ADAPT T3.5.1 Seminar 3

-proposals for improved and adjusted routes

EUROPEAN UNION
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Interreg
Central Baltic

Summary
The aims of ADAPT was to reach safer, more time- and fuel efficient routes. To achieve this, tools and methods for route planning and routine development was created, and updates of navigational charts preformed. The main part of the environmental goal has been fuel efficiency and a reduction in greenhouse gas emissions. However, other parameters such as reducing erosion along sensitive shorelines are also included in the analyses. During seminar three, route analyses of corridors and nodes in the sea borne public transport systems of Åland and Stockholm archipelagos were carried out and the results are presented in this report. To optimize the routes keeping the customers' interests in focus has been important during the analyses. The developed tools and knowledge exchange has been very important in this part of the process.

To enable a proper route analysis hydrographical surveys was performed with multibeam echo sounding. In Stockholm archipelago the survey result generated identification of over 100 safety issues along the corridors and nodes, and over 50 notices to mariners was produced. There are 38 corridors and 14 nodes in the Stockholm archipelago. Due to the hydrographical survey results, the adjustments and developments of these foremost include increased safety measures. In Åland on the other hand, the results show great saves in travel time and fuel use along with a significant reduction in emissions. One reason for this is that the fairways here had great potential for improvement and that the survey results generated, showed that the alternative routes were great options. Another reason for this is that larger measures was possible for the proposed 8 corridors and 23 nodes in Åland.

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1 Background and project outputs

This report is an output of the third seminar within Work package 4: Route Adjustments, which was held in Norrköping on the 24-28th of September, 21st of November 2018 and 17th of January 2019.

Participants during parts or the whole seminar were:

- Linda Blied (Swedish Maritime Administration, SMA)
- David Modig (Swedish Maritime Administration, SMA)
- Indrek Pöldma (Sjöblick AB)
- Ian Bergström (Government of Åland, ÅLR)
- Linn Gardell (Swedish Maritime Administration, SMA)
- Michael Levin (Swedish Maritime Administration, SMA)
- Åsa Gren Tivelius (Stockholm County Council, TA)

The aim of ADAPT is to achieve more safe and efficient transportation of people and goods in the Stockholm- and Åland archipelagos. Improving routes, optimizing vessel use, developing solutions to challenge and secure reliable traffic in difficult conditions are parts in achieving the aim. This will entail positive effects such as reduced travel time for passengers, and reduced greenhouse gas emissions. The transportation system within the Stockholm archipelago is divided in timetable areas which are connected to other modes of public transportation. The time table areas are reviewed as corridors that connect to the other modes of transportation via nodes (route crossings, ports or jetties), see definition of corridors and nodes in section 3. In the Åland archipelago the objective was to suggest new routes contributing to a more sustainable transportation system, achieved by shortening ferry routes and by increasing the integration with land-based transport. Emphasis was the analyses of travel time resulting from the shortened routes and connecting the corridors to nodes for changing to land-based transport.

The purpose of the seminar was to finalize proposals of new, adjusted and developed routes in the two archipelagos. The proposals were based on analyses of the material gained through the hydrographical surveys in Stockholm- and Åland archipelagos. The target value was to find 40 transport corridors or nodes where route developments or improvements could be achieved. The corridors were linked to the notices to mariners (heron called Swedish NtM) issued in the corridor areas to secure navigation before the navigational charts updates. There are approximately 60 Swedish NtM:s of this kind issued for the Stockholm archipelago following the ADAPT surveys. The navigational chart update is a separate deliverable meant to be a completion with the proposals of route changes in this report. Therefore, the updates of the navigational charts are not mentioned further in this report. The three main emphasized aspects for the suggested route alterations were:

- Safety measures (ensuring the fairway depths and locate unknown obstacles with reliable navigational charts to lower risk of accidents and secure traffic punctuality)
- Environmental measures (increasing fuel efficiency, reducing CO_2-emissions in Stockholm- and Åland archipelagos and reducing NO_x- and SO_x-emissions in Åland archipelago, spare vulnerable areas)
- Time efficiency (shortening of routes, insure efficient interchange between different modes of traffic, optimizing vessel use)

2 Methodology

2.1 Hydrographic surveys

The hydrographic surveys was carried out using multi-beam echo sounding system. These systems are complex with many parameters to take into account to eliminate sources of errors. The multi-beam sounding system is mounted under the hull of the boat. A survey vessel can move in all directions when travelling through the water, a motion detector is positioned centrally in the boat to keep track of the movements. The data from the movement detector is applied to the data from the multi-beam sounding system. The sound velocity depends on the density of the water, and therefor it changes through the water column. The density of the water changes according to salt level and temperature. To keep track of the sound velocity a sound velocity profiler is sent down to the bottom and up again at even intervals through the full survey. This data is applied to the sounding data. The sea level also differs throughout the survey sessions. To keep track of the current sea level a sea level gauge gathers data through the surveys. This is added, correcting the sounding data. To position the depth data correctly a GPS is used. For ADAPT the used positioning method was Network-RTK (Nätverks-RTK), where RTK stands for Real Time Kinetics. What differs this positioning method from others is that it modules corrections utilizing a virtual reference station via satellite/ internet. The gathered and corrected data is cleaned from errors. Errors can occur if there has been items such as fish or garbage in the water during the surveys or if the sounding instrument has collected any other sounds occurring in the sea. A large part of this is manual work, the automatic tools can only do so much.

To plan the areas for where to locate the surveys in Stockholm archipelago, Waxholmsbolagets route map was used, together with Automatic Identification System-tracks (AIS-tracks) to cover the parts where vessels might not follow the exact routes.

The Government of Åland is Finland's second largest fairway holder with approximately 505 km of fairways. The fairways are public and meet the Finnish Transport Administration's requirements for public fairways. The government of Åland's transport system in the archipelago is mostly conducted in public fairways, however, a few exceptions exist. When planning the fairways, type vessels, fairway depth and fairway class, these are defined based on which type of transportation are to use the fairway. The fairway class implicates a planning directive where curve radius, propagation, safety margins for depth-secured areas, rules for marking, etc. are defined. One can summarize the fairway planning with: The fairway plan presents the secured areas for the fairway depth and the fairway class chosen, based on the type of traffic (type vessel) the fairway is planned for. The navigational charts show fairway depths and marks reported and depth-secured areas, see table 1.

In Åland, the fairway holder guarantees the fairway depth in the fairways under normal conditions. The safety margin between fairway depth and depth-secured areas is selected based on the conditions that apply to the fairways' location.

When the fairways are hydrographically surveyed in Åland, both multibeam echo sounding- and bar sweeping methods are used. The motivation for using the multibeam sounding system is so that a digital model of the seabed can be established for the entire fairway area, see figure 1. Based on the multibeam results, some areas need to be bar sweeped to meet the fairway depth guarantee. The areas that are selected to be bar sweeped are the areas that are shallower than the fairway depth + safety margin for fairway depth (X m in table 1) + the safety margin for multibeam echo (Y m in the table 1). When the bar sweeping is completed, the bar is hung on the fairway depth + safety margin during fairway depth (X m in table 1) which then becomes the fairway's secured depth, see figure 1.

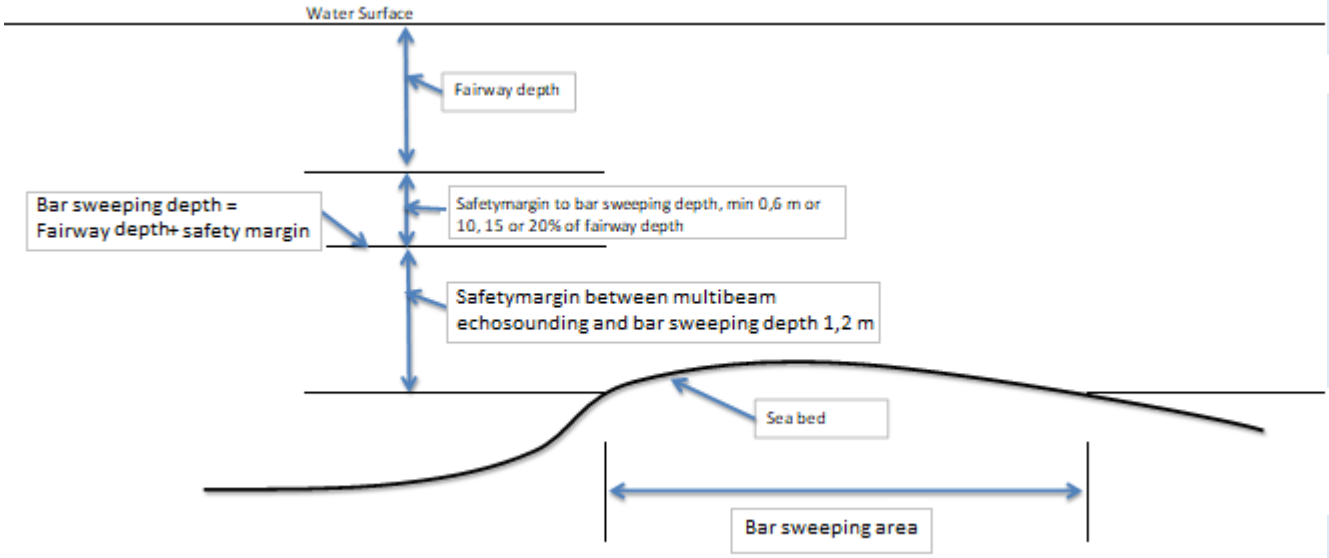


Figure 1. The figure above shows how the safety margins relate to the fairway depth during the hydrographical measurements and planning of fairways.

Table 1. The figure above shows the classification of the Åland and Finnish shipping routes.

DIVISION		FAIRWAY, CLASS		Safety margin under fairway depth X m	Bar sweeping depth	Safety margin for Multibeam echo sounding Y m	Bar sweeping is done at the following depth
2	Shallow fairways (Fairways for other transportation)	VL3	Shallow fairways for commersial traffic	At least 0,6 m or 10% (Inner archipelago) 15% (archipelago) eller 20% (outer archipelago) of	Fairway depth+X m	1,2 m	Fairway depth+X m+Y m
		VL4	Main fairways flr boat traffic	At least 0,6 m or 10% (Inner archipelago) 15% (archipelago) eller 20% (outer archipelago) of	Fairway depth+X m	1,2 m	Fairway depth+X m+Y m
		VL5	Local fairways for boat traffic	At least 0,6 m or 10% (Inner archipelago) 15% (archipelago) eller 20% (outer archipelago) of	Fairway depth+X m	1,2 m	Fairway depth+X m+Y m
		VL6	boating routes	0,6 m	Fairway depth+X m	0,6 m	Fairway depth+X m+Y m

Based on the result of the multibeam echo soundings and the bar sweeping, fairway areas (depth-secured) will be defined where the fairway's draft is guaranteed under normal conditions. In the charts, the depth-secured areas will be marked with boundary lines and colored areas. Figure 2 shows the fairway area with yellow color.

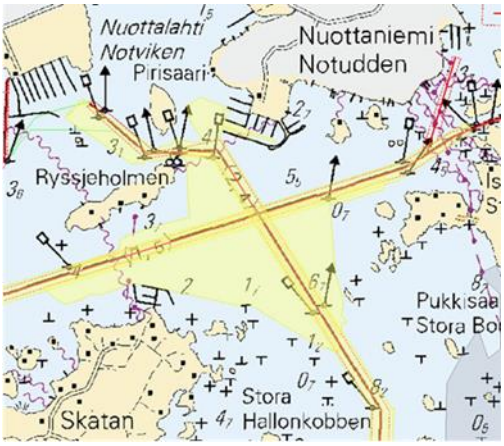


Figure 2. The figure shows an example of how fairway areas, fairway depth and marking of fairways are displayed in the sea charts.

Any depth restrictions and other restrictions on the sea based traffic are reported in the fairway plans and, by extension, in the official charts. The government of Åland do not have its own staff that performs maritime surveys and fairway planning. Therefore, the government did purchase the services that are needed. Already in 2014, an EU procurement was made for framework agreements for maritime surveying and fairway planning services. Three framework agreements were signed with various suppliers. The most advantageous framework agreement (supplier Oy Civil Tech Ab) where used for the sea surveys and fairway planning assignments that have been included in ADAPT.

2.2 Calculation of energy efficiency

The volume of travel and transportation of goods in Stockholm archipelago and in Waxholmsbolaget (heron addressed Wåab) traffic, varies significantly over a year. Although, service is maintained all around the year, seven days a week, the bulk of travel is made during weekends and summer time. This makes it difficult to draw conclusions regarding environmental effects after generalizing passenger numbers over a full year. This suggests that it would be of value to study a ship or a passenger individually, based on specific voyages or trips.

Wåab register the number of passengers on board electronically after departure from each node, according to local rules and regulations. Route distances from the vessels' navigation systems are also readily available. These two facts in combination gives exact data on the actual work carried out between two jetties, e.g. passenger-kilometres (pkm) used, see table 2. Mean passenger occupancy was calculated for every trip.

Fuel consumption is used for the energy use in the calculations. Where energy- and carbon content of fuel is derived from fuel supplier's datasheets. By calculations based on these more detailed figures it is possible to understand energy consumption and environmental effects, although, some generalizations remain. Furthermore, it is possible to compare different solutions between individual vessels and timetable solutions.

Comparisons has been made with public transportation on rail or by bus, although, only generalized numbers are available for these modes of transport. The actual numbers are derived from annual reports from TA. Sailing time between ports and jetties and times for rail and bus are respectively derived from timetables.

Comparing reduction of carbon dioxide in Stockholm archipelago has been complicated by the fact that all public transportation on rail and with bus is fossil free. Comparisons with baseline 2012 are therefore difficult regarding carbon dioxide. Comparisons in energy consumption has been made to compensate for this.

Table 2. Results, where applicable, are calculated as in table below.

Transport mode	Parameters	Unit
Ship	Energy consumption/trip	kWh/passenger
Ship	Carbon dioxide emissions/trip	Kg CO2/passenger
Ship	Energy consumption/passenger-kilometer	kWh/passenger-kilometer
Ship	Carbon dioxide emissions/passenger-kilometer	Kg CO2/passenger-kilometer
Bus	Energy consumption/trip	kWh/passenger
Rail	Energy consumption/trip	kWh/passenger

The transport system in the Åland archipelago comprises both transport of passengers, goods and vehicles. The goods are mainly transported between the islands by trucks or lorries. Therefore, the calculation of energy efficiency of the vessel and the passengers' energy consumption cannot be separated. As a result, the comparison has been made between the calculations of one type of trip for baseline and for the developed or adjusted fairways, proposed in this report. The difference in energy consumption, -CO_2, -NO_X -and SOx emissions is reported for each fairway.

2.3 Figures used for analysis in Stockholm archipelago

The figures showing the developed and adjusted routes in Stockholm archipelago were produced via a tool constructed to make the hydrographic data easily accessible to the project partners. The tool is a map service, constructed using ArcGIS online[1]. The tool displaying the hydrographic surveys from the archipelago of Stockholm was updated continuously during the survey period. The surveys are presented in 0.5-metre intervals down to a 4.5-metre depth. The reason for choosing this interval was that the ferries utilised by Wåab has a draft of maximum 3.5-metres and that the information below 6-metres is confidential. The routes of Wåab are also roughly presented in the tool. Features such as contours, depth areas and soundings presented in the tool, were produced via the Swedish Maritime Administrations' program WinEko.

As some areas had been surveyed in other errands, there were "holes" or "stamps" in the surveys for ADAPT. These *stamps*, were measured in 2013, with the hydrographic survey vessel Peter Gedda, as the areas were critical. The data covering *stamps* were added to the tool in the autumn of 2018 previous to seminar 3, where analysing of the routes took place. To separate the *stamps* from the measurements of ADAPT they where symbolized in a specific way. They were presented with one colour for areas shallower than 4.5 metres and one colour for areas deeper than 4.5 metres. As a background map navigational charts from the autumn of 2016 were used, it was also possible to view orthophotos in the tool if wanted.

2.4 Figures used for analysis in Åland archipelago

In the Åland archipelago, public navigational charts have been established in the project. These sea charts and fairway planning follow national- and international regulations for public sea charts. The changes that ADAPT proposes can be implemented after the Government of Åland have made a management decision to implement them. Finnish shipping authority Trafikcom (after 1/1 2019, formerly the Finnish Transport Administration) must also approve the changes to be published as official charts.

[1] ESRI 2017. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

3 Corridors and nodes

A corridor is defined by the extent of a route or existing fairway. The section from the starting point to the end point of the pre-existing time tables in the two archipelagos used in seminar two for establishment of the baseline. Within a corridor, support routes may be found and developed as sub corridors. These developed corridors may for example function as substitute routes in hard weather, during winter or be a section where a better alternative to the original route has been found. A node within the project has been defined as the location of a port, a jetty or an intersection with another fairway. Nodes can be found in the corridors and mainly consist of locations where safety issues has been located and measures are required. Totally 46 corridors and 40 nodes was located during the project.

4 Corridors and nodes in Stockholm archipelago

Altogether, 38 corridors and 14 nodes has been established in the archipelago of Stockholm, listed in table 4-5, along with location and suggested measure. Some of the corridors can partly overlap geographically, but there may still be vast differences in the flow of passengers and the emissions per kilometre and person, depending on the total extent of the route. Table 3 is a guide of which of the following figures show the geographic location of and extent of the corridors and nodes in Stockholm archipelago. Table 4 contain information about the locations of the corridors within the archipelago, and the public transportation network. Table 5 lists the nodes, with location and to what corridor they belong.

Table 3. Geographic location and extent of the corridors and nodes in the following seven figures.

Figure number	Corridor number	Node number
3	13, 15, 16, 17, 18, 30, 31, 34, 37, 38	5, 6, 10, 11
4	9, 10, 11, 13, 14, 15, 16, 28, 29, 30, 34, 36, 37	4, 5, 10
5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14 28, 29, 32, 35, 36	1, 2, 3, 4, 9
6	1, 2, 3, 4, 12, 20, 21, 22, 23, 24	1, 2, 7, 8
7	2, 3, 8, 19, 20, 21, 22, 23, 32	7, 12
8	21, 22, 23, 24, 25, 33	8
9	25, 27, 33	

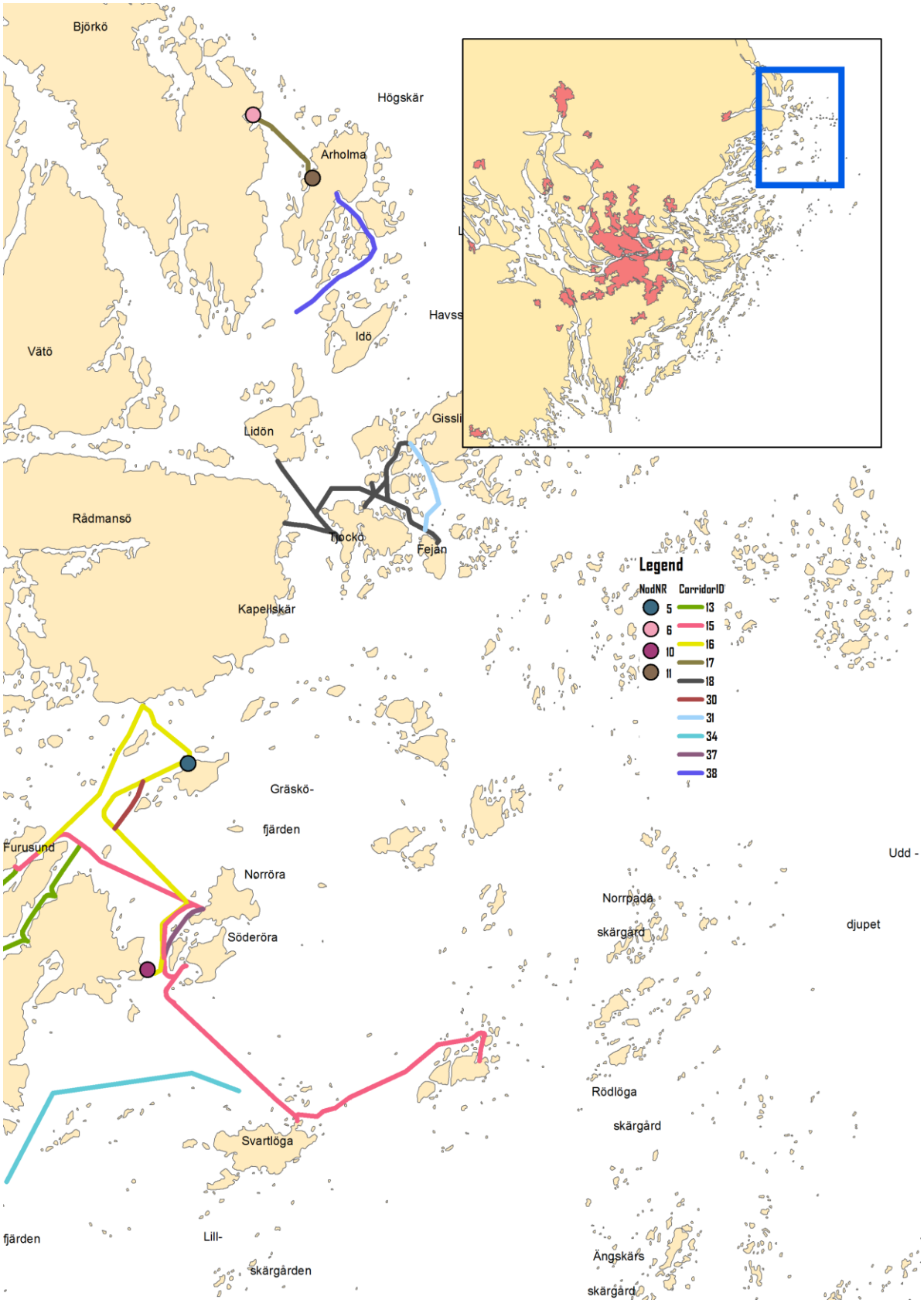


Figure 3. Geographic extent of corridor 13, 15-18, 30, 31, 34, 37 & 38 and nodes 5, 6, 10 & 11.

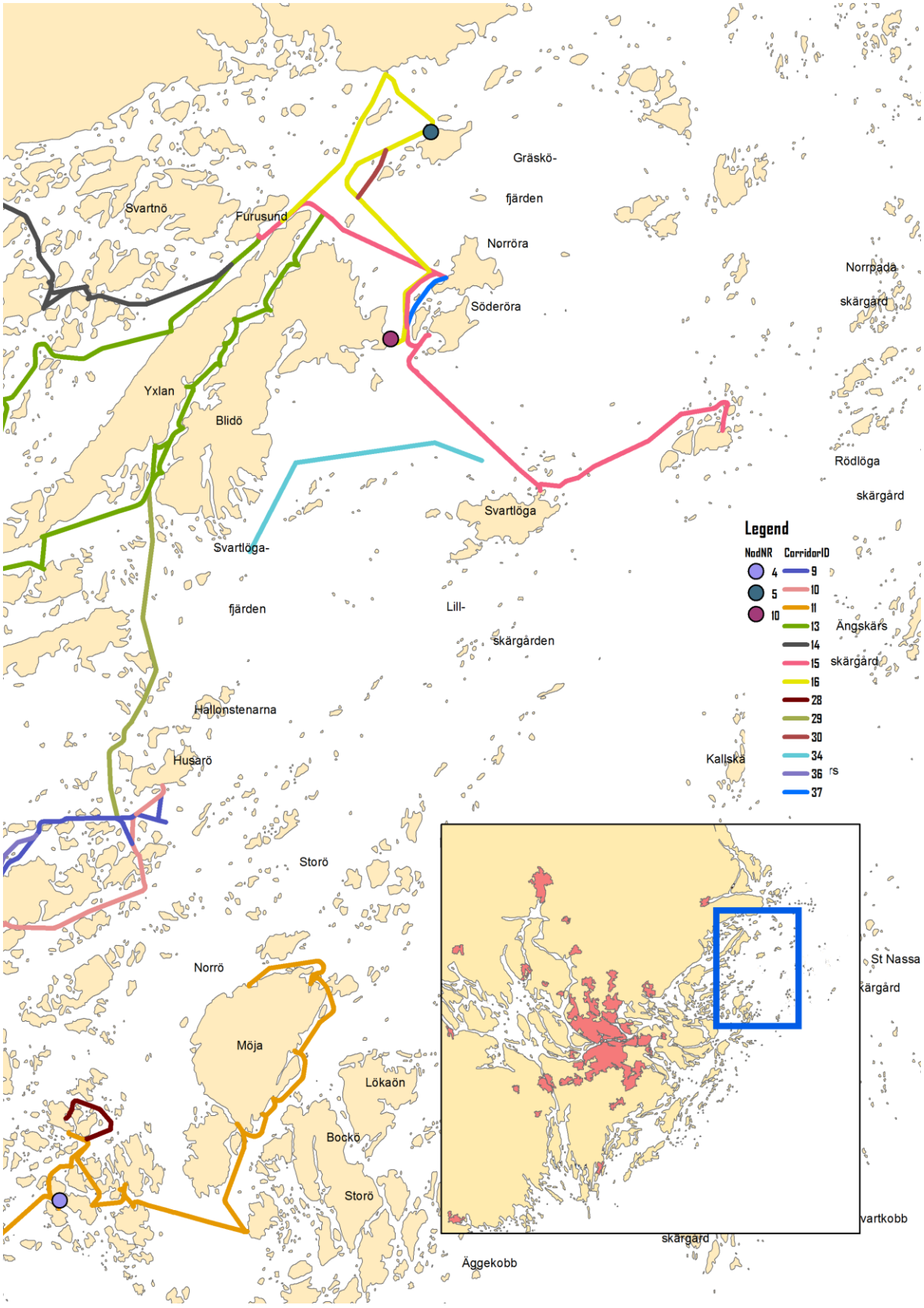


Figure 4. Geographic extent of corridor 9, 10, 11, 13–16, 28-30, 34, 36, 37 and nodes 4, 5, 10.

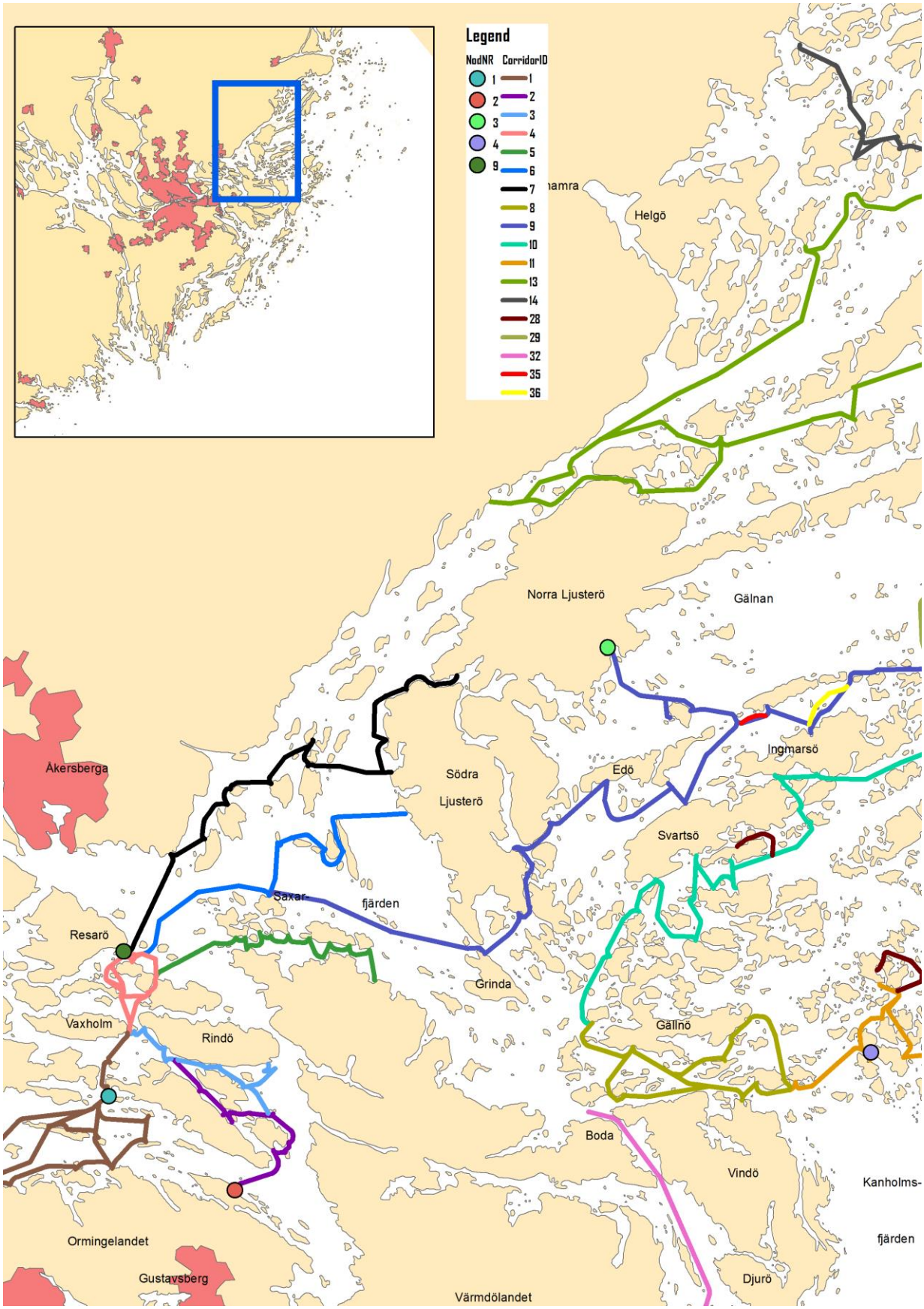


Figure 5. Geographic extent of corridor 1 – 11, 13, 14, 28, 29, 32, 35 & 36, nodes 1-4 & 9.

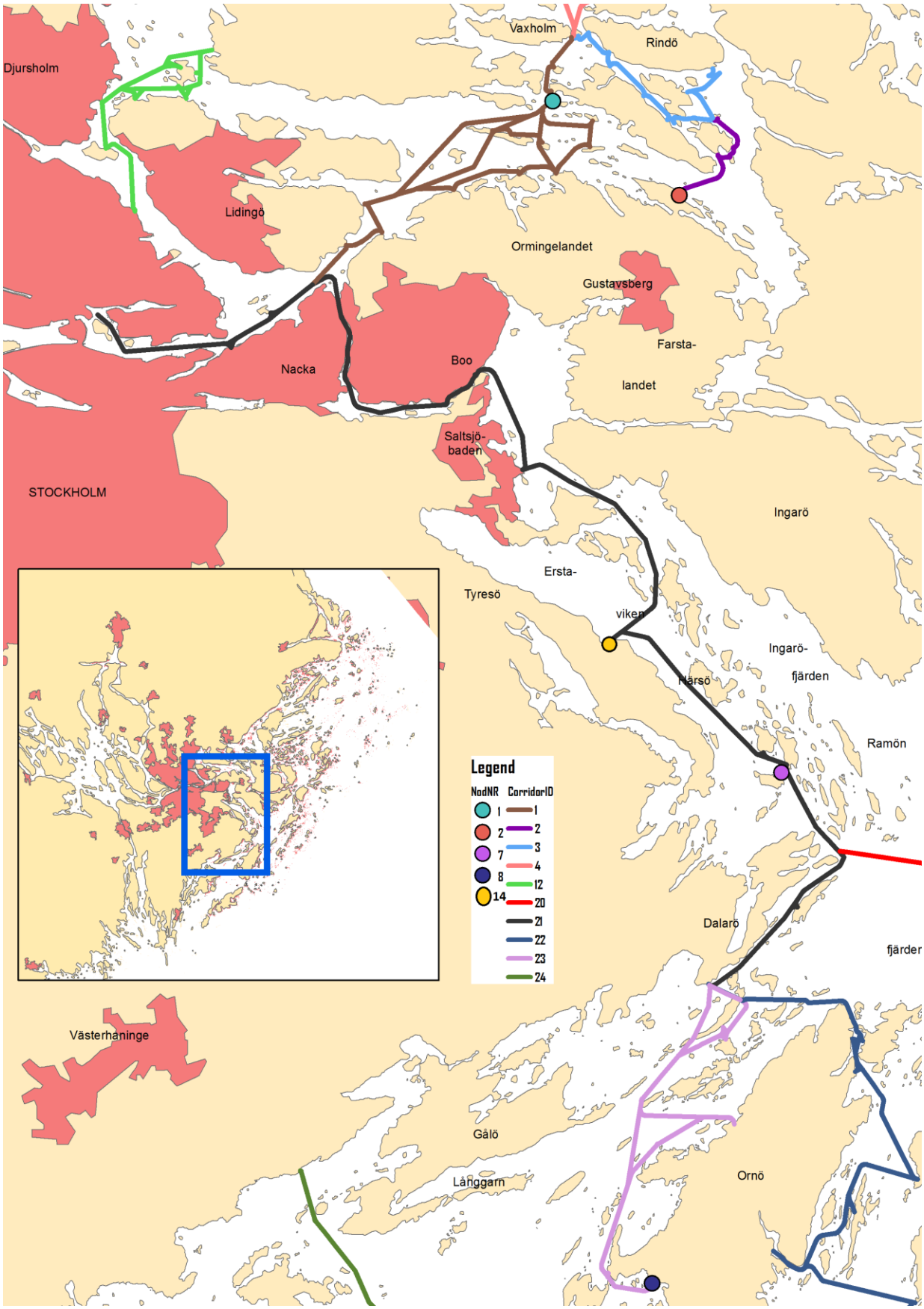


Figure 6. Geographic extent of corridor 1-4, 12, 20- 24 and nodes 1, 2, 7, 8 & 14.

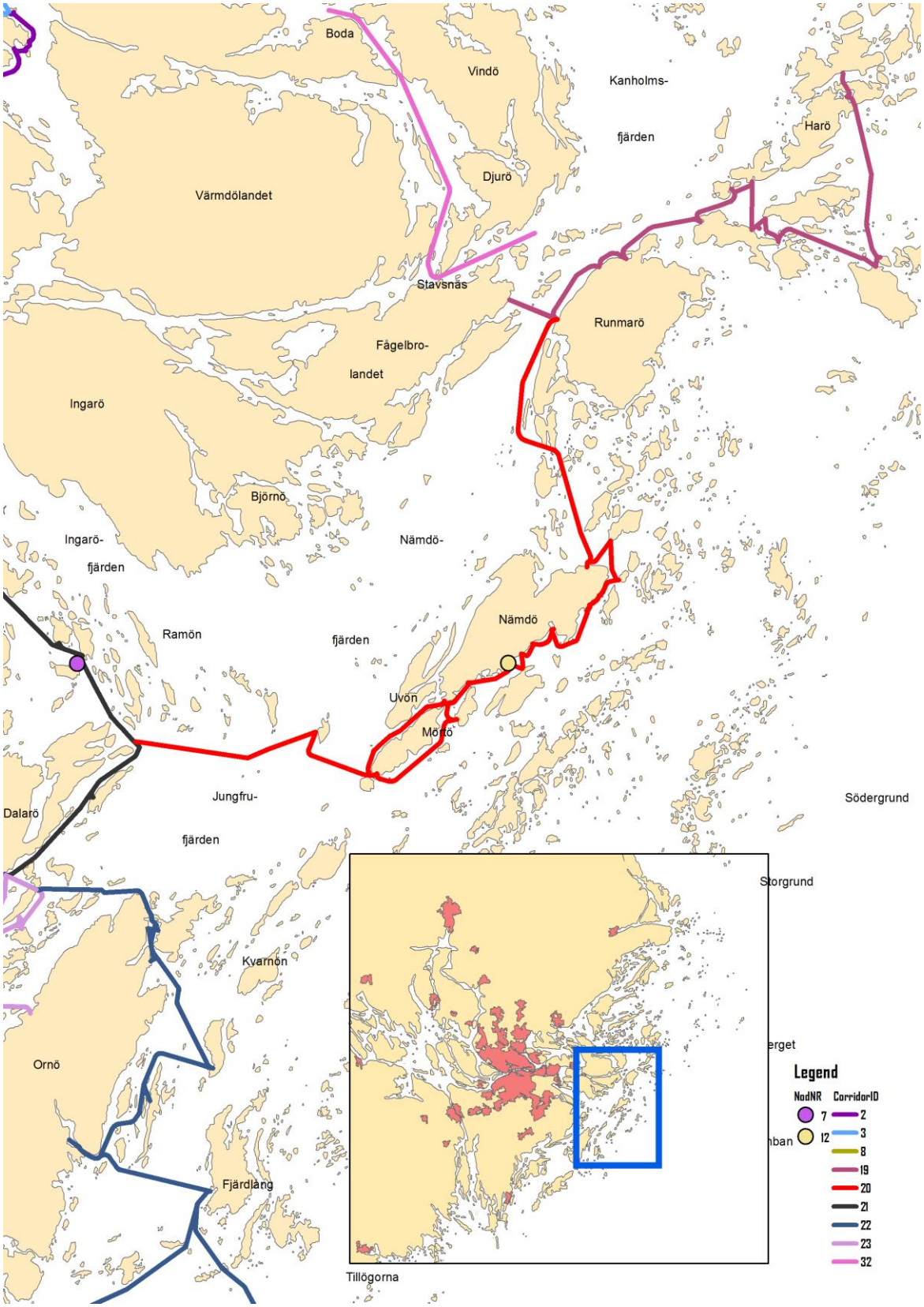


Figure 7. Geographic extent of corridor 2, 3, 8, 19, 20 - 23 & 32 nodes 7 & 12.

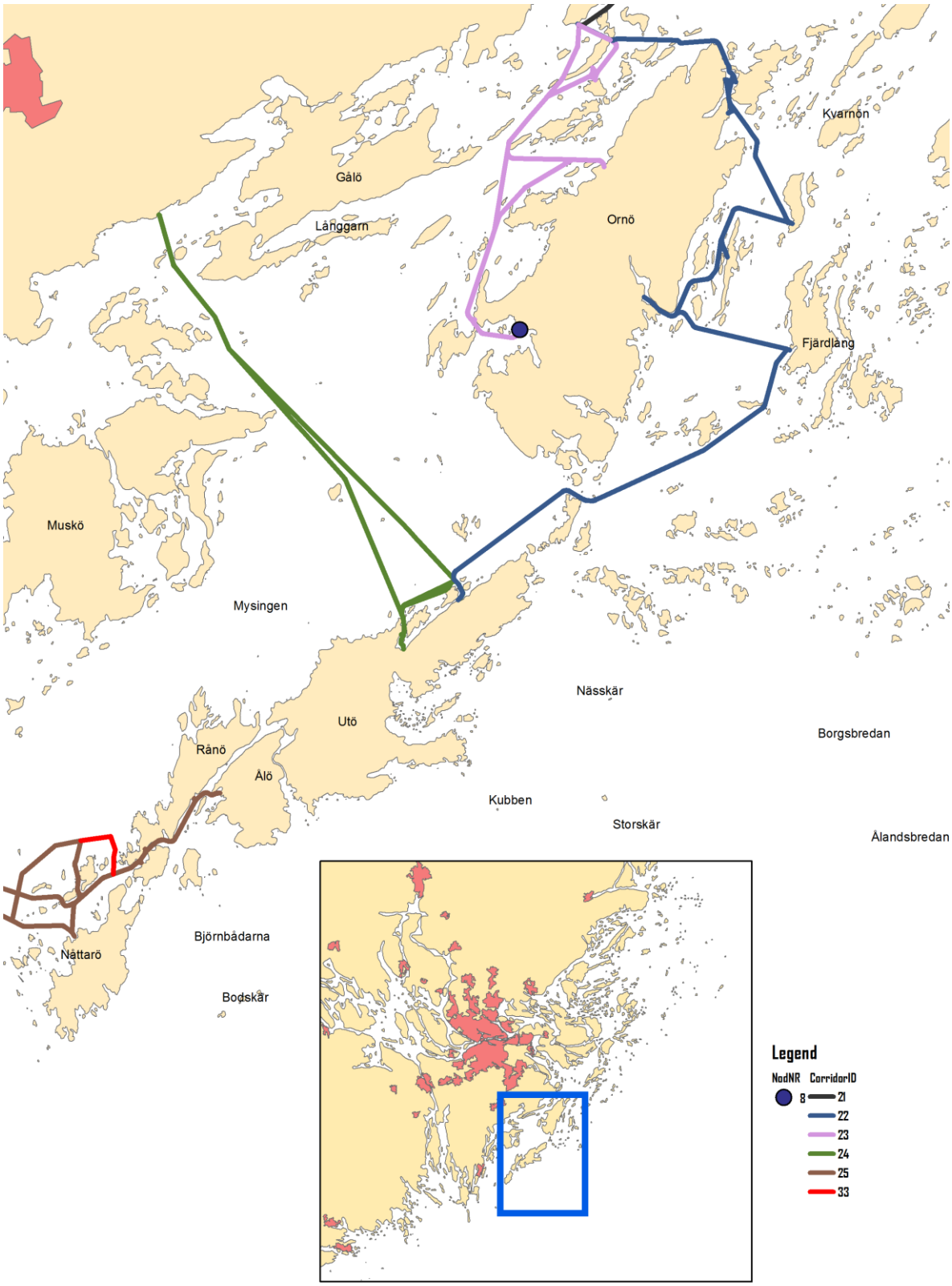


Figure 8. Geographic extent of corridor 21-25 & 33, nodes 8.

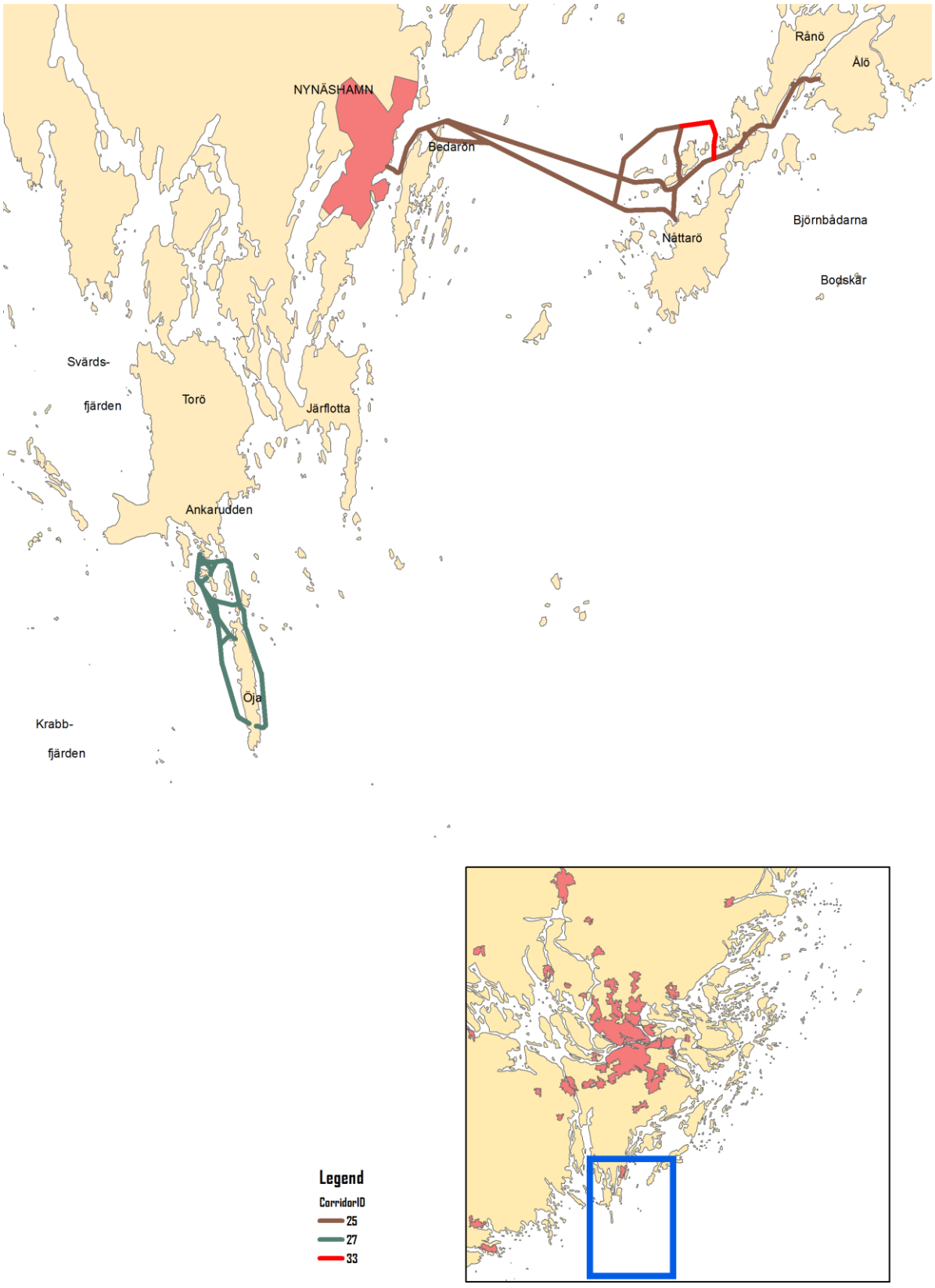


Figure 9. Geographic extent of corridor 25, 27 & 33.

Table 4. The corridors identified during the seminar, their location within the archipelago and to which public transportation route they belong is listed in the table.

Corridor-ID	Route extent	Local traffic line	Location
1	Stockholm – Vaxholm	1, 2	Middle archipelago
2	Stockholm – Norra Lagnö	3	Middle archipelago
3	Stockholm – Ramsö	4	Middle archipelago
4	Stockholm – Vikingsborg	5	Middle archipelago
5	Stockholm – Lindalssund	7	Middle archipelago
6	Stockholm – Grundvik	8	Middle archipelago
7	Stockholm – Väsbystrand	9	Middle archipelago
8	Stockholm – Sollenkroka	11	Middle archipelago
9	Stockholm – Edö – Husarö	12	Middle archipelago
10	Stockholm – Alsvik – Husarö, Baseline comparison section 4.6	13	Middle archipelago
11	Stockholm – Möja	14	Middle archipelago
12	Ropsten – Storholmen	81	Middle archipelago
13	Stockholm – Norrsund	24	North archipelago
14	Solö – Furusund	25	North archipelago
15	Stockholm – Rödlöga	26	North archipelago
16	Furusund – Rödlöga, Baseline comparison in section 4.18	28	North archipelago
17	Simpnäs – Arholma	30	North archipelago
18	Räfsnäs – Fejan, Baseline comparison section 4.20	31	North archipelago
19	Stavsnäs - Hagede	16	South archipelago
20	Stavsnäs – Nämdö - Stockholm	17	South archipelago
21	Stockholm – Dalarö	18	South archipelago
22	Stockholm – Utö	19	South archipelago
23	Dalarö - Ornö	20	South archipelago
24	Årsta - Utö	21	South archipelago
25	Nynäshamn - Ålö	22	South archipelago
27	Ankarudden – Landsort	29	South archipelago
28	Godslinje 3		Middle archipelago
29	Husaröleden	40	North archipelago
30	Developed support route Tjärstören	28	North archipelago
31	Developed route Gisslingö – Fejan, Baseline comparison 4.34	31	North archipelago
32	Ångbåt Norrskär	15	Middle archipelago
33	Developed route Furuklubben/ Trålhålet	22	South archipelago
34	Developed route Svartlögafjärden (korridor 15)	15	North archipelago
35	Adjusted route Syd Äpplarö	9	Middle archipelago
36	Developed route Äpplarö Norskobblarna	9	Middle archipelago

37	Developed support route Dämmans Ören	28	North archipelago
38	Developed support route Arholma östra	30	North archipelago

Table 5. The nodes identified during the seminar, their location within the archipelago, which corridor they belong and suggested measure for the node is listed in the table.

Node	Belongs to corridor	Location	Suggested measure
1	1	Vasholmen	Limiting line at the harbour
2	2	N. Lagnö	Limiting line and vessel draft
3	9	Åsättra	Extension of traffic into winter
4	11	Träskögåln, väst om Karsholm	Limiting line
5	16	Gräskö	Leading line
6	17	Simpnäs	Limited depth/ vessel size
7	21	Kalvholmen (Haninge)	Limited depth/ vessel size, changed berthing
8	20	Lättinge	Limited depth/ vessel size, limiting line
9	4	Ytterby	Leading line
10	16	Bromskär	Limited depth/ vessel size
11	17	Arholma	Limited depth/ vessel size
12	20	Sand	Shallow area, limiting line
13	38	Arholma Östra	Protected deep harbour
14	21	Erstaviken	Limiting lines

4.1 Corridor 1 Stockholm - Vaxholm

The corridor contains one area with safety issues caused by shoals, and one node. Limiting lines and correct positioning of the shoals found outside of the navigational chart curves, are proposed as safety adjustments of the corridor, see figure 10. The intention of the limiting line is to assure that the vessels trafficking the corridor will keep a safe distance to the shoals**.** Actions affect navigational safety and environmental protection, as the risk of accidents decrease significantly.

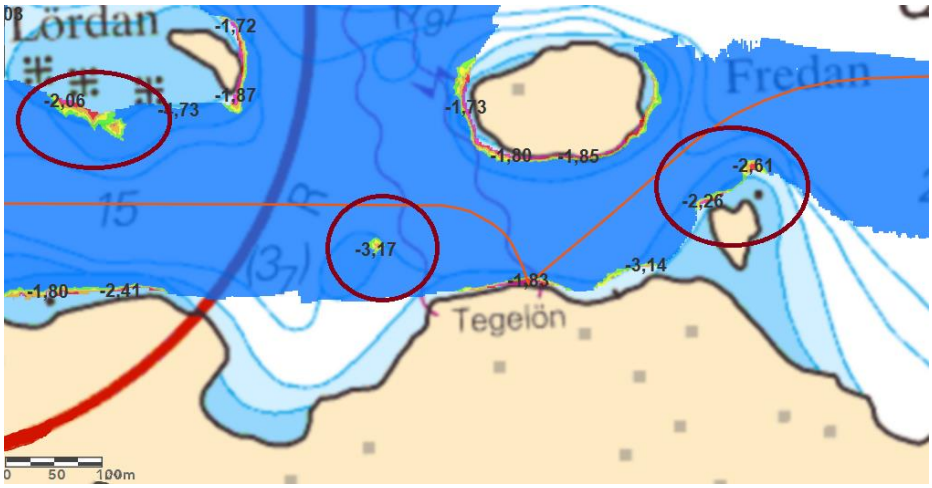


Figure 10. Circled are the safety issues found in the designated area. The circles to the left and right show found areas where lesser depths are found than indicated by depth curves. The centre circle shows a shoal with lesser depth and differently positioned than indicated by chart.

4.1.1 Node 1

Suggesting an adjustment of the node by establishing a limiting line next to the port of Vasholmen to prevent ferries to ground on the shoal identified outside of the 3 metre navigational chart curve, see figure 11. This is especially important when berthing at the jetty. The proposed limiting line and correct positioning of the shoal affect the navigational safety and environmental protection.

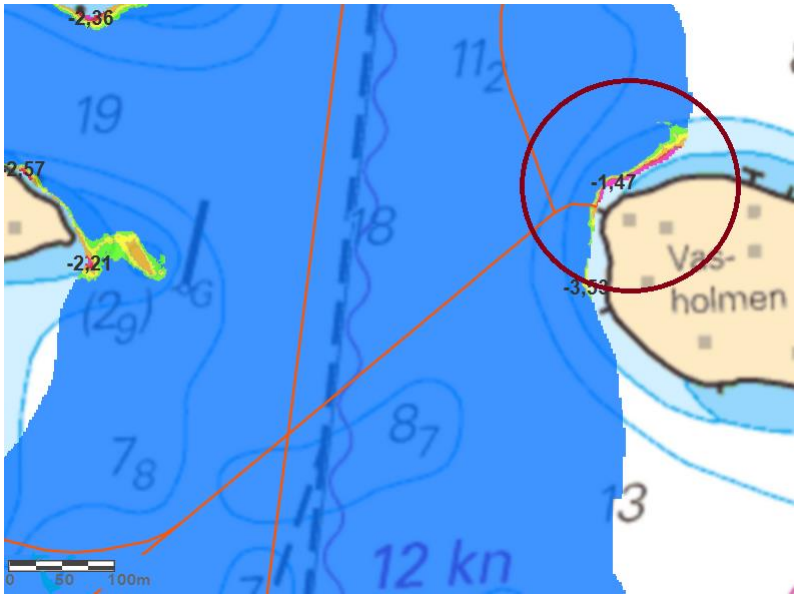


Figure 11. The circled area shows the shoal outside of the Vasholmen jetty, where the limiting line is suggested for safer berthing.

4.2 Corridor 2: Stockholm – Stora Lagnö (3)

In corridor 2 several issues were found. Firstly, a shoal was found next to Ramsöholm where a limiting line and correct positioning of the shoal is suggested as an adjustment of the location of the route, to eliminate risk of

vessels grounding, see figure 12. The implementation impacts the navigational safety and environmental protection positively.

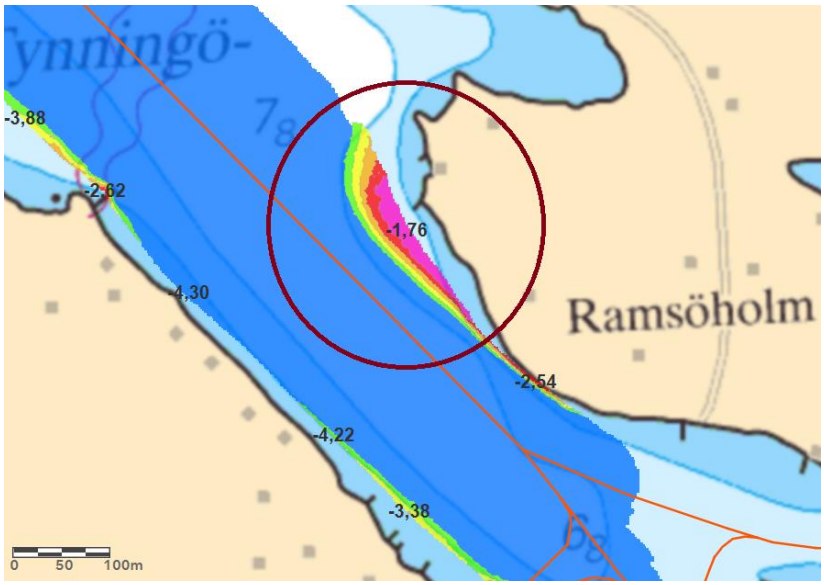


Figure 12. A shoal was found next to Ramsöholm where a limiting line has been proposed as a safety measure for this location in corridor 2.

At the second location a greater depth than known was found, opening up to more vessels, and provide more freedom in the use of the fairway, see figure 13. Limiting lines and correct positioning of shoal are proposed. The actions affect vessel capacity and route optimization, the impact on travel time is, however, limited.

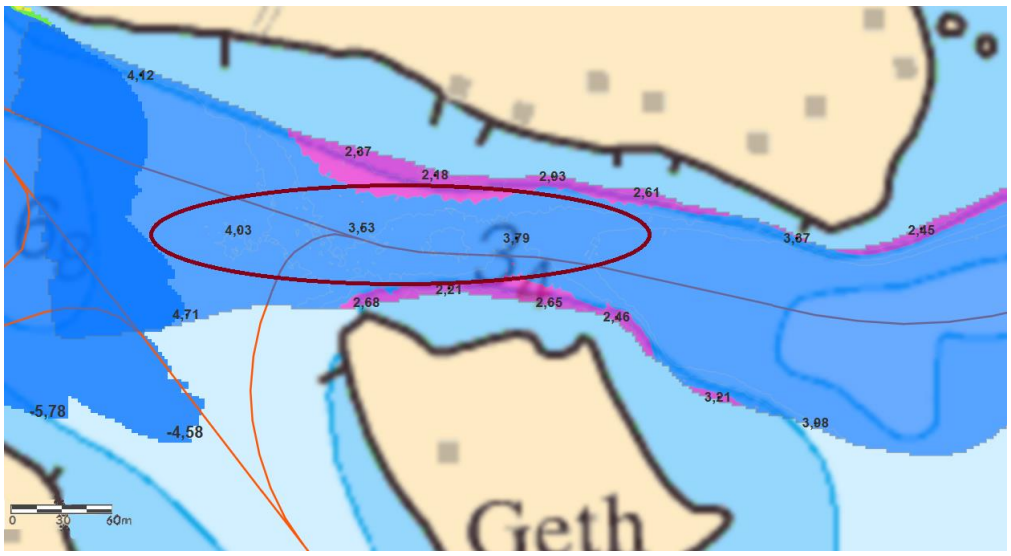


Figure 13. A greater depth in the fairway north of Getholmen was found, leading to a larger freedom for the vessels using it. The circle shows the newly found 3.6 m depths in the area previously known to be 3.4 metres deep.

The third suggestion is to insert a limiting line where the passage between Skogsön and Hästholmen is narrower than known. Furthermore, the passage is shallower than known, with a found depth of 3.7 metres in an area previously known to be 4.2 meters deep, see figure 14. Limiting lines and correct positioning of the contours in the passage are proposed. The actions affect the navigational safety and environmental protection.

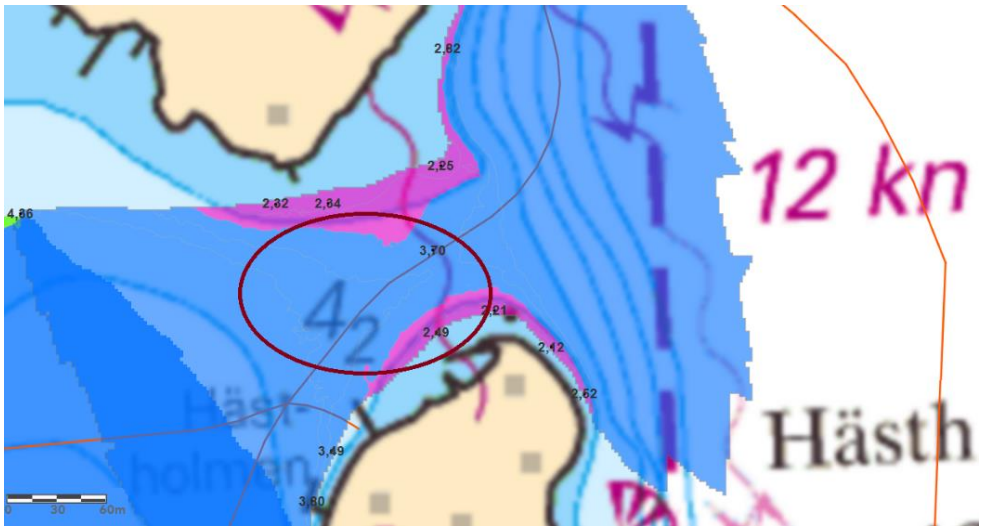


Figure 14. The circle shows the passage between Skogsön and Hästholmen, which is found to be slimmer and shallower than known.

The last proposal in corridor 2 is to insert a limiting line at Tynningöudd, where a shoal was found outside of the 3-metre navigational curve, see figure 15. Limiting line and correct positioning of shoal affects the navigational safety and environmental protection positively.

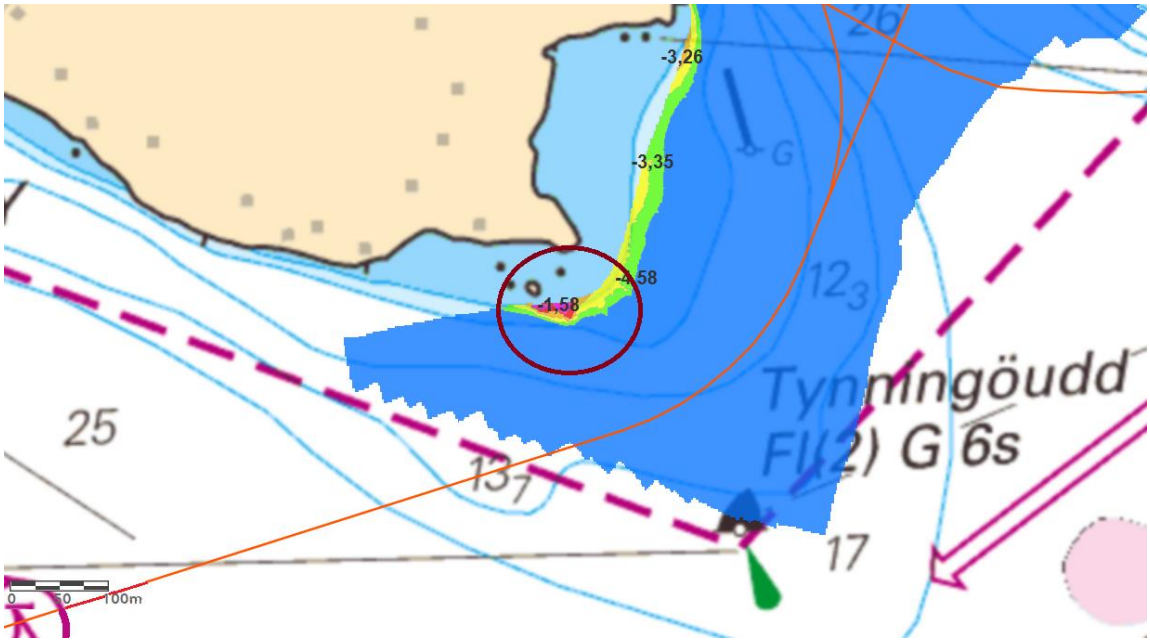


Figure 15. The area next to Tynningöudd was found to be shallower than previously known. Adjusting the corridor by the addition of a limiting line is suggested.

4.2.1 Node 2

The area around the jetty at N. Lagnö was found to be a location where it is hard to berth safely. Multiple shoals were found, and the area was generally shallower than known, see figure 16. A stricter berthing route for approaching this jetty is proposed along with limiting lines to assure safe berthing for the vessels operating the jetty. The actions also decreases the risk of environmentally damaging accidents.

