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Detailed Unexploded Ordnance Risk Assessment

In Respect Of:
Skye to Ornsay Underground Cable Route

For:
Cnoclee Limited

Report Reference:
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safelaneglobal.com

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SafeLane Global Limited

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This Report has been produced in compliance with the Construction Industry Research and Information Association guidelines for the preparation of Detailed Unexploded Ordnance Risk Assessments in the management of UXO risks in the construction industry. This report has been compiled using all due diligence and expertise and having made all proper but reasonable enquiries within given time limitations. However, in accepting and implementing the recommendations contained in this report, the client does so strictly at his own risk.

SafeLane Global Limited

Unit 3, The Courtyard, Campus Way, Gillingham Business Park,
Gillingham, Kent, ME8 0NZ

Tel: +44 (0)1634 471340

Email: info@safelaneglobal.com

www.safelaneglobal.com

Registered in England No. 03431843.

VAT Registration No. GB 171 628 112

Executive Summary

The Site	
OS National Grid Reference:	Start point: NG 70147 12310 End point: NG 70857 12358
Site Description:	The site comprises a proposed cable route approximately 780m in length, running from the north of Camus Croise in the west to the Isle of Ornsay in the east. The site passes sections of vegetated ground, sand / shingle and into the Sound of Sleat.
Proposed Works	
The proposed works include a cable plough and open cut install of electrical cables to a maximum depth of 1.8m bgl. In addition, the majority of the cable is to be ploughed across a beach.	
Risk Assessment	
Risk Assessment Methodology: In accordance with CIRIA guidelines this assessment has carried out research, analysed the evidence and considered the likelihood that the site has been contaminated with unexploded ordnance; that such items remained on site; the risk that they could be encountered during any intrusive works and the consequences that could result. Appropriate risk mitigation measures have been proposed.	
UXO Risk Rating	**LOW from all UXO types:**
The full UXO Risk Assessment and a breakdown of the UXO Risk Level can be found in Section 11.	

Recommended Risk Mitigation		
Risk Level	**Planned Site Activity**	**Recommendations**
Low	**All**	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course

In making this assessment and recommending these risk mitigation measures, the proposed works outlined in the 'Scope of the Proposed Works' section were considered. Should the planned works be modified, or additional intrusive engineering works be considered, SafeLane Global should be consulted to see if re-assessment of the risk or mitigation recommendations is necessary.

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Glossary of Terms

AAA	Anti-Aircraft Artillery
ARP	Air-raid Precautions
BDO	Bomb Disposal Officer
EOD	Explosive Ordnance Disposal (current term for "bomb" disposal)
HE	High Explosive
HG	Home Guard
IB	Incendiary Bomb
Kg	Kilogram
LM	Land Mine
LSA	Land Service Ammunition (includes grenades, mortars, etc.)
Luftwaffe	German Air Force
m bgl	Metres Below Ground Level
MoD	Ministry of Defence
OB	Oil Bomb
PM	Parachute Mine
RAF	Royal Air Force
SI	Site Investigation
SAA	Small Arms Ammunition (small calibre cartridges used in rifles & machine guns)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	"Doodlebug" the first cruise type missile, used against London from June 1944. Also known as 'Flying Bomb'
V-2	The first ballistic missile, used against London from September 1944
WWI	First World War (1914 -1918)
WWII	Second World War (1939 – 1945)

Detailed Unexploded Ordnance Risk Assessment

In Respect of

Skye to Ornsay Underground Cable Route

1 Introduction

Cnoclee Limited has commissioned SafeLane Global to conduct a Detailed Unexploded Ordnance Risk Assessment of the Skye to Ornsay Underground Cable Route project.

Unexploded Ordnance (UXO) presents a significant risk to construction projects in parts of the UK as a result of enemy actions during the two 20th Century World Wars and historic British and Allied military activity.

