



Research & Strategies - Managing UXO Risk For Marine Power Cables

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A moment for safety

Gemeinsam sorgen wir für ein sicheres Arbeitsumfeld, in dem wir aus Fehlern lernen und der Austausch von Ideen, Bedenken und Fragen eine Selbstverständlichkeit ist.



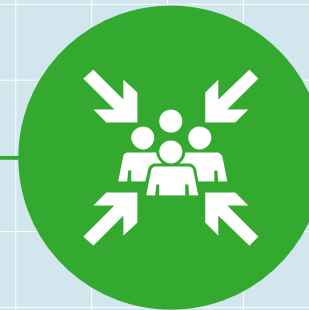
Im Falle einer Evakuierung der Räumlichkeiten möchten wir auf folgende Sicherheitsmaßnahmen hinweisen



Benutzen Sie die angegebenen Fluchtwege



Benutzen Sie nicht den Aufzug sondern die Treppe



Begeben Sie sich zum Sammelplatz



Befolgen Sie die Anweisungen der betrieblichen Evakuierungshelfer

Managing UXO Risk For Marine Power Cables

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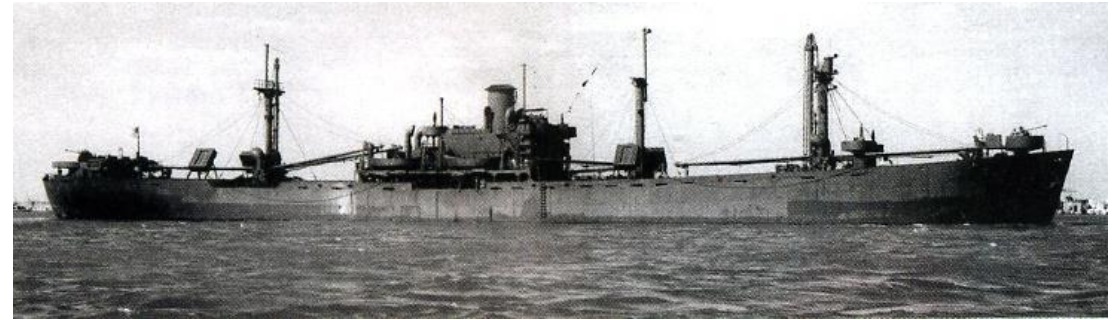
- What We Are Doing
- Where It Is
- What It Is
- How We Deal With It

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Developments In UXO Risk & Marine Power Cables

An Historical Perspective

River Medway 1944



BritNed installation 2008/9



1400 tons of munitions remain on the wreck of the *SS Richard Montgomery*

River Medway 2021

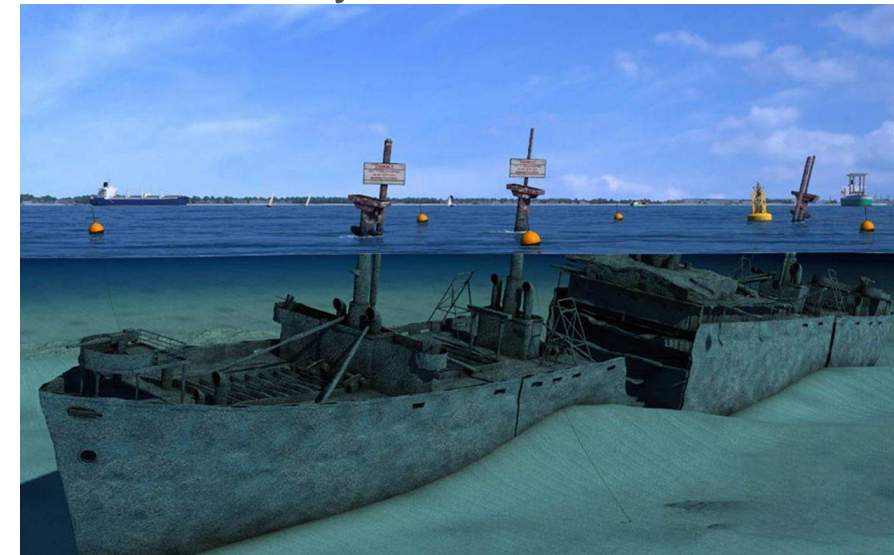


Image source : Daily Telegraph. 29 December 2021.
<https://www.telegraph.co.uk/news/2021/12/29/sunken-warship-river-thames-explosives-board-could-cause-mass/>

Developments In UXO Risk & Marine Power Cables

An Historical Perspective

2008 - A Project Briefing

- Raising awareness on vessel prior to construction works
- No UXO level survey undertaken
- No assessment of different activities on potential UXO objects
- No object removal
- Assessment during operations - “Ordnance Identification”
- Provision of a ‘what to do’ - decision and contact flow chart

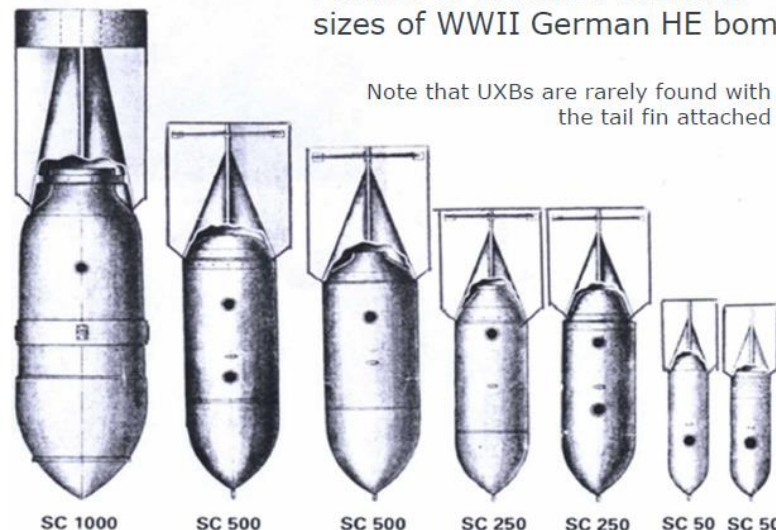
...“*The Purpose of the Briefing is to: Make you aware of the possible presence of Explosive Ordnance during the cable laying works...*”.

.Houston ... do we have a problem...?