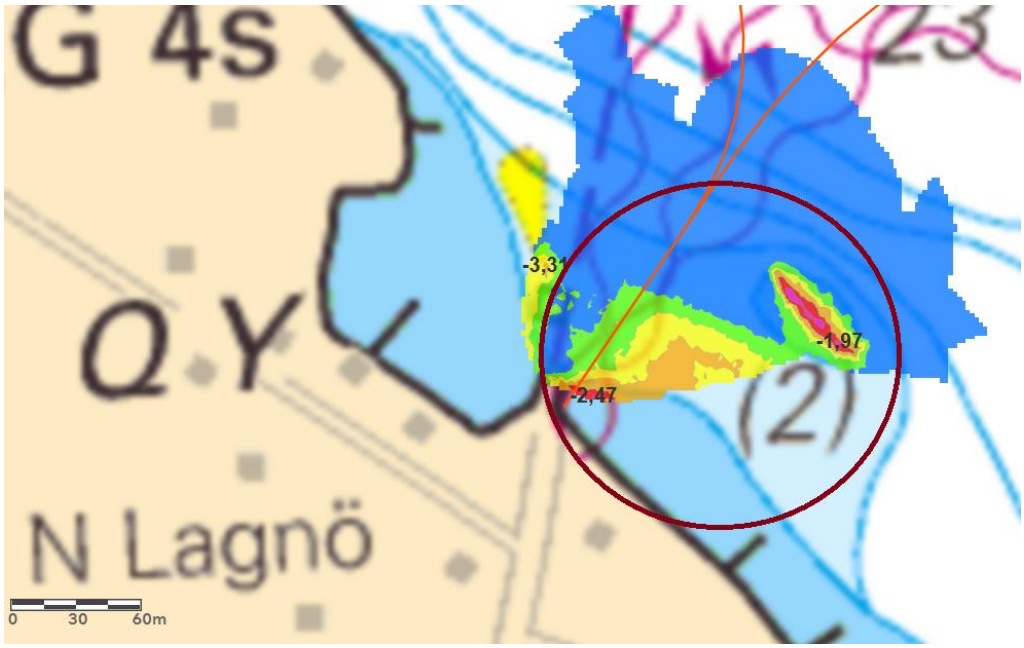


Figure 16. The circle shows the shoals found close to the jetty at N. Lagnö, where a strict navigation line is suggested to achieve safer berthing at the jetty.

4.3 Corridor 3: Stockholm – Ramsö (4)

A greater depth than previously known was found next to Björnholmen. Furthermore, a shoal was found in the middle of the passage, see figure 17. A buoy to mark the shoal and a limiting line for the ferry traffic is proposed, as ferries currently are found to navigate on both sides of the channel. These actions affect the navigational safety and decreases the environmental risks.

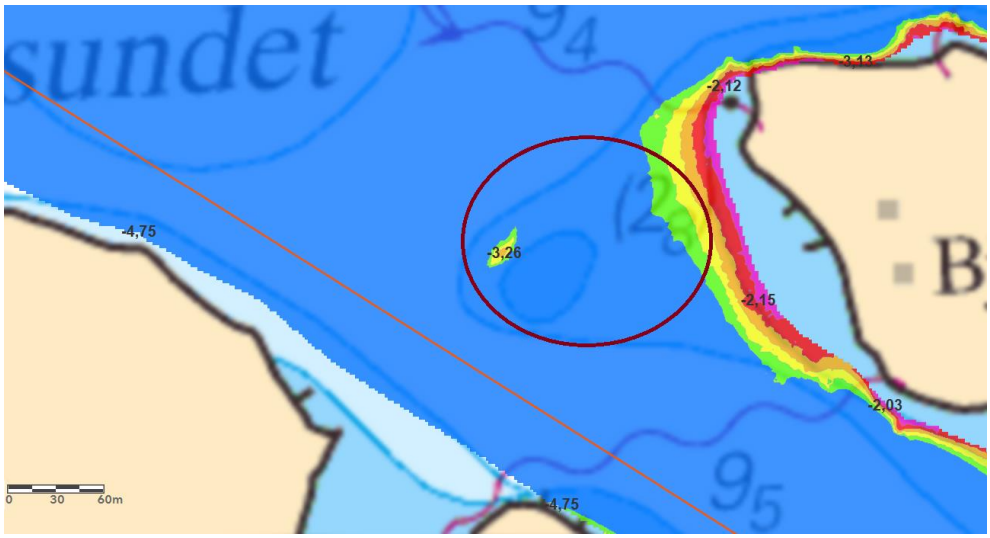


Figure 17. The circle marks the shoal found outside of Björnholmen.

4.4 Corridor 4: Stockholm – Vikingsborg (5)

In corridor 4, one node and three safety issues leading to safety proposals at two locations were found. The first safety issue found was the channel Finnhålet, which was shallower than previously known, with a depth of only

2.9 metres. Suggested safety measure is therefor to use vessels with a depth according to this new information, see figure 18. Moreover, a limiting line and correct positioning of the shoal was also proposed. The actions impacts the navigational safety and environmental protection, but the travel time impacts are limited.

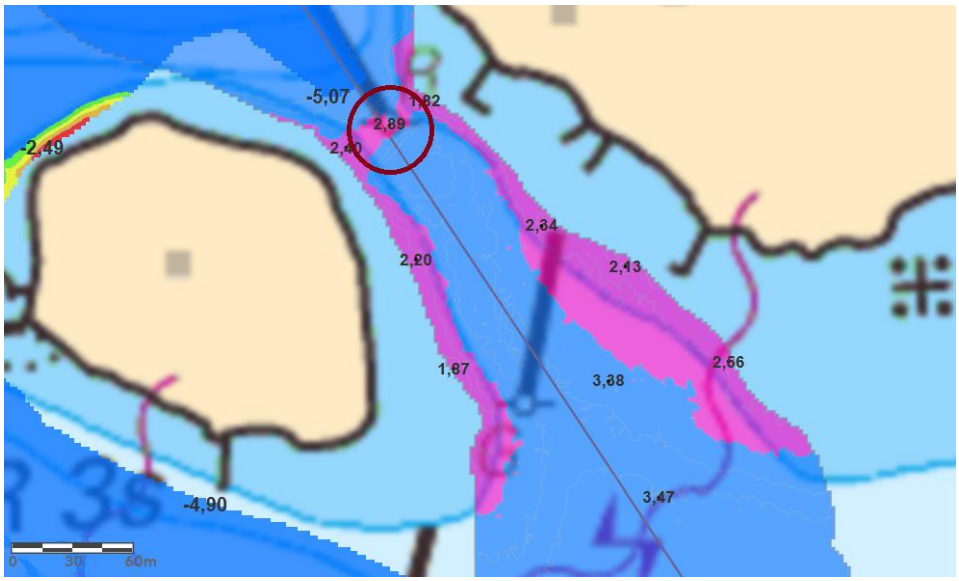


Figure 18. The depth in the channel next to Finnhålet was found to only be 2.9 metres, see circled area in the figure.

The second safety measure that is proposed is the addition of a safety distance to the shoal found by West Rindö. The shoal reaches further into the navigated area than previously known, see figure 19. Limiting line and correct positioning of the shoal are also proposed. The actions affect the navigational safety and environmental protection.

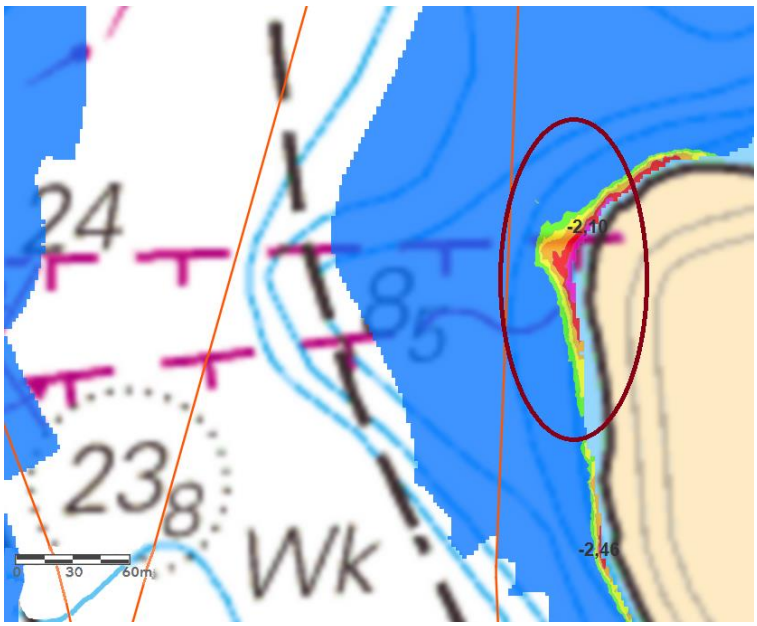


Figure 19. The shallow area next to W. Rindö reaches further out than known. The circled area shows how close it is to the general navigation line.

4.4.1 Node 9

Node 9 is found in corridor 4, the jetty located south of Ytterby. The shoal was found between fairway route approaching and leaving the jetty. Proposing a leading navigational line, limiting lines and correct positioning of the shoal, to navigate by when approaching the jetty for a safe berthing and departure. These actions impacts the navigational safety and environmental protection.

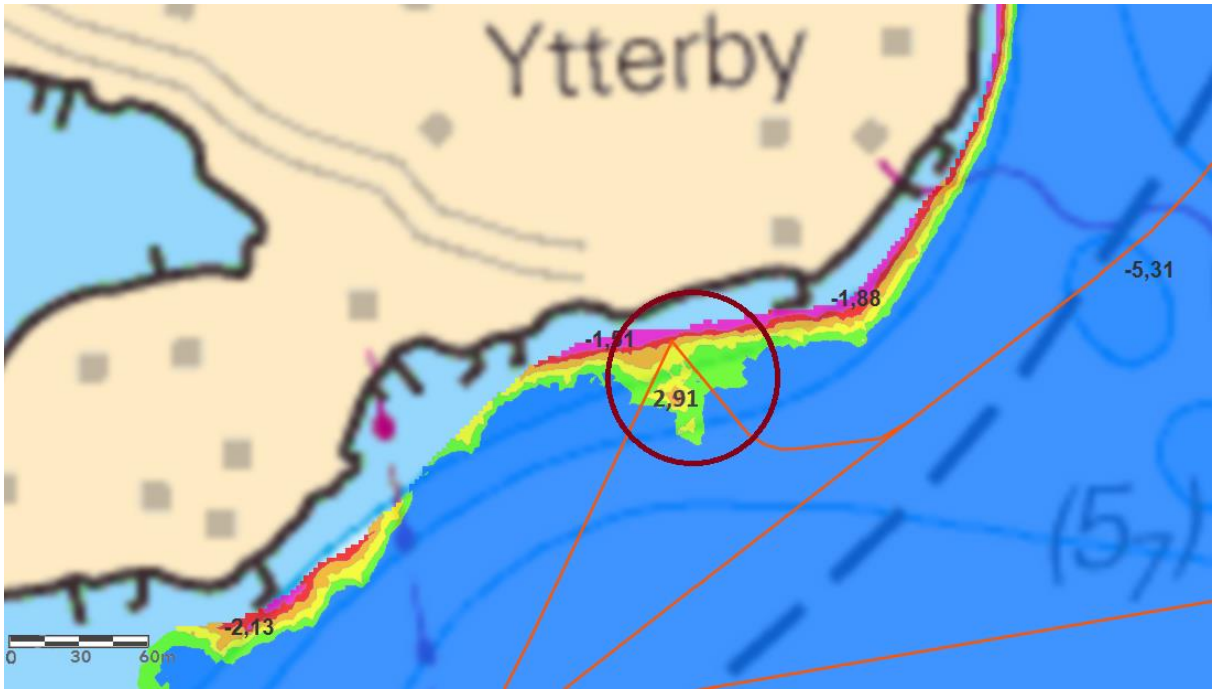


Figure 20. Circled shoal found limiting the accessibility to the jetty south of Ytterby.

4.5 Corridor 5: Stockholm – Lindalssund

In corridor 5, no hydrographical survey was carried out during the project.

4.6 Baseline analysis of route 1301 Stockholm – Vaxholm – Stegesund – Lindalssundet – Grinda

An in-depth analysis of baseline route 1301, located in corridor 10 compared to an alternative route is described in the following section. For route extension, see figure 21.

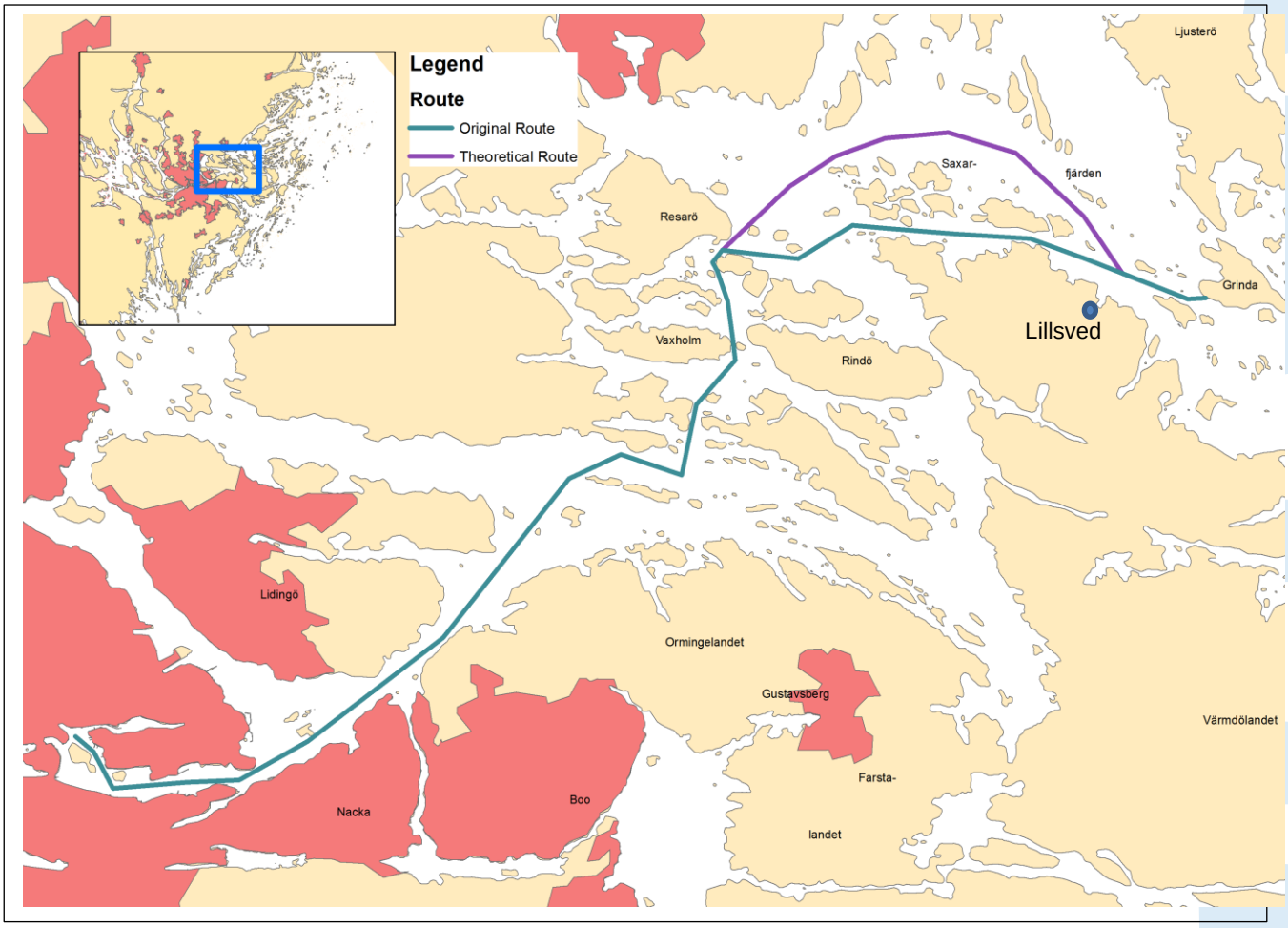


Figure 21. Map dislpaying the middle part of Waxholmsbolaget's network area. Route 1301 and the theoretical alternative is marked.

To briefly describe the route, route 1301 runs Monday to Friday midmorning during the summer timetable from Strömkajen via Lindalssundet and Södra Grinda to Södra Ingmarsö in corridor 10. During the summer of 2015, which this analysis is based on, route 1301 was operated by the vessel *Skärgården.* The maximum passenger capacity is 297 passengers of which 168 are seats. Congestion starts at 168 passengers. The summer of 2015 was rainy. The ship carried an average of about 80 and 100 passengers between Stockholm and Grinda. About half of these passengers disembarked on Grinda. On sunny days another 150-200 passengers utilized the vessel to the islands of Vaxholm and Grinda, see figure 22. The travellers utilizing the service were residents, part-time residents and visitors.

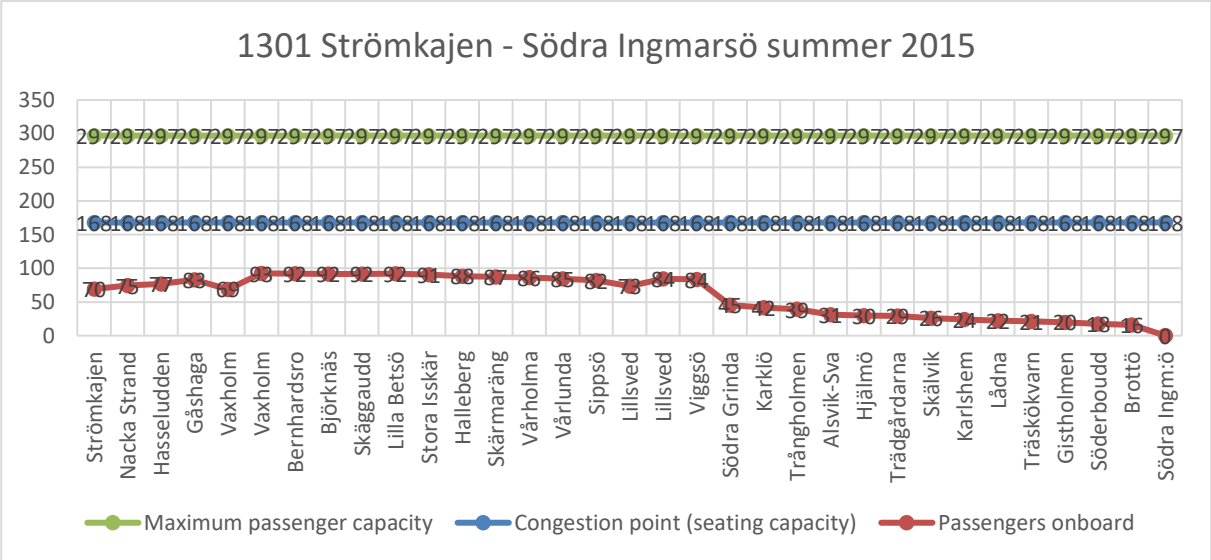


Figure 22. Line diagram presenting vessel capacity (green), congestion point (blue) and average occupancy (red).

The study compares route 1301 with a theoretical route where the ship heads straight for Grinda after Vaxholm, without calling at any of the stops in Lindalssundet (Bernhardsro – Lillsved). Route 1301 is also compared with route 0701, which runs between Stockholm – Vaxholm – Lindalssundet – Lillsved and has been in service since the summer of 2017, see table 6.

Table 6. A table over the three routes compared in the analysis.

Object of comparison	Route extent
Route 1301	Stockholm-Vaxholm-Stegesund-Linddalssundet-Grinda
Theoretical alternative	Stockholm-Vaxholm-Stegesund-Grinda
Route 0701	Stockholm-Vaxholm-Lindalssundet

Journey time for route 1301 from Stockholm (Strömkajen) to Grinda was 1 hour and 55 minutes. It took 1 hour and 45 minutes from Stockholm (Strömkajen) to Lillsved, see figure 21 for Lillsveds location. Journey time for the theoretical alternative from Stockholm (Strömkajen) to Grinda is calculated to approximately 1 hour and 40 minutes. Journey time for route 0701 from Stockholm (Strömkajen) to Lillsved was 2 hours and 10 minutes.

Energy consumption per person for route 1301 from Strömkajen to Södra Ingmarsö was 67 kWh, see table 7. Energy consumption per person for the theoretical alternative from Strömkajen to Grinda is calculated to be 65 kWh, see table 8. Thus, the routes are equal in terms of energy consumption per person. Although, calling at the intermediate stops in Lindalssundet results in better use of energy. Energy consumption is 1.07 kWh/pkm for route 1301 and slightly higher, 1.1 kWh/pkm, for the theoretical alternative. Energy consumption per person for route 0701 from Stockholm (Strömkajen) to Lillsved was 166 kWh, see table 9. Tables 10 and 11 show possible reductions in CO2 emissions and travel time per passage and annually. Following tables are the result of the calculations and the base for the comparison between baseline and alternative route extensions.

Table 7. Calculation of energy use per trip with route 1301 from Stockholm to South Ingmarsö.

Route 1301 from Stockholm (Strömkajen) to South Ingmarsö		
Trip length (km)	62,2 km	
Sailing time (h)	3,17 h	
Fuel consumption (l/h)	130 l/h (Roslagen)	

Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption (kWh)	H*l/h*kWh/l	4 018 kWh
Weighted occupancy	62,3 passagengers (Excel)	
Passenger kilometres (pkm)	3 760 pkm (Excel)	
Energy consumption per pkm	kWh/pkm	1,07 kWh/pkm
Energy consumption per passenger for whole trip	(kWh/pkm)*km	66,6 kwh/p
Co2 content diesel MK1 (g CO2ekv/kWh)	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO^2ekv/kWh)	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	15 kg CO2/p
Calculated CO2 emission per passenger diesel HVO (20 %)	kWh/p*40*0,2	1 kg CO2/p
Total CO2 emissions per passenger		16 kg CO2/p
Travel time Strömkajen –Grinda		1,9 h

Table 8. Calculation of energy use per trip with the theoretical route from Stockholm to South Ingmarsö, with no calls to the jetties in Lindalssundet, calculated for the same conditions as for route 1301.

Theoretical alternative route from Stockholm (Strömkajen) to South Ingmarsö		
Trip length (km)	59 km	
Sailing time (h)	3,0 h	
Fuel consumption (l/h)	130 l/h (Roslagen)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption (kWh)	H*l/h*kWh/l	3 803 kWh
Weighted occupancy	5,47 passengers (Excel)	
Passenger kilometres (pkm)	3 493 pkm (Excel)	
Energy consumption per pkm	kWh/pkm	1,1 kWh/pkm
Energy consumption per passenger for whole trip	(kWh/pkm)*km	64,9 kwh/p
Co2 content diesel MK1 (g CO2ekv/kWh)	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO^2ekv/kWh)	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	15 kg CO2/p
Calculated CO2 emission per passenger diesel HVO (20 %)	kWh/p*40*0,2	1 kg CO2/p
Total CO2 emissions per passenger	16 kg CO2/p	
Travel time Strömkajen – Grinda		1,7 h

Table 9. Calculation of energy use per trip with route 0701 from Stockholm to Lillsved.

Tour 0701 from Strömkajen to Lillsved		
Trip length (km)	21,0 km	
Sailing time (h)	2,17 h	
Fuel consumption (l/h)	148 l/h (Waxholm 1)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	

Energy consumption (kWh)	H*l/h*kWh/l	3 131 kWh
Weighted occupancy	9,4 passengers (Excel)	
Passenger kilometres (pkm)	397 pkm (Excel)	
Energy consumption per pkm	kWh/pkm	7,89 kWh/pkm
Energy consumption per passenger for whole trip	kWh/pkm)*km	165,7 kwh/p
Co2 content diesel MK1 (g CO2ekv/kWh)	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO²ekv/kWh)	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	38 kg CO2/p
Calculated CO2 emission per passenger diesel HVO (20 %)	kWh/p*40*0,2	1 kg CO2/p
Total CO2 emissions per passenger		39 kg CO2/p
Travel time Strömkajen – Grinda		2,2 h

Table 10. CO_2-reduction for route 1301 compared to the combination of the theoreticalroute together with route 0701.

CO_2 reduction by passenger with tour 1301 instead of combination of theoretical tour completed with tour 0701		
CO2 reduction/passage		39 kg CO2/passage
CO2 reduction/year	8 annual passages	312 kg CO2/year
Reduction of travel time/passage		0,3 h/passage
Reduction of travel time/year		2,4 h/year

Table 11. CO_2-reduction by ferry, calculated for the scenario when route 0701 is replaced by 1301 instead of the combination of the theoretical route together with route 0701.

CO2 reduction by ship for 1301 compared to 0701 +the theoretical route		
Sailing time (h)	2,2 h	
Fuel consumption (l/h)	157 l/h (Gällnö)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption	h*l/h*kWh/l	3368 kWh
Co2 content diesel MK1 (g CO2ekv/kWh)	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO²ekv/kWh)	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission diesel MK1 (80 %)	kWh*285*0,8	768 kg CO2
Calculated CO2 emission HVO (20 %)	kWh*40*0,2	27 kg CO2
Calculated CO2 emission per tour		795 kg CO2
Annual tours	8	
Calculated annual CO_2 emissions to be saved		6 360 kg CO2

Route 1301 alone emits 16 kg CO_2 per person for the whole journey. The theoretical alternative also emits 16 kg CO_2 per person for the whole journey, but another 39 kg CO_2 per person must be added from route 0701 to Lindalssundet. Travel time is also increasing from 1,9 hours to 2,2 hours see figure 23.

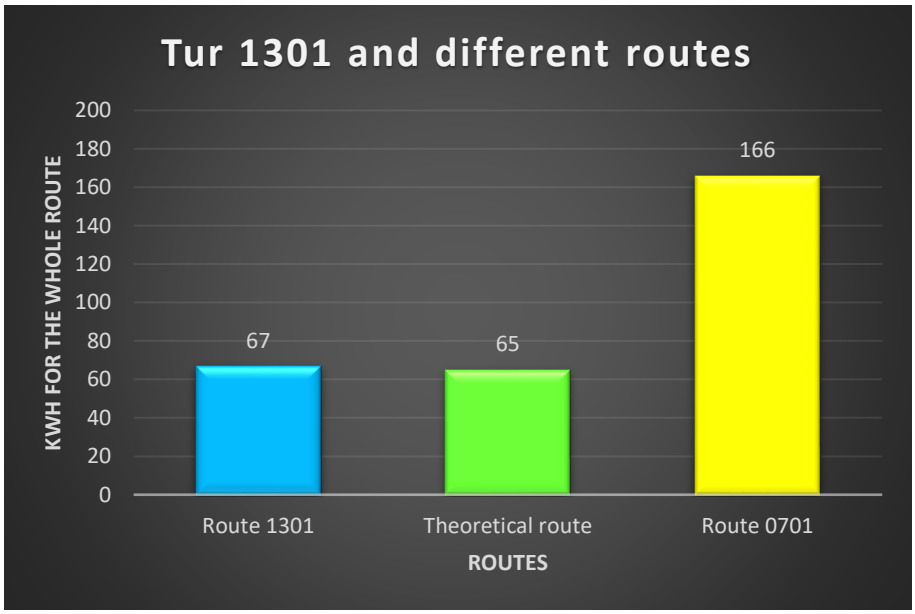


Figure 23. Bar graph comparing consumption for route 1301 with the theoretical route.

Knowledge through ADAPT
There is an alternative route over Saxarfjärden, but it is a full speed route, which results in higher fuel consumption. To sail by the jetties in Lindalssundet, without calling at any of them, results in minimal improvement of the energy consumption per person for the whole route. Another vessel must then also stop at these jetties – which results in a substantial exacerbation of both energy consumption per person and carbon dioxide emissions.

4.7 Corridor 6: Stockholm – Grundvik (8)

A limiting line and correct positioning of the shoal is proposed to attain a safer navigation when passing the found shoal next to Stor-Saxaren, see figure 24. These actions increases the navigational safety and environmental protection.

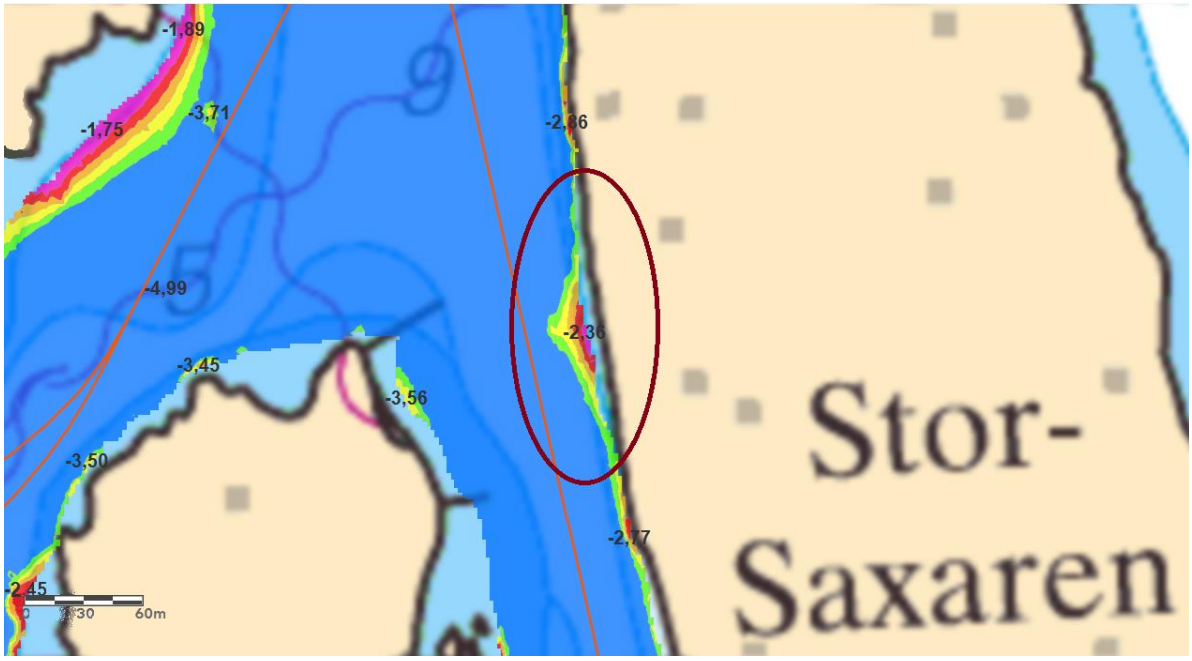


Figure 24. Adjusting the route passing Stor-Saxaren is proposedto reach a higher safety level and to avoid grounding on the shoal located in the hydrographic survey.

4.8 Corridor 7: Stockholm – Väsbystrand (9)

This corridor navigate many of the same areas as corridor 6. The passage between Alskäret and Fåglarö was found to be deeper than previously known, which opens up to more vessel types to utilize the passage. Limiting lines and correct positioning of shoal is proposed, see figure 25. The measures affect navigational safety and environmental protection, but the impact on the travel time is limited.

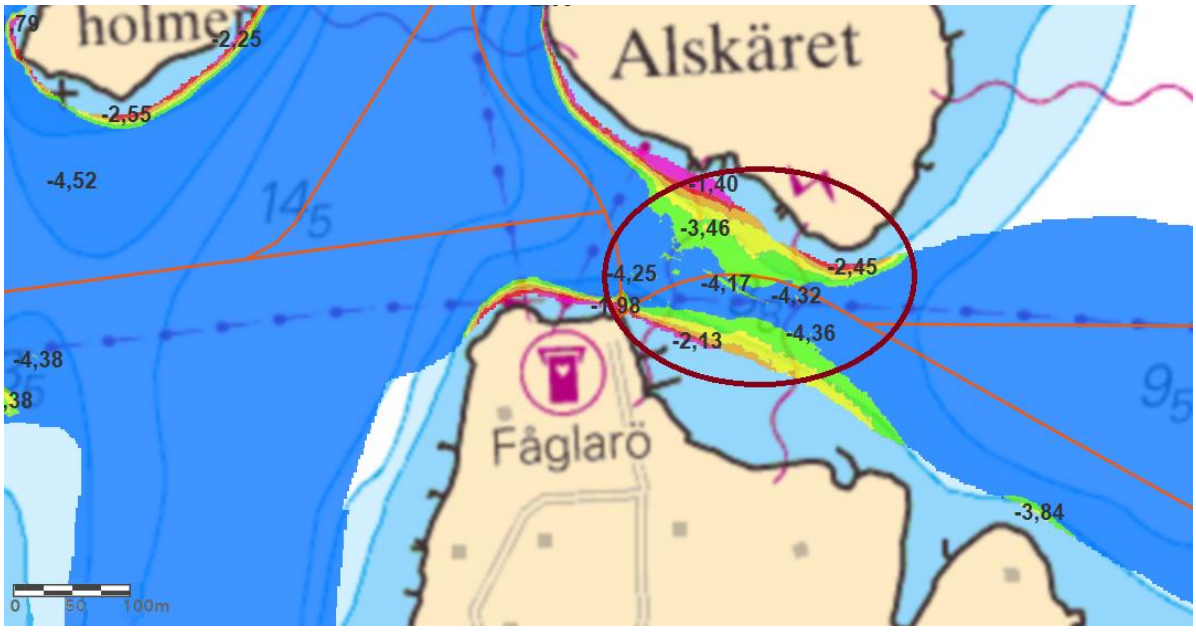


Figure 25. A greater depth than known was found in the channel between Fåglarö and Alskäret, circled in the figure.

4.9 Corridor 8: Stockholm – Sollenkroka (11)

In corridor 8 two safety issues were found when studying the hydrographic survey data. The first is situated west from Småholmarna where a shoal measuring 3.8 metres in the marked 4.2-metre deep fairway was found, see figure 26. Limiting lines and correct positioning of shoal to be proposed. Actions impact on navigational safety and environmental protection.

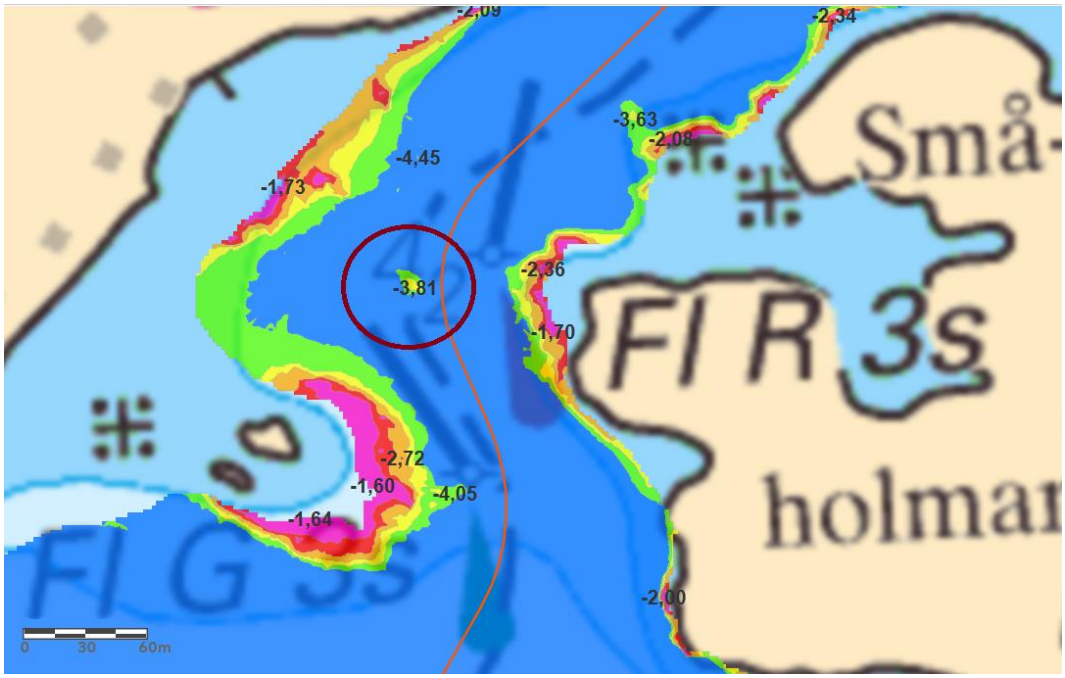


Figure 26. Circled shoal located in the middle of the fairway, next to Småholmarna, causing a navigational safety risk.

The second safety issue was found between Gällnönäs and Skagsnäs. A shoal measuring 3 metres is located further out in the navigational area for ferries turning into the jetty at Gällnönäs, see figure 27. Proposing limiting lines and correct positioning of the shoal to increase the navigational safety and reduce the environmental risks.

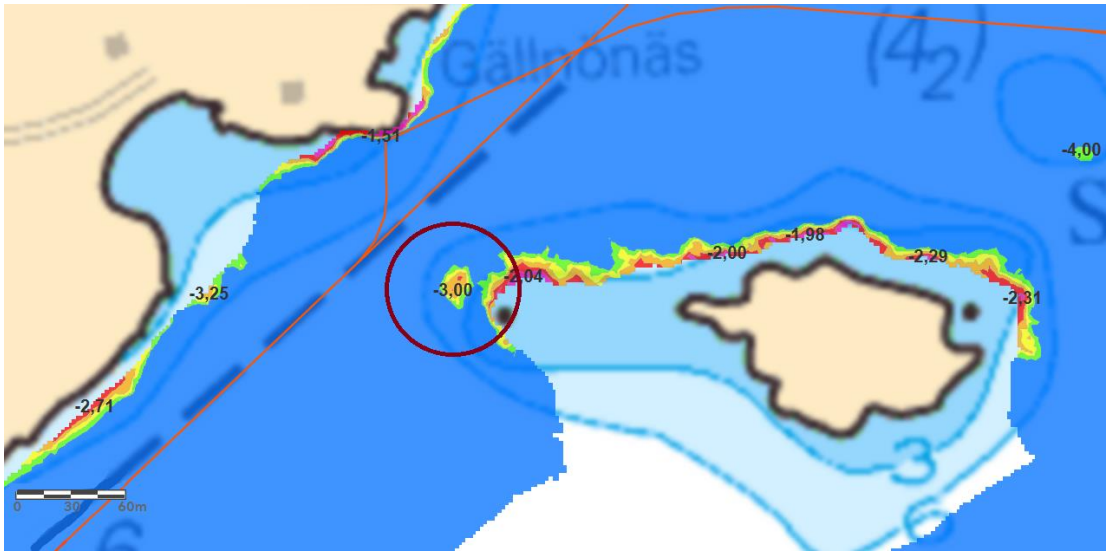


Figure 27. Circled shoal located in the analysis of the survey data, found between Gällnönäs and Skagsnäs.

4.10 Corridor 9: Stockholm – Husarö (12)

In corridor 9 multiple safety issues were found. Firstly, the area of Borghålet was found to be shallower than known, limiting the vessel types that are able to operate in this passage, see figure 28. Limiting lines and correct positioning of depth is proposed. The actions influences the navigational safety and environmental protection., but impact on travel time is limited.

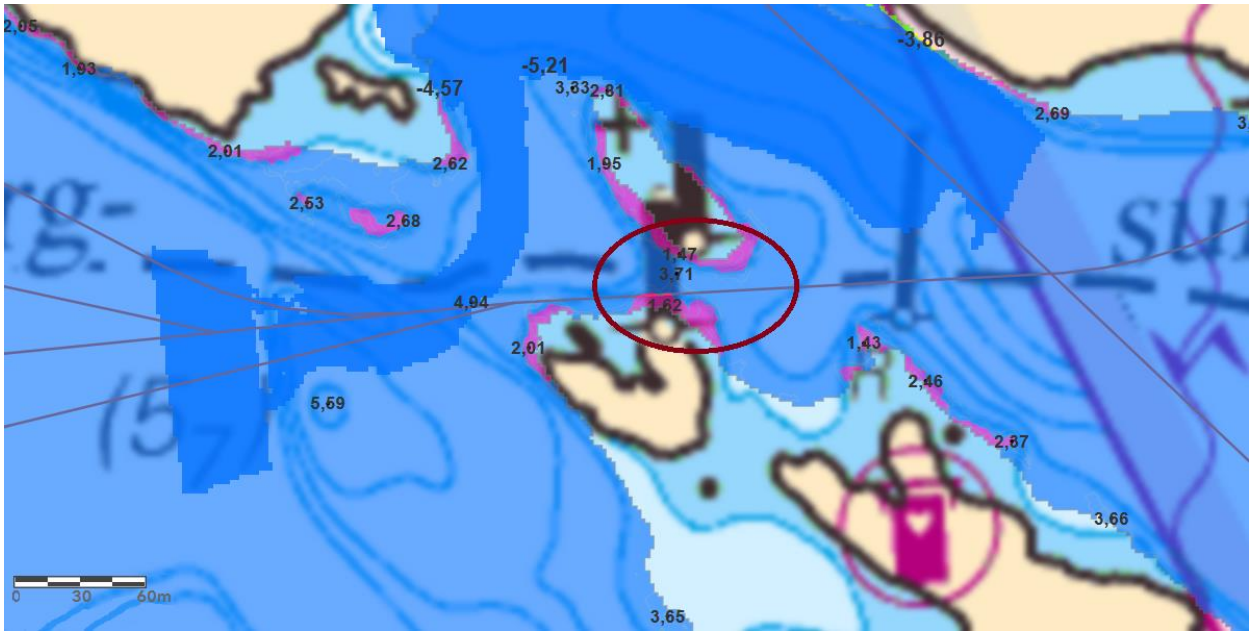


Figure 28. The circle shows the area in Borghålet, found to be shallower than previously known.

For the second area, a limiting line and correct positioning of shoal is proposed to secure the shallow areas outside of the 3-metre curve in the navigational chart, see figure 29. Actions impact on navigational safety and environmental protection.

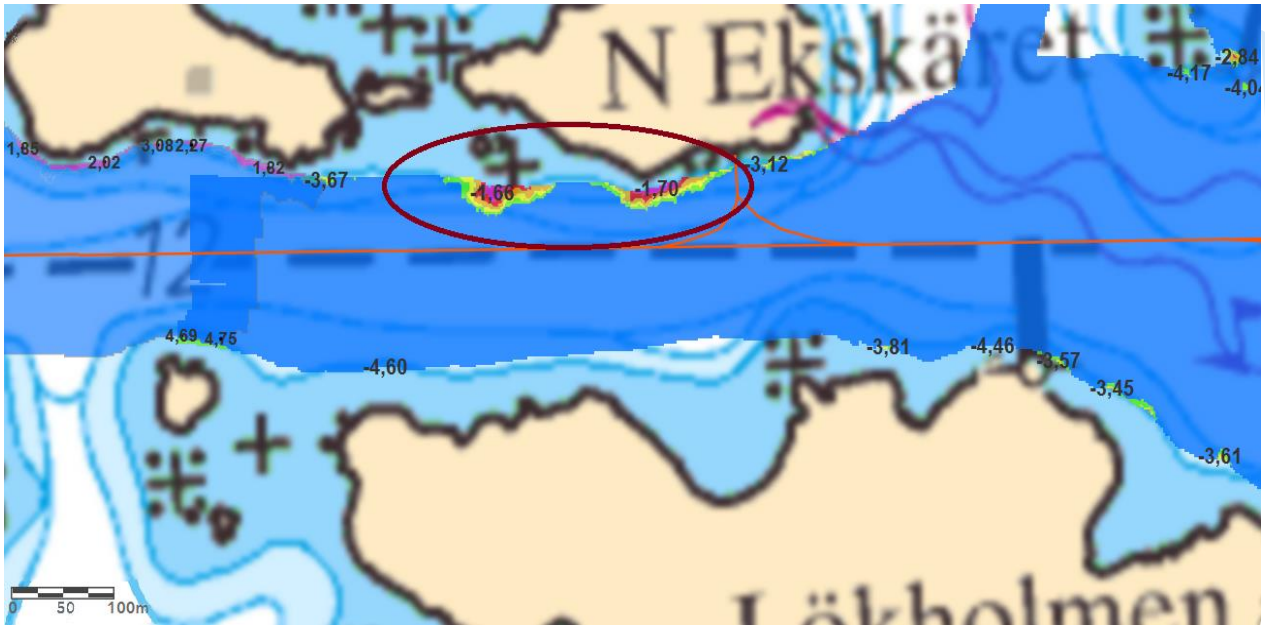


Figure 29. The circle shows the shoals pointed out as safety issues next to Norra Ekskäret.

Thirdly, in the area next to Västerholmen, shoals were found outside of the 3- and 6-metre navigational chart curves, see figure 30. This was also announced in Swedish NtM 11713. Limiting lines and correct positioning of shoal is proposed. Actions influence navigational safety and environmental protection.

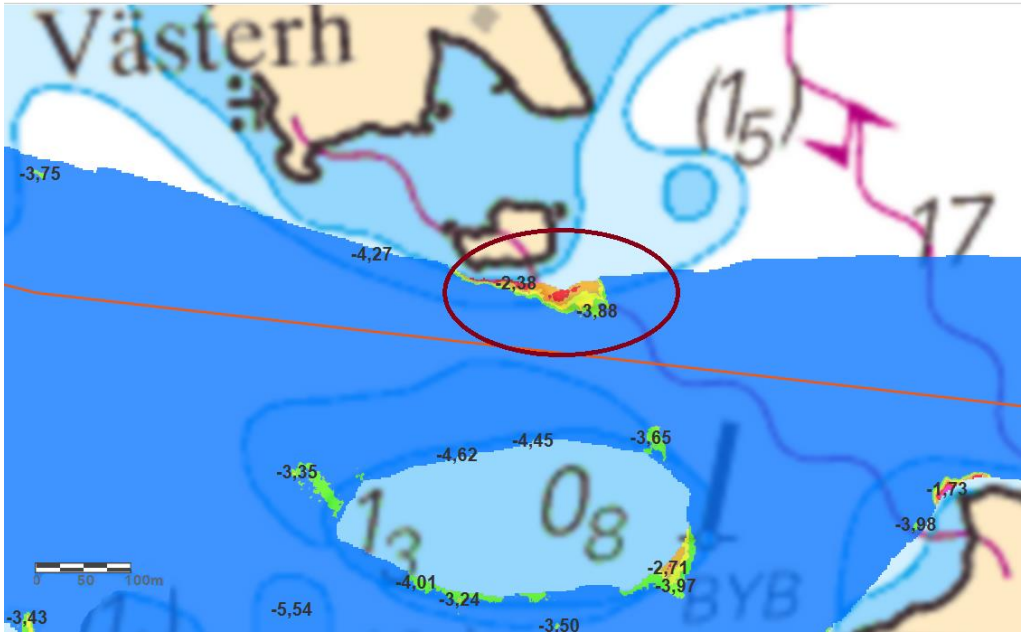


Figure 30. The circled area show the shoal north west of Nässlingen and Suth from Västerholm.

An adjustment to the ferry route is proposed south of Äpplarö where many errors were found in the depth information, see figure 31. This has been notified via the Swedish NtM 12182.

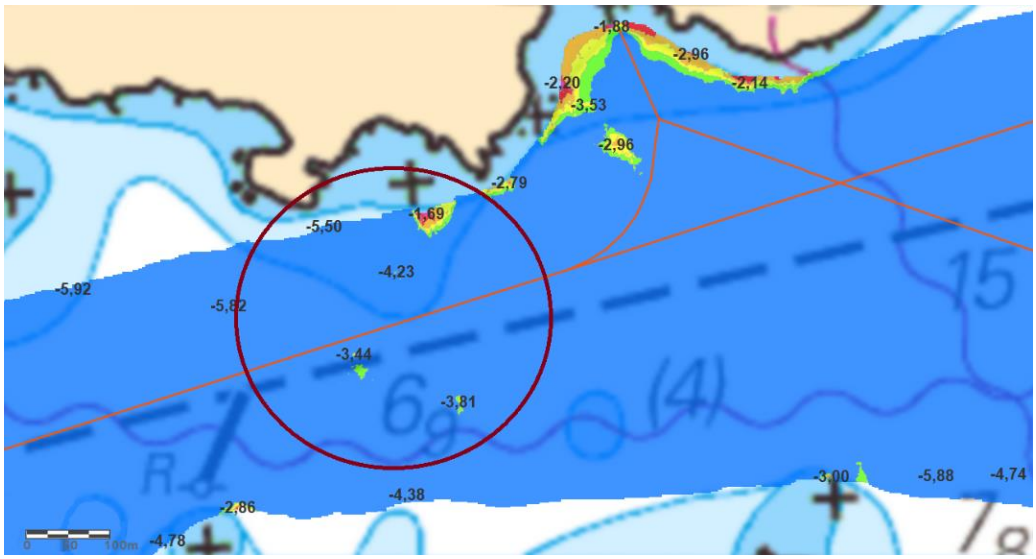


Figure 31. Multiple shoals were located south of Äpplarö, circled in the figure. The shoals are causing safety issues for navigating through the area.

The area west of Särsö was found to be shallower than known. This has been notified in the Swedish NtM 12650, see figure 32. An adjustment of this area of the corridor is proposed, with restrictions in vessel draft to reach a safer navigation in the shallow area. Proposed actions also impact the environmental protection positively.

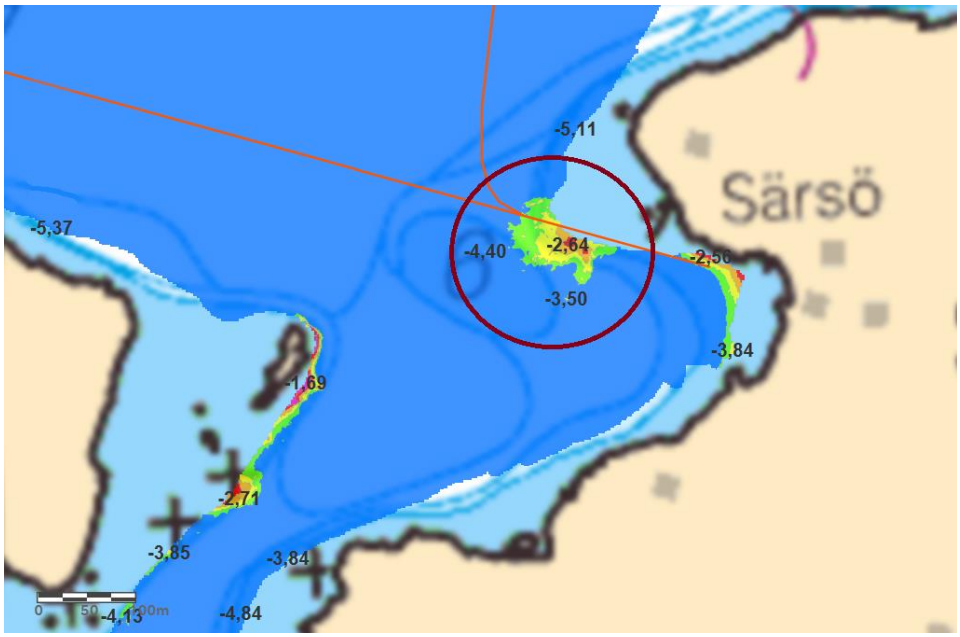


Figure 32. Circled shoal located at the inlet to Särsö jetty, causing navigational safety issues.

A limiting line is proposed as an adjustment to the navigational route north of Trätskär in Örsöfjärd, where a shoal was found, see figure 33. This was notified in the Swedish NtM 11710. Limiting lines and correct positioning of the shoal to be proposed. Actions impact on navigational safety and environmental protection.

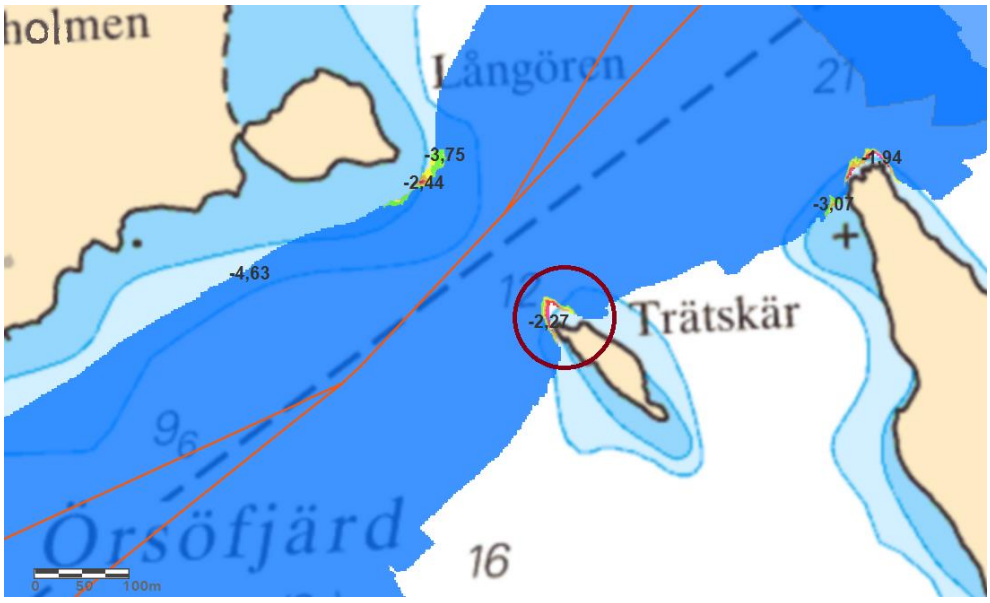


Figure 33. Circled shoal north of Trätskär in Örsöfjärd, causing a safety risk for the ferry traffic.

4.10.1 Node 3

The inlet to the jetty at Åsättra is shallow. More shallow than previously known, see figure 34. Utilising the jetty during the winter would be an improvement for the corridor and the travellers. Dredging is proposed to increase the safety level of the ferry traffic. Dredging the route influences the navigational safety and environmental

protection. A positive impact on travel time can be achieved by allowing vessels with greater draft during winter and icy conditions.

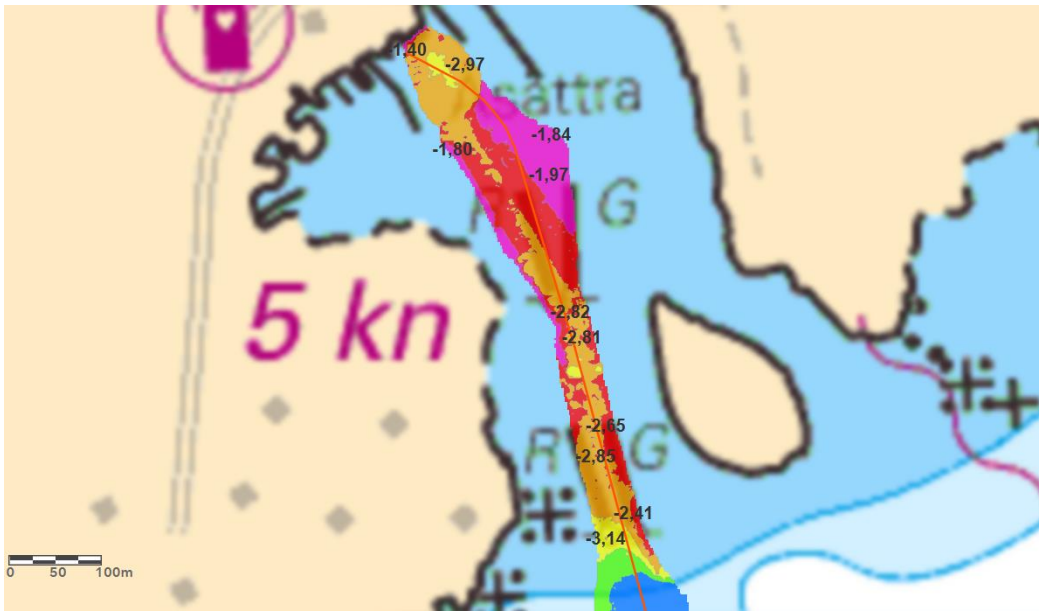


Figure 34. The shallow inlet to Åsättra jetty, where dredging is proposed to reach a better safety level for berthing at the jetty.

4.11 Corridor 10: Stockholm – Husarö (13)

Three safety issues were found in corridor 10. Firstly, limiting lines are proposed to insure a safety distance to the shoals found further out than the navigational chart implies between Brännskär and Grötskär, see figure 35. Limiting lines and correct positioning of shoal to be proposed. The actions impacts the navigational safety and environmental protection positively.

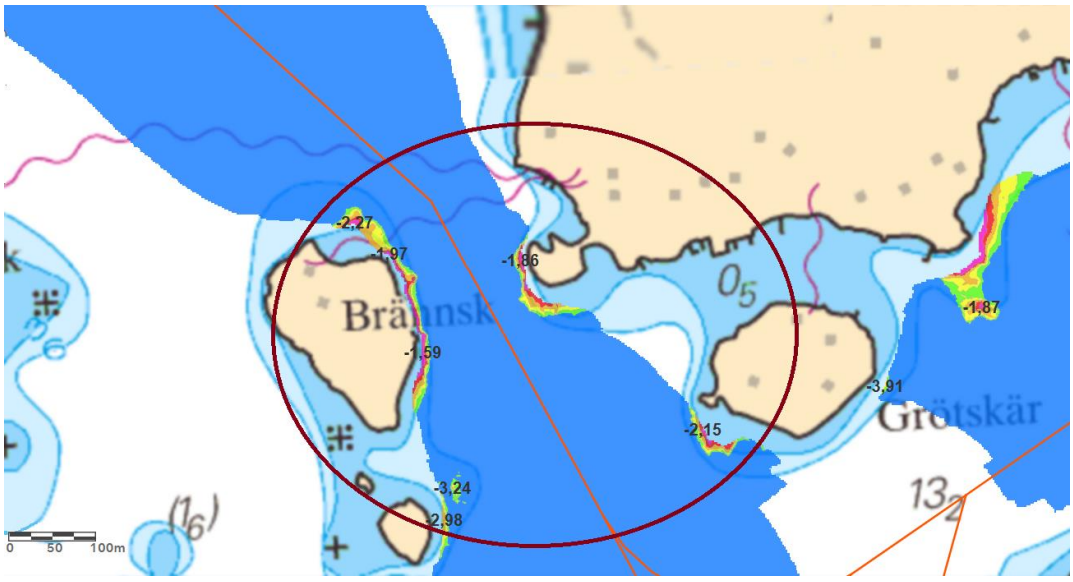


Figure 35. Many locations were shallower than known along the passage between Brännskär and Grötskär, circled in the figure.

Secondly, a 3.1 metre depth was found outside of the 6-metre navigational chart curve, se figure 36. A limiting line is proposed to insure a safety distance between the ferry traffic and the shoal. Limiting lines and correct positioning of the shoal is proposed. These actions influences the navigational safety and environmental protection positively.

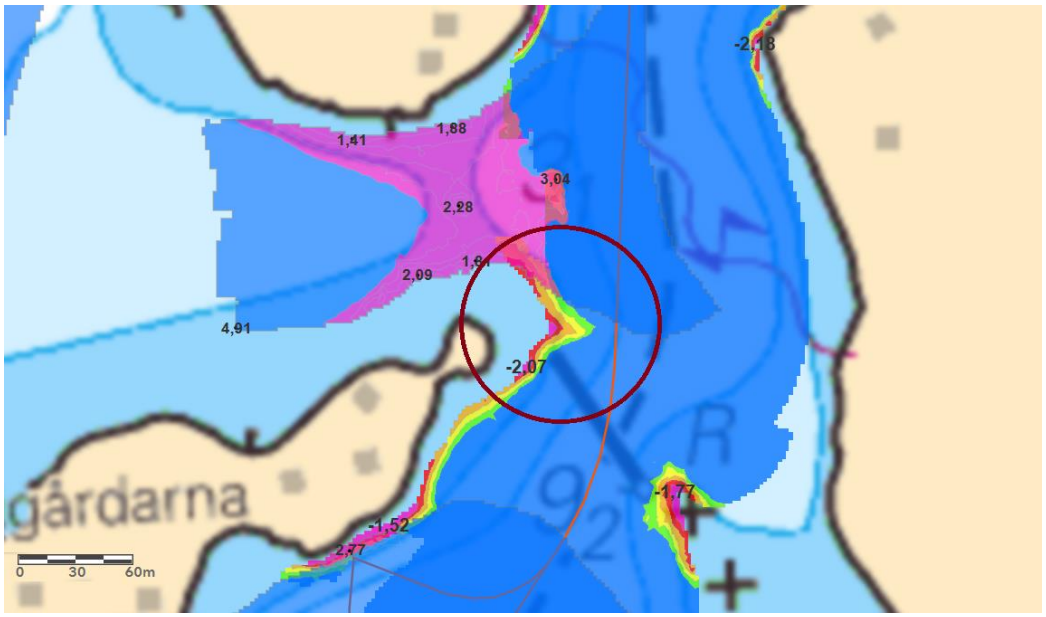


Figure 36. East of Trädgårdarna a depth of 3.1 metres was found in the analysis of the survey data, circled in the figure.

Thirdly, the 3-metre navigational chart curve is not covering a few if the shoals found in the hydrographical surveys, see figure 37. A limiting line is suggested for a more secure navigation passing south of the island Oxholmen. This was notified in the Swedish NtM 12353. Limiting lines and correct positioning of shoal to be proposed. The actions impacts the navigational safety and environmental protection positively.

Figure 37. Circled shoals south west of Oxholmen, where a limiting line is proposed as a safety measure.

4.12 Corridor 11: Stockholm – Möja (14)

Corridor 11 contains a few different safety issues. Firstly, a shoal was found close to the general navigational route next to Möja and north east of Dragedet, see figure 38. This was notified in the Swedish NtM 13147. A limiting line is proposed as safety measure. Limiting lines and correct positioning of the shoal is proposed. The actions influence the navigational safety and environmental protection positively.

Figure 38. Circled shoal next to Möja and north east of Dragedet.

A second shoal found, is located by Möja west of Dragedet, see figure 39. Limiting lines and correct positioning of shoal is proposed to secure a safety distance to the shoal. The actions influence the navigational safety and environmental protection positively.

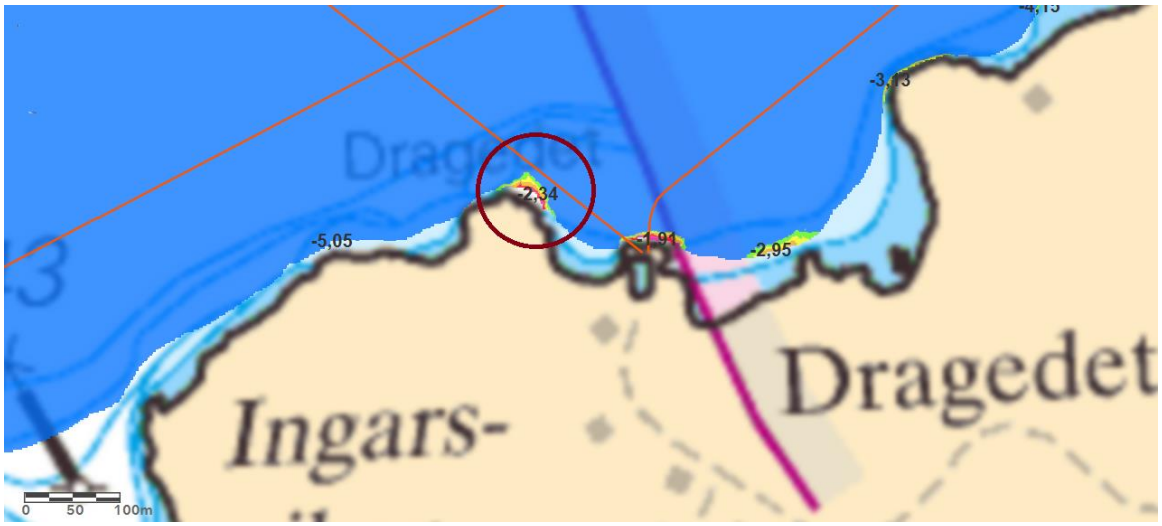


Figure 39. Circled shoal north of Möja and west from Dragedet jetty.

