KYSTVERKET

Rev.	Issued date	Description	Made by	Chk'd by	Disc. appr.	Proj. appr.	Client appr.
01B	13.05.2026	Issued for Construction, IFC	SDA	TNM		EHØ	
01A	20.03.2026	Issued for Review, IFR	SDA	TNM		EHØ	
A	18.03.2026	Issued for SDC/IDC	SDA	TNM		EHØ	

Contractor: subsea 7

Client: KYSTVERKET

Contract No.: **N/A**

Study no:	Study title:				
260022/ EN5001	**U-864 MERCURY CARGO RECOVERY - FEASIBILITY STUDY**				
Document sub-type: RE	Platform(s):	Area(s):	System(s):	DFO code:	Tag(s)

Document title:
FEASIBILITY STUDY REPORT

Document no.: EN

Rev.: 01B

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REVISION RECORD SHEET

Revision	Issue Date	Purpose	Description of Updated/Modified Sections
A	18.03.2026	SDC / IDC	Internal review
01A	20.03.2026	IFR	Internal review comments implemented
01B	13.05.2026	IFC	Missing information and Client comments implemented

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1. SUMMARY

In this study, three normalized methods for recovery of mercury has been reviewed and commented on from a marine operation perspective. These three methods were based on the proposals from 5 different subsea companies provided to Norwegian Coastal Administration in 2013-2014.

The three methods have been reviewed and evaluated as outlined in chapters 5 to 7. The methods differ in their technical principles, and the evaluation aimed to see the three methods in a relative perspective. The conditions are similar, but the scheduled durations will differ slightly and create some differences in the estimated cost of the different marine operations.

The information about the wreck site, the knowledge about the situation at the seabed, the condition of the two submarine wreck sections, the seabed sediments and the distribution of registered pollution in the wreck area, has gradually lead to a wider understanding of the tasks that need to be done to recover mercury from the keel of the submarine wreck parts. This study provides marine operations input on how to execute the three proposed methods, what tools and equipment is required, and which vessels are required to perform the work. In addition, the durations of the work activities are reviewed in detail, and cost estimates have been worked out.

The results indicate that the favourable method is **Method 3: Cradle**. This assessment is based on the combined technical, economical and risk assessments done for the three methods. The evaluation results are summarized in section 1.1 below.

Having reviewed the formerly proposed methods, an alternative **Method 4: Cut** was proposed as part of the study work. A concept design for this method was developed based on somewhat different principles than what was the actual work task, namely to recover only mercury. The alternative method focused on reducing the vessel requirement, reducing subsea work tasks, and to transfer work from the seabed to topside. This was done by establishing a cutting method where the vital parts of the submarine containing mercury was cut-out to reduce the weights of the submarine parts to be lifted. This cutting allows for loading below 400ton structural loading/weight in air, and the possibility to lift the two submarine sections by a large HCV which is in a lower cost range then the HLV required for lifting the full sections of the two wreck parts.

A mechanical claw was designed that can grip the reduced size submarine tubes from the outside, avoiding all the detailed work to get access to the pressure vessel to connect lifting wires to the hull like method 3 requires. Avoiding much of the dredging and connection work allows for a large reduction in the operation periods. Together with the moving of mercury recovery to surface, this change can lead to significant expected cost reduction for Method 4: Cut.

To the presented cost for Method 4: Cut, Norwegian Coastal Administration need to add the cost of the additional topside work required to handle the two submarine parts and the removal of the mercury bottles at a suitable site.

1.1 Evaluation of Methods for Recovery of Mercury Cargo

Table 1-1 below summarizes the evaluation of the four methods versus simple evaluation criteria set up in a scale from 1-5:

1. Easier than a regular offshore operation.
2. Like a typical offshore operation.
3. Somewhat more challenging than a typical offshore operation.
4. Significantly more challenging than a typical offshore operation

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5. As a marine offshore contractor, we will recommend not executing an operation like this.

The idea is that this evaluation, together with the economic evaluation of the methods, can provide a useful relative comparison between the methods.

Table 1-1: Evaluation Criteria for comparison of methods.

Criteria	Roll	Rig	Cradle	Cut
1. Technical Feasibility To what extent the method requires available equipment and established work practices, as well as to what extent the solution is flexible and robust and provides room for alternative measures if the planned progress cannot be carried out as intended.	**5**	**4**	**4**	**3**
2. Maturity and Technology Readiness To what extent the method is documented, tested, and technically qualified, and to what extent the feasibility is independent of the development of new methods, processes, or equipment.	**5**	**4**	**4**	**3**
3. Environmental Risk Overall assessment of risk to personnel and the external environment, including risks associated with the handling and potential detonation of torpedoes.	**4**	**3**	**3**	**3**
4. Cost level and uncertainty Indicative comparison of cost levels and associated uncertainty between the alternatives, based on available knowledge and experience.	1449 mill. kr	1650 mill. kr	1229 mill. kr	918 mill. kr
5. Schedule Duration Overall estimate of operation time usage from start to completion, based on known assumptions.	36 weeks	31 weeks	29 weeks	12 weeks

1.2 Conclusions

1) The Method 3: Cradle is assessed as the favourable method of the three formerly developed methods for recovery of mercury.

2) If the principles for recovery are slightly changed, one can achieve cost reductions by making cut outs of the submarine parts in line with Method 4: Cut out smaller sections and recover only the parts that can theoretically contain mercury. This imply only sections of the submarine are recovered and much time-consuming subsea work is transferred to topside. This is a major simplification of the subsea scope of work, and lead to larger cost reductions. Note that some topside cost must be added by Norwegian Coastal Administration to this estimate.

3) A decision to not lift the cut out parts, but leave them at the seabed on the frame represents an alternative solution. In this M4B variant, the mercury need to be recovered from the submarine parts located on the frames, somewhat similar to the M3: Cradle method. In this case, the expected economic benefits will be reduced compared to method 4, but is still expected to be more favourable than Method 3: Cradle.

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4) The method 4 will handle also the torpedo hazard in an acceptable manner allowing for a potential detonation of the torpedoes as the ship parts are pulled away from the wreck.
5) A potential detonation will not lead to significant increased pollution if the area below the bow and stern sections are sand bagged before the cut operation.

1.3 Recommendations for Further Work

It is recommended to continue working towards the principles of the proposed Method 4: Cut with recovery of two smaller sections of the submarine without opening the keel cases subsea by WROV's due to its simpler subsea scope and the much shorter duration for this work. Such a focus ensures the overall cost will be much lower than the alternatives of Methods 1-3. Note that this approach requires extending the topside scope of handling the mercury to include opening of the keel cases and the full inspection of the keel cases onshore.

It is recommended to focus on three operational uncertainties of Method 4, under the activity preparations for cutting. The three major issues are:

1. **Gaining access for the DWS cut wire** - The exact locations of the cuts need to be decided first. Thereafter, the DWS must be positioned in the terrain model to confirm coordinates of the diamond wire cut line. Based on this, the dredging work can be planned at exact positions to ensure wire can be led all the way down and through the entire submarine outer hull. This may require drilling/hammering away sufficient rock volumes to establish movement of freedom for the DWS arms.

2. **Anchor Handling Vessel pulling points** - Investigate the rough integrity of the pull-point at the bow and find a suitable or useful way to prepare a pull-point for the stern section.

3. **Stabilisation of wreck parts at the seabed** - Prepare a detailed plan for stabilisation of remaining and cut-off sections, with a particular focus on the fore and aft sections containing torpedoes. The idea is to maintain a stable position for the remaining section to be lifted by the claw, while the cut-off section shall move away in a planned manner by the aid of an Anchor Handling Vessel (AHV). The cut-off section can later be stabilized and buried by the planned sand/rock dumping.

4. **Add topside work to cost estimate** - It is recommended to add plans and cost calculations for the topside part of the mercury recovery process to complement the revised subsea scope to get full overview of the overall mercury recovery operation.

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2. INTRODUCTION

2.1 Background

2.1.1 The Wreck Site

The German submarine U-864 was sunk by the British submarine HMS Venturer on February 9, 1945, about 2 nautical miles west of the island of Fedje in Hordaland. The submarine was on its way from Germany via Norway carrying war materials to Japan and may have transported nearly 70 tons of metallic mercury (in liquid form), stored in steel containers in keel cases at the bottom of the submarine. Parts of this cargo have been found scattered on the seabed around the wreck, which lies at a depth of 140–170 meters, leading to mercury leakage into the surrounding water. /1/

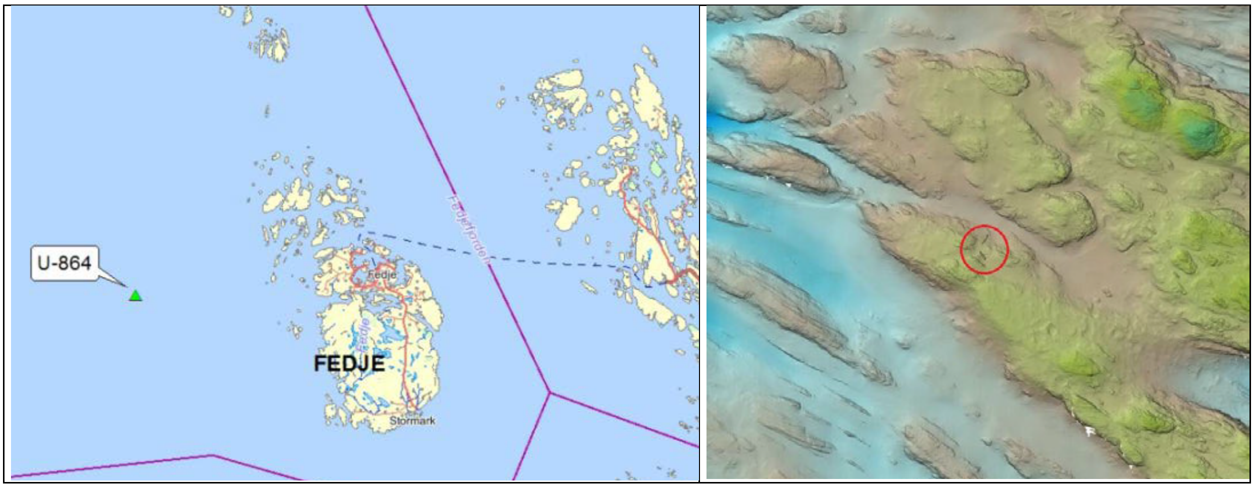

Figure 2-1: The location is shown in left image, while the right image is a sonar DTM image of the wreck of U-864 lying in two main parts the seabed (ref. DoF /16/).

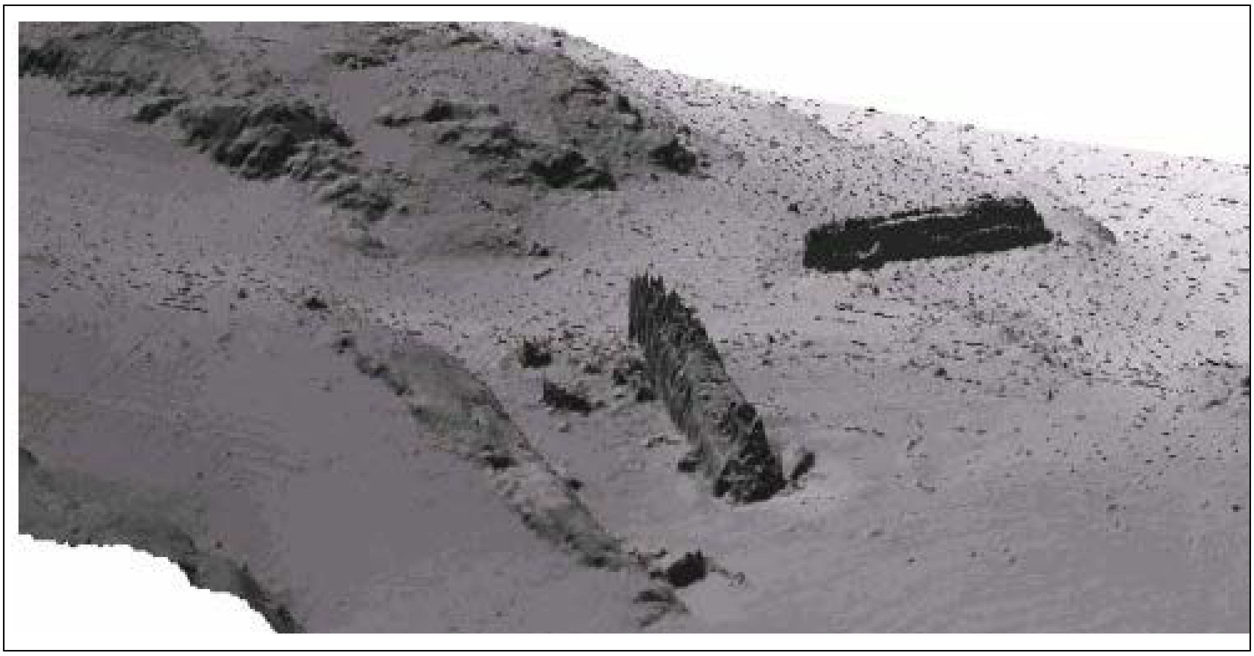

Figure 2-2: The early sonar DTM image of the wreck of U-864 lying in two main parts at the seabed (ref. Geoconsult).

The Figure 2-3 below shows more details of the keel case and the placement of the mercury containers illustrated for an intact submarine. The extent of the keel case in the longitudinal

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direction is marked by red colour in the figure and is divided into two by a vertical centre plate. The width of the keel case is approximately 1.2 m, and the length of each chamber is 0.7 m. The U-864 submarine had a total of 130 keel cases before being torpedoed.

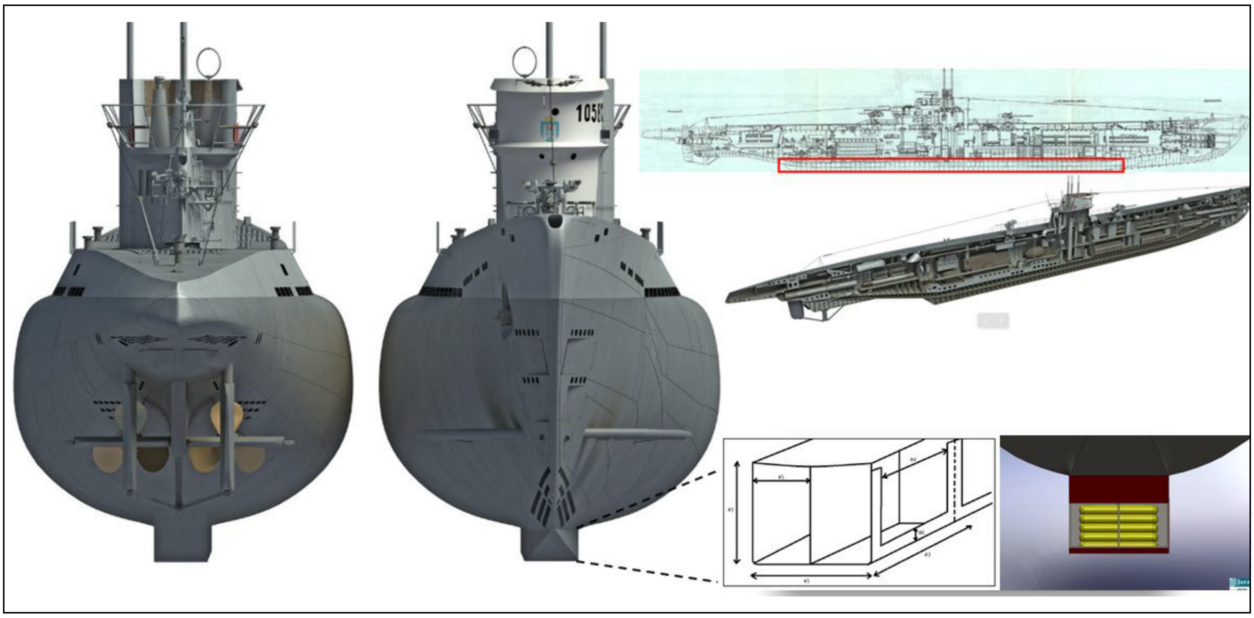

Figure 2-3: The placement of the keel case at an intact submarine. Lower right illustration shows how the cylinders with mercury was stored inside the cases.

2.1.2 Previous Work and Development of Alternative Solutions

The project "Environmental measures at the wreck of U-864" ("Miljøtiltak ved vraket av U-864") was established in 2006. Since then, several investigations have been carried out by Norwegian Coastal Administration to determine what should happen to the wreck and its cargo. The Norwegian Coastal Administration (No. "Norwegian Coastal Administration") has on several occasions recommended that it be covered. Covering is a method that isolates the pollution and can withstand various external events such as earthquakes, emergency anchoring, trawling, and wreck collapse.

A soil investigation was performed in 2006 (NGI, 2006). In January 2013 a new soil investigation was performed as part of a larger survey. /3/

During the period leading up to the preliminary project and the preparation of the Central Management Document (No. Sentralt Styringsdokument, SSD) /4/, many studies and investigations of the wreck have been carried out to ensure the best possible information about the wreck and the geology at the wreck site. In the course of carrying out the preliminary project, the previous studies have been supplemented with new investigations where this has been deemed necessary, and practically feasible, to better assess the possibilities and challenges for an operation to raise the cargo.

In 2013, DNV GL was awarded the task of assisting the Norwegian Coastal Administration in developing a central management document /4/ for the preliminary project. The included an analysis of costs, progress, and risks for relevant measures planned to be executed. In October 2013, a feasibility study for recovery of the Mercury load was executed in terms of

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work shops with relevant industrial partners from the offshore sector. Five offshore companies took part in this work shop.

In 2014, the Pre-study "Forprosjekt heving av last" on the handling of U-864 outlined *four alternatives* to be further investigated:

1) The zero alternative of doing nothing
2) Alternative 1: Covering the wreck and contaminated sediments
3) Alternative 2: Raising the entire wreck and covering the sediments, and
4) Alternative 3: Lifting the cargo (mercury containers) and covering the contaminated sediments.

For Alternative 3, a solution for raising the load has not been developed. This is expected to be a very challenging operation, and there may be many different solutions for carrying it out.

After the new seabed surveys in the action area around U-864 in 2013, geotechnical experts from NGI and DNV GL recommended that the placement of support rock fill should be initiated as soon as possible. The work was carried out in the spring of 2016 by the company VanOrd.

No final political decision has been made, and in 2020 the Norwegian government established an expert committee to reassess what should be done. The expert committee's recommendation was to remove as much of the mercury as possible before the wreck and seabed are covered, partly due to the risks associated with raising parts of the wreck.

2.2 Current Situation at Seabed

During the autumn of 2024, the Norwegian Coastal Administration (No. Kystverket) received a commission from the Ministry of Trade, Industry and Fisheries to conduct a survey to map the wreck of U-864 and the surrounding areas, with the aim of *reducing uncertainties* in a plan for the possible salvage of parts of the mercury cargo.

In May 2025, an offshore campaign was carried out by Norwegian Coastal Administration with the aid of Reach Subsea at the wreck site with the purpose of collecting data and mapping the wreck parts and seabed as a basis for a 3D model of the area. Photogrammetry images from the 3D model are shown below providing a very good overview of the position of the wreck parts on the seabed. The report from Reach Subsea AS provides further visual presentations. /5/

2.3 Purpose

The purpose of this report is to present the context and the basis for the study and document the feasibility level assessments executed for the removal of mercury from U-864. This assessment is partly focused on the removal of mercury when applying the three existing methods as described in /2/, and the alternative stepwise approach as developed in this study.

The purpose of the procurement is to enter into a contract for the purchase of technical assistance to conduct a feasibility study related to the lifting of mercury cargo from U-864. The purpose of the feasibility study is to assess the feasibility of different methods to secure access to the refrigerated box on the two wreck sections of U-864, in order to gain access to as many mercury containers as possible. Furthermore, the purpose is to provide a cost estimate for and duration of the operation, and describe the risks associated with the different methods.

2.4 Scope

From the preliminary project in 2014, five companies presented different solution proposals for raising the mercury cargo. Based on this work, DNV combined the different descriptions into three different methods for recovery of the mercury load /4/:

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- **Roll** - digging and sideways rolling of the submarine parts to gain access to the keel.
- **Rig** - lifting the wreckage in a rig placed on the seabed to expose the keel for further recovery work.
- **Cradle** - lifting the wreckage from a surface vessel and placing it in a cradle where further mercury work can be done.

The scope of work for the feasibility study comprises the following main activities /1/:

1. Overall assessment of methods 1, 2 and 3 in terms of implementation, type of marine operations, and the associated equipment.
2. Assessment of practical methods for attaching to the pressure hull and possibly other ways to move or stabilize the wreckage (applies to all methods).
3. Assessment of limitations regarding weather (Max Hs)
4. Present a modified self-developed method/solution
5. For all methods, cost estimate for the marine operations is to be presented.

During the feasibility study, the formerly developed methods are evaluated in the perspective of personnel safety, the engineering design, fabrication and marine operations. Building on the former work, additional methods are proposed to improve the execution of recovery of mercury from U-864.

2.5 Definitions and Abbreviations

Table 2-1: Definitions and Abbreviations.

Abbreviation	Description
AHC	Active Heave Compensation
AHV	Anchor Handling Vessel
CoB	Centre of Buoyancy
CoG	Centre of Gravity
DAF	Dynamic Amplification Factor
DFO	Documentation for Operations
DoL	Depth of Lowering
DP	Dynamic Positioning
DSV	Dive Support Vessel
DTM	Digital Terrain Model
DWS	Diamond Wire Saw
GPS	Global Positioning System
HiPAP	High Precision Acoustic Positioning system
HCV	Heavy Construction Vessel

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Abbreviation	Description
HLV	Heavy Lift Vessel
LC	Lifting Claw
LCV	Light Construction Vessel
MBES	MultiBeam Echo Sounder
OBSROV	Observation ROV
ROV	Remotely Operated Vehicle
SBP	Sub Bottom Profiler
TSHD	Trailing Suction Hopper Dredger
UTM	Universal Transverse Mercator projection
WROV	Working Remotely Operated Vehicle

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2.6 References and Standards

Relevant references are provided in the following table.

Table 2-2: References and Standards.

ID	Document Number	Rev.	Title
/1/	N/A	V1.0	Konkurransegrunnlag Mulighetsstudie v1.0
/2/	N/A	1 (foreløpig versjon)	Kystverkets vurderinger og anbefalinger etter undersøkelse og kartlegging av U864 i 2025
/3/	20120738-01-R	0	U-864 2013 Soil survey, Geotechnical report, 17. April 2013
/4/	N/A	1.0	Sentralt Styringsdokument for Miljøtiltak ved vraket av U-864, Alternativ 3 Heving av last og tildekking av vrak og forurenset havbunn, 20.05.2014.
/5/	REACH-600057-SR-001	2	Reach Survey Report, Kystverket - U-864 Wreck Investigation 2025 Campaign 1
/6/	Vedlegg V3.03	12.05.2014	DNV GL Miljøtiltak ved vraket av U-864, Kvalitativ risikoanalyse Alt. 3 Heving av last
/7/	Vedlegg V3.06	12.05.2014	DNV GL Miljøtiltak ved vraket av U-864, Mulige tiltak for heving av last
/8/			Vedlegg V0.03 Geoteknisk vurdering av stabilitet ved tildekking
/9/			Keel Inspection U-864 (Phase 3b) (DOF Subsea)
/10/	Appendix V3.09		ENVIRONMENTAL MEASURES FOR THE WRECK OF U-864, Report from the visit to U-534
/11/			Vedlegg V0.10 Metode for usikkerhetsanalyse
/12/			Vedlegg V3.01 Fremdriftsanalyse Alt3 v.1.0
/13/			Vedlegg V3.03 Kvalitativ risikoanalyse Alt3 v1.0
/14/			Vedlegg V3.04 Use of divers to raise the mercury v1.0
/15/	600246-PJ-O15-0001	14.05.2014	Keel Inspection U-864 (Phase 3B) Report, DOF
/16/	600225-DSNO-O15-0002	18.04.2013 03	U-864 Phase 3A Survey and Geotechnical Campaign
/17/	DNV-RP-A203	09-2019	Technology Qualification - Recommended Practice

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3. PREREQUISITES

3.1 State of the Submarine IXD2 U-864

The technical state of the submarine wreck has been revealed during several survey missions with work tasks aiming to clarify the deterioration. The document /V3.06/ refers to the following reports and studies that are used to develop different solutions for recovery of mercury from the keel cases:

1. **Report** - KVU (January 2011) /D01/
2. **Report** - KS1 of KVU (November 2011) /D02/
3. **Mission 3a to U-864** - Basic investigations at the wreck site of U-864 (January 2013) (cf. Appendix V0.07)
4. **Recovered plate material** - Material testing of steel plate from the pressure hull (April 2013) (cf. Appendix V3.07)
5. **Study trip** – A team visit to U-534 (September 2013) (cf. Appendix V3.09)
6. **Feasibility study for raising cargo** - Workshops conducted with five offshore companies where measures for raising cargo were investigated (October 2013) (cf. Appendix V3.05.00-3.05.06)
7. **Trip 3b to U-864** - Testing of excavation and dredging at the stern section of U-864, opening of two keel boxes, and testing of real-time environmental monitoring program on U-864 (January 2014) (cf. Appendix V0.12)
8. **Keel case material** - Material testing of steel plates from keel cases (February 2014) (cf. Appendix 3.08)
9. **Environment** - Environmental objectives and acceptance criteria for measures on U-864 (February 2014) (cf. Appendix 3.01)
10. **Diving operations** - Use of divers to raise the mercury (April 2014) (cf. Appendix 3.04)

These documents has been available to Subsea7's study team. Combined with the survey data of the seabed and wreck sections and parts in the area, it was possible to get a reasonable good impression of the wreck's condition.

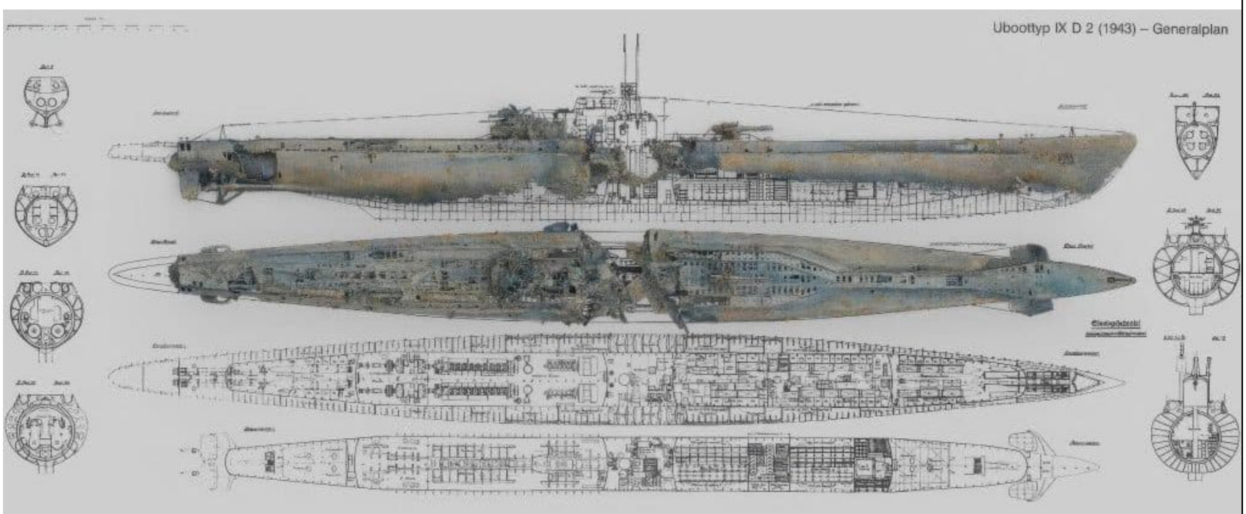

Figure 3-1: From the Norwegian Coastal Administration's report 15.09.2025 – Drawings of U-864 with photogrammetry from wreck parts clearly showing the fracture zone of the parts of the wreck that are above the sediments.