Profiles of the most common sizes of WWII German HE bombs

Note that UXBs are rarely found with the tail fin attached

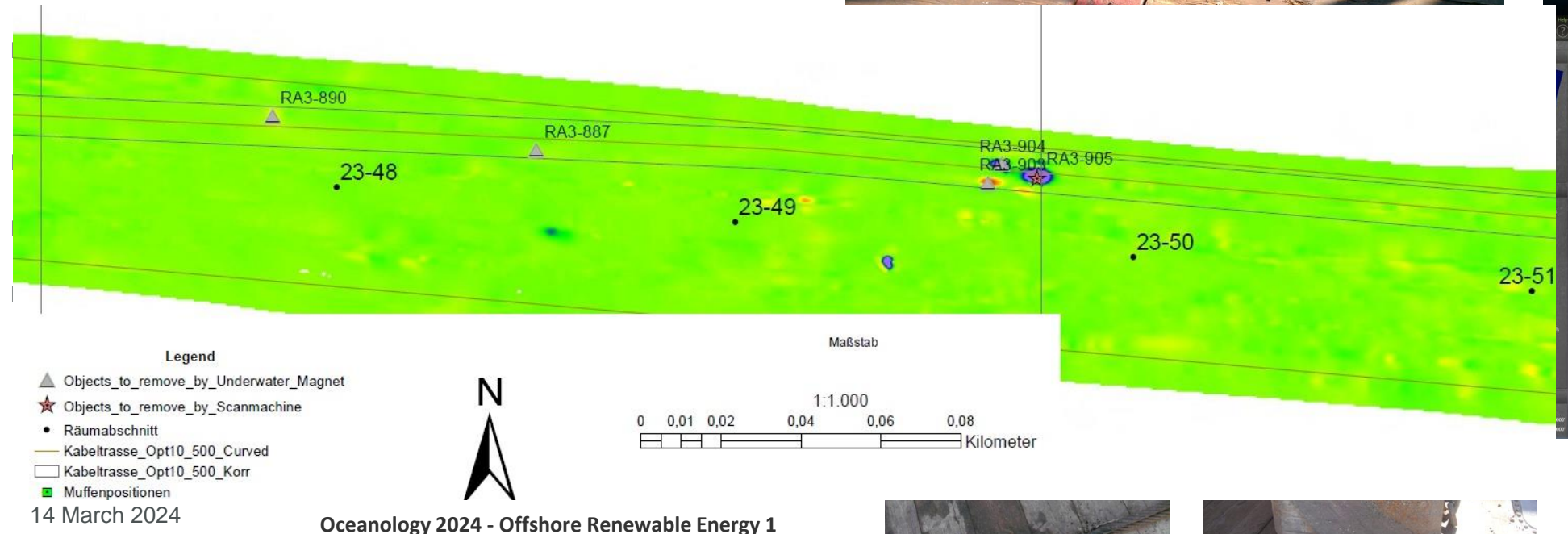
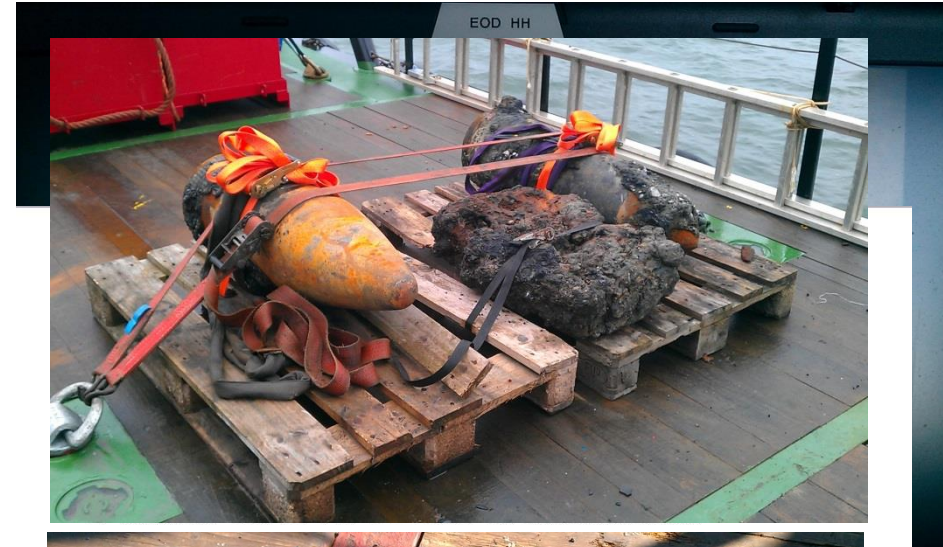


Developments In UXO Risk & Marine Power Cables

An Historical Perspective

2012 - Riffgat Installation

- UXO level survey across area of seabed influenced by installation / anchor handling.
- Review of geophysical data.
- Verification of *all* anomalies.



Developments In UXO Risk

Early Tennet UXO operations considered:

- What To Do?
- Where Is It ?
- What Is It ?
- How To Deal With It ?

Since 2015 Tennet ongoing programme of R&D to improve:

- What We Are Doing (Together).
- Where It Is
- What It Is
- How We Deal With It.

Developments In UXO Risk What To Do?

Legislative Requirements

- Inshore 12nm
- Outside 12nm

Country Specific Requirements

Country Specific Results

- Clearance Certificates
- ALARP – “*what is considered “Reasonably Practicable” is ultimately defined by the party responsible for safety and for the costs*”*

* Tennet. Nov 2022. “UXO A proportional approach of UXO’s At Sea”. (W. Snip)
<https://www.explosievenopsporing.nl/en/dossiers/wscs-oce/>

Common Starting Point - Risk Assessment

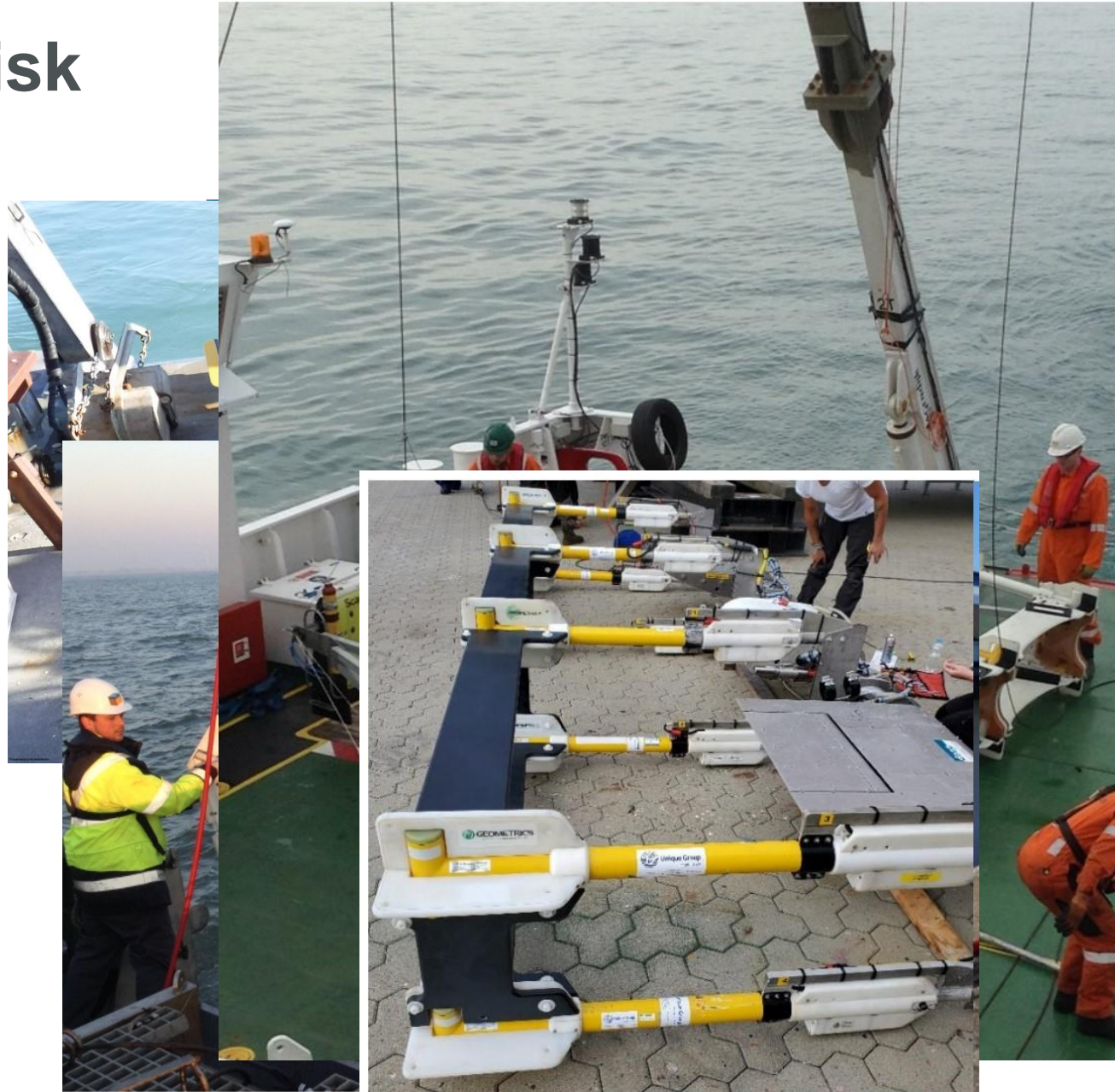
https://www.gesetze-im-internet.de/sprenngg_1976/__20.html
https://www.gesetze-im-internet.de/sprenngg_1976/__7.html
<https://www.issee.co.uk/resources/national-occupational-standards/12>



Developments In UXO Risk Where Is It?

Improvement In Survey Methods

- Single G882 Unit :1 unit
- Transverse Gradiometer : 2x1
- Fixed frame array – ‘Box design’ 2x2
- In-line array - Soft tow with ‘Evia’ 4x1
- Fixed frame array - ‘W design’ with ‘Evia’ scan fish elevation control. 2 units / 3 units
- Fixed frame array - ‘Box design’ with ‘Evia’ 4x2



Developments In UXO Risk

What Is It?