The passage Between Fornbyholmen and Möja ström was found to be shallower than previously known, see figure 40. The navigational chart 3-metre curve was found too close to the shore and not covering the shallow areas reaching out into the passage. Proposed actions are draft restrictions for public transport vessels and

correct positioning of the shoals, to reach a higher safety level. This affects the navigational safety and environmental protection positively.

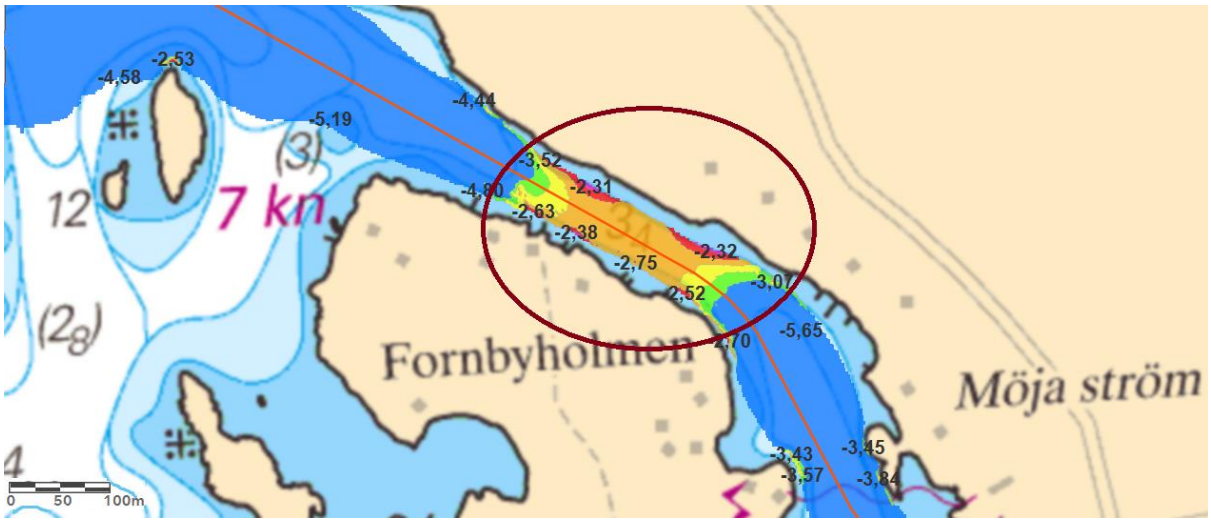


Figure 40. The circled passage between Fornbyholmen and Möja Ström was found to be shallower than previously known.

Two shoals were located north of Möja and Klobben, creating a safety problem to the general navigation line for the ferry traffic passing, see figure 41. A limiting line is proposed as an adjustment to the route. Limiting lines and correct positioning of the shoals are proposed. The actions impact the navigational safety and environmental protection positively.

Figure 41. two shoals circled north of Möja and Klobben.

In the area north of Möja and Tornö a shoal was found, measuring less than a 3- metre depth, causing high safety risks, see figure 42. The Swedish NtM 12094 informs about this shoal. Limiting lines and correct positioning of the shoal is proposed. The actions positively affect the navigational safety and environmental protection.

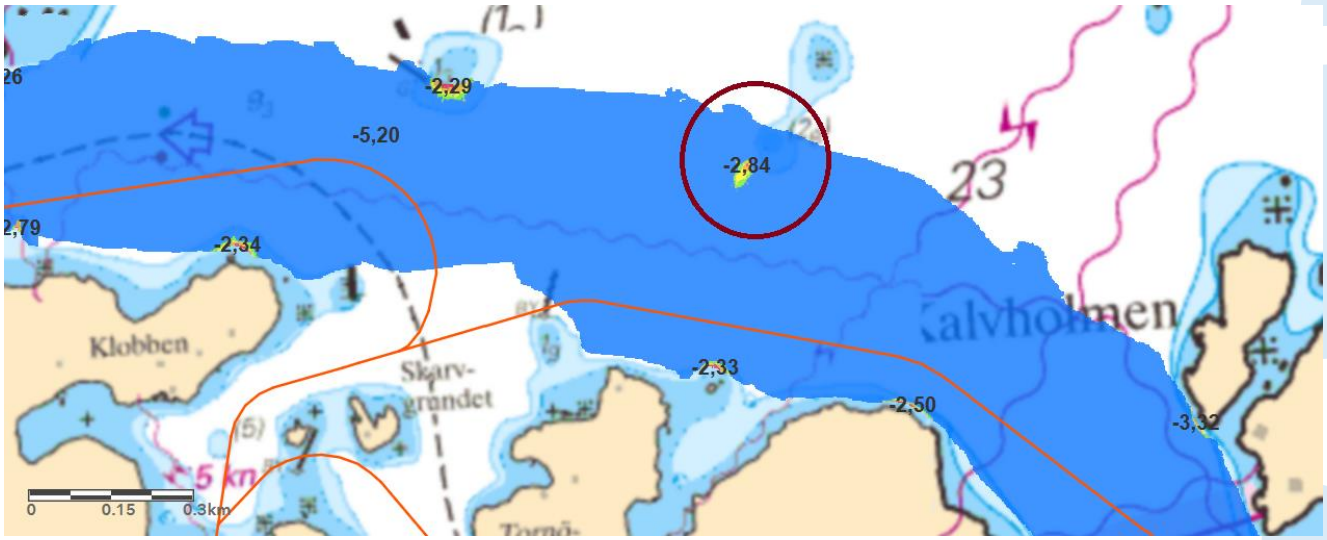


Figure 42. The figure circles the shoal found north of Möja and Tornö.

A shoal was found at the inlet to Ramsmora port causing a serious safety risk, see figure 43. A limiting line along with correct positioning of the shoal is proposed as adjustment to the route at this location. The action impact on the navigational safety and environmental protection positively.

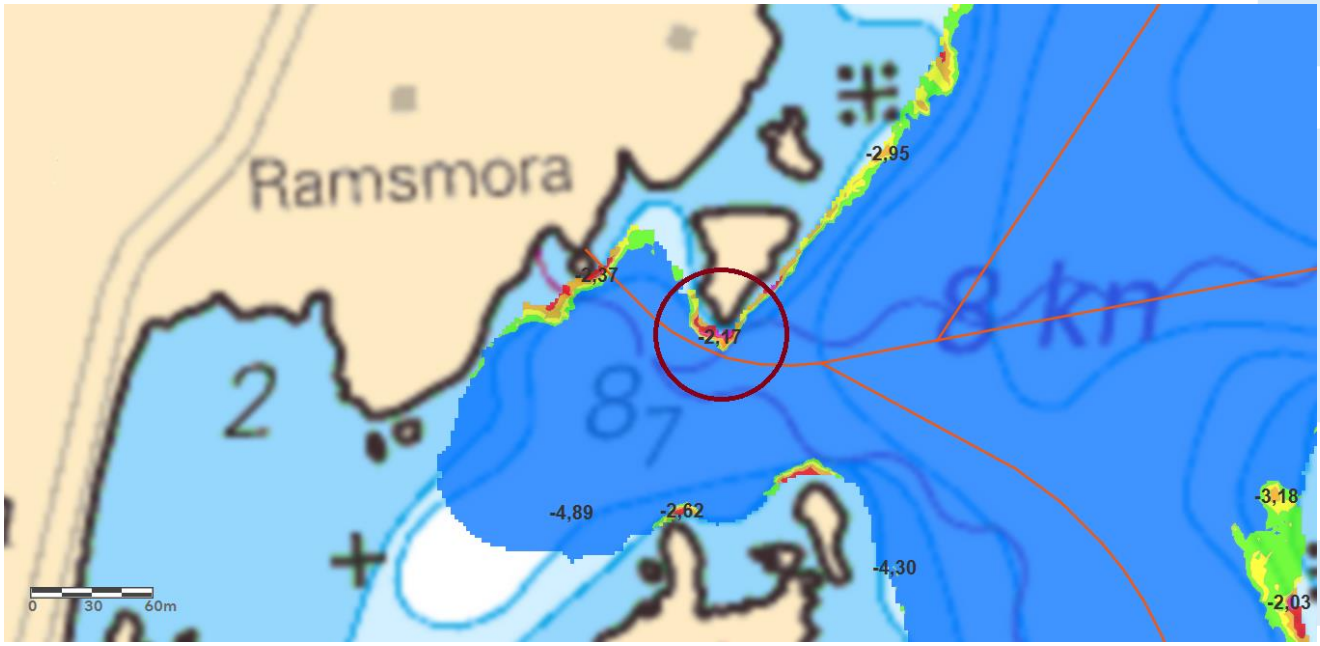


Figure 43. The circle shows the dangerously located shoal outside of Ramsmora.

The 3-metre curve on the navigational chart was found to be too far inland, not covering the shallow point south east of Arbodaön, see figure 44. Limiting lines and correct positioning of the shoal is proposed and these actions will positively affect navigational safety and environmental protection.

Figure 44. The circle shows the shallow area southeast of Arbodaön.

4.12.1 Node 4

At node 4, shoals has been located at the turning point for the ferries berthing at Träskögåln jetty, see figure 45. Proposing a limiting line, both, at the turning point and at the edge of the inlet where another shoal was found. Limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection.

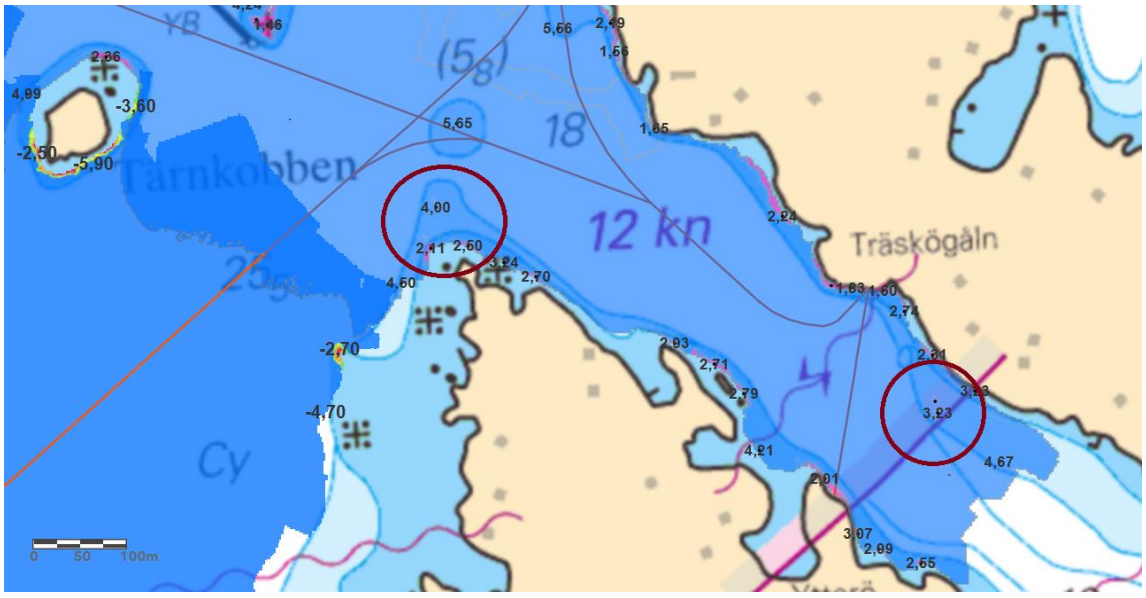


Figure 45. The two shoals close to the jetty of Träskögåln are circled, the circle furthest to the right is also the turning area for the ferries operating the jetty.

4.13 Corridor 12: Ropsten – Storholmen (81)

Four security issues were found in corridor 12. At south Storholmen a very shallow location was found at the 6-metre area in the navigational chart, see figure 46. This area is well trafficked, so it was of high importance that

these shoals were found. An adjusted navigational line and correct positioning of the shoals are proposed, to reach an adequate safety level. This was notified in the preliminary Swedish NtM 12522. The actions impacts the navigational safety and environmental protection.

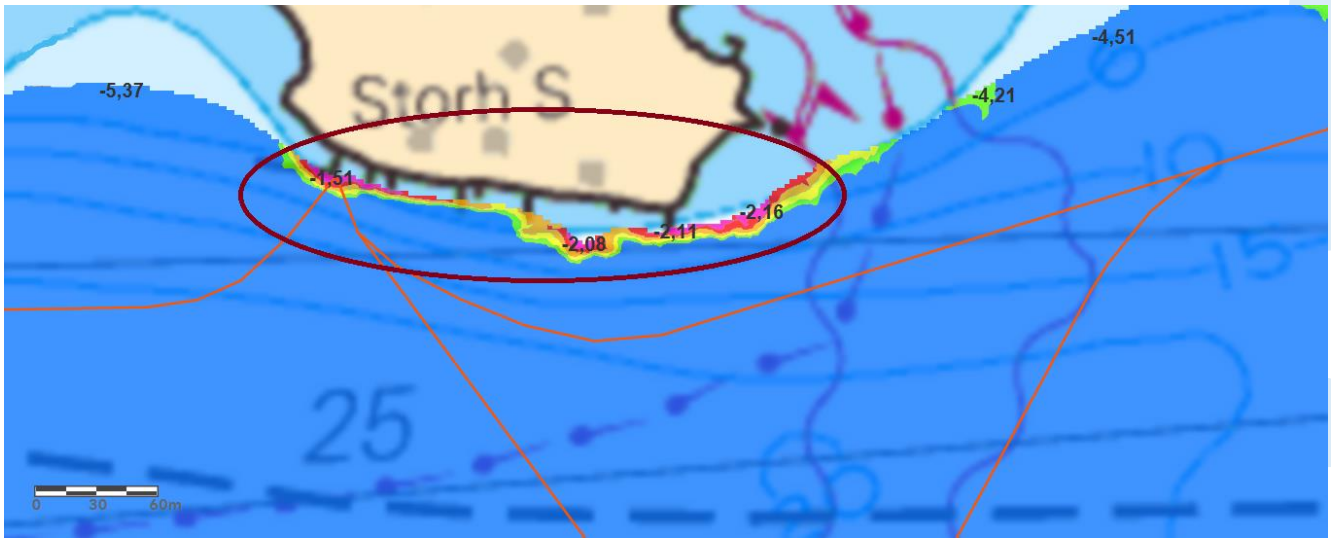


Figure 46. The shallow area south of Storholmen includes a shoal not even 2 metres deep, cicled in the figure.

South east of Storholmen a shoal with a depth less than 2 metres was found close to the general navigation route. Adjusting the route with limiting lines to keep out from the shallow corner and correct positioning of the shoal is proposed, see figure 47. These actions impacts on navigational safety and environmental protection.

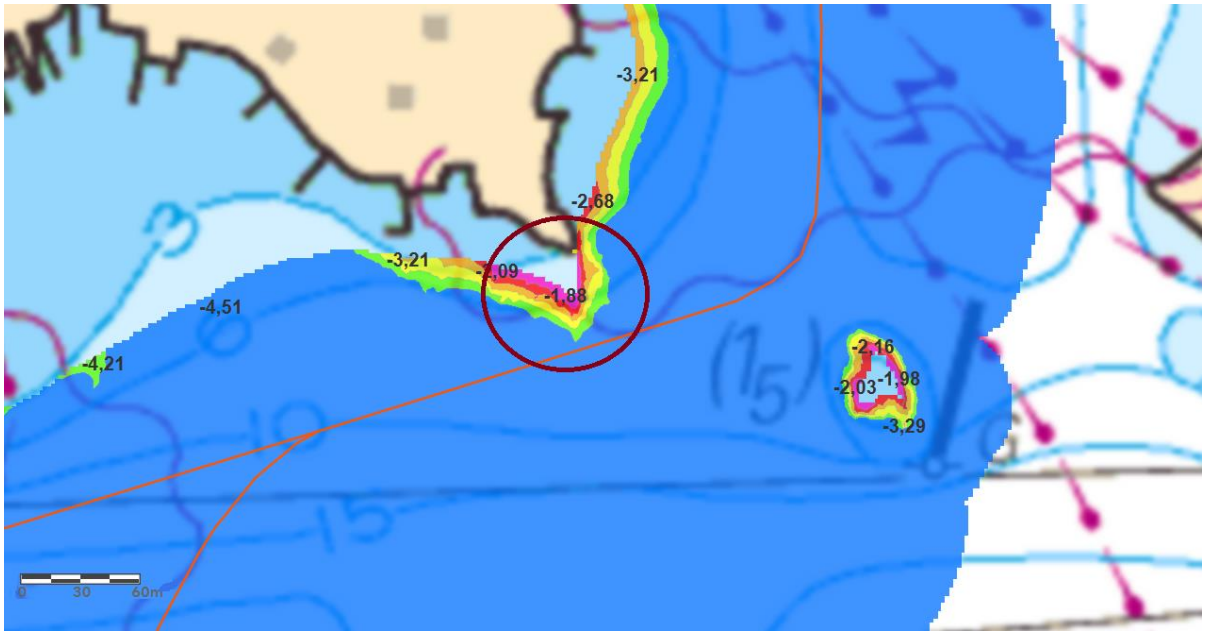


Figure 47. An area less than 2 metres deep found southeast of Storholmen is circled in the figure.

The area northwest of Storholmen contains two shoals further out than the navigational chart suggests, see figure 48. Limiting lines and correct positioning of shoal is proposed for a safer navigation through the area. The actions impacts on the navigational safety and environmental protection positively.

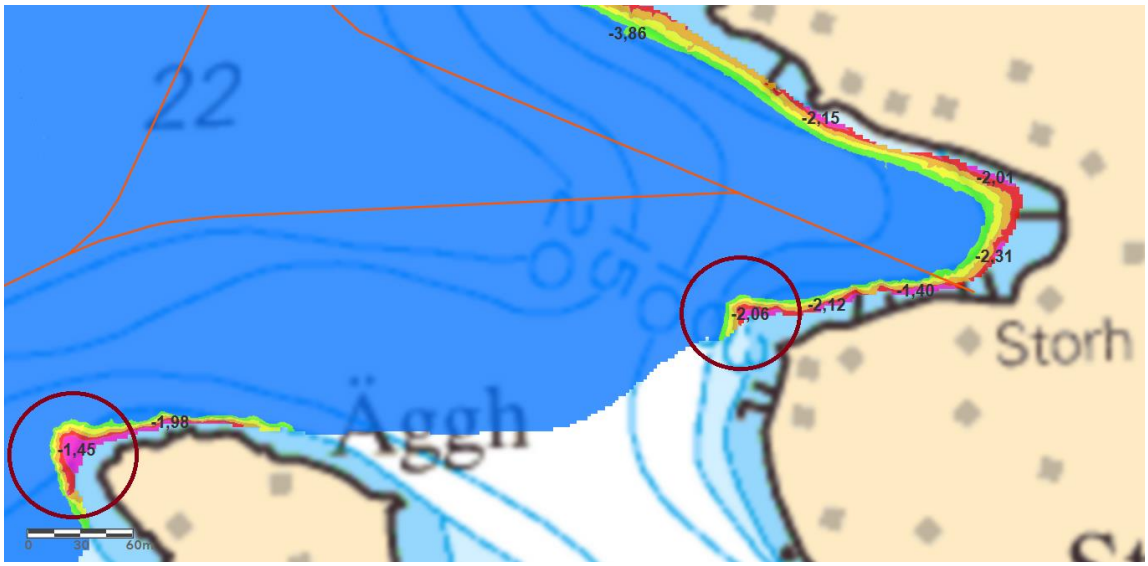


Figure 48. Circled shoals found northwest of Storholmen.

Next to Äggholmen and Tistelholmen, west of Storholmen shoals were found further out in the passage than previously known, see figure 49. This was issued in the Swedish NtM 11733. Limiting lines and correct positioning of shoal is proposed to create a safety distance to the shoals. The actions impacts on the navigational safety and environmental protection.

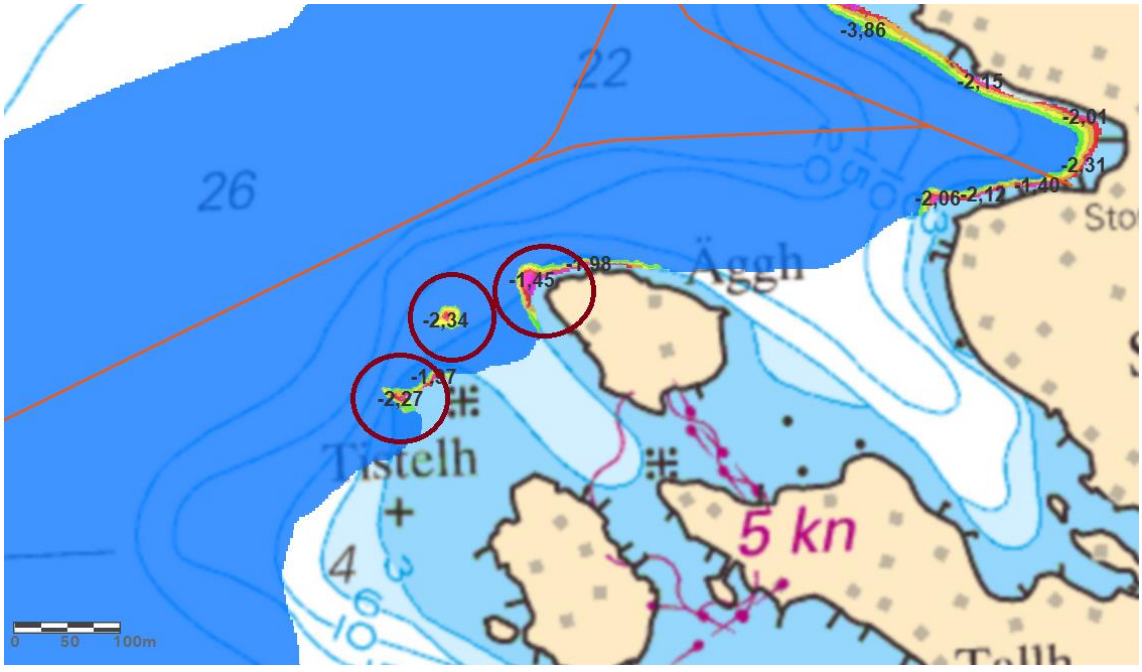


Figure 49. The circles show the areas in which the shoals were found, located west of Storholmen and close to Tistelholmen and Äggholmen.

4.14 Corridor 13: Stockholm – Norrsund

In corridor 13 multiple safety issues were found. The Swedish NtM 11619 is increasing the safety level of the corridor. Firstly, a proposed adjustment of the corridor is located next to Blidösund and Bruket

to avoid a shoal measuring 2.4 metres, see figure 50. Limiting lines and correct positioning of the shoal is proposed. The suggested measures impacts the navigational safety and environmental protection.

Figure 50. The circle shows the area in whichthe shoals were found in Blodösund, close to the jetty of Bruket.

Secondly, many shoals and shallow locations was found in an area by Grönskären, see figure 51. This was notified through the Swedish NtM 11709. Limiting lines and correct positioning of the shoals are proposed for safer navigation past the shallow edges of the passage. The measures affect the navigational safety and environmental protection positively.

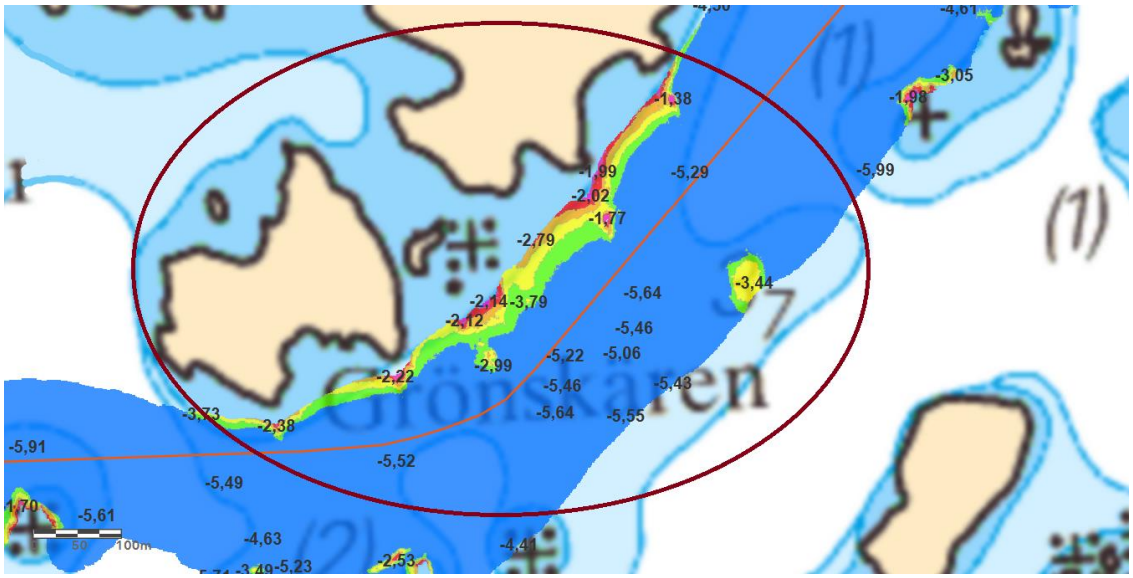


Figure 51. The circled area by north Grönskären contains multiple shoals discovered by studying the hydrographical surveys.

In Gåsskär multiple shoals were found further out than the navigational chart implies, see figure 52. Limiting lines are proposed together with correct positioning of the shoals. The actions impacts the navigational safety and environmental protection positively.

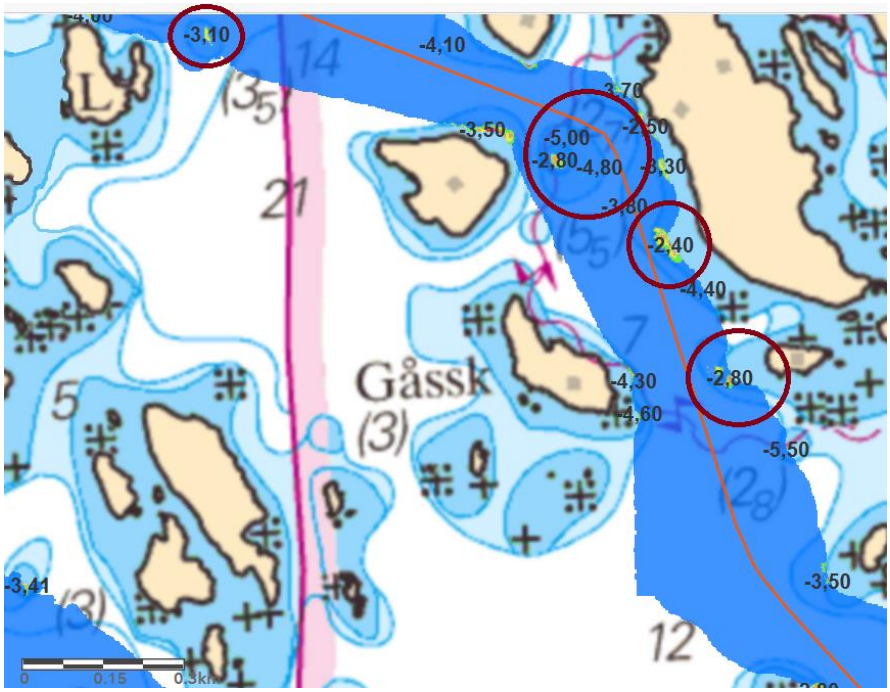


Figure 52. Circled shoals along the route in Gåsskär.

Furthermore, an adjustment of the corridor to avoid a shoal found outside of Skatholmen is proposed, see figure 53. The depth measures 2 metres, where the navigational chart shows a depth of 3 – 6 metres. This was notified in the Swedish NtM 11615. Limiting lines and correct positioning of the shoal is proposed. The actions impacts the navigational safety and environmental protection positively.

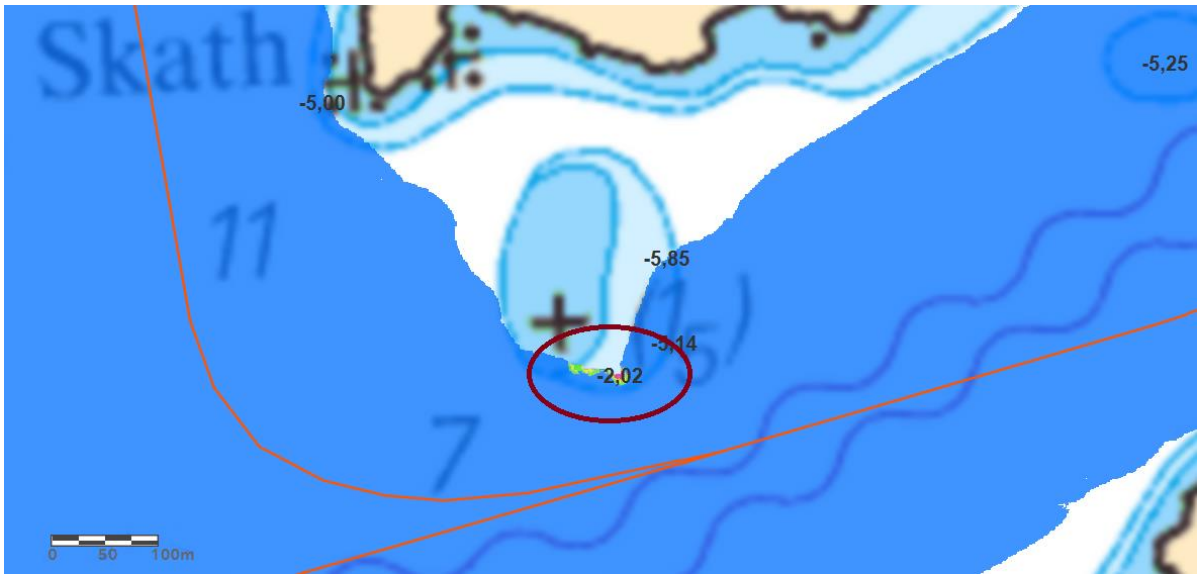


Figure 53. Circled shoal south of Skatholmen in a corner of the route causing a risk of grounding.

4.15 Corridor 14: Solö – Furusund

Two safety issues was found in corridor 14. The first one is located in the passage between Arnö and Solö where the depth was 4.9 metres not 6 as the navigational chart shows, see figure 54. Limiting lines and correct

positioning of shoal are proposed. The actions impacts the navigational safety and environmental protection positively.

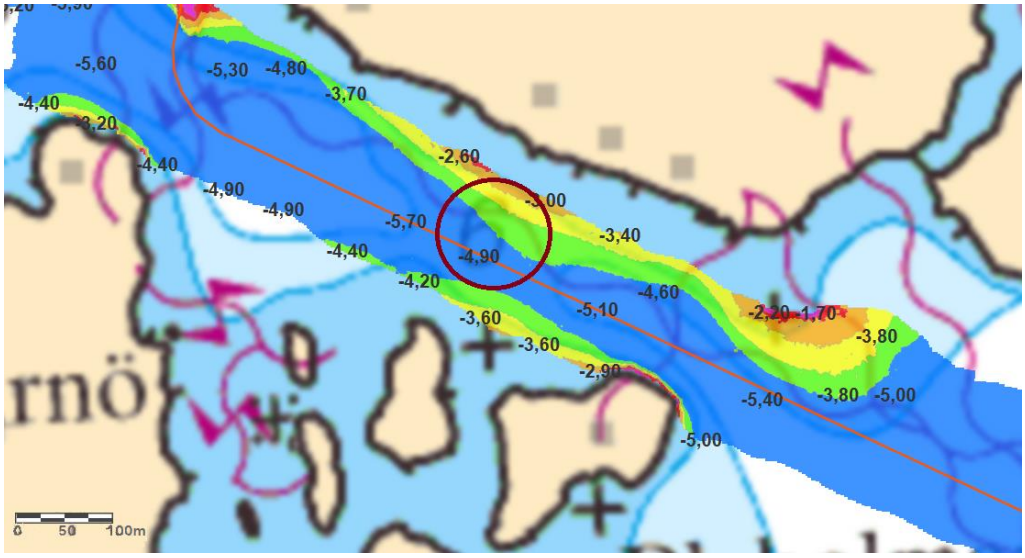


Figure 54. The area between Solö and Arnö was found to be shallower than previously known, the circle highlights an example of this.

Secondly, multiple shoals and shallow areas were found west from Löparasken, see figure 55. An adjustment of the route is proposed to avoid grounding. This was notified in the Swedish NtM 11988. Limiting lines and correct positioning of the shoals are proposed. These measures impacts the navigational safety and environmental protection positively.

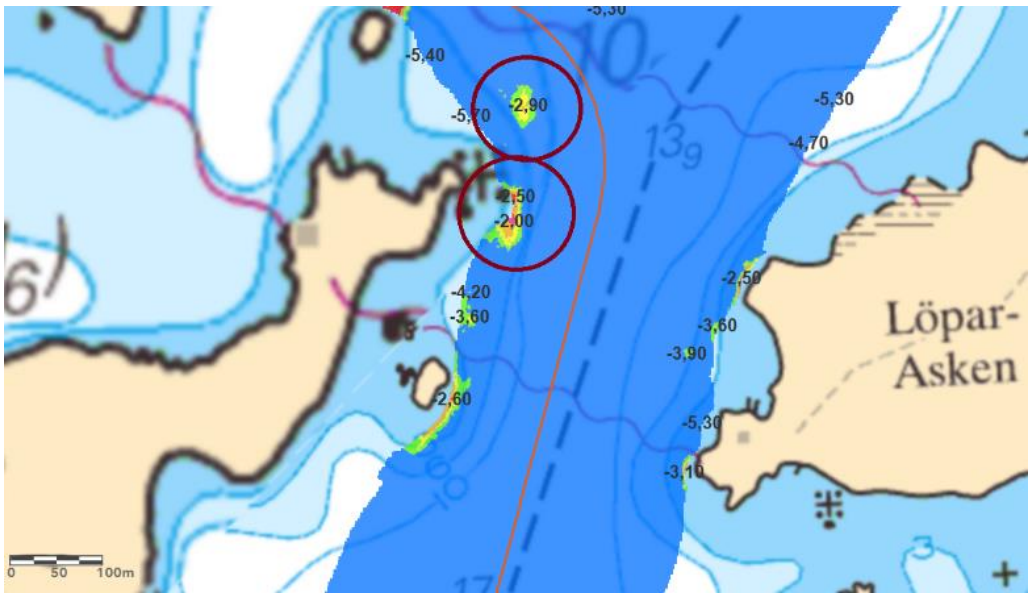


Figure 55. The discovered shoals causing a navigational risk, at the corner next to Vädersö and Löparasken are circled in the figure.

4.16 Corridor 15: Stockholm – Rödlöga

In corridor 15 many safety issues were found. Firstly, multiple shoals were found at the inlet of Norröra, see figure 56. Proposing adjustments of the routes crossing this area. Additional buoys, limiting lines and correct

positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

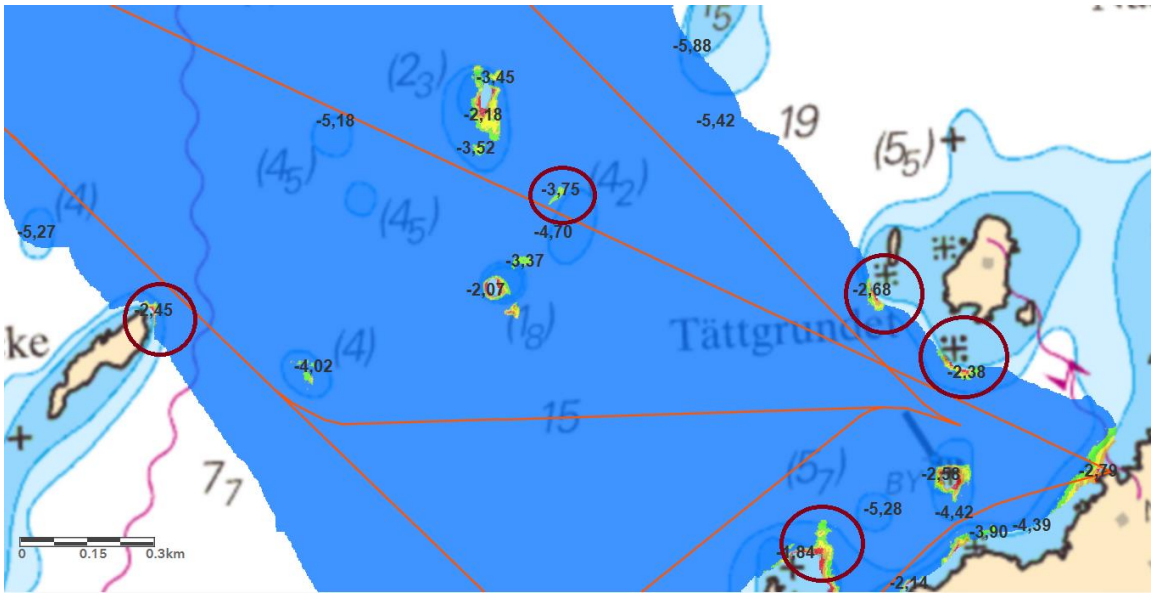


Figure 56. Multiple shoals were found at the inlet to Norröra jetty, of which some are exemplified and circled in the figure.

Secondly, to reach a safer navigation between Norröra and Söderöra, a route sheltered from hard weather is proposed at the location, see figure 57.

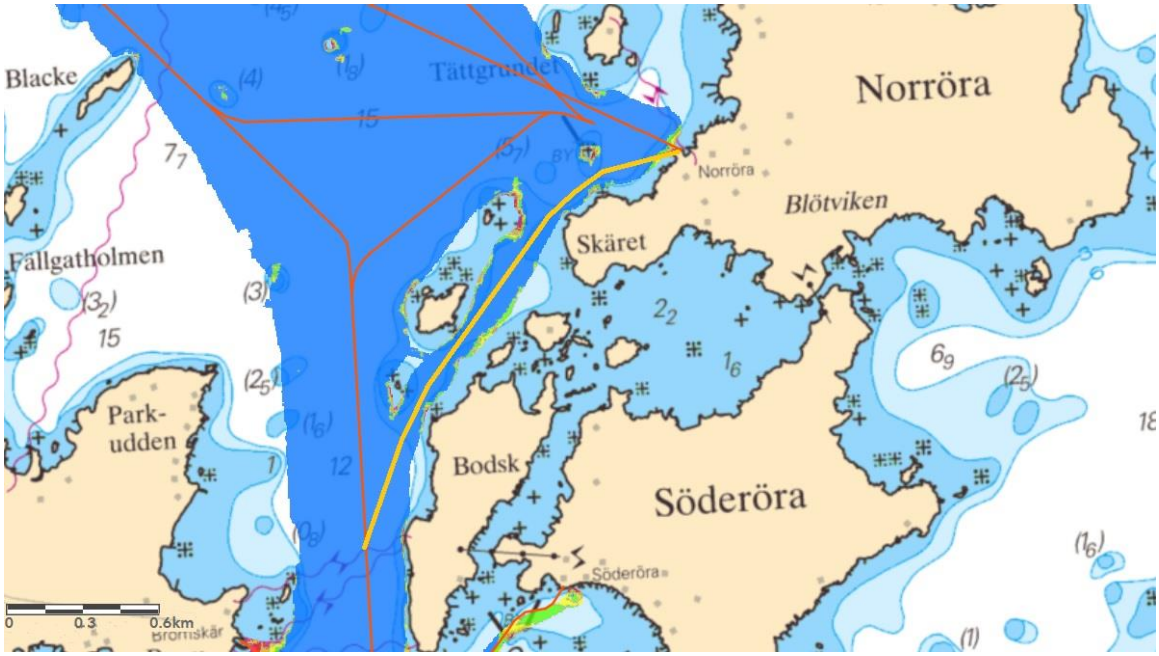


Figure 57. The red lines symbolise the original routes through the corridor area between Norröra and Söderöra. The yellow line symbolise the proposed adjusted route, more sheltered from hard weather.

In the adjusted route area, a greater depth than known was found at Norröra/ Skäret, see figure 57.

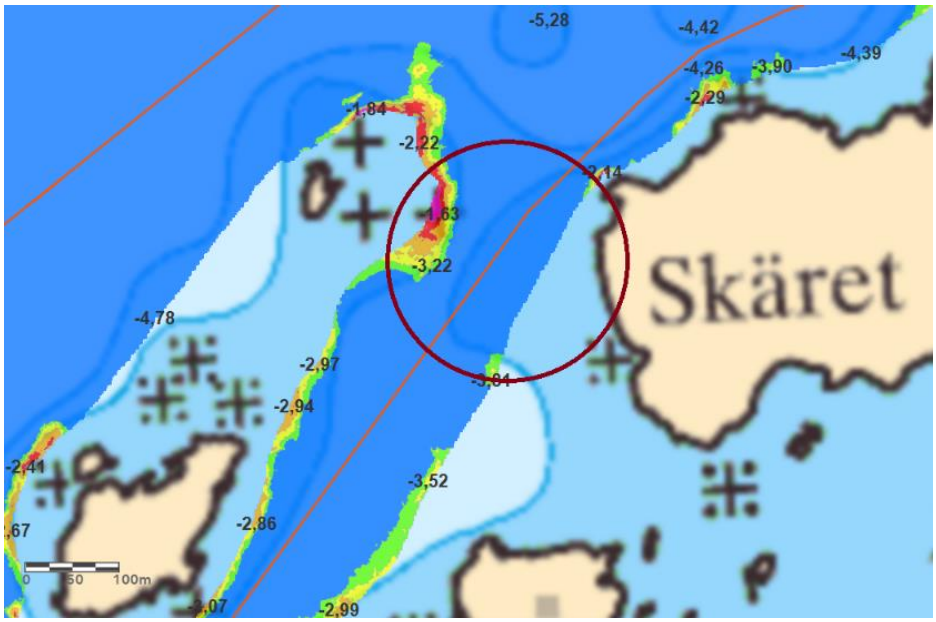


Figure 58. Circled shoal, increasing the risk of grounding located at Norröra/ Skäret.

Furthermore, in the end of the new passage next to Söderöra and north west of Bodskär the passage was found to be narrow, see figure 59. A limiting line is proposed to reach a high safety level for the passage. These shoals were notified in the Swedish NtM 11538. Limiting lines and correct positioning of shoals is proposed. These actions impacts the navigational safety and environmental protection.

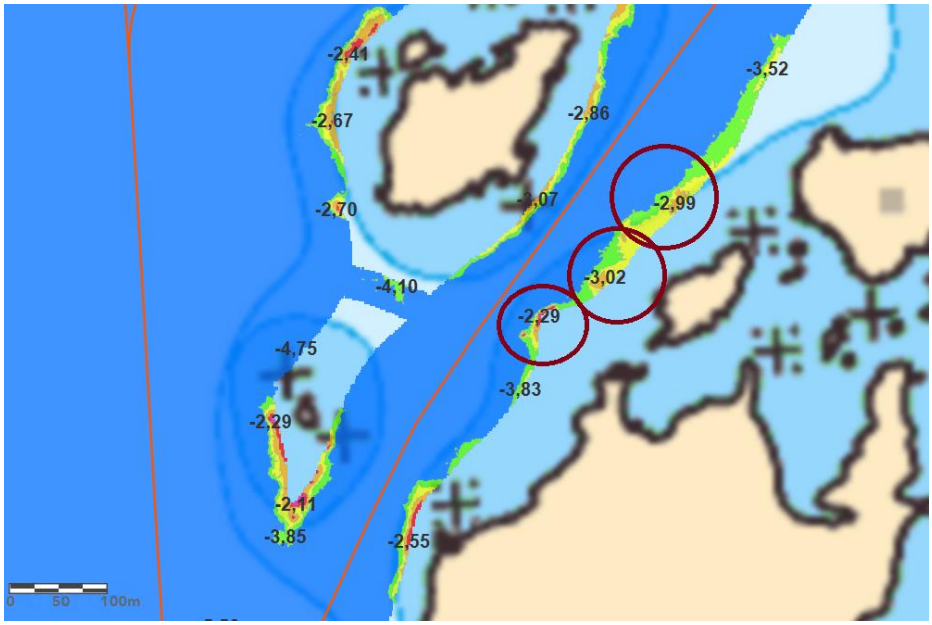


Figure 59. The passage next to Söderöra and northwest of Bodskär was found to be slimmer than known, circled shoals along the edge of the passage.

A shoal causing a safety issue at the corner to the inlet of Söderöra/ Bodskär was found, see figure 60. A limiting line is proposed for a safe passage around the corner.

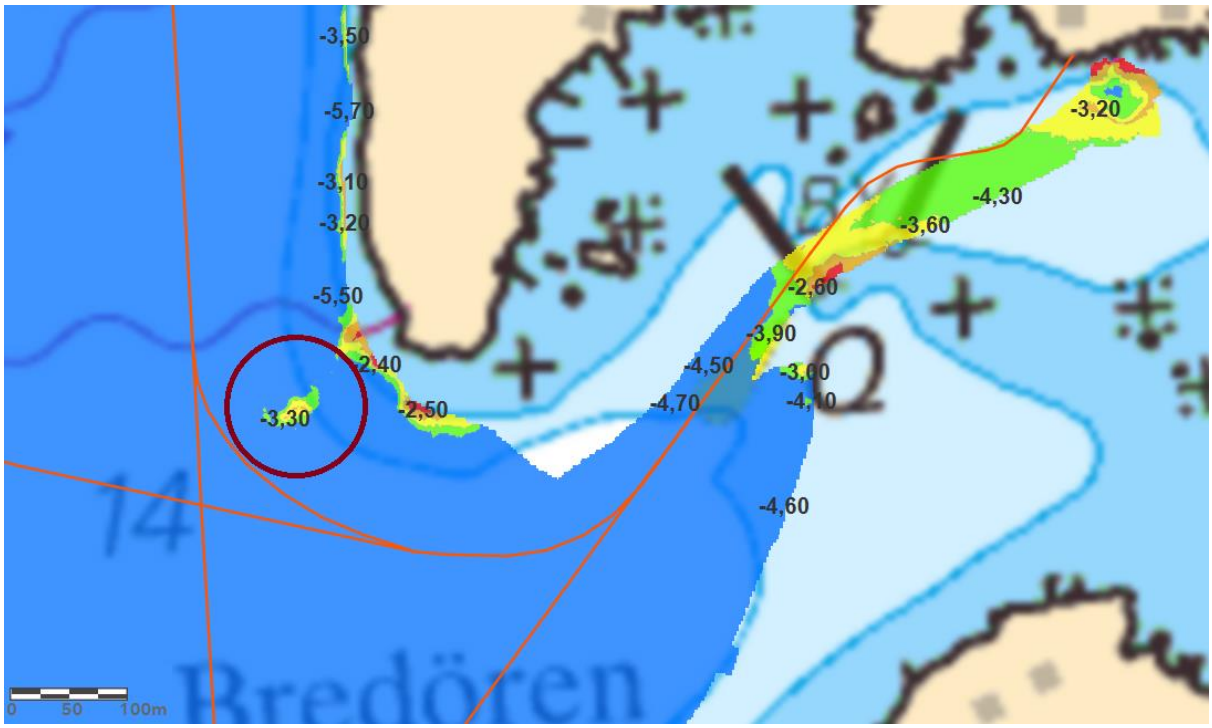


Figure 60. Circled shoal at the corner to the inlet of Söderöra/ Bodskär.

The inlet to Söderöra jetty was found to hold multiple shoals and shallow areas, see figure 61. To reach a safe navigational level the proposal is to enhance navigational aids at the inlet channel to the jetty. Additional buoys, limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

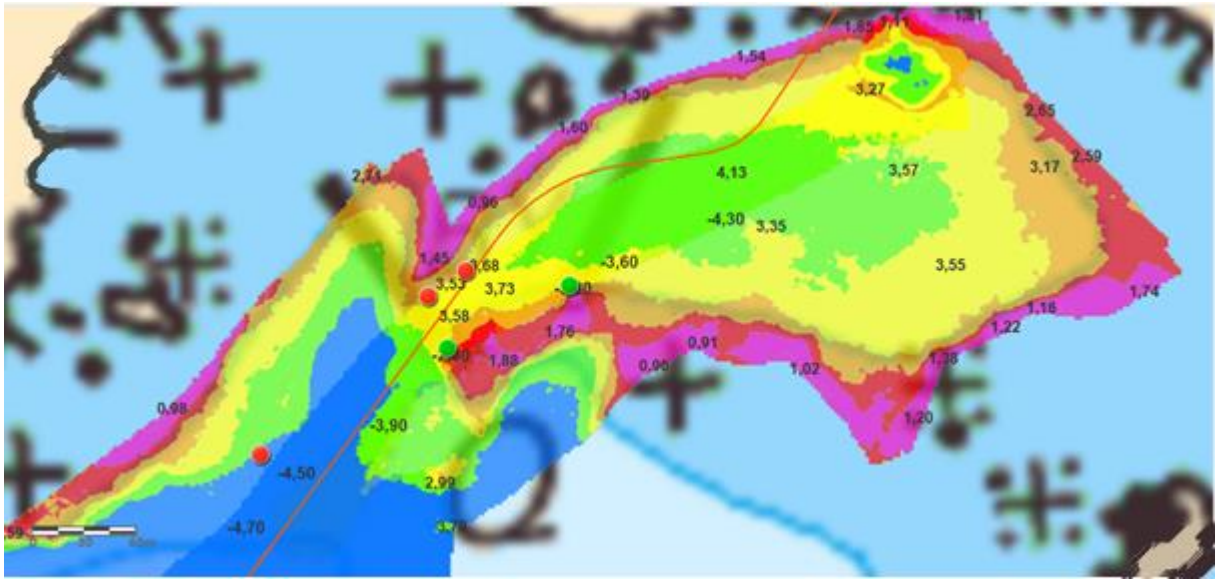


Figure 61. The narrow channel at the inlet to Söderöra jett, with proposed position for additional navigational aids.

Two shoals were found close to the route south of Söderöra, see figure 62. A route adjustment including limiting lines and correct positioning of the shoals is proposed to secure the navigation around this corner of the corridor. This was notified in the Swedish NtM 11537. The actions impacts the navigational safety and environmental protection positively.

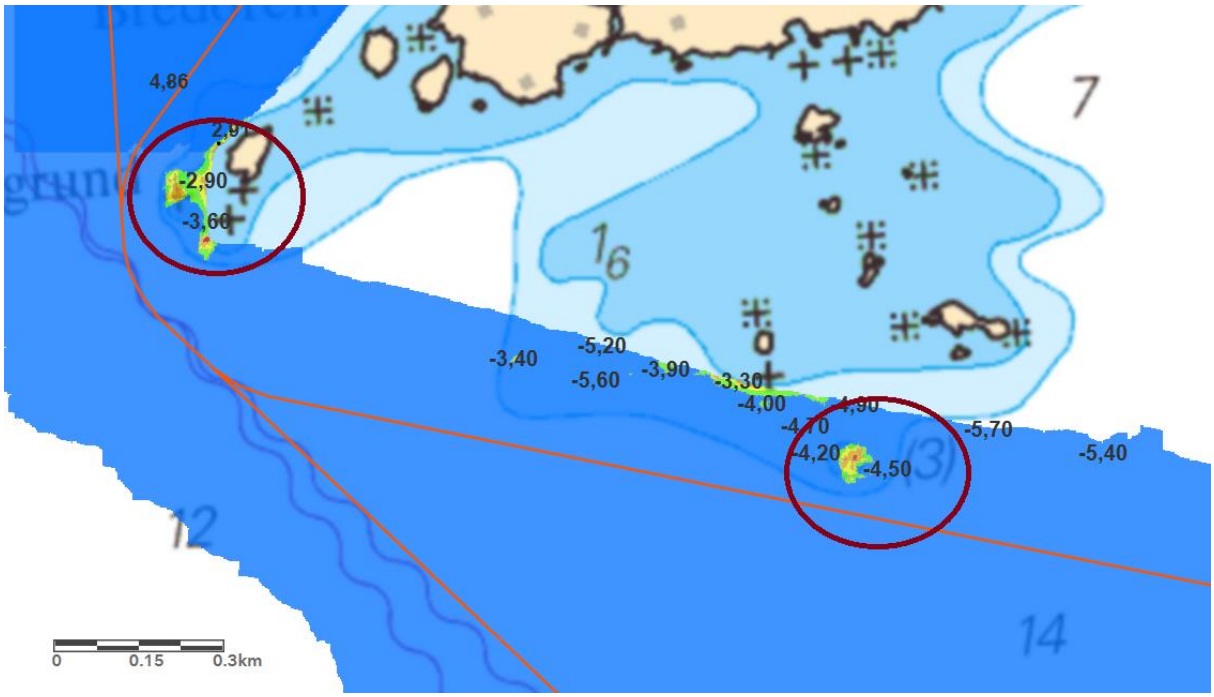


Figure 62. Circled to the left is a shoal risking a safe pass around the corner, south of Söderöra. The circle to the right is another shoal close to the navigational area for the ferry traffic.

The inlet area to Svartlöga was found to hold multiple shoals, see figure 63. This was notified in the Swedish NtM 11537. The shoals are proposed to be correctly positioned in the sea charts to reach a safer navigation. The actions influence the navigational safety and environmental protection positively.

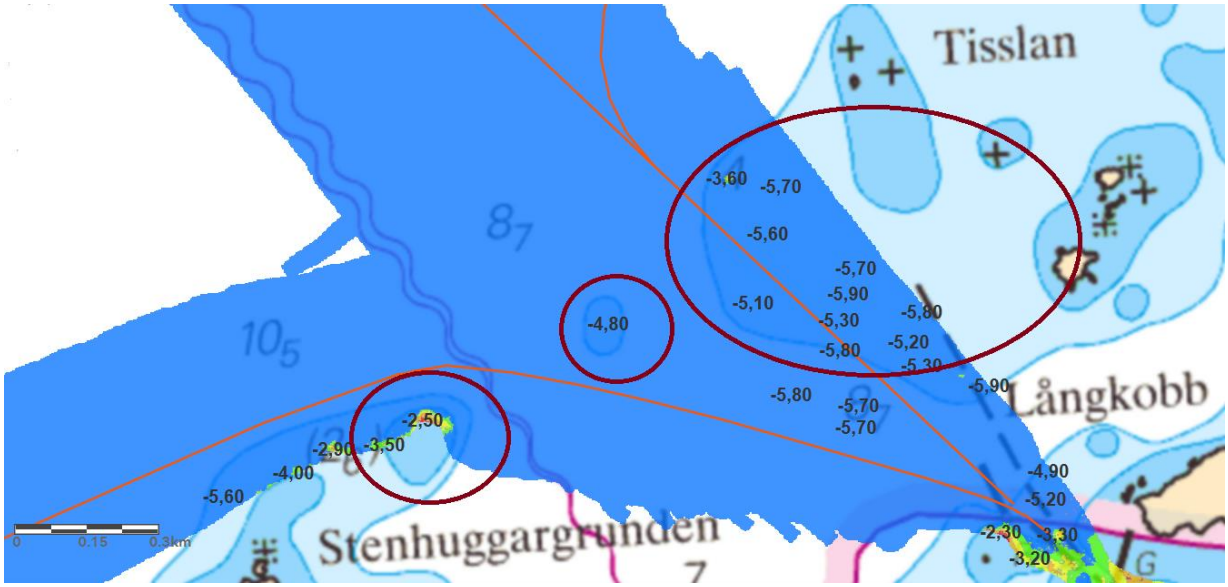


Figure 63. Circled shoals around the area of Stenhuggargrunden, Långkobb and Tisslan.

An adjustment of the fairway using limiting lines and correct positioning of the shoals is proposed to manage the difficult area at the Svartlöga passage, see figure 64. The passage was found to be generally shallower than known, which causes safety issues when passing the area.

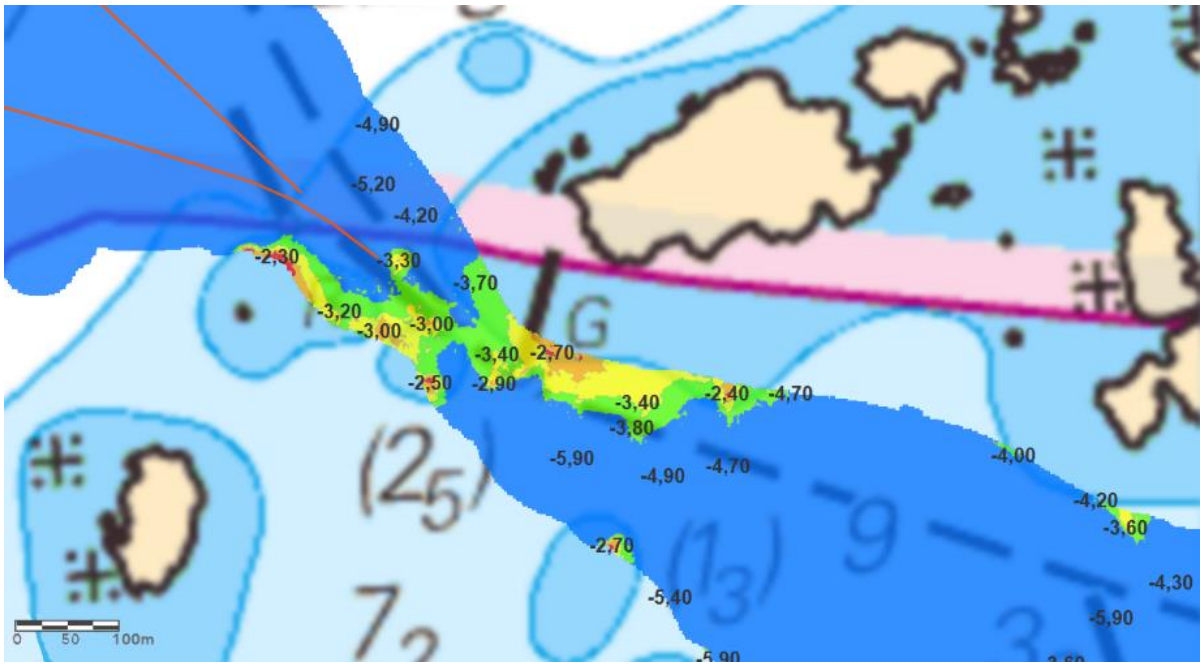


Figure 64. The figure show part one the shallow area of the Svartlöga passage.

In part two of the Svartlöga passage additional buoys, limiting lines and correct positioning of the shoals are proposed, see figure 65. The actions impacts the navigational safety and environmental protection positively.

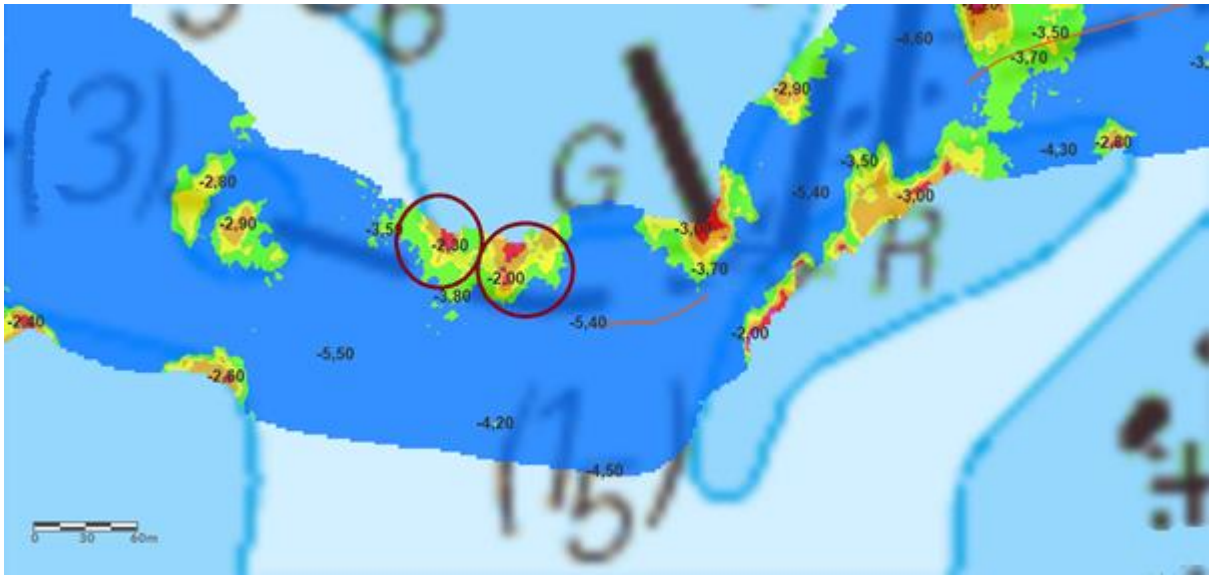


Figure 65. The figure overviews part two of the shallow area in the Svartlöga passage.

Approaching Rödlöga, a shoal was found to be wider than previously known north of island Askören, see figure 66. Limiting lines, a buoy and correct positioning of shoals are proposed. Actions impacts the navigational safety and environmental protection positively.