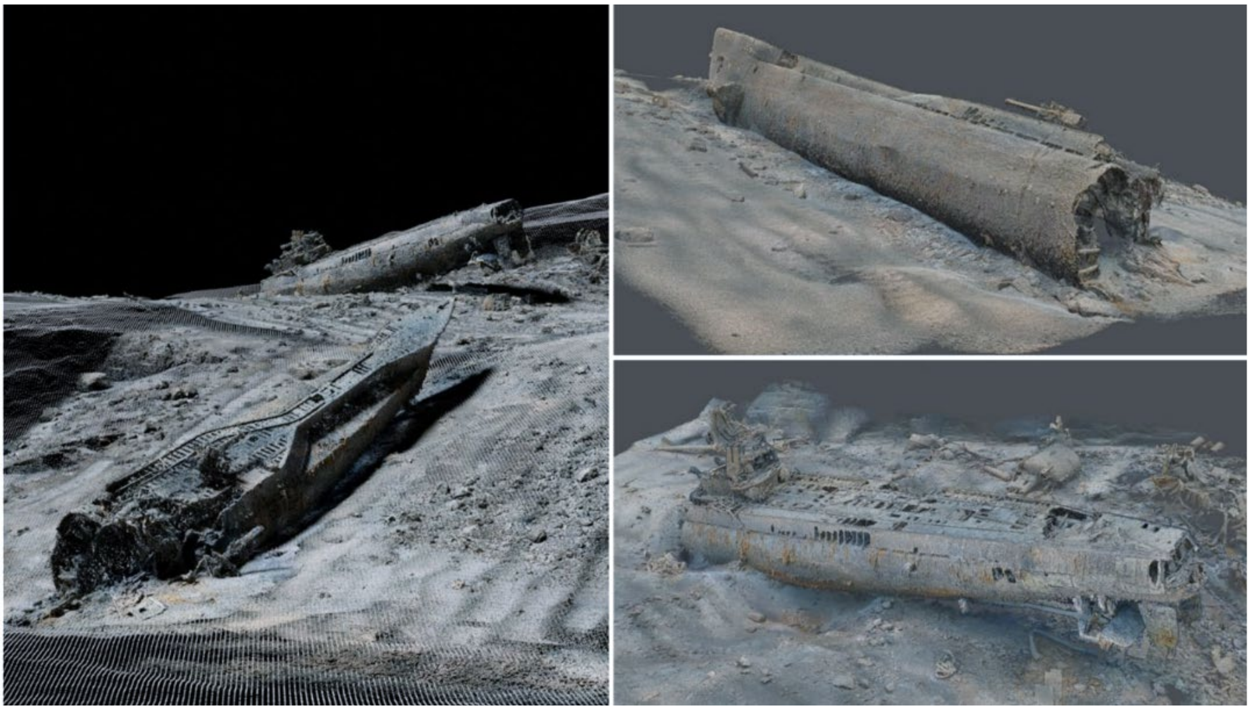

Figure 3-2: The photogrammetry images resulting from the video surveys of Reach Subsea in 2025 provides a very good overview of the situation at the seabed.

3.2 Norwegian Coastal Administrations prerequisites

The following overall guidelines for the solutions found by DNV in collaboration with Kystverket are:

1. The slope at the fore-section has been stabilized to prevent sediment slippage during work on the wreck. It is assumed that this issue has now been handled, and that there is no further danger for sliding movements.
2. Work in the sediments (excavation, dredging, and use of equipment on the sediments) must be minimized to reduce turbidity. Alternatively, measures must be implemented to ensure that contaminated materials are contained within the action area.
3. A real-time environmental monitoring system must be established and operational throughout the entire operation. If threshold values are exceeded, all work must stop, and the cause of the elevated values must be investigated and changes implemented to prevent further exceedances before work can resume.
4. Attachment of wire to the wreck parts must be done on the pressure hull, and the wire must run along the pressure hull, not on the outer hull.
5. To access the keel, the wreck must either be lifted out of the sediments or sufficient force must be applied by rolling so that the keel is forced upwards. Efforts should be made to reduce suction forces between the keel and sediments to minimize the force required and the risk of damage to the keel.
6. All actions on the wreck must be carefully planned and carried out in such a way that uncontrolled movements do not occur, as this could damage the keel and/or stir up contaminated sediments.
7. The solution must consider that access to the keel compartments must be possible from both sides. The side plates should primarily be removed by drilling out the screws that secure the plates.

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8. Saturation divers are assumed to be one optional intervention method in operations on the seabed. It is fully possible to implement risk reducing measures to ensure the safety of divers during this kind of work with regards to pollution. However, if the evaluation of the risk of detonation of torpedoes conclude that torpedoes can detonate, it is not acceptable within the normal operation planning of the offshore industry to accept this risk to personnel.
9. Mercury bottles and containers used for collecting liquid mercury should be gathered and temporarily stored.

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4. DEVELOPMENT AND EVALUATION OF METHODS

4.1 The Development of a Technical Solution

The development of a full technical solution shall typically apply through a FEED study, tender and project execution. The development of a technical solution shall typically encompass the following steps:

1. Understanding and defining the scope of work and interfaces including design functional requirements.
2. Reviewing applicable standards and previous relevant experience.
3. Developing a solution in accordance with Engineering Principles.
4. Involving engineering experts and operational specialists.
5. Ensuring adequate Safety in Design via relevant Engineering Reviews.
6. Preparing, producing, checking and approving fit for purpose engineering deliverables.

When the technical solutions are only described according to the *feasibility level* like in this study, the verification of the solutions is about ensuring confidence that the proposed technical solution is realistic, constructible, safe, and aligned with the client's project goals, without doing the full level of engineering performed in later project phases as mentioned above.

4.2 Study Deliverable Structure

The study delivers the following documentation:

- **Presentation** (EN-5001-260010-PR-02) outlining important aspects of the evaluation of the three former methods, their key risk exposures with regards to marine operations, proposed schedule durations, vessel setup and equipment for each method, and the cost estimates with comparisons for the different methods under evaluation.
- **Study report** (EN-5001-260010-RE-01) outlining the evaluation of formerly developed methods including:
  - Assessment of methods and activities
  - Schedule durations for Methods
  - Marine Operations Risk
  - Cost Estimate for execution of methods
  - Evaluation and Conclusion for all methods

Numerical models and digital spreadsheets used to develop a technical solution will typically not be shared with Clients and 3rd parties except when there is a contractual requirement.

4.3 Safety and Risk Screening

4.3.1 Qualitative Risk Assessment

A standardized, industrial approach for the risk assessment has been proposed in DNV GL document *Vedlegg V3.03 Kvalitativ risikoanalyse Alt. 3 "Heving av last"* /6/. This feasibility report seek to align with the similar methodology to allow for easy integration of new risks into the overall risk assessment picture for Norwegian Coastal Administration.

This report aims to add risks that we see as threats to the marine operation as assessed by the study team. Some of the risks we highlight may already be among previously proposed risk items an earlier stage, but we have tried to avoid overlapping risks.

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The Risk Assessment Matrix is a visual methodology used to identify, evaluate, and prioritize risks by plotting them on a grid based on their probability and consequence. It is often referred to as a Probability-Consequence Matrix.

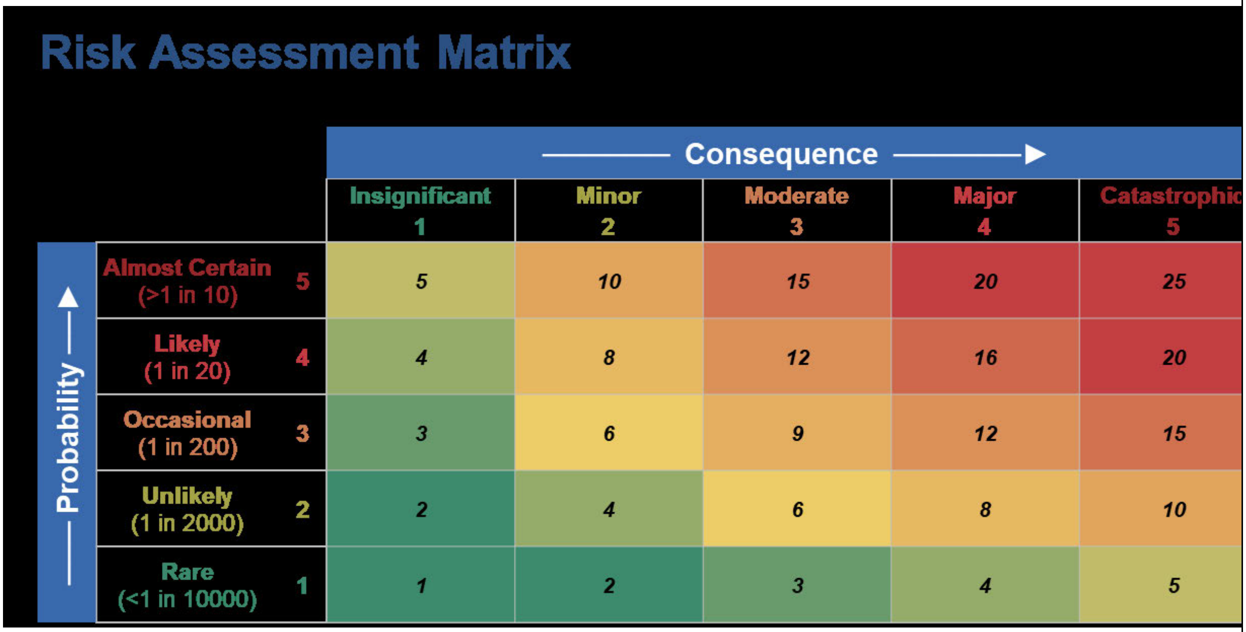

Figure 4-1: The standard industrial accepted Risk Assessment Matrix.

In a marine operation risk matrix, the combination of probability and consequence is considered. Consequences are often divided into the three categories: Peoples Health, Environment and Economic/Material consequences. This is in alignment with other similar assessments.

The key principles in a methodical approach to risk assessment and the associated engineering of solutions are listed below.

- **Likelihood (Probability):** The estimated chance that a risk event will occur, typically rated from "Rare" to "Almost Certain".
- **Consequence (Severity):** The extent of damage or disruption if the risk occurs, ranging from “Insignificant" to "Catastrophic". Consequences can be related to human safety, environmental safety or to project economics.
- **Risk Identification:** List all potential hazards or events (operational, financial, or strategic) that could affect the organization.
- **Establish Criteria:** Define the scale for the matrix. Common formats typically include 3x3, 4x4, or 5x5 grids. We apply 5x5 grid here.
- **Assessment and Plotting:** Assign scores to each risk based on expert judgment or data and place them in the corresponding cell on the grid.
- **Prioritization:** Risks are categorized into color-coded zones to guide action:
- **High (Red):** Critical risks requiring immediate mitigation and senior management oversight.
- **Medium (Yellow/Amber):** Moderate risks that need monitoring and contingency planning.
- **Low (Green):** Acceptable risks that require minimal attention or are managed through routine procedures.

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- **Risk Mitigation:** Develop strategies to avoid, reduce, transfer, or accept the identified risks.

The three formerly developed methods have been thoroughly screened for safety and risks previously. Results are summarized in the document "*Miljøtiltak ved vraket av U-864, Kvalitativ risikoanalyse Alt. 3 Heving av last, Vedlegg V3.03.*" /6/ The study team accept the overall risk picture as presented in the document /6/. The critical risks revealed in /6/ is referred in Table 4-1: Critical risks from previous studies as summarized in /6/.Table 4-1 below:

Table 4-1: Critical risks from previous studies as summarized in /6/.

ID	Name
R-0087	Center of gravity/total weight falls outside the tolerance range during lifting from the seabed -> capacity or stability problems during lifting and overloading of the lifting system.
R-0154	Worse weather conditions than planned for -> the operation will be significantly delayed.
R-0265	Project organization functions inefficiently => Increased costs, reduced goal achievement and/or longer project completion time.
R-0269	Resuspension of contaminated sediments during operation on/at the wreck => contaminated sediments spread across the action area.
R-0275	Wreckage parts fall off the wreck and damage the ROV or other subsea equipment => material damage and/or delays.
R-0279	Problems with retrieving the mercury bottles from the keel boxes => more than 30 tons of mercury remain on the seabed and the measure has not achieved the objective of the operation.
R-0283	The sediments around the wreck contain a lot of stones and wreckage => time-consuming to dig and/or dredge and result in large delays and the spread of contaminated sediments.
R-0284	Equipment used on the seabed becomes contaminated with mercury => the equipment cannot be cleaned and must therefore be scrapped/replaced.
R-0288	Resuspension of sediments during work around the wreck => limited visibility and results in significant delays.
R-0290	Failed to stabilize wreck in installation on the seabed => The installation sinks on one or more legs and gets an angle that causes the lifting operation to be aborted and the foundation to be repaired.

In addition to the risk ID's mentioned, the study team has revealed *marine operation risks* for the individual methods 1 to 4. These risks are identified under the chapters of the individual methods and can be added to the overall risk register for systematic risk management.

For each method, the team evaluates the planned work and performs a risk assessment by listing the most pronounced risk issues as evaluated by the team, and list these with probability and consequence indicators attached.

4.3.2 Torpedo Detonation Threat

Special attention is paid to the presence of torpedoes in both the bow and the stern sections of the submarine wreck.

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Safety to all involved personnel is the absolute first priority. The Norwegian Maritime Authority operates with a vision of zero fatalities and serious injuries. Risk to personnel shall be reduced as far as practicable (ALARP principle), and operations shall be stopped immediately if safety cannot be guaranteed. For this reason, it seems right to establish a plan that applies remote operations to remove the torpedo detonation risk from the immediate vicinity of the two wreck part work sites. We understand that planning for diving operations will not be in line with the safety principles due to the torpedo issue.

Working with a vessel straight above the torpedo locations will be riskier than having a work plan where the surface vessel is not positioned above or even close to the wreck site.

4.3.3 Dredging Contaminated Sediments

Dredging contaminated sediments is a risk that need to be planned for in this work. Environmental safety has gained significant weight in recent years through stricter discharge and acute pollution requirements. And this is a particular focus area in this study, where mercury has spread out and contaminated the seabed surrounding the wreck.

The proposed dredging method(s) need to ensure both operational efficiency and minimal disturbance to the surrounding environment.

4.3.4 Vessel Availability

Vessel availability is always a risk to plan for in the subsea industry. Heavy construction vessels (HCVs)—such as heavy-lift vessels and large subsea construction vessels—are scarce, high-value assets. Vessel availability risk is therefore a major driver of cost and schedule uncertainty.

Tight global supply - The global fleet of HCVs is limited and highly specialized. Demand can spike quickly due to:

- Large offshore wind build-outs
- Major oil & gas developments moving to execution at the same time
- Regional campaign overlaps (e.g., North Sea + Brazil + US GoM)

The impact of tight global supply can be

- Vessels become unavailable at short notice
- Day rates escalate rapidly
- Contractors may reprioritize higher-margin work

Contractual overbooking - Contractors may pre-commit vessels to multiple projects, assuming schedule float. Delays in one project may cascade into others and this may create various problems such as late vessel arrival with the consequences of forced resequencing or standby costs for offshore spreads.

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Typical consequences of vessel availability risk are:

- Schedule delays (often on the critical path)
- Significant cost escalation (standby, re-mobilization, rate escalation)
- Increased HSE exposure due to compressed execution windows, or work is pushed into worse weather seasons.

Contractual disputes over delays and responsibility may be caused by

- Schedule delays, often on the critical path.
- Significant cost escalation (standby, re-mobilization, rate escalation).

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- Increased HSE exposure due to e.g. compressed execution windows or work pushed into worse weather seasons.
- Contractual disputes over delays and responsibility.

Common risk mitigation measures fovessel availability are:

1. As a risk reducing measure, it is beneficial to specify the vessel as "low" as possible to perform the work required. In this case, the risk of not getting the vessel when you need it is reduced.
2. Another risk reducing measure on this specific matter is to reserve the required vessel at an earlier date. To charter the vessel requires a contract. Thus, vessel availability will be an important input to the chosen contract strategy of NCA
3. Schedule float specifically around vessel campaigns to "dampen" consequences.
4. Split installation scopes to reduce reliance on single vessels. Perhaps the 100% number of scheduled operation days can be covered by 90% LCV and 10% HCV? And in addition, the work site can be prepared by 90% LCV well before the arrival of the 10% HCV to avoid dependencies between the two project operation phases.
5. Clear contractual clauses on substitution, force majeure, and delay liability.

4.3.5 Divers versus Remotely Operated Operation

The idea of using diver intervention instead of ROV intervention is understandable. However, with both the torpedo risk and the pollution risk related to mercury, it is natural to think about an operation without the use of divers. This will also lower the requirements for the operation vessel.

When comparing *Diver* vs. *Remotely Operated Vehicle* (ROV) interventions, the marine operations industry follows a strict "Safety First" logic. If a task can be done by the ROV, it should typically be done by an ROV to avoid putting human life at risk.

Engineers of today design subsea equipment specifically to be "ROV-friendly" by using standardized handles and valves to eliminate the need for divers entirely. This can easily be introduced to the tool systems planned for this kind of operation as described herein.

4.3.6 Time Consuming Activities

There are large schedule related risks that need to be evaluated thoroughly to avoid schedule risk and associated knock-on effect of such risks. By adding low-cost vessels for the generalized, time-consuming tasks, one can prepare well for short intense periods using a higher specification vessel.

4.4 Marine Operational Feasibility

For the different methods, the study shall assess whether the four different methods can be operated reliably with regards to operating philosophy, vessel setup with crane requirements, intervention strategies and operability in poor weather conditions.

4.4.1 Operating philosophy

Typically, the vessels will operate based on Dynamic Positioning (DP) class 2 or 3. Two WROV systems and a OBSROV system will ensure the vessel is utilized in an efficient manner. The relevant DP capability (footprint) plots will provide information for the vessel movements, and ROV systems must be able to operate within the limitations of the vessel. Note that the DP footprints should only be used as guidance during planning of a DP Operation and should not be seen as any other than a theoretical model.

Using this setup mean one can work on two-three different tasks at the same time. If one the systems need assistance from one of the others, this can be provided on short notice.

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4.4.2 Vessel setup with crane capacity requirements

During planning of a subsea crane lifting operation, the lifting requirements that must be evaluated are typically grouped around load characteristics, splash zone loads, hydrodynamic loads, crane/vessel capability, rigging, dynamic effects, clearances, and environmental limits.

The characteristic loads to be lifted need to be determined. Dry weight, submerged weigh and added mass are important components of the load assessments. On top of these loads one need to scale up the crane capacity to also include the weight of the rigging equipment as well as the dynamic effects working on the lifting operation. The rigging for lifting needs to be designed. Typically, it is necessary to multiply the highest load to be lifted by a factor of 1.5-2 this early in the feasibility phase of the assessment.

The maximum load is important, but also the crane curve which determines how far out from the centre of the crane pedestal one may handle the load at. And it is relevant to gain control of the 3D Centre of Gravity of the lift. The latter is particularly important for U-864 lifted objects since there will be some uncertainty to where the cuts are done and what is inside the tube.

4.4.3 Intervention strategies

There are two main risks to diving and topside personnel at the wreck site, the pollution from mercury and the potential consequences of detonation of one or more torpedoes left inside the bow and the stern parts of the submarine. The first of these risks is possible to mitigate by protection gear and routines for handling "dangerous materials" similar to what is done in the offshore industry. The second risk on detonations is more difficult to handle. As it is difficult to guarantee there will be no detonation, it will be difficult to document that the risk has been reduced ALARP unless divers are replaced by ROV's.

Using divers may be seen as relevant for the work tasks related to the cutting of holes for anchors into the pressure hull. Also the removal of mercury from the keel cases is detailed technical work that could be better performed by divers than the WROV's. Obviously, this kind of work would be done more efficiently by divers. On the contrary, if we re-think the required work tasks to those of proposed Method: 4 Cut, then the work tasks have been tuned to fit streamlined WROV and OBSROV tasks. This process ensures that the safety of personnel is well undertaken since personnel has actually left the site and stay at a safe distance during the final cut off and pull-away.

4.4.4 Environmental and metocean Criteria

Operational limits are related to maximum significant wave height, wind speed and current velocity.

With regards to the operation window, the schedule will provide an estimate of the expected duration of the critical activity. The combination of location, time of year and activity duration will be applied to determine an acceptable weather window forecasted prior to initiation of the critical lifting operation.

The former sub-section introducing an un-manned intervention strategy also supports the wider operation window for the WROV systems as compared to divers. If most of the work tasks are related to work operations from a LCV, it is possible to work with the ROV's in H_S<3-4m typically. This is dependent on the combination of vessel and ROV system. See Fig. below. This provides a reasonably good weather window for most of the durations.

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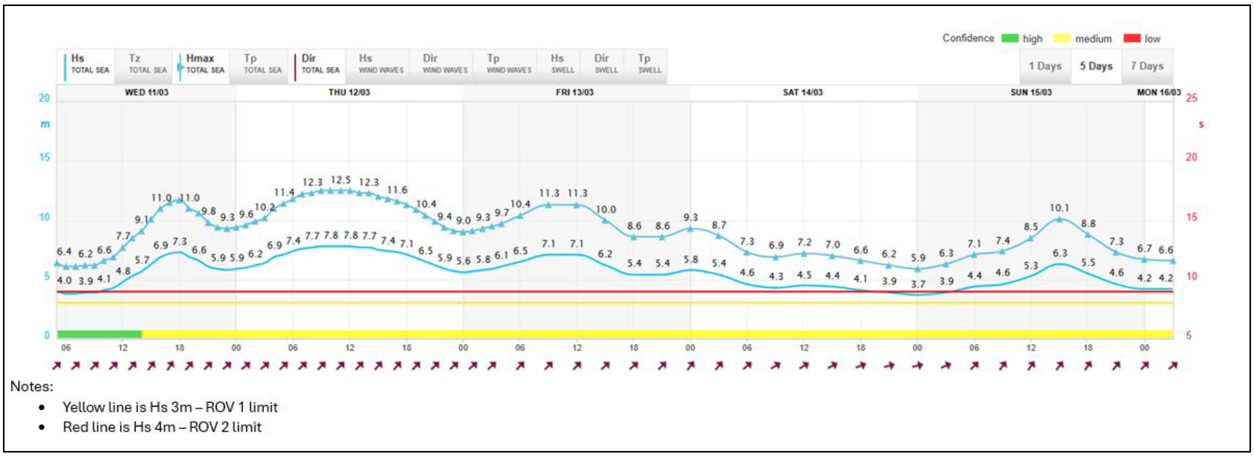

Figure 4-2: Anonymized wave forecast for a poor weather period in the Norwegian Sea. Notice the red and yellow lines that indicates the limitation for launching ROV's from two different vessels.

The lower limiting period will be related to lifting operations where heavy loads are transferred through the splash zone and up onto the vessel deck. In this case there are two particular issues to handle well, namely the added mass from trapped water inside the object, and crane tip motions that creates dynamic additions to the static loads. Typical H_S for such operations will be around 1-1.5m.

4.5 Cost & Schedule Verification

4.5.1 Basis and assumptions for cost estimate

The cost of marine and subsea operations is strongly related to the vessel and equipment required to perform the activities of the schedule, as well as the estimated duration of the activities. At this level of documentation, the estimates have larger uncertainty, but are still at a level which ensure:

- The solution is within the right order of magnitude.
- The cost drivers are understood.
- Major schedule constraints are identified.
- The concept fits within the particular study assumptions.

The estimate is further based on the following:

- Estimate is an indicative and high-level price and should not be used as future benchmark
- Estimate for work equipment is based on former indicative prices from suppliers of equipment without any commitment.
- Estimate for tool development is based on comparison of formerly designed and developed tools with associated control systems. In this case, a qualification development is typically included to document that the system works according to the intention, and that this qualification process is supervised by a verificatory, such as e.g. DNV.
- Expenses due to Bank Guarantee and Insurance not included.
- Estimated PM&E derived as % of Total cost.
- Estimated Logistics & QC has not been included.
- Estimate is based on the vessel proposed is actually available locally. This is particularly relevant in the case of a HLV, where mobilisation fees can be significant.

- Waiting on Weather is included by 5% of schedule duration. This will typically be dependent on which part of the year the operation is performed at.

4.5.2 Basis for Schedule Duration Estimates

The basis for the schedule activities is the process breakdown as provided in Figure 4-3 showing the process for recovery of mercury from the submarine U-864. The individual methods are broken down into individual activities. The former estimates of durations provided in the 2014 report has been listed, and a comparable duration has been given as the 2026 estimate of similar activity. Where there are large discrepancies, a remark is provided to explain why the particular duration is differing significantly from the 2014 estimate.

4.5.3 Output from the cost and schedule estimates

The output of a feasibility study will typically be of Class 5 estimate (±40–50%), and level 1–2 schedule. The assessment of schedules have followed the original activity setup with reference to 2014 estimates for comparison. Then it becomes easy to recognise the different duration estimates wrt methods.

Table 4-2: Summary of Schedule durations estimates. For detailed estimates, see individual chapters.

Mercury Recovery Operations 2026 Duration Assessments		Method 1: Roll					Method 2: Rig					Method 3: Cradle					Method 4: Cut				
		Duration 2014	Duration 2026	Vessels			Duration 2014	Duration 2026	Vessels			Duration 2014	Duration 2026	Vessels			Duration 2014	Duration 2026	Vessels		
	Operation Activities			LCV	TSHD	Grout SV			LCV	HLV	Vessel			LCV	HLV	RIV			HCV	RIV	AHV
1	Mobilisation	5	[redacted]				5	[redacted]				4	[redacted]				N/A	[redacted]			
2	Preparations	51					61					44					N/A				
3	Gain access to the keel	45					11					10					N/A				
4	Open the keel cases	2					2					2					N/A				
5	Recover the Hg-bottles	6					11					10					N/A				
6	Clean-up work at wreck site	16					13					11					N/A				
7	Demobilisation	3					3					3					N/A				
	Schedule Duration	128	315	252	25	38	106	309	214	95	0	84	266	204	55	7	N/A	85	73	7	5

The summary schedule estimates are applied as a vital parameter in the cost estimates performed for the different methods under evaluation. Detailed estimates are provided in individual chapters, but the summary estimate is provided in table 4-3 below.

Table 4-3: Summary of Cost estimates. For detailed estimates, see individual chapters.

Summary	Method 1: Roll			Method 2: Rig			Method 3: Cradle			Method 4: Cut		
	Indikative Manhrs Days	%	NOK	Indikative Manhrs Days	%	NOK	Indikative Manhrs Days	%	NOK	Indikative Manhrs Days	%	NOK
1. Project Administration & Engineering	[redacted]											
2. Procurement & Subcontracts												
2.1 Subcontracts												
2.2 Third Party Services												
2.3 Other												
3. Operations												
4. Contingency												
Sales Price	Sum	100%	kr 1,449,246,500	Sum	100%	kr 1,650,070,500	Sum	100%	kr 1,228,825,000	Sum	100%	kr 918,295,000

4.6 Risk & Opportunity Assessment

An overall risk and opportunity assessment is performed by comparing the different methods, evaluating their required investments in specialized equipment to execute the method, and by including the required risk reducing measures to ensure the operation can be performed as planned. For this reason, the vessel setup, the intervention strategies, the tooling required and the hire equipment setup will vary between the methods.

A summary of the comparisons of the methods at high level is provided in Table 1-1. Subsea7 have provided consulting input to the overall Risk & Opportunity Assessment, but it is underlined that the final assessment itself must be done by Norwegian Coastal Administration.

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4.7 Process for Mercury Recovery

The NCA have sought to find some fundamentally different solutions for lifting cargo based on the overall information and findings revealed during the studies performed until date. These different solutions formed the basis for an analysis of costs, progress and risk for the sub-operation "recover cargo". The purpose of providing several possible solutions is to better capture the scope and associated uncertainty for the choice of solution in the current phase of the project. The assessments led to the following three main process solutions in the previous assessments:

1. Establish access to the keel boxes by rolling the wreck onto its side.
2. Establish access to the keel boxes by lifting the wreck from the sediments using a lifting rig placed on the seabed.
3. Lift the wreck parts from the seabed using a crane vessel and into their respective adapted cradles on the seabed.