One of the legacies of this conflict is buried unexploded air-dropped bombs or anti-aircraft projectiles resulting from the failure of a proportion of the weapons to function as designed. It is commonly accepted that the failure rate of these munitions was approximately 10% and, depending on their shape, weight, velocity and ground conditions, many penetrated the ground and came to rest at depth.

In addition, it is estimated that over 20% of the UK landmass has been used by the military at some point and between 2006 and 2009, over 15,000 items of British / Allied ordnance (excluding small arms ammunition) were found on UK construction sites (CIRIA).

Intensive efforts were made during and after the war to locate and render safe all UXO but, unsurprisingly, not all were found and dealt with. This is evidenced by the regular, on-going discoveries of UXO during construction-related intrusive ground works.

As a result of a generally increased risk awareness amongst professionals involved in ground engineering works and proactive health and safety measures, the risk to life and limb from UXO has been minimised. However even the simple discovery of a suspected device during on-going works can cause considerable disruption to production and cause unwanted delays and expense.

Such risks can be more fully addressed by a better understanding of the site-specific risk and the implementation of appropriate risk mitigation measures.

2 Construction Industry Duties and Responsibilities

2.1 The UK Regulatory Environment

There is no legal requirement for the control and mitigation of UXO risk in the construction industry, but guidelines for good practice, information, and solutions with regards to UXO risk are detailed within CIRIA (C681): Unexploded Ordnance (UXO) A Guide for the Construction Industry.

These guidelines provide the construction industry with a set process for the management of risk associated with UXO, from preliminary risk assessment to implementation of site-specific risk mitigation strategies.

Specific legislation does however exist for health and safety, and is addressed under a number of regulatory instruments, as outlined below.

In practice, the regulations impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground-intrusive operations (such as archaeology, site investigation, drilling, piling or excavations) from any reasonably foreseeable UXO risk.

2.2 The Health and Safety at Work Act, 1974

The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.

2.3 Construction (Design and Management) Regulations 2015

CDM 2015 ensures that health and safety within the construction industry is continually improved:

- Works are sensibly planned and managed.
- Competent staff are engaged in the works.
- Risks are identified and managed.
- All parties cooperate and coordinate activities.
- Communication flows to those who require it.
- Workers are consulted and engaged about risks and how they are being managed.

In line with CDM 2015 legislation, SafeLane Global are able to assist parties in their discharge of CDM duties as follows:

- Assist Principal Designers with pre-construction information and risk assessments.
- Assist the Designer with the Designer's Risk Assessment.
- Issue UXO risks as have been identified and manage risks accordingly.
- Assist the Principal Contractor with the construction phase information, in particular risk assessments and mitigation strategies.
- Plan, manage and monitor survey and clearance works under SafeLane Global's control.

2.4 Other Legislation

Other relevant legislation includes the "Management of Health and Safety at Work Regulations 1999" and "The Corporate Manslaughter and Corporate Homicide Act 2007".

3 The Role of the Authorities and Commercial Contractors

3.1 The Authorities

The Police have the responsibilities for co-ordinating the emergency services in the case of an ordnance-related incident on a construction site. They will make an initial assessment (i.e. is there a risk that the find is ordnance or not?) and if they judge necessary impose a safety cordon and/or evacuation and call the military authorities (JSEODOC - Joint Services Explosive Ordnance Disposal Operations Centre) to arrange for investigation and/or disposal. In the absence of an EOD specialist on site many Police Officers will use the precautionary principle, impose cordon(s)/evacuation and await advice from the JSEODOC.

The priority given to the request by JSEODOC will depend on their judgement of the nature of the risk (ordnance, location, people and assets at risk) and the availability of resources. They will respond immediately or as resources are freed up. Depending on the on-site risk assessment the item of ordnance may be removed or demolished (by controlled explosion) in situ. In the latter case additional cordons and/or evacuations may be necessary.

Note, that the military authorities will only carry out further investigations or clearances in very high profile or high-risk situations. If there are regular ordnance finds on a site, the JSEODOC may not treat each occurrence as an emergency and will encourage the construction company to put in place alternative procedures (i.e. the appointment of a commercial contractor) to manage the situation and relieve pressure from the JSEOD disposal teams.

