Offshore project planning

The planning of ROV operations for rigleg inspections from a support vessel

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Summary

This thesis describes the different stages in planning a fictive offshore project and how that project could be conducted. The aim of the thesis is to gain an understanding of the different stages included in an offshore project. The main objective is to describe how to do a rigleg inspection with a Remotely Operated Vehicle (ROV) and the preparations for the operations. Information and material for the project was obtained by interviewing personnel at a Dutch offshore and subsea company and by visiting the multipurpose vessel Stril Server and a jack-up oil rig.

Books and documents about ROVs and inspections were also used. The basic understanding of offshore work and drilling for oil was gathered at courses at the Maritime Institute Willem Barentsz.

The project consists of taking the vessel Stril Server from Waalhaven in Rotterdam to the oil and gas field Gina Krog in the Norwegian sector of the North Sea. On the Gina Krog field stands the jack-up oil rig Hans Deul which has requested inspections of one of its riglegs. The rig is already jacked up so the inspections has to be done by an ROV.

Language: English Key words: offshore, ROV, inspection

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Abstrakt

Det här examensarbetet beskriver vilka olika delar ett offshore projekt kan bestå av. Arbetet är uppbyggt som ett fiktivt projekt men är ändå realistiskt på så sätt att de fartyg, företag och den oljerigg som använts som exempel i projektet finns på riktigt. Syftet med examensarbetet är att få en uppfattning om hur ett offshore projekt kan byggas upp och vilka utmaningar som finns. Målet med arbetet är att beskriva hur man inspekterar benen på en oljeplattform med en så kallad undervattensrobot (ROV) och att beskriva alla förberedelser som ska göras före man kan börja en inspektion.

Information och material för arbetet hittades genom att intervjua personal på ett holländskt offshore företag som gör inspektioner med ROV. Besök gjordes också till fartyget Stril Server och jack-up oljeriggen Paragon. Böcker och dokument om inspektioner och ROV användes också. Grunderna om offshore branschen och oljeborrning lärdes ut vid sjöfartsskolan Willem Barentsz i Holland.

Projektet som examensarbetet handlar om går ut på att fara med fartyget Stril Server från Waalhaven i Rotterdam till olje- och gasfältet Gina Krog i den norska sektorn av Nordsjön. På Gina Krog fältet står jack-up oljeriggen Hans Deul som behöver en inspektion av ett av benen. Riggen står på havsbottnen så inspektionen måste göras med en undervattensrobot.

Språk: engelska Nyckelord: offshore, ROV, inspektion

OPINNÄYTETYÖ

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Tiivistelmä

Opinnäytetyö kuvailee fiktiivisen offshore-projektin eri suunnitteluvaiheita ja mahdollista toteutusta. Opinnäytetyön tavoite on selventää mitä eri asioita pitää ottaa huomioon projektin eri vaiheissa. Työn päämäärä on selvittää miten jack-up öljynporauslautan tukijalan tarkastus tehdään kauko-ohjattavalla sukellusrobotilla (ROV) sekä siihen liittyvät valmistelut. Tiedot projektia varten on kerätty haastattelemalla hollantilaisen ROV-yrityksen henkilökuntaa sekä vierailuilta monitoimialus Stril Serverillä ja jack-up öljynporauslautalla. Lisäksi tietoa on haettu ROV operointia käsittelevistä kirjoista ja ohjeistuksista.

Projekti sisältää Stril Serverin siirtäminen Waalhavenista Rotterdamissa, Norjan talousalueella olevalla Gina Krogin öljy- ja kaasukentälle. Gina Krog öljykentällä toimii öljynporauslautta Hans Deul joka on tilannut tarkastuksen yhteen tukijaloistaan. Tarkastus on tehtävä ROV:llä koska suurin osa tukijalasta on veden alla.

Kieli: englanti Avainsanat: offshore, ROV, tarkastus

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Abbreviations and explanations used in this work

AUV	Autonomous underwater vehicle
DP	Dynamic Positioning
ECDIS	Electronic Chart Display and Information System
FMD	Flooded Member Detection
ICCP	Impressed current cathodic protection
IMCA	International Marine Contractors Association
LARS	Launch and recovery system
mobilisation	Taking on board, preparing and installing equipment needed for a specific voyage or project
MODU	Mobile offshore drilling unit
MPSV	Multipurpose support vessel
NDT	Non- Destructive Testing
Offshore work	In the shipping industry offshore work means the drilling for oil at sea and the shipping assisting that drilling
ROV	Remotely operated vehicle
ROV System	All the equipment required for operating the remotely operated vehicle including TMS, LARS, umbilical and control stations
TMS	Tether management system
VTS	Vessel Traffic Service

1 Introduction

Shipping in the offshore industry is a specialised field of seafaring with ships built for a specific purpose. Working on ships in the offshore industry requires understanding of the planning and different stages in offshore projects, which can be quite different from other merchant shipping. The offshore industry has its own regulations for shipping which have to be followed and taken into account when planning the work.

This thesis is done as a part of the Offshore and Dredging Minor studies at Maritime Institute Willem Barentsz in Holland. The thesis is built up as a fictive offshore project in the Norwegian sector of the North Sea. The reason for writing the thesis as a fictive project is that it gives a more practical view of the offshore work and gives an example of how a project could be planned and what type of equipment could be used.

In the oil and gas field called Gina Krog the jack-up drilling rig Hans Deul is drilling for oil. The drilling company has hired the company Bluestream to make a rigleg inspection of the forward leg of the Hans Deul rig. Bluestream is a Dutch offshore and subsea work company with expertise in remotely operated vehicles (ROV), diving and rope access. The inspection work is a part of a bigger project which includes drilling of exploitation wells, installing a production facility for the production of the recovered oil and gas and installing a pipeline to transport the gas to an existing pipeline.

This thesis describes the ROV work done by Bluestream, starting from the mobilisation of a project ship in Den Helder, Holland. The different stages of the inspections with an ROV will be described. Most of the procedures in the project are planned according to the rules of the International Marine Contractors Association. Information is gathered from books and documents about ROV operations and non-destructive inspections but also by interviewing personnel at Bluestream and visiting the ship Stril Server and the jack-up rig Paragon in Den Helder.

The thesis consists of two parts. The first part includes information about ROVs, jack-up rigs and the different kinds of inspections that can be done on the riglegs. The other part describes the actual project planning. Included in the project plan are the schedule for the project, voyage plan and mobilisation of the ship, and instructions how to carry out the rigleg inspections with the ROV.

1.1 Objective

The objective of this thesis is to plan the offshore work to be done by Bluestream and to find out what has to be taken into account when planning such a project. The goal is to get an overall understanding of project planning in which one of the main objectives is to find out how to do a rigleg inspection with a remotely operated vehicle from a multipurpose support vessel.

The aim for this particular project was to develop:

- a project plan with a time schedule
- a safety analysis of the launching of the ROV
- a description of the mobilisation of the vessel Stril Server in Rotterdam
- a voyage plan from Waalhaven, Rotterdam to the location of the rig Hans Deul
- a procedure for the arrival at the Hans Deul location
- a description of the ROV equipment onboard
- a plan and preparations for inspections of the rigleg with an ROV.

1.2 Research questions

This thesis aims to answer the following questions:

- What has to be taken into account when planning an offshore project?
- How is a rigleg inspection done with a remotely operated vehicle?
- What are the possible outcomes of a rigleg inspection and what is the next step after finishing the first inspections?

1.3 Delimitation

There are many simultaneous operations going on when drilling for oil and gas, especially in the beginning of a project. This thesis is limited to the work and planning carried out by Bluestream although other operations will take place at the same time. These other operations will be done by other companies. The work on the ship is seen from the navigational point of view, focusing on the cooperation between the bridge and the ROV team. Preparations or work in the engine room will not be discussed although that would also be part of a project. Because the focus is on the ROV operations, the technical side of the different kind of inspections on the riglegs will be discussed more briefly.