Each of these alternatives were evaluated through the process steps as outlined in Figure 3-1 below. The qualitative risk assessment outlined in the document "Vedlegg V3.03 Miljøtiltak ved vraket av U-864, Kvalitativ risikoanalyse Alt. 3 Heving av last" outlines the associated risks. This evaluation is not re-assessing the risks identified in this document. The assessment is focusing more on the execution of the operations as described, and the associated risks and opportunities are highlighted for the methods under evaluation.

In the following, comments are provided to the main steps of the part-process 4.1-4.6 which requires a method description. Information is based on NCA /1/, /4/ and DNV /7/. Quotes are provided from the /7/ where Subsea7's comments are related to quoted pharagraph(s) of the working process.

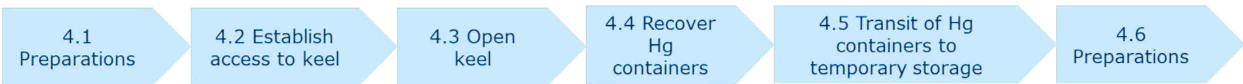

Figure 4-3: The process for recovery of mercury from the submarine.

1. Preparations: Prepare the wreck for moving/lifting and installing necessary equipment on or around the wreck.

2. Establish access to the keel: Make the keel accessible so that ROVs and/or divers can work against the keel.

3. Open the keel cases: Remove the side panels on the keel structure so that any contents in the keel are made accessible.

4. Remove Hg bottles: Remove mercury bottles from the keel-boxes that are the last to be removed, and remove any liquid mercury that has leaked out of the bottles.

5. Transit Hg bottles to interim storage: Remove mercury bottles to the surface and transport them to an interim storage facility. Further transport to the final disposal site when this site can accept the bottles.

6. Stabilize the wreck before covering: Remove any equipment from the seabed and secure the wreck so that it is in a stable position the covering begins.

It is expected that the major time consumptions and the associated risks of these process steps will be dominated completely by the tasks of process steps *4.2 Establish access to the keel*. Here lies the key to the recovery operation – to reveal a methodology that makes it possible to gain access to the keel in a safe and economically viable operation without disturbing the seabed much to avoid further pollution.

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The above process steps have been reviewed in the assessment of the following 3 methods as described in /7/. The key issues have been referred to in this report to put Subsea7's own assessments into the previous assessment context.

4.8 Three Methods for Recovery of Mercury

In previous investigations of U-864, in connection with a preliminary project for the salvage of cargo in 2014, different methods for lifting the cargo were considered through a feasibility study in which five different companies contributed to developing various solutions. The methods that were proposed were further developed by the Norwegian Coastal Administration and resulted in three fundamentally different methods, documented in a separate report /7/.

Three different methods for recovering mercury cargo were developed based on the industry input. These unified methods were:

- Method 1: "Roll" – dredging and digging with sideways rolling to gain access to both sides of the keel.
- Method 2: "Rig" - lifting the wreck parts by overhead winches in a rig placed at the seabed to get access to the keel from both sides.
- Method 3: "Cradle" - lifting the wreck parts from surface vessels and placing them in a cradle for removal work.

In 2014, the weight of the wreck parts was estimated. The number of lifting points in the pressure hull sufficient for lifting the wreck parts using methods 2 and 3 was calculated.

Assessments were also made of the condition of the pressure hull as a basis for determining how much lifting force each point could handle based on hull thickness and the necessary safety factor. /1/

In the following sections, the evaluation of the methods refers to /6/. Selected text paragraphs are quoted in the text to direct feedback on the proposed methodology to the relevant part of the described activities of the methodology. Thereafter a comment relevant to the text is given. For those text paragraphs not mentioned, the feedback is in general that we do not have any comments, and agree those described activities can be executed as proposed.

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5. EVALUATION OF METHOD 1: ROLL

This method applies winches with wires connected to the submarine pressure hull on the opposite side of the winch position. Placing winches on both sides of the forward or aft ship sections makes it possible, in principle, to rotate the sections in the wreck parts transverse direction. 6 Winches and 6 towers are typically installed by CSV's with crane capacities of 400ton in heave compensated mode.

Comment M1-1: Engineering and fabrication cost of rigging equipment is significant - The method requires large subsea winches, sheaves and support structures. By comparing the dimensions of the sheave towers to the submarine wreck itself, one can understand the rigging equipment becomes larger in dimensions than the submarine itself. Engineering of the entire winch system including the remote control system becomes a task on its own. We cannot see that such a system exists today. The larger weights will lead to the need for heavier crane capacities for installation, which again increases risks related to availability of vessel and waiting on weather for several heavy lifts.

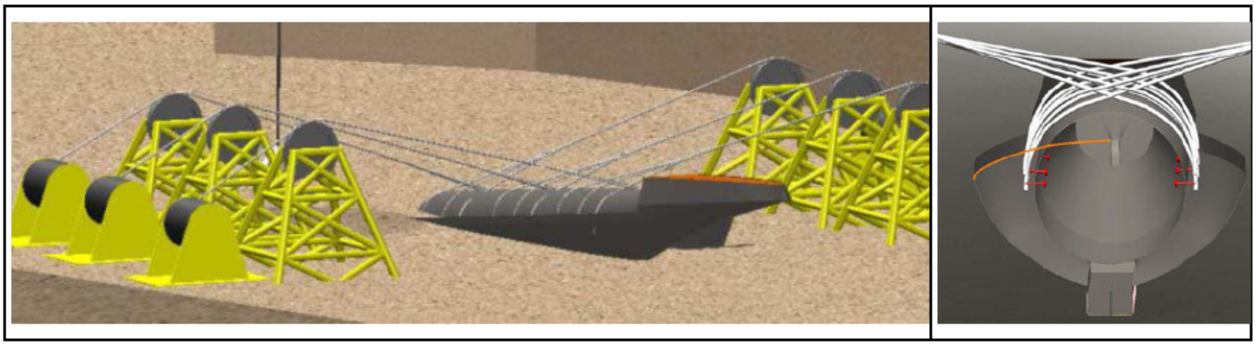

Figure 5-1: The Roll method applies large winches mounted to structures resting at the seabed. Winches must be anchored to the seabed, and winch wires connected to the pressure hull.

5.1 Preparations

Parts of the profile hull must be removed so that anchors can be attached to the pressure hull and so that wire can be run along it.

Wire and winches are installed. Winches are attached to rock or using suction anchors. Wire is attached on both sides of the pressure hull to maintain control over rotation.

Comment M1-2: Foundation for and anchoring of winches - This winch solution requires the winch bases to be attached firmly to the seabed. According to the geotechnical assessments with the associate Isopac sedimentation maps in the wreck area, there is not enough available uniform seabed sedimentation depth to enable a firm suction can foundation for the winches sufficient to document holdback forces. Thus, to anchor the large number of winches to the seabed requires a large amount of drilling work to bolt the winches to the rock. Typically, this would be better to do with divers than with a remote operation. The task is somewhat similar to the anchoring of a bridge. Before one can bolt the winch foundations to the rock, the sediments have to be cleared away. Therefore, with the size of the winches, we see that large areas of the seabed sedimentation containing mercury need to be removed in order to get to the stage where winches can be connected to the hull. This large volume must be treated as contaminated materials requiring special treatment. This is time consuming and will lead to additional disturbance of the mercury with increased risk of further pollution. In addition, the winches needs to be levelled before they are bolted to the ground. Therefore, foundations for the winches must be grouted. The consequences lead to a large number of days in preparation operations, including DP vessel for handling of contaminated materials, and therefore represent a high economic risks.

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Sub-comment M1-2a: TSHDs or Remote Dredging – Remote (Autonomous) dredgers are remotely controlled dredging systems, ideal for sensitive or hazardous tasks when small volume dredging is to be performed. They are typically used in marine infrastructure projects, offering precision and continuous operation without human intervention. The traditional hopper dredgers rarely work autonomously, but subsea-based dredging systems and USVs (Unmanned Service Vessels) are now pushing dredging into deeper waters—approaching or exceeding the 100–150 m depth range, depending on technology. The difficult issues are related to volume of sediments to remove. For larger volumes, one may apply Trailing Suction Hopper Dredgers (TSHDs) that can carry all the polluted sediments and water that arrives from the seabed. Using this kind of a vessel close by the OCV or LCV creates a requirement for the Dynamic Positioning system (DPS) for both vessels to ensure they are able to operate well nearby each other. In principle, this operation mode with two vessels working close to each other will raise the risk exposure to this part of the operation.

Comment M1-3: **Time-consuming cutting of access holes for connection of winches -** In order to connect the winch wires to the pressure hull, one need to make access to the individual connection points of the pressure hull. In total there are 9+9 holes times 2 wreck parts, or 36 holes to cut in total. The work implies removal of the external profile hull, thereafter removal of all structures and piping and other equipment that is located in the interim space between the external hull and the pressure hull. This is time consuming cutting steel profiles works. For the Kursk operation, the similar work processes claimed around 3 weeks of work when using divers, or about 2 days per access hole. For 36 holes by diver work, we could estimate 72 days of DSV operation. The change of intervention method from divers to remotely operated would again double the duration, leading to an estimate of about 144 days/20 weeks for gaining access to the pressure hulls for connection of winches to the two hull parts.

5.2 Establish Access to the Keel

Sediments are removed from both sides of the wreck so that the keel is made accessible and unnecessary forces are not applied when rolling.

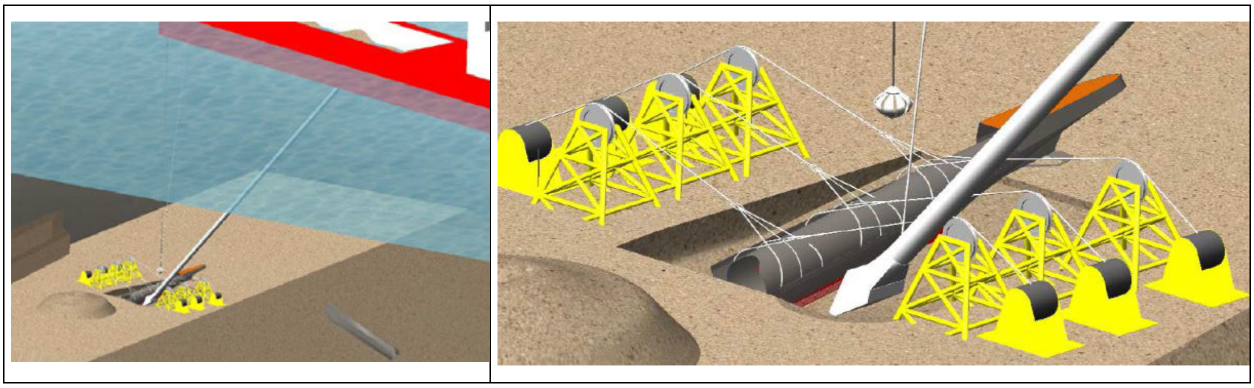

Figure 5-2: The hopper dredger will probably not work well due to the compressed sediment layers nearby and under the submarine wreck part.

This is mainly done with a claw, while dredging is necessary up to the wreck. Dredging is done with a "hopper dredger" for suction dredging in a closed system where the sediments are sucked up to a floating work platform. This is to reduce the spread of contaminated sediments.

Comment M1-4: Difficult access for excavators - This methodology only works for the loose upper layer of the volume to be removed. Previous reports on former works close to the submarine hull have indicated that the seabed is harder than indicated from geotechnical samples in these areas. Therefore, the removal of sufficient sediments and clay will become a cumbersome task, which leads to longer durations and extensive economic risk when large

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volumes are to be excavated. The hopper dredger may not solve the task at all. The clay may be so hard around the key wreck part that an excavator is required to be able to remove a lot of the volume. Both comments lead to extended operation durations and increased dayrates of the vessel(s) since more equipment and operating personnel is required.

Another issue that can be seen from the figure above is that it will become very difficult to operate an excavator between the winch wires. A standard operation would aim to have free movement possibilities in the area around the equipment to be operated to avoid any entanglements.

Comment M1-5: Probably one-sided access must be planned for - To gain access to one side of the keel, if the excavation method should work, it may be a reasonable task to execute. One would start with the favorable side first. To gain access to the second side is much more difficult and requires that the wreck part has been turned over by the winches to rest on the other side. This is a complex operation which is likely to cause large damage to the external hull of the submarine. It would also lead to disturbances in the seabed sedimentation which still contain the second half of the mercury bottles that are not yet removed. Crushing more of the well corroded bottles may easily happen, with additional "disturbance" pollution as a result. It is difficult to see that this method will work well at all.

5.3 Open the Keel Cases

> *The screws that secure the side panels must be drilled out to remove the entire side panel. Alternatively, holes must be cut in the side panel.*

Assuming it is difficult or impossible to execute the roll method, it may still be possible to remove seabed sediments from one side. In this case, having reached the point in the process that the keel cases are to be opened, this needs to be executed from the first side and thereafter to cut through the vertical plate in the center of the keel.

It can be expected that the opening of the external plating is efficiently done under the assumption that access from side is established. Mercury bottles can be recovered from inside the external plating as per sub-section 4.3.4.

Comment M1-6: Cutting through a load bearing structure – The inner hull transfer its load onto the vertical plates between the keel case and the pressure hull. The forces of the self weight is further transferred into the keel case, and most of it via the vertical plate in the center of the keel. Cutting this plate will be somewhat similar to "cutting off the branch one sit on". The external hull will also transfer loading directly to the sediments. However, the steel components under the center line are the really stiff structures. Cutting off the plates may lead to some movements in the structures and potential crushing of what is sitting inside the closed space, namely the mercury bottles. We also believe it can be difficult to cut this area. However, a specialized tool may be developed to mill out the plate to gain access to the other side. It does not feel right to initiate a method like this, with so many flaws up front.

5.4 Retrieve the Mercury canisters from keel to seabed

We can read from /7/ section 4.4 that:

> *"Cases containing mercury bottles are emptied of these. If the bottles are corroded together, it must be considered whether the entire unit (several bottles) can be lifted out together, or whether the bottles need to be separated."*

Comment M1-7: Difficult assessments and unpredictable results – This operation is far from ideal to execute. It will be difficult to get access to the area under the hull, and one must stretch out to get in under the keel. As keel cases are opened, one may risk that any free liquid mercury inside will leak out to the seabed and cause additional recovery work.

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> *"Mercury bottles and containers with collected liquid mercury are moved to intermediate storage on the seabed or on land. In the case of storage on the seabed, this can be kept until it can be transported further to the final disposal site. This must happen before the seabed is covered. If coverage occurs before a disposal solution for the mercury bottles is determined, they must be placed in an intermediate storage on land."*

Comment M1-8: Exposure of bottles increase risk of pollution – Although the above quote seems to be reasonable to execute by both divers and WROV's, the opening of the keel cases is increasing the risk of additional mercury pollution since the mercury is more directly exposed outside the keel case.

5.5 Recover mercury canisters and free floating Mercury from seabed to surface

No comments.

5.6 Stabilise wreck before capping

> *If access to both keel boxes is not possible by rolling over to one side, the same section must be rolled over to the opposite side to provide access to the opposite side of the keel.*

Comment M1-9: Roll execution is not obtainable – Due to the difficulties in the foundation of the subsea winches and towers, it is expected that one cannot execute the main function of the roll-method. Therefore, the method will only allow for work access from one side. The below schedule have still included for the solution to reveal the economic impact of a solution like this.

5.7 Vessel Requirements

The vessel requirements for this method will partly be determined by the weights of the winches and the towers, and the volume of the sediments that need to be recovered to place the winches and towers firmly at the seabed. Winches and towers are individual lifted loads of weights less than about 50-60 ton each. Therefore a Light Construction Vessel with a 200-250T crane will be sufficient to handle this kind of loads. The limitation may be to position all deck loads, but the short distance to e.g. Coast Center Base (CCB) makes it easy to transit to the base to pick up the loads that did not fit onto the first mobilisation. Thus, including for 2 WROV systems and an OBS ROV system, a Light Construction Vessel like e.g. the Siem Stingray may be a suitable vessel for the work.

Figure 5-3: Examples of suitable vessels are the left Siem Stingray and the right Skandi Acergy.

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Alternatively, a HCV like Skandi Acergy will have larger deck space and a larger 400T heave compensated crane. The key point is that there are several LCV's and HCV's that are useful for this kind of operations when loads are not so large.

In addition, attention must be paid to the specialized excavation equipment required such as the removal of larger areas of sediments. A Trailing Suction Hopper Dredger (TSHD) is a type of dredging vessel designed to remove sediment from the seabed and transport it to a designated placement or disposal area. It is one of the most versatile and widely used dredger types in coastal, offshore, and port development projects. In this case, a vessel of capacities in the range of 6-15,000 m^3 is required to be handled by this vessel.

Finally, it is worth noting that the grouting of foundations for the winches and towers at the seabed requires a grouting spread. To organize this in a good manner, it may be best to prepare all locations for grouting first, and then come out with a grouting spread on a separate barge to complete all the foundations. A Grout Support Vessel (GSV) have been proposed for this purpose.

5.8 Schedule for Method 1: Roll

Schedules are based on original schedules developed for the individual methods. The activities provided in Norwegian has been translated to English. The same activities are given herein to avoid any confusion, but some additional activities are added to provide a cost estimate in line with normal estimating routines for marine operation studies.

For M1 in particular, additional activities are accounting for the removal of sediments, treating it as "contaminated sediments". The fixing of winches and towers of this method to the bedrock led to the requirement of removal of larger volumes of sediments on either sides of the two main wreck parts to make the roll method work. This work include a specialized service vessel that can handle this amount of sediments in the range of 3-5000m^3. A *Trailing Suction Hopper Dredger* (TSHD) is a self-propelled ship that acts like a giant floating vacuum cleaner to maintain and deepen waterways. Unlike other dredgers that require separate barges, a TSHD stores the material it collects in its own internal hold, called a hopper.

This offshore work period has previously been estimated to last for a period of 128 days. The new work is based on WROV intervention and assessments of the marine operations has led to an overall schedule of 227 days. This large discrepancy is caused partly by the addition of the TSHD-vessel and partly the previously underestimated extent of work related to removal of the submarine's external hull to connect the roil wires to the hull structures. Finally, the additional work required to build foundations for remotely operated winches caused additional vessel and work related to fixing the winches and towers to the bedrock. Finally, WOW has been added for each vessel campaign.

Table 5-1: Estimated durations for M1: Roll from 2014 study and from the 2026 study.

Item	Activity	Duration 2014	Duration 2026	Comments
1	**Onshore Work**			**Approximately 1 ½ year**
1.1	Project Management	360+128 days	[redacted]	
1.2	Engineering for marine operations	360+128 days		
1.3	Design and development of subsea winch solution, including the remote control system.	-		

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Item	Activity	Duration 2014	Duration 2026	Comments
1.4	Fabrication and testing of subsea winch and towers solution.	-	[redacted]	
4A.0	**Mobilisation**	**5 days**	**3 days**	
4A.0.0	Light Construction Vessel, LCV with 2xWROV systems.	2 days	[redacted]	
4A.0.0	Medium TSHD (6,000–15,000 m³): mid-range cost, good for mid-distance haul.	2 days		
	Transit from CCB to wreck site to wet store first set of equipment.	-	[redacted]	
4A.0.0	Treatment system for sediments and water brought to deck.	-		
4A.1	**Prepararations**	**51 days**	**159 days**	
	LCV Transit to wreck site and setup for work	-	[redacted]	

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Item	Activity	Duration 2014	Duration 2026	Comments
	Preparatory dredging work for installation of winches and towers	-	[redacted]	
4A1.1	Remove parts from the external hull and attach anchors to the pressure hull for lifting straps.	29 days	[redacted]	
4A1.2	Install the wire support structures.	8 days		
4A1.3	Install anchors for the winches to pressure hull.	6 days		
4A1.X	<u>Additional construction activity</u>: Drill holes for anchoring winches, insert grout and steel reinforcement bars, install moulds, grout moulds, waiting for curing period to be finalized, remove moulds.	N/A		

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Item	Activity	Duration 2014	Duration 2026	Comments
4A1.4	Install subsea winches.	6 days	[redacted]	
4A1.5	Tighten up the wires	2 days		
4A.2	**Gain access to the keel**	**45 days**	**44 days**	
4A.2.1	Remove stones and wreckage with a mechanical claw.	7 days	[redacted]	
4A.2.2	Brushing along the keel.	12 days		
4A.2.3	Brushing along the opposite side of the keel.	12 days		
4A.2.4	Roll the wreck onto its side.	2 days		
4A.2.5	Clear/remove wreckage to give ROV access	4 days		
4A.2.6	Install work rig	2 days		
4A.2.7	Clean cooling plates	4 days		
4A.2.8	Roll over the wreck to other side	2 days		
4A.3	**Open the keel cases**	**2 days**	**12 days**	
4A.3.1	Drill/cut the side plates	2 days	[redacted]	
4A.3.2	Remove side plates.	2 days		

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Item	Activity	Duration 2014	Duration 2026	Comments
4A.4	**Recover the Hg-bottles**	**6 days**	**10 days**	
4A.4.1	Remove loose bottles	6 days	[redacted]	
4A.4.2	Recover bottles that have corroded together	6 days		
4A.4.3	Remove liquid mercury	6 days		
4A.4.4	Move mercury bottles to wet storage	6 days		
4A.4.5	Move liquid mercury to wet storage	6 days		
4A.6	**Clean-up work at wreck site**	**16 days**	**18 days**	
4A.6.1	Re-locate subsea winches to forward section	5 days	[redacted]	
4A.6.2	Re-locate wire towers	5 days		
4A.6.3	Re-locate lifting anchors to forward section	6 days		
4A.6.3	Re-locate the working rig to forward section	-		
4A.0	**De-mobilisering**	**3 days**	**3 days**	
4A.0.1	Light Construction Vessel	3 days	[redacted]	
4A.0.2	TSHD Hopper dredger vessel	2 days		
	Total Duration	**128 days**	**252 days**	

5.9 Risk Method 1

In general, Method: 1 Roll the comments to the risk assessment performed by Subsea7 include additional points not previously outlined in former methods for the risk of this method.

Table 5-2: Critical risks for Method 1

M1	Failure Mode	Cause of Failure	P(E)	Effect of Failure	C(E)	Risk Score
R1	Schedule overrun	Cumbersome connection of winch wires to pressure hull	4	Large schedule overrun with associated high cost effects	3	**12**
R2	No fixing of winches and towers to the bedrock	Shallow sediments cannot hold the winch forces applied	5	Method Not Applicable without additional dredging and foundation.	3	**15**
R3	Difficult to dredge out hard sediments	The impact of the submarine sections have hardened sediments in the keel area making it difficult to dredge.	5	May have to switch to secondary dredging methods that increase the execution time significantly, and therefore cost.	3	**15**
R4	Damages to hull and keel during rolling	Non-intentional force paths in structure & poor condition of steel plates	4	Fragile mercury bottles may easily be damaged as the rolling operation is	4	**16**

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				ongoing, leading to additional leaking of mercury in the keel area		
R5	Additional mercury leaks during rolling	Spreading of mercury contaminated sediments when stabilising the wreck and excavating the keel	4	Rotation work may lead to Spreading of mercury contaminated sediments when stabilising the wreck and excavating the keel	4	**16**

M1-R1 Cumbersome connection of winch wires to pressure hull - The connection of transverse wires for rolling of the submarine section requires removal of the the outer hull for most of the upper half of the submarine section. To strip off the external profile hull, as well as all the intermediate piping, tanks and structures will become a very cumbersome task to do. There are large potential for problems and obstacles in this work.

M1-R2 No fixing of winches and towers to the bedrock - A major risk of this method is related to the lack of fixing of the winches to the ground. There need to be a firm connection in order to apply forces in a realistic manner. The sub-bottom assessments does not seem to provide a clear picture of the conditions for all locations. The masses of a large area on either side of both wreck sections need to be removed to gain access to the bedrock. Since this is contaminated materials, both the masses and any water raised to a vessels deck needs to be treated as contaminated material. There is a large economical risk related to this method. As a mitigating measure to handle the material, a specialised vessel can be introduced for the purpose of receiving the contaminated sediments. This vessel need to stay in the field for the sediment removal period, and add much cost to this method.

M1-R3 Dredging of hardened sediments under profile hull – The impact of the submarine may have compressed the sediments under the submarine sections. This makes the dredging work harder and more time consuming to execute.

M1-R4 Damages to hull and keel during rolling - There is a danger of the profile outer hull can deform or collapse during the rolling, leading to large deformations at the lower part of the vessel with internal structural elements puncturing the shell and thus sticking out of the plates. Also the keel itself may be damaged since it is in the lower most position, buried into the sediments. As the section is rolled, with associated damages to the keel, the risk of causing new leaks seems to be obvious just by looking at the concept images. Fragile mercury bottles may easily be damaged as the rolling operation is ongoing.

M1-R5 Additional mercury leaks during rolling - Spreading of mercury contaminated sediments when stabilising the wreck and excavating the keel is a significant risk but can be mitigated. Development of new technology may be most efficient mitigation but will require unknown resources on research and testing. Mechanical dredging using a smaller suction dredge or a small suction pump can be an option. Mechanical dredging will give moderate spreading but may increase the time of the operation.

5.10 Cost Estimate M1: Roll

The cost estimates provided have applied the durations for the various schedules in combination with dayrates for fully equipped vessels with a setup relevant for the work it is supposed to execute. The hire rates for project specific equipment has been added to the vessel dayrates, and the sum of rates is multiplied by the durations of each activity. Low and high values are added in Attachment B Varigheter og enhetspriser for kostvurderinger. /XX/ For the cost buildup in tables for the various methods, the expected value or P(50) value has been applied.

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Table 5-3: Cost estimate for method 1 Roll

Method 1: Roll This method applies 6 remotely controlled subsea winches with associated wire towers to connect to the submarine sections from two sides to be able to roll the submarine sections in transverse directions. Requires a development project to prepare winch solutions, and fabrication of two structures tailored to the seabed conditions.		Indikative Manhrs/ Days	Rate	Unit	NOK	%
1	Project Administration & Engineering	[redacted]	[redacted]	NOK/Hr	[redacted]	[redacted]
2	Procurement & Subcontracts	[redacted]	[redacted]		[redacted]	[redacted]
2.1	Subcontracts	[redacted]	[redacted]		[redacted]	[redacted]
2.1.1	Design and development of remotely operated winch system with wire towers. Qualification testing.	[redacted]	[redacted]	Contract	[redacted]	[redacted]
2.1.2	Design and development of remotely operated core drilling system. Qualification testing.	[redacted]	[redacted]	Contract	[redacted]	[redacted]
2.1.3	Fabrication of 100T steel working frame for WROV's	[redacted]	[redacted]	NOK/kg	[redacted]	[redacted]
2.1.4	Lifting arrangement for 100T steel working frame	[redacted]	[redacted]	NOK	[redacted]	[redacted]
2.2	Third Party Services	[redacted]	[redacted]		[redacted]	[redacted]
2.2.1	Treatment system for sediments and water brought to deck.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.2	Special polluted material basket for subsea storage of mercury bottles under transport to vessel deck.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.3	Drilling spread for foundations	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.3	Grouting spread and personnel	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.3	Other	[redacted]	[redacted]		[redacted]	[redacted]
2.3.1	20 off anchors for connection to the pressure hull	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.3.2	Winch wire arrangement for connection to lifting/rolling anchors	[redacted]	[redacted]	NOK	[redacted]	[redacted]
2.3.3	WROV working tools package for cutting steel, etc.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3	Operations	[redacted]	[redacted]		[redacted]	[redacted]
3.1	HCV 400T Crane + 2WROV systems	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3.2	TSHD 6-15,000 m^3 (vessel for dredging)	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3.3	Grout Support Vessel	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3.4	Waiting on Weather, 5% of operation days	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
4	Contingency at feasibility level, 30% of cost	[redacted]	[redacted]		[redacted]	[redacted]
Selling					kr 1,449,246,500	100.0%

5.11 Evaluation and Conclusion

The design of the required appliances will lead to a very high cost of both the structures and the associated winch requirements. The dimensions indicate the size of the overall solution is larger than the submarine sections. The equipment is currently not existing, and must be engineered, fabricated and tested.