3.2 Commercial Contractors

In addition to pre-construction site surveys and follow-on clearance work, a commercial contractor is able to provide a reactive service on construction sites. The presence of a qualified EOD Engineer with ordnance recognition skills will avoid unnecessary call-outs to the authorities and the contractor will be able to arrange for the removal and disposal of low risk ordnance. If high risk ordnance is discovered actions will be co-ordinated with the authorities with the objective of causing the minimum possible disruption to site operations whilst putting immediate, safe and appropriate measures in place.

4 This Report

4.1 Aims and Objectives

The aim of this report is to examine the possibility of encountering any explosive ordnance during any intrusive works at the site. Risk mitigation measures will be recommended in line with the CIRIA C681 guidelines, to reduce the risk of initiating UXO, and the subsequent risk of harm / damage during the envisaged works to as low as reasonably practicable (ALARP).

4.2 Risk Assessment Methodology

The following issues will be addressed in the report:

- The likelihood that the site was contaminated with unexploded ordnance.
- The likelihood that unexploded ordnance remains on site.
- The likelihood that ordnance may be encountered during any intrusive works.
- The risk that ordnance may be initiated.
- The consequences of initiating or encountering ordnance.

Risk mitigation measures, appropriate to the assessed level of risk and site conditions, will be recommended.

4.3 Approach

In preparing this Unexploded Ordnance Risk assessment, SafeLane Global has considered general and, as far as possible, site specific factors including:

- Evidence of German bombing and delivery of UXBs.
- Site history, occupancy and conditions during WWII.
- The legacy of Allied military activity.
- Details of any known EOD clearance activity.
- The extent of any post war redevelopment.
- Scope of the current proposed works.

4.4 Sources of Information

SafeLane Global has carried out detailed historical research for this Unexploded Ordnance Risk Assessment including accessing military records and archived material held in the public domain and in the MoD.

Material from the following sources has been consulted:

- The National Archives.
- The British Newspaper Archives.
- Landmark Maps.
- Relevant information supplied by the client.
- Available material from 33 Engineer Regiment (EOD) Archive.
- SafeLane Global's extensive archives built up over many years of research and hands-on Explosive Ordnance Disposal activities in the UK.
- Open sources such as published books, local historical records and the internet.

4.5 Reliability of Historical Records

4.5.1 General Considerations

This report is based upon research of historical evidence. Whilst every effort has been made to locate all relevant material SafeLane Global cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date.

The accuracy and comprehensiveness of wartime records is frequently difficult or impossible to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance risk can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. SafeLane Global cannot be held responsible for inaccuracies or gaps in the available historical information.

4.5.2 Bombing Records

During WWII, considerable efforts were expended in recording enemy air raids. Air Raid Precautions (ARP) wardens were responsible for making records of bomb strikes either through direct observation or by post-raid surveys. However, their immediate priority was to deal with casualties and limit damage, so it is to be expected that records are often incomplete and sometimes contradictory. Record keeping in the early days of bombing was not comprehensive and details of bombing in the early part of the war were sometimes destroyed in subsequent attacks. Some reports may cover a single attack, others a period of months or the entire war.

Records of raids that took place on sparsely or uninhabited areas were often based upon third party or hearsay information and are not always reliable; records of attacks on military or strategic targets were often maintained separately from the general records and have not always survived.

5 The Site and Scope of Proposed Works

OS National Grid Reference	Start point: NG 70147 12310 End point: NG 70857 12358	
Site Description	The site comprises a proposed cable route approximately 780m in length, running from the north of Camus Croise in the west to the Isle of Ornsay in the east. The site passes sections of vegetated ground, sand / shingle and into the Sound of Sleat.	
Proposed Works	The proposed works include a cable plough and open cut install of electrical cables to a maximum depth of 1.8m bgl. In addition, the majority of the cable is to be ploughed across a beach.	
References	**Site Location Maps**	**Annex A**
	Recent Aerial Photograph	**Annex B**

6 Ground Conditions

Data Source		Description
British Geological Survey Mapping	Superficial Deposits	• Raised Marine Deposits, Late Devensian 1 – Gravel, Sand and Silt (east). • Marine Beach Deposits – Gravel, Sand and Silt (centre). • Raised Marine Deposits of Holocene Age – Gravel, Sand and Silt (west).
	Bedrock	Lewisian Complex – Orthogneiss.