1.4 Method

To be able to plan the project in the thesis to be as realistic as possible, I have studied relevant literature about remotely operated vehicles, jack-up drilling rigs and underwater inspections. For the project I have also used the International Marine Contractors Associations (IMCA) guidelines for ROV operations and underwater work. Another document which has been useful is the Guidelines for Offshore Marine Operations, made with the intention to serve as a standard global approach to safe vessel operations in the offshore oil and gas industry. To get a more practical view of this kind of projects and inspections, I have interviewed personnel at the company Bluestream about their work. The recommendations from IMCA have been taken into account when choosing which ROV type and deployment system to use. Also the visit to the vessel Stril Server helped in the planning. The basic understanding of offshore work and offshore oil drilling I learned from courses at Willem Barentsz maritime school. The thesis contains pictures to facilitate understanding if the reader is not familiar with the subject.

1.5 Previous research

A lot of previous research relating to offshore work can be found but it is mostly too technical to be helpful for this kind of project. Previous research relating to offshore and merchant shipping has been done by L. Liljelund in the work *Offshore-kentän elinkaari (A life cycle of an offshore field),* where she describes the different types of oil drilling platforms, the surveys before starting the drilling, drilling for oil, and production and transportation. More information can be found in the work *Introduction to Norwegian offshore and marine operation,* written by P-A. Ikonen. His work is similar to the work of L. Liljelund but includes also information about Dynamic Positioning, ROV and subsea work, regulatory bodies and economics.

2 What is an ROV?

An ROV, a remotely operated vehicle, is an underwater robot which can be used for inspections and work on underwater constructions and on the seabed. The ROVs are also used in marine archaeology, marine research and accident investigation. The ROV is invented to replace divers when conducting underwater operations and thus increase the safety and save time on some work tasks under the water. ROVs are suitable for work at great depths in the oceans and they can act as the eyes on the sea bottom via a camera mounted on the ROV. There are several different ROVs designed for many types of work tasks ranging from really small vehicles with only a camera on top of it which can only be used for observations, to vehicles with manipulators and tools which can weigh up to 6000 kg. The differences in size and equipment vary a lot so there is no exact way to describe an ROV but they are divided into different classes depending on what kind of tasks they can do. (Marine technology society, 2015)

The ROV is operated from the surface of the water by an ROV pilot. The pilot operates the ROV with a joystick, on a remote control on the deck of a ship, or in a control room with several screens where he/she can see the ROV. The ROV system consists of a vehicle with manipulators, cameras, tools and sensors. The number of tools or sensors attached to the vehicle can vary depending on ROV class and which type of inspections are to be carried out at the moment. The vehicle is connected to a tether or umbilical that goes to the remote control on the surface. The umbilical consists of electric cables and cables for video and data signals going between the operator station on the surface and the sensors on the vehicle. (Marine technology society, 2015)

There are two ways to operate an ROV: either as free-swimming or with a tether management system (TMS). When a free-swimming vehicle is launched from a ship to the water, it is lowered down with a crane to the water level. When using a tether management system, the ROV is inside a cage which is lowered down into the water to the working depth where the vehicle is released from the cage (*Figure 4*). The use of the tether management system protects the vehicle from damage when lowering it down from the vessel to the water level. The vehicle is also more protected from waves and damage when going through the splash zone if it is inside the TMS cage when lowering it down. Another advantage with the TMS is that it decreases the drag on the tether in the water. Especially while working at great depths where the catenary grows so much that it increases the drag on the umbilical, it is much more efficient to have the umbilical to the TMS straight down to the working depth and operate the vehicle from there with a much shorter tether. In the worst case, the drag on the umbilical of a free- swimming ROV is greater than the thrust force of the ROV which makes the vehicle unable to move forward. (Seaeye, 2015)

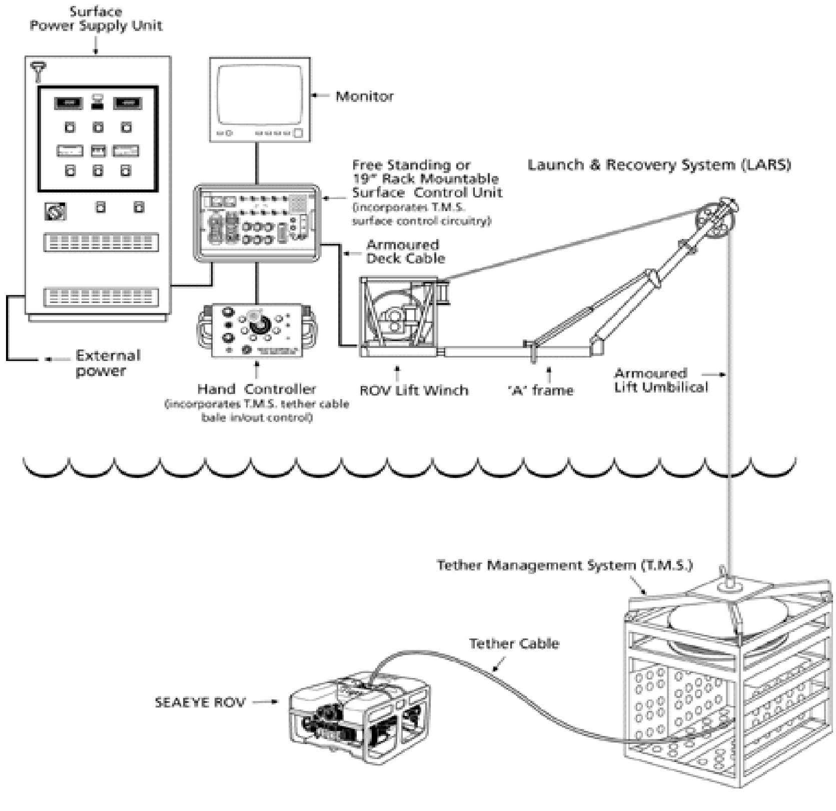

Figure 4. ROV system with tether management cage

An ROV can be launched from the vessel to the water with a crane over the side, through a moonpool inside the vessel or through a side hatch on both sides of the vessel, depending on the layout of the particular vessel. If lowering down the vehicle to the water over the side of the vessel, either a regular crane or an A-frame specially designed for lowering down ROV's can be used. When lowering the ROV through a side hatch it is most convenient to use an A-frame.

2.1 Different types of ROVs

The Remotely Operated Vehicles can be divided into different classes depending on their equipment, tooling or the tasks they can be used for. The classes are decided by The International Marine Contractors Association (IMCA).

Class 1 consists of small vehicles used for observations, which can carry only a camera and a light, and in some cases one additional sensor.

Class 2 are observation ROVs with payload option and fitted with two cameras. They can carry several additional sensors and usually there is also room for a basic manipulator on the vehicle. The class 2 vehicles should manage to operate normally without loss of any original function when carrying two additional sensors or manipulators.

Class 3 vehicles are called work class vehicles and they are able to carry sensors and manipulators at the same time. The work class vehicles are often more powerful and larger than the class 1 and class 2 ROVs. Deepwater vehicles are usually of class 3. The capability and power can vary a lot between the work class vehicles.

Class 4 includes towed and bottom crawling vehicles that do not have as much manoeuvrability as the others. The bottom crawling ROVs are heavy and large and designed for a specific purpose. They move forward with a wheel or track system and can thus move along the seabed and for example bury or make a trench for a cable on the seabed.

