Under Keel Clearance For Ships Carrying Dangerous Goods

A Study on Groundings and Pilotage in Danish Waters

By Kristoffer Guldbæk Stentebjerg & Maria Skov Engqvist
Master thesis, Geoinformatics at Aalborg University, Copenhagen

Aalborg University Copenhagen
L-study Board
A.C. Meyers Vænge 15, 2450 København SV

Secretary: Jette Nielsen

Synopsis

Project Title
Under Keel Clearance for Ships Carrying Dangerous Goods
A Study on Groundings and Pilotage in Danish Waters

Semester
4th semester, Geoinformatics

Project Period
4th of February 2013 – 13th of June 2013

Hand-in
June 13th 2013, 12⁰⁰ CET

Supervisors
Associate Professor Thomas Balstrøm
Professor Esben Munk Sørensen

Group Members

Kristoffer Guldbæk Stentebjerg
Study no.: 20082677

Maria Skov Engqvist
Study no.: 20082678

Number of copies: 2
Number of pages: 103
Number of appendixes: 2
Number of CD-appendix: 1

Transportation of goods at sea is common, and several national, as well as international, regulations are provided in that field.

To prevent ships from colliding or grounding, different actors plays a part by monitoring the ships and make analysis on the traffic patterns. This takes places in real-time as well as on historic data.

This project concerns ships navigating with dangerous goods in the Danish waters. The danger and cost of ships grounding with the seabed can have a huge impact, and therefore the use of pilots is important when requested.

The different regulation and factors that plays a role when navigating in Danish waters are investigated, for an analysis to be performed.

The analysis concerns whether ships have been in a critical situation, i.e. where the under keel clearance have been less than recommended.

It is furthermore investigated if ships are using pilots when regulated and if there are any locations outside the regulated areas, where pilotage should be compulsory.

The methods used in the project as well as the results, are discussed and evaluated in the last phase of the project.

AALBORG UNIVERSITY
COPENHAGEN

Preface

This project is created by two students from the Master's Programme in Surveying, Planning and Land Management specializing in Geoinformatics at Aalborg University, Faculty of Engineering and Science.

The project has been developed in the period of February 4th 2013 to June 13th 2013, in the context of our thesis at 30 ECTS and is based on the study guide for the thesis of the Master's programme in Surveying, Planning and Land Management

The subject of the project have been decided in collaboration with associated professor Thomas Balstrøm who has contacts in the field.

The project has been supported by Associate Professor Thomas Balstrøm, Professor Esben Munk Sørensen, Data Analyst Svend Jacob Senstius, Geographer Charlotte Bjerregaard, Nautical Caseworker Søren Nielsen and Hansi from Great Belt VTS, whom have helped by supervising, supplying data as well as replying to questions.

Reading Guidelines

The following serves as guidelines on how to read and interpret the content of the report, including but not limited to references and translated definitions.

References

This report makes use of the Chicago method as reference system. The sources are listed continuously through the text as follows:

([author] [publishing year])

The position of the reference indicates the extent of the reference, in accordance with the examples below. The full titles and information can be found in the bibliography.

Example 1:

These examples are written to show how the references from the bibliography are referring to various sections, one section or a line.

In this example, the reference refers to more than one section.

(Christensen, 2013)

Example 2:

As the previous referred to several sections, this example refers only to one section. The difference on these two examples is the space between the sentences.
(Christensen, 2013)

Example 3:

When the reference is standing after a sentence, it refers to the sentence. (Christensen, 2013)

Cross-references and appendixes are referred to by type and number, as for example *Chapter 2.1* and *Appendix 2*.

Figures are numbered continuously through the report, and are referred to by their name, as for example *Figure 10*.

Appendix

In addition to the report, an appendix is presented that comprises the facts and studies conducted during the project.

Applied Programs

- Python
  - PyScripter
- ArcGIS
  - ModelBuilder

Data

The data used in this project is:

- AIS-data
- Pilot-data
- Digital Depth Model
- Boundary of inner and outer Danish territorial waters

Data was received provided that we do not deliver the data to third parties and that MMSI-numbers is not mentioned in the report. The individual ships is thereby mentioned as Ship01, Ship02 etc.

Translations

Many geographic locations are used in the project. Some of the most important, and most used, are listed below with their English and Danish names, respectively.

Translation	Danish
The Little Belt	Lillebælt
The Great Belt	Storebælt
The Kiel Channel	Kielerkanalen
The Sound	Øresund

Orders

Through the report, a number of laws and orders are used. Instead of using the complete names, their abbreviations are used instead. In the table below, the laws and orders used are noted.

Abbreviation	Order
BEK no. 386	Bekendtgørelse om Meddelelser fra Søfartsstyrelsen B, teknisk forskrift for skibes bygning og udstyr m.v.
BEK no. 449	Bekendtgørelse om Anvendelse af Lods
LOV no. 567	Lodslov
BEK no. 1077	Bekendtgørelse om udstedelse af lodscertifikat og lodsfritagelsesbevis
BEK no. 1142	Bekendtgørelse om Bestilling af Lods
BEK no. 1349	Bekendtgørelse om indberetning af oplysninger om farligt eller forurenende gods om bord på skibe

Maps

Esri et al. provide the imagery basemaps used in ArcMap.

The maps created in this project are all facing north.

Content

Phase 1

1 Introduction

The Danish waters are narrow and shallow in several locations. This results in high concentrations of shipping traffic where large ships are navigating with only a few centimetres between the ship and seabed. The shallow water increase the risk of ships grounding and therefore, IMO have recommended that large ships and ships carrying dangerous goods use pilots when navigating through the international channels in the Danish waters.

Recently the Danish media have been focusing on this issue and according to Lund & Hansen (2012 (a)), many ships navigate through the Danish waters without a pilot despite IMO's recommendation. The world's largest shipping companies are among those choosing not to use pilots. This practice affects competitiveness and has an impact on the smaller companies, who are forced not to pay for the use of pilots to remain competitive in the market. This is problematic since it increases the chance of collision or grounding, which harms the Danish marine environment and has significant economic costs. Often, companies choose not to use pilots because it is an extra expense and because they believe that their master of ship is fully capable of navigating the waters safely.

(Lund and Hansen 2012 (a))

Every year the amount of oil transported in Danish waters increases and studies indicate that approximately each eleventh year a large oil spill will occur in this region. (Lund and Hansen 2012 (b))

Today it is possible to track the ship traffic in the Danish waters through the information that AIS-systems deliver. With AIS-signals, it is possible to narrow down the number of ships and investigate which ships that have been at a given location or within a radius of a location at a specific time. This can be utilised to identify which ship is responsible for future oil leaks.

The issue concerning large ships navigating through the Danish waters and lack of pilotage is the focus of the report. In order to keep the project on track, a timetable and a structure of the report needs to be prepared.

2 Project Structure

A successful project needs planning and structure so that the members of the team are aware of the elements of the project, and know how to get from start to finish. (Larson and Gray 2011)

2.1 Timetable

Figure 1 shows the timetable used throughout this project. The timetable splits the project period into smaller sections, each with its own milestone, to ensure that all steps will be finished before the deadline.

Milestones							
Task	Start date	End date	February	Marts	Aril	May	June
Collection of data	01-02-2013	15-02-2013					
Problem statement	05-02-2013	05-02-2013					
Analysis and preliminary investigations	15-02-2013	10-04-2013					
Writing report	10-04-2013	29-05-2013					
Correction	29-05-2013	05-06-2013					
Poster	05-06-2013	10-06-2013					
Printing and finishing	10-06-2013	13-06-2013					
Hand-in	13-06-2013	13-06-2013					

FIGURE 1 THE PROJECT DIVIDED INTO SMALL SECTIONS AND THE MILESTONES FOR THE INDIVIDUAL SECTIONS.

The project is divided into eight main sections, the first being collection of data. Having decided on a topic it is important that data is available – if not, the project cannot be completed. The first 15 days were used to collect the data relevant for this project and define the problem statement.

Working on the analysis and writing the report is given approximately the same amount of time. This way, it is possible to get an understanding of the subject and work intensively with the analysis. After the text for the report is complete, it has to be corrected for the project to be presentable. The poster will be created focusing on the report and the project is then ready to be printed and handed in.

2.2 Structure of the Report

According to Rienecker, et al. (2008, 41) projects are written as a tripartite division. The first phase is the describing phase, the second phase is the analysing and comparing phase and the third and last phase is the discussing and evaluating phase. This tripartite division model forms the basis for the project.

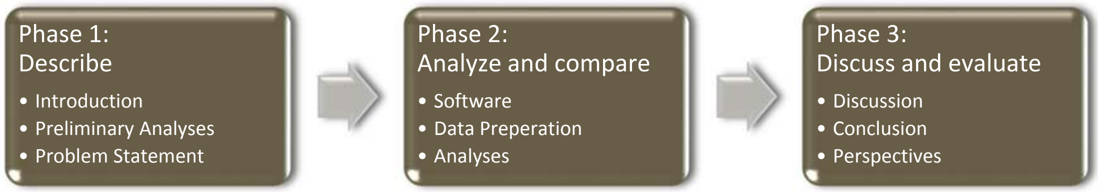


FIGURE 2 THE PROJECT IS DIVIDED INTO THREE PHASES, THE DESCRIBING PHASE, THE ANALYSING AND COMPARABLE PHASE AND THE DISCUSSING AND EVALUATING PHASE.

Figure 2 shows the three phases of the report as well as the main content of each phase. In phase 1, the required background information to answer the problem statement is presented, in addition to the problem statement. In phase 2, the software used to perform the analysis, the data and preparation of this, as well as the results of the analysis, are presented. In the final phase, the method and results are discussed, in order to conclude the project. Once the discussion and conclusion is completed, the perspective can be compiled.

While investigating the different elements for the project and preparing the report, some of these elements have been performed parallel to each other, as visualised in the flow diagram, Figure 3.

In phase 1, the elements in the background were performed parallel to each other so that the gained information has been used between the five elements. During the data preparation in phase 2, the quality of the data was investigated to understand the outcome, and additionally, the calculations used in the analysis were studied.

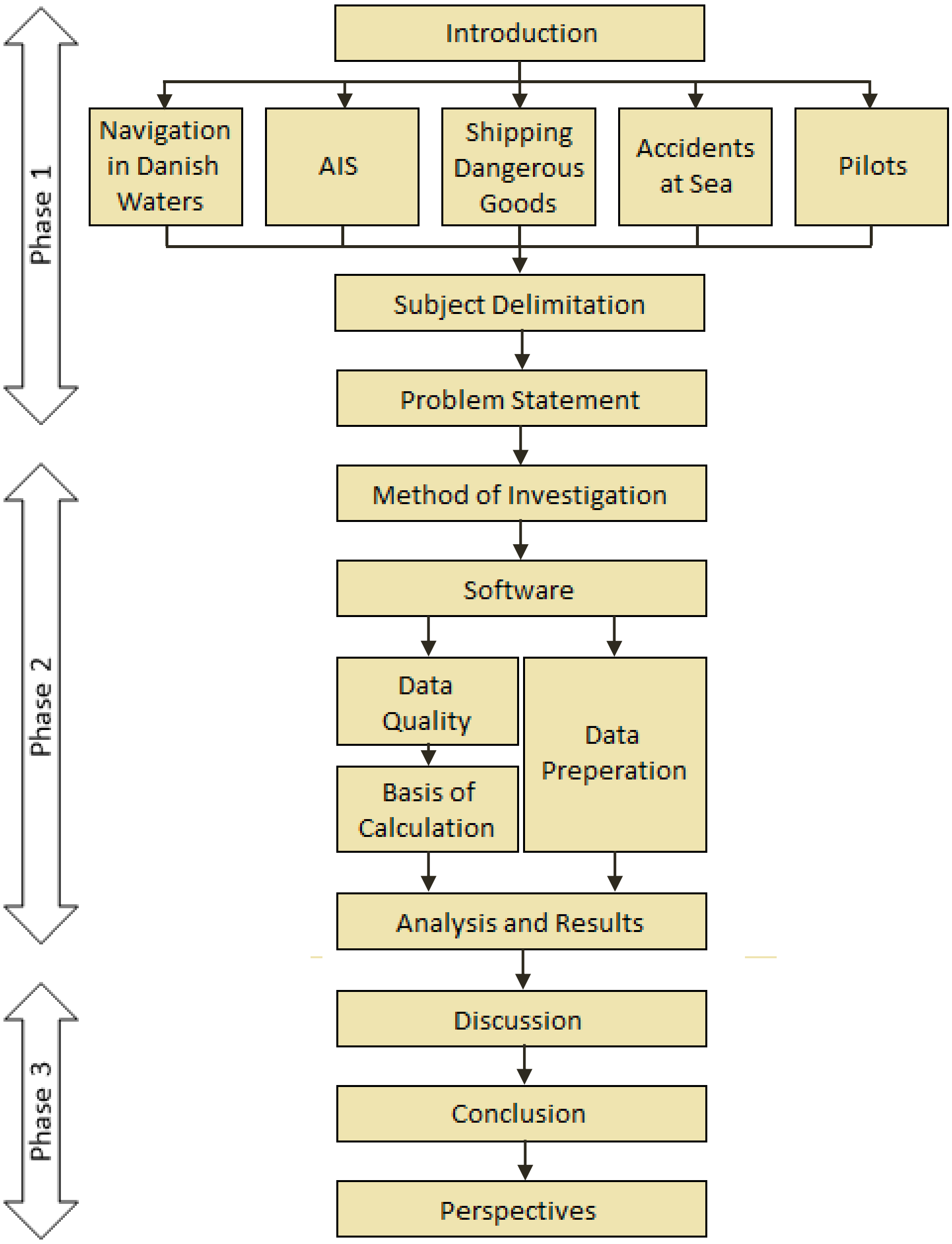


FIGURE 3 A FLOW DIAGRAM SHOWING THE WORK PROCESS.

To better comprehend the components of the analysis in phase 2, a preliminary analysis is presented in the following section.

3 Background

To understand the analysis performed in this project, a background dealing with different factors such as shipping and navigation, accidents, and regulations and laws, will be represented in the following sections.

3.1 Navigation in the Danish Waters

Shipping is a transport form that goes all the way back to the Vikings and is used to transport people as well as goods. Today passenger transport primarily occurs by air, whereas the majority of international transport of goods takes place at sea. The primary reason is that shipping is a cheaper form of cargo transport. The low cost of ship transport has resulted in competitive prices on products worldwide and has played a key role in the growth of the global economy.

(Gyldendal n.d. (a)) (Gyldendal n.d. (b))

When sailing a ship, no matter the size, it is mandatory to possess navigational charts - the use of electronic navigational charts (often called ENC), was authorized in 1995. Due to the price of ENC systems, they are more commonly found on larger ships (Sørensen 2013). ENC systems are updated from a central database and the updated charts can be distributed easily to the ships, while paper charts must be updated manually based on instructions from the national hydrographic offices. For an ENC to be valid for navigation, it has to comply with the standard presented in the International Hydrographic Organization's (IHO) publication named S-57.

Navigational charts are used to plan routes, and contain information regarding depths, beacons, signals etc. Ships have the possibility to navigate to and from the Baltic Sea through four routes within Danish waters; the Kiel Canal, the Little Belt, the Great Belt or the Sound. The routes are displayed in Figure 4.

FIGURE 4 THE NAMES AND LOCATIONS OF THE DIFFERENT CHANNELS. (SØFARTSSTYRELSEN N.D. (A))

When navigating through one of these routes, a number of different organisations becomes relevant – such as International Maritime Organization (IMO) and United Nations Conference on the Law of the Sea (UNCLOS).

IMO "*is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships".* (International Maritime Organization n.d.) Today IMO consist of 169 member states and have specialized committees focused on adopting new and updating existing legislation. (International Maritime Organization n.d.)

IMO publishes Maritime Safety Committee (MSC) Resolutions containing recommendations for safe navigation at sea. Resolution MSC.138 (76) concerns navigation through the entrances to the Baltic Sea. The international route through the Great Belt, defined as *Route-T* and the international route through the Sound, defined as *the Sound*.

United Nations is responsible for the United Nations Conference on the Law of the Sea (UNCLOS). The UNCLOS III convention defined the rights and responsibilities at sea, known as the United Nations Convention on the Law of the Sea (also called UNCLOS).

According to article 17 and 18 in UNCLOS, ships of all states have the right of innocent passage, in this case through the Danish straits. A passage happens when a ship continuously and expeditiously navigates through the straits without entering the internal waters – in exceptional cases ships can stop and anchor.
(UNCLOS 1982, Art. 17 & 18)

A *"Passage is innocent so long as it is not prejudicial to the peace, good order or security of the coastal State. Such passage shall take place in conformity with this Convention and with other rules of international law."* (UNCLOS 1982, Art. 19)

Despite the mentioned articles, ships must comply with IMO's resolutions regarding Route-T and the Sound, further described later in this chapter. If a ship violates IMO's recommendations, The Danish Pilotage Authority reports the violation to the flag state, who in turn has the responsibility of collecting the money to pay the fine from the shipper. One of the purposes of this legislation is to prevent accidents at sea, similar to road based traffic legislation designed to prevent road accidents.

Another way to avoid accidents is by monitoring the traffic. In general, the Admiral Danish Fleet (SOK) performs the surveillance of the Danish waters. SOK is the main authority and are involved in many aspects of monitoring safety in Danish waters. (Admiral Danish Fleet n.d. (a))

When a ship is sailing in Danish waters, it is under constant surveillance from Maritime Assistance Service (MAS), which is a group under SOK. MAS is a central unit with the purpose of guiding and helping ships travelling through Danish waters by providing non-stop support to ships. (Søværnets Operative Kommando n.d. (a))

In addition to MAS, two VTS centres are located in Korsør and Malmø. The one in Korsør, called Great Belt VTS, was established in 1993 to protect the construction work on the Great Belt Bridge, but was made permanent in 1998 when the bridge opened (Vessel Traffic Service Storebælt n.d.) The one in Malmø is a joint operation between Danish and Swedish authorities, making it the first VTS centre to operate on two countries at the same time. (Admiral Danish Fleet n.d. (b))

MAS and the VTS centres have a system, made by Navicon, used for tracking each ship in Danish waters. The system can make direct contact with the ships in case of emergencies. In early April 2011, the system was used three times, within two days, to avoid potential grounding accidents. The potential groundings were identified by watching the route of the ship and comparing the draught to the depth of the predicted course. (Søværnets Operative Kommando n.d. (b))

According to IMO (2007, 8) resolution SN.1/Circ. 263 eastwards beyond the Great Belt, Route-T has a maximum obtainable depth of 17 meters in stagnant water. The depth decreases up to 2 meters because of sand migration together with tides and meteorological conditions. It is therefore recommended to navigate with a safe draught, taking the variation of up to 2 meters into account.

Hansi (2013), employed at the Great Belt VTS centre, confirms that there is no regulations on the field to his knowledge, but that pilots use an under keel clearance (UKC, chapter 7.3) of at least 2 meters in the Great Belt, which he states has been working well since the implementation of VTS.

The Little Belt is primarily used by smaller ships and has a maximum obtainable depth of 13 metres. The Sound has a maximum obtainable depth of 7.4 meters in the Eastern passage, called Flinttrannan, and a maximum obtainable depth of 7.5 meters at the Western passage, called Drogden. The recommended UKC of the passages is 40 and 60 cm, respectively.
(Platzöder 1996)

The Kiel Canal has a maximum obtainable depth of 11 meters and the allowed draught for ships with a length up to 160 meters is 9.5 meters – for ships longer than 160 meters a scheme is created in which the draught is found, ranging from 9.5 to 7.0 depending on the length and width of the ship. Furthermore, 15 km/h is the maximum allowed speed. (United Canal Agency GMBH 2005)
Based on the maximum obtainable depth it is recommended for larger ships to navigate through the Great Belt. (Platzöder 1996)

Besides the draught of the ship, the water level influences the UKC. Factors influencing the water level will be discussed in the following section.

3.1.1 Water Level

Water levels are not constant, but vary based on conditions such as meteorological elements and the tide – with the tide and the weather being the two key factors in Denmark. (Task Force for Klimatilpasning n.d.)

The water level is important when navigating by sea, especially for larger ships with a deep draught - the ships might be able to navigate through in normal circumstances but has a critical UKC during ebb.

The decrease and increase in the water level, also known as ebb and flow, is due to tidal currents driven by lunar and solar attractions. Observations of the tide are measured from different locations in Denmark – these observations are published in a tide table and can be used to calculate the ebb and flow in the future. This gives the master of ship an idea of whether an area is navigable at a given time.
(Gyldendal n.d. (c))

The tide table contains information on 16 ports, with each month having four measurements a day. The largest flow noted in the table is 2.3 meters in Havneby, which is on the western coast of Jutland. In 2012, the highest measured flow in Kattegat South was 30 cm, but most of the time the tide varied from -20 to 20 cm.

The tide in October 2012 varied 40 cm, going from -20 to 20 cm compared to the charted water level in Kattegat South. Figure 5 visualises the water level at Slipshavn from the 1st to the 3rd of October 2012.
(DMI 2012)

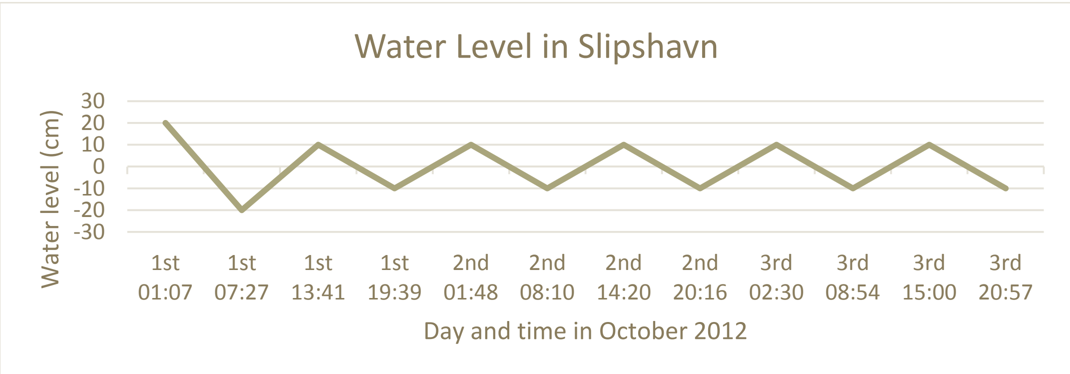


FIGURE 5 MEASURED WATER LEVEL IN SLIPSHAVN FROM OCTOBER THE 1ST TO THE 3RD 2012. (DMI 2012)

The water level decreases when the air pressure is high – an air pressure increase of one hPa causes a decrease of 1 cm. Wind stowage has the opposite effect – when the wind pushes the water into the coast, the water level is increased. When the wind is very powerful, storm surges occur. In Kattegat, storm surges are defined as a water level increase of 1-1.5 meters, which is a rare phenomenon. (DMI n.d.)
(Task Force for Klimatilpasning n.d.)

The previously mentioned factors have a short-term impact on water levels. Factors with a long-term impact are salinity, melting icecaps, isostatic uplift etc. The factors that affect the water level on a daily basis, and thereby have an influence on ship navigation, are the ones categorised as short-term factors. The master of ship are notified about changes in the long-term factors, through updates to his navigational charts, and therefore the long-term factors will not be further explained.

Having addressed the factors influencing navigation through Danish waters, the amount of traffic will be examined in order to pinpoint areas with heavy traffic.

3.1.2 Ship Traffic

Every ship has the right to innocent passage. To make sure the ships are navigating directly through the Danish waters without making a stop in a port, transit routes are defined for the ships to navigate through, Figure 6. The International routes follow these transit routes. The transit is checked-up at so-called passage lines from which ships are given a certain amount of time to navigate to the next line. If the ships are not able to do it within the given time, it is certain that they had a stop somewhere on their way through the transit route, thus the voyage cannot be considered as innocent passage. (Søfartsstyrelsen n.d. (a))

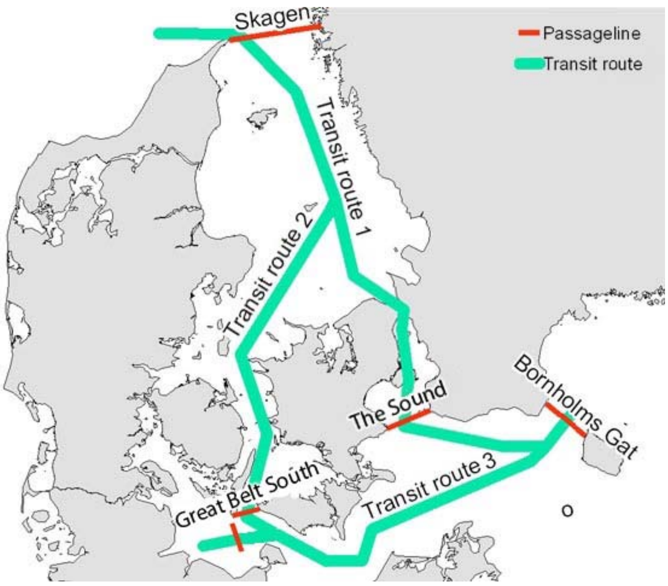


FIGURE 6 TRANSIT ROUTES AND PASSAGE LINES IN KATTEGAT. (SØFARTSSTYRELSEN N.D. (A))

For each of the three transit routes, statistics are kept of the number of ships navigating through the passage lines, including the type of ship and the draught.

When taking a closer look at the type of ships navigating through the transit routes, the statistics for transit route 1 and 3 are close to identical, Figure 7. Cargo ships are the main type, accounting for just over 75 percent of the traffic. The second most common type, tankers, account for just below 20 percent while the rest are passenger ships and others. For transit route 2 however, the numbers are quite different. Here the shares of cargo ships and tankers are almost equal. This can be explained by the fact, that transit route 2 is the deepest route, and that tankers are some of the biggest ships navigating the Danish waters and require deep water. (Danmarks Skibskredit n.d. (a))

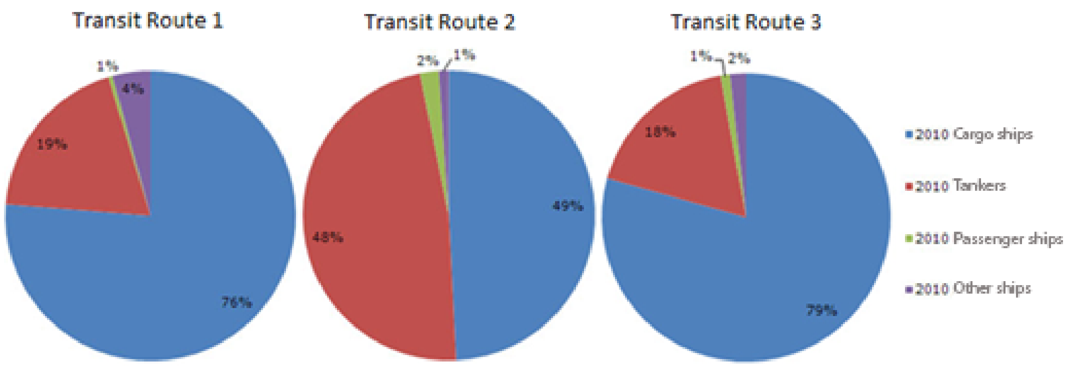


FIGURE 7 STATISTICS OF THE TYPE OF SHIPS NAVIGATING THE TRANSIT ROUTES. (SØFARTSSTYRELSEN N.D. (B)), (N.D. (C)) AND (N.D. (D))

The fact that transit route 2 is the deepest route and the large ships navigate through that route, is consistent with the numbers on the draught, Figure 8. Transit route 2 have ships with draughts larger than 15 meters, whereas transit route 1 and 3 only have ships with a maximum draught of 9 and 11 meters, respectively.

Draught (m)	0-7	7-9	9-11	11-13	13-15	> 15	Unknown	Total
Transit Route 1	8695	2660	0	0	0	0	144	11499
Transit Route 2	148	2463	2833	686	892	232	67	7321
Transit Route 3	9035	3508	540	0	0	0	121	13204

FIGURE 8 STATISTICS OF THE DRAUGHT OF THE SHIPS NAVIGATING THE TRANSIT ROUTES. (DATA FROM 2010) (SØFARTSSTYRELSEN N.D. (B)), (N.D. (C)) AND (N.D. (D))

Besides the statistics from the passage lines, The Danish Maritime Authority have published sailing patterns of all ships with an AIS-signal on board – both the A-signal and the B-signal, Figure 9.

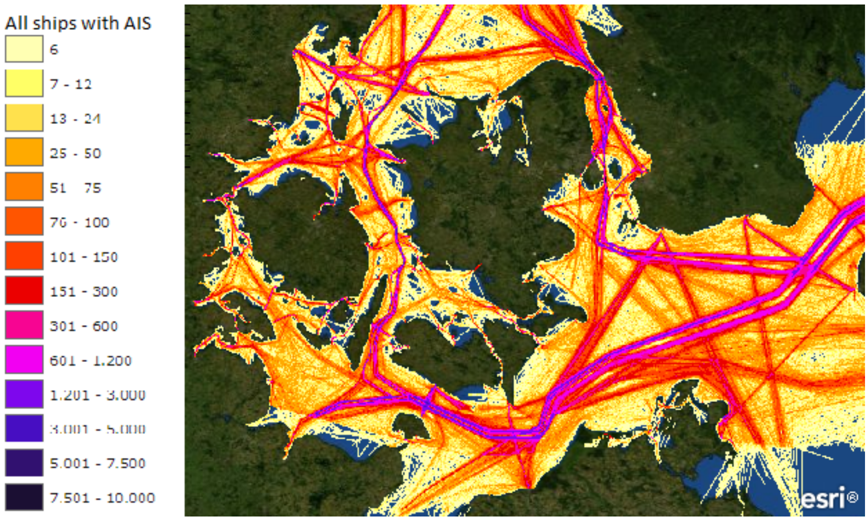


Figure 9 Sailing patterns of all ships with both AIS A-signal and B-signal in the period of July-August 2009. (Søfartsstyrelsen 2009)

Due to limited time available to this project, the focus will be on the areas with the highest density of traffic. Figure 9 shows that the most used routes are the mentioned transit routes, and therefore the Little Belt will not be considered. The project will focus on ship traffic in Danish waters - the Kiel Canal is in German territorial waters and will also not be considered, leaving the Great Belt and the Sound.

Because of constant sand migration, heavy traffic, narrow straits and transit routes merging, the risk of grounding or colliding increases when navigating through the Danish waters. (Søfartsstyrelsen n.d.) The risks of grounding will be explained further in chapter 3.4.

With much traffic going through the Danish waters, it is necessary to be able to monitor the ships. The system used to track shipping in Danish waters will be explained further in the following section.

3.2 AIS

The Automatic Identification System (AIS) is designed to identify and locate ships, and consists of transmitters and receivers. AIS transmitters are found on board many ships and are used as a supplement to radar systems. It transmits an AIS-signal from the ship to the receivers via VHF-signals (Very High Frequency), which makes it possible to exchange information between ships equipped with an AIS transmitter as well as an AIS base station onshore. The signals consist of information regarding cargo, position, heading, origin, destination, draught etc.

"2.4 All ships operating in international voyages with 300 BT or more, cargo ships not operating in international voyages with 500 BT or more, and passenger ships regardless of size must have AIS transmitters equipped on the ship…" (Translated from Danish) (Erhvervs- og Vækstministeriet 2012 (b))

This means that not all ships have to be equipped with AIS transmitters, though it is beneficial for all sizes of ships, because the system can prevent collisions.

AIS-systems must be tested by an authorized inspector or an approved testing or servicing institution on a yearly basis. (Erhvervs- og Vækstministeriet 2012 (b)) The transponders equipped on the ships is available in two classes; class A and class B. Class A is the transponder required to comply with regulation 2.4. Class A is a full implementation of the system whereas class B is for ships that does not require the system, but would like to have it for safety reasons. Class B has fewer features and capabilities and cost less than the half of a class A-unit. (The Bosun's Mate n.d.)