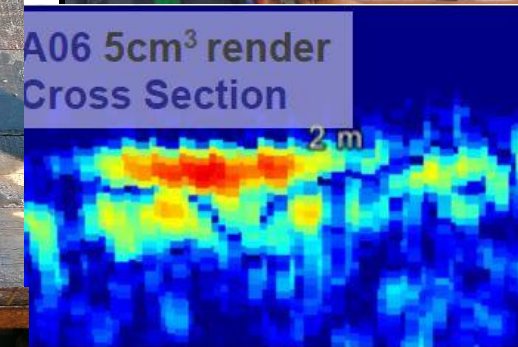
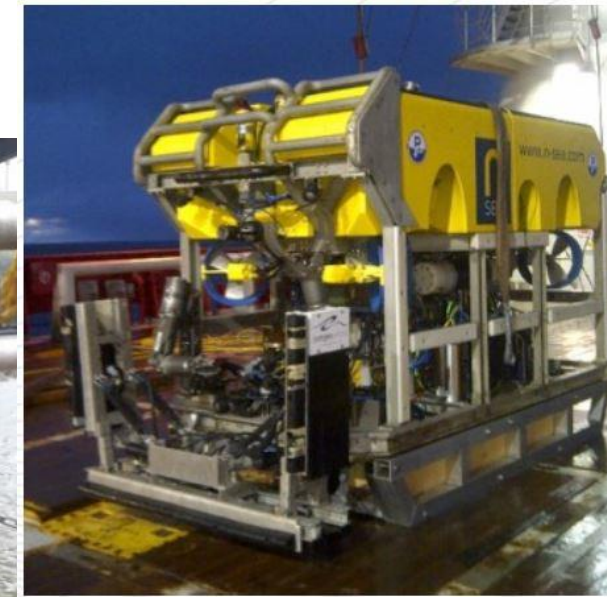
Anomalies – Targets – Contacts – UXO status

Identification Methods

Visual Sonar

Airlift / Dredge Pump

3D Seismic - PanGeo



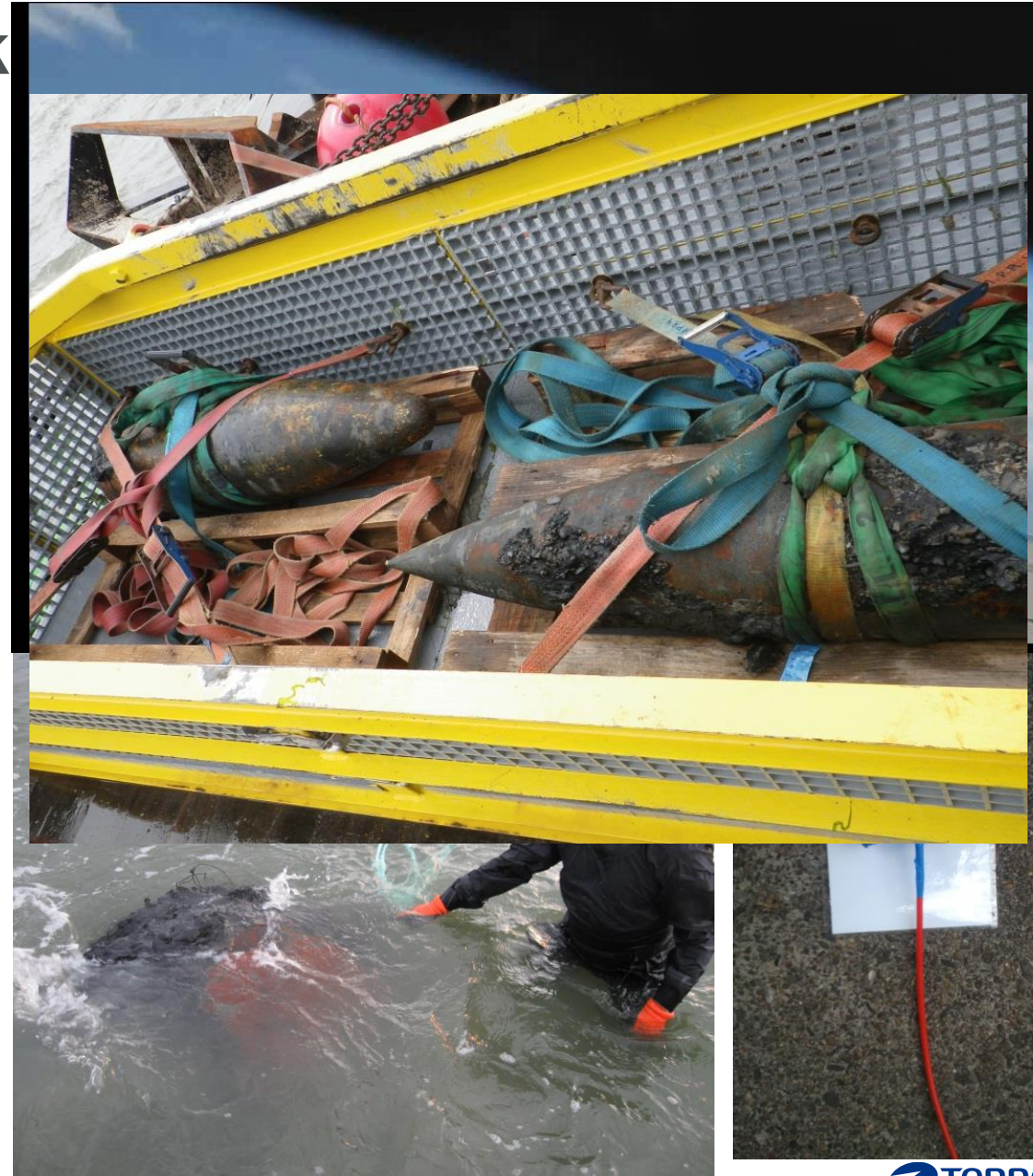
Size	Actual Size	PanGeo Interpretation	Found
56m (deep)	1.40 x 0.50m (surface to 0.3m deep)	Oblong elongated object	Metal frame

Developments In UXO Risk

How To Deal With It

Previously UXO Projects Typified by

- Low thresholds.
- Large avoidance distances.
- UXO mobility.
 - Reduced re-routing opportunities – maximised clearance scope.
- Neutralisation of all items
 - Transport from site to shore for disposal.
 - Transport to coastal site for high order detonation, or
 - In-situ high order detonation & use of bubble curtains.



Developments In UXO Risk

Effect Of UXO On Projects

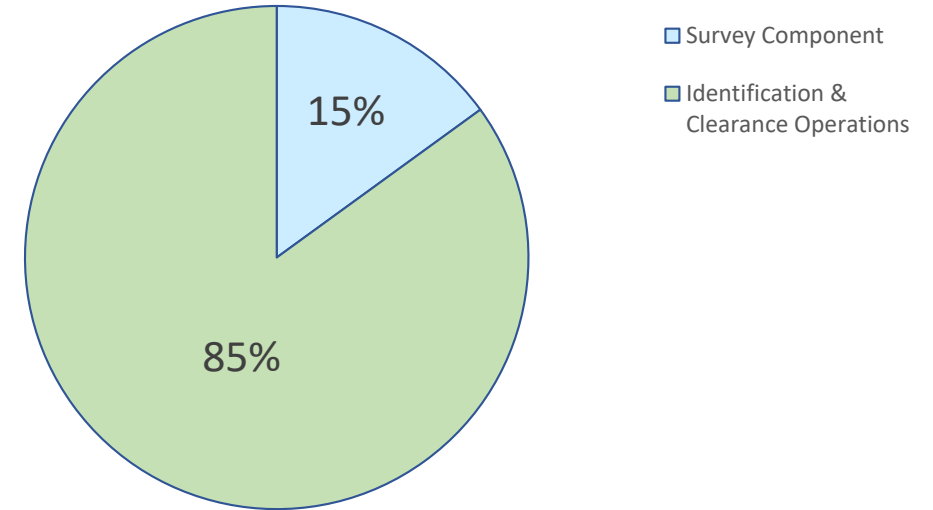
- Cost Elements - Survey / ID&C ⁽¹⁾
- UXO Programme Costs ⁽²⁾ ⁽³⁾
 - €100k ⁽¹⁾ to €150k ⁽²⁾ per km of cable route.
 - can be up to €250k ⁽³⁾ per km of cable route
- Identification & Clearance Success Rates ⁽⁴⁾ ⁽⁵⁾
- Programme Delays

