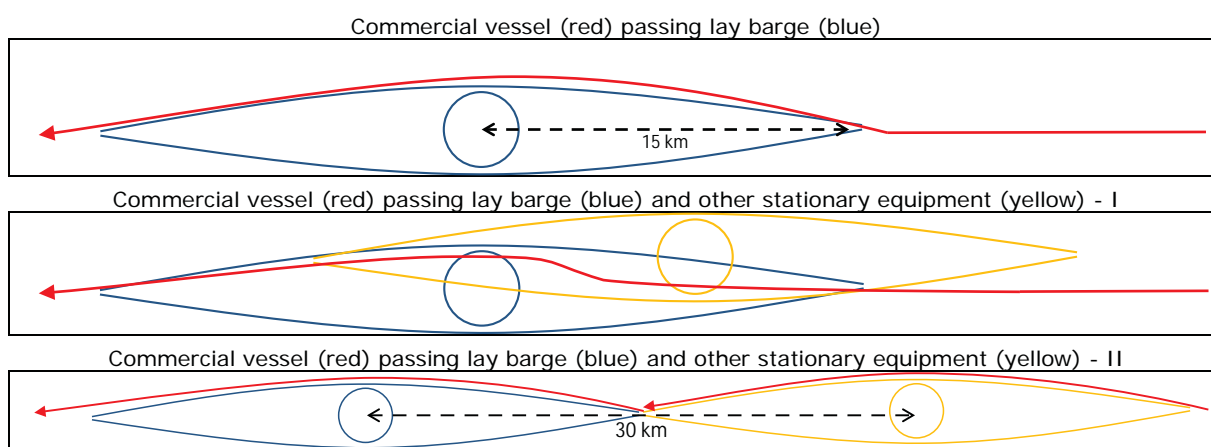


Figure 4-8. Sketches illustrating a commercial vessel (red) passing lay barge (blue) and other stationary equipment (yellow) at various locations. The ellipses illustrate the observed preferred course of the commercial vessel when avoiding the obstacles.

Based on the observations, and as illustrated in the sketches in Figure 4-8, it is recommended to maintain a minimum distance between stationary construction vessels of at least 30 km; this in order for commercial vessels to pass one obstacle at a time.

It has also been analyzed whether the larger commercial ships keep a greater distance to the lay barge than smaller ships in this area. Table 4-1 shows the average length of ships passing the lay barge at different intervals. On the basis of Table 4-1 there does not seem to be a tendency for

larger ships to maintain a greater distance from the lay barge. This may be due to the limited space in this area, especially when the rock placement vessel was situated as shown in Figure 4-6.

Table 4-1. Average length of vessels passing the lay barge at different distances

Distance	Average ship length (m)	Number of ships
0-1 nm	145.7	60
1-1.5 nm	143.1	149
1.5-2 nm	145.6	128

4.3 Finnish waters outside the Gulf of Finland

The third study in Finnish waters analyzes a location just outside the Gulf of Finland (see Figure 4-9 and 'Finland 1' arrow on Figure 3-1). Here the lay barge passed the main westbound traffic coming from the Gulf of Finland. The analysis covers 17 days from June 10 to 26, 2011. The result is shown in Figure 4-10. In this area the anchor-positioned lay barge *Castoro Sei* was used. The safety zone around this vessel was 1.5 nm (2778 m).