The fundamental problem with this method is the need for removal of large areas of sediments to anchor winches to the seabed. This seems to have been overlooked in the past. It is hardly possible to base the foundation on secure winches in the varying depth of the sediments using suction cans. The introduction of dredging away the loose masses requires large seabed areas need to be cleaned to get firm bedrock ground for fixing the winch bases and support towers. This causes a need for massive recovery and treatment of loose seabed sediment materials and associated water. A separate vessel is required for this purpose, that can handle the polluted masses and transport it to shore. This work will become very expensive. Materials and water need to be treated on a surface vessel, making this work a very cumbersome and time-consuming activity.

The key benefit of the Roll-method is supposedly that it provides access to both sides of the keel cases. However, it is likely that the very hard seabed sedimentation nearby and under the submarine wreck parts becomes a large problem for the excavation work. If an excavator is required, this is difficult to position in between the winch wires of the rolling system. This would lead to extensive increases in excavation duration, if possible at all. This is likely to become a very difficult task that could lead to failure of this method in getting rid of the required masses.

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The submarine hull will become more damaged from the rotation, and more mercury will leak from keel to seabed. Internal equipment may move during rotation. The method requires cutting into the pressure hull at 9+9 places along each structure. Effect is that the larger parts of the external hull need to be removed. Very time consuming, heavy and expensive equipment required during several operations.

Conclusion: *As a marine operation contractor we cannot recommend this method to be chosen. Of the three evaluated, it is assessed as the least favourable from a risk assessment perspective due to the large uncertainty to the required task of removing sediments down to the bedrock.*

Accounting for the required risk reducing measures introduced into the cost estimates, it is also an unfavourable economical solution. It is the least favourable method of the three proposed, hardly possible to reaching a good result, and highly exposed to cost level and additional pollution.

For this method, the Client has specifically asked for answers to the following questions:

1. Will the wire get in the way of the excavation operation and the use of ROVs with umbilicals? **Reply:** *The wires will get in the way of both the WROVs and any potential excavators.*
2. What will be required of seabed installations and the costs for this? **Reply:** *See cost estimates and description of this equipment in rest of this chapter.*
3. Type of vessel for the installation of structures and costs (day rate) Reply: The vessel required will be a Light or Heavy Construction Vessel (LCV/HCV) with a crane(s) capacity in the range of typically 200ton/400 ton.
4. Expected duration of the operation. **Reply:** *The total duration was estimated to 128 days in 2014. A similar estimate in 2026 which is accounting for the handling of the revealed risks is 315 days in total*.

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6. EVALUATION OF METHOD 2: RIG

The “Rig” method applies two tailor made steel rigs with winch platforms designed for vertical lift of the two wreck sections. The vertical oriented winch lift system may be similar to the horizontal pull system, but winches probably need to be designed for larger vertical forces than the 6 roll-winches.

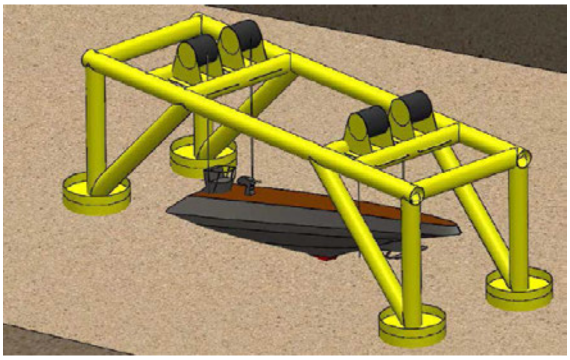

Figure 6-1: *The lifting frame for the stern part is designed to fit a horizontal seabed.*

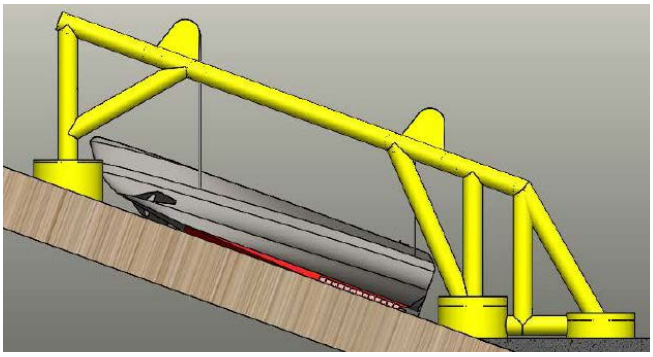

Figure 6-2: *The lifting frame for the bow part is designed to match the 15 degrees slope of the seabed in this area.*

From the figures above, it is reasonable to estimate the weight of the structures as heavier than the submarine bow part, that is >800 ton. Thus, a reasonable estimate for the structure weights is around 1000-1100 ton. The implication of this is that the structures require to be both installed and recovered by a Heavy Lift Vessel (HLV). The estimated duration for this vessel is about 95 days since it need to stay in the site for the full duration. This kind of planning is not recommended, the concept does not seem to be “tuned” wrt the marine operational aspects.

In the following sub-sections, the commented parts of the method description is quoted and comments are given after each quoted paragraph.

6.1 Preparations

> *“Parts of the profile hull must be removed so that anchors can be attached to the pressure hull.*
>
> *Strength calculations have been made of the anchor attachments to calculate how many attachment points are required. Calculations show that there will be a need for in the order of 30 anchors for each of the sections, which have an estimated weight of 800 tons.”*

Comment M2-1: Gaining access to the pressure hull - The preparation work is related to gaining access to preparing the anchoring points in the pressure hull. In order to get access to the pressure hull, one need to decide the relevant tool to prepare. One alternative is to make a larger hole in the external hull to make access for “cleaning the pathway” through the intermediate route between the two hulls, before the final hole can be cut in the pressure hull. However, this is seen as a cumbersome method due to the short distance between each hole. Practically speaking, most of the external hull must be removed then. Alternative two will be to prepare a cutting tool for a core drilling using the same or two different diameters for the core driller. A larger diameter can be applied for the external hull and the intermediate space, while a smaller hole can be used for the final cut through the pressure hull. No matter which method is chosen, the estimated work duration per hole will become critical for the method M2 as well as method M3. By estimating e.g. 2 day per hole, the cutting work per wreck section becomes around a month of duration. Note that the submarine wreck parts are resting in positions with out of centre lines angles to both horizontal and vertical axes. In

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order to direct the core drilling in the right direction, a drill rig is required to adjust the centre line of the core drilling to ensure one hit the right target. A core driller with a diameter sufficient for insertion of the lifting anchors for method 2 and 3, and installed into an adjustable jig, is a vital tool to design and operate remotely for the success of this method. After the hole is drilled a suitable lifting pin can be installed and secured.

Figure 6-3: *The Core drilling (left side) can be executed by WROV holding it, or more advanced by the placement of a jig with core driller inside, to be adjusted to its relevant position on the submarine. The lower right pictures shows a conductor lifting pin c/w 35Te shackle and locking dogs activated. Can be applied for the M1: roll method.*

Comment M2-2: Distribute loads via a lifting beam – The images of Figure 6-1 and Figure 6-2 shows a system with only four winches, while the strength calculations documents that a distributed load carrying system is required to lift the structure. Therefore, the system need to account for horizontal lifting beams between the top roof and the load attachment lines – 15 on each side in total. Such a distribution imply a distance of about 2.5m distance between each of the vertical lines to the lifting beam. Illustration in left of **Figure 6-4** below shows a rigging system that requires a certain height to assure reasonable angles for the individual strops versus their attachment points to the pressure hull. For the structure on the right side of **Figure 6-4** we can see that the required height is not in place for this kind of lifting arrangement. For this system to work, the winches need to pull on two beams with 15 individual lines down to the pressure hull for each beam. This creates a very complex and challenging lifting arrangement to be remotely controlled.

> *"Each anchor is tightened with the pulling force that must be used during lifting, to ensure that the attachment holds and that any pipes etc. inside the pressure hull that are clamped inside the anchor are clamped flat before the lift is carried out."*

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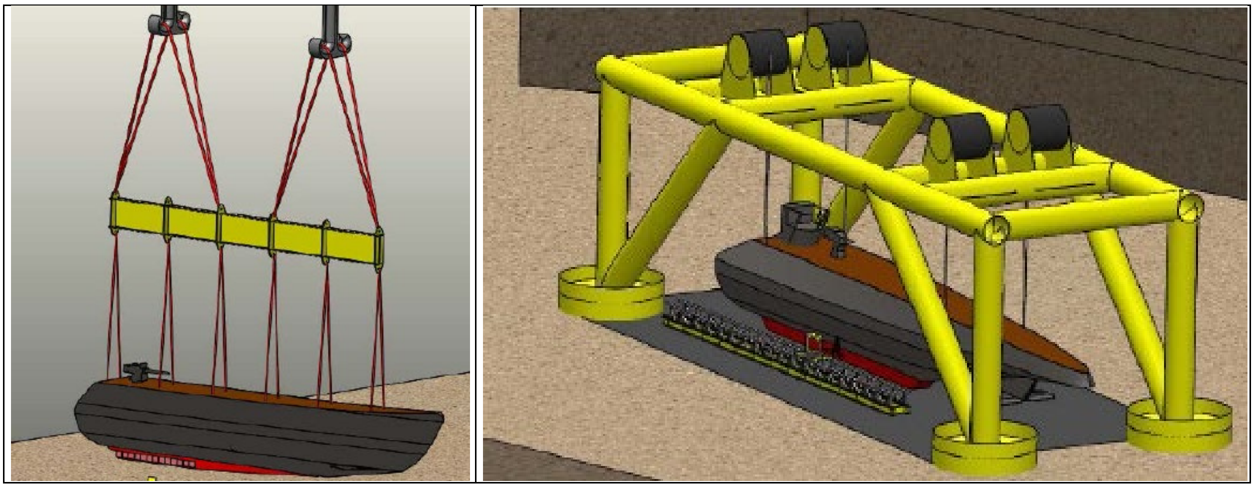

Figure 6-4: *To satisfy the structural requirements as analysed by DNV in /XX/, it is necessary to make use of two beams like shown in the left figure between the wreck part and the underside of the tubulars. This increases the requirements for height above the submarine hull.*

Comment M2-3: No advanced synchronized lifting – The "crushing process" is understandable here, although the process requires a synchronization of the individual wires that is not accounted for in the visualized lifts of the report /7/ if it is to be executed as described in the text. As can be seen in the cut out image of **Figure 6-4** above, the lifting system is static with no possibility for adjustment of the lifted object. For a subsea operation it is important to plan a simple, static operation without unnecessary complexities. This means that the static lifting of the bow section will be initiated by the deepest part first. This happens slowly to allow for the proposed "crushing process" internally. As the lift is gradually hoisted, several wires will engage until the lift is hanging in a horizontal orientation with fully distributed loads. This gradual engagement is also favourable w.r.t. any potential suction forces.

> *"Lifting rig with subsea winches is placed on the bottom (above the wreck). The strength of the sediments must be calculated and possibly improved if necessary (use of sandbags on which the rig can be placed, foundation construction, etc.). Two rigs must be made, one for each section. For the fore section, the lower legs of the frame are placed directly on the supporting embankment. Foundations must be deployed first and the geometry of the frame must be adapted to the actual position of the foundations"*

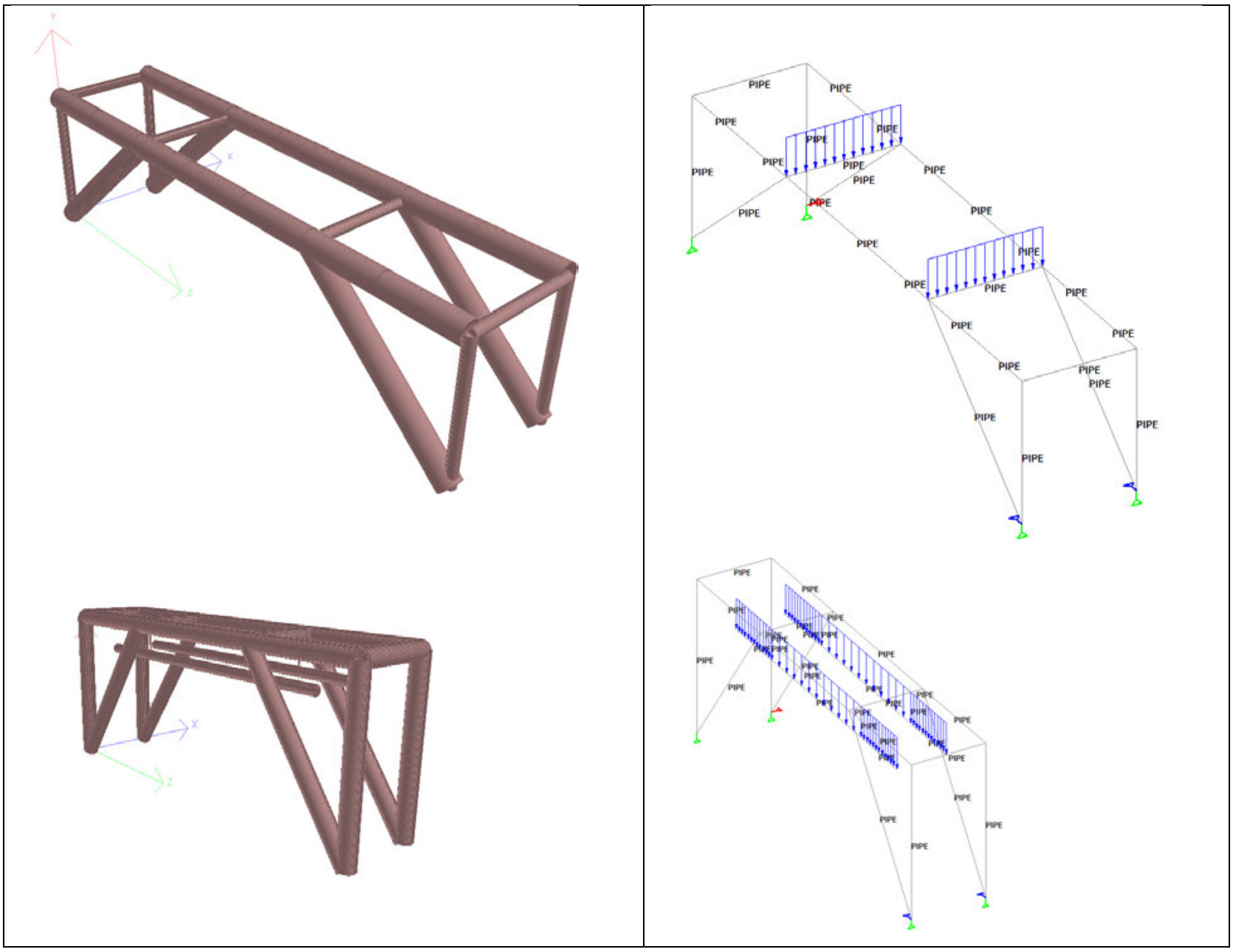

Figure 6-5: *To satisfy the structural requirements as analysed by DNV in /7/, it is necessary to make use of two beams like shown in the left figure between the wreck part and the underside of the tubulars. This increases the requirements for height above the submarine hull.*

Comment M2-4: Two expensive rigs - The need for application of two expensive rigs for the same purpose makes this method very expensive. Subsea structures like proposed are heavy welded structures built in offshore fabrication yards. This fabrication requires high-spec welding quality and typically NORSOK/ISO qualification. This places them near the upper end of fabrication cost ranges in developed fabrication markets such as Norway, Netherlands, UK. Assuming a fabrication cost of about 100 NOK/kg settle a fabrication cost of 120MNOK per structure. Assuming two structures of 1200 tons brings a fabrication cost of approximately 240 MNOK for the structures. In addition to this will be the transport and installation cost, roughly estimated to 160MNOK to be added, bringing the cost to about 400MNOK. In addition, the subsea winches and associated lifting arrangements will raise the cost higher.

6.2 Establish Access to the Keel

A tarpaulin can be placed under the keel to collect any liquid mercury that may spill when the keel cases are opened.

A work rig is installed along the keel. This prevents equipment from working directly on contaminated sediments, and it provides equipment (ROV) that is connected to it with the possibility of more power transfer and stable positioning.

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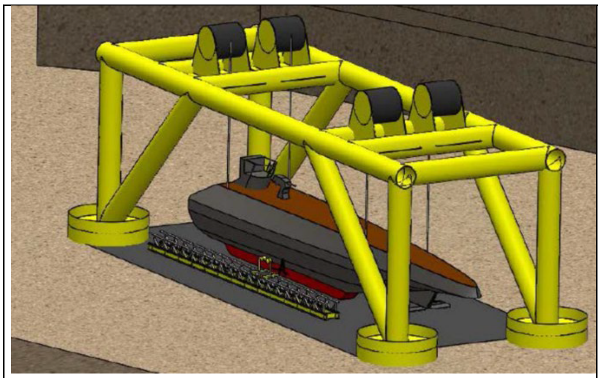

Figure 6-6: *To*

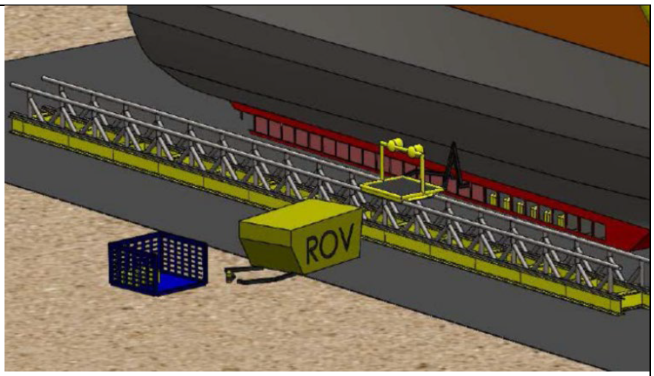

Figure 6-7: *To*

Comment M2-4: Placement of working rig for WROV – The use of a working rig seems good from the perspective of supporting the WROV operations. However, there are several concerns with bringing in this kind of equipment. Firstly, to make the beam useful, it needs to be placed closely in towards the outer hull of the submarine. This imply that the support-beam need to be placed outside of the structure initially. Thereafter lifting arrangement have to be de-attached and re-attached to inside the structure. In order to land the support beam in a useful way, it need to be *aligned with the keel*. The seabed is partly uneven and inclined at the two wreck locations, which makes it difficult to achieve the required and useful alignment without being adjustable in height. This part of the work could potentially be better executed by divers. Alternatively, the WROV may just sit down at the seabed or alternatively use some blast mats/polymats to sit on to minimize seabed disturbance and work with the keel cases directly.

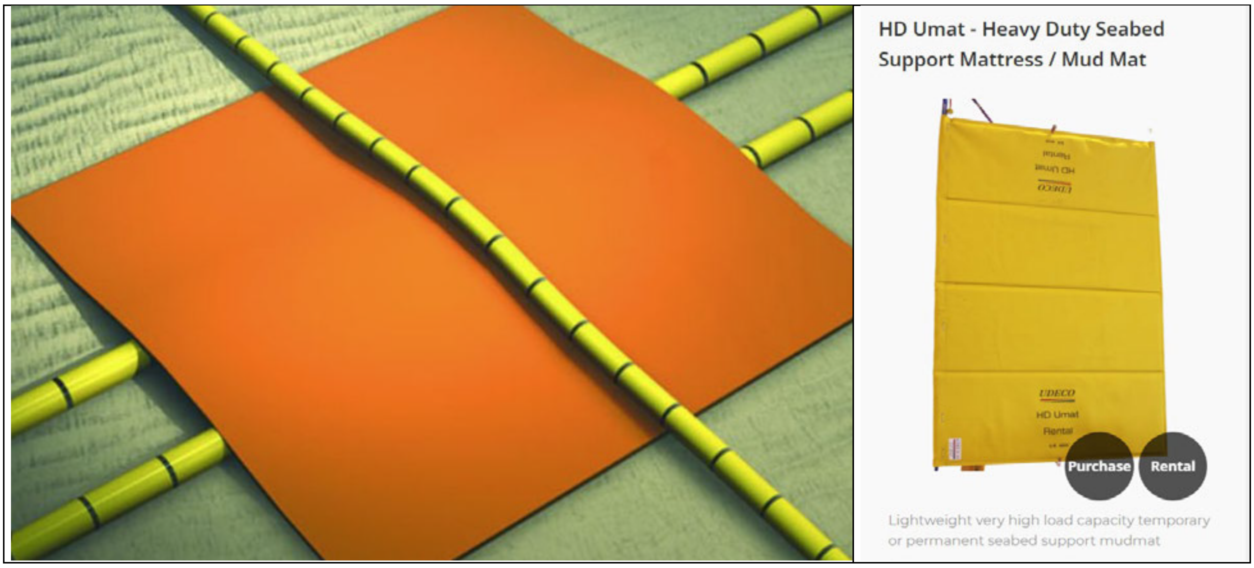

Figure 6-8: Example of *typical subsea mud mats to be applied as local seabed protection to minimize seabed disturbance. Mats could be left in place under the permanent rock dump.*

A working rig would also require some kind of controls, that would make the rig complicated both in fabrication and operation.

6.3 Open the Keel Cases

Comment M2-5: Avoid working rig for WROV – Assuming that WROV is sitting on seabed on a mud-mat using a subsea grinder to cut into the keel to gain access, it could be an idea to avoid the entire frame for the WROV. It is assumed to take approximately 6hrs pr keel box to cut hole. Mat can be pulled into next position when required.

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6.4 Retrieve the Mercury canisters from keel to seabed

No comments.

6.5 Recover mercury canisters and free floating Mercury from seabed to surface

No comments.

6.6 Stabilise wreck before capping

The wreck is lowered to the seabed and the wire is disconnected.

Comment M2-6: Releasing the lifting wires – As the submarine is lowered to the seabed, the wreck part will lean over to one side if it is not installed into a cradle. This may still be OK.

Rig with subsea winches is lifted up by crane vessel.

Comment M2-7: Dependency on HLV – This method uses the HLV to install structures and to recover the structures again. There is an inbuilt dependency inherited in the method that requires the HLV to stay at the wreck location from the day it first arrives until the day all keel work is completed on the two wreck parts. This means that the methodology uses the HLV as support vessel during the entire work. According to the schedule period from mobilisation to demobilisation, the number of estimated days will be about 106 days. With a day rate of, say 5 MNOK, this vessel hire only will be about 530 MNOK. For this period, one only need the lifting capacity for installation of the structures at the seabed, and for recovery of the structures after the work has been completed. Thus, the method logics becomes non-efficient for the mercury recovery task from an economic perspective.

Suction anchors are removed if possible.

No comments.

6.7 Vessel Requirements

The method 2 Rig requires the following vessel setup:

- A Light Construction Vessel for supporting the large dredging work and the preparatory work for gaining access to the pressure hull.
- A heavy Lift Vessel for execution of the heavy lifts required to be done. Due to the few types of vessels available in the market for these loads, it is natural to plan for a short and hectical lifting period. In this case, that is not feasible to do as the plan need the HLKV both early, in the mid and late in the process. So the duration of the vessel stretches out, and the method seems to be less interesting from an economical point of view.

6.8 Schedule M2

Note that the activities are summed in the table for both the bow section and the stern section of U-864.

Table 6-1: 2014 and 2026 duration estimates for method 2 Rig.

Item	Activity	Duration 2014	Duration 2026	Comments
	Project Management & Administration	715 days	[redacted]	
	Engineering	715 days		

Item	Activity	Duration 2014	Duration 2026	Comments
	Engineering of subsea rig for WROV support		[redacted]	
	Engineering for subsea lifting rig and associated winch solution			
	Fabrication and testing of lifting rig and associated winch solution			
	Fabrication of subsea rig support solution for WROV			
4B1.1	**Mobilisering**	**5 days**	**3 days**	
4B1.0.1	Heavy Lift Vessel, HLV > 1500T crane	5 days	[redacted]	
4B1.0.2	Light Support Vessel, LCV	4 days		
4A.0.0	Support Vessel, SV	2 days		
4B1.1.1	**Preparatory Work**	**61 days**	**150 days**	
4B1.1.1.1	Remove parts of the external hull, cut through external and internal hulls and connect the anchors inside the pressure hull.	30 days	[redacted]	
4B1.1.1.2	Prepare area for rig	12 days		
4B1.1.1.?	Install lifting beam with 15 wires per side.	-		
4B1.1.1.3	Install rigg 1 stern section and rig 2 bow section	6 days		
4B1.1.1.4	Install subsea winches	8 days		
4B1.1.1.5	Install buoyancy elements	3 days		

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Item	Activity	Duration 2014	Duration 2026	Comments
4B1.1.1.6	Install wires to the hull section	2 days	[redacted]	
4B1.1.1.7	Inject water inn under the hull to reduce suction forces.	(2 days)		
4B1.1.2	**Get access to the keel**	**11 days**	**11 days**	
	Note that at this stage of the method it becomes clear that the method has flaws that are not much appreciated. One has installed the two overhead rigs and are ready to continue working process without the HLV. But the cost of de-mobilizing and re-mobilizing this vessel can hardly be justified. The time period from completed installation of rigs until one can recover the rigs again put an un-fruitful strain on the project economy of Method 2.			
4B1.1.2.1	Lift the wreck part from seabed	3 days	[redacted]	
4B1.1.2.2	Remove stones and wreckage with a mechanical claw and / or WROV	4 days		
4B1.1.2.3	Brushing along the keel.	2 days		
4B1.1.2.4	Install working rig for WROV	2 days		
4B1.1.3	**Open Keel Cases**	**2 days**	**17 days**	
4B1.1.3.1	Drill and cut away the side plates	2 days	[redacted]	
4B1.1.3.2	Remove sideplates	2 days		
4B.1.1.4	**Recover Hg-bottles**	**11 days**	**17 days**	
4B1.1.4.1	Remove loose Hg bottles	11 days	[redacted]	
4B1.1.4.2	Remove bottles that are corroded into each other	10 days		
4B1.1.4.3	Remove liquid Hg0	10 days		

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Item	Activity	Duration 2014	Duration 2026	Comments
4B1.1.4.4	Transfer basket filled with Hg-bottles to wet storage	10 days	[redacted]	
4B1.1.4.5	Move the (free floating) liquid mercury to wet storage	10 days		
4B1.1.5	**Hg-bottles to intermediate storage**	**0 days**	**0 days**	
4B1.1.5.1	Hg-bottles to intermediate storage	0 days	[redacted]	
4B1.1.6	**Stabilise stern wreck section and clean-up Work**	**13 days**	**13 days**	**Remove working rig and stabilise wreck**
4B.1.6.1	Remove buoyancy elements	1 day	[redacted]	
4B.1.6.2	Remove subsea winches, towers, clean and transfer to bow section area.	5 days		
4B.1.6.3	Remove wire rigging from hull	7 days		
4B.7	**Demobilisering**	**3 days**	**3 days**	
4B.0.0	Light Construction vessel	2 days	[redacted]	
4B.0.0	Heavy Lift Vessel w/ ≥1500 te crane	1 days		

6.9 Risk for Method 2

The key risks identified with the method have been added to the table below.

Table 6-2: Risk estimate for method 2 Rig.