Class 5 includes vehicles which does not fit into the other classes or those still considered as prototypes. The autonomous underwater vehicles (AUV) also belong to this class. The AUVs have no tether nor umbilical; they swim freely in the water. (IMCA, 2009, p. 5-6)

3 Rigleg inspections on a Jack-Up rig

A jack-up oil rig is a mobile offshore drilling unit (MODU), and is the most popular type of rig for offshore exploration and development drilling. The jack-up is a so called bottom supported and self-elevating rig, which means that the platform is towed to the drilling site, its legs are lowered to rest on the bottom, and finally, the platform is jacked up from the water by a jacking system on the legs. Usually three or four legs go through the platform and provide a stable drilling platform. (Rigzone, 2016)

A spudcan is a round, conical foot of the leg which stabilizes the rig. The spudcan goes into the seabed or partly stays on the seabed, depending on the type of soil. The spudcan increases the soil bearing area, thus less soil strength is required. Another possibility is to use a mat footing under the legs which connects the legs together. The mat footing puts a lower bearing pressure on the soil but it cannot be used on an uneven seabed or in places where there are a lot of underwater structures such as pipelines on the seabed. Another reason for using spudcans or mats is to try to avoid a so called punch through of the legs in the soil, which means that the soil cannot bear the weight of the leg and it goes too deep into the soil. A punch through of a leg can make the whole platform unstable and make drilling impossible. (Vazquez, Michel, Alford, Quah and Foo, 2005, p. 6)

There are two types of legs on jack-up rigs, cylindrical and trussed steel legs. Trussed steel legs have a smaller resistance to environmental loads like wind, waves and current than the cylindrical ones. Therefore the trussed legs are more often used especially for the jack-up's operating in deep water. Trussed legs consist of chords and braces: there are three or four chords in the corners of the legs, and braces between the chords for strengthening the structure (*Figure 5*). Braces can be constructed in different 'patterns' with some difference in strength against loads depending of the type of pattern. (Vazquez, Michel, Alford, Quah and Foo, 2005, p. 6-7)

What to inspect on a rigleg depends on what possible problem has come up when taking the rig to the drilling site and placing it on the right spot on the seabed. The soil can also behave in an unexpected manner so that the legs, or one of the legs, will sink into the seabed more than another leg and more than was predicted after the surveys of the soil and the seabed. This can lead to bending of the steel members of the rig or damage to the spudcans. Another reason to do a rigleg inspection could be that something has happened to the rig under the transportation to the drilling site or that a yearly inspection has to be done by the classification company. The jacking system of the rig has to be inspected for broken parts or wear of the teeth on the legs. (Vazquez, Michel, Alford, Quah and Foo, 2005, p. 6)

F*igure 5. Part of a rigleg and jacking system of the Paragon jack-up rig*

3.1 Types of rigleg inspections

There are several different types of rigleg inspections depending on what has to be examined. The most common inspections are non-destructive testing of welds, wall thickness inspection, inspection of the cathodic system, and corrosion and visual inspection of the legs. These inspections can be done to a part of the leg where some possible problem is detected or to the whole leg in question. Two of the most common types of inspections will be described here.

3.1.1 Underwater none-destructive testing (NDT)

Non-destructive testing can be defined as inspecting, testing and evaluating a material in a way that does not harm the material being tested. After the inspection, the material is intact and can still be used as before the inspection. A non-destructive testing is carried out to control that the quality of the material remains the same after installation or use of the material or the product (The American society of non-destructive testing, 2015).

An underwater non-destructive testing is carried out by a diver using physical test methods and visual inspection on the worksite or by an ROV via a camera. The reason to conduct a non-destructive inspection on a leg of a jack-up rig is to find cracks in the steel or water inside the steel parts due to damage somewhere in the steel. Another reason could be to find out if there is corrosion on the riglegs. (Davey, Forli, Raine and Whillock, 1999, p. 4-6)

There are several different types of non-destructive testing on a jack-up rig of which the most common are Flooded Member Detection (FMD), General visual inspection and Ultrasonic Wall thickness test. To detect if there is water inside a steel member, the Flooded Member Detection inspection can be done by using ultrasonic or gamma x-ray. (Davey, Forli, Raine and Whillock, 1999, p. 22)

To detect cracks in the steel or measure the thickness of the steel an Ultrasonic wall thickness inspection can be done. The thickness of the steel can be reduced because of corrosion or damage on a part of the rigleg. For measuring the steel thickness at a specific location (ultrasonic point thickness measurement), a digital thickness meter is used. By measuring the point thickness it is possible to have some indication if that part is affected by corrosion. (Davey, Forli, Raine and Whillock, 1999, p. 22)

3.1.2 Cathodic protection

To prevent the steel on jack-up riglegs from corrosion caused by seawater, a cathodic protection system is used. There are two types of cathodic protection systems. A simple method for cathodic protection is to weld sacrificial anodes on the rigleg and spread them evenly around the whole leg. The anodes are blocks of metal which will corrode faster than steel, for example zinc or aluminium. Thus the steel will be protected from corrosion when the anodes are connected directly to the steel. (National Physical Laboratory, 2015, p. 2)

Impressed current cathodic protection (ICCP) is another way to protect underwater steel structures from corrosion. The working principle of the system is based on feeding a controlled amount of DC current over the steel structure. Anodes and reference cells connected to a control panel are mounted on the steel. The current produced by the system is more powerful than the natural electro-chemical activity on the steel surface, and that activity can therefore be suppressed and spare the steel from corrosion. The ICCP system constantly monitors the electrical potential and adjusts the current according to this. (Cathelco, 2015)

The cathodic protection system can be visually inspected by an ROV, checking the size of the anodes and checking that all anodes are still in place on the structure. The length and breadth can also be measured if a more exact inspection is needed or when deciding if the anodes have to be replaced by new ones.

4 Project plan

The project is divided into five parts consisting of the schedule, information about the project ship, the mobilisation of the project ship before departure, voyage planning and the procedures for the arrival to the Hans Deul rig. The project is developed by gathering information from interviews and literature. The type of inspection, the water depth and the size of the vehicles has been taken into account when choosing what ROV equipment should be used in the project. Although it is a fictive project, it is made as realistic as possible by using an existing ship and ROV equipment. Procedures have been developed with help of the IMCA guidelines.

4.1 The schedule of the project

The schedule for the project is planned so that the ship will be alongside the platform in the operation position and the inspection work can start on the 1st of February 2016. The planned duration of the mobilisation is 48 hours. The duration of the voyage after the pilot embarking position is calculated with a speed of 12 knots and will thus take 35 hours.

Date/ Time	**Operation**
28th of January 2016, 14:00	Starting the mobilisation in Waalhaven
30th of January, 14:00	Mobilisation finished
14:30	Taking pilot on board
15:00	Departure from Waalhaven
30th of January, 18:00	At pilot embarking position
1st of February, 05:00	Approaching the last waypoint and going through the pre-entry checklist for the 500 m zone
06:30	Entering the 500 m zone of Hans Deul
07:00	Positioning the vessel by DP at a distance of 150 m from the platform
08:00	Briefing before starting the inspection work
1st of February 2016, 09:00	Starting the inspections by launching the ROV

4.2 Project ship

The ship used for the project and acting as the base for the ROV operations is the multipurpose support vessel (MPSV) Stril Server (*Figure 1*), owned by the Norwegian shipping company Simon Mokster Shipping. The Stril Server is designed for subsea operations such as diving and working with ROV’s operated from the ship. Due to the large accommodation spaces, it is also possible to use the ship as additional accommodation for persons working in offshore projects. (Simon Mokster Shipping, 2014)

Dimensions:

- L.o.a: 85,40 m
- Breadth: 18,00 m
- Draught design/scantling 4,75 / 5,50 m
- Accommodation: 90 persons

Engines and propulsion:

- Main power supply: 2 x QSK60 prime power 1900 kW, 1800 rpm and 2 x QSK50 prime power 1343 kW, 1800 rpm
- Main propulsion: 2xRR AZP85 CP, 1600KW Azimuth propellers
- Generators: Marelli 2x1825 kW, 690V 60Hz and Marelli 2x1343 kW, 690V 60Hz
- Azimuth bow thrusters: 2x Rolls Royce AZ thruster swing-up type
- Tunnel thruster: 1xTunnel thruster RR, TT2000 DPN CP, 880 KW

ROV equipment:

- ROV hangar (for workclass size ROV), starboard and port of the ship
- Transponder handling winch

DP system:

- Kongsberg K-pos DP-21, classified by DNV as a Dynamic Positioning system of class 2

Other equipment:

- Taut wire LTW Mk15, position reference system
- Cy scan MK4, position reference system
- Active Heave Compensated (AHC) Main crane knuckle boom 70T + 15 T -900 m
- Palfinger provision crane 1,4T 20m

(Simon Mokster Shipping, 2014)

Figure 1. The project ship Stril Server.