7 Pre and Post-WWII OS Mapping

	Date	Observations	Reference	Source
Pre-WWII	1903	• The site and surrounding area appears to remain largely consistent with conditions presented in recent aerial photography. • The western section of the route is surrounded by a number of structures, including a *Smithy* (20m north) and a *Hotel* (70m north). • The land sections of the route pass through areas of rough pasture. • The sites centre is occupied by sand, with shingle present on the shoreline.	Annex C-1	Landmark Maps
Post-WWII	1966	• The surrounding area is largely consistent with conditions presented in pre-war mapping. • The position of the low water mark for the *Sound of Sleat* appears to have drawn closer to the route. • The water level in the area appears to have risen, with sections previously occupied by rough pasture now comprising sand and shingle. • Two structures to the north of the site appear to have been cleared.	Annex C-2	Landmark Maps

8 The Threat from Aerial Bombing

8.1 General Bombing History of Skye and Western Scotland

8.1.1 First World War

Neither Western Scotland nor the Isle of Skye were subject to any aerial or naval bombardment during WWI and therefore this conflict will not be further addressed in this report.

8.1.2 Second World War

Due to its remote location and lack of industrial or military targets, the Isle of Skye was relatively safe from any large-scale bombing raids. The majority of WWII bombing raids in Scotland took place over the east coast ports and their associated shipping channels.

The closest potential target in the wider region of the site included a bombing decoy on the outskirts of Fort William, situated approximately 57km to the south-east of the study area. The nearest known occurrences of bombing occurred over Fort William, where five raids were recorded during wartime.

8.2 Generic Types of WWII German Air-delivered Ordnance

The nature and characteristics of the ordnance used by the Luftwaffe allows an informed assessment of the hazards posed by any unexploded items that may remain today.

- HE Bombs: In terms of weight of ordnance dropped, HE bombs were the most frequent weapon deployed. Most bombs were 50kg, 250kg or 500kg (overall weight, about half of which was the high explosive) though large bombs of up to 2,000kg were also used. HE bombs had the weight, velocity and shape to easily penetrate the ground intact if they failed to explode. Post-raid surveys would not always have spotted the entry hole or other indications that a bomb penetrated the ground and failed to explode, and contemporary ARP documents describe the danger of assuming that damage, actually caused by a large UXB, was due to an exploded 50kg bomb. Unexploded HE bombs therefore present the greatest risk to present–day intrusive works.
- Blast Bombs/Parachute Mines: Blast bombs generally had a slow rate of descent and were extremely unlikely to have penetrated the ground. Non-retarded mines would have shattered on most ground types, if they had failed to explode. There have been extreme cases when these items have been found unexploded, but this was where the ground was either very soft or where standing water had reduced the impact. SafeLane Global does not consider there to be a significant risk from this type of munition on land.
- Large incendiary bombs: This type of bomb ranged in size from 36kg to 255kg and had a number of inflammable fill materials (including oil and white phosphorus), and a small explosive charge. They were designed to explode and burn close to the surface, but their shape and weight meant that they did have penetration capability. If they penetrated the ground, complete combustion did not always occur, and, in such cases, they remain a risk to intrusive works.
- 1kg Incendiary Bombs (IB): These bombs, which were jettisoned from air-dropped containers, were just over 30cm in size and therefore highly likely to go unnoticed. They had the potential to penetrate soft ground and left a very small entry hole. Furthermore, if bombs did not initiate and fell in water or dense vegetation or became mixed with rubble in bomb damaged areas, they could have remained hidden to this day. Some variants had explosive heads, and these present a risk of detonation during intrusive works, particularly due to their shape, which leads them to often be misidentified.
- Anti-personnel (AP) Bomblets: AP bombs had little ground penetration ability and should have been located by the post-raid survey unless they fell into water, dense vegetation or bomb rubble.

