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Unexploded Ordnance (UXO) Threat & Risk Assessment with Risk Mitigation Strategy for Cable Installation

Project*: *NorthConnect

Client*: *MMT

***Report Number*: P5530**

Disclaimer

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Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery
AC	Alternating Current
AHT	Anchor Handling Tugboat
ALARP	As Low As Reasonably Practicable
BD	Bomb Disposal
BDO	Bomb Disposal Officer
BMAPA	British Marine and Aggregate Producers Association
BML	Below Mean Sea Level
BMO	British Minelaying Operations
BPD	Bomb Penetration Depth
CIRIA	Construction Industry Research and Information Association
CLV	Cable Laying Vessel
CPT	Cone Penetration Testing
DC	Direct Current
DDV	Drop Down Video
dGPS	Differential Global Positioning Systems
EMP	Emergency Management Procedures
EO	Explosive Ordnance
EOD	Explosive Ordnance Disposal
ERW	Explosive Remnants of War
GI	Geotechnical Investigation
GIS	Geographical Information System
HDD	Horizontal Directional Drilling
HE	High Explosive
HEM	High Energy Manoeuvres
HMX	High Molecular (mass) RDX
HV	High Voltage
HSE	Health and Safety Executive
IB	Incendiary Bomb
JSEODOC	Joint Service Explosive Ordnance Disposal Operations Centre

kHz	Kilohertz
Kg	Kilogram
Kv	Kilovolt
Km	Kilometre
lb	Pound (weight)
LAT	Lowest Astronomical Tide
LAW	Light Anti-Armour Weapon
LMB	Luftmine Bomben
LSA	Land Service Ammunition
m	Metres
MBES	Multibeam Echo Sounder
MCM	Mine Countermeasures
MDA	Mine Danger Area
MCA	Maritime and Coastguard Agency
mm	Millimetres
MoD	Ministry of Defence
ms	Metres per second
MW	Megawatt
NEC	Net Explosive Content
NEQ	Net Explosive Quantity
NGR	National Grid Reference
Nm	Nautical Mile
OWF	Offshore Wind Farm
PETN	Pentaerythritol tetranitrate
PEXA	Military Practice and Exercise Areas
PI	Pulse Induction
PLGR	Pre Lay Grapnel Run
RAF	Royal Air Force
RC	Route Clearance
RDX	Research Department (composition) 'X'
ROTV	Remotely Operated Towed Vehicle
ROV	Remotely Operated Vehicle

RN	Royal Navy
RSP	Render Safe Procedure
SAA	Small Arms Ammunition
SBP	Sub-bottom Profiling
SI	Site Investigation
SOP	Standard Operating Procedure
SSS	Side Scan Sonar
SQRA	Semi Quantitative Risk Assessment
SVT	Survey Verification Test
TI	Target Investigation
TNT	Trinitrotoluene
TVG	Transverse Gradiometer
QA/QC	Quality Assurance/Quality Control
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
USBL	Ultra Short Baseline System
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
WTG	Wind Turbine Generator
WWI	World War One
WWII	World War Two

Executive Summary

INTRODUCTION

The planned *NorthConnect* cable route crosses the *North Sea*, making landfall near *Boddam* in *Scotland* and *Simadalen* in *Norway*, a distance of approximately 655km with a Survey Corridor width of 500m and a Search Area of 2km. *NorthConnect* will join the electricity systems of the two countries via high voltage subsea cables to link the *Nordic* and *British* energy markets. This study assesses the marine Unexploded Ordnance (UXO) risks presented by proposed cable installations, to three prospective path alterations, including Pre-Lay Grapnel Run (PLGR), Route Clearance (RC), laying, pre-trenching, ploughing, jet trenching, rock dumping and Horizontal Directional Drilling (HDD), barge operations and diving associated with the cable landfall. Given the length of the cable route and the variation in natural conditions, the Site has been subdivided into three corridor sections; LOT A – *UK nearshore*, LOT B – *North Sea* and LOT C – *Norway Fjord*. The water depths, geology, proposed works and potential UXO threats associated with the Site will all be taken into consideration in order to provide an accurate risk assessment and to provide sufficient and appropriate risk mitigation measures to reduce UXO risks to As Low As Reasonably Practicable (ALARP).

KEY UXO THREATS

The key UXO threats, which might be encountered at this Study Site, include:

- Incendiary Bombs and High Explosive Bombs;
- Sea mines (ferrous metal variants);
- Torpedoes;
- Ship wreck related munitions;
- Depth charges and Mortars;
- Artillery projectiles;
- Dumped munitions (Conventional High Explosive types);

With a background threat posed by:

- Sea mines (non-ferrous metal variants);
- Anti-Invasion Devices;
- Land mines.

SUMMARY OF RECOMMENDED UXO RISK MITIGATION MEASURES

The following measures are to be implemented in order to reduce the level of UXO risks on this project to ALARP:

PLGR, RC, Laying, Pre-Trenching, Ploughing, Jet Trenching and Rock Dumping - Proactive Measures

- Geophysical UXO Survey;
- Survey Verification;
- Geophysical Survey Data - Anomaly Grading and Selection;
- Avoidance;
- Investigation.

Horizontal Direction Drilling and Trenching – Proactive Measures

- Non-Intrusive Survey/Banksman Support.

Appendix 12 and 13 identify areas of low, medium and high risk to human life, the vessel and to GI equipment as well as low, medium and high probability of UXO encounter. In areas where the probability of UXO encounter is considered low, a reduced survey approach such as side scan sonar only may be required to detect any unforeseeable items that might be located upon the seabed's surface. In all areas where the probability of UXO encounter is considered medium and high, conventional magnetometry and side scan sonar is required in all areas where GI operations are to be undertaken.

All Operations – Reactive Measures
The following procedures are to be written and briefs delivered:

- Emergency Management Procedures (EMPs);
- Tool Box Briefs (TBBs).

ALARP Sign-off Certification
Once the UXO risk mitigation measures have been successfully implemented, the risks will have been reduced to ALARP and all cable installation operations can take place safely, within the surveyed area, without the requirement for further UXO risk mitigation activities. However, in the event that significant (e.g. large Net Explosive Quantities) and/or dangerous UXO are discovered, the risk and risk mitigation measures are to be professionally reviewed.

6 Alpha's sign-off certificates are generally valid for not less than one year from their issue date; other consultants might have different criteria. Our minimum safety avoidance radii are currently set at 15m for all cable installation operations. Extraordinarily, if 15m is too great an avoidance distance then it might be reduced, but engineering and EOD calculations would have to be modified and professionally endorsed through the provision of a formal Technical Note(s).

UXO Project Management, and Quality Assurance/Quality Control
Given the scope of the overall strategy and the need to undertake real-time decisions during various phases of the project, *6 Alpha* recommend that specialist UXO Project Management staff are either permanently engaged and/or on-call to assist and to oversee key elements of the UXO risk mitigation work.

Next Steps for the NorthConnect Cable Route
This assessment has identified that the main UXO threat items associated with the *NorthConnect* cable installation operations are primarily: HE bombs and IBs, ferrous metal sea mines, torpedoes, shipwreck related munitions, depth charges and mortars, artillery projectiles, and conventional dumped munitions together with a background threat posed by, non-ferrous metal sea mines, anti-invasion devices and land mines.

An appropriately specified geophysical UXO survey is now required in order to provide raw data capable of being professionally and appropriately processed in order to identify threat spectrum UXO (including non-ferrous varieties) in advance of all cable installation operations. Critically, such data processing will help to discriminate UXO from scrap and other benign seabed detritus, and in doing so, it will not only reduce the number of targets for avoidance/investigation but also save resources and time. A Survey Verification Test (SVT) is also required in order to prove-out the survey equipment employing surrogate UXOs (with known dimensions and magnetic responses).

Once all anomalies that model as prospective UXO have been identified (and they have been avoided or verified/rendered safe), the nominated UXO consultant will be in a position to deliver ALARP sign-off certificates to support the cable installation campaign.

1 Introduction

1.1 Overview

MMT (“*the Client”)* has commissioned *6 Alpha Associates Limited* (“*6 Alpha*”) to undertake a detailed, desk based Unexploded Ordnance (UXO) threat and risk assessment study for the planned *NorthConnect* cable project in order to support the proposed cable installation operations.

The Site crosses the northern sector of the central *North Sea*, extending from *Boddam* in *Scotland* to *Simadalen* in *Norway,* a distance of approximately 655km with a Survey Corridor width of 500m. The Site location is presented at *Appendix 01*. For the purposes of this UXO threat and risk assessment the Site has been subdivided into three LOTs namely:

LOT	Country
A	*UK Nearshore*
B	*North Sea*
C	*Norway fjord*

1.2 UXO Threats in the *North Sea.*

Items of UXO are regularly encountered in the *North Sea*, as has been confirmed by a variety of discoveries, *Royal Navy (RN)* clearance tasks, and associated media reports. UXO rarely becomes inert or loses its effectiveness with age. Over time, trigger mechanisms (such as fuzes and gaines) can become more sensitive and therefore more prone to detonation. This applies equally to items that have been submersed in water and/or lodged within the seabed. It is possible that the generation of significant kinetic energy over a short duration, which might be created by the cable installation and support operations (such as Pre-Lay Grapnel Run (PLGR), Route Clearance (RC), laying, pre-trenching, ploughing, jet trenching, rock dumping, Horizontal Directional Drilling (HDD), trenching and barge operations), could cause an inadvertent detonation of sensitive UXO.

In all circumstances, sufficient project time needs to be allowed, not only for the geophysical UXO survey to be undertaken but also data processing, anomaly grading and target selection (to differentiate prospective UXO from other seabed detritus). Where such work cannot eliminate entirely all of those targets (which resemble/model as UXO), then additional time will be required to verify them (via ROV and/or diver investigation). If UXO is discovered it is generally preferred to render it safe, typically by sympathetic detonation. All of the aforementioned events and the time associated with the delivery of aspects of them, must to be planned for, in order to enable the timely delivery of ALARP safety sign-off certificates in advance of cable installation operations.

1.2.1 Munitions Migration

If there is to be a significant period of time (generally more than 12 months) between the geophysical UXO survey and the cable installation operations, then a Munitions Migration Assessment should be undertaken. The principal advantage associated with taking into account prospective munitions migration, is that the longevity of such geophysical UXO survey(s) and importantly, the associated ALARP safety sign-off certificates (warranting that the risks of UXO encounter/initiation will have been reduced to ALARP), might not only be significantly extended but also, that all of the geophysical UXO survey might be undertaken at once. Such an approach may eliminate the more conventional requirement for “just in time” geophysical UXO survey(s) for the purposes of UXO avoidance, and therefore significant schedule and resource savings can be generated.

In summary, given the dynamic environmental nature of the Site, an assessment of the potential for migration of UXO at the Site may be considered beneficial. Following geophysical UXO survey, the recommended safety avoidance distances might also be extended, in order to take into account prospective munitions migration with respect to time.

1.3 Marine Risk Management Framework

In order to ameliorate UXO risks in the marine environment *6 Alpha* has developed a Marine Risk Management Framework, which is presented at *Appendix 03*. The Marine Risk Management Framework is divided into four parts, namely:

1. Detailed UXO Threat and Risk Assessment;
2. Strategic Risk Management Options;
3. Risk Mitigation Design and Specification;
4. Implementation of Risk Mitigation Measures.

However, in this instance and specifically at the Client’s request, *6 Alpha* have also undertaken a stand-alone marine Preliminary UXO Threat Assessment (specifically for LOT A), which was provided in advance of Stages 1 and 2, to provide the Client with an initial indicator of the prospective UXO threats that may be encountered.

1.4 Purpose

The purpose of this report is to address stages 1 and 2 of the overarching UXO Marine Risk Management process by providing a holistic overview of the UXO threats and risks for all operations, together with a strategy for the amelioration of those risks presented.

Therefore, *6 Alpha* aims to proactively employ this study to inform the Client not only about the risks associated with UXO on this project but also, how those risks can be managed safely and at best value. This methodology will include the employment of background research and factual data, which has been provided *inter alia* by third parties, and upon which we have relied.

1.5 Client Intention

In commissioning *6 Alpha*, it is assumed that *MMT* and their commissioning Client intends to:

- Provide a safe working environment for all vessels and their crew;
- Ensure that all cable installation operations may be undertaken without delay;
- Ensure that appropriate best practice UXO risk mitigation measures are delivered and evidenced as such;
- In undertaking such measures the Client intends to safeguard workers, vessels and equipment and their collective reputations;
- Procure the most time efficient and cost effective means of managing and mitigating the UXO risks presented, in accordance with recognised best practice.

2 Report Methodology and Best Practice

2.1 Methodology

This study consists of a desk-based collation and review of readily available documentation and records generated by detailed archive research relating to the possibility of encountering UXO and/or dangerous Explosive Ordnance (EO) related paraphernalia, within the study area. This risk management methodology is based on best practice for UXO risk management within the marine environment in accordance the Construction Industry Research and Information Association's (CIRIA's) publications covering the management of offshore UXO risk (CIRIA C754, published 2016, London) as well as fulfilling the legal requirements associated with English and EU Law (for a further explanation on the legal position see *Annex A*).

2.2 Constaints and Limitations

Certain information obtained by *6 Alpha* may be either classified or restricted under protective marking schemes, or may otherwise be considered confidential to the business therefore, summaries of such information have been provided. Please note that our appraisal relies significantly upon the accuracy of the information contained in these and other third party documents. *6 Alpha* are not responsible for the accuracy of such third party information or associated historical data.

2.3 Scope

In agreement with the Client the following facets have been covered within this report:

- War fighting and other relevant history of the region has been considered;
- Historic and modern military records have been researched and presented;
- Wartime activities have been researched and presented;
- The holistic UXO threat has been considered, including the types of ordnance that could be encountered, the probabilities of encountering them as well as exposing their potential initiation mechanisms and their likelihood of detonation;
- An outline assessment of how UXO interacts with the natural environment and conditions has been made;
- The proposed cable installation methodologies have been considered;

- The risks regarding UXO have been assessed employing our proprietary, semi-quantitative risk assessment (SQRA) model;
- The consequences of an inadvertent High Explosive (HE) detonation have been considered;
- Conclusions have been drawn;
- Recommendations have been made in the form of a risk mitigation strategy.

2.4 Sources of Information

The following UXO sources of information have been consulted:

- Royal Navy (Diving Units);
- The National Archives, Kew;
- Naval Historical Centre, Portsmouth;
- UK Hydrographic Office, Taunton;
- Archaeology Data Service;
- The "6 Alpha Azimuth ©" data-base which contains digitised historic maps, aerial photographs and records;

The following project background information has also been consulted:

- *NorthConnect* report titled '*Marine Survey Frame Agreement Appendix A – Scope of Work', 7th* October 2016;
- *NorthConnect* report titled '*Desk top survey and route engineering study Route Option Analysis Report NorthConnect ks*.'
- *NorthConnect* report titled *'Marine Survey Frame Agreement Appendix E – Company Documents', 7th* October 2016.

3 On-Site Operations

3.1 Proposed Operations

Whichever installation methodology is used, the key factor concerning UXO risk is that the resultant kinetic energy employed during such prospective cable installation operations, might be considered sufficient to initiate a variety of different types of UXO. Depending on the proximity of the cable installation equipment and vessels/crew to the initiation event, the equipment itself could be damaged or even destroyed, and vessels might be endangered. In such worst-case circumstances, personnel might be injured (prospectively fatally). For this cable installation risk assessment, *6 Alpha* have considered the risks associated with PLGR, RC, laying, pre-trenching, ploughing, jet trenching, rock dumping and HDD.

3.2 Pre-Lay Operations

3.2.1 Offshore Geophysical UXO Survey

Non-intrusive offshore geophysical UXO survey includes any methodology which does not require direct physical contact of survey equipment with the seabed. In terms of offshore survey, the methodology generally employs remote and direct sensing (e.g. swathe bathymetry, sub-bottom profiling (aka "pinger"), magnetometry and SSS), all of which use the reflection of energy sources to generate data that can be interpreted to provide a "picture" of the seabed. Whilst it may be theoretically possible that some of these energy sources could initiate very sensitive marine explosive ordnance, it is considered practically impossible to do so. Furthermore, there is no evidence of historic UXO in the marine environment (or elsewhere), being initiated by conventional methods of marine geophysical survey.

Offshore Geophysical Survey will be undertaken along the cable corridor however, various locations along the cable corridor will have been previously surveyed ahead of any Geotechnical Investigations within the Site, therefore previous survey results may be used in these areas (if it was carried out within 12 months of the installation), all other areas along the cable corridor will need to be surveyed.

3.3 Marine Cable Installation

The cable installation shall be performed with purpose built equipment and appropriate vessels for operation the equipment along the entire route corridor. The following methods have been identified in the *NorthConnect* report titled '*Appendix E':*

- Pre-lay Grapnel Run
- Route Clearance
- Cable Laying
- Ploughing
- Jet Trenching
- Rock Dumping

3.4 Cable Landfall

Where the cable makes landfall in *Scotland*, HDD will take place to install the cable. This will involve an entry and exit point which may pose a UXO risk, however there is an extremely low probability of encountering UXO between these two entry and exit points as the drilling will be undertaken at a significant depth within the bedrock below the expected level of penetrated UXO. In addition, barge operations may be required at the exit point and diving and trenching work is likely to be required at Landfall in *Norway*.

4 Sources of UXO Contamination

4.1 Generally

As a result of detailed archive research, it is apparent that there are seven prospective sources of UXO contamination that may influence the project, which are summarised at *Table 1*. Appendix 11, 12, and 13 provide more information regarding the characteristics of these threat items and their probability of encounter along the route.

POTENTIAL SOURCES OF UXO CONTAMINATION	LOT A	LOT B	LOT C	POSSIBLE THREAT ITEMS	PRIMARY DETECTION TOOL
Aerial Bombing	Likely; *Peterhead* was the most heavily bombed populated area of Scotland during WWII.	Possible; unrecorded and bombing within the Site's vicinity should always be considered a possibility.	Highly Likely; two Ships were sunk by air raids within 1.5km of the Site and aerial bombing was recorded near *Eidfjord* within 0.9km of the Site	GP250 UXB GP500 UXB SC 50 UXB SC 250 UXB SC 500 UXB	*Magnetometer + SSS*
Sea Minefields (*Axis* and *Allied*)	Possible; the East Coast was mined by Axis troops in WWI, although specific locations were not accurately recorded, it is thought they were located approximately 3.5km to the north and 3km south of the Site.	Highly Likely; five WWII Axis mine lays and three Axis minefields are located on-Site.	Likely; the Site was located within an Allied declared minefield area with British and American mine lays located throughout the fjords.	German EMA British MkVI German BM1000 Ground Mine German EMC II British MK XVII Mine	*Magnetometer + SSS*
				German Luftmine A German Luftmine B	*PI + SSS (Magnetometer)*
Training Areas	Highly Likely; the Site is situated within the firing range of a coastal defence gun site near the coastal landfall.	Highly Likely; modern day and military training has been conducted on Site.	Highly Likely; modern day and military training conducted on Site.	6" Artillery Projectile Training munitions.	*Magnetometer + SSS*
Munitions Related Shipwrecks	Possible; one vessel with a potential UXO threat was sunk within 5km of the Site.	Highly Likely; 13 vessels were sunk with 5km of the Site, all of which are linked with munitions.	Likely; three vessels were sunk with 5km of the Site, all of which pose a UXO threat.	Various UXO and munitions	*Magnetometer + SSS*
Munitions Dumping	Remote; there were no munitions dumping areas	Remote; there were no munitions dumping areas	Likely; one recorded munitions dumping ground	Dumped tri-service munitions.	*Magnetometer + SSS*

POTENTIAL SOURCES OF UXO CONTAMINATION	LOT A	LOT B	LOT C	POSSIBLE THREAT ITEMS	PRIMARY DETECTION TOOL
	within 5km, however the likelihood of unrecorded and unpremeditated dumping within the Site's vicinity should always be considered possible.	within 5km, however the likelihood of unrecorded and unpremeditated dumping within the Site's vicinity should always be considered possible.	was located within the Norwegian fjords in close proximity to the Study Site.		
Coastal Defenses	Highly Likely; the Site is situated within the firing range of a coastal defence artillery.	Highly Likely; *Norway* had a huge network of coastal defences extending along the western coastline.	Highly Likely; Norway had a huge network of coastal defences extending along the western coastline.	Artillery projectiles of varying calibres, land mines, large HE shells and possible booby trapped munitions.	*Magnetometer + SSS*
Naval Battles	Possible; convoy raids from motor torpedo boats, destroyers and escort ship engagements.	Possible; convoy raids from motor torpedo boats, destroyers and escort ship engagements.	Highly Likely; a ship was sunk 0.8km from the Site in a naval battle.	Mk VII Depth Charge Torpedo G7a 6" Artillery Projectile SC 50 UXB	*Magnetometer + SSS*

Table 1 – Summary of Potential UXO Contamination

The details of all prospective UXO threats are described in detail subsequently and their locations are presented at *Appendices 4 to 9.*

4.2 Aerial Bombing

4.2.1 Generally

British and *allied* shipping was commonly attacked in WWI in the *North Sea* by air as well as the surface and sub surface fleet. Such shipping was gathered into convoys in order to afford them protection and the convoy system was also adopted in WWII. Nonetheless, thousands of HE bombs were employed to attack convoys as well as regularly targeting independent vessels. Aerial bombing was not however, the only threat posed to convoys – sea mines were also extensively employed in order to disrupt, damage and destroy shipping.

Records indicate that several convoy routes crossed the Site boundary and documentation shows that a number of successful attacks on convoys occurred within five kilometres of it. Given the poor accuracy of aerial bombing generally, aerial attacks on shipping lanes are likely to have resulted in light UXB contamination in the vicinity, and although the probability of encountering HE bombs in this area is considered low, although this cannot be corroborated because there is a paucity of records. There is however, a higher probability of encountering HE bombs closer to the coastline given that *Peterhead* was heavily targeted.

Nonetheless, although air dropped iron bombs might be encountered in any areas where aerial conflict and attacks on shipping has occurred, the location of unexploded bombs (UXB) has not been well documented, especially offshore where indiscriminate aerial bombardment and/or the practice of jettisoning unused munitions before returning to air bases, constrains accurate analysis. Notwithstanding these limitations, the available historical data associated with each of the three LOTs has been summarised below:

4.2.2 LOT A – UK Nearshore

As a result of *Peterhead's* geographical position, being the closest *UK* urban area from *German*-occupied *Norway* it is was the most heavily bombed (populated) area in *Scotland* during WWII, having been the subject of 28 air raids throughout the war. Although there are no official (locality specific) records of the proposed landfall Site having been targeted, given the intense level of regional bombing it is considered both possible and likely that it was bombed. Because the accuracy of the delivery of aerially deployed bombs was relatively poor during WWII, air raids commonly missed their targeted sites. In addition, typical failure to function rates of aerially deployed bombs during WWII was then 10% and therefore, it is possible that UXBs might be in *Peterhead* and/or its adjacent shoreline region.

Additionally*, Aberdeen County Register of Air Raids* recorded that two High Explosive (HE) bombs fell within the Study Site just off the coast of *Longhaven* on the 24th April 1941. It is highly likely that other HE bombs landed in the sea due to either, poor bombing accuracy (although this is more likely to affect the near-shore end of the Search Area); and/or, from *Luftwaffe* aircraft dropping munitions onto opportunistic targets (such as vessels and land based primary targets); and/or, bombs may have been jettisoned when (*Allied* or *Axis*) aircraft were returning to/from *Europe,* so that they could land safely at airfields without bombs on board.

4.2.3 LOT B – North Sea

Aerial bombing records were not available for LOT B. Nonetheless, two ships were sunk by air raids during WWII, with shipwrecks recorded as the *R-56* and *SS Tauri*, located approximately 1.2km and 0.7km from the Site boundary respectively. Because a number of bombing attempts are likely to have preceded a successful attack on shipping, and that some of those bombs may not have exploded, it is possible that UXB may be in the vicinity of those shipwrecks.

4.2.4 LOT C – Norway Fjord

Aerial bombing records were not available for LOT C. However, *Bergen* (which is located approximately 20km to the north-west), *Vossevangen* (which is located 25km to the North-east) and *Odda* (which is located 45km to the south-east), were all heavily bombed during WWII. While such bombing does not directly pose a threat to the Site, bombs may have been jettisoned in the region. Additionally, on the 12th December 1944 the *RAF* attacked *Axis* vessels in *Eidfjord*, which is located approximately 0.9km to the south of the Search Area and UXBs may have been generated as a result.

4.3 Sea Minefields (Axis and Allied)

4.3.1 Generally

A naval mine is a self-contained explosive device placed in the water in order to destroy ships and/or submarines. They were fused so that they might be detonated by the close proximity (or in some cases contact) with a ship. In WWI and WWII, naval mines were employed offensively, for example to constrain movement or defensively for example, to protect shipping and create safe movement zones. During both wars defensive minefields were often laid by surface vessels, whereas offensive minefields were often laid in WWII by aircraft or submarines, thus delivering an element of secrecy to those mine laying operations. Nonetheless, A*xis* forces also laid non-ferrous mines by aircraft and U-boat in WWII. Whilst there is no formal evidence that such mines were laid at any point along the Search Area, it is quite possible such items might form part of a background threat. The locations of the known mine lays and minefields are discussed below and are presented at *Appendices 4 to 6 inclusive.*

4.3.2 Mine Clearance by Vessels

Wartime mine clearance was made more difficult due to the lack of precise information regarding the location, types and extent of mine laying. Whether all the mines that were laid were recovered during clearance operations cannot be confirmed however, it is very unlikely that the mine clearance was entirely successful (100% clearance of minefields, even with modern technology and methods, is not always achievable).

Nonetheless, post WWII mine clearance operations were generally undertaken by one of two methods:

- Using two minesweepers, a sweep-wire (with a serrated edge and an “otter” or “kite” to keep the sweep wire at the required depth), was deployed into the water and both ends were attached to a winch at the stern of each ship. Both vessels towed the sweep-wire over a mined area and, when connected with the mooring stay of a tethered mine, the ships momentum would then force the stay to the serrated edge of the sweep wire, which cut it. The mine would then (usually), float to the surface for disposal;
- An alternative method was to use only one ship with the sweep wire attached to an oropesa float (to keep the sweep wire away from the ships themselves), and the wire would then cut the mooring stay of the mine (as described above). The untethered mine would then (usually) float to the surface for disposal.

For moored mines (that had been cut by sweeping), disposal was sometimes by rifle fire. However, on occasions, the rifle bullet only penetrated the outer casing of the mine without detonating it, allowing water to ingress and resulting in the mine sinking to the seabed; an explosive hazard thus remained.

The towing of gear for snaring and cutting the cable, by which conventional moored or contact mines were anchored to the seabed, would not work with magnetic mines. This is because magnetic mines were ground varieties, which rest on the bottom of the seabed, rather than being moored or anchored.

An alternative method for the clearance of magnetic mines was an approach termed LL. This entailed towing two parallel pairs of electric cables on floats behind a vessel. These cables emitted electro-magnetic pulses every few seconds and the resultant magnetic fields (which were much greater than those of ordinary, non-pulsing, electromagnets), detonated magnetic mines at a safe distance from clearance shipping. Clearly, the LL cables had to be employed in the appropriate contaminated zones in order to effect clearance.

4.3.3 Mine Clearance Analysis

Whilst wartime sea mines undoubtedly pose a potential residual hazard, it is not possible to say how many – if any – might be located near to or upon the Site. Nonetheless, the clearance of moored mines was generally more successful than clearance of “ground” mines, which were often laid to provide a deterrent to minesweepers. Therefore, ground mines are considered more likely to pose the main residual threat today.

4.3.4 First World War (WWI) Minefields

Records of *British* mine laying from WWI are relatively poor (as compared with the quality and accuracy of those associated with WWII). *Royal Naval* charts from this period merely recorded the area where mines were to be sown, rather than depicting individual mine lays. Nonetheless, by the end of 1914 the *Royal Navy* had formed a mine laying squadron (consisting of four mine laying cruisers, escorted by destroyers), which had laid 3,064 mines (locations of the mines were not however, recorded in the source data). Records of WWI *British* minefields located within the Site and its surrounding area are unavailable however, opportunistic and unrecorded mine lays may have occurred.

During WWI, *Germany* laid more than 43,000 mines worldwide, which sank 497 merchant vessels. In addition to this, the *British Merchant* and *Royal Navy* lost 44 warships and 225 auxiliary vessels to mines. *German* mining of the *North Sea* was undertaken by U-Boat and surface vessels. U-Boat mines were more frequently deployed in this area because they met less resistance than surface vessels and the *North Sea Mine Barrage* and *Channel Mine Barrage* (laid by *British* and *American* forces) forced *German* forces into this zone. The most common U-Boat mine employed at this time was the UC 200, a moored contact mine equipped with a 200Kg HE charge.

In August 1915, *German* forces laid a large minefield across the *Moray Firth*, an area which falls within the curtilage of the Site. Anecdotal evidence has been found to suggest that the coastline around *Peterhead* was subjected to considerable offensive mining activity by *German* forces. Extensive research associated with WWI *Axis* and *Allied* minefields along the East Coast of Britain has identified that two *German* minefields were located approximately 3.5km to the north-west and 3km to the south of LOT A. In addition, a WWI *German* minefield intersects the Study Site within LOT B and the WWI *Northern Barrage* minefield intersects the eastern sector of LOT B. The approximate location of these minefields has been depicted in *Appendix 6*.

4.3.5 WWII Minefields

Axis forces are known to have laid several offensive minefields along the coast of the *UK* and throughout the *North Sea*, not only to disrupt military movement, but also to hinder fishing and merchant supply vessels. It is also likely that unrecorded *German* mine laying activities took place, delivering mines either by air, submarine or surface vessels.

4.3.6 LOT A – UK Nearshore

Allied and *Axis* records of WWII mine laying are more accurate and informative in comparison to records made during WWI. *Axis* forces are known to have laid several offensive minefields along the *British* coast and throughout the *North Sea*. The closest recorded *German* WWII minefield was located 30.2 km to the south-west near *Aberdeen*.

4.3.7 LOT B – North Sea

Due to *Axis* mining activity in WWII, proposals were made in November 1939 to lay *Allied* mines in the *North Sea*. Defensive minefields were typically deployed around *UK* coastal waters by *British* forces and the *East Coast Mine Barrage* of 1939, comprising of approximately 100,000 mines, was then deployed along the entire eastern coast. Several *Allied* mine lays are located within 50km of the Site which formed part of the *East Coast Mine Barrage*, two of which are located within the boundary of the Site. The minefields consist predominantly of *British Mark XVII* mines, which were usually placed at a depth of 8 to 12 feet (approximately 2.5 to 3.5 metres), in a linear formation. In addition, nine mine lays are located within 40km of the Site which formed part of a *North Sea German Minefield*, situated close to the *British-Norwegian* maritime boundary, three of which are located within the boundary of the Site. Furthermore, seven mine lays are located within 40km of the Site, which formed part of a *British* minefield that covered the *Norwegian* coastline, and extended into the *Hardangerfjord* however, none were located on site. The Site also falls within a broader *British* WWII declared mining area.

The threat from *Axis* and *Allied* mine fields therefore, poses a high level of threat to the Site. Although the Site is only partially covered by a minefield, it is possible that *Axis* and/or *Allied* mines could have drifted over the proposed Search Area from other local minefields or during the clearing process (when they may have been dislodged, drifted and then sunk within the Site).

4.3.8 LOT C – Norway Fjord

A *British* WWII declared mining area is located across the entire proposed route within LOT C. In addition, *American* mine lays were identified through the *Norwegian* fjords which have been presented at *Appendix 4*. A summary of WWII mine fields that could possibly affect the Search Area within LOT's B and C are presented in *Table 2*.

NAME	DESCRIPTION	CLOSEST DISTANCE FROM EXPORT SEARCH AREA
SN15A	British Minefield	On-Site
SN12	*British* Minefield	On-Site

NAME	DESCRIPTION	CLOSEST DISTANCE FROM EXPORT SEARCH AREA
SN13	*British* Minefield	8.7 km
SN16C	*British* Minefield	26.1 km
SN16G	*British* Minefield	31.2 km
SN16B	*British* Minefield	37.5 km
SN16F	*British* Minefield	42.1 km
SN16E	*British* Minefield	49.7 km
SN16A	*British* Minefield	50.0 km
A6	*German* Minefield	On-Site
A5	*German* Minefield	On-Site
A3	*German* Minefield	On-Site
595Y	*German* Minefield	12.9 km
A4	*German* Minefield	13.8 km
A9	*German* Minefield	27.3 km
A7	*German* Minefield	34.2 km
A1	*German* Minefield	36.5 km
B29	*German* Minefield	36.5 km
FD 19 Group 4	*British* Minefield	10.9 km
FD 19 Group 3	*British* Minefield	11.5 km
FD 19 Group 1	*British* Minefield	12.2 km
FD 19 Group 2	*British* Minefield	12.4 km
Spellbinder 1	*British* Minefield	32.2 km
Spellbinder 2	*British* Minefield	35.6 km
Spellbinder 3	*British* Minefield	37.0 km

Table 2 – Mine Lays within 50km of LOT's B and C

4.4 Training Areas

4.4.1 Historical Training Areas

Records of WWII training areas were generally inaccurate and activities were often carried out beyond the boundary specified by records. These historical ranges have been identified within *Appendix 7.*

4.4.2 LOT A – UK Nearshore

There is currently no available evidence found that would confirm the existence of historic military or naval training areas within LOT A of the Site. However, two former armament training ranges from WWII era are located within 25km of Lot A and Lot B. The first armament range is located approximately 7km north of the Site. The maximum range of fire of this site was recorded as being 40,000 ft (approximately 12.2 km). Therefore, it is likely that remnant munitions from this training range could have landed within the Search Area and/or migrated on-Site over time. A WWII armament training range is located approximately 7km to the south of the Site and has a recorded maximum range of 20,000 ft (approximately 6.1 km). It is not known what calibre weapons were used however, it is considered unlikely that they were greater than the 6-inch Naval Weapons (discussed at paragraph 4.5.1).

4.4.3 LOT B – North Sea

The *Norwegian* coastline was designated a “Coastal Armament Range”, upon which artillery use was recorded. Gun calibres are likely to have varied and projectiles/shells are expected to be encountered along the Search Area within LOT B and LOT C. Given that the proposed Search Area passes through the coastal armament range for a distance of 147.5km, it is likely that training and live firing occurred within the Site and therefore projectiles might be encountered.

4.4.4 LOT C – Norway Fjord

The *Norwegian* “Coastal Armament Ranges” (mentioned above) are also located within LOT C, although it is assumed that most of the firing that took place at these sites would have been fired out to sea and therefore, munitions relating to this range are more likely to be found within LOT B.

4.4.5 Modern Training Areas

Modern training ranges have been georeferenced and presented separately at *Appendix 8*. PEXA sites can be over land or water, or both, and may involve the firing of live munitions. The airspace associated with these areas can be categorised as either; “danger, restricted or prohibited”, depending on the type of activities that are undertaken. Modern defence training protocols operate to a much higher safety standard than those undertaken during WWII, and modern forces rigorously adhere to boundary limits during live fire training.

4.4.6 LOT A – UK Nearshore

There are no known modern training areas, located within the Site boundary of LOT A however, a modern *Air Force* training site (D613A) is located approximately 22km to the south of LOT A. The training site is used for air-to-air combat training involving high-energy manoeuvres and potential live fire practice. Given the distance of the training area to the Site boundary and the type of munitions likely to be involved in training, it is unlikely that HE UXO from this source will have contaminated the Site.

4.4.7 LOT B – North Sea

There is a known modern military exercise area located within the western sector of LOT B. In addition, two military training areas are located 16 km to the north and 20 km to the north-west of LOT B however, it is not known what activities are carried out within these areas. The *D613A Air Force* training site mentioned above also extends to the south of eastern sector of LOT B.

4.4.8 LOT C – Norway Fjord

There are no known modern training areas, located within the boundary of LOT C.

4.5 Coastal Defensive Features

4.5.1 LOT A – UK Nearshore

During WWII, many of the beaches located on the east coast of the *UK* were assessed and categorised as possible landing sites for a *German* Invasion. Defensive measures were taken to protect these beaches from amphibious assault, which included barbed wire entanglements, pillboxes containing machine gun positions, anti-tank obstructions and minefields. Intentions to strongly defend *Peterhead* can be confirmed by the fact that at least two defensive coastline pillboxes and one long-range coastal artillery battery were located within the *Peterhead* area. The artillery battery was located at *Salthouse Head,* on the southern tip of *Peterhead* harbour which is 2.9km to the north of the Site. It was equipped with two seaward facing gun emplacements, armed with two 6-inch (153mm) Mk XII calibre naval guns capable of a maximum firing range of 23,300 metres at 45 degrees elevation. In addition, two pillboxes were located approximately 3.6km to the northwest and 4.7km to the south-west of the Site boundary. Although it is likely that they were equipped with machine guns, small arms and light anti-armour weapons (LAW), none of the aforementioned weapon systems were formally recorded.

Other forms of anti-invasion defences also supplemented coastal artillery batteries. For example, land mines and other anti-tank obstacles were not only emplaced on the beaches themselves but also in shallow waters just off shore and below the high water mark. Such defences were commonly booby-trapped with high explosives and/or lined with land mines in order to hamper their removal. Small arms and machine-gun arcs of fire as well as mortar and artillery fire typically covered such features. The intent of emplacing such obstacles was to destroy and/or immobilise *German* landing craft before they could disembark troops and supplies. It is therefore possible that those, which may not have been completely cleared post WWII, might also pose a threat to the Search Area.

4.5.2 LOT B – North Sea

LOT B was generally beyond the range of coastal defensive features with the exception of the eastern sector as the Site extends near shore to the *Norwegian* coastline.

4.5.3 LOT C – Norway Fjord

The *Norwegian* coast was defended by the *Atlantic Wall*, an extensive system of coastal defences and fortifications built by *Axis* forces between 1942 and 1944. This defensive network extended along the *Scandinavian* and *Continental European* coast in anticipation of an *Allied* invasion launched from *Britain*. Coastal defences were recorded 2.2km to the south-east, 2.0km to the south-east, 1.8km to the north-west, 1.2km to the north and 7.9km to the south-east of the Site.

Coastal gun batteries were also supplemented with other forms of anti-invasion defences eg infantry positions, equipped with machine gun and LAW fire. In accordance with conventional military doctrine it is highly likely that such positions were also supported by mortar and artillery fire, minefields and anti-invasion/anti-tank obstructions (as in the British case, the latter may well have been booby-trapped with HE and/or land mines). Such obstacles were typically concealed in shallow waters just off-shore and below the high-water mark. The intent of emplacing such obstacles was to destroy and/or canalise enemy landing craft before they could disembark troops and other war fighting supplies. It is therefore possible that those, which may not have been completely cleared post WWII, might also pose a threat.

4.6 Naval Battles

Many naval skirmishes occurred all along the north eastern *British* coastline throughout WWI and WWII. Minor *Axis* activities around the *Aberdeenshire* coastline were generally focussed upon merchant shipping vessels and their surface escorts. *German U-boats* also operated within the area during WWI and WWII (proven by the existence of a wreck (U-1206) located approximately 17.7km south east of landfall), despite the presence of *British* minefields designed and emplaced to deter them. Furthemore, *HNOMS Sæl* is a *Norwegian* torpedo boat that was shipwrecked after being involved in a naval battle; it is located 0.8km to the north-west of the Site within the *Hardangerfjord*.

4.7 Shipwrecks

Appendix 9 shows potential UXO wrecks within the region. Both merchant and naval vessels that were sunk in WWI and WWII may have contained munitions and/or weapon systems. Empirical evidence has shown that munitions may have spilled from such ships as they sank and subsequently broke-up. In general, the risk of munitions contamination is somewhat reduced in the vicinity of wrecks (as compared with munitions dump-sites), because the munitions within the body of wrecks generally remain enclosed and immobile. However, it may be possible that some munitions may have been thrown clear of the vessel as it sank or they could become exposed and migrate as the wrecks gradually broke up.

Regardless of the type of weapons system employed to attack the ships, direct fire weapons systems lacked the first time strike accuracy of their more modern counterparts and is unlikely that any vessel was sunk in the first exchange of fire. As a result, many of the weapons systems employed are likely to have missed the target at first instance and it is entirely feasible that a number of exchanges of fire would have preceded a successful disabling attack. As a result, there may also be UXO (deck gun projectiles more specifically), generated by this sort of exchange of fire, in the regions of those wrecks that may have been sunk by gunfire.

A total of 28 wrecks have been recorded within 5km of the Site. Details of those wrecks that might be associated with UXO are summarised in *Table 3*.

Name	Year	Latitude	Longitude	Description	Distance from Site	Lot	Comment
FV Windward Ho	1917	57.42473	-1.7575	*British* Trawler	3.3km	A	Sunk by mine
SS Muriel	1918	57.53503	-1.73733	*British* Cargo Ship	4.9km	B	Torpedo
SS St. Magnus	1918	57.53792	-1.72822	*British* Passenger/ Cargo Ship	4.8km	B	Torpedo
SS Wrangler	1917	57.5473	-1.71977	*British* Trawler	4.9km	B	Sunk by mine
HMT Flotta	1941	57.45528	-1.68942	*British* Minesweeper	3.0km	B	Foundered
SS Blomvang	1917	57.6575	-1.33075	*Norwegian* Cargo Ship	3.2km	B	Gunfire-shelled
SS Pollux	1917	57.70028	-1.15077	*Norwegian* Passenger/ Cargo Ship	2.5km	B	Torpedo
FV Golden Hope	1917	57.6979	-1.06878	*British* Sailing Ship	On-Site	B	Charges/ explosives
SS Marshall	1917	57.66197	-1.03762	*Norwegian* Cargo Ship	3.6km	B	Gunfire-shelled
FV Largo Bay	1917	57.74822	-0.99842	*British* Trawler	3.0km	B	Gunfire-shelled
U-29	1915	58.33267	0.948317	*German* Submarine	2.9km	B	Rammed
U-15	1914	58.59517	1.911	*German* Submarine	5.0km	B	Rammed
SS Marstonmoor	1918	59.56613	4.90138	*British* Cargo Ship	2.8km	B	Torpedo
U-13	1914	58.4896	1.673883	*German* Submarine	On-Site	B	Missing
R-56	1944	59.67335	5.319067	*German* Minesweeper	1.2km	C	Air raid
SS Tauri	1941	59.7	5.4	*Finnish* Cargo Ship	0.7km	C	Air raid
HNOMS Sael	1940	59.92117	5.723667	*Norwegian* Torpedo Boat	0.8km	C	Naval battle

Table 3 – Potential Munitions Related Shipwrecks Within Close Proximity of the Site

Because such munitions related warship wrecks have been found on or near the Study Site the prospective UXO threat from these sources is categorised as high.

4.8 Munitions Dumping

4.8.1 Generally

Stockpiles of conventional and chemical munitions that had been earmarked for wartime use, were commonly disposed of at the end of WWI and WWII. As a cost effective and military expedient, conventional and chemical munitions were dumped offshore. Whilst the centre of mass of such dump-sites were recorded, the logistical accuracy of dumping such munitions was less than perfect. Given that those vessels commissioned with dumping munitions were incentivised for speed and volume, rather than accuracy of dumping, and because such activities were not the subject of strict Quality Assurance nor Quality Control (QA/QC), it is common to find munitions dumped on the approach to, and on the exit from, such registered dumping grounds, a practice commonly and collectively referred to as "short-dumping". Although such munitions were commonly short-dumped and although some chemical and conventional munitions were dumped in containers, the effect of munitions migration is likely to have since further spread the theoretical and initial extent of such contamination. These sites have been identified at *Appendix 10*.

4.8.2 LOT A – UK Nearshore

There are no recorded munitions dumps located within close proximity to LOT A. However, one conventional dumpsite was located approximately 35km to the south-west of the Site.

4.8.3 LOT B – North Sea

There are no recorded munitions dumps located within close proximity to LOT B. Munition dumps were often located near shore so vessels could dispose of munitions quickly, in order to make several return journeys.