4.3 Mobilisation of Stril Server

The mobilisation of the project ship Stril Server will be done at Waalhaven in the port of Rotterdam. The mobilisation includes the ROV equipment with spare parts which will be transported from Bluestream in Den Helder. Food, bunker and crew will be taken on board in Waalhaven, and the A-frames for the ROVs will be welded to the hangar deck. The estimated time for the mobilisation is 48 hours with some room for unforeseen events. The size of the crew is planned according to what is customary by Mokster Shipping and so that the ship can operate 24 h/day. When planning the mobilisation, the *IMCA mobilisation checklist* can be used. The deck in the ROV hangar on Stril Server is 190 m^2 so the two ROVs with A- frame can fit in and there is still room for working with the equipment if maintenance is needed. The ROV control room containers and a container with spare parts will be loaded on the main deck, in the "cargo hold" of the ship.

Equipment

- ROV Seaeye Lynx with control container
- ROV Seaeye Surveyor Plus with control container
- transponder for ROV
- 2 LARS A- frames
- Spare parts for ROV

Bunker

Bunker and lubrication oil are taken on board to last for the voyage to the Hans Deul location, for the project and back to Waalhaven. Stril Server has a fuel oil tank capacity of 600 m^3.

Crew and other persons on board

- Captain, Chief Officer, 1st Officer, 2nd Officer, 3rd Officer
- Chief Engineer, 1st Engineer, 2nd Engineer, Electrician
- 3 Able Seamen and 2 Crane handlers/Able seamen
- Chief Steward, Night and Day Cook, 2 Stewards
- 2 ROV pilots
- ROV supervisor
- 2 ROV mechanics
- ABS rig classification inspector
- Noble drilling representative (the client)
- 2 Survey persons

Food

Food and other household equipment needed for a crew of 28 persons will be taken on board in Waalhaven. Stril Server has a fresh water tank capacity of 240 m^3. If necessary, more water can be made during the voyage by two reverse osmosis water makers with a maximum of 20 m^3/ 24h water by each.

4.4 Voyage planning

The voyage begins in Waalhaven in the port of Rotterdam where the ship is mobilised and the crew is coming on board. The route goes from Waalhaven along Nieuve Waterweg to Hoek van Holland. After Hoek van Holland, the voyage continues in the Northwest direction using the Maas North West TSS (*Figure 2*). Outside Maas North West TSS the route continues northbound towards the Hans Deul location.
The route passes the Sleipner field to the last waypoint on the edge of the 500 m zone of the Hans Deul platform. The total length of the route is 449 Nm. The complete waypoint

list of the whole voyage can be found in *Appendix 1* and a picture of the rest of the route in *Appendix 2*. The voyage is planned using a Kongsberg ECDIS and Admiralty books.

Figure 2. Routeplan from Waalhaven.

4.4.1 Pilotage

- Compulsory for vessels of 75 m LOA or more.
- Pilot has to be ordered 48 hours prior to the estimated time of departure with the information including the name of the ship, maximum draught of the ship, destination and the time for when the pilot is expected to board.
- Pilot ordering by e-mail to: rotterdam@dirkzwager.com
- Pilot embarking in position: 52°03,8’ N, 003°48,8’ E
- Website for pilotage in the Netherlands: http://www.loodswezen.nl/

4.4.2 Vessel Traffic Service (VTS)

- The VTS area along the route from Waalhaven to Maas North West TSS is divided into six sectors (see *appendix 3*).
- The reporting points outbound from Waalhaven are: 1) when entering sector Eemhaven, 2) when entering sector Botlek, 3) when entering sector Maassluis, 4) when entering sector Rozenberg, 5) when entering sector Maas Entrance, 6) when

entering Pilot Maas area, 7) at the beginning of Maas North West TSS and the last reporting point is situated after the TSS on the way northbound.

- The VTS is operated from three Traffic Centres: Traffic Centre Rotterdam (VHF Channel 11), Traffic Centre Botlek (Ch 11) and Traffic Centre Hoek van Holland (Ch 11).
- Harbour Coordination Centre on VHF Channel 14 is responssible for questions, messages, reports, tidal window requests, mooring and emergencies.

  Telephone: +31102521000, E-mail: hcc@portofrotterdam.com

4.4.3 Electronic Data Interchange (EDI)

- Notification 3h before departure if carrying dangerous goods including information: A, B, G, I, O, P, T1, U and W
- Notification 3h before loading noxious and/or dangerous cargo including information: A, B, G, I, O, P, T1, U and W
- reporting of ETD information 3h prior to departure including information about: A, I, J, K, O, P, Q, T1, T2, U, W, X1, X2, X3

4.5 Procedures for the arrival at the Hans Deul rig

Because of the high risk environment when working with offshore operations most of the offshore installations have a safety zone of 500 m and specific rules for approaching that safety zone. It is also clearly stated what is allowed inside the safety zone, and what station keeping method has to be used on the ship when inside the safety zone. A safety zone can be set around a structure or a vessel. Although there is no safety zone around an offshore installation, it would be good to use certain practices when arriving to avoid collision. When approaching, the vessel must have its course like a tangent to the safety zone; it is forbidden to approach the offshore installation directly. The position of the offshore installation cannot be used as the last waypoint. Before a vessel enters a safety zone, a pre-entry checklist must be completed. The setting up of the DP-system and completing the pre-entry checklist is preferably done in a drift-off position if possible. After completing the pre-entry checklist, the vessel has to ask the platform for permission to enter the safety zone. When planning for the arrival and the work inside the safety zone, the weather and the sea state must be taken into account. Wind and wave limits for safe work have to be set, and the station keeping method of the vessel has to be decided. Inside most safety zones the ship has to be in dynamic positioning mode. Which station keeping method is required depends on the location, weather, type of platform or structure, and can most often be decided by the Master or Watchkeeping Officer. (Guidelines for Offshore Marine Operations (GOMO), 2013 p.64-66)

The planned procedure for the arrival with Stril Server to the Hans Deul jack-up rig can be seen in *Figure 3*. According to the routeplan for Stril Server, the course for approaching the last waypoint is 015^{o}. As can be seen in *Figure 3*, the last waypoint is at the edge of the 500 m zone, from where the range and bearing to Hans Deul are 0,3 Nm and 284,9^{o}. Depending on the wind and waves at the location, the course and side for approaching may have to be changed in order to have the vessel in a drift-off position from the platform. But in that case the new course should also be planned in the same manner, like a tangent to the safety zone.

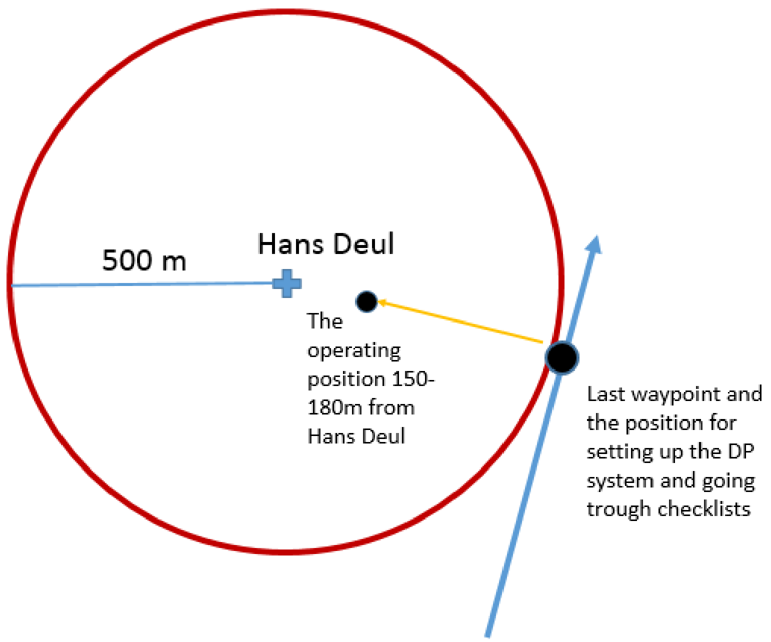

Figure 3. The arrival at the 500 m zone around Hans Deul.