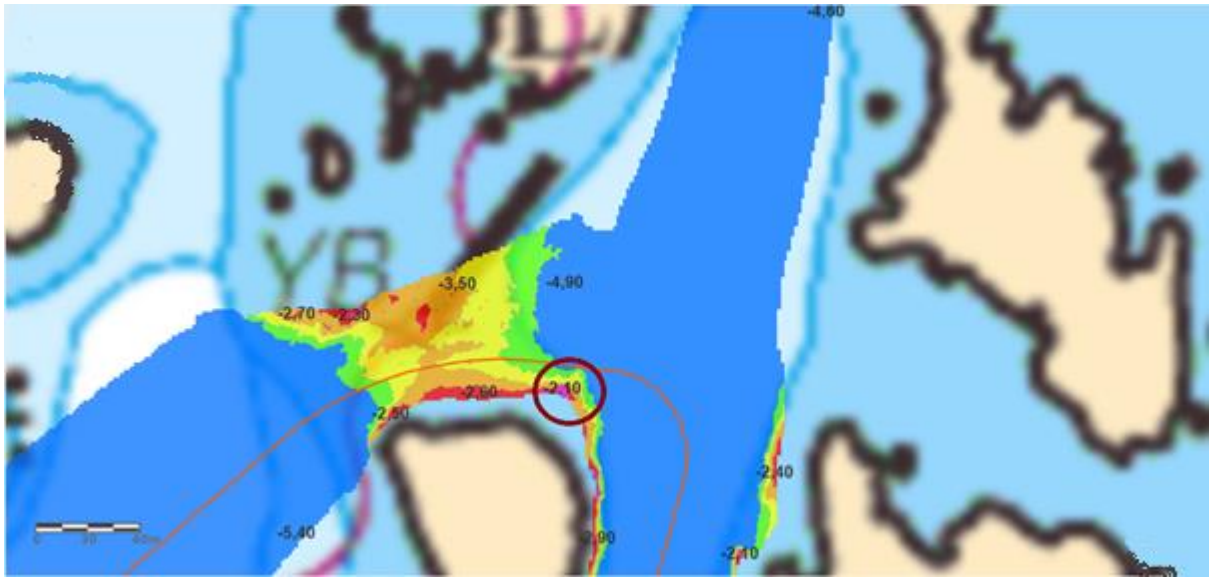


Figure 66. Shoal in a shallow corner of close to Askören, with a different extent than previously known.

4.17 Corridor 16: Furusund – Rödlöga (28)

Multiple shoals were found south of Östernäsin corridor 16. Some of the previously known shoals' full extent were measured and some areas that were shallower than previously known and indicated by the navigational chart were also found at this location, see figure 67. This was notified in the Swedish NtM 11914. Limiting lines and correct positioning of the are proposed. The measures impact the navigational safety and environmental protection positively.

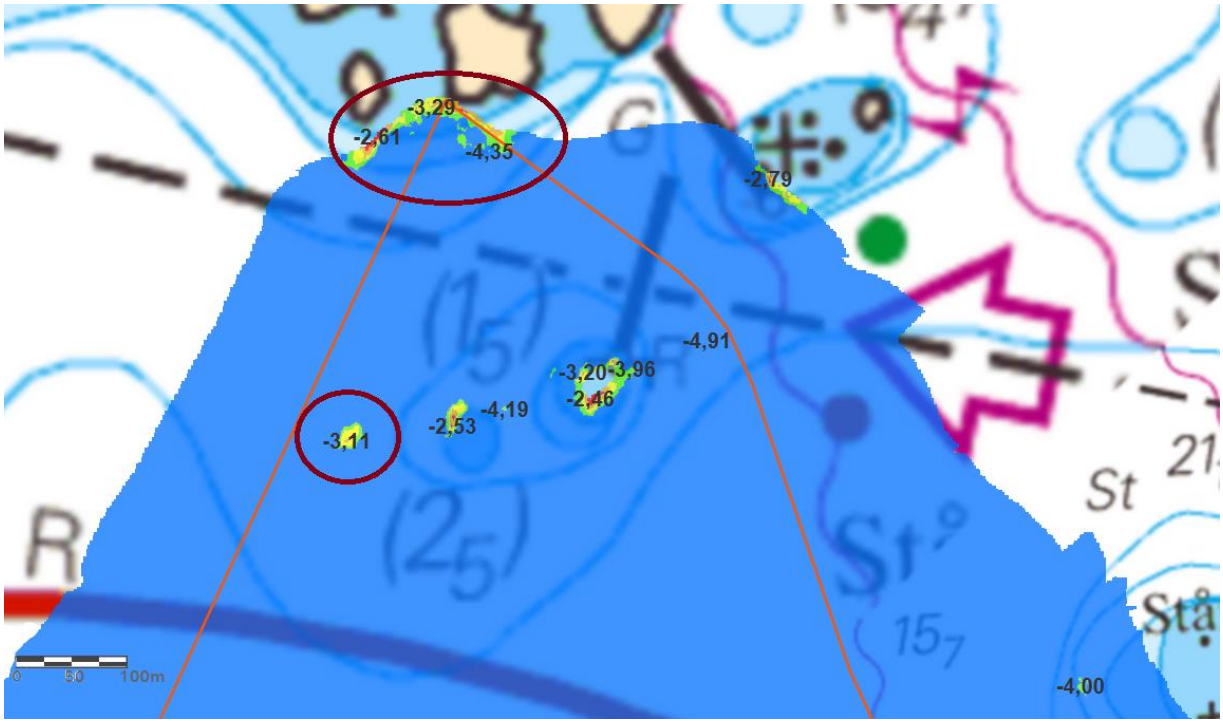


Figure 67. The shoals found in the area of Östernäs are circled in the figure. The circle furthest to the south shows a shoal with a depth measuring 3.11 metres at a segment known to be 15 metres deep in the navigational chart.

4.17.1 Node 5

Node number 5, found in corridor 16 is the jetty situated at Gräskö. Multiple shoals were found outside of the 6-metre area in the navigational chart, and in front of the jetty, causing a great safety risk, see figure 68. Proposing leading navigational lines to realise a safe approach and departure, as well as a buoy, limiting lines and correct positioning of the shoals. These actions impacts the navigational safety and environmental protection.

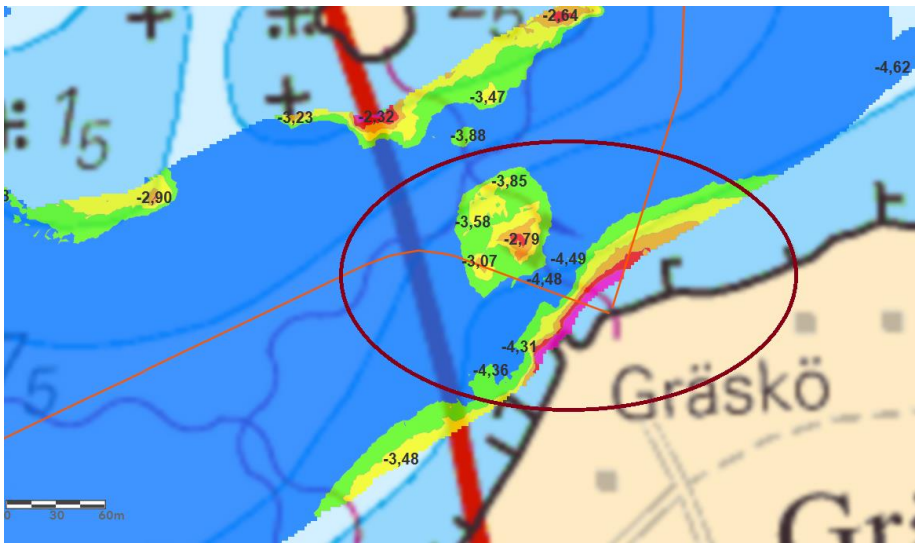


Figure 68. Circled shoals found outside of Gräskö jetty. The shoals cause a safety risk for approach and departure to the jetty.

4.17.2 Node 10

The area of Bromskär was found to be generally shallow, see figure 69. Proposed dredging of the area to increase the safety level for berthing at the jetty. The action impacts the travel time, navigational safety and environmental protection positively. The travel time can be shortened if the area is dredged, as the ferries will have a greater depth to navigate in and an easier berthing process.

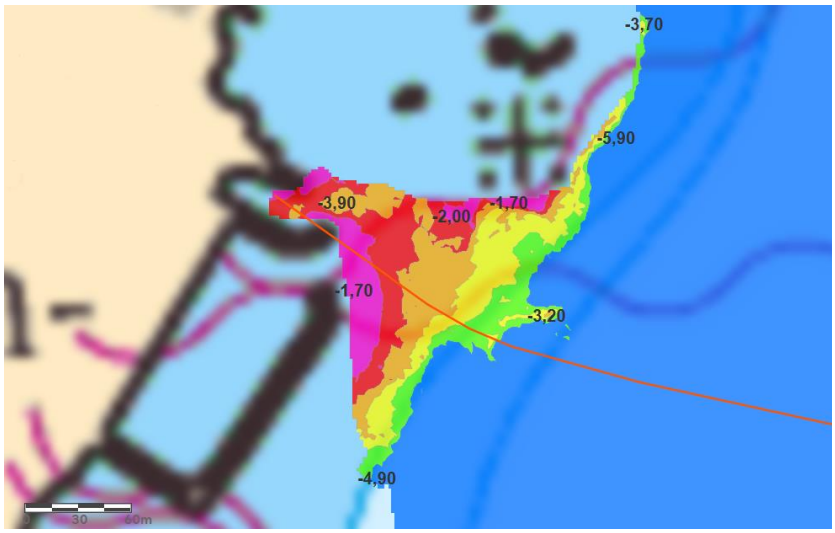


Figure 69. The shallow inlet to the Bromskär jetty, where dredging is proposed to increase the safety level of the berthing process.

4.18 Baseline analysis of route 3809 Furusund – Norröra

Route 3809 runs Monday to Friday midmorning during the winter timetable from Furusund via Gräskö to Norröra in corridor 16 (Wåab route area 28). The baseline specifies the route as Solö – Furusund – Norröra, but Solö is not part of the route and Söderöra functions as the end point of the route, see figure 70.

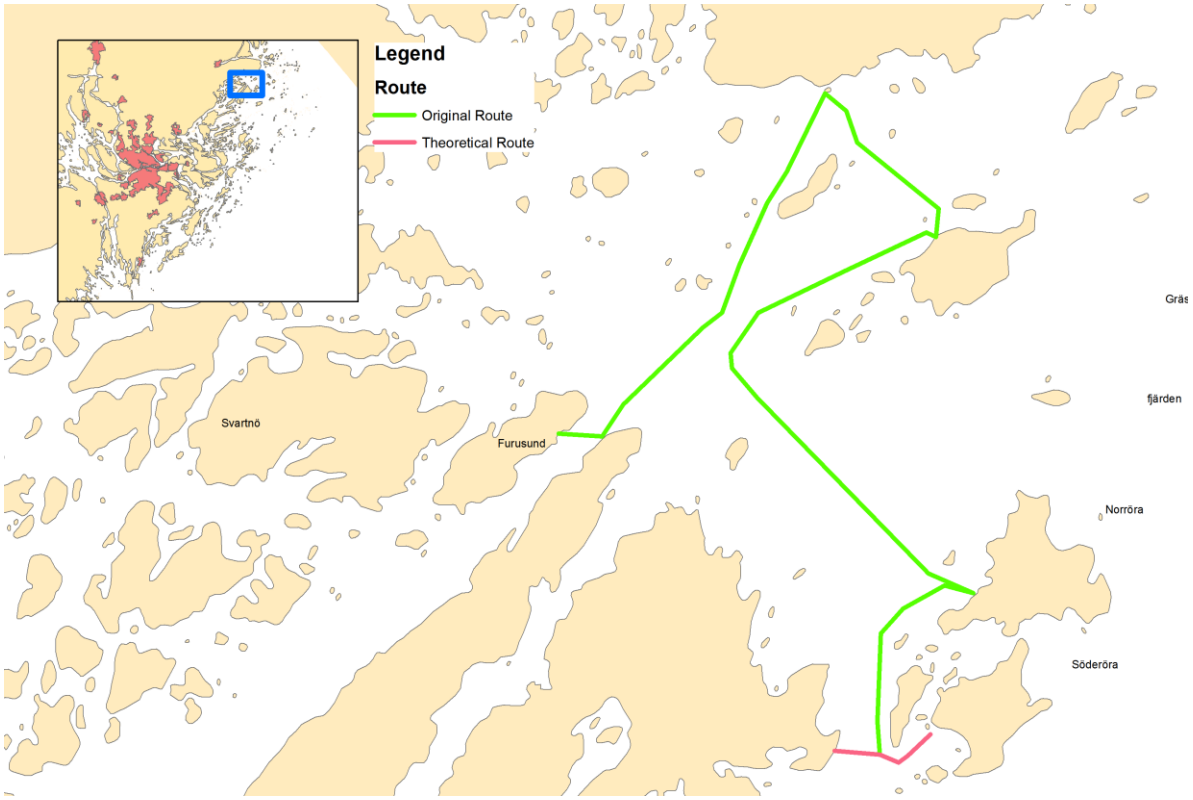


Figure 70. Map of the northern part of Waxholmsbolagets' operating area. The extent of the route of interest in this analysis is mapped as well as theoretical route, used in the comparison.

During the winter of 2015–2016, route 3809 was operated by the vessel *Riddarfjärden* whose maximum passenger capacity is 120 passengers. *Riddarfjärden* has 100 seats and congestion starts at 100 passengers, see figure 71. The route had low occupancy throughout the measuring period. The travellers mainly consisted of residents and part-time residents.

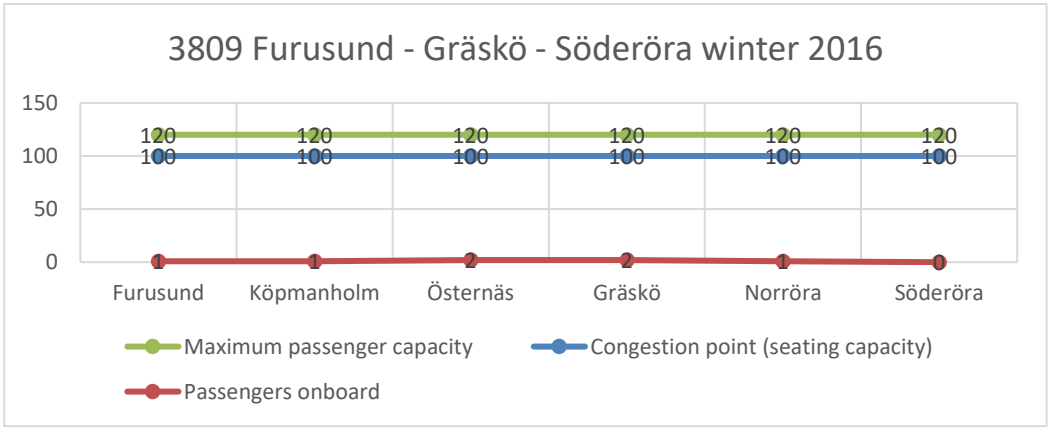


Figure 71. The line diagram shows the vessel capacity, congestion point and occupancy for route 3809 in the analysed period.

The baseline analyse compares route 3809 to an alternative intermodal route requiring the passenger to travel by bus from Furusund to Bromskär, only utilising the ferry the last part of the journey, see table 12. The energy consumption for the ferryboats, on which the bus needs to ride between Furusund and Yxlan plus Yxlan and Blidö, is not considered.

Table 12. The table list the two routes compared in this sections baseline analysis.

Object of comparison	**Tur**
Route 3809	Furusund – Söderöra
Alternative route	Furusund – Bromskär – Söderöra

Journey time for route 3809 from Furusund to Söderöra was 1 hour and 25 minutes. Journey time for the intermodal route from Furusund via Bromskär to Söderöra with bus and boat was calculated to approximately 40 minutes, using timetables for the different modes of transport. Energy consumption per person for the entire journey of route 3809 from Furusund via Gräskö to Söderöra was 357 kWh, see table 13 for an overview of calculations and numbers. The energy consumption per person for the entire journey on the alternative intermodal route should be 29 kWh, see table 14 for an overview of the calculations and numbers. The calculation of the alternative route is executed using the same conditions as route 3809, see table 15. This means that the alternative intermodal journey would reduce energy consumption per person with 328 kWh, see figure 72.

Table 13. The table identifies the numbers used in the calculations for the energy consumption for route 3809.

Route 3809 Furusund - Söderöra		
Trip length (km)	21 km	
Sailing time (h)	1,42 h	
Fuel consumption	38 l/h (Riddarfjärden)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption (kWh)	H*l/h*kWh/l	526 kWh
Weighted occupancy	1,53 passengers (Excel)	
Passenger kilometres (pkm)	31 pkm (Excel)	
Energy consumption per passenger kilometre	kWh/pkm	17 kWh/pkm
Energy consumption per passenger for whole trip	(kWh/pkm)*km	357 kwh/p
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	81 kg CO2/p
Calculated CO2 emission per passenger diesel MK1 (20 %)	kWh/p*40*0,2	3 kg CO2/p
Total CO2 emission per passenger		84 kg CO2/p
Travel time Furusund - Söderöra		1,4 h

Table 14. The table identifies the numbers used to calculate the energy consumption for the theoretical intermodal alternative to route 3809. The theoretical route utilises the bus to Bromskär and the boat from Bromskär to Söderöra.

Theoretical intermodal route Furusund – Söderöra.		
Distance with bus	7,3 km	
Energy consumption per passenger kilometer with bus	0,374 kWh/pkm (TF Miljöredovisning 2016)	
Energy consumption per passenger with bus	kWh/pkm*km	3 kWh/p
Distance by boat (km)	1,5 kilometer	
Sailing time (h)	0,08 timmar	
Fuel consumption	38 liter/timme (Riddarfjärden)	
Energy content (kWh/l)	9,75 kWh/liter (OKQ8)	
Energy consumption (kWh)	Tfs*bränsleförbrukning*energiinnehåll	30 kWh
Weighted occupancy	1,53 passagerare (kalkylark)	
Passenger kilometres (pkm)	31 pkm (Kalkylark)	
Energy consumption per passenger kilometre	Energiförbrukning/pkm	17 kWh/pkm
Energy consumption per passenger for whole trip	(Energiförbrukning/pkm)*km	26 kwh/p
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content diesel HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh*285*0,8	6 kg CO2/p
Calculated CO2 emission per passenger diesel MK1 (20 %)	kWh*40*0,2	0,2 kg CO2/p
Total CO2 emission per passenger		6 kg CO2/p
Travel time Furusund – Söderöra by bus and boat		0,7 h
Energy consumption per person from Furusund – Söderöra by bus and boat		29 kWh/p
Reduction of energy consumption and travel time per passenger		
kWh reduction/passage		328 kWh/p
kWh reduction/year	815 annual passages	267 320 kWh
Reduction of CO2 by boat/passage		78 kg CO2/p
Reduction of CO2 by boat/year		63 570 kg CO2/p
Reduction of travel time/passage		0,7 h/passage
Reduction of travel time/year		570 h

Table 15. The table overview the calculation of the CO_2-reduction for each vessel.

Reduction CO2 by ship		
kWh reduction/passage		496 kWh
kWh reduction/year	815 annual passages	404 240 kWh
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content diesel HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per ship diesel MK1 (80 %)	kWh*285*0,8	92 167 kg CO2
Calculated CO2 emission per ship diesel MK1 (20 %)	kWh*40*0,2	3 234 kg CO2
Total reduction CO2/year		95 401 kg CO2

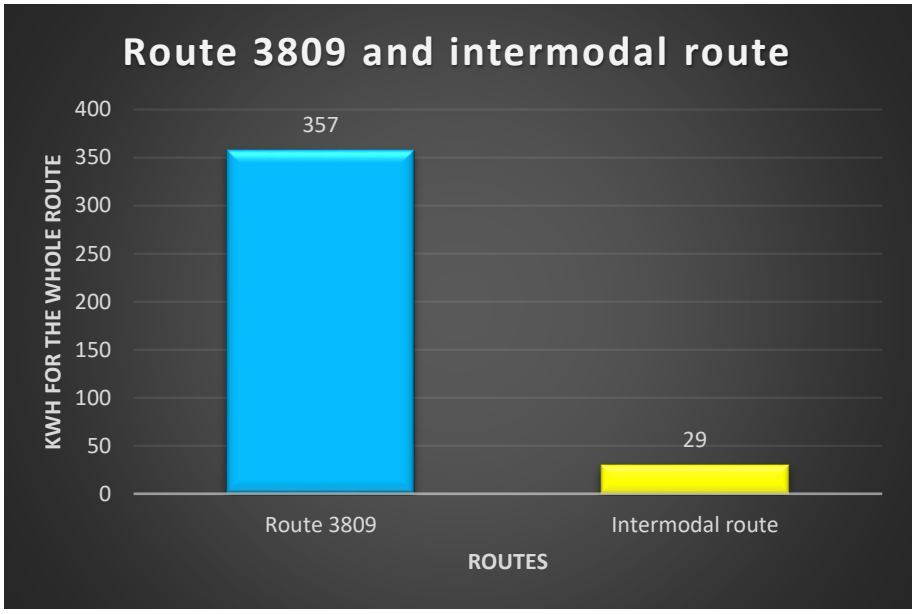


Figure 72. The graph compares the energy consumption for route 3809 and the theoretical route.

Knowledge through ADAPT

Route 3809 had such a low occupancy during the analysis period, which can be a result of the rainy summer. This fact makes it difficult to draw any conclusions for the baseline, based only on this period. It can be concluded that the average traveler utilizing route 3809, is bound for Norröra or Söderöra. The route to Söderöra from Bromskär is considerably shorter, approximately 15 minutes instead of approximately 1.5 hours. Although, heavier vessels cannot utilize the jetty of Bromskär, as the area surrounding it is too shallow. Hydrographical surveys have shown that Bromskär may be an alternative if the jetty area is dredged.

4.19 Corridor 17: Simpnäs – Arholma

In corridor 17 one area containing safety issues and two nodes were found. The passage through Kasholmsören was shallow and multiple shoals were found, see figure 73. At one point a depth of only 2.89 metres was found outside of the 3-metre area in the navigational chart. Proposing an adjustment of the route using limiting lines and correct positioning of the shoals. The actions impact the navigational safety and environmental protection.

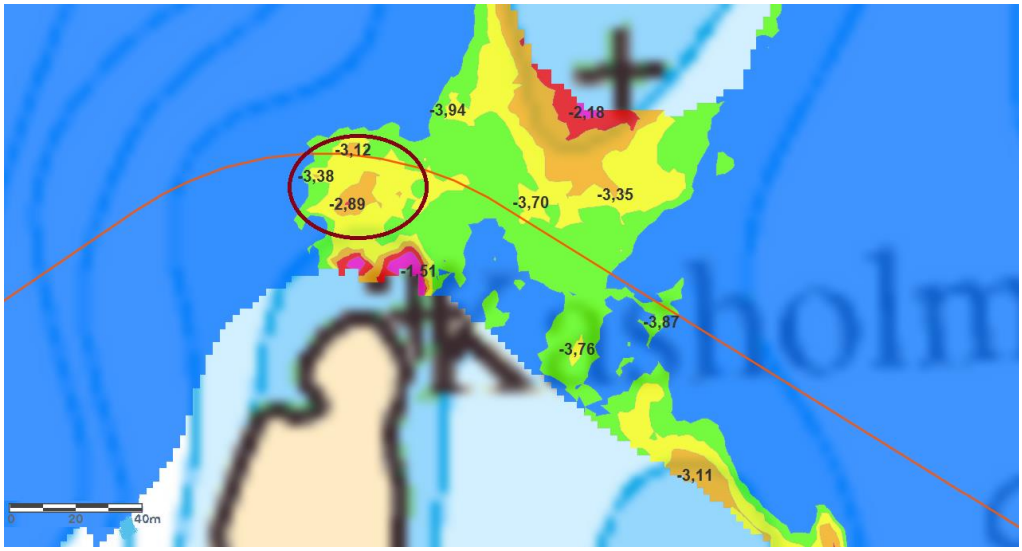


Figure 73. The shallow passage through Kasholmsören, where the circle shows the shoals that were discovered analysing the survey data.

4.19.1 Node 6

At the inlet to the jetty of Simpnäs a shoal measuring 2.65 metres was found outside of the 6-metre navigational chart area, see figure 74. Proposing that the area is dredged, to reach a safe level for the berthing process. The action impacts the navigational safety and depending on the seabed properties it can affect the ecology of the areas. A separate analysis is needed before this proposal can be determined.

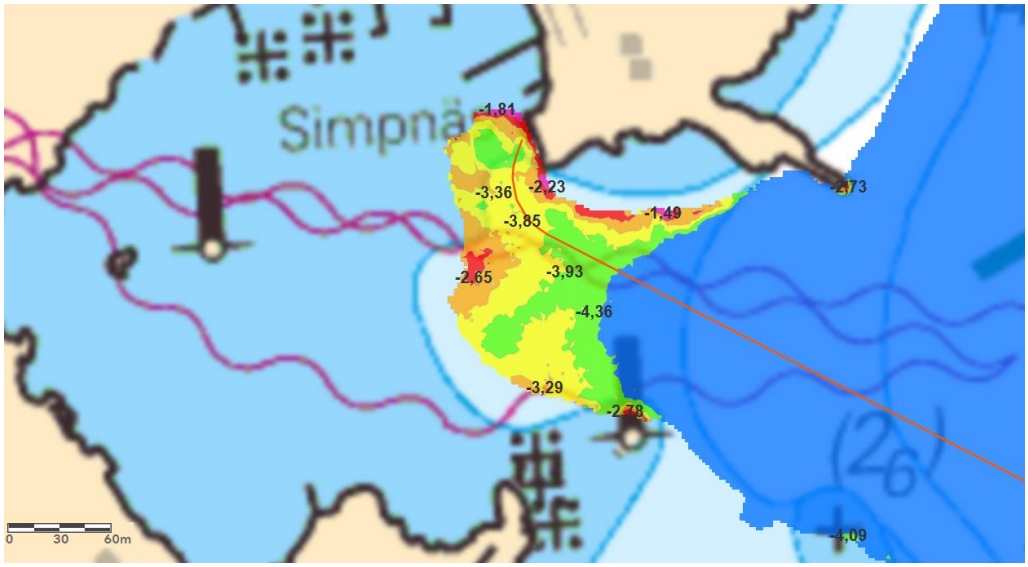


Figure 74. The area around the jetty of Simpnäs was found to be shallower than previously known.

4.19.2 Node 11

In corridor 16, the next node was found at the jetty of Arholma, see figure 75. The area around the jetty has a limited depth creating safety issues for the utilisation of the jetty. Proposing that the area is dredged to reach a safe berthing at the jetty. The action impacts the navigational safety and depending on the seabed properties it can affect the areas' ecology. A separate analysis is needed before this proposal can be determined.

Figure 75. The shallow area around the jetty of Arholma is proposed to be dredged.

4.20 Corridor 18: Räfsnäs – Fejan

In corridor 18, shoals south from Lidön were found to cause a safety risk for vessels approaching the jetty, see figure 76. This was notified in the Swedish NtM 11458. Additional limiting lines and correct positioning of the shoals are proposed. The actions impact the navigational safety and environmental protection positively.

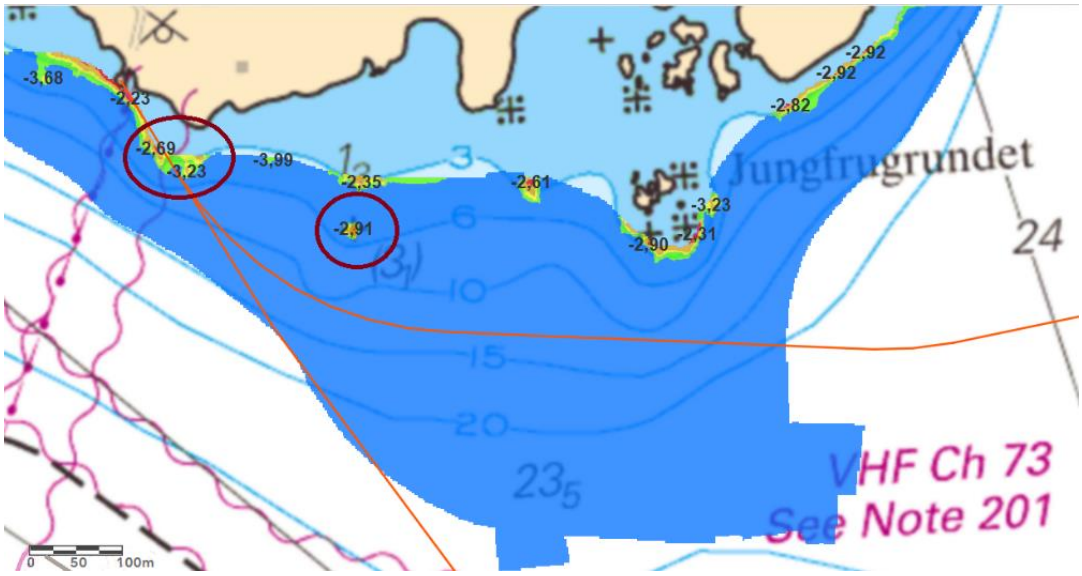


Figure 76. Circled shoals south of Lidön are found to cause a safety risk for the vessels approaching the jetty.

4.21 Corridor 19: Stavsnäs – Hagede

In corridor 19 multiple safety issues were found. The Swedish NtM:s 11356 and 11493 are increasing the general navigational safety of the corridor. Firstly, next to Hagede, a shoal measuring a depth of 2.35 metres was found in a 15-metre deep area, according to the navigational chart, see figure 77. Additional limiting lines and correct positioning of the shoals are proposed to secure the turning point for the ferries utilizing the jetty. The actions impacts the navigational safety and environmental protection positively.

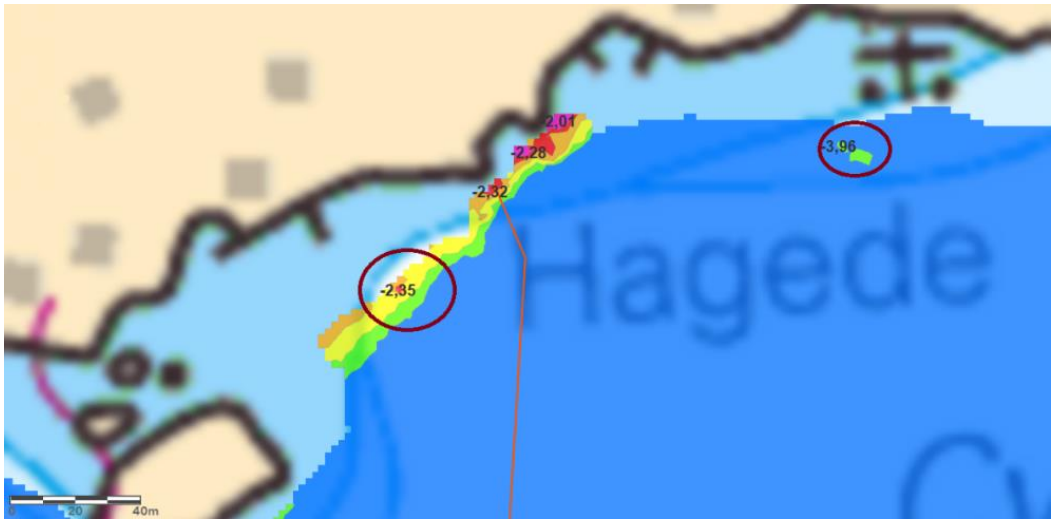


Figure 77. Circled shoals found close to the jetty of Hagede.

Secondly, a shoal was found north of Idholmen, see figure 78. This was notified in the Swedish NtM 11423. Correct positioning of the shoal are proposed to reach a safe navigation past the shoal. Actions impacts the navigational safety and environmental protection.

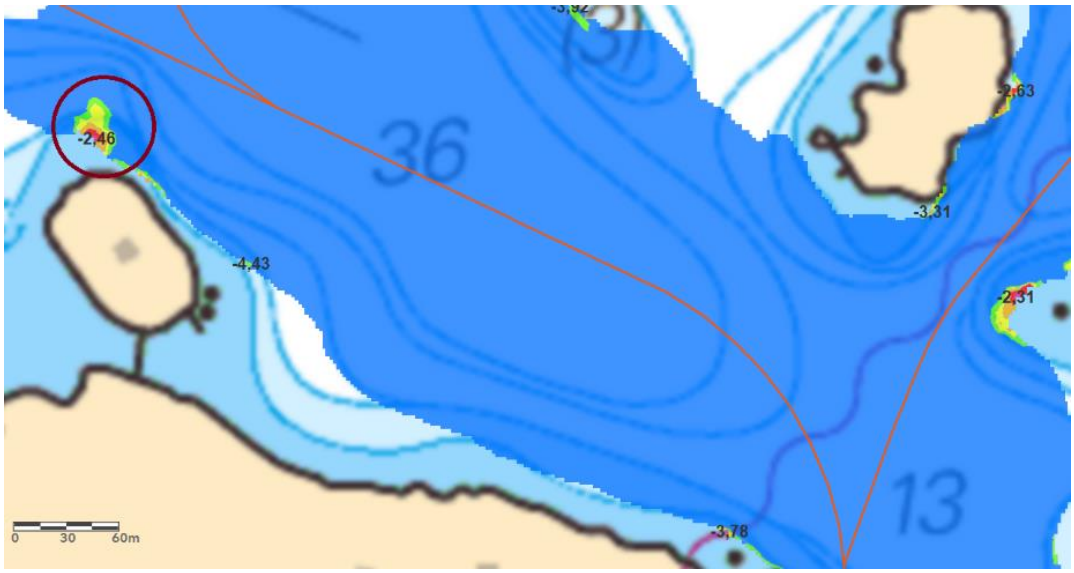


Figure 78. Circled shoal north of Idholmen was found close to the ferry routein corridor 19, causing a safety risk.

A shoal was found north of Berghamn, causing a safety issue for the passing traffic, see figure 79. This was notified in the Swedish NtM 11960. Additional limiting lines and correct positioning of the shoal are proposed. The actions impact the navigational safety and environmental protection positively.

Figure 79. Circled shoal north of North Berghamn was found further out than the sea chart curves states.

Multiple shoals were found surrounding the entry to the passage between north east Gummerholmen and northwest Lisslö, see figure 80. This was notified in the Swedish NtM 11423. Additional limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

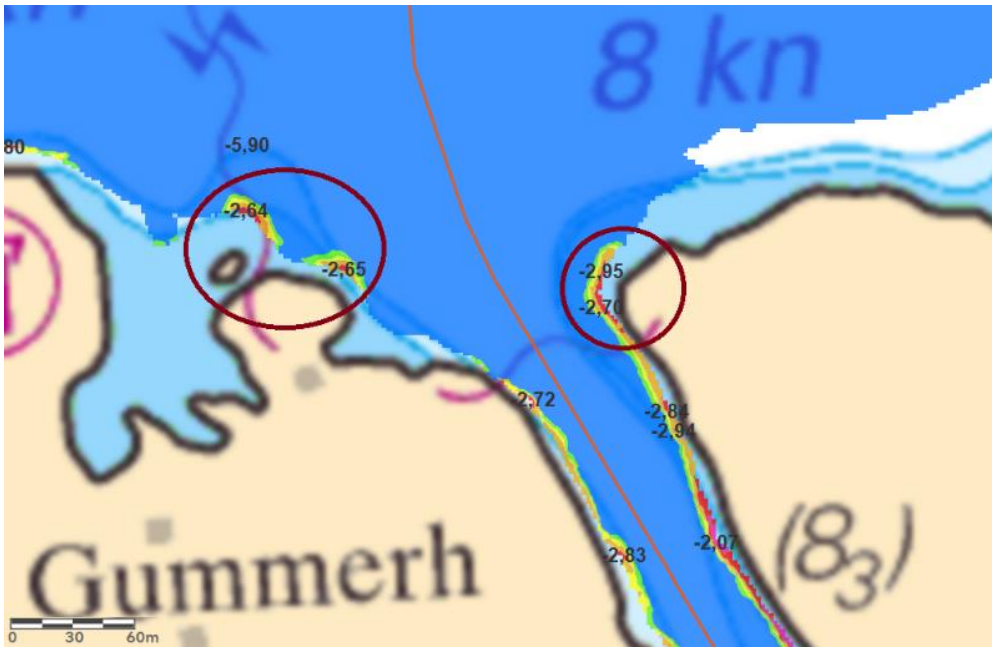


Figure 80. The shoals that are circled, are surrounding the entry of the passage between northeast Gummerholmen and northwest Lisslö.

A shoal measuring 2.92 metres was found in a 6-metre area, according to the navigational chart, see figure 81. Additional limiting lines and correct positioning of the shoal are proposed. These actions impacts the navigational safety and environmental protection positively.

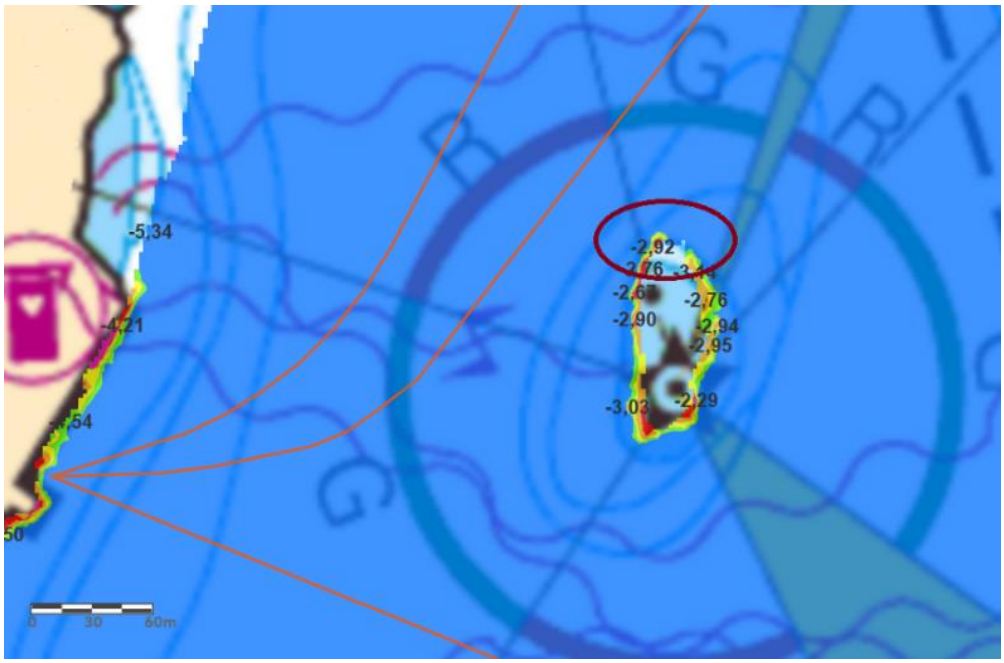


Figure 81. Circled shoal next to Stavsnäs and north of the lighthouse Tegelhällan.

4.22 Corridor 20: Stockholm- Nämdö – Stavsnäs

Several navigational safety issues were found in corridor 20. Following, many Swedish NtM:s has been issued for the extent of the route. The notices 11280, 11332, 11422, 11720, 11918, 11919, 11961 and the preliminary 12469 are all improvements for a safe navigation along the corridor.

Firstly, a shoal was found further into the passage than known, see figure 82. The shoal was notified in the Swedish NtM 11420. Adding limiting lines and correct positioning of the shoal are proposed. The action impacts the navigational safety and environmental protection positively.

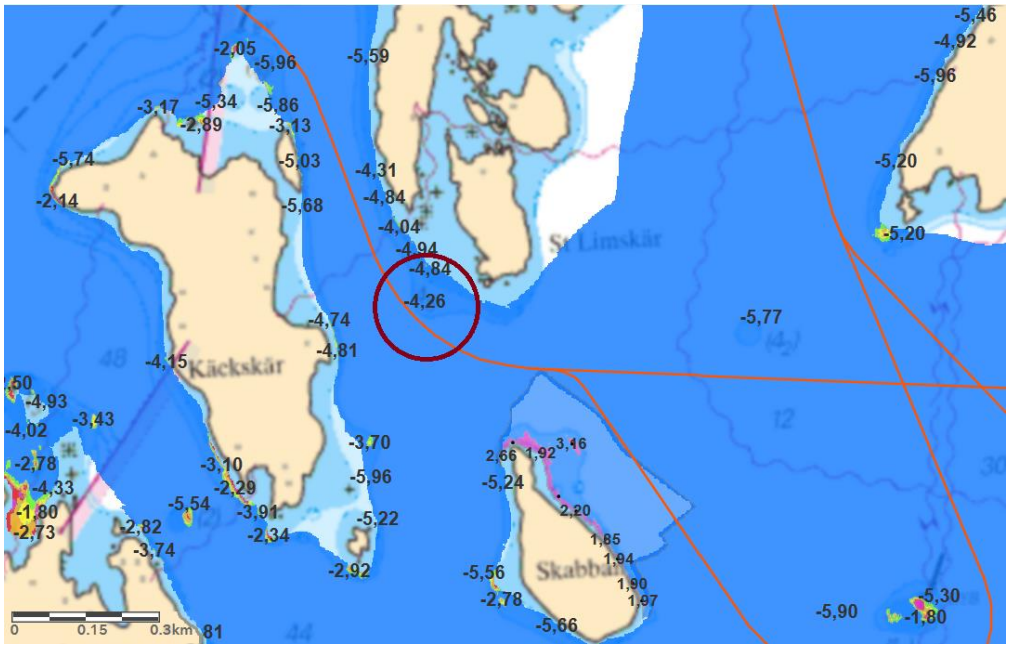


Figure 82. Circled shoal east of Käckskär and southwest of Stora Limskär.

Secondly, two shoals were found adjacent to manoeuvring area at Mörtö jetty, see figure 83. This was notified in the Swedish NtM 11924. Additional limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

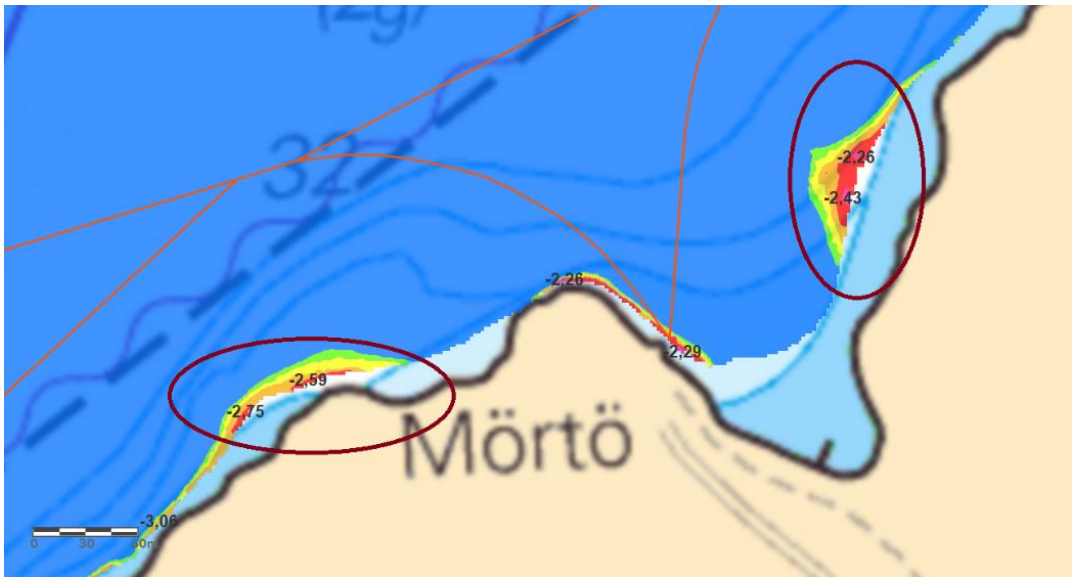


Figure 83. Circled shoals close to Mörtö jetty and the turning point for the berthing process.

Furthermore, the 3-metre navigational curve south of Mörtö was found to be located too far into the passage. This permits larger vessel types in the passage, the area of the jetty however, is still shallow, see figure 84. Additional limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

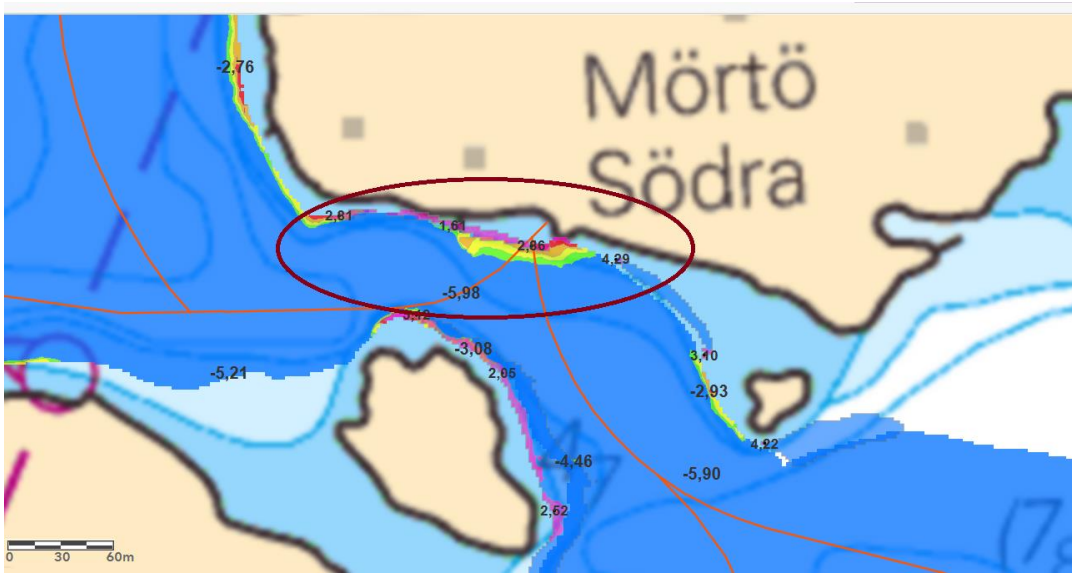


Figure 84. The passage south of Mörtö Södra was found to have a greater depth than known, although, the area around the jetty, circled in the figure was still as shallow as known.

In Munkösundet shoals measuring 4.02 and 4.31 metres was found at a location previously known to be 8.7 metres deep, see figure 85. There are multiple shoals in the area, causing a safety risk for vessel traffic in the passage. Additional limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection.

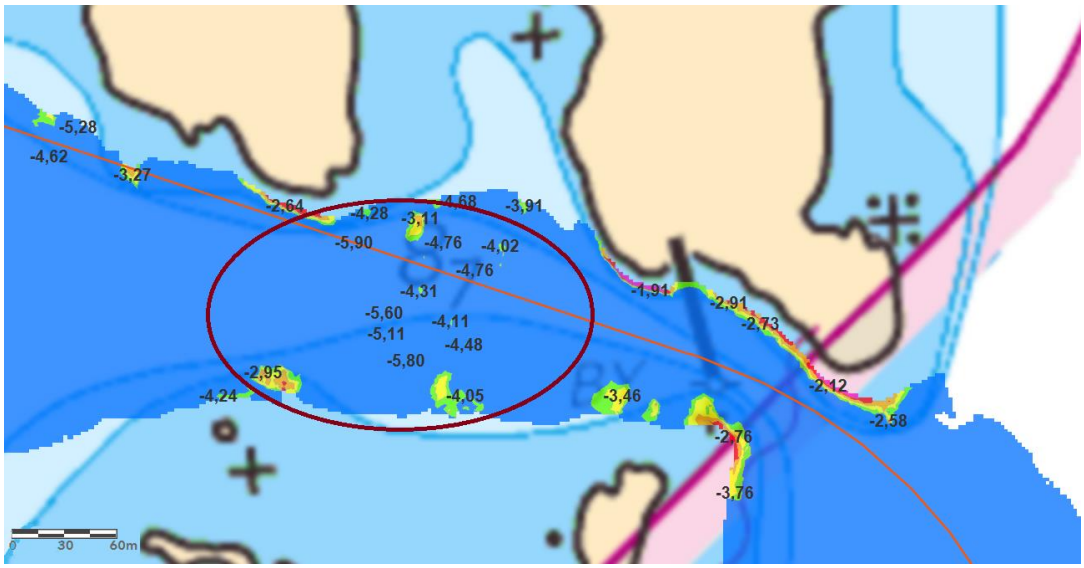


Figure 85. Circled shoals found in the passage north of Munkö.

Northwest of Nämdö and north of Rönnskär the depth was found to be shallower than known. At one point it was 4.9 metres, not 6.5 as the navigational chart indicated, see figure 86. This was notified in the Swedish NtM 11421. Additional limiting lines and correct positioning of the shoals are proposed. Actions impacts the navigational safety and environmental protection positively.

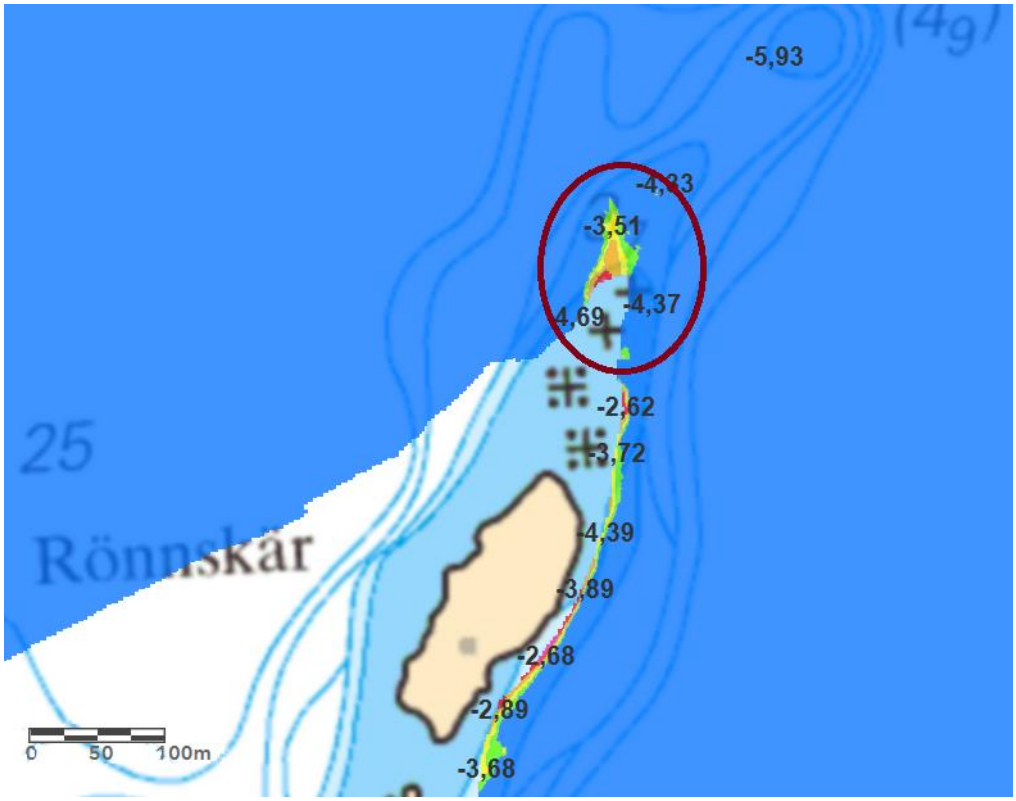


Figure 86. Circled shallow area north of Nämdö and Rönnskär.

In the area between Boskapsön and Nämdö multiple shoals were found, see figure 87. Additional limiting lines and correct positioning of the shoals are proposed. These actions impacts the navigational safety and environmental protection positively.

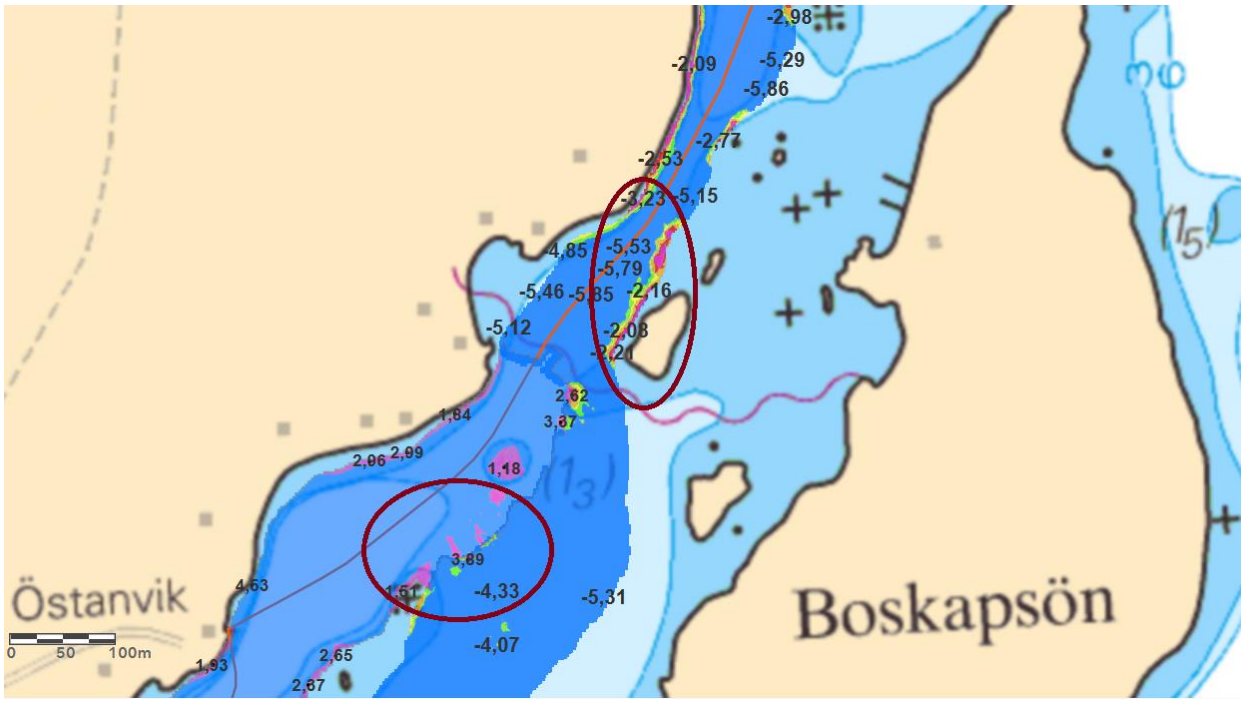


Figure 87. Circled areas containing shoals between Nämdö and Boskapsön.

North of Nämdö Böte a shoal was found further out than previously known, see figure 88. Proposed adjustment is to move the existing buoy slightly southeast to the actual location of the shoal. The adjustment of the buoy and correct positioning of the shoal are proposed. The actions impacts the navigational safety and environmental protection positively.

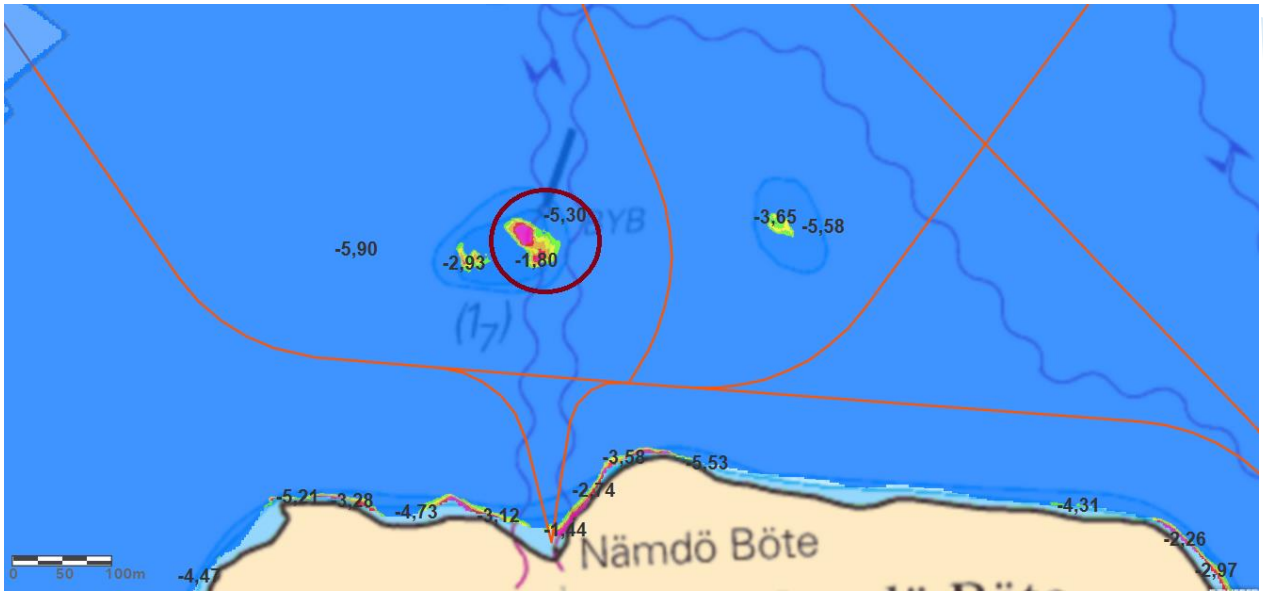


Figure 88. The location of the shoal north of Nämdö Böte, circled in the figure, and the existing buoy at the old location.

A depth of 3.77 metres was found outside of the 6-metre navigational curve, see figure 89. Proposed adjustment is to put a limiting line for the vessel navigation route, along with correct positioning of the shoals. The actions impacts the navigational safety and environmental protection positively.

Figure 89. Circled shoals found close to Nämdö and northeast of Getholmen.

The 3-metre curve of the navigational chart by Midsommargrundet and south west of Ekholmen needs adjustment according to the actual depth found in the hydrographical surveys, see figure 90. To reach a safer navigation route past the area the vessel operators needs to be aware of the findings. Correct positioning of shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

Figure 90. The 3-metre curve on the navigational chart next to Nämdö and south west of Ekholmen is positioned too far in. Shallow areas further out than the curve are circled in the figure.

Multiple shallow locations were found outside of the 3-metre curve in the navigational chart, see figure 91. Proposed adjustment is a limiting line for the ferry traffic utilizing this area of the route. Additional limiting lines and correct positioning of the shoals are proposed. The actions impact the navigational safety and environmental protection positively.

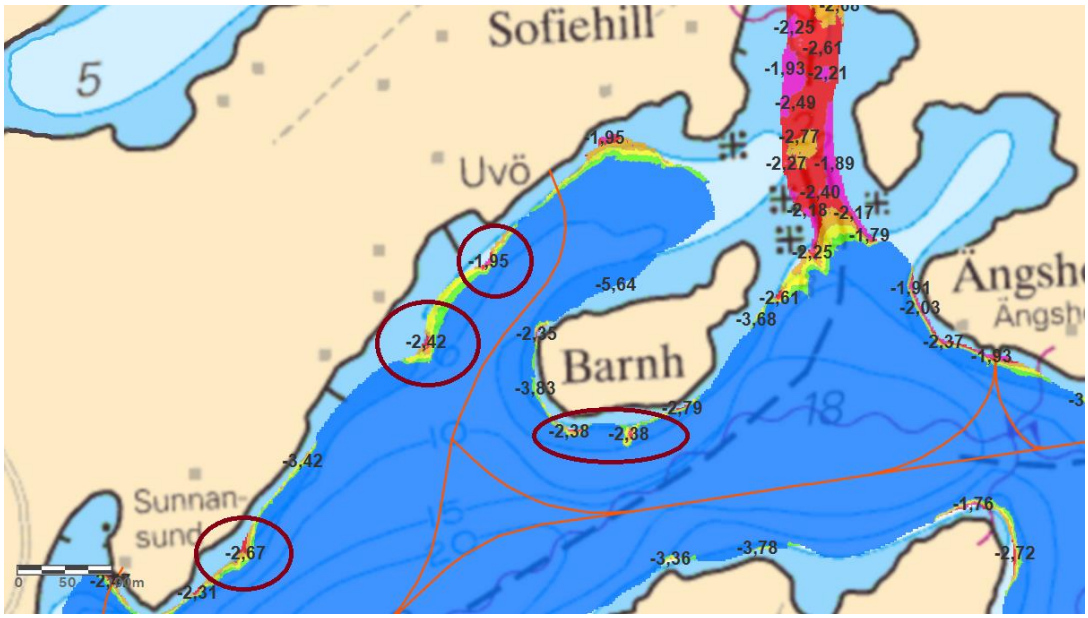


Figure 91. Circled shallow locations further out than the navigational chart suggest, next to Sunnansund, Uvö and Barnholmen.

4.22.1 Node 12

The areas along the sides of the Sand jetty are shallower than previously known, see figure 92. Additional limiting lines and correct positioning of the shoals are proposed to reach a higher safety level for approaching, berthing at, and departure from the jetty. The actions impacts the navigational safety and environmental protection positively.

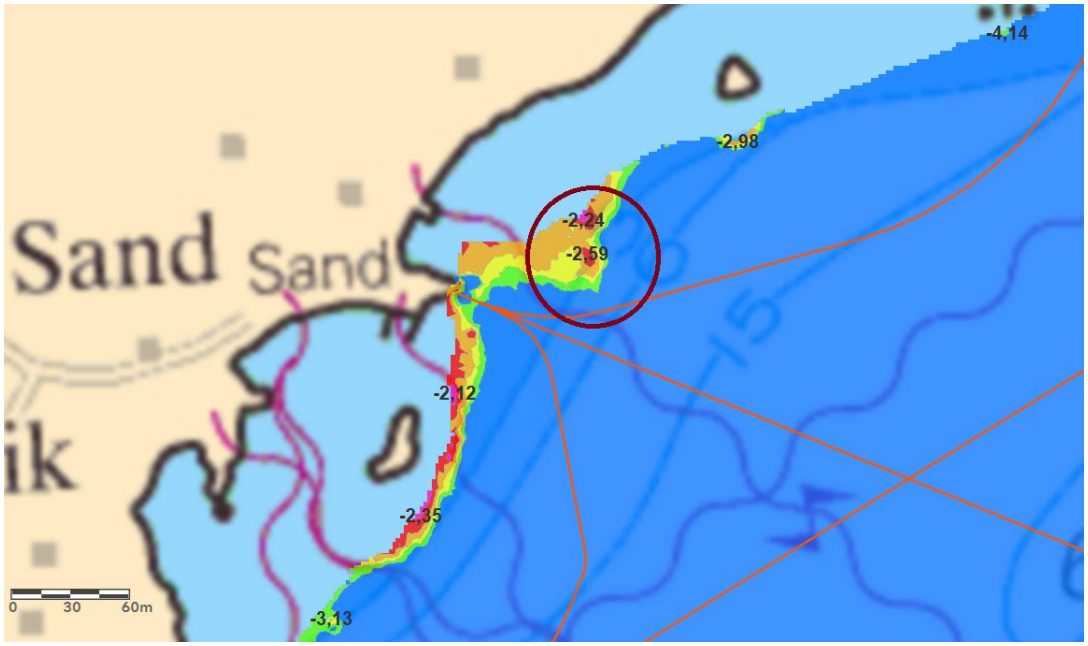


Figure 92. The area around the Sand jetty is shallow and a specifically dangerous shallow location is circled in the figure.