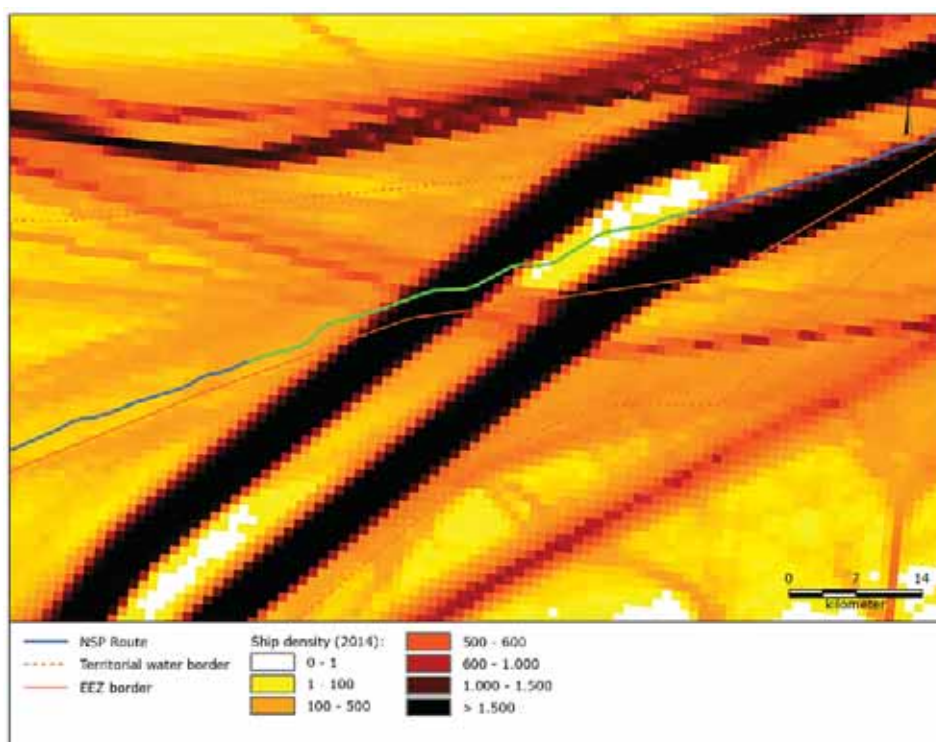


Figure 4-9 The analyzed area in Finnish waters is just outside the Gulf of Finland and indicated in green.