- Specialist Bombs (smoke, flare, etc): These types do not contain high explosive and therefore a detonation consequence is unlikely. They were not designed to penetrate the ground.

Examples of the most commonly deployed German bombs are presented in the *Ordnance Specifications and Information* appendices at the end of this document.

8.3 Second World War Bombing Statistics

The following table summarises the quantity of German bombs (excluding 1kg incendiaries and anti-personnel bombs) falling on the Local Authority of Inverness (in which the site was located) between 1940 and 1945.

Record of German Ordnance Dropped on the Local Authority of Inverness	
Area Acreage	2,692,361
High Explosive Bombs (all types)	98
Parachute Mines	-
Oil Bombs	-
Phosphorus Bombs	-
Fire Pots	-
Pilotless Missile (V1)	-
Long Range Rocket (V2)	-
Total	98
Items Per 1,000 Acres	**0.4**

Source: Home Office Statistics

Detailed records of the quantity and locations of the 1kg incendiary and anti-personnel bombs were not routinely maintained by the authorities as they were frequently too numerous to record.

Although the incendiaries are not particularly significant in the risk they pose, they nevertheless are items of ordnance that were designed to cause damage and inflict injury and should not be overlooked in assessing the general risk to personnel and equipment. The anti-personnel bombs were used in much smaller quantities and are rarely found today but are potentially more dangerous. This table does not include UXO found during or after WWII.

8.4 Site Specific WWII Bombing Records

8.4.1 Original ARP Bombing Incident Records

Throughout WWII, records of bombing incidents were kept by the ARP and Civil Defence Office. These records were kept in the form of typed or hand-written notes and/or presented on bomb plot maps. Some other organisations, such as port authorities and railways, maintained separate records.

Written ARP records were reviewed for	Scotland
Source	National Archives
Records of bombing on / near the site were found	✖

8.4.2 Home Office Intelligence Reports

The Home Office Intelligence reports document enemy action on British domestic soil and were prepared twice a day for the Home Security War Room. The summaries were prepared by intelligence staff, who compiled reports received from the twelve civil defence regions.

However, available records only document time and general location of attack and numbers of casualties. The intelligence officials generally only recorded locations on municipal level (town, village, or city), rarely providing specific addresses. No records of bombing within the Island of Skye could be obtained within the timeframe of this report.

8.4.3 WWII-era RAF Aerial Photography

No WWII-era aerial photography of the site was available within the timeframe of writing this report.

8.4.4 Bombing Decoy Sites

A national decoy authority headed by Colonel John Fisher Turner was set up in July 1940, and following earlier experiments in Glasgow and Sheffield, a system of urban lighting decoys was set up. These were known as "Civil" sites; Civil 'QL' for urban lighting simulation, and Civil 'QF' for dummy fires. "Q" – sites were equipped with assorted electrical and pyrotechnical apparatus to simulate the flare given from furnace doors, steel-making, railway marshalling yards, and light given off by inefficient blackout precautions.

Other sites simulated small fires started by incendiary bombs, with oil-storage area fire simulation being developed near large oil installations. A further variation on fire decoy sites was the "SF", or "Special Fires" sites. A larger, longer-burning type of fire was provided at these sites - known as "Starfish" sites - to draw incendiary bombs, and hopefully as a consequence the full enemy payload, from falling on the larger conurbations and defence installations during heavy air raids. Decoy sites had a good level of success – airfield decoy sites across Britain for example had received 359 attacks by the end of 1941. The real airfields were bombed 358 times.