4.23 Corridor 21: Stockholm – Dalarö

Three locations containing safety issues were located in the corridor. A notification increasing the general safety of the corridor area was issued in the Swedish NtM 12905. At the first location depths measuring 2 metres were found further out into the navigational route than known. They were found to be located outside of the 3-metre curve in the navigational chart, see figure 93. Additional limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

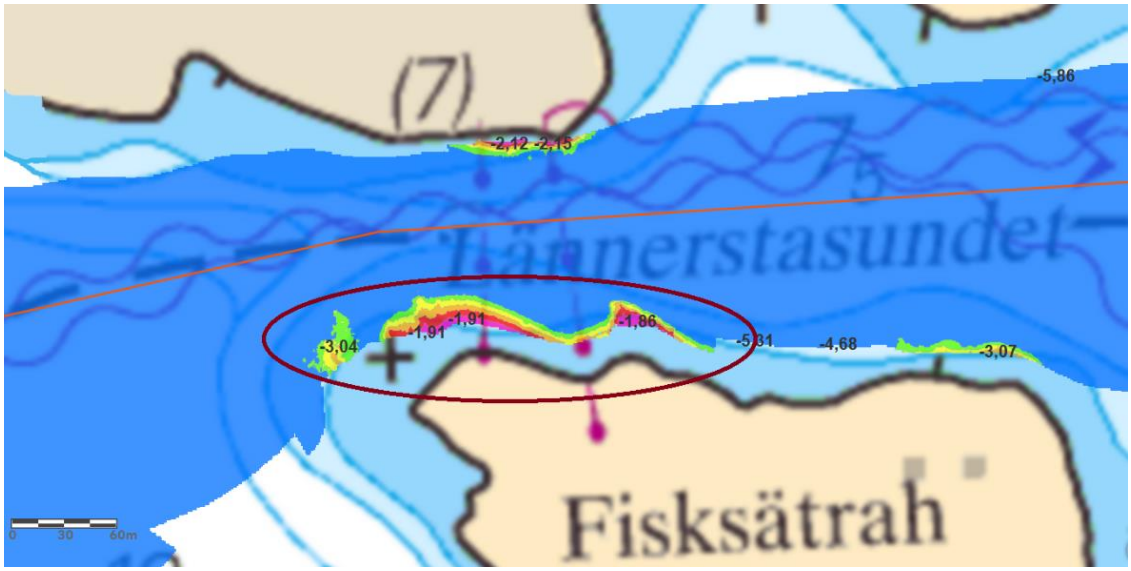


Figure 93. Circled shoals measuring 2 metres outside of the 3-metre curve in the navigational chart were found in Länneröstasundet, north of Fisksätra Holme.

4.23.1 Node 14

Around Erstaviken jetty, shoals measuring less than 2.5 metres where found further out than the 3-metre navigational curve suggests, creating safety issues for vessels berthing at the jetty, see figure 94. This was notified in the Swedish NtM 11338. Additional limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

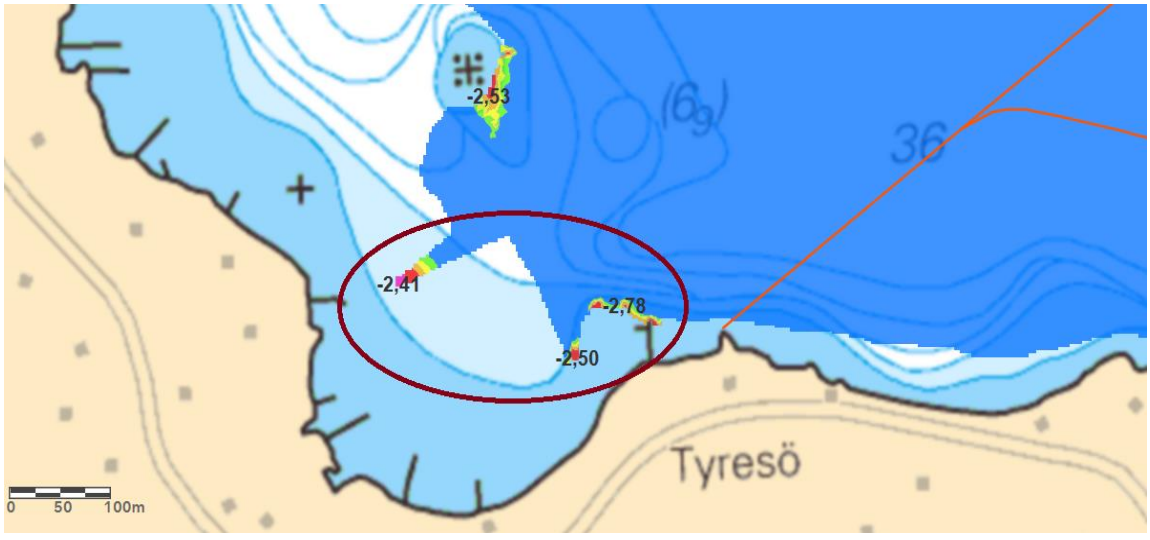


Figure 94. Circled shoals creating a safety issue for berthing at the jetty of Erstaviken.

4.23.2 Node 7

The area around the jetty of Kalvholmen was shallower than known, see figure 95. A limitation in vessel size- and draft for berthing at the jetty, to avoid the risk of grounding. Additional limiting lines and correct positioning of shoals to be proposed. The actions impacts the navigational safety and environmental protection positively.

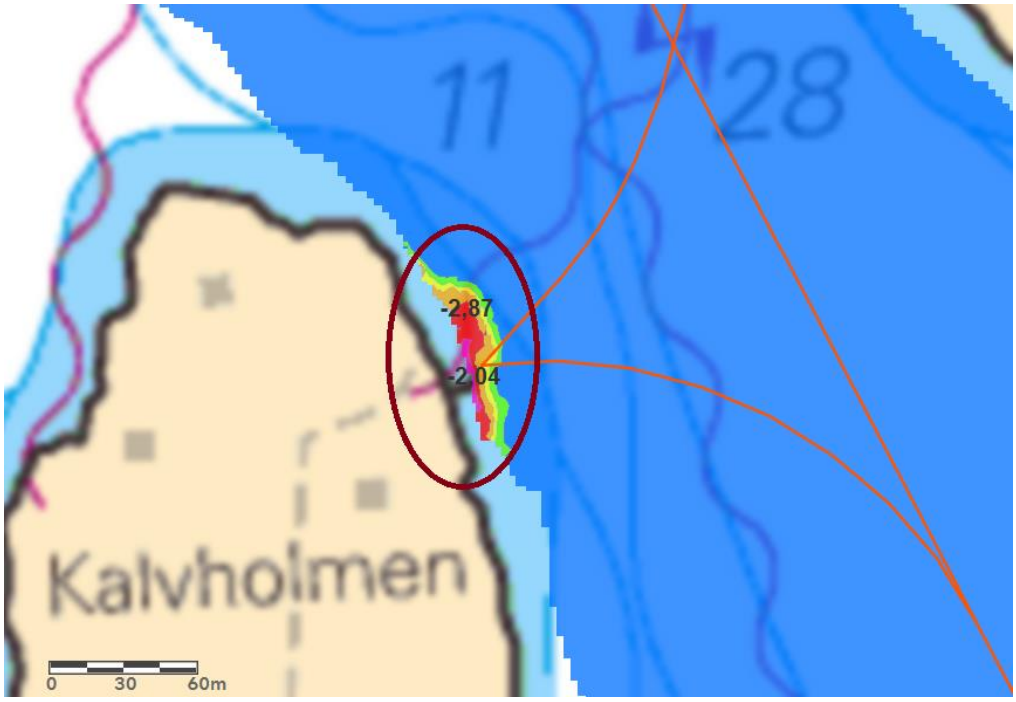


Figure 95. The shallow area around the jetty of Kalvholmen is circled in the figure.

4.24 Corridor 22: Stockholm – Utö

No safety issues were found in corridor 22.

4.25 Baseline analysis of route 1801 Stockholm – Utö

Route 1801 runs Monday to Thursday morning during the summer timetable from Strömkajen to Utö in corridor 21 (Waxholmsbolagets route area 18), see figure 96. The travellers mainly consisted of part-time residents and visitors going to Kymmendö-Ornö Kyrka. The visitors going to Fjärdlång and Utö (Gruvbryggan, Näsudden and Spränga) were mainly tourists.

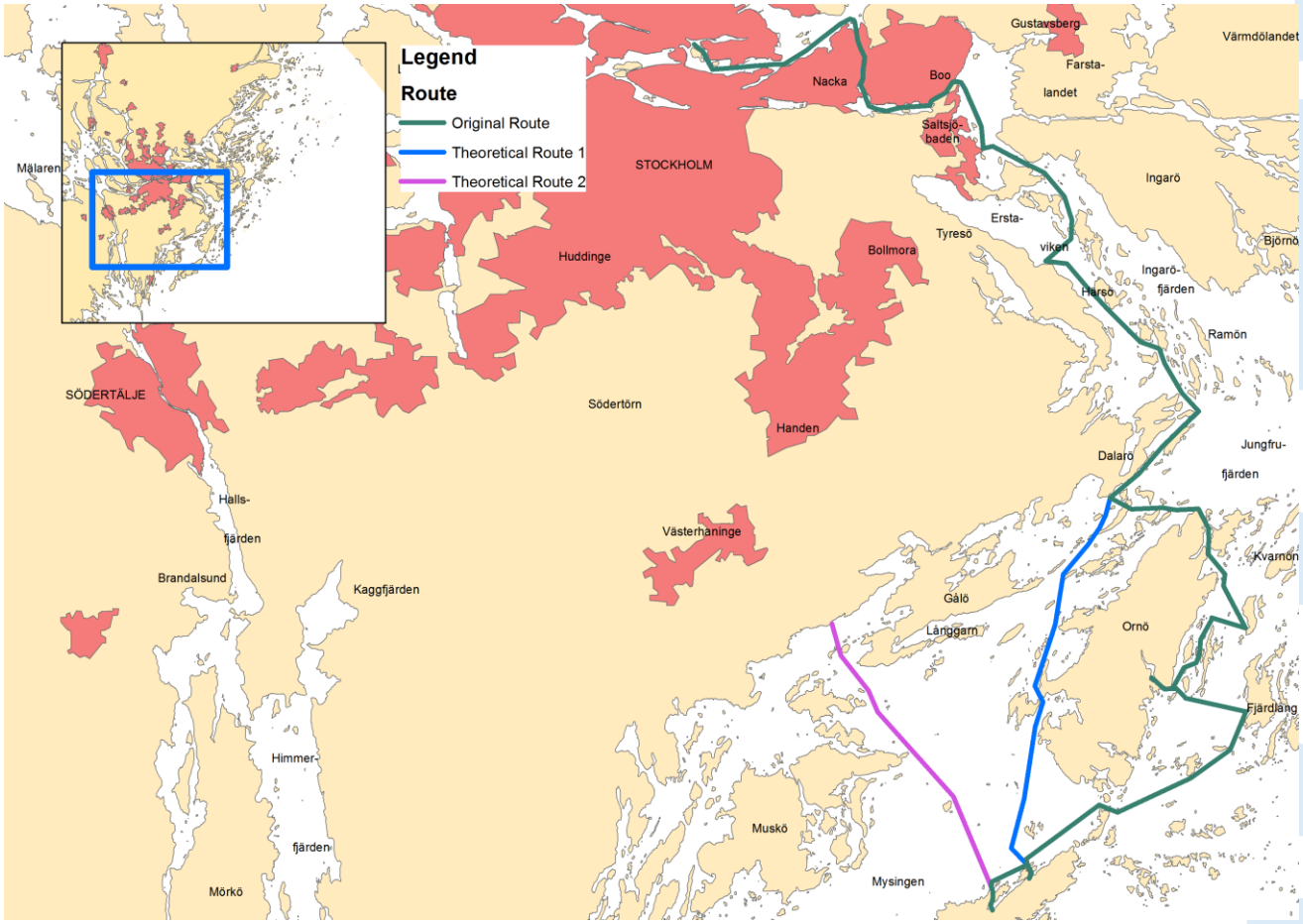


Figure 96. Map of the southern part of Waxholmsbolagets' operating area. The extent of the route of interest in this analysis is mapped as well as the two theoretical routes used in the comparison. Current route area is marked in the top left corner.

During the summer of 2015, route 1801 was operated by the vessel *Saxaren,* whose maximum passenger capacity is 340 passengers. *Saxaren* has 148 seats and congestion starts at 148 passengers. The summer of 2015 was rainy. The ship carried an average of about 65 and 85 passengers during the whole journey. Sunny days another 100-150 passengers utilised the route to Fjärdlång and Utö. Congestion occurs on the route depending on the weather, see figure 97.

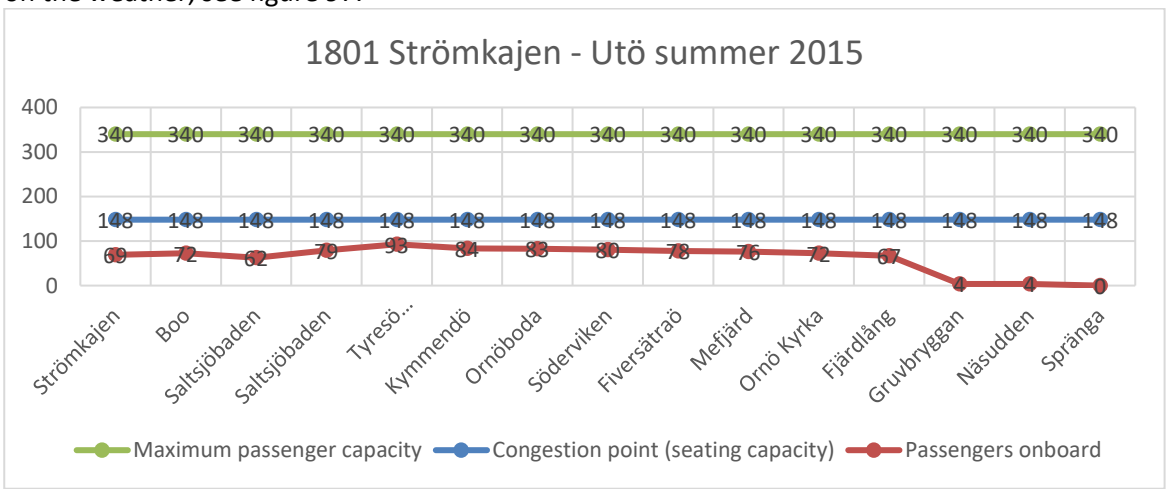


Figure 97. Line diagram showing vessel capacity, congestion point and average occupancy for route 1801, between Stockholm (Strömkajen) and Utö during the summer of 2015.

The study compares route 1801 with two different alternative routes, see table 16. The alternative route 1975 is a more direct service to Utö. The alternative intermodal route 2157 requires the passenger to travel by commuter train from Stockholm to Västerhaninge and then by bus to Årsta, and from Årsta by ferry to Utö.

Table 16. The table list the three routes compared in this baseline analysis.

Object of comparison	Route
Route 1801	Stockholm – Trinntorp – Dalarö – Kymmendö – Fjärdlång – Utö
Alternative route 1975	Stockholm – Trinntorp – Dalarö – Ornö insida – Utö
Alternative intermodal route 2157	Stockholm – Årsta – Utö

Route 1975 runs Friday afternoon during first four weeks of the autumn timetable from Strömkajen to Utö. Considering the short period of operation, the autumns of 2015, 2016 and 2017 have all been analysed to reach larger and more comparable sample size. During the autumns of 2015, 2016 and 2017, route 1975 was operated by the ship *Mysing,* whose maximum passenger capacity is 247 passengers. *Mysing* has 97 seats, which is the congestion point. The route had low occupancy during the whole measuring period, with no congestion occurrence. The travellers were mainly consisted of part-time residents and visitors, see figure 98.

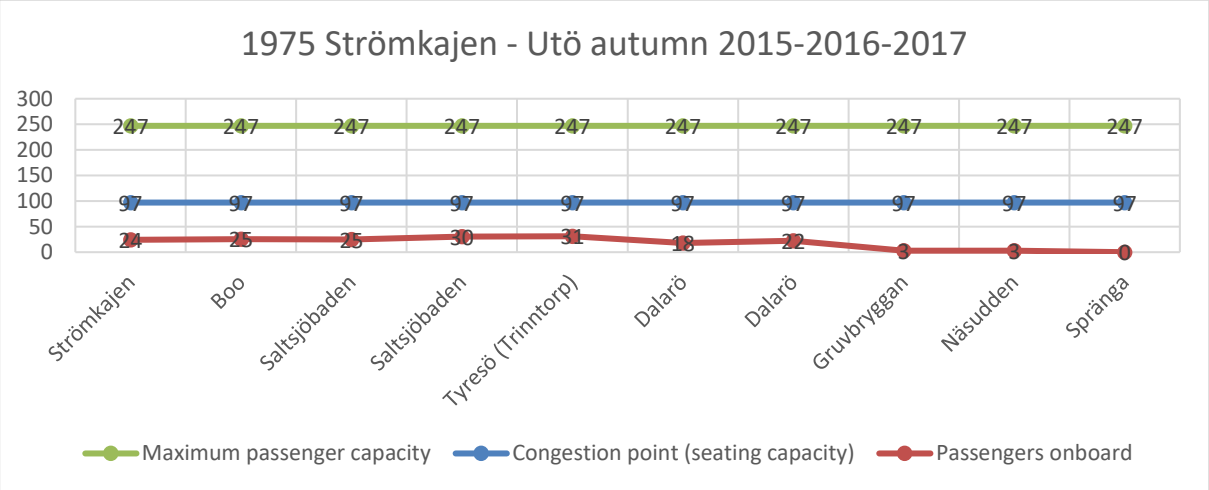


Figure 98. Line diagram showing vessel capacity, congestion point and average occupancy for the alternative route 1975.

Route 2157 runs Saturday midmorning during the spring timetable from Årsta to Utö. During the spring of 2016, route 2157 was operated by the vessel *Silverpilen,* whose maximum passenger capacity is 346 passengers. Silverpilen has 141 seats and congestion starts at 141 passengers. The ship carried an average of about 40 passengers when departing from Årsta. Most of the passengers disembarked at Gruvbryggan which is the major stop at Utö. Congestion generally did not occur on the route, see figure 99. The travellers mainly consisted of part-time residents and visitors.

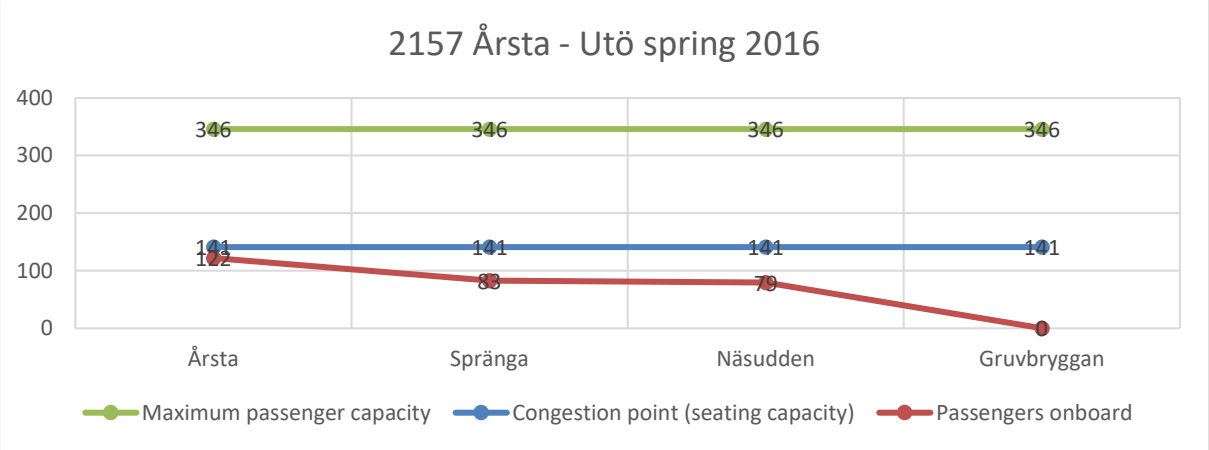


Figure 99. Line diagram showing vessel capacity, congestion point and average occupancy for route 2157.

Journey time for route 1801 from Stockholm (Strömkajen) to Gruvbryggan (the major stop on Utö) was 3 hours and 45 minutes. Journey time for route 1975 from Strömkajen to Utö (Gruvbryggan) was 3 hours and 10 minutes. Journey time for the intermodal route from Nybroplan via Västerhaninge to Utö (Gruvbryggan) with metro, commuter train, bus and boat (route 2157) was about 2 hours and 5 minutes.

Energy consumption per person for the entire journey utilising route 1801 from Stockholm (Strömkajen) to Utö (Gruvbryggan) was 80 kWh. Energy consumption per person for the entire journey with the alternative route 1975, which has fewer stops, is calculated to 189 kWh. Energy consumption per person for the entire journey on the alternative intermodal route is calculated to 14 kWh. This means that the alternative route 1975 doubles the energy consumption per person, while the intermodal route 2157 reduces the energy consumption to approximately one-eighth, see figure 100. Route 1801 emits 18, 9 kg CO_2 per passenger for the whole journey. The faster alternative, route 1975, emits 44, 6 kg CO_2 per passenger for the whole journey. Tables 17 through 21 show possible reductions in CO2 emissions and travel time per passage and annually.

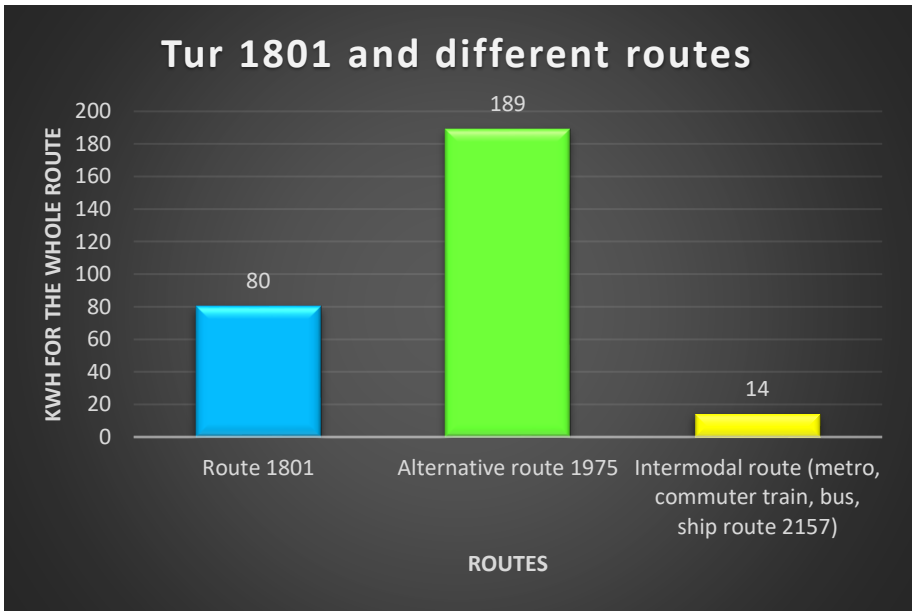


Figure 100. Bar graph comparing the energy consumption of route 1801 with the alternative routes 1975 and 2157. Results show that the alternative, intermodal route 2157, has a significantly lower energy consumption, than the other two routes.

Table 17. The table identifies the numbers used for calculating the energy consumption and CO_2-emmissions for route 1801.

Tour 1801 from Stockholm (Strömkajen) to Utö passing east of Ornö		
Trip length (km)	83,7 km	
Sailing time (h)	4,08 h	
Fuel consumption	148 l/h (Saxaren)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption (kWh)	H*l/h*kWh/l	5 887 kWh
Weighted occupancy	70 passengers (Excel)	
Passenger kilometres (pkm)	6 138 pkm (Excel)	
Energy consumption per passenger kilometre	kWh/pkm	0,96 kWh/pkm
Energy consumption per passenger for whole trip	(kWh/pkm)*km	80,4 kwh/p
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	18 kg CO2/p
Calculated CO2 emission per passenger diesel MK1 (20 %)	kWh/p*40*0,2	1 kg CO2/p
Total CO2 emission per passenger		19 kg CO2/p
Travel time Strömkajen-Gruvbryggan (Utö)	3, 75 h	

Table 18. The table identifies the numbers used for calculating the energy consumption and CO_2-emmissions for route 1975.

Tour 1975 from Stockholm (Strömkajen) to Utö passing west of Ornö		
Trip length (km)	70,8 km	
Sailing time (h)	3,42 h	
Fuel consumption	142 l/h (Mysing)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption (kWh)	H*l/h*kWh/l	4 735 kWh
Weighted occupancy	24,4 passengers (Excel)	
Passenger kilometres (pkm)	1 769 pkm (Excel)	
Energy consumption per passenger kilometre	Energiförbrukning/pkm	2,67 kWh/pkm
Energy consumption per passenger for whole trip	(Energiförbrukning/pkm)*km	189,0 kWh/p
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	43 kg CO2/p
Calculated CO2 emission per passenger diesel MK1 (20 %)	kWh/p*40*0,2	2 kg CO2/p
Total CO2 emission per passenger		45 kg CO2/p

Travel time Strömkajen-Gruvbryggan (Utö)	3,2 h	

Table 19. The table identifies the numbers used for calculating the energy consumption and CO_2-emmissions for the alternative intermodal route.

Alternativ route with subway, commuter train, bus and ferry from Årsta jetty to Utö		
Distance by subway	1 km	
Energy consumption per passenger kilometer with subway	0,108 kWh/pkm (TF Miljöredovisning 2016)	
Energy consumption per passenger with subway	kWh/pkm*km	0,108 kWh/p
Distance by commuter train	27 km	
Energy consumption per passenger kilometer with commuter train	0,108 kWh/pkm (TF Miljöredovisning 2016)	
Energy consumption per passenger with commuter train	kWh/pkm*km	2,916 kWh/p
Distance by bus	8,3 km	
Energy consumption per passenger kilometer with bus	0,374 kWh/pkm (TF Miljöredovisning 2016)	
Energy consumption per passenger with bus	kWh/pkm*km	3,104 kWh/p
Tur 2157 by boat from Årsta jetty to Utö		
Trip length (km)	19,5 km	
Sailing time (h)	0,83 h	
Fuel consumption	109 l/h (Silverpilen)	
Energy content (kWh/l)	9,75 kWh/liter (OKQ8)	
Energy consumption (kWh)	H*l/h*kWh/l	882,1 kWh
Weighted occupancy	109 passengers (Excel)	
Passenger kilometres (pkm)	2 208 pkm (Excel)	
Energy consumption per passenger kilometre	kWh/pkm	0,40 kWh/pkm
Energy consumption per passenger for whole trip	(kWh/pkm)*km	7,8 kWh/p
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content diesel HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh*285*0,8	2 kg CO2/p

Calculated CO2 emission per passenger diesel MK1 (20 %)	kWh*40*0,2	0 kg CO2/p
Total CO2 emission per passenger		2 kg CO2/p
Travel time Strömkajen-Gruvbryggan (Utö)	Subway Östermalmstorg-Centralen Commuter train Stockholms central-Västerhaninge Bus Västerhaninge-Årsta Boat Årsta-Gruvbryggan (Utö)	2,1 h
Energy consumption per person from Nybroplan to Utö by subway, commuter train, bus and boat	T-bana+pendeltåg+buss+båt	13,9 kWh/p

Table 20. The table show the calculated reduction in energy consumption and travel time/passenger between tour 1975 and intermodal trip

Reduction of energy consumption and travel time/passenger between tour 1975 and intermodal trip		
kWh reduction/passage		181 kWh/p
kWh reduction/year	16 annual passages	2 896 kWh
Reduction of CO2 by boat/passage		43 kg CO2/p
Reduction of CO2 by boat/year		688 kg CO2/p
Reduction of travel time/passage		1,1 h/passage
Reduction of travel time/year		17,6 h

Table 21. The table show the calculated reduction in CO_2-emmissions/ vessel between tour 1975 and intermodal trip.

Reduction CO2 by ship passenger between tour 1975 and intermodal trip		
kWh reduction/passage		3853 kWh
kWh reduction/year	16 annual passages	61 648 kWh
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content diesel HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per ship diesel MK1 (80 %)	kWh*285*0,8	14 056 kg CO2
Calculated CO2 emission per ship diesel MK1 (20 %)	kWh*40*0,2	493 kg CO2
Total reduction CO2/year		14 549 kg CO2

Knowledge through ADAPT

The model shows how you can compare different alternative routes. The intermodal route including metro, commuter train, bus and boat appears to be the most efficient way to travel considering energy consumption per person. The alternative route 1975 indicates high-energy consumption and carbon dioxide emissions per person.

Travel time differs a lot between the routes. The intermodal route is the fastest and takes about 2 hours and 5 minutes. Route 1801 is the slowest and takes 3 hours and 45 minutes.

4.26 Corridor 23: Dalarö – Ornö

Several safety issues were found in corridor 23. General safety improvements for the extent of the corridor are notified in the Swedish NtM:s 11236, 11238, 11239, 11820 and 12779. North of Stora Gryt the 3-metre navigational curve do not cover the shoal correctly, the line suggests that it finishes further inland than it actually does, see figure 101. This was notified in the Swedish NtM 11132. Proposed adjustment is limiting lines and correct positioning of the shoals to facilitate a safe passage for vessel traffic. The actions impacts the navigational safety and environmental protection positively.

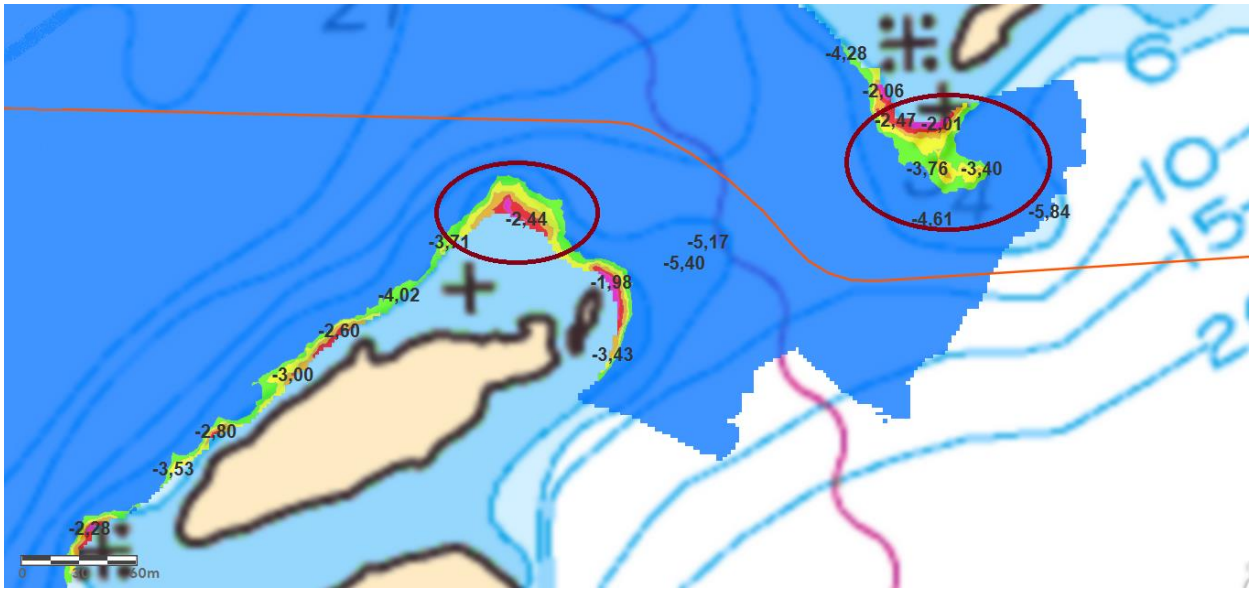


Figure 101. Circled shoals located in the passage North of Stora Gryt.

The passage between Aspön and Korsholmen contains shallower locations than previously known and that is presented in the navigational charts, see figure 102. This was notified in the Swedish NtM 11185. Proposed adjustment are additional limiting lines and correct positioning of the shoals. The actions impact the navigational safety and environmental protection positively.

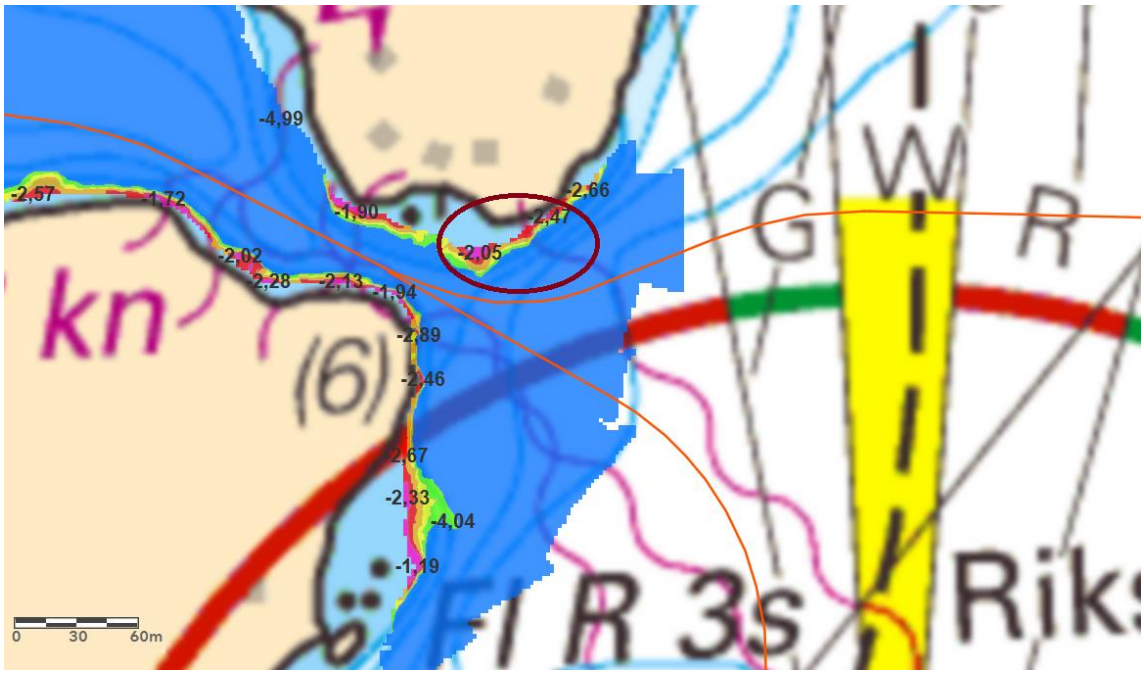


Figure 102. Circled shoal at the outlet between Korsholmen and Aspö.

The vessels passing through Björkösund has a draft of 3.5 metres. The hydrographic survey shows that the passage is narrow, see figure 103. The proposed adjustment are additional limiting lines and correct positioning of the shoals. The actions impact the navigational safety and environmental protection positively.

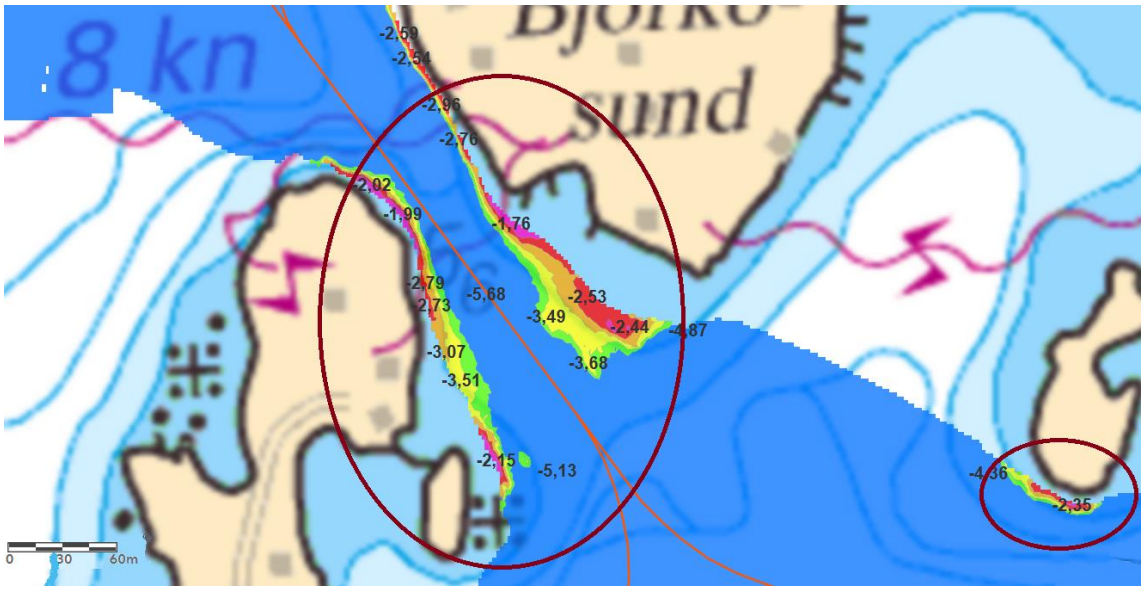


Figure 103. The passage of Björkösund was found to be narrower than previously known.

4.26.1 Node 8

Depths around Lättinge jetty was found to be shallower than the navigational chart suggests, see figure 104. The difference in depth and the draft of the vessels utilizing the jetty is small for completely safe navigation. Proposed adjustment are additional limiting lines and correct positioning of the shoals. The actions impacts the navigational safety and environmental protection positively.

Figure 104. Circled shoals found outside of the jetty of Lättinge.

4.27 Corridor 24: Årsta – Utö

The changes following the Swedish NtM 11101 raises the safety level of the corridor. Corridor 24 contains two safety issues. Firstly, an underwater rock was found between the buoys at Utö Kyrkviken, see figure 105. This causes confusion of where to navigate even if the depth is found to be deep enough for a safe passage. The proposed solution to this is to remove the symbol in the navigational chart, only showing the depth at this location. Additional limiting lines will also help achieving a safe passage. The actions impact the navigational safety and environmental protection positively.

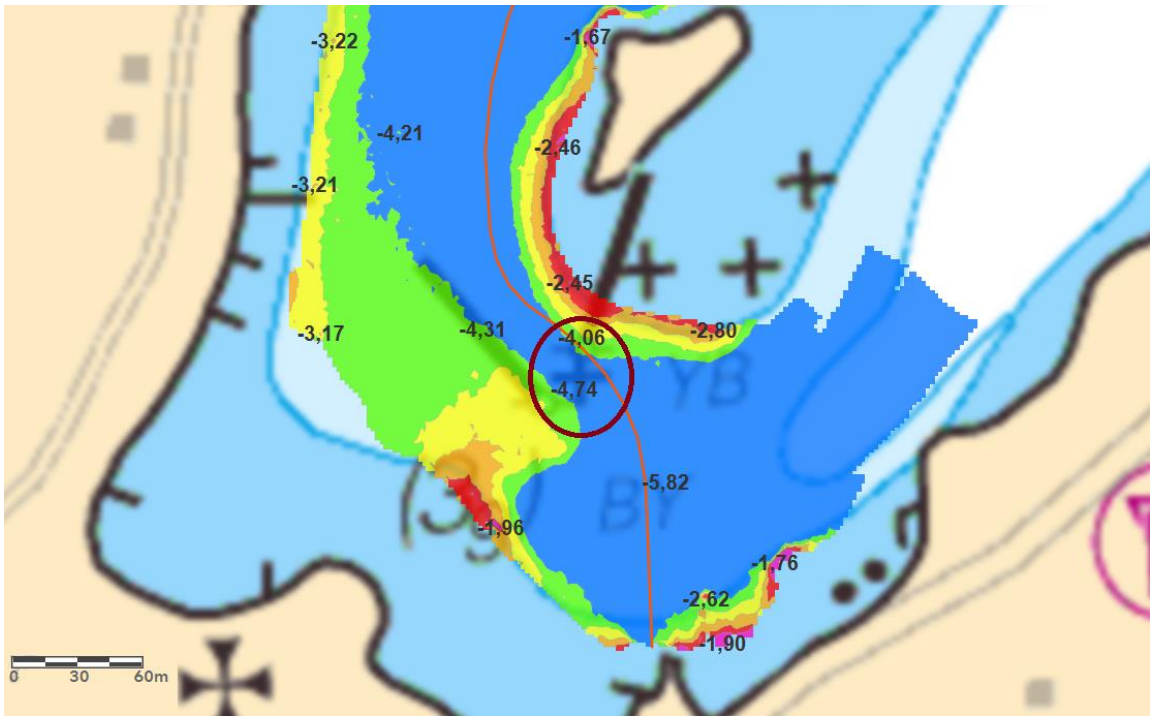


Figure 105. Circled underwater rock between buoys at Utö Kyrkviken.

Secondly, a 3-metre depth was found outside of the 6-metre curve in the navigational chart, see figure 106. This was notified to mariners in the Swedish NtM 11104. Proposed adjustment is adding a limiting line to help the passing traffic to avoid the shoal and reach a higher safety for the passage. Correct positioning of the shoals are also proposed. The actions impact the navigational safety and environmental protection positively.

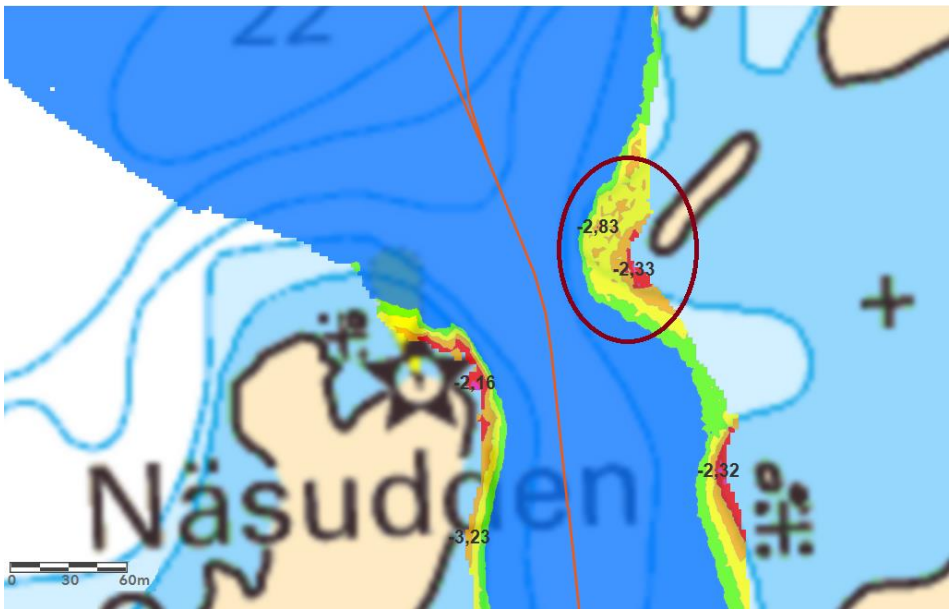


Figure 106. Circled shoal, causing a narrower outlet north of Näsudden.

4.28 Corridor 25: Nynäshamn – Ålö (22)

Corridor 25 contain multiple safety issues. At Örnäsudden a shoal measuring 3.39 metres was found further out than the buoy and 6-metre curve in the navigational chart suggests, see figure 107. This was notified in the Swedish NtM 12485. Limiting lines and correct positioning of the shoals are proposed. The actions impact the navigational safety and environmental protection positively.

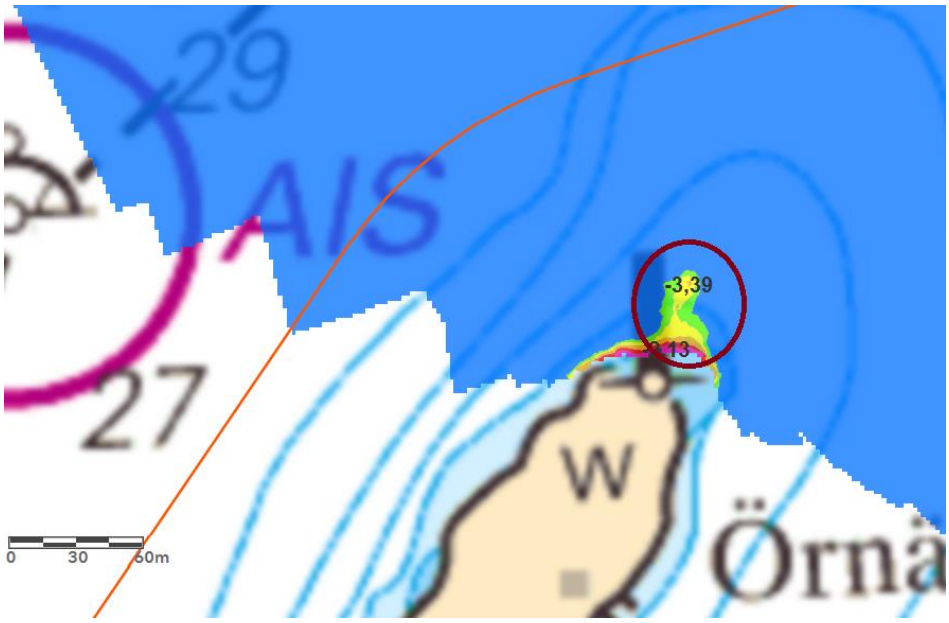


Figure 107. The circled shoal, located north of Örnäsudden, is found further out than the buoy and sea chart suggests.

The area between Bedarön and Norra Stegholmen was shallower and slimmer than known, see figure 108. This was notified in the Swedish NtM 12415. Proposed action is an adjustment of existing buoy and establishment of

an additional buoy, additional limiting lines and correct positioning of the shoals. The actions impacts the navigational safety and environmental protection positively.

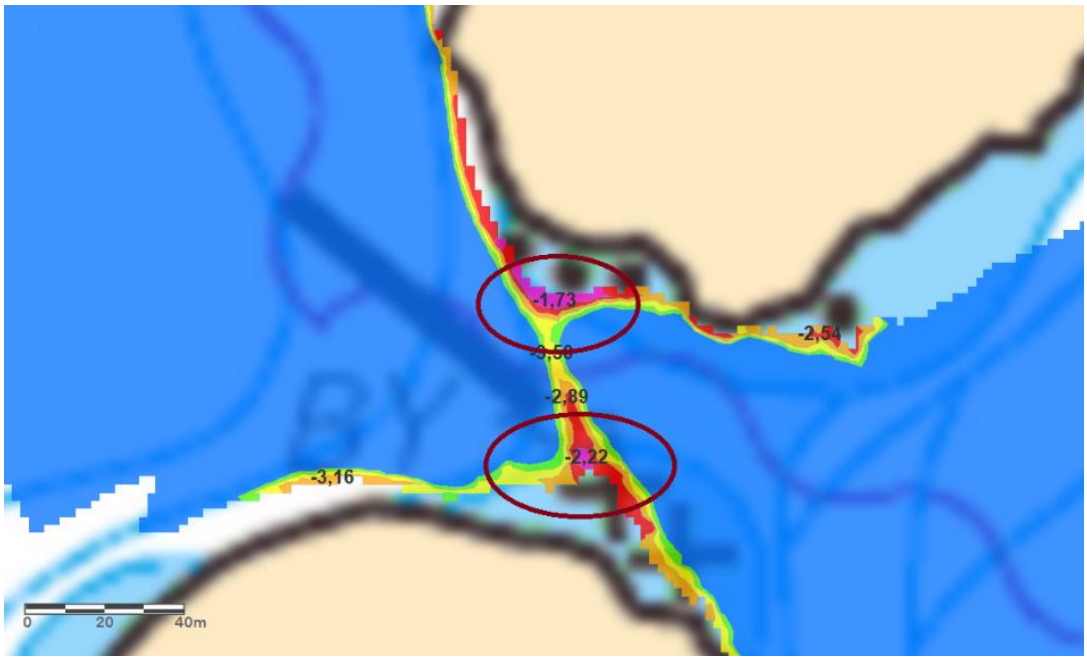


Figure 108. The circled shoals narrowing the passage between Bedarön and Norra Stegholmen.

Next to Finnhällorna a shoal measuring 1.75 metres was found further out than the 3-metre curve in the navigational chart suggests, see figure 109. Proposed adjustment is to add limiting lines.

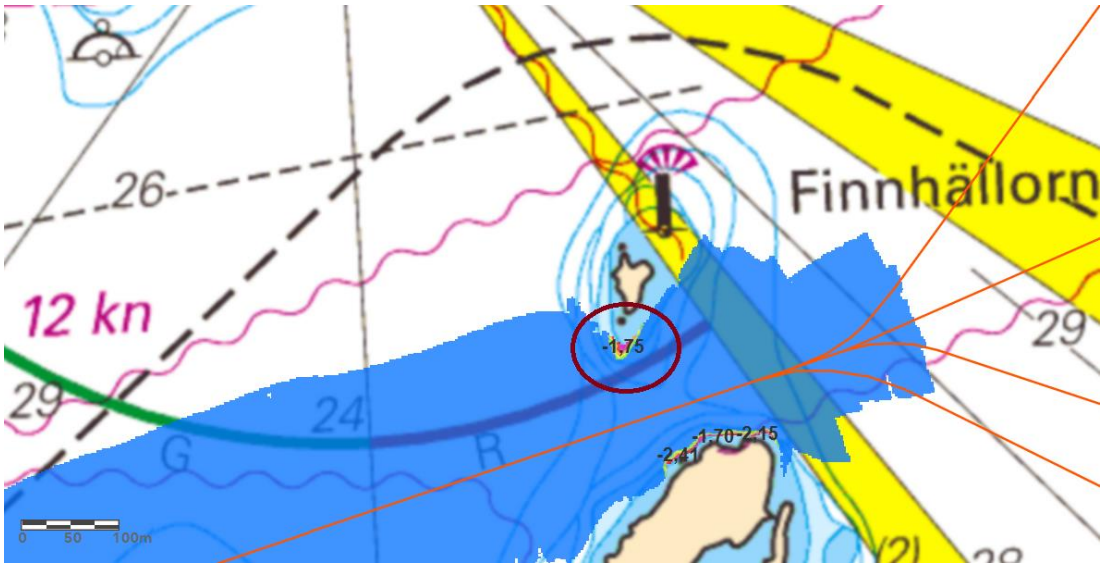


Figure 109. Circled shoal close to Finnhällorna, causing a safety issue for the passing vessel traffic.

Along the passage of Kapellsundet multiple shoals where found, see figure 110. Two of these need to be considered carefully, as they are located at the turning point for the Norrö jetty. This was notified in the Swedish NtM 12446. To secure the traffic operating the passage limiting lines and correct positioning of the shoals are proposed to raise the safety level. The actions impacts the navigational safety and environmental protection positively.

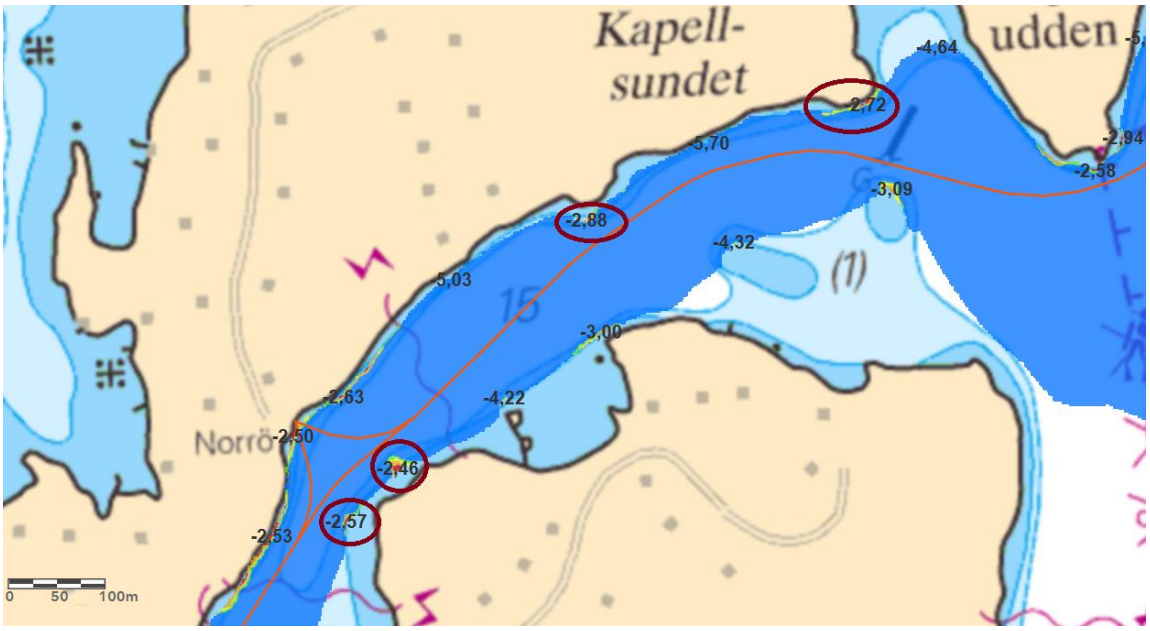


Figure 110. The shallow passage through Kapellsundet, with the located shoals circled.

At the turning point towards Norrö jetty two shoals measuring approximately 2.5 metres were found outside of the 6-metre curve in the navigational chart, see figure 111. Proposed adjustment is to add limiting lines and correct positioning of the shoals to ensure safe navigation. The actions impact the navigational safety and environmental protection positively.

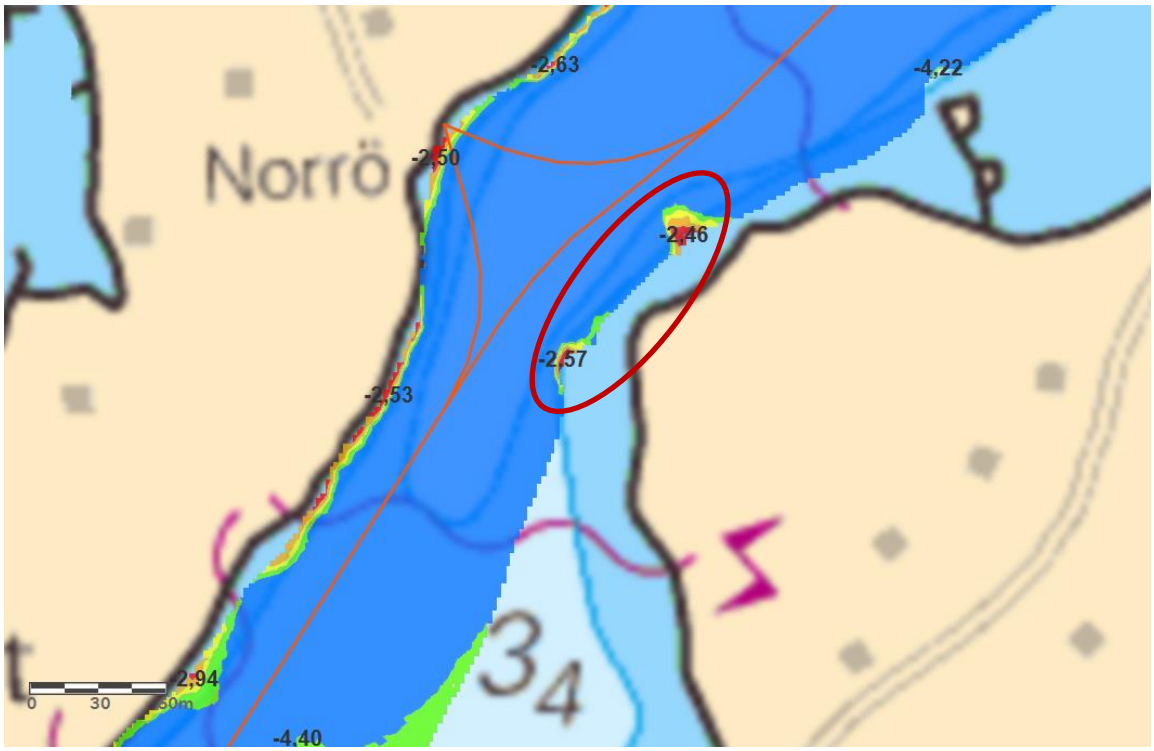


Figure 111. The shoals (circled) opposite the Norrö jetty causing a safety risk for the turning process.

4.29 Corridor 26:

In corridor 26, no hydrographical survey was carried out during the project.

4.30 Corridor 27: Ankarudden - Landsort (29)

In corridor 27 two safety issues were found. East of Norrudden a major security risk was found, caused by an unknown shoal measuring 3.57 metres at 10-metre waters according to the navigational chart, see figure 112. The shoal was located in the fairway of the traffic operating the route and the proposal is to reroute it accordingly. This was notified in the Swedish NtM 11110. Additional limiting lines and correct positioning of the shoals are proposed. The actions impacts the navigational safety and environmental protection positively.

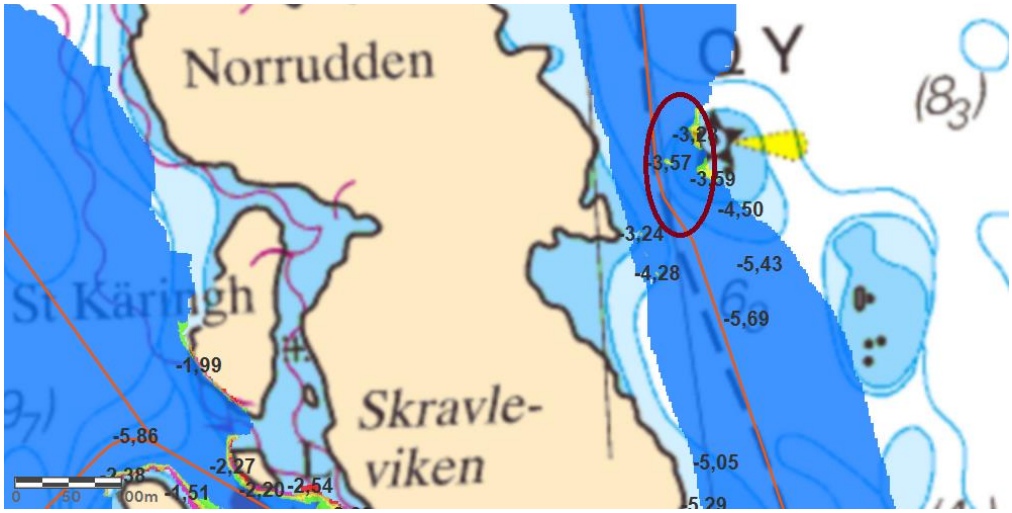


Figure 112. The shoal found at 10-metre deep water according to the navigational chart is circled in the figure. The shoal is situated East of Öja and Norrudden.

The second safety issue was found west of Krokskär. A shoal measuring 2.42 metres was found further out than the 3-metre curve in the navigational chart suggests, see figure 113. This was notified in the Swedish NtM 11875. Additional limiting lines and correct positioning of the shoals are proposed. The actions impact the navigational safety and environmental protection positively.

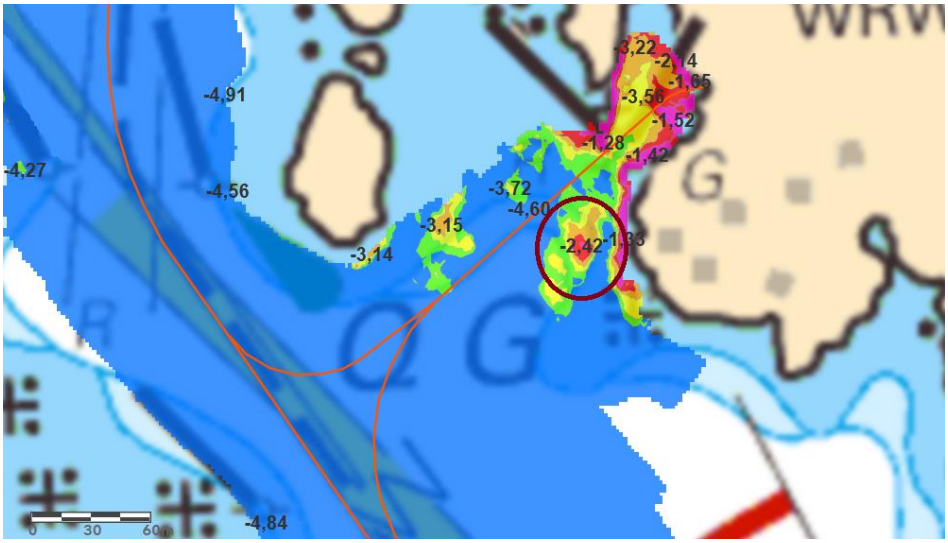


Figure 113. circled shoal at the inlet to the jetty at West Krokskär.

4.31 Corridor 28: Godslinje 3 (Goods route 3)

This corridor mainly transports goods and it intertwines with many of the other corridors. In the analysis of corridor 28, only the parts that are not shared with other corridors were studied. Multiple safety risks were found in the hydrographical survey data. Shoals measuring less than 3 metres were found further out than the the navigational chart suggests, see figure 114. Proposed adjustments are limiting lines clearly marking the edge of the passage containing the shoals, together with correct positioning of the shoals. The actions impacts the navigational safety and environmental protection positively.

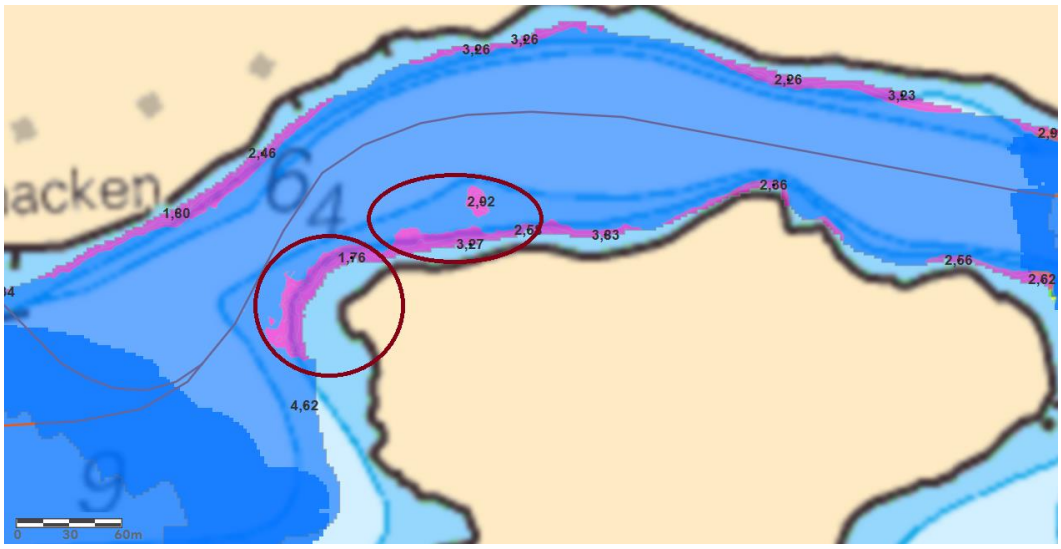


Figure 114. Circled shoals at Lådnamacken, are further out than the navigational chart suggests.