- ID&C Programme - limit on when installation starts

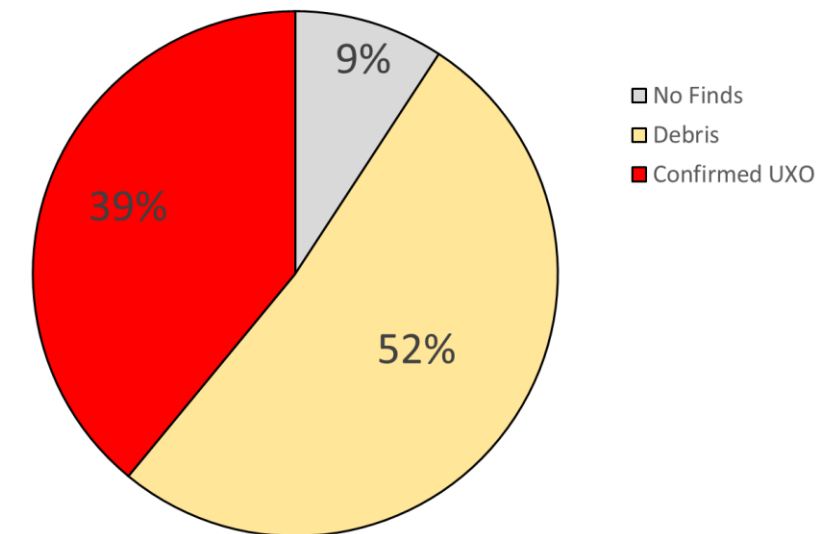
- ¹ Based on 15 German cable routes : *excluding* Riffgat & Nordergrunde HVAC export cables which passed through known UXO dump sites.
- ² Based on 5 Dutch export cable routes, total of 777km (Tennet. Nov 2022. "UXO A proportional approach of UXO's At Sea". (W. Snip))
- ³ Crisis Lab. May 2022 : "UXO North Sea - An Exploratory Risk Assessment for Unexploded Ordnance in the North Sea". (Ed: Helsloot, I. and Helsloot, M.)
- ⁴ Based on 597 inspected objects in UXO dump site.
- ⁵ Based on results of 1297 inspected objects across 15 cable routes.

14 March 2024

UXO Programme - Cost Elements



Investigation Outcomes - UXO Dump Site



Tennet's Management Of UXO Risk

What We Are Doing... a collaborative approach

2015 & Onward

Risk Assessments still form framework – but limits on extent of areas

Research topics to provide answers on

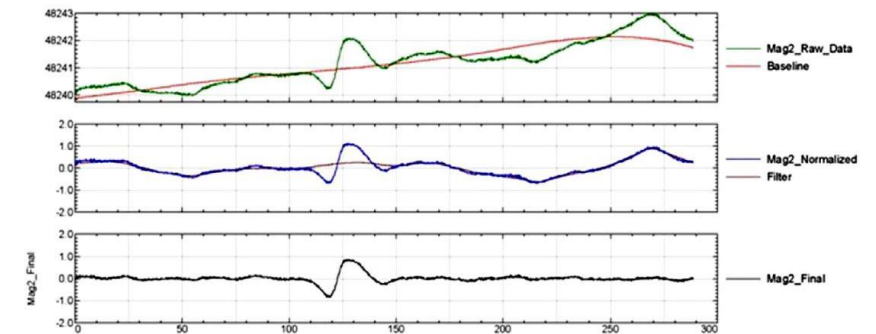
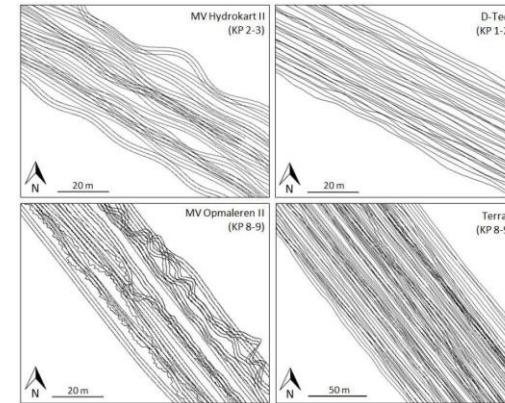
- Where It Is
 - Improve survey technology
 - Reduce avoidance distances
 - Improve understanding of UXO mobilisation
- What It Is
 - Define appropriate thresholds for investigation
 - Optimise investigation scope
 - Optimise clearance activities
- How To Deal With It
 - Reduce / change disposal activities

Where It Is Improve Survey Technology

2015 First internal comparative assessment (BW3 - DW3).

2018 to date : Industry wide collaborative approach

- Minimise anomalies by optimising survey strategy
- Data acquisition quality. 15 : 85 cost ratio
 - Equipment and survey parameters
 - Line Keeping
 - Elevation Range Control
 - Equipment Requirements & Design
- Processing, modelling and interpretation
 - 'Intelligence led'
 - Large extensive data library
 - 224 known UXO objects used



Where It Is Improve Survey Technology



Previously : No consistency in equipment, acquisition, data processing or target selection

Research outcomes: Requirements for data acquisition, data processing, target selection - drive improvements in data quality

Now : Better data quality, smaller investigations, better success rates

References : **Jack Brighthouse, ALM Geophysics & Dr. Sara Lise Underhay, Deep BV.**
‘Enhancing magnetic surveys for unexploded ordnance detection: Insights and best practices from collaborative industry research’. Oceanology 2024.

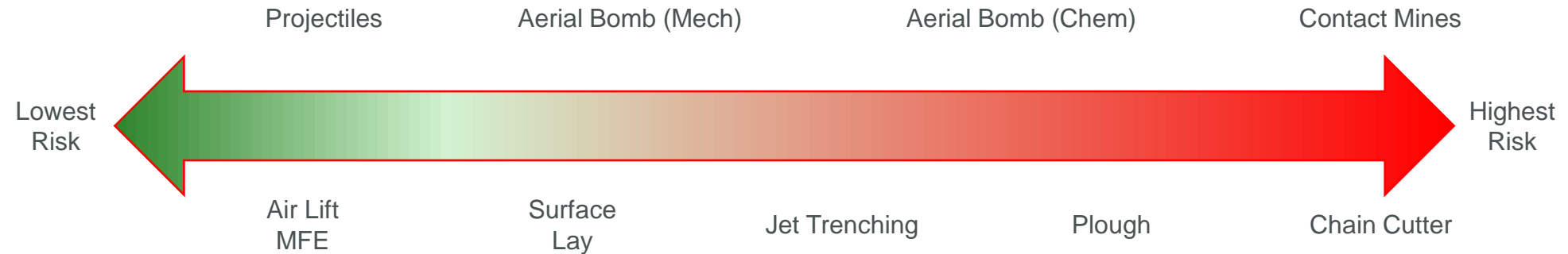
Tennet's Management Of UXO Risk

Where It Is – Reduce Avoidance Distances

Trigger Study – what are objects of risk & how close can we be?

26 offshore activities

40 different UXO objects & designs : DE11 / US 5 / UK 24



Reference : TNO (Netherlands Organisation for Applied Scientific Research). May 2022. Report 'TNO 2019 R10272'. "Ammunition trigger study".

Tennet's Management Of UXO Risk

Where It Is – Reduce Avoidance Distances

Past : Avoidance distances 15m+ or greater, more targets to investigate, less flexibility for re-routing

Research outcomes: Any initiation requires at least direct contact

Now : Avoidance distances a function of survey positioning $\pm 5\text{m}$, smaller scope for investigations, increased options for re-routing.