4.8.4 LOT C – Norway Fjord

On May 8th 1945, the *German* occupation of *Norway* officially ended and thousands of tonnes of ammunition and armaments were left behind. These munitions were dumped in various lakes and fjords located throughout the country. These sites have been georeferenced and presented separately at *Appendix 10*. It is estimated that nearly 168,000 tons of munitions were dumped in such circumstances and more than three dozen ships were sunk along with their guns, shells and bombs. One explosive dumping ground has been identified in LOT C within a *Norwegian* fjord and it may pose a UXO threat to the Site. There is also one (now disused) conventional munitions disposal area located to the south west of the Site along the eastern coast. However, the munitions dumpsite is approximately 34km from the proposed Search Area and given this distance, it is not considered close enough to pose a significant UXO threat to the Site.

Despite small items of UXO being capable of migrating significant distances, it is considered to be highly unlikely that larger items such as mines or depth charges will have migrated from this source onto the Site by natural means. However, long distance UXO migration through unintentional anthropogenic methods such as by munitions being caught in trawling nets is possible.

As has been noted, not all munitions dumping occurred at designated disposal sites and, as empirical evidence from other projects has shown, there may have been unrecorded and/or inaccurate munitions dumping within other areas of the seabed and potentially within the Study Area. Furthermore, given the nature of the *Buchan Deep* being a significantly deep basin together with its proximity to the mainland, it may have been considered as an appropriate improvised dumpsite and caution must be exercised at first instance, until the area has been proven threat free.

5 UXO - Seabed Conditions, UXO Migration, and Detonation

5.1 Generally

In the marine environment it is possible that UXO that enters the sea with significant kinetic energy (e.g. aerially delivered bombs or artillery projectiles), might have the capacity to bury themselves into the seabed. However, all other things being equal, the depth of water significantly influences the potential for penetration. In regions of deep water, munitions might enter the water and come to rest upon the seabed. Such items may then migrate across the seabed subject to, amongst other things, their shape as well as seabed geology and current/tidal action.

When establishing the practicalities associated with UXO migration, it is important to ascertain the level of potential sediment cover and seabed mobility, especially in those areas of proposed GI operations. This section therefore explores, in outline, the factors to be considered whilst assessing munitions penetration, migration and/or their subsequent burial.

5.2 Local Sea Bed Conditions

5.2.1 Bathymetry

To determine the bathymetry of the study area, *6 Alpha* has referred to the "European Marine Observation and Data Network Portal for Bathymetry" which shows that the depth along the *NorthConnect* Search Area increases through the *North Sea* from 0m at the *Scottish* coastline to 293m at the *Norwegian* coastline. Furthermore, the depth along the Search Area within the *Hardanger Fjord* ranges from 134m to 851m.

In addition, *6 Alpha* has referred to the report "Desk top survey and route engineering study Route Option Analysis Report NorthConnect ks – Appendix J", which corroborates the depth profile of the proposed route identifying increasing water depth eastwards across the North Sea towards Norway. The "Marine Survey Frame Agreement Appendix E" report suggests that water depths are greater than 800m within the fjord and the client has stated that water depths within LOT A are between 10m and approximately 60m.

5.2.2 Seabed Conditions

To determine the seabed conditions, *6 Alpha* has referred to the report "Desk top survey and route engineering study Route Option Analysis Report NorthConnect ks" which shows that the seabed conditions are variable along the planned Search Area. 'Appendix E' describes the seabed conditions as follows:

LOT A – UK Nearshore

The seabed consists of sand to gravel with occasional exposure to bedrock at the nearshore. Within deeper waters, soft to very soft clay is present. The seabed comprises of unstable sandy sediments with variable trenching resistance and occasionally very resistant sediments. The water depths in this region range from 10m to approximately 60m and benthic conditions are present.

LOT B – North Sea

The seabed comprises of unstable sandy sediments with occasionally exposed stiffer sediments on the *North Sea Plateau* and very soft sediments in the *Norwegian Trench.* There is variable trenching resistance and occasionally very resistant sediments. There is an undulating longitudinal trough along the western slope of the *Norwegian Trench* (iceberg scars, free span, local slope stability issues) which may require a wider corridor. Another factor which may require a wider corridor is the high density of pockmarks in the *Norwegian Trenc*h (up to 100-200m in diameter and 10m deep). This will induce free spans or active routing.

LOT C – Norway Fjord

The water depth varies significantly throughout this Lot (100m to more than 850m) and comprises of very variable seabed conditions (iceberg scars, long areas of rugged exposed bedrock across sills, and long sections of very soft clay/mud along the deeper sections). There are possible corals on exposed bedrocks and large boulders as well as numerous slide scars from earlier slide events, both from the steep sidewalls and centrally in the fjord. Possible sources/triggers of this are sediment overload, rock avalanches/rock falls, earth quakes, flooding etc.

5.3 UXO Penetration

The main UXO threat items to this Site are variously: bombs (HE and incendiary varieties); sea mines (ferrous metal and aluminium varieties); torpedoes; a variety of ship wreck related munitions; depth charges, artillery projectiles and conventional type of dumped munitions. A background threat is also posed by anti-invasion devices and land mines.

Deep water reduces the velocity of ordnance as they enter the sea, reducing their potential for seabed UXO penetration (even from high altitude aircraft). Nonetheless, significant UXB penetration is generally more prevalent in shallow water (less than 20m LAT) and softer soil/mobile seabed conditions. Given the water depths on Site, it is unlikely that high velocity

UXO might have penetrated the seabed upon initial deployment, however, in shallower waters (less than 20m LAT) where the Site makes landfall, this may in fact be the case.

5.4 UXO Migration

Munitions can migrate both across the seafloor and within mobile sediments. The main factors concerning the degree of movement include: the strength and direction of currents; the overall shape of the UXO (influencing the degree to which they are free to move without constraint); ordnance protrusions such as fins and lugs (the latter being employed for suspension from the aircraft in flight, the former for aerodynamic or hydraulic ballistics); and the UXO position on the seabed e.g. on the seabed, or partially or wholly buried within the sediment. Such UXO might also gather within natural seabed gradients and may become trapped in natural seabed recesses, all of which could significantly enhance or impede prospective movement.

Smaller natures of UXO (eg small calibre artillery or deck-gun projectiles), could conceivably migrate onto the Site eg from associated wrecks. However, larger projectiles, bombs and ground mines, which were generally used by the *Axis* against *Allied* shipping, weighed hundreds of kilograms and are unlikely, in the conditions on site, to migrate as far as smaller mass items, if at all. Additionally, migration can also take place as a result of human activities such as fishing, trawling and dredging.

5.5 UXO Detonations

A full description of UXO detonation effects is presented at *Annex C*. Nonetheless. Such effects can damage, disable or sink vessels, cause significant damage and/or destruction of cable installation equipment and in such circumstances it is possible (in shallow water conditions especially), that personnel might be injured (prospectively fatally).

5.6 Shock Wave Effects

Significant shock wave amelioration can occur where there is a sufficient depth of water between an item of UXO and a sensitive receptor. The consequences of UXO initiation on the seabed can be partially mitigated therefore, in areas of deeper water. On the Site, water depths are expected to range from 49m to 851m LAT, therefore the level of fragmentation amelioration by the deeper water is likely to be partially (if not wholly) ameliorated, especially where risks may be posed by small NEQ items of UXO.

Larger items of UXO (e.g. HE sea mines and bombs), may be on the verge of their vessel damage threshold at depths beyond 40m, however the risks are not wholly ameliorated (e.g.

large volume gas bubbles could still create significant vessel damage), and it is anyway, not best practice for vessels to be in close proximity of such a prospective high-order explosive event.

Even in deeper water, installation equipment might be severely damaged as a result of a small (or large) NEQ item being initiated either directly (by the cable installation equipment) or indirectly initiated whilst the cable installation equipment is in close proximity of such an event. In very shallow waters the initiation of a small NEQ item might also have the potential to do significant harm to vessels, personnel and equipment, as well as to the environment and mammals.

6 UXO Risk Assessment Factors

6.1 Source – Pathway – Receptor

The UXO risk assessment model relies upon source (UXO); pathway (the route and/or prospective cause of UXO initiation) and receptor (those sensitive receptors in their close proximity).

The prospective UXO threats in this instance must be considered in light of the proposed cable installation operations, as well as the impact on key receptors such as personnel and cable installation vessels, together with any other high-value or sensitive receptors in close proximity e.g. third party support vessels, equipment, the local environment as well as marine mammals, fish and birds.

6.1.1 Sources

The principal UXO sources on this site are those identified and summarised in the threat assessment, namely:

- *IB and HE bombs;*
- *Sea mines (ferrous variants);*
- *Torpedoes;*
- *Ship wreck related munitions;*
- *Depth charges and Mortars;*
- *Artillery projectiles;*
- *Dumped munitions (Conventional HE types);*

With a background threat posed by:

- *Sea mines (non-ferrous metal variants);*
- *Anti-Invasion Devices;*
- *Land mines.*

6.1.2 Pathways

The pathway is described as the route by which the sources reach the receptors. Given the nature of the Site the pathways could be generated during the following cable installation activities:

- **Pre-lay grapnel run;**
- **Route Clearance;**
- **Pre-Trenching;**
- **Laying;**
- **Ploughing;**
- **Jet trenching;**
- **Rock dumping;**
- **HDD;**
- **Trenching;**
- **Barge Operations.**

It is possible that geophysical UXO survey, that might be conducted in advance of cable installation in order to mitigate UXO risks, might generate a prospective pathway, but only if the geophysical survey equipment was to make inadvertent contact with UXO.

6.1.3 Receptors

Sensitive receptors may include:

- All cable installation vessels and crew;
- All cable installation and/or geophysical UXO survey equipment;
- Other ships/vessels and crew indirectly associated with or in support of cable installation;
- Third party shipping/vessels in the immediate vicinity. Note: extended safety distances for detonations underwater apply (for reasons articulated separately in *Annex C*);
- The marine environment in general and marine life in particular (especially marine mammals, fish and birds).

Clearly where such risks present themselves, they may be either avoided or ameliorated.

7 Semi-Quantitative Risk Assessment

In undertaking a series of Semi-Quantitative Risk Assessments (SQRAs) for this project we seek to analyse and quantify those UXO risks to cable installation generated by threat spectrum UXO. We have employed technical data associated with threat spectrum UXO (as presented and summarised within this report) and the proposed scale and nature of the cable installation work.

For this Study Site, the main UXO threat items are: IB and HE bombs, ferrous metal sea mines, torpedoes, shipwreck related munitions, depth charges and mortars, projectiles and conventional (HE) dumped munitions, as well as a background threat being posed by non-ferrous metal sea mines, anti-invasion devices and land mines. While there are several threat items associated with the Site, sea mines, HE bombs and torpedoes pose the highest risk, therefore the semi-quantitative risk assessment will only consider these high NEQ items that are considered a risk to cable installation. The cable installation activities that will be undertaken on-site are assessed to be different in nature, with PLGR, RC, pre-trenching, ploughing and jet trenching being intrusive and aggressive and laying and rock dumping being non-intrusive, therefore for the purpose of this risk assessment, risk levels have been calculated separately for cable laying and rock dumping. In addition, HDD at the entry and exit points may pose a UXO risk, however the drilling between these two points will be at a significant depth that the probability of encountering UXO is considered remote. Barge operations may be required at the exit point in LOT C and trenching and diving may be required at the landfall in LOT C. Therefore, this risk assessment will consider the risk associated to the entry and exit points of HDD and barge operations in LOT A and trenching and diving operations in LOT C.

The risk level is calculated primarily, based on a risk to human life and cable installation vessels as well as the risk to equipment. Therefore, in areas of the Site that have a water depth of less than 100m (I.e. LOT A) there is a risk associated with human life, vessels and equipment. Whereas in water depths greater than 100m the risk is primarily associated with damage to equipment operating on or near the seabed; this is because the depth of water is sufficient to ameliorate the direct and indirect effects of a prospective high NEQ, initiation event.

The tables below outline and display the numeric semi-quantitative scored assessment for the cable installation campaign. The transparent methodology and calculations used in developing the scores, are followed by descriptors and an analysis of the risks to cable installation that serve to inform the risk mitigation strategy. An explanation of the SQRA process is presented separately at Annex D. A second table then displays the numeric scored assessment calculated based on the risk associated to each area after appropriate risk mitigation measures have been carried out.

7.1.1 Lot A – UK Nearshore

Activity: PLGR, RC, Pre-Trenching, Ploughing and Jet Trenching

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	$\boxed{6}$	8	10
1	1	2	3	4	5
	1	2	3	4	5

Consequence

Risk Score:
6

Risk Mitigation

Proactive Measures

- Side Scan Sonar
- Analysis of survey data to detect Geophysical Anomalies that model as UXO for Grading and Selection.
- Targets to be Avoided by not less than 15m or investigated.

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	$\boxed{3}$	4	5
	1	2	3	4	5

Consequence

Reduced Risk Score:
3

Activity: Rock Dumping

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Risk Score:

6

Risk Mitigation

Proactive Measures

- Side Scan Sonar
- Analysis of survey data to detect Geophysical Anomalies that model as UXO for Grading and Selection.
- Targets to be Avoided by not less than 15m or investigated.

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Reduced Risk Score:

3

Activity: HDD Entry and Exit Points, Barge Operations

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	$\boxed{10}$
1	1	2	3	4	5
	1	2	3	4	5

Consequence

Risk Score:

10

Risk Mitigation

Proactive Measures

- NI Survey/EOD banksman Support

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	$\boxed{5}$
	1	2	3	4	5

Consequence

Reduced Risk Score:

5

7.1.2 Lot B - North Sea

Activity: PLGR, RC, Pre-Trenching, Ploughing and Jet Trenching

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	**15**
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Risk Score:

15

Risk Mitigation

Proactive Measures

- Geophysical UXO Survey
- Analysis of survey data to detect Geophysical Anomalies that model as UXO for Grading and Selection.
- Targets to be Avoided by not less than 15m or investigated.

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	**5**
	1	2	3	4	5
	Consequence				

Reduced Risk Score:

5

Activity: Rock Dumping

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Risk Score:

8

Risk Mitigation

Proactive Measures

- Geophysical UXO Survey
- Analysis of survey data to detect Geophysical Anomalies that model as UXO for Grading and Selection.
- Targets to be Avoided by not less than 15m or investigated.

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Reduced Risk Score:

4

7.1.3 Lot C - Norway Fjord

Activity: PLGR, RC, Pre-Trenching, Ploughing and Jet Trenching

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	$\boxed{15}$
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Risk Score:

15

Risk Mitigation

Proactive Measures

- Geophysical UXO Survey
- Analysis of survey data to detect Geophysical Anomalies that model as UXO for Grading and Selection.
- Targets to be Avoided by not less than 15m or investigated.

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	$\boxed{5}$
	1	2	3	4	5
	Consequence				

Reduced Risk Score:

5

Activity: Rock Dumping

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	$\boxed{8}$	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Risk Score:

8

Risk Mitigation

Proactive Measures

- Geophysical UXO Survey
- Analysis of survey data to detect Geophysical Anomalies that model as UXO for Grading and Selection.
- Targets to be Avoided by not less than 15m or investigated.

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	$\boxed{4}$	5
	1	2	3	4	5
	Consequence				

Reduced Risk Score:

4

Activity: Trenching and Diving Operations

Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Risk Score:

10

Risk Mitigation

Proactive Measures

- NI Survey/EOD banksman Support

Reactive Measures

- Emergency Management Procedures (EMPs)
- Tool Box Briefs (TBBs).

Reduced Risk

Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

Reduced Risk Score:

5

7.2 Key Findings – Generally

Generally, there is varying probability of encountering UXO due to the different threat sources which may affect the Study Site. The main UXO threat items identified for the *NorthConnect* route are principally from:

- *IB and HE bombs;*
- *Sea mines (ferrous metal variants);*
- *Torpedoes;*
- *Ship wreck related munitions;*
- *Depth charges and Mortars;*
- *Artillery projectiles;*
- *Dumped munitions (Conventional HE types).*

With a background threat posed by:

- *Sea mines (non-ferrous variants);*
- *Anti-Invasion Devices;*
- *Land mines.*

The Risk levels takes into account the probability of encounter and of initiation as well as the consequences of initiation. Some threat items are considered to have a low probability of encounter on the Site, but are considered to have high consequences associated with their initiation. Conversely, some threats have high a probability of encounter but have low consequences associated with their initiation. For risks posed to human health and life, rather than those posed to cable installation equipment, the probability of encounter and initiation remain the same, however the consequences of initiation differ significantly.

For the purposes of UXO risk assessment, it is helpful to define the terms high and low NEQ. Whilst the terms are necessarily subjective, they will be defined in terms of the quantity (specifically NEQ), of high explosives that they contain and critically, the type of damage, destruction or injuries that might be sustained in the circumstances associated with their unexpected discovery and a concurrent detonation event. The critical threshold is therefore, that NEQ contained within UXO, when detonated, might cause the following categories of events:

- **Low NEQ**; typically up to 10kg of NEQ within a, projectile, anti-aircraft artillery shell or land service ammunition equivalent e.g. mortar, grenade. Underwater detonation effects are likely to damage cable installation equipment (requiring a repair, either on board or on-shore) if UXO is in close proximity. In such circumstances however, the safety and security of the cable installation vessel (or support vessels in close proximity) is not expected to be jeopardised nor are crew expected to be injured, seriously or otherwise, unless the water depth is shallow eg less than 20m;

- **High NEQ**; typically (and with reference to the detonation of low NEQ) more than 10kg of NEQ within a bomb or sea mine (usually the minimum threshold might include a 50kg bomb) – which might contain 25kg of high explosives – whilst a large bomb or sea mine might contain >200kg - >500kg of high explosives. In general, those items with a ferrous magnetic mass of ≥ 25kg are considered to have a “high NEQ” for the purposes of this analysis. Underwater detonations effects are likely to be an order of magnitude greater than those effects associated with low NEQ events. In addition to those (low NEQ) effects described, they are not only likely to destroy cable installation equipment (potentially beyond repair), but a high NEQ event is also likely to jeopardise the safety and security of the cable installation vessel (in that it is likely to sustain sufficient damage to render it inoperable and/or sink it). And support vessels in sufficiently close proximity (which may be as far away as 100m and more) could be damaged/incapacitated. Clearly in such circumstances the vessels crews’ might be seriously and/or fatally injured. However, where there are large NEQ items in water depths exceeding 100m the surface vessel effects are for practical purposes, likely to be negligible.

The highest risk levels are therefore, associated with initiation scenarios of sea mines, HE bombs and torpedoes. These threat items have the highest probability of encounter on Site and have a high NEQ resulting in higher consequences of initiation than for example, artillery projectiles, which have a comparatively low NEQ.

7.2.1 Key Findings – Lot A – UK Nearshore

While not included in the semi-quantitative assessment, artillery projectiles and dumped munitions are considered to present a relatively low risk to all operations within LOT A, because there is a low probability of encountering them during all operations and because they are generally low NEQ items; therefore, the consequences of initiation are generally reduced. Although the water depth in LOT A is significantly shallower than B and C it is still considered likely to ameliorate most of the effects of initiation of such low NEQ items both to the vessel, or to the vessel itself and its crew (subject to there being more than 20m of water) although any initiation may cause damage to cable installation equipment. However, if UXO are recovered to deck via launch and recovery procedures and they are in an unstable state, they may pose a severe threat and a risk to personnel in close proximity if they are initiated. Nonetheless, the highest risk levels are associated with initiation scenarios of IBs and HE bombs using intrusive methods of cable installation, because those threat items have a high NEQ resulting in higher consequences of initiation.

Geophysical UXO Survey operations are considered to pose a low risk as the equipment utilised will not make intentional contact with the seabed nor with any potential UXO. However, PLGR, RC, pre-trenching, ploughing and jet trenching carry a high level of risk, due to the enhanced probability of initiating UXO during such activities and the proximity of sensitive receptors, such as personnel and cable installation equipment, at the point of operations, which might result in severe injuries or fatalities and significant consequences to equipment/vessels if an initiation was to occur. HDD, laying, barge operations and rock dumping carry a medium risk due to the less aggressive nature of the activities and the reduced probability of initiation. there is an extremely low probability of encountering UXO between the two entry and exit points involved with HDD as the drilling will be undertaken at a significant depth within the bedrock below the expected level of penetrated UXO.

Appendix 12 and 13 show that there is a low probability of encountering UXO in Lot A with a low risk to the vessel and to human life, as well as a low risk to cable installation equipment.

7.2.2 Key Findings – LOT B – North Sea

LOT B of the Site has been subjected to WWI and WWII *British and German* mine lays and it is possible that motor torpedo boat raids took place against convoys and other targets of opportunity in the vicinity.

The highest risk levels are associated with the initiation scenarios of a WWI and WWII sea mine or torpedoes, during intrusive cable installation operations. Those threat items have a high NEQ resulting in significant consequences if they are initiated close to cable installation equipment, however the water depth ameliorates the risk to human life and to vessels. The probability of encountering and initiating artillery projectiles is ranked a low probability, and their relatively low NEQ, reduces their risk to ALARP for most operations (thus their specific detection by geophysical UXO survey is not strictly necessary).

Geophysical UXO survey operations are considered to pose a low risk as the equipment utilised will not make intentional contact with the seabed and any potential UXO. However, rock dumping carries a medium level of risk, due to the enhanced probability of encounter as well as an enhanced probability of initiating UXO during such activities. Though, the substantial water depths that have been recorded within LOT B are likely to ameliorate the risk to human life and to vessels therefore reducing the risk slightly. In addition, the proximity of sensitive receptors, such as cable installation equipment, at the point of operations, might result in significant consequences to equipment if an initiation was to occur and therefore, PLGR, RG, pre-trenching, ploughing and jet trenching are considered a high risk due to their aggressive nature and the substantial cost of the equipment.

Appendix 12 and 13 identify that there is a range of low to high probability of UXO encounter along this section of the cable route. The risk to human life and the vessel varies depending on the depth of the water and the potential threat items and therefore, also ranges from low to high risk. The risk to the installation equipment remains high across all areas of this section due to its close proximity to an initiation event.

7.2.3 Key Findings – LOT C – Norway Fjord

LOT C of the Site was the subject of *British* WWII and *American* mine lays. In addition, it is possible that aerial bombing and motor torpedo boat raids against convoys and other targets of opportunity took place in the local vicinity. The Site also passes through a modern military training range.

The highest levels of risk are associated with the initiation scenarios of a WWII sea mine, HE bombs and torpedoes during intrusive cable installation operations. Those threat items have a high NEQ resulting in higher consequences of initiation to cable installation equipment however, the risk to human life and to vessels is significantly ameliorated by the water depth. The probability of encountering and initiating artillery projectiles is ranked a low probability, and their relatively low NEQ, reduces their risk to ALARP for most operations (thus their specific detection by geophysical UXO survey is not strictly necessary).

Geophysical UXO survey operations are considered to pose a low risk as the equipment utilised will not make intentional contact with the seabed and any potential UXO. However, rock dumping and trenching carry a medium level of risk, due to the enhanced probability of encounter as well as an enhanced probability of initiating UXO during such activities. Though, the substantial water depths that have been recorded within LOT B are likely to ameliorate the risk to human life and to vessels therefore reducing the risk slightly. In addition, the proximity of sensitive receptors, such as cable installation equipment, at the point of operations, might result in significant consequences to equipment if an initiation was to occur and therefore, PLGR, RC, pre-trenching, ploughing and jet trenching are considered a high risk due to their aggressive nature and the substantial cost of the equipment.

Appendix 12 and 13 identify that there is a range of low to high probability of UXO encounter along this section of the cable route. The risk to human life and the vessel varies depending on the depth of the water and the potential threat items and therefore, also ranges from low to high risk. The risk to the installation equipment remains high across all areas of this section due to its close proximity to an initiation event.

8 Recommendations

8.1 UXO Risk Mitgation Strategy

UXO undoubtedly poses a risk to the *NorthConnect Cable Route*, and is supported by the fact that there have been many encounters with UXO throughout the *North Sea*. Indeed, the same cable installation methodologies outlined in this report have been successfully and safely employed in similar UXO contaminated environments. Therefore, the presence of UXO should not present a barrier to cable installation operations, especially when a suite of proven risk mitigation measures has already preceded it.

In view of the general UXO risk in this region and considering the proposed scope of cable installation work, *6 Alpha* has designed the following mitigation strategy to reduce the risks to a level that conforms with the ALARP principle, upon which best practice risk mitigation measures are founded.

6 Alpha's view is that the avoidance of anomalies associated with high risk UXO, is the key to successful UXO risk management in this environment. The size of the avoidance radii is to be determined not only by the type of UXO likely to be encountered at the site but also the accuracy and reliability of the survey data. For this project a geophysical UXO survey is to be designed to detect threat spectrum UXO, which should be avoided by not less than 15m during all cable installation and vessel support operations, together with procedures (SOPs) endorsed by *6 Alpha*. By adhering to such robust procedures and operational guidelines, the prospective risks to the on-going operations can be significantly ameliorated and reduced to ALARP.

However, the risk from UXO can never be considered "zero" in the offshore environment, because there is always the potential for UXO to be buried either beyond the capacity of a geophysical survey to detect it and/or low NEQ items might be otherwise encountered. Additionally, *6 Alpha* have assumed that the time between any proactive risk mitigation works (namely geophysical UXO survey) and the proposed installation works will be minimised (to not exceed 12 months between events). If the 12-month guideline is to be breached, then a Munitions Migration Assessment (MMA) ought to be employed to extend the longevity of the ALARP safety sign-off certification.

8.2 Risk Management Factors

Considering the cable installation methods, the probability of UXO encounter is categorised as medium/high on the Site due to the prospective presence of high NEQ UXO (HE bombs, sea mines and torpedoes). Cable installation methods that are both intrusive and aggressive (e.g. PLGR, RC, pre-trenching, ploughing and jet trenching) present a potential level of risk that ought to be ameliorated.

However, empirical evidence generally suggests that UXO is not likely to be uniformly distributed neither throughout the site nor throughout the depth of seabed. Most items of UXO, regardless of their mass and shape are likely to remain upon the surface of the seabed (unless buried beneath mobile sediments) especially where there is deep water. Large items of UXO (which have a high NEQ and therefore are potentially more dangerous), are unlikely to bury themselves (as a result of scour action) to not more than 50% of their diameter. Iron bombs and large shells (more than, say, 155mm calibre) are likely to be subject to similar burial constraints. And even if such items are totally buried (subject to seabed mobility and prospective sand wave action); it is unlikely they will be buried deep (beyond 2m). Therefore, such items are highly likely to be detected by appropriately designed and specified geophysical UXO survey in the form of high resolution SSS and/or magnetometry.

It is possible that smaller items (such as artillery projectiles or LSA), which have a smaller NEQ (and therefore, *de facto* pose a reduced risk as compared with higher NEQ items), might be buried deeper or even beyond magnetometer detection range (typically this is approximately 2m below seabed). However, any prospective high explosive event involving smaller items of UXO cannot be considered as significant, and the risk (whilst certainly not zero), may be considered reduced to ALARP and it is therefore not necessary to identify such items below the reasonable detection depth associated with UXO magnetometry.

8.3 Summary of Recommended Risk Mitigation Methods

8.3.1 PLGR, RC, Laying Pre-Trecnhing, Ploughing, Jet Trenching and Rock Dumping – Proactive Measures

- **Geophysical UXO Survey**; Various locations along the Search Area will have been surveyed previously ahead of geotechnical investigations, therefore these areas will not need to be surveyed again however, all other areas within the bounds of the cable installation corridor, together with their associated working space (the size of that area is to be appropriately defined by the client and approved by the cable installation contractor, and it is also to be subject to the size of the installation vessel), will be surveyed in order to detect threat spectrum UXO, employing conventional magnetometry to identify ferrous UXO above and below the seabed, and high-resolution side scan sonar (SSS) operating at a sufficiently high frequency to identify UXO that might be located upon the seabed’s surface, so that they might be identified and avoided;

- **Survey Verification;** the geophysical UXO survey is to be verified employing threat spectrum UXO surrogates, with known magnetic responses;
- **Geophysical Survey Data - Anomaly Grading and Selection;** the project's nominated UXO consultant might further refine and grade geophysical UXO survey anomalies, in order to identify those which model as prospective UXO and in doing so, reduce the number of "false UXO" anomalies.
- **Avoidance;** those anomalies that model as prospective UXO, are to be avoided wherever possible, by not less than 15m (radius);
- **Investigation;** if potential UXO anomalies cannot be avoided (by the specified safety avoidance radius) then they are to be investigated, perhaps by ROV, to verify if they are, or are not, UXO. Items of confirmed UXO will usually need to be disposed of. Additionally, in order to prevent unnecessary Render Safe Procedures (RSP) on benign or what might be "obvious" training items – which is a common conflict of interest – independent EOD Client Representatives ought to be on board, during installation activities.

Appendix 12 and 13 identify areas of low, medium and high risk to human life, the vessel and to GI equipment as well as low, medium and high probability of UXO encounter. In areas where the probability of UXO encounter is considered low, a reduced survey approach such as side scan sonar only may be required to detect any unforeseeable items that might be located upon the seabed's surface. In all areas where the probability of UXO encounter is considered medium and high, conventional magnetometry and side scan sonar is required in all areas where GI operations are to be undertaken.

8.3.2 Horizontal Direction Drilling – Proactive Measures

- **EOD Banksman Support;** EOD Engineer should trial a non-intrusive survey across the Site and, if successful, it shall be employed to clear the Site of any potential UXB/UXO in advance of intrusive ground works. However, if the non-intrusive survey proves ineffective then the EOD Engineer should supervise all intrusive excavations for UXO and to identify any suspicious items as the work proceeds in the EOD Banksman role.

8.3.3 All Operations – Reactive Measures

The following procedures are to be written and briefs delivered:

- **Emergency Management Procedures (EMPs);** are to be written for all Vessel Masters, and Deck Foremen involved with all cable installation operations;

- **Tool Box Briefs (TBBs);** are to be delivered for all vessel crews' involved with all cable installation operations. TBB can be delivered either in person by an EOD Engineer or remotely via a pre-recorded streamed link over the internet. The latter form of service provision is generally more consistent, convenient and provides both flexibility and better value for money.

8.3.4 ALARP Sign-off Certification

Once the UXO risk mitigation measures have been successfully implemented, the risks will have been reduced to ALARP and all cable installation operations can take place safely, within the surveyed area, without the requirement for further UXO risk mitigation activities. However, in the event that significant (e.g. large NEQ) and/or dangerous UXO are discovered, the risk and risk mitigation measures are to be professionally reviewed.

6 Alpha's sign-off certificates are generally valid for not less than one year from their issue date; other consultants might have different criteria. Our minimum safety avoidance radii are currently set at 15m for all cable installation operations. Extraordinarily, if 15m is too great an avoidance distance then it might be reduced, but engineering and EOD calculations would have to be modified and professionally endorsed through the provision of a formal Technical Note(s).

8.3.5 UXO Project Management and Quality Assurance/Quality Control

Given the scope of the overall strategy and the need to undertake real-time decisions during various phases of the project, *6 Alpha* recommend that specialist UXO Project Management staff are either permanently engaged and/or on-call to assist and to oversee key elements of the UXO risk mitigation work.

8.4 Next Steps for the NorthConnect Cable Route

This assessment has identified that the main UXO threat items associated with the *NorthConnect* cable installation operations are primarily: HE bombs and IBs, ferrous metal sea mines, torpedoes, shipwreck related munitions, depth charges and mortars, artillery projectiles, and conventional dumped munitions together with a background threat posed by, non-ferrous metal sea mines, anti-invasion devices and land mines.

An appropriately specified geophysical UXO survey is now required in order to provide raw data capable of being professionally and appropriately processed in order to identify threat spectrum UXO (including non-ferrous varieties) in advance of all cable installation operations. Critically, such data processing will help to discriminate UXO from scrap and other benign seabed detritus, and in doing so, it will not only reduce the number of targets for avoidance/investigation but also save resources and time. A Survey Verification Test (SVT) is also required in order to prove-out the survey equipment employing surrogate UXOs (with known dimensions and magnetic responses).

Once all anomalies that model as prospective UXO have been identified (and they have been avoided or verified/rendered safe), the nominated UXO consultant will be in a position deliver ALARP sign-off certificates to support the cable installation campaign.

Appendices

Appendix 1

Site Location

LEGEND

GENERAL

Preferred Route

Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Site Location

DRAWING NUMBER

P5530/TARA/001

PURPOSE

FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
GCS WGS 1984	1:10,000,000	A4	DR	01-NOV-16	RR

W W W . 6 A L P H A . C O M
E: enquiry@6alpha.com | T: +44 (0)203 371 3900

6 alpha ASSOCIATES

Appendix 2

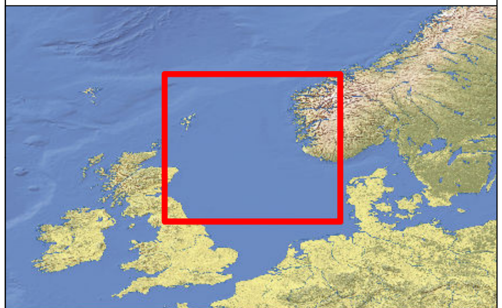
Preferred Route for NorthConnect

LEGEND

GENERAL

Preferred Route

Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors



PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Preferred Route for NorthConnect

DRAWING NUMBER

P5530/TARA/002

PURPOSE

FOR INFORMATION USE ONLY

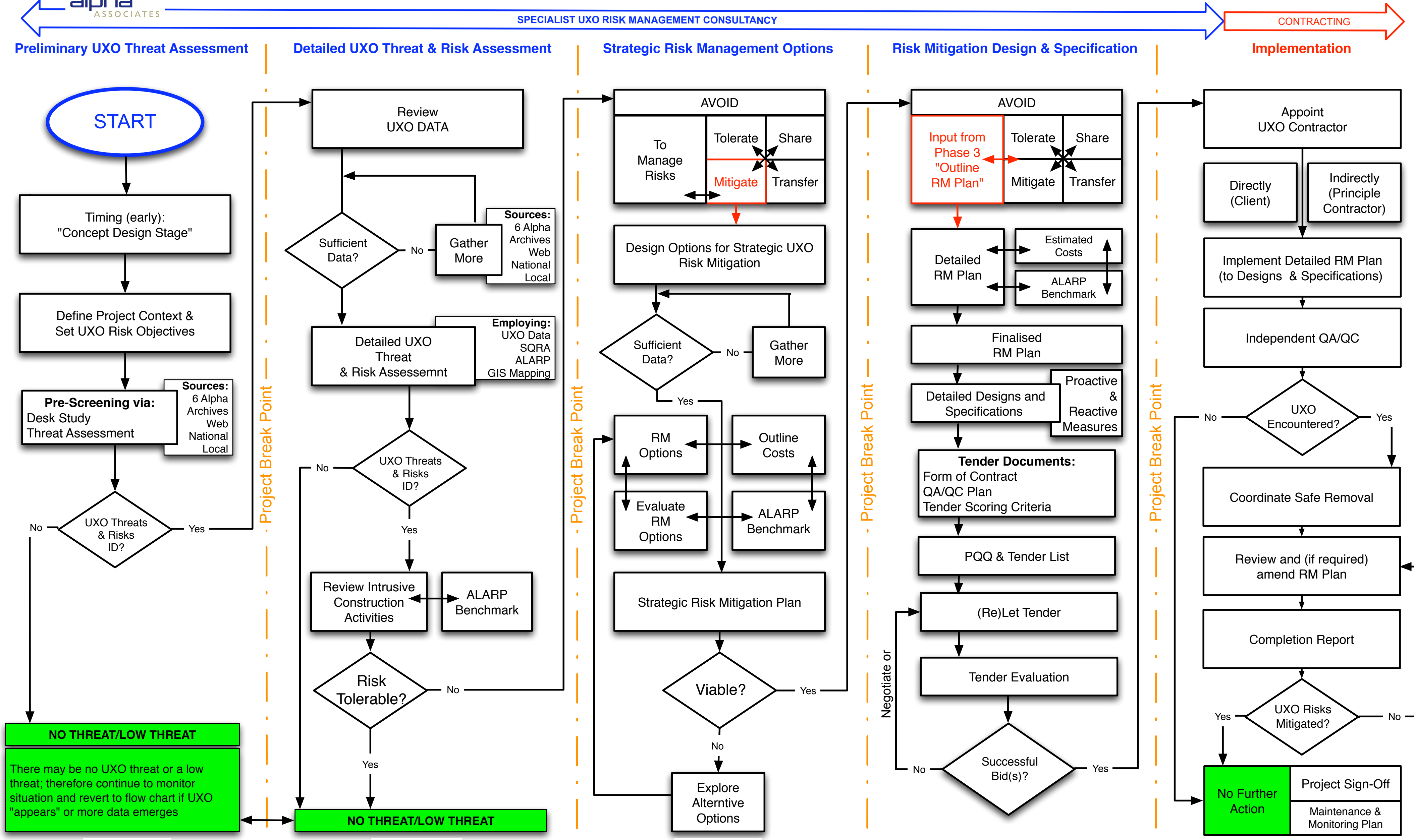
alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
GCS WGS 1984	1:5,500,000	A4	DR	04/11/2016	RR

W W W . 6 A L P H A . C O M
E: enquiry@6alpha.com | T: +44 (0)203 371 3900

Marine Risk Management Framework

MANAGING UNEXPLODED ORDNANCE (UXO) - A RISK MANAGEMENT FRAMEWORK FOR THE MARINE INDUSTRY



Expected Outputs

Preliminary UXO Threat Assessment
Expected Consultancy Outputs:
Concise Report
Supported by:
GIS Mapping &
Research Data
Conclusions
Recommendations - move to next step (or not)?

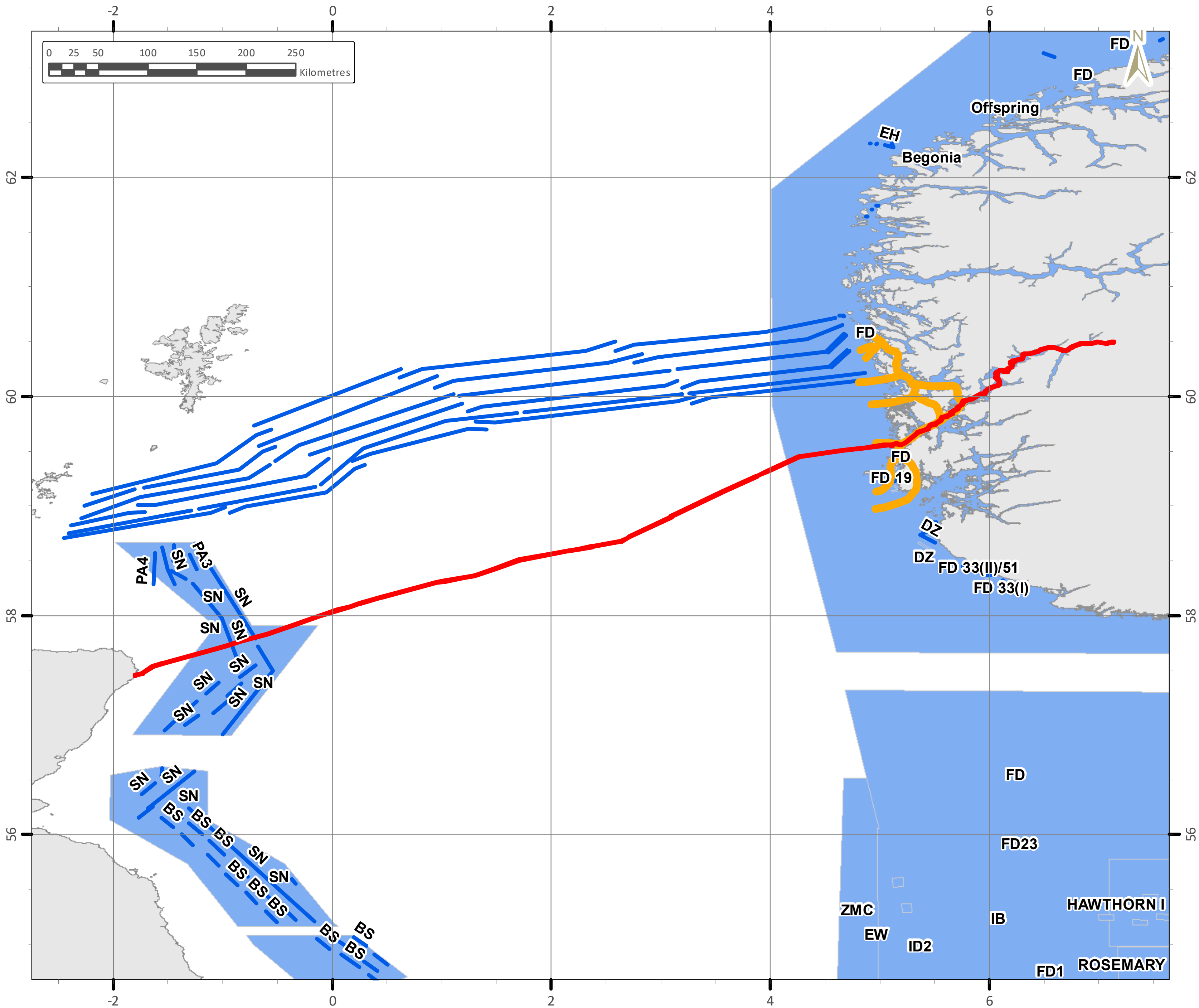
Detailed UXO Risk Assessment
Expected Consultancy Outputs:
UXO Threat Assessment employing:
Comprehensive UXO Data Sources
Semi-Quantitative Risk Assessment (SQRA) & ALARP
GIS Mapping
Independent/Robust/Transparent Assessment
Comprehensive & Informative Report

Strategic Risk Management Options
Expected Consultancy Outputs:
Strategic Risk Mitigation (RM) options
Criteria for selection of mix of options
Selection of best mix of options
Benchmark with Client's Tolerance of UXO Risk
Strategic Risk Mitigation Plan

Risk Mitigation Design & Specification
Expected Consultancy Outputs:
Detailed Risk Mitigation Design
Accompanying Risk Mitigation Specifications
Sufficient for Incorporation into Tender Documents

Implementation
Expected Consultancy & Contractor Outputs:
Safe Removal of UXO
Independent QA/QC on Contractor
Completion Reposts
Independent Consultancy Sign-off
Post Construction Maintenance/ Monitoring Plan

WWII British and American Mining Operations



LEGEND

GENERAL

Preferred Route

POTENTIAL UXO THREATS

American Minelays

British Minelays

British Minefields

Footnote: This shows the charted extent of British minefields NOT mine positions

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

WWII British and American Mining Operations

DRAWING NUMBER

P5530/TARA/004

PURPOSE

FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED		
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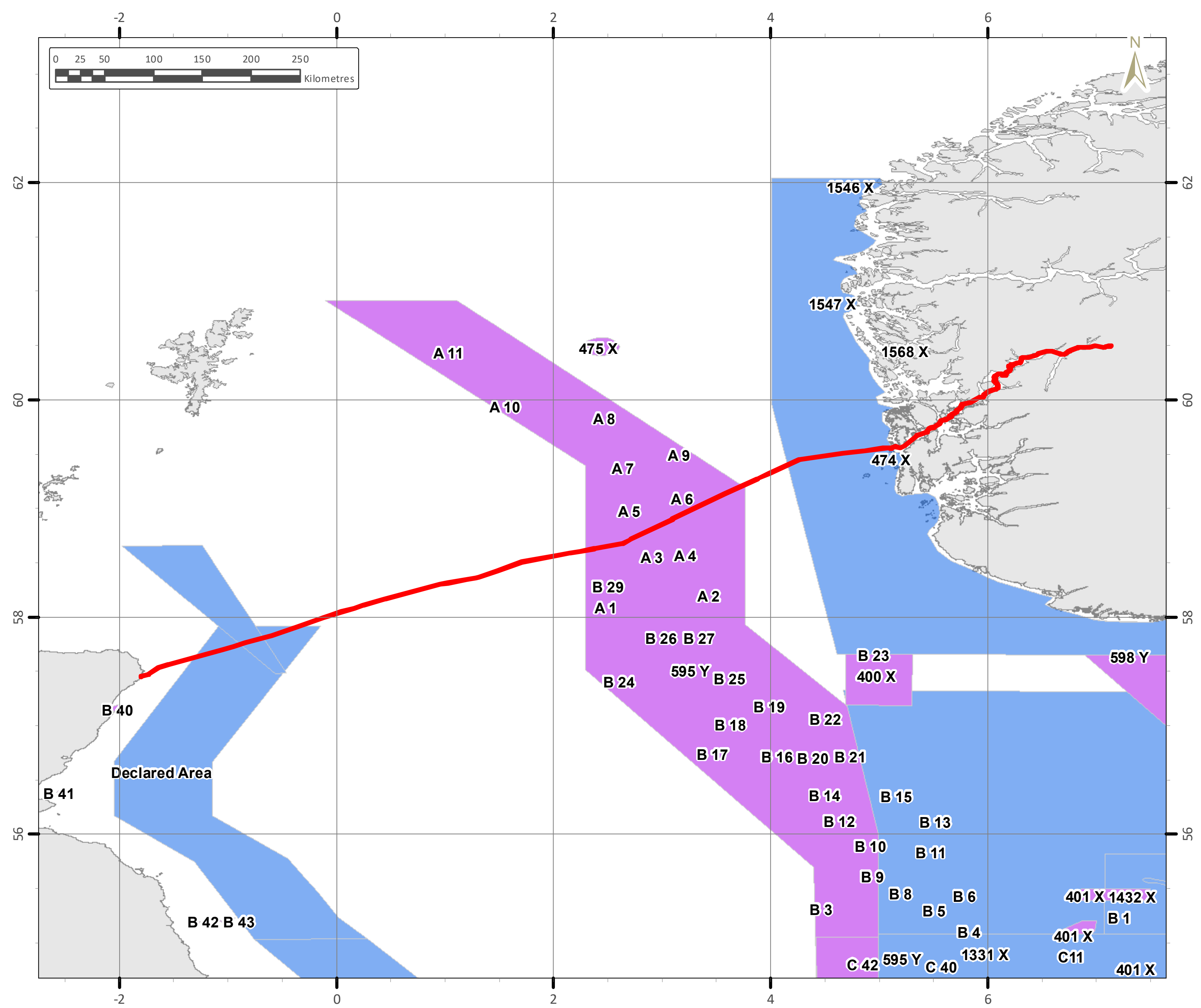
United Kingdom Hydrographic Office WWII Mining Charts