M2	Failure Mode	Cause of Failure	P(E)	Effect of Failure	C(E)	Risk Score
R1	Lifting arrangement	The method requires more lifting points to handle the 8-900+ ton lift, and the arrangement must allow for spreader beams.	5	Method must be corrected, and cost raise due to heavier structures and requirement for HLV.	4	**20**
R2	Winch structures requires HLV	The increased size of the structures lead to a total weight exceeding 1000 ton for these structures.	5	The consequence of this is that the two structures need to be launched and recovered by a Heavy Lift Vessel to much higher cost.	4	**20**
R3	Schedule overrun	Cumbersome access for connection of winch wires to pressure hull. Most of the outer hull needs to be removed to make connections.	4	Large schedule overrun with associated high cost effects.	3	**12**

M2-R1 Lifting arrangement – The method applies overhead lifting in four points. According to DNV's assessments of the hull strength, the lifted weight requires some 2x15 holes to be prepared to anchor the lift in the pressure hull. This implies that the current sketches of the lifting arrangement is demonstrating a non-realistic lifting principle. The two lifting points on either side needs to be replaced by two columns of 15 holes, in total 30 lifting anchors and lines for each lift. In order to allow for this revised configuration, the lifting arrangement need

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to include a lifting beam for each column of holes. Thus, the winch vertical positions must be lifted higher to allow space for this. And thus, the structure grows higher, more expensive and leads to heavier requirements to the heavy lift vessel crane height.

M2-R2 Winch structures requires HLV – Winch structure becomes very large when additional lift-height shall be accommodated. Accounting for 10-15 m higher, additional weight of lifting arrangement, the total weight will exceed 1000 ton for these structures. The consequence of this is that the two structure lifts from deck to seabed, and the recovery lifts in the opposite direction, need to be performed by a Heavy Lift Vessel in the range above 1500-2000te crane capacity. The idea of this solution originally must have been to avoid a HLV and to be independent of the surface wave motions. This will render the solution obsolete, because the HLV need to stay in the area for quite a long term anyway. And if so, why not move to M3 instead without the high structure cost?

M2-R3 Cumbersome connection of winch wires to pressure hull lead to schedule overrun – The method applies overhead lifting in 30 anchor points. Cutting 15 x 2 holes into the pressure hull, i.e. cutting 30 penetrations in the two hulls and removing any other steelwork in the wire paths is a very difficult and time-consuming task for the WROV's. The work requires removal of most of the profile hull structure and much of the underlying structures, piping, tanks and other structures.

Need to build a complex winch lifting arrangement with remote control system. This is pre-installed on one structure. If it is to be moved to the second structure, this will require a very uncertain change over time period with the HLV in standby mode. This becomes a high economic risk. Alternatively, one need to build two complete systems, with the associated cost consequences.

6.10 Cost Estimate M2: Rig

Table 6-3: Cost estimate for Method 2: Rig.

Method 2: Rig This method applies two tailored steel rig constructions with remotely operated subsea winches for the lifting of the two submarine sections to gain access to the keel area. The weight of the structures lead to the requirement for a HLV to install and recover structures.		Indikative Manhrs/ Days	Rate	Unit	NOKeqv	%
1	Project Administration & Engineering	[redacted]	[redacted]	NOK/Hr	[redacted]	[redacted]
2	Procurement & Subcontracts	[redacted]	[redacted]		[redacted]	[redacted]
2.1	Subcontracts	[redacted]	[redacted]		[redacted]	[redacted]
2.1.1	Design and development of remotely operated winch system with wire towers. Qualification testing.	[redacted]	[redacted]	Contract	[redacted]	[redacted]
2.1.2	Design and development of remotely operated core drilling system. Qualification testing.	[redacted]	[redacted]	Contract	[redacted]	[redacted]
2.1.3	Fabrication of 100T steel working frame for WROV's	[redacted]	[redacted]	NOK/kg	[redacted]	[redacted]
2.1.4	Lifting arrangement for 100T steel working frame	[redacted]	[redacted]	NOK	[redacted]	[redacted]
2.2	Third Party Services	[redacted]	[redacted]		[redacted]	[redacted]
2.2.1	Treatment system for sediments and water brought to deck.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.2	Special polluted material basket for subsea storage of mercury bottles under transport to vessel deck.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.3	Drilling spread for foundations	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.4	Grouting spread and personnel	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.3	Other	[redacted]	[redacted]		[redacted]	[redacted]
2.3.1	20 off anchors for connection to the pressure hull	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.3.2	Winch wire arrangement for connection to lifting/rolling anchors	[redacted]	[redacted]	NOK	[redacted]	[redacted]
2.3.3	WROV working tools package for cutting steel, etc.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3	Operations	[redacted]	[redacted]		[redacted]	[redacted]
3.1	LCV 250T Crane + 2WROV systems	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3.2	HLV (vessel for heavy lifting > 2000 ton)	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3.3	Waiting on Weather, 5% of operation days	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
4	Contingency at feasibility level, 30% of cost	[redacted]	[redacted]		[redacted]	[redacted]
Selling					kr 1,650,070,500	100.0%

6.11 Evaluation and Conclusion

For this method, the Client has specifically asked for answers to the following questions:

1. Verify the size of the lifting frame (one for each wreck section) => *Reply: The weigh of this structure may exceed 1000te.*
2. Quantity of steel and unit price, finished processed and welded => *Typical cost from manufacturer can be found from weight of structure multiplied by approximately 120 NOK/kg for this kind of structures.*
3. Type and size of platforms/foundations the legs can stand on => *Reply: The structure need to sit on mud mats designed to transfer the relevant loads to the underlying bedrock.*
4. For soft seabed – possible need for soil replacement? *Reply: Yes, if the seabed have sediments of a significant amount, then the footing areas have to be dredged and suitable size of mud mats need to be designed.*
5. Use of balloons for increased buoyancy of wreck sections, is current a problem? *Reply: Buoyancy introduces uncertainty and risk for unexpected events to the lifting arrangement. There is large variability in the current leading to variation. The application of balloons is not recommended for the safety of the subsea operation. In addition, there are not many natural attachment points. What are the points to attach to? Why use buoyancy?*
6. Equipment to be used for lifting (wire, winch, etc.). *Reply: See the proposed equipment and rigging.*
7. Type of vessel for installation of structures and costs (daily rate). *Reply: See separate assessment of vessels and cost. Typically a Light Construction Vessel for the WROV work and most preparation work. Bokalift 1 (2-3000 t) could be an example for calculation purposes. Such a HLV is priced in with a large cost of mobilisation, and then dayrates of typically about 1-2.000.000 NOK.*

M2: Not so realistic case where two huge structures + winch systems need to be designed and fabricated to lift about 900t + any suction to the hull. Need large and expensive subsea winches like M1. Number of lifting points seems to be low compared to other solutions and the remaining wall thickness of the pressure hull. Has been modified in the overall assessment. This is in itself very expensive structures, and the remotely operated winch systems will add complexity and weight to this. Large weight for combined winches and structure probably lead to the requirement of HLV. Uncertainty related to foundation for pads. Structures need to be designed to follow terrain. Positive for no trapped water since hydrodynamics is largely isolated. Two operations required. Evaluation: Medium method, Very expensive.

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7. EVALUATION OF METHOD 3: CRADLE

7.1 Preparations

Parts of the profile hull must be removed so that anchors can be attached to the pressure hull.

Strength calculations have been made of the anchorages to determine how many attachment points are required. Calculations show that around 30 anchors will be needed for each of the sections, which have an estimated weight of 800 tonnes.

Comment M3-1: Short distance between holes – The calculated number of strops with anchors for attachment at the inside of the pressure hull is estimated to 2 x 15 = 30 attachments. The distance between each hole will then be around 2,5m. If the outer profile hull plates are to be removed, two long stripes along each upper side of the outer profile hull need to be removed to make space for work inside the profile hull. Alternatively, the holes can be established by core drilling like previously proposed.

Comment M3-2: Engagement of lifting wires to anchors – The two lift configurations are somewhat different. The aft section is perhaps more flat than the bow section laying in a 15 degrees slope. Thus, the lift configuration will differ as well. This imply that the lifting strops need to be checked out for each configuration. In addition, the preparations for the lifts need to be conducted well prior to the arrival of the HLV to ensure the hire period remains short as possible. Thus both rigging arrangements need to be prepared for fast engagement when the HLV arrives the wreck site.

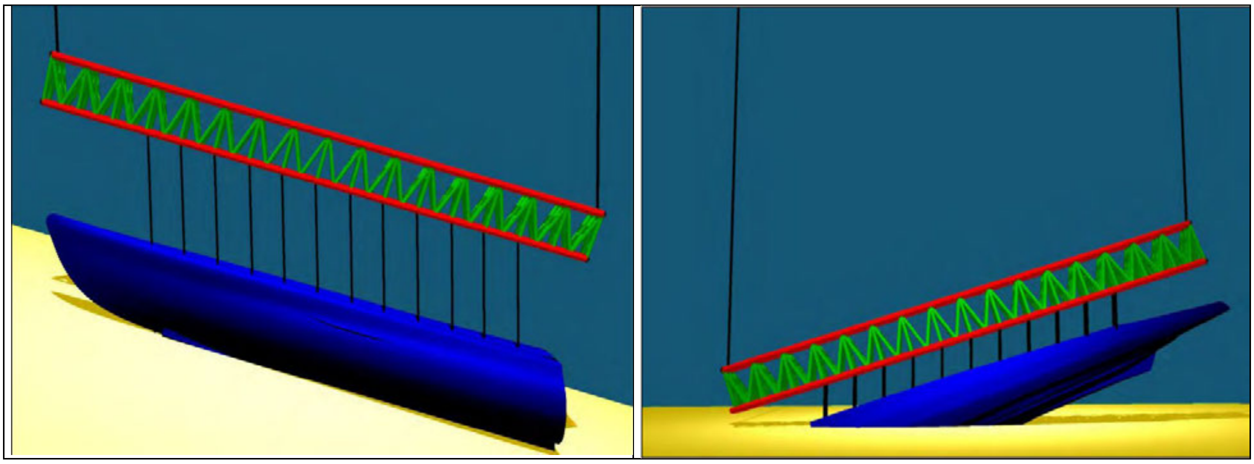

Figure 7-1: *Previously proposed rigging arrangement principle for lifting the fore and aft wreck parts from the seabed. There may be up to 2x15 strops leading to a total of 30 strops from the above lifting beam.*

Comment M3-2: Expected suction forces between sediments and submarine - suction forces are highly dependent on soil type (sand vs. soft clay), permeability, consolidation state plate size and geometry, presence/absence of perforations, uplift velocity and degree of embedment (if any). Therefore, most studies present qualitative behaviour or relative trends, not fixed values.

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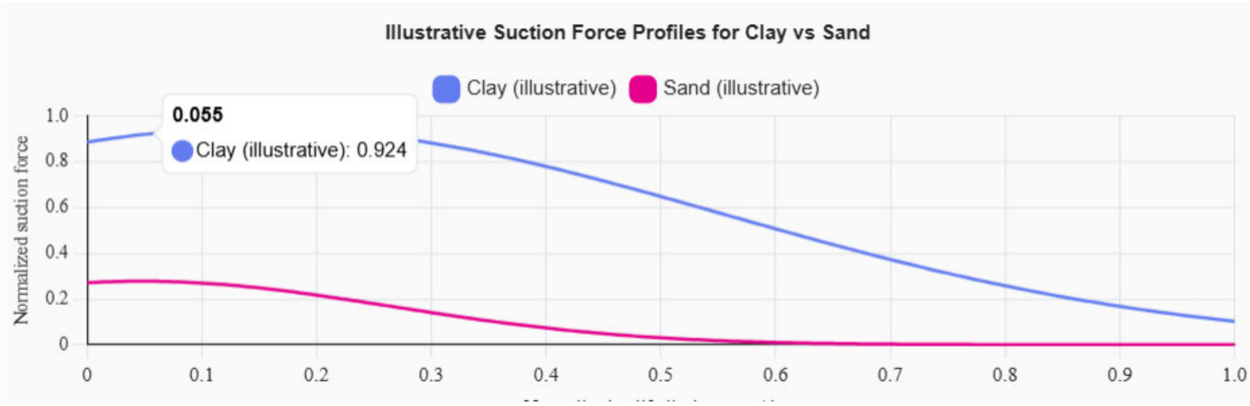

Figure 7-2:*Typical normalized relationship between suction forces for structures situated in clay and sand respectively.*

Studies consistently show that clay soils generate strong suction forces at the soil–structure interface during uplift. Similar suction forces is far less pronounced in sand due to its high permeability. Sand allows water to flow and equalize pore pressures quickly, limiting the negative pressure buildup. Localized suction effects can still be important in fine sands or when lift rates are high. For the two submarine structures, we can note that the Bow section is largely resting in compressed clay sediments, while the stern part is hardly situated in much sediments, and mostly in sand. Thus we can expect more suction forces on the Bow section than on the stern section. For the bow section, we also note that large parts of the bow section is actually seated above the seabed. For such areas, we do not expect additional suction forces at all.

> *A cradle for each section is placed on the support fill, which has good strength and flatness. The cradle must be designed to provide good access to the keel cases.*

Comment M3-3: Groundwork for cradle support – The cradle support is different to the rig-lifted structure in the way that the submarine wreck parts are lifted from their position into an angled position and landed on the horizontally placed support structure. The first question will be if suitable designated landing areas for the support structures can be found in the nearby area, and within the area which is supposed to be covered by sand and gravel after recovery of mercury? The initial plan would be to apply an area on top of the rock dump berm from 2016 for positioning of the cradles. If such flat areas of sufficient bearing capacity are not present, there must be established a suitable rock dumping plan areas. Then the loads of the submarine wreck parts and the associated support structures can be transferred to the ground via large enough mud mats and the underlying rock dump carpet which is evening out the seabed. It is natural to select a sand dominating area with not so deep sediments. A rock carpet is used to even out the seabed If required.

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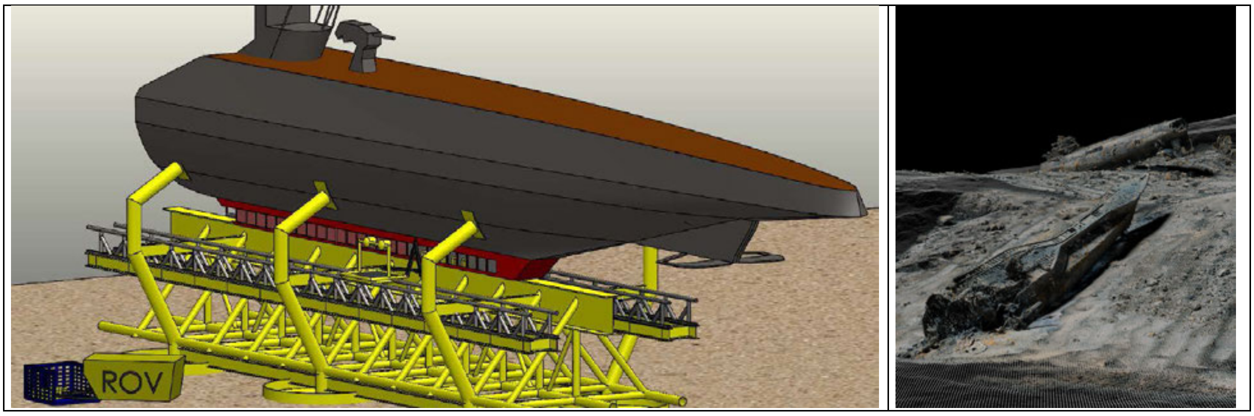

Figure 7-3: *Looking at the reported bathymetry and seabed conditions in the wreck area leads to the question if there are sufficient flat areas for the placement of two support structures in the vicinity of the wreck site.*

Comment M3-4: Cradle support structure – The structure proposal seems to be a bit high raised. The key issue is to set the sub-part down onto a longitudinal beam. Additional plating may be cut to match the profile hull making sure the submarine does not tilt over to any of the sides. This could be similar to the system for support of e.g. separators inside a support frame. Alternatively, the supports can be attached to adjustable members in a system like shown in below.

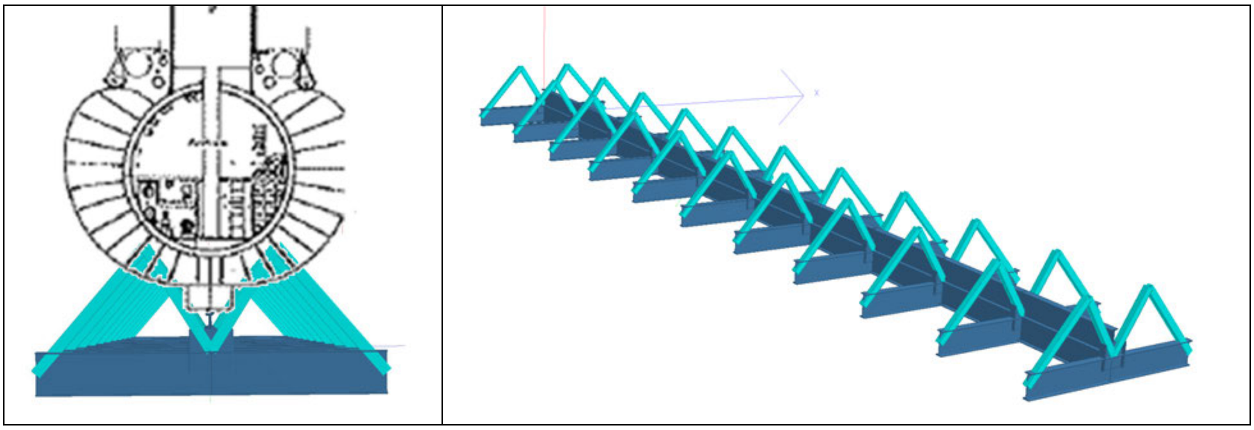

Figure 7-4: *The support structure need to support directly onto the pressure hull*

The above principal figure is there for weight estimation and for demonstrating the force flow in the loadbearing system. The system would of course be designed to allow for a well designed geometry that ensures stable working on the keel cases after the submarine part has been landed in the now lower cradle. In this way, we can reduce the weight and cost of the cradles as compared to the previously proposed methods.

The above frame was modelled with HEB1000 bottom beams, HEB1000 center beams, and SHS250 side supports. The idea is that the supports can support the pressure hull at approximately clock angles of 04:30 and 19:30. These can be made adjustable, without the concept model of above figure demonstrating that for now.

The frame assumes that the rock dump carpet is firm and can support the weight of the submarine. The model is built with a supporter at the very end of the HEB1000, which is conservative for the capacity of the frame.

The utilization of the frame is about 85%. The load applied is 1000 tons multiplied by a load factor of 1.3 and a DAF of 1.15. There is probably little dynamics when the frame is standing

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still. However, side loads are also there, but this must be looked into in a later detailed design. There are relatively low lateral forces involved, although there will be quite some drag forces due to periodic current.

It may well be that the geotechnical assessment would point at plates between the bottom flanges on the HEB1000. The model as shown here is about 75 tons, without plates between the bottom flanges. If one assumes, for example, 20mm steel plates between the bottom flanges, it increases by at least 50 tons extra. The overall weight of the structure is estimated to 175 ton.

The large question on the support structure is how to support the submarine? Shall this happen towards the external profile hull, or in against the more firm pressure hull? The inspections of the condition of the submarine may provide some answers to what can be expected. The above proposal indicates that the profile hull may crush against the supports. This could very well be the original plan, or one count on the capacity of the structural elements between the profile hull and the pressure hull.

Anyway, the resulting support structure(s) will typically become lower than previously proposed.

Comment M3-5: Cradle support structure foundation – The cradle structure need to be located within the already polluted area, nearby the existing structures. Looking at the survey images of the area, it is hard to find useful places without the need for any preparatory work. Therefore, it is suggested that there must be included for a rock dump champaign to install two carpets of approximately width 25m* breadth 40m * 2 areas = 2000m^2. Assuming a depth of 1m for these rock dump carpets, the resulting cost of the rock-dump may be estimated to about \$400-1200/m^3 or say 1000\$ * 2000m^3 = 2 M\$, or about 20 MNOK. The **Figure 7-5** shows areas where the potential rock dump can be positioned to serve the useful purpose. If the rock counter fill installed to stabilise the bow section is deemed sufficient flat, the entire activity can be dropped and frames can be supported at the previously installed rock counterfill.

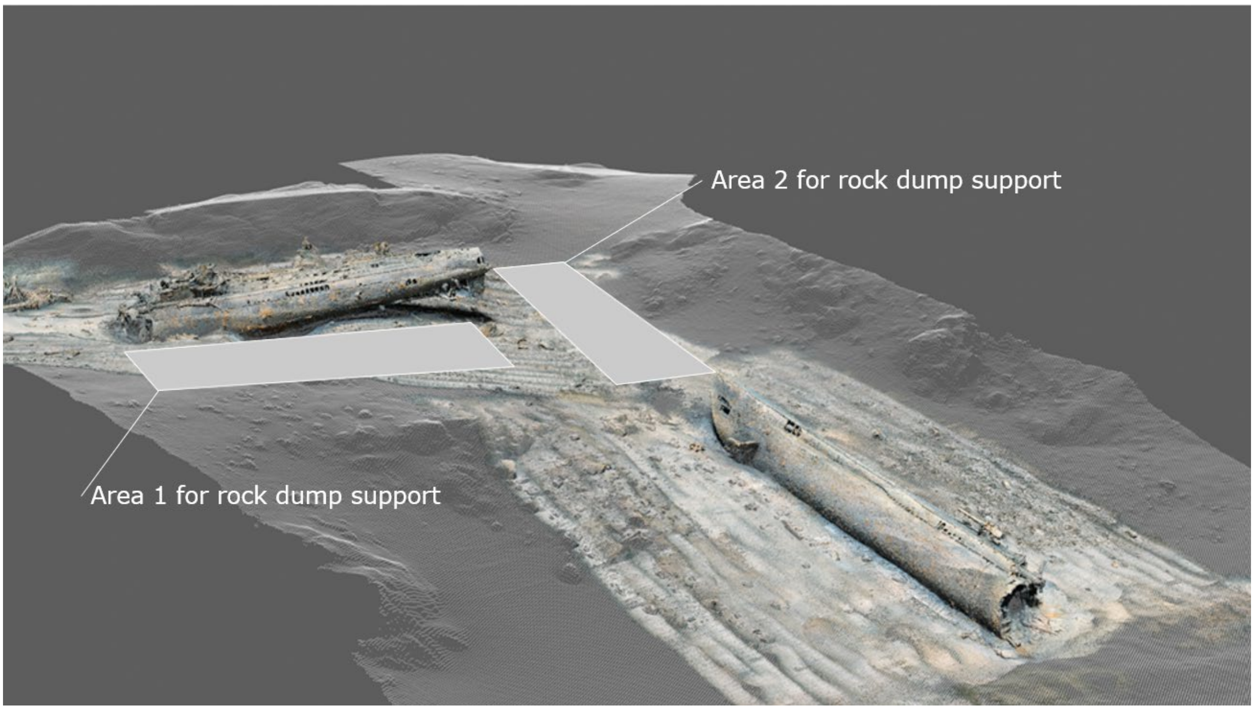

Figure 7-5: *Potential location of rock dump areas for positioning of the two cradle structures.*

With the above comments implemented, one can pre-install the lifting arrangement for both bow and stern sections, and finalise the preparations before the HLV arrives.

7.2 Establish Access to the Keel

Assuming the submarine bow and stern sections are now resting in their respective cradles, the work on establishing access to the keel cases would be the most favourable case of the three methods proposed.

7.3 Open the Keel Cases

No comments.

7.4 Retrieve the Mercury canisters from keel to seabed

No comments.

7.5 Recover mercury canisters and free floating Mercury from seabed to surface

No comments.

7.6 Stabilize wreck before capping

> *The wreck is lifted out of the cradle by a crane vessel and lowered to the seabed in a suitable location. The wreck should be placed in a location that reduces the amount of material needed for the cover. This could be next to a mountainside or on the supporting embankment against the slope. The crane wire is disconnected. The cradles are lifted up by a crane vessel. Or alternatively, the wrecks can be left in the cradles on the supporting embankment.*

Comment M3-6: Earlier de-mobilisation of HLV and more gravel – In this latter case, there is no need to re-mobilize the crane vessel, but the amount of material for the cover may increase somewhat due to the increased height (wreck + cradle), if this solution is chosen.

Comment M3-6: Cradle support structure – If the structure proposal is modified to lower the height, it may be beneficial to just leave the submarine parts resting in the cradles. Additional materials can be added locally. This would save HLV time and cost but increases a bit on the rock dump cost.

7.7 Vessel Requirements M3

This method requires the following setup:

LCV with two WROV and one OBSROV system mobilised. This will support the main activities. Furthermore, a Heavy Lift Vessel is required to break free and lift the submarine parts from the seabed and into the cradles positioned on the former rock dump area stabilizing the seabed below the bow section.

A Rock Installation Vessel has also been accounted for in case one does not find useful areas for parking the cradles. So there is an opportunity to reduce cost in this area.

7.8 Schedule M3: Cradle

This method outlines the use of a designated support rig to land each of the submarine sections into for enabling the removal of mercury cans from the keel cases. This imply that a 40m long structure is required for this purpose, previously estimated to about 150T-200T weight. This corresponds to a design and fabrication cost of approximately 125 NOK/kg * 175 000 kg equals about 22 MNOK for each structure.

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Prior to the mobilisation of the HLV, sufficient time has to be allowed for the time-consuming preparatory work to be completed. This includes the cutting of holes for lifting anchor attachments to the pressure hulls of the two sections. In addition, areas for landing of the submarine need to be determined and prepared.

The preliminary work will prepare for the lifting and shifting of the submarine sections from either a LCV (2 MNOK/day) or from a DSV (3 MNOK/Day).

This method is dependent on the preliminary work to be completed until the step when the 2x30 anchor points are all attached and the lifting arrangement is ready to be lifted by the HLV. At this stage, the HLV is mobilised, and the two lifts are performed in a few days to move the two parts into the cradles. Then the HLV can be demobilised, and work continues on the mercury recover at the keel cases. We can see that this method is much more efficient w.r.t. HLV compared to the Method 2.

Table 7-1: Estimated durations for M3: Cradle from 2014 study and from the 2026 study.

Item	Activity	Duration 2014	Duration 2026	Comments
	Project Management & Administration		[redacted]	[redacted]
	Engineering		[redacted]	[redacted]
	Engineering of subsea cradles for Stern and Bow section support		[redacted]	[redacted]
	Fabrication of subsea rig support solution for WROV		[redacted]	[redacted]
4B2.0	**Mobilisering**	**4 days**	**4 days**	
4B2.0.1	Light Construction Vessel	4 days	[redacted]	[redacted]
4B2.0.2	Heavy Lift Vessel, construction vessel w/3000ton crane	4 days	[redacted]	[redacted]
4B2.0.3	Rock installation vessel	2 days	[redacted]	[redacted]
4B2.1	**Stern & Bow Sections**			
4B	**Preparatory Work**	**44 days**	**124**	
4B2.1.1.1	Remove parts of the external hull, cut through external and internal hulls and connect the anchors inside the pressure hull.	30 days	[redacted]	[redacted]
4B2.1.1.2	Prepare areas for cradle	7 days	[redacted]	[redacted]
4B2.1.1.3	Install cradles	6 days	[redacted]	[redacted]
4B2.1.1.4	Attach the rigging arrangement from lifting beam to HLV to the lifting anchors inside pressure hull	2 days	[redacted]	[redacted]

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Item	Activity	Duration 2014	Duration 2026	Comments
4B2.1.1.5	Inject water underneath the hull	1 day	[redacted]	[redacted]
4B2.1.2	**Get access to keel**	**10 days**	**13 days**	
4B2.1.2.1	Lift the wreck section using the HLV	2 days	[redacted]	[redacted]
4B2.1.2.2	Remove stones and wreckage with a mechanical claw and / or WROV	4 days	[redacted]	[redacted]
4B2.1.2.3	Brushing along the keel.	2 days	[redacted]	[redacted]
4B2.1.2.4	Install working rig for WROV	2 days	[redacted]	[redacted]
4B2.1.3	**Open Keel Cases**	**2 days**	**9 days**	
4B2.1.3.1	Drill and cut away the side plates	2 days	[redacted]	[redacted]
4B2.1.3.2	Remove sideplates	2 days	[redacted]	[redacted]
4B2.1.4	**Remove Hg-bottles**	**10 days**	**14 days**	
4B2.1.4.1	Remove loose Hg bottles	11 days	[redacted]	[redacted]
4B2.1.4.2	Remove bottles that are corroded into each other	10 days	[redacted]	[redacted]
4B2.1.4.3	Remove liquid Hg	10 days	[redacted]	[redacted]
4B2.1.4.4	Transfer basket filled with Hg-bottles to wet storage	10 days	[redacted]	[redacted]
4B2.1.4.5	Move the (free floating) liquid mercury to wet storage	10 days	[redacted]	[redacted]

Item	Activity	Duration 2014	Duration 2026	Comments
4B2.1.5	**Hg-bottles to intermediate storage**	**0 days**	**0**	
4B2.1.5.1	Hg-bottles to intermediate storage	0 days	[redacted]	[redacted]
4B2.1.6	**Stabilise stern wreck sections and clean-up work**	**11 days**	8 Days	
4B2.1.6.1	Lift wreck from cradle and position at the seabed in a stable situation.	1 days	[redacted]	[redacted]
4B2.1.6.2	Remove lift anchors and any wire rigging from hull.	5 days	[redacted]	[redacted]
4B2.1.6.3	Recover cradle to vessel deck.	5 days	[redacted]	[redacted]
4A.0	**Demobilisering**	**3 days**	**3 days**	
4A.0.0	Heavy Construction Cessel	2 days	[redacted]	[redacted]
4A.0.0	Rock Installation vessel	1 day	[redacted]	[redacted]
4A.0.0	Large Offshore construction vessel w/ ≥400 t crane	3 days	[redacted]	[redacted]

7.9 Risk Method 3: Cradle

For this method, the key risks of method 1 and 2 are removed. One remaining risk is related to the 60 holes to be cut. This has been accounted for by adding what is believed to be sufficiently amounts of hours to cover expected duration.