At Västra Tistronskäret two shoals were found causing a safety risk, see figure 115. Proposed adjustment is the addition of limiting lines and correct positioning of the shoals to secure a safe passage for the vessel traffic operating the route. The actions impacts the navigational safety and environmental protection positively.

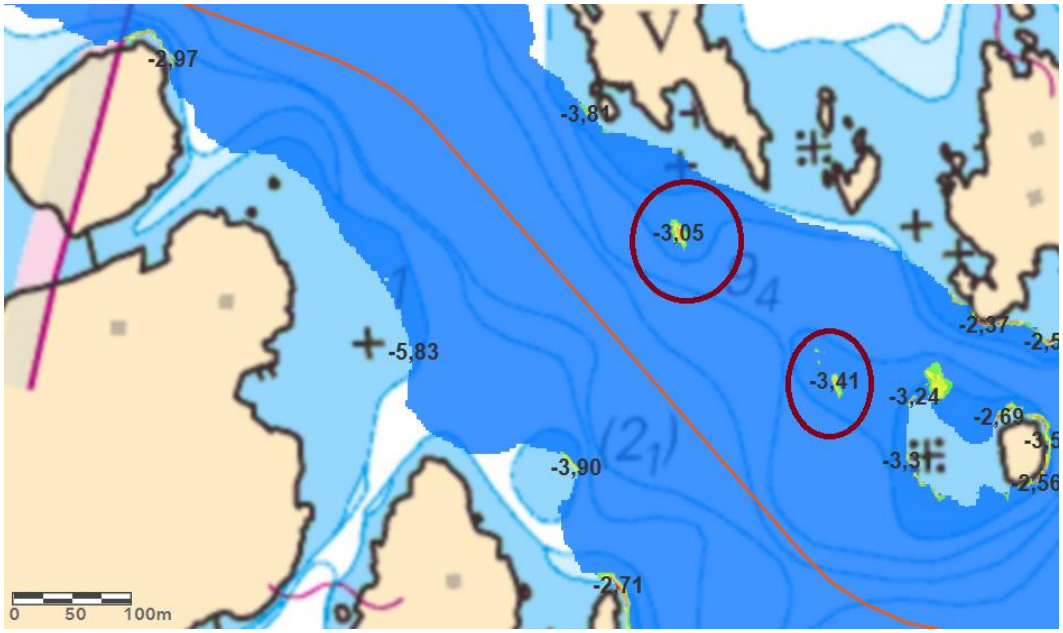


Figure 115. Circled shoals causing a safety risk in the passing of Västra Tistronskäret.

Between Träskö and Korsholmen shoals were found causing a security risk, see figure 116. This was notified in the Swedish NtM 12036. Proposed adjustment are addition of limiting lines and correct positioning of the shoals to secure a safe passage for the vessel traffic operating the route. The actions impacts the navigational safety and environmental protection positively.

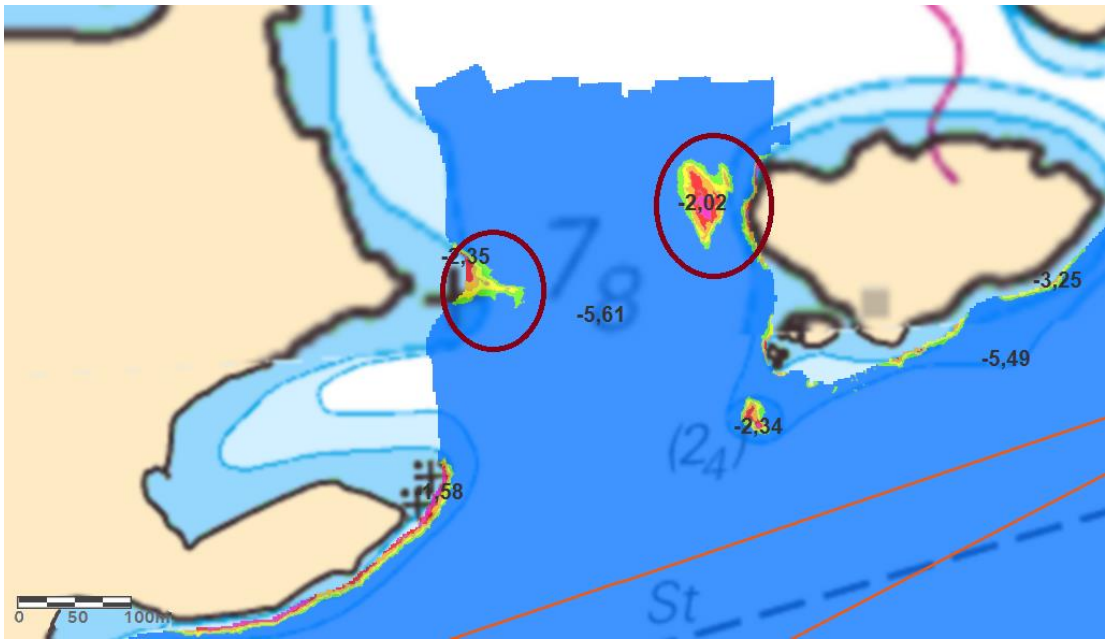


Figure 116. Circled shoals between Träskö and Korsholmen.

4.32 Corridor 29: Husaröleden

Two shoals were found in corridor 29, see figure 117. This was issued in the preliminary Swedish NtM 12518. The passage was, previous to ADAPT, known to be slim, and the studies of the hydrographical surveys corroborated this with the finding of the two new shoals. Proposed adjustment is addition of limiting lines and correct positioning of the shoals to secure a safe passage for the vessel traffic operating the route. The actions impacts the navigational safety and environmental protection positively.

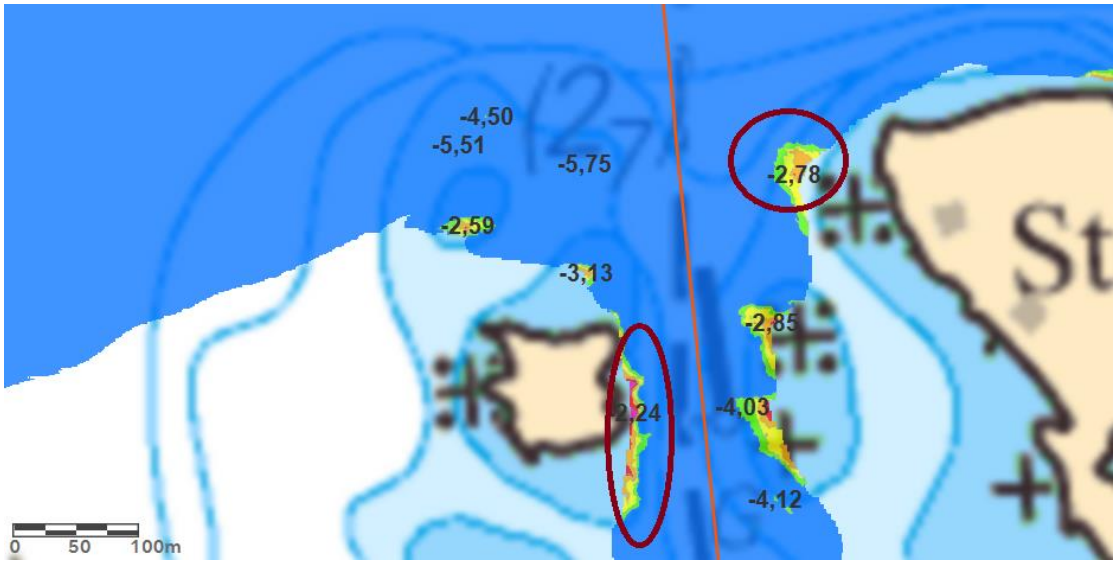


Figure 117. Shoals found alongside the passage of Husaröleden, causing a safety risk are circled in the figure.

4.33 Corridor 30

Proposing a developed support route to corridor 16, between Tjärstören and Gåsö, see figure 118. Additional limiting lines and correct positioning of the shoals are proposed. The actions impact the navigational safety and environmental protection positively.

Figure 118. Circled shoals found along the proposed developed route in Tjärstörsleden. Proposed route in yellow.

The proposed sheltered route impacts the travel time positively as well as navigational safety and environmental protection. Proposed route is approximately 7.5 percent shorter than original route from Norröra to Gräskö (7 020 metres compared to 7 590 metres). Table 22 below show possible CO_2-reductions.

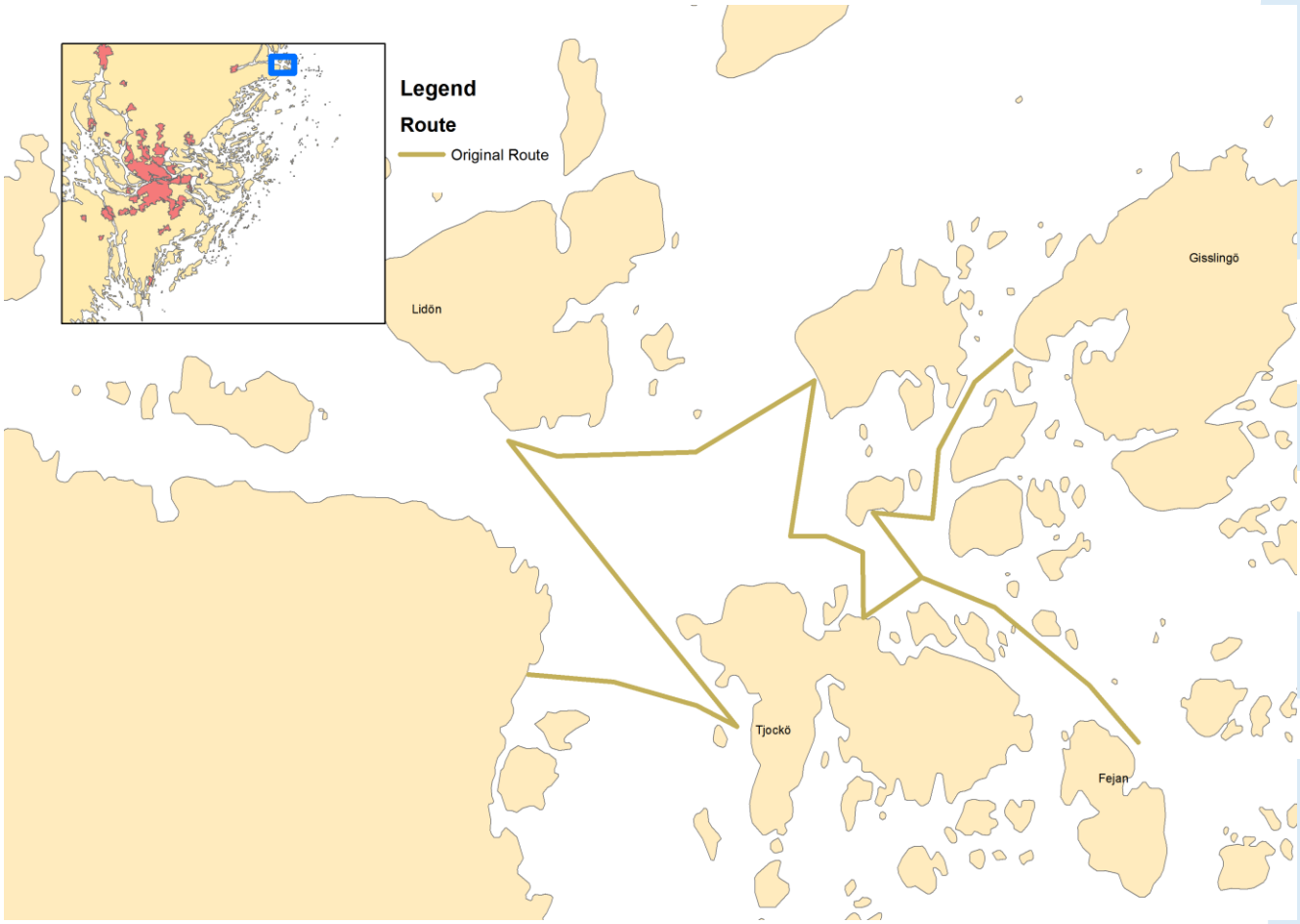
Table 22. Possible CO_2-reductions per passage and per year utilising the proposed route.

Possible improvements with new route		
Distance reduction (M)	0,31 nautical miles	
Sailing time (h)	0,03 hours@11 knots	
Fuel consumption (l/h)	100 litres/hour (Yxlan)	
Energy content (kWh/l)	9,75 kWh/litres (OKQ8)	
Energi consuption (kWh)	Tfs*fuel consumption*energy content	29,25 kWh
CO2 content Diesel MK1 (g CO2ekv/kWh)	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO2ekv/kWh)	40 g/kWh (Energimyndigheten)	
80 percent diesel MK1	(0,8*29,25*285)/1000	6,7 kg CO2
20 percent HVO	(0,2*29,25*40)/1000	0,2 kg CO2
Calculated CO2 reduction/passage		6,9 kg CO2
Annual passages	1131	
Calculated CO2 reduction/year	6,9*1131	7 804 kg CO2

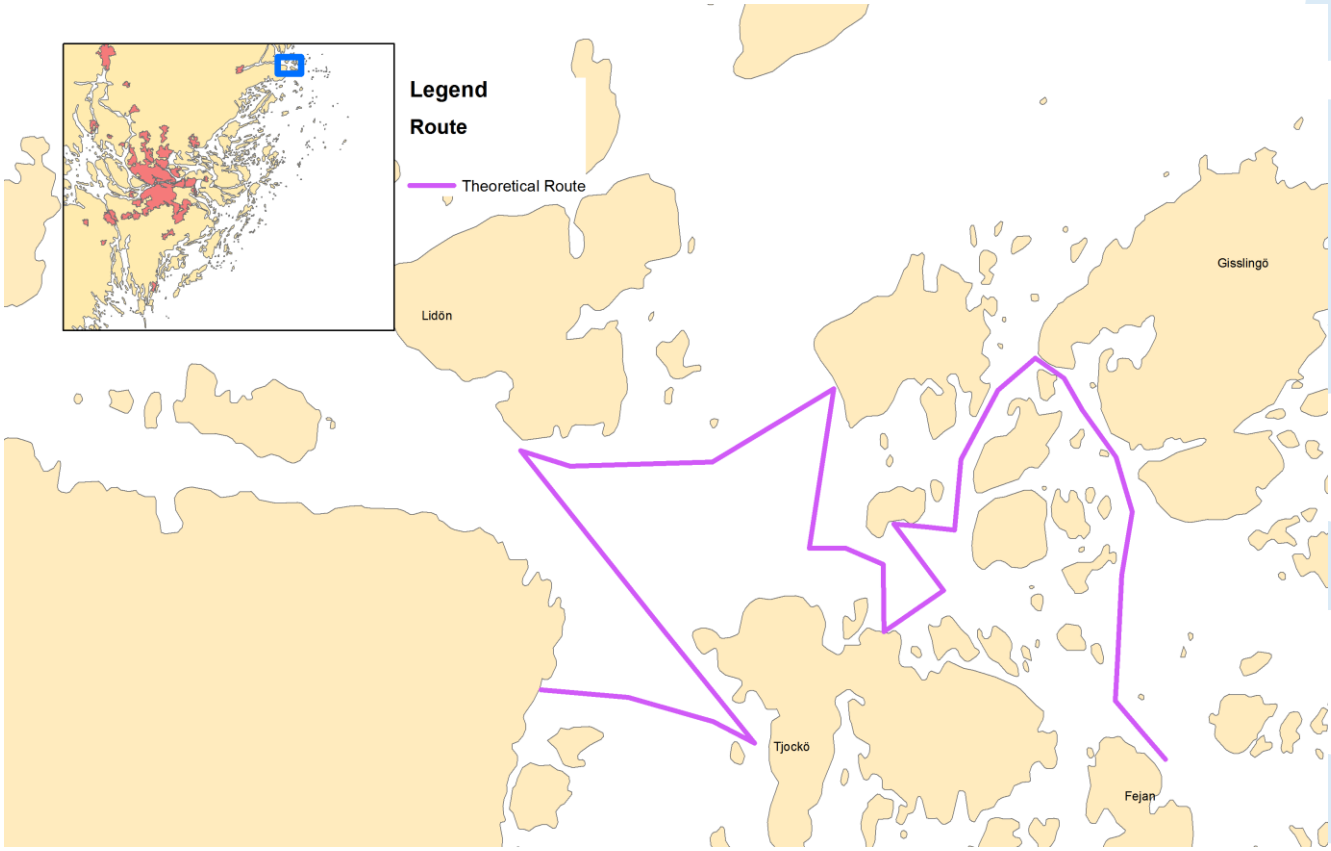
4.34 Baseline analysis of route 3107 Räfsnäs – Fejan (Corridor 31)

A route development was found to reduce travel time is proposed between Gisslingö and Fejan. Originally the route has an arm where the ferries need to go back and forward during the journey to reach Gisslingö, see the original route in figure 119. Through the survey analysis, the possibility for a circular route extent was found,

where the ferries do not need to travel the same route section twice, see figure 120. The developed route shortens the travel time substantially.



119. Map of the northern part of Waxholmsbolagets' operating area. The extent of the original route is mapped and the current route area is marked in the top left corner.



120. Map over the theoretically developed circular route extent. The surveys showed possibilities to travel via Gisslingö to Fejan directly. Current route area is marked in the top left corner.

Route 3107 runs Monday to Thursday midmorning during the summer timetable from Räfsnäs to Fejan in route area 31 (corridor 18). During the summer of 2015, route 2015 was operated by the vessel *Romina,* whose maximum passenger capacity is 100 passengers. Romina has 50 seats and it is the congestion point. The vessel carried an average of approximately 10–20 passengers during the whole journey, see figure 121. Thus, congestion did not occur during the analysis period. The travellers mainly consisted of part-time residents and visitors.

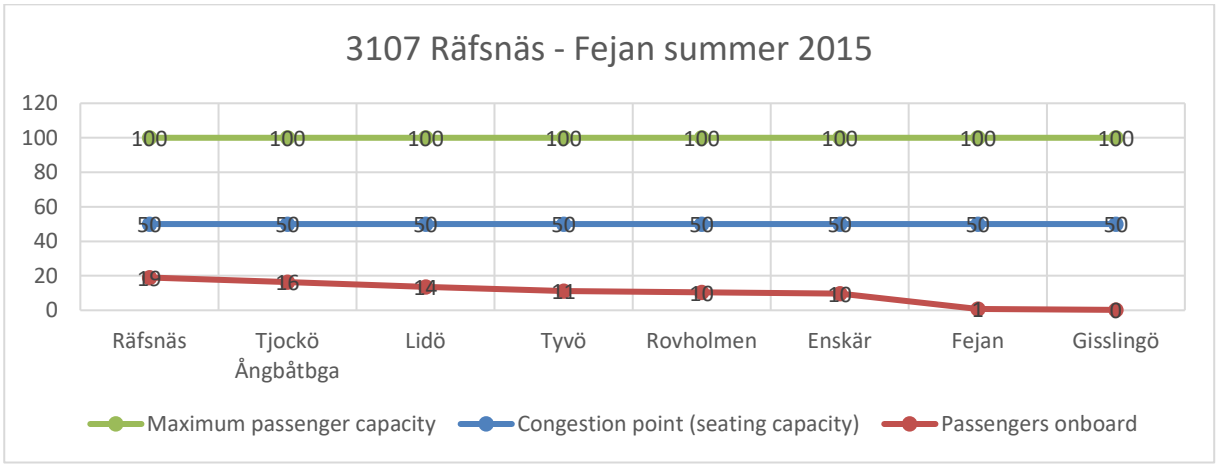


Figure 121. The diagram shows the vessel capacity, congestion point and average occupancy for route 3107.

The comparison in based on the original route from Räfsnäs to Fejan and via Gisslingö on an ineffective subseciton, and the developed circle route via Gisslingö to Fejan, see table 23. This development is possible because of the collected survey material within the project.

Table 23. The table list the original and theoretically developed route used in the baseline comparison.

Object of comparison	**Route**
Route 3107	Räfsnäs – Fejan
Theoretical, circular route	Räfsnäs – Gisslingö – Fejan

Travel time for route 3107 from Räfsnäs via Gisslingö to Fejan was 55 minutes. With return the total travel time is 1 hour and 50 minutes. The developed circular alternative route has a total travel time of 1 hour and 25 minutes with return. Energy consumption per person for the entire journey on route 3107 from Räfsnäs to Fejan was 50 kWh, see table 24. The energy consumption per person for the entire journey on the alternative theoretical route is calculated to 15 kWh, see table 25. This developed circular route is calculated to decrease energy consumption per person considerably, see figure 122. Every passenger utilising the original route 3107 is calculated to emit 22 kg CO_2 per journey, see table 24, while the alternative route is estimated to emit 3 kg CO_2 per person, see table 25.

Table 24. Calculated energy consumption for the original route Räfsnäs – Gisslingö – Fejan.

Route 3107 Räfsnäs - Gisslingö - Fejan		
Trip length (km)	18 km	
Sailing time (h)	0,92 h	
Fuel consumption (l/h)	60 l/h (Romina)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption (kWh)	h*l/h*kWh/l	994 kWh
Weighted occupancy	10,61 passengers (Excel)	
Passenger kilometres (pkm)	194 pkm (Excel)	
Energy consumption per passenger kilometre	kWh/pkm	5 kWh/pkm
Energy consumption per passenger for whole trip	(kWh/pkm)*km	90 kWh/p
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content diesel HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	21 kg CO2/p
Calculated CO2 emission per passenger diesel MK1 (20 %)	kWh/p*40*0,2	1 kg CO2/p
Total CO2 emission per passenger		22 kg CO2/p

Table 25. The calculations of energy consumption for the theoretical circular route.

Theoretical route Räfsnäs - Gisslingö - Fejan		
Trip length (km)	13,3 km	
Sailing time (h)	0,37 h	
Fuel consumption	60 l/h (Romina)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	

Energy consumption (kWh)	h*l/h*kWh/l	216 kWh
Weighted occupancy	10,61 passagerare (Excel)	
Passenger kilometres (pkm)	194 pkm (Excel)	
Energy consumption per passenger kilometre	kWh/pkm	1 kWh/pkm
Energy consumption per passenger for whole trip	(kWh/pkm)*km	13 kwh/p
CO2 content diesel MK1 (g CO2 ekv/kWh	285 g/kWh (Energimyndigheten)	
CO2 content diesel HVO (g CO2 ekv/kWh	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission per passenger diesel MK1 (80 %)	kWh/p*285*0,8	3 kg CO2/p
Calculated CO2 emission per passenger diesel MK1 (20 %)	kWh/p*40*0,2	0 kg CO2/p
Total CO2 emission per passenger		3 kg CO2/p

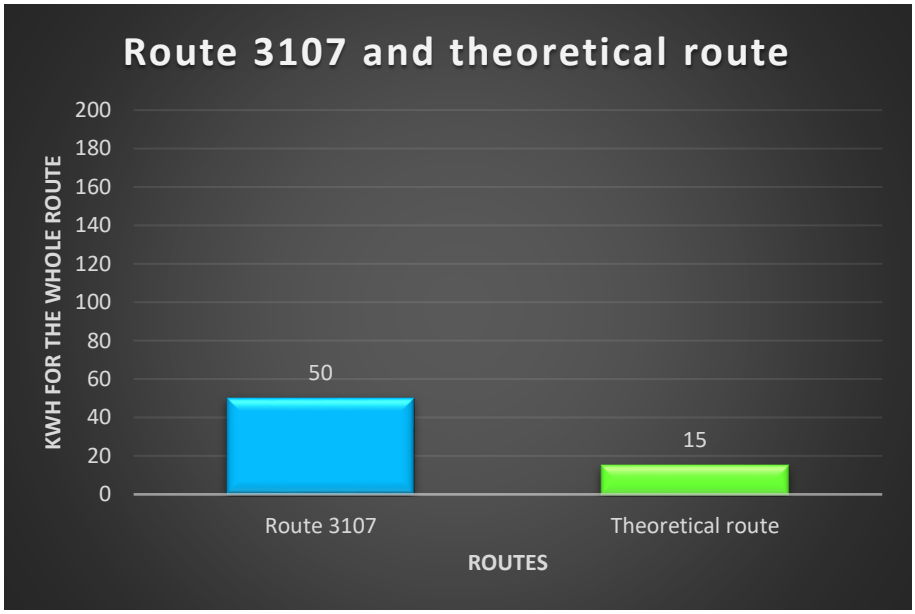


Figure 122. The graph is comparing the energy consumption for route 3107 with the developed circular route.

Tables 26 and 27 below show calculation for CO2 per passenger and by vessel per trip and annually.

Table 26. The table show the reduction in travel time and CO_2-emissions per person utilizing the theoretically developed route, compared to the original route 3107.

CO2 reduction per passenger with developed route		
CO2 reduction/passage		21 kg CO2/passage
CO2 reduction/year	345 annual passages	7 245 kg CO2
Reduction of travel time/passage		0,55 h/passage
Reduction of travel time/year		190 h

Table 27. The table show the CO_2 reduction per vessel utilizing the theoretically developed route, compared to the original route 3107.

CO2 reduction by vessel with developed route		
Reduction in sailing time (h)	0,55 h	
Fuel consumption (l/h)	60 l/h (Romina)	
Energy content (kWh/l)	9,75 kWh/l (OKQ8)	
Energy consumption	h*l/h*kWh/l	322 kWh
Co2 content diesel MK1 (g CO2ekv/kWh)	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO2 ekv/kWh)	40 g/kWh (Energimyndigheten)	
Calculated CO2 emission diesel MK1 (80 %)	kWh*285*0,8	73 kg CO2
Calculated CO2 emission HVO (20 %)	kWh*40*0,2	3 kg CO2
Calculated CO2 emission per route		76 kg CO2
Annual tours	345 annual tours	
Calculated annual reduction in CO2-emissions		26 220 kg CO2

Knowledge through ADAPT

The sea surveys within the project has made a new circular route possible instead of the current route. The improvement considering energy consumption per person for a journey to Gisslingö is substantial. A circular route reduces the total travel time with 25 minutes. The developed route is calculated to emit about 3.5 kg CO_2 per journey, which is considerably less than the current 11.8 kg emitted from the original route per journey.

4.35 Corridor 32: Developed route for the vessel *Norrskär*

Proposing a developed support route for the steamboat *Norrskär* through Vindö Strömmar. The survey showed that a development of the steamboats *Norrskär* is possible, but a few adjustments are needed to reach a sufficient safety level of the route. In the first part, a shoal was found further out than the sea chart suggests east of Djuröbron, see figure 123. Additional limiting lines and correct positioning of the shoal are proposed, see figure 123. These actions raises the navigational safety and environmental protection level.

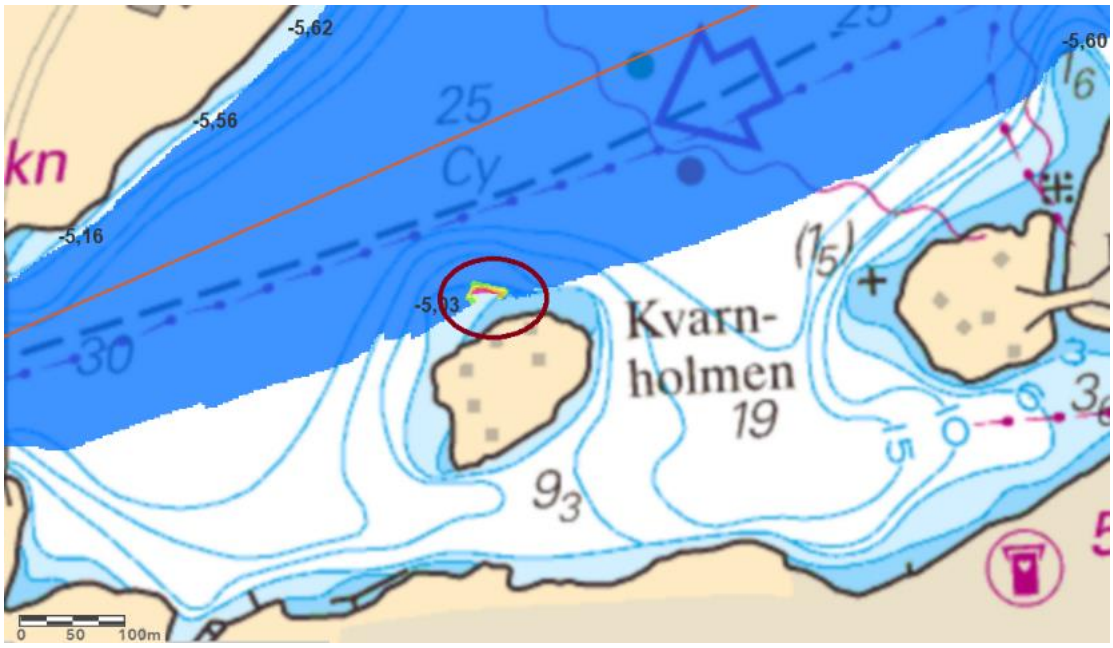


Figure 123. The circled shoal east of Djuröbron and west of Kvarnholmen.

Furthermore, a shoal discovered north of Vindö Strömmar is a situated along the developed route, it was notified in the Swedish NtM 11362, see figure 124. Additional limiting lines and correct positioning of the shoal are proposed measures. These actions raises the navigational safety and environmental protection level.

Figure 124. Circled shoal north of Vindö Strömmar and south of Aborrkroken.

Thirdly, a shoal discovered north of Tegelhällan and Stavsnäs in the developed route section, see figure 125. This was notified in the Swedish NtM 11434. Additional limiting lines and correct positioning of the shoal are proposed. The actions raises the navigational safety and environmental protection level.

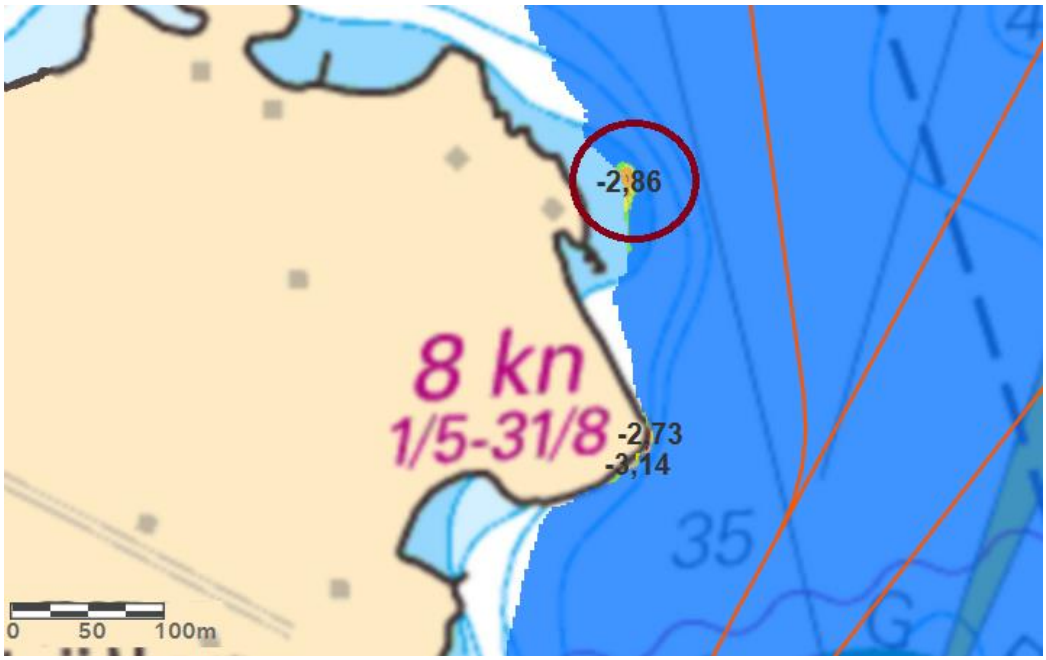


Figure 125. Circled shoal next to Stavsnäs and north of Tegelhällan in the proposed developed route.

4.36 Corridor 33: Furuklubben/ Trålhålet

In corridor 25 a development of the route was found possible, as the hydrographical surveys secured the depth in the passage through Trålhålet and Furuklubben, see figure 126. The developed corridor 33, is proposed as an alternative in adverse weather conditions, when alternative courses are needed to be taken.

Figure 126. The developed route in corridor 33, the line shown in yellow, is an alternative route for vessels operating corridor 25. The corridor was proposed as the depth through Trålhålet East of Furuklubben was secured by the hydrographical survey.

To utilize the developed route it is important that the depth curves are correctly marked in the sea charts as it is a narrow passage, see figure 127. Additional limiting lines and correct positioning of the shoals are proposed. The actions raises the navigational safety and environmental protection level, although, the impact on travel time is limited.

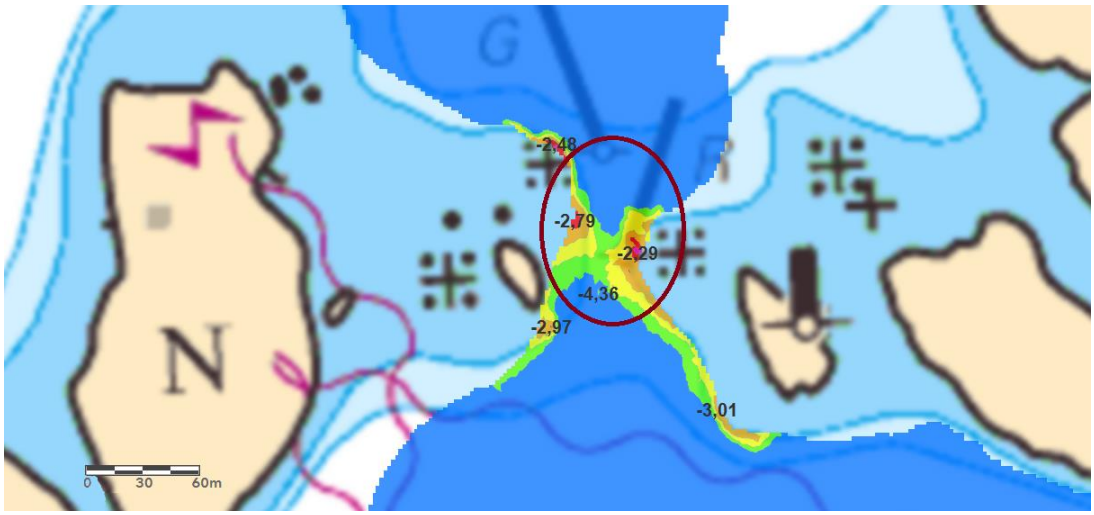


Figure 127. The hydrographical survey added detailed knowledge about the narrow passage Trålhålet, admitting the use of it in adverse weather conditions.

4.37 Corridor 34

The hydrographic survey shows multiple shoals and shallow patches in the area along the general navigation line in corridor 34. A development to the route is proposed to reach a higher safety level, see figure 128. This was notified in Swedish NtM 11542. The new route impacts the navigational safety and environmental protection. The impacts on the travel time is limited, but slightly longer. The increased safety is weighted more important than the travel time.

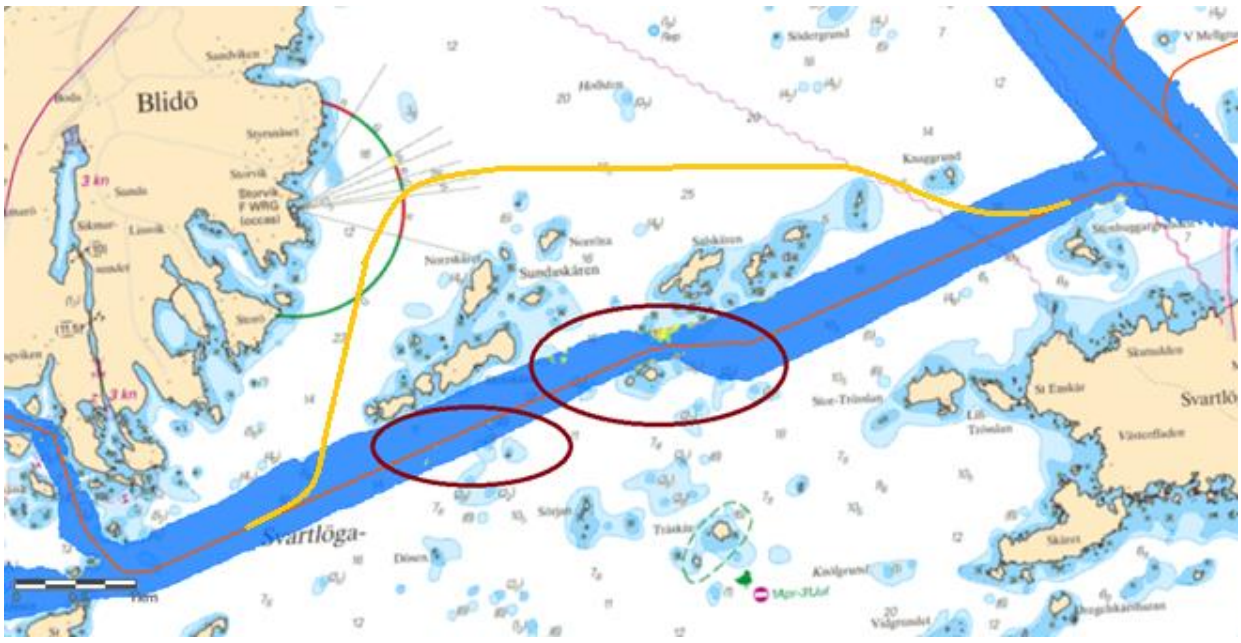


Figure 128. Circled areas contain too many shoals and shallow areas. To reach a safe navigation between south Blidö and Svartlöga a developed route is proposed and presented in yellow.

4.38 Corridor 35

Proposing a developed support route to corridor 17 (time table 30 for Waxholmsbolaget). The developed route will be a more secure alternative passage in unfavourable weather conditions. It is also an alternative for cargo shipments and other vessels with higher draft, see figure 129. Limiting lines and correct positioning of the shoals are proposed. Actions impacts the navigational safety and environmental protection positively.

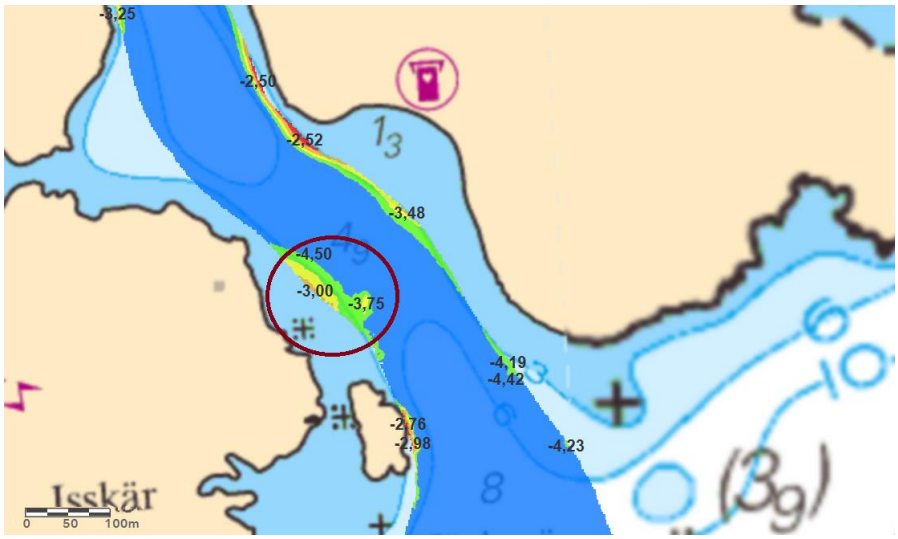


Figure 129. Circled shoals between Arholma and east Isskär in the proposed developed route to corridor 17.

4.39 Corridor 36

Proposing a developed route between Äpplarö and Norskobblarna, to save the beaches at Ingmarsö and Svartsö, where there currently has been erosion caused by the backwash of the ferry traffic, see figure 130. The new route primarily impacts the environmental protection positively, but also the residents. Impacts on the travel time is limited.

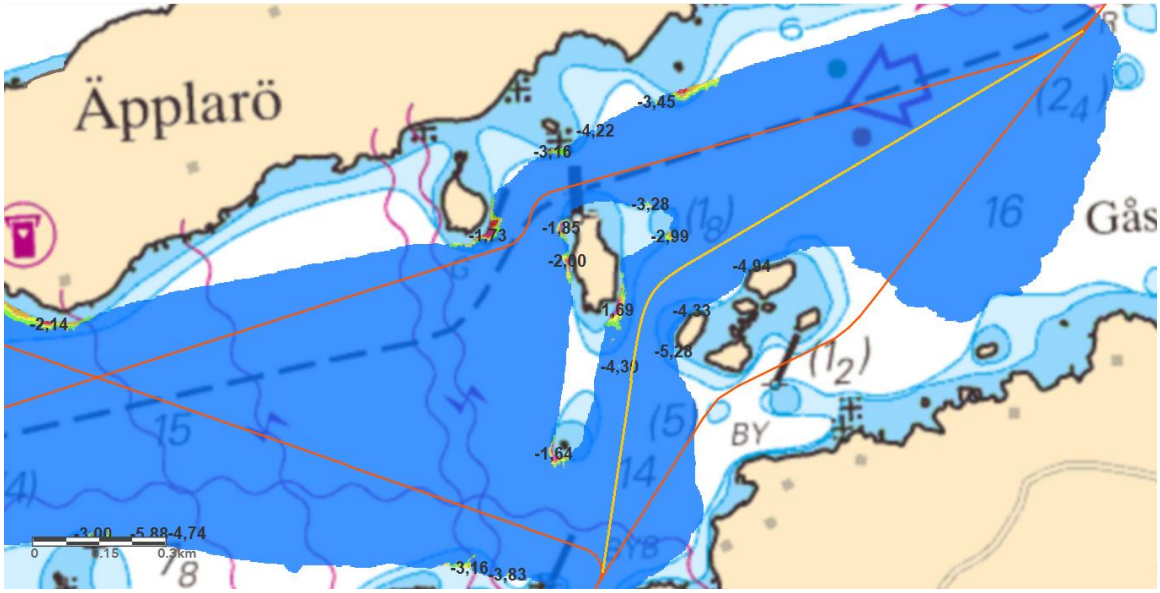


Figure 130. A developed route between Äpplarö and Norskobblarna is suggested to save the environment at Svartsö beaches from erosion caused by the waves from the ferries.

4.40 Corridor 37

A sheltered and shorter possible route was found between Norröra and Söderöra. The proposed sheltered route passes east of Dämmans Ören, as shown in figure 131. Additional limiting lines and correct positioning of the shoals are proposed. The actions impact the navigational safety and environmental protection positively.

Figure 131. Proposed sheltered route between Norröra and Söderöra, the red lines are the original route extent and the yellow line represent the developed route.

Proposed sheltered route has positive impacts on the travel time slightly, as well as the navigational safety and environmental protection. Proposed route is 20 percent shorter than the original route (2 130 metres compared to 2 670 metres). Possible CO_2 reductions are calculated to 8998 kg CO_2 per year, see table 28.

Table 28. Possible CO_2 reductions/passage with proposed route.

Possible improvements for the new route		
Distance reduction (M)	0,3 nautical miles	
Time for sailing (Tfs)	0,03 hours@11 knots	
Fuel consumption (l/h)	100 litres/hour (Yxlan)	
Energy content (kWh/l)	9,75 kWh/litres (OKQ8)	
Energi consuption (kWh)	Tfs*fuel consumption*energy content	29,25 kWh
CO2 content Diesel MK1 (g CO2ekv/kWh)	285 g/kWh (Energimyndigheten)	
CO2 content HVO (g CO2ekv/kWh)	40 g/kWh (Energimyndigheten)	
80 percent diesel MK1	(0,8*29,25*285)/1000	6,7 kg CO2
20 percent HVO	(0,2*29,25*40)/1000	0,2 kg CO2
Possible CO2 reduction/passage		6,9 kg CO2
Annual passages	1304	
Possible CO2 reduction/year		8 998 kg CO2

5. Corridors and nodes in Åland archipelago

Altogether in Åland archipelago, 8 corridors and 26 nodes has been established, listed in table 1-2. Geographic location and extent for corridor: 2756, 2810, 2845, 2860 se figure 132. Corridor Potential port are shown in figure 133. Figure 134 show the locations of corridor 2870, 2895, 2905. Some of the corridors can partly overlap geographically, but there may still be vast differences in the flow of passengers and the emissions per kilometre and person. Lists of the corridors and nodes are found in the tables 29-30. Table 29 contain information about the corridors location within the archipelago, which public transportation route the corridor connects with. Table 30 lists the nodes, with location, what corridor they belong to.

The corridors and nodes were investigated thoroughly during the analyses for identification of issues in need of attention corresponding to the aims stated in section 1. For some of the corridors and nodes multiple concerns were found. This section will present the proposals of new-, adjusted- or developed corridors- and nodes, presented with the background to the proposals. The proposals for Stockholm archipelago are shown in corridor 1 – 36 and nodes 1 – 14. These corridors has a marked (red) line for the generally suggested navigation route, the vessels trafficking the corridors might deviate from it depending on the captain and other factors such as weather conditions etc. The proposals for Åland archipelago are shown in corridor 2756 – 2905 and nodes 1 – 26. The nodes are either at the beginning or at the end of the fairways, at intersections between fairways or ports that the fairways enter

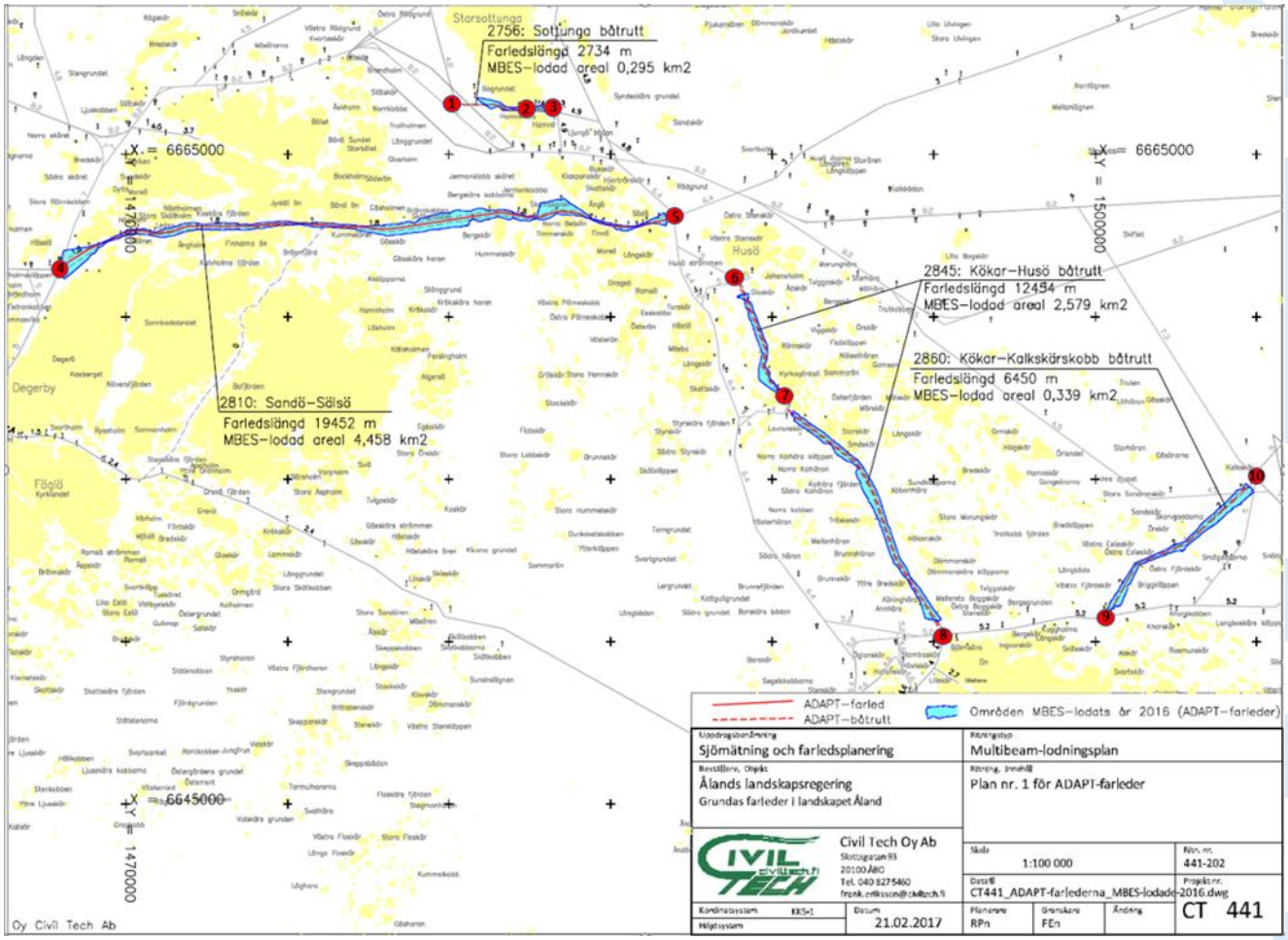


Figure 132. The southeast area of the Åland archipelago with marked existing fairway-corridors (Corridor-ID: 2756, 2810, 2845, 2860) and nodes (marked with ●).

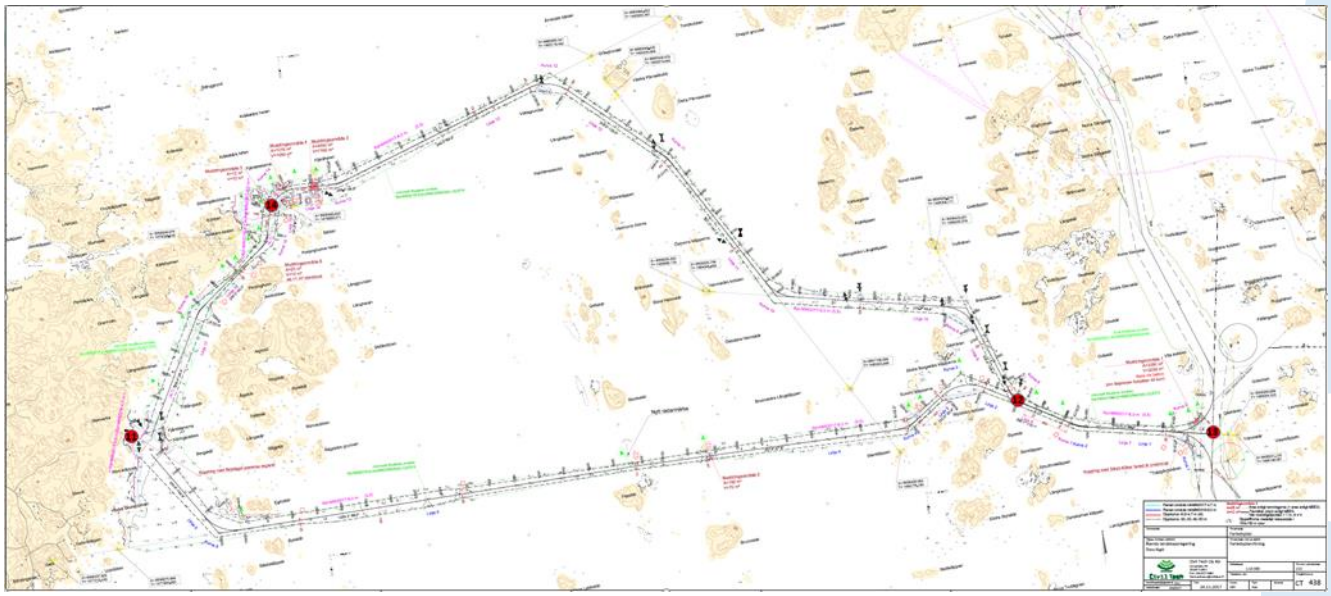


Figure 133. The southeast area of the Åland archipelago with marked new fairway-corridor (Corridor-ID: potential port) and nodes (marked with ●).

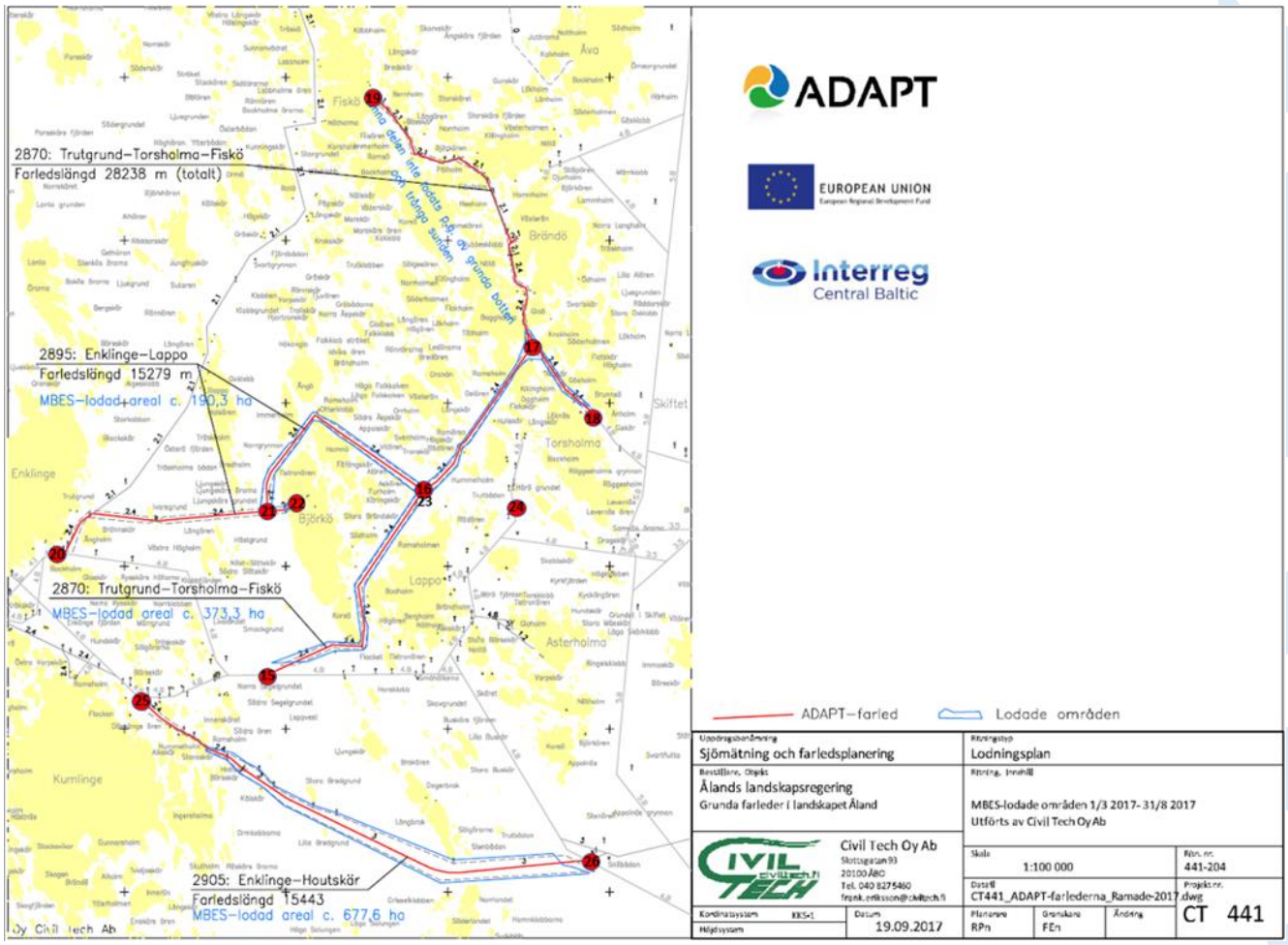


Figure 134. The northeast area of the Åland archipelago with marked existing fairway-corridors (Corridor-ID: 2870, 2895, 2905) and nodes (marked with ●).

Table 169. The corridors identified during the seminar, their location within the archipelago and to which public transportation route they belong is listed in the table.

Corridor-ID	Route extent	Local traffic line	Area within archipelago
2756	Sottunga boat route		South east archipelago
2810	Sandö-Sälsö fairway		South east archipelago
2845	Kökar-Husö Boat route		South east archipelago
2860	Kökar-Kalkskärskobb fairway		South east archipelago
Potential port	Hastersboda-Tränskär		South east archipelago
2870	Trutgrund-Torsholma-fiskö fairway		North east archipelago
2895	Enklinge-Lappo fairway		North east archipelago
2905	Enklinge-Houtskär fairway		North east archipelago

Table 30. The nodes identified during the seminar, their location within the archipelago, which corridor they belong and suggested measure for the node is listed in the table.

Node	Belongs to corridor	Location	Suggested measure
1	2756	Intersection with fairway 2760 Kumlinge-Mosshaga-Sottunga	Depth increases to 4,1 mtrs by dredging of fairway, new marks suggested to be placed at fairway borders.
2	2756	Sottunga harbour	Depth increases to 4,1 mtrs by dredging at north and south side of fairway, new marks suggested to be placed at fairway borders.
3	2756	Intersection with fairway 2755 Sottunga-Kumlinge	Depth increases to 4,1 mtrs, new marks suggested to be placed at fairway borders.
4	2810	Intersection with fairway 2805 Apotekarens fairway	Depth increases to 2.4 mtrs by dredging of fairway, new marks suggested to be placed at fairway borders.
5	2810	Intersection with fairway 2840 Sälsö-Kökar fairway	Depth increases to 2.4 mtrs by dredging of fairway, new marks suggested to be placed at fairway borders.
6	2845	Intersection with fairway 2840 Sälsö Kökar near Husö harbonour	Depth increases to 3,6 mtrs, new marks suggested to be placed at fairway borders.
7	2845	Kyrkogårdsö harbour	Depth increases to 4,1 mtrs, new marks suggested to be placed at fairway borders.
8	2845	Intersection with fairway 2850 Kökar Norrharu	Depth increases to 4,1 mtrs, new marks suggested to be placed at fairway borders.

9	2860	Intersection with fairway 2850 Kökar Norrharu	Depth increases to 4,1 mtrs, new marks suggested to be placed at fairway borders
10	2860	Intersection with fairway 29630 Gustaf Dahlén-Kalkskär	Depth increases to 4,1 mtrs, new marks suggested to be placed at fairway borders
11	Potential Port	Hastersboda Harbour	New fairway, planned depth 4,1 mtrs, dredging needed in harbour area.
12	Potential Port	Källskär	New fairway, planned depth 4,1 mtrs, dredging needed east of Källskär.
13	Potential Port	Intersection north of Styrskär	New fairway, planned depth 4,1 mtrs, Dredging needed north of Brunnskär.
14	Potential Port	Intersectiom with fairway 2840 Sälsö_kökar, west of Trännskär	New fairway, planned depth 4,1 mtrs, Dredging nedden at the north border at the intersection.
15	2870	Intersection with fairway 2740 Långnäs-Gustavs north of Norra Segelgrundet	New or moved existing marks suggested to be placed at fairway borders.
16	2870	Intersection with fairway 2895 Enklinge-Lappo	New or moved existing marks suggested to be placed at fairway borders.
17	2870	Intersection north of Skinnarskär	New or moved existing marks suggested to be placed at fairway borders.
18	2870	Intersection with fairway 2740 Långnäs-Gustavs east of Torsholma	New or moved existing marks suggested to be placed at fairway borders.
19	2870	End of fairway in Östra hamnen, Fiskö	New or moved existing marks suggested to be placed at fairway borders.
20	2895	Intersection with fairway 2740 Långnäs-Gustavs east of Vedgrundet	Depth increases to 3,6 mtrs, dredging suggested in three places between Ivarsgrund and Ljungskärsgrundet, new marks suggested to be placed at fairway borders.
21	2895	Intersection east of Ljungskärsgrundet	Depth increases to 3,6 mtrs, new marks suggested to be placed at fairway borders.
22	2895	Björkö Ångbåtsbrygga	Depth increases to 3,0 mtrs, new marks suggested to be placed at fairway borders.
23	2895	Intersection with fairway 2870 Trutgrund-Torsholma-Fiskö	Depth increases to 3,6 mtrs, new marks suggested to be placed at fairway borders.

24	2895	Intersection with fairway 2740 Långnäs-Gustavs west of Härö grundet.	Depth increases to 3,6 mtrs, new marks suggested to be placed at fairway borders.
25	2905	Intersection with fairway 2740 Långnäs-Gustavs east of Fögelvarpsören	New or moved existing marks suggested to be placed at fairway borders.
26	2905	Intersection at Snöbådan	New or moved existing marks suggested to be placed at fairway borders.

5.1 Corridor 2756: Sottunga Boat route

Suggesting an adjustment of the fairway by dredging and adding new markers limiting the area of the fairway, see figure 135 and 136. The intention are to increase the depth of the fairway between node 1 and 2 to assure that the vessels trafficking the corridor will keep a safe distance to the sea bed.

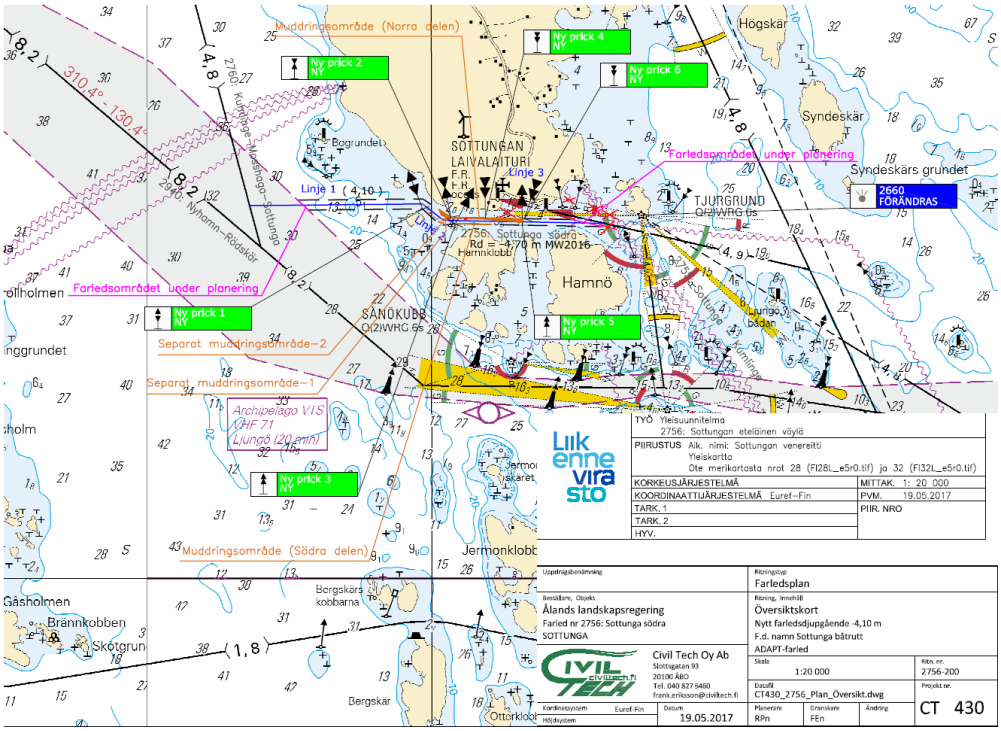


Figure 135. Shows the suggested improvements in ADAPT, fairway 2756.