5 Conducting a rigleg inspection on the Hans Deul jack-up rig

The Hans Deul rig (*Figure 6*), owned by the offshore drilling company Noble is situated in the Gina Krog field in the Norwegian area of the North Sea. The Gina Krog gas and oil field is located in the block 15/5 and 16/6, and the rig is situated in the position 58º 34'8.62 N, 001º 42' 10.61 E. The water depth at the location is 120 m. Hans Deul is a jack-up rig with three triangular formed, trussed steel legs with spudcans. The derrick is situated on a cantilever.

Details of the Hans Deul rig:

- Type of rig: Jack-up
- Rig design: Friede and Goldman JU 2000 E
- Building year and location: 2008, Dalian shipyard, China
- Classification: American Bureau of Shipping (ABS)
- Operating water depth: 122 m
- Drilling depth: 9155 m
- Leg length: 167 m
- Leg spacing: 45,7/ 47,5 m
- Leg diameter: 18 m

Figure 6. Hans Deul jack-up rig

5.1 Type of inspections requested by Hans Deul

The drilling company requests a rigleg inspection of the forward leg of the Hans Deul rig. The rig has been transported to the site quite recently and jacked up in the right position. During the jacking, there was a small punch trough of the forward leg, it went deeper into the seabed than the other two legs which could have caused damage or bending to the leg and therefore, it must be inspected. Furthermore, they want to clean the rigleg of marine growth on five places at different heights and locations to check if there is corrosion or any indication of cracks in the welds. If corrosion is found then the thickness of the steel has to be measured to make sure if the corrosion is on the surface or if it has gone deeper and possibly decreased the thickness of the steel. By inspecting at five places of the rigleg, a good overview of the rigleg's overall condition will be obtained. If severe damage or corrosion is detected, maintenance work and further inspections will be required.

5.2 Description of the ROV equipment on board Stril Server

On board the Stril Server there will be two ROVs available for the inspections. One of them is the light workclass ROV Seaeye Lynx (see *appendix 4*). The Seaeye Lynx is designed for light work, observation, inspection and diver support. The depth range of Seaeye Lynx is 1500 m and it can operate in harsh conditions and strong currents. Lynx has a payload of 34 kg which makes it possible to add many additional tools and sensors, but also use changeable tool skids under the vehicle. The vehicle can be used as free swimming or with a tether management system of type 8. The tether inside the TMS is 200 m long. Four live video cameras with HD capability can be mounted on the vehicle. (Bluestream, 2015)

Equipment that can be mounted on Seaeye Lynx:

- Sonar systems, altimeter
- CP Probe
- CTD probe for measuring bathymetric and conductivity, temperature and pressure
- Ultrasonic thickness gauge
- Tracking system

- Changeable tooling skids, water-jet, four functioning manipulator, cutting tool and cleaning brush
- Flooded member detection tool skid

The other ROV taken on board the Stril Server is a Seaeye Surveyor Plus (see *appendix 5*) which is bigger than the Lynx but is also designed for inspection, survey and observation work. The Surveyor can also be used for construction and drill support up to 600 m deep, and it can carry a payload of 45 kg. The vehicle has eight vectored horizontal thrusters and two vertical thrusters, and it can be set on auto heading and depth. The Surveyor can carry the same equipment as Seaeye Lynx but the Surveyor is able to use a multi-function manipulator and has also a colour zoom camera and a low light camera. (Bluestream, 2015)

5.2.1 Briefing before the inspection

A briefing will be held on the ship before the inspection and ROV work starts. The objectives of the inspections, the ships operating mode, the risk assessment, communication and possible useful information about the type of inspections will be discussed. Possible simultaneous operations on the rig during the ROV work will also be discussed, if they will affect the inspection work.

People involved in the project:

- Noble drilling (the client)
- Survey personnel
- ROV team: ROV supervisor, 2 ROV pilots, 2 ROV mechanics
- Bridge team: 2 DP operators, Able seamen
- Inspector from the American Bureau of shipping

5.2.2 Communication

Communication is a very important part of ROV operations. Radio communication is needed between the bridge and the ROV control room and the handling system control station when operating the A-frame. Instead of operating the A-frame from a handling system station, a wireless handling system can be used in some cases to make it easier to see the operations. The bridge has to communicate with the platform before launching the ROV or conducting other operations which could affect the work on the platform.

Communication between the positioning sensors and the ROV control room has to be maintained continuously so that the position of the ROV is known all the time. Access to camera feed has to be maintained for all operating personnel, also on the bridge and in the platform control room. If divers are working in the vicinity of the ROV or together with the ROV, there must be radio communication between the dive control and the ROV control room. (IMCA, 2013, p.10)

5.2.3 Tools attached to the ROV

Different tools will be attached to the ROV by changing the tool skid under the vehicle. The tool skids needed in these inspections will be a skid with a brush for cleaning the surface to be inspected and a tool skid with a manipulator which can grab things or do some work. Tool skids with flooded member detection equipment will also be used in the inspections. A water jet skid can be needed for more thorough cleaning of the steel structure from marine growth. On top of the vehicle, a transponder for the location reference system will be mounted.

5.2.4 International Marine Contractors Association

The International Marine Contractors Association (IMCA) represents companies and organisations working in the offshore industry with marine and underwater solutions like diving and ROV. IMCA provides its members with regulations and technical guidance. IMCA operates via technical committees with experts from the member companies, which have compiled a wide range of guidance documents. Bluestream is a member of IMCA and its working procedures thus follow the IMCA Guidelines for ROV operations. (IMCA, 2015)

5.2.5 Pre- and post-dive checks of the ROV

To detect possible problems or failures, the ROV has to be checked before launching it to the sea. The vehicle should be checked for loose parts, unsecured wires or hoses, oil leakage, obstructions in the thrusters, or dirty camera lenses. The command controls should be tested and the vehicle response and indicators checked. Vehicle ‘Power-on’ checks should also be done. Possible additional tools have to be checked. Inspection of the electrical lines and connections, hydraulic system, and fluid levels must also be checked according to the check lists.

The post-dive check includes the same checks as the pre-dive check but includes also washing the vehicle with fresh water if possible. (IMCA, 2009, p. 24)

5.3 Launching the ROV

There are two ROV hangars on the Stril Server, one on each side of the ship. The ROV will be launched to the water through a side hatch with an A-frame situated inside the hangar (*Figure 7*). During the mobilisation, the A-frame is welded to the deck inside the hangar to keep it in place in heavy weather and to avoid damage to the personnel or the expensive equipment. The A-frame is a launch and recovery system (LARS) in which the ROV hangs inside a frame. The ROV will be attached to the tether management system. The ROV is attached to the A-frame so that the frame is positioned with the docking collar over the umbilical attachment place. The umbilical is winched through until the TMS is engaged to the docking collar. Before turning on the electrical power, the pre-dive check will be carried out. Then the vehicle is ready to be lifted off the deck after the permission is given from the bridge. The TMS with the ROV is lowered down until it reaches the working depth and there, after a final check of the underwater conditions the latches will be released and the ROV is operated out of the TMS. There is a tether payout counter inside the TMS so the ROV pilot knows how much tether is free in the water when operating the vehicle. (Fugro)

Figure 7. Launching the ROV with an A-frame from a side hatch

5.3.1 Location reference system and marking

To find the places to be inspected, some kind of location reference system has to be used. When conducting rigleg inspections with the ROV, a transponder beacon will be mounted on the vehicle. The transponder is part of the vessel's HiPAP location reference system. The Stril Server has a transducer under the hull which is transmitting an acoustic signal to the transponder, whereby the position of the ROV related to the vessel is known.