A bombing decoy site was established in close proximity to the site	✖

8.4.5 Abandoned Bombs

A post-air raid survey of buildings, facilities and installations would have included a search for evidence of bomb entry holes. If evidence was encountered, Bomb Disposal Officer teams would normally have been requested to attempt to locate, render safe and dispose of the bomb. Occasionally evidence of UXBs was discovered but due to a relatively benign position, access problems or a shortage of resources the UXB could not be exposed and rendered safe. Such an incident may have been recorded and noted as an Abandoned Bomb.

Given the inaccuracy of WWII records and the fact that these bombs were 'abandoned', their locations cannot be considered definitive, nor the lists exhaustive. The MoD states that 'action to make the devices safe would be taken only if it was thought they were unstable'. It should be noted

that other than the 'officially' abandoned bombs, there will inevitably be UXBs that were never recorded.

SafeLane Global holds records of officially registered abandoned bombs at or near the site	✗

8.5 UXB Ground Penetration

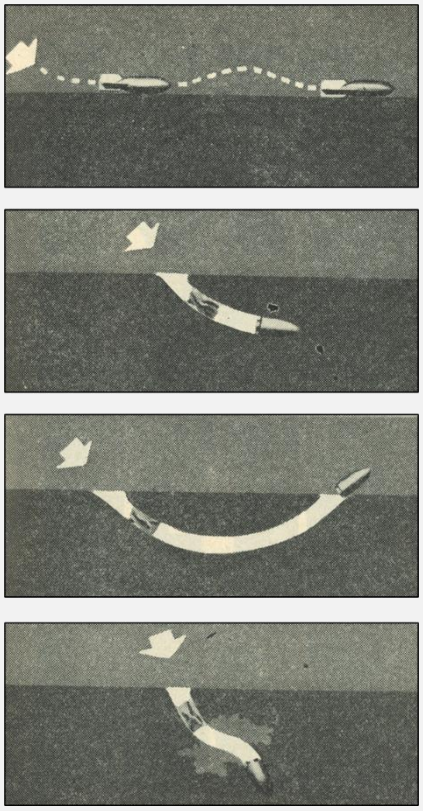
8.5.1 General Considerations

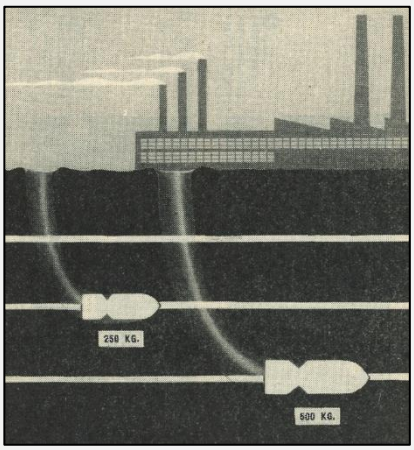
The actual penetration depth of aerial delivered bombs into the ground will have been determined by the mass and shape of the bomb, the velocity and angle of the bomb on impact (dependent on the height of release) and the nature of the ground and ground cover; the softer the ground, the greater the potential penetration. Peat, alluvium and soft clays are easier to penetrate than gravel and sand. Bombs are brought to rest or are commonly deflected by bedrock or large boulders.

8.5.2 The "j" Curve Effect

An air-dropped bomb released from normal bombing altitude (approx. 5,000m) on its curved trajectory can reach a terminal velocity of between 350-400 ms-1. In this case of high-level bombing, the angle of which the bomb enters the earth is approx. 15° from the perpendicular and its exact path is difficult to trace. The bomb is being driven by its kinetic energy can unless deflected, will continue its line of flight and can turn in an upwards curve towards the ground surface as it comes to rest. The upwards curve is caused by the transfer of energy as the bomb travels through the ground. The nose of the bomb travels slower than the rear of the bomb due to the drag/friction of it passing through the ground. The rear of the bomb, having more energy due to less drag/friction is travelling much quicker.

The location of the bomb is thus ''offset'' from the hole of entry. This ''offset'' from vertical is generally understood to be about one third of the penetration depth but can reach up to (and have been found at) 15m/50 ft from point of entry, dependent on ground conditions and the bomb's angle of impact. The figure below depicts the various paths of UXB through homogenous ground, showing how the J-curve effect can lead to a UXB coming to rest beneath undamaged buildings.