LEGEND

GENERAL

Preferred Route

POTENTIAL UXO THREATS

WWII UKHO Mining Charts

British

German

Footnote: This shows the charted extent of minefields NOT mine positions

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
United Kingdom Hydrographic Office WWII Mining Charts

DRAWING NUMBER
P5530/TARA/005

PURPOSE
FOR INFORMATION USE ONLY

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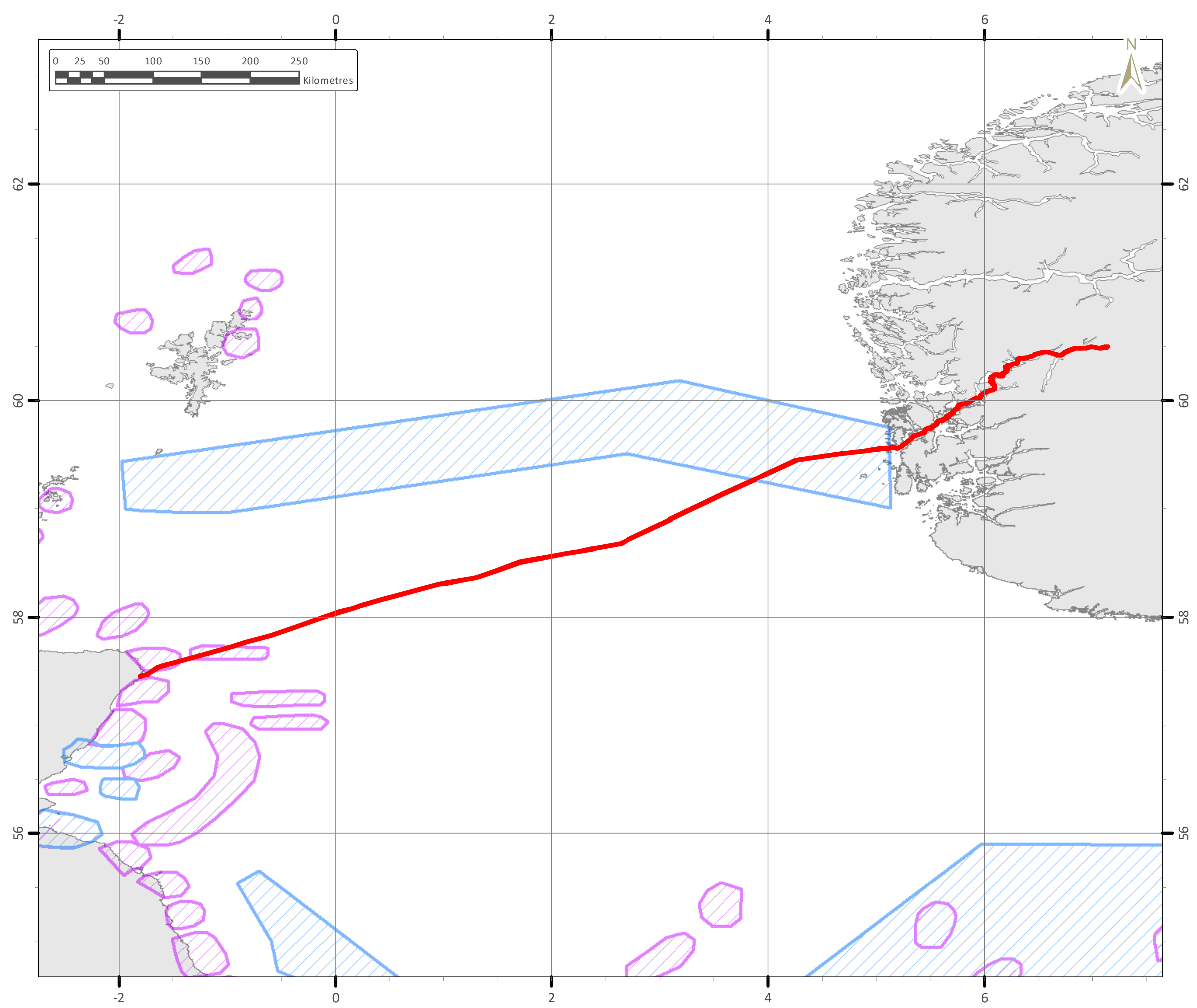
Appendix 6

WWI Mining Charts



LEGEND

GENERAL

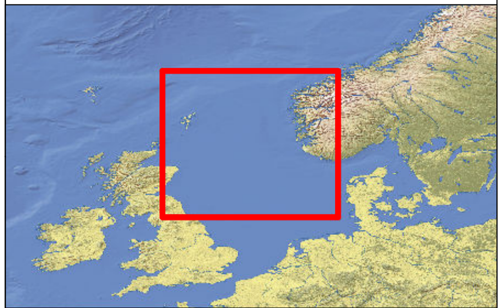
Preferred Route

POTENTIAL UXO THREATS

WWI Minefields

Allied

German



PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

WWI Mining Charts

DRAWING NUMBER

P5530/TARA/006

PURPOSE

FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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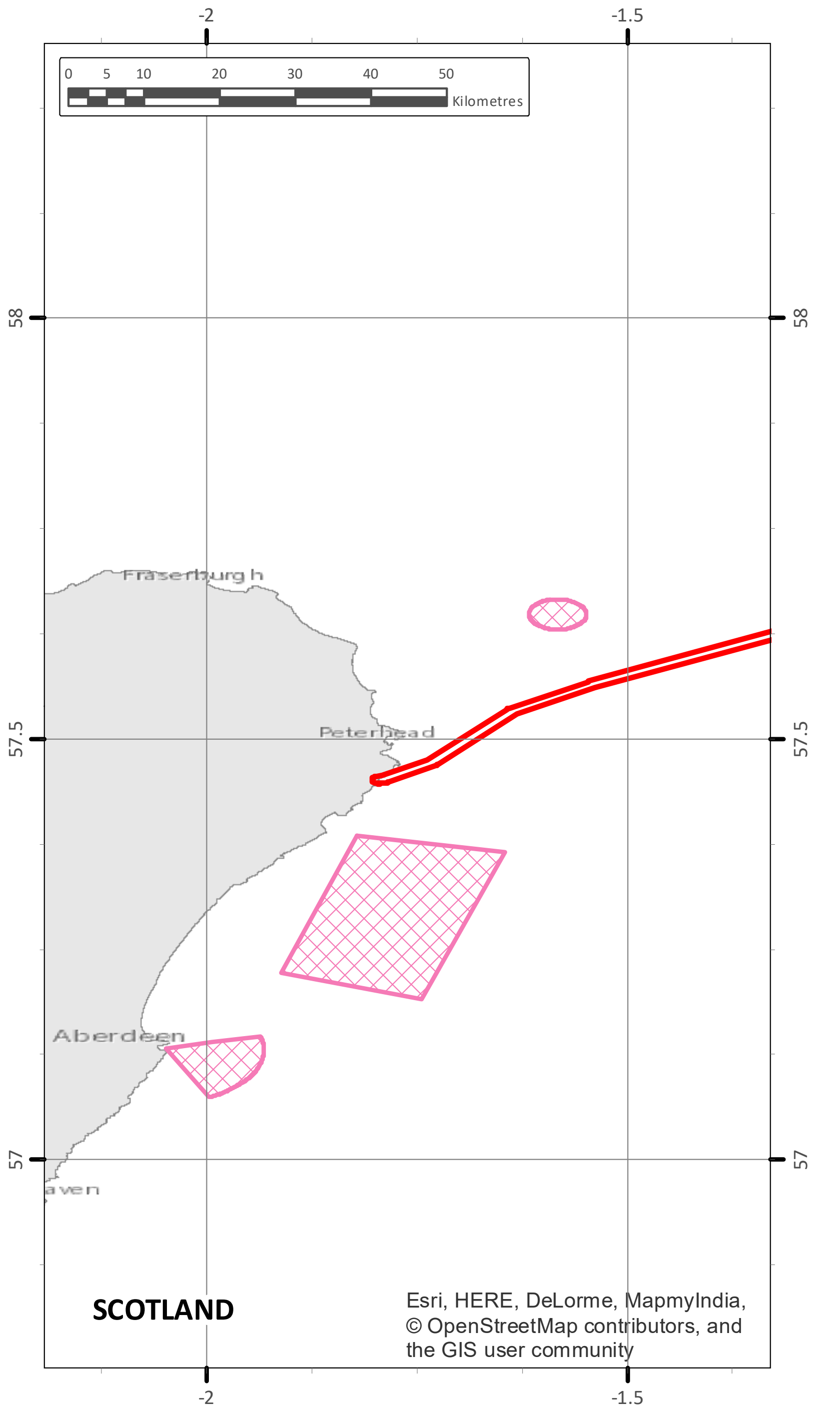
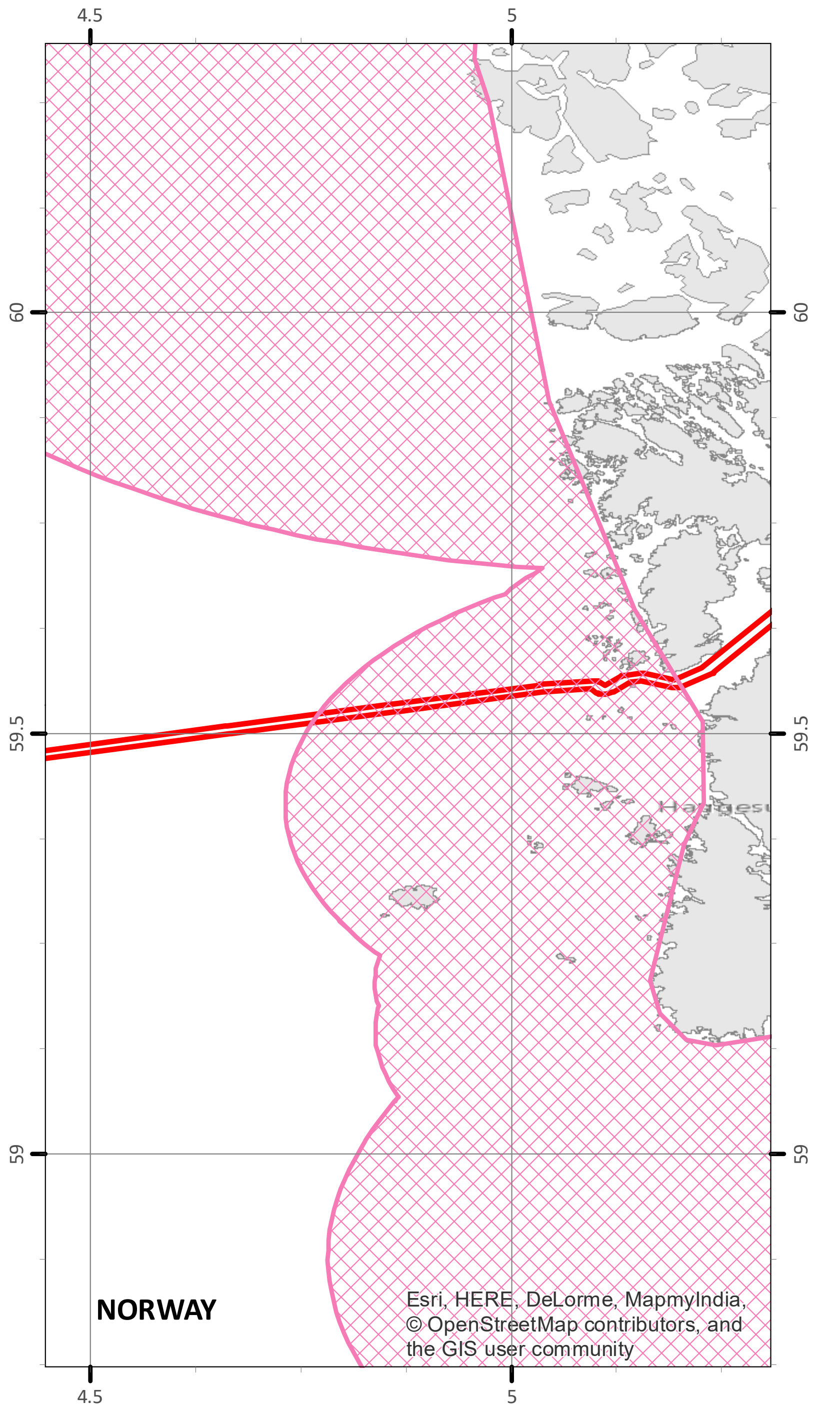
Appendix 7

WWII Armament Range and Training Areas





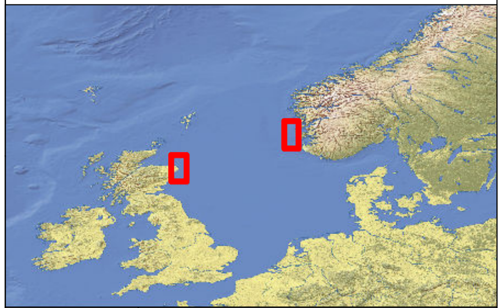
LEGEND

GENERAL

Preferred Route

POTENTIAL UXO THREATS

WWII Armament Range Areas



PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

WWII Armament Range and Training Areas

DRAWING NUMBER

P5530/TARA/007

PURPOSE

FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED		
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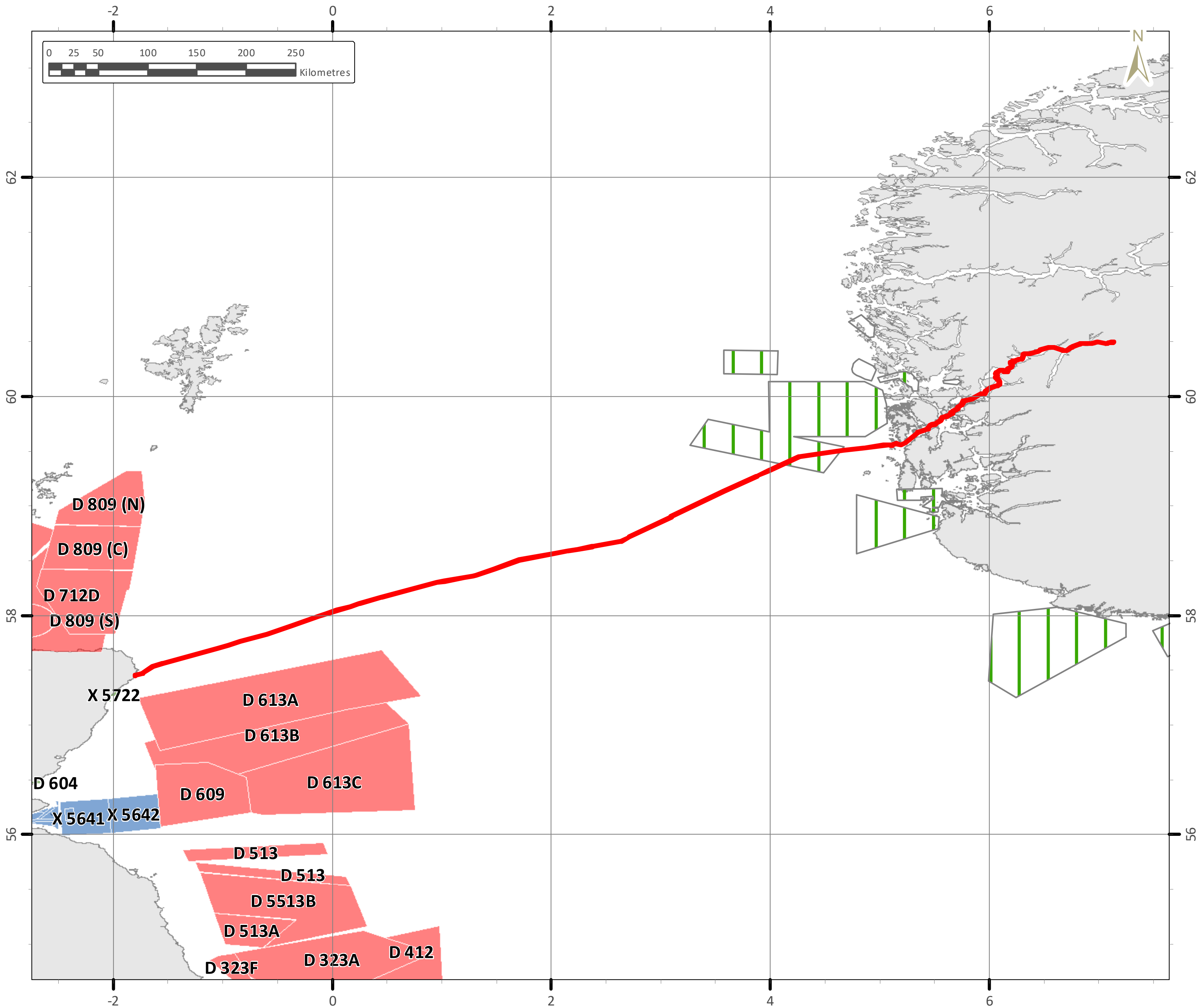
Appendix 8

Modern Military Practice and Exercise Areas



LEGEND
GENERAL
Preferred Route
POTENTIAL UXO THREATS
Norwegian Military Exercise Areas
British Military Exercise Areas
Air Force
Army
Navy
Unknown

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Modern Military Practice and Exercise Areas

DRAWING NUMBER
P5530/TARA/008

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
GCS WGS 1984	1:5,500,000	A4	DR	01-NOV-16	RR

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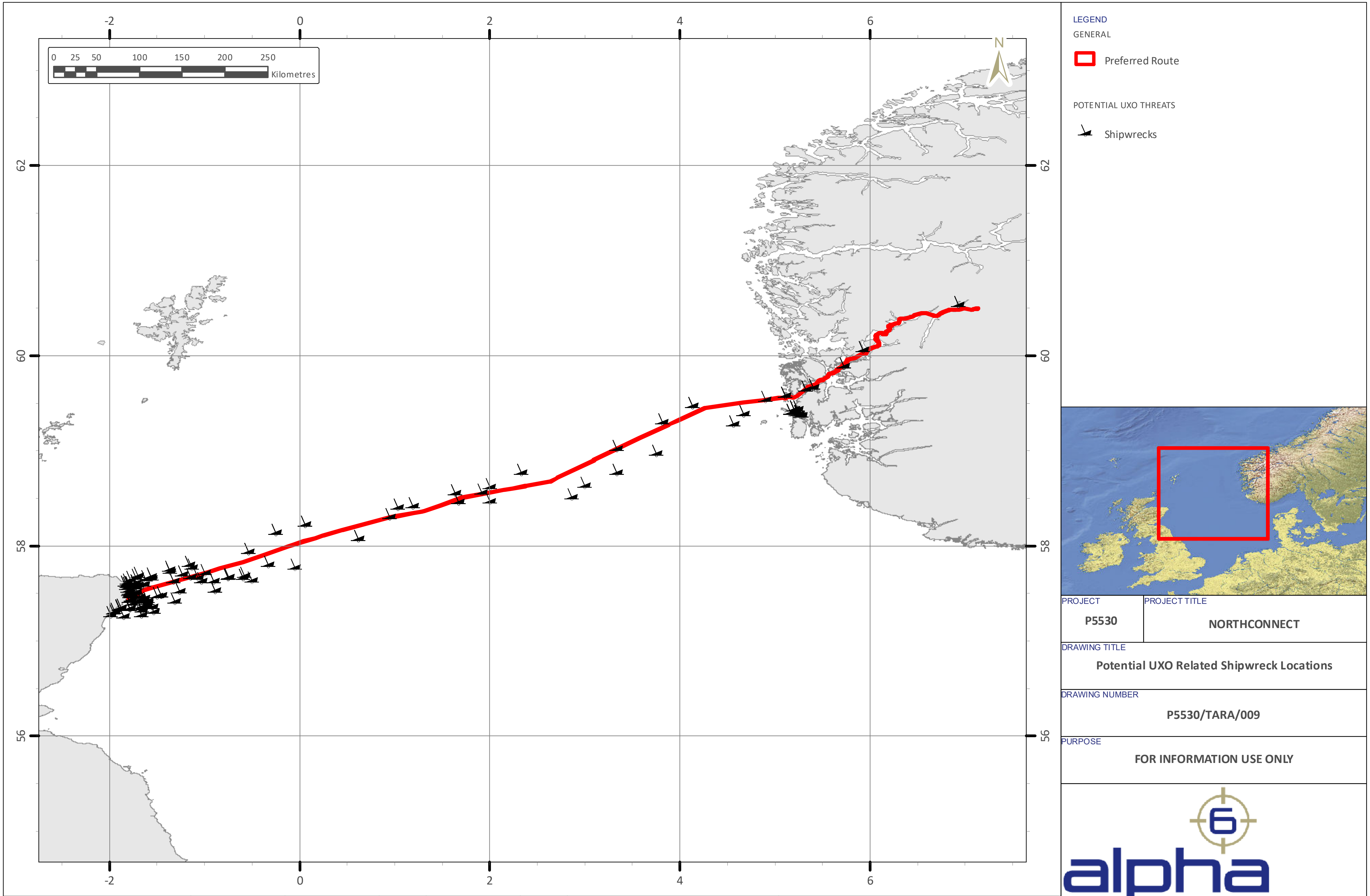
Appendix 9

Potential UXO Related Shipwreck Locations



PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Potential UXO Related Shipwreck Locations

DRAWING NUMBER
P5530/TARA/009

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
GCS WGS 1984	1:5,500,000	A4	DR	01-NOV-16	RR

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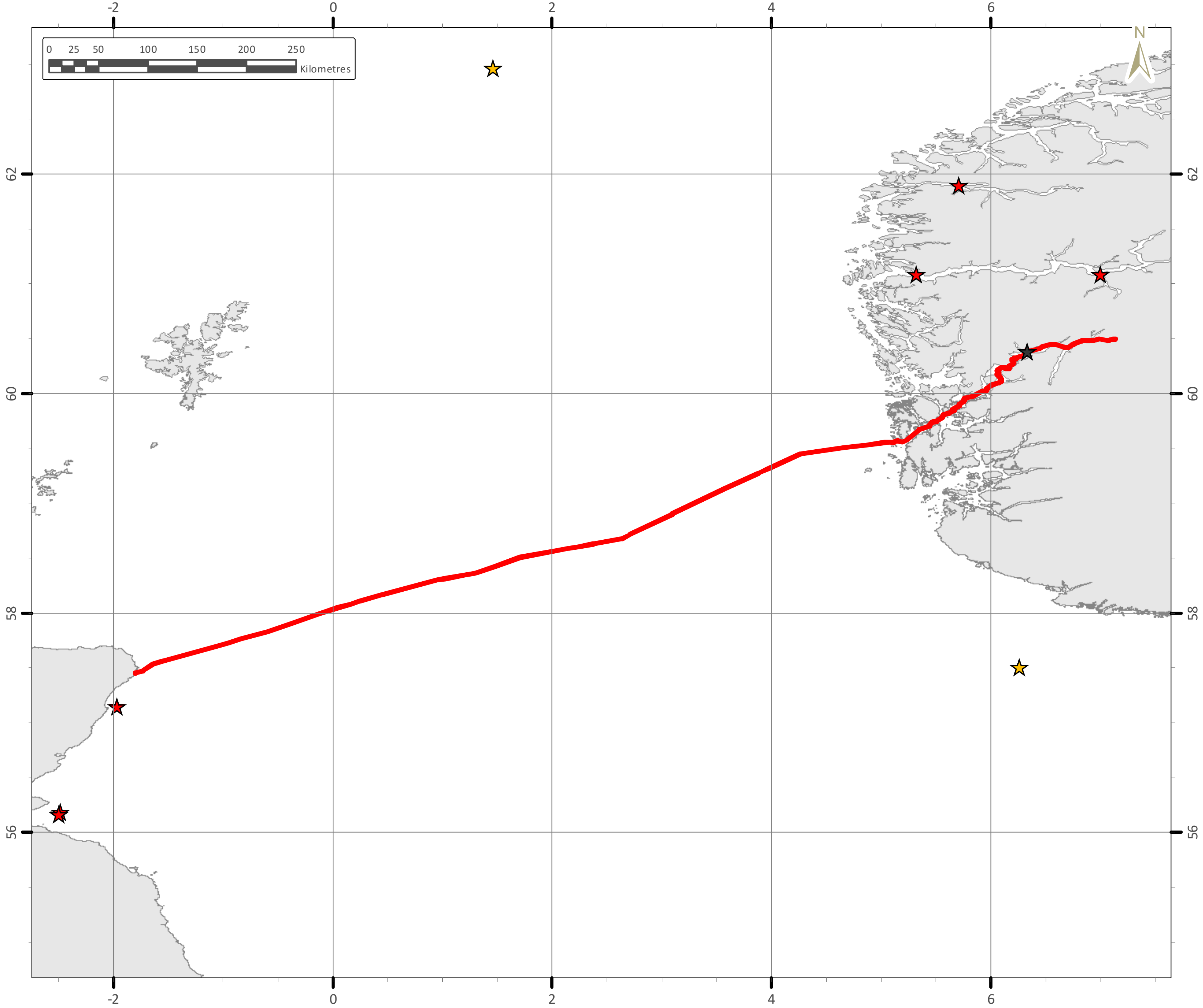
Appendix 10

Munitions Dumping Sites



LEGEND

GENERAL

Preferred Route

POTENTIAL UXO THREATS

Munitions Dumping

Chemical

Chemical & Conventional

Chemical - Mustard Gas

Chemical -Tabun

Conventional

Unknown

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Munitions Dumping Sites

DRAWING NUMBER

P5530/TARA/010

PURPOSE

FOR INFORMATION USE ONLY

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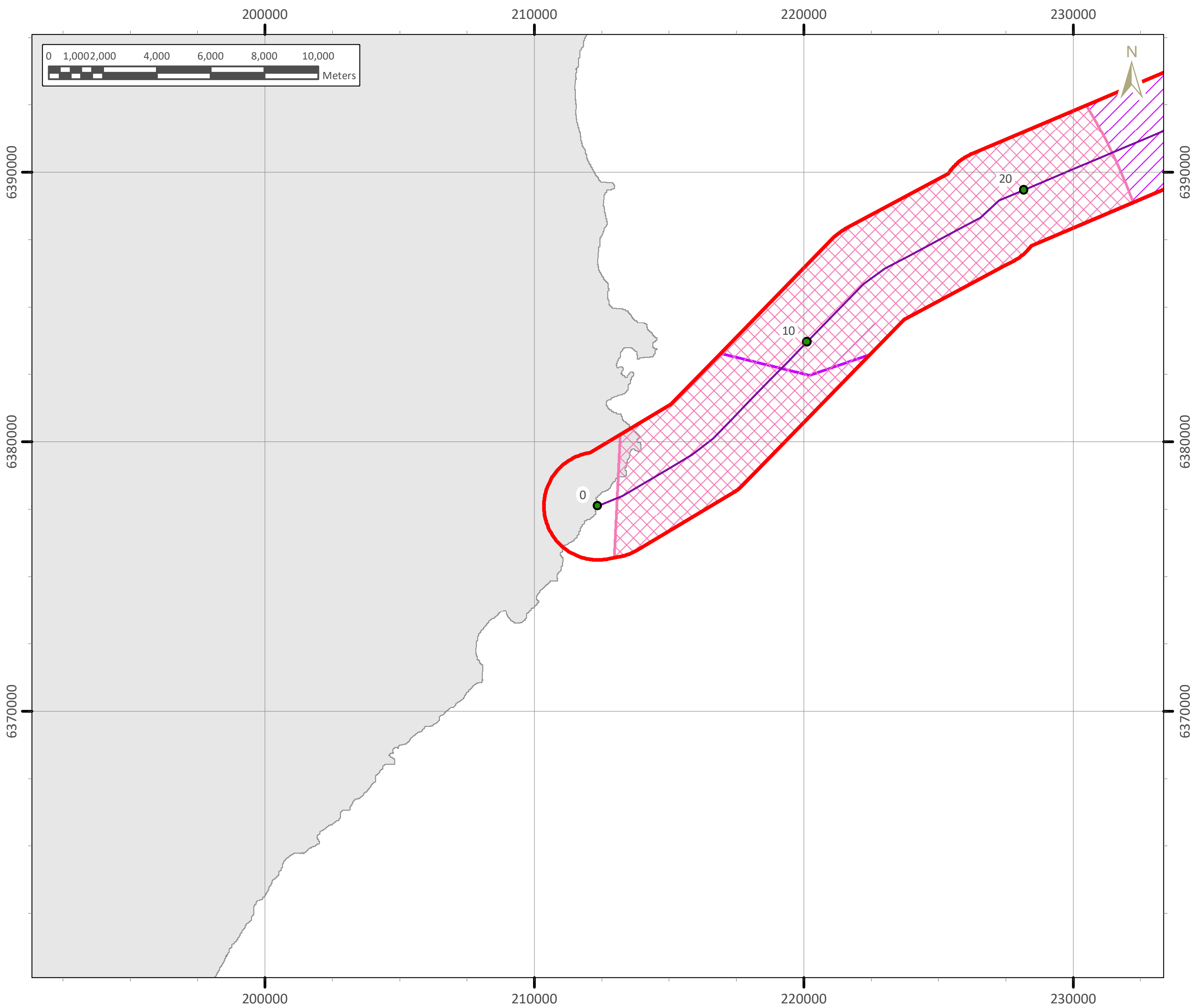
Appendix 11

Consolidated UXO Threats



LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- HAA Battery Range
- WWI Axis and Allied Minefields

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/1

PURPOSE
FOR INFORMATION USE ONLY

alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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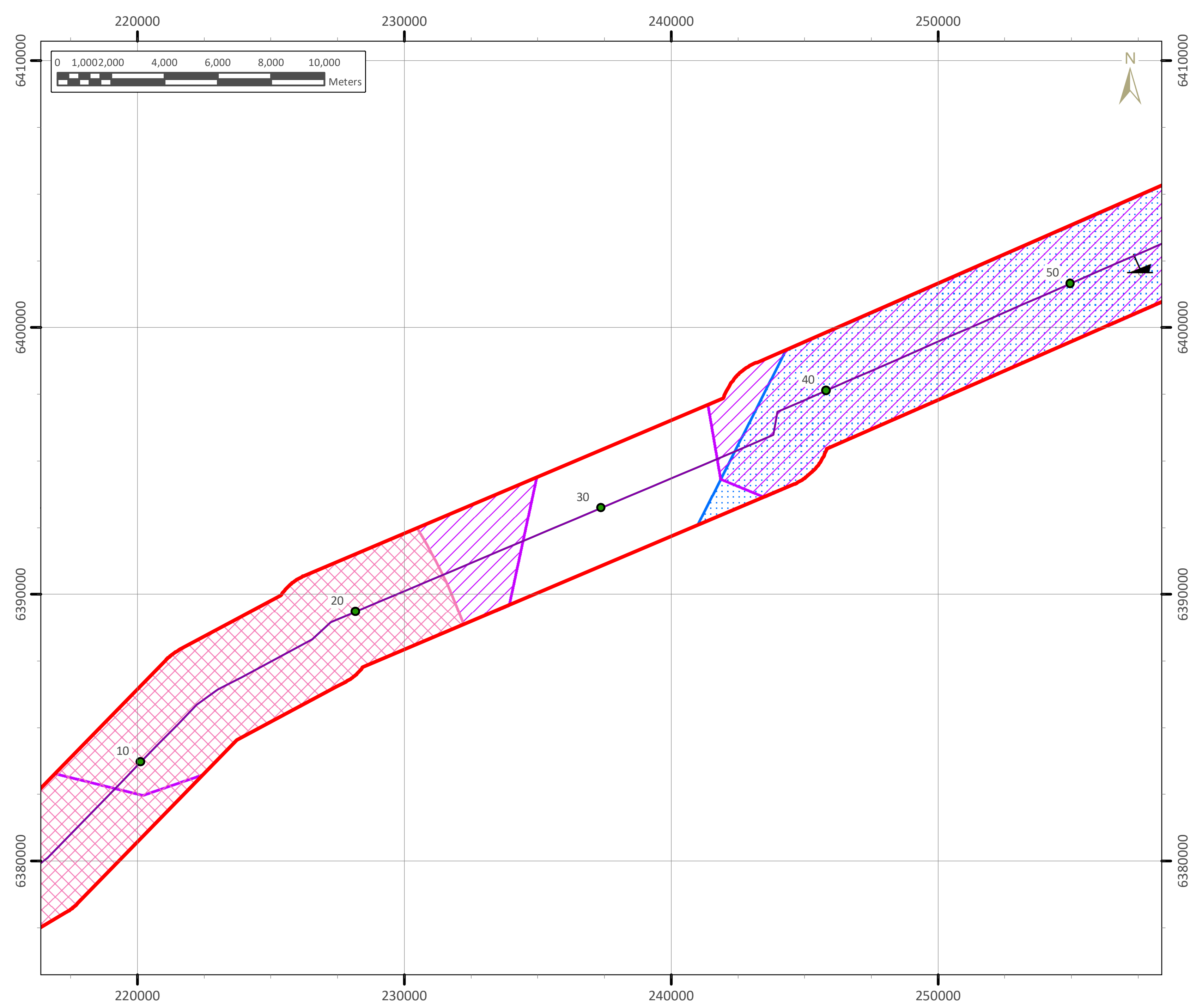

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks
- HAA Battery Range
- WWI Axis and Allied Minefields
- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Consolidated UXO Threats

DRAWING NUMBER

P5530/TARA/2

PURPOSE

FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

W W W . 6 A L P H A . C O M
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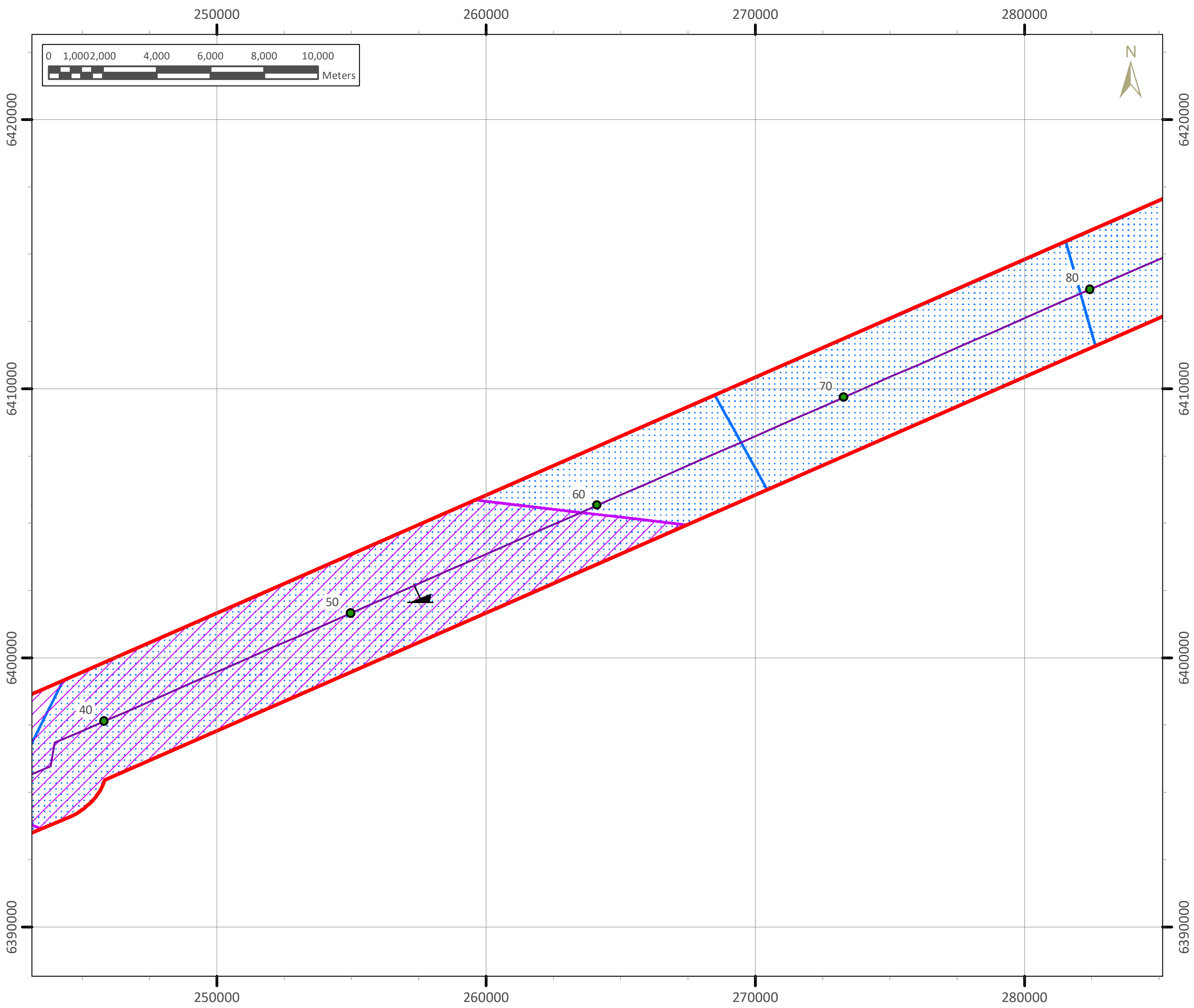

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks
- WWI Axis and Allied Minefields
- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/3

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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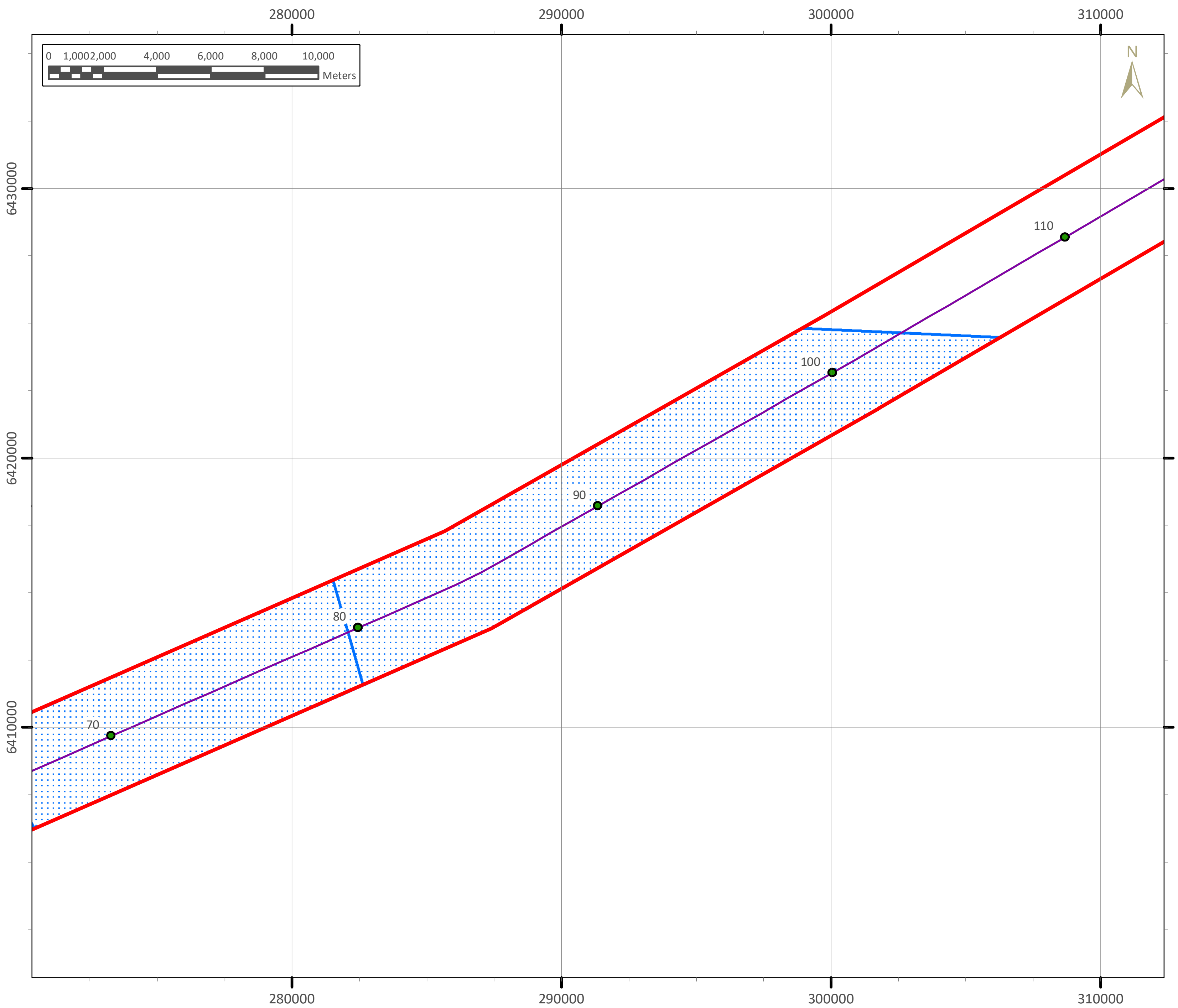


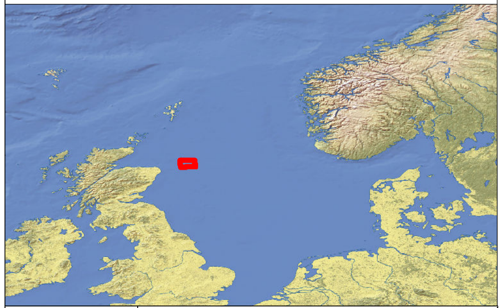
LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- WWII Minefields Historic



PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/4

PURPOSE
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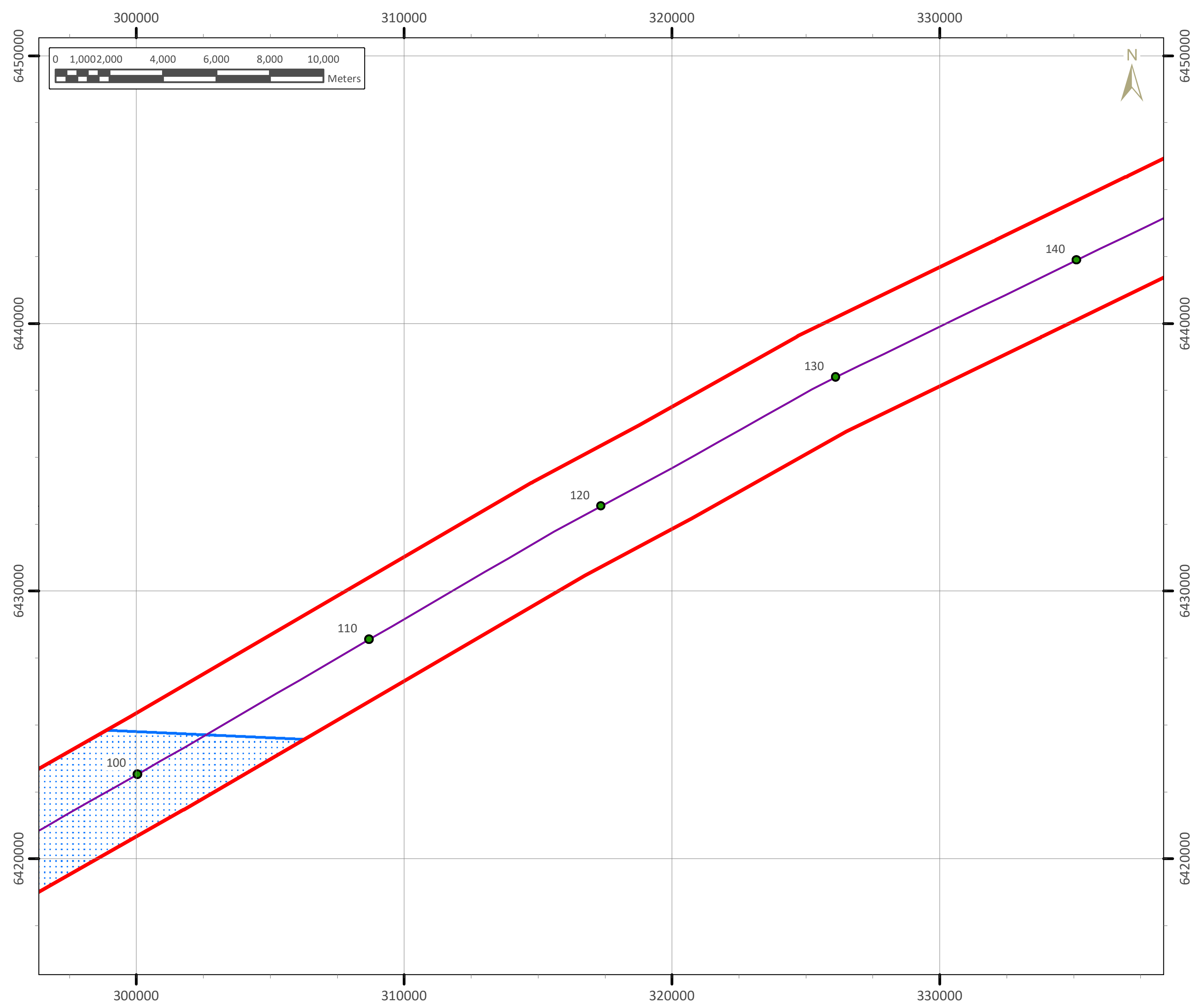
COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

W W W . 6 A L P H A . C O M
E: enquiry@6alpha.com | T: +44 (0)203 371 3900



LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/5

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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W W W . 6 A L P H A . C O M
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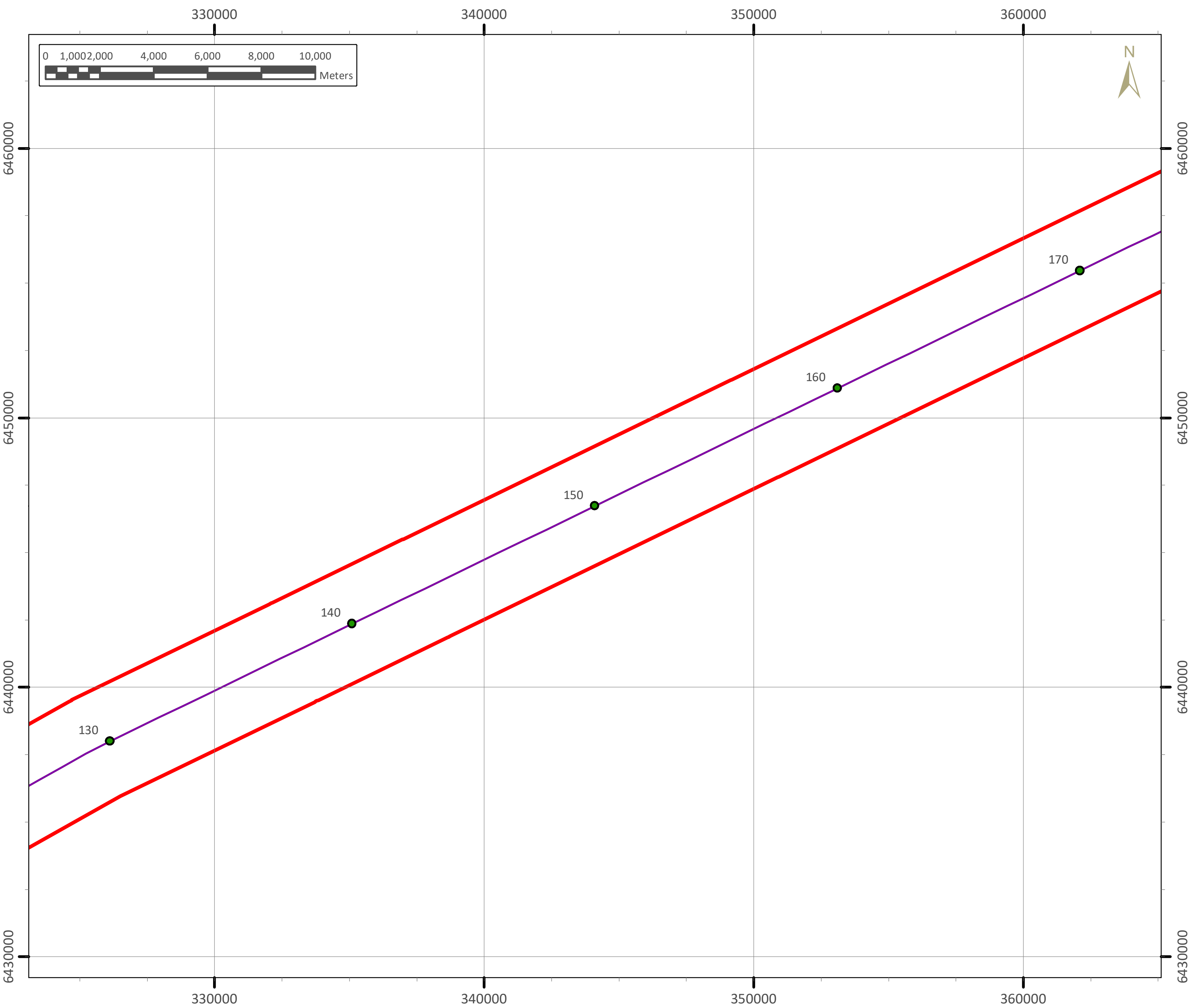

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/6

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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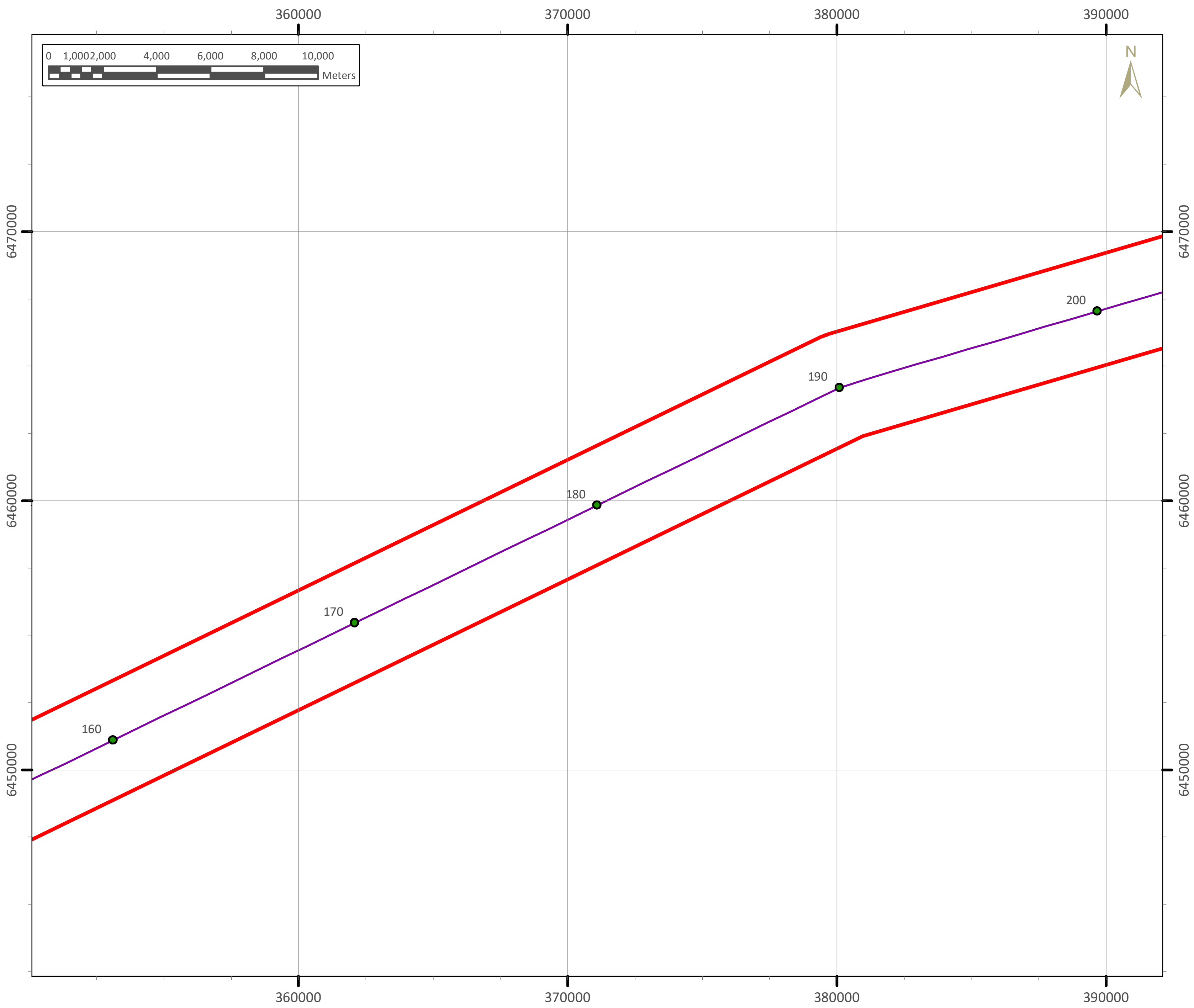

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/7

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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W W W . 6 A L P H A . C O M
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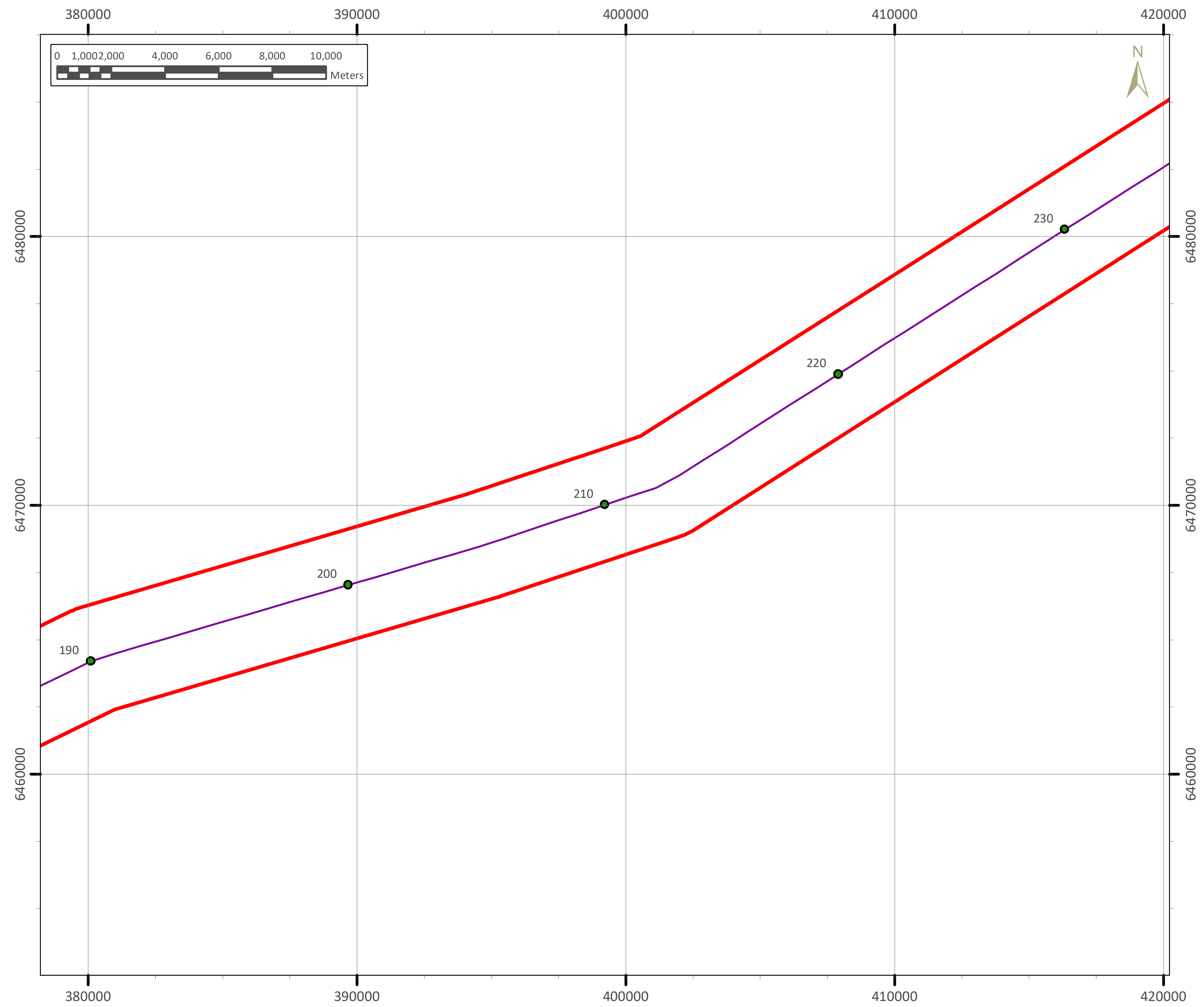

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/8

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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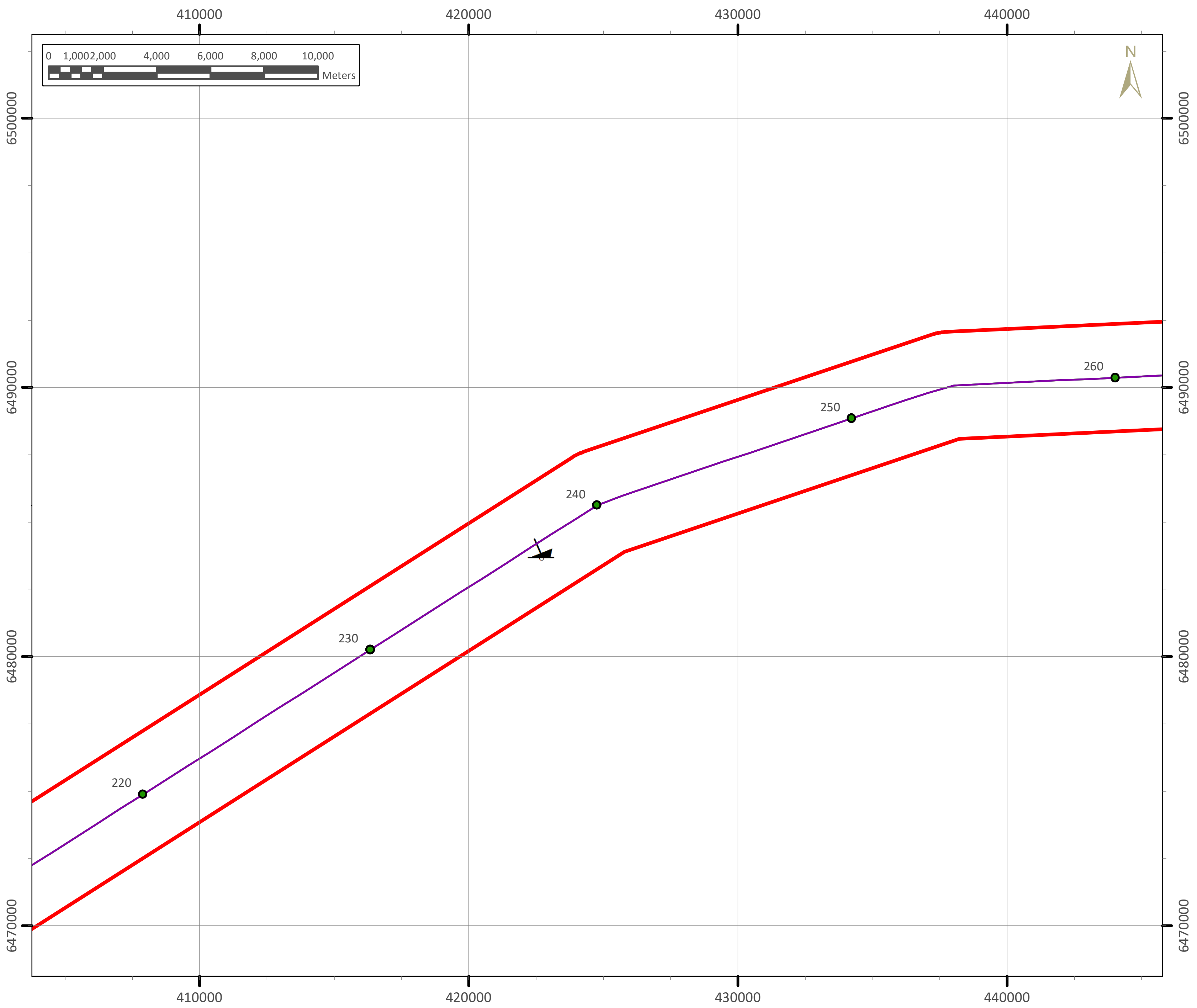
E: enquiry@6alpha.com | T: +44 (0)203 371 3900



LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/9

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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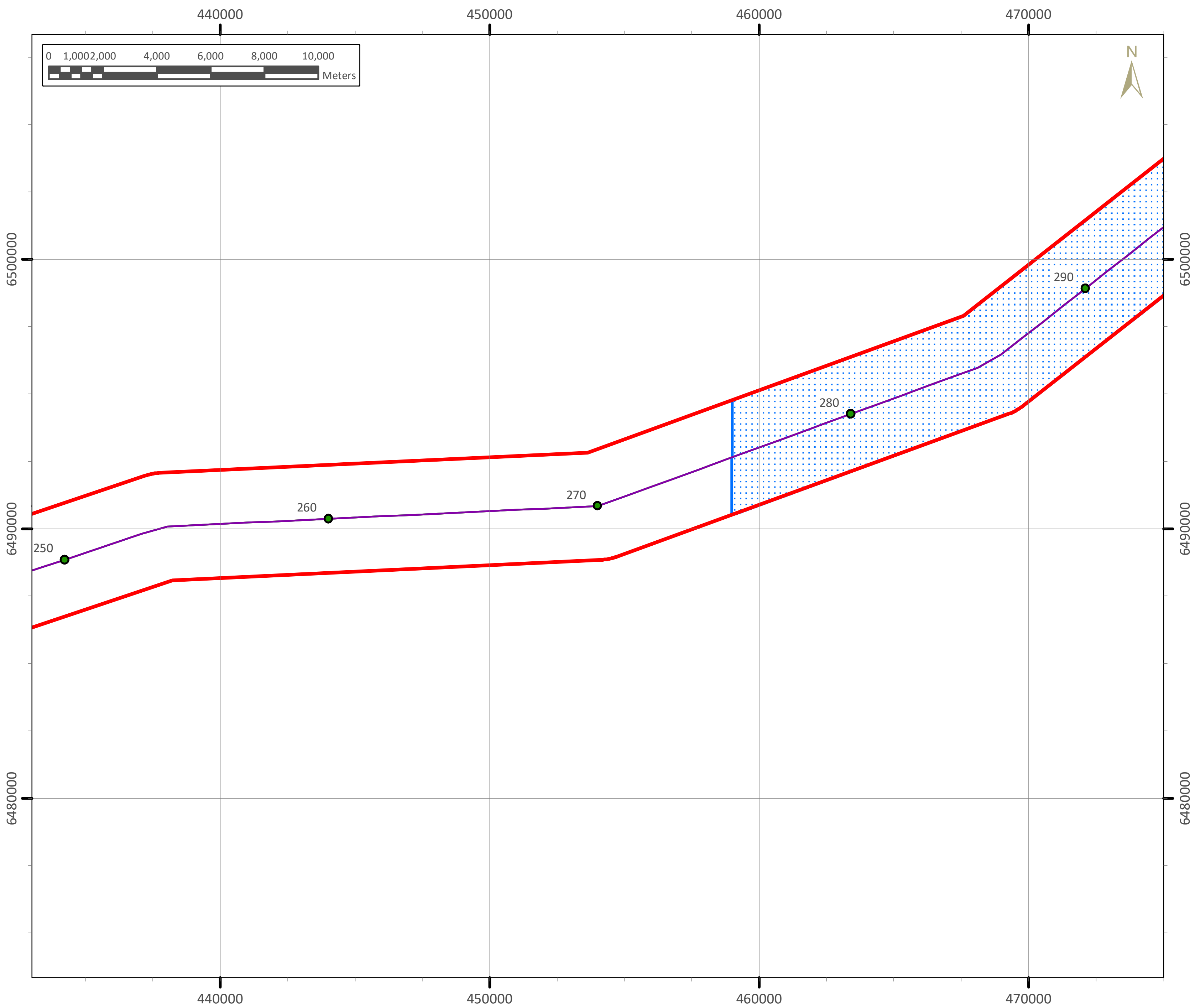

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/10

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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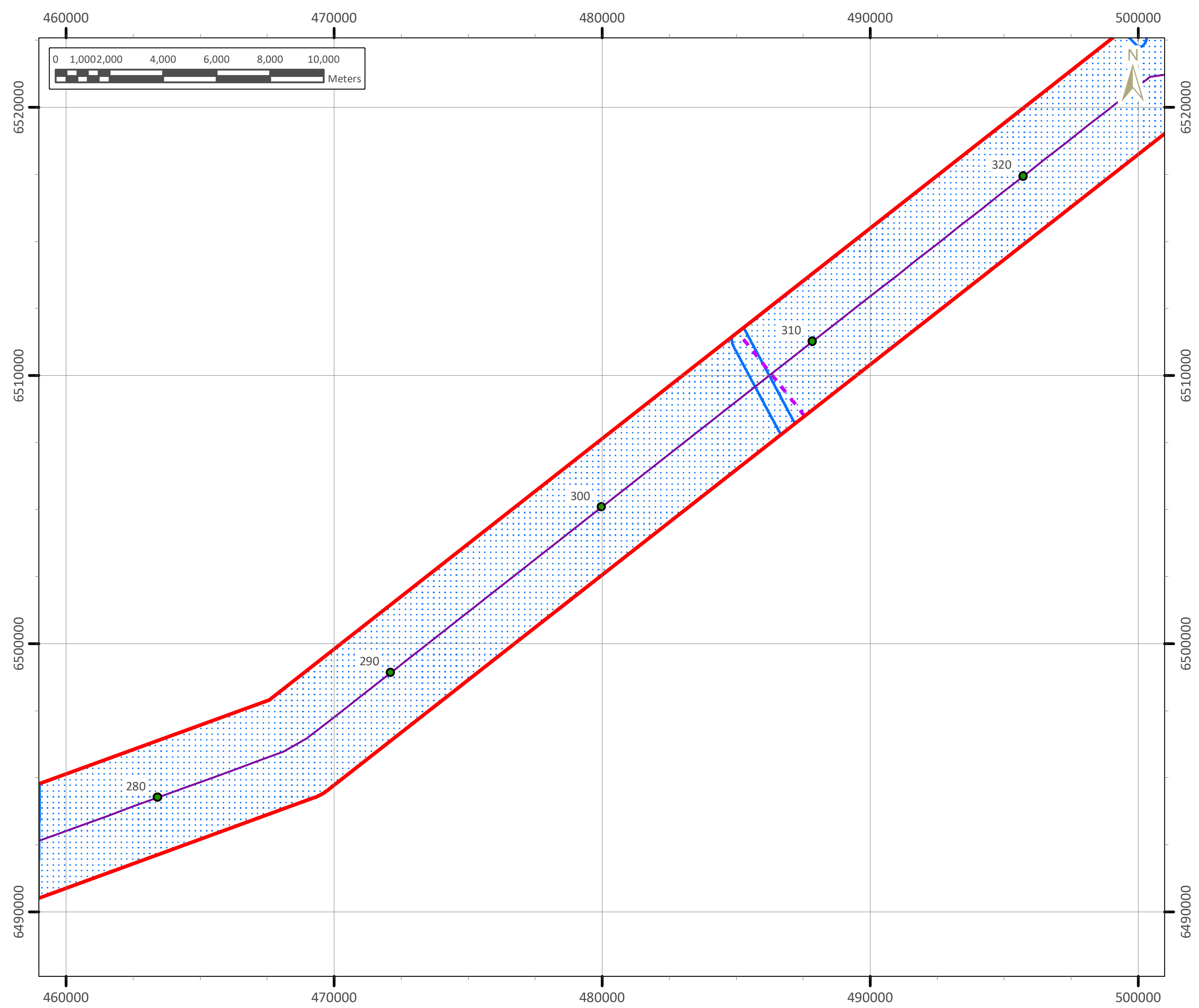

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- EU Axis Minelays
- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/11

PURPOSE
FOR INFORMATION USE ONLY

6 alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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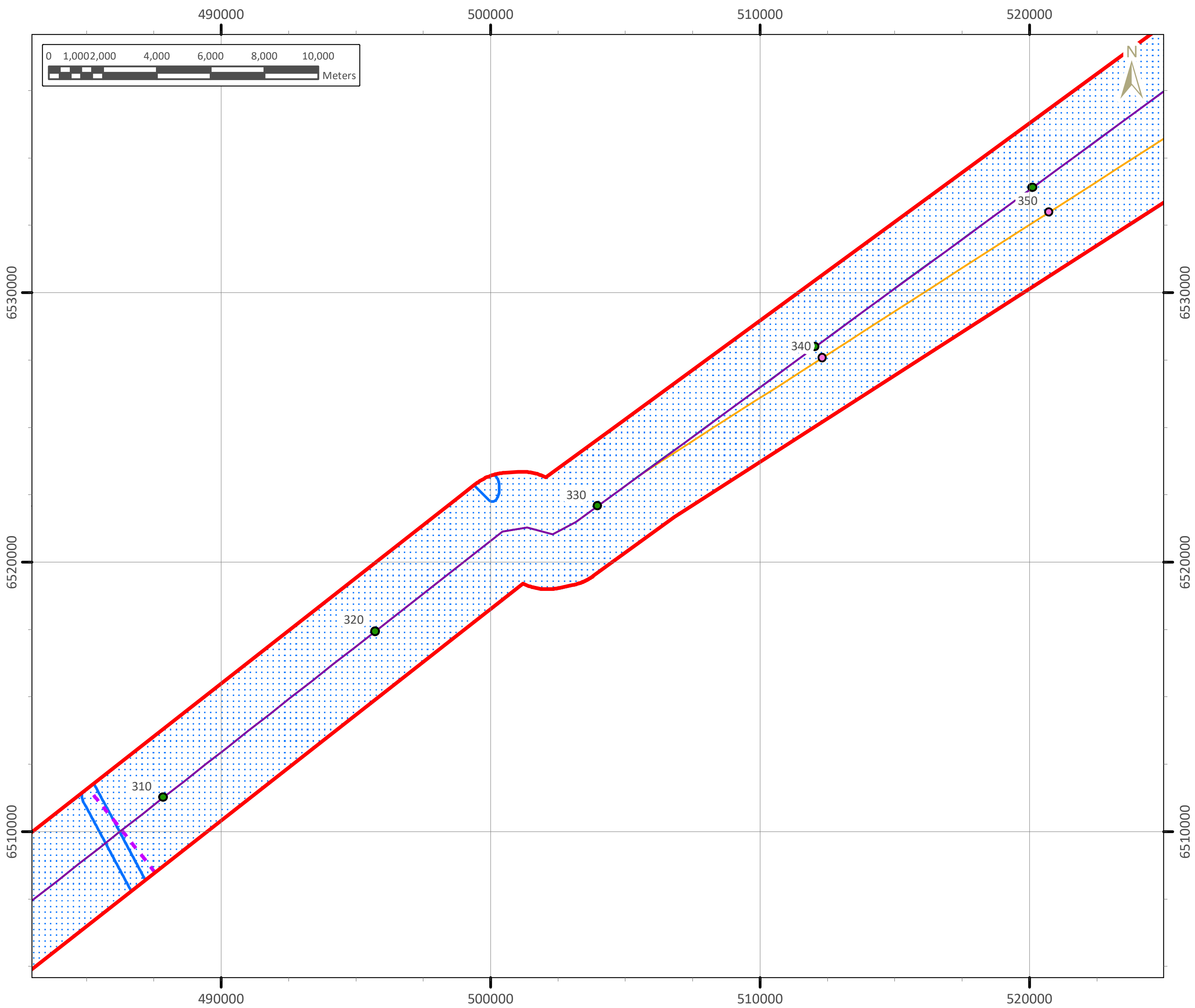
W W W . 6 A L P H A . C O M
E: enquiry@6alpha.com | T: +44 (0)203 371 3900



LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- EU Axis Minelays
- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Consolidated UXO Threats

DRAWING NUMBER

P5530/TARA/12

PURPOSE

FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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W W W . 6 A L P H A . C O M
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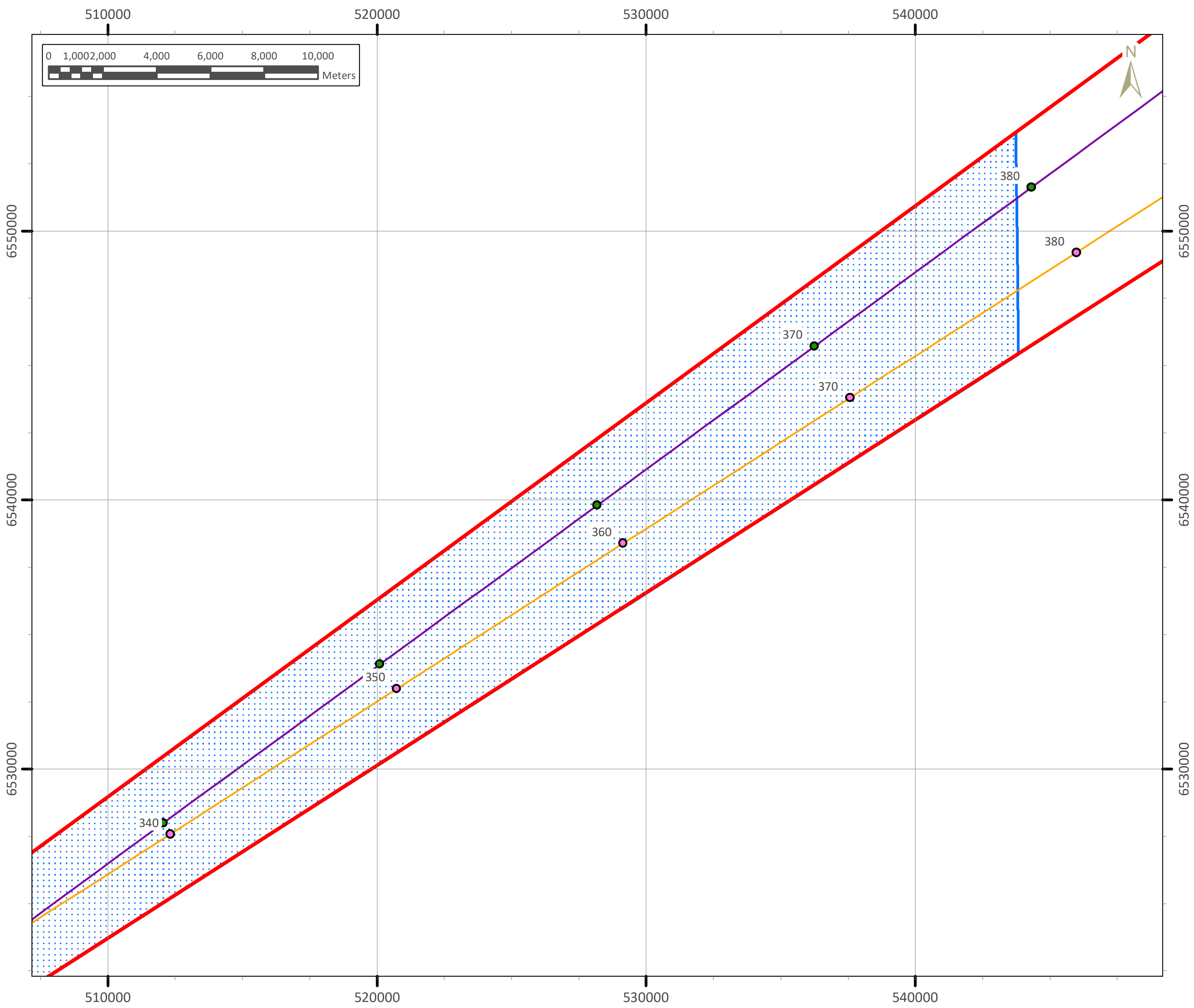

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/13

PURPOSE
FOR INFORMATION USE ONLY

6 alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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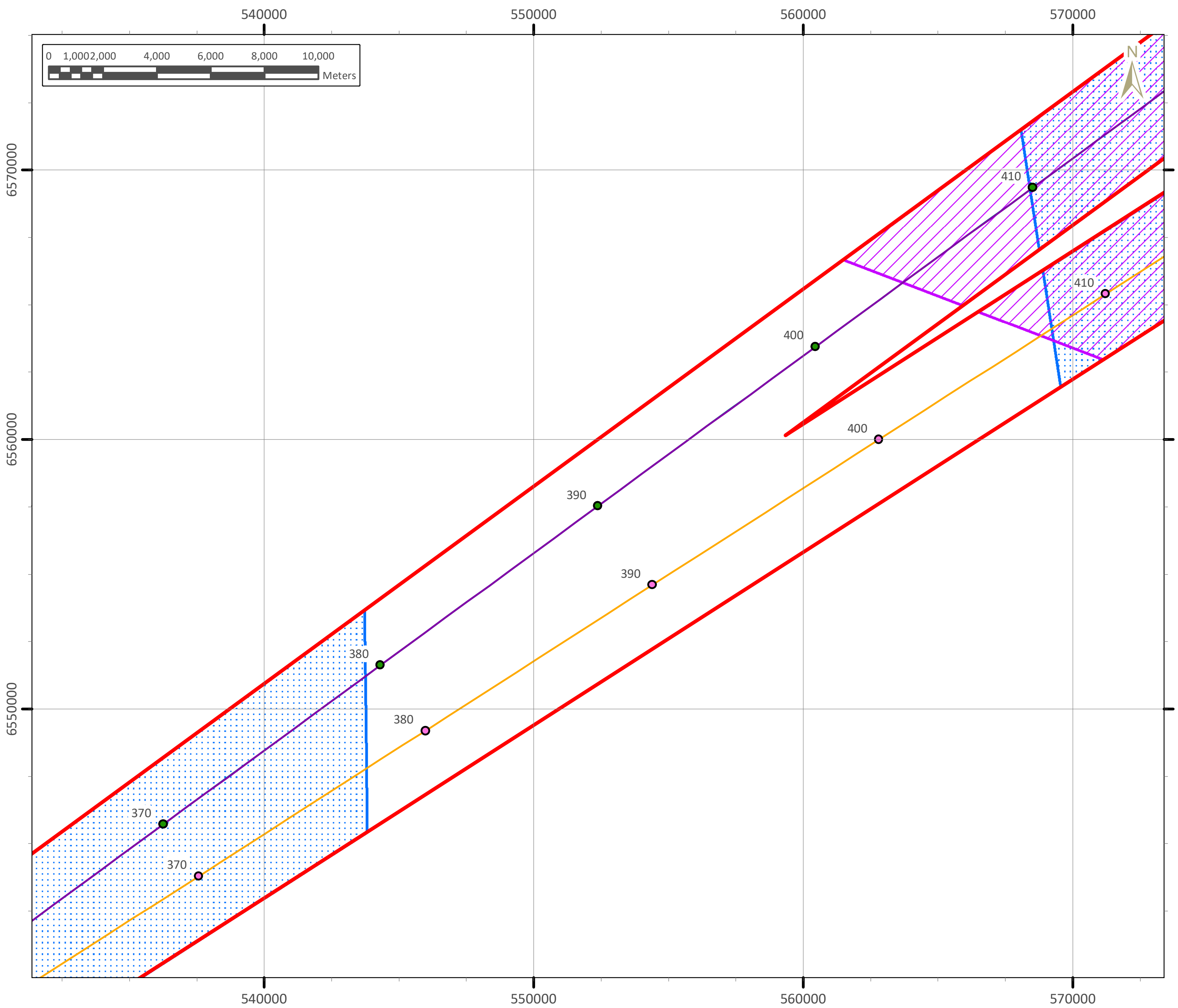
W W W . 6 A L P H A . C O M
E: enquiry@6alpha.com | T: +44 (0)203 371 3900



LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- WWI Axis and Allied Minefields
- WWII Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Consolidated UXO Threats

DRAWING NUMBER

P5530/TARA/14

PURPOSE

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alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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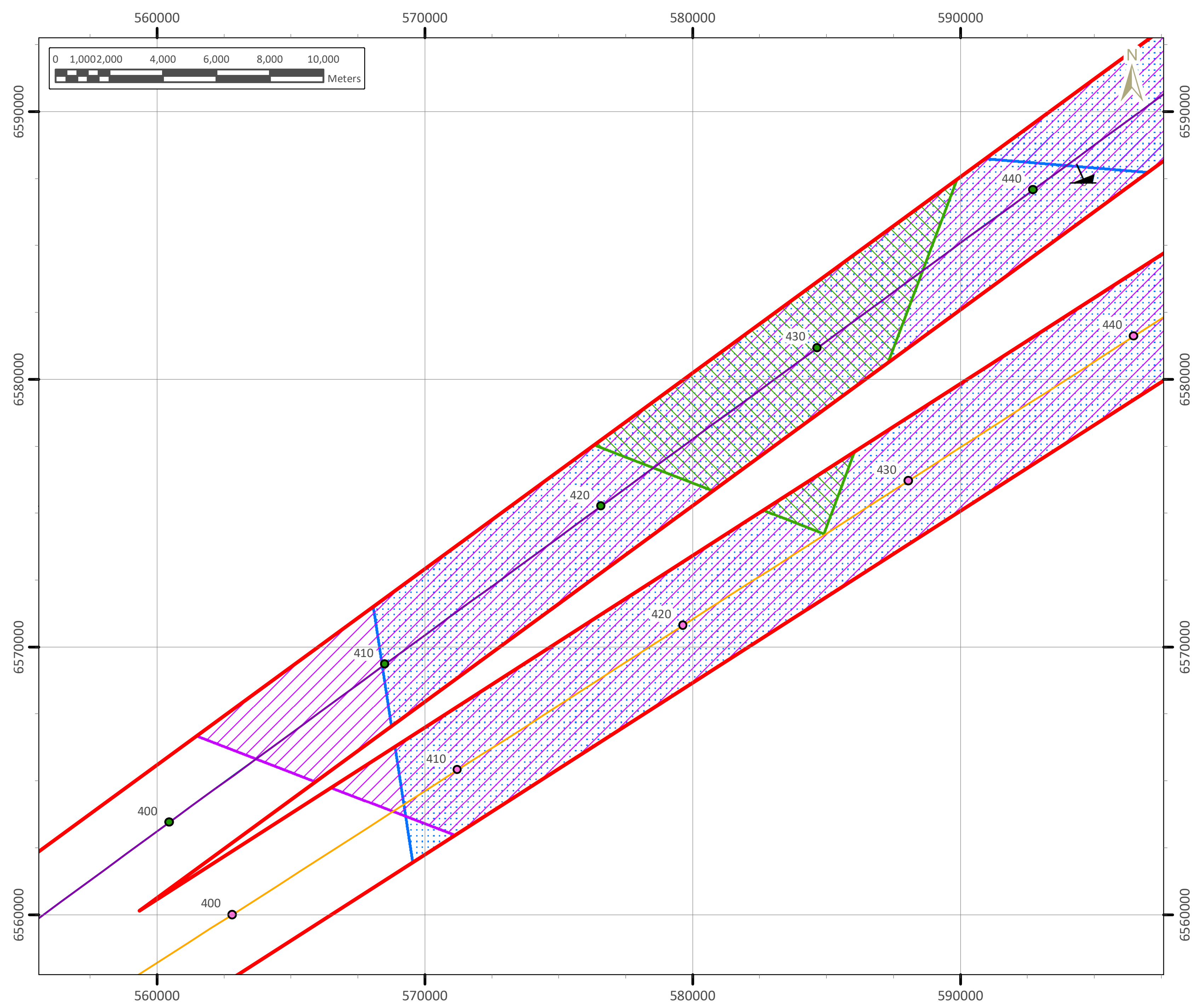

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks
- Norwegian PEXA Modern
- WWI Axis and Allied Minefields
- WWII Minefields Historic
- WWI Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/15

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED		
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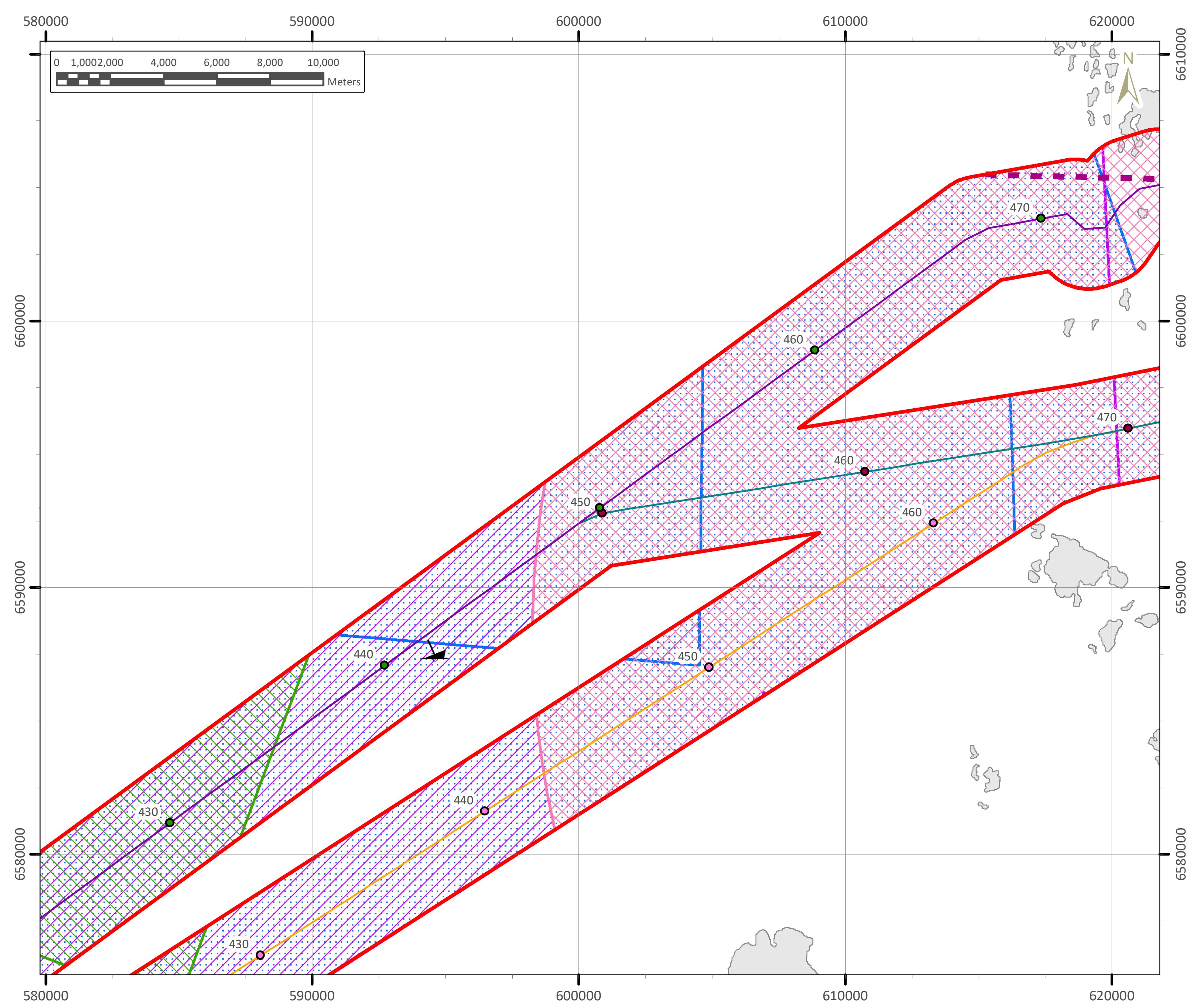