The position can be seen on a screen in the ROV control room on a chart made by the survey department. If something is found during the inspections which has to be repaired or inspected further, it has to be marked on the chart which makes it possible to find the spot again later. The use of navigational charts (WGS 84) is not convenient when operating on a small area. Therefore UTM (Universal Transverse Mercator) charts are used for ROV operations and other offshore work. The UTM chart is divided into zones and a position is expressed in Northings and Eastings in meter. Some kind of physical marking can also be put on the structure. (Bluestream interview 16.11.2015)

A long baseline transponder array will be placed on the seabed for the placing of the legs on the right spots before the arrival of the rig. These transponders can also be used for the DP- system of the ship for more accurate positioning.

5.4 Safety Analysis of launching the ROV

The launching of the ROV is a critical operation which can injure personnel or lead to damaged equipment if something goes wrong. The weather can also be a reason for accidents during launching, and the impact of the weather must be estimated before starting ROV operations. It is important that the work is planned thoroughly and a safety analysis is made before commencing the work. Guidance documents for the safe operating of ROVs can be found among the IMCA Guidelines.

This safety analysis is done similarly to a job safety analysis for a specific job, task by task. There are, however, also many other ways to do a safety analysis or risk assessment. This safety analysis is done for this particular part of the project and cannot be used for other stages in the project.

Table 1. Safety analysis of launching the ROV with an A-frame through a side hatch.

Situation	Hazard	Effect	Prevention
Opening the door to the side hatch.	A person or equipment can be squeezed by the door.	Severe injury to personnel or equipment because of squeezing.	One person have to check the door when another one is operating it and communicate with the operator.
Open side hatch	Person can fall overboard through the side hatch.	Injury or hypothermia to personnel but also risks for the MOB crew when rescuing.	Use of safety harness when working near the hatch when it is open.
Pre-dive check of the ROV	Leaking oil from the vehicle or other parts of the equipment.	Personnel inspecting can be exposed to hydraulic oil or oil can leak on deck making it slippery. Oil leaking to the sea.	Use of gloves and goggles when inspecting the vehicle. Always have oil absorbing material ready for use near the vehicle.
Lifting the vehicle off the deck with the A-frame.	Damaging the equipment because of wrong handling of the lifting system.	The team is unable to continue the work and time and money is needed for repair.	Checking the manual before operating, especially with new systems.
	Damage to the vehicle or lifting equipment because of high waves.	The team is unable to continue the work and time and money is needed for repair.	Always check the weather before starting the lifting. Change the heading of the ship to avoid rolling.
Lowering the vehicle to the sea through the splash zone.	Breaking the umbilical because of too fast and unexpected load on the umbilical caused by waves.	Damaging the umbilical or losing the vehicle if the umbilical breaks.	Lowering the vehicle through the splash zone with a smooth continuous movement.
Operating the vehicle out of the TMS cage.	Colliding the vehicle with underwater structures.	Damage to cameras or tools mounted on the ROV.	Detailed planning of how to navigate the ROV to the right place and good maintenance of the cameras and sensors.

5.4.1 Permit to work

Most ships have a permit to work system which has to be used before conducting more unusual or hazardous work. The permit to work system can also be seen like a check before starting the work to help making it safer. It is also a way of communicating between the bridge team, ROV team and the offshore facility. In this case, the permit to work system of Mokster shipping should be used because the work is done from the Stril Server. The permit to work is given for a specific work task and for a clearly specified time. Simultaneous operations and restrictions because of that have to be identified. The need for physical or other barrier arrangements or emergency arrangements is written in the permit to work. Also the personal protective equipment which has to be used in the work is included. The permit to work has to be approved and signed by the issuing authority and the result communicated to all involved parties. (GOMO, 2013, p.27)

5.4.2 Tool box talk

A tool box talk for the personnel involved in the work should be carried out before starting. The individual roles in the work are discussed and the tools and methods to be used. The permit to work and risk assessment are reviewed but also the emergency actions and exit routes from the work site are described. The type of personal protective equipment required is also stated. (GOMO, 2013, p.28)

5.4.3 Safe weather conditions

The A-frame launching system can be used in waves up to 3,9 meters and a sea state of 5 - 6. The system can be operated normally in these conditions. (Bluestream interview 30.9.2015) If the wave height increases the ROV should be left under the surface until a sea state which allows a safe recovery. The free swimming ROV can withstand far less weather than the A-frame system. The actual limits for when the work is stopped depends on company regulations and the type of ship. If the ship is rolling a lot, it can be a risk for the personnel even if the ROV system could stand the weather. The sea current at the location has also to be taken into account when planning the work but it seldom makes the work with an ROV impossible. (Robert D. Christ and Robert L. Wernli, 2007, p. 192)

Other factors affecting the safe launching of an ROV are wind speed, wave direction, visibility and surface current. Sea state 6 on the Beaufort scale, with a wave height of 4,25 m and wave period of 8-10 sec, is usually seen as the maximum possible sea state for operating an ROV system. The ROV supervisor should make an estimate of the weather situation and decide whether it is safe to work or not. (IMCA, 2013, p.12)

5.5 Inspection work and the possible outcome of the inspections

For the first part of the inspections, a tooling skid with a cleaning brush will be attached to the Seaeye Lynx ROV. After the ROV has been launched to the sea and released from the TMS cage, it will be manoeuvred to the first inspection place where the steel is cleaned from marine growth using the brush tool and then inspected for corrosion. The right place to inspect will be found from the survey chart on a screen in the ROV control room and with the help of information from the depth and position sensors on the ROV.

On the way down to the inspection place, the cathodic protection anodes will be inspected with a quick visual inspection and the condition of the anode will be determined and the need for replacement considered. If the amount of corrosion found in the inspection is considered so severe that it could affect the thickness of the steel, it has to be measured later with point steel thickness measuring equipment. If a crack in the steel is found, a flooded member detection inspection (see *figure 8*) has to be carried out to ensure that there is no water inside the steel member. Water inside the steel member can cause the steel to corrode on the inside which is hard to detect. A huge amount of water inside the steel members can also change the center of gravity and weight of the rigleg. When moving around the rigleg with the ROV, the structure is also visually checked for possible bending of the steel members or chords. The bending could have been caused by a small punch trough during the positioning of the rig.

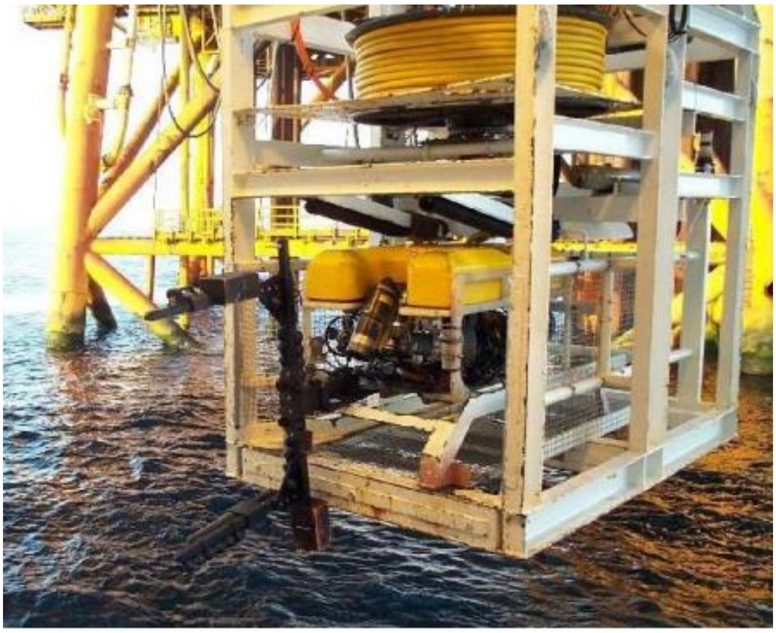

Figure 8. ROV inside the TMS cage with flooded member detection (FMD) equipment attached to the vehicle.