Reference : **TNO (Netherlands Organisation for Applied Scientific Research). May 2022. Report 'TNO 2019 R10272'. "Ammunition trigger study".**

Tennet's Management Of UXO Risk

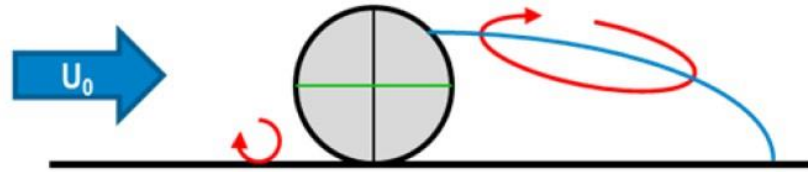
Where It Is – UXO Mobilisation



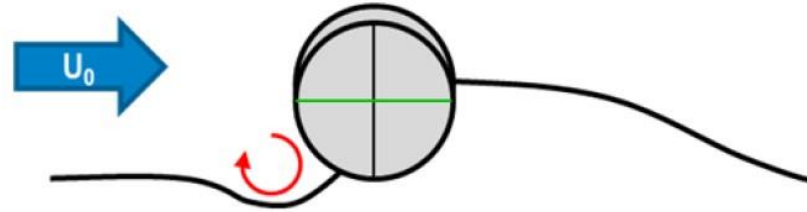
Tennet's Management Of UXO Risk

Where It Is – UXO Mobilisation

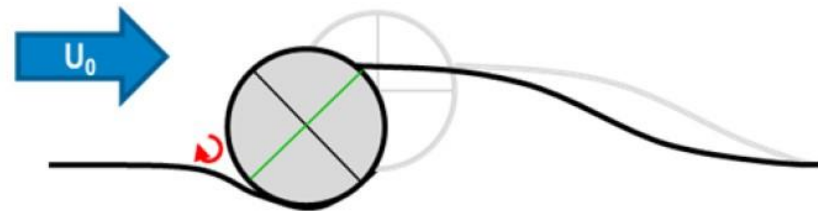
1. Forming of the horseshoe vortex



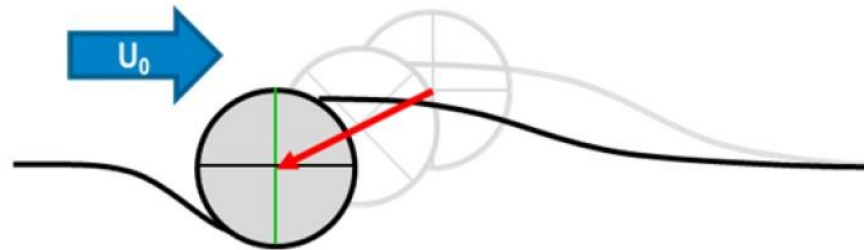
2. Scour and tilting



3. Rolling into the scour hole

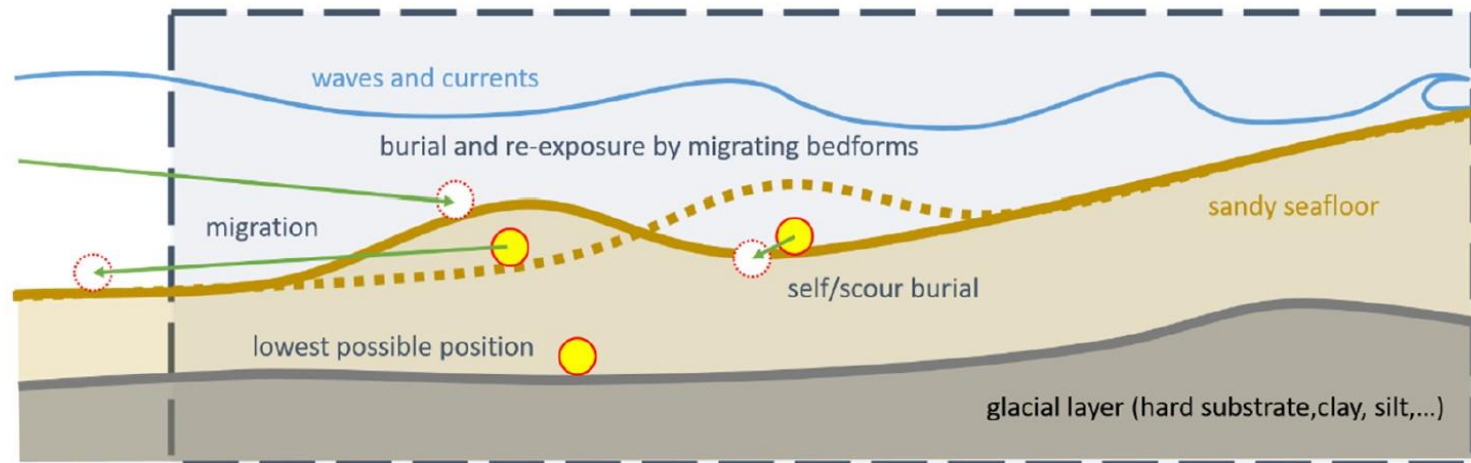
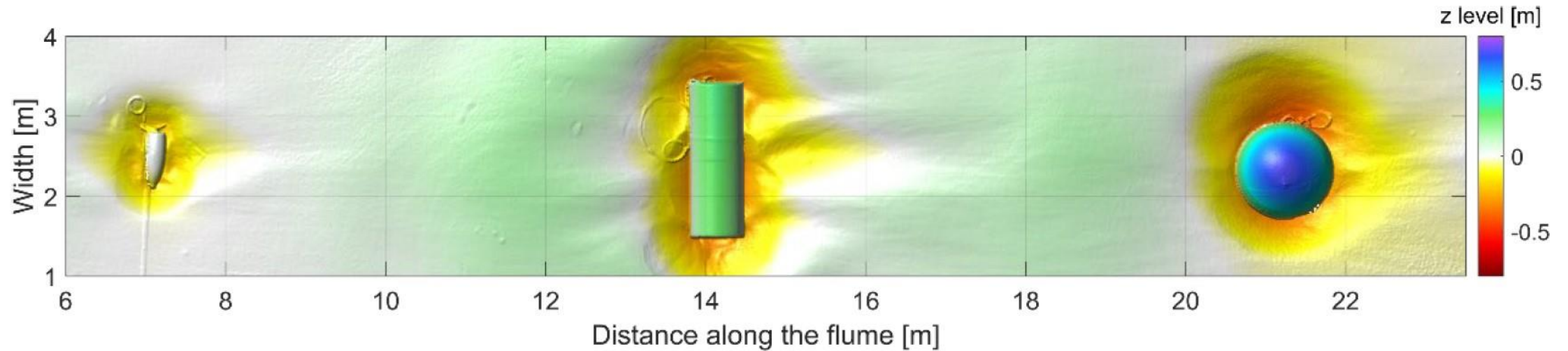


4. Continuous scour build-up and rolling into the scour hole.



Tennet's Management Of UXO Risk

Where It Is – UXO Mobilisation



Tennet's Management Of UXO Risk

Where It Is

Past : Temporal validity to survey, ID&C operations, clearance certification.

Research outcome : German Bight UXO mobility not an effective transport vector. *

*Exception : Non granular sediments on seabed surface preventing object burial.

Now : Extended periods for which both survey and clearance is valid > operational requirements.

References :

Menzel, P.; Schütt, C.; Wranik, H.; Paschen, M.; Drews, A. 2018. *'Towards a general prediction model for the current-induced mobilization of objects on the sea floor'*. *Ocean. Eng.* 2018, 164, 160–167.

Menzel, P., Drews, A.; Mehring, T.; Otto, C.; Erbs-Hansen, D.R. 2022. *'Mobilization of Unexploded Ordnance on the Seabed'*. *Toxics* 2022, 10, 389. <https://doi.org/10.3390/toxics10070389>

Menzel, P. *'NO mobilization of UXO – A review of 10 years of Research'*. *Oceanology* 2024

Tennet's Management Of UXO Risk

What We Are Doing

2017 & Onward

Research topics to provide answers on

- Where It Is
 - Improve survey technology
 - Reduce avoidance distances
 - UXO mobilisation
- What It Is
 - Define appropriate thresholds for investigation
 - Optimise investigation scope
 - Optimise clearance activities
- How To Deal With It
 - Shallow water investigations
 - Reduce disposal activities / role of bubble curtains