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks
- Atlantic Wall Ranges
- WWII American Minelays
- WWI Axis and Allied Minefields
- Norwegian PEXA Modern
- WWII Minefields Historic
- EU Axis Minelays
- WWI Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/16

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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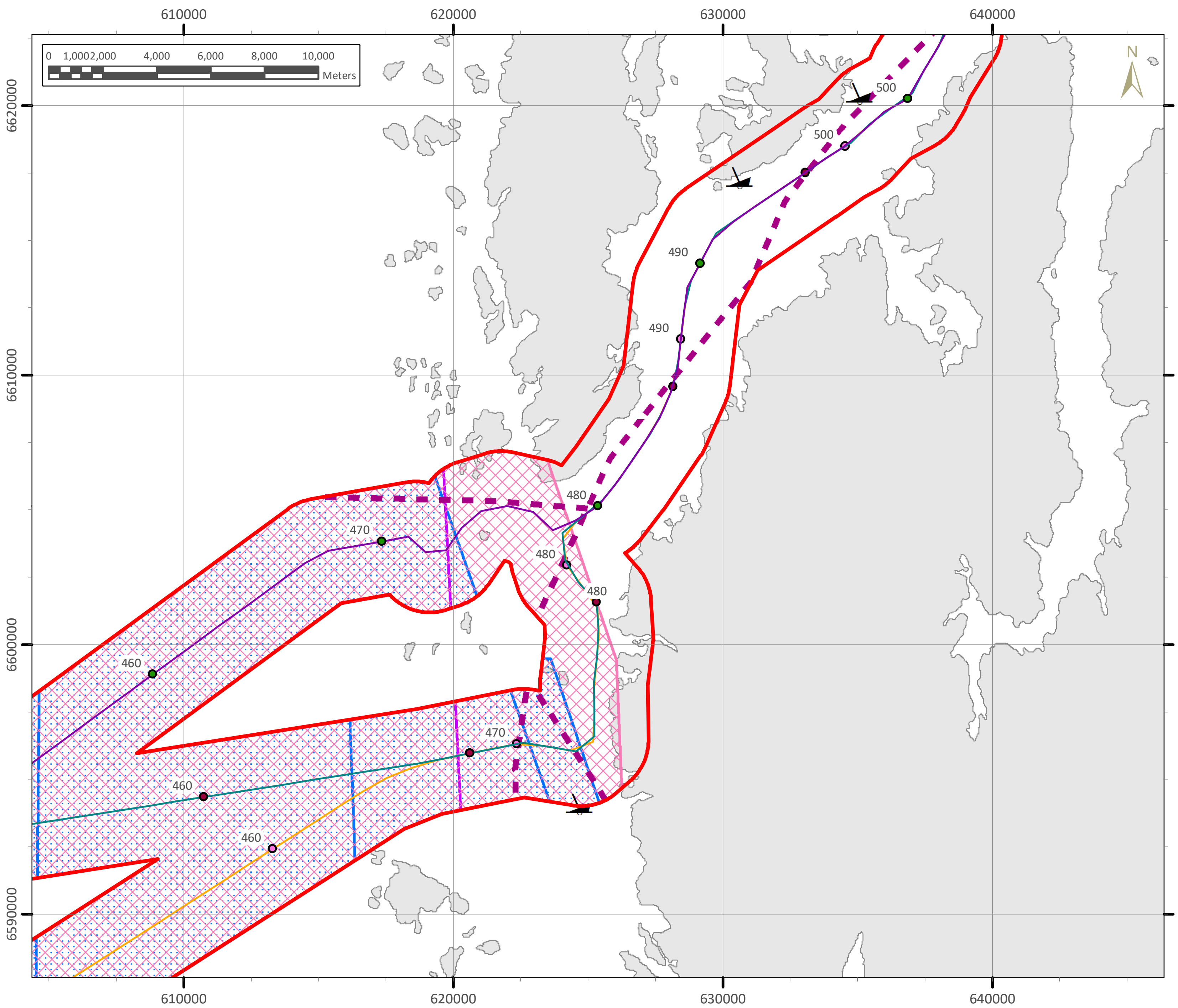

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks
- WWI Axis and Allied Minefields
- WWII American Minelays
- WWII Minefields Historic
- Atlantic Wall Ranges
- WWI Minefields Historic

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/17

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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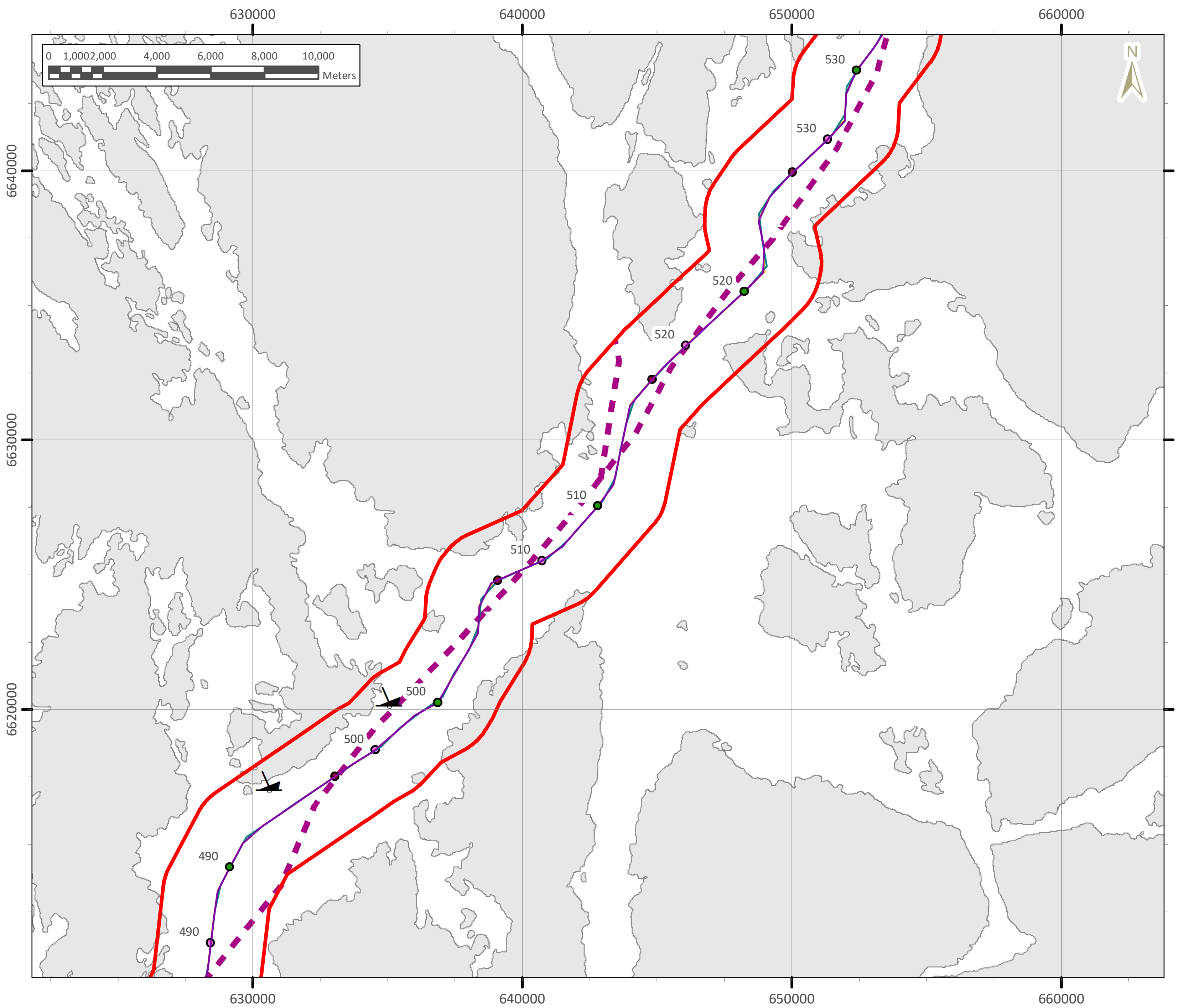

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks
- WWII American Minelays

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/18

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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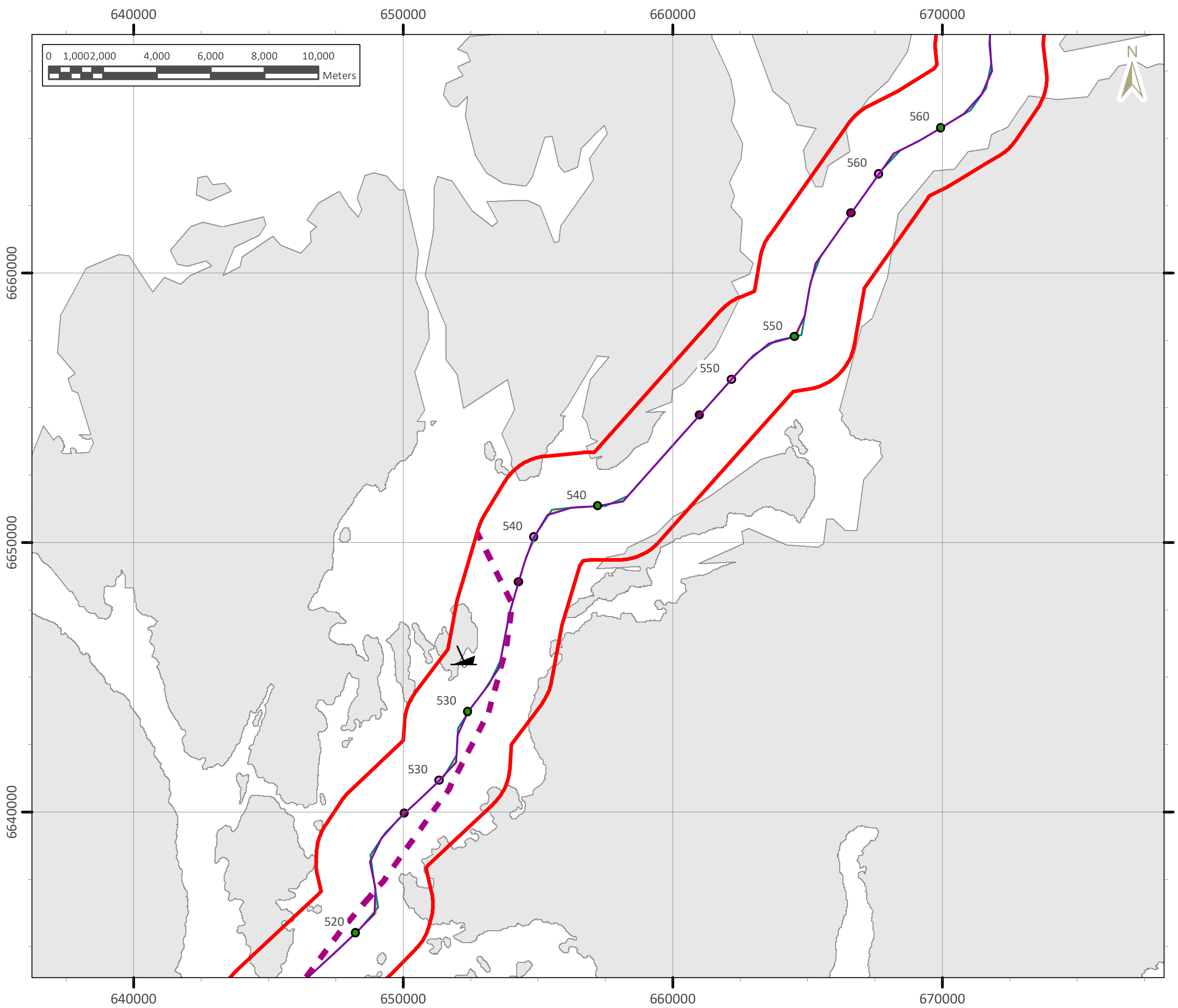

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Wrecks
- WWII American Minelays

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/19

PURPOSE
FOR INFORMATION USE ONLY

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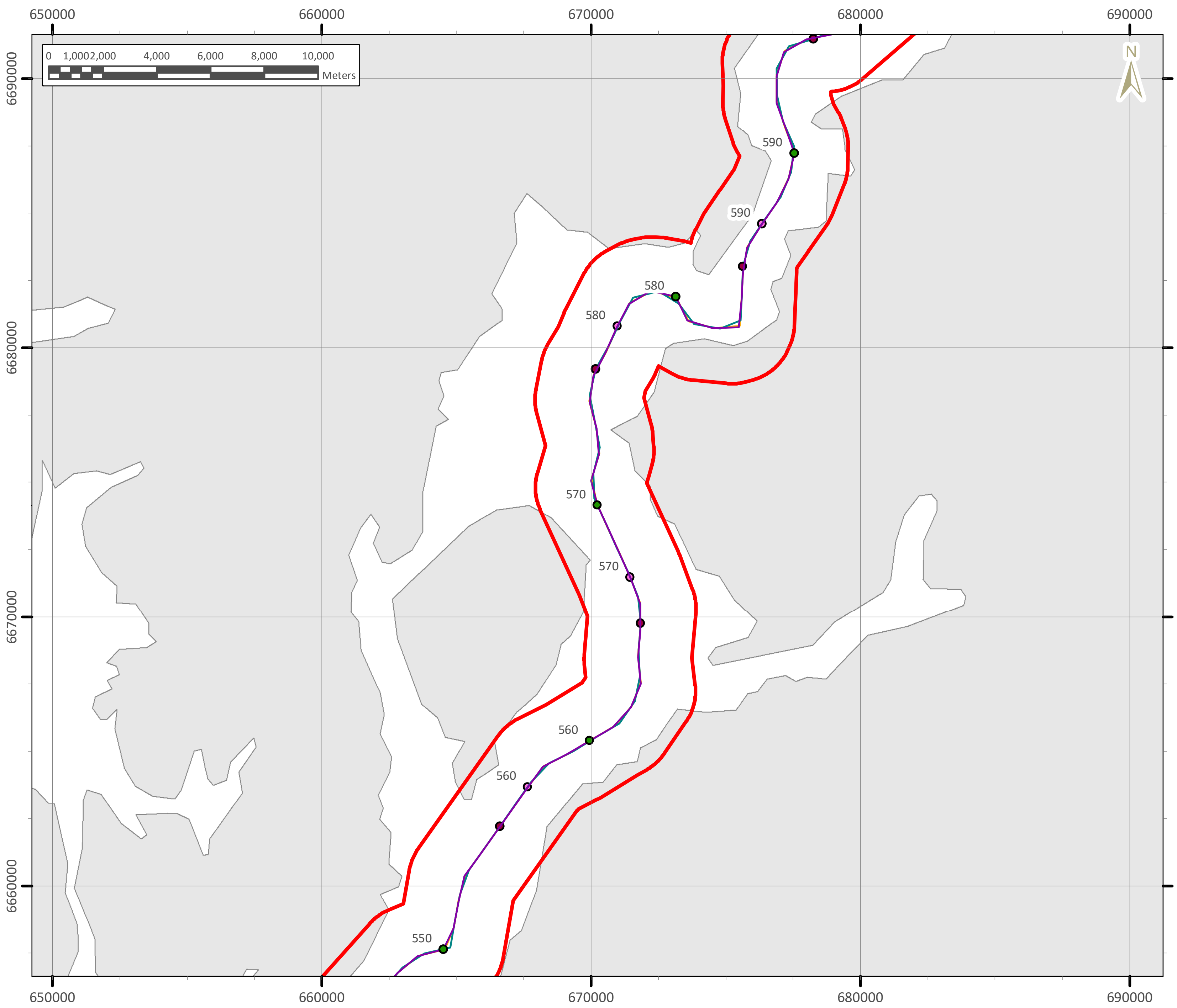

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/20

PURPOSE
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ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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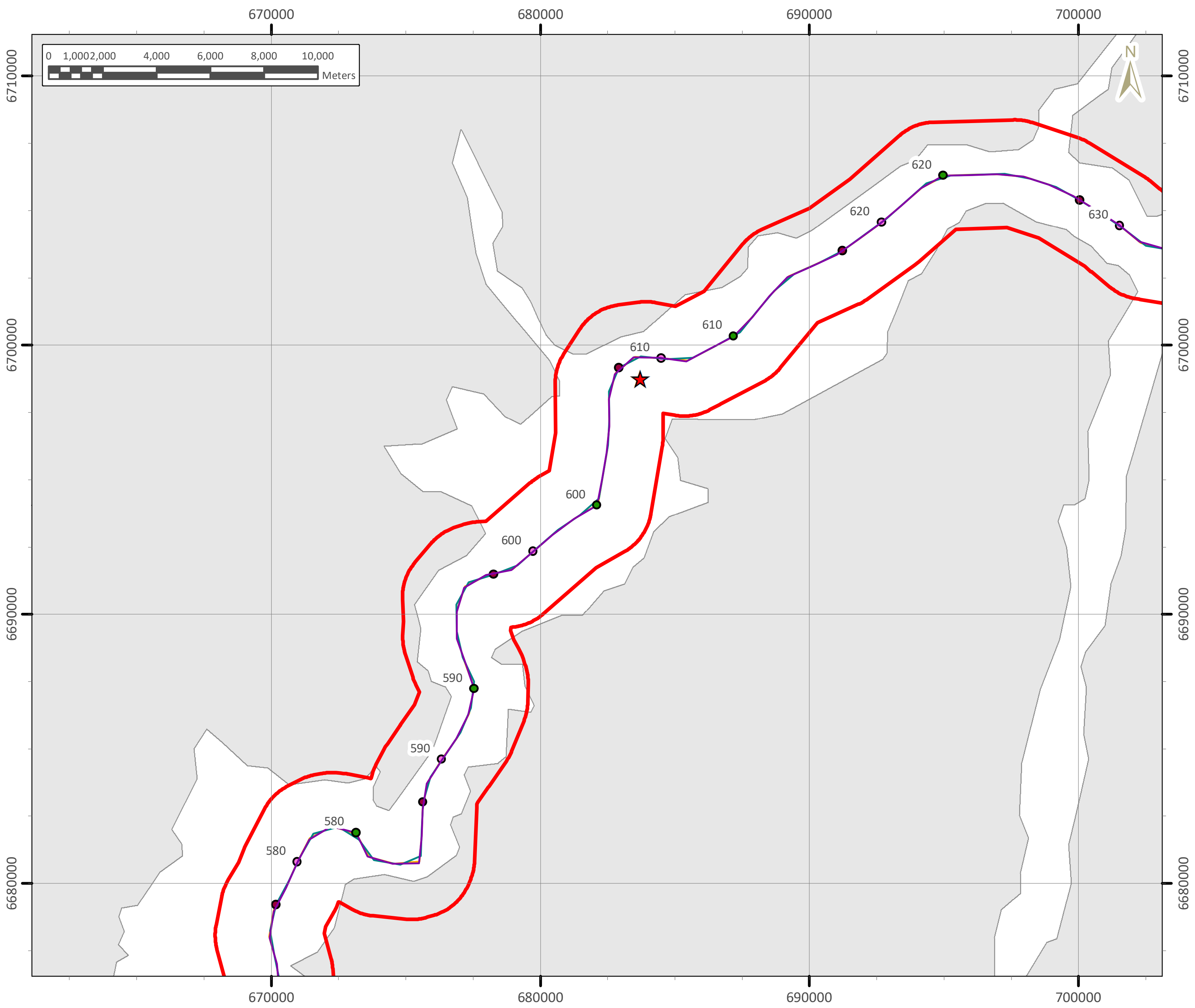

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Munitions Dumps

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/21

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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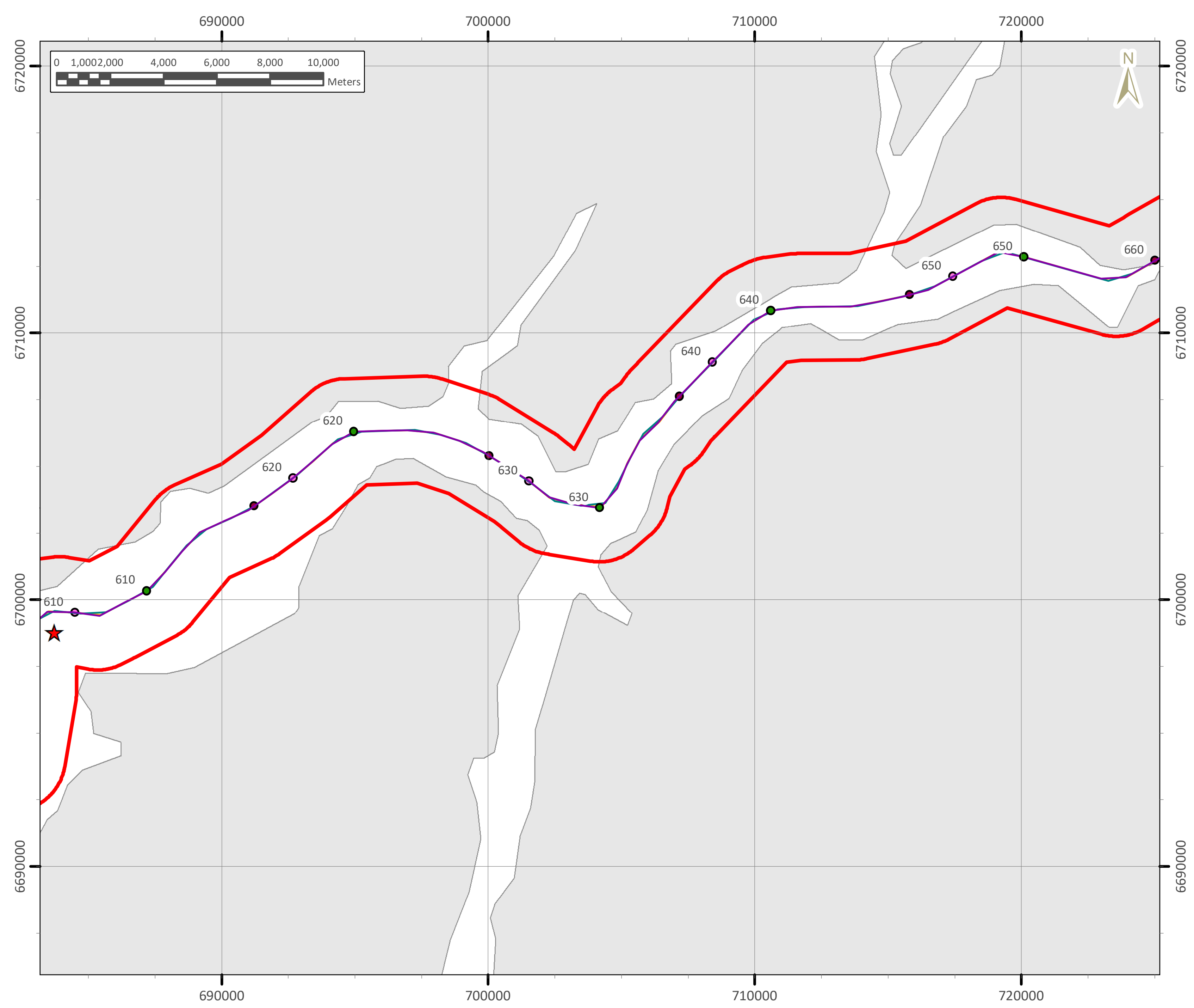

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

- Munitions Dumps

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/22

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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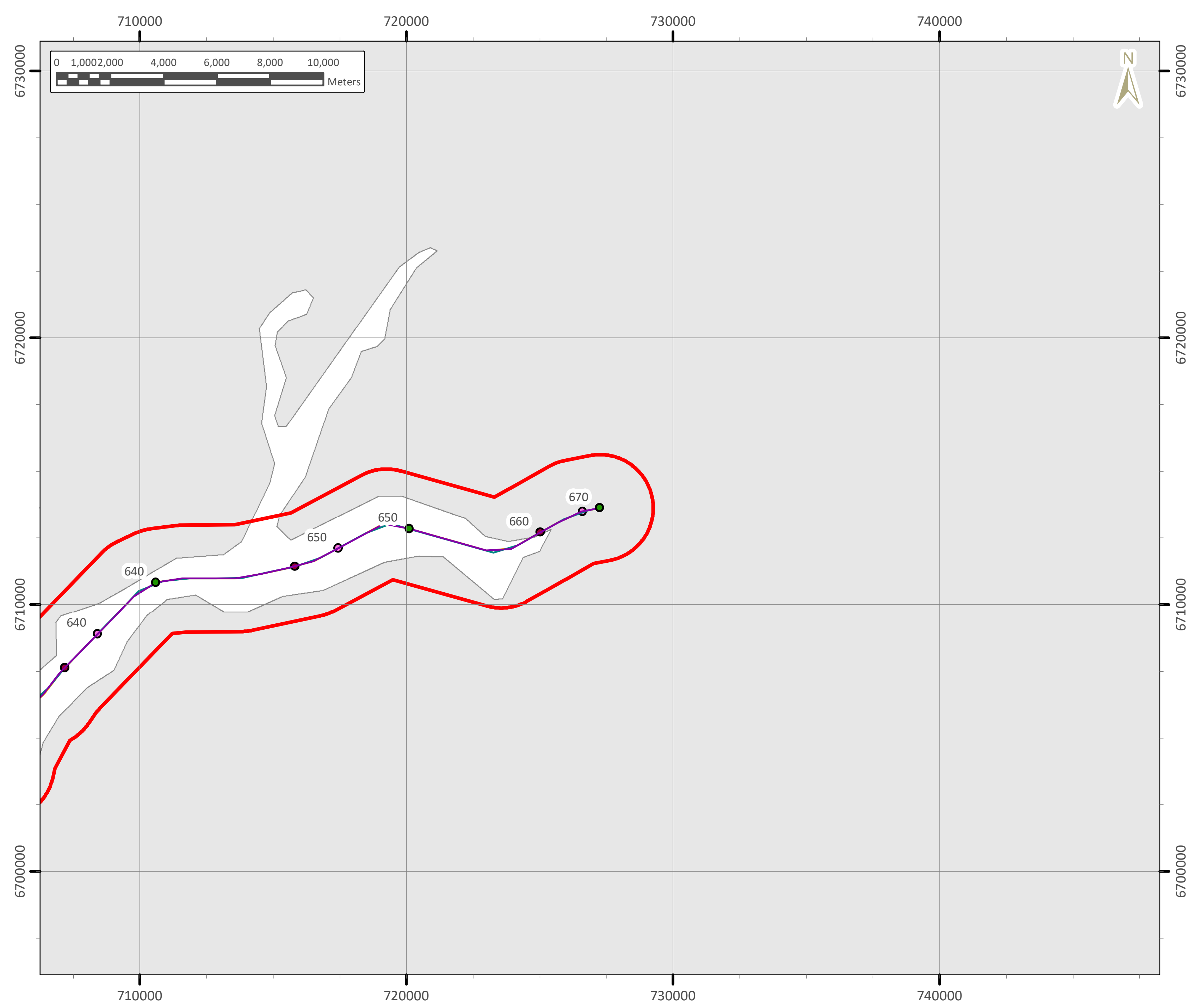

LEGEND

GENERAL

- North A KP 10km
- North A Route
- South B KP 10km
- South B Route
- South C KP 10km
- South C Route
- Route Buffer

POTENTIAL UXO THREATS

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Consolidated UXO Threats

DRAWING NUMBER
P5530/TARA/23

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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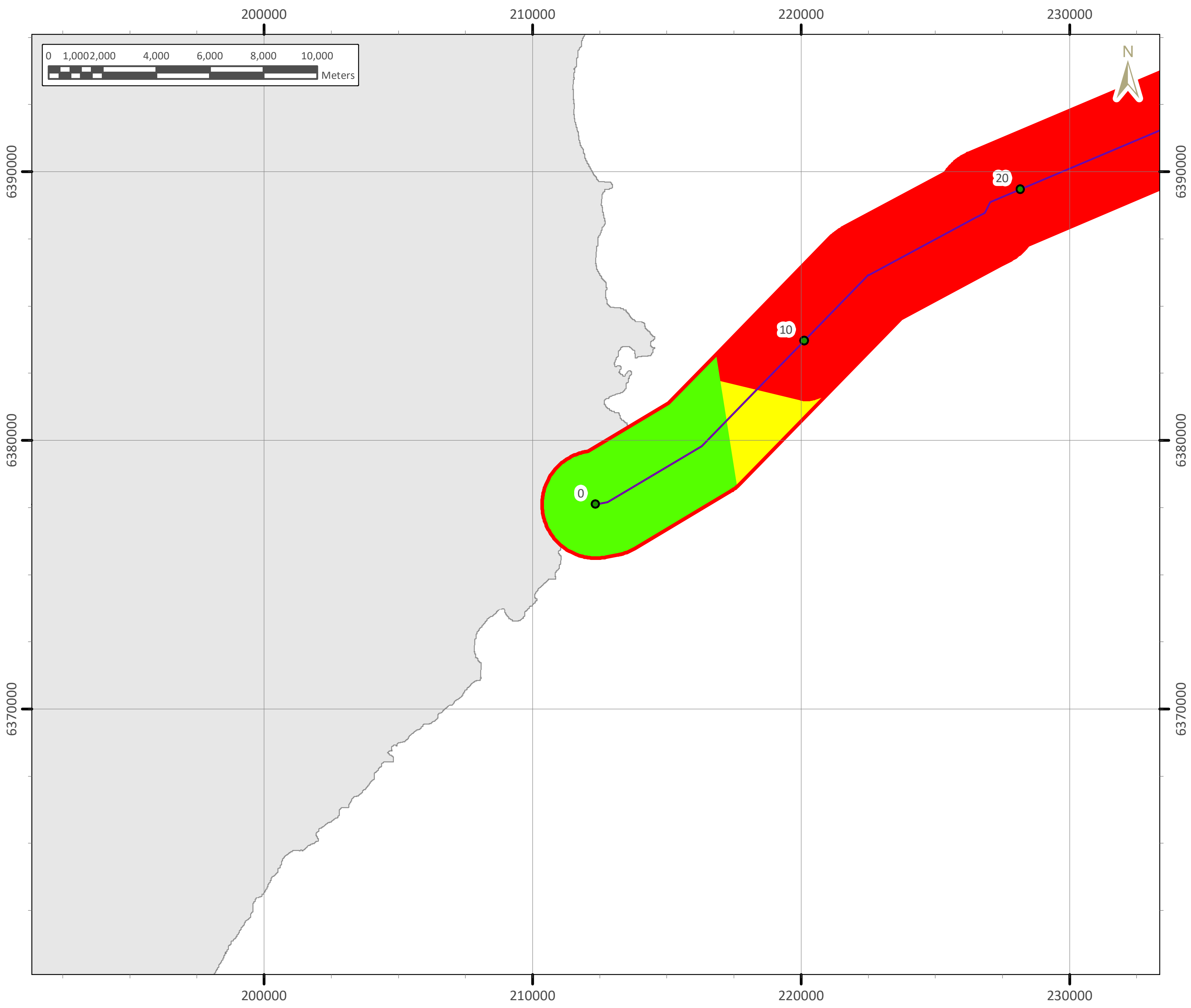
Appendix 12

Probability of UXO Encounter



LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/1

PURPOSE
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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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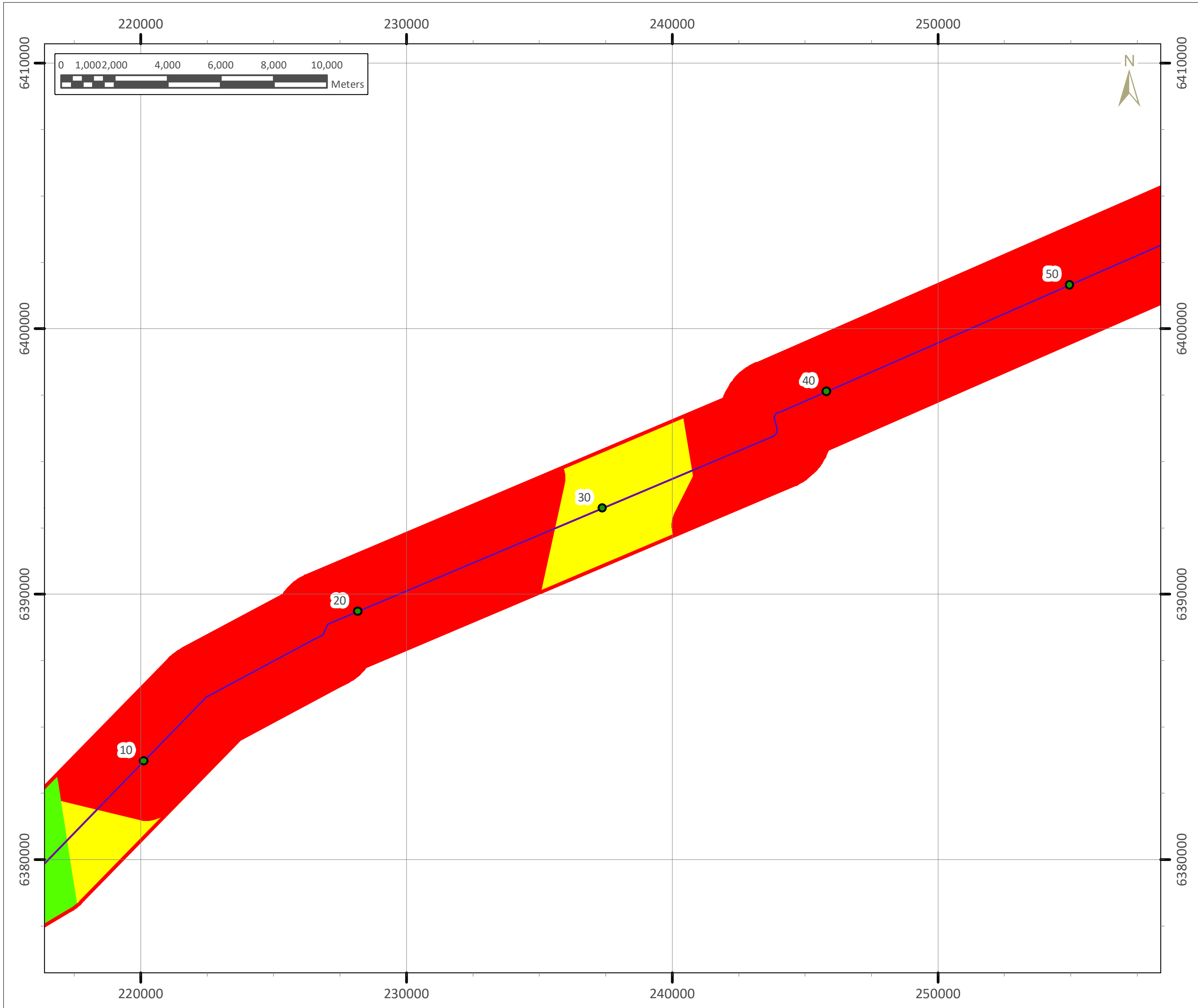

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/2

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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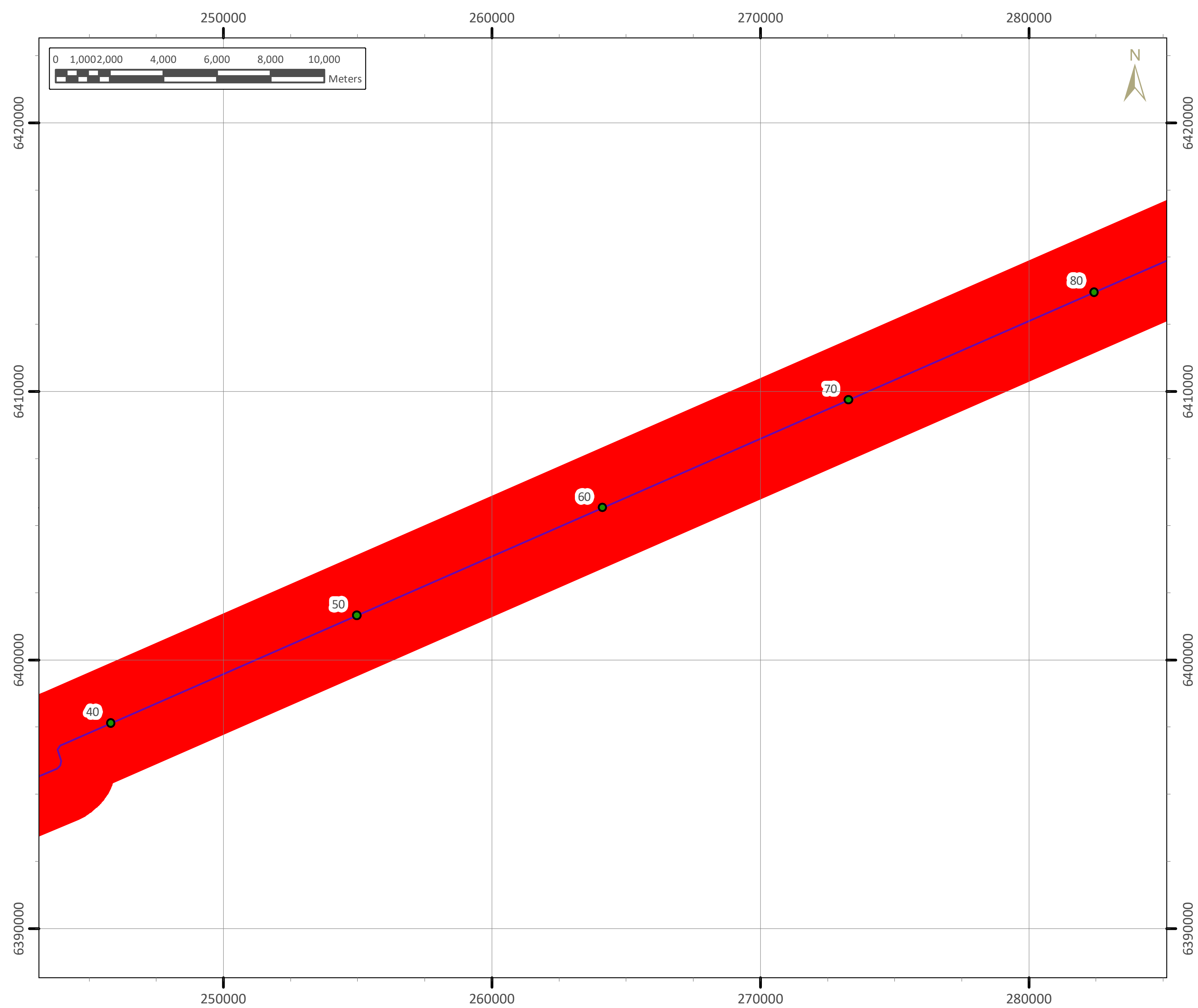

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/3

PURPOSE

FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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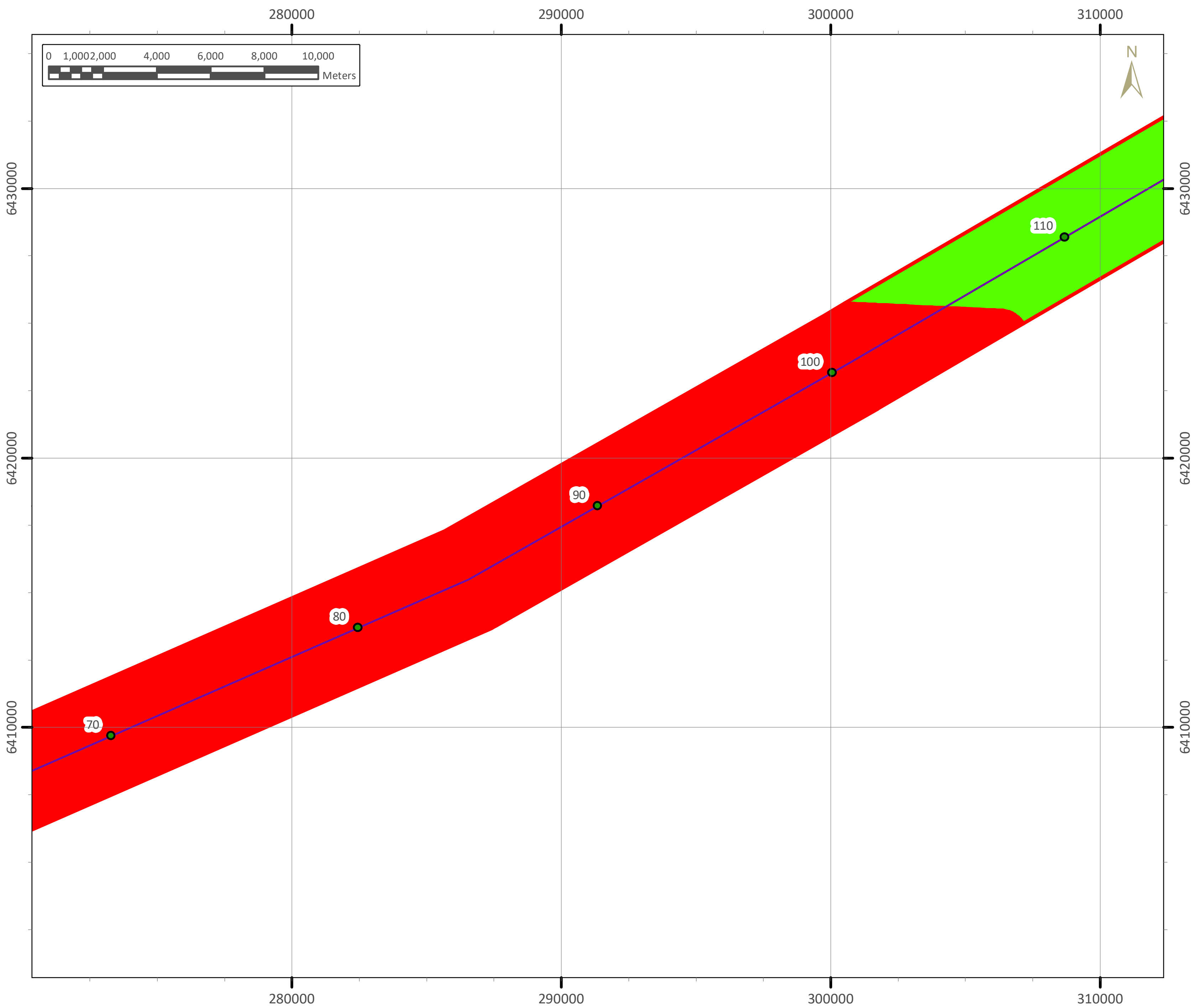