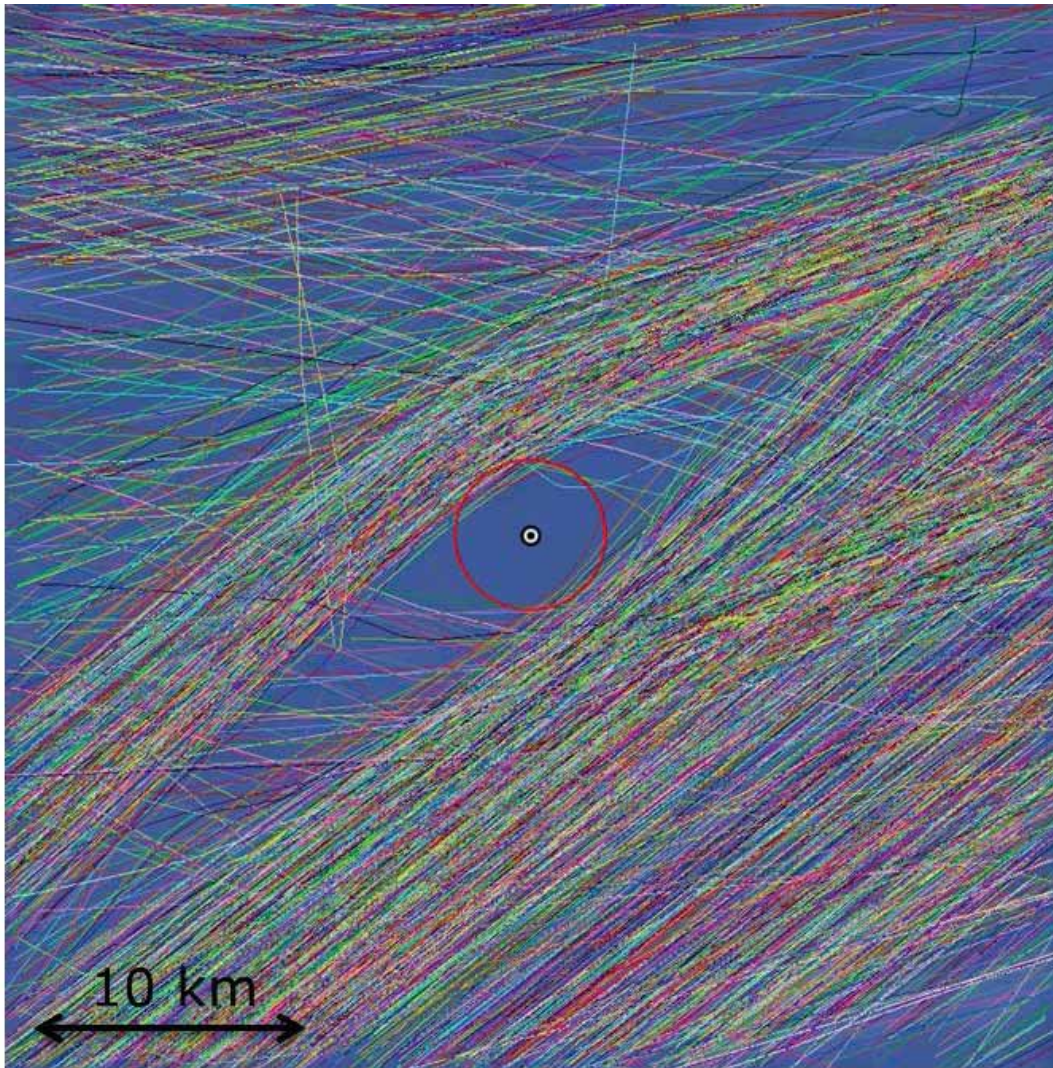


Figure 4-10 Commercial ship tracks around the lay barge in Finnish waters just outside the Gulf of Finland (as seen in Figure 4-9). The radius of the red circle is 1.5 nm and equal to the safety zone around the lay barge (note that safety zone is larger than plots related to the Gulf of Finland).

In Figure 4-10, the light blue track which enters the safety zone from the north-east and makes a late course adjustment was actually part of the construction traffic and should therefore not have been included in this figure.

In general, the ships keep a reasonable distance from the lay barge, and most of them remain outside or at the perimeter of the safety zone. The ship that comes closest to the safety zone passes the lay barge at a distance of 2 km. Most of the ships make a course adjustment at least 15 km before they pass the lay barge.

4.3.1 Space occupied by an anchor-positioned lay barge

The amount of space occupied by the anchor-positioned lay barge *Castoro Sei* and its support vessels has been analysed. The construction traffic is primarily comprised of tugs/offshore support vessels similar to the ship in Figure 4-11.



Figure 4-11 The tug *Boulder* acting as a support vessel in the Swedish area.

The analysis has been carried out by plotting the tracks of the construction traffic instead of the commercial traffic but still uses a coordinate system that is centred on the lay barge. The result of the analysis is presented in Figure 4-12. Each support vessel has its own colour in the plot.

The following two plots are made with data from the Swedish waters east of Gotland. However, the tracks from the support vessels around *Castoro Sei*, in the Swedish waters, are also representative for the situation in the waters outside the Gulf of Finland where the anchor-positioned lay barge *Castoro Sei* is used.

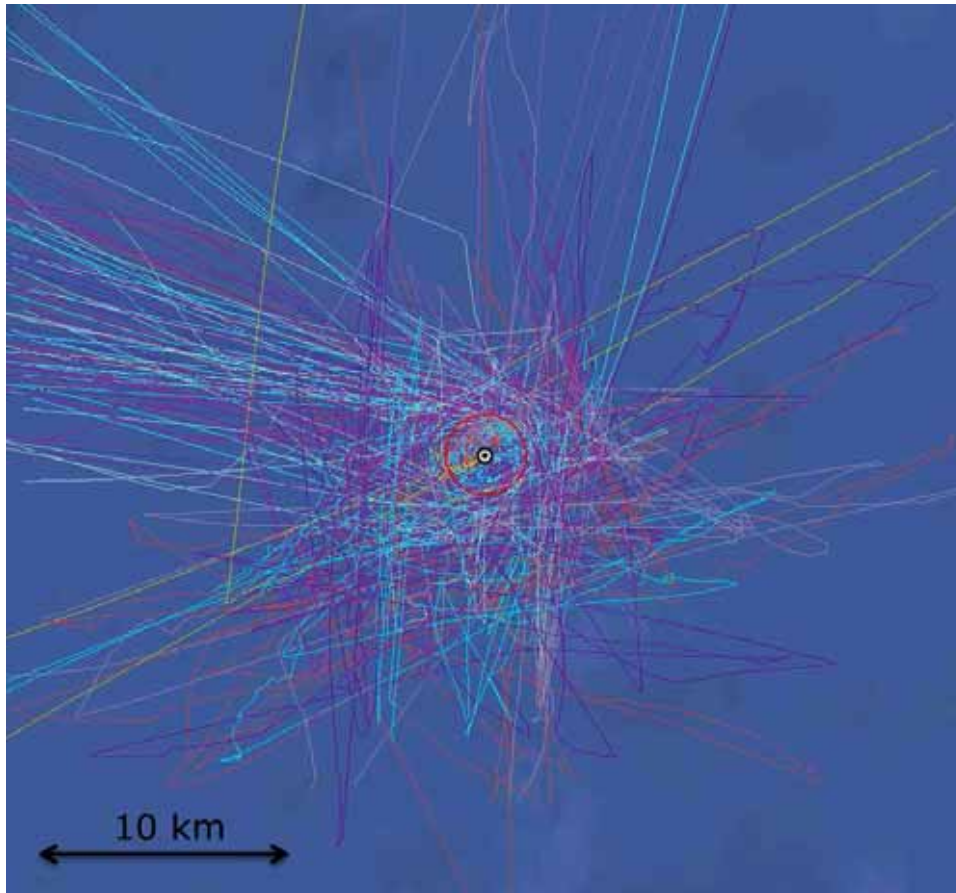


Figure 4-12 Support vessel tracks around the lay barge in Swedish waters east of Gotland. The red circle has a radius of 1,600 m.