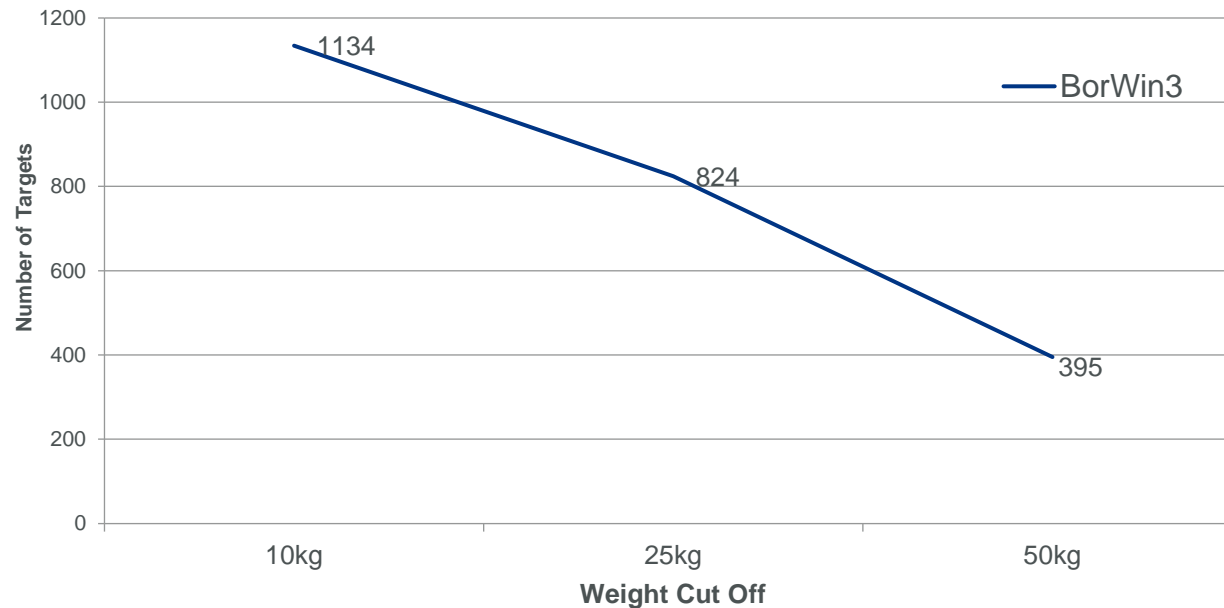
Tennet's Management Of UXO Risk

What It Is - Thresholds for Investigation

Threat Item Size : Size to Number Of Targets

Higher threshold - fewer targets

What size is a risk ?



IABG. January 2021. Report 'B-TA 4368. "UNDEX Simulations for the Risk Assessment of Ship Structures

Vessel Study

Operational scenarios:

- Offshore and Nearshore operating ships
- different distances UXO - ship
- different probability of occurrence of different UXO types

Explosion scenarios:

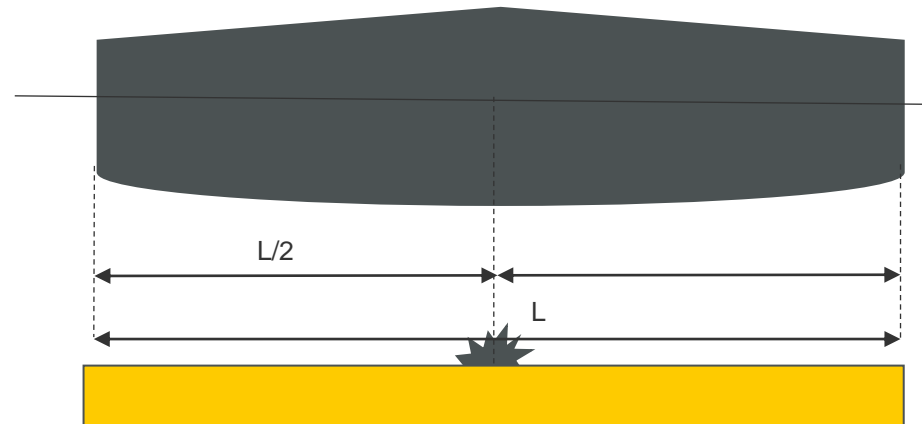
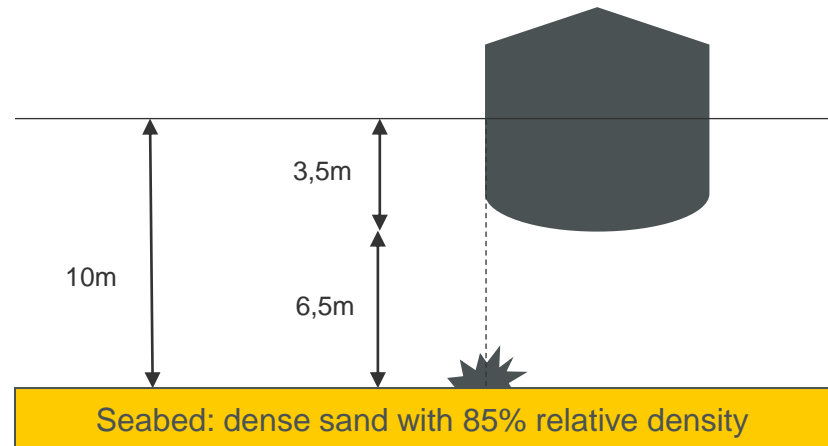
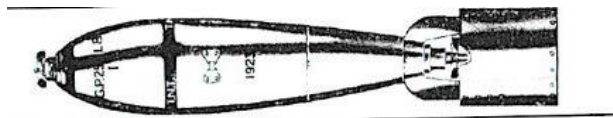
- Cable installation by Simultaneous Lay & Burial with towed equipment
- Cable installation by Simultaneous Lay & Burial with vertical injector
- Cable installation by Post Lay Burial
- Cable repair