The five spots at different heights the client wanted an inspection of are cleaned with the brush and inspected. If there is a need for further inspections, these will be written down and marked on the charts. For further inspections, the ROV is recovered from the water and the tooling skids are changed to flooded member equipment or steel point thickness measuring equipment according to what is needed. Another way to do it is to launch the other ROV with for example a tooling skid for flooded member detection and swim it down to the inspection site while the other ROV is coming up. However, if doing so there is a high risk to entangle the tethers. When operating ROVs from a ship with side hatches, it is not common to operate two at the same time due to the small distance between them which is a risk for damaging the vehicles or to get the tethers entangled.

A daily progress report is given to the client including information about the inspections and the outcome of the inspections during the day. Writing maintenance reports and system breakdown reports is a part of the work. Logs of the operations are also kept, both in written form and as video material from the cameras. It is important that all the different stages and times in the project are written down together with the outcome of the inspections. At the end of the project, a summary of the inspections is written and possible further maintenance or repair of the rigleg is planned if required.

6 Discussion and conclusions

The method used for this thesis seemed to be successful because I found enough material to draw my own conclusions about the different parts of an offshore project, and combining them with the recommendations from the personnel actually working with this kind of projects made a good result. The research questions could have been smaller because the project turned out broader than I expected.

The biggest challenge was to find information about rigleg inspections. How to actually conduct the inspections in a practical way was the hardest matter to find out and it did not turn out as good as I expected. Another interview with the personnel from Bluestream could have been useful because the first one was mainly about asking quite basic questions about ROV operations and the capabilities of the vehicles as my knowledge about ROVs was not that good at that stage. They also showed some vehicles and equipment in the maintenance hall. During the writing process, more questions about practical issues came up. Unfortunately there was no time for another long interview, only for short questions by e-mail. A better result for how to conduct the inspections on the rigleg could have been achieved by also interviewing another company working with sub-sea operations or a company owning a drilling platform. I contacted a drilling company but they did not reply.

A question that came to my mind when writing the thesis is how well the bridge crew is prepared for ROV operations from their vessel. Do they have enough knowledge about ROVs and possible safety related issues? Is the communication between the ROV team and the bridge team sufficient? This could be an interesting question for further research. Another area to research could be how to operate the DP- system on a vessel during ROV operations.

Overall, I think it was an interesting subject and I learned a lot during the process. Especially my knowledge about ROV has improved from barely knowing what an ROV is, to having a good understanding of the different parts and deploying of an ROV system. I think it would be interesting to work on a ship conducting this kind of operations.

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List of figures

Appendix 1

Waypoint list for the route Waalhaven to Gina Krog

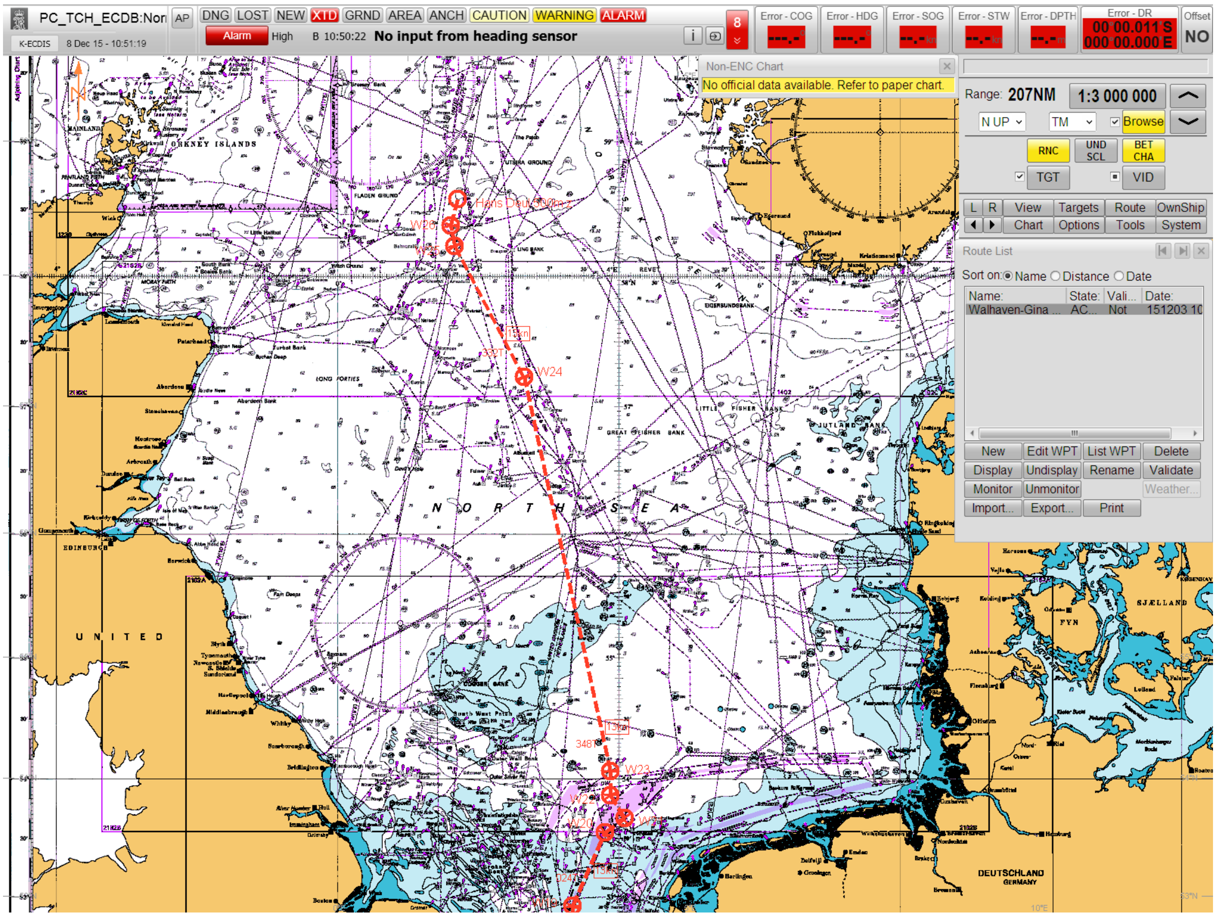
Waypoint List

Route Name: Walhaven-Gina Krog MSV Stril Se Edit... Route Not Changed. - Not Validated