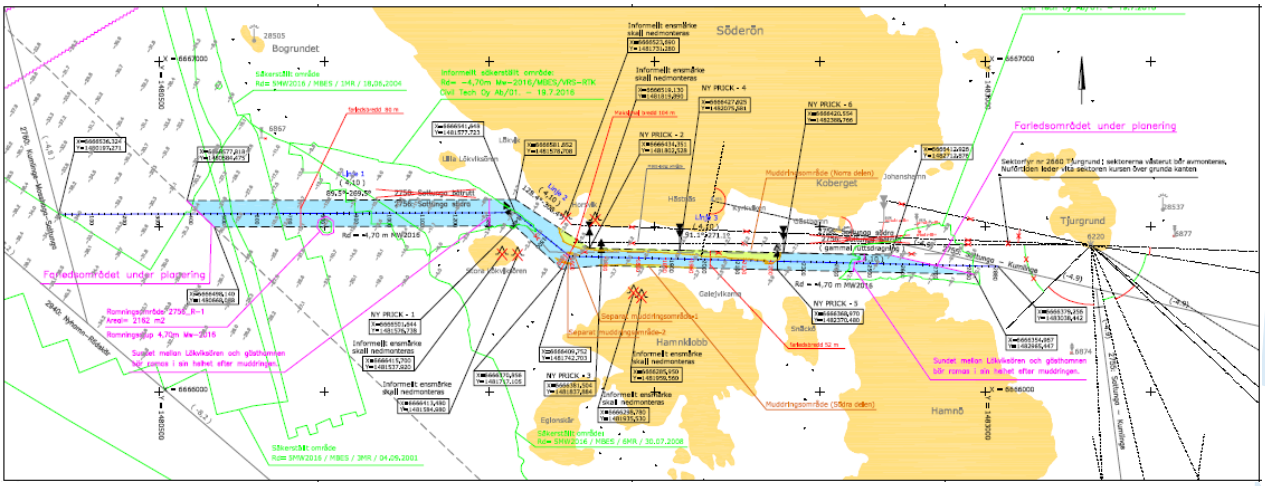


Figure 136. Shows a more detailed drawing of the suggested improvements in ADAPT, fairway 2756.

Time saves are approximately 13 minutes per journey when baseline for route 2756 are compared to the proposed developed route, see figure 137 and 138.

Fairway 2756 Sottunga boat route (VL6), present

Speed:	9,8 knop	18,15 km/h	The average speed of the vessel on the route is 20%,
Distance:		6,80 km	5 knots, 80% 11 knots
Time:		0,37 h	
		22,48 minutes	

Figure 137. Shows the "Baseline" route before suggested improvements following ADAPT for fairway 2756.

Fairway 2756 Sottunga south (VL3), dredged according to proposal for fairway plan ADAPT

Speed:	8,6 knop	15,93 km/h	The average speed of the vessel on the route is 40%,
Distance:		3,40 km	5 knop, 60% 11 knop
Time:		0,21 h	
		12,81 minuter	

Figure 138. Shows the route after suggested improvements following ADAPT for fairway 2756.

Fuel efficiency measures: The fuel consumption decreases with approximately 280 l x 13/60= 61 l diesel fuel per route. The ferries are trafficking the route about 2200 times a year.

Environmental issues: When the depth of the fairway increases clouding in the water, caused by the ferries, decreases. Although, an effect of dredging is clouding, however, measures to limit the clouding exist. One example is curtains of geotextile.

The improvements that the proposal suggests can reduce the emissions of CO_2 with 218 tonnes per year, and shortens the route for the ferries in the archipelago transport system. The ferries connects to Sottunga approximately 2200 times a year. Table 31 shows the calculation of reduced emissions.

Table 31. Numbers and calculations for fuel consumption, reduction and reduced emissions per year utilising the developed route extent.

Fairway 2756 Sottunga, ADAPT node 1, 2, 3						
	Emission per kg of fuel		Reduction of fuel consumption due to ADAPT per year		Reduction of emissions per year	
Emission CO_2	2,66	kg/kg fuel	-82 000	kg/year	- 218 120,00	kg CO_2/ year
Emission NO_x	0,055	kg/kg fuel	-82 000	kg/year	- 4510,00	kg NO_x/ year
Emission SO_x	0,000005	kg/kg fuel	-82 000	kg/year	- 0,41	kg SO_x/ year

Safety: The navigational safety increases after dredging, and when new markers are placed. Today the ferries can not pass each other or meet in the narrow fairway channel. However, after proposed dredging, there will be room enough for the ferries to meet in the fairway.

5.2 Corridor 2810 Sandö-Sälsö fairway

Corridor 2810 is mainly utilised by smaller leisure boats. Several issues were found in the corridor. Firstly, there is a matter of safety. Larger leisure boats, mainly sailing boats, that needs greater depth chooses the more northern fairway instead. This northern fairway is mainly intended for commercial vessels. This creates the safety issue, mainly in summer time. The proposal is that the fairway is dredged to a depth of 2.4 meters, as shown in figure 139, 140 and 141 between node 3 and 4. The baseline route, see figure 142, is compared to the proposed development of the route, see figure 143.

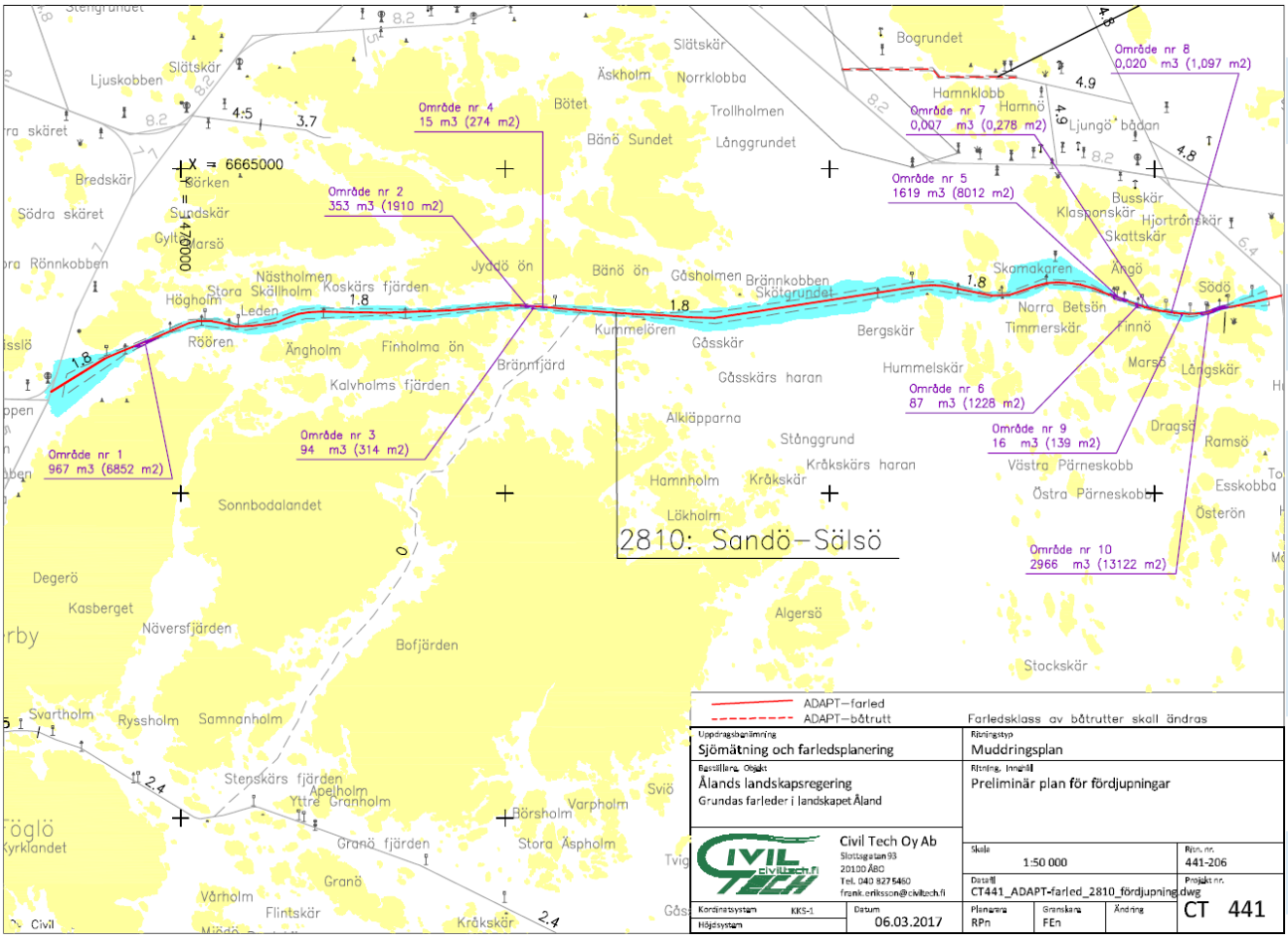


Figure 139. Shows the suggested improvements in fairway 2810.

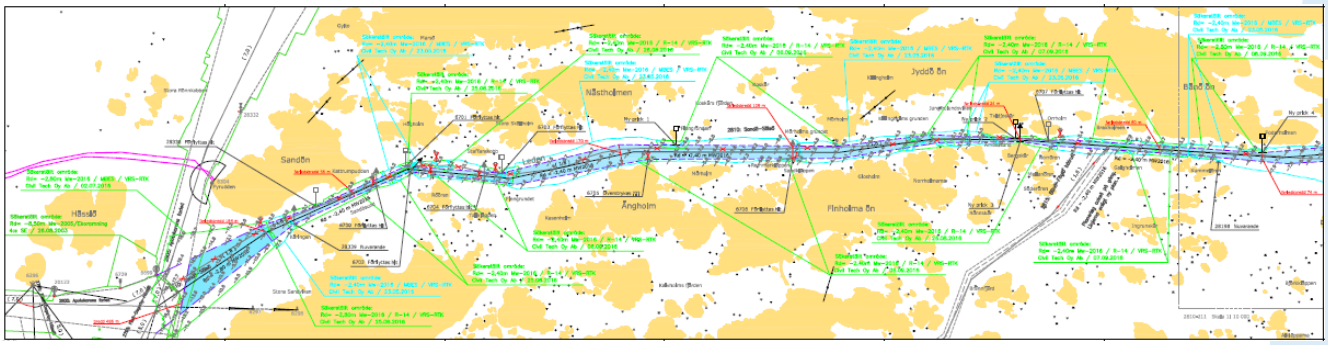


Figure 140. Shows a more detailed drawing of the suggested improvements in the first part of fairway 2810.

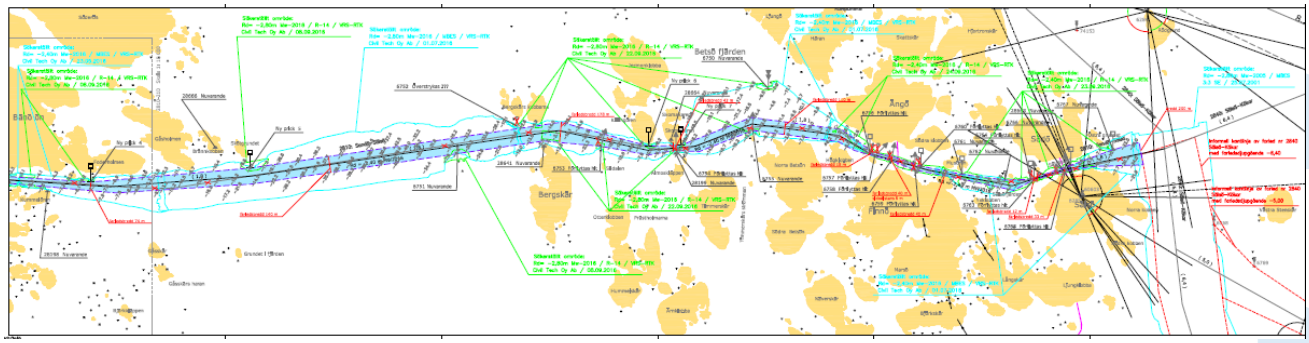
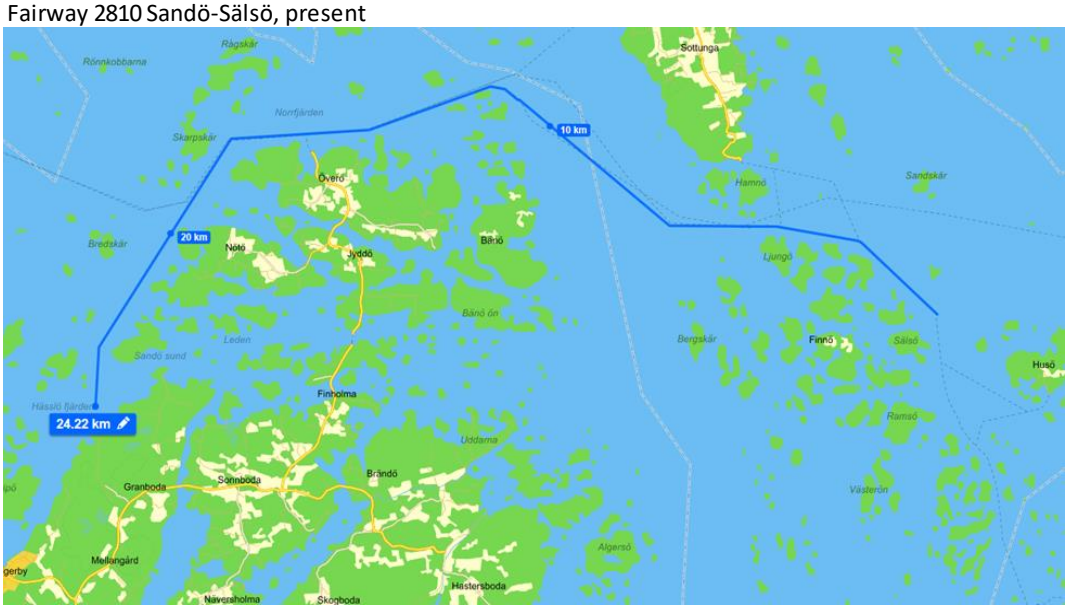


Figure 141. Shows a more detailed drawing of the suggested improvements in the second part of fairway 2810.

Time saves: Approximately 21 minutes per journey using fairway 2810 instead of the alternate more northern fairway.

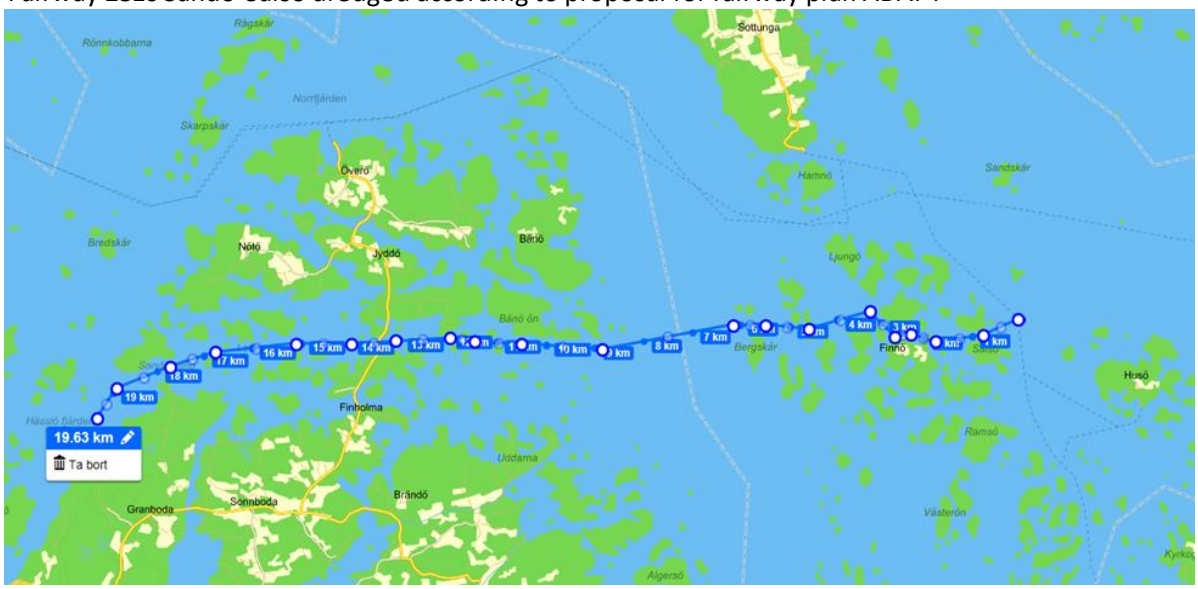
Fairway 2810 Sandö-Sälsö, present



Speed:	7 knots	12,96 km/h
Distance:		24,22 km
Time:		1,87 h
		112,10 minutes

Figure 142. Shows the "Baseline" route before suggested improvements in fairway 2810.

Fairway 2810 Sandö-Sälsö dredged according to proposal for fairway plan ADAPT



Speed:	7 knots	12,96 km/h
Distance:		19,63 km
Time:		1,51 h
		90,85 minutes

Figure 143. Shows the route after suggested improvements in fairway 2810.

Fuel efficiency measures: The distance decreases with approximately 20 %, see table 32.

Environmental issues: When the dredging is performed, there is clouding in the water, however, measures to limit the clouding exist. One example is curtains of geotextile. Table 32 shows the reduction of emissions of climate gases if the archipelago traffic uses the ADAPT fairway (between nodes 4 to 5) for one trip.

Table 32. Calculation of reduction of climate gases for one trip utilising the suggested improved route.

Fairway 2810 Sandö-Salsö, ADAPT node 4 & 5						
	Emission per kg of fuel		Reduction of fuel consumption due to ADAPT per year		Reduction of emissions per year	
Emission CO_2	2,66	kg/kg fuel	- 50	kg/year	- 133,00	kg CO_2/ trip
Emission NO_x	0,055	kg/kg fuel	- 50	kg/year	- 2,75	kg NO_x/ trip
Emission SO_x	0,000005	kg/kg fuel	- 50	kg/year	- 0,00	kg SO_x/ trip

Safety issues: There will be better possibilities to separate leisure vessels and commercial vessels by making it possible for larger leisure vessels to use fairway 2810 instead of the fairway north of Överö.

5.3 Corridor 2845 Kökar-Husö fairway

In corridor 2845, it is possible to increase the depth of the fairway without dredging. For the northern part of the fairway between node 5 and 6 the depth can be increased to 3.6 metres from the existing 1.8 metres

between node 5 and 6. For the southern part, the depth can be increased to 4.1 metres between node 6 and 7. The figures 144, 145 and 146 shows the suggested improvements for the fairway. The southern part of the fairway gives a safer journey in bad weather conditions if the proposed improvements are executed.

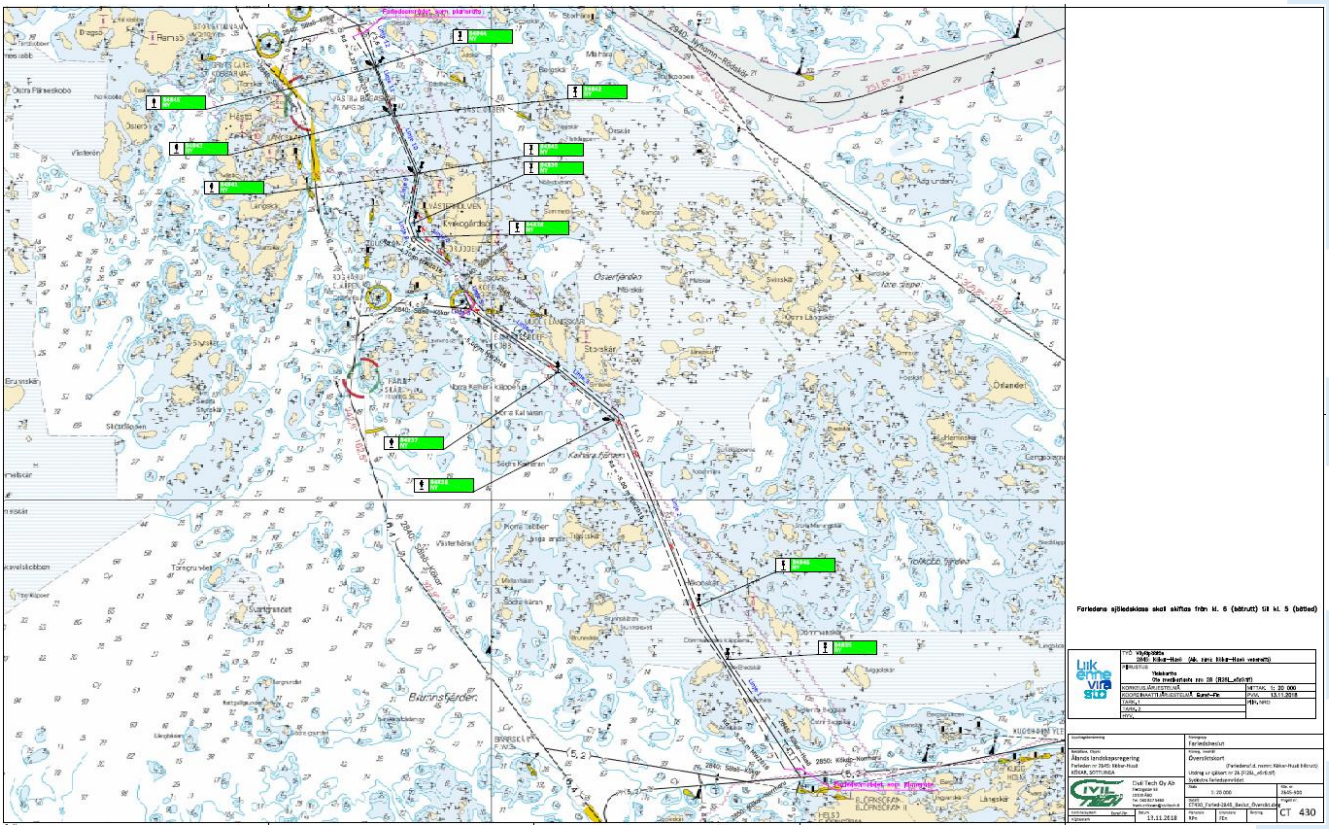


Figure 144. Shows the suggested improvements in fairway 2845.

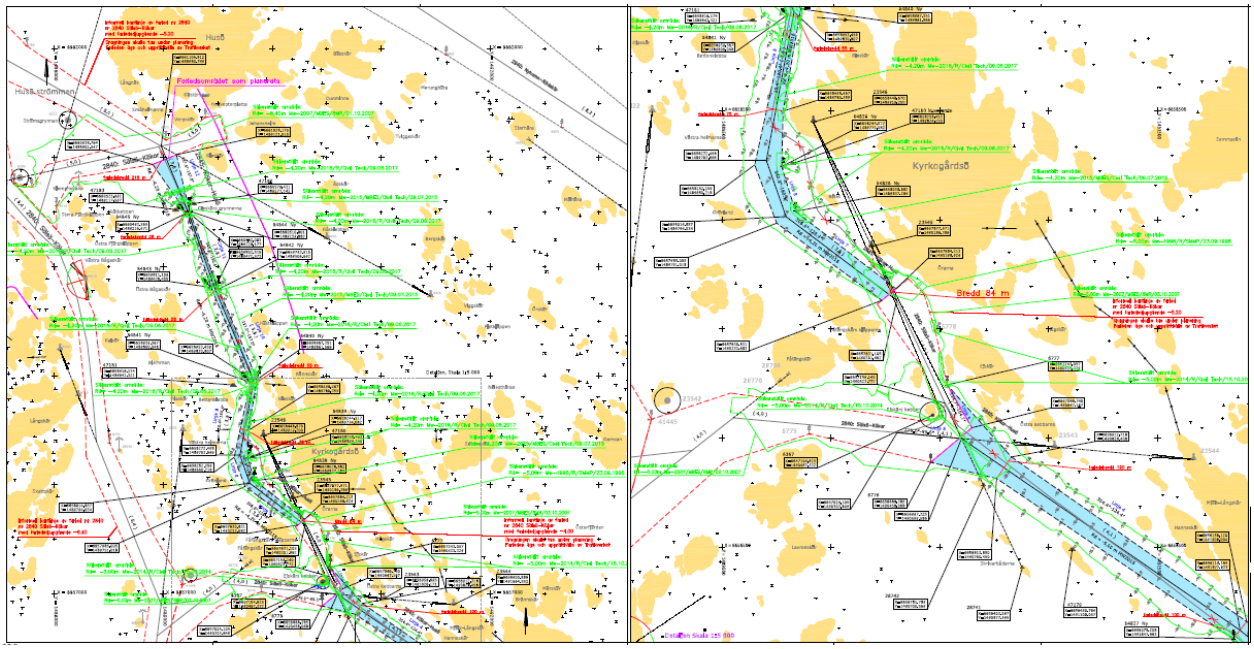


Figure 145. Shows a more detailed picture of the suggested improvements in the northern part of fairway 2845.

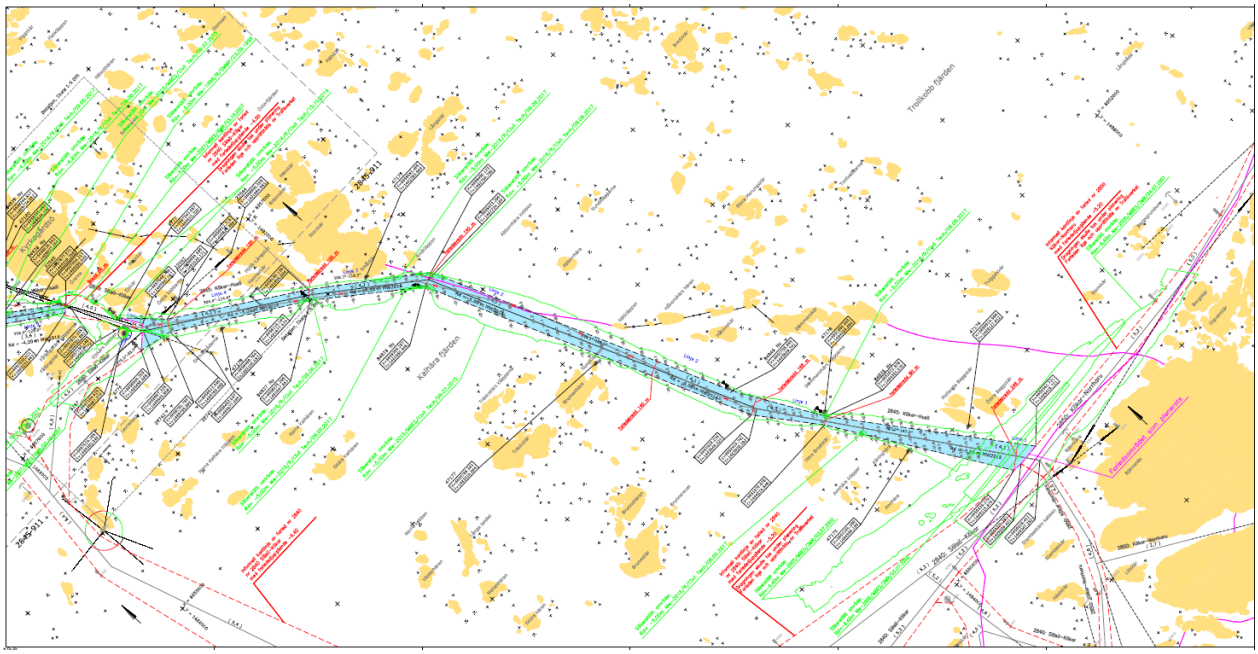


Figure 146. Shows a more detailed picture of the suggested improvements in ADAPT, southern part of fairway 2845.

Time saves: Northern part of fairway – 10 minutes per journey, see figure 147.

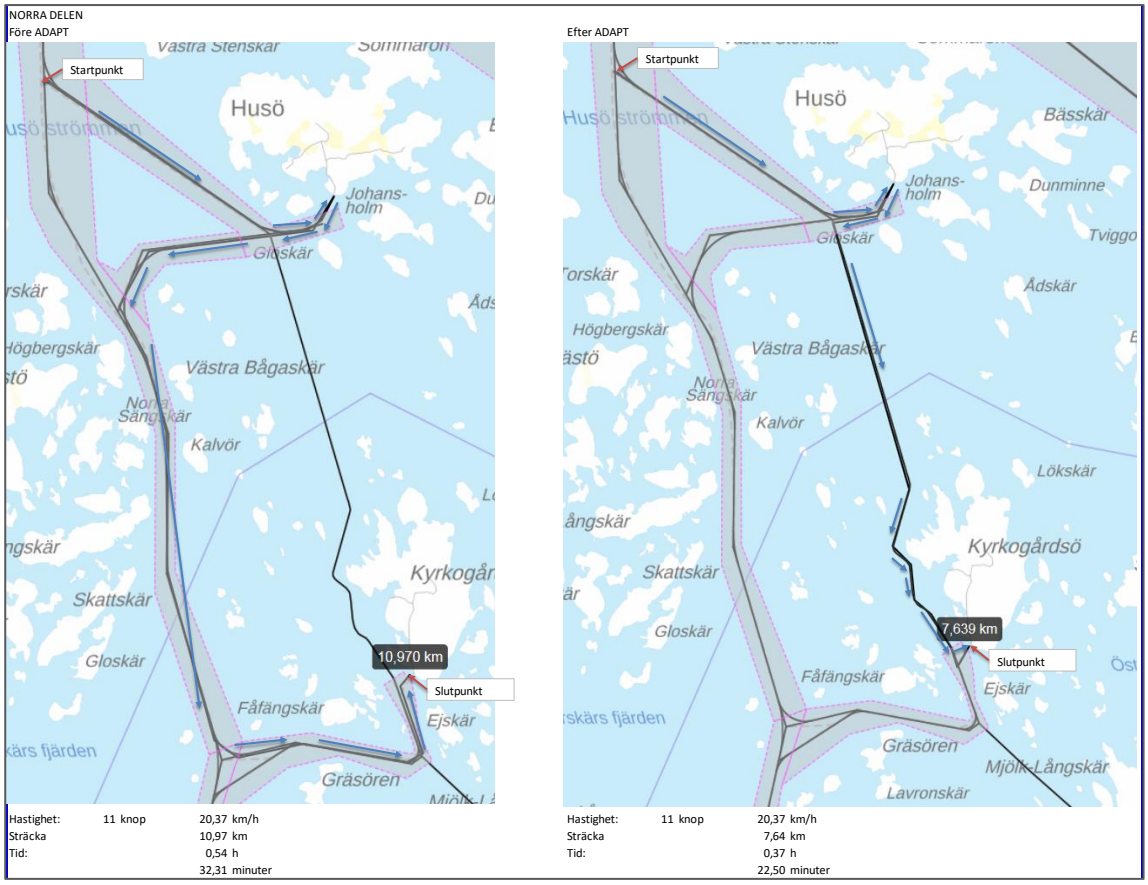


Figure 147. Shows the baseline route before and after proposed improvements of the northern part of fairway 2845.

Time saves: Southern part of fairway – 6 minutes per journey, see figure 148.

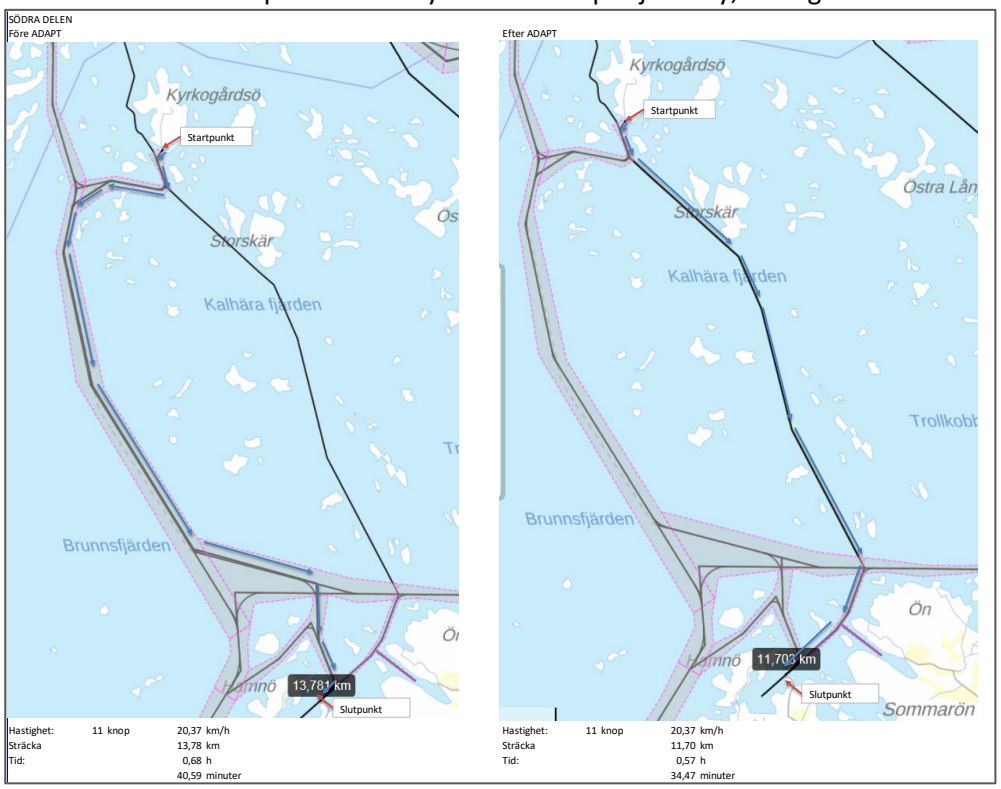


Figure 148. Shows the baseline route before and after the proposed improvements of the southern part of fairway 2845.

Time saves: Fairway 2845 from Kökar to Husö – 16 minutes per journey, see figure 149.

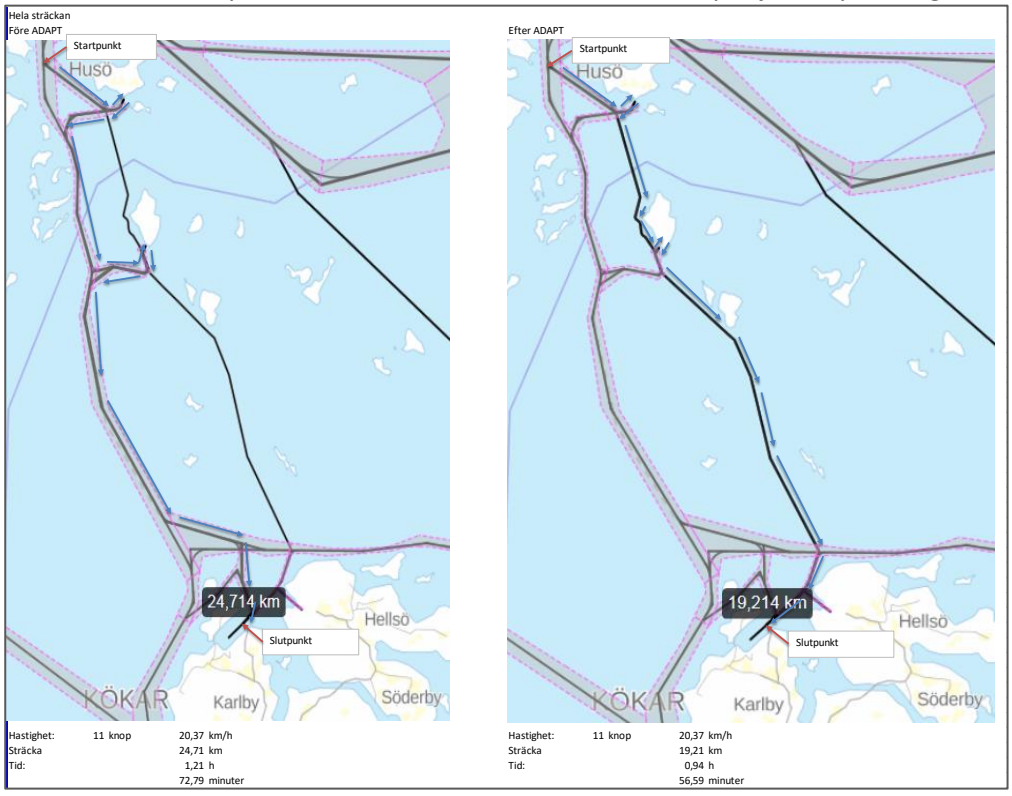


Figure 149. Shows the baseline route before and after proposed improvements of fairway 2845.

Fuel efficiency measures: The fuel consumption decreases with approximately 280 l/h x 16/60= 75 l diesel fuel per route. The ferries traffics the route circa 2200 times a year

Environmental issues: At present, the fairway is mainly used by recreational boats. By changing the depth of the fairway, larger and more vessels can use it. This can have a greater environmental impact from shipping when vessels that today uses a fairway with greater depth can take the shorter upgraded ADAPT-fairway om it´s route. At the same time, the upgraded fairway will offer a shorter journey, as well as a less weather-affected and safer fairway. There´s a significant reduction of climate gas emissions, especially CO_2, if the archipelago traffic uses the developed fairway (between nodes 6, 7 and 8) for one year, see table 33. The calculation is based on the 2017 service level.

Table 33. Calculation of climate gas reduction utilising the proposed developed route instead of the original route 2845.

Fairway 2845 Kökar-Husö, ADAPT						
	Emission per kg of fuel		Reduction of fuel consumption due to ADAPT per trip		Reduction of emissions per trip	
Emission CO_2	2,66	kg/kg fuel	- 53 000	kg/year	- 140 980,00	kg CO_2/ year
Emission NO_x	0,055	kg/kg fuel	- 53 000	kg/year	- 2 915,00	kg NO_x/ year
Emission SO_x	0,000005	kg/kg fuel	- 53 000	kg/year	- 0,27	kg SO_x/ year

Safety issues: The improvement, suggested in ADAPT, for the southern part of the fairway improves the safety by adding new markings of the fairway.

5.4 Corridor 2860 Kökar-Kalkskärskobb fairway

The improvements proposed for corridor 2860 is mainly suggestions for an increased maritime safety. To reach a higher safety level, creating an alternative route for the ferries is proposed. Suggested safety measure is therefor to use vessels with a depth according to this new information, see figure 150.

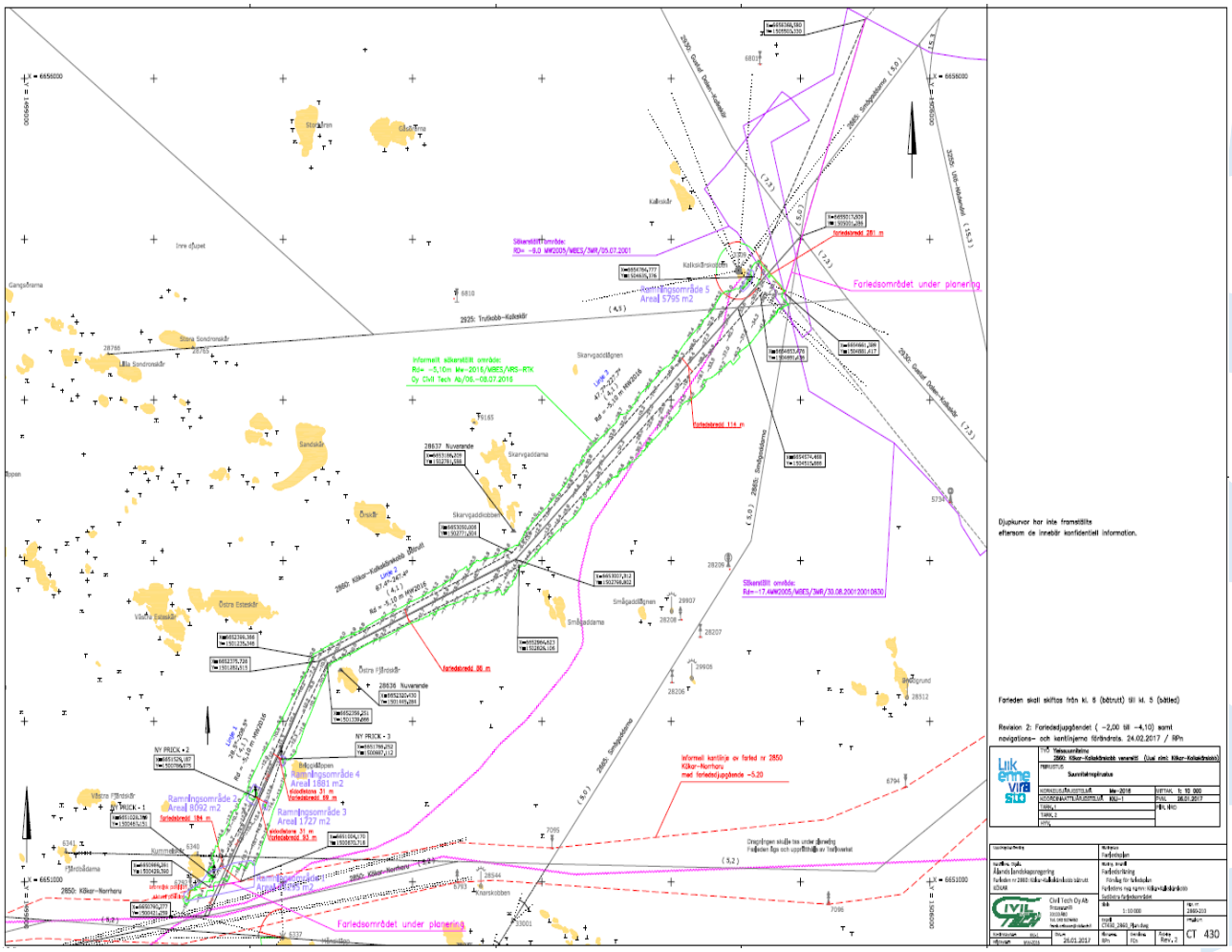


Figure 150. The suggested improvements for fairway 2860 increases safety and creates an alternate route.

Time saves: Approximately 2 minutes per journey, see figure 151.

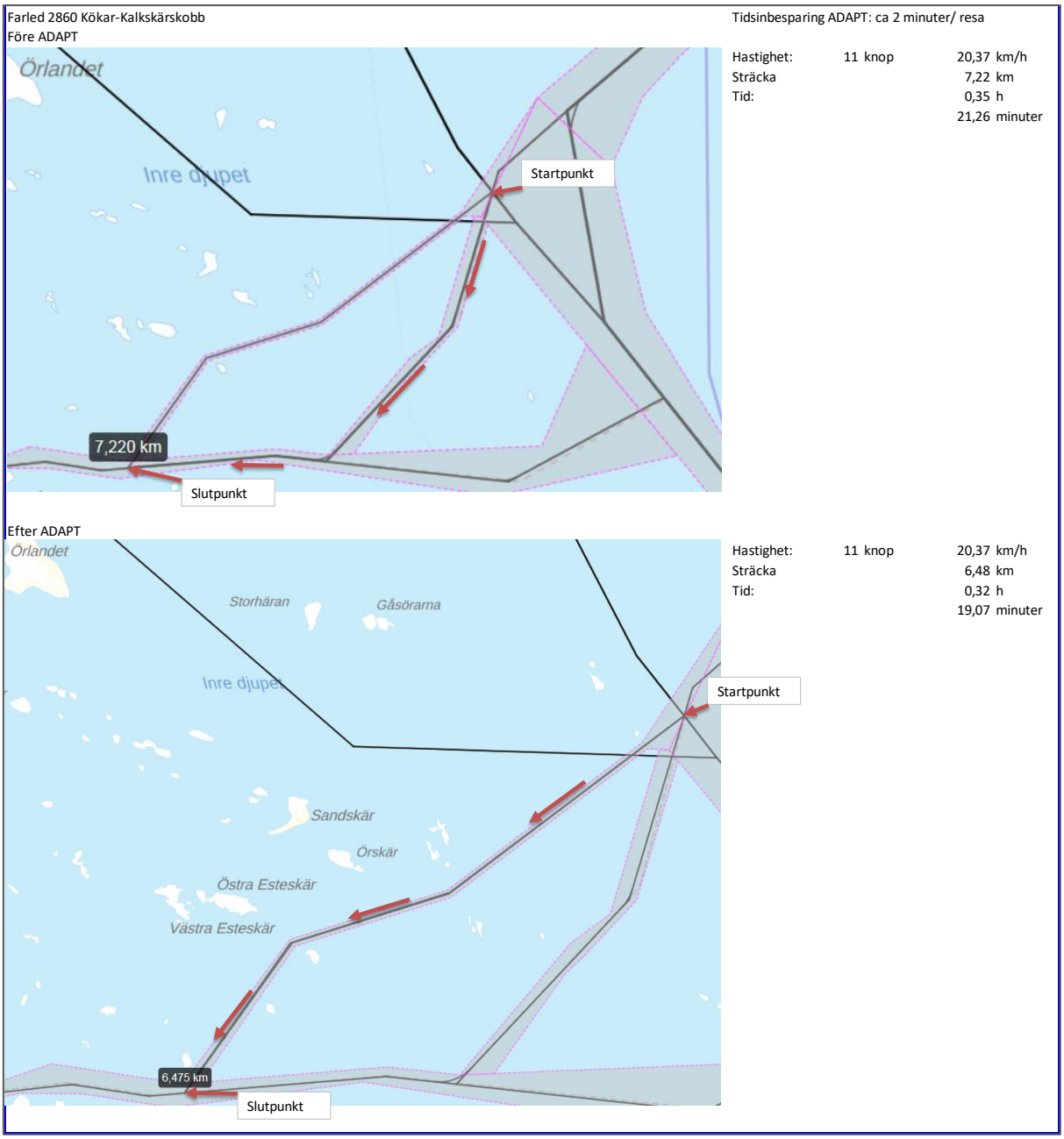


Figure 151. The top illustration shows the baseline route before the suggested improvements to fairway 2860, and the bottom show the developed fairway section.

Fuel efficiency measures: No effect. The travel distance shortage is so small that it does not affect the fuel consumption of the journey in practice.

Environmental issues: No effect. The change is so small that the environmental effects cannot be assessed.

The change proposed in ADAPT is so small that it must be considered theoretical. The theoretical reduction of emissions of climate gases for one trip, if the archipelago traffic uses the developed fairway (between nodes 9 and 10), are small, see table 34.

Table 34. Calculations of the reduction of fuel use and climate gas emissions for the developed route compared to the original route 2860.

Fairway 2860 Kökar-Kalkskärskobb, ADAPT node 9 & 10						
	Emission per kg of fuel		Reduction of fuel consumption due to ADAPT per trip		Reduction of emissions per trip	
Emission CO_2	2,66	kg/kg fuel	- 8	kg/trip	- 21,28	kg CO_2/ trip
Emission NO_x	0,055	kg/kg fuel	- 8	kg/trip	- 0,44	kg NO_x/ trip
Emission SO_x	0,000005	kg/kg fuel	- 8	kg/trip	- 0,00	kg SO_x/ trip

Safety: Creates an alternative route for public transport.

5.5 Corridor Potential Port

The corridor “Potential Port” is one part of a larger change of the existing transport system in the archipelago. Today, the south-east archipelago (Föglö, Sottunga, Kökar) is reached from harbours in Långnäs or in Svinö. The main ferry transport to Sottunga and Kökar departs from Långnäs. The ferry-line that starts from Svinö is mainly for transport to Föglö. The improvements proposed by ADAPT means that traffic going to the south-eastern archipelago is, to a greater extent, concentrated on the route Svinö-Föglö and the route Hastersboda-Sottunga or Hastersboda-Kökar which both originate from Hastersboda on eastern Föglö. The traffic connection (Svinö-Föglö) on western Föglö will be moved to a new port on Mellanholm by a new road connection and a bridge being built between Degerö and Gripö. The traffic connection further east, would use the existing road network at Föglö to Sommarö village. From Sommarö village a road is will be built to Hastersboda, where the connection port for the traffic to Sottunga and Kökar is built. The color scheme included in the corridor "Potential Port" includes the fairways that are needed to realize the connection from Föglö to Sottunga and Kökar. The new ferry pass between Svinö and Mellanholm on Föglö shortens the driving time for this part of the route to 20 minutes. The project also includes replacing the current diesel-powered ferry to a rechargeable electric hybrid ferry with greater capacity to cope with the traffic need on the line, as the traffic to the southeastern archipelago that previously departed from Långnäs would now be moved to the route between Svinö and Mellanholm. The new ferry also allows public transport to accompany Föglö and create an intermodal connection with ferry traffic to Kökar and Sottunga in the new harbour in Hastersboda. Figure 152 shows the developed fairway plan and enables the traffic system change.

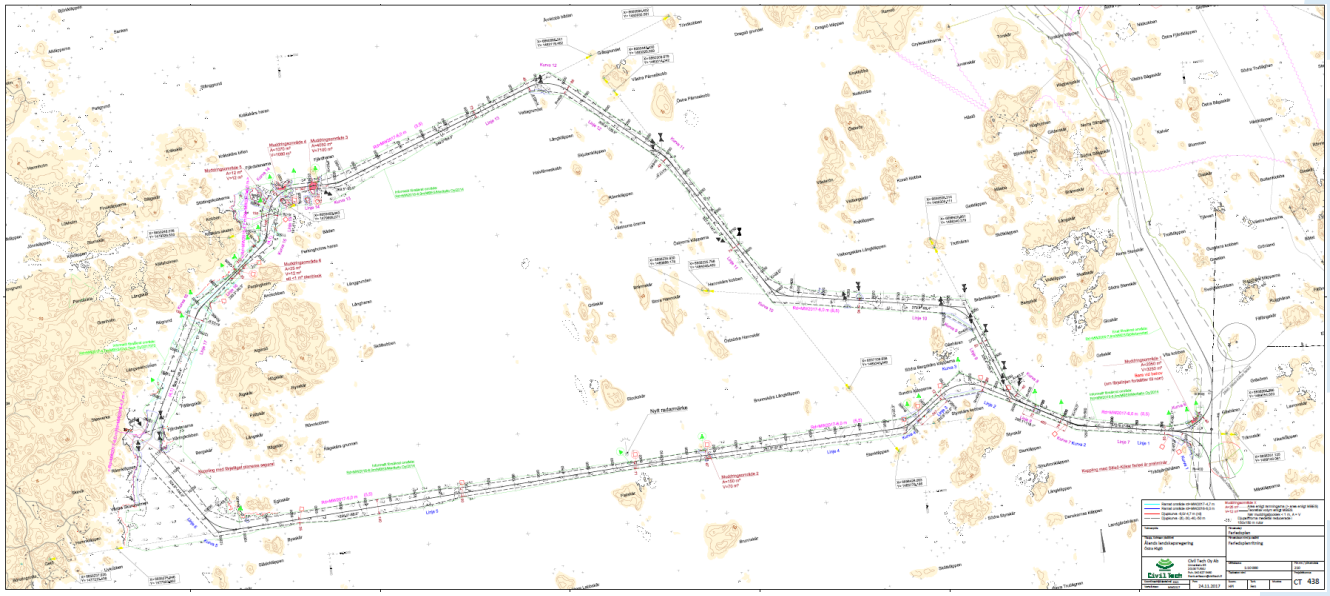


Figure 152. Shows the developed fairway "Potential Port" and the top route in the map show the original route.

Time saves: The theoretical time saving can be reduced to 50 minutes per single trip. A reasonable assessment when taking into account waiting times and coordination between the ferry lines is that the travel time is shortened by about 35-40 minutes per single trip, see table 35 a & b.

Table 35a. The calculations of travel time for baseline and the developed route "Potential Port".

	Before ADAPT		**After ADAPT**	
	Travel on road [km]		Travel on road [km]	
	4,7	Svinö VS-Långnäs	2,5	Svinö VS-Svinö
			17,4	Norra Gripö-Hastersboda
Sum:	4,7	km	19,9	km
	Travel on water [km]			
	14	Långnäs-Överö	5,8	Svinö-Norra Gripö
	11	Överö-Sottunga	22,4	Hastersboda-Harparnäs
	24,1	Sottunga-Harparnäs		
Sum:	49,1	km	28,2	km

Table 35b. The calculations of travel time for baseline and the developed route "Potential Port".

	Before ADAPT					
					60	
Speed on road	55	km/h	0,085	hours	5,1	minutes
Speed on water	20,37	km/h	2,41	hours	144,6	minutes
Number of harbours	2	cpl	5	minutes	10,159,8	minutes
Sum. travel time					02:40:00	h:min:sec

	After ADAPT					
					60	
Speed on road	55	km/h	0,362	hours	21,7	minutes
Speed on water	20,37	km/h	1,384	hours	83,1	minutes
Number of harbours	1	cpl	5	minutes	109,8	minutes
Sum. travel time					01:50:00	h:min:sec

Figure 153 shows the ”Base line” journey before implementation of improvement developed in ADAPT, figure 154 shows the improved journey after ADAPT. Table 35 shows calculation of the time saves following the improvements and new route.

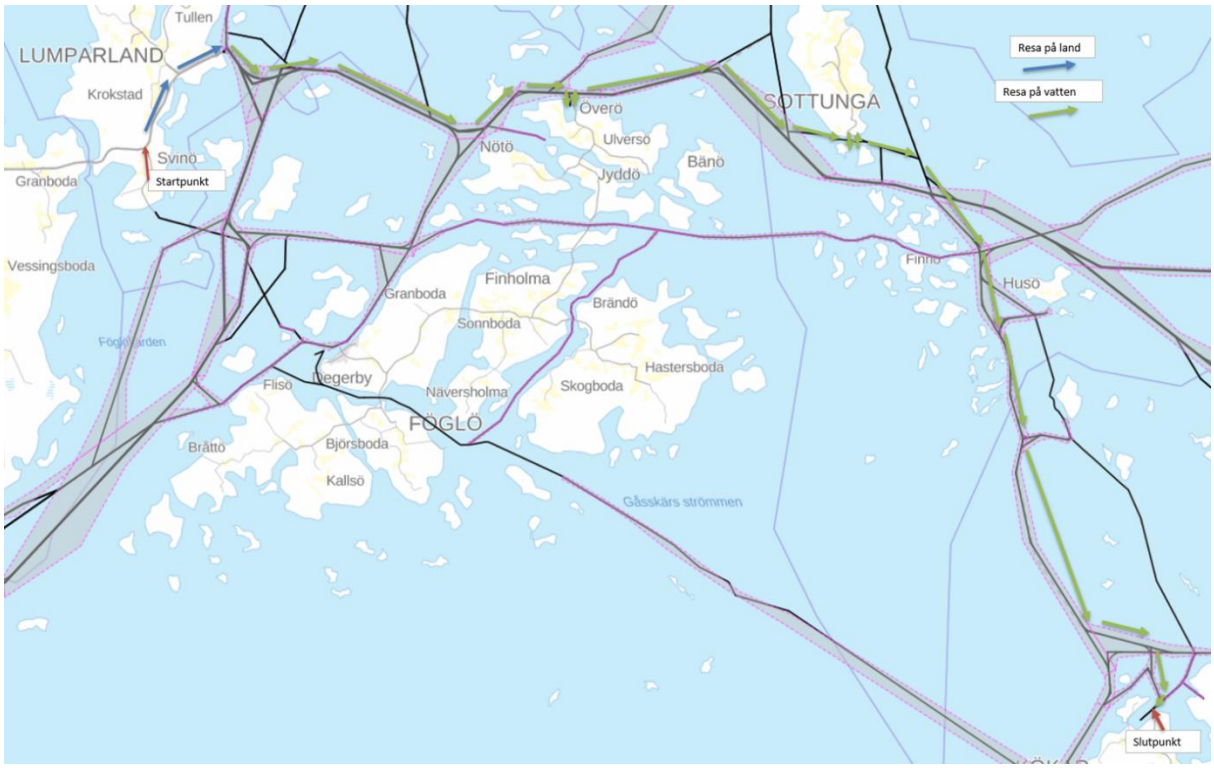


Figure 153. The figure shows the original baseline route.

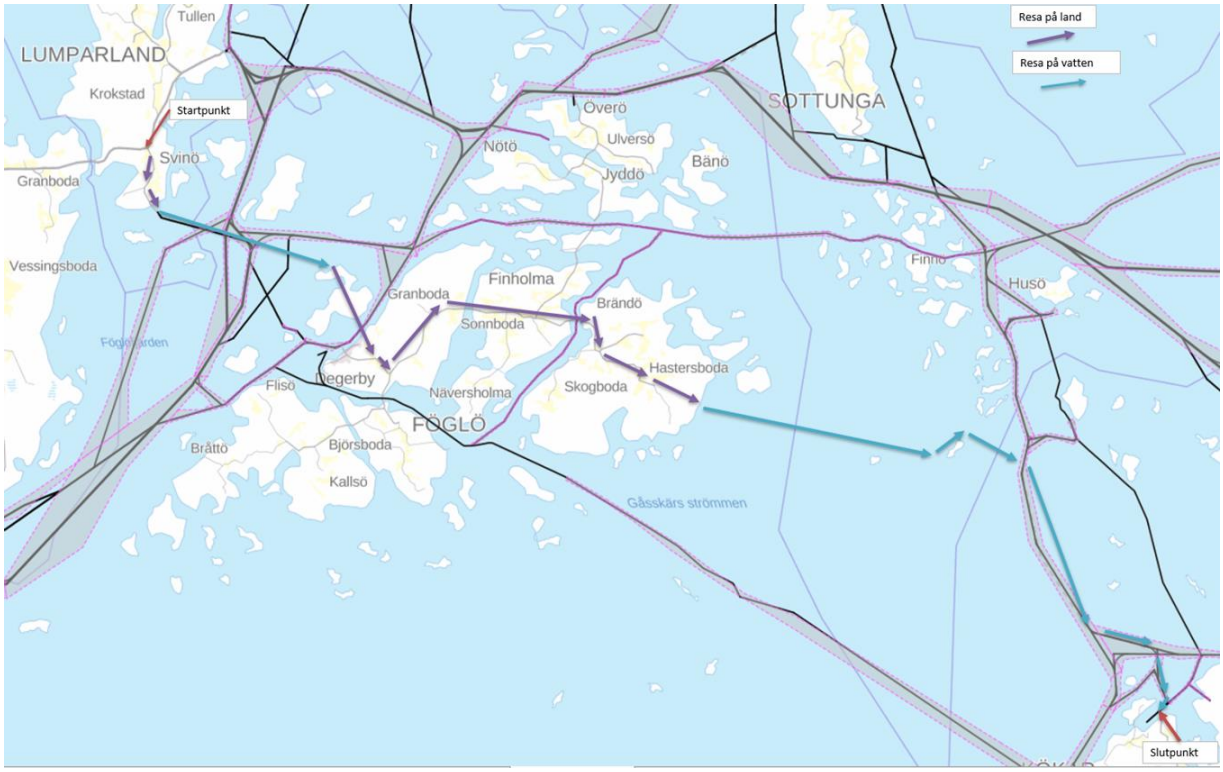


Figure 154. Shows the developed route "Potential Port".

Fuel efficiency measures: The comparison shows that the change proposed by ADAPT reduces fuel consumption by more than 40% for the route by choosing bus and ferry via Föglö instead of via Långnäs. The fuel consumption for a journey according to the route ADAPT suggests is about 394 l compared to 676 l for baseline. Table 36 a & b, shows the calculation of fuel consumption for the baseline route. Table 37 shows the calculation over fuel consumption for the developed route. Table 37 show the numbers used for calculating of the fuel consumption for different modes of transport

Table 36a. The table shows the calculation over the fuel consumption for the baseline route.

Potential Port - Base line								
Start/stop	Distance road		Distance ferry		Travel time road	Travel time Ferry	Waiting time	Sum travel time
		[enh]		[enh]	[minutes]	[minutes]	[minutes]	[minutes]
Svinö VS	0,0	km			-			-
Långäs	4,7	km			5,13			5,13
Överö			14,0	km		41,23	5,00	51,36
Sottunga			11,0	km		32,40	5,00	88,76
Harparnäs			24,1	km		70,98		159,74
Sum:	4,7	km	49,1	km	5,13	144,61	10,00	159,74
							Hours	2,66
							H:Min	02:40:00

Table 36b. The table shows the calculation over the fuel consumption for the baseline route.

Potential Port - Base line							
Bus		Car		Ferry		SUM	
Fuel consump-tion road		Fuel consump-tion road		Fuel consump-tion water		Fuel consump-tion one journey Base Line	
0,30	l/km	0,07	l/km	13,74	l/km		
						0,00	
1,41	l					1,41	
				192,42	l	192,42	
				151,19	l	151,19	
				331,24	l	331,24	
1,41	l	0,00		674,85	l	676,26	l

Table 36. The calculation of fuel consumption for the developed route.

Potential Port - ADAPT								
Start/slut	Distance road		Distance ferry		Travel time road	Travel time Ferry	Waiting time	Sum travel time
		[enh]		[enh]	[minutes]	[minutes]	[minutes]	[minutes]
Svinö VS	0,0	km			-			-
Svinö ff	2,5	km			2,73			2,73
Mellanholm (norra Gripö)			5,8	km	-	17,08		19,81
Hastersboda	17,4	km			18,98	-	5,00	43,79
Harparnäs			22,4	km	-	65,97		109,76
Summa:	19,9	km	28,2	km	21,71	83,06	5,00	109,76
							Hours	1,83
							H:Min	01:50:00

Potential Port - ADAPT							
Bus		Car		Ferry		SUM	

Fuel consump-tion road		Fuel consump-tion road		Fuel consump-tion water		Fuel consump-tion one journey ADAPT	
0,30	l/km	0,07	l/km	13,74	l/km		
						0,00	
0,75	l					0,75	
				79,72	l	79,72	
5,22	l					5,22	
				307,87	l	307,87	
5,97	l	0,00		387,59	l	393,56	l

Table 37. The table shows the calculation of the fuel consumption for various modes of transport, used in the analysis.