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/4

PURPOSE

FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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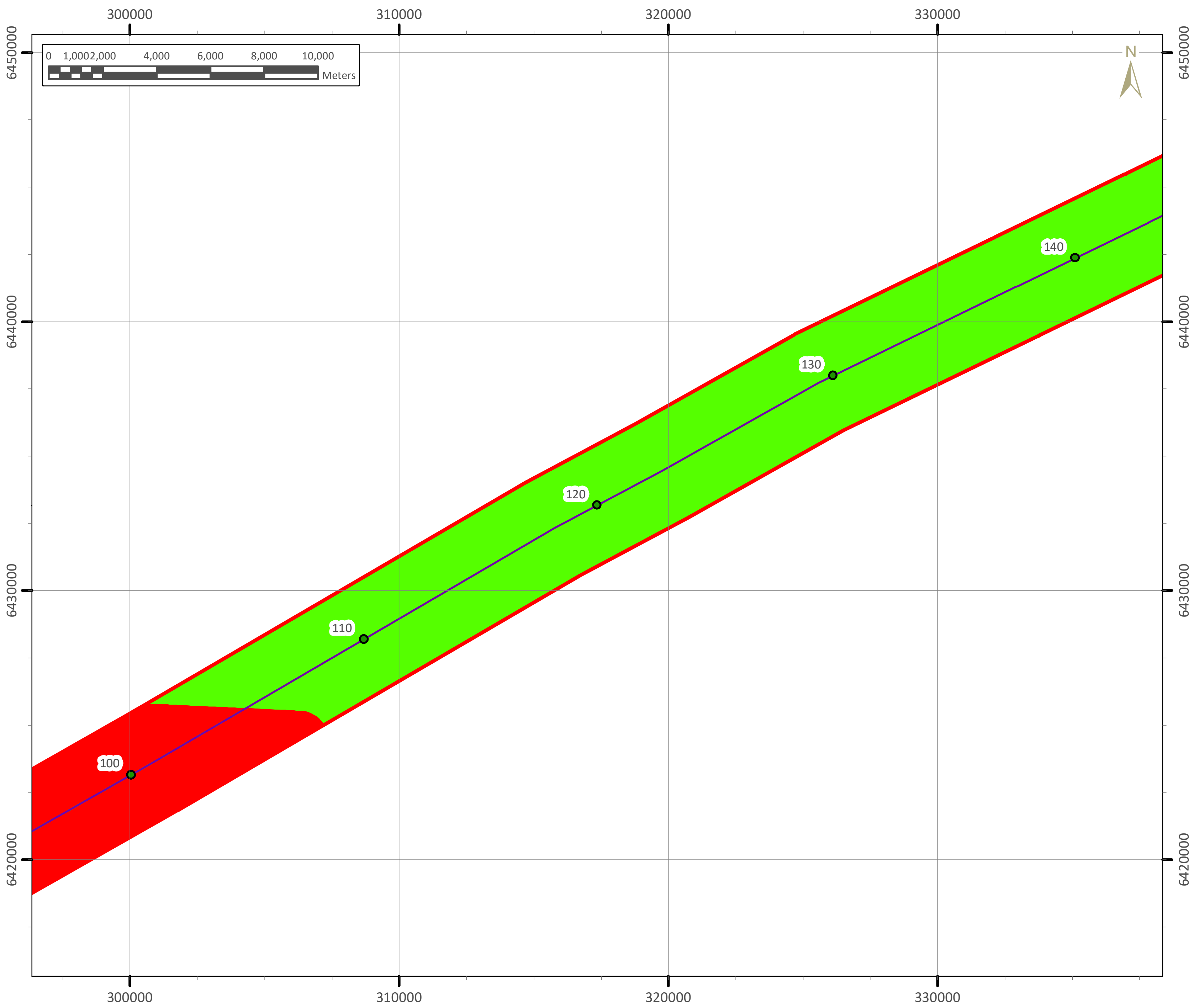

LEGEND

GENERAL

North A KP 10km

Route North A

South B KP 10km

Route South B

South C KP 10km

Route South C

Route Buffer

POTENTIAL UXO THREATS

High Probability of UXO Encounter

Medium Probability of UXO Encounter

Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/5

PURPOSE

FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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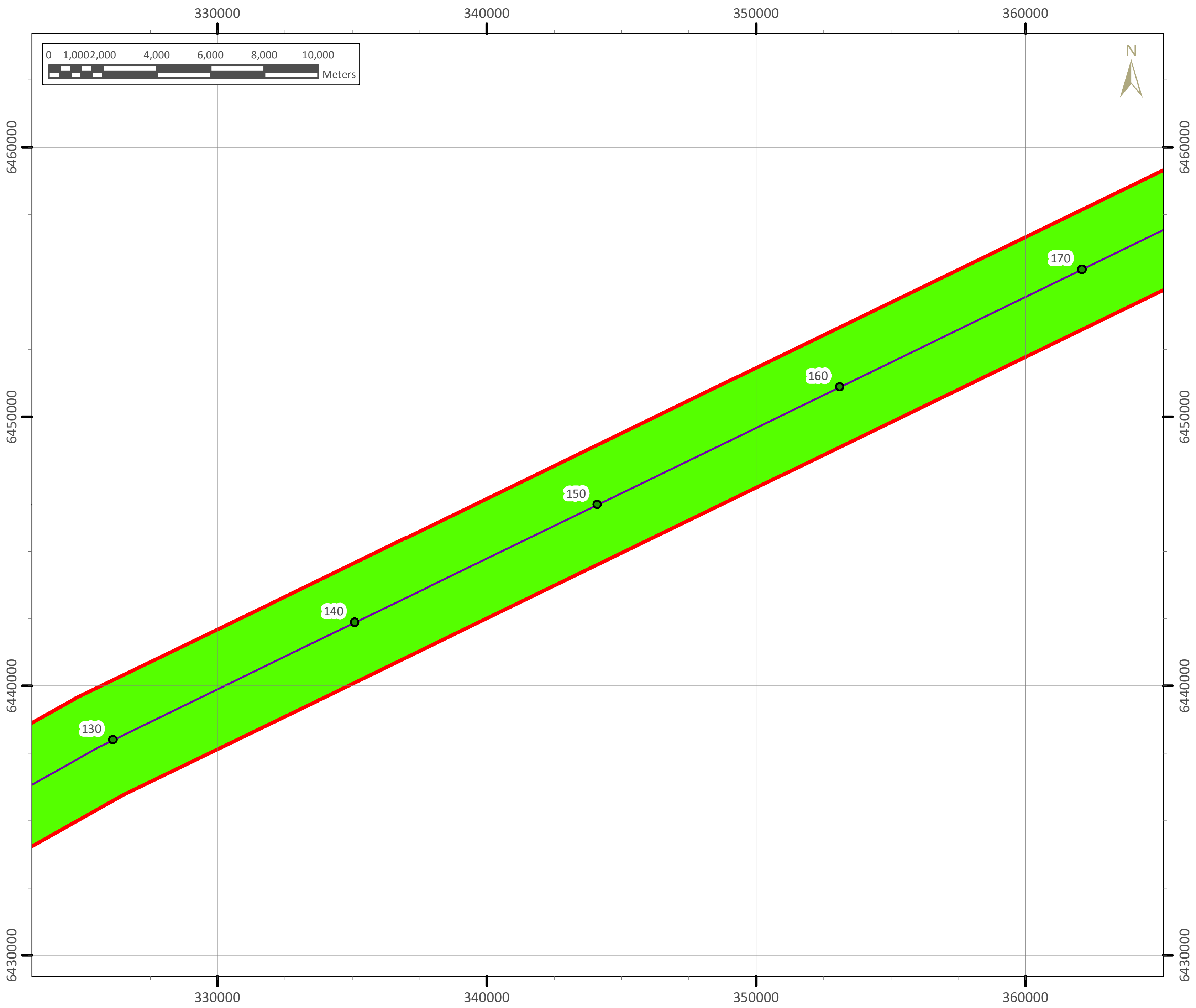

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/6

PURPOSE

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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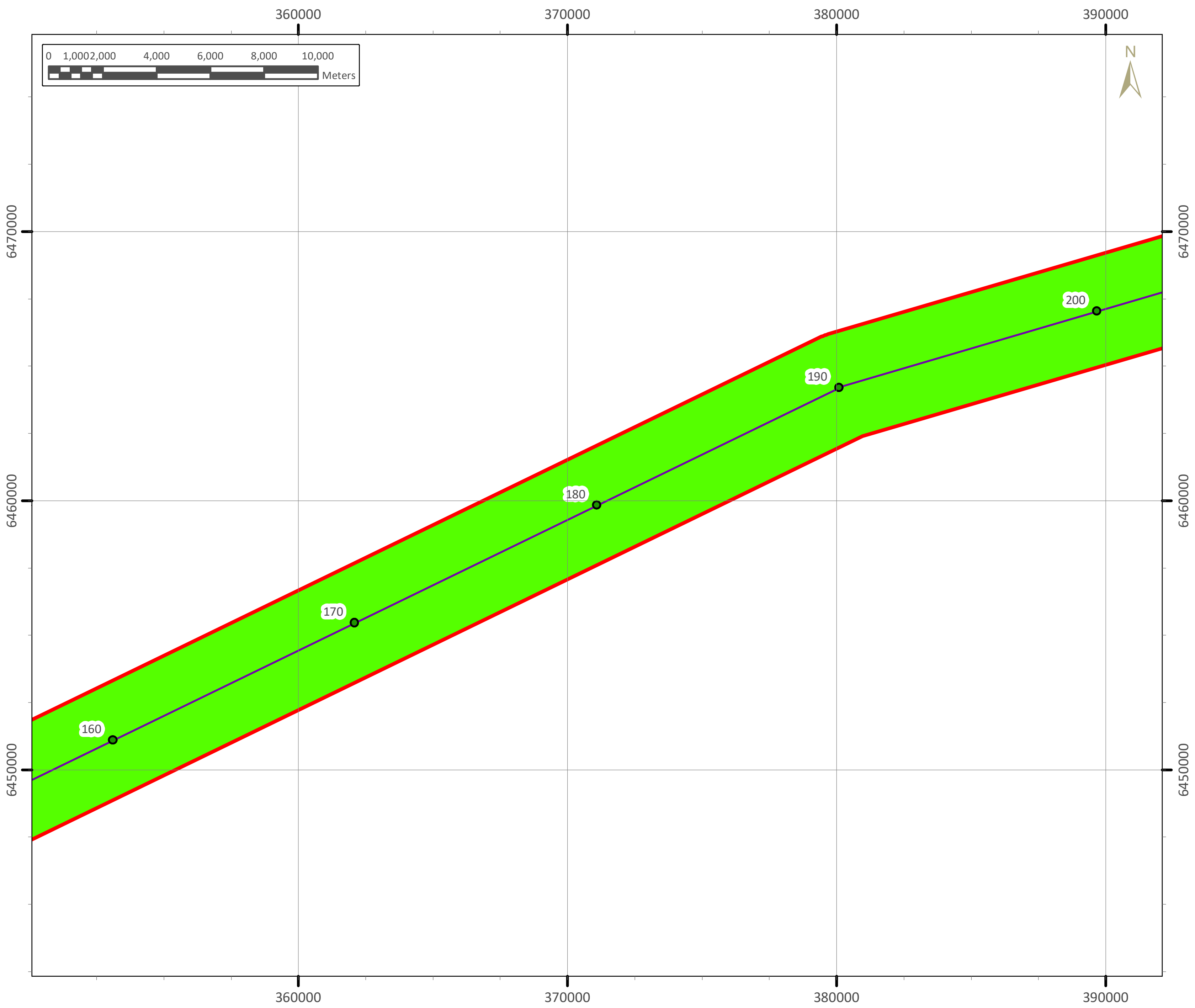

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/7

PURPOSE

FOR INFORMATION USE ONLY

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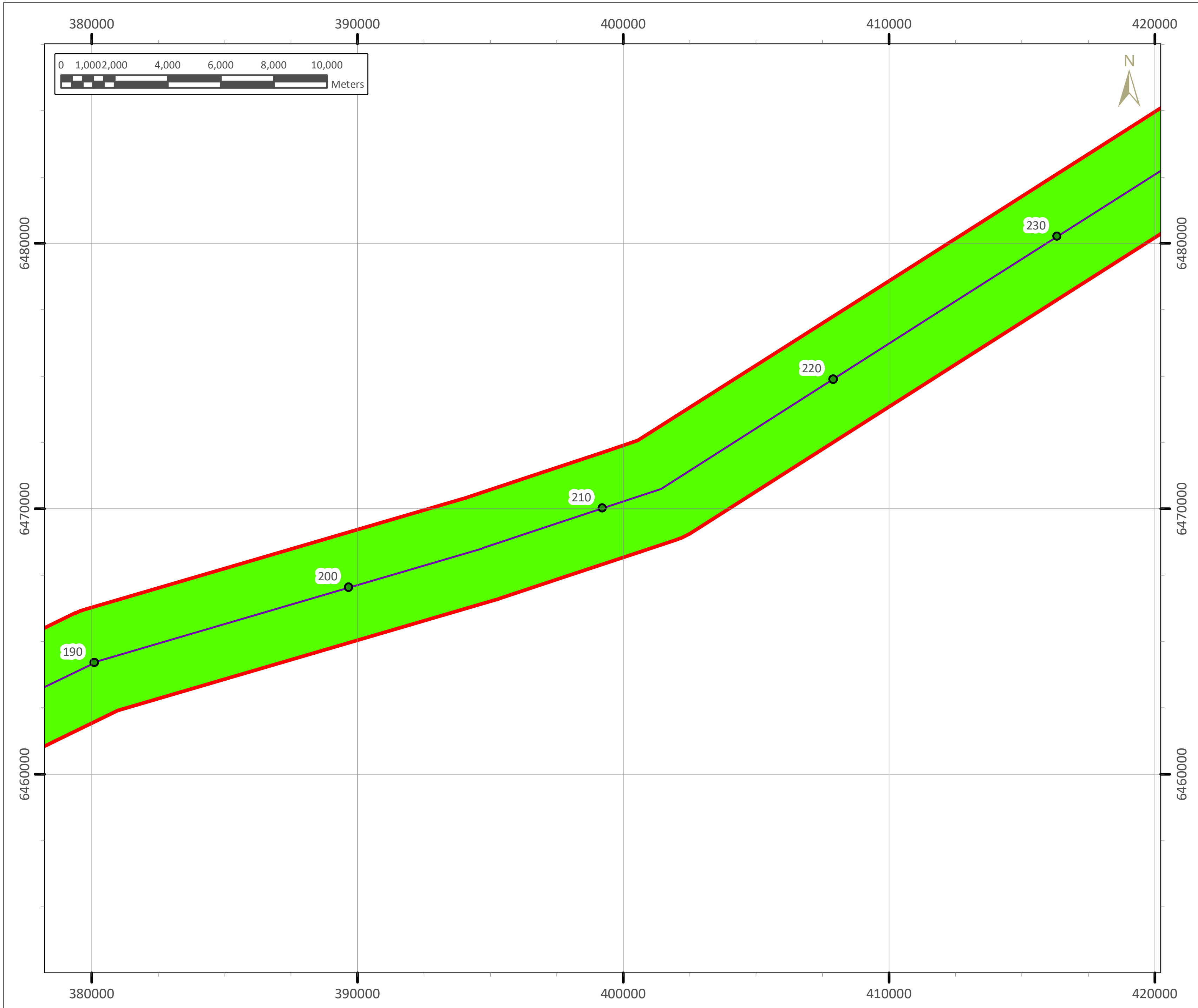

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/8

PURPOSE

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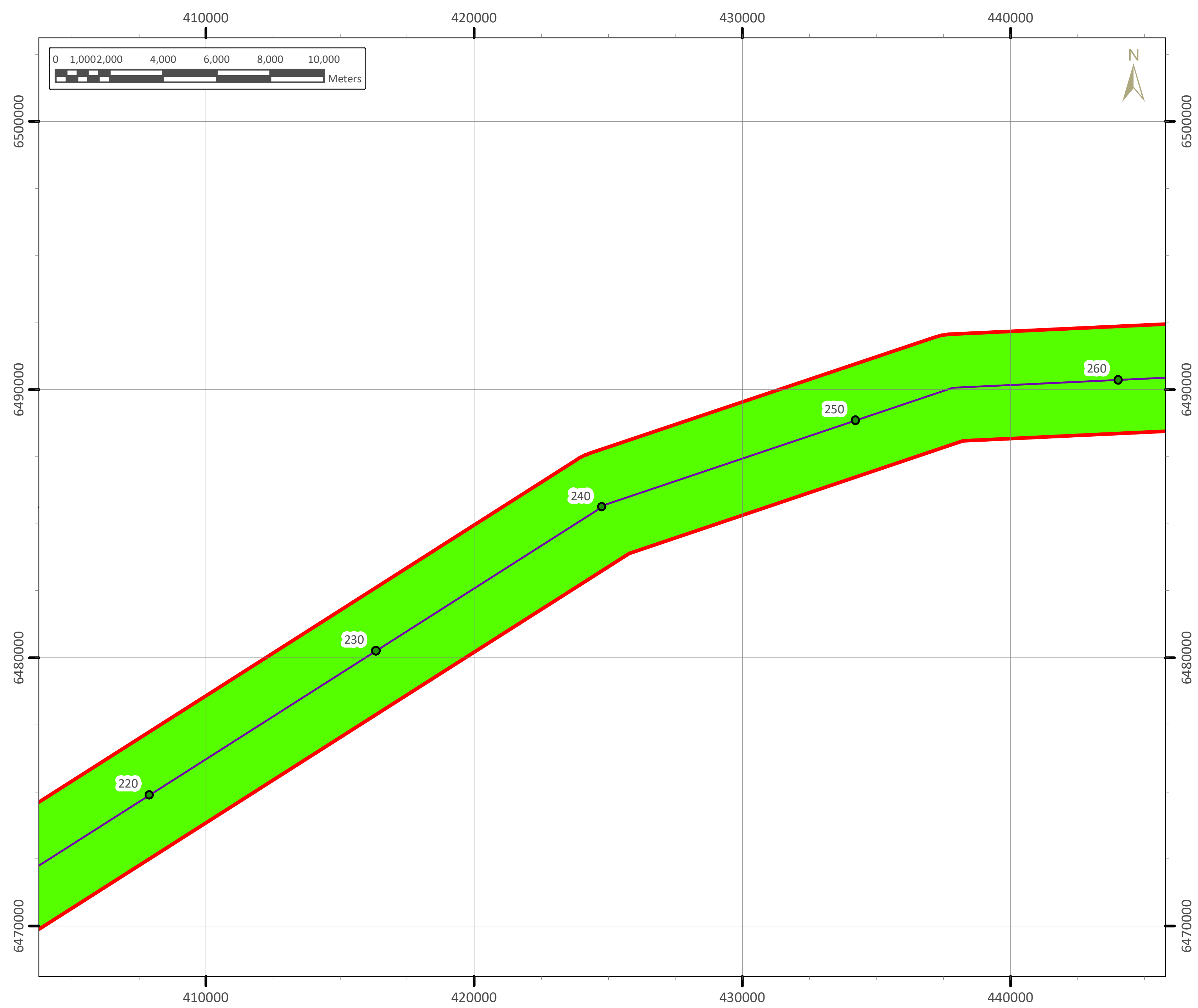

LEGEND

GENERAL

North A KP 10km

Route North A

South B KP 10km

Route South B

South C KP 10km

Route South C

Route Buffer

POTENTIAL UXO THREATS

High Probability of UXO Encounter

Medium Probability of UXO Encounter

Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/9

PURPOSE

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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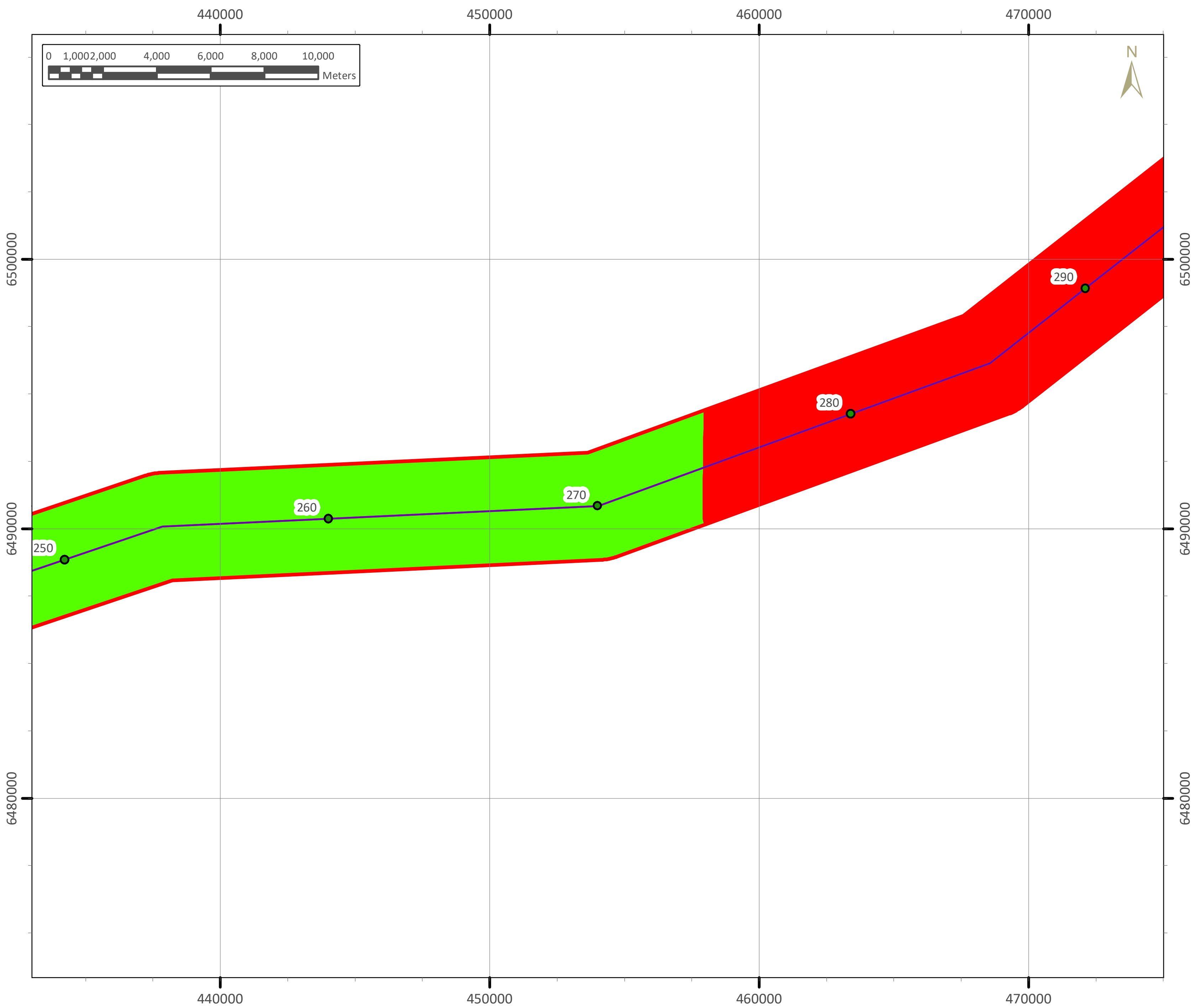

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/10

PURPOSE

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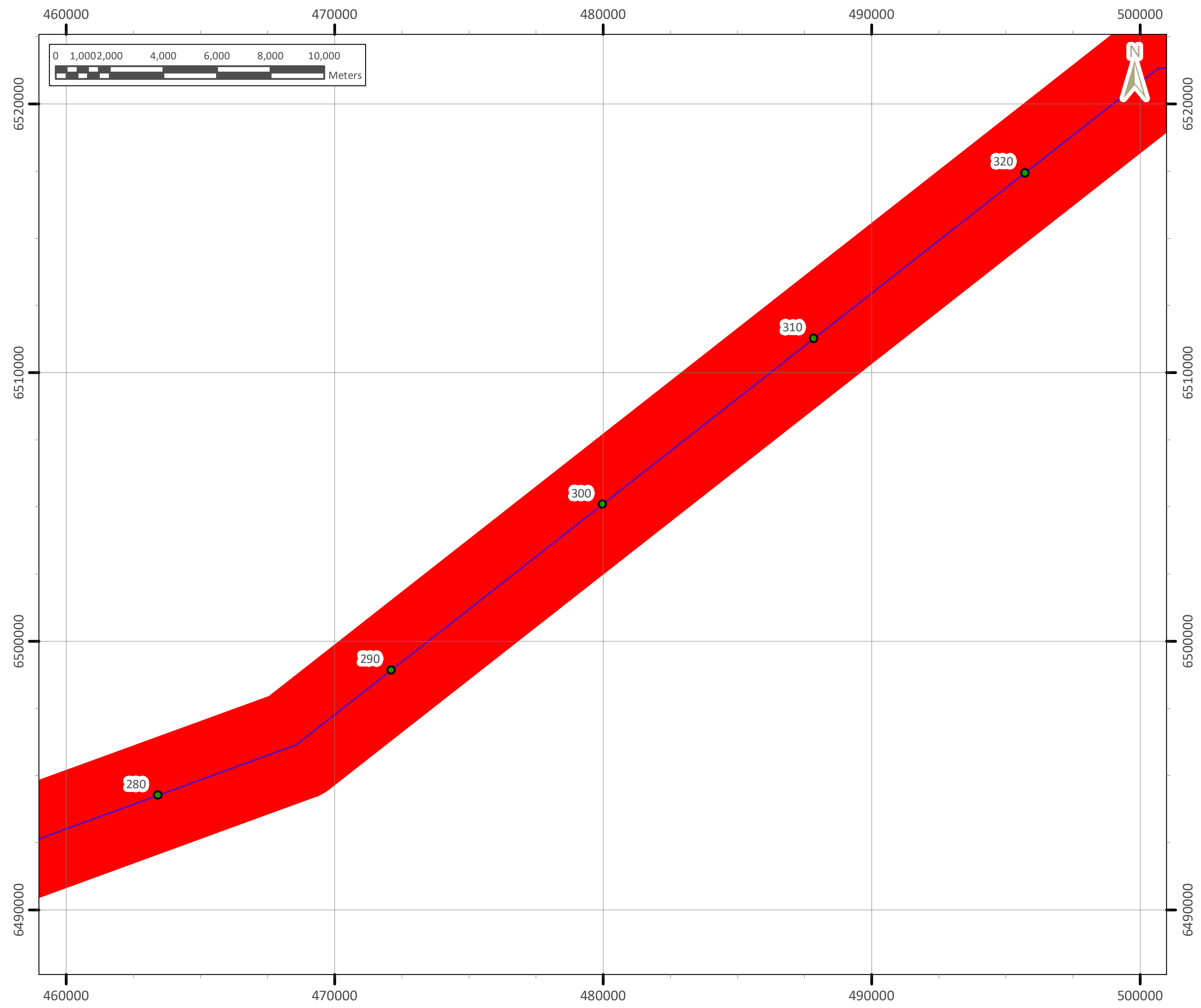


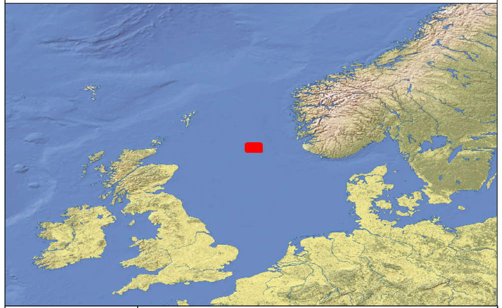
LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter



PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/11

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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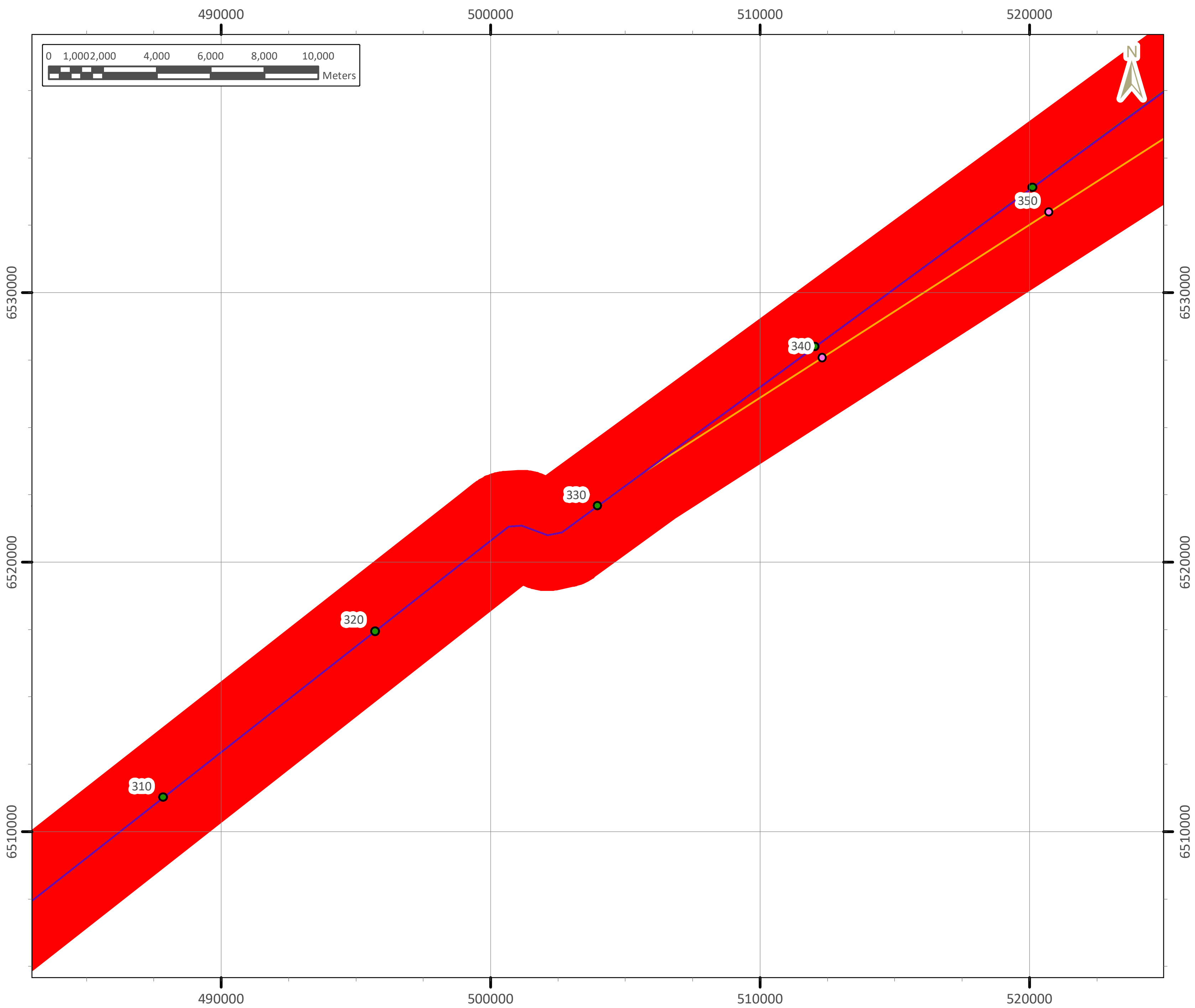

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/12

PURPOSE
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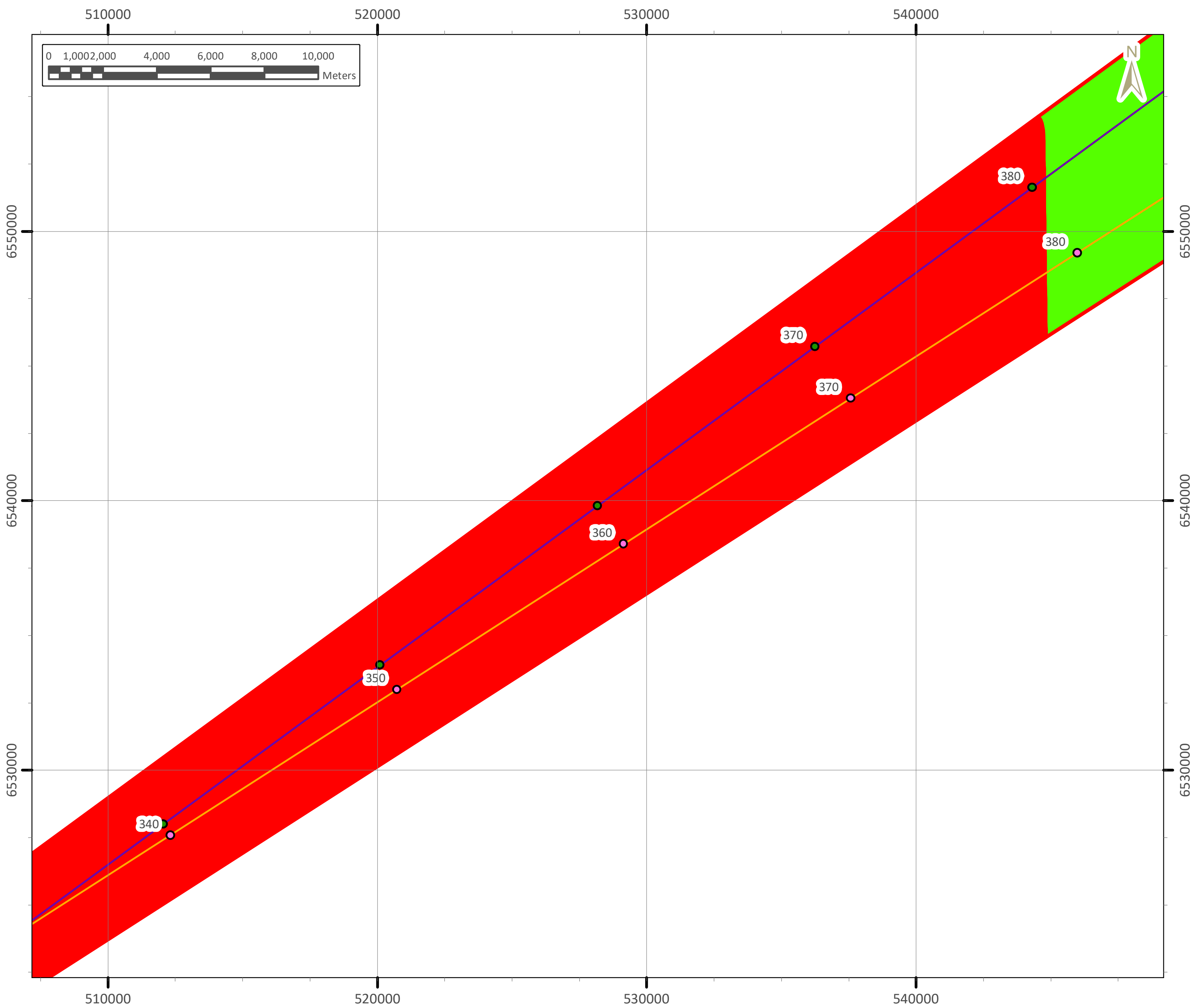

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/13

PURPOSE

FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

W W W . 6 A L P H A . C O M
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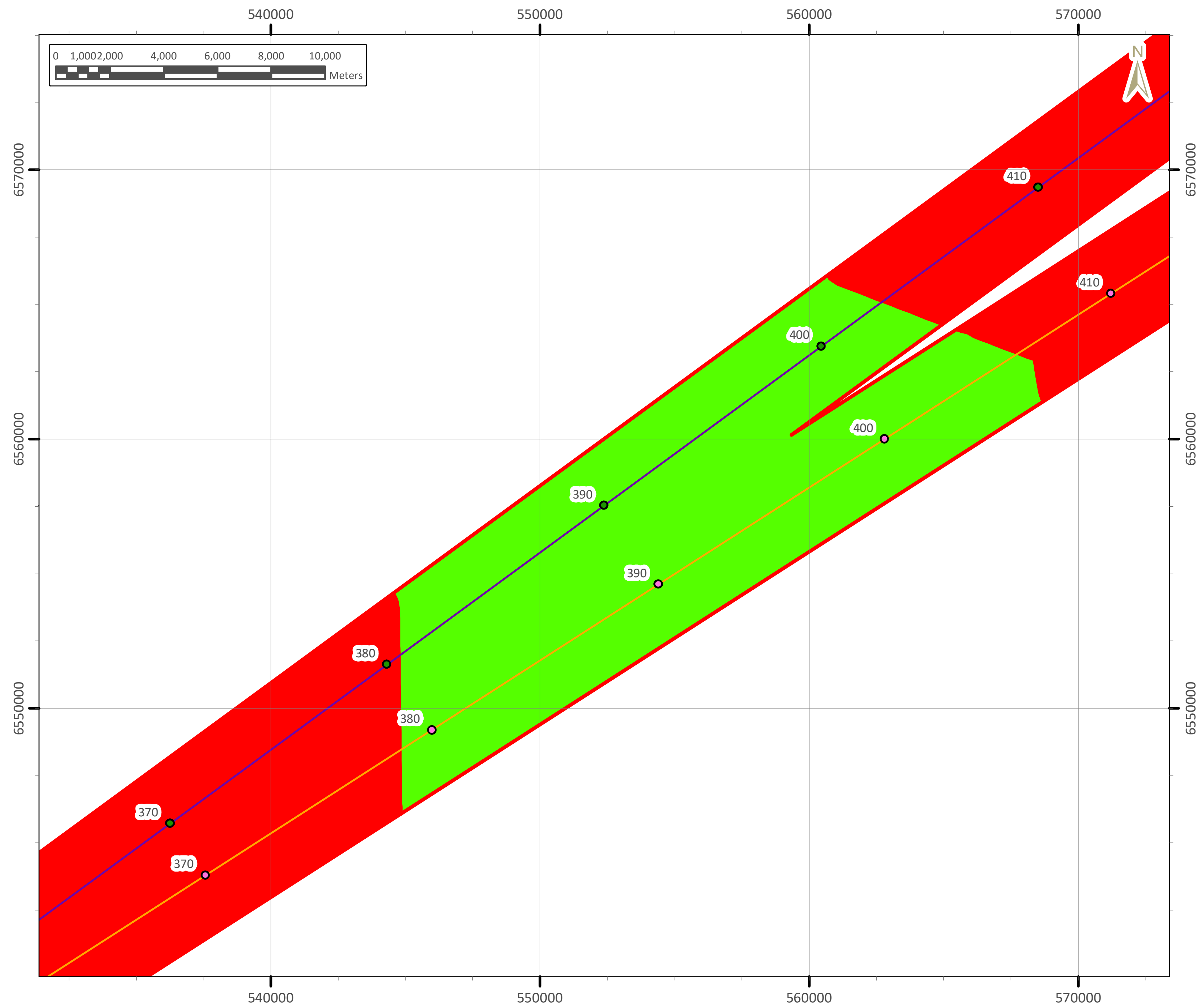

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/14

PURPOSE

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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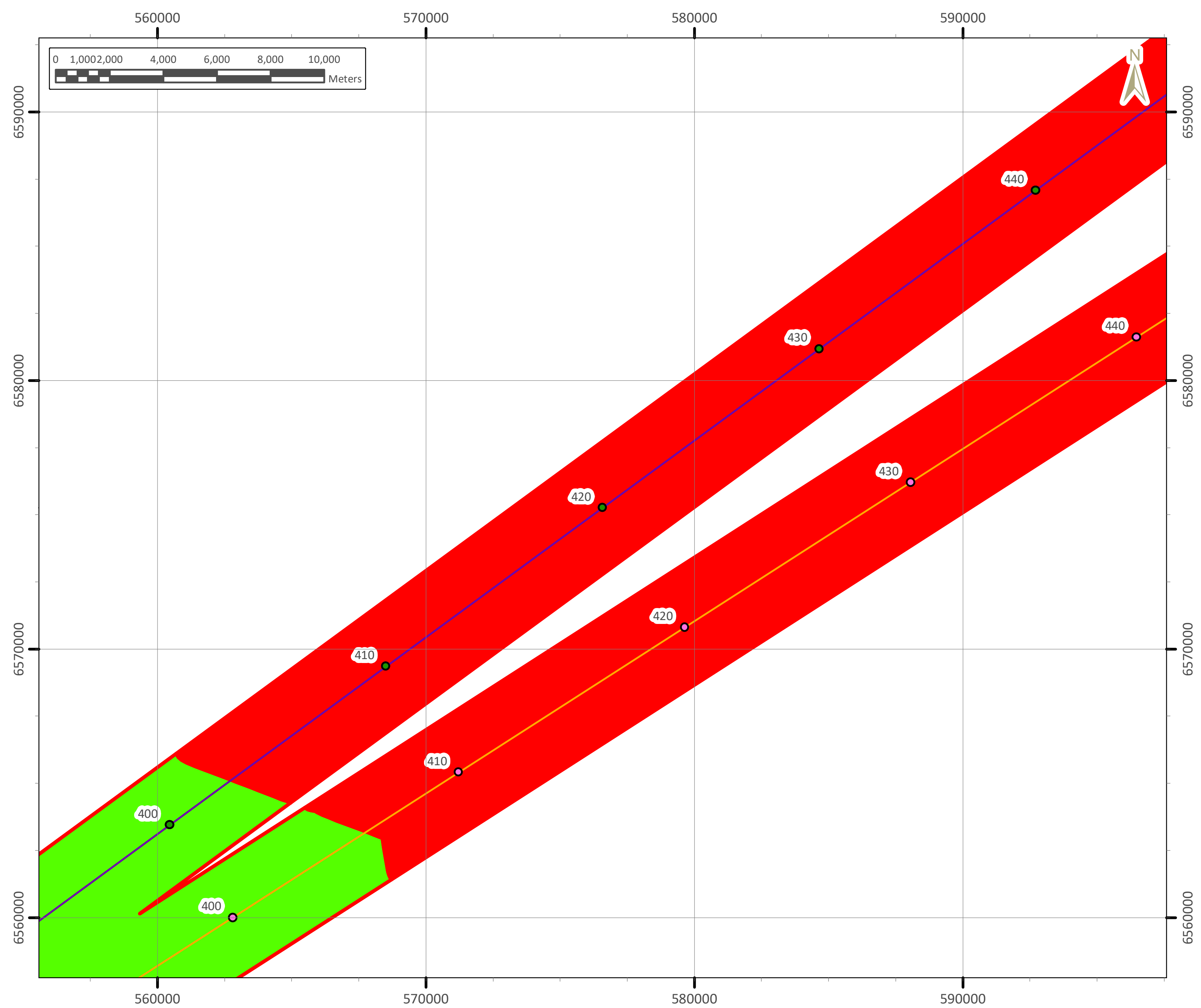

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/15

PURPOSE
FOR INFORMATION USE ONLY

alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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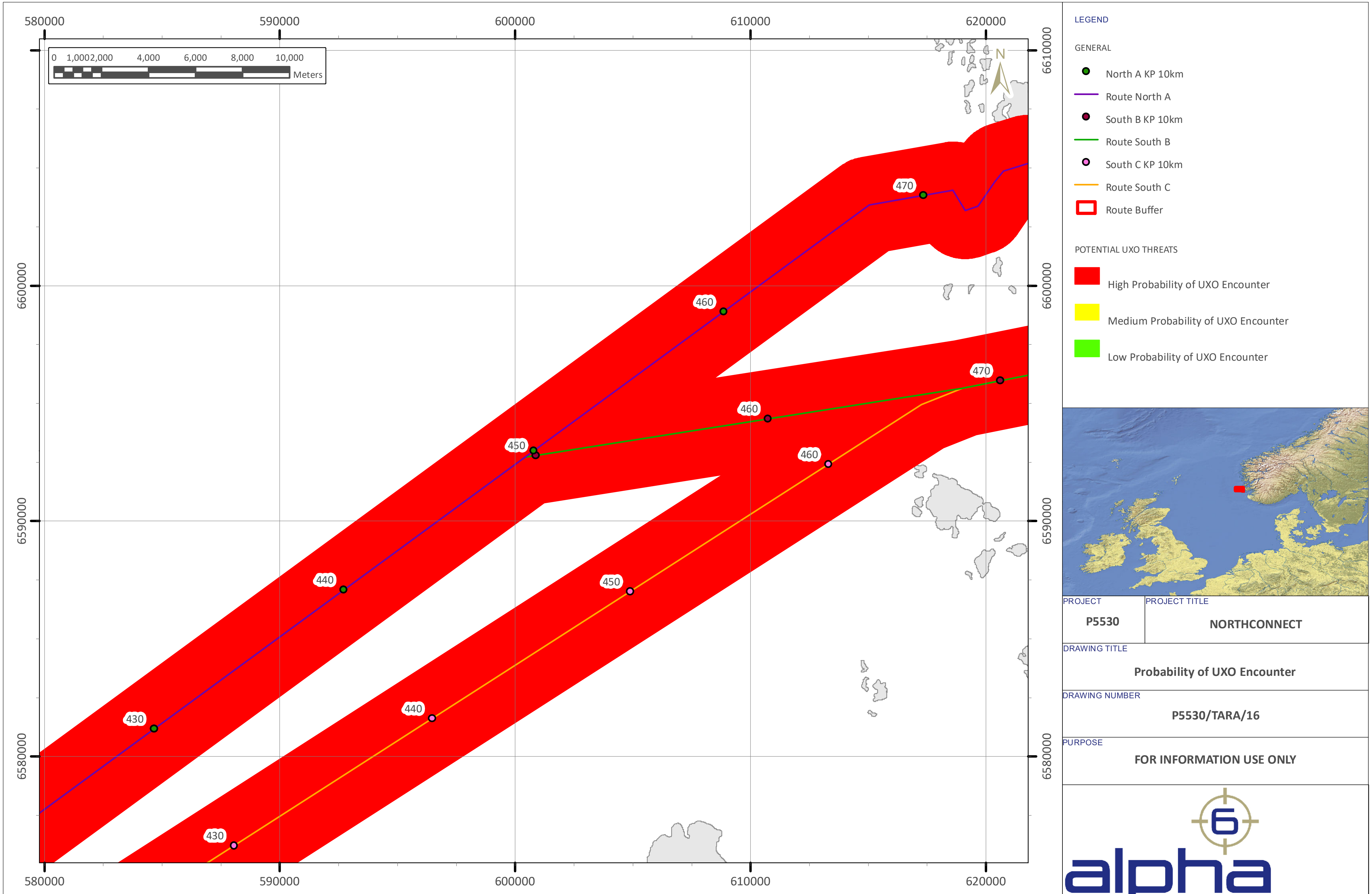