Figure 10 shows a visualization of what an AIS-system in class B consist of. The system consists of a VHF antenna so that it is possible to transmit and receive radio signals through the VHF transmitter and the two VHF receivers. It is only necessary for the AIS-system to have one radio channel, but to avoid interference problems and communication loss from other ships the system is equipped with two radio channels. (U.S. Coast Guard Navigation Center n.d (b)) The system furthermore have a built-in or external GPS, to get information about position and time. All other information is obtained through the AIS-signals.
(Australian Maritime Safety Authority 2008)

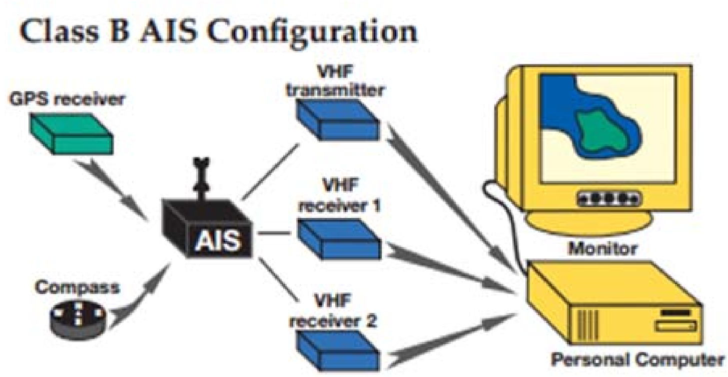


FIGURE 10 COMPONENTS IN AN AIS CLASS B CONFIGURATION
(AUSTRALIAN MARITIME SAFETY AUTHORITY 2008)

A position message fits into a timeslot and each minute consists of 2250 timeslots, each timeslot represents 26.6 milliseconds. The AIS-system is equipped with two radio channels and as a result, it "… *is capable of handling well over 4,500 reports per minute and updates as often as every two seconds.*" (U.S. Coast Guard Navigation Center n.d. (a)) By continuously synchronizing, the system prevents overlapping of the slot transmissions and in cases where more than 4500 reports are transmitted, the system is capable of sharing the slots. This means that the system can be overloaded by 400 to 500 percent and still provide nearly 100 percent correctness in ship-to-ship mode within 15 kilometres. One of the reasons is that nearby ships are prioritised over ships further away, and class A messages are prioritized over class B messages.
(Danish Maritime Authority n.d.)

In general, the AIS-system has a range of around 40 kilometres, depending on the height of the mast and the environment – narrow channels with mountains on the sides reduce the distance.

(U.S. Coast Guard Navigation Center n.d (b))

AIS is a multi-purpose system used by VTS services to monitor the traffic through their waters. In Denmark, AIS is used for: "*live monitoring of maritime traffic", "displaying of navigation patterns", "statistics of the ships sailing", "create virtual navigation marks"* and *"automatic transmission of navigational warnings*" among other things. (Translated from Danish) (Bang and Bjerregaard 2008) Several of the different uses will not be explained further.

The live monitoring of maritime traffic is an important tool in preventing accidents, which in turn prevents the spillage of oil or other dangerous goods into Danish waters.

3.3 Shipping Dangerous Goods

Transporting goods at sea is currently the most common method, it accounts for approximately 90 percent worldwide. (Castonguay n.d.) A small part of this is so-called dangerous goods - goods classified as dangerous for the crew or the maritime environment. This include empty tanks or similar, in which dangerous goods have been stored, unless they have been cleaned and dried in accordance with regulation.

When transporting dangerous goods at sea, a Dangerous Goods Declaration is required regardless of the size of the ship. A dangerous goods declaration is a *"document prepared by a consignor or shipper to certify that the dangerous goods being transported have been packed, labelled, and declared in accordance with the standard international shipping* *regulation"* (Business Dictionary 2013). The dangerous goods declaration regulations are located in chapter 3 of BEK no. 1349:

"Ships in a Danish port, regardless of the size, are not allowed to offer transportation or load dangerous or polluting goods unless a declaration has been declared to the master of ship or the operator before the ship is loaded with the information that is required according to appendix 1." (Translated from Danish) (Miljøministeriet 2011, § 3)

To comply with this legislation the shipper needs to apply for and receive the required documentation before loading the ship. The documentation must contain details and specific information about the dangerous goods in the ships hold. In addition, ships transporting dangerous goods from a non-EU port into a Danish port also need this declaration from the shipper. (Miljøministeriet 2011, § 3 stk 2)

The declaration of dangerous goods include information about the technical name of the goods, classification from IMO codes, the amount of goods, information in accordance with IMO resolution MSC.150(77) concerning the material safety data sheets mentioned in MARPOL appendix I, among others. (Miljøministeriet 2011, Appendix 1)

According to BEK no. 1349 § 9, a fine will be given to the responsible parts in the event that the regulation is not complied with. In case, information written in the declaration is not identical to the shipped goods, the shipper will be fined according to § 3. (Miljøministeriet 2011, § 9 stk 3)

Additional information is required when a ship is leaving a Danish port destined for or arriving from a non-EU country. This includes the location at which the ship was loaded as well as a detailed list containing the dangerous goods. (Miljøministeriet 2011, § 4, Appendix 2)

The use of the dangerous goods declaration "… *gives the receiving authority complete, accurate and timely information about your consignment. So they have clear and precise details on how your goods should be handled*." (GOV.UK 2013)

Dangerous goods are shipped in different ways depending on the type of dangerous goods. BEK no. 386 defines the Danish regulations dealing with dangerous goods. Chapter VII in the regulation concerns transportation of the dangerous goods and has divided the dangerous goods into several categories, Figure 11. According to The Danish Maritime Authority, the most common way to transport dangerous goods is as bulk cargo. (Kristensen 2011)

Type of carriage	Code
Packaged form	IMDG-code (International Maritime Dangerous Goods Code)
Bulk solid form	IMSBC-code (or BC-code) (International Maritime Solid Bulk Cargoes Code) IMDG-code (in some cases)
Bulk liquid chemicals	IBC-code (International Bulk Chemical Code)
Bulk liquefied gases	IGC-code (International Gas Carrier Code)
Special provisions – irradiated nuclear fuel, plutonium and high level radioactive waste	INF-code (International code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level radioactive Wastes on Board Ships) Loading in accordance with IMDG-code class 7

FIGURE 11 TABLE OF MAIN CARRIAGE TYPES AND THE INTERNATIONAL CODES THEY ACQUIRES TO BE PACKED AFTER WHEN BEING CARRIED (KRISTENSEN 2011)

Transportation at sea often happens through international waters, which have resulted in international frameworks for the transportation. International codes have been designed for the transportation of each type of dangerous material, Figure 11. In BEK no. 386, it is regulated which international code that has to be complied with when dealing with different types of dangerous goods. The codes are obtained from IMO for a sum of money, and provides guidance for travelling safely with dangerous goods at sea when crossing territorial waters.

Transportation of dangerous goods in packed form must be documented in accordance to the IMDG-code. The IMDG-code provides a list of dangerous goods, divided into nine groups that consist of subdivided groups as well. This is classes such as explosives, radioactive materials, gasses etc.
(Kristensen 2011)

The message of the AIS-signal declares whether the ship is carrying dangerous goods from one of four categories; Z, Y, X and Other Substances (OS). The categories are consistent with the IBC-code, where category X is the most dangerous, and category OS is the least dangerous.
(IMO n.d. (a))

As with the IMDG-code and the IBC-code, the other mentioned codes have regulations regarding how different types of dangerous goods must be handled. The different regulations in the codes will not be discussed further.

There are many regulations needed when transporting dangerous goods, because if an accident occurs, the environmental consequences are dependent on the type of cargo.

3.4 Accidents at Sea

In the following section, the frequency and the consequences of accidents within the Danish waters will be investigated.

When discussing accidents at sea, there are generally two types; collisions and groundings. Both types have the potential to be catastrophic for the environment as well as expensive.

Collision is a term used when a ship hits another object, with the possibility of significant damage. Collisions between two ships tend to be more serious than groundings (Vanem and Skjong 2004).

In 2001, the ship Baltic Carrier collided with the ship Tern between Falster and Bornholm. The damage inflicted on one of the cargo tanks of Baltic Carrier, loaded with 2700 tons of oil, resulted in the oil spilling out. (Division for Investigation of Maritime Accidents 2001) The cost of cleaning the coast of Denmark after the accident is thought to be near 100,000,000 DKK (Miljøskib n.d. (a)), while as many as 20,000 birds are believed to have died due to being exposed to oil (Storstrøm Amt and Guldborgsund Municipality 2007).

Another example of a collision between two ships, leading to pollution, happened on the 31st of May 2003, where the ship Fu Shan Hai collided with the smaller ship Gdynia. Fu Shan Hai had 68,000 tons of potassium carbonate, a compound used for making fertiliser, as well as 1,680 tons of oil on board, as the ship sank later that day. The process of cleaning up the oil took five months, involving several ships. The total cost of the operation is estimated to almost 90,000,000 DKK.

(Miljøskib n.d. (b))

Many precautions must be taken to avoid collisions. One of these precautions is establishing traffic separation schemes - these are employed in heavily trafficked areas. A separation zone is implemented to create a zone between shipping traffic moving in opposite directions to prevent collisions. Separation zones must remain free of traffic, and in either side of the zone are shipping lanes where the traffic moves in one direction. Ships are however allowed to cross lanes, but it should be done at an angle as close to 90 degrees as possible.

(IMO n.d. (b))

Grounding is a term used when a ship is stuck on the seabed, with damage to the ship as a possible consequence. Groundings are not very frequent in the Baltic Sea, and according to a HELCOM study the number of yearly groundings in the Baltic Sea is declining, Figure 12. (Helsinki Commission 2012)

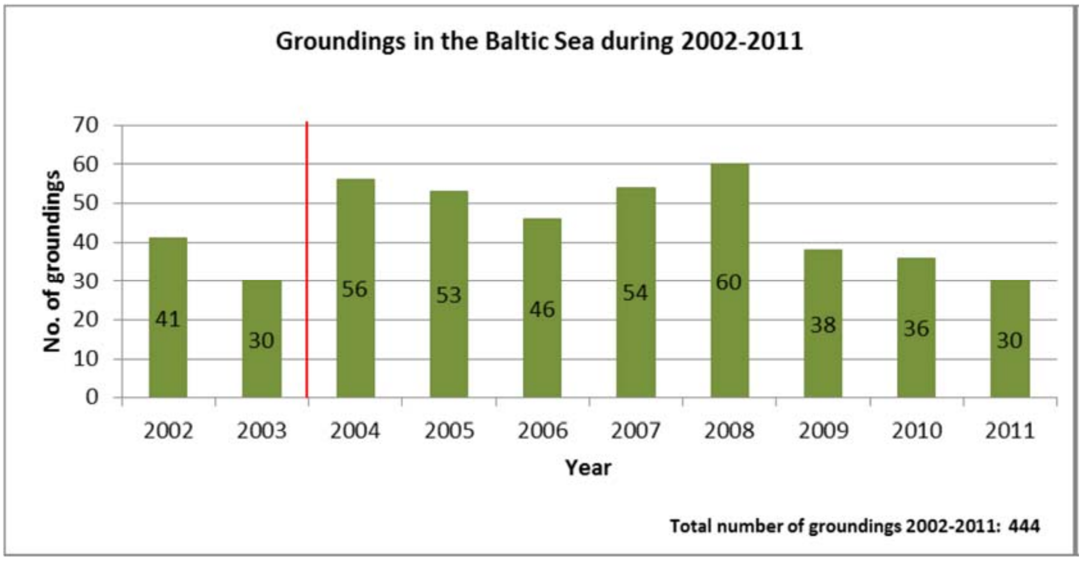


FIGURE 12 THE AMOUNT OF YEARLY GROUNDINGS IN THE BALTIC SEA. DATA FROM BEFORE 2004 IS NOT 100 PERCENT COMPARABLE TO THE OTHER YEARS, AS INDICATED BY THE RED LINE. (HELSINKI COMMISSION 2012)

To obtain knowledge on the local number of accidents, the Great Belt VTS were contacted: ”*Regarding groundings, we had two of them during 2011, one within the VTS area and one at the pier in Kalundborg. In 2012 there were no groundings in the VTS area.*”(Translated from Danish) (Hansi 2013). The statement would suggest that while groundings occur in the Great Belt area, they are generally uncommon.

As mentioned before, the yearly number of groundings is declining, however a large number of the occurring groundings happen in Danish waters, Figure 13. According to HELCOM, 64 percent of the groundings occurs without a pilot being present on the ship (Helsinki Commission 2012), which underlines the need for pilots when navigating shallow water or seas that are otherwise difficult or unknown to the master of ship.

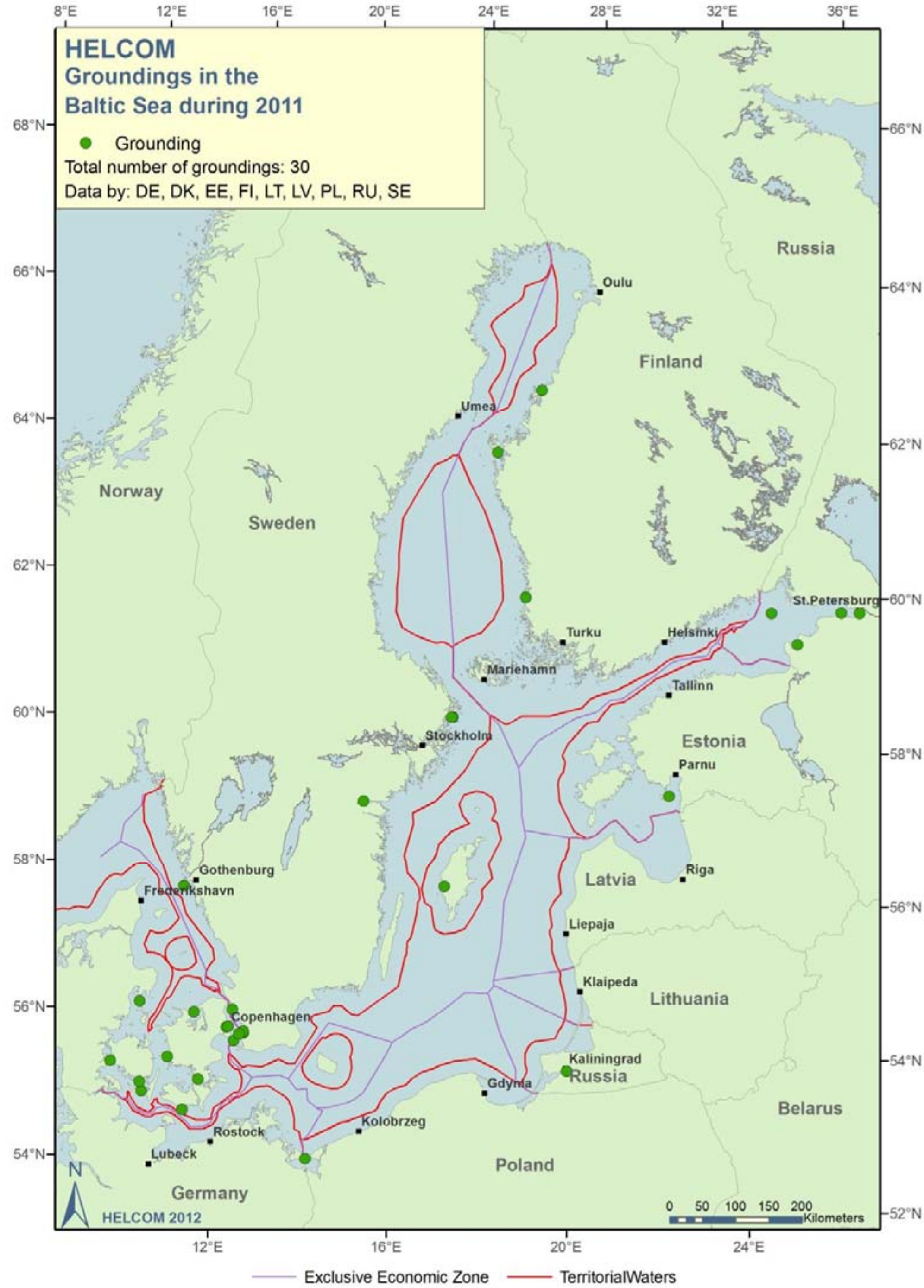


FIGURE 13 LOCATIONS OF GROUNDINGS IN THE BALTIC SEA DURING 2011. (HELSINKI COMMISSION 2012)

In January 2012, the cruise ship Costa Concordia and its 4200 passenger grounded in the Mediterranean Sea, resulting in the loss of 32 lives. The cost of salvaging the ship, as well as the loss of property, is estimated to 3.000.000.000 DKK. (CBC news 2013)

In some cases, the ships carrying goods lose a container or other packing when navigating from one location to another. Since containers can be quite big, some of them being as big as 12.19*2.44*2.59 meters (Pro-trans A/S n.d.), these can have a large impact on the depth of the water. If a ship has dropped a container in the Sound, where the depth of the water is only 7.4 meters and the container protrudes 2.2 meters, the water depth on that specific location is only 5.2 meters. The protruding container could thereby cause a shipping accident.

To avoid ships colliding with lost items, the master of ship must according to BEK no. 386 report the accident of lost packing containing dangerous goods to the nearest coastal state at the time when the packing is lost. (Erhvervs- og Vækstministeriet 2012 (b))

In 2011, The World Shipping Council (WSC) completed a survey on the yearly number of containers lost in the sea. The survey indicates that, including catastrophic losses where ships have lost for example 50 containers or more at once, the approximate number of containers lost yearly is 675. The number of incidents where only a few containers are lost is approximately 350 annually.
(World Shipping Council 2011)

Having studied the locations and amounts of accidents, as well as some specific cases, the impact of the seabed type will be explained in the following section.

3.4.1 Seabed Type

One factor that can influence the risk of grounding, as well as the severity of a potential grounding, is the type of seabed. Due to the forces that affects a ship when grounding, the type of seabed has a huge impact on the deformation, or perforation, of the hull. Therefore, it is relevant to inspect the type of seabed in the Danish waters. As can be seen by Figure 14, the seabed in this region consists mainly of sand.

The deformation occurring through groundings on sand dunes is very different from that which occurs through groundings on cliffs. Cliffs are considered the most dangerous type of seabed because they can tear a hole in the hull when grounding, while sand dunes are more likely to cause a deformation. In some cases deformations can be fatal to the strength of the hull, resulting in severe structural damage. (Hong and Amdahl 2010)

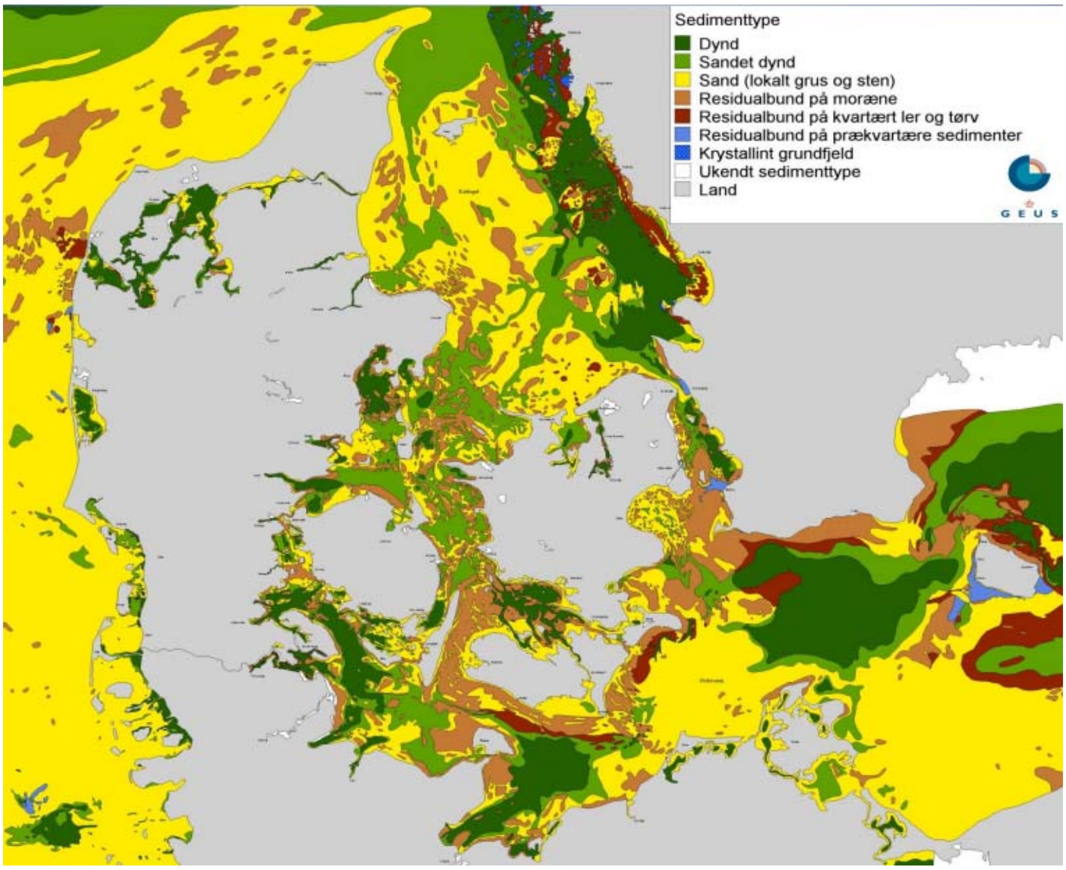


FIGURE 14 TYPES OF SEABED IN THE DANISH WATERS (LETH 2012)

Since the seabed in Denmark mostly consists of sand, the subject will not be further elaborated in this report.

3.5 Pilots

A pilot is by Oxford Dictionary defined as *"a person with special knowledge of a difficult area of water, for example, the entrance to a harbour, whose job is to guide ships through it"* (Hornby 2005). A pilot is an expert in local waterways; he boards incoming ships and advises the master of ship when navigating through challenging areas, such as ports or low water areas. The Danish waters are shallow at several locations, so when large ships lies deep, or are carrying dangerous goods, are navigating through these waters, they need a pilot to prevent groundings. By Danish law, a pilot is a person whom himself has a background as a master of ship and is in possession of a valid pilot certificate issued by The Pilotage Authority. (Forsvarsministeriet 2006, § 11)

When navigating the sea, different factors such as wind and sea level can be a challenge, as mentioned in chapter 3.1.1. Before boarding a ship, the pilot examines these factors and estimates, among other things, the duration of the passage, as well as the draught of the ship based on the speed, weight etc. (Farvandsvæsenet n.d.)

3.5.1 Legislations and Regulations in Danish Waters

Pilots enhance ship safety at sea in Danish waters and are regulated by law. These regulations can inter alia be found in BEK no. 449, BEK no. 1142 and LOV no. 567.

When ordering a pilot to a ship, the captain must obey BEK no. 1142. In this act, a deadline for ordering a pilot is 18 hours when the ship arrives from offshore and four hours if the ship needs a pilot when departing from a port. Arriving from offshore, the order has to be confirmed four hours before the ship arrives to the location from where the pilot boards the ship. (Forsvarsministeriet 2011, § 2) This act applies unless the pilot is ordered via a private pilotage service, in which case the company's rules apply. According to LOV no. 567 § 19 the pilot service is obligated to make a pilot available if the pilot is ordered within the deadline.

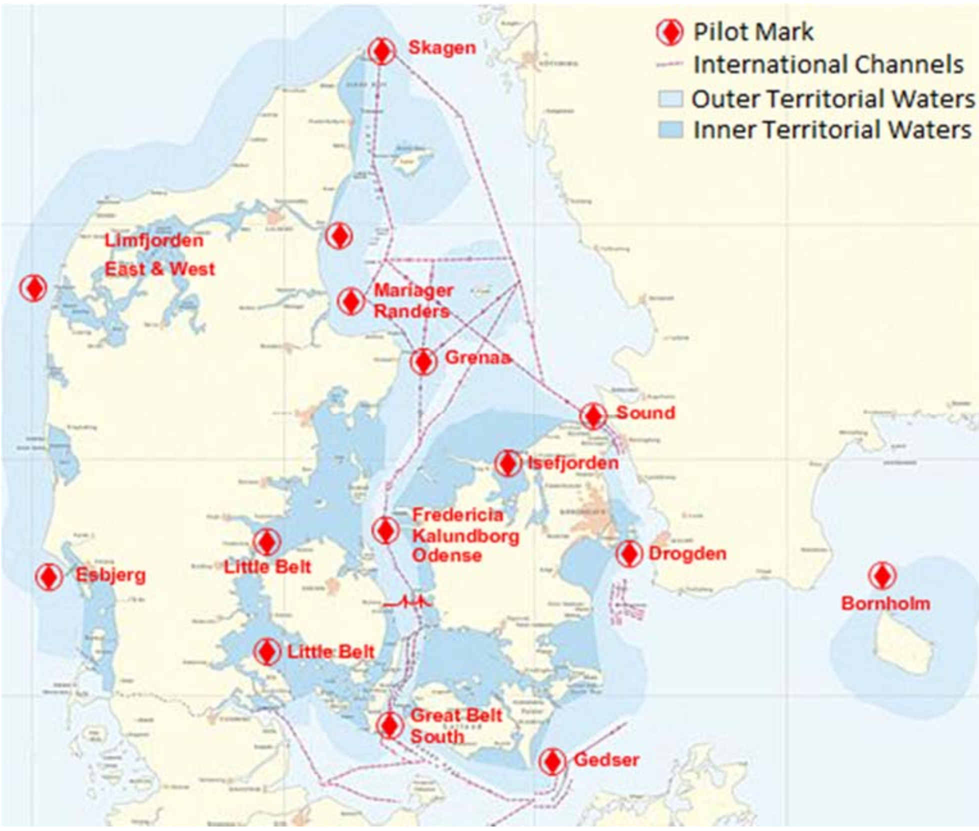


FIGURE 15 THE LOCATION OF PILOT MARKS INCLUDING THE INNER AND OUTER TERRITORIAL WATERS. (DANPILOT N.D.)

To request a pilot the individual ship has to contact DanPilot which *"… is the Government licensed pilotage through Danish waters*" (DanPilot 2011). DanPilot have 141 pilots employed and had 18,183 pilotages in 2011. (DanPilot 2011) DanPilot have pilot marks at 15 locations in the Danish waters, from where the pilots board the ships, Figure 15.

The request for a pilot must include information for the pilot to be able to identify the ship and calculate the best route based on its dimensions, weight, destination etc. § 3 in BEK no. 1142 deals with the information that must be disclosed when ordering a pilot. The section contains information such as name and call sign of the ship, type of goods carried, draught, speed, time and place of pilotage, defects in manoeuvrability etc. (Forsvarsministeriet 2011, § 3)

According to LOV no. 567 § 4, pilotage is compulsory for ships navigating the Danish inner or outer territorial waters, if these are carrying dangerous goods such as oil, gases, chemicals or highly radioactive materials etc., as described in chapter 3.3. (Forsvarsministeriet 2006)

§§ 1 and 2 in BEK no. 449 provides general provisions applicable for the use of pilots in ports. When a towed ship is navigating through dredged channels or marked waterways near a port, or is not able to propel by its own engine power, the ship is required to use a pilot. The use of pilots is excepted if, the length of the towed ship is less than 28 meters or if the gross tonnage is less than 150 GT. (Erhvervs- og Vækstministeriet 2012 (a)) The National Maritime Authority measures the gross tonnage of a ship, which is defined as the volume of every closed room in the ship, according to international regulations. (Gyldendal (e)) Furthermore §§ 4 to 15 in BEK no. 449 provides specific regulations for some individual ports, bridges and channels.

Pilot Exemption Certificate

In some circumstances, it is not necessary to use a pilot - this is when the master of ship has a pilot exemption certificate.

According to § 1 in BEK no. 1077 a pilot exemption certificate is;

"A certificate issued by the Danish Maritime Authority, which exempts a ship pilotage if the proprietor of the pilot exemption certificate navigates the ship, and if the pilot exemption certificate includes the type, the conditioning and the territorial waters the ship operates in." (Erhvervs- og Vækstministeriet 2012 (c), § 1)

To get a pilot exemption certificate issued or sustained the proprietor has to comply with some requirements including the sailing frequency. Sailing frequency is divided into three categories; A, B and C. All of the categories deal with the number of navigations through the area and the risks of the ports in which the ship navigates too.

- Category A: High-risk ports with at least 20 sailings
- Category B: Medium-risk ports with at least 10 sailings
- Category C: Low-risk ports with at least five sailings
  (Erhvervs- og Vækstministeriet 2012 (c), Bilag 3)

A pilot exemption certificate is valid for a period of five years, however if the proprietor of the certificate does not comply with the requirements, the certificate must be returned to the Danish Maritime Authority. (Erhvervs- og Vækstministeriet 2012 (c), § 16)

According to the Danish Pilotage Authority, 269 pilot exemption certificates were active the 27th of May 2013, distributed on 114 Navigators (Lodstilsynet 2013). This means, that some of the navigators hold several pilot exemption certificates. Of the 269 certificates, 34 of them concerns the Great Belt as shown on Figure 16.

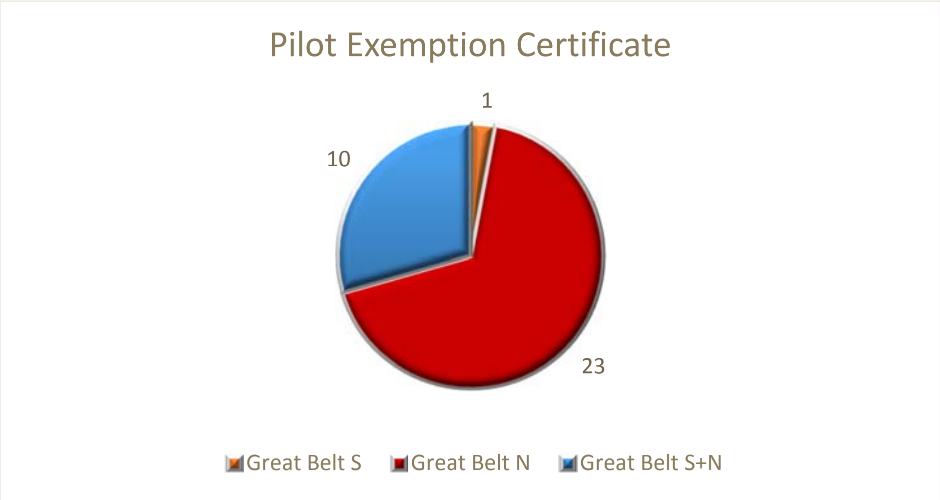


FIGURE 16 THE DISTRIBUTION OF PILOT EXEMPTION CERTIFICATES CONCERNING THE GREAT BELT

3.5.2 Legislations and Regulations in International Waters

The Great Belt and the Sound consist of international channels meaning that by international resolution, ships are not required to use pilots in the channels:

"§ 6 Ships are not covered by an obligation according to §§ 4 and 5 if it in pursuance of international rights have the admittance to navigate through the waters without the use of a pilot." (Translated from Danish) (Forsvarsministeriet 2006)

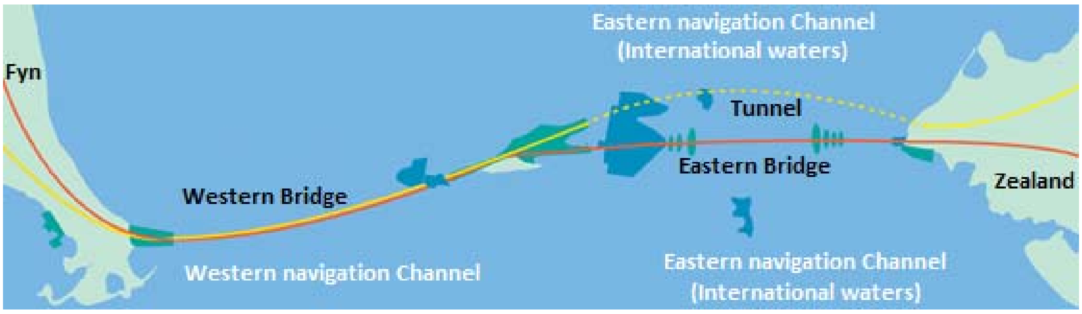


FIGURE 17 NAVIGATION CHANNELS IN THE GREAT BELT (SUND & BÆLT A/S 1999)

There has been discussions about trying to enforce the use of pilots, however for the current laws to change, a unanimous decision is required and so far, Russia has proved unwilling to support the proposals regarding the use of pilots. (Schleswig-Holsteinischer Landtag 2007)

In the Great Belt, the international channel is located at the east trench of the bridge, Figure 17. Because these channels traverse the Great Belt and the Sound, an international agreement about the matter has to be settled. (Regeringen 2010) In 2010, the Danish government prepared a strategy, *En Samlet Maritim Strategi*, where an objective was:

"Investigate the international negotiation climate in relation to impose pilotage when navigation through the Danish straits" (Translated from Danish) (Regeringen 2010)

Based on this the Danish government established a workgroup with the purpose of achieving international support in the matter of getting larger ships or ships carrying dangerous goods to use pilots.