W.	Name:	Lat:	Lon:	Crs:	Dist:	Leg:	TDist:	RDist:	Spd(...	ETA:	RTime:	ETD/Wait:	Radius:	Offtrack:	Max(...
1	Waal...	51°53.690'N	004°26.332'E	335.3	0.5NM	RL	0.0NM	448.7NM	5.0	00:00	1d 09:46	00:00	0.10NM	100m	0.0
2		51°54.161'N	004°25.982'E	274.6	0.3NM	RL	0.5NM	448.3NM	5.0	00:05	1d 09:40	00:00	0.10NM	100m	0.0
3		51°54.185'N	004°25.483'E	253.5	1.2NM	RL	0.7NM	448.0NM	10.0	00:08	1d 09:37	00:00	0.50NM	100m	0.0
4		51°53.834'N	004°23.566'E	280.4	1.2NM	RL	1.9NM	446.8NM	10.0	00:15	1d 09:30	00:00	0.50NM	100m	0.0
5		51°54.057'N	004°21.598'E	248.4	0.9NM	RL	3.1NM	445.6NM	10.0	00:23	1d 09:23	00:00	0.50NM	100m	0.0
6		51°53.613'N	004°19.786'E	280.4	1.9NM	RL	4.1NM	444.7NM	10.0	00:28	1d 09:17	00:00	1.50NM	100m	0.0
7		51°53.894'N	004°17.313'E	301.3	1.8NM	RL	5.9NM	442.8NM	10.0	00:39	1d 09:06	00:00	0.50NM	100m	0.0
8		51°54.779'N	004°14.962'E	306.3	0.5NM	RL	7.7NM	441.0NM	10.0	00:50	1d 08:55	00:00	0.50NM	100m	0.0
9		51°55.118'N	004°14.216'E	322.9	1.0NM	RL	8.2NM	440.5NM	10.0	00:53	1d 08:52	00:00	0.50NM	100m	0.0
10		51°55.904'N	004°13.255'E	300.5	1.3NM	RL	9.2NM	439.6NM	10.0	00:59	1d 08:46	00:00	0.50NM	100m	0.0
11		51°56.550'N	004°11.479'E	307.8	3.1NM	RL	10.5NM	438.2NM	10.0	01:07	1d 08:38	00:00	0.50NM	100m	0.0
12		51°58.459'N	004°07.493'E	290.6	3.2NM	RL	13.6NM	435.1NM	10.0	01:26	1d 08:20	00:00	0.50NM	100m	0.0
13		51°59.550'N	004°02.782'E	293.5	3.5NM	RL	16.8NM	432.0NM	13.5	01:45	1d 08:01	00:00	0.50NM	100m	0.0
14		52°00.958'N	003°57.540'E	298.0	6.1NM	RL	20.3NM	428.4NM	13.5	02:00	1d 07:45	00:00	0.50NM	100m	0.0
15	Pilot	52°03.796'N	003°48.866'E	291.1	7.7NM	RL	26.4NM	422.4NM	13.5	02:27	1d 07:18	00:00	0.50NM	100m	0.0
16		52°06.577'N	003°37.169'E	307.1	6.3NM	RL	34.0NM	414.7NM	13.5	03:01	1d 06:44	00:00	0.50NM	100m	0.0
17		52°10.468'N	003°28.817'E	349.4	23.8NM	RL	40.4NM	408.4NM	13.5	03:30	1d 06:16	00:00	0.50NM	100m	0.0
18		52°33.701'N	003°21.701'E	358.7	21.0NM	RL	64.2NM	384.6NM	13.5	05:15	1d 04:30	00:00	0.50NM	100m	0.0
19		52°54.698'N	003°20.932'E	023.7	41.0NM	RL	85.1NM	363.6NM	13.5	06:49	1d 02:57	00:00	0.50NM	100m	0.0
20		53°32.201'N	003°48.361'E	053.9	12.2NM	RL	126.1NM	322.6NM	13.5	09:51	23:54	00:00	0.50NM	100m	0.0
21		53°39.563'N	004°05.304'E	327.8	13.9NM	RL	138.3NM	310.4NM	13.5	10:45	23:00	00:00	0.50NM	100m	0.0
22		53°51.181'N	003°52.951'E	360.0	12.3NM	RL	152.2NM	296.5NM	13.5	11:47	21:58	00:00	0.50NM	100m	0.0
23		54°03.339'N	003°52.945'E	347.6	194.8...	RL	164.5NM	284.3NM	13.5	12:41	21:04	00:00	0.50NM	100m	0.0
24		57°13.265'N	002°39.187'E	332.0	68.0NM	RL	359.3NM	89.5NM	13.5	1d 03:08	06:37	00:00	0.50NM	100m	0.0
25		58°13.166'N	001°39.697'E	350.6	9.3NM	RL	427.2NM	21.5NM	13.5	1d 08:10	01:35	00:00	0.50NM	100m	0.0
26		58°22.343'N	001°36.821'E	014.7	12.2NM	RL	436.5NM	12.2NM	13.5	1d 08:52	00:54	00:00	0.50NM	100m	0.0
27	Han...	58°34.024'N	001°42.650'E			RL	448.7NM	0.0NM	13.5	1d 09:46	00:00	00:00	0.50NM	100m	0.0

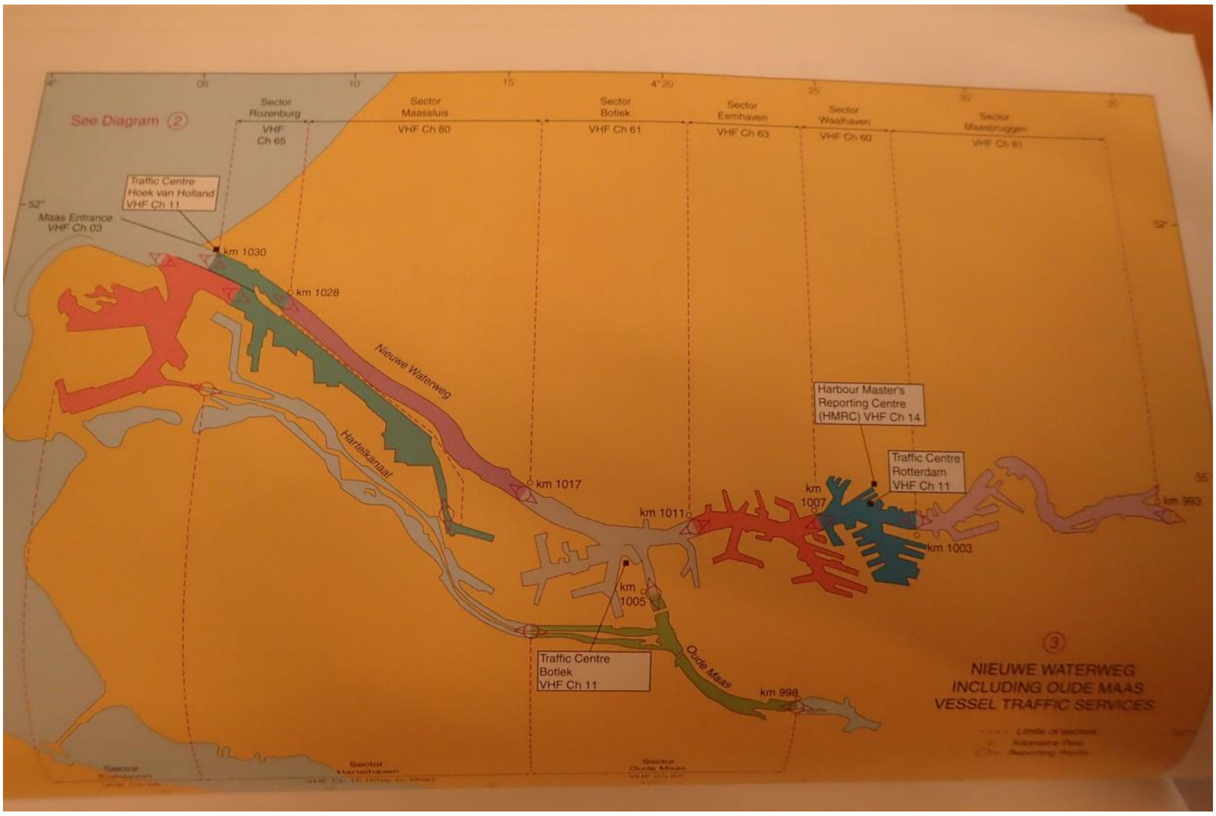
Appendix 2

Overview of the route Waalhaven to Gina Krog field



Appendix 3

Rotterdam VTS information



Appendix 4

Seaeye Lynx ROV

The Lynx is slightly larger and benefits from a fibre optic link to the surface, a depth rating of 1500m and a second vertical thruster.

The following options are available:

- TMS type 8 or free-swimming operation
- Up to four (live) video cameras
- HD video capability
- Sonar systems, altimeter
- Scientific measurement systems (bathy, CTD, etc)
- CP probe (contact or proximity)
- Tracking systems
- Ultrasonic thickness gauge
- Tooling skids: water jet, 4-function manipulator, cutting tool, cleaning brush
- Flooded Member Detector (FMD) tool orientation skid.

Appendix 5

Seaeye Surveyor Plus ROV