Calculation of fuel consumption						
Type of transportation:			**average speed:**		**Average consumption:**	
Bus			55	km/h	0,30	l/km
Car			55	km/h	0,07	l/km
Ferry	280	l/h	20,372	km/h	13,74	l/km

In total, the "Potential Port" fuel consumption decreases by approximately 628,000 l per year, if the comparison is for the developed route, with the same level of service as the traffic in baseline today.

Environmental measures: The necessary infrastructural investments in harbours, bridges and roads gives a negative effect for the environment, due to the construction work needed. The savings gathered for travel time will mainly originate from the trips with reduced deductions. It's possible to reduce the number of deductions through the shorter route that the corridor "Potenital Port-fairway" entails. The reduction means less shipping traffic, hence less environmental impact such as emissions.

In total, the "Potential Port" reduces emissions of climate gases by about 1 380 tonnes of CO_2, 28 tonnes of NO_X and 3 kg of SO_X per year, comparing the same level of service as the traffic in baseline route today.

Safety issues: The fairways that are part of the Potential Port have been planned according to the Finnish traffic regulations for public fairways. The planned fairway has a high safety level. By collecting traffic to the south-eastern archipelago to a traffic line, the redundancy disappears, but at the same time, by gathering the resources to one line, the preparedness and reliability needs to be increased.

5.6 Corridor 2870 Trutgrund-Torsholma-Fiskö

When ADAPT started, one of the objectives for corridor 2870 was to be able to deepen the fairway to create an alternative trip to the baseline route. The MBES-soundings and fairway planning have shown that unfortunately

there is no possibility of increasing the depth of the fairway without unreasonably much dredging. On the other hand, the goal of raising maritime safety for the fairway could be achieved with the basis for fairway plans that are presented with new and more accurately placed marks as a result of the developed proposal in ADAPT. Figure 155 and 156 shows the new plans for the fairway.

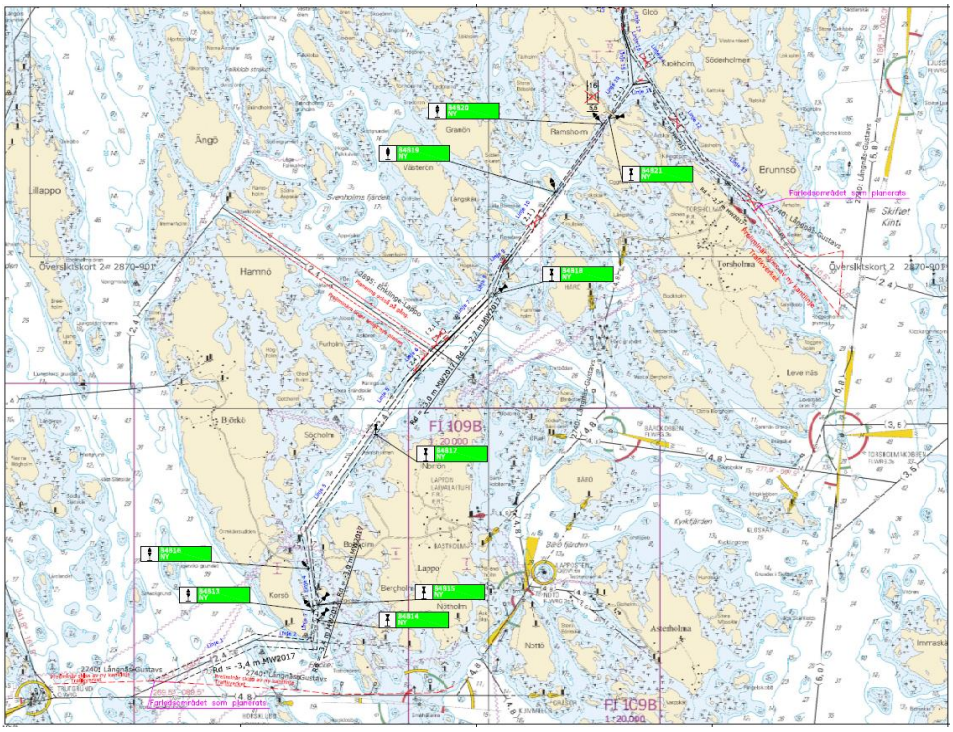


Figure 155. Shows the new fairway plan for the southern part of fairway 2870.

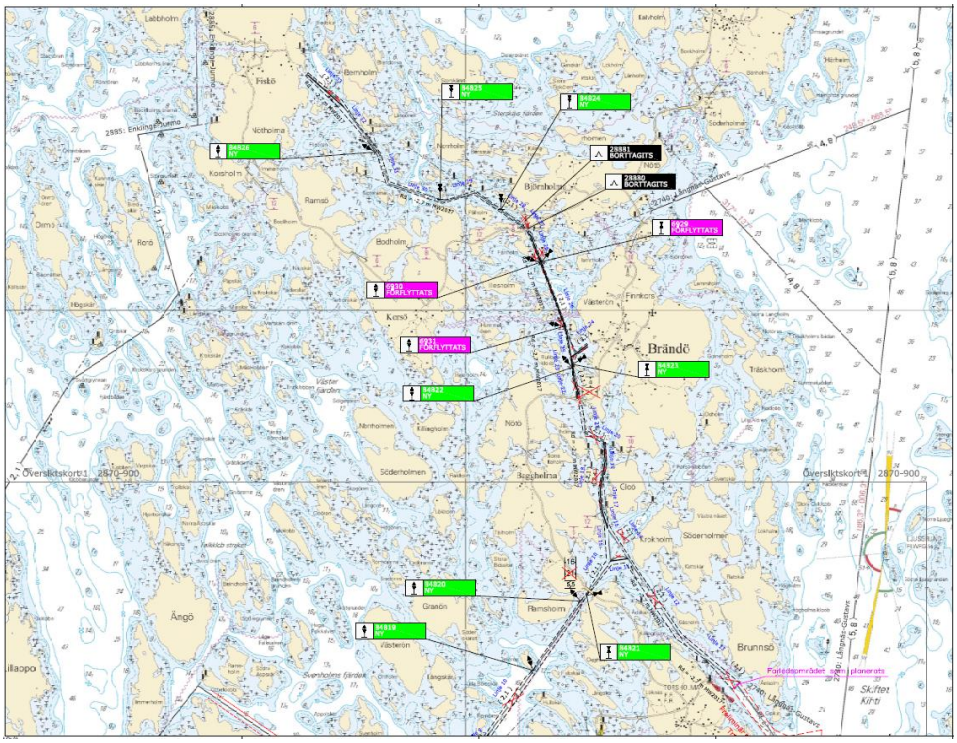


Figure 156. Shows the new fairway plan for the northern part of fairway 2870.

Time saves: The planned measures that ADAPT investigated would mean that a theoretical time saving of about 22 minutes per trip would be made. As the measures are not feasible, the improvements that were the target with this fairway are not achieved. Figure 157 shows the baseline route and planned developed improvement. Table 38 shows a calculation of the theoretical time-save that ADAPT could have resulted in

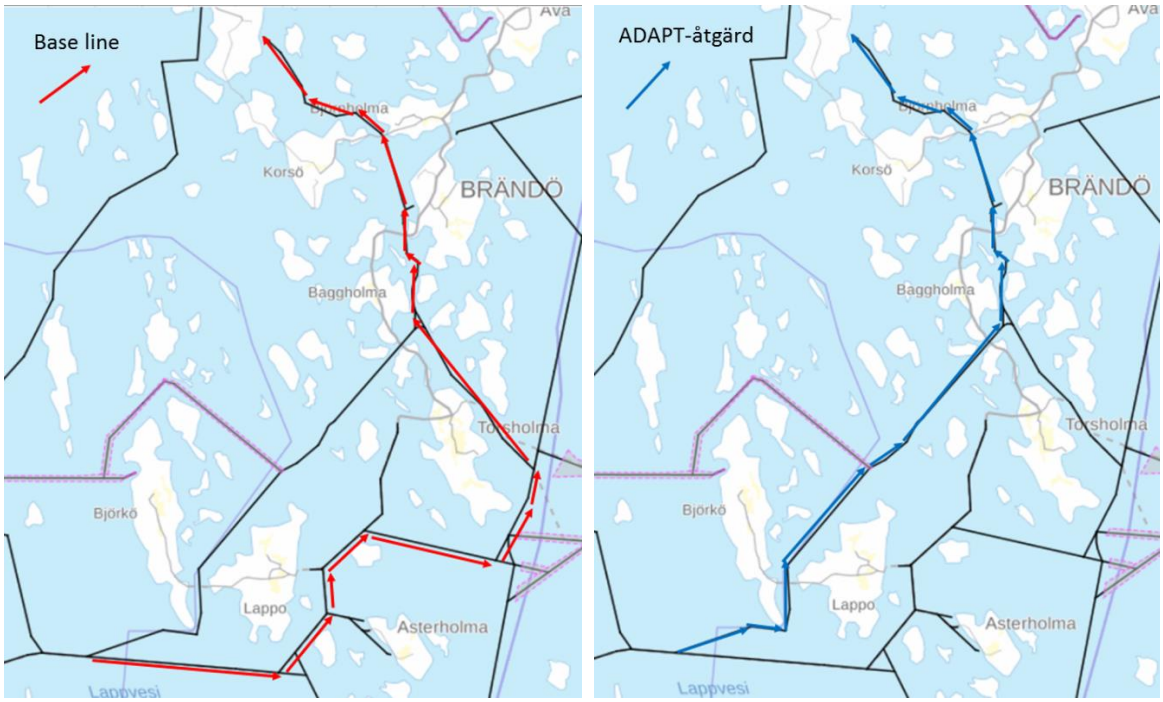


Figure 157. To the left shows the baseline route and to the right is the planned ADAPT developments for fairway 2870.

Table 38. Time-save calculation for the planned ADPAT development for fairway 2870.

	Baseline		**Developed route**	
Distance	31,9	km	24,3	km
Speed	20,37	km/h	20,37	km/h
Time	1,57	h	1,19	h
Time	94,0	minutes	71,6	minutes
Difference			-22,4	minutes

Fuel efficiency measures: No result

Environmental measures: The result of the analysis shows that improvements to reach a greater depth for the fairway, to enable larger vessels to use it, cannot be made without considerable dredging efforts. These dredging efforts will have a significantly greater negative environmental impact than the positive environmental impact the more efficient shipping traffic would lead to an improved fairway.

Table 39 shows the theoretical reduction of emissions of climate gases if the archipelago traffic uses the ADAPT fairway (between nodes 15and 19) during one trip.

Table 39. The calculation of reduction of climate gases for the developed fairway compared to fairway 2870.

Fairway 2870 Trutgrund-Torsholma-Fiskö, ADAPT node 15 19						
	Emission per kg of fuel		Reduction of fuel consumption due to ADAPT per trip		Reduction of emissions per trip	
Emission CO_2	2,66	kg/kg fuel	- 20	kg/trip	- 53,20	kg CO_2/ trip
Emission NO_x	0,055	kg/kg fuel	- 20	kg/trip	- 1,10	kg NO_x/ trip
Emission SO_x	0,000005	kg/kg fuel	- 20	kg/trip	- 0,00	kg SO_x/ trip

Safety issues: Maritime safety are increased for the fairway by new and more accurately placed marks. Figure 158, 159 and 160 shows the detailed plans for new marks for the fairway.

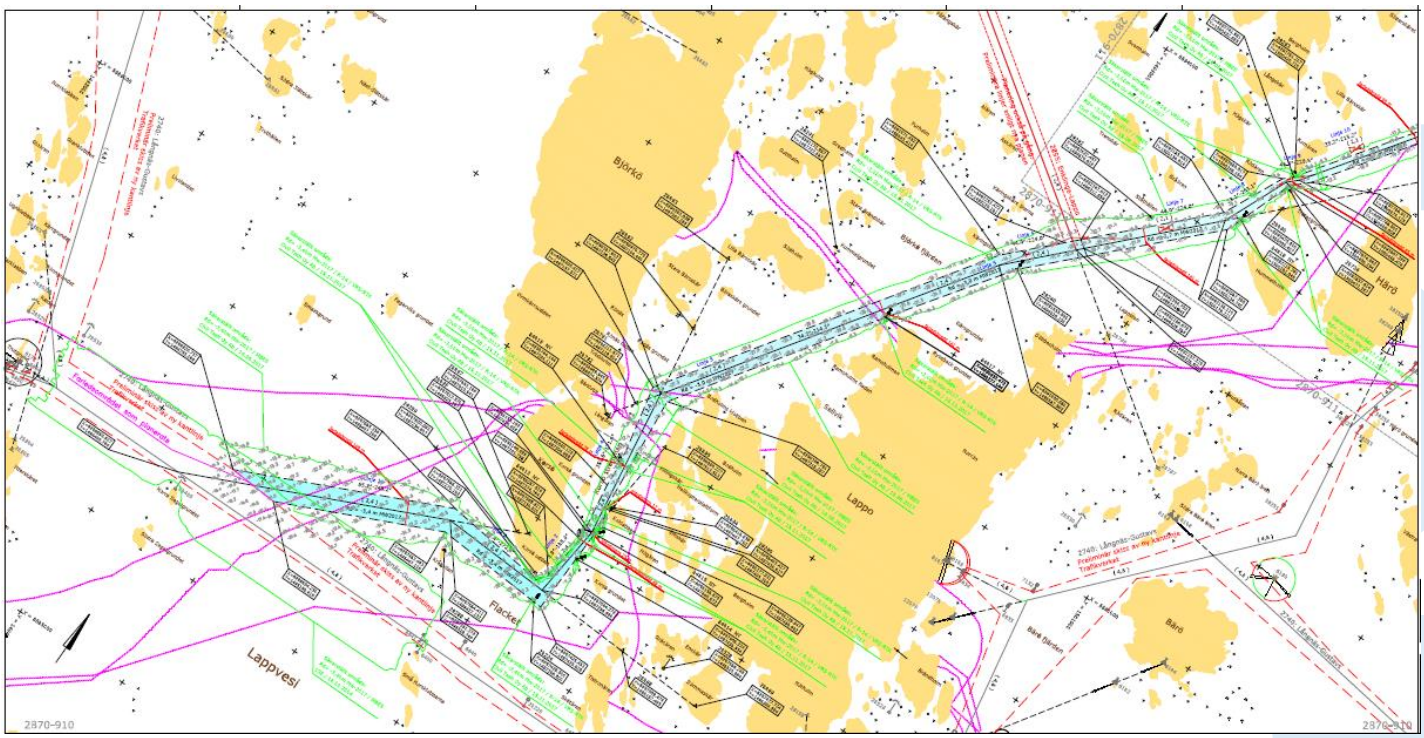


Figure 158. Shows the developed route improvements for the southern part of fairway 2870.

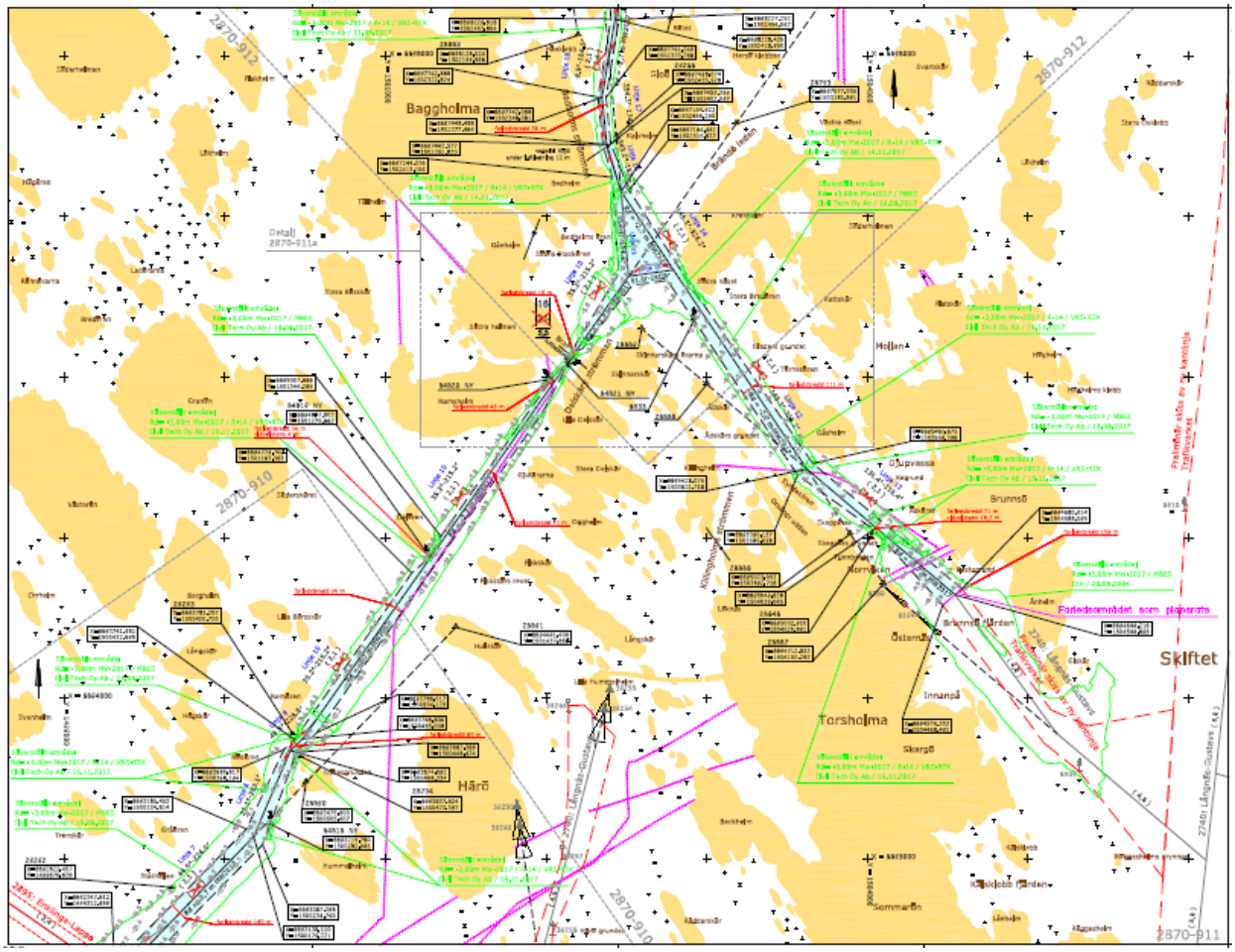


Figure 159. Shows developed route improvements for the middle part of fairway 2870.

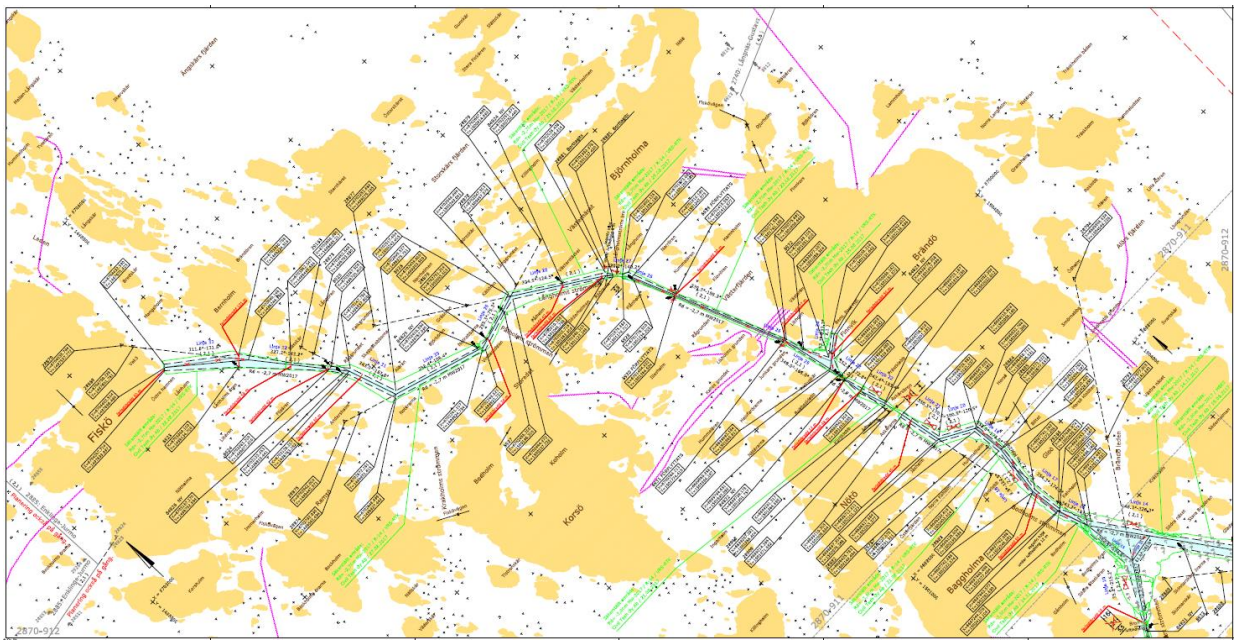


Figure 160. Shows developed route improvements for the northern part of fairway 2870.

5.7 Corridor 2895 Enklinge-Lappo

Through ADAPT one can observe that corridor 2895 Enklinge-Lappo can be deepened to a fairway depth of 3.6 metres by dredging smaller parts of the fairway between node 20, 21, 23 and 24. The maritime safety can be increased by placement of new floating sea safety devices. Between node 21 and 22, the fairway can hold a depth of 3.0 metres. By deepening the fairway and extending it so that it connects to the fairway 2740 Långnäs-Gustavs in node 23, an opportunity for an abbreviated route is created. Figure 161 shows the fairway-plan before the ADAPT proposal. Figure 162, 163 and 164 shows the improved, proposed plan for the fairway.

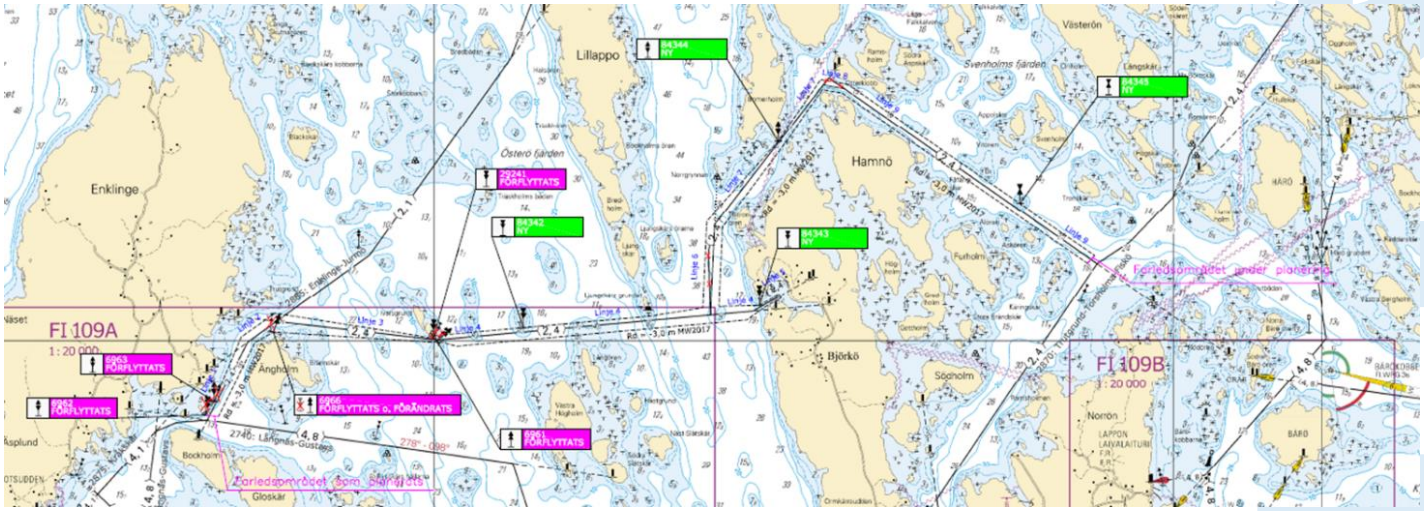


Figure 161. Shows the existing fairway plan for fairway 2895. Note that the fairway stops at node 23, intersection with fairway 2870.

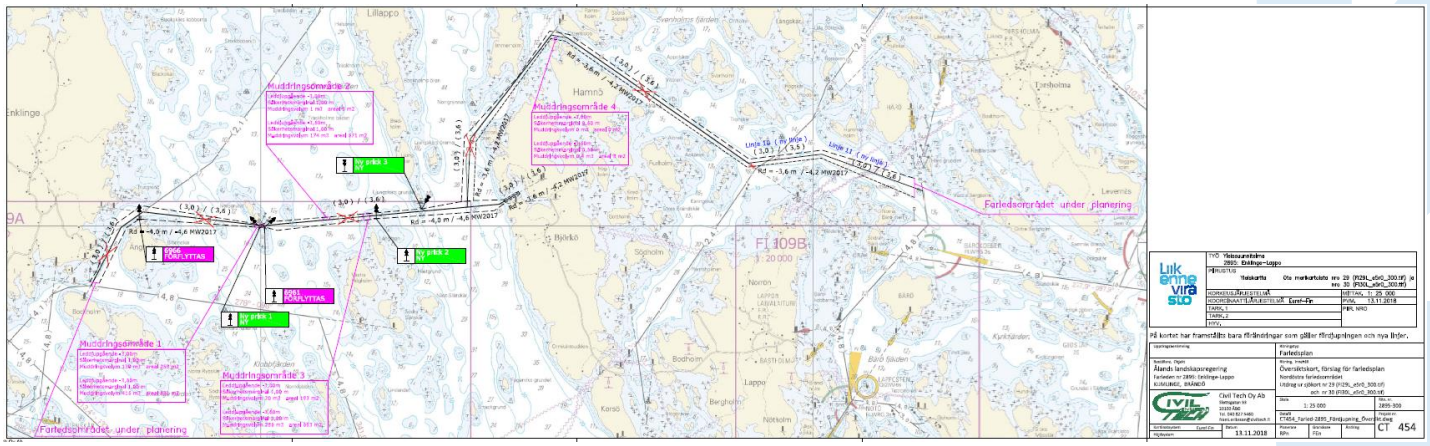


Figure 162. Shows the developed fairway plan for fairway 2895 originating in the analysis of the survey data gathered in ADAPT.

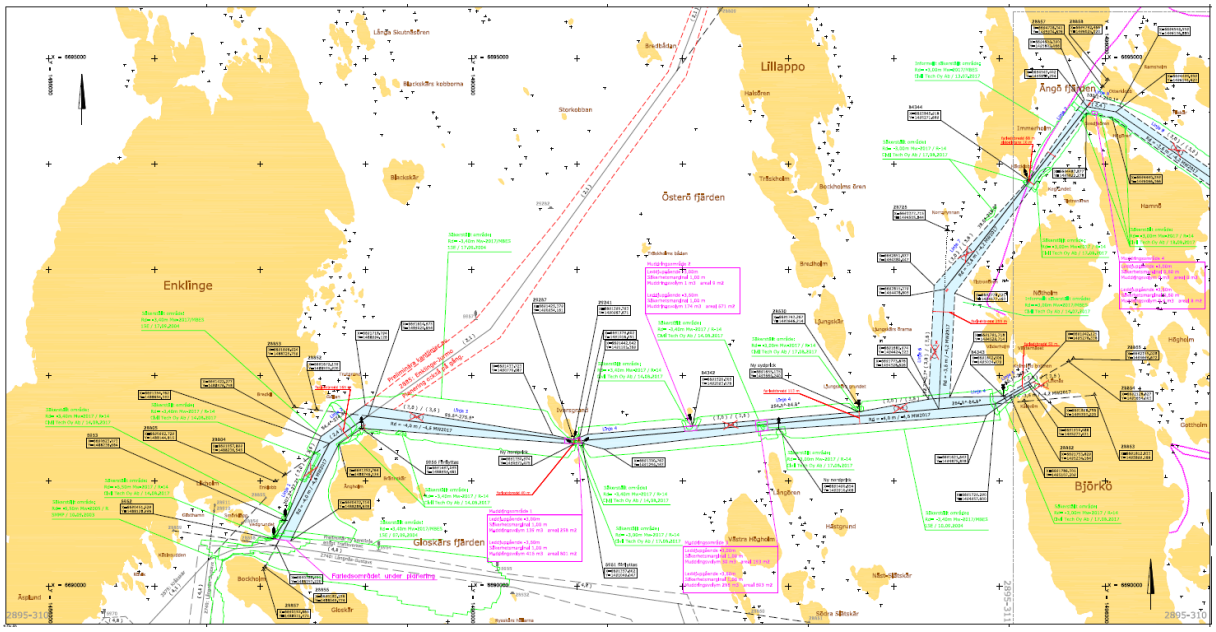


Figure 163. Shows the developed fairway plan for the western part of fairway 2895.

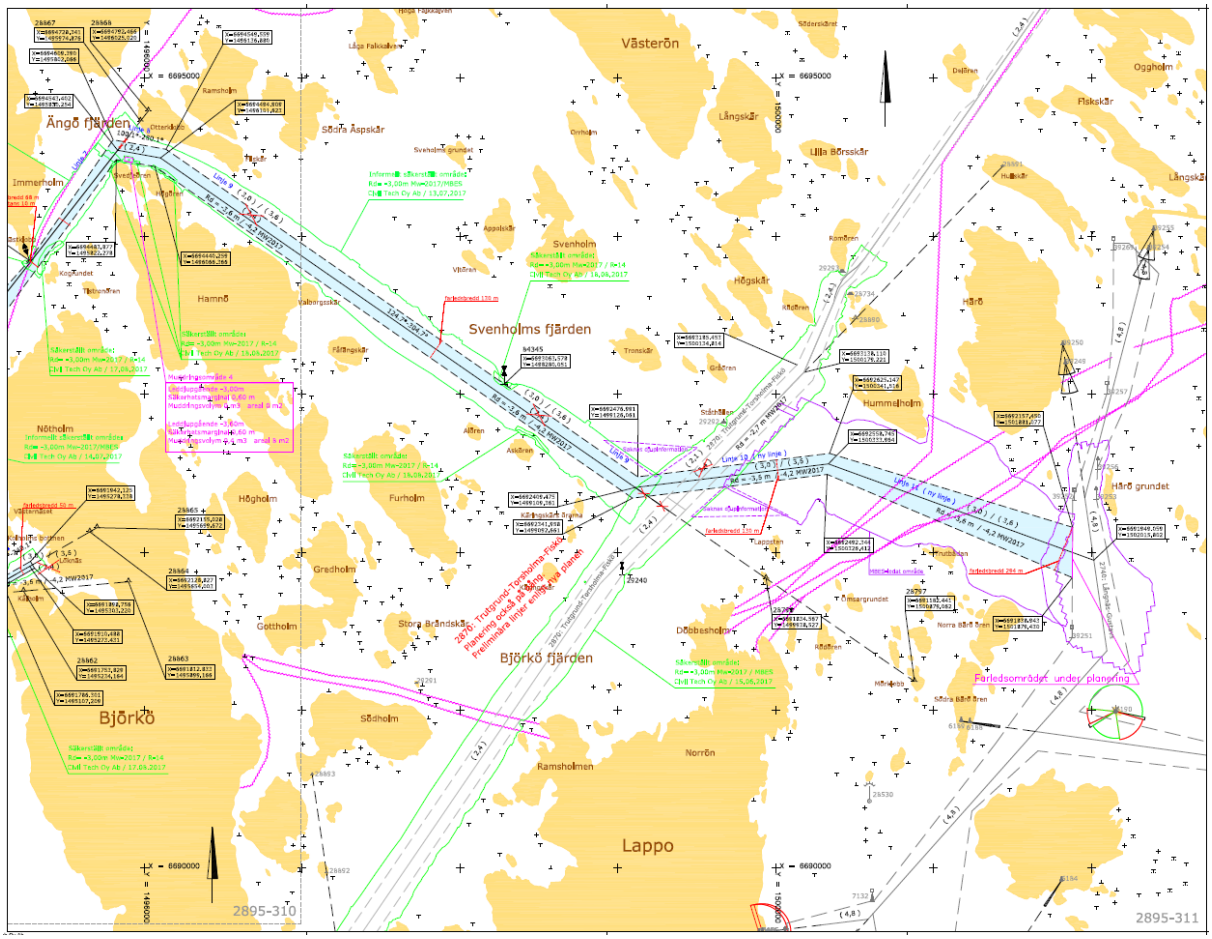


Figure 164. Shows the developed fairway plan for the eastern part of fairway 2895.

Time saves: By realizing the changes produced by ADAPT, the travel time can be reduced by 9 minutes. The distance decreases by 3.1 km. Figure 165 shows baseline and figure 166 the proposed improvements to the route. Table 40 shows the travel time calculation based on the abbreviated distance proposed in ADAPT.

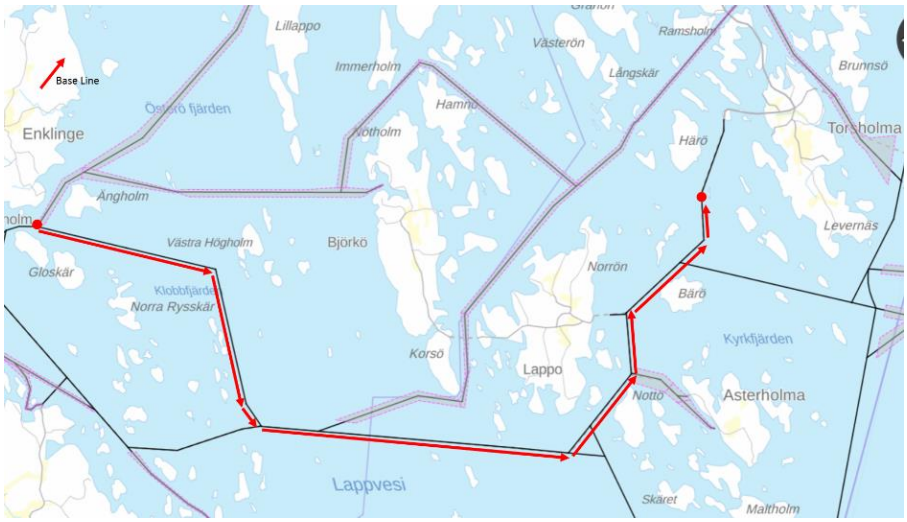


Figure 165. Base line for fairway 2895.

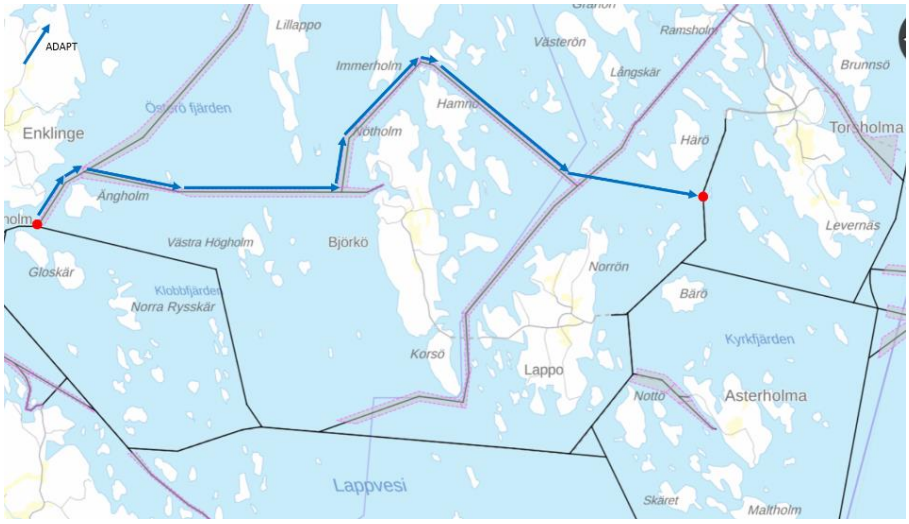


Figure 166. Proposed ADAPT-improvement for fairway 2895.

Table 40. The calculations for the time saves for the developed route compared to the original fairway 2895.

	Baseline 2895		**Proposed developed alternative route**	
Distance	20,3	km	17,2	km
Speed	2,37	km/h	20,37	km/h
Time	0,99	h	0,85	h
Time	59,8	minutes	50,7	minutes
Total			-9,1	minutes

Fuel efficiency measures: The fuel consumption decreases with approximately 280 l/h x 9/60= 42 l diesel fuel per trip.

Environmental issues: The measures proposed in ADAPT results in that the fairway can be operated with a greater number -and size vessels. This can adversely affect the marine environment, mainly through beach erosion and clouding. By constantly improving the markings of the fairway and deepening the most critical passages, one can reduce the negative effects of the shipping traffic. The improved status also means that the risk of accidents with emissions of environmentally hazardous substances is reduced.

The result of the analysis of the fairway and developed alternative, shows that the developments in the fairway will enable larger vessels to use it, and that this can be achieved with small dredging efforts. The dredging efforts will generate a greater positive environmental impact, through the more efficient vessel traffic enabling the measure, than the negative environmental impact of the dredging. Table 41, shows the reduction of emissions of climate gases if the archipelago traffic uses the developed fairway (between nodes 20 and 24) calculated per trip.

Table 41. Show the calculations of reduction in climate gas emissions utilising the developed alternative route instead of the route 2895.

Fairway 2895 Enklinge-Lappo, ADAPT node 20 - 24						
	Emission per kg of fuel		Reduction of fuel consumption due to ADAPT per year		Reduction of emissions per year	
Emission CO_2	2,66	kg/kg fuel	- 34	kg/trip	- 90,44	kg CO_2/ trip
Emission NO_x	0,055	kg/kg fuel	- 34	kg/trip	- 1,87	kg NO_x/ trip
Emission SO_x	0,000005	kg/kg fuel	- 34	kg/trip	- 0,00	kg SO_x/ trip

Safety Issues: The measures proposed entail an improved marking and deepening of the fairway, which means that the maritime safety is improved. In addition, the change allows more and larger vessels to utilise the fairway, as it provides a safer voyage in difficult weather conditions. Figure 162, 163 and 164 shows the updated plan with improved safety.

5.8 Corridor 2905 Enklinge-Houtskär

When the corridor was analysed, an observation was that the section extending from node 25 to the north mark, north of Hattskär is difficult to deepen. It is advisable to increase the fairway depth to 3.6 m if you dredge two areas in this fairway section. In the fairway section from Hattskär to node 26, the fairway can be deepened considerably more. Figure 167 shows the baseline route for fairway 2905 Enklige-Houtskär and figure 168-170 below shows the proposed developments and improvements.

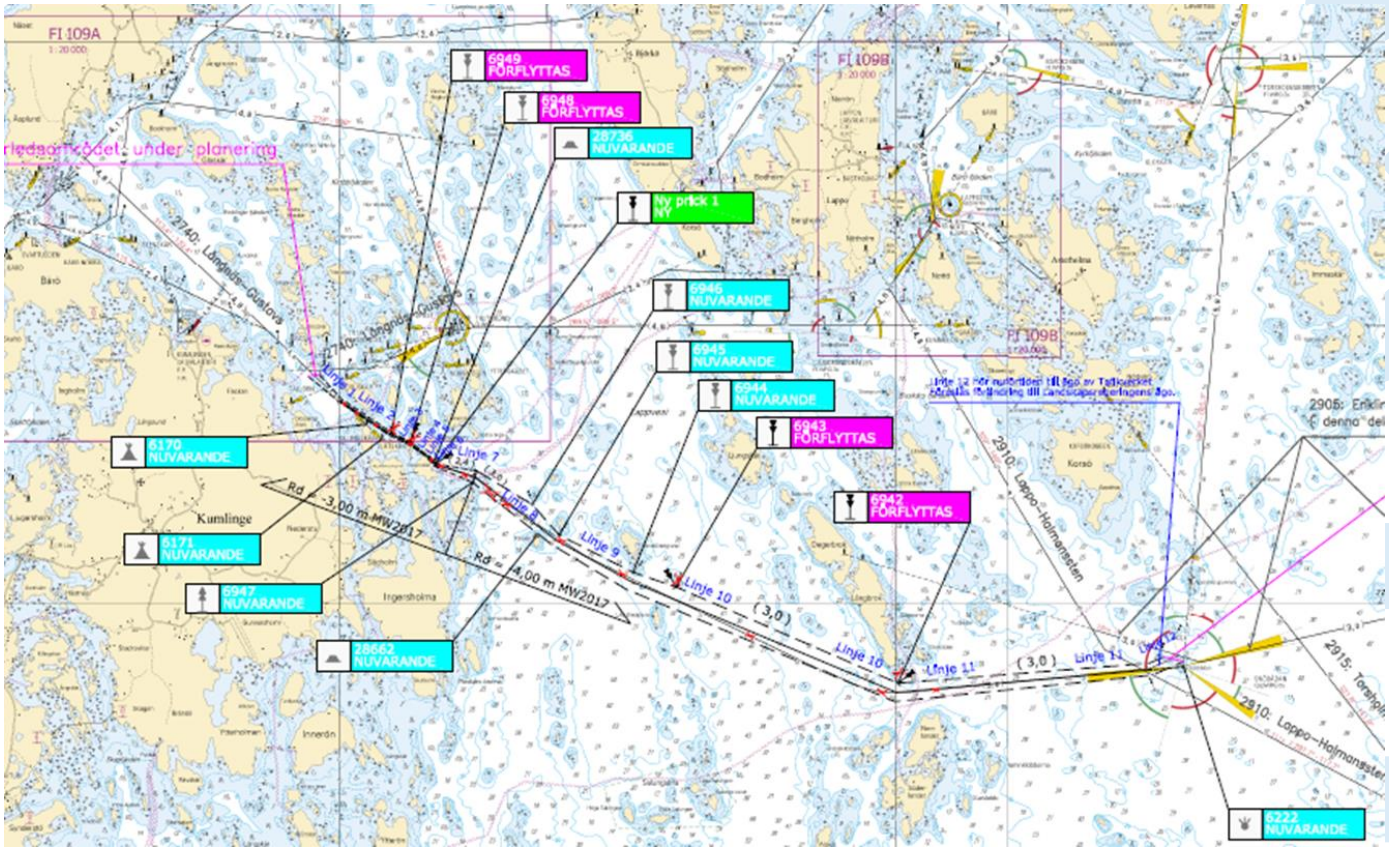


Figure 167. Shows fairway 2905, Enklige-Houtskär, original route.

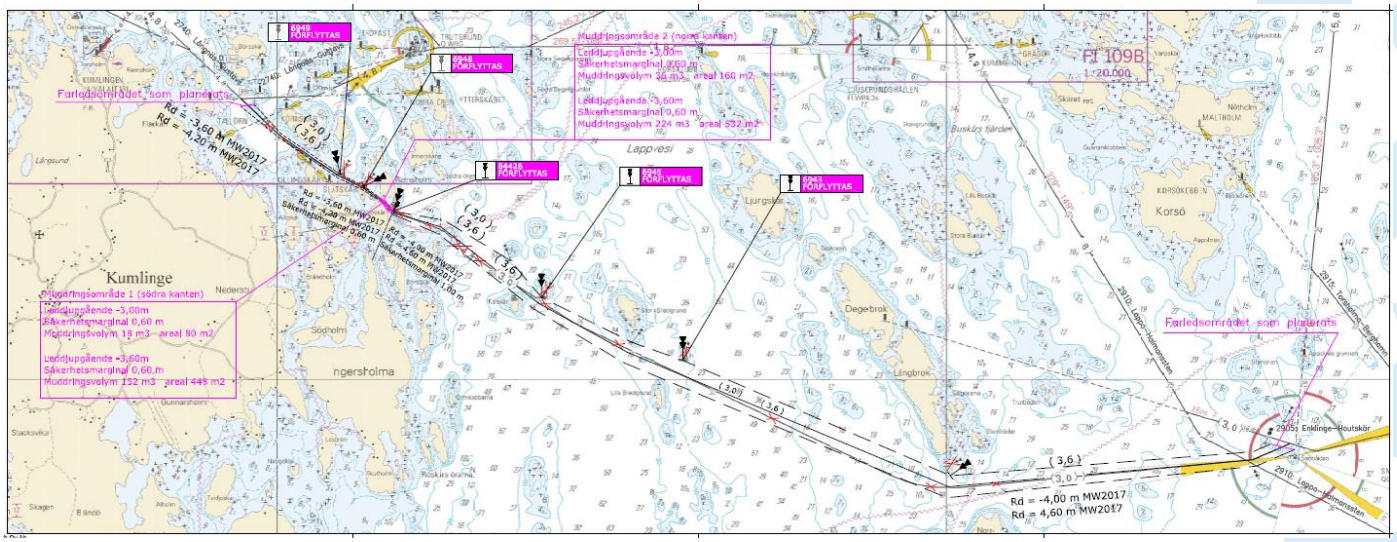


Figure 168. Shows the developments proposed by ADAPT fairway 2905 Enklinge Houtskär.

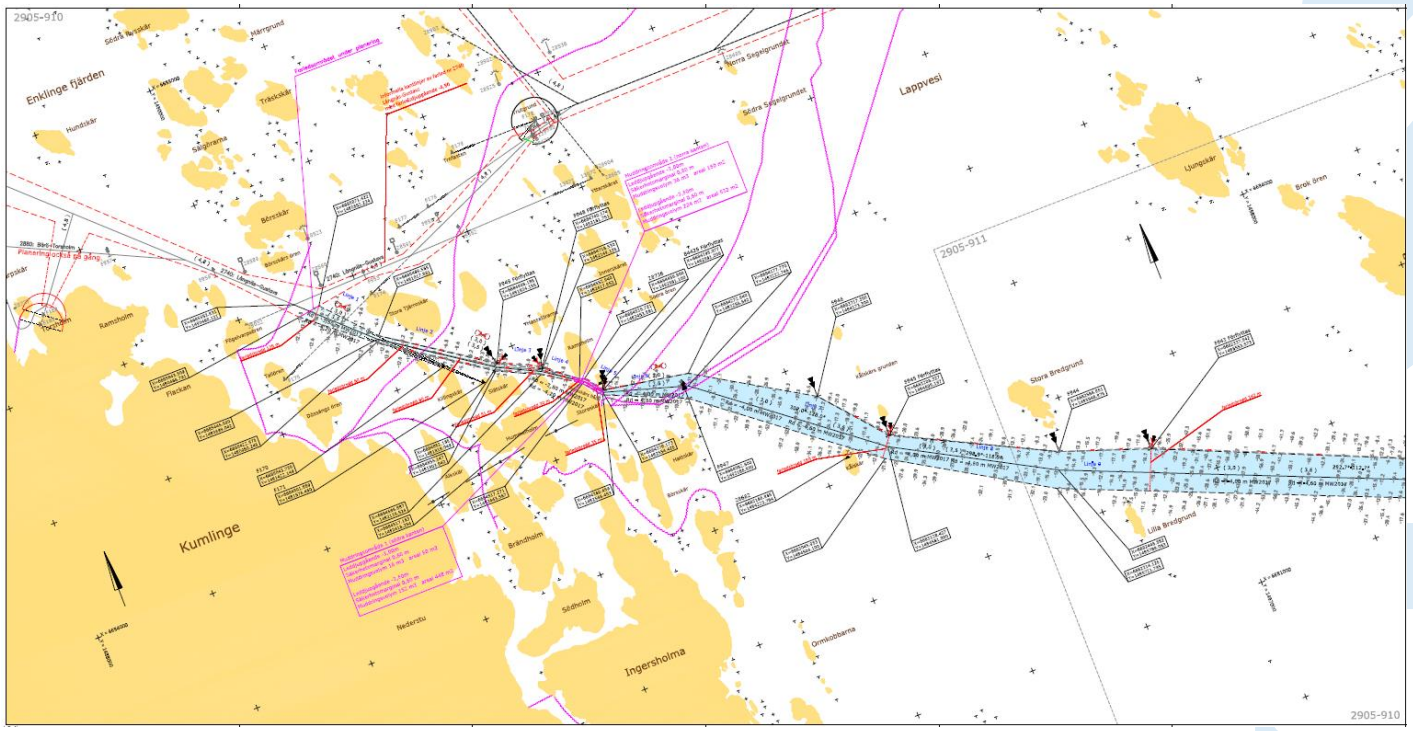


Figure 169. Shows the developments proposed by ADAPT in the northern part of fairway 2905.

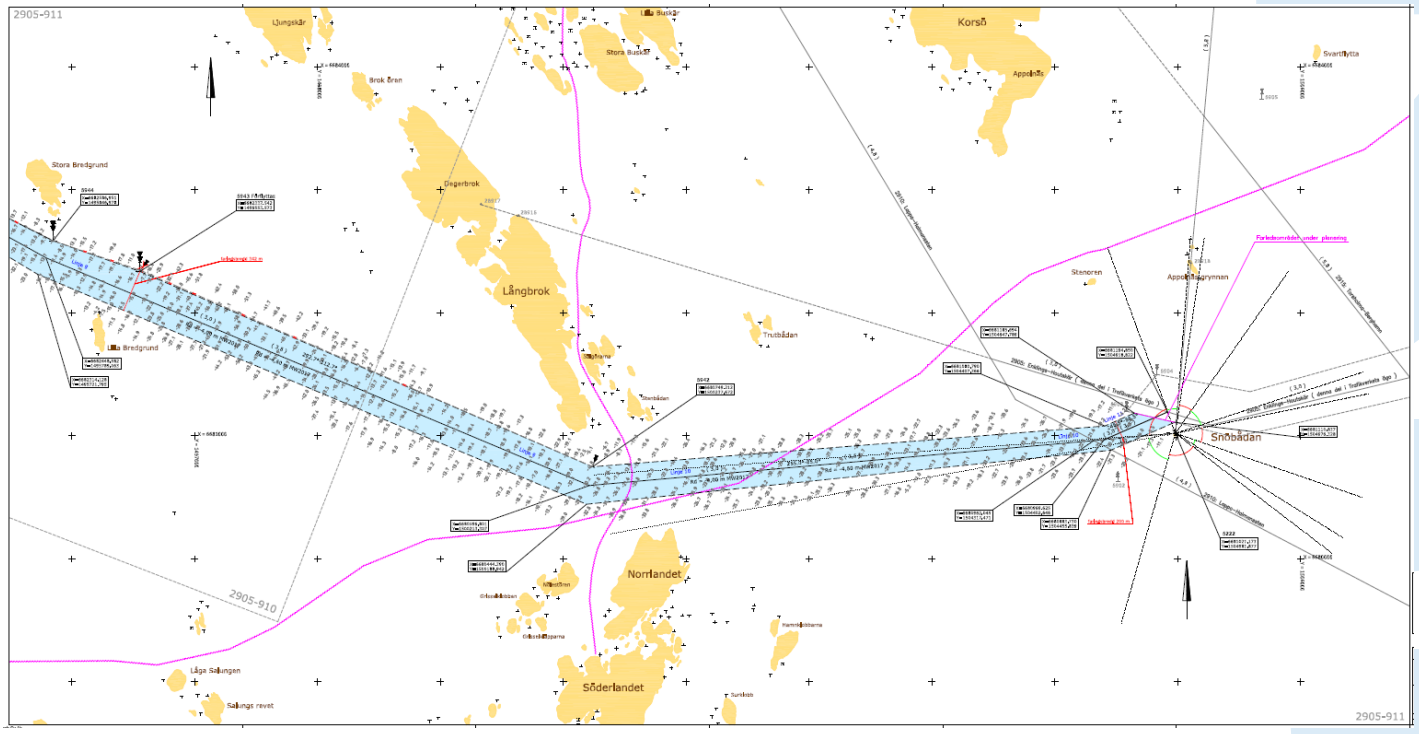


Figure 170. Shows the developments proposed by ADAPT in the southern part of fairway 2905.

Time saves: The time savings will be about 5 minutes per journey if you choose to implement the measures proposed by ADAPT for the fairway. Figure 171 below shows the Base Line for the fairway. Figure 172 shows the proposal from ADAPT for the same fairway. Table 42 shows the calculation of travel time for each option.

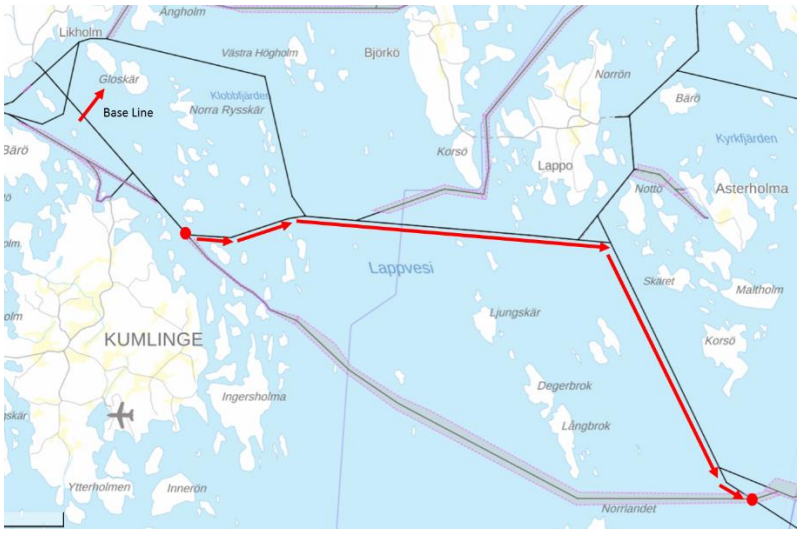


Figure 171. Shows baseline for fairway 2905 Enklige-Houtskär.

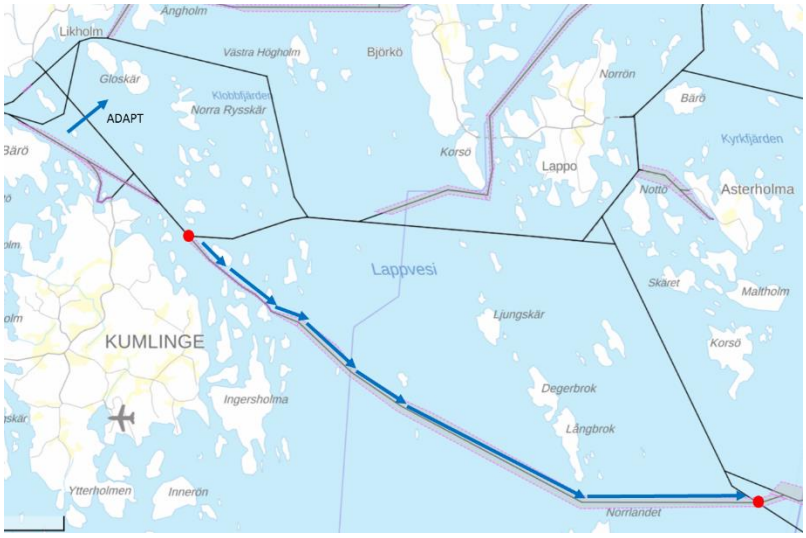


Figure 172. Shows the proposed development to baseline 2905 Enklige-Houtskär.

Table 42. Shows the calculation of travel time for each option for fairway 2905 Enklinge-Houtskär.

	Baseline 2905		**Proposed developed alternative route**	
Distance	17,2	km	15,4	km
Speed	20,37	km/h	20,37	km/h
Time	0,84	h	0,76	h
Time	50,7	minutes	45,4	minutes
Total			-5,3	minutes

Fuel efficiency measures: The fuel consumption decreases with approx 280 l/h x 5/60= 23 l diesel fuel per route.

Environmental issues: An abbreviated route consumes less fuel and reduces the negative impact of traffic during the whole time the fairway is used. The dredging is required to move vessels traffic from baseline to the proposal

ADAPT suggests, adversely affecting the environment through, among other things, clouding. To remember is that it is a one-time impact but that there are long-term environmental benefits too.

Table 43, shows the reduction of emissions of climate gases if the archipelago traffic uses the ADAPT fairway (between nodes 25 and 26 and 8) during one trip.

Table 43. The calculated reduction of emissions of climate gases comparing the developed alternative to baseline route 2905.

Fairway 2895 Enklinge-Lappo, ADAPT node 20 - 24						
	Emission per kg of fuel		Reduction of fuel consumption due to ADAPT per year		Reduction of emissions per year	
Emission CO_2	2,66	kg/kg fuel	- 20	kg/trip	- 53,20	kg CO_2/ trip
Emission NO_x	0,055	kg/kg fuel	- 20	kg/trip	- 1,10	kg NO_x/ trip
Emission SO_x	0,000005	kg/kg fuel	- 20	kg/trip	- 0,00	kg SO_x/ trip

Safety Issues: The proposed measures entail an improved marking and deepening of the fairway, which means that maritime safety is improved. In addition, the change allows more -and larger vessels to utilise the fairway, as it would provide a safer voyage in difficult weather conditions. Figure 168 show the updated plan with improved safety.

6. Discussion and conclusions

During the project hydrographical surveys was executed for an area of over 240 km^2 totally in the two archipelagos. This includes 8 fairways in Åland, and sections or whole parts routes within the public transport operated by Waxholmsbolaget in Stockholm archipelago. The sections are analysed as corridors and the ports, jetties and fairway crossings as nodes. When planning the areas for the hydrographic surveys there was a significant difference in the selection approach between the two archipelagos. The selection in Stockholm archipelago was based on increasing the safety along the existing routes. Whereas, the selection in the archipelago of Åland was based on finding alternatives outside of the existing routes. This is one reason for why the results differ and are presented somewhat differently throughout this report. A fundamental difference in the execution of the project between the parties is that the Government of Åland is responsible for general navigational routes and follows the Finnish Supervisory Authority, Traficom´s, rules for maritime surveying and fairway planning of public fairways. The government of Åland therefore guarantees the depth of the fairway stated in the chart, within the entire fairway area towards the users.

In some cases, the theoretical alternative for an existing route might implicate a reduction in energy use and greenhouse gas emissions or a great reduction in travel time, this however, does not automatically mean that the alternative route is preferable. The travelers' need and the reason why the routes exist has to be considered when proposing new routes. If you fail to meet the anticipations, you risk running empty ferries.

To create a route system that is effective and takes public demands in consideration is complex, and the shared knowledge between the partners has been of great importance when creating the tools and methods for the analyses. Through the project it has been shown that even a seemingly ineffective ferry, can be effective if used at the right location. Furthermore, it has become clear that the largest saves comes from meticulous comparisons, the right tools and strategic analyses. Systematic work and targeted efforts in cooperation with directives where the local politics are aligned with the demand is preferable.

The methods and tools to carry out the analyses, calculations and optimization of the routes originates in workshops and seminars throughout the project period. The exchange of knowledge between partners is a very positive result. Finding methods of changing routes or parts of routes and still respond to the travellers' needs and wishes is one example of when the knowledge exchange has been of great importance. Questions met for traffic planning and analyses, such as when to change vessel size or type? or what are the purposes for the trip on different routes and for different travellers?, they are the same within the two archipelagos. The knowledge exchange between the partners has therefore been of great importance for the result to come out the way it has.

The results are of great importance for the public transport systems in the archipelagos and over 100 safety issues has been addressed in Stockholm archipelago and time saves can be as high as 30 minutes for one single trip in the Åland archipelago. Altogether, there are 46 corridors and 40 nodes identified and analysed through ADAPT. The developed routes presented in this report are all contributing to the optimization of the public transport in the archipelagos. 34 corridors in Stockholm and 7 in Åland has an increased safety level. Furthermore, 6 corridors in Stockholm and 5 in Åland has reduced their emissions of greenhouse gases. With an optimized transport system, the positive outcome is immeasurable.

There are many positive outcomes of the project, most of the type that the traveller might not notice. Such an example is the great increase in safety level of the routes. Now that the depths of the corridors are fully known the focus has been redirected to development many previously intended opportunities has shown feasible. There are locations where the routes has been elongated to secure the ferries from the risk of groundings. In the Åland archipelago, ADAPT has resulted in improvements to the marking of all existing fairways. This is a direct safety-enhancing measure that The Government of Åland has come to implement in the spring of 2019.

Although, in other locations where there has been proposed changes in the routes there is a time save or no change in travel time. The environmental benefits of the reduced distances are primarily the reduction in fuel use and greenhouse gas emissions. There are, however, other environmental parameters taken into regard in the analyses with benefits such as reduced erosion along the shore of Svartsö as a result of the proposed adjustment of corridor 36. The benefits are also of great general benefit to the society. Leisure boaters also benefits from the updated navigational charts and without a change of habit an optimized transport system enable the travellers to spend less time on the ferries and simultaneously reduce their ecological footprint.

This project has been of great value, firstly the knowledge of previously unknown depths in many ways enable the traffic in the archipelagos. The project has opened up for future possibilities and highlights the importance of similar projects. There is a great value in preforming hydrographical surveys in these types of waters, to secure the fairways and public transport routes in areas with high density of mariners. These shallow and high trafficed areas have a general need of hydrographical surveys for reach a safe navigation and optimised traffic management all through the archipelagos.

One of the problems discovered during the project is that it is difficult to estimate the large amount of work that the follow-up and the account of the project creates during the application phase. During the project, it has been found that it is difficult, at the stage when the budget is established, to estimate the extent of maritime measurements, especially in shallow water areas and the downtime the weather causes. Through an early and careful planning of the maritime surveying areas where we planned that we always year after the theoretical maritime measurement areas were MBES-surveyed we would complement the surveys based on the knowledge acquired in the previous year. Many "unnecessary" maritime surveys were eliminated outside the fairway areas. The experience is that you can save time and financial resources through good planning based on analysis of relevant facts.

Participants in meetings within ADAPT

Meeting WP 4 - seminar 3

Place Swedish Maritime Administration, Norrköping

Date 24 - 28 September 2018

Participants attended whole or part of time.

Called to attend	Signature
David Modig	
Ian Bergström	
Indrek Pöldma	
Linda Blied	
Linn Gardell	
Mikael Levin	
Åsa Gren-Tivelius	

Participants in meetings within ADAPT

Meeting WP 4 - seminar 4

Place Swedish Maritime Administration, Rosenvik Stockholm

Date 21 November 2018

Participants attended whole or part of time.

Called to attend	Signature
David Modig	
Ian Bergström	
Indrek Pöldma	
Linn Gardell	
Åsa Gren-Tivelius	

Participants in meetings within ADAPT

Meeting WP 4 - seminar 3.3

Place Rosenvik, Stockholm

Date 17 Januari 2019

Participants attended whole or part of time.

Called to attend	Signature
David Modig	
Ian Bergström	
Indrek Pöldma	
Linn Gardell	
Åsa Gren-Tivelius	