As illustrated in Figure 4-12, the construction traffic is sometimes situated very far from the lay barge. The construction vessels should not create any problems for the commercial ship traffic because they must follow the normal rules of the sea and because in this case they are able to move. The problem is greater when the support vessels are working close to the lay barge (this will mostly be related to anchor-handling), as the presence of these vessels will increase the area which the commercial traffic has to avoid. In Figure 4-13, the tracks are shown close to the lay barge.

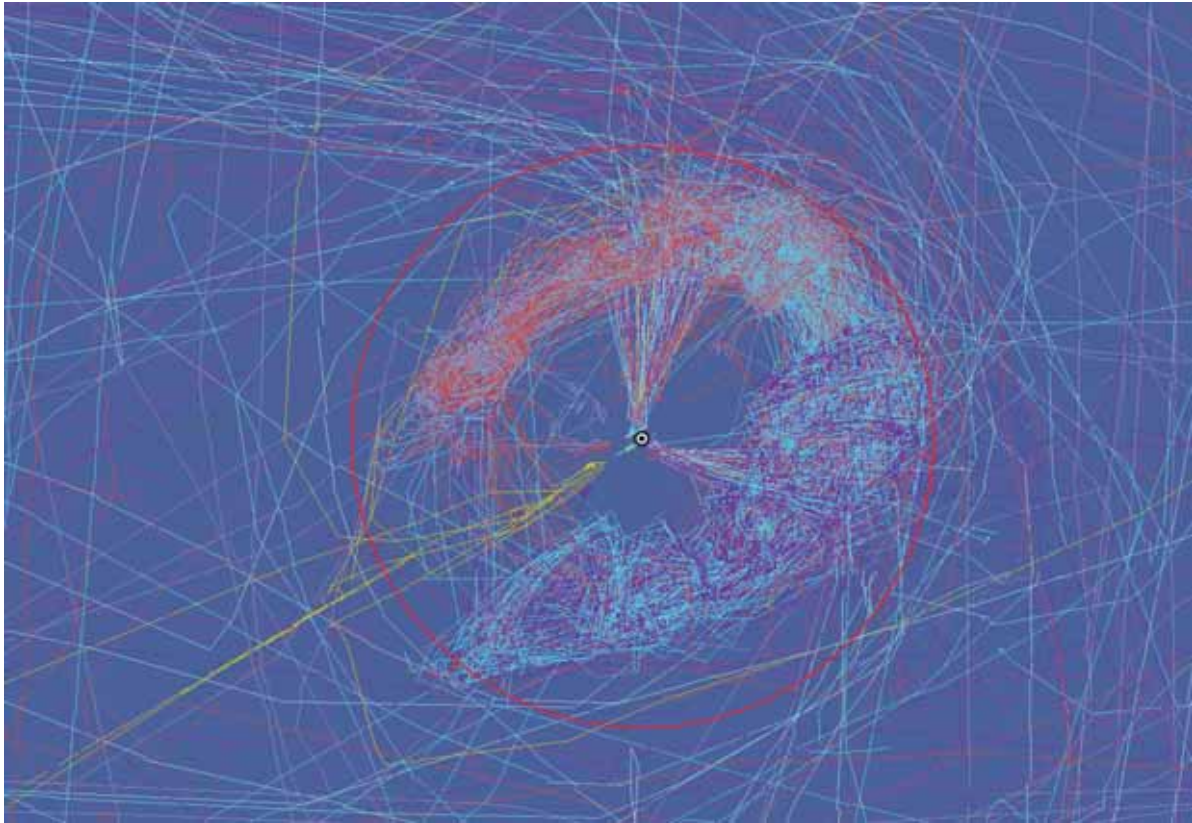


Figure 4-13 Support vessel tracks around the lay barge in Swedish waters east of Gotland. The radius of the red circle is 1,600 m. This figure is a close-up of Figure 4-12.