IMO resolution MSC.138 (76) concerns navigation through the entrances to the Baltic Sea. When a ships draught is 11 meters or more, or when a ship is carrying specified dangerous goods, the ship should employ a pilot from a local service when navigating through Route-T. (The Maritime Safety Committee 2002) It is in BEK no. 1142 § 17 also defined that § 4 in LOV no. 567 does not apply to ships, with a draught less than 11 meters, traveling through Route-T. (Erhvervs- og Vækstministeriet 2012 (a))

When an oil tanker with a draught of 7 meters or more, or ships carrying gas, chemicals etc. must navigate through the Sound, it should make use of a local pilot service, meaning from Denmark or Sweden. (The Maritime Safety Committee 2002)

4 Project Focus

Having studied the elements, factors and regulations for shipping in Danish waters it is now possible to define a more specific problem to investigate and set a delimitation, in order to complete the analysis.

4.1 Subject Delimitation

The project time is limited to one semester, which is approximately 4½ months, to complete the project. The delimitation must be defined in order to complete the project within the timeframe. It will be determined which geographical area, which period, which type of ships and for what purpose the project is concerned.

The focus in this project will be the Danish waters within a geographical extent of UTM 56°46’N; 54°50’N; 9°58’E and 13°21’E defined in Google maps, Figure 18. The reason for this is the issues of large ships navigating through the Danish waters with a lack of pilots, as mentioned in chapter 1. The strait between Zealand and Sweden, called the Sound, will not be investigated thoroughly. Part of the Sound is Swedish territorial waters, thus the Danish bathymetric model that we have acquired do not cover that area.

Figure 18 Geographic boundary for the project

There is an economic cost as well as an environmental cost when ships have accidents at sea. A large part of the ships navigating through the Danish waters are transporting goods and since dangerous goods lead to greater damage in an accident, ships carrying dangerous goods in the Danish waters will be in focus.

The lack of pilots is an actual problem and therefore the data used in this project should be relevant for this period. Since the project began in the start of 2013, it is decided, that the AIS and pilot-data used in the project must cover October and November 2012.

As mentioned in chapter 3.2, AIS is created to prevent collision of ships. Apps and other programs to watch online maritime traffic already exists, thus this project will instead focus on groundings and the use of pilots.

The previous content of this report is leading to the following problem statement.

4.2 Problem Statement

How can it be analysed whether ships carrying dangerous goods are using pilots, as required by law, and if the ships have been in danger of grounding with the seabed?

- What is the importance of using pilots when sailing in Danish waters?
- Can the use of pilots be incorporated in the analysis, to be able to identify if a ship is using pilots when requested?
- How can the sea depth be compared to the draught?
- Are there critical paths outside the pilotage requested areas where pilots should be compulsory?

5 Completion of Phase 1

Phase 1 is the descriptive phase in which the elements affecting navigation at sea and the regulation of shipping have been investigated.

Shipping is a broad field with multiple local and international regulations and stakeholders. When navigating the Danish inner or outer territorial waters, pilotage is required by law. This regulation does not apply to the international channels going through the outer territorial waters, but a resolution from IMO recommends ships in the international channel going through the Great Belt to use pilots.

The importance of using pilots in Danish waters is to avoid groundings in the narrow and difficult waters, by having a person who is an expert of the area to guide the master of ship. Before boarding the ship, the pilot investigates the different elements that have an impact when navigating the waters. Depending on the time and location, elements such as the tide and the weather conditions influences the water level and the differences in the typical water level in Kattegat South is at approximately 40 cm.

Grounding and collision have a huge impact on the maritime environment not to mention the economy. The AIS-system prevents ships from colliding and is furthermore used to monitor ships to prevent groundings.

In the following, an analysis on groundings and ships navigating critical areas will be completed. The analysis will focus on ships carrying dangerous goods in Danish waters during the period of October and November 2012.

Phase 2

6 Method of Investigation

To answer the problem statement, we are going to analyse the data collected for the project. This includes two months of AIS-logs for a geographical area in the Southern Kattegat, pilot-data, the boundaries of inner and outer territorial waters and a digital bathymetric model.

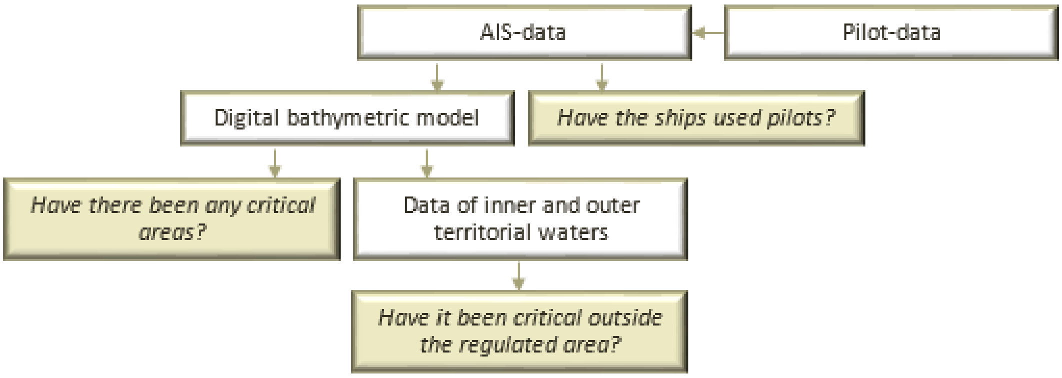


FIGURE 19 THE DATA IS USED TO ANSWER THE QUESTIONS IN THE PROBLEM STATEMENT.

The AIS-data forms the basis of our data into which the pilot-data will be incorporated. Feature classes with associated attributes will represent the AIS-data, where the information about pilot-data will be in the attribute table. By comparing the AIS-data with the pilot-data, statistics will show whether the ships have used pilots.

Comparing the draught from the AIS-data with a digital bathymetric model it is possible to analyse if there have been any critical areas where ships have grounded or been close to the seabed.

To investigate risky areas outside the regulated areas, meaning the inner and outer territorial waters, the most represented draught of the ships are investigated. Using the digital bathymetric model, areas with water depths lower than the draught are investigated.

Having an idea of how the analysis should be performed, the work method for the data preparation is presented in the following section.

6.1 The Agile Development Method

The word *agile* is defined as *"…able to think and understand quickly"* (Oxford Dictionaries 2013) and "*quick and well-coordinated in movement*" (Dictionary.com 2013).

The Agile Development Method is a software development method based on iterative and incremental development. Iterative development works as cycles in which the different steps in the process repeat until a satisfactory result is produced and the incremental development adds a part of the software to each cycle. Accordingly iterative and incremental development means that for each cycle it is possible to develop a part of software, test it, and for each cycle add additional parts until the finished software is developed.
(Rouse 2011)

The main principle for progress in The Agile Development Method is when software is working correctly. When one part of the software works correctly, you can then incorporate the next part of the software in the existing part. This method of development is minimizing risks during the project because of the continuous testing and design.

One of the advantages of The Agile Development Method is its opportunity to implement changes. The method makes it possible to implement changes both in the early and late stage of the development. As a result, of the iterative development model, it is possible to focus on quick responses to change and the incremental development with focus on continuous development.

During this project, The Agile Development Method is used for the programming section in which the data is prepared for use in ArcMap.

In Figure 20 is an example of the cycle of progress. The figure visualizes the process starting with the planning phase and ending up with a result. The first step is the planning procedure where it is decided what the purpose of the coding is. Next the programming starts, in this case programming to be able to split the existing files into new defined files. In the first iteration, the code defines how to read one input file, next how to create an output file. When having a code that can read an input file and create an output file, the code is then modified to be able to read several files and split it into several new files. When the code is at a satisfactory outcome, the cycle ends at the result. In some cases throughout the project it has been necessary to go back and make some changes – it is possible with use of this method to move from the result back to planning or from the result to programming as a part of the iteration.

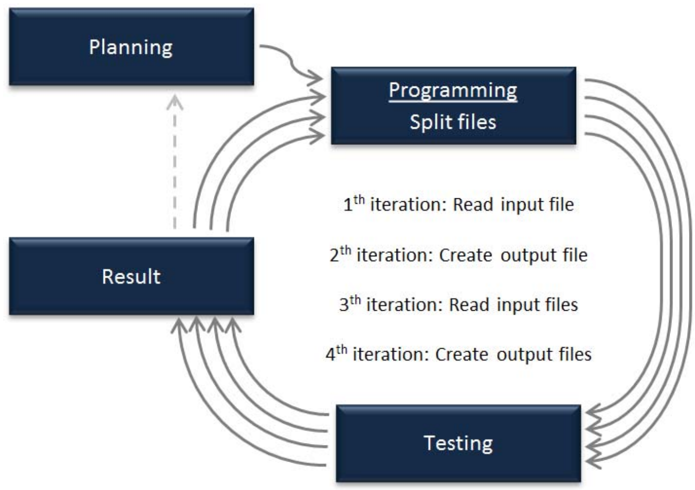


FIGURE 20 EXAMPLE OF THE AGILE DEVELOPMENT METHOD

All the scripting is created from the concept of The Agile Development Method - the individual scripts are explained further in chapter 7.4.

7 Data Handling

Before an analysis, it is important to decide on what kind of software should be used to perform the analysis, not to mention visualise it. Additionally, the data used in the analysis must be collected and studied to determine its quality, otherwise it can be difficult to make sense of the result. In the end, the data must be prepared so that it is ready to be analysed.

7.1 Software

ArcGIS and Python are the main software used in the analyses and will be briefly introduced in the following section.

7.1.1 ArcGIS

ArcGIS is a software package developed by ESRI. It specialises in processing spatial data, and is the backbone of the analysis done in this project. The ArcGIS-package consists of a number of programmes, the main one for this project being ArcMap. ArcMap includes a number of extension with different tools, for specialising in different branches of GIS. ArcGIS is compatible with several file types, such as rasters, vectors and tables.

ArcGIS 10.1 was used for this project.

(ESRI n.d.)

ModelBuilder

When working with ArcGIS, one way of managing your analysis is through ModelBuilder. ModelBuilder is a way to design your analysis step-by-step by creating a model of the workflow. This enables using the output from one tool as an input to the next tool without running the tools first. By using ModelBuilder, analysis with many steps become easier to edit and adjust, and complex models consisting of many steps can be run through in a given sequence without having to start each step manually.

(Esri 2012 (a))

7.1.2 Python

Through the project, the programming language Python will be used to prepare the data received from our sources. This will be mentioned further in chapter 7.4.

Python is a widely used programming language, incorporated in many web applications, such as Google Docs. Python is included in the ArcGIS-installation by default, and in this project it is used both stand-alone and as an extension to ArcGIS, through the arcpy-module.

As mentioned before, Python is included in the ArcGIS-installation. With the ArcGIS 10.1 desktop installation, Python 2.7(32-bit) is included. This is the newest version that is able to run the arcpy-module.

(Lutz 2006)

PyScripter

PyScripter is an open-source development environment for Python, which can be used free of charge. (PyScripter n.d.) PyScripter is ideal for working with Python, and offers language-specific syntax in the coding process, making the code more manageable. In addition to that, it has integrated Python-engines, and supports external ones as well, meaning that you can run the scripts and programmes directly from the PyScripter interface. PyScripter comes in a number of different versions, depending on what Python installation you are running.

The software was chosen because of previous experience and knowledge of them. Alternatives exists, but the selected software works well together and it is capable of handling all the demands and formats of the collected data.

7.2 Data Collection and Quality

One of the first steps of the project was to collect data. However, the quality of the data must be assessed before use. In the following section, the data used in the project will be explained and the quality of said data will be evaluated.

Referring back to the problem statement and chapter 3.5, we need some data concerning:

1. Inner and outer territorial waters which require pilots by law
2. pilots on board of ships
3. ships carrying dangerous goods
4. a bathymetric model and the draught of the ships to investigate groundings

Data needs to be collected from several different suppliers. Re 1 ships within the inner and outer territorial waters are required to use a pilot and data of these boundaries are therefore going to be collected. Geographer Charlotte Bjerregaard at The Danish Geodata Agency (GST) has provided us with this data.

Re 2, the pilot-data is going to be used to analyse whether the ships are using pilots within these areas. Pilot inspector Frank Adler Gottlieb was contacted and he referred us to Nautical Caseworker Søren Nielsen at The Danish Maritime Authority, who provided us with pilot-data for the Great Belt. Data from the Great Belt is defined by pilot-data within the Great Belt VTS areas, Figure 21.

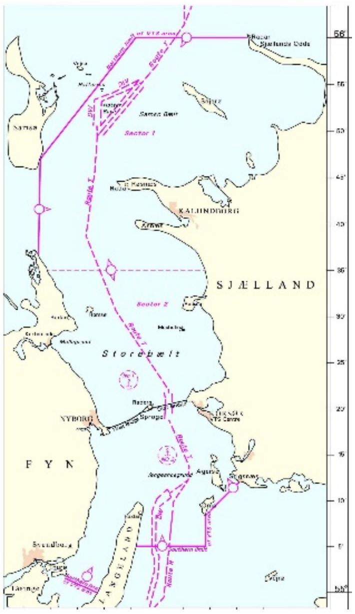


FIGURE 21 GREAT BELT VTS AREA (IMO 2006)

Re 3 and 4, AIS-data provides information about the ships' routes, the type of carriage, the draught etc. as described in chapter 3.2. Data Analyst at DTU Svend Jacob Senstius provided us with this data.

The AIS-database contain AIS-data from all ships with integrated AIS. Due to the problem statement, not all ships should be included – the project will only include ships navigating with dangerous goods. As mentioned in chapter 3.3 four categories define ships with dangerous goods and according to Senstius (2013) an addition to these categories is a category with undefined data. Since it is unclear, whether undefined means that the dangerous goods is undefined or if it is undefined whether the ship is carrying dangerous goods, it was decided to filter the data as "not undefined" cargo type. This provides data with dangerous goods within the four categories; Z, Y, X and OS.

The geographical boundary of the received AIS-data is offset to the east, compared to the original boundary mentioned in chapter 4.1. This means that the Little Belt is no longer in the boundary, Figure 22. Since the received pilot-data only covers the Great Belt, it was decided to continue with the received boundary in our project.

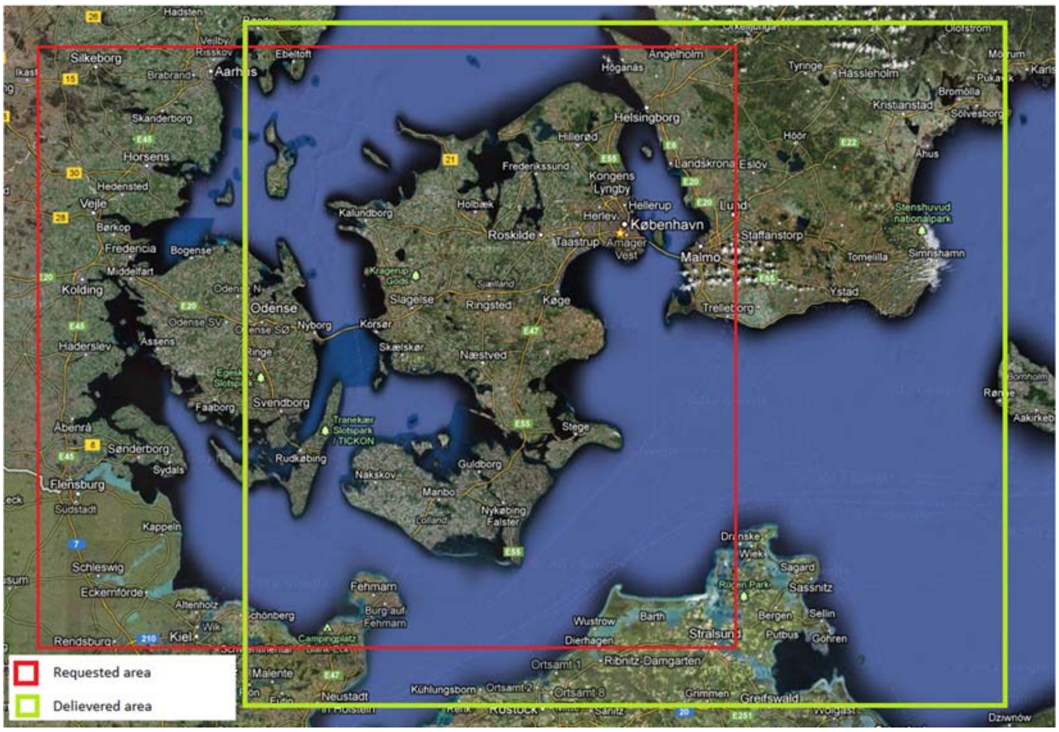


FIGURE 22 SHOWS THE BOUNDARY OF THE REQUESTED AREA OF AIS-DATA AND THE DELIVERED AREA.

Re 4, data containing information about the depth of the water is going to be used to analyse how close the bottom of the ships are to the seabed. Data of Kattegat South was sourced online from GST.

Data collected for the analysis is:

- A digital bathymetric model
- AIS-signals
- Pilot-data
- Boundaries of inner and outer territorial waters

There are some requirements for the different datasets to be able to work together. The datum and projection are important factors when working with geographical data, since they control the way the data is displayed. Furthermore, the MMSIs and the timestamps are important in order to compare and combine the pilot-data with the AIS-data.

In the following section, the quality of the collected datasets will be discussed.

7.2.1 Digital Bathymetric Model

In 2006, The Danish Maritime Safety Administration created the digital bathymetric model used in this project. This agency no longer exists but its hydrographical surveys were transferred to GST. GST has the copyright of the digital bathymetric model and provides the data as free source data that can be obtained from their webpage.

The digital bathymetric model is modelled based on the Danish Exclusive Economic Zone (EEZ). The data is divided into four areas and the area that covers the delimited area in this project is *Kattegat South*, left picture in Figure 23.

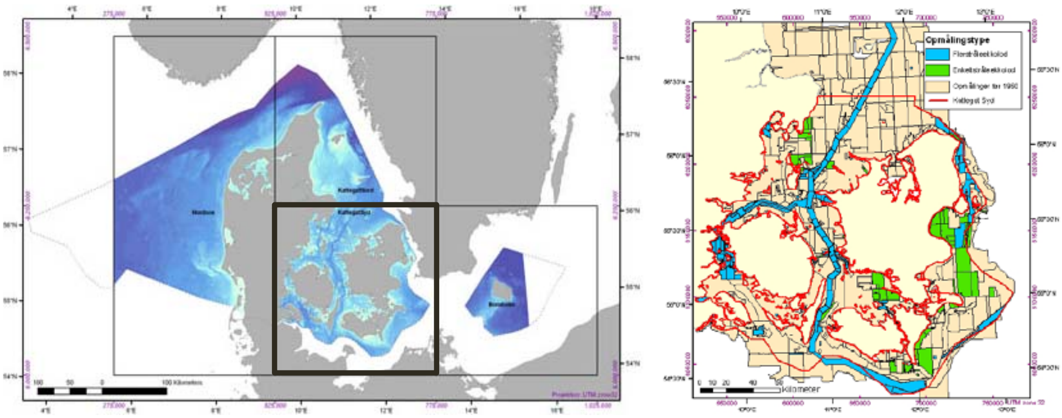


FIGURE 23 LEFT PICTURE: KATTEGAT SOUTH (IN THE BLACK SQUARE) IS THE DATASET USED IN THE PROJECT. RIGHT PICTURE: THE LOCATION OF THE DIFFERENT TYPES OF MEASUREMENT. (DANISH GEODATA AGENCY N.D. (A))

Regarding the reference system used in the digital bathymetric model for *Kattegat South*, all the horizontal datum is in WGS84 with a projection of UTM zone 32 and the vertical datum is DVR90, explained further in chapter 7.2.4.

The surveys used for the digital bathymetric model are measured by various methods depending on the age of the survey. Some of the areas in the model were measured before 1950 by older technology and some are digitalized based on navigational charts. The more critical or heavily trafficked areas are updated often and are measured with newer technology. The right picture in Figure 23 visualises the types of measurements in Kattegat South; Measurements from before 1950, single beam echo sonar and multi beam echo sonar.

Some of the areas in the digital bathymetric model are digitalized by navigational charts, since the measured data stored in the GST database does not cover all areas in the EEZ. This involves some smaller areas around Hasselø and in the South Funen Archipelago.

(Farvandsvæsenet 2008)

Before 1950, the trigonometric method was used to measure the geographical location and the depth was measured manually or mechanically (implemented in the late 70s) by sounding lines. The trigonometric method is based on specific (triangulation) points on shore that are measured and put into a triangulation grid. At the locations from where the depths are measured, the ship is measuring into two of the known points from the triangulation grid and the angle between these points are measured. By measuring into two more points and finding the angel between these, it is possible to find the location of the ship. A circle can be created from each measured angel and the ship is located at some point on that circle. Since two angles are measured, two circles can be created – the location of the ship is determined by intersecting the circles.
(Balstrøm, Jacobi and Bodum 2006) (Kort og Matrikelstyrelsen 2012)

The measurements from the period before 1950 have poor data accuracy and completeness – it is far from full coverage of the seabed, since the location of the measured points have a distance of around 400 meters. The uncertainty involved in the measurements also concerns the type of seabed, the plumb might sink into a soft seabed or between rocks leading to the depth measurement turning out deeper than in reality. The risk of colliding with objects on the seabed, not described in the navigational charts, is high because of the poor coverage of the seabed.

In earlier surveys, the precision of the geographical position was at around 100-200 meters near the coastline and 300 meters further out. Around 1950, the precision was enhanced to 10-30 meters and 100 meters, respectively.

The precision of the measurements of the depth in present time is "*less than 20 cm when the depth is less than 20 m*" (Translated from Danish) (Kort og Matrikelstyrelsen 2012). The greater the distance that has to be measured, the more inaccurate the data. Furthermore, factors changing the water level, such as tidal corrections, plays an additional role in the inaccuracy – in the inner Danish waters this inaccuracy is set to be around 10-40 cm.

(Kort og Matrikelstyrelsen 2012)

After 1950, the draught of the ships became deeper and concurrently the requirement for higher quality navigational charts was necessary.

The introduction of the echo sonar resulted in better data quality and the possibility to measure in deeper water than previously – and became the main measuring device for measuring the depth of the sea. (Danish Geodata Agency n.d. (b))

There is a distinction between single beam echo sonar and multi beam echo sonar. The single beam echo sonar is a transducer with a combination of a microphone and a speaker in which the speaker transmits an acoustic beam (sound pulse) towards the seabed for the acoustic beam to be reflected, returned and detected by the microphone. Half of the time that it takes for the acoustic beam to reach the seabed and return to the transducer is an expression of the depth, left picture of Figure 24. This kind of sonar has a high precision, but a low coverage since it only covers what is below the ship. Therefore, measurements with this kind of equipment is not considered 100 percent accurate. The method is especially vulnerable to objects on the seabed as well as shoals.
(Danish Geodata Agency n.d. (c))

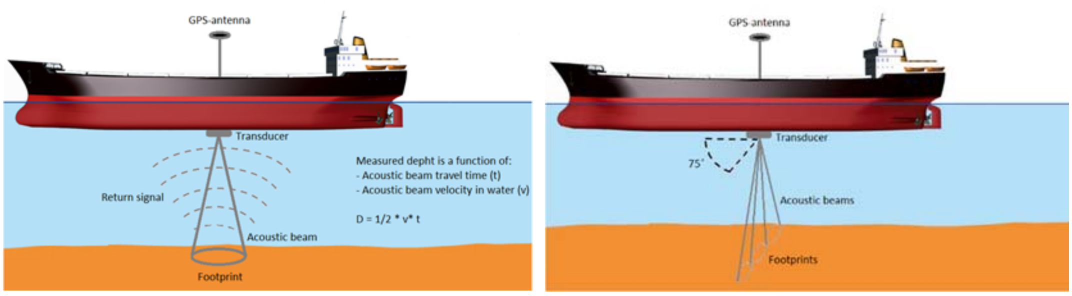


FIGURE 24 LEFT PICTURE: SINGLE BEAM ECHO SONAR AND THE FUNCTION FOR THE MEASURED DEPTH, RIGHT PICTURE: MULTI BEAM ECHO SONAR.

In addition to the mentioned single beam echo sonar, multi beam echo sonar is capable of sending and receiving several acoustic beams, right picture in Figure 24. The acoustic beam is transmitted in the transverse direction of the ship and can measure up to a distance of 75° from the vertical plane. The main difference between the single beam and the multi beam echo sonar is that the single beam only transmit one beam at a time and does not fully cover the seabed, whereas the multi beam transmit many beams at once which results in a 100 percent coverage of the seabed. In the transit routes of the Danish waters, a minimum depth is guaranteed. For route-T, that minimum depth is 17 meters.

The Danish Geodata Agency (n.d. (c)) states that today's equipment can measure 512 soundings in a profile and that "*for measurements at around 10 m depth, a sounding is transmitted for each 7 cm…*" (Translated from Danish). For areas measured with multi-beam sonar and DGPS, the precision and coverage is expected to be 100 percent accurate (Kort og Matrikelstyrelsen 2012).

The information measured from multi beam echo sonar in the digital bathymetric model contains millions of points; therefore, the points are averaged in a 25 * 25 meters grid to prune the data.

The Danish coastline is represented by approximately 400.000 coastal points, which is given the value 0 and is located for at least every 20 meters along the coast.

The digital bathymetric model is produces as a 50 * 50 meters grid in which one value is given for each cell. This value is defined by interpolating the values of the neighbouring cell in the case that the cell does not have a measured point.

(Danish Geodata Agency n.d. (a))

In a natural neighbour interpolation, Thiessen polygons are created from a dataset containing points, Figure 25. Thiessen polygons are polygons created around each single point and drawn in the middle of two points, so that every location within the polygon is closest to the associated point. The interpolation is based on the created Thiessen polygons meaning that a new polygon is created around the point that is going to be interpolated. The interpolated point is given a value from the proportion of overlap that the new polygons covers the initial polygons – these proportions are used as weights. (Esri 2011 (a))

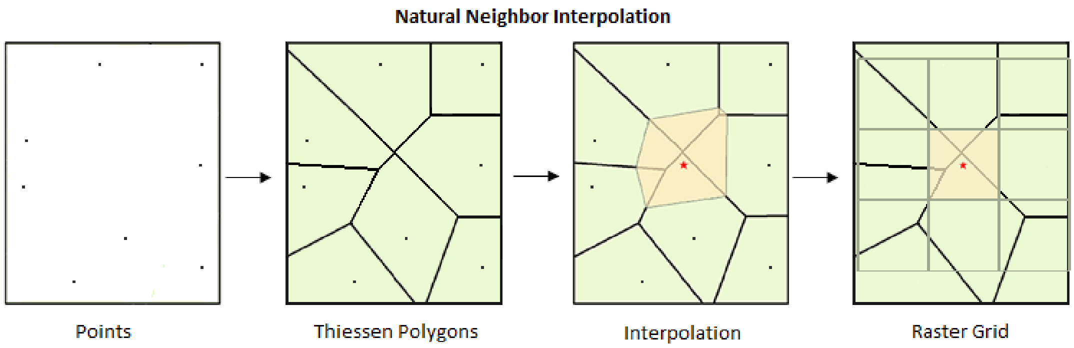


FIGURE 25 THE WORKFLOW OF THE NATURAL NEIGHBOUR INTERPOLATION METHOD. (ESRI 2011 (A))

When an interpolation is performed, it is to estimate the depth of the area – this way both areas with lots of information and areas with less information can be given an estimate.

In 2001, the GST and Statistics Denmark developed the Danish Grid, which is a national square grid system. The grid has the purpose of acting as a standard for geographical data so that different types of data is comparable. Since the GST have developed the digital bathymetric model, it is assumed that the data is based on the Danish Grid. Other raster data will therefore be snapped to the digital bathymetric model during the analysis. (Kort og Matrikelstyrelsen, Danmarks Statistik 2012)

The positional data for the model is measured with DGPS (Differential Global Positional System). This means that besides the signal received from the satellites, the GPS-receiver also receives a radio signal from a base station on shore. The position of the base station is known, and the base station receives signal from the satellites as well, which means that the radio signal from the base station can be used to eliminate errors and uncertainty, thus heightening the data quality. By using DGPS, a horizontal accuracy of 0.5 meters can be achieved (Kort og Matrikelstyrelsen 2012). Near the shoreline, RTK (Real Time Kinematic) measurements can be used, achieving even better accuracy, this requires distances from the GPS-receiver to the base station to be <20 km, and that there is at least five visible satellites on the horizon.

7.2.2 AIS-data

The positional accuracy of the coordinates delivered through the AIS-signals can vary from ship to ship, depending on the quality of the GPS-system. Some of the most accurate maritime GPS-systems, using differential GPS (DGPS), deliver a position that is accurate down to 1 meter (SAM Electronics 2010). The DGPS-systems uses land-based stations, with a known position, to eliminate some of the errors associated with GPS, to enhance the accuracy of the position. In optimal conditions, DGPS can deliver positions with a horizontal accuracy <10 cm (NASA n.d.). The precision in Danish waters is relatively high because the straits are narrow. This means, that the distance to the nearest land-based station never exceeds 150 km (Kort og Matrikelstyrelsen 2012).

The timestamps in the AIS-logs are not as precise, since that comes from the server and not the transmitter on board of the ship (Støttrup and Engberg 2006). In situations where the servers have problems, that could result in AIS-signals queuing up and thus getting almost the same timestamp once the server is running again.

The AIS-data received in this project is in WGS 1984 geographical coordinates, and the accuracy of the position is expected to be high, though the timestamp may not be precise. The quality and origin of the rest of the data varies significantly with each ship, and it is therefore impossible to conclude anything in general.

The interval of the timestamps for the received AIS-data is between 3 and 6 minutes, which indicates that data has been pruned.

7.2.3 Pilot-data

The collected pilot-data originates from the database of the Great Belt VTS. Søren Nielsen (2013) states that upon creation of a passage and on completion of this passage, timestamps are noted. This means the date and time at which the ship arrives to the VTS area and the pilot boards the ship is noted, and the date and time at which the ship navigates out of the VTS area and the pilot gets off the ship is noted.

The timestamp originates from Signalis' system for Vessel Traffic Service. The system is used by Great Belt VTS to monitor the ship traffic through the Great Belt. Signalis states that their *"… Vessel Traffic Services (VTS) systems provide operators with an overview of their areas of interest, enabling them to monitor and interact to critical maritime situations, and provide the means to quickly communicate to all relevant authority."* (Signalis n.d.)

The needs for a VTS system is different depending on the monitored area. Because of that the sensor network is geared to gain the request for the specific area. Hansi (2013) from Great Belt VTS states that the system's integrated clock, which run on Coordinated Universal Time (UTC), determines the timestamps.

Some errors may occur because of the extract requested for the project, but overall the quality and accuracy of the data provided by the Great Belt VTS is expected to be very good.