Cutting 30 penetrations in the two hulls may take long time. This is relevant for the activity: *4A.1.1 Forberedende tiltak.* This work should be done long before the HLV is mobilised for the lifting operation to reduce risk of not being completed before HLV is mobilised.

Table 7-2: Additional risks identified to M3 from the 2026 study.

M3	Failure Mode	Cause of Failure	P(E)	Effect of Failure	C(E)	Risk Score
R1	Schedule overrun	Cumbersome work to make access for connection of lifting wires from spreader beam to pressure hull.	5	Large schedule overrun with associated high cost effects.	3	**15**
R2	Schedule overrun	Time-consuming work on the cradle removing gaining access to keel lockers and moving bottles into safe containers.	4	Large schedule overrun with associated high cost effects.	3	**12**
R3	Overloading	The suction forces may lead to high peak loads when breaking away from the soil. Also, there may be considerable amounts of sediments inside the hulls.	4	During the initial phase before all wires are engaged, the forces may become very high on the first engaged wires. This is in line with the risk R-0087 of Table 4-1.	3	**12**
R4	Vessel dependencies	HLV dependent on completed LCV work.	3	One vessel waiting for anther. Can lead to high overrun with associated high cost effects.	3	9

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7.10 Cost Estimate M3: Cradle

Table 7-3: Cost estimate for Method 3: Cradle.

	Method 3: Cradle This method applies a heavy lift vessel to lift each of the two submarine sections into a cradle to enable access to the keel at the bottom of the submarine. This enables access to the keel cases carrying the mercury for recovery. The key cost components are related to the preparatory work for attachm,ent of the 30 lifting anchors in the pressure hull.	Indikative Manhrs/ Days	Rate	Unit	NOKeqv	%
1	Project Administration & Engineering	[redacted]	[redacted]	NOK/Hr	[redacted]	[redacted]
2	Procurement & Subcontracts	[redacted]	[redacted]		[redacted]	[redacted]
2.1	Subcontracts	[redacted]	[redacted]		[redacted]	[redacted]
2.1.1	Design and development of remotely operated core drilling system. Qualification testing.	[redacted]	[redacted]	Contract	[redacted]	[redacted]
2.1.2	Fabrication of 2 x160T steel working frame for WROV's	[redacted]	[redacted]	NOK/kg	[redacted]	[redacted]
2.1.3	Lifting arrangement for 160T steel working frame	[redacted]	[redacted]	NOK	[redacted]	[redacted]
2.2	Third Party Services	[redacted]	[redacted]		[redacted]	[redacted]
2.2.1	Treatment system for sediments and water brought to deck.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.2	Special polluted material basket for subsea storage of mercury bottles under transport to vessel deck.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.2.3	Grouting spread and personnel	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.3	Other	[redacted]	[redacted]		[redacted]	[redacted]
2.3.1	20 off anchors for connection to the pressure hull	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
2.3.2	Winch wire arrangement for connection to lifting/rolling anchors	[redacted]	[redacted]	NOK	[redacted]	[redacted]
2.3.3	WROV working tools package for cutting steel, etc.	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3	Operations	[redacted]	[redacted]		[redacted]	[redacted]
3.1	HCV 400T Crane + 2WROV systems	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
	Heavy Lift Vessel, 1500-3000 Ton	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3.3	Rock Installation Vessel	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
3.4	Waiting on Weather, 5% of operation days	[redacted]	[redacted]	NOK/Day	[redacted]	[redacted]
4	Contingency at feasibility level, 30% of cost	[redacted]	[redacted]		[redacted]	[redacted]
Selling					kr 1,228,825,000	100.0%

7.11 Evaluation and Conclusions

This method is seen as the method of least risk exposure to the marine operation work. The method applies a similar lift arrangement as for the rig alternative M2, but has a much more comfortable lifting system without the lifting structures involved in M2. On the contrary, it is dependent on the high cost resource HLV which will build up a high cost. Since the HLV is only there for the short lifting period, the two low raise support structures will enable demobilisation of the HLV immediately after the two lifted movements. Economically, this favour M3 before M2.

Of the three methods for evaluation, this is the most favourable in our opinion. For this method, the Client has specifically asked for answers to the following questions:

1. **Verify the size of the cradles.** Reply: Dimensions are given in the text.
2. **Amount of steel and unit price finished processed and welded**. Reply: The cost of the two 175 ton structures has been estimated to cost around 120 NOK/kg * 2 structures * 175 000 kg/structure = 42 MNOK.
3. **Installation of the cradle – what groundwork is necessary?** Reply: It is proposed to establish a rock dump carpet that will ensure a flat rock dump area for parking the two support cradles for the submarine wreck parts.
4. **It is assumed that the cradle can be placed on the support fill**. Reply: Yes, that is the assumption.

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5. **Type of lifting vessel and onboard equipment for lifting, and costs for vessel hire.** Reply: This heavy lift vessel should be capable of performing lifts in the range of 3-4000 ton. Vessels of this type requires some [redacted] in dayrates. In addition, there would typically be a mobilisation fee related to moving the vessel to the site.
6. **Expected duration of the operation including mobilization and demobilization.** Reply: It is proposed to re-arrange the activities according to the different vessel champaigns required to complete the work. First there should be a preparation campaign, thereafter a short lifting campaign, and then finally a mercury recovery campaign. This split allows for better selection of vessels useful for different stages of the work:
    a. Preparatory work using a LCV with two WROV teams onboard, or alternatively a DSV with two diving teams and two WROV teams to reduce number of working days.
    b. Rock dumping with preparation of the two cradle areas.
    c. HLV performing installation of cradles and relocation of the two submarine sections onto the cradles.
    d. LCV performing mercury recovery.

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8. 2026 METHODOLOGY FOR RECOVERY OF MERCURY FROM U-864

8.1 Background

Several known wrecks at seabed have been split into sections by the application of abrasive cable saw cutting, here denote Diamond Wire Saw (DWS) in general. Three wrecks are mentioned to serve as relevant references for the alternative proposed method of this study.

8.1.1 K-141 Kursk - origin of modern subsea diamond wire cutting

After the 2000 disaster, Russian authorities required the Kursk to be raised—but only after removing the devastated bow, which contained unstable torpedoes remnants, distorted, weakened structure and with a potential radiological risk during the planned lift. Ref. Kursk

The diamond cutting wire method was chosen as an alternative to avoid risk of detonations from conventional cutting by explosives or shears. Thermal cutting was deemed impossible at depth. A vibration-tolerant method was chosen. This is very similar to the reasonings for choosing the similar method for the U-864.

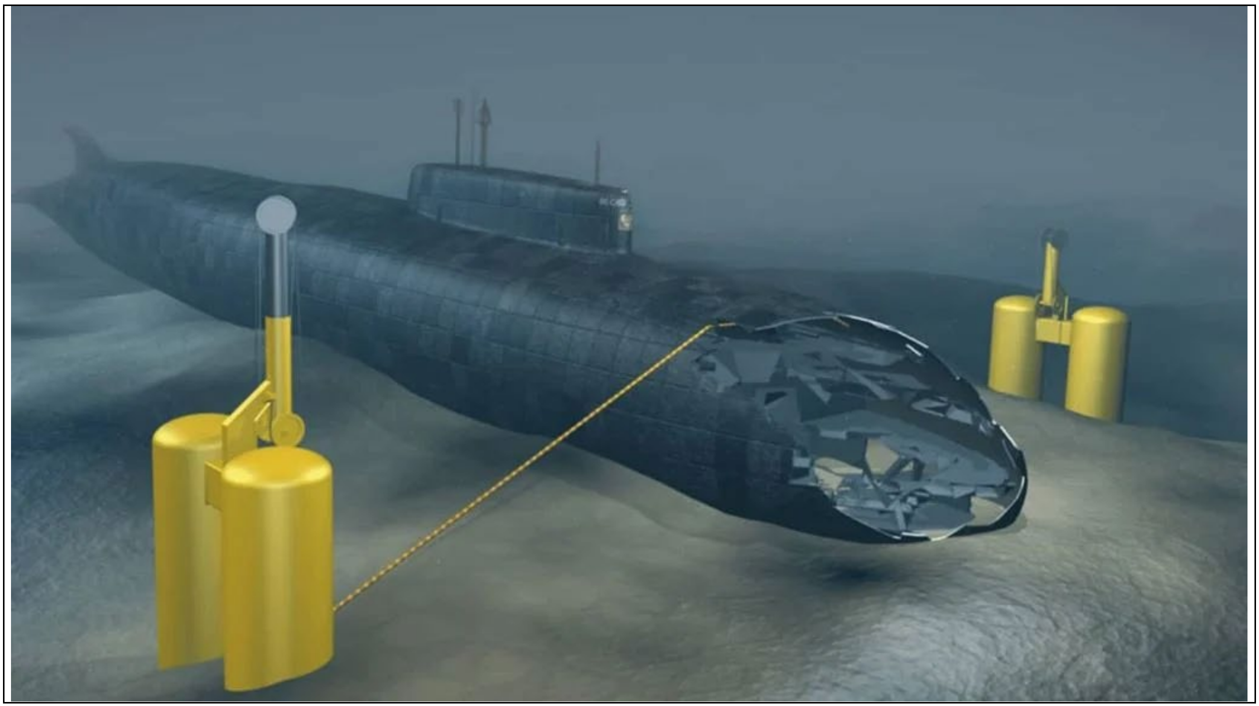

Figure 8-1: *The cutting wire system was anchored by suction anchors on the seabed. Wire reciprocated hydraulically across the hull, and the cut was completed in ~31 hours at 108 m depth.*

This operation effectively invented deep-water abrasive wire wreck-cutting. Reference is made to:
https://magazines.marinelink.com/Magazines/MaritimeReporter/200203/content/develops-highpowered-removal-207855

The cutting operation left the bow section on seabed, allowing the straight cut remaining section of ~9,000 t to be safely lifted and transported to Murmansk. This is still the deepest heavy salvage cut ever executed.

8.1.2 The MV Baltic Ace - industrialization of the Kursk method

After sinking in 2012 in one of Europe's busiest shipping lanes, Baltic Ace posed:

- A navigational hazard

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- An environmental risk (fuel + cars)
- Legal pressure for total removal

Referencs is made to the articles Wreck removal, Baltic Ace and MV Baltic Ace - Wikipedia.

From the article of BangShift.com See How The Wreck Of The Car Hauler "Baltic Ace" Was Removed Off Of The Ocean Floor Over The Course Of Two Years! - BangShift.com:

> *"When the M/V Baltic Ace sank on December 5th, 2012 after being hit by the container ship M/V Corvus J., she settled in 115 feet of water in the middle of the shipping lanes that serviced the port of Rotterdam, one of the worst locations possible. Knowing that the wreck was impeding ship traffic and worried about the ship's fuel oil and the cargo of 1,400 or so Mitsubishi vehicles on board and the potential environmental impacts that could take place if something were to happen in the rough North Sea conditions, the Dutch Rijkswaterstaat (a public works section of the government that overseas, among other things, water management) put out a contract for the salvage of Baltic Ace, which was awarded to Royal Boskalis Westminster and their partner Mammoet. Starting in 2014 and working for two years during the months of March-October, the ship was drained of fuel oil, then cut up into sections using the diamond-sleeved wire method first seen on the recovery of the Russian submarine Kursk and removed."*

As can be read from the article, a direct lineage is explicitly acknowledged by salvage contractors. The process was conducted as follows below:

1. Fuel oil removed (2014)
2. Hull surveyed—found too weak for single lift
3. Wreck cut into 8 major sections using diamond wire
4. Sections lifted by floating cranes and recycled ashore

This was Kursk's bespoke solution turned into a repeatable industrial process. The key experiences from this work demonstrated faster cutting rates, and secondly, some deck sections collapsed and were removed by grabs instead of wire.

8.1.3 U-534 Diamond Wire Cutting on Land

After being salvaged in 1993, the German submarine U-534 initially remained intact. By the mid-2000s, when the rescue company Merseytravel decided to relocate the submarine to the Woodside Ferry Terminal, moving the 76.8-m-long and heavily corroded steel hull in one piece was prohibitively expensive and risky.

Figure 8-2: *Submarine U-534 of type IXC/40 had a displacement of 1,144 tonnes. It was initially recovered in one piece but was later cut into five larger sections of maximum 240*

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tonnes. The diamond wire cutting was performed onshore. Ref. The web site COME ON!! 39 images of recovered U-Boat U534 (left picture). Ref. https://www.alamy.com/stock-photo/u-534-world-war-german-submarine.html?sortBy=relevant (right picture).

According to Recovery of German U-Boat U534 (scroll down for video) | War History Online, cutting the submarine allowed:

- Transport using standard heavy-lift cranes.
- Safer handling of weakened 1940s steel structures.
- Public viewing of the interior rather than just the outer hull.

Each final section still weighed up to 240 tonnes, underscoring why precision cutting was essential. The diamond wire cutter provided

- on land cold cutting.
- extremely straight, narrow kerf cuts.
- ability to cut thick, heterogeneous steel structures safely.

This diamond wire cutting of the U-534 was a controlled heritage engineering exercise providing a high-quality result that can serve as a very good and relevant example on what is possible to achieve with this method also for the U-864.

8.1.4 Conclusion on Experiences with Diamond Wire Cutting Method

1) Kursk pioneered diamond wire cutting for extreme subsea nuclear salvage.
2) Baltic Ace proved diamond wire cutting as a scalable wreck-removal industry standard.
3) U-534 used diamond wire cutting for heritage logistics. This object is very close to U-864.

Smit invented the method and applied it to Kursk, Baltic Ace industrialized it, U-534 demonstrated its finesse. From this background we can clearly see that diamond wire cutting is a suitable principle for cutting the U-864 bow and stern sections into smaller sections more suitable for lifting.

8.2 Description

Based on the knowledge gained from previous work performed in 2014 and 2025, and the three methods proposed in DNV document /7/, alternative activity steps are proposed herein based on the similar main process. The alternative 2026 Methodology for recovery of Mercury from U-864 denoted *Method 4* assumes a decision has been taken that divers are not to be applied in the planning of the methods due to the underlying threat of the existing torpedoes in bow and stern sections.

The main principles of the alternative method are based on the following:

- The key task is to recover as many mercury bottles as possible from the keel of the vessels bow and stern sections.
- Many preparation activities of the formerly proposed methods are related to *duration uncertainty* due to the complexity of the double-hull submarine structure, lack of experience in executing the tasks by WROV's, and due to uncertainty in the wreck condition and material capacity aspects. Instead of planning the WROVs to dive in towards the submarine's pressure hull, one can plan for approaching the two submarine sections from the outside directly. This will largely remove the duration uncertainty because those tasks are not required to be performed when using the new method.
- A low vessel resource setup will be less vulnerable for duration critical campaigns. If the focus can be directed to the sections of the submarine parts that can in theory contain mercury bottles, the main task can still be achieved, namely, to recover as

many bottles as possible. By cutting off the parts that cannot or has a low probability of containing mercury bottles, the remaining vessel weights are reduced for the parts that may contain mercury bottles. By reducing the loads to be lifted to below 400 ton, one may choose to recover mercury at the seabed or at the topside without having to mobilize a very large lifting setup in both cases.

- By cutting off the torpedo room sections of the wreck parts, focusing on separating out the parts that can, theoretically, contain mercury in the keel cases, the overall weight to move is reduced to below 400ton for each of the parts. This reduces the requirements for crane capacity from HLV to HCV.
- If the environmental issue of the potential torpedo detonation is limited, it becomes possible to rock dump the separated sections.
- If mercury removal activities are chosen to be performed topside after recovery of bow and stern sections, it is possible to eliminate most of the detailed and time-consuming subsea work. The overall cost is significantly reduced under the assumption that subsea work is much more expensive than mercury removal work onshore after the bow and stern sections on cradles are transported from wreck site to a suitable yard for treatment of polluted materials.
- This approach requires somewhat larger focus on tool development to execute plans, and perform focused dredging at the tool application locations. Relevant tools and dredging equipment are previously used and several projects have used similar tools and therefore demonstrated the methods applicability.
- Although the subsea work is dramatically reduced in the M4 cut alternative, one need to remember that the activities and cost of topside cleaning and handling work related to the mercury in the keel need to be added to the subsea work estimate.

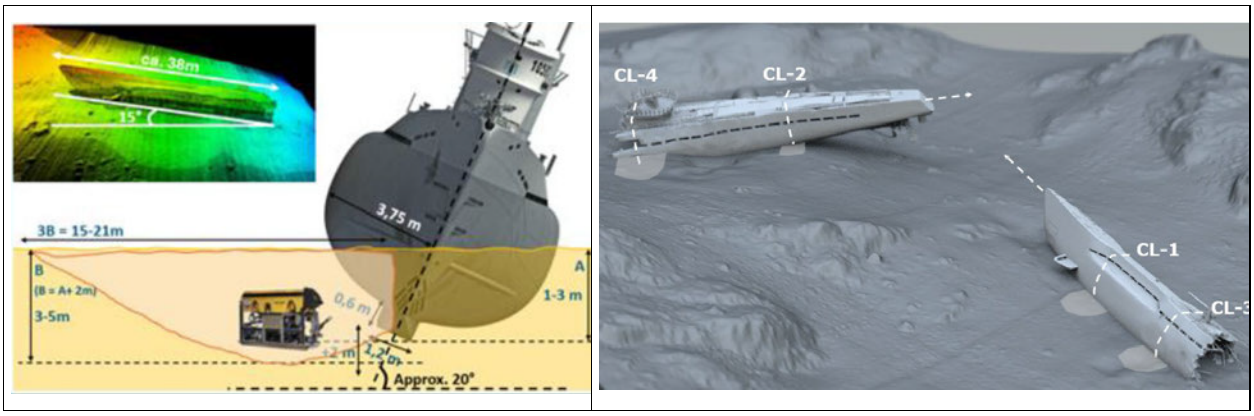

Figure 8-3: *Due to the heel and slight burial of the two submarine keels, local areas need to be excavated to allow access for the DWS for execution of the cut lines CL-1 to CL-4. Lower left image by Scanmudring.*

8.3 Preparatory work

The preparatory work can be executed from a LCV or a HCV. The lifting must be done with a sufficient crane capacity by a HCV or a HLV. The difference between the vessel types are particularly related to the crane capacity in this case.

The purpose of the preparatory work is to ensure a safe and efficient operation at the seabed where the two wreck parts of the submarine are reduced to minimum of what needs to be lifted, while still keeping the most likely parts of the keel which could contain mercury bottles. The remaining mercury can be located in those parts of the keel that were not heavily damaged by the torpedo hit and the subsequent breaking of the ship into the two main parts, the bow and the stern sections. These most likely areas of the keel is shown as the yellow marked sections of the keel in **Figure 8-4** below.

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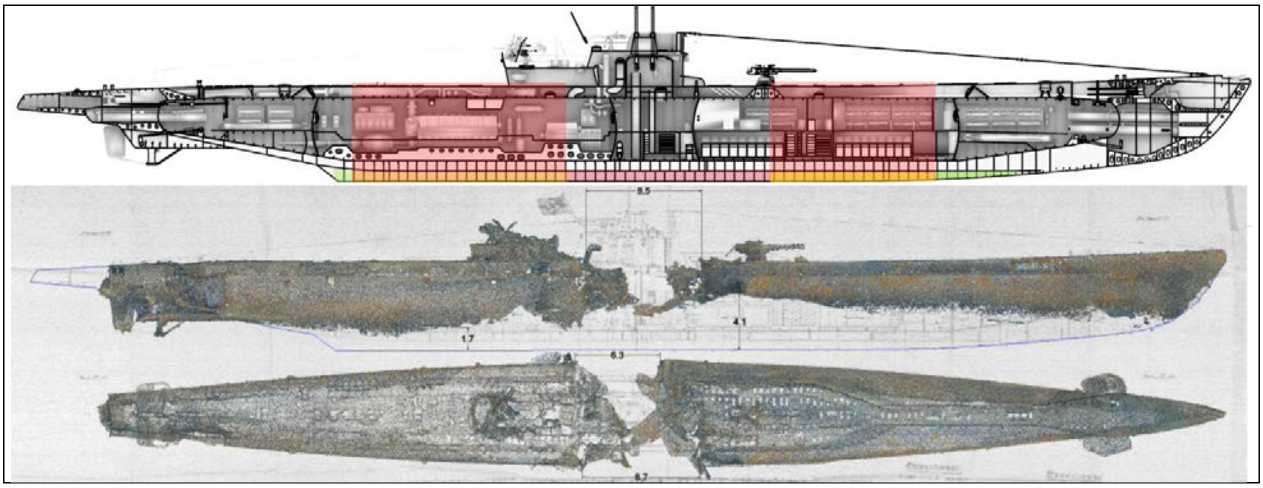

Figure 8-4: *The assembled wreck parts illustrates what parts of the keel that are most likely to be crushed and heavily damaged (red marked), and which keel cases that are most likely to contain mercury (yellow marked). The green marked areas of the keel has been confirmed to be without mercury bottles inside.*

The **Figure 8-4** also shows two red marked sections of the vertical submarine hull cross-section at the top of the illustration. These two areas match with the yellow marked keel cases that may contain mercury. The implication is that those reduced bow and stern sections marked by red are the smallest reduceable sections of each bow and stern sections that can be achieved, while still ensuring that as much of the mercury is recovered as possible.

The reduction of the objects to be lifted can serve several important purposes for the recovery plan:

1. The cutting of the submarine parts into smaller sections can split away the torpedo(s) located in the stern and bow torpedo rooms. This will ensure that the torpedo hazard can be handled in a safe manner prior to the lifting of a reduced bow or stern section. With the torpedoes away, it is safe to handle the remaining part more "roughly", like using a claw from outside to tighten the grip and lift the reduced section out of the seabed.
2. The lifted weight is largely reduced from estimated 900tonnes to less than 400tonnes when excess lengths are cut away. This increases the number of vessels in the market that have sufficient crane capacity to handle the two loads. A reduction in the vessels day rate will directly reduce the cost of the entire operation.
3. By clamping around the vessel from the outside using a remotely operated hydraulic mechanical claw, the duration of the costly subsea operation can be dramatically reduced since one avoid all the complex work on gaining access to the inner hull for attachment of lifting anchors.

One can now see that it can be a good strategy to perform all preparatory work on cutting the submarine parts into the reduced bow section and reduced stern section first. Thereafter, when all preparatory work is completed, the LCV/HCV can be demobilised and the HCV/HLV can arrive for performing the two lifts to complete the subsea operation.

This sectioning work contains the necessary preparations to:

- Measure out the four correct cut positions and confirm coordinates of the tool installation.
- To prepare the trench for the DWS working envelope a trencher and/or a "Rock Cutter" will be used. See **Figure 8-5** below.

- Dredge the areas where the feet's of the DWS will be located. Soil sediments are collected into the subsea container. If required due to harder soil, an excavator may be needed for this purpose.
- The same excavator may also be used for hammering away rock if needed. See **Figure 8-5** below. This may be required to ensure the DWS pathway will move all the way through the submarine hull and keel at the bottom.
- Remove any masses and make sure the space is sufficient for installation of the DWS.
- The WROV equipped with grinder tool and cable cutting tool will survey and clean up the area at cut location. Typical items to considered cut/removed are protruding and unsupported small-bore pipes and brackets that could vibrate heavily in engagement with the diamond wire.
- The rigging and fixation for pulling the cut stern torpedo room section free from the central hull section will be installed and lined up for the upcoming pulling operation.
- Sandbags may be position underneath the side hull and sand disposal underneath and along the stern torpedo section to reduce the distance the torpedo section can rotate and fall towards the seabed during the later part of the cutting operation. Some sort of "sand" will also be dumped in the direction of the pull (a few meters), to avoid a bumpy pull and to reduce or at least have a more know seabed friction status.

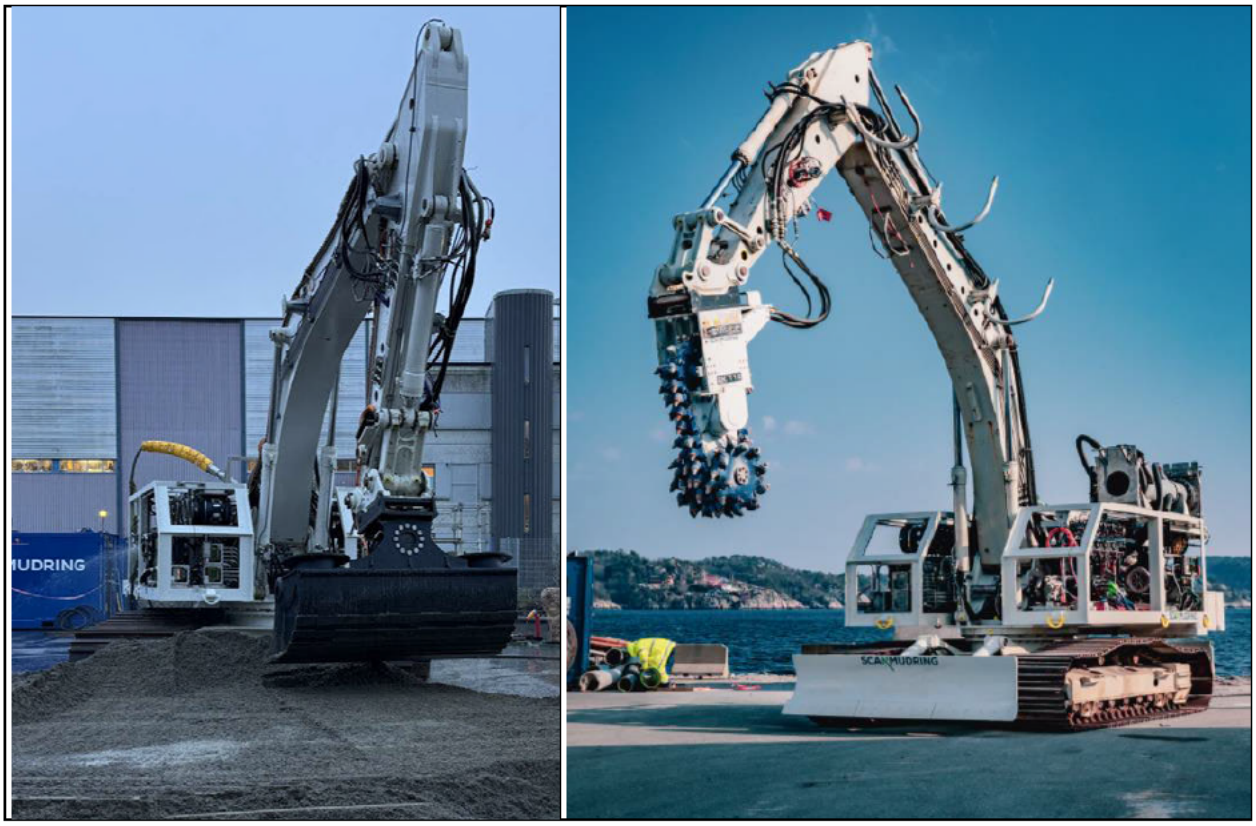

Figure 8-5: Example on *potential excavator tools that can work on the local spots for positioning of the DWS cut locations.*

8.4 Cutting Bow Section Torpedo Room Off

Having prepared the ground for setting down the DWS, this tool can be installed at the first cut-line of the bow section CL-1, as shown on **Figure 8-3** above. The purpose of this cut is to remove the section with torpedo's and reduce the weight of the section to be lifted.