As indicated in Figure 4-13, there is a lot of traffic between 500 m and 1,600 m from the lay barge. These are believed to be anchor-handling vessels. Most of the support vessel traffic in front of and behind the lay barge remains within a distance of around 1,600 m from the lay barge. On each side of the lay barge the support vessel traffic remains within a distance of around 1,200 m from the lay barge.

5. LAY BARGE PASSING THROUGH TSS

Analyses of the lay barge passing through the TSS areas are presented in this section. The areas indicated in Figure 3-3 are covered in the following subsections.

5.1 TSS off Kalbådagrund Lighthouse

The lay barge *Solitaire* has passed through the TSS off Kalbådagrund Lighthouse between October 31 and November 14, 2010. On December 01, 2010, the TSS was moved slightly east, to the location shown in Figure 5-1.

Ship tracks are shown in Figure 5-1 (a) between November 30 and December 14, 2010 when no lay barge was operating in the area. Figure 5-1 (b) shows ship tracks between October 31 and November 14, 2010 with *Solitaire* operating in the area (the track from *Solitaire* is the light green track). When the lay barge operated in the area, an assisting vessel was used to assist commercial ships passing close to the area just north of the TSS area with 13 m water depth. The movements of this vessel are indicated in the figure with brown colored ship tracks.

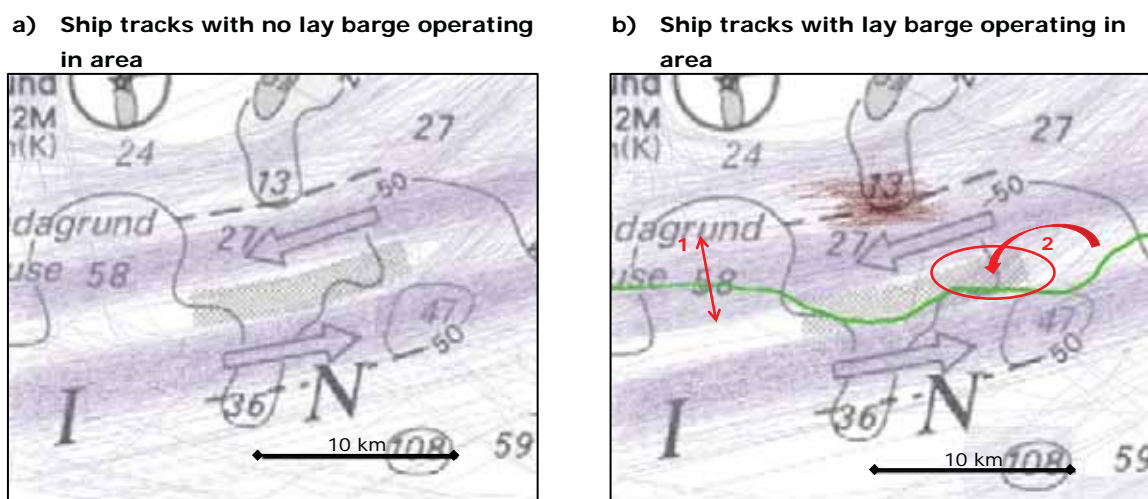


Figure 5-1. Ship tracks at TSS off Kalbådagrund Lighthouse when lay barge passes.

Two main differences are seen as indicated in Figure 5-1 and described below:

- 1) The westbound traffic avoided the lay barge by occupying a larger area when the lay barge passed in the middle of the traffic lane. The width of the effective traffic lane (red arrow) west of the TSS area was approximately 4 km. It is noted that the commercial vessels tended to stay within the marked traffic lane within the TSS area.
- 2) Eastbound vessels, changing course to northeast after the TSS, tended to turn earlier when the lay barge occupied the space right east of the TSS. This is mainly due to movement of TSS on December 01.

In general, it is observed that commercial vessels to a very large extent respect the TSS; also when a lay barge is in the TSS. The width of the area used by the westbound traffic immediately west of the TSS is only approximately 4 km, which implies that the safety zone with a radius of 2 km around the lay barge cannot be honored. This supports the results seen in Section 4.1 when analyzing the ship tracks near the lay barge. The conclusion is that navigators choose to stay within the TSS even if it means that they have to violate the prohibited area around the lay barge.

5.2 TSS off Porkkala Lighthouse

The lay barge Solitaire has passed through the TSS off Porkkala Lighthouse between November 28 and December 19, 2010. On December 01, 2010, the TSS was made wider, to the location shown in Figure 5-2.