7.2.4 Reference Systems

The datum attached to the boundary of the Danish inner and outer territorial waters, the AIS-data and the digital bathymetric model is the World Geodetic System 1984 (WGS84), Figure 26. The pilot-data is based on MMSIs and timestamps and does not have an attached reference system.

Through the introduction of satellites, it was necessary for the creation of a datum that represents the entire globe in the best possible way. Since the global geodetic reference system WGS84 is based on the GRS80 ellipsoid, which characteristics is a centrum in the earth's centre of mass, satellites can move around the centre meaning that WGS84 is a datum representing the entire globe in the best possible way.
(Dueholm, Laurentzius and Jensen 2005)

Data	Reference system
Inner and outer territorial waters' boundaries	WGS84, GCS
AIS-data	WGS84, GCS
Pilot-data	None
Digital bathymetric model	WGS84, UTM Zone 32, DVR90

FIGURE 26 EXITING REFERENCE SYSTEM IN THE RECEIVED DATASETS

The boundary of the inner and outer waters territory and the AIS-data is attached to a geographical coordinate system where the digital bathymetric model is attached to a universal transverse Mercator (UTM) projection.

The geographical coordinate system consist of the three spatial coordinates; longitudes, latitudes and elevation. Coordinates are defined as decimal degrees meaning degrees, minutes and seconds.
The UTM projection is an international projection that depicts the earth by 60 cylinders. Denmark is located in zone 32 and 33 respectively, with the largest part of Denmark located in zone 32. By using the UTM projection, positions are defined with metres instead of degrees.

(Dueholm, Laurentzius and Jensen 2005)

Danish Vertical Reference 1990 (DVR90) is the standard when referencing heights in Denmark and is defined from the mean sea level in the area surrounding Denmark. (The Danish Geodata Agency n.d.)

Since the project is local and only concerns Kattegat South, it is optimal to use the UTM projection Zone 32 and DVR90 in this analysis. In the following data preparation, all data is transformed from their current coordinate system into datum WGS84, projection UTM Zone 32.

7.3 Basis of Calculations

In chapter 3.1 it is determined that the recommended UKC when navigating through the Great Belt is 2 meters. When pilots follow this recommendation, the chance of grounding is minimal since the water level in Kattegat does not differ more than 40 cm (under normal circumstances) according to chapter 3.1.1 The guideline for finding relevant ships in the analysis is therefore ships with a UKC less than 2 meters.

When discussing UKC, two different definitions exists – the real UKC and the static UKC. To find the static UKC only two factors have to be known; the draught of the ship and the depth of the water in a given location, Figure 27. As the draught is in positive numbers and the depth in the digital bathymetric model is negative, the formula used will be:

- Depth + Draught = - Static UKC

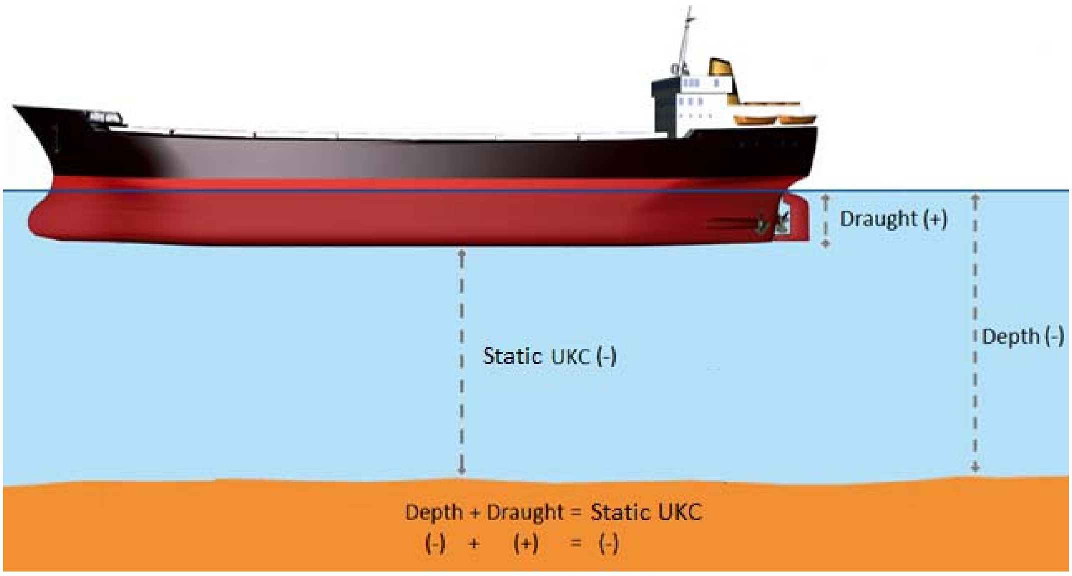


FIGURE 27 VISUALIZES THE TWO ELEMENTS AND THE FORMULA FOR CALCULATING THE STATIC UKC.

The static UKC is a good starting point to have an idea of whether some of the ships have considered the recommendation, but does not visualise the actual conditions. That is where the actual UKC comes into play.

The Marine Exchange of Southern California (MXSOCAL) (2013) defines UKC as; *"Under-keel clearance (UKC) means the minimum clearance available between the deepest point on the vessel and the bottom in still water.*

UKC = (Charted Depth of Water + Height of Tide) – (Static Deep Draft)

… Masters and pilots should apply a plus or minus allowance for the tide when calculating depth of water"

If a ship is found having a UKC less than 2 meters using the formula for the static UKC, the tide will be calculated and brought into the analysis subsequently to find the actual UKC and give a more accurate picture of the situation. Other factors, such as the weather can be taken into account in order to get an even more accurate result, however this will not be done in the analysis.

To evaluate our findings, it is interesting to determine when an UKC is actually critical. Hansi (2013) states that it is not possible to give a definitive number, since it depends on various parameters such as size and type of ship, velocity and type of seabed. Since calculating the critical UKC for each ship would take too many resources, we have chosen to take an offset in the IMO recommendation, stating that the UKC should be minimum 2 meters. In addition to this, the analysis will be based on the static UKC, and will only take the tide into consideration on ships with a static UKC less than 2 meters.

7.4 Data Preparation

The data received from outside sources can be structured in various ways. For the data to be usable, some data editing is needed. In this section of the report, the important functionality of the scripts and tools used in the project will be explained. The complete scripts are available in CD-appendix.

Figure 28 shows the flow of our data preparation. The data has been processed before we received it. Data from AIS-transmitters starts as binary code, which is transmitted every few seconds. The data is sent to land-based servers, which then parses the binary code into ASCI-format that we process.

In step 1, we receive the data as .txt-files, as logs of ship activity for each day. These files are split into files representing each MMSI instead of each day. The files are cleaned of redundant information to facilitate the amount of data when running the scripts. To be able to delete duplicates the lines in the files are sorted - thus, the files are split, cleaned and sorted using four sub-steps in a Python-script. The result of this is also .txt-files, but there is now one file for each ship.

In step 2, the .txt-files run through another Python-script that converts them into feature classes. As feature classes, the data can be manually cleaned and inspected in ArcGIS, because they are visualized graphically.

In step 3, the files are converted from feature classes to raster in order to compare them to the bathymetric model, via a tool in ArcGIS.

In step 4 the pilot-data will manually be implemented into AIS-data and it will be assessed whether the two datasets are inconsistent.

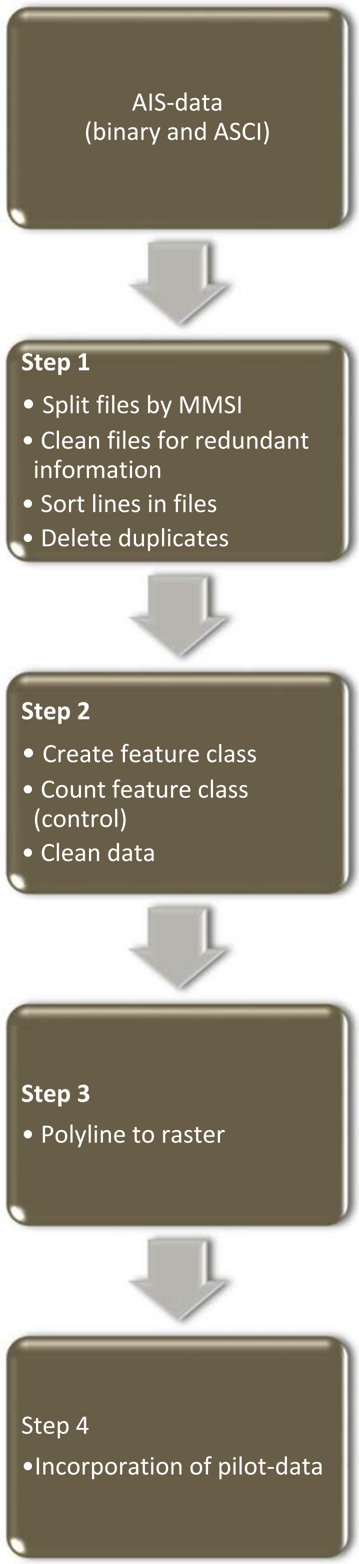


FIGURE 28 FLOW OF THE DATA PREPARATION

During the four steps mentioned, the data is manipulated and changed significantly. Figure 29 shows how the format of the files changes throughout the project. Please note that three different "stages" are involved in processing the data, as indicated by the colours.

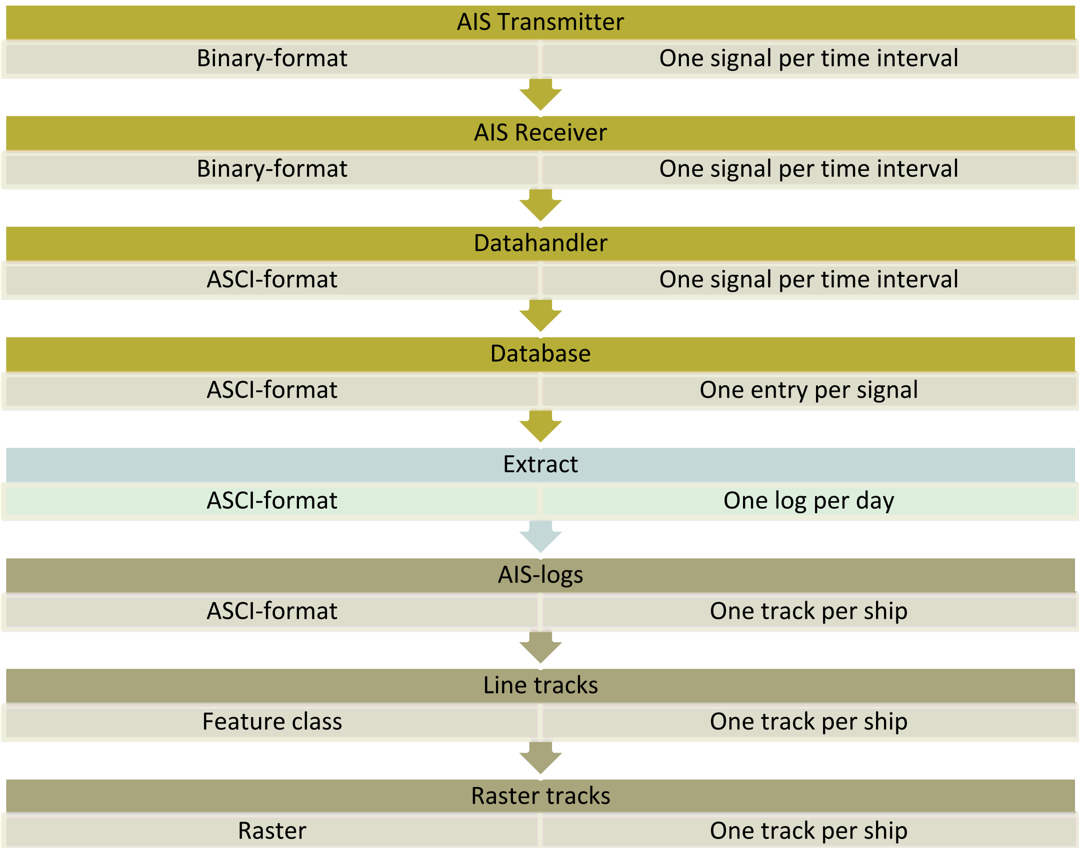


Figure 29 The light green colour indicates steps done before this project, the light blue colour indicates steps done by Svend Jacob Senstius and the dark green colour indicates steps done in this project using Python scripts.

In addition to converting the AIS signals from binary to ASCI-format, the data handler also prunes the data. By doing this, the amount of data is drastically reduced, lightening the capacity required in the database. However, pruning the data means reducing the accuracy of the tracks produced later on. The pruning is done using linear approximation, Figure 30, which results in problems, especially in connection to ships turning.

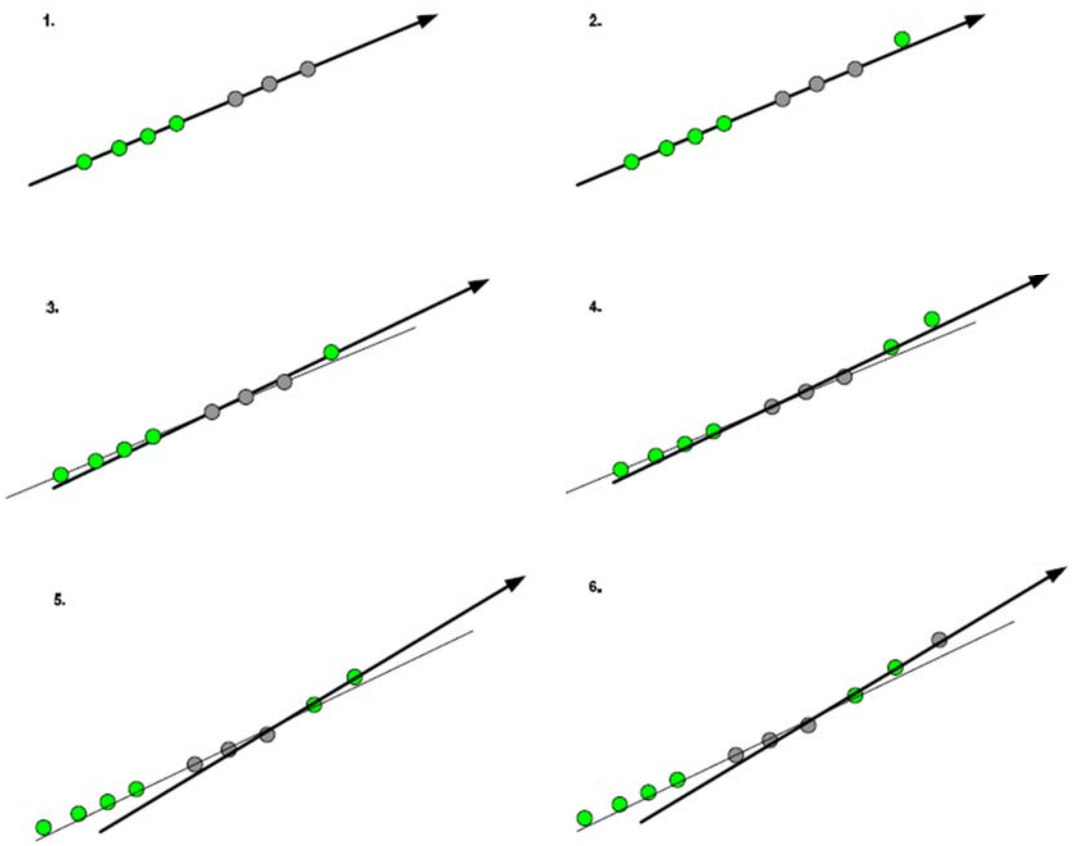


FIGURE 30 ***"1. WHEN THE SHIP FIRST ARRIVES IN THE COVERAGE AREA OF AIS SYSTEM THE FIRST 4 SAMPLES ARE USED FOR INITIALIZING THE LINEAR APPROXIMATION ALGORITHM. THUS, THE FIRST 4 SAMPLES WILL ALWAYS PASS THE FILTER. THE NEXT 3 SAMPLES RECEIVED IN THIS EXAMPLE ARE LOCATED WITHIN A CONFIGURABLE MAXIMUM DISTANCE, $\Delta_{MAX\ DIST}$, FROM THE LINE AND ARE THEREFORE REMOVED BY THE FILTER.***
2. THE NEXT SAMPLE IS TOO FAR AWAY FROM THE LINE AND WILL THEREFORE PASS THE FILTER.
3. A NEW LINE WILL BE COMPUTED BASED ON THE LAST 4 SAMPLES (I.E. THE LAST GREEN ONE AND THE THREE GRAY ONES).
4. THE NEXT SAMPLE IS AGAIN TOO FAR AWAY FROM THE LINE
5. A NEW LINE IS COMPUTED
6. THE NEXT SAMPLE IS ON THE LINE AND THEREFORE WILL BE REMOVED BY THE FILTER."
(ENGBERG 2009)

In the example shown, the amount of data is cut down with 40 % (10 samples, four is discarded and six is kept). To ensure that too much data is not discarded, another filter can be applied to ensure a minimum interval between points. This is especially useful when ships are travelling a long distance in a straight line, which could otherwise result in a very long distance between each point. We have no certain knowledge of the filter applied on our data, but based on the timestamps it is assumed that the minimum interval is set to around 6 min.

With the general conditions of the data established, the manipulation of data will be elaborated in the following section.

7.4.1 Preliminary Steps

Python scripts are used to manipulate and rearrange the data acquired as well as for converting the AIS-logs to ArcGIS-compatible formats.

When we received the AIS-data from Svend Jacob Senstius, we first did some manual cleaning of the files. The original data contained timestamps in the format "02 nov 2012 12:00:01.000 UTC". To be able to easily sort the data according to the timestamp, we changed the format to YYYY-MM-DD HH:MM:SS.FFF by doing a simple search and replace in our text editor - at the same time, we removed "UTC". This was done to make sure that Python, more specifically the datetime-module, could understand the format of the timestamp.

In general, when we read input files in our scripts, we use "readlines", which reads the entirety of the file at once, storing it in the memory of the computer. In this project, that did not lead to any problem since the amount of data processed is not large. However, should these tools be run on a larger dataset e.g. all of the Danish waters and for 2-3 years, it could potentially lead the system to crash. To prevent this from happening, "readlines" could be substituted with "xreadlines", which is slower, but more stable and less prone to crashes, because it only process one line at a time. Another solution could be the even slower "readline", which reads one character at a time, making it much slower but also much less prone to crashing due to full memory.

In some of the scripts, elements from the arcpy-module are used. This module is part of the ArcGIS installation, and requires Python 2.7 (32-bit) to run (Esri 2012 (b)).

7.4.2 Part I – AIS-logs

The first script, written in Python, has the overall purpose of getting the data cleaned, sorted and re-arranged with a file for each ship, instead of having the files arranged based on date. As mentioned, each of the original files contains all data for one day. If that file were to be displayed on a map, it would result in a significant number of points representing various ships in various positions. In order to show the individual ship, the data must be sorted based on MMSI.

This script contains many elements used in our other scripts. In the following section, the most important parts of the script will be shown and explained. The first can be seen in Figure 31.

```
import os, os.path
```

FIGURE 31

This line is used for initiating the os-module as well as the os.path-module, which is needed for a lot of the basic functionality of file and folder paths and the operating system in general (Python Software Foundation n.d.). One of the key-functions of the os.path-module is the ability to use relative paths to files and folders used in the script - part of the line in Figure 32 is used for exactly that purpose.

```
inFolder = os.path.dirname(__file__) + "\\Input"
```

FIGURE 32

What the above line does is telling that the variable “inFolder” is the folder “Input” in the same directory as the script. By using this line instead of an absolute path, e.g. C:\\<USERNAME>\Python\Data\etc.\etc., it is ensured that the script can be run on all compatible machines, as long as the folder structure beyond the script is preserved. This has been very helpful during this project, since the scripts have been created using different computers.

Another line of code often used throughout the project is show in Figure 33.

```
inList=os.listdir(inFolder)
```

FIGURE 33

The line creates a list-variable, in this case called “inList”, which consists of all files in the folder that “inFolder” represents. This functionality instructs the script to loop through a high number of files placed in the same folder. More specifically, the AIS-data received consisted of 61 files - one for each day in a two-month period. When a list is made, a loop such as the one in Figure 34 is used to go through each file and perform the desired action.

```
for fname in inList:
    inFile = open(inFolder + "\\" + fname,'r')
    indhold = inFile.readlines()
    inFile.close()
```

FIGURE 34

The above code, in turn, opens all files as read-only and reads their content into a variable called “indhold”. It then closes the file. This method ensures that the original data is not contaminated.

Since the data is put into a variable, it is safe to progress and edit it. The first step of the editing process is to put the data into separate files based on the MMSI, which is comparable to a license plate for ships. To be able to do that, the script must be told how to read the data. In this case, the data is comma separated, so the line in Figure 35 is used.

```
for line in indhold:
    itemList = line.split(",")
    MMSI = itemList[0]
```

FIGURE 35

The above line is directing the script to go through each line and separate it into items based on the placement of commas. Since each line contains the same information in the same position, it is easy to extract the MMSI, found as the first item in each line - it is important to remember that the first place in a list is called place 0. The MMSI is used to create a new file, as shown in Figure 36.

```
outFile=open(outFolder + "\\" + MMSI + ".txt", "a")
```

FIGURE 36

Note that in this case, the letter “a” is used in the end of the code to make the file open in append-mode. This means, that each new line is put in the bottom of the existing file. After all the input files have been run through, and the data have been split into new files based on the MMSI, it is time to pick out which columns are needed later in the project as well as getting the lines sorted based on the timestamp.

The output files from the first part of the script are used as input for this part of the code, and again the files are opened in read-mode and the content is put into a variable called “indhold”. To sort the data, the simple line in Figure 37 is used.

```
list.sort(indhold)
```

FIGURE 37

You could choose to sort on a specific column, in this case, the second column contains the timestamps, and since the entry in the first column is the same for each line in each file, the function will look to the second column in order to sort the content. The timestamp format was changed to “YYYY-MM-DD HH:MM:SS.FFF”, and therefore the first occurring timestamp will be sorted to the top of the file.

We read the data from the input file and then store it temporarily in the variable named “indhold”. This way, we can overwrite the input file in order to save disk space. This is done, as shown in Figure 38, with a line similar to that of Figure 36.

```
outFile = open(outFolder + "\\" + fname,'w+')
```

FIGURE 38

As can be seen, this time the last part of the line is "w+", which is the part that makes the script overwrite the existing file. To decide which data is to be put into the new version of the file, the second line from Figure 35 is used to split each line into numbered items, which can then be placed into the new file by the line shown in Figure 39.

```
outFile.write(str(itemList[0]+","+itemList[1]+", "+itemList[2]+
…   and so forth
```

FIGURE 39

Having made a new version of the file, where only the wanted data is present and sorted based on timestamps, it is possible to remove possible duplicate entries. Once again, the file is parsed into a variable. Since the data is sorted based on the timestamp, it is simple to compare each line to the next one. The comparison is done with the if-statement shown in Figure 40

```
if oldx == x and oldy == y and oldt == t:
    bad += 1
    badLines.write(line)
else:
    outFile.write(line)
    good += 1
```

FIGURE 40

The loop compares the coordinates as well as the timestamp and if the values coincide, the line is not passed to the output file but into another text file holding all the duplicate lines. This way we can see which lines were skipped, in the event that something goes wrong.

The result of the script is 457 timestamp-sorted .txt-files, one for each MMSI in our data. One of the files is represented with MMSI 999999999. This MMSI is reserved for ships with fault in their setup of the AIS-transmitter. (Harati-Mokhtari n.d.) In addition, the content of the file is arranged differently compared to the others, thus this file is disregarded.

7.4.3 Part II – Feature Classes

The second script, also written in Python, has the purpose of converting the text files to ArcGIS-compatible feature classes. This is done through the arcpy-module in Python, which is imported the same way that the os and os.path-modules were imported in the first script. In addition to arcpy, parts of the basic math-module and the datetime-module is imported as well.

After the modules are imported, two functions are defined for later usage in the script, see Figure 41 and Figure 42.

```
def base(lon1, lat1, lon2, lat2):
    lon1, lat1, lon2, lat2 = map(radians, [lon1, lat1, lon2,
lat2])
    dlon = lon2 - lon1
    dlat = lat2 - lat1
    a = sin(dlat/2)**2 + cos(lat1) * cos(lat2) * sin(dlon/2)**2
    c = 2 * atan2(sqrt(a), sqrt(1-a))
    Base = 6371 * c
    return Base
```

FIGURE 41

The code for the function "base" is used to calculate the length, in kilometres, between each timestamp. The length is used later on to define the speed with which the ship is sailing. This can be used to identify errors in the tracks.

```
def bearing(lon1, lat1, lon2, lat2):
    Bearing =atan2(cos(lat1)*sin(lat2)-
sin(lat1)*cos(lat2)*cos(lon2-lon1), sin(lon2-lon1)*cos(lat2))
    Bearing = degrees(Bearing)
    return Bearing
```

FIGURE 42

The code for the function "bearing" is used to calculate the bearing of the ship, in degrees. Again, this can be used to identify errors in the tracks.

When working with geographic data, it is important to assign the correct coordinate system to the data. When working with arcpy, this is done with the line shown in Figure 43.

```
arcpy.env.outputCoordinateSystem = 4326
```

FIGURE 43

The number 4326 is equivalent to the GCS_WGS_1984 coordinate system, as defined in the ArcGIS documentation. Another important parameter when working with arcpy is the workspace, which is determined by the line in Figure 44. The workspace determines where the created files are stored.

```
arcpy.env.workspace = datapath + "\\" + FGDBname
```

FIGURE 44

"datapath" and "FGDBname" in the line above are variables defined earlier in the script, and are used to make the script easier to debug. That way, you do not have as many parameters to alter if you are changing something.

With the parameters ready, the feature class itself can now be created, Figure 45.

```
arcpy.CreateFeatureclass_management(datapath + "\\" +
FGDBname,os.path.basename(fc),"polyline")
```

FIGURE 45

As seen in the last word of the line, the created feature classes are of the type “polyline”. Each attribute of the feature classes are added using lines similar to the ones in Figure 46.

```
arcpy.AddField_management(fc, "ShipID", "TEXT",10)
arcpy.AddField_management(fc, "Pilot", "SHORT")
```

FIGURE 46

With the basic structure of the feature class ready, data can be added. To make new rows in the attribute table of the feature class, a so-called cursor is used to indicate the active row, in which to paste data. The cursor is created via the first line in Figure 47. At the same time, an array and a point object is created, since they are required to create the single features in the feature class.

```
cur = arcpy.InsertCursor(fc)
lineArray = arcpy.Array()
pnt = arcpy.Point()
```

FIGURE 47

The first line of the input files are read via “readline”, since the first line is needed separately to start the comparison of each of the following lines. The following lines are read and then split into separate items, based on commas. The coordinates are used to create a point, using the point object, which is in turn put into the array - the array is then used as a definition of the geometric shape and data is put into the respective cells, as shown in Figure 48.

```
x1 = float(itemList[3])
pnt.X = x1
y1 = float(itemList[2])
pnt.Y = y1
lineArray.add(pnt)
…
feat = cur.newRow()
feat.shape = lineArray
feat.Destination = itemList[12]
feat.Pilot = 0
```

FIGURE 48

After this, the other attributes are placed in their right places by referring to their numbered place in the list. An important part of this is another check up on the timestamps. In Figure 40, the script was tested for identical timestamps AND coordinates. Now it tests if the time difference between two on each other following timestamps are identical without looking at the coordinates. This is done to identify possible errors in the track. The last line in Figure 49 shows the use of the previously mentioned “bearing”-function.

```
if time_diff_secs > 0:
    feat.Speed_Km = float((length/time_diff_secs) * 3600 + 0.5)
else:
    print "time_diff_secs is 0 in record no. ", count, " x1,y1=
", x1,y1
feat.Bearing = int(bearing(x1,y1,x2,y2) + 0.5)
```

FIGURE 49

The result of the script is, 456 feature classes, in the geographical coordinate system WGS 1984, for use in ArcGIS.

Project Feature Class

In chapter 7.2.4 it is stated that the reference system that is going to be used throughout this project is datum WGS 1984 and projection UTM zone 32, therefore the data has to be transformed.

The transformation is performed in ArcMap with use of the Batch project tool. The tool contain five parameters; Input feature class or dataset, output workspace, output coordinate system, template dataset and transformation, whereas the three last mentioned is optional.

The Batch project tool is compatible with feature datasets and feature classes, which the AIS-data was transformed into in the earlier stage. The tool is able to obtain all 457 feature classes by the input parameter which is the parameter that locates all the feature classes for which the projection needs to be converted – since this tool already exist and is simple, we chose to use it instead of incorporate the transformation into the python script when creating the feature classes.

In the output workspace parameter, the location of the output feature classes is defined.

The output coordinate system parameter defines the coordinate system of the output files. The output coordinate system is set to *WGS_1984_UTM_Zone_32N*.

Instead of using the output coordinate system parameter, we could have used the template dataset parameter. In this parameter a path to a specific feature class or feature dataset could have been define and then the coordinate system in the output would be defined by the coordinate system in the located feature class/dataset.

Even though both the output coordinate system parameter and the template dataset parameter are optional parameters, one of them has to be defined for the tool not to fail.

The transformation parameter was not used in our case because it is not required to transform the datum. The datum in both cases are WGS 1984 and we therefore just have to convert the projection as chosen in the output coordinate system.

Manual Clean of Feature Classes

The result of the previous steps is feature classes representing each ship navigating with dangerous goods inside the boundary set for this project. The left picture in Figure 50 visualises all the feature classes at once and, as can be seen, many of the ships have lines crossing land, which makes it easy to detect some of the errors in the dataset.

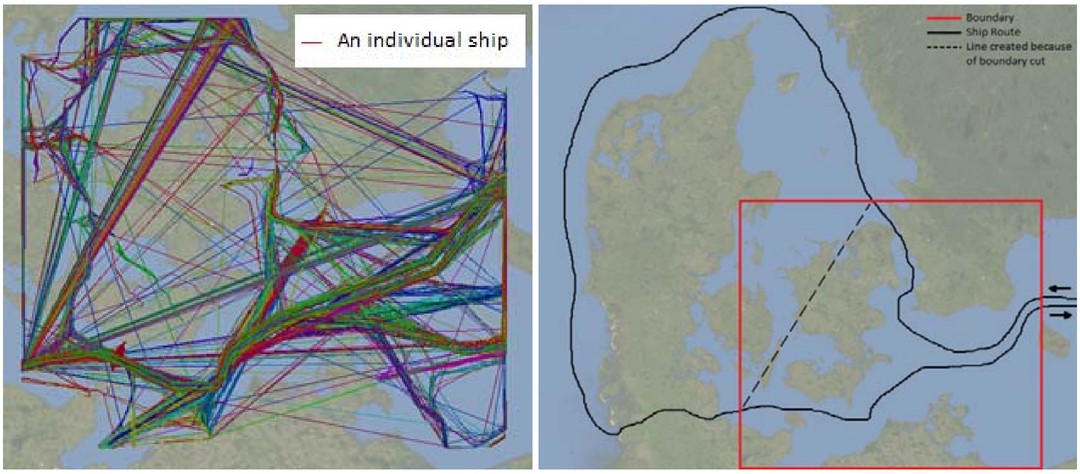


FIGURE 50 LEFT PICTURE: LINES CROSSING OVER LAND. EACH COLOUR REPRESENTS AN INDIVIDUAL SHIP. RIGHT PICTURE: BY THE BOUNDARY BOX, ONLY SOME OF THE DATA IS COLLECTED WHICH RESULTS IN ERRORS.

The boundary set when collecting the data is responsible for the creation of the lines. For example, when a ship navigates from the Baltic Sea, through the Sound, to the North Sea, and then back to the Baltic Sea through the Kiel Canal, it has navigated in and out of the boundary, right picture in Figure 50. We only have the data from within the boundary, and in the script in which the feature classes are created, it is determined that from every geographical location defined in the AIS-data a line should be created to the next geographical location based on timestamps.