A UXB can come to rest beneath undamaged buildings due to the J-Curve effect if it lands in nearby soft ground.

Image source: Field Manual for Unexploded Bombs: Organisation and Operation For Disposal, United States War Department 1943

Left: Path of UXB in soft ground:

1. Ricochet resulting from low level attack: UXB stays perpendicular to ground and rests at surface.
2. Buried UXB with J-Curve: Bomb curves horizontally and rests perpendicular to surface.
3. UXB returning to surface due to J-Curve: Bomb points towards surface but may remain partially or completely below ground level.
4. UXB deflected by buried objects: Results in unpredictable path and unusual shift.

8.5.3 Second World War Bomb Penetration Studies

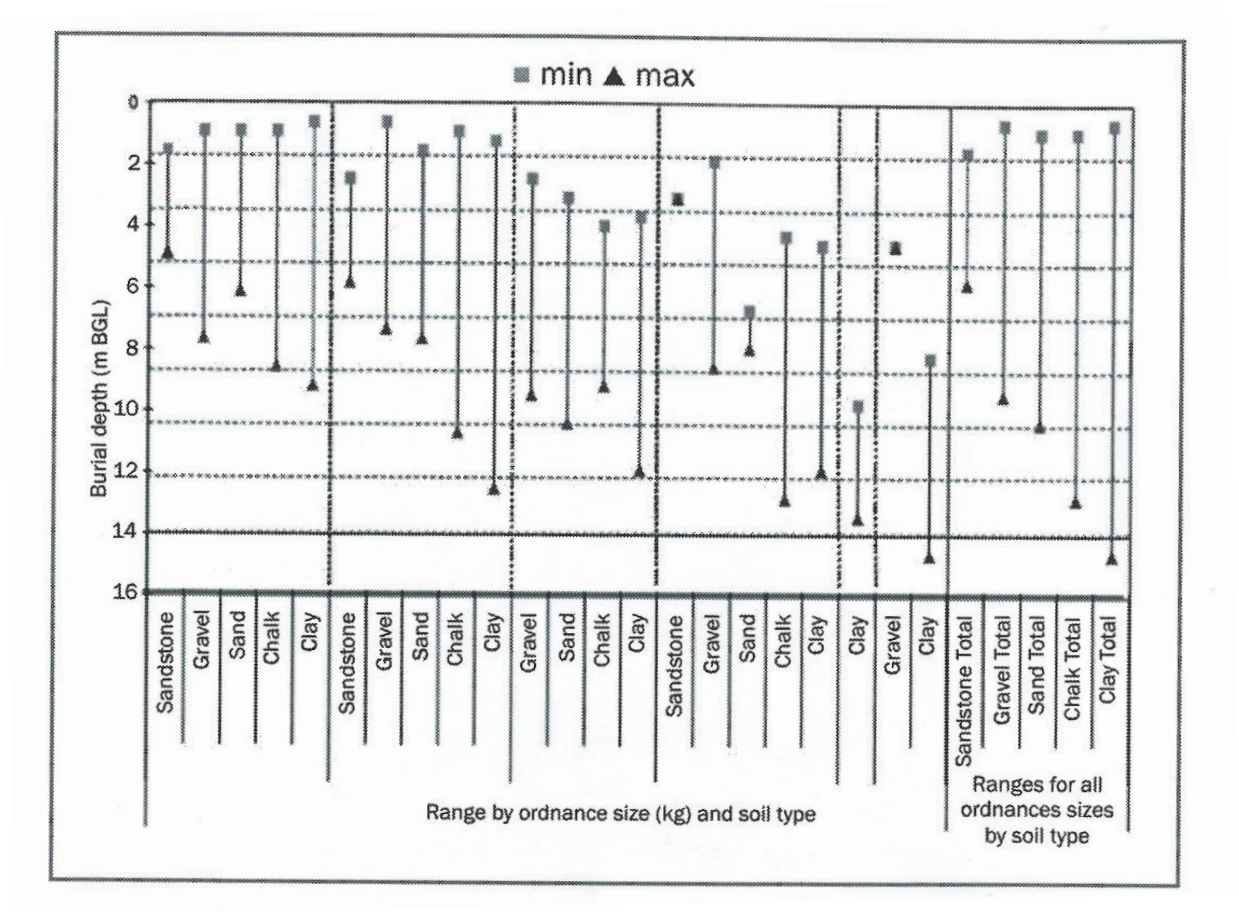
During WWII, the Ministry of Home Security undertook a major study on actual bomb penetration depths, carrying out statistical analysis on the measured depths of 1,328 bombs as reported by Bomb Disposal, mostly in the London area. They then came to conclusions as to the likely average and maximum depths of penetration of different sized bombs in different geological strata.