The ship tracks are shown in Figure 5-2 (a) between July 29 and August 18, 2010 where no lay barge was operating in the area, and (b) between November 28 and December 19, 2010 when Solitaire passed through the area (the track from Solitaire is the light green track). The assisting vessel that guarded the area north of the TSS off Kalbådagrund Lighthouse was also present in the area north of TSS off Porkkala Lighthouse as indicated in Figure 5-2 (b) with brown colored tracks.

a) Ship tracks with no lay barge operating in the area



b) Ship tracks with Solitaire passing the TSS

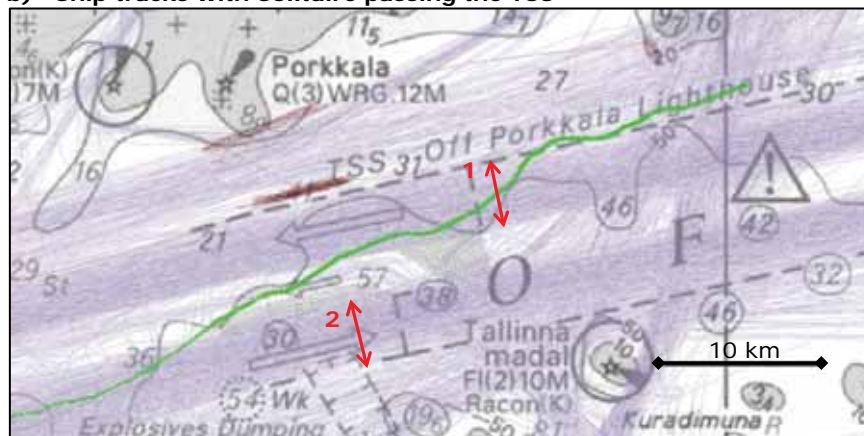


Figure 5-2. Ship tracks at TSS Off Porkkala Lighthouse

The same main difference is seen for both the eastbound and the westbound traffic:

- 1) The westbound commercial ships seemed to use slightly more space when the lay barge operated in the area. But in general all ships followed the TSS and the ship traffic lane. The width of the area used by the commercial ships was slightly more than 4 km.
- 2) The eastbound commercial ships also seemed to use slightly more space when the lay barge operated in the area. But also here, all commercial ships in general followed the TSS and the ship traffic lane. The width of the area used by the commercial ships was slightly less than 4 km.

Both differences are probably partly due to widening of the TSS on 01 December, 2010. Again, the conclusion is that navigators choose to stay within the TSS even if it means that they have to violate the prohibited area around the lay barge (see results in Section 4.2).

5.3 TSS off Hankoniemi Peninsula

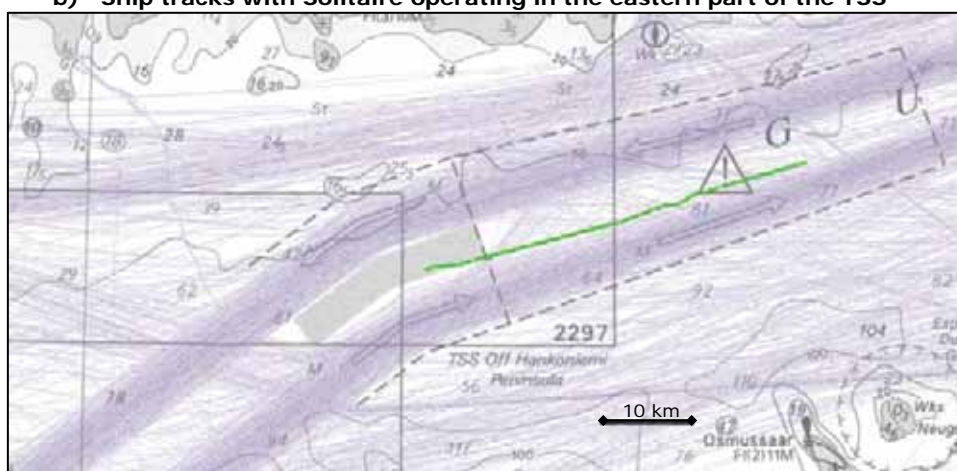
Both lay barges, Solitaire and Castoro Sei, were used within this TSS area. Solitaire was used in the eastern part of the TSS while Castoro Sei was used in the western part leaving the Gulf of Finland. Therefore two different time periods have been analyzed; one between January 3 and 18, 2011 when Solitaire was operating in the area, and one between June 9 and 30, 2011 when Castoro Sei was operating in the area. For comparison, the time period between May 3 and 30, 2011 is also analyzed to illustrate a time period with no lay barge operations in the area.