In order to avoid these problem two elements in the AIS-data could be used. In the earlier stage, one of the following methods could have been implemented;

1. In case the distance between to geographical location is greater than a given distance, the two points should not be connected.
2. In case the time difference in the timestamps is longer than a given interval, the two points should not be connected.

Re 1, it is possible that a ship is getting back into the boundary close to the location from where it left the boundary which means that it will still connect those two points. If it were evaluated based on timestamps, re 2, the long time period from leaving, to entering the boundary would define that the two points should not be connected. This method is therefore the most practical of the methods.

Since the feature classes are created by connecting each geographical location with the next, the information from the first geographical location is attached to the created line. When these lines are deleted from the AIS-data, the information attached to the line will also be deleted from the data. Since this only happens in cases where the ship is navigating out of the boundary, it will not have a huge impact on the analysis.

The errors were detected late in the process and because of that, a decision was made to delete the crossing lines manually. Had there been more data, and thus more of the traversing lines, it may as well have been easier to implement it and re-run the script on the original data.

When the data was cleaned in the script, it was defined that each time identical lines were identified in the AIS-logs, only the first of these was transferred into the new file. In chapter 7.4.2, the script identifies identical timestamps though with different coordinates and writes it in a log-file. By looking through the log-file, we have been able to locate these errors, Figure 51. We have not been able to determine why the errors occur.

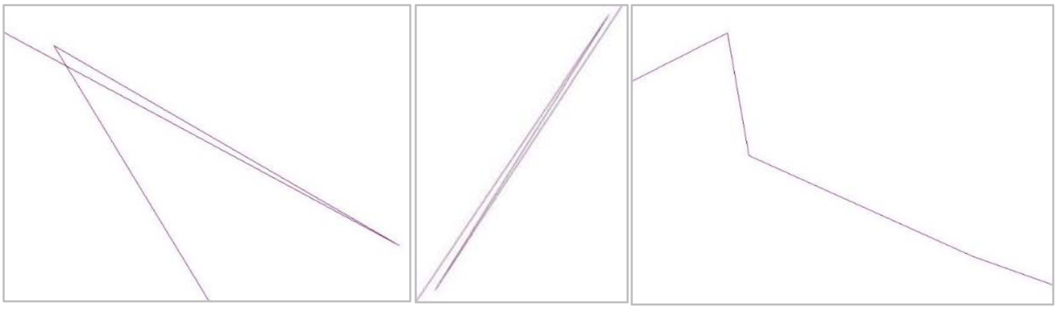


FIGURE 51 EXAMPLES OF THE OCCURRED ERRORS WHERE TIMESTAMPS ARE IDENTICAL, BUT COORDINATES ARE DIFFERENT.

These sort of errors could have an impact when incorporating the pilot-data into the feature classes. If we would like to select features to see how many passages that have been through the Great Belt and compare it to how many times these transits were registered in the pilot-data, we would get a wrong result. If the selection was done with a line, and the line is drawn where the error is, three passages would be registered instead of one passage and then an inconsistency would appear.

Since it is not possible for one ship to be at two locations at once, one of the locations must be wrong. If the false position is in an area in which it seems like the ship has grounded, it will have an impact on the project. This error could also have an impact on the distance of a trip that most likely would be calculated longer than it actually is. However, since the distance is not a priority in this project, the impact will be minimal.

The errors could be automatically identified and discarded by detecting sudden changes in the ships bearing, which is calculated in the script, but due to limited resources, this was not prioritized in the project. We are aware of this error but do not resolve it unless it occurs at a critical point in the analysis. Should that be the case, we will have to manually look at the individual location and assess based on the bearing and distance of the lines.

7.4.4 Part III – Raster Datasets

The result of the previous stages is 456 feature classes containing vectors that represents the ship tracks, with reference system WGS 1984 UTM zone 32.These vectors are going to be compared to the digital bathymetric model, which is in raster format. Because of this, each of the 456 feature classes containing vectors will be converted into raster format. The digital bathymetric model could have been converted from raster to vector in the form of polygons. However, this would not simplify the process, thus the method of converting the feature classes to raster was chosen.

To convert vector format into raster format a model is created in ModelBuilder. The model contains one of the 12 iterators from the iterator toolset and a tool turning polylines into raster, Figure 52

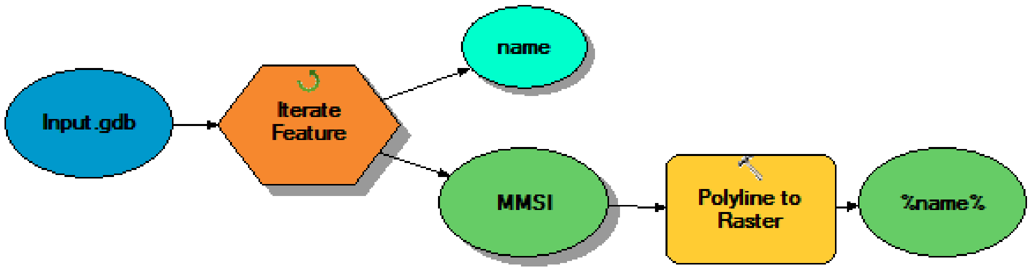


FIGURE 52 MODEL THAT CONVERT FEATURE CLASSES TO RASTER DATASET

The “iterate feature classes” iterator used in the model, has the function of repeating a process on a number of inputs, in this case feature classes. The iterator contains four parameters of which the latter three are optional. The required field is *Workspace or feature dataset* in which the folder containing all the tracks is specified. The three optional parameters *Wildcard, Feature Type* and *Recursive* are not used in the model.

In case we only want to run the tool on filenames starting with “S_20”, “S_20*” could be written in the wildcard parameter and only these files would then be processed by the iterator. The wildcard helps limit the inputs by name whereas the feature type parameter limits the result by feature type, as the name suggests. In case a folder contains both points and polylines, the polylines could be chosen and the raster would only be created based on these. The recursive parameter defines whether subfolders in the chosen folder are included as well. Since we only have one feature type in a single folder, these three optional parameters were not used. *”When the iterator Iterate Feature Classes runs, it creates an output variable for both the path of the feature class and the name of the feature class.”* (Esri 2011 (b))

The process that repeats in this model is a conversion from polyline features to raster dataset, meaning that the polylines in the feature class will be represented by cells. This is done with the tool Polyline to Raster, which contain six parameters; *Input Features, Value field, Output Raster Dataset, Cell assignment type, Priority field* and *Cellsize*.

The feature class that have to be converted is defined in the input features parameter. The input of the polyline to raster tool is the output path of the iterator and since the iterator runs all the feature classes in the defined folder, meaning all the tracks, they are all input to the Polyline to Raster tool.

Each cell in a raster contains a value and since the polyline has several attributes, the value field parameter is used to define which field in the attribute table that should assign values to the cells in the raster dataset - the draught is the field that forms the basis of the values in the raster dataset.

The name and location of the output raster dataset is defined in the Output Raster Dataset parameter and is located in a file geodatabase. The output variable for the name of the feature class is used as an inline variable substitution in the name of the Polyline to Raster output. The path written in the Output Raster Dataset parameter is therefore C:\fileGeodatabase\%name%_raster meaning that when the tool is executed the name of the feature class will be replacing %name% so that the path of the output is similar to C:\fileGeodatabase\S_304944000_raster.

The AIS-signals, as mentioned earlier, are covering two months of navigation, and since the digital bathymetric model is in 50 * 50 meters cells there is a risk of the same ship navigating within the same cell when it is following the same route more than once within the two months.

It is important for the analysis that the maximum draught of all the polylines will represent the cell, because the maximum draught represents a better picture of whether the ship has been close to a collision with the seabed. Tests were performed to understand how to get the polyline with the highest value to overrule when several of polylines are crossing a cell.

Two parameters in the Polyline to Raster tool can be used to define how values are assigned to the cells; the Cell Assignment Type and the Priority Field. The Cell Assignment Type determines whether it is the feature with the longest length covering a cell or the feature with the longest combined length that determines the value assigned to the cell, when more than one feature is within it. Since the draught attribute is the important part of this analysis, the test deals with whether the Priority Field overrules the Cell Assignment Type and if the output ends up as it should for this project.

Esri (2012 (c)) states that the Priority Field; *"… is used when a feature should take preference over another feature with the same attribute."* The attribute used to assign values to the raster is the draught and we want to make sure that the highest value (draught) is assigned to the cells.

The following example is based on two datasets; one representing a raster dataset containing a single cell at 50 * 50m, another representing a vector dataset containing nine polylines assigned with five values going from 1 to 5. The conversion of a feature class to a raster dataset was performed as 50 * 50m grid, 25 * 25m grid and 10 * 10m grid, respectively.

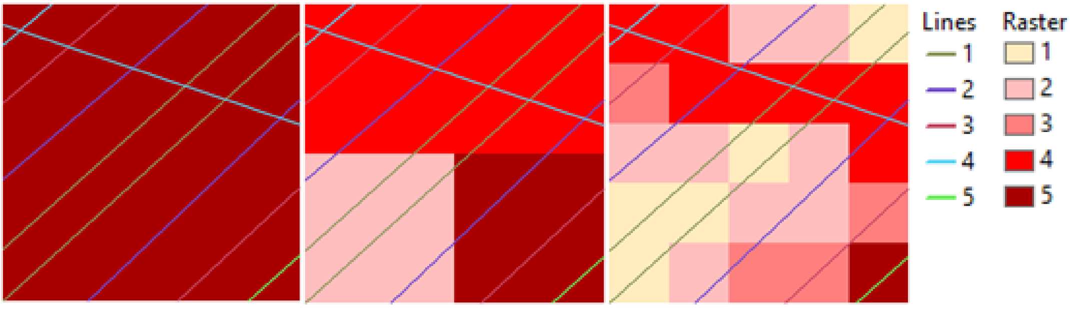


FIGURE 53 FROM LEFT TO RIGHT; 50 *50 METERS CELL, 25 * 25 METERS CELLS AND 10 * 10 METERS CELLS.

Figure 53 displays the results of the performed conversions. The line with value 5 in the lower right corner overrules in all three examples and the cell is given a value of five, which is the highest value. This is how the value should be determined, and therefore the Priority Field is the Draught. As a result, the highest draught value overrules the others in a cell.

The last parameter in the Polyline to Raster tool is the Cellsize and since the digital bathymetric model is in a 50 * 50m grid, we have chosen to use that resolution for our tracks as well. We could have chosen a smaller resolution, such as 10*10m, but that could give a misleading result, where a 10*10m cell could represent a critical point, even though we cannot be sure of the depth in this 10*10m cell, due to the higher resolution of the bathymetric model. With a 10*10m resolution, as seen to the rightmost on Figure 53, one would believe that the lowest UKC is found in the bottom right corner. However, that is not necessarily an accurate representation, since the actual depth in that cell could be 2 meters deeper than the average depth in the 50*50m cell.

Another aspect of the model is to configure the Environment settings, performed in Model Properties where Snap Raster is located under Processing Extent. In this setting the path for the digital bathymetric model is written, meaning that the raster from the track will align to the raster from the digital bathymetric model. This is done to make sure, that the UKC values can be calculated. If the raster datasets are not aligned, half of a track raster cell could be positioned on one depth, while the other half could be positioned on another depth, making it difficult to get an accurate representation of the UKC. The Snap Raster searches for the nearest corner, left picture Figure 54, in order to align the two rasters, starting with the lowest left corner. If that corner is already aligned with the other raster, no adjustments will be made.

In left picture Figure 54, the nearest corner is the lower right one, thus the raster would snap to that corner, shown on right picture Figure 54.

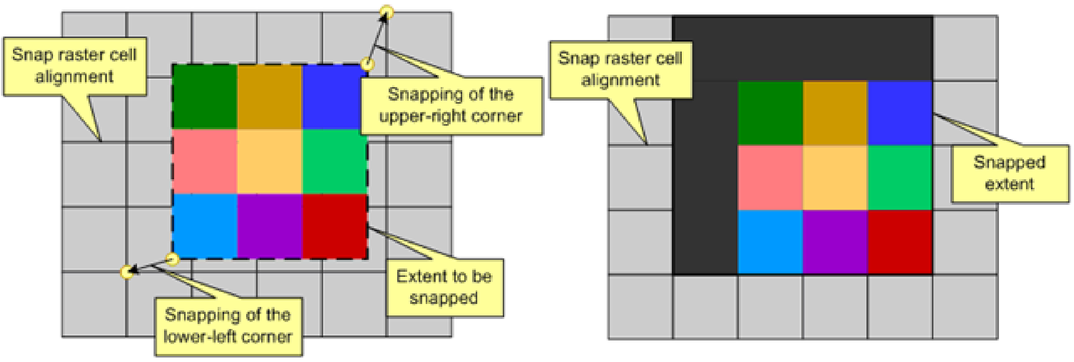


FIGURE 54 THE STAP RASTER FUNCTION SEARCHES FOR THE NEAREST CORNER WHEN SNAPPING THE RASTER (ESRI 2012 (D))

The two outputs of the iterator are the first file in the defined folder and the name of the file. The output file is the input file of the polyline to raster tool and after successfully running the model the results are raster datasets in 50 * 50 meters grid for each of the feature classes.

Figure 55 contains three pictures; the first illustrates the basemap and a track as a feature class. This picture clarifies that the track is located in the water, however the second picture illustrates that when the feature class is converted to a raster, it does not cover the entire track. The reason for this is the high resolution of the digital bathymetric model – the two cells not created in the tracks are not a part of the model and since the tracks is created by snapping to the digital bathymetric model, this part of the track has become "no data". This means that in areas where tracks are located close to the coast, some cells may not be created.

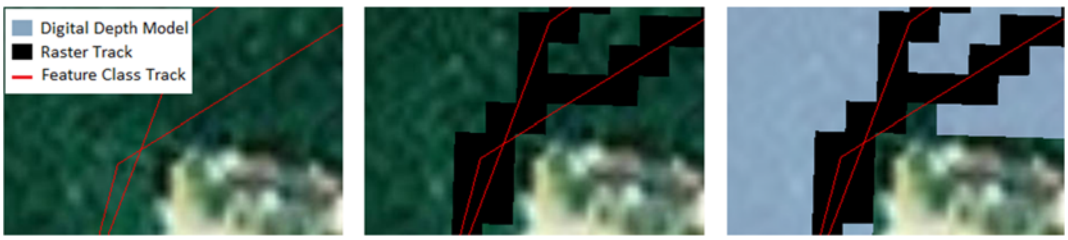


FIGURE 55 EXAMPLE OF TRACKS CLOSE TO LAND, WHERE A PART OF THE VECTOR TRACK IS NOT TRANSFORMED INTO RASTER CELLS SINCE THE CELLS ARE DEFINED AS LAND IN THE DIGITAL BATHYMETRIC MODEL.

7.4.5 Part IV – Pilot-data

In part II the feature classes are created, projected and cleaned, meaning that it is now possible to incorporate the pilot-data into the feature classes. This indicates whether a pilot has been on board the ships in critical areas.

The received pilot-data contains not only the ships we are working with in the project but also all other large ships that have been navigating through the Great Belt in October and November 2012. Based on the received timestamps from both October and November 2012, 25 percent of the total number of 3662 timestamps are included in the AIS-data as well, Figure 56.

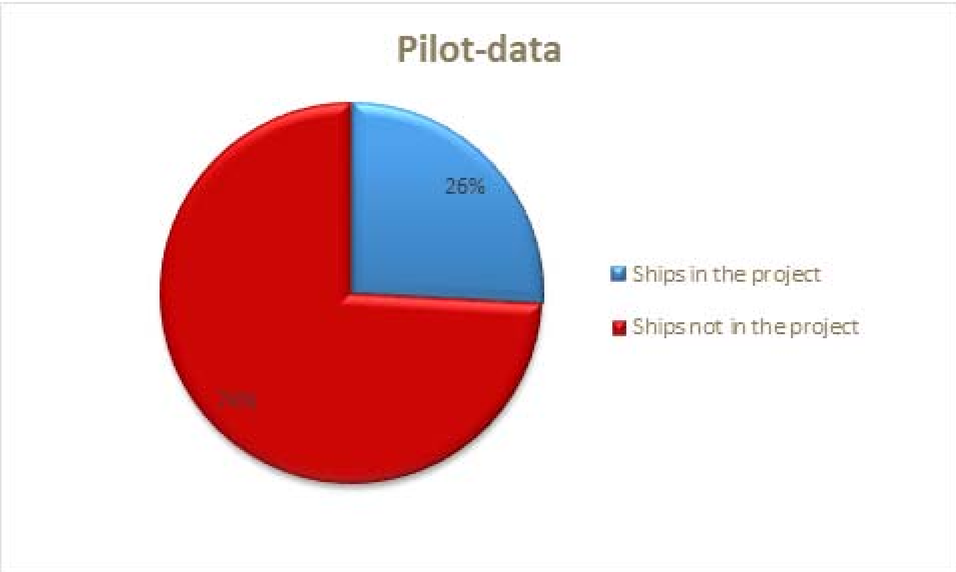


FIGURE 56 STATISTIC OF THE RECICED PILOT-DATA AND THE USED PILOT-DATA

In the following section, only the MMSIs used in the project will be taken into consideration.

As explained in chapter 7.4.3, an attribute called pilot with a default value of “0” was created in the feature classes. The pilot attribute defines whether a pilot is on board the ship or not when navigating through the Great Belt. The three numbers 0, 1 and 2 defines the three ways the pilot-data is represented:

- “0” represents that there is no data about pilots for the given timestamp, or that the AIS-data is outside the Great Belt.
- “1” represents ships navigating through the Great Belt without pilots.
- “2” represents ships navigating through the Great Belt with a pilot on board.

When looking at the feature classes it is obvious that the majority of the timestamps are represented with “0” and based on this, the default value was set to “0”. The next step is to compare the two datasets and type in “1” and “2” in the fields in which the timestamps from the pilot-data is consistent with the timestamps from the AIS-data. This is done manually by looking at each feature class, compare it with the pilot-data and assigning a value of “1” or “2”, respectively, depending on whether the ships were navigating with a pilot in the Great Belt. Via this method, we were visually able to discover the tracks that were not mentioned in the pilot-data but in the AIS-data whilst looking through the Great Belt. This process could be done manually because we are working with less than 500 feature classes – to save time and money it would be an advantage to use another method if the number of feature classes was higher.

Such a method could use the datetime-module to compare timestamps. In attribute tables in ArcGIS, there is a tool called “select by attribute”. This tool can select and give values based on a statement. Figure 57 is an example of such a statement. It would require the timestamps to be registered with the type “date”, which was not the case in this project due to lack of foresight.

```
Date '01-01-2013 10:00:00' < "Timestamp" AND "Timestamp" < date '01-01-
2013 20:00:00'
```

FIGURE 57 EXAMPLE OF STATEMENT USED TO SELECT ALL TIMESTAMPS BETWEEN 01-01-2013 10:00:00 AND 01-01-2013 20:00:00.

As visualised in Figure 58, the majority of the timestamps are good tracks, which means that the pilot-data is consistent with the AIS-data. However, 20 percent of the timestamps are bad tracks, meaning that the pilot-data is either inconsistent with the AIS-data or vice versa. When these 20 percent were analysed it became evident that only 6 percent of the 20 percent is because the AIS-data is inconsistent with the pilot-data. The remaining 14 percent is the pilot-data that is not consistent with the AIS-data.

During the AIS-data collection all data categorized as “not undefined” was extracted, so that only ships that knowingly carried dangerous goods would be a part of the analysis. It is possible that ships in some cases are categorised in either category A, B, C or D the first time going through the Great Belt, but are undefined in the next passage. This can explain why 14 percent of the pilot-data is inconsistent with the AIS-data. We do not have a logical explanation why the AIS-data is inconsistent with the pilot-data.

As mentioned, the received pilot-data covers the Great Belt and by focusing on the 80 percent of the timestamps in the pilot-data, in which no errors were found, it is possible to discover whether the ships use pilots when navigating through the Great Belt.

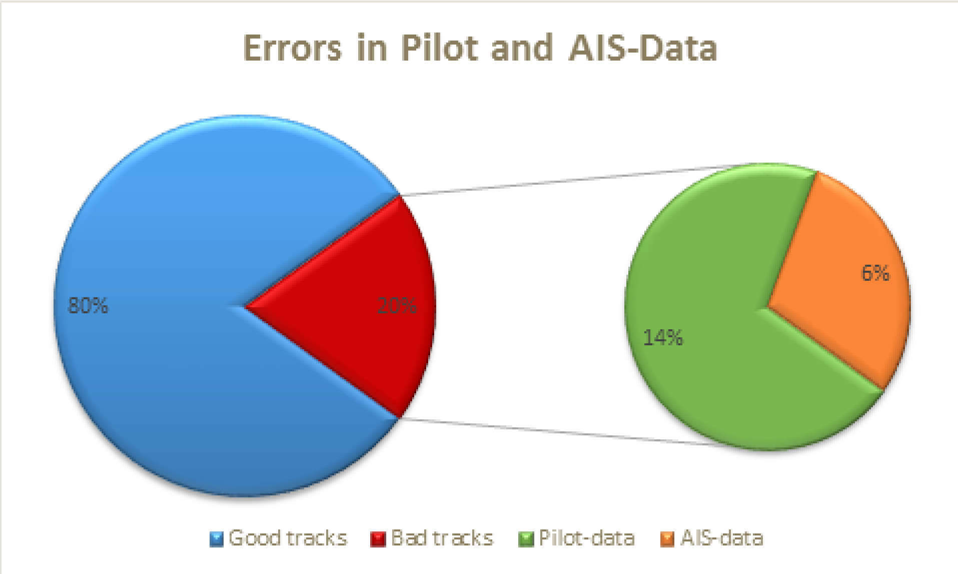


FIGURE 58 STATISTIC ON DATA WITH OR WITHOUT ERRORS

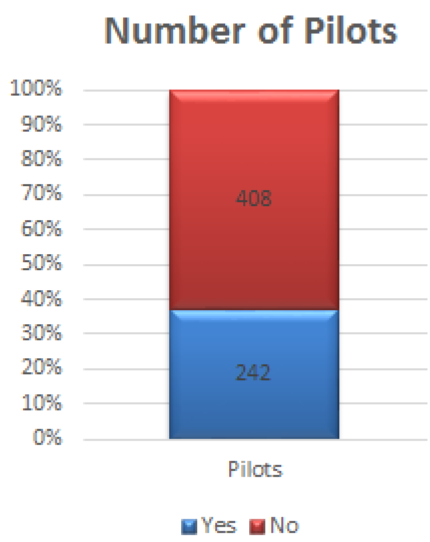


FIGURE 59 NUMBER OF PILOTS USED OR NOT USED WHEN NAVIGATING, COMPARED TO THE NUMBER OF TRACKS.

Out of the 650 timestamps left, pilots have only been used in 242 of the cases, meaning that for 65 percent of the timestamps pilots were not on board the ships, Figure 59.

A reason for this could be that some ships are navigating through this area regularly and are familiar with it, and therefore might have a pilot exemption certificate.

Having prepared the AIS-data and looked at statistics for the pilot-data, the analysis can now be performed.

8 Analyses

The data prepared in the previous chapter is used to analyse whether ships have been in danger of grounding, including the locations where the risk of grounding occurred, and if the ships used pilots at the location and time they were at risk.

8.1 Compare Raster Tracks to Digital Bathymetric Model

The first step of the analysis is another Python-script. The script has the purpose of calculating the UKC, which is the difference between the draught of the ship and the depth of the sea. The script runs through all the rasters in a geodatabase and creates a new raster with a value equal to the UKC. The script uses a lot of the previously explained functionality and only a few new steps, which will be explained in the following section.

To identify all raster in a geodatabase, a function similar to the previous list-tool is used. The difference is that this line only takes files of the raster type into account, Figure 60.

```
inRaster = arcpy.ListRasters()
```

FIGURE 60

Since the depth model has a negative value, and the draught has a positive value, the two rasters added together results in the static UKC. This is done using the tool “plus”. The functionality of the tool can be seen in Figure 61.

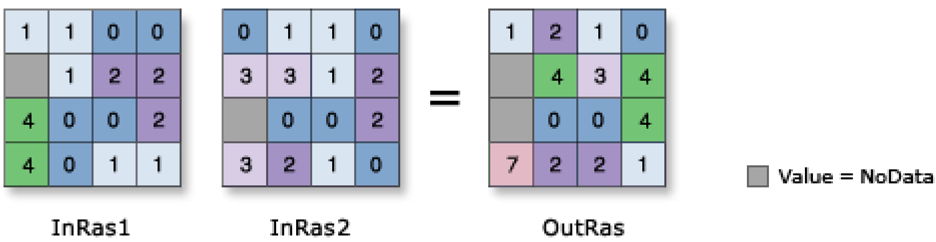


FIGURE 61 THE FUNCTIONALITY OF THE PLUS TOOL (ESRI 2012 (E))

By using this method, negative numbers will define the value of the static UKC, as mentioned in chapter 7.3, and only cells covered by both sets of data is presented in the result. The two rasters are added in the first line in Figure 62.

```
outPlus = Plus(dybde, raster)
outPlus.save(path + "/5 rasterOutput.gdb/UKC " + raster)
```

FIGURE 62

After adding the two files, the output is saved to another file, using the second line in Figure 62.

To verify the raster files, which should all have a negative value, the maximum value of the raster is printed in the terminal-window via the lines in Figure 63.

```
fn = path + "/5_rasterOutput.gdb/UKC_" + raster
Result = arcpy.GetRasterProperties_management(fn, "MAXIMUM")
Max_Value = Result.getOutput(0)
```

FIGURE 63

This script has produced two kinds of output; raster files containing tracks with the UKC-value and a file containing the maximum value of each raster file. Figure 64 is an example of maximum values as output.

```
UKC_S_XXXXXXXXX_Raster has a minimum UKC of: -2,41168403625488
UKC_S_XXXXXXXXX_Raster has a minimum UKC of: -9,51888847351074
UKC_S_XXXXXXXXX_Raster has a minimum UKC of: -4,61168384552002
UKC_S_XXXXXXXXX_Raster has a minimum UKC of: -1,25443458557129
```

FIGURE 64

8.2 Results

By examining the file containing the maximum values, we realized that some of the values were positive even though we only expected to find negative values. Since there are both positive and negative values, these will be investigated individually.

8.2.1 Positive Values

The file containing the maximum values pointed out 58 feature classes containing positive values. According to chapter 7.3, the static UKC should appear as a negative value – the farther from the seabed, which is defined by 0, the larger the negative value and the closer to the seabed the smaller the negative value. This means that when the static UKC is a positive value the ship has supposedly grounded - the larger the number, the further into the seabed the ship is, Figure 65.

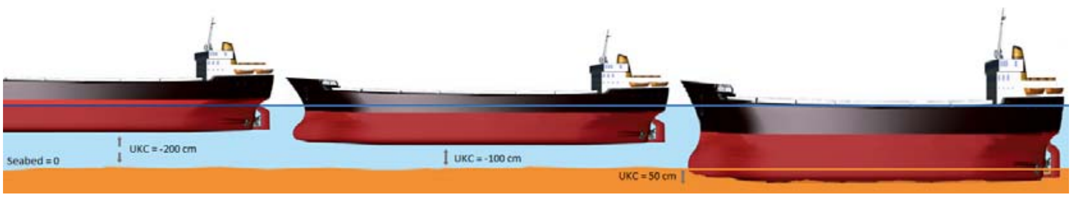


FIGURE 65 NEGATIVE AND POSSITIVE UKC VALUES

In the analysis, it appears as if 58 ships have grounded during October and November 2012. Chapter 3.4 states that the Great Belt VTS area did not have any groundings during 2012 and since the total number of groundings in the Baltic Sea in 2011 is 30, it seems unlikely that there have been 58 groundings during only two months, in the project area. Because of that, locations where the positive values appear are registered, Figure 66.

FIGURE 66 NUMBER OF FEATURE CLASSES WITH POSITIVE UKC-VALUES AT THE RESPECTIVE LOCATIONS.

Positive values appear 69 times for 58 different ships at 11 different locations and the majority of these locations are in ports. Two ports where the problem repeats itself are Kalundborg and Nordhavn, the number of ships that appears to have been grounded at these locations is 24 and 22, respectively, Figure 67.

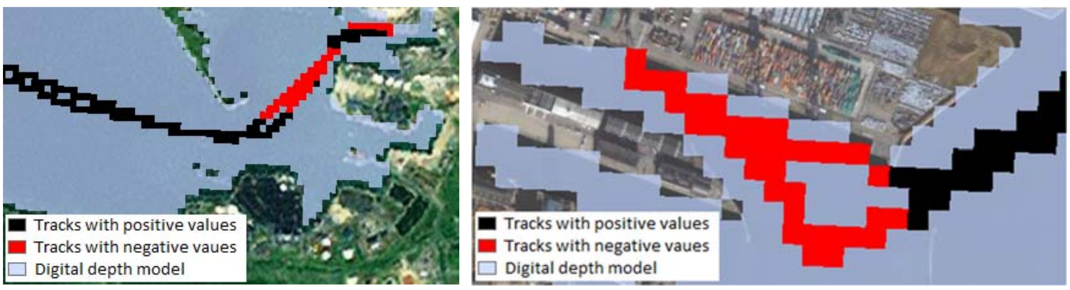


FIGURE 67 LEFT PICTURE: KALUNDBORG PORT. RIGHT PICTURE: NORDHAVN

As mentioned in chapter 7.2.1, the cells in the digital bathymetric model are interpolated using a nearest neighbour interpolation. Interpolation and cell size can have a significant effect on the analysis, especially in ports or other areas where ships have been navigating close to the coast. The impact of interpolation and cell size is discussed further in chapter 10. Because of this impact, the ships have not grounded as it appears from the analysis.

Kalundborg is the location at which the largest number of positive values appears, and because of the fact that we have pilot-data for this area, the danger of grounding in the area is investigated further.

In the area of Kalundborg, there are three ports; Asnæsværkets Port, Statoil Oil pier and Kalundborg Port. (Geodatastyrelsen 2013 (a)) This area contains various water depths, the deepest is in the 100 meters wide dredged channel which has a depth of 15 meters. The maximum allowed draught of the three piers are found when approaching the Statoil Oil pier, where a draught at 14.2 meters is allowed.
(Geodatastyrelsen 2013 (b))

The majority of the ships that have entered this area and resulted in positive values in the analysis have a draught between 6.0 and 7.6 meters. Overall the draught is ranging from 3.7 up to 13.5 meters, however only one ship with 13.5 meters and one with 12.2 meters occurs, the rest of the ships have a draught under 9.8 meters. The two ships with a draught of 13.5 and 12.2 are both complying with the regulated maximum draught.

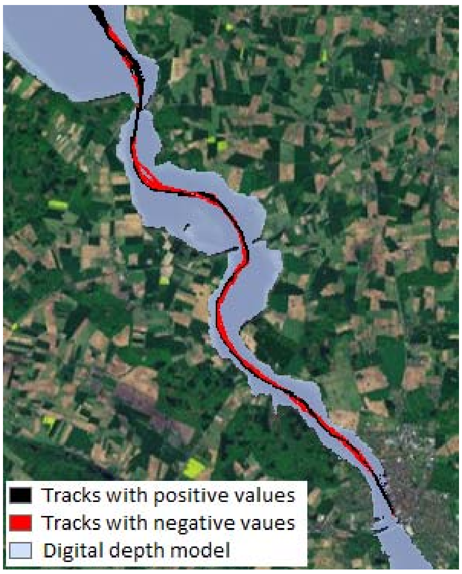


FIGURE 68 THE SHIP NAVIGATING BETWEEN LOLLAND AND FALSTER HAS A POSITIVE UKC.