Tennet's Management Of UXO Risk

What It Is - Thresholds for Investigation

**Worst case: Cable installation
with Vertical Injector**

Example simulation British 250lbs bomb.
Charge 30.8kg TNT

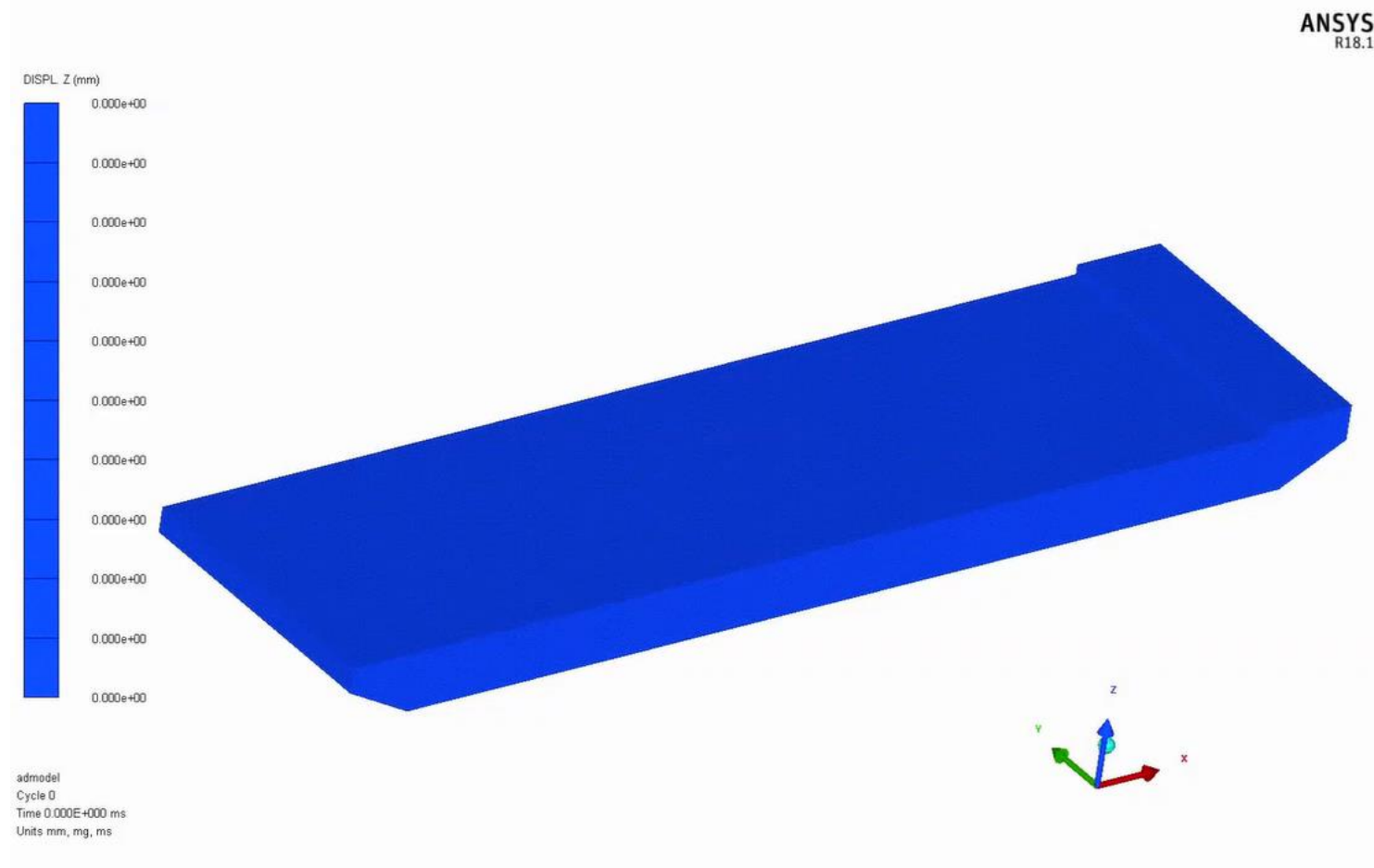


IABG. January 2021. Report 'B-TA 4368. "UNDEX Simulations for the Risk Assessment of Ship Structures

Tennet's Management Of UXO Risk

What It Is - Thresholds for Investigation

Example simulation
Hull distortion
British 250lbs bomb
charge 30.8kg TNT



Hull integrity

Equipment

Personnel

IABG. January 2021. Report 'B-TA 4368. "UNDEX Simulations for the Risk Assessment of Ship Structures

Tennet's Management Of UXO Risk

What It Is - Thresholds for Investigation

Past : Low thresholds for investigation (10kg to 25 kg Fe mass).

Research outcome: Only UXO objects that represents a risk to people and vessel should form threshold. (Installation equipment can be fixed / cables repaired).

Now : Higher threshold values. Offshore cable installation 500lb to 1000lb items ($\pm 100\text{kg}$ to $\pm 200\text{kg}$ Fe mass) / Construction : 250lb ($\pm 50\text{kg}$ Fe mass)
Smaller scope of investigation (the 85% cost driver).

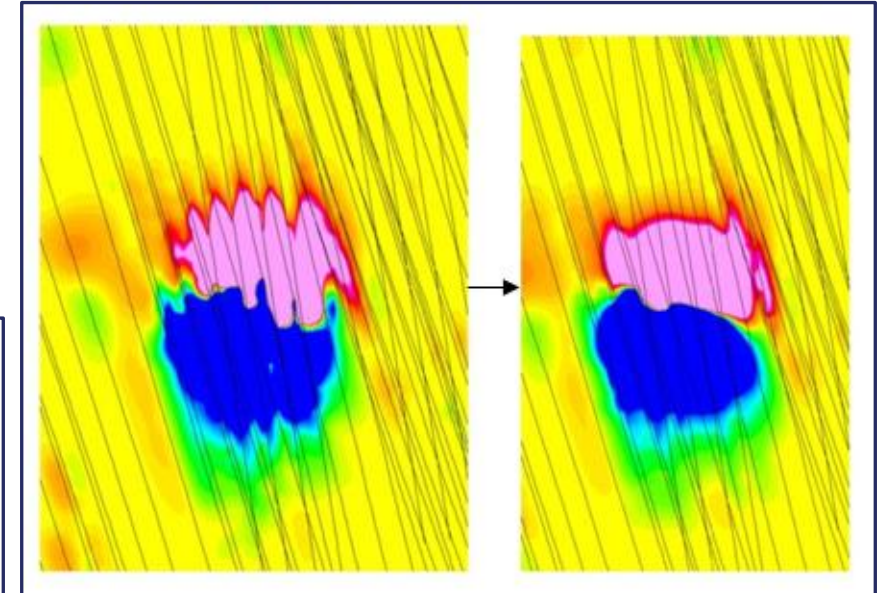
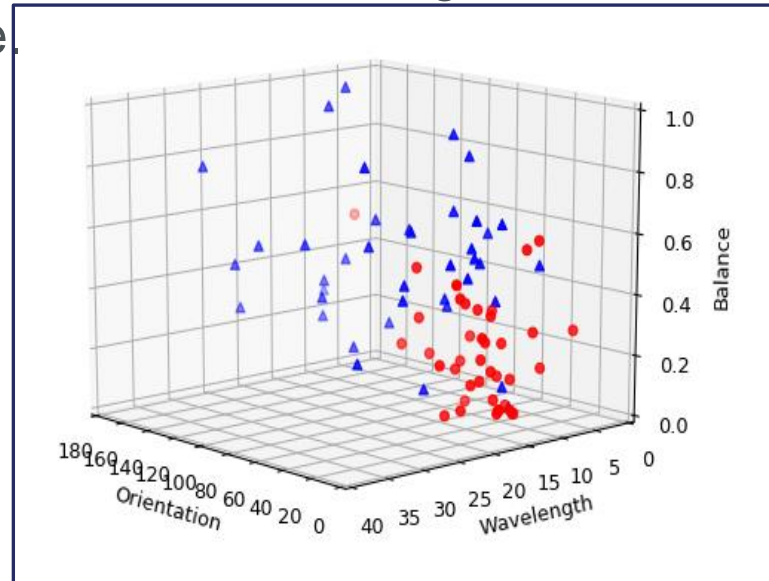
References : **IABG. January 2021. Report 'B-TA 4368. *'UNDEX Simulations for the Risk Assessment of Ship Structures'***.

Tennet's Management Of UXO Risk

What It Is - Optimise Investigation Scope

Target Classifier

- Based on retrospective processing
- Known outcomes from confirmed UXO
- Objective – reduction in number of targets for the Identification Phase.



Brighthouse et al. 2024. "Applied and Marine Geophysics Inverse modelling and classification of magnetic responses to improve marine unexploded ordnance rationalization". Geophysical Journal International. (2024) 237, 123–144

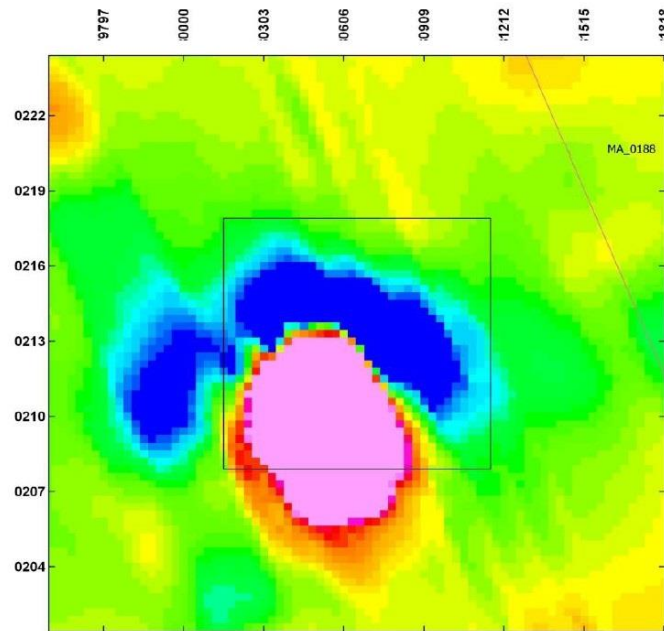
Tennet's Management Of UXO Risk

What It Is - Optimise Clearance Activities

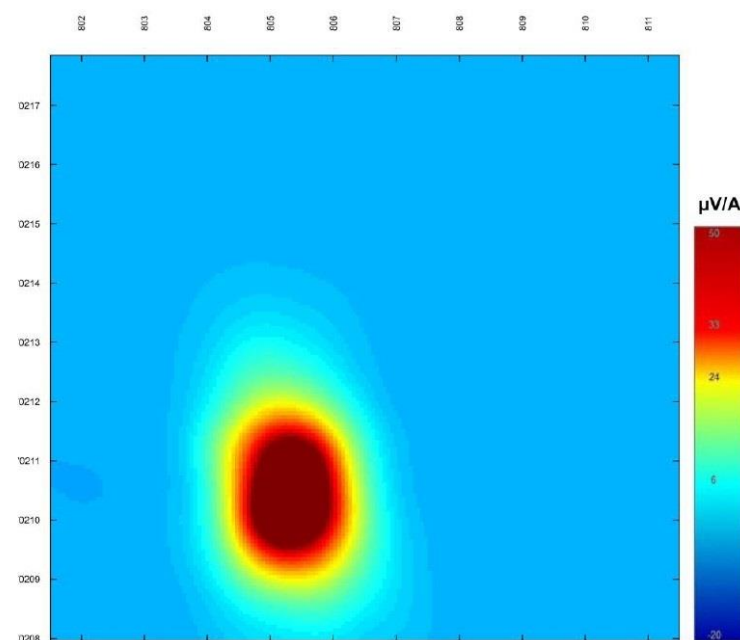
During ID&C Phase

- Iterative target evaluation
- Correlate found objects to other target signal responses during operation.
- Target sign off based on findings / 'Real Time' classifier approach.