The ship tracks are seen in Figure 5-3 (a) for a situation with no lay barge operating in the area, (b) for a situation where Solitaire operates in the eastern part of the area, and (c) for a situation where Castoro Sei operates in the western part of the area. The lay barges are shown using light green tracks.

a) Ship tracks with no lay barge operating in the area



b) Ship tracks with Solitaire operating in the eastern part of the TSS



c) Ship tracks with Castoro Sei operating in the western part of the TSS

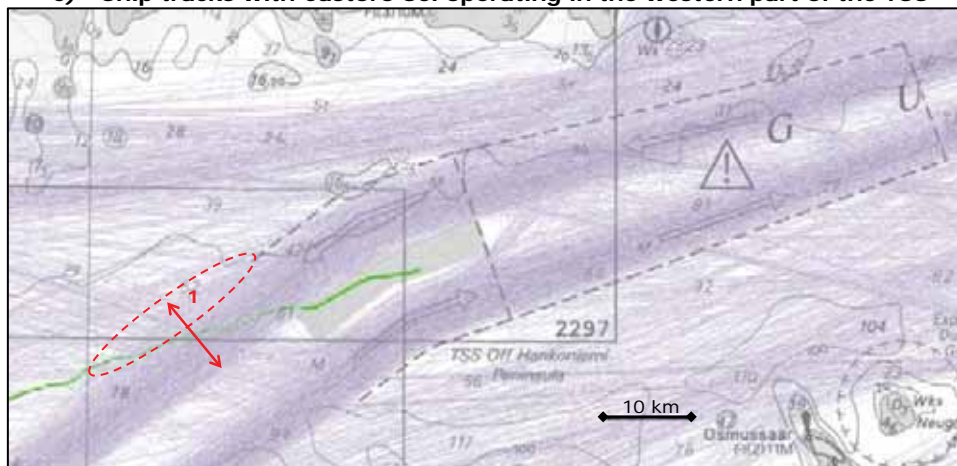


Figure 5-3. Ship tracks at TSS Off Hankoniemi Peninsula.

One difference is noted as described below:

- 1) The westbound commercial ships occupied a slightly larger area when Castoro Sei passed the westbound traffic lane immediately west of the TSS. The width of the effective traffic lane (red arrow) west of the TSS area was approximately 9 km. It is noted that the commercial vessels tended to stay within the marked traffic lane within the TSS.

Solitaire's operations in the central part of the TSS had no significant effect on the ship tracks as there was space enough to follow the normal traffic flow. The only minor effect may be that the area between the eastbound and westbound lanes was even freer of commercial ships due to the presence of the lay barge.

The safety zone around Castoro Sei was 3 km. The conclusion here is that the space available for the westbound ship traffic was in general sufficient for commercial ships to pass the lay barge at a reasonable distance. This is also seen from the analysis in Section 4.3.

6. CONCLUSION

In general, the commercial ship traffic is passing the lay barge at a minimum distance of 1 nm (1,852 m). In a few locations, a smaller distance is observed (around 800 – 1,000 m is the smallest distance observed).

Violations of the official safety zone are observed rather frequently, but the extent to which the commercial ship traffic respects the safety zone varies from area to area. Near TSS off Porkkala Lighthouse and TSS off Kalbådagrund Lighthouse, the safety zone of the dynamically positioned lay barge is sometimes violated. This is partly because of an unfortunate positioning of a rock placement vessel (see Section 4.2), but also very much related to the heavy traffic in the area and the limited space within the TSS areas (see Sections 5.1 and 5.2). In principle, the commercial ships need to respect both the TSS limits and the safety zone of the lay barge. If this is not possible in situations where the lay barge is in a TSS, the navigators choose to stay within the TSS even if it means that they have to violate the prohibited area around the lay barge.

A possible consideration for NSP2 would be to make the safety zones slightly smaller but make sure that they are actually respected; especially when the lay barge passes through a TSS.

In the area near TSS off Hankoniemi Peninsula the lanes in the TSS are wide enough to contain both the lay barge, with its prohibited area, and the commercial ship traffic. Therefore, situations where the commercial ships violate the prohibited area around the lay barge are rarely seen.

Most of the ships are making a course adjustment to avoid the lay barge 15 km (or more) before the actual passing. No very close or dangerous situations between the commercial ship traffic and the lay barge have been observed in the data analyzed.

6.1 Recommendations

The following recommendations are given based on the analyses and conclusions above.