Besides the ships navigating into and out of Kalundborg there is one case where a ship navigates in Guldborg Sound between Lolland and Falster into the port of Nykøbing Falster. This is a narrow strait, and a positive static UKC displayed for most of the route through the strait, Figure 68. The maximum allowed draught at Nykøbing Falster Port is 5.8 meters (Geodatastyrelsen 2012 (a)) and since the ship's draught is between 5.0 and 5.8 meters in the AIS-data, this is consistent with the maximum allowed draught.

All the ships have complied with the rule of maximum draught and because of that, it does not seem like any of the ships have been in danger of grounding.

Besides the draught of the ships, whether the ships have used pilots when navigating into and out of the ports is investigated. We do not have pilot-data for Guldborg Sound and therefore the focus will be on ships navigating to Kalundborg. In the left diagram of Figure 69 each route into and each route out of the port was studied, and it shows that a pilot has been on board in 77 percent of the cases.

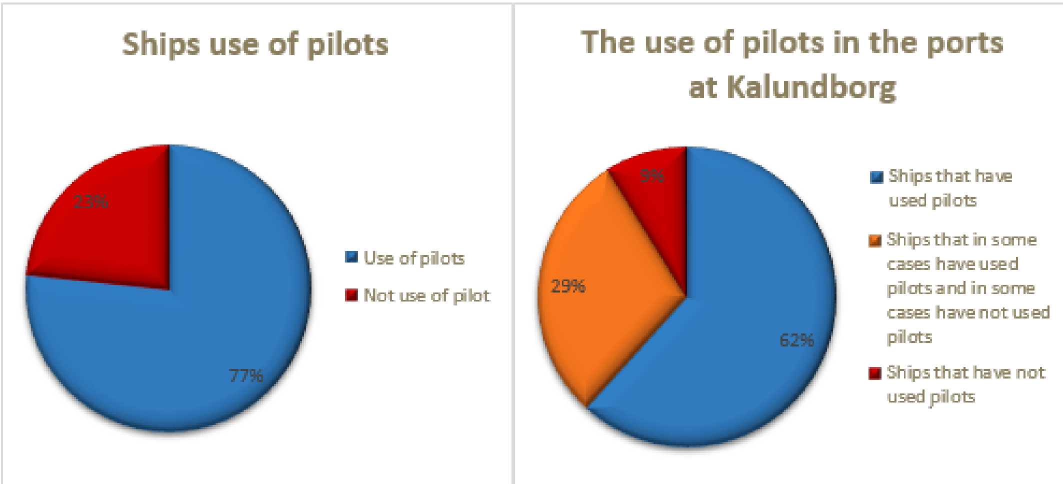


FIGURE 69 LEFT DIAGRAM: THE PERCENTAGE OF SHIPS USING PILOTS. RIGHT DIAGRAM: THE PERCENTAGE OF SHIPS USING PILOTS IN PORTS AT KALUNDBORG.

By looking at each ship instead of each route, 62 percent of all the ships have used pilot each time they have navigated to or from the port and 9 percent of the ships have not used a pilot at all, as seen in the right diagram of Figure 69. The 9 percent of the ships that have not used pilot might be due to the master of ship having a pilotage exemption certificate. Besides this, 29 percent of the ships did in some cases use pilots and in other cases not – we do not know why the ships shifts between using and not using pilots.

Having investigated the positive values from the analysis, the next step is to investigate the negative values. The files mentioned in this chapter will not be looked further into regarding the ports, though the files will be looked through to see if they have any values between 0 and -2 outside the ports – in that case, the files are included in the following section.

8.2.2 Negative Values

In chapter 3.1 it was mentioned that ships are recommended to have an UKC of at least 2 meters in the Great Belt, and 40 or 60 cm in the Sound depending on the route. Since the location of the negative values are not yet known, all data will be analysed according to the recommendation of 2 meters and then later be looked further into and assessed with focus on the location specific recommendations.

Out of the 456 raster tracks that were processed and compared to the digital bathymetric model, 96 of the tracks have static UKC values between -2 and 0. Some of the tracks have such static UKC values in more than one location and in Figure 70 the locations of the static UKC going from -2 to -1 and from -1 to -2 are illustrated.

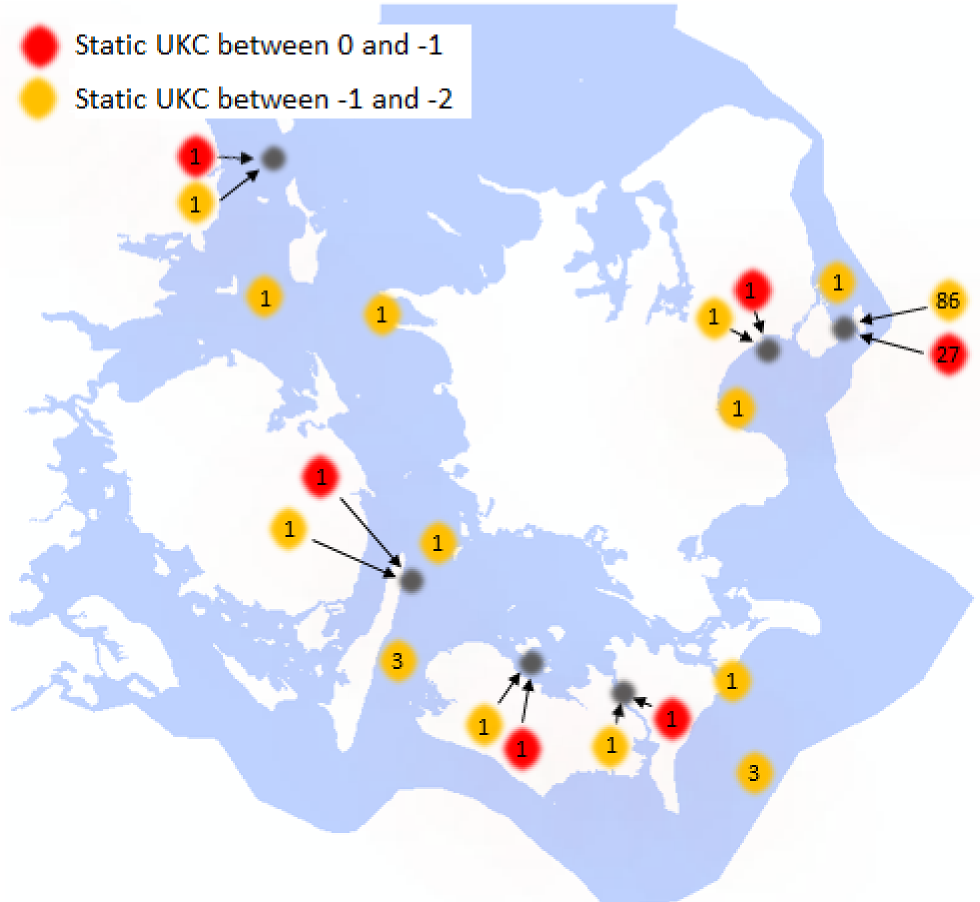
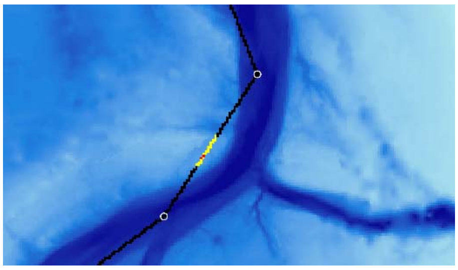


FIGURE 70 THE LOCATION OF WHERE SHIPS WHERE LOCATED WHEN THEY HAD A UKC LESS THAN 2 METERS.

The ships located in Figure 70 are defined by the static UKC of the ships, and since the UKC gives a more realistic picture than the static UKC, the UKC is calculated from the tide defined in the tide table, Appendix 1. This provides a more correct idea of the UKC and with the tide included, some of the ships can be excluded from being critical – if there is flow the UKC might be less than -2 meters. See Appendix 2 for illustrations of all the ship tracks including pilot information.

An error that occurs in most of the ship tracks is that the location of the cell with a value above -2 is not consistent with the timestamp given in the AIS-data. This means that the location is between two timestamps, for more details Chapter 10.3.

Looking at Ship01 there is 12 min between the timestamps in the AIS-data and the ship has travelled a distance of 3.72 km during this time. Left picture Figure 71 depicts route-T with a darker blue colour, showing that the two locations from the AIS-data is within the channel. It is most likely that the ship has been following the channel, but because of the time difference and the long distance, it is visualised as if the ship is cutting the corner. Another example is Ship05 with only a time difference of 3.3 min and a distance of 2.08 km. In both cases the ship is turning but the smooth turn is not illustrated.



2012-10-03 01:25:35.000 UTC
2012-10-03 01:49:56.000 UTC
2012-10-03 02:20:36.000 UTC
2012-10-03 02:32:46.000 UTC
2012-10-03 02:38:46.000 UTC
2012-10-03 03:03:15.000 UTC
2012-10-03 07:10:36.000 UTC
2012-10-03 07:17:16.000 UTC
2012-10-03 07:23:16.000 UTC

FIGURE 71 LEFT PICTURE: THE CRITICAL LOCATION IS BETWEEN TWO TIMESTAMPS GIVEN IN THE AIS-SIGNAL. RIGHT PICTURE: TIMESTAMP OF WHERE THE INTERVAL IS IRREGULARLY.

Ship01 and Ship03 have errors in the timestamp, meaning that there is around 30 and 50 minutes between the timestamps where the UKC is under the recommended, Figure 71. Because of this, the result is not reliable. The interval of the points should be shorter, for the data to be reliable, see chapter 10.3.

Ship04 and Ship08 are both on their way into or out of a port, in both cases the ships have been navigating along the dredged channel. The dredged channel to Kalundborg is 15 meters deep and the one to Avedøreværkets Port is 7 meters. (Geodatastyrelsen 2012 (b)) As mentioned in chapter 8.2.1, the permissible draught for ships navigating to Kalundborg is 14.2 meters and since Ship04 has a draught of 13.5 meters, this is not considered critical. Ships navigating to Avedøreværkets Port are allowed to have a draught of 6.5 meters (Geodatastyrelsen 2012 (b)) and since Ship08 have a draught of 6.2 meters, this is not seen as being critical either.

In an area where the water depth is set to be 20 meters or greater, Ship12 shows static UKC values from -2 and up to positive values. Ship12 normally has a draught between 6.6 and 7.7 meters and therefore an error must have occurred. The error is in the draught, which is noted to be 25.5 meters by the crew of the ship. This error indicates that the AIS-signal is not always reliable since typing errors can occur.

Ship09 has UKC of -0,955 meters at the same location as we have AIS-data, meaning that the location from the AIS-signal and the location of the UKC is consistent, left picture Figure 72. Since this ship is more than 1 meter under the recommended UKC, this is identified as critical.

FIGURE 72 CRITICAL UKC AT SAME LOCATION AS THE TIMESTAMPS OF THE AIS-SIGNAL.

In the Sound, 86 of the ships have a static UKC between -1 and -2 meters and 24 ships have a static UKC between 0 and -1 meters. Since the recommended UKC in the Sound is between 40 and 60 cm, only the 24 cases will be investigated.

While investigating the UKC of the 24 ships, only Ship22 has a UKC of less than 60 cm, Appendix 2. Ship22 has a UKC of -0,313 meter at a location consistent with the AIS-data, right picture Figure 72. Since the UKC is less than recommended and the location is consistent with the AIS-signals location, we see this ship as having been in a critical situation, because naturally occurring phenomena affecting the sea level such as waves or tide could have cause the ship to hit the seabed or even ground.

With a baseline of 96 ships with tracks visualised to have a critical UKC, only Ship09 near Køge and Ship22 in the Sound ended up having a UKC as being critical, Figure 73.

FIGURE 73 SHIPS WITH CRITICAL UKC

Only Ship01 had information about pilots in one of its tracks, in which it did not have a pilot on board, Appendix 2. Therefore it has not been possible to assess whether a pilot have been on board the two ships with a critical UKC.

8.2.3 Critical Areas Outside the Pilot Requested Area

In addition to finding critical points based on the UKC of each individual ships, a general analysis was performed. This analysis used the average draught of 10 random samples to identify areas outside the inner and outer territorial waters that could potentially pose a threat to ship traffic. This was done to investigate if pilotage should be compulsory in other areas than the Danish inner and outer territorial waters.

The average draught from the 10 samples was 7.73 meters, which was rounded up to 8 meters. The bathymetric model was then re-classified to show two classes: <8 m and >8 m, respectively. Unfortunately, this did not yield any potentially critical areas, left picture Figure 74.

The values were raised 1 meter at a time, in order to see what values would give critical areas outside the territorial waters. At <15 m and >15 m the potentially critical areas is appearing outside the boundary of the territorial waters, meaning that the ship have to have a draught around 15 meters for it to be critical, right picture Figure 74. After realising this, the analysis was ended.

The analysis was performed on the extent of the digital bathymetric model, thus there could potentially be critical areas outside of the model.

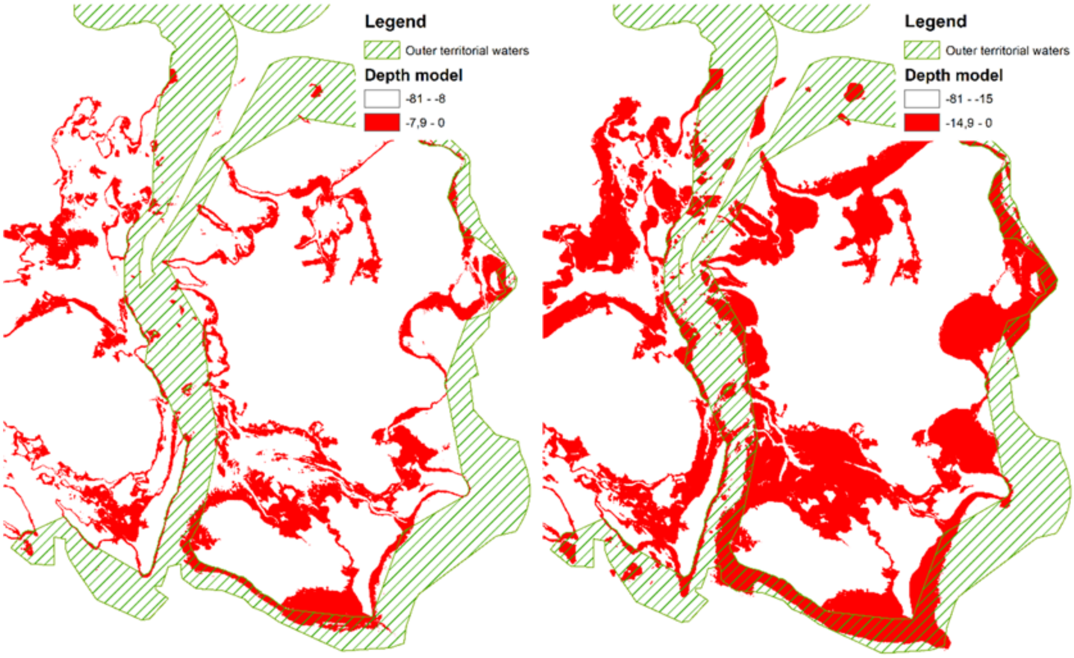


Figure 74 Left picture: critical areas with a water depth <8.
Right Picture: critical areas with a water depth <15.

9 Completion of Phase 2

Phase 2 is the analysing and comparable phase in which the software is determined, the data collected, discussed and prepared, and the analyses performed.

The programming language Python performs the scripting in the data preparation and the analysis. ArcMap is used to perform visualisations, further investigation of the data and the result of the analysis.

The use of pilotage is investigated by comparing the AIS-data and the pilot-data. Statistics for this shows that pilots were used in less than 40 percent of the track in the Great Belt. However, we are not able to say if the master of ship has a pilotage exemption certificate.

AIS-data and a digital bathymetric model of Kattegat South was used for the analysis investigating if ships have been at a critical location. Besides the coordinates, the draught is the main attribute in the AIS-data used to calculate the static UKC. By adding the draught represented as a raster and the digital bathymetric model, the negative static UKC is calculated.

The result of the calculation was tracks with both positive and negative static UKC’s. By further investigation, the positive values tended to be in ports because of the interpolation used on the digital bathymetric model. The negative value resulted in two tracks with a critical UKC; one in the Sound with a UKC of 0.313 meter where it is recommended to have 60 cm, and one near Køge with a UKC of 0.955 meter where the recommended UKC is 2 meters.

An analysis to investigate whether pilotage should be compulsory in areas outside the regulated area was performed via the use of the digital bathymetric model and the AIS-data. In the AIS-data the average draught of 10 random ships was calculated, giving the result of 8 meters. The cell value of the digital bathymetric model was then divided into two classes, showing <8 m and >8 m. The analysis gave the result that no further areas should require the use pilots.

Phase 3

10 Discussion

Throughout the project we have run into several obstacles; the cell size on the digital bathymetric model, the interval of information in the AIS-data, the interpolation of the digital bathymetric model, lack of pilot-data, the ship problematic in the Sound and the working method. In the following section, these subjects will be discussed.

10.1 Interpolation in Digital Bathymetric Model

As mentioned in chapter 7.2.1, the digital bathymetric model is interpolated by the method of natural neighbour interpolation. This method is suitable for giving an estimate in areas where there is a lack of measured points so that the whole area is covered by the model, and not only at the specific points measured. However, this interpolation is not ideal for all cases, and results in some incorrect outcomes in areas close to the coast and at ports. In chapter 8.2.1, many results with a static UKC as a positive value were investigated, where it proved to be mainly ports and in some cases areas close to the coast. To understand what happens in the interpolation an example was performed, Figure 75.

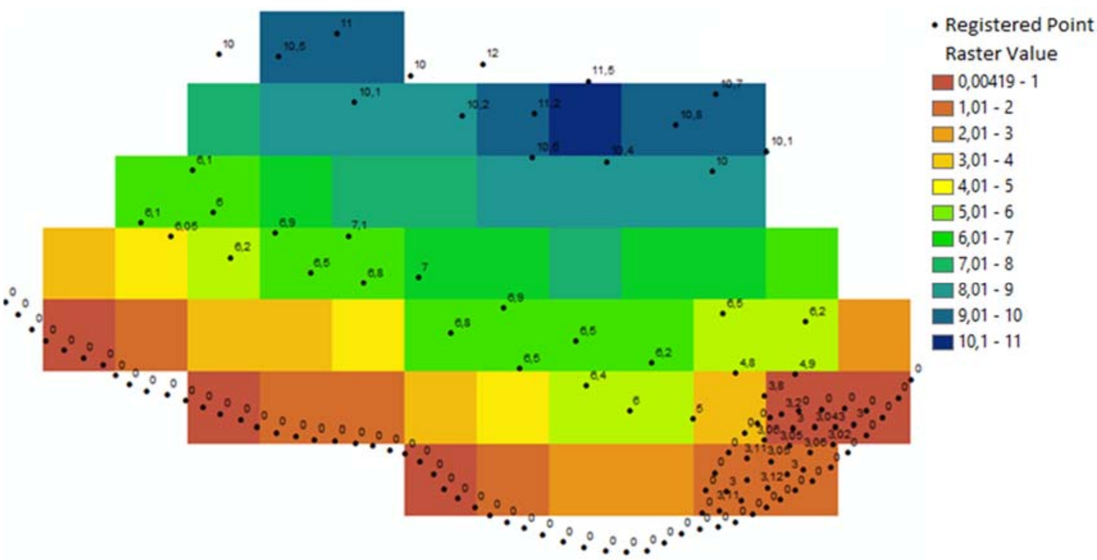


Figure 75 Example of natural neighbour interpolation as a result of the point cloud.

In the example, points with a value of zero for each 20 meters represent the coastline, as is the case with the digital bathymetric model. 100 meters and 200 meters out are two belts of observations, mimicking data from a single beam echo sonar, it is presumed that the ships can measure closer than the draught permit. In the lower right corner of the figure a port is illustrated, in which the pier is given the value zero, and inside the port, several depth observations are present.

The point observations are the input of the natural neighbour interpolation, creating a raster as it is explained in chapter 7.2.1. The result of this interpolation in the example is a raster with values between 0.0042 and 11 meters.

A point of critique when interpolating points with this method is that the method assumes a gradual change in the depth, although the steepness can vary significantly. The problem is larger the more interpolation that has to be done, e.g. when the amount of observations are low. This further underlines uncertainty regarding the depth close to the coastline, where survey ships can have trouble faring.

Ports are areas in the model that have a very different output than desired, Figure 76. The depth observations inside the port has values of 3 and higher, but because of the vast amount of points along the coastline and the pier, with the value 0, the real observations gets overruled and the value for the cells are much less than the observed depths. The result of this is that the cells covering the port has values ranging from 0.004 to 1.93 metres, thus giving a difference of up to 3 meters compared to the observed depths.

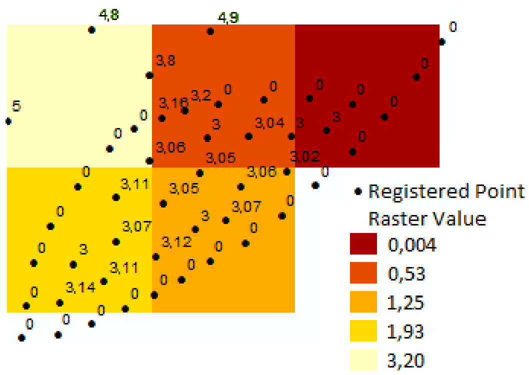


FIGURE 76 INTERPOLATION IN AND AROUND THE PORT

Looking at this example it is not surprising that the analysis gave a result of 58 feature classes with positive values in the ports or near the coastline. The national neighbour interpolation used to create the digital bathymetric model, ending up costing us a lot of time on an issue that did not yield any usable results.

10.2 Cell Size of Digital Bathymetric Model

Within 50*50 meters, the depth of the water can vary significantly. In a country with narrow straits and many dredged channels, this can have an impact on the analysis. A dredged channel is surrounded by shallower water. If it is assumed that a dredged channel is 200 meters wide and the cell size is 50 meters, half of the cells might overlap the dredged area and the other half the shallower water. The result of this is an averaged value of the cell given from the measured points in the dredged channel and in the shallower water, see also the following example with the pier.

When a cell has large dimensions, it can be hard to outline whether the cell should be defined as water or land when close to the coastline. This can be problematic for the analysis when ships are navigating close to the coastline. In the case mentioned in chapter 7.4.4, parts of the raster track are not created because a cell covering both water and land mass is defined as land, meaning that the cell is defined as "No data" in the digital bathymetric model.

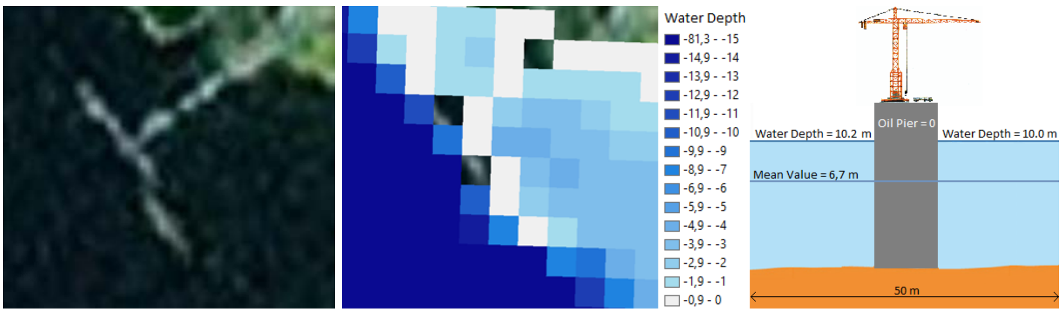


Figure 77 Left picture: oil pier near Stigsnæs. Middle picture: Digital bathymetric model at the location of the oil pier. Right picture: Different values results in a middle value that in some cases is wrong from reality.

Left picture Figure 77 displays an oil pier located near Stigsnæs and the middle picture Figure 77 illustrates the values of the digital bathymetric model for the given location. Two of the cells are defined as "No data" even though there is also water in the cell. The neighbouring cells are very shallow, which might have appeared from the averaging in the interpolation. In the right picture of Figure 77, an area of 50 meters seen from the side is illustrated. There is a pier given the value of 0 and a water depth on each side of the pier at 10.0 and 10.2, respectively. These values results in a mean value of 6.7 meters for the given area, so that if a ship with a draught of 8.1 meters is navigating to the pier, it would seem like the ship has grounded in the analysis.

A cell size of 50*50 meters is too large for this analysis. However, the cell size can also appear too small. Figure 77 illustrates a ship and a raster where the track of the ship is visualised by the red line. Assuming that the ship has a width of 25 meters, and the cell size is 5*5 meters, the track of the ship will only be represented by 5 meters (yellow cells) and not 25 meters (grey cells), which would have been more accurate. In this case, the cells size should therefore be around 25 meters or slightly less, though ships are not always navigating in the centre of a cell, and might navigate in the side of a cell such as a ship actually navigating in two cells, which cannot be visualised in the data.

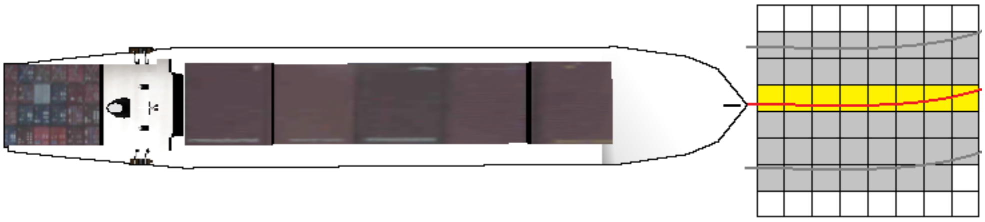


FIGURE 78 ILLUSTRATION OF A WIDE CARGO SHIP IN LOW RESOLUTION RASTER.

The different types of cargo ships have a width between 16 and 46 meters (Danmarks Skibskredit n.d. (b)), though ships such as the Emma Mærsk have a width of 56 meters.

10 random ships from our AIS-data have been used to calculate an average width of the ships, to provide an idea of what the cell size should have been to obtain a more accurate result. The width of the ships varied between 12 and 44 and gave an average at 21.4 meters. The cell size should therefore have been between 20 and 25 meters.

10.3 Interval of Information in the AIS-data

As mentioned in chapter 7.2.2, the time between the AIS-signals generally varies between 3 to 6 minute intervals. This leads to problems when ships are following channels that have bends. Figure 79 shows two slightly different routes, one made by connecting the logged positions, and one that illustrates a more plausible route with more points in between the logged points.

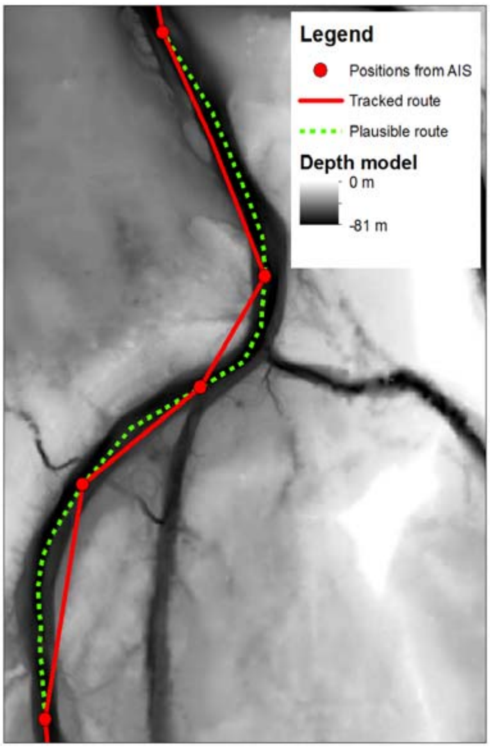


FIGURE 79 THE CALCULATIONS USED TO DEFINE THE MAXIMUM INTERVAL BETWEEN AIS-SIGNALS

High speed of the ship becomes an issue, since that will make the distance between logged points longer. Since the bathymetric model has a 50 meters resolution, the optimal maximum distance between points from the AIS-tracks would be 50 meters. To get an average speed of the ships involved in this project, 10 random samples were taken and the speed of the ships were averaged, giving a speed of 22,7 km/h. This average speed gives a maximum interval of the AIS-signals of 8 seconds;

$$\frac{22{,}7km/h}{3{,}6} = 6{,}3m/s$$

$$\frac{50m}{6{,}3m/s} = 7{,}93s \sim 8s$$

The higher frequency of AIS-signals would result in the processing of more data, however the accuracy of the tracks would be much higher and with less random errors. The extra time spend processing the data would be recovered by not having to correct as many errors.

Figure 80 shows an example of the difference in accurateness of the tracks, based on two different frequencies of logged points.

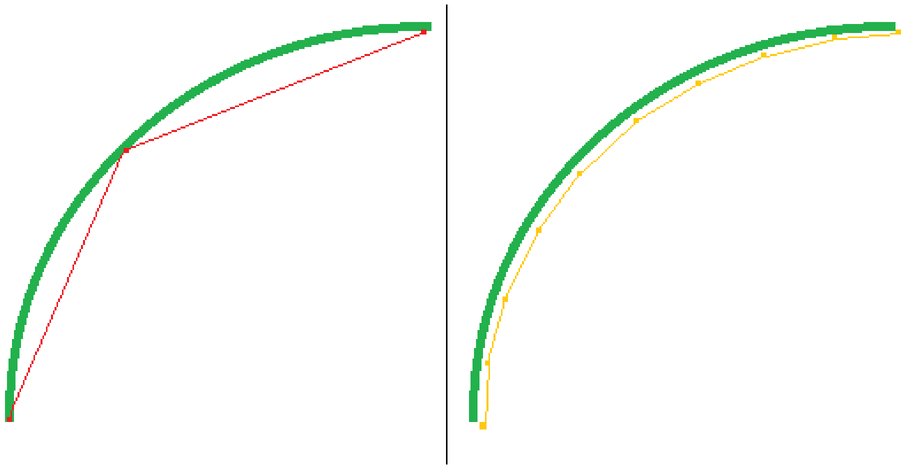


FIGURE 80 SHOWS THE PRINCIPAL OF TWO DIFFERENT INTERVALS OF LOGGED POINTS, RED AND ORANGE, COMPARED TO THE ACTUAL ROUTE OF THE SHIP, GREEN. THE HIGHER THE FREQUENCY, THE HIGHER THE ACCURATENESS OF THE REPRESENTATION.

Due to the low frequency of logged points, another method for identifying critical points on the tracks could have been used. As documented in chapter 7.4.3, we received AIS-data in the form of log-files containing points, which were converted to polyline feature classes. The polylines were then converted to rasters in order to calculate the UKC. Instead, we could have made point feature classes, and by spatially joining the value from the bathymetric model to the point feature classes, the UKC in the logged points could have been calculated. This would have resulted in a more correct analysis, since we have no way of knowing the exact route of the ships between the logged points. However, this would not identify possible critical points between logged points, but only at the position of the points. Considering the method used for interpolating the bathymetric model, as well as the number of errors seen near ports, this method would probably have saved a lot of time and work, and provided and equally usable result.

10.4 Lack of Pilot-data

When we acquired pilot-data, we hoped that we could use that data to investigate whether or not ships used pilots when required by law, e.g. when navigating inner or outer territorial waters. However, since we were only able to acquire pilot-data for the Great Belt, this was not possible.

Through the project, we have acquired knowledge about the fact that the master of ship is able to achieve a pilotage exemption certificate. Since we are not aware of which master of ship was on board the ship and if the master of ship has achieved the pilotage exemption certificate, we have not manage to figure out if pilotage service is used when required by law.

Thus, as mentioned in chapter 6, the pilot-data has only been used for statistical matters and when looking into tracks with critical values.

11 Conclusion

The project was developed in three phases. Phase 1 was the descriptive phase in which the basis of the project is presented by preliminary elements.

Various elements and regulations plays a role when talking about shipping, among these is the use of pilots. A pilot has expert knowledge about a specific area that is difficult to navigate, and is therefore capable of guiding the master of ship when navigating through said area.