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/16

PURPOSE
FOR INFORMATION USE ONLY

6 alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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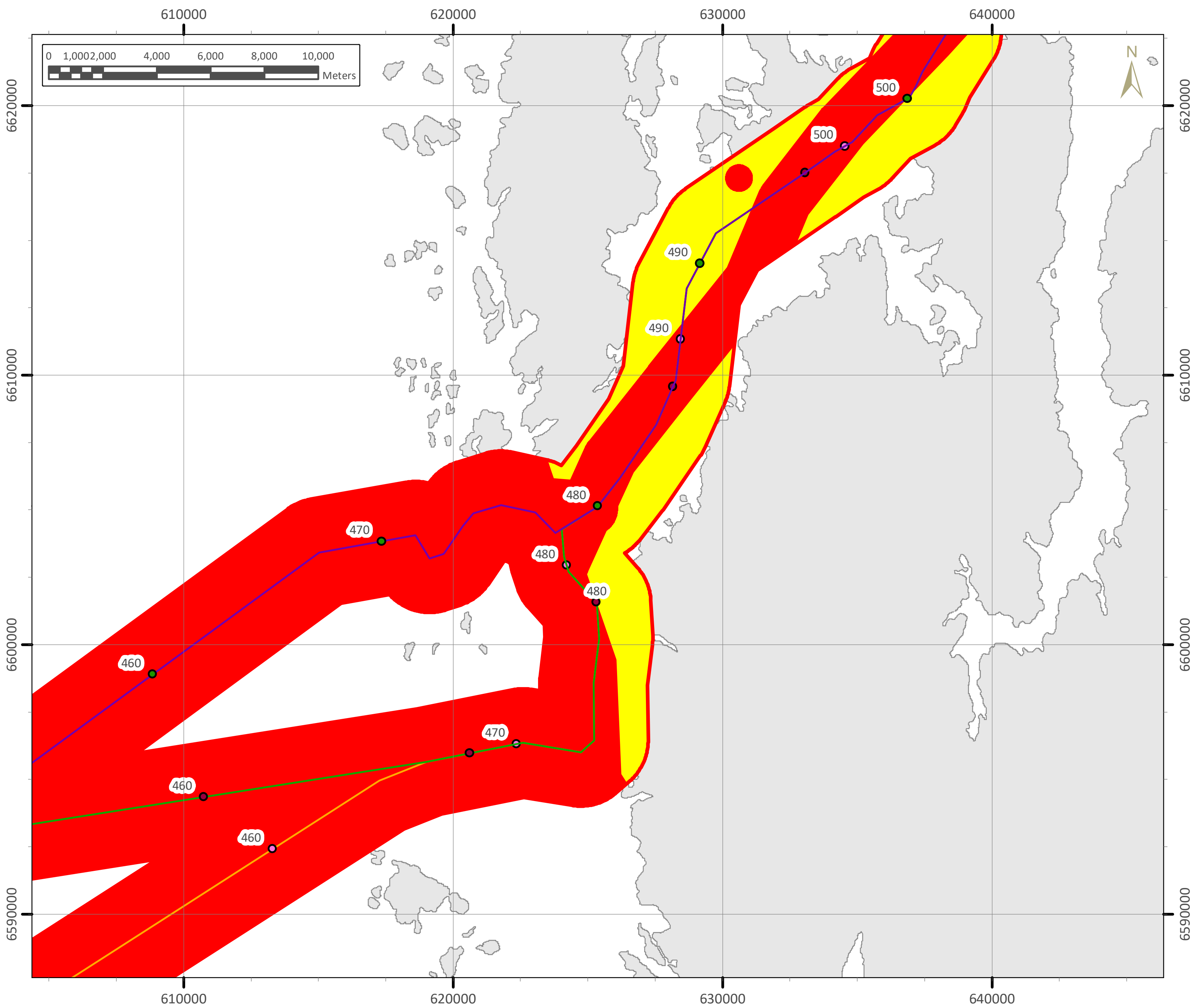

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/17

PURPOSE

FOR INFORMATION USE ONLY

6 alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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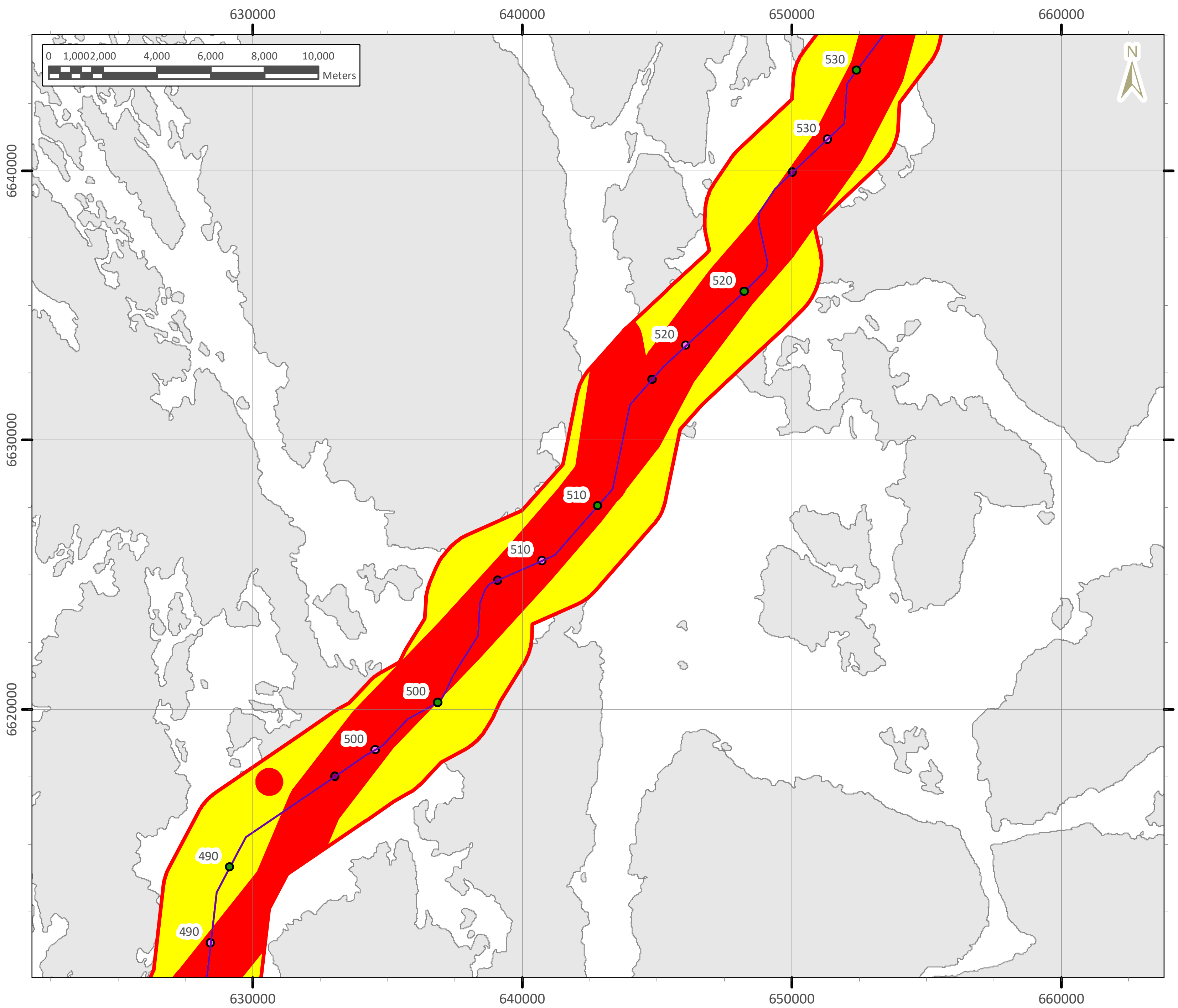

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/18

PURPOSE
FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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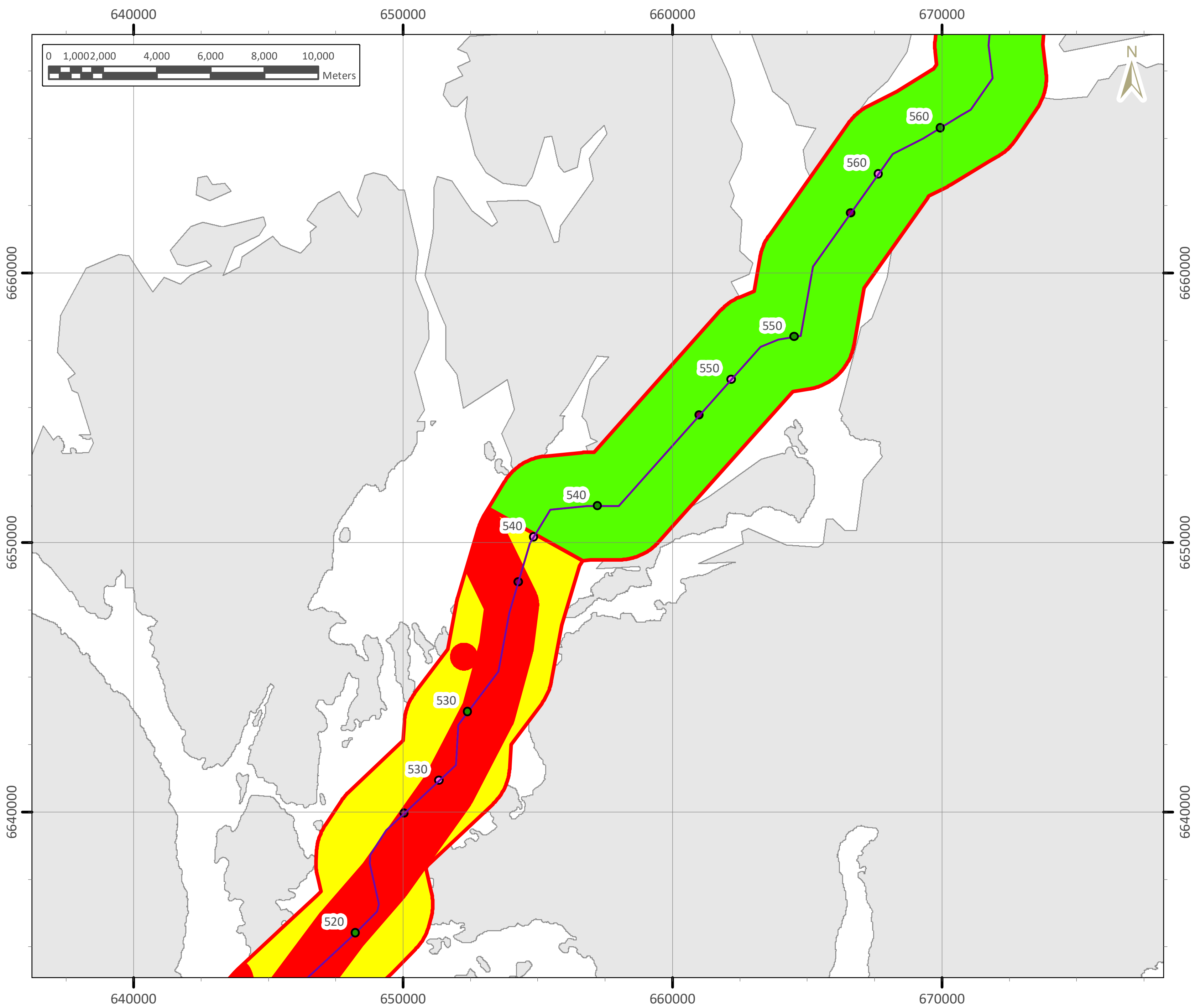

LEGEND

GENERAL

North A KP 10km

Route North A

South B KP 10km

Route South B

South C KP 10km

Route South C

Route Buffer

POTENTIAL UXO THREATS

High Probability of UXO Encounter

Medium Probability of UXO Encounter

Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/19

PURPOSE

FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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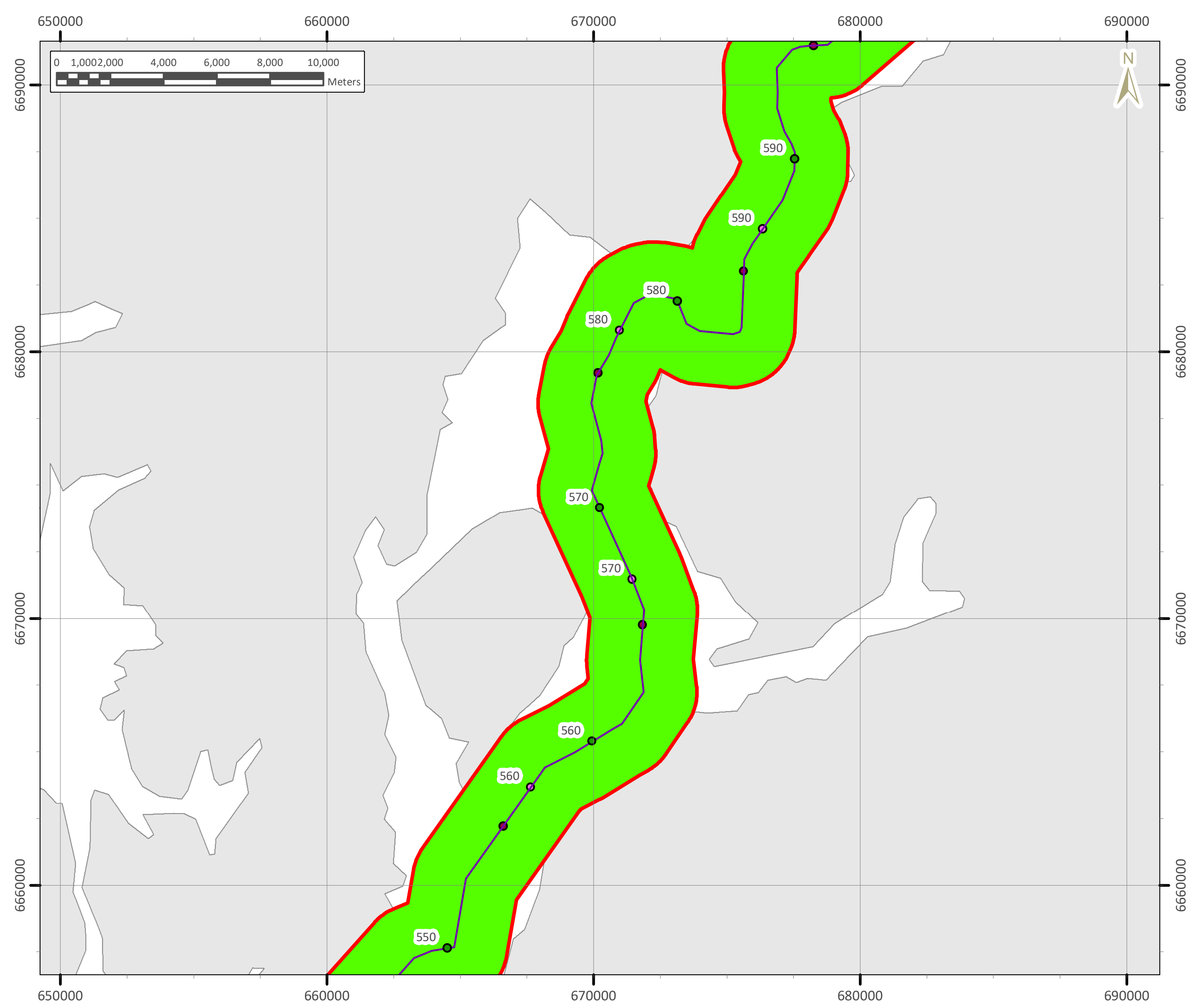

LEGEND

GENERAL

North A KP 10km
Route North A
South B KP 10km
Route South B
South C KP 10km
Route South C
Route Buffer

POTENTIAL UXO THREATS

High Probability of UXO Encounter
Medium Probability of UXO Encounter
Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE
Probability of UXO Encounter

DRAWING NUMBER
P5530/TARA/20

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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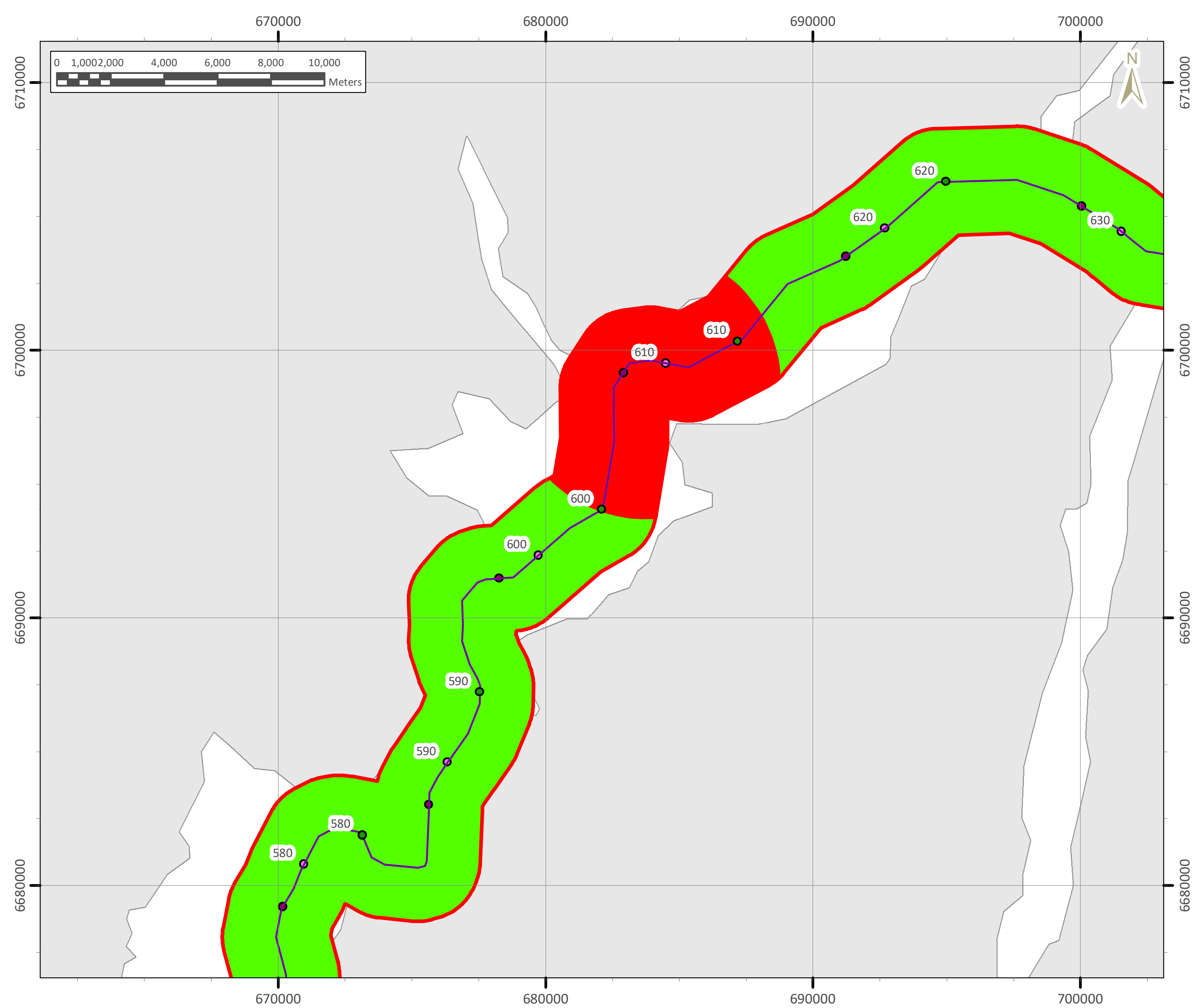

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/21

PURPOSE

FOR INFORMATION USE ONLY

alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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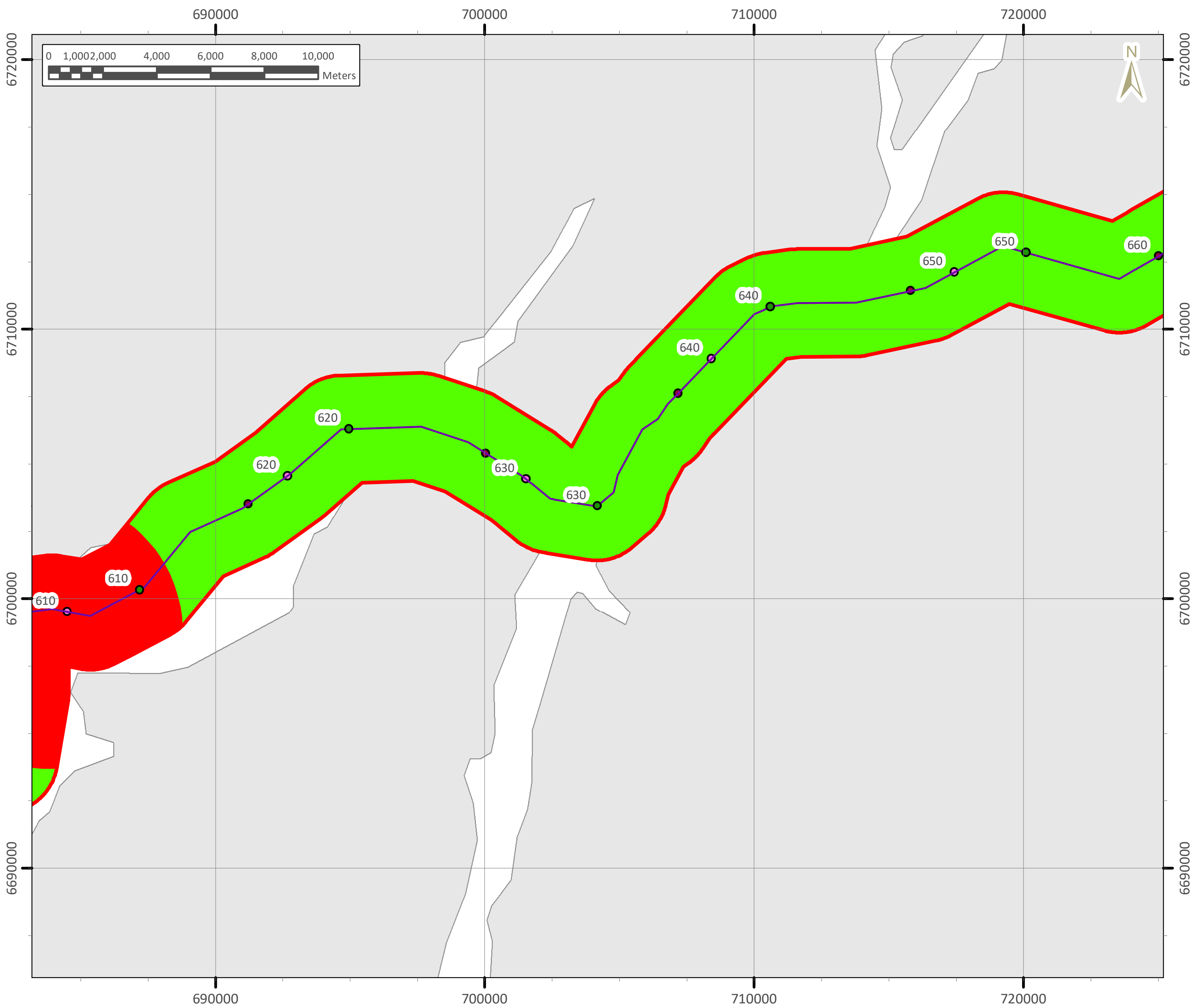

LEGEND

GENERAL

North A KP 10km

Route North A

South B KP 10km

Route South B

South C KP 10km

Route South C

Route Buffer

POTENTIAL UXO THREATS

High Probability of UXO Encounter

Medium Probability of UXO Encounter

Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/22

PURPOSE

FOR INFORMATION USE ONLY

alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

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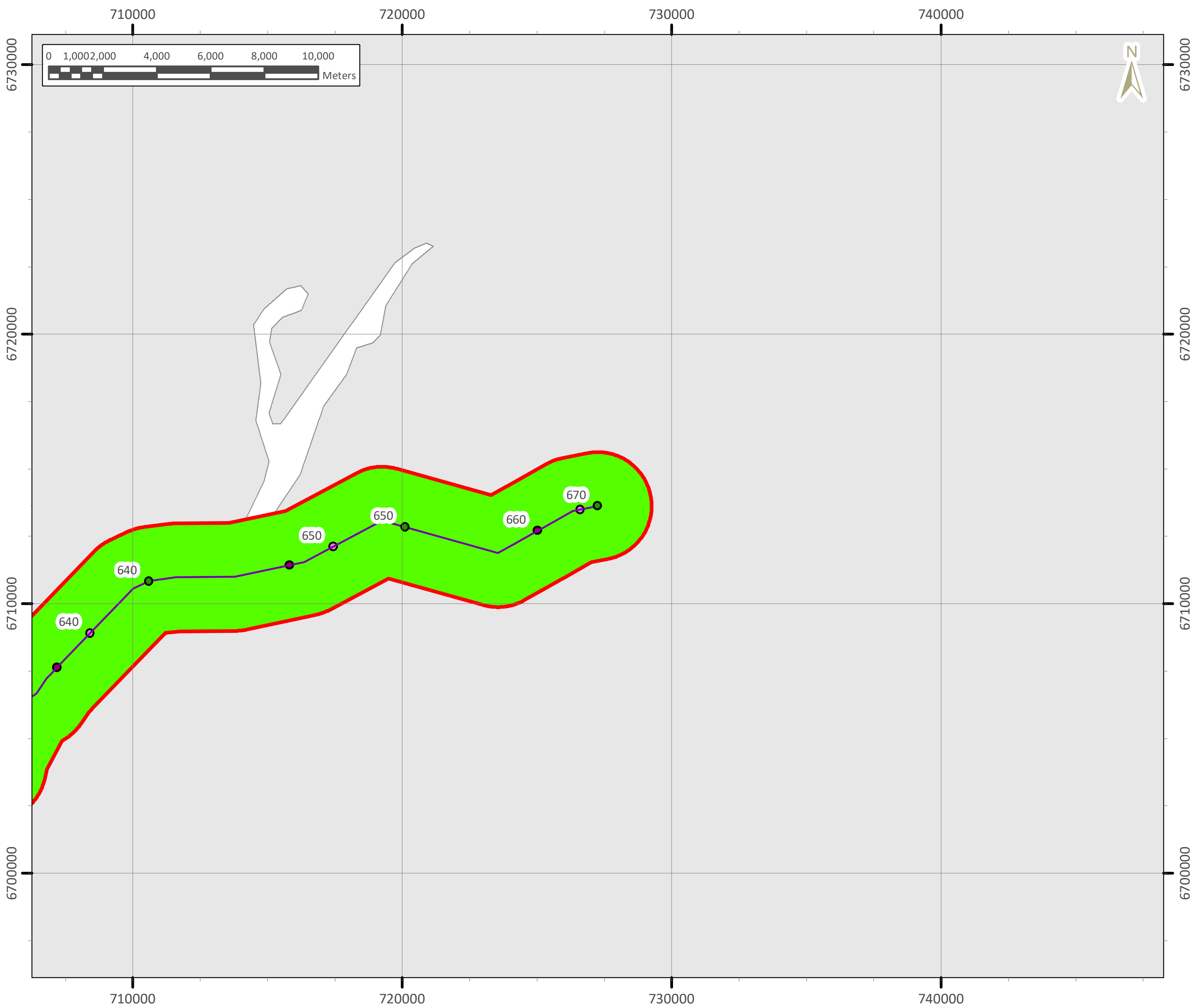

LEGEND

GENERAL

- North A KP 10km
- Route North A
- South B KP 10km
- Route South B
- South C KP 10km
- Route South C
- Route Buffer

POTENTIAL UXO THREATS

- High Probability of UXO Encounter
- Medium Probability of UXO Encounter
- Low Probability of UXO Encounter

PROJECT	PROJECT TITLE
P5530	NORTHCONNECT

DRAWING TITLE

Probability of UXO Encounter

DRAWING NUMBER

P5530/TARA/23

PURPOSE

FOR INFORMATION USE ONLY

alpha ASSOCIATES

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
ETRS 1989 UTM Zone 31N	1:200,000	A4	RG	29/03/2017	RR

W W W . 6 A L P H A . C O M
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Appendix 13

Calculation of Risk to Surface and Sub-Surface Assets

North A – Calculation of Risk to Surface and Sub-Surface Assets: Based on UXO Type, Water Depth and Sensitivity of Receptor

KP (NORTH A)	Probability of UXO Encounter	Approximate Water Depth (M)	Risk to Vessel/Human Life	Risk to Installtion Equipment	UXO Source	Survey Recommendations
0 - 5.9	LOW	0 to -18	LOW	LOW		
5.9 – 8.6	MEDIUM	-18	HIGH	HIGH	• Artillery range • Background threat items	Magnetometer + SSS
8.6 – 23.5	HIGH	-55	HIGH	HIGH	• WWI German minefield • Artillery range • Background threat items	Magnetometer + SSS
23.5 - 28	HIGH	-80	MEDIUM	HIGH	• WWI German minefield • Background threat items	Magnetometer + SSS
29 – 33.7	MEDIUM	-90	MEDIUM	HIGH	• Background Threat Items	Magnetometer + SSS
33.7 – 104.8	HIGH	-80 to -120	MEDIUM	HIGH	• WWI German minefield • WWII British minefield • Wreck related ordnance • Background threat items	Magnetometer + SSS
104.8 - 237	LOW	-110 to -150	MEDIUM	HIGH	• Background threat items	SSS
237 - 238	LOW	-115 to -120	MEDIUM	HIGH	• Wreck related ordnance • Background threat items	SSS
238 – 274.2	LOW	-120 to -95	MEDIUM	HIGH	• Background threat items	SSS
274.2 – 380.5	HIGH	-95 to -270	MEDIUM	HIGH	• WWII German minefield • WWII Axis minelay • Background threat items	Magnetometer + SSS
380.5 – 402.8	MEDIUM	-270 to -285	LOW	HIGH	• Background threat items	Magnetometer + SSS
402.8 – 487.6	HIGH	-285 to -369	LOW	HIGH	• WWI British minefield • WWII British minefield • PEXA training area • Artillery range • WWII American minelays • Background threat items	Magnetometer + SSS
487.6 – 492.9	MEDIUM	-369	LOW	HIGH	• Background threat items	Magnetometer + SSS
492.9 – 535.9	HIGH	-252 to -513	LOW	HIGH	• WWII American minelays • Background threat items	Magnetometer + SSS
535.9 – 600	LOW	-487 to -858	LOW	HIGH	• Background threat items	SSS
600 – 611.2	HIGH	-856 to -858	LOW	HIGH	• Conventional munition dump • Background threat items	Magnetometer + SSS
611.2 – 670	LOW	-856 to -10	HIGH	HIGH	• Background threat items	SSS

South B – Calculation of Risk to Surface and Sub-Surface Assets: Based on UXO Type, Water Depth and Sensitivity of Receptor

KP (SOUTH B)	Probability of UXO Encounter	Approximate Water Depth (M)	Risk to Vessel/Human Life	Risk to Installtion Equipment	UXO Source	Survey Recommendations
0 - 5.9	LOW	0 to -18	LOW	LOW		
5.9 – 8.6	MEDIUM	-18	HIGH	HIGH	• Artillery range • Background threat items	Magnetometer + SSS
8.6 – 23.5	HIGH	-55	HIGH	HIGH	• WWI German minefield • Artillery range • Background threat items	Magnetometer + SSS
23.5 - 28	HIGH	-80	MEDIUM	HIGH	• WWI German minefield • Background threat items	Magnetometer + SSS
29 – 33.7	MEDIUM	-90	MEDIUM	HIGH	• Background Threat Items	Magnetometer + SSS
33.7 – 104.8	HIGH	-80 to -120	MEDIUM	HIGH	• WWI German minefield • WWII British minefield • Wreck related ordnance • Background threat items	Magnetometer + SSS
104.8 - 237	LOW	-110 to -150	MEDIUM	HIGH	• Background threat items	SSS
237 - 238	LOW	-115 to -120	MEDIUM	HIGH	• Wreck related ordnance • Background threat items	SSS
238 – 274.2	LOW	-95 to -120	MEDIUM	HIGH	• Background threat items	SSS
274.2 – 380.5	HIGH	-97 to -270	MEDIUM	HIGH	• WWII German minefield • WWII Axis minelay • Background threat items	Magnetometer + SSS
380.5 – 402.8	MEDIUM	-270 to -285	LOW	HIGH	• Background threat items	Magnetometer + SSS
402.8 – 492.3	HIGH	-285 to -369	LOW	HIGH	• WWI British minefield • WWII British minefield • PEXA training area • Artillery range • WWII American minelays • Background threat items	Magnetometer + SSS
492.3 – 497.7	MEDIUM	-355	LOW	HIGH	• Background threat items	Magnetometer + SSS
497.7 – 540.6	HIGH	-355 to -506	LOW	HIGH	• WWII American minelays • Background threat items	Magnetometer + SSS
540.6 – 604.7	LOW	-506 to -857	LOW	HIGH	• Background threat items	SSS
604.7 – 616	HIGH	-856 to -857	LOW	HIGH	• Conventional munition dump • Background threat items	Magnetometer + SSS
616 – 663	LOW	-10 to -856	HIGH	HIGH	• Background threat items	SSS

South C – Calculation of Risk to Surface and Sub-Surface Assets: Based on UXO Type, Water Depth and Sensitivity of Receptor

KP (SOUTH C)	Probability of UXO Encounter	Approximate Water Depth (M)	Risk to Vessel/Human Life	Risk to Installation Equipment	UXO Source	Survey Recommendations
0 - 5.9	LOW	0 to -18	LOW	LOW		
5.9 – 8.6	MEDIUM	-18	HIGH	HIGH	• Artillery range • Background threat items	Magnetometer + SSS
8.6 – 23.5	HIGH	-55	HIGH	HIGH	• WWI German minefield • Artillery range • Background threat items	Magnetometer + SSS
23.5 - 28	HIGH	-80	MEDIUM	HIGH	• WWI German minefield • Background threat items	Magnetometer + SSS
29 – 33.7	MEDIUM	-90	MEDIUM	HIGH	• Background Threat Items	Magnetometer + SSS
33.7 – 104.8	HIGH	-80 to -120	MEDIUM	HIGH	• WWI German minefield • WWII British minefield • Wreck related ordnance • Background threat items	Magnetometer + SSS
104.8 - 237	LOW	-110 to -150	MEDIUM	HIGH	• Background threat items	SSS
237 - 238	LOW	-115 to -120	MEDIUM	HIGH	• Wreck related ordnance • Background threat items	SSS
238 – 274.2	LOW	-95 to -120	MEDIUM	HIGH	• Background threat items	SSS
274.2 – 378.6	HIGH	-95 to -270	MEDIUM	HIGH	• WWII German minefield • WWII Axis minelay • Background threat items	Magnetometer + SSS
380.5 – 402.8	MEDIUM	-270 to -285	LOW	HIGH	• Background threat items	Magnetometer + SSS
402.8 – 487.6	HIGH	-285 to -355	LOW	HIGH	• WWI British minefield • WWII British minefield • PEXA training area • Artillery range • WWII American minelays • Background threat items	Magnetometer + SSS
487.6 – 492.9	MEDIUM	-355	LOW	HIGH	• Background threat items	Magnetometer + SSS
492.9 – 538.9	HIGH	-355 to -507	LOW	HIGH	• WWII American minelays • Background threat items	Magnetometer + SSS
538.9 – 603	LOW	-507 to -857	LOW	HIGH	• Background threat items	SSS
603 – 614.2	HIGH	-856 to -857	LOW	HIGH	• Conventional munition dump • Background threat items	Magnetometer + SSS
614.2 – 670	LOW	-10 to -857	HIGH	HIGH	• Background threat items	SSS

Characteristics of UXO Threat Items and their Primary Detection Tool

Location	UXO Reference Target	Dimensions (Diam./Length) [m]	Material	Net Explosive Quantity	Primary Detection Tool
Background Threat Items	GP250 UXB	0.28 m × 0.91 m	Steel	58kg Amatol / Pentolite.	Magnetometer + SSS
	GP500 UXB	0.36 m × 1.14 m	Steel	121kg TNT /Amatol.	Magnetometer + SSS
	SC 50 UXB	0.76 m x 0.20 m	Steel	25kg TNT / Amatol / Trialen.	Magnetometer + SSS
	SC 250 UXB	0.37 m x 1.19m	Steel	130kg TNT / Amatol	Magnetometer + SSS
	SC 500 UXB	0.47 m x 1.45 m	Steel	220kg TNT /Amatol / Trialen.	Magnetometer + SSS
	Mk VII Depth Charge	0.45 m × 0.70 m	Steel	132kg TNT / Amatol.	Magnetometer + SSS
	Torpedo G7a	0.53m x 7.18 m	Steel	280kg Hexanite.	Magnetometer + SSS
Artillery Range	6" Artillery Projectile	0.15m x 0.68 m	Steel	3.6kg TNT	Magnetometer + SSS
WWI Minefield	German EMA sea mine	0.86 m x 1.17 m	Steel	150kg Hexanite	Magnetometer + SSS
	British MkVI sea mine	0.86 m x 0.86 m	Steel	100kg TNT	Magnetometer + SSS
WWII Minefield	German Luftmine A	0.66 m x 1.73m	Aluminium	300kg Hexanite	PI + SSS (Magnetometer)
	German Luftmine B	0.66 m x 2.64 m	Aluminium	705kg Hexanite.	PI + SSS (Magnetometer)
	German BM1000 Ground Mine	0.66 m x 3.21 m	Steel	725kg Hexanite	Magnetometer + SSS
	German EMC II	1.16 m x 1.23 m	Steel	300kg Hexanite	Magnetometer + SSS
	British MK XVII Mine	1.02 m x 1.22 m	Steel	145kg TNT /Amatol	Magnetometer + SSS
PEXA Modern	Practice 10lb bomb	0.08 m x 0.46 m x	Steel	0kg	Magnetometer + SSS
Munition Dump	All Types	Various	Steel	Various	Magnetometer + SSS
Shipwrecks	Mk VII Depth Charge	0.45 m × 0.70 m	Steel	132kg TNT /Amatol	Magnetometer + SSS
	Torpedo G7a	0.53m x 7.18 m	Steel	280kg Hexanite	Magnetometer + SSS
	6" Artillery Projectile	0.15m x 0.68 m	Steel	3.6kg TNT	Magnetometer + SSS
	SC 50 UXB	0.76 m x 0.20 m	Steel	25kg TNT / Amatol / Trialen.	Magnetometer + SSS

Annexes

Annex A

UXO Risk and Legal Position

Contents

1 UXO Risk and Legal Position

1.1 Introduction

6 Alpha's view is that our clients' need to have a coherent view of what the law is likely to require concerning potential UXO risk. The purpose is not only to discharge both statutory and tortuous legal duties, but also to protect those that might be exposed to UXO risks in the marine environment.

The primary regulation and minimum standard requirement for all *European Union* (EU) countries and all businesses residing in and/or working within the EU is the Council Directive 89/391/EEC of 12th June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work. Other EU standards such as the EEC Directive 383/91/EEC provide the framework for the correct extraction of business with regards to Health and Safety within the EU.

The interpretation of EU legislation concerning UXO is *6 Alpha*'s interpretation. This has not been subjected to formal legal scrutiny or any form of legal test, nor has it been endorsed (formally or informally) by the EU or other National legal entities. Nonetheless, we believe that it is accurate and founded upon significant empirical legal research and UXO project management experience.

Ultimately however, it is for both National and ultimately EU courts to decide whether or not duty-holders have complied with the law. The following legal interpretation, the subsequent UXO risk assessment and associated risk mitigation measures upon which they are founded, aim to discharge legal duties in relation to the ALARP principal in general and its applicability to UXO risks in particular.

1.2 Appropriate Legislation, UXO Guidelines and ALARP Application

In the construction/civil engineering arena (in the EU), relevant statutory instruments (with which the Client will have to comply) are in general, likely to encompass Health and Safety at Work legislation in its various forms.

The Client may also face a common law liability (for negligence and a potential breach of duty) if reasonable steps are not taken to identify and appropriately ameliorate risks posed by UXO.

If UXO is unexpectedly discovered and presents a life-threatening situation, then the relevant emergency authorities may lend assistance. 6 Alpha has assumed however, that the identification of risks and their amelioration is the primary responsibility of the Client and its principal sub-contractors as in the experience of development within or beyond UK/Channel Island territorial waters.

We have assumed that *European Union* (EU) law, specifically that concerned with the protection of workers from work-place hazards, will apply in a similar way and will be otherwise applicable; either directly or indirectly through its application in the Channel Islands and/or EU Law. Further standards and guidance are presented in the main document at section 2.3.

In terms of dealing with UXO hazards and risks, we believe that by applying broad EU guidelines in terms of risk assessment, risk treatment and risk management**,** together with our own UXO expertise will enable the Client to comply with EU statutory and Basic Law. In addition, if and when this is employed as a legal and technical benchmark (including outside UK territorial waters or overseas), it is also likely to meet with any other reasonable legislation, guidance and standards that might be encountered.

1.3 Determining that UXO Risk has been reduced to ALARP

Determining that UXO risks have been reduced to ALARP involves an assessment of the **UXO risk** to be avoided, an assessment of the **sacrifice** (in terms of money, time and effort) involved in taking control measures to avoid or mitigate that risk, and a **comparison** of the two. A diagrammatic representation for meeting with ALARP is presented at Figure 1.3.

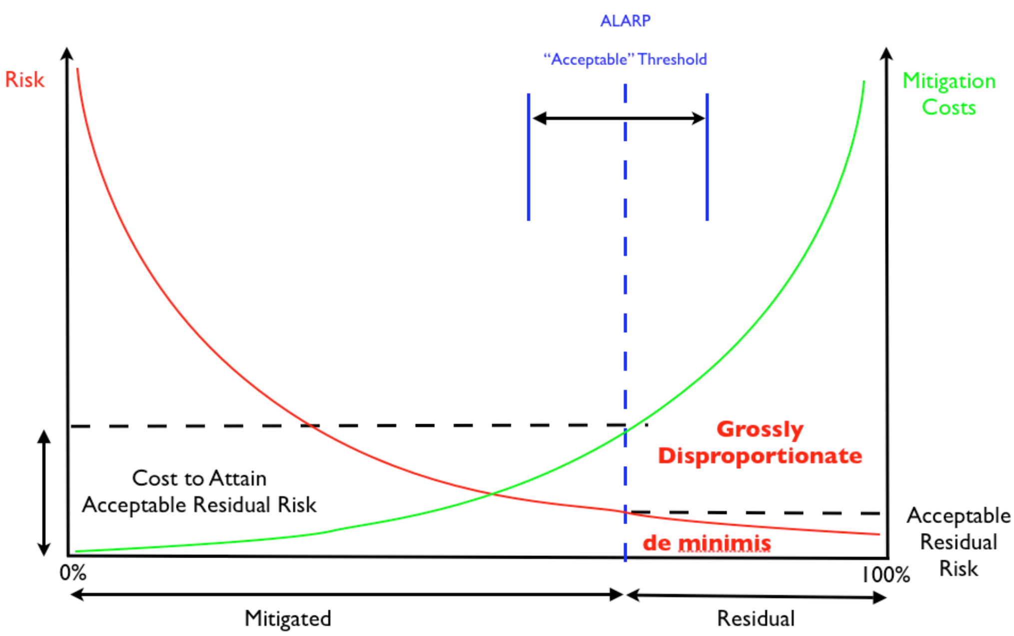

Figure 3.3 – Meeting with ALARP

1.4 UXO Risk Tolerance

6 Alpha have made certain assumptions about The Client as well as its acceptance of UXO risk. Our assumptions include that the following interrelated elements are to be considered:

- **Corporate Governance** – is the system by which companies are managed and controlled. It is assumed that The Client will wish to adhere to the highest international standards of corporate governance. Discharge of corporate responsibility is expected to be on risk-based criteria and it is expected that The Client will have in place a framework for managing risk for good governance. It is anticipated that safety and risk management are integrated in the Client's business culture.
- **Risk Management –** The Client will expect the highest standard of risk and safety management to be applied to this project and will have a risk management system in place for responding to business, programme and project risks. Any risks posed by UXO will have to be assessed based upon probability and consequence criteria. High rated UXO risks will have to be avoided or otherwise mitigated not only in accordance with the law, but also with best proactive UXO risk management guidelines. The Client will not only rely upon *6 Alpha's* experience and independence to identify UXO risks, but also to design appropriate UXO risk management solutions in accordance with the law in general and the ALARP principal in particular; and, to warrant that the geophysical survey and UXO risk mitigation contractors responsible for the subsequent execution of those works, perform to appropriate quality and best practice standards.
- **Safety –** Personnel safety will assume the highest priority. The protection and preservation of equipment, property and the environment, whilst highly important, will remain subservient to the safety of personnel.