- It is recommended to maintain a minimum distance between stationary construction vessels of at least 30 km; this in order for commercial vessels to pass one obstacle at a time (see Section 4.2)
- For TSS areas, it is recommended to plan and agree in advance the size of safety zones around the lay barges together with the relevant authorities. A possible solution could be to plan a reduced safety zone for the lay barges when operating near or inside TSS areas; if relevant combined with other risk reducing measures to be agreed with the authorities.

APPENDIX 1
MOVIE SHOWING THE TRAFFIC AROUND THE LAY BARGE

In order to illustrate how the ship traffic passes the lay barge a movie has been made showing the ship traffic around the lay barge *Solitaire* on one day (5 December, 2010). All vessels are shown in the video, including support vessels. The *Solitaire* is positioned in the Gulf of Finland south-west of Helsinki, as indicated in Figure 6-1. It is therefore in an area with heavy ship traffic.

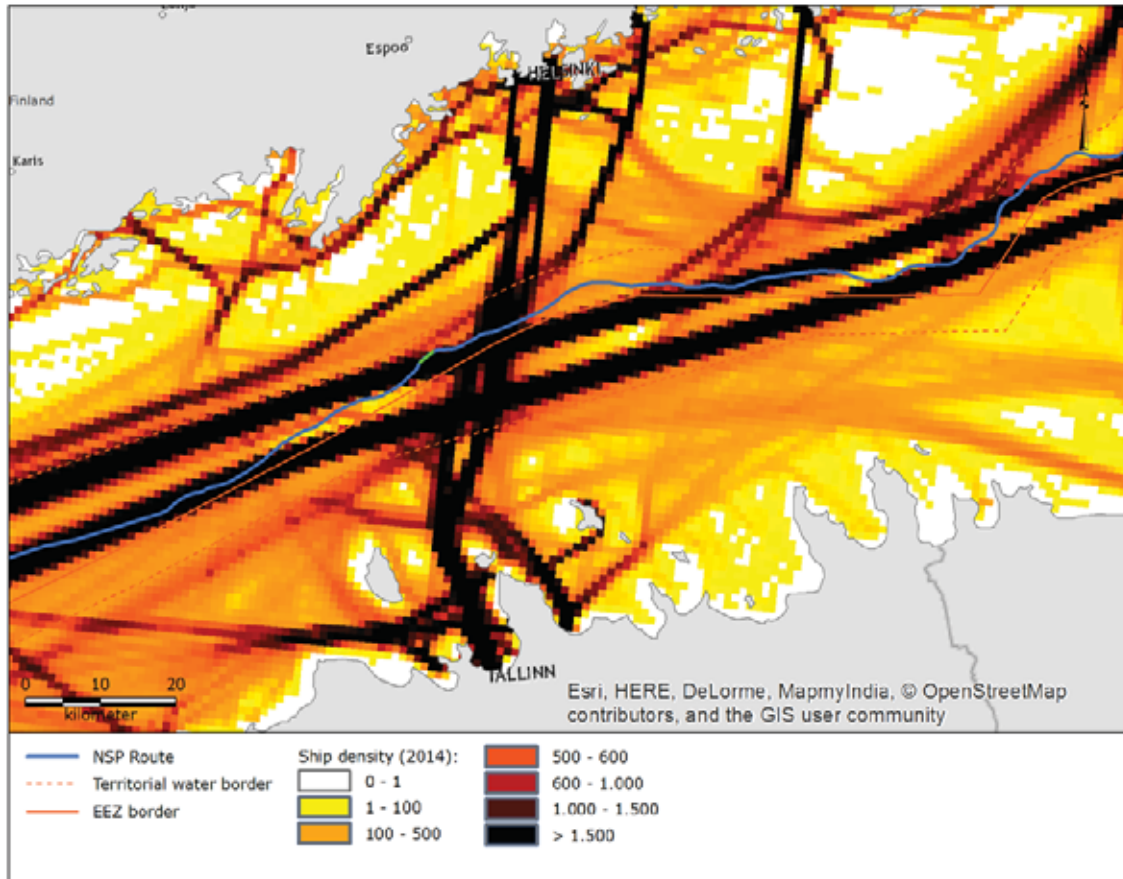


Figure 6-1 On 5 December 2010 the lay barge *Solitaire* travels along the green line.



Figure 6-2 Movie showing the ship traffic around the lay barge Solitaire on 5 December, 2010. In PDF version, click on the figure in order to play the movie. The still image illustrates a heavy traffic situation.