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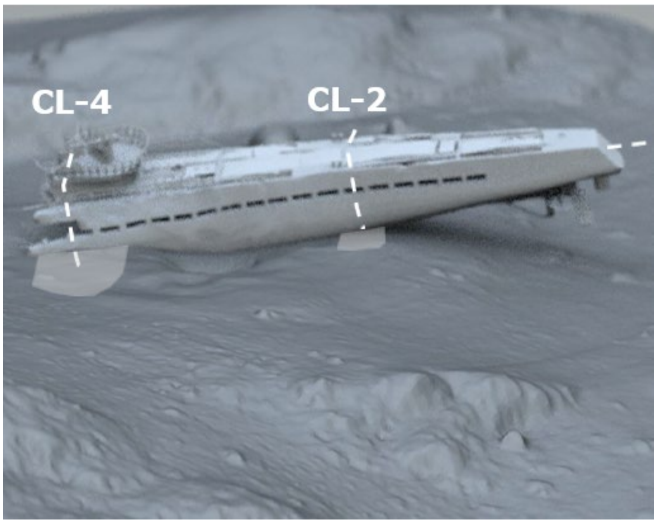
All DWS operations on U-864 will start with surveying and identifying position for cutting. The preferred cut position is in-between the internal ring-stiffeners members on the pressure hull. By cutting in-between the ring stiffeners we also avoid the structure members supporting the outer (shape) hull and the vertical stiffeners plates in the keel cases. This approach is based on the assumptions that the structural members supporting the outer hull and the vertical stiffeners plates in keel cases are positioned direct on the pressure hull ring stiffeners.

[redacted]



[redacted]

Figure 8-6: *The cut lines need to be marked by confirming the accurate positions (left).* [redacted]

The DWS can then be landed onto the cut location and the WROV will guide and verify correct position.

The power & control umbilical will be connected to the DWS allowing for tuning of the DWS elevation by extending or retract the four legs with mudmat inviably, as pair or all at same time.

[redacted] When the cut is completed, the DWS is either recovered back to deck for replacement of the diamond wire if it is close to wearied out or relocated if the monitoring and inspection of the diamond wire confirm that next cut can be carried out without replacing the diamond wire.

The deck winch onboard AHV is connected to the pre-laid pull line connected to the pull eye at the bow section of U-864 if this has been pre-inspected and accepted for a pulling operation. As the WROV and OBSROV are in position to monitoring the pulling/separation operation, the AHV can start the controlled pulling operation in accordance with the agreed procedure for this operation. As the cut is finalized, the AHV pull away.

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8.5 Clean Cutting of Fractured Areas

The purpose of second cut is to reduce the weight as much possible without cutting into keel cases that could potentially contain Mercury bottles. In addition, the geometry of the lifted object becomes more controllable with regards to Center of Gravity (CoG) and Centre of Buoyancy (CoB). [redacted]
This feature then allows cutting larger section away without cutting all the way to the bottom of the keel. If the access is limited the priority will be to cut out as much outer hull, gear, cannon pedestal etc. to reduce the weight to be lifted.

The horizontal cutting operation is somewhat more critical due to a higher risk of jamming the diamond wire following a potential fall of heavy sections that becomes loose during cutting with rapid closing of the working slot/path for the diamond wire as a consequence. If the diamond wire fail, wear out or get stuck, the DWS need to be recovered to deck for replacement. And the cut path must be re-evaluated if the cut path is failing several times in a row.

The WROV will be equipped with steel cable cutter, allowing the WROV to cut loose the DWS and to remove damaged diamond wire from the cut area.

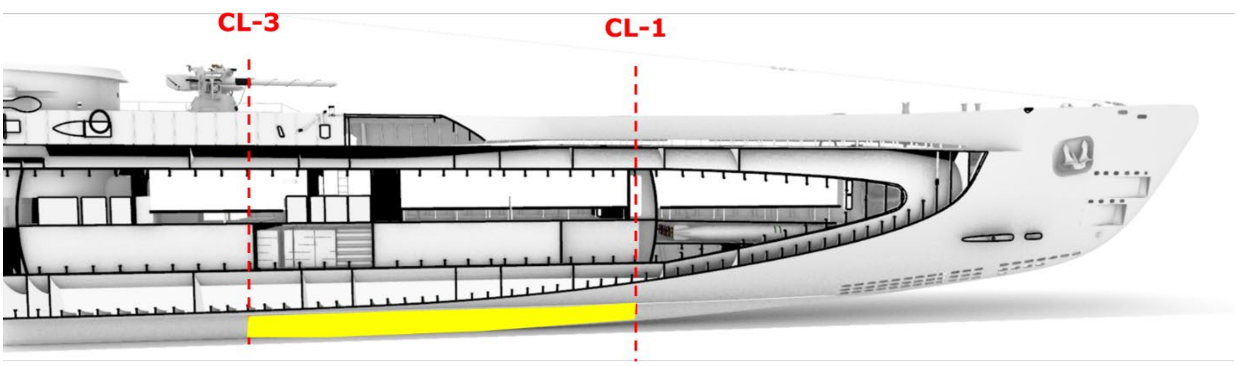

Figure 8-7: *The image shows the naming of bow section parts and the approximate location of cut lines 1 and 3.*

The reason why the cut lines are ordered “1” and “3” is that the first and second cut lines will enable cut away of the bow and stern torpedo room sections. For this part of the operation, an anchor handling vessel (AHV) is required to create a pull in the structure to slide away the part from the remaining structure. For schedule reasons, these two cuts are done first.

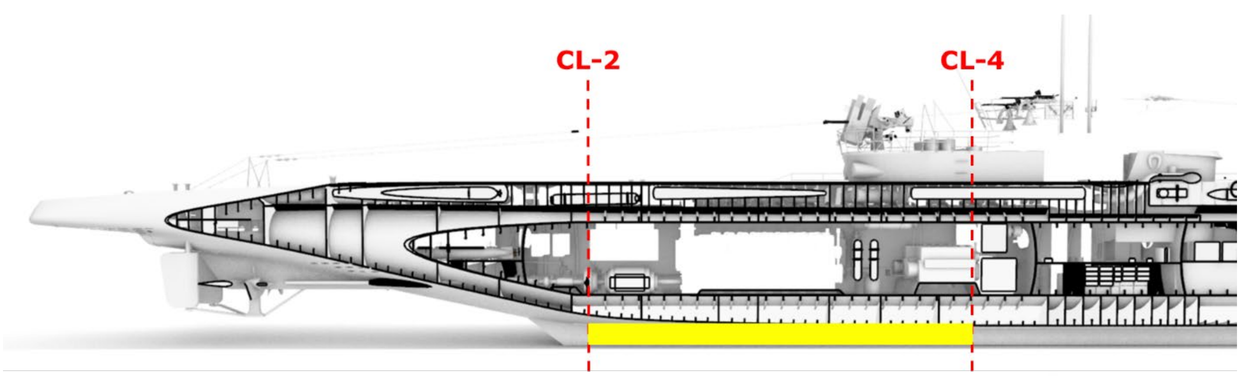

Figure 8-8: *The image shows the naming of stern section parts and the approximate location of cut lines 2 and 4.*

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8.6 Lifting the Reduced Sections

Since the stern section is laying on "hard" seabed it is assumed that the hull is less exposed for suction during lift off. This is to some degree different for the bow section, which seems to be resting in more sediments than the stern section.

Another issue to evaluate is the influx of sediments into the opening of the two tubes. This can clearly be seen from Reach's photogrammetry survey, particularly as shown in **Figure 8-9**.

Figure 8-9: *There are sediments visible in the photogrammetry survey image of the bow section in lower right corner.*

The cut line number 3 can be seen in **Figure 8-7**. Note that the same image shows a bulkhead under the location of the (now blown away) forward part of the conning tower structure, and another **Figure 8-3**just in front of the torpedo room. It is not likely that much sediments can have penetrated through the bulkhead since the opening is of a very small diameter here. The consequence is that by removing the Cut-off Section Bow, one reduces the uncertainty of having much sediments located in the Reduced Bow Section.

Figure 8-10: *The situation for the stern section is different for the stern section as for the bow section. For the stern section, the nearest bulkhead is crushed, leaving the interior more exposed to inflow of sediments.*

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This is important particularly in relation to the load situation when lifting the Reduced Bow Section out of the water. At that stage it is important that any *trapped water* can freely flow out of the tube.

The same situation is relevant to evaluate for the Reduced Stern Section. The Reduced Stern Section is longer than the Reduced Bow Section. Both have the same diameter of the tube. Thus, the weight of the Reduced Stern Section is expected to be higher than the Reduced Bow Section. When following the proposed cut lines of **Figure 8-8:** *The image shows the naming of stern section parts and the approximate location of cut lines 2 and 4.*, the Reduced Stern Section will represent the largest load to lift.

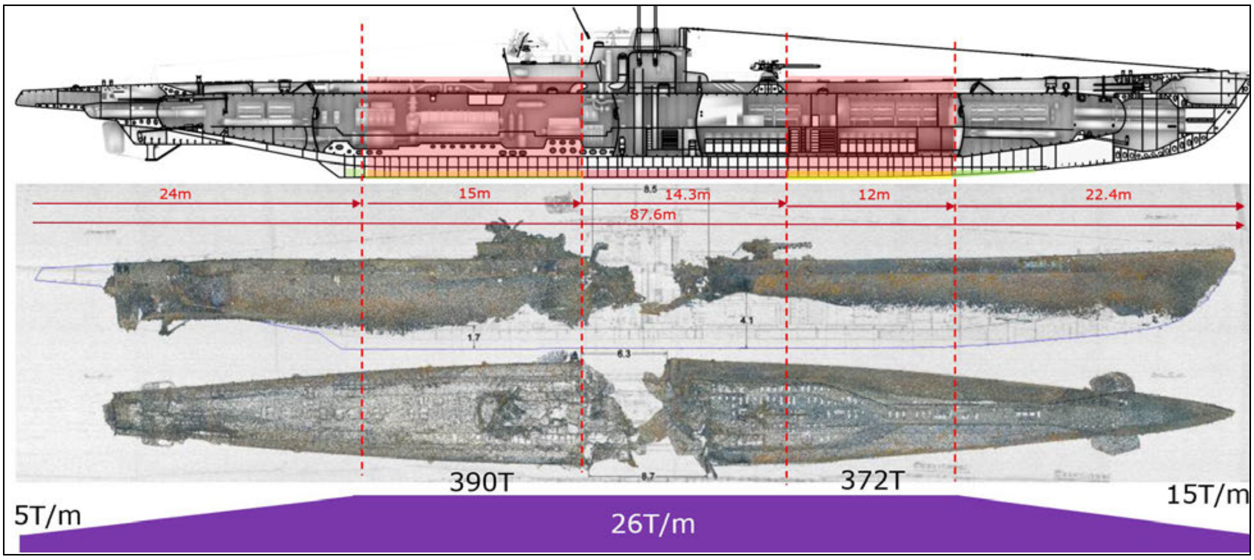

Figure 8-11: *The estimated weights of the two Reduced Stern and Bow Sections are 390 and 372 tonnes respectively.*

The **Figure 8-11**illustrates the estimated weight distribution (violet colour) along the 87.6m ships length. Average weight distribution can be estimated to 1800T / 87.6m = 20T/m. The weight distribution is not equally distributed over the entire structure, the mid-section of the submarine is obviously heavier.

In the parts that contains the Reduced Sections to be recovered to surface, the diameter of the pressure hull is at its maximum, about 25-27ton/m. The two sections are approximately 15m (stern) and 12m (bow) long, leading to estimated weights of 390 and 372tonnes.

The maximum lifted load needs to account for dynamic effects and the weight of the lifting arrangement, including the mechanical claw. Any suction forces are relevant at the lift off from seabed, but will not be relevant later. And the dynamic effects have been estimated to 1,1 using the Seven Arctic crane system. It seems reasonable to estimate a total lifted weight of about 500tonnes for assessment of minimum crane capacity.

The lifting operation can be initiated after the DWS is relocated or brought back to deck. On the contrary, it would be a benefit to complete as many cuts as possible before the HCV or HLV arrives with the larger crane and the claw tool for lifting. By completing all cuts up front, one avoid any schedule dependencies and potential waiting on operational steps.

The Lifting Claw must be function tested and proven prior to mobilisation. The claw arms will be retracted to match the actual cut sequence to be executed.

The first choice to be made is if the lift shall be a transfer of loading at depth to the storage frame for recovery of mercury, or if the Reduced submarine section shall be recovered to deck. An option is to transfer to transport frame as this has been evaluated as the preferrable step to execute. There is less uncertainty related to the transport frame compared to lifting

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by the claw, particularly during the transport through the splash zone with most movements and potential danger of trapped water that can increase the object load significantly.

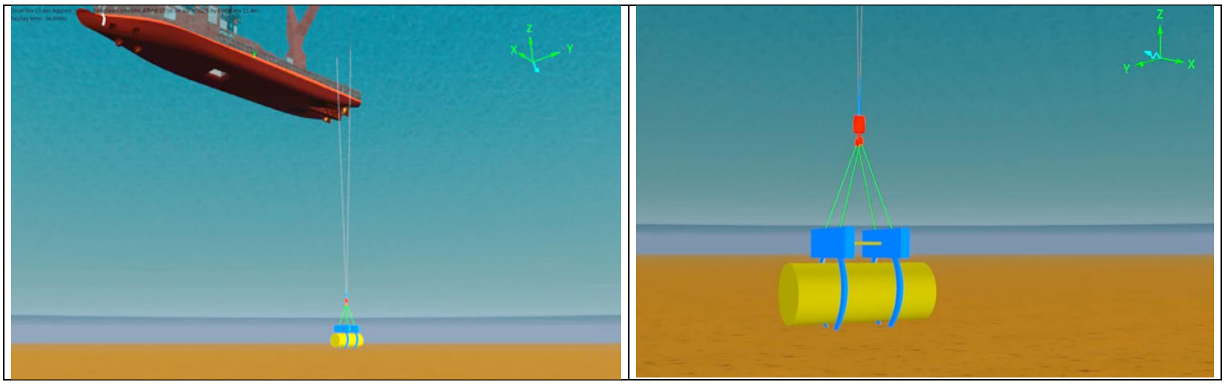

Figure 8-12: *The estimated Dynamic Amplification Factor (DAF) resulting from the Orcaflex analysis indicated a DAF of 1.1 for a typical sea state for AHC lift subsea around 2m-2.5m.*

The position for engaging the Lifting Claw (LC) will be based on an estimate of COG position for remaining section. The self-weight of Lifting Claw can crush partly in the outer hull when "dropped" onto the top of stern section. With the Lifting Claw resting onto the partly crushed/deformed outer hull, the WROV connect the hydraulic stab to the control panel on LC and apply hydraulic pressure to the clamp cylinders. When it is confirmed that the claw arms are fully engaged below the centre of the pressure hull, the WROV disconnect the hydraulic stab, and the initial test lift can take place.

If the Reduced Stern Section lifts with an acceptable slope, the transfer to the Seabed Parking Frame (or U-864 Lifting Frame) can continue. If test lifting indicate that COG is outside the LC envelope, then the LC must be repositioned.

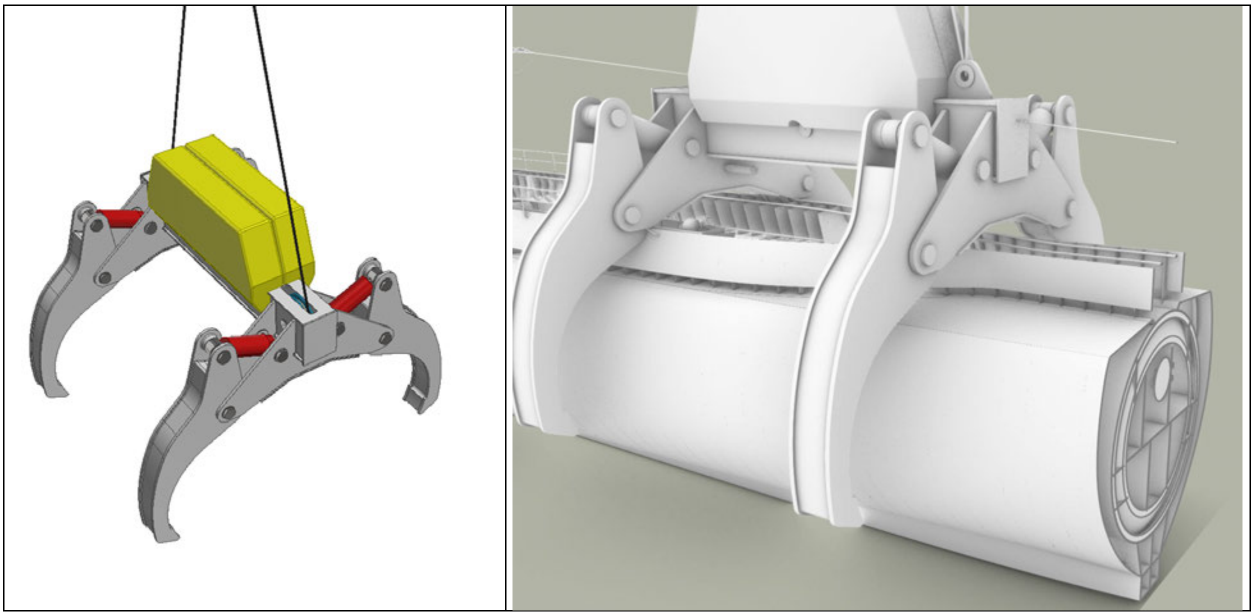

Figure 8-13: *The remotely operated claw can grip around the outer shell with individual claws.*

[redacted] When landing the stern section onto the Seabed Parking Frame (or U-864 Lifting Frame), the lifting operation is into critical phase since the hull must stand on its keel, but the hull is likely partly rotated when lifted off the seabed. The landing has to be well coordinated to allow the stern section to swing back on the keel when lowered towards the *Seabed Parking Frame* (SPF) and utilizing the uprating effect in the frames adjustable side supports. Note that friction between the Seabed Parking Frame need to higher than the side forces applied towards the SPF.

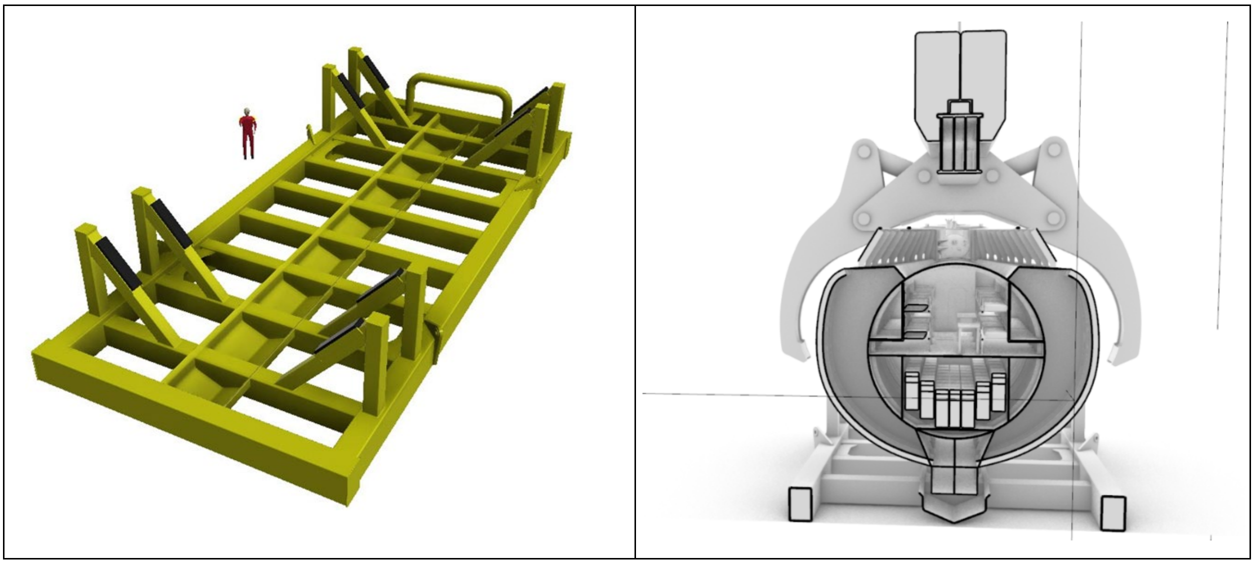

Figure 8-14: *The SPF will be positioned at the seabed before the lifting of the reduced sections are lifted. The reduced sections are moved into position. Adjustable guiding arrangements can be applied to guide and force the keel into the final resting position.*

A similar working method will be repeated for the bow and stern sections. The key for the economics is to complete as much preparations as possible using a lower price Light Construction Vessel, LCV. Then, when preparatory work is completed, the more expensive HCV or HLV arrives to perform the lifting operations. Thereafter, the HCV or HLV leaves for CCB or another base with the two submarine sections that can theoretically contain mercury bottles in the keel.

8.7 Vessel Requirements

The initial preparation works can be conducted by the use of a LCV equipped with the required excavation systems required for the preparation of the diamond wire cutting locations. The preparation work can commence, and all four locations are dredged and prepared before the DWS is installed in place for first cutting.

A larger Heavy Construction Vessel equipped with OBSROV, 2 Work ROV systems and typically minimum of about 600Tonnes Heave Compensated (HC) main crane that would come in at a later stage with the claw to perform the main lifts after the LCV has prepared and cut of the required sections. This will limit the vessel campaign for this vessel and reduce risk for contractual issues relating to schedules.

Figure 8-15: *Left picture shows the AHTS Horizon Arctic, and the Right picture shows HCV Seven Arctic. The latter vessel is equipped with a 900T HC crane.*

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An anchor handling tug vessel AHTS can be connected to the bow/stern objects to be pulled slightly away from the submarine as the cut is about to be completed. This ensures a safe pull-away of 10-20m of the part(s) that includes the torpedoes.

The Seven Arctic HCV has a 900ton crane capable of lifting the 500tonnes load to surface. There will be some dynamics and there will be additions from trapped water as the object is slowly lifted out of the water hanging in the grab, to let water purge out of the submarine tube. This operation requires good weather conditions in the range of 1-1.5 m significant wave height.

8.8 Schedule

Table 8-1: Estimated durations for M4: Cut from the 2026 study.

Item	Activity	Duration 2014	Duration 2026	Comments
4.1	Project Management & Administration	N/A	12 months	Standard project execution process
4.2	Engineering for marine operations	N/A	12 months	Standard marine operation work process.
4.3	Design, fabrication and testing of diamond wire saw (DWS) system	N/A	12 months	Includes design and testing activities that can be verified by DNV TRL process. Already high TRL on this.
4.4	Design, fabrication and testing of mechanical Lifting Claw (LC) system	N/A	12 months	Includes design and testing activities that can be verified by DNV TRL process. Already high TRL on this.
4.5	Design, fabrication and testing of seabed parking frame or U-864 Lifting Frame	N/A	6 months	Includes design and testing activities that can be verified by DNV TRL process. Already high TRL on this.
4B2.0	**Mobilisering**	N/A	**5 days**	
4B2.0.1	Light Construction Vessel	N/A	3 days	For all preparatory work prior to lifting in the claw. Requires 200T crane for the lifting of the frames for the two cut-out sections. These are mobilised onto the LCV.
4B2.0.2	Heavy Construction Vessel	N/A	3 days	Requires a min of 600T crane for the completion of the lifting. The splash zone hydrodynamics will represent a critical part of the assessments in the next phase.

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Item	Activity	Duration 2014	Duration 2026	Comments
4B2.0.3	Rock Installation Vessel (RIV)	N/A	1 days	Go directly to site if required. Proposal is to set frames on the rock dumped area installed by VanOrd in 2016. Thus, the entire mobilisation of this vessel can be avoided if there are suitably flat areas available.
4B	**Preparatory Work**	**N/A**	**52 days**	
4B2.1.1.1	Prepare seabed areas for the four cutting locations by dredging and rock removal.	N/A	28 days	Excavator removes soft and hardened soil sediments by WROV-1. Suck soil into container for 6 days. Rock biter operated by WROV-2 crushes any rock in the way for the Diamond Wire Saw Tool. 4 days per cut location, times four locations = 16 days, plus g days for some unidentified tasks, in total 6 + 16 + 6 = 28 days.
4B2.1.1.2	Install frames for the two cut-out sections, rock dump only if required.	N/A	2 days	Transport frames for each cut off section. 1 day per frame, in total two days.
4B2.1.1.2	Install sandbags for stabilization and easy slide-away pathway of the cut-off bow and stern sections.	N/A	4 days	Sand bags are applied as required nearby and under the hull in parallel to the planned pull line of the AHV to smoothen the initial bump when front or rear parts are pulled away.
4B2.1.1.2	Investigate and prepare strong points for pull-off rigging.	N/A	4 days	There exists strong point in the bow. Check stern. Make required point when necessary. Install pull off rigging for anchor handler vessel.
4B2.1.1.2	Install Diamond cutting tool and perform first cut on bow section.	N/A	4 days	Install tool into the previously prepared cut places. Cut as required. Monitor behaviour during cutting and communicate with AHV v.r.t. initiation of the pull. Observe effect.
4B2.1.1.2	Pull away bow section by using the AHV.	N/A	2 day	The section can be pulled a short distance or a longer distance if required. The latter is outside of the immediate polluted area to reduce the effect of any torpedo detonations.

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Item	Activity	Duration 2014	Duration 2026	Comments
	Lift and relocate DCWT and perform clean-cut on bow section.	N/A	2 days	Not likely to require pull off.
	Relocate vessel and install DWCT and perform first cut on stern section.	N/A	2 days	Will require pull off to remove unstable section.
	Pull away stern section.	N/A	2 day	Note that the order can change to minimize vessel time for AHV. The stern section could be cut immediately after the bow section.
	Install DWCT and perform second clean cut of stern section.	N/A	2 days	Not likely to cause instability.
4B2.1.1.5	Inject water underneath the hull.	N/A	N/A	This is less likely to be required, but the possibility is covered as a backup method.
4B2.1.2	**Get access to keel**	**10 days**	**7 days**	
4B2.1.2.1	Lift the wreck section 1 (foreship) using the mechanical claw and transfer to Transport Frame 1	N/A	2 days	The wreck part is transferred to transport frame hanging in the claw from HCV. Lowered into rest position in Transport Frame and locked.
4B2.1.2.2	Lift the wreck section 2 (foreship) using the mechanical claw and transfer to Transport Frame 2	N/A	2 days	The wreck part in transport frame is lifted to vessel deck.
4B2.1.2.3	Lift Transport frame with foreship to deck.		1 day	Note that the lift operation requires good weather to allow trapped water to flow out of the submarine section as the lift is approaching the surface.
4B2.1.2.4	Lift Transport frame with aftship to deck.		1 day	Note that the lift operation requires good weather to allow trapped water to flow out of the submarine section as the lift is approaching the surface.
	Transit to CCB (or similar base) for demobilisation.	N/A	1 day	Only few hours away.
4B2.1.3	**Open Keel Cases**	**N/A**	**0**	
4B2.1.3.1	Drill and cut away the side plates	N/A	0 days	To be done onshore after recovery.
4B2.1.4	**Remove Hg-bottles**	**10 days**	**0 days**	
4B2.1.4.1	Remove loose Hg bottles	N/A	0 days	To be done onshore after recovery.
4B2.1.4.2	Remove bottles that are corroded into each other	N/A	0 days	To be done onshore after recovery.