Outcome: Investigate fewer targets



14 March 2024



Oceanology 2024 - Offshore Renewable Energy 1



Tennet's Management Of UXO Risk

What It Is

Past : **All** targets above a threshold selected for investigation.

Research outcomes: Intelligence led target selection.

Now : Small target lists, better clearance productivity.

References : **Brighthouse et al. 2024. 'Applied and Marine Geophysics Inverse modelling and classification of magnetic responses to improve marine unexploded ordnance rationalization'. Geophysical Journal International. (2024) 237, 123–144 .**

Tennet's Management Of UXO Risk

What We Are Doing

2017 & Onward

Research topics to provide answers on

- Where It Is
 - Improve survey technology
 - Reduce avoidance distances
 - UXO mobilisation
- What It Is
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- How To Deal With It
 - Shallow water investigations
 - Reduce disposal activities / role of bubble curtains

Tennet's Management Of UXO Risk

How To Deal With It - Shallow Water Investigations

Diver Operations

Diver rings for shallow water
deep detection



Outcome: Improve working time

Tennet's Management Of UXO Risk

How To Deal With It – Reduce Disposal Activities

Past : UXO items disposed of with in-situ explosion / use of bubble curtain.



Source <https://www.bbc.com/future/article/20231106-the-big-bubble-curtains-protecting-porpoises-from-wind-farm-noise>
(Image credit : Hydrotechnik Lübeck)

Tennet's Management Of UXO Risk

How To Deal With It – Reduce Disposal Activities

Past : UXO items disposed of with in-situ explosion / use of bubble curtain.

...“none of the considered bubble curtains [single or double] are efficient enough to attenuate the pressure signal from the assumed UNDEX event such that noise levels that are fulfilling the requirements of the Dual Noise Criterion are achieved” (IAGB, 2022).

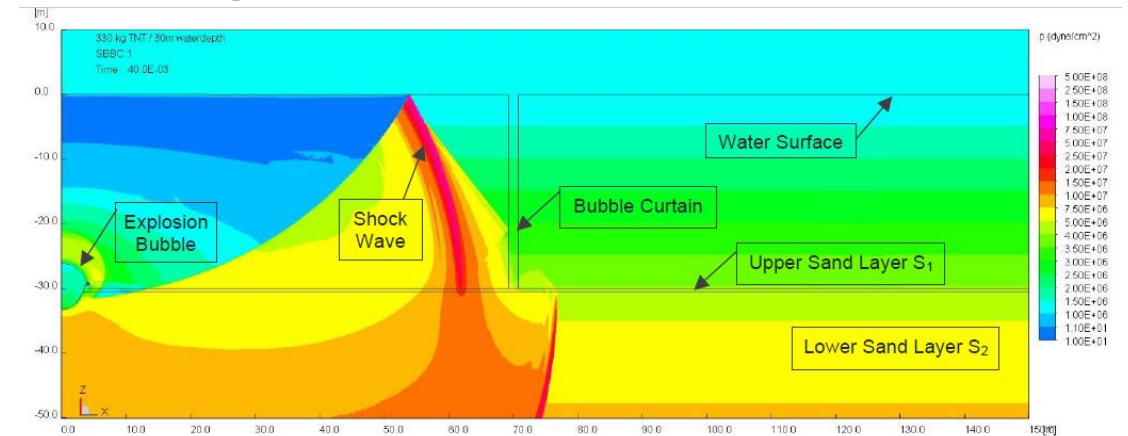


Figure 7.2: Pressure Distributions for SBBC 1 Bubble Curtain at t = 40 ms

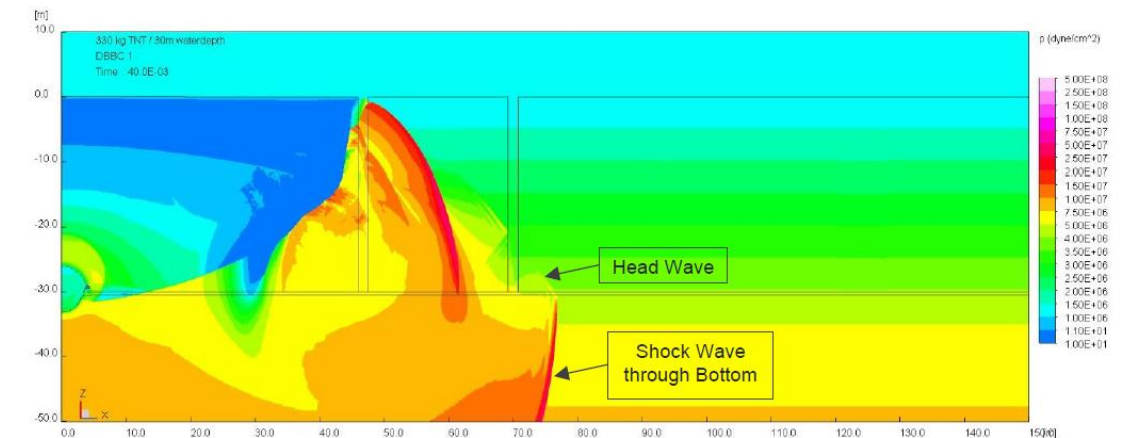


Figure 7.3: Pressure Distributions for DBBC 1 Bubble Curtain at t = 40 ms

Tennet's Management Of UXO Risk

How To Deal With It

Past : UXO items disposed of with in-situ explosion / use of bubble curtain.

Research outcomes:

Low order deflagration of items

Efficacy of additional bubble curtain vessel for single/double curtains is questionable.

Now :

Reduce high order detonations

Opportunity to limit SBBC / DBBC ops

Not all confirmed UXO items are neutralised.

References : **IABG. 07 November 2022. Report TA-B-000667. *'Bubble Curtain Optimisation for Offshore Applications'*.**

IABG. 07 November 2022. Report 'TA-B-000667'. "Bubble Curtain Optimisation for Offshore Applications".

Tennet's Management Of UXO Risk

Conclusions & Closing Comments

UXO

- Change in UXO risk perception – significant cost increase and programme risk.

Management Of Risk

- Quality Risk Assessment as a start¹.
- Define survey areas.
- Define threshold object size appropriate to activity.

Reduce Costs

- Survey data quality – *critical*, the driver to enable cost reduction.
- UXO mobility and avoidance distances – maximise re-routing.
- Refine target populations – known responses / 'Classifier' approach

¹ Stefan Lang, S. Sainsbury M., Eriksen A. 2015. 'UXO Risk Assessment – Where are we 6 years on from the Publication of CIRIA's UXO Guidance? Zetica Limited, 2015.

Tennet's Management Of UXO Risk

Conclusions & Closing Comments

Way Forward (?)

HSE justification for vessel based operations to manage UXO

“..when using a ship to survey the North Sea as a mitigating measure for the UXO risk, employees on this survey ship are exposed to a risk that probably is higher than the UXO risk for dredging and cable burial” §

References:

§ Crisis Lab. May 2022 : *‘UXO North Sea - An exploratory Risk Assessment for Unexploded Ordnance in the North Sea’*. (Ed: Helsloot, I. and Helsloot, M.)

Oceaology 2024. *‘A proportional approach of the UXO risk at sea’*. Wino Snip, TenneT TSO GmbH

Last Chance To See?



Source : Andy MacLeay – Ultrabeam Hydrographic

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Questions ?

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