The Danish waters are challenging to navigate in general, since they are narrow and shallow in many locations. Therefore, Danish law requires ships carrying dangerous goods to use pilots when navigating Danish inner or outer territorial waters. Before boarding the ship, the pilot evaluates the multiple elements that may have an impact on navigating at the specific time, including the tide, as well as facts regarding the ship. This ensures that he is prepared to help upon arriving at the ship, so that the delay is minimized as much as possible.

It is of great importance to have a pilot on board to guide the master of ship, in order to avoid grounding in the challenging waters and thus avoiding damage to the maritime environment as well as the economic cost connected to groundings.

The importance of pilots has caused us to investigate the use of them further throughout phase 2, i.e. by studying how data can be incorporated to identify whether they have been used when requested by law. In this project, we collected data from the Great Belt VTS area, which was joined into the attribute table of the AIS tracks by manually entering the data. A smarter and less time-consuming way to incorporate the pilot-data would have been to make use of the datetime-module to compare timestamps. To help identifying ships using pilots, information regarding the use of pilots could be implemented in the AIS-signals. The information could be cross-referenced, through random sampling, with data provided by the local pilotage authorities, in order to verify and make sure that the shippers are not providing false information.

The Danish waters are covered by 15 pilot marks from where pilots boards the ships. Had we collected data for all waters, it would have been possible to analyse if pilots had been used, but since we only have data from the Great Belt VTS area, it was not possible to determine this for the entire region. Statistics from comparing the pilot-data with the AIS-data shows that ships have only used pilots in 35 percent of the cases. This means, that either the ships are not complying with the law, or the ships' masters have pilotage exemption certificates - since we do not know whether they have such ones or not, we are not capable of knowing if the ships are complying with the law or not. However, the 408 passages without pilots on board, compared to the 269 pilot exemption certificates in the Great Belt, would suggest that most ships are following IMO's recommendations on the use of pilots.

To investigate if a ship has been in risk of grounding, the static UKC was calculated by adding the draught of the ship, from the attribute of the feature classes, to the bathymetric model. In cases where this showed a static UKC of less than 2 meters, the tide was incorporated for a more precise picture of the UKC.

In addition, the bathymetric model was used to investigate potentially critical areas where pilotage is currently not demanded. This was done by calculating a mean value and compare this to the depth of the water. The mean value of 10 randomly chosen ships' draught was calculated to 8 meters, and it was investigated if any areas outside the inner and outer territorial waters had a depth of 8 meters or lower. Again, the analysis is based on the bathymetric model obtained, thus only covering Kattegat South. Within the investigated area, the ships should have had a draught of at least 15 meters for it to be critical, meaning that there is no areas outside the requested areas where the use of pilots should be compulsory.

From the analysis performed in phase 2, one ship navigating the Sound and one ship navigating near Køge were considered critical at certain times. Both ships had an UKC less than the recommended value for their geographic location, though none of the ships had been only a few centimetres from the seabed, as was stated by the media.

In order to improve the general quality of the analyses, a higher resolution on the bathymetric model is needed. However, the resolution must represent the actual depth of the water, and not rely as much on interpolation near the shore as the obtained model does, since that tends to distort the values too much.

Another point of improvement regards the way tracks were presented; the feature classes used in this project were lines, which was not an optimal solution. This is due to too long interval between the timestamps in the collected data, which causes the tracks to cut corners when ships have been turning. It would have been more preferable to use points to represent the location of each timestamp, in order to get a representation of where the ships have actually been. This would greatly minimize the amount of comparable data, but would produce less false-negatives.

The methods used throughout this project is based on historic data, which makes it easy to analyse and find potentially critical situations that have occurred. However, the method is not very suitable for preventing groundings – the most reasonable way to do this, is by real-time tracking and reacting before potentially critical situations arise, which is what is done by MAS. The method used in this project is more suitable for identifying ships that do not comply with IMO's recommendations regarding the use of pilots – had the AIS-signals held information regarding the use of pilots, our method could have been greatly improved.

12 Perspectives

The huge impact and value of ship transport makes it an interesting area to monitor. Safety at sea and AIS-signals are areas that are constantly evolving at the moment, only this February, Aalborg University (in cooperation with GST) had a satellite put into orbit in order to monitor the Arctic Ocean and the waters around Greenland. The whole AIS-system around the North Pole is different compared to the systems in use other places, since it is based on satellites as means of communication. Instead of transmitting AIS-signals to land-based receivers, the signals are sent in bundles to satellites. This is done because of the extreme conditions in the area, meaning that maintenance of land-based stations would be difficult and costly.

The satellite-based system opens up to new opportunities of monitoring ship traffic in distant parts of the world. With the AIS-data being available through the VHF-radio, interested people are easily able to obtain the data. This combined with the general tendency of crowdsourcing being applied more and more often, means that surveillance of ship traffic in the future could reach heights that has so far seemed unreachable. The result of this could be a future with fewer marine catastrophes. One of the great obstacles, however, is the vast amount of organisations and stakeholders involved, as well as the enormous amounts of data that needs to be processed. This further underlines the need for standardisation, both in regards to laws and regulation, but also in regards to maintaining and updating data involving ships.

Crowdsourcing has already helped creating OpenSeaMap, an open source web service, with the possibility of offline use, intended for sailors. OpenSeaMap is for use alongside official navigational charts, and can never fully replace professional navigational charts. However, it offers a wide range of extra features that are not available from other ENCs, e.g. 8-day weather forecasts from over 5000 harbours, satellite background-images etc.

We believe that a lot can be done to prevent future disasters and accidents at sea, but much depends on the legislators serving the public, as well as the lobbyists representing economic interests of the shipping companies. Standardisation and cooperation are two of the keywords for future progress in the field, both in regards to national as well as international organisations and agencies.

12 Bibliography

Admiral Danish Fleet. *About us: Admiral Danish Fleet HQs.* n.d. (a). http://forsvaret.dk/SOK/ENG/ABOUT/Pages/default.aspx.

—. *Vessel Traffic Service (VTS) and Traffic Separation Schemes (TSS).* n.d. (b). http://forsvaret.dk/SOK/eng/National/VTS_TSS/Pages/default.aspx.

Australian Maritime Safety Authority. "Automatic Identification System (AIS) Class B." Canberra: Australian Government, October 2008.

Balstrøm, Thomas, Ole Jacobi, and Lars Bodum. *Bogen om GIS og Geodata.* København NV: Forlaget GIS og Geodata, 2006.

Bang, Jakob, and Charlotte Bjerregaard. "AIS i Farvandsvæsenet - en hjælp til den maritime trafik." *Perspectiv nr. 14*, 2008: 52-56.

Business Dictionary. "Dangerous goods declaration." *Business Dictionary.* 2013. http://www.businessdictionary.com/definition/dangerous-goods-declaration.html (accessed Marts 2013).

Castonguay, James. "International Shipping: Globalization In Crisis." *Witness - an online magazine*, n.d.

CBC news. "Cost of removing Costa Concordia may hit $530M." The Associated Press, 12 January 2013.

Danish Geodata Agency. "Download dybdedata." *Geodatastyrelsen.* n.d. (a). http://www.gst.dk/Emner/Soekortognavigation/soeopmaaling/downloaddybdedata/ (accessed Marts 2013).

—. "Søopmåling." *Geodatastyrelsen.* n.d. (b). http://www.gst.dk/Emner/Soekortognavigation/soeopmaaling/ (accessed Marts 2013).

—. "Søopmålings teknik." *Geodatastyrelsen.* n.d. (c). http://www.gst.dk/Emner/Soekortognavigation/soeopmaaling/soeopmaalingsteknik.htm (accessed Marts 2013).

Danish Maritime Authority. *AIS of classes A and B .* n.d. http://www.dma.dk/AIS/WORTHKNOWINGABOUTAIS/Sider/AISclassAandB.aspx.

Danmarks Skibskredit. *Danmarks Skibskredit.* n.d. (b). http://www.skibskredit.dk/da/SHIPPING-RESEARCH.

—. “Segmenter.” *Danmarks Skibskredit.* n.d. (a). http://www.skibskredit.dk/SHIPPING-RESEARCH/Tankskibe/Raaolietankskibe/Segmenter (accessed May 2013).

DanPilot. n.d. http://www.danpilot.dk/ (accessed 2013).

DanPilot. “Facts about DanPilot.” *DanPilot Lodseriet Danmark.* 2011. http://www.danpilot.dk/index.php?id=facts-about-danpilot (accessed February 2013).

Dictionary.com. “Agile.” *Dictionary.com.* 2013. http://dictionary.reference.com/browse/agile (accessed Marts 2013).

Division for Investigation of Maritime Accidents. *Casulty Report: Collision on 29 March 2001 between the Tanker BALTIC CARRIER, registrated on Marshall Island and The Bulk Carrier TERN, registrated on Cyprus.* Copenhagen Ø: Danish Maritime Authority, 2001.

DMI. “Stormfloder og Stormflodsvarsling.” DMI, n.d.

—. “Tidevandstabeller for danske farvande 2012.” 2012.

Dueholm, Keld, Mikkel Laurentzius, and Anna B.O. Jensen. *GPS.* København V: Nyt Teknisk Forlag, 2005.

Engberg, Per. *Land Based AIS DB-LSS - Detailed Design Description.* Nr. Sundby: Gatahouse.dk, 2009.

Erhvervs- og Vækstministeriet. “Bekendtgørelse om anvendelse af lods (BEK nr 449 af 10/05/2012).” 10 May 2012 (a).

—. “Bekendtgørelse om Meddelelser fra Søfartsstyrelsen B, teknisk forskrift om skibes bygning og udstyr m.v. (BEK nr 386 af 27/04/2012).” 27 April 2012 (b).

—. “Bekendtgørelse om udstedelse af lodscertifikat og lodsfritagelsesbevis (BEK nr 1077 af 21/11/2012).” 21 November 2012 (c).

Esri. *ArcGIS Desktop 10.* 13 September 2011 (b). http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Examples_of_inline_model_variable_substitution/002w0000005w000000/.

—. *ArcGIS Desktop 10.* 29 June 2011 (a). http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/How_Natural_Neighbor_works/009z00000077000000/ (accessed 2013).

—. *ArcGIS Help 10.1.* 2. October 2012 (b). http://resources.arcgis.com/en/help/main/10.1/index.html#//000v00000001000000 (senest hentet eller vist den 2013).

—. *ArcGIS Help 10.1.* 29 October 2012 (a). http://resources.arcgis.com/en/help/main/10.1/index.html#//002w00000001000000.

—. *ArcGIS Help 10.1.* 24 October 2012 (c). http://resources.arcgis.com/en/help/main/10.1/index.html#//001200000031000000 (accessed 2013).

—. *ArcGIS Help 10.1.* 29 October 2012 (d). http://resources.arcgis.com/en/help/main/10.1/index.html#/How_the_Snap_Raster_environment_setting_works/001w00000011000000/ (accessed 2013).

—. *ArcGIS Help 10.1.* 11 August 2012 (e). http://resources.arcgis.com/en/help/main/10.1/index.html#//009z00000096000000 (accessed 2013).

ESRI. *Introduction to ArcGIS.* n.d. http://resources.arcgis.com/en/help/getting-started/articles/026n00000014000000.htm (accessed May 29, 2013).

Farvandsvæsenet. "Dybdemodel for Kattegat Syd (Metadata)." Center for Sejladsinformation, April 2008.

—. "Lær af Lodsen." *Farvandsvæsenet.* n.d. http://frv.dk/Viden_om/Temaer/Pages/Lodstjeneste.aspx (accessed February 2013).

Forsvarsministeriet. "Bekendtgørelse om bestilling af lods (BEK nr 1142 af 18/11/2006)." 18 November 2011.

—. "Lodslov." *Retsinformation.* 10 Juni 2006. https://www.retsinformation.dk/forms/R0710.aspx?id=6472#K3 (accessed Februar 1, 2013).

Geodatastyrelsen. *Den danske havnelods.* 8 April 2013 (a). http://www.danskehavnelods.dk/#HID=619.

—. *Den danske havnelods.* 30 January 2013 (b). http://www.danskehavnelods.dk/#HID=667.

—. *Den danske havnelods.* 13. June 2012 (a). http://www.danskelods.dk/#HID=237.

—. *Den danske havnelods.* 29. August 2012 (b). http://www.danskehavnelods.dk/#HID=683.

GOV.UK. "Transport Document Completion." *GOV.UK.* 16 October 2013. https://www.gov.uk/transport-document-completion (accessed Marts 2013).

Gyldendal. "Skibsmåling." *Den Store Danske: Gyldendals åbne encyklopædi.* (e). http://www.denstoredanske.dk/Bil%2c_b%C3%A5d%2c_fly_m.m./S%C3%B8fart/Skibe_generelt/skibsm%C3%A5ling (accessed February 2013).

—. *Søfart.* n.d. (a). (http://www.denstoredanske.dk/Bil%2c_b%C3%A5d%2c_fly_m.m./S%C3%B8fart/F%C3%A6rgefart_og_s%C3%B8fart_generelt/s%C3%B8fart).

—. "Tidevand." *Den Store Danske: Gyldendals åbne encyklopædi.* n.d. (c). http://www.denstoredanske.dk/Geografi_og_historie/Geografix/Geografi/Naturgeografi/Oceanografi/tidevand (accessed May 2013).

—. *Transport - søtransport.* n.d. (b). http://www.denstoredanske.dk/Samfund%2c_jura_og_politik/%C3%98konomi/Transport-_og_trafik%C3%B8konomi/transport/transport_(S%C3%B8transport).

Hansi, Storebælt VTS, interview by Maria Skov Engqvist. *Metode for indsamling af lods-data* (23 April 2013).

Harati-Mokhtari, Abbas. "Automatic Identification System (AIS): A Human Factors Approach." n.d.

Helsinki Commission. *Report on shipping accidents in the Baltic Sea area during 2011.* Helsinki Commission, 2012.

Hong, Lin, and Jørgen Amdahl. "Rapid assessment of ship grounding over large contact surfaces." *Ships and Offshore Structures Volume 1*, 25 August 2010: 5-19.

Hornby, A S. *Oxford Advanced Learner's Dictionary of Current English 7th edition.* New York: Oxford University Press, 2005.

IMO. *Carriage of chemicals by ship.* n.d. (a). http://www.imo.org/ourwork/environment/pollutionprevention/chemicalpollution/Pages/Default.aspx.

—. *Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs).* n.d. (b). http://www.imo.org/about/conventions/listofconventions/pages/colreg.aspx.

IMO. *RESOLUTION MSC.230(82).* IMO, 2006.

—. "SN.1/Circ. 263." 23 October 2007.

International Maritime Organization. "About IMO." *International Maritime Organization (IMO).* n.d. http://www.imo.org/About/Pages/Default.aspx (accessed February 2013).

Kort og Matrikelstyrelsen. "Bag om søkortet - Opmåling, pålidelighed, anvendelse 2. udgave." 28 september 2012.

Kort og Matrikelstyrelsen, Danmarks Statistik. "Det danske kvadratnet v.2." København: Kort og Matrikelstyrelsen, Danmarks Statistik, June 2012.

Kristensen, Palle. "Transport af farligt gods." *Søfartsstyrelsen.* 14 September 2011. http://www.soefartsstyrelsen.dk/Skibe/farligtgods/Sider/Transportaffarligtgods.aspx (accessed Marts 2013).

Larson, Erik W., and Clifford F. Gray. *Project management: the managerial process.* New York: The McGraw-Hill Companies, 2011.

Leth, Jørgen O. "Havbundstyper i de indre danske farvande." *De Nationale Geologiske Undersøgelser for Danmark og Grønland.* 7 July 2012.

Lodstilsynet. *Holders of Pilot Exemption Certificates (PEC).* 27. May 2013. http://www.lodstilsyn.dk/files/oversigt%20lodsfritagelsesbeviser%2027-05-2013.pdf (senest hentet eller vist den 10. June 2013).

Lund, Michael, and John Hansen. "Danmark er sårbar - stor risiko for alvorlige olieulykker." *Politikken*, 20 September 2012 (b).

—. "Verdens største rederier nægter at sejle med lods." *Politikken*, 2 October 2012 (a).

Lutz, Mark. *Programming Python, 3rd Edition.* Sebastopol: O'Reilly, 2006.

Miljøministeriet. "Bekendtgørelse om indberetning af oplysninger om farligt eller forurenende gods om bord på skibe (BEK nr af 15/12/2011)." *Retsinformation.* 28 December 2011. https://www.retsinformation.dk/forms/R0710.aspx?id=139192#Kap2 (accessed Marts 2013).

Miljøskib. *Baltic Carrier; medio 2001.* n.d. (a). http://www.miljoeskib.dk/pages/balticcarrier.html.

—. *Fu Shan Hai; medio 2003.* n.d. (b). http://www.miljoeskib.dk/pages/fushanghai.html.

MXSOCAL. "XIV. UNDER-KEEL CLEARANCE ." *The Marine Exchange of Southern California.* 2013. http://www.mxsocal.org/pdffiles/Chap%20XIV%20Underkeel%20Clearance.pdf (accessed May 2013).

NASA. *The Global Differential GPS System.* n.d. http://www.gdgps.net/ (accessed 2013).

Nielsen, Søren, interview by Maria Skov Engqvist. *Lods-data til speciale* (15 April 2013).

Oxford Dictionaries. "Agile." *Oxford Dictionaries.* 2013. http://oxforddictionaries.com/definition/english/agile (accessed Marts 2013).

Platzöder, Renate. *The Baltic Sea: New Developments in National Policies and International Cooperation.* The Hague, The Netherlands: Martinus Nijhoff Publishers, 1996.

Pro-trans A/S. *Info.* n.d. http://www.pro-trans.dk/192-containere.htm.

PyScripter. n.d. https://code.google.com/p/pyscripter/ (accessed April 2013).

Python Software Foundation. *Python v3.3.2 documentation.* n.d. http://docs.python.org/2/library/os.html.

Regeringen. "En samlet maritim strategi." 2010.

Rienecker, Lotte, Peter Stray Jørgensen, Lis Hedelund, Signe Hegelund, and Christian Kock. *Den gode opgave - Håndbog i opgaveskrivning på videregående uddannelser.* Frederiksberg C: Forlaget Samfundslitteratur, 2008.

Rouse, Margaret. "Definition: iterative development." *SearchSoftwareQuality.* November 2011. http://searchsoftwarequality.techtarget.com/definition/iterative-development (accessed Marts 2013).

SAM Electronics. *R4 Navigation System - GPS and DGPS Navigators.* Hamburg: L3 Communications, 2010.

Schleswig-Holsteinischer Landtag. "Tankschiffverkehr in der Ostsee." Schleswig-Holsteinischer Landtag, 24 May 2007.

Senstius, Svend Jacon, interview by Kristoffer Stentebjerg. *Data-udtræk* (22 January 2013).

Signalis. “Vessel Traffic Services.” *Signalis.* n.d. http://www.signalis.com/products/vessel-traffic-services/ (accessed April 2013).

Storstrøm Amt and Guldborgsund Municipality. *"Baltic Carrier" oliforureningen.* Nykøbing Falster: Storstrøm Amt, 2007.

Støttrup, Michael, and Per Engberg. *Land Based AIS Architectural Design.* Nr. Sundby: Gatehouse, 2006.

Sund & Bælt A/S. *Storebælt og Miljøet.* Copenhagen: Sund & Bælt Holding A/S, 1999.

Søfartsstyrelsen. “Guidelines for pilotage.” *Søfartsstyrelsen.* n.d. http://us.lodstilsynet.dk/496/strait-regime-for-the-great-belt-(route-t) (accessed April 2013).

—. *Kieler Kanal.* n.d. (d). http://www.soefartsstyrelsen.dk/ais/Transitruter/Sider/KielerKanal.aspx.

—. “Sejladsmønstre.” *Søfartsstyrelsen.* 2009. http://soefartsstyrelsen.dk/ais/Sejladsmoenstre/Sider/default.aspx (accessed May 2013).

—. *Storebælt.* n.d. (c). http://www.soefartsstyrelsen.dk/ais/Transitruter/Sider/Storebaelt.aspx.

—. *Sundet.* n.d. (b). http://www.soefartsstyrelsen.dk/ais/Transitruter/Sider/Sundet.aspx.

—. “Transitruter.” *Søfartsstyrelsen.* n.d. (a). http://www.soefartsstyrelsen.dk/ais/Transitruter/Sider/default.aspx (accessed May 2013).

Sørensen, Esben Munk. »Brugen af ENC.« Copenhagen, 2013.

Søværnets Operative Kommando. *Hurtig assistance og maritimt bindeled.* n.d. (a). http://forsvaret.dk/SOK/Nationalt/MAS/Pages/default.aspx.

—. *Tre grundstødninger afværget.* n.d. (b). http://forsvaret.dk/SOK/Nyt%20og%20Presse/nationalt/Pages/Tregrundst%C3%B8dningerafv%C3%A6rget.aspx .

Task Force for Klimatilpasning. “Vandstanden ved de danske kyster.” Task Force for Klimatilpasning, n.d.

The Bosun's Mate. “Marine Automatic Identification System (AIS).” *The Bosun's Mate.* n.d. http://www.bosunsmate.org/ais/#freq.

The Danish Geodata Agency. “DVR90.” *The Danish Geodata Agency.* n.d. http://www.gst.dk/English/Geodesy+and+Surveying/Reference+Systems/DVR90/ (accessed April 2013).

The Maritime Safety Committee. “Resolution MSC.138(76).” 5 December 2002.

U.S. Coast Guard Navigation Center. *Automatic Identification System Overview.* n.d. (a). http://www.navcen.uscg.gov/?pageName=AISmain.

—. *How AIS Works.* n.d (b). http://www.navcen.uscg.gov/?pageName=AISworks.

UNCLOS. “Part II - Territorial sea and contiguous zone.” *Oceans and Law of the Sea.* 10 December 1982. https://www.un.org/depts/los/convention_agreements/texts/unclos/part2.htm (accessed April 2013).

United Canal Agency GMBH. “General Information about Kiel-Canal transits.” UCA, 15 June 2005.

Vanem, Erik, and Rolf Skjong. *Collision and Grounding of Passenger Ships - Risk Assessment and Emergency Evacuations.* Det Norske Veritas, DNV Research, 2004.

Vessel Traffic Service Storebælt. *Fakta om VTS.* n.d. http://forsvaret.dk/VTSSTB/Fakta%20om%20Storeb%C3%A6lt%20VTS/Pages/default.aspx.

World Shipping Council. »Containers Lost at Sea.« World Shipping Council, August 2011.

Content

Appendix 1: Tidal Calculations

The value of high and low tide including the timestamp for these tides are given in the timetable. To determine the approximate tide between the high and low tide, an interpolation table (based on a simple sine curve) is used.

In the tide table the two extremes, which our timestamp is in between, are found. The height difference and the time different between the two extremes are calculated as well as the time difference between our time and the time for the high tide. The two time differences are used in the interpolation table to find a coefficient. Having the coefficient, this formula is used:

$$(coefficient * water\ level\ difference) + \ the\ hight\ of\ the\ nearest\ low\ water\ extreme$$

MMSI	Tidsstempel	Tidspunkt	Tidsforskel	Tidevand	Koefficient	Beregnet tidevand
Storebælt		Korsør/Slipshavn				
XXXXXXXXX	03-10-2012 00:06	20:36		-0,1		
		02:44	02:38	0,1		
			06:08	**0,2**	**0,61**	**0,022**
XXXXXXXXX	03-10-2012 01:25	20:36		-0,1		
		02:44	01:19	0,1		
			06:08	**0,2**	**0,89**	**0,078**
XXXXXXXXX	03-10-2012 02:20	20:36		-0,1		
		02:44	00:22	0,1		
			06:08	**0,2**	**0,99**	**0,098**
XXXXXXXXX	19-10-2012 03:11	03:00	00:11	0,1		
		09:15		-0,1		
			06:15	**0,2**	**1**	**0,1**
XXXXXXXXX	03-10-2012 01:10	20:36		-0,1		
		02:44	01:34	0,1		
			06:08	**0,2**	**0,86**	**0,072**
XXXXXXXXX	06-10-2012 14:54	11:38		-0,1		
		17:41	02:47	0,1		
			06:03	**0,2**	**0,54**	**0,008**

MMSI	Tidsstempel	Tidspunkt	Tidsforskel	Tidevand	Koefficient	Beregnet tidevand
Kadetrenden		Gedser				
XXXXXXXXX	14-11-2012 00:27	00:21		-0,1		
		07:04	06:37	0		
			06:43	**0,1**	**0**	**-0,1**
XXXXXXXXX	20-11-2012 09:29	04:49		-0,1		
		11:42	02:13	0,1		
			06:53	**0,2**	**0,77**	**0,054**
XXXXXXXXX	22-10-2012 12:50	12:15	00:35	0,1		
		18:01		(-)0		
			05:46	**0,1**	**0,97**	**0,097**
Køge		København				
XXXXXXXXX	02-11-2012 05:48	05:00		(-)0		
		10:33	04:45	0		
			05:33	**0**		**0**
XXXXXXXXX	27-11-2012 14:25	08:54	05:31	0		
		14:45		-0,1		
			05:51	**0,1**	**0,01**	**-0,099**
Lolland_Falster		Gedser				
XXXXXXXXX	04-10-2012 10:27	09:47		0		
		15:17		(-)0		
				0		**0**
XXXXXXXXX	08-11-2012 12:16	07:29		-0,1		
		14:20	02:04	0		
			06:51	**0,1**	**0,8**	**-0,02**
North of Funen		Korsør				
XXXXXXXXX	03-10-2013 13:09	08:54		-0,1		
		15:03	01:54	0,1		
			06:09	**0,2**	**0,8**	**0,06**
XXXXXXXXX	19-10-2013 12:38	09:15		-0,1		
		15:30	02:52	0,1		
			06:15	**0,2**	**0,58**	**0,016**

MMSI	Tidsstempel	Tidspunkt	Tidsforskel	Tidevand	Koefficient	Beregnet tidevand
The Sound		København				
XXXXXXXXX	22-10-2013 06:16	03:32	02:44	0,1		
		09:44		-0,1		
			06:12	**0,2**	**0,83**	**0,066**
XXXXXXXXX	04-10-2013 14:41	11:33		0		
		17:44		(-)0		
				0		**0**
XXXXXXXXX	05-10-2013 20:23	19:03		(-)0		
		02:06		0		
				0		**0**
XXXXXXXXX	23-11-2013 11:06	06:20	04:46	0,1		
		12:18		-0,1		
			05:58	**0,2**	**0,09**	**-0,082**
XXXXXXXXX	16-11-2013 22:08	16:42		-0,1		
		23:15	01:07	0,1		
			06:33	**0,2**	**0,92**	**0,084**
XXXXXXXXX	24-11-2013 04:06	00:55		-0,1		
		07:09	03:03	0,1		
			06:14	**0,2**	**0,52**	**0,004**
XXXXXXXXX	24-10-2013 07:18	05:45	01:33	0,1		
		11:49		-0,1		
			06:03	**0,2**	**0,85**	**0,07**
XXXXXXXXX	09-10-2013 10:17	05:33	04:44	0,1		
		11:33		-0,1		
			06:00	**0,2**	**0,12**	**-0,076**
XXXXXXXXX	03-11-2013 13:14	11:25	01:49	0		
		18:05		-0,1		
			06:40	**0,1**	**0,82**	**-0,018**
XXXXXXXXX	18-11-2013 00:02	17:48		-0,1		
		00:24	00:22	0,1		
			06:36	**0,2**	**0,99**	**0,098**
XXXXXXXXX	29-10-2013 04:44	03:18		-0,1		
		09:16	04:30	0,1		
			05:58	**0,2**	**0,15**	**-0,07**
XXXXXXXXX	03-11-2013 00:44	23:45		0		
		05:48		(-)0		
				0		**0**

XXXXXXXXX	07-11-2013 08:39	04:49	03:50	0,1		
		10:42		(-)0		
			05:53	**0,1**	**0,26**	**0,026**
XXXXXXXXX	24-10-2013 15:44	11:49		-0,1		
		17:53	02:09	0,1		
			06:04	**0,2**	**0,71**	**0,042**
XXXXXXXXX	13-11-2013 08:44	08:25	00:19	0,1		
		14:25		-0,1		
			06:00	**0,2**	**0,99**	**0,098**
XXXXXXXXX	05-11-2013 08:41	08:27		(-)0		
		14:16		0		
				0		**0**
XXXXXXXXX	04-11-2013 03:29	01:00		0		
		07:00		(-)0		
				0		**0**
XXXXXXXXX	07-10-2013 20:17	15:28	04:49	0		
		21:54		-0,1		
			06:26	**0,1**	**0,15**	**-0,085**
XXXXXXXXX	09-11-2013 08:48	06:21	02:27	0,1		
		12:12		-0,1		
			05:51	**0,2**	**0,61**	**0,022**
XXXXXXXXX	04-11-2013 17:30	12:44	04:46	0		
		19:32		-0,1		
			06:48	**0,1**	**0,2**	**-0,08**
XXXXXXXXX	06-10-2013 15:31	14:08	01:23	0		
		20:33		-0,1		
			06:25	**0,1**	**0,9**	**-0,01**
XXXXXXXXX	14-11-2013 22:16	21:30	00:46	0,1		
		03:42		-0,1		
			06:12	**0,2**	**0,96**	**0,092**
XXXXXXXXX	12-10-2013 20:53	19:16	01:37	0,1		
		01:42		-0,1		
			06:26	**0,2**	**0,85**	**0,07**
XXXXXXXXX	29-11-2013 23:35	21:51	01:44	0,1		
		03:48		(-)0		
			05:57	**0,1**	**0,82**	**0,082**

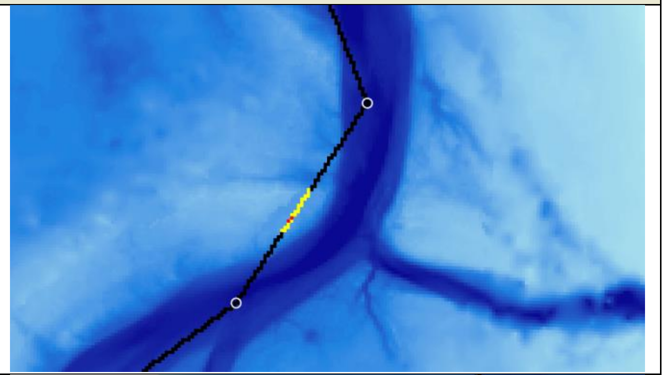
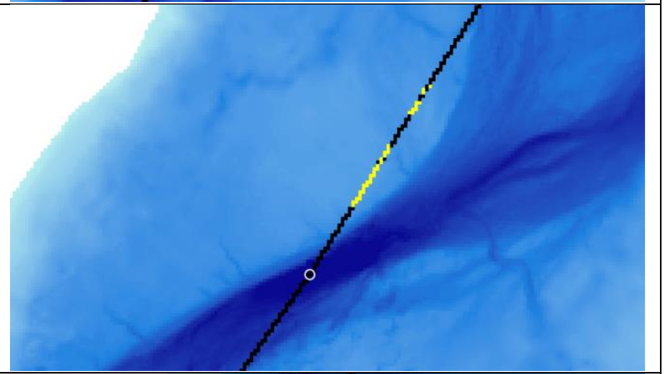
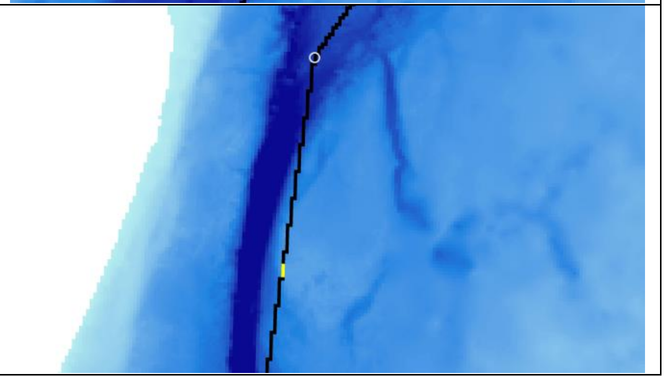
Appendix 2: Ships With Critical UKC