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Item	Activity	Duration 2014	Duration 2026	Comments
4B2.1.4.3	Remove liquid Hg	N/A	0 days	To be done onshore after recovery.
4B2.1.4.4	Transfer basket filled with Hg-bottles to wet storage	N/A	0 days	Not necessary
4B2.1.4.5	Move the (free floating) liquid mercury to wet storage	N/A	0 days	Not necessary
4B2.1.5	**Hg-bottles to intermediate storage**	N/A	**0 Days**	
4B2.1.5.1	Hg-bottles to intermediate storage	N/A	0 days	Not necessary
4A.0	**Demobilisering**	**N/A**	**3days**	
4A.0.1	Light Construction Vessel	N/A	2 days	
4A.0.2	Anchor Handling Vessel	N/A	1 day	
4A.0.3	Heavy Construction Vessel	N/A	3 day	

8.9 Risk Method 4: Cut

Risks are also revealed for the new method proposed. These are listed in the table below.

Table 8-2: Additional risks identified to M4 from the 2026 study.

M4	Failure Mode	Cause of Failure	P(E)	Effect of Failure	C(E)	Risk Score
R1	Schedule overrun	Cumbersome work to dredge and remove rock to make access for landing the DWS at four different locations.	3	The work may take longer than planned leading to schedule overrun with associated cost effects.	3	**9**
R2	Schedule impact	Jammed diamond wire. Sudden deformation/sag of the pressure hull can cause the DW to jam	3	The DWS need to be recovered to deck for DW replacement. Hg cleaning procedure to be executed for every tool recovery to deck.	2	**6**
R3	Overloading	The suction forces may lead to high peak loads when breaking away from the soil. Also, there may be some amounts of sediments inside the hulls.	2	Load above the crane capacity. Mitigating measures here would be to lift at one end or both ends to break the suction forces, then perform "normal lifting" in the hull centre.	3	**6**
R4	Cut section over-tilt	The section to cut away start to overturn during cutting, due seabed slope, COG , and unsuccessful support from sandbags etc.	2	Risk of Torpedo firing and damaging of the DWS.	4	**8**
R5	Operation - Repositioning of lifting claw	Lifting Claw to be landed offset previous clamped section, could cause skew grip and/or offset movement during clamping.	3	Lifting the hull in a less advantageous position.	2	**6**
R6	Operation – Landing cut section onto	Lifted object heavier than Seabed Parking Frame.	3	Seabed Parking Frame slides on the seabed and does not provide sufficient righting	3	**9**

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	Seabed Parking Frame			force, so that the section does not land on the keel section. Work takes longer time.		

8.10 Cost Estimate

Table 8-3: *Cost estimate for Method 4: Cut.*

	Method 4: Cut **This method focuses on simplifying work activities, avoiding the high cost vessels to reduce the day rate exposure and make the loads to be moved smaller in dimensions. Complex worktasks are done topside. Instead of focusing on the large wreck parts, one cut off the parts that cannot conatain mercury inside. Thus, loads are reduced from 8-900T to below 400T.**	Indikative Manhrs/ Days	Rate	Unit	NOKeqv	%
1	Project Administration & Engineering	[redacted]	[redacted]	NOK/Hr	[redacted]	[redacted]
2	Procurement & Subcontracts					
2.1	Subcontracts					
2.1.1	Design and development of remotely operated diamond wire cutting system (34 ton) c/w control system. Qualification testing.			Contract		
2.1.2	Design, fabrication and testing of mechanical claw tool system. Qualification testing.			Contract		
2.1.3	Design and fabrication of 2 x 90T steel working frame for parking or lifting of submarine parts, including hydraulic operation of support arms. Qualification testing.			Contract		
2.1.4	Lifting arrangement for 90T steel working frame			NOK		
2.2	Third Party Services					
2.2.1	Hire of treatment system for sediments and water brought to deck.			NOK/Day		
2.2.2	Special polluted material basket for subsea storage of mercury bottles under transport to vessel deck.			NOK/Day		
2.3	Other					
2.3.1	WROV working tools package for cutting steel, etc.			NOK/Day		
3	Operations					
3.1	HCV 900T Crane + 2WROV systems+OBSROV			NOK/Day		
3.2	Rock Installation Vessel, RIV			NOK/Day		
3.3	AHS 200 ton Bollard Pull			NOK/Day		
3.4	Waiting on Weather, 5% of operation days			NOK/Day		
4	Contingency at feasibility level, 40% of cost					
Selling					kr 918,295,000	100.0%

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9. INTERVENTION METHODS

9.1 General

At this stage, one have a set of three initial methods, where one of the methods, M3, is evaluated as the most favourable method of the three. In addition, a fourth method has been proposed involving the cutting of the submarine parts into smaller sections.

9.2 Diving

The application of divers for the mercury recovery has been evaluated. Two major concerns have been raised:

- The risk of getting in touch with mercury contaminated materials.
- The non-rejected risk of detonation of torpedoes.

From IMCA D021 Guidance on Diving in Contaminated Waters:

> *"Heavy metals do not normally have acute (sudden) effects but tend toward chronic (long term) health effects. Skin contact will normally have to be repeated and prolonged to become a serious hazard and there will usually be little or no toxic vapors given off that may contaminate, for example, the inside of a bell. The main risk is if the heavy metals are ingested which means that the risk to divers from heavy metals on their own is often relatively small."*

Mitigating actions to reduce diver risk associated with Mercury are typically:

- Use ROVs to excavate, dredge, or relocate contaminated sediments before divers enter the area.
- Barrier mats, geotextiles, or suction tools can isolate contamination zones
- Take environmental samples once mitigating actions are performed to verify effectiveness
- Use enhanced diving procedure for entirety of the project. Involves divers wearing protective suits, barrier creams, monitoring systems in the bell and cleaning regime for divers and their umbilicals upon return to bell. Similar operation procedure is applied when working in various oil fields today.

Conclusion 1: The hazard of working with mercury can be mitigated by regular protection routines.

Conclusion 2: The hazard of working with the potential of a detonation of torpedoes during the work at the submarine is leading to the conclusion that it is not recommended to apply divers for this work.

9.3 WROV Systems

It seems natural to mobilise two WROV systems and one OBSROV system for all the different methods. This is a traditional setup for remote operations. Note that the entire work procedure for chosen method need to reflect the work tasks of that specific method. Still, some activities will always be “similar” in type. The ROV will execute subsea work and conduct the following typical activities:

1. As-Found Survey – Inspect site. Visual inspection of submarine parts as required. General area visual inspection.
2. Support vessel by spotting crane/item during deployment & recovery operations. Connect wires for assist or load control through splash zone.

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3. Operate the dredging equipment to remove sediments where required. A stand-alone dredging system can be used. These systems can be fitted with flexible discharge hoses to allow the discharge material to be deposited in the desired location.
4. Power Diamond Wire Saw (DWS) During Setup/Cutting Operations – The WROV shall be supplied with a Remote Auxiliary Work Pack (RAWP) complete with hydraulic hoses and hot stabs, to allow the WROV system to power the DWS.
5. Monitor DWS during cutting operations – WROV to monitor DWS completed a clean cut as per procedure.
6. Guide lifting claw(s) into position. Monitor LC during gripping and lifting phase(s) from both sides of the submarine part to provide feedback as required.
7. Help installing the Seabed Parking Frame.
8. Guide in landing the lifted object onto the seabed parking frames.
9. Clear equipment, construction parts and debris away as required.
10. Guide in the operation of the rock hammer if required.
11. As-Left Survey – Inspect for any debris left after spools decommissioning and clean the site.

9.4 Typical Equipment Setup

A Light Construction Vessel typically equipped with 2 Work ROV systems and a 100 Te - 250Te main crane would typically be used for prep and intervention work. Preparing the seabed and work area equipped with required dredging systems, gripper claw, cutting tool.

Typical tooling to be used:

Figure 9-1: *ROV grinder to cut into steel plates and pipes to gain access.*

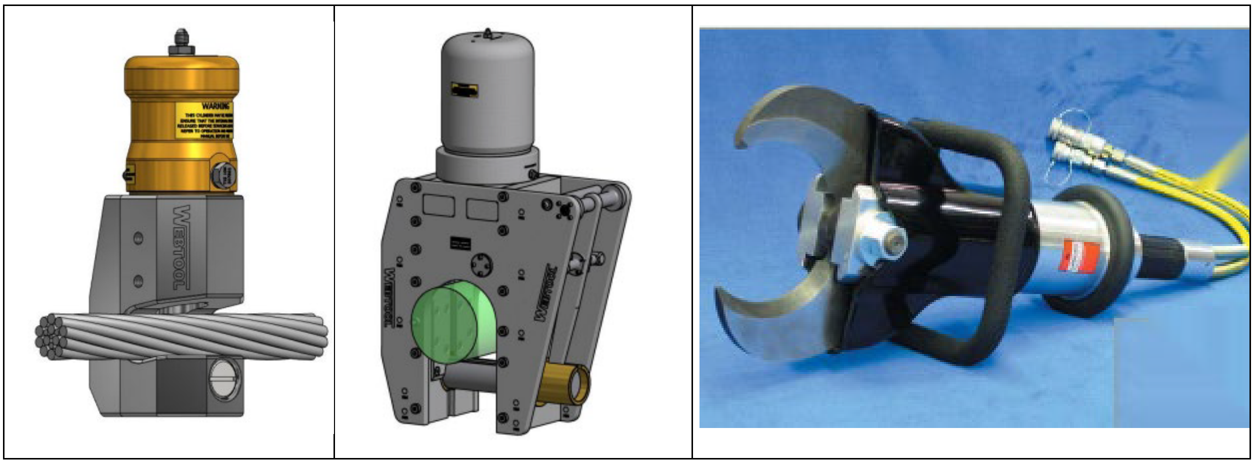

Figure 9-2: *ROV cutters to cut wires, thick piping etc. These comes in different sizes. Secretors to cut smaller piping and softer materials.*

Figure 9-3: *Dimond wire saw comes in differnet sizes and can be used for cutting. Lifted in place by crane and assisted by ROV. Could also be equipped with buoyance for ROV operation.*

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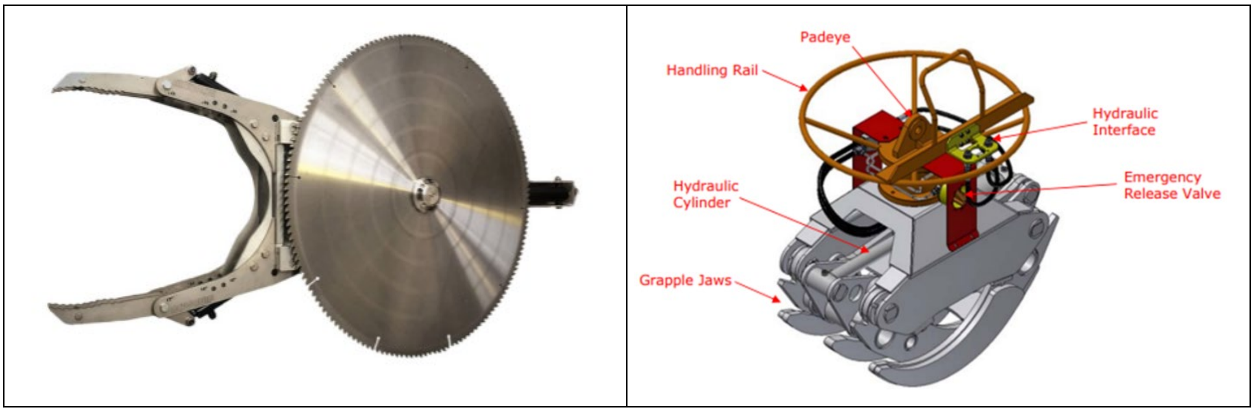

Figure 9-4: *Chop saw and Grippers to lift and clear debri.*

Figure 9-5: *Shear cutters for heavier cutting operation. Can be used on crane or be equipped on a subsea digger.*

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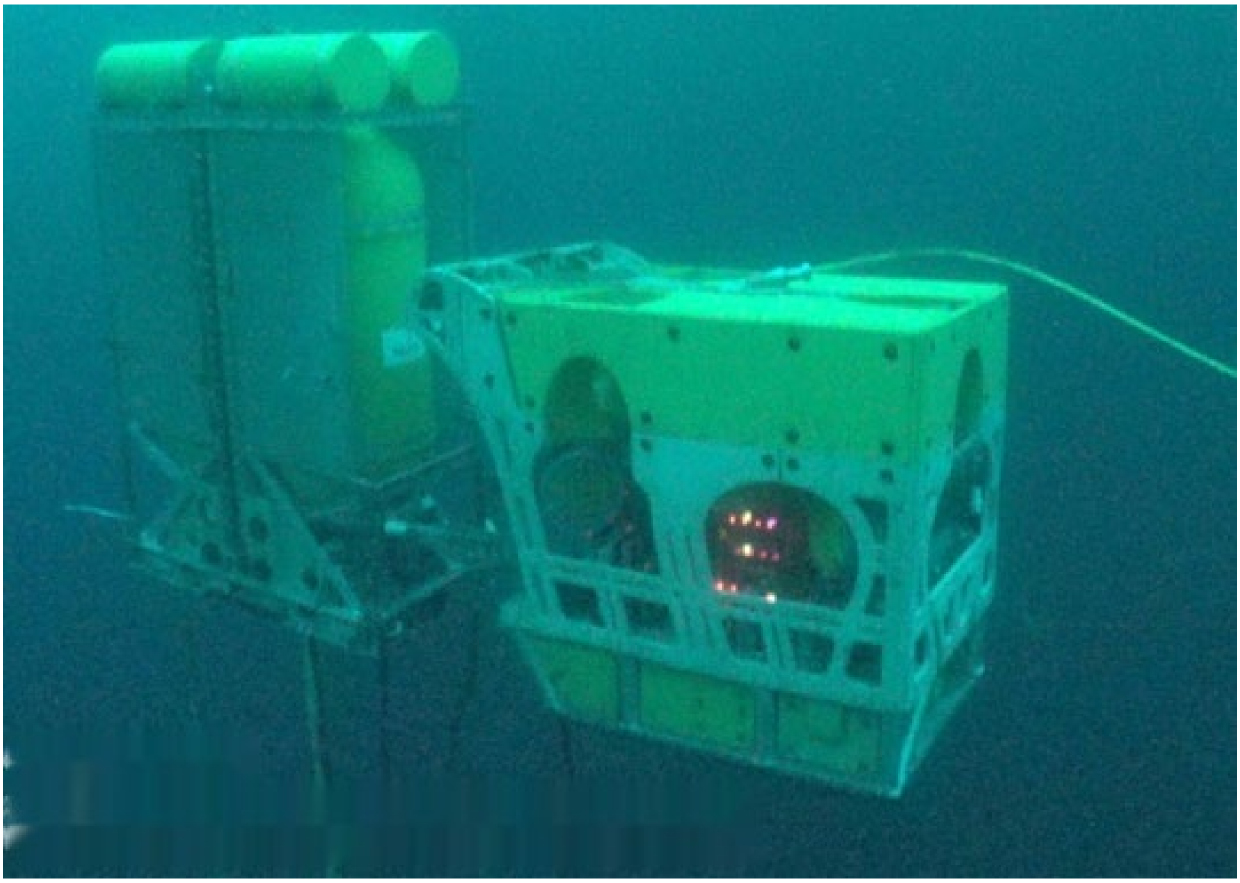

***Figure 9-6**: Varioable buoyancy systems can be used to lift and move debris on the seabed without being affected by vessel motion.*

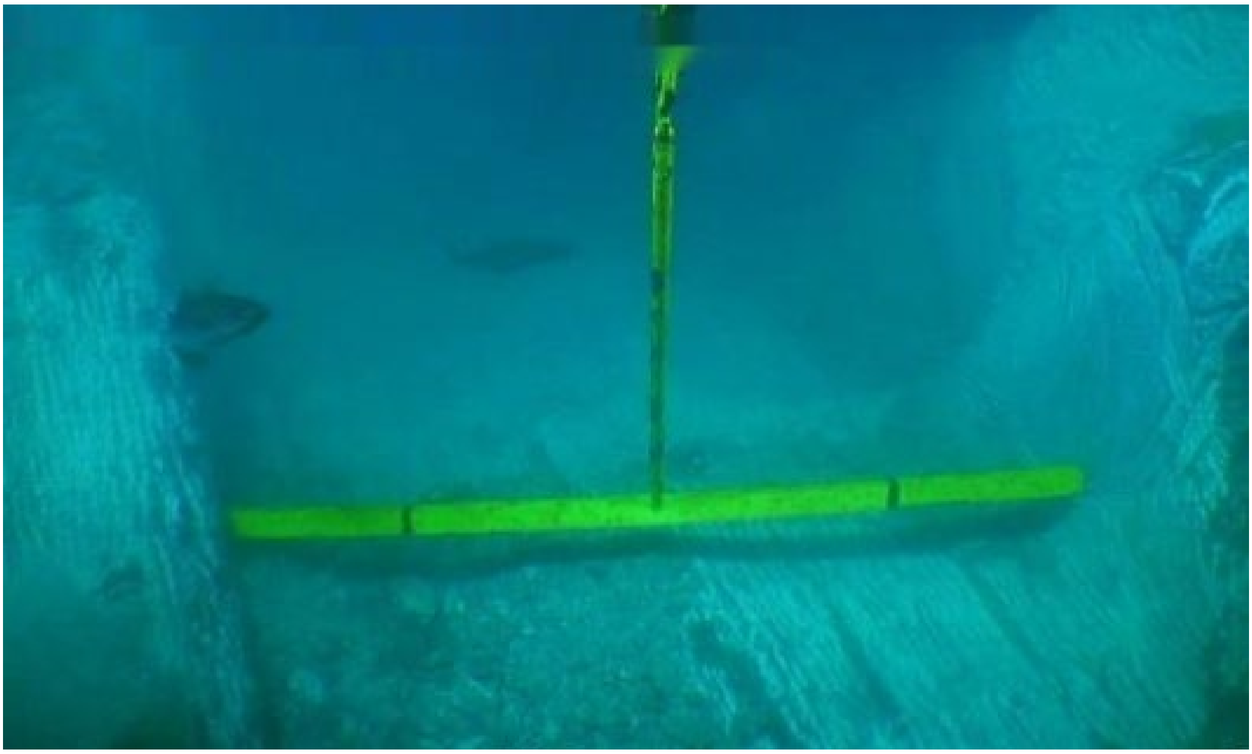

Figure 9-7: Subsea diggers can be equipped with dredging equipment, shear cutters and digging teeth's that can loose up and remove hard seabed and rock.

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APPENDIX A. SCHEDULE METHOD 4: CUT

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Kystverket - Mercury Cargo Recovery - Method 4: Cut

Feasability Study

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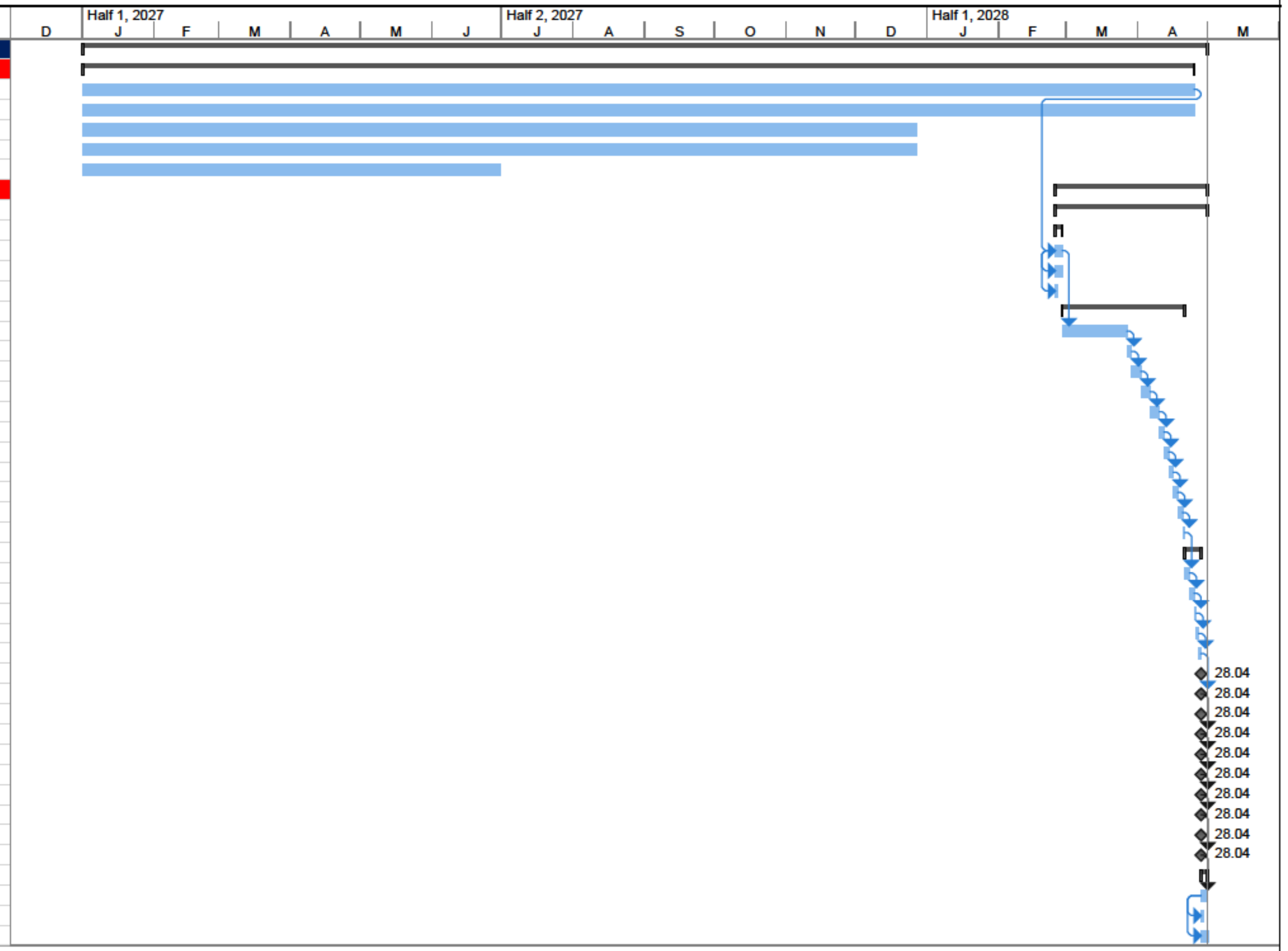
ID	Task Name	Duration	Start	Finish	Predecessors	Successors	Constraint Type
1	**U-864 KYSTVERKET MERCURY CARGO RECOVERY - FEASIBILITY STUDY SCHEDULE**	**486 days?**	**01.01.2027**	**01.05.2028**			**As Soon As Possible**
2	**PROJECT MANAGEMENT & ENGINEERING**	**480 days**	**01.01.2027**	**25.04.2028**			**As Soon As Possible**
3	Project Management & Administration	[redacted]	[redacted]	[redacted]		11FS-2 mons	Start No Earlier Than
4	Engineering for Marine Operations	[redacted]	[redacted]	[redacted]			Start No Earlier Than
5	Design, fabrication and testing of diamond wire cutting tool (WCT) system	[redacted]	[redacted]	[redacted]			Start No Earlier Than
6	Design, fabrication and testing of mechanical claw tool (MCT) system	[redacted]	[redacted]	[redacted]			Start No Earlier Than
7	Design, fabrication and testing of mechanical transport-frame tool (MTFT) system	[redacted]	[redacted]	[redacted]			Start No Earlier Than
8	**MARINE OPERATIONS**	**66 days?**	**25.02.2028**	**01.05.2028**			**As Soon As Possible**
9	**2026 OPERATIONS**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
10	**Mobilisation**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
11	Light Construction Vessel (LCV)	[redacted]	[redacted]	[redacted]	3FS-2 mons	12SS;13SS;1	As Soon As Possible
12	Heavy Construction Vessel (HCV)	[redacted]	[redacted]	[redacted]	11SS		As Soon As Possible
13	Rock Installation Vessel (RIV)	[redacted]	[redacted]	[redacted]	11SS		As Soon As Possible
14	**Preparatory Work**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
15	Prepare seabed areas for the four cutting locations by dredging and rock removal	[redacted]	[redacted]	[redacted]	11	16	As Soon As Possible
16	Install frames for the two cut-out sections, rock dump only if required	[redacted]	[redacted]	[redacted]	15	17	As Soon As Possible
17	Install sandbags for stabilization and easy slide-away pathway og the cut-off bow and stern sections	[redacted]	[redacted]	[redacted]	16	18	As Soon As Possible
18	Investigate and prepare strong points for pull-off rigging	[redacted]	[redacted]	[redacted]	17	19	As Soon As Possible
19	Install Diamond cutting tool and perform first cut on bow section	[redacted]	[redacted]	[redacted]	18	20	As Soon As Possible
20	Pull away bow section by using the AHV	[redacted]	[redacted]	[redacted]	19	21	As Soon As Possible
21	Lift and relocate DCWT and perform clean-cut on bow section	[redacted]	[redacted]	[redacted]	20	22	As Soon As Possible
22	Relocate vessel and install DWCT and perform first cut on stern section	[redacted]	[redacted]	[redacted]	21	23	As Soon As Possible
23	Pull away stern section	[redacted]	[redacted]	[redacted]	22	24	As Soon As Possible
24	Install DWCT and perform second clean cut of stern section	[redacted]	[redacted]	[redacted]	23	25	As Soon As Possible
25	Inject water underneath the hull	[redacted]	[redacted]	[redacted]	24	27	As Soon As Possible
26	**Get access to keel**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
27	Lift the wreck section 1 (foreship) using the mechanical claw and transfer to Transport Frame 1	[redacted]	[redacted]	[redacted]	25	28	As Soon As Possible
28	Lift the wreck section 2 (foreship) using the mechanical claw and transfer to Transport Frame 2	[redacted]	[redacted]	[redacted]	27	29	As Soon As Possible
29	Lift Transport frame with foreship to deck	[redacted]	[redacted]	[redacted]	28	30	As Soon As Possible
30	Lift Transport frame with aftship to deck	[redacted]	[redacted]	[redacted]	29	31	As Soon As Possible
31	Transit to CCB (or similar base for demobilisation)	[redacted]	[redacted]	[redacted]	30	33	As Soon As Possible
32	**Open Keel Cases**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
33	Drill and cut away the side plates	[redacted]	[redacted]	[redacted]	31	35	As Soon As Possible
34	**Remove Hg-bottles**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
35	Remove loose Hg bottles	[redacted]	[redacted]	[redacted]	33	36	As Soon As Possible
36	Remove bottles that are corroded into each other	[redacted]	[redacted]	[redacted]	35	37	As Soon As Possible
37	Remove liquid Hg	[redacted]	[redacted]	[redacted]	36	38	As Soon As Possible
38	Transfer basket filled with Hg-bottles to wet storage	[redacted]	[redacted]	[redacted]	37	39	As Soon As Possible
39	Move the (free floating) liquid mercury to wet storage	[redacted]	[redacted]	[redacted]	38	41	As Soon As Possible
40	**Hg-bottles to intermediate storage**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
41	Hg-bottles to intermediate storage	[redacted]	[redacted]	[redacted]	39	43	As Soon As Possible
42	**Demobilisation**	[redacted]	[redacted]	[redacted]			**As Soon As Possible**
43	Light Construction Vessel (LCV)	[redacted]	[redacted]	[redacted]	41	44SS;45SS	As Soon As Possible
44	Anchor Handling Vessel	[redacted]	[redacted]	[redacted]	43SS		As Soon As Possible
45	Heavy Construction Vessel (HCV)	[redacted]	[redacted]	[redacted]	43SS		As Soon As Possible



Date: 12.05.2026 | Task | Split | Milestone | Summary | Start-only | Finish-only | Deadline | Progress