Annex B

Technical Ordnance Details

Contents

1 Explosive Threat Items

1.1 General

Having established potential contamination sources, the following generic ordnance groups are considered likely to present a threat to the proposed development. Clearly, some varieties of UXO are likely to be more common within the project area than others.

1.2 Weapon Fill Materials

1.2.1 High Explosives (HE)

HE compounds detonate at velocities ranging from 1,000m to 9,000m per second, and may be subdivided into two explosives classes, differentiated by their respective sensitivity:

- **Primary Explosives** – are extremely sensitive to mechanical shock, friction and heat to which they will respond by burning rapidly or detonating. Examples include mercury fulminate and lead azide. This characteristic makes them unsuitable to use as base (i.e. main-fill) explosives in military ordnance. Sensitivity is an important consideration in selecting an explosive for a particular purpose, e.g. the explosive in an armour-piercing projectile must be relatively insensitive, or the shock of impact would cause it to detonate before it penetrated the target.

- **Secondary Explosives** – are relatively insensitive to shock, friction and heat. They may burn when exposed to heat in small-unconfined quantities, although the risk of detonation is always present (especially when they are confined and/or are burnt in bulk). Dynamite, TNT, RDX and HMX are classed as secondary high explosives, which are commonly used as, base explosives in military ordnance. PETN is the benchmark compound; those explosives that are more sensitive than PETN are classed as primary explosives.

1.2.2 Low Explosives

A low explosive is usually a mixture of a combustible substance and an oxidant that decomposes rapidly (in a process akin to very rapid burning and known as deflagration).

Under normal conditions, low explosives undergo deflagration at rates that vary from a few centimetres per second to approximately 400m per second. Low explosives are normally employed as propellants, included in this group are, for example; gun-powders, pyrotechnics and illumination devices such as marine markers or flares.

1.2.3 Propellants

In ballistics and pyrotechnics, a propellant is a generic name for those chemicals used for propelling projectiles (e.g. artillery shells or mortars) from a weapon system.

Propellants are always chemically different from high explosives (as compared with those used in munitions for "target effect" for example) they are not designed to release their energy as quickly and as a result do not produce a blasting/shattering effect (because such an effect would significantly damage or destroy the associated weapons platform e.g. gun/howitzer or mortar).

However, some explosive substances can be used both as propellants and as "burster charges", (e.g. gunpowder), and some of the ingredients of a propellant may be similar to those employed to make explosives. If bulk propellants are confined and burn very rapidly the result can be similar to that witnessed by a (small) high explosive charge. Propellants therefore remain highly dangerous and can come in various forms, e.g. powder or thin sticks and can be contained in pre-formed containers or bags.

A very typical propellant burns very rapidly but controllably and non-explosively to produce thrust (generated by rapidly expensing gas, generating pressure) and thus accelerating a projectile/rocket from a weapon platform. In this sense, common or well-known propellants include:

- Gun propellants, such as:
    - Gunpowder (black powder);
    - Nitrocellulose-based powders;
    - Cordite;
    - Ballistite;
    - Smokeless powders.
- Compounds, which may be mixed with a solid oxidiser (such as ammonium perchlorate or ammonium nitrate) or a rubber (such as HTPB or PBAN), or a powdered metal (commonly aluminium).

1.3 Artillery Projectiles

Artillery projectiles may be classified and grouped as follows:

- **HE –** High Explosives are designed to cause damage by a combination of high explosive blast and fragmentation;
- **Fragmentation** – designed to be used primarily against personnel.

- **AP and SAP –** Armour Piercing (AP) and Semi-Amour Piercing (SAP) shells are always base fuzed and are generally designed for the attack of lightly armoured vehicles, concrete emplacements dug outs etc. they are not intended for heavily armoured targets.
- **Smoke** – Used for the production of smoke screens; various fillings are used, the most common being white phosphorous.
- **Illuminating** – designed to illuminate an area or specific target at night; a burning flare is suspended from a small parachute to provide an intense white light.
- **Practice –** Commonly a solid shot fitted with a so-called "spotting charge" which gives an indication of where it lands.

1.4 Torpedoes

Torpedoes were utilised by a range of vessels including submarines and the surface fleet. Unlike sea mines (which are a "mass-weapon" system deployed in order to strike an opportunity target), torpedoes were usually specifically targeted (i.e. fired and/or guided to a known target) rather than deployed in mass.

The guidance systems used in torpedoes are often sophisticated and include homing systems reliant upon *inter alia* acoustic signature. However, any power supply (upon which guidance and initiation systems rely) in WWII torpedoes is considered expended and it is therefore highly unlikely that any residual current in fact exists, or that a tiny amount which may theoretically exist, could not be considered sufficient to enable the torpedo to function as originally intended.

Whilst it is possible that unexploded torpedoes might be encountered, it is anticipated that their potential discovery is likely to be significantly less frequent than other "mass" naval weapons e.g. sea mines. They are nonetheless less dangerous. Given they are manufactured from ferrous metal and they have generally a very long slender profile, they are usually relatively easy to detect by geophysical survey for UXO.

1.5 Sea Mines

1.5.1 General

Sea mines (which were employed by both sides engaged in WWI and WWII), were designed either to be buoyant or to sink; the former variety tended to be moored but if they were not initiated (or cleared at the end of the war), then they often sank and drifted on the seabed with tides/weather.

Some British mines could be programmed to self neutralise, often by sinking themselves and allowing the ingress of salt water to render the firing circuit inoperable. Although self-neutralising sea mines could not function today as originally designed, the detonators and HE charges remain intact; they are dangerous. Official records also state that not all of the mines had the "sterilisation plugs" fitted to enable self-neutralisation.

Additionally, the detonators in mines are, by design, made from a sensitive explosive compound (often picric-acid based), which remains susceptible to shock to this day, although exposure to saltwater does not generally increase this sensitivity. All WWII vintage sea mines are filled with HE (usually ammonium nitrate and TNT compositions e.g. ammonal or minol), which often remains in sufficiently good condition to detonate to this day; thus they are dangerous.

1.5.2 Fuzing

Sea mines can be armed with complex fuzing and initiation mechanisms, which may be categorised as follows:

- **Hydrostatic Fuzing** – A valve that detects the difference in water pressure (i.e. generated by a passing vessel). Some sophisticated German WWII mines had this type of fuzing;
- **Magnetic Fuzing** – A fuze that detects a displacement of the ambient magnetic field, normally by the introduction of a ferrous metal object (such as a passing vessel);
- **Sonar Fuzing** – Based upon a similar principle as radar (i.e. "Doppler Shift'), whereby any "positive shift" (i.e. closing), underwater sonar signal to the sea mine, is interpreted as a potential target vessel and therefore the arming sequence is initiated.
- **Contact Fuzing** - The externally mounted chemical horns (or spikes), consisted of a lead outer sheath, which contained two separated chemical ampoules. Upon contact, the external horn would crumple, thereby crushing the ampoules and allowing the chemicals to mix. The resultant mixture would immediately produce either an electrical charge or combustion, forming the basis for an explosive chain-reaction and the detonation of the bulk high explosive contained within the main body of the mine. The older generation of moored sea mines were, more commonly, designed to function upon contact with a ship or vessel.

1.5.3 German Influence Mines

After completing their initial sea mine campaigns, the German military sought to exploit the potential value of so called "influence mines", which could be laid by aircraft. The mine was fabricated from aluminum and was cylindrical in shape with a rounded nose. Originally designed as a magnetically triggered sea mine, the two (German) designations were Luftmine A (LMA) and Luftmine B (LMB), which were 500 kg and 1,000 kg masses and 1.7 m and 2.6 m long, respectively. They were in fact modified land mines, which could be easily modified for deployment by surface craft. Although LM series of mines had a range of different initiation devices, the basic design appears to have changed little throughout WWII.

When used as parachute mines, they were armed by a clockwork fuze mechanism (although such mechanisms are considered highly unlikely to be in working order today, the HE in the adjacent fuzes remain sensitive and potentially, highly dangerous).

They were very widely used by the Germans during WWII with devastating results. The firing system was most commonly initiated by magnetic influence, but acoustic types were also used, sometimes in combination with magnetic influence (i.e. both influences were required to initiate the mine). Later in WWII, water-pressure sensing initiation systems were also developed.

The primary disadvantage of employing air delivered varieties of influence mines against shipping, was their low rate of descent which was deliberately retarded by parachute; (otherwise they may have broken up upon (un-retarded) impact with the water). It was therefore very difficult to emplace them with any accuracy, e.g. into known shipping lanes. To enhance delivery accuracy, the mines had to be dropped from a relatively low altitude, which made the deploying aircraft more vulnerable to anti-aircraft fire. These problems were probably the main reason for the Luftwaffe's development of the BM mine series, the first variant of which was dropped in the same manner as a conventional HE bomb i.e. in free-fall without any retarding features.

1.6 Land Mines

Landmines fall into two broad categories:

- **Anti-Tank**; designed to destroy armor or vehicles, employing a relatively large Net Explosives Quantity (NEQ) of High Explosives (HE); they may be emplaced in all categories of minefield;
- **Anti-Personnel**; designed to severely injure (e.g. cause sufficient injury to warrant traumatic amputation of a lower limb, but not to kill) dismounted infantry. Anti-personnel mines employ a relatively small NEQ of HE; they may be emplaced within all categories of minefield in order to hinder minefield-breaching assets and to generate a barrier to dismounted infantry movement.

The most commonly deployed land mine on the “Atlantic Wall” was the “S-Mine” (an anti-personnel mine). The “S-Mine” is cylindrical in shape and is 130mm tall and 100mm in diameter and it weighs approximately 4 kilograms. The main charge of the mine uses TNT as its explosive and the propelling charge is black powder. The standard pressure sensor for this device is designed to activate if depressed by a weight of approximately 7 kilograms.

The most commonly deployed anti-tank mine deployed on the “Atlantic Wall” was the “Teller Mine”. This device has a height of 76mm, a diameter of 318mm and a weight of 9.1kg. The explosive content is 5.5kg of TNT and the pressure sensor is designed to activate if depressed by a weight of approximately 90kg.

1.7 Depth Charges

The depth charge was designed to counter the threat posed by submarines/U-Boats. The generic design resembles a drum containing HE with a hydrostatic fuze, which initiated the main charge at a preset depth (as a result of the ambient water pressure). They were fired from the stern or sides of ships (or a combination of both). As the war progressed, the Royal Navy introduced the so-called “Hedgehog” and “Squid” systems, which enabled their depth charge to be fired forward from the bow of the ship (which were also known as forward throwing charges).

Depth charges varied in size (from 55 kg to 300 kg) and consequently the mass of HE changed to suit the type of target being attacked. Towards the end of WWII the RN were using a “Mark X” depth charge, which contained 1,000 kg of explosives; they were fired from tubes mounted on the decks of war-ships.

1.8 Air-Delivered Weapons

1.8.1 Iron Bombs

Generally, most iron (i.e. air-delivered) bombs are of similar generic construction, consisting of a steel container, a fuze either located in the nose/tail of the bomb or located laterally (though sometimes in combined locations), and a stabilizing device (i.e. the bomb “tail” to aid accurate aerodynamic flight from the aircraft to the target). The steel container (i.e. the bomb body) contains either the HE content (or other contents e.g. sub-munitions).

Iron bombs are designed in broadly similar shapes (with some variations to give shape/angle), but in a much wider variety of masses, depending on the intention of the bombing mission and the targets. Iron bombs are generally categorised as follows:

- **General Purpose** – Designed, as the name suggests, to attack a variety of targets and they normally contain an explosive content of approximately 50% of the overall mass of the bomb.
- **Armour Piercing** – Designed to create a mechanically driven entry point in the target prior to detonation, in order to maximise the consequent blast and fragmentation effect. Bunker busting systems, anti-shipping, anti-armoured fighting vehicle and counter-tunnel systems are good examples of the tactical deployment of armour piercing bombs. In general, only 30% of the overall mass contains HE with the remaining 70% made up of steel (in order to maximise penetration and any subsequent fragmentation effect). Armour piercing bombs are always fitted with tail-fuzes.
- **Anti-Submarine** – As the name suggests, primarily designed to attack known underwater targets. These types of bombs are always equipped with a tail fitted hydrostatic fuse and 85 – 90% of the overall mass consists of HE.
- **Incendiary** – These are normally constructed of a thin metal casing containing a thermite (manganese/aluminium) compound. Generally, once the compound is exposed to oxygen, an instantaneous combustion takes place with the heat generated reaching in excess of 800 °C. These bombs were often targeted against high concentrations of industry, general urban development and shipping.
- **Fragmentation** – Fragmentation bombs are normally deployed to maximise the secondary effects of an explosion. The bomb is generally constructed from thick (sometimes segmented), steel, designed for maximum fragmentation effect. Fragmentation bombs are generally deployed against "soft" unprotected targets.

The larger size high-explosive varieties were used against shipping i.e. 1,000 kg mass and greater, (compared with the smaller bombs (e.g. 50 kg and 250 kg variants), which were often used during "carpet-bombing" campaigns on land).

1.9 Land Service Ammunition

Land Service Ammunition was utilised by the *Axis* forces defending the *Normandy* coastline and includes mortars and grenades. Mortars work by a striker hitting a detonator. There is a possibility that the striker may be in contact with the detonator and if this were the case It would only take a slight increase in pressure to create an initiation. In a similar fashion, shock may cause a grenade to function if the grenade striker is in contact with the detonator or is still retained by a spring under tension. A grenade can have an explosive range of 15-20m.

The most commonly used grenade by *Axis* forces along the “Atlantic Wall” was the “Stielhandgranate 24”. This consisted of a cylindrical body of thin gauge steel, containing a bursting charge. It was fitted with a wooden handle which contained a friction type ignite, operated by a pull cord. The bursting charge of loose TNT was enclosed in a waxed-paper container, and was filled into a steel cylinder. Initiation was by a friction ignite and a detonator push fitted into the ignite assembly. The length of this grenade was 365mm, the diameter was 70mm and the TNT filling was approximately 0.62kg.

Annex C

UXO Detonation Effects

Contents

1 UXO Detonations

1.1 UXO – Generic Design and Detonation Sensitivity

In simple terms, large NEQ items of UXO tend to have the following basic components:

- **Case**; i.e. the bomb (or mine) body, which is usually (but not always) manufactured from ferrous metal (N.B. G Mine cases are manufactured from non-ferrous metal). The case shatters when the high explosive charge is initiated which generates primarily fragmentation;
- **Main Charge**; a secondary high explosive "main charge" is usually manufactured from an insensitive explosive compound;
- **Booster**; a secondary high explosive "booster charge" is usually manufactured from slightly more sensitive explosive compound. The booster charge is usually relatively small, as compared with the main charge;
- **Fuse**; a primarily high explosive "fuse" is usually manufactured from explosives which are sufficiently sensitive to be initiated by a "trigger" device (e.g. by chemical or mechanical means (i.e. shock or friction)). The fuse is usually relatively small as compared with the booster, and is often housed in a "fuse pocket" in extremely close proximity to the booster (in order to initiate it);
- **Trigger**; a mechanical, electrical or chemical trigger mechanism is employed to initiate the fuse, at the appropriate time. It is generally accepted that WWII-era munitions, which often relied on an electrical capacitor in their firing systems (e.g. aerially delivered bombs and sea mines), would not retain enough electrical charge to function as designed. Very old items, which rely on magnetic or acoustic fusing to initiate them via an electrical charge may however, be detonated by direct or indirect impacts that generate enough kinetic energy to cause a detonation. Therefore whilst items of WWII UXO may pose a risk to installation operations, their initiation by their original electrical or mechanical fusing is considered practically impossible.

1.2 Initiation Generally

An explosive chain reaction is triggered when sufficient energy (mechanical, electrical or chemical) is generated to initiate the fuse, which will initiate (practically instantaneously), the booster and the main charge itself. The fuse component is always relatively small and is always located in a specific part of the UXO (in a bomb, for example, it might be "nose" and/or "tail" and/or "transverse" fused). In a mine, the "triggers" might be located on the surface (in the form of contact horns for example) but the fuse is often located centrally, within the body of the mine.

Explosives in old munitions (especially primary high explosives) deteriorate over time and can leach onto the surface of munitions, often near the fuse pocket (or gather within the pocket itself). When this happens, this residue is often especially sensitive to friction and shock, which can initiate the fuse (and hence the booster and main charge).

1.3 Initiation Scenarios in the Offshore Environment

In terms of offshore platform, WTG foundation or cable installation, the aim is to ensure, wherever possible, to avoid contact with prospective (or real) or UXO. **However, if residual energy is transmitted as a result of local intrusive cable lay activities then that should also be insufficient to initiate an explosives chain reaction**. By undertaking UXO risk mitigation measures and by employing safety avoidance distances such an outcome should be reduced to ALARP.

Nonetheless, it is important to consider and to understand conventional site investigation and installation activities that might otherwise initiate (either directly or indirectly) the most sensitive (fuze) components, which could lead to a “high-order” explosion. The following activities, might lead to a UXO encounter and will therefore be subject to risk mitigation measures:

- Geophysical Survey and ROV investigation;
- Geotechnical investigation;
- PLGR;
- Platform, WTG foundation or cable installation;
- Anchoring;
- Diving.

In such circumstances, a variety of UXO initiation scenarios are possible, namely:

- **Direct Impact;** onto the main body of the munition or its fuse pocket;
- **Indirect Impact**; e.g. by over-pressure that may initiate a hydrostatic fused munition (where present and in very close proximity); or indirect shock (transmitted through the body of the UXO, to or through the fuse pocket) but only where a mechanical impact is made; or a light friction impact (e.g. “grazing”) the fuse pocket, or the fuse itself (where it is exposed).

1.4 Explosive Constituents

The main charge may contain one of two main explosive constituents, high or low explosives. Propellants are also described for the purpose of completeness of description.

1.4.1 High Explosives (HE)

HE Compounds detonate at velocities generally ranging from 1,000m to 9,000m per second, and may be subdivided into two explosive classes, differentiated by their respective sensitivity, namely;

Primary Explosives – are extremely sensitive to mechanical shock, friction and heat to which they will respond by burning rapidly or detonating. Examples include mercury fulminate and lead azide. This characteristic makes them unsuitable to use as base (i.e. main fill) explosives in military ordnance. Sensitivity is an important consideration in selecting an explosive for a particular purpose, e.g. the high-explosive employed in an armour-piercing projectile must be relatively insensitive or the shock of impact would cause it to detonate prematurely before it penetrated the target.

Secondary Explosives – are relatively insensitive to shock, friction and heat. They may burn when exposed to heat in small-unconfined quantities, although the risk of detonation is always present (especially when they are confined and /or burnt in bulk). Dynamite, TNT, RDX and HMX are classed as secondary high explosives, which are commonly used as base explosives in military ordnance. PETN is the benchmark compound; those explosives that are more sensitive than PETN are classed as primary explosives.

1.4.2 Low Explosives

A Low explosive is usually a mixture of a combustible substance and an oxidant that decomposes rapidly (in a subsonic process akin to very rapid burning and known as deflagration).

Under normal conditions, low explosives undergo deflagration at rates that vary from a few centimetres per second to approximately 400m per second. Low explosives are normally employed as propellants, for example; gun-powders, pyrotechnics and illumination devices such as marine markers or flares.

1.4.3 Propellants

In ballistics and pyrotechnics, a propellant is a generic name for those components used for propelling projectiles (e.g. artillery shells or mortars) from a weapon system.

Propellants are always chemically different from high explosives (as compared with those used in munitions for “target effect” for example they are not designed to release their energy as quickly and as a result do not produce a blasting/shattering effect (because such an effect would significantly damage or destroy the associated weapons platform (e.g. gun/howitzer or mortar).

However, some explosive substances can be used both as propellants and as “burster charges”, (e.g. gunpowder), and some of the ingredients of a propellant may be similar to those employed to make explosives. If bulk propellants are confined and burned very rapidly, the result can be similar to that witnessed by a (small) high explosive charge. Propellants therefore remain highly dangerous and can come in various forms, e.g. powder or thin sticks and they are often contained in pre-formed containers or bags.

A typical propellant burns very rapidly but controllably and non-explosively to produce thrust (generated by rapidly expanding gas, generating pressure) and thus accelerating a projectile/rocket from a weapon platform.

In this sense, common or well-known propellants include:

- Gun propellants, such as:
    - Gunpowder (black powder);
    - Nitrocellulose-based powders;
    - Cordite;
    - Ballistite;
    - Smokeless powders;
- Compounds, which may be mixed with a solid oxidiser (such as ammonium perchlorate or ammonium nitrate), a rubber (such as HTPB or PBAN), or a powdered metal (commonly aluminium).

1.5 Effects of Detonation of UXO in the Marine Environment

The effects of munitions detonation in the marine environment depend upon a number of variables, most notably;

- Age and condition of the UXO (including the estimated sensitivity concerning the components that make up the explosives “chain”);
- The type of explosive and/or fill (e.g. high explosive, incendiary, or specialist);
- Where a high explosives fill is present, the estimated power of the high explosive “main charge” element;

- Mass and explosives composition of the “main charge” element (commonly referred to as the Net Explosive content (NEQ) for a single article or Net Explosive Quantity (NEQ) for multiple articles);
- Location of the item which might be:
    - Floating on the body of water (buoyant mines only and their being unlikely to be discovered today);
    - On the seabed;
    - Partially buried;
    - Totally buried.
- The proximity of sensitive receptors (e.g. people, mammals, vessels and equipment), at the time of the detonation event;
- The construction and structural strength of any vessel, equipment or structures near the site of an explosion;
- The robustness of those sensitive receptors and any direct or indirect protection they might be afforded at the time of an event, as well as their juxtaposition;
- The column of water (generally the depth) and the lateral separation between the UXO and the sensitive receptor, which might ameliorate the effects.

1.6 Underwater High Explosive Detonations

1.6.1 Underwater Detonation Hazards

When an item of UXO detonates there are generally four main hazards to consider:

- Fragmentation – Which distances and effects are limited underwater (as compared with similar effects in air);
- Shockwave – comprising peak over pressure and positive impulse;
- Gas Bubble – A pulsing and rising gas bubble – comprising bubble pressure and high velocity water jet.

1.6.2 Direct Effects of Ordnance Detonation

If a large item of high explosive UXO detonates then the effect is very similar to that experienced at the surface although if a mine or a bomb detonated underwater, fragmentation is not usually a primary hazard (unless a receptor is in close proximity). Nonetheless, a high order detonation causing a shock wave would certainly destroy or significantly damage vessels, their crews, investigative and/or installation equipment as well as mammals and the natural environment.

Direct damage is usually only created by contact (most commonly with mines) and ordinarily results in a hole being explosively blown through the hull of the ship or whatever other item the UXO comes into contact with. In such circumstances and, depending upon crew location, they might be killed outright (if they are close to the seat of the explosion), or otherwise suffer from associated blast and/or fragmentation/shrapnel wounds.

Where vessels are concerned, flooding typically occurs in one or more watertight compartments, which can sink smaller ships or disable larger ones. Direct Damage by floating mines damage occurs at or close to the waterline near the bow, but depending on circumstances a ship could be hit amidships (or anywhere) on its outer hull surface.

Similarly, when installation equipment is being returned to the vessel/deck, any UXO initiation at the point of return is likely to have a similar blast and fragmentation effect.

1.6.3 Indirect Effects of Ordnance Detonation

On detonation of a high explosive charge, the explosive gases rapidly form a rising oscillating spherical bubble. The momentum imparted to the water in the early stages enables the water to expand until the pressure in the bubble has far less than the hydrostatic pressure of the surrounding water. A violent contraction therefore takes place, followed by a second expansion (almost as rapid as the first) that may be followed by further expansions and contractions.

Each expansion causes a pressure wave that is propagated outwards throughout the water in all directions. As water is highly incompressible, the maximum pressure in the initial shockwave is very much higher than would occur in either the ground or in air (but the peak pressure is of much shorter duration). Although these shockwaves become gradually weaker as the bubble rises, the origin of those shockwaves (i.e. centre point of the rising bubble) often closes with the intended target (i.e. the underside of a floating ship), and therefore still has sufficient energy to cause considerable shockwave damage at significant distance from the point of initiation. The energy is designed to sink vessels and may also incapacitate or seriously/fatally injure their crews as well as mammals in close proximity. Any investigative or installation equipment (e.g. cable lay equipment and support vessels) would also be subject to destruction or damage, subject to their proximity and relative strength.

The indirect damage of a high explosive underwater detonations on vessels are therefore dependent upon two factors; the initial energy generated by the explosion and the distance between the target and the point-source of detonation. When taken in reference to ship hull plating, the term Hull Shock Factor (HSF) is commonly used, while keel damage is termed Keel Shock Factor (KSF). If the explosion is directly underneath the keel, then HSF is equal to KSF, but explosions that are not directly underneath the ship will have a lower KSF value.

Another indirect effect known as the “bubble jet” effect occurs when a mine detonates in the water a short distance away from the ship. The explosion creates a bubble in the water, and due to the difference in pressure, the bubble will collapse from the bottom. The bubble is buoyant and so rises towards the surface. If the bubble reaches the surface as it collapses, it can create a pillar of water that may rise over a hundred metres into the air (known as a "columnar plume"). If conditions are right and the bubble collapses onto the ship's hull, the damage to the ship can be extremely serious. The collapsing bubble forms a high-energy jet that can break a significant hole (possibly up to 1m diameter) straight through the hull of the ship, flooding one or more water tight compartments. The forces are capable of breaking smaller ships apart. The crew in the area, if hit by the water pillar, are likely to be killed instantly.

However, if the mine or bomb detonates at some distance from the ship, the change in water pressure can cause the ship to resonate. This is frequently the most damaging type of explosion if it is strong enough. In such circumstances, the whole ship is dangerously shaken and loose objects on board may be dislodged with considerable force, sufficient to cause disabling injuries (for example to knees/hips and other joints in the body, particularly if the affected person stands on surfaces connected directly to the hull (such as a steel deck)). Similarly, ships’ engines can be torn from their mountings, power cables from their fastenings etc., which may also cause secondary injuries to ship’s crew. A badly affected ship usually sinks quickly, as a result of hundreds, or even thousands of small leaks all over the ship. Bilge pumps often fail to cope as a result of the pace of water ingress and/or localised power supply failures as a result of the shock effect.

Divers are especially vulnerable to underwater shock wave effects and can be injured by the detonation of relatively small high-explosive charges at a distance of a nautical mile or further (subject to UXO NEQ).

Clearly, mammals in close proximity as well as investigative and/or installation equipment could be similarly damaged/injured or destroyed.

1.7 Water Depth and Shockwave Suppression

As compared with high order explosion event on land, water has a significant capacity to absorb fragmentation, subject to water depth and UXO NEQ. Whilst the effects from large NEQ items of UXO (e.g. large capacity bombs and sea mines) might only be partially mitigated, effects generated by smaller NEQ items (e.g. AAA and small HE projectiles) may well be completely ameliorated.

Large NEQ items are likely to need significant depths of water (beyond 50m) to ameliorate their high explosive effects. Clearly though, the deeper the water the greater it’s ameliorative effect upon blast and fragmentation but the relationship between the two (i.e. depth and amelioration) is unlikely to be linear.

In deep water the bubble theory is completely dissipated as is the primary shock wave, due to the separation and the laws of thermodynamics combined with gravitational effect. Thus, in very shallow areas shallow buried UXO might pose a more significant risk (if it was to be inadvertently initiated) because the high explosives pathway to sensitive receptors would be both short and incapable (in very shallow water/air) of significant blast amelioration.

Annex D

Semi-Quantitative Risk Assessment

Contents

1 Semi-Quantitative Risk Assessment

1.1 Overview

In undertaking a series of Semi-Quantitative Risk Assessments (SQRA) across the project, we have employed the technical data associated with the items presented within this report and the proposed operation. The following sections outline transparently the methodology and calculations used in conducting the SQRA for the project. Risk assessment tables are presented separately, in the main report.

1.2 Risk Rating

For the purposes of this report, **Risk** (R) is a function of **Probability** of occurrence (P) and **Consequence** of occurrence (C), where R = P x C. In each case, the Probability and Consequence of the identified threats has been assessed on a scale of 1 to 5. (Where 1 = Very Low, & 5 = Very High) based on expert judgement. These ratings are multiplied together to create Risk scores with a maximum of twenty-five. This allows relative weighting and comparison of risk across the project. Colour coding is provided for ease of use, grouping figures in Green as Low Risk, in Yellow as Medium Risk and Red as High Risk.

Probability	Very High	**5**	5	10	15	20	25
		4	4	8	12	16	20
	Medium	**3**	3	6	9	12	15
		2	2	4	6	8	10
	Very Low	**1**	1	2	3	4	5
			1	**2**	**3**	**4**	**5**
			Very Low		Medium		Very High
					Consequence		

Table 1.2 – Risk Matrix

1.3 Risk Rating Criteria

It is important that the numerical values assigned to the potential probability and impact of a risk match the risk tolerance of the Client**.** *Table 1.3* outlines the risk rating rationale that has been applied in this analysis:

Risk Rating (P x C)	Grading	Risk Appetite (Tolerance)	Action Required
1-5	**Low**	Tolerable or Partly Tolerable	Little/No specific Risk Mitigation Required. Situation should be monitored. Reactive UXO risk mitigation required during operations, but overall, residual risks are carried.
6 - 12	**Medium**	Intolerable	Advance Mitigation Measures should be considered. Situation should be monitored. Risks to be mitigated subject to the mitigation being reasonable, practical and affordable. Note: High Consequence or High Probability that score as Medium Risk events should be afforded the same status as Highly Intolerable but assessed on a case-by-case basis.
15 - 25	**High**	Highly Intolerable	Risk Mitigation Measures should / will be implemented. All risks to be mitigated.

Table 1.3 – Risk Tolerability Table

The risk levels are used to determine the level of mitigation required to reduce the risk to conform with the ALARP principle. In producing the risk mitigation strategy the risk levels are benchmarked against the various degrees of tolerability (shown in *Table 1.3* above), in order to determine what degree of risk is considered acceptable.

1.4 Definition of Consequence and Probability

As is accepted practice in formalised Risk Management, the Risk Rating scales are dimensionless, allowing the user to apply these methods to any desired terminology in order to fit their discrete needs.

1.4.1 Consequence

If the key consequence is financial, then 5 on this scale should equate to the amount of money that will either, stop the contract, close the operation, exceed agreed budget or any other defined critical financial figure. The scale then sub-divides that amount into 5 equal portions down to zero financial impact.

If the key impact figure is the loss of a vessel, then 5 on the scale is equal to total loss of the vessel as an operational asset and the sliding scale represents vessel operational efficiency loss i.e. 1 = loss of 0% to 20% operational efficiency, while 5 = loss of 81% to 100% operational efficiency.

If the critical impact figure is loss of 50% of operational efficiency, then the scale represents loss of between 0% and 50% in 5 equal steps. This can be applied to any number of scenarios.

The critical consequence associated with UXO however is that associated with injury or death. Both are considered unacceptable and therefore such circumstances should be avoided or the risk appropriately managed or otherwise mitigated to ameliorate such a consequence.

1.4.2 Consequences Specific to this Project

The detonation consequence assessment assigns a site-specific consequence level to any potential UXO that may be encountered at the site. This is achieved by combining the UXO impact distance from sensitive receptors, the Net Explosive Quantity (NEQ) of the item and, where applicable, the average water depth range.

A rating system for assigning impact levels has been derived based on the expected effects of a detonation event on each of the receptors identified in the project consequence matrix, which is presented at *Table 1.4.2*. The expected impacts are ranked from 1 (no significant effect) to 5 (major widespread effects / catastrophic).

Impact Level	*NEQ*	Expected Consequences			
		Human Health	**Plant and Equipment**	**Vessels**	**Environment**
1	*Low Explosive <10kg & High Explosives <5 kg*	Injury requiring medical treatment	No noticeable effect	No noticeable effect	Minor disturbance
2	*High Explosive 5-15 kg*	Lost time injury < 3 days	Slight superficial damage	Slight superficial damage	Significant disturbance
3	*High Explosive 15-50 kg*	Serious debilitating injury	Minor component replacement repair	Repairs - non-structural	Moderate damage to habitats.
4	*High Explosive 50-250 kg*	Localised fatalities	Significant component replacement repair	Repairs – structural	Moderate damage to habitats. Some long term effects.
5	*High Explosive >250 kg*	Multiple fatalities over extended area	Unit destruction	Localised structural failure and collapse	Localised destruction of habitats. Moderate long-term effects.

Table 1.4.2 – Consequence Matrix

1.4.3 Probability

The Probability scale is simply the assessed likelihood of an event-taking place. If units are required, then the scale frequently used on Project Risk Registers may be utilised.

1.4.4 Probabilities Specific to this Project

Based on 6 Alpha's significant experience of assessing the probability of UXO contamination, it is not always possible to present an accurate statistical (or purely quantitative) measure, simply because the base data is largely qualitative i.e. it is drawn from a variety of different historical and environmental sources.

However, 6 Alpha's semi-quantitative approach blends together professionally informed judgements made upon empirical, qualitative evidence and introduces a transparent statistical approach which has been successfully employed on a variety of marine (and land) based sites where the environmental context remains relatively constant and the quantity and type of munitions employed, together with expected failure rates, is recorded.

For this purposes of this study the probability levels presented in the matrix at *Table 1.4.4*, which have been employed together to chart and to code the overarching probability ratings for this specific project:

Probability Level	Probability of Encountering UXO
1	Remote
2	Possible
3	Likely
4	High Likely
5	Almost Certain

Table 1.4.4 – Probability Matrix

6 Alpha have collated, reviewed and analysed the historical data presented in our desk study and conducted a separate assessment based on the levels in *Table 1.4.4* to produce a chart that demonstrates "probability of UXO encounter". The chart is an important tool not only in informing the subsequent and associated risk management process but also in helping to reduce risks to As Low as Reasonably Practicable (ALARP), because it visually displays areas as false colours, showing which might require UXO risk mitigation as well as others, which might be avoided.

However, there are some limitations associated with practical employment of this chart. Primarily, it should not be used as a "risk chart" as it does not incorporate the construction activities that might be associated with a UXO "encounter". Moreover, it does not consider the complete threat (i.e. net explosive quantity (NEQ) and fuzing) posed by any particular item. Therefore, this chart cannot address the cause and initiation, nor the likely consequences; therefore it only informs one part of the risk process (i.e. part of the probability element); it does not address potential types of encounter nor the potential consequences.

The UXO threat locations and safety buffering have been produced by digitising *inter alia* historical naval records and/or plotting coordinates provided by third parties. Because much of this data was gathered in a wide variety of circumstances, by different agencies, to different standards, over a long time-frame, some of that data may not be accurate or as detailed as 6 Alpha would like. Nonetheless, this data is the best that can be obtained and although 6 Alpha have relied upon it, and we have employed our best endeavours to ensure that it is both relevant and accurate, we are not responsible for any inherent historical inaccuracies that it might contain.

Notwithstanding this, 6 Alpha have taken all reasonable care to ensure that all base data employed is as accurate as possible and any potential inaccuracies have been taken into consideration in the final “probability” buffering. Moreover, UXO buffer areas also take into consideration potential for drift/movement since the time of UXO placement.

Annex E

Marine Geophysical Techniques

Contents

1 Marine Geophysical UXO Detection Techniques

1.1 Overview

The key geophysical survey methods for detecting UXO and that are recommended in the risk mitigation measures section of the threat and risk assessment are presented below. Other survey methodologies can be used however these methods are the most commonly employed and have a proven success rate in detecting UXO.

1.2 Side Scan Sonar

Side scan sonar is an acoustic survey methodology that is generally used to identify objects on the surface of the sea bed and to determine the nature of sea bed sediments.

Side scan sonar is generally operated from a vessel with the “tow fish” containing the survey array being deployed behind the vessel. Towing the sonar allows the altitude of the fish (height above the sea bed), to be controlled, which maintains data quality and ensures the optimal aspect ratio is obtained for target verification. Due to the higher positional accuracy required in UXO survey applications, side scan sonar position is usually determined by Ultra Short Base Line (USBL) acoustic positioning. However, tracking the location of the side scan sonar fish becomes difficult at greater depths because the accuracy of the acoustic positioning is range dependent. In deeper water a remote platform, i.e. ROV or AUV, might also be used to conduct side scan sonar survey.

The side scan sonar fish contains a transducer which acts as a transceiver (i.e. it emits a high frequency acoustic pulse which hits the sea bed and it also receives the return signal from the sea bed). The sea bed absorbs some of the energy from this pulse, whilst most is forward-scattered and some is back-scattered. The receiver records the energy of the pulse returning from the sea bed and produces the results in the form of a two-dimensional (2D) acoustic pseudo-image of the sea bed, which is commonly displayed as a grey scale image (with the level of grey proportional to the amplitude of the signal recorded). Historically, when paper records were used to display side scan sonar data, items on the sea bed were identified by a reflective signal (dark grey) followed by an acoustic shadow (light grey) where no signal has been reflected. However, with modern digital technology the inverted colour scale is nowadays quite common as it gives a more familiar look to the images (i.e. the absence of returned energy, or "shadows", are displayed as dark grey).

Side scan sonar is capable of imaging a large area of the sea bed with relative speed and efficiency and it is therefore widely used for UXO (and other sea bed) surveys. In order to detect items of UXO a frequency of 500kHz or higher is recommended, as this will usually deliver suitable resolution for the measurement of anomalies identified on the sea bed. Additionally, dual frequency sonars are even more valuable as the inclusion of a low(er) frequency channel (typically 100 kHz) often increases certainty of the interpretation.

Survey should allow for full coverage of the sea bed (usually by covering the area in two separate survey swaths, thus generating more than 200% coverage) in order to eradicate the nadir 'blind spots' and so that any static contacts identified are picked up on multiple lines, allowing for better contact verification. Side scan sonar is often combined with other survey methodologies (e.g. those which are capable of identifying buried items of UXO).

1.3 Magnetometry

Ferrous metal objects on the sea bed produce a distortion of the Earth's magnetic field, which can be recorded as a magnetic anomaly. Magnetometers are instruments that can be used to measure the strength of this anomaly at a point in time and space, employing either "total-field" (i.e. omni-directional) sensors (which are commonly mounted in tow-fish or frames/wings) or "flux-gate" sensors (which are commonly mounted in pairs, within tubes). As the majority of UXO are constructed from ferrous metal, and hence produce this measurable distortion in the Earth's magnetic field, magnetometry can locate many prospective UXO items on the sea bed and buried at shallow depths beneath it.

Typically, in the offshore environment (unless the water depth is very shallow), towed total-field sensors are most commonly deployed from support vessels for wide area (or long linear) surveys, whilst multi-channel flux-gate sensors are more commonly deployed form an ROV for UXO verification purposes.

When magnetometers are deployed in pairs or arrays, the difference between the sensed magnetic fields (i.e. magnetic field gradients) can be determined. In this case, the term "gradiometers" is more commonly used as it is the gradient in the magnetic field, rather than solely the strength of the magnetic field, that is detected. One of the principal advantages in using a (vertical or horizontal) gradiometer configuration is that no correction for diurnal variation in the Earth's magnetic field is necessary.

The most common type of total-field magnetometer used in marine UXO surveys is the Geometrics G882 caesium optically pumped magnetometer, which is generally towed behind a vessel. As an all field sensor, they need to be towed at a suitable distance behind the vessel so as not to be affected by ferrous components of the vessel itself. G882's can be operated in a wide range of water depths (although their accurate deployment with respect to a fixed sea bed flying altitude in deep water is challenging). For a UXO survey, a magnetometer or gradiometer (comprising two or more magnetometers) should be towed behind the vessel. The optimum survey altitude and line spacing should be set by a UXO specialist with geophysical survey experience for the detection of UXO and it is to be confirmed prior to undertaking the main survey by means of equipment verification testing.

Close magnetometer and vessel (line) spacing is required to deliver successful results and controls on the altitude of the tow fish can be relatively time consuming; this should be factored into any survey time schedule. In order to obtain best value from any magnetometer survey, its design (including magnetometer and vessel line spacing) should be based on the types of potential UXO threats and their depth of burial and the number and type of magnetometers to be employed. Since it is not possible to state a generic magnetometer and vessel line spacing, a UXO specialist should be involved in its design and specification.

The results of a magnetometer (or gradiometer) survey are typically depicted in a false colour map detailing areas of high and low magnetic variations. The output from the survey is recorded in nanoteslas (nT) and, when a gradiometer is used, is measured as a variation over distance (i.e. nT per metre). Interpretation of the data is more complex, compared with side scan sonar or other acoustic methodologies, and requires significant experience as incorrect manipulation of the data can result in items of UXO being masked (false negatives) in the dataset. Similarly, false positive anomalies (ferrous metal scrap) might inadvertently be selected. False positive anomalies can also be caused by the presence of permanently magnetised rock which can also mask items of UXO.

Conventional magnetometry cannot discriminate non-ferrous metal and, therefore, it will not identify items of UXO such as aluminium air-deployed sea mines (which the Germans employed during WWII). Therefore, if such non-ferrous metal items are identified by the threat (and risk) assessment(s) then other methods of identifying them may need to be employed, such as pulse induction magnetometry.

Magnetometry has the capacity to identify buried items of UXO up to depths of approximately 2-3m below sea bed (depending upon the mass of the item(s) being sought and other factors). However, unlike side scan sonar, there are no definitive measurements (such as length or width). Therefore identifying UXO and separating it from other ferrous items of debris on the sea bed is sometimes difficult. Often a magnetometer survey of this type will be combined with a side scan sonar survey to provide further evidence for contact clarification.

1.4 Pulse Induction Magnetometry/Electromagnetic Survey

Pulse induction (PI) magnetometry (Electromagnetic (EM) survey) is an active (rather than a purely passive) survey system, which has the capacity to detect both ferrous and non-ferrous metal (including aluminium, e.g. air-delivered sea mines, which the Germans deployed during WWII. Pulse induction magnetometers have the capacity to detect UXO on the surface of the sea bed (and on land) as well as shallow buried UXO.

The system relies upon a transmitter and receiver system arranged in a coil (or loop). An alternating current (AC) is passed thought the coil (oscillating in pulses), which acts as the transmitter, producing a pulsed magnetic field. If a metal source (e.g. UXO) is in the vicinity, eddy currents are induced. Another coil (acting as the receiver and de facto as a magnetometer) detects this change in the magnetic field and thus detects the metal source, in this case UXO.

The signal strength and detection capability (including depth of sub sea bed detection) depends upon a number of variables including: the mass of metal in the UXO; its distance from the instrument; the size of the loop; the strength of current being employed, the frequency of pulses being generated and the sensitivity of the magnetometer (receiver) component; as well as the presence of other non-UXO scrap metal in proximity (which generates noise and might otherwise mask UXO).

Such systems are most commonly employed on land, in hand held detectors and are most commonly used by the military and commercial organisations for land mine detection, or the security industry. Hand held PI systems are also employed underwater by divers for metal detection purposes. Large loop systems are also employed underwater, but because they require precise control they are commonly mounted on an ROV and they are slow and therefore expensive to employ therefore they are not best employed for wide area survey.