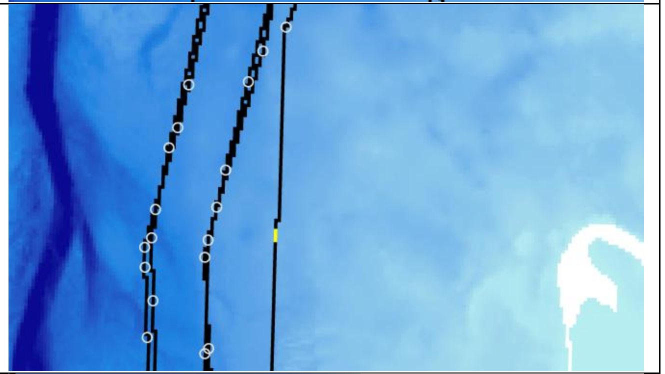
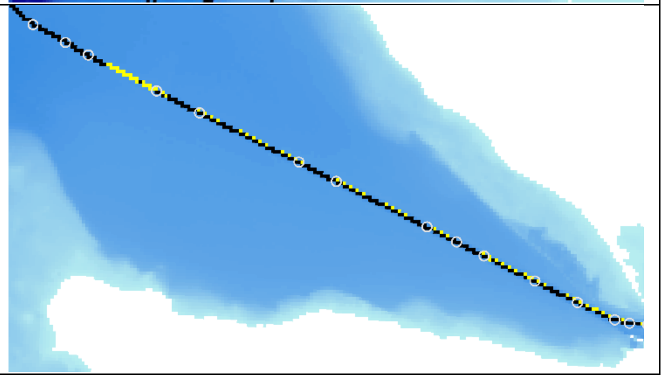
In this appendix is a list of the ships appearing with critical static UKC. For each ship is listed:

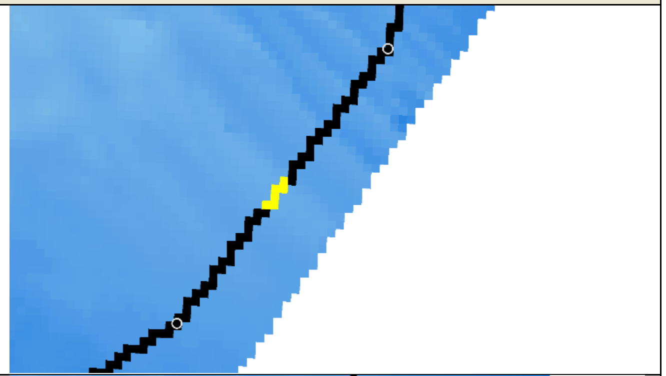
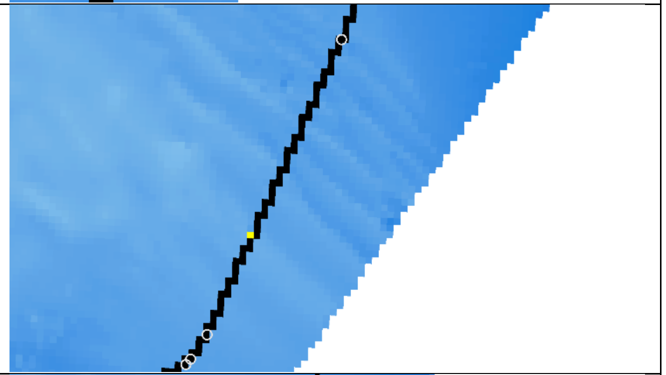
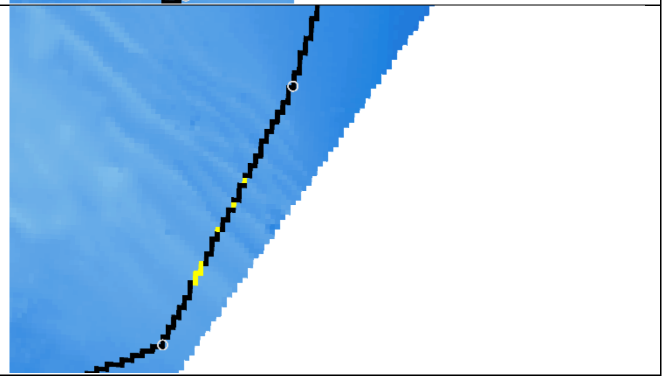
- The critical static UKC and timestamp for the location of the critical static UKC
- The calculated tide and the UKC – the calculated tide is added to the static UKC to find the UKC
- The use of pilotage
- A picture of the situation

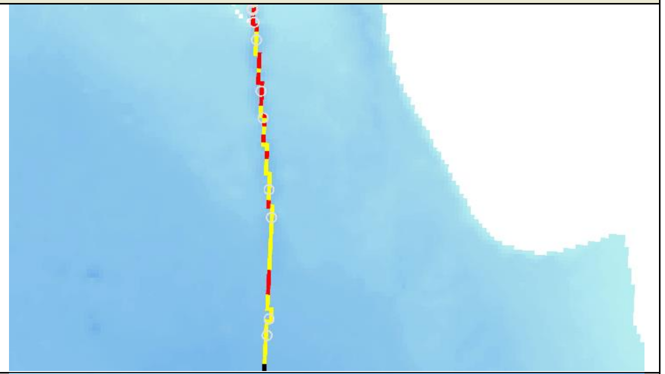
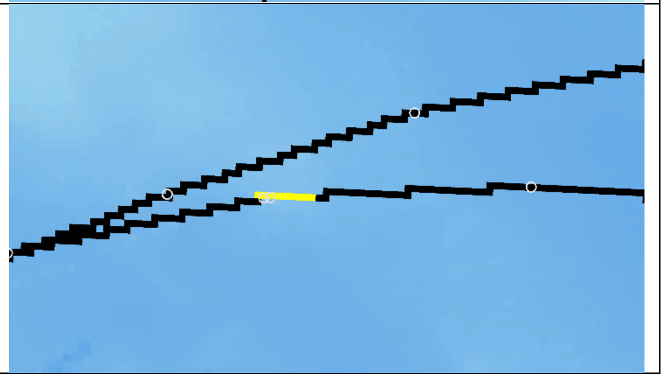
The list is divided into different areas:

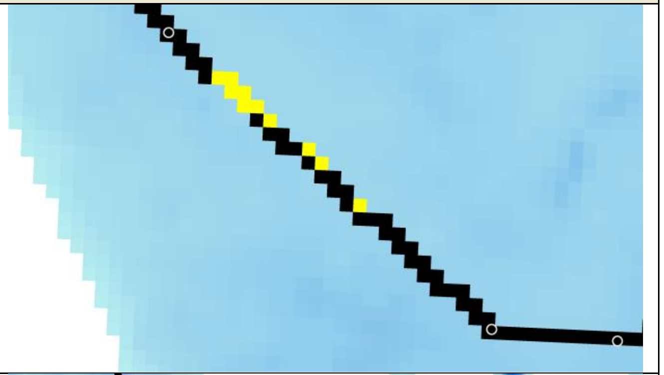
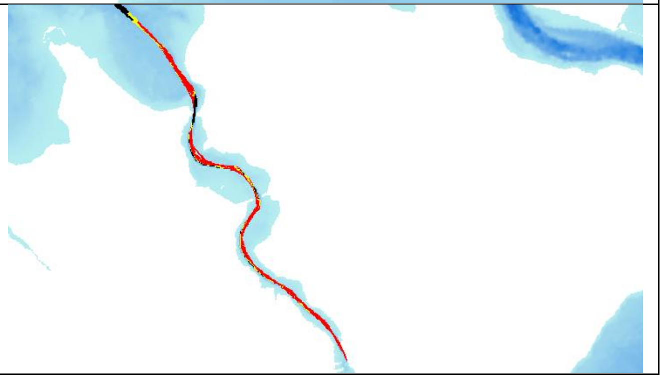
- The Great Belt
- The Kadet Channel
- Koge
- Lolland_Falster
- North of Funen
- The sound

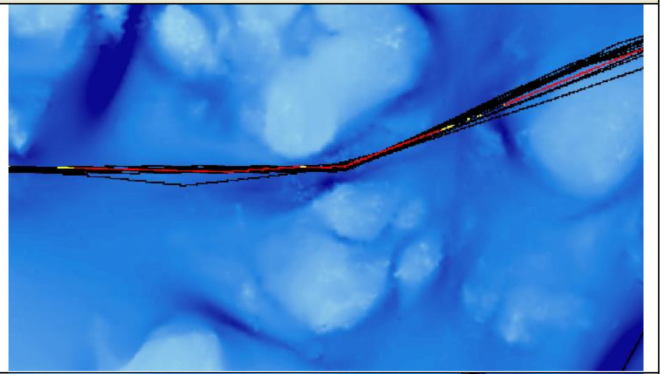
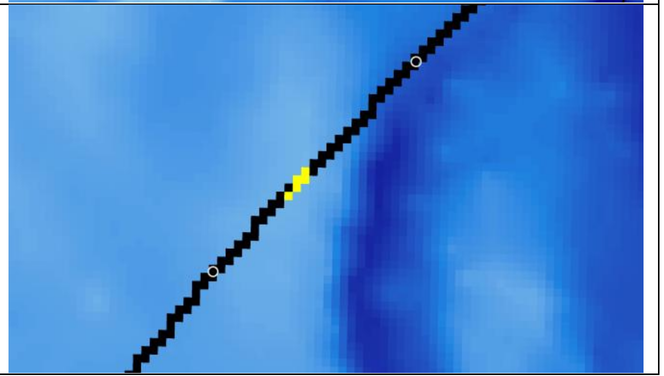
Ship	Time (2012)	Static UKC (m)	Tide (m)	UKC (m)	Pilot	Picture
The Great Belt						
Ship01	10-03 00:06:26	-0.599	0,022	-0,621	Nej	
	10-03 01:25:35	-1.086	0,078	-1,164	No Data	
	10-03 02:20:36	-1.228	0,098	-1,326	No Data	

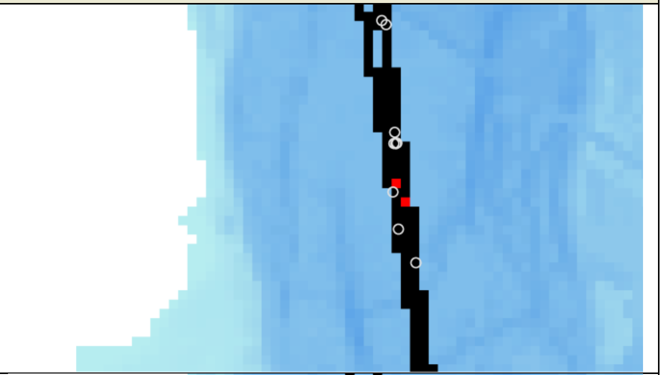
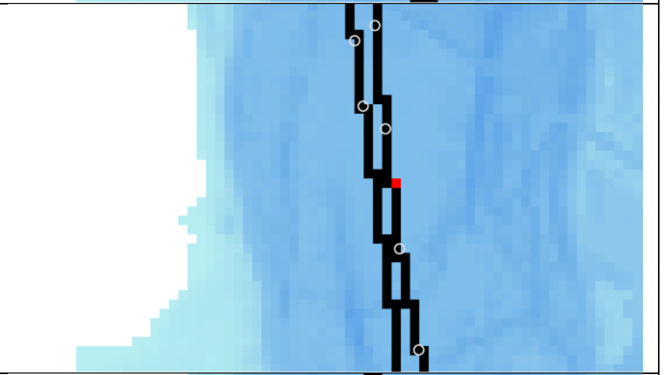
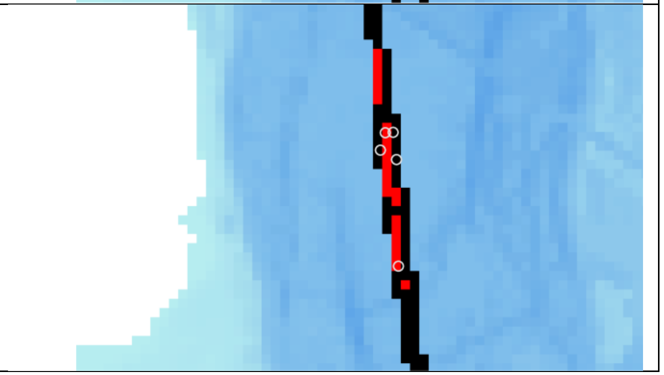
The Great Belt						
Ship02	10-19 03:11:13	-1.832	0,100	-1,932	No Data	
Ship03	10-03 01:10:48	-1.379	0,072	-1,451	No Data	
Ship04	10-06 14:54:12	-1.515	0,008	-1,523	No Data	

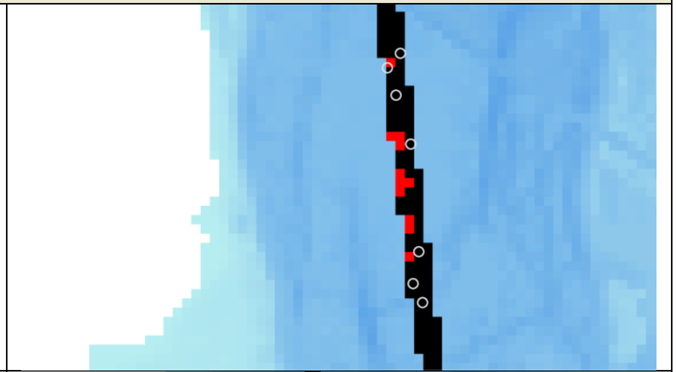
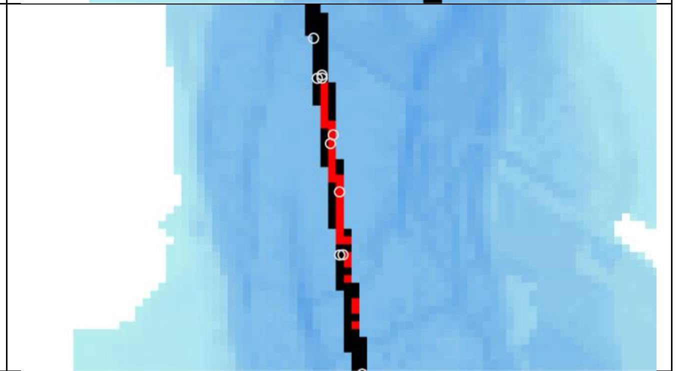
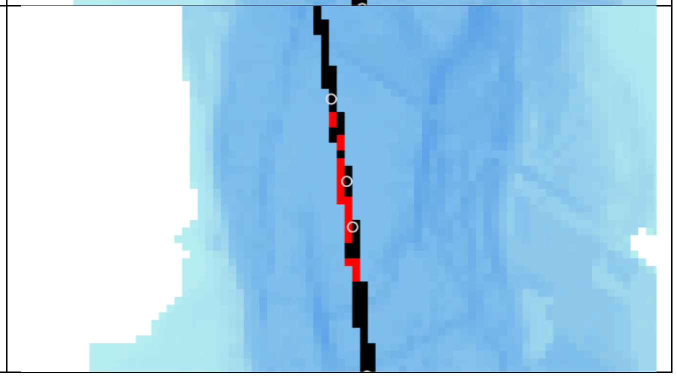
The Kadet Channel						
Ship05	11-14 00:27:50	-1.427	-0,100	-1,327	No Data	
Ship06	11-20 09:29:03	-1.974	0,054	-2,028	No Data	
Ship07	10-22 12:50:14	-1.398	0,097	-1,495	No Data	

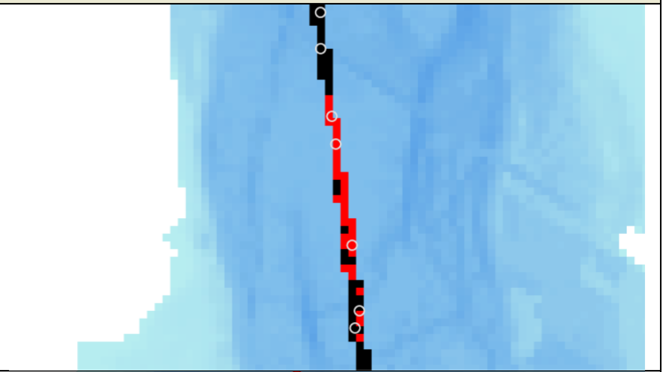
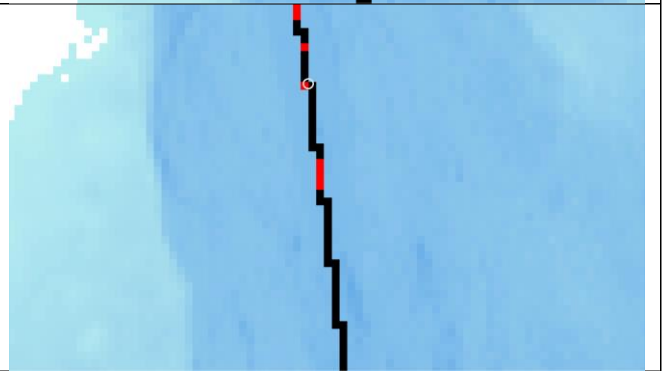
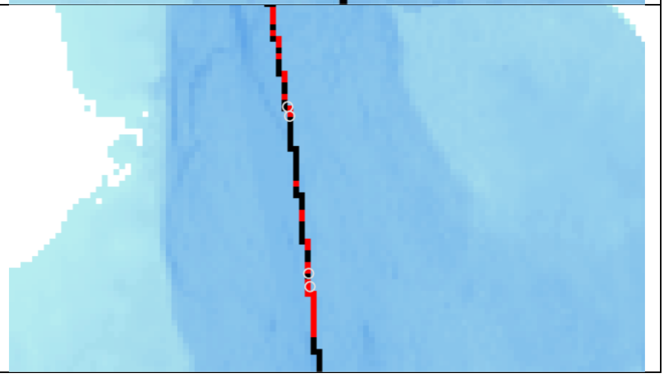
Køge						
Ship08	11-02 05:48:23	-0.650	0	-0,650	No Data	
Ship09	11-27 14:25:17	-1.054	-0,099	-0,955	No Data	

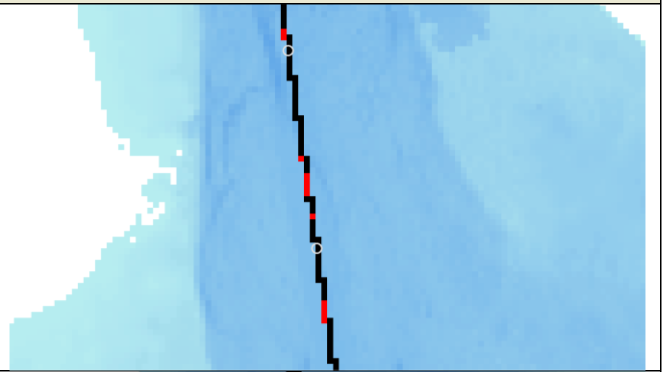
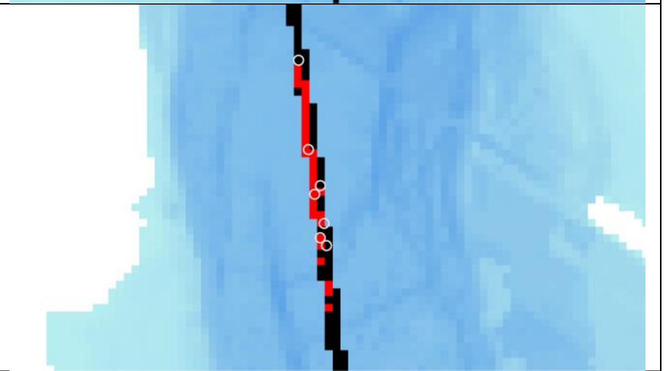
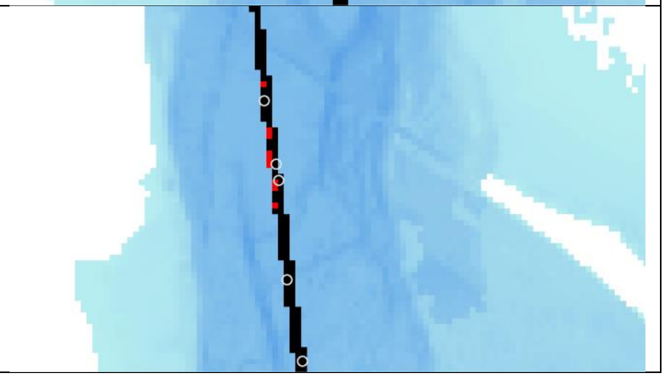
Lolland_Falster						
Ship10	10-04 10:27:03	-1.687	0	-1,687	No Data	
Ship11	11-08 12:16:07		-0,020		No Data	

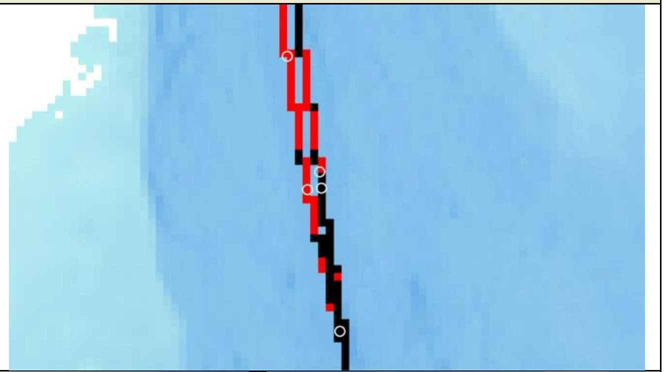
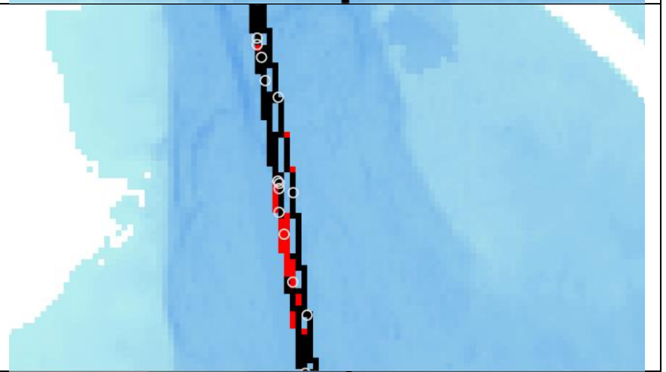
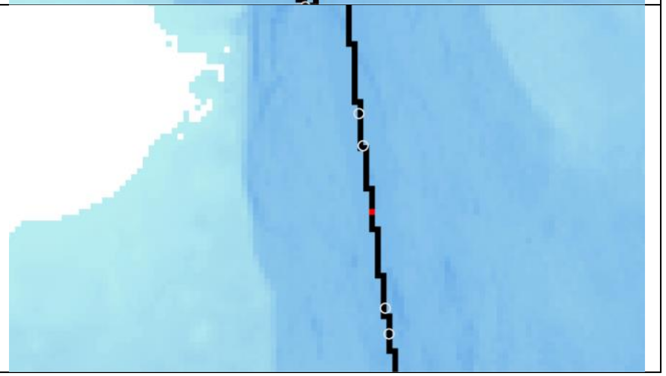
North of Funen						
Ship12	10-03 13:09:23		0,060		No Data	
Ship13	10-19 12:38:38	-1.717	0,016	-1,733	No Data	

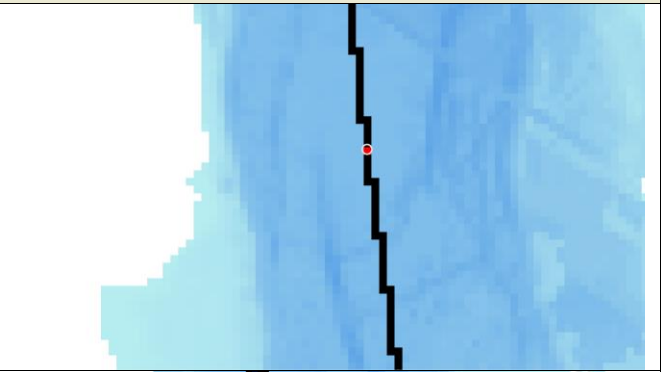
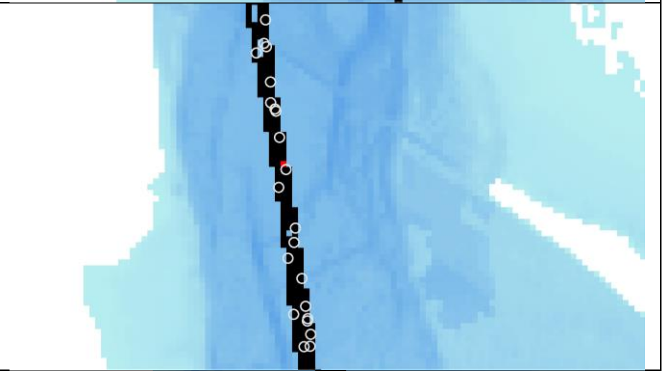
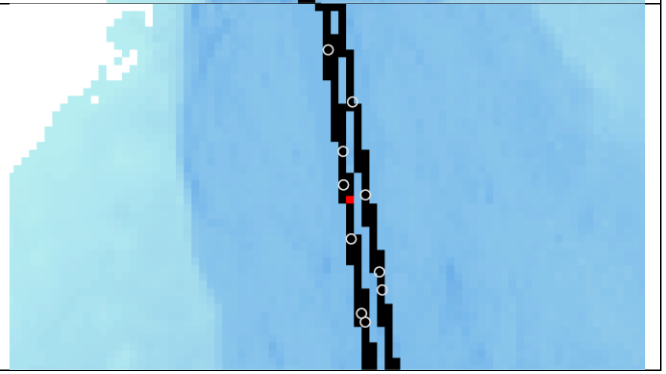
The Sound						
Ship14	10-22 06:16:24	-0.982	0,066	-1,048	No Data	
Ship15	10-04 14:41:14	-0.999	0	-0,999	No Data	
Ship16	10-05 20:23:13	-0.817	0	-0.817	No Data	

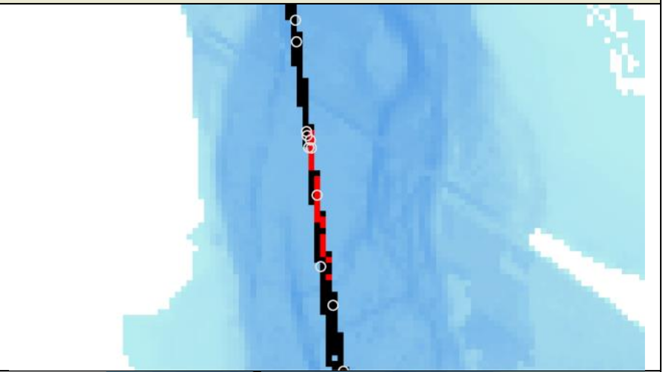
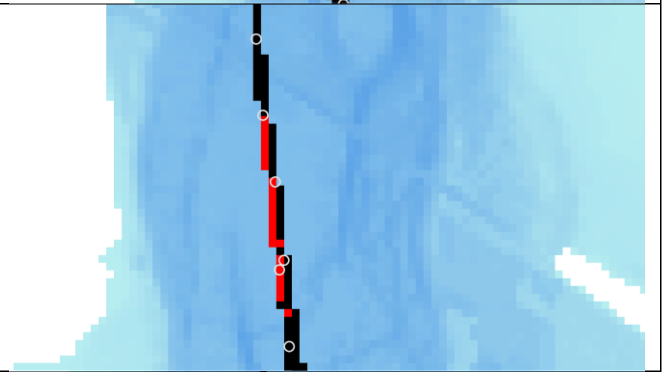
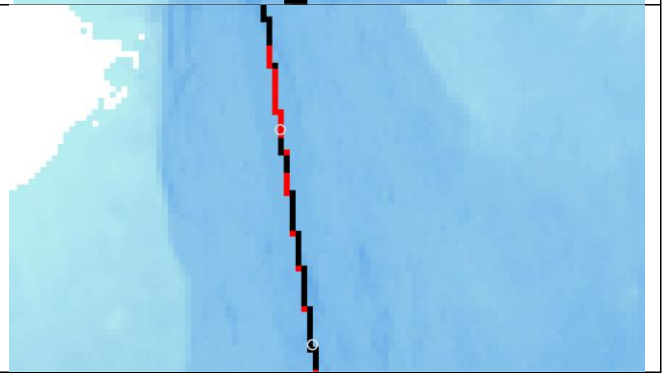
The Sound						
Ship17	11-23 11:06:48	-0.917	-0,082	-0,835	No Data	
Ship18	11-16 22:08:00	-0.699	0,084	-0,783	No Data	
Ship19	11-24 04:06:18	-0.830	0,004	-0,834	No Data	

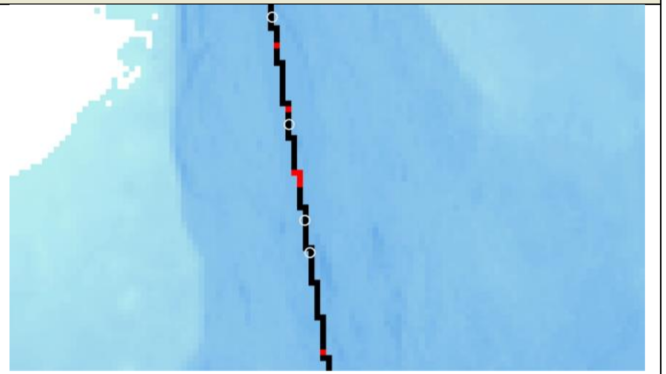
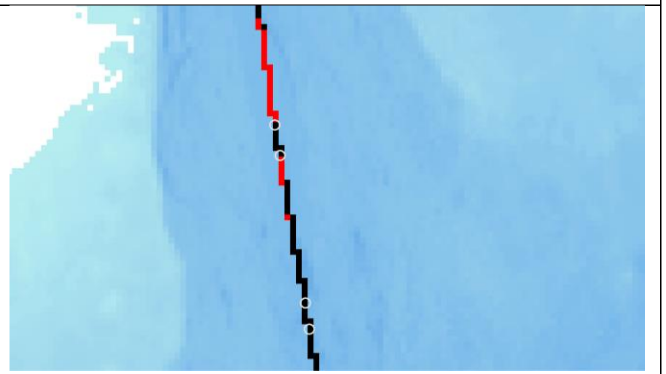
The Sound						
Ship20	10-24 07:18:47	-0.682	0,070	-0,752	No Data	
Ship21	10-09 10:17:14	-0.873	-0,076	-0,797	No Data	
Ship22	11-03 13:14:12	-0.331	-0,018	-0,313	No Data	

The Sound						
Ship23	11-18 00:02:20	-0.873	0,098	-0,971	No Data	
Ship24	10-29 04:44:11	-0.699	-0,070	-0,629	No Data	
Ship25	11-03 00:44:13	-0.917	0	-0.917	No Data	

The Sound						
Ship26	11-07 08:39:44	-0.673	0,026	-0,699	No Data	
Ship27	10-24 15:44:03	-0.631	0,042	-0,673	No Data	
Ship28	11-13 08:44:03	-0.973	0,098	1,071	No Data	

The Sound						
Ship29	11-05 08:41:23	-0.999	0	-0,999	No Data	
Ship30	11-04 03:29:17	-0.999	0	-0,999	No Data	
Ship31	10-07 20:17:47	-0.973	-0,085	-0,888	No Data	

The Sound						
Ship32	11-09 08:48:43	-0.817	0,022	-0,839	No Data	
Ship33	11-04 17:30:48	-0.817	-0,080	-0,737	No Data	
Ship34	10-06 15:31:34	-0.724	-0,010	-0,714	No Data	

The Sound						
Ship35	11-14 22:16:31	-0.873	0,092	-0,965	No Data	
Ship36	10-12 20:53:32	-0.773	0,070	-0,843	No Data	
Ship 37	11-29 23:35:03	-0.737	0,082	-0,819	No Data