The median penetration of 430 x 50kg German bombs in London Clay was 4.6m and the maximum penetration observed for the SC50 bomb was 9m.

They concluded that the largest common German bomb, 500kg, had a likely penetration depth of 6m in sand or gravel but 8.7m in clay. The maximum observed depth for a 500kg bomb was 10.2m and for a 1,000kg bomb 12.7m. Theoretical calculations suggested that significantly greater penetration depths were probable.

8.5.4 CIRIA Bomb Penetration Depth Specifications

As stated within C681, the ground conditions at any individual site are likely to be highly variable and this results in a large range of burial depths for each different size bomb. The below chart shows the observed variation in burial depths of various sizes of air-delivered UXO for different ground conditions.



8.5.5 Site Specific Bomb Penetration Considerations

When considering an assessment of the bomb penetration at the site, the following parameters would be used:

- Geology – Superficial marine deposits of gravel, silt and sand with a bedrock of Lewisian Complex – Orthogneiss.
- Impact Angle and Velocity – 80-90° from horizontal and 267 metres per second.
- Bomb Mass and Configuration – The 500kg SC (General Purpose) HE bomb, without retarder units or armour piercing nose. This was the largest of the common bombs used against Britain.

Taking into account the above-mentioned factors it has been assessed that a 500kg bomb would have had an approximate maximum bomb penetration depth of between 8-10m below WWII ground level. Penetration depth could potentially have been greater if the UXB was larger (though only 4% of German bombs used in WWII over Britain were of that size). Note that UXBs may be found at any depth between just below the WWII ground level and the maximum penetration depth.

8.6 Likelihood of Post-raid UXO Detection

Utilising the available historical bombing records as reviewed in Section 8.4, it is possible to make an assessment of the likelihood that evidence of UXO would have been noted on a site during the war and the incident dealt with or recorded at the time. Factors such as bombing density, frequency of access, ground cover, damage and failure rate have been taken into consideration.

8.6.1 Density of Bombing

Bombing density is an important consideration for assessing the possibility that UXBs remain in an area. A very high density of bombs will have increased the likelihood of errors in record keeping at the time, as civil defence personnel and emergency services may have been overwhelmed. A higher density of bombing also increases the number of UXBs actually occurring in a given area.

The type and specific location of recorded bomb strikes is also an important consideration. If a stick of bombs (one individual aircraft's bomb load) is plotted in line with a site or is shown to straddle a site, then this raises the possibility that an unrecorded UXB from the same stick struck that site.

8.6.2 Bomb Damage

In Blitzed cities / towns throughout Britain, bomb sites were often not cleared of rubble until after the war and mid-war repairs to buildings were only carried out on the most vital facilities (power stations, gas works, weapons factories etc.). However, if a building only sustained bomb damage to its upper floors, any subsequent UXB strike to the structure will still have caused obvious damage, at ground floor level, which would have been reported and dealt with at the time.

HE bomb strikes to open ground will have resulted in a large crater and local soil disturbance. Any subsequent UXB strike will not have resulted in an easily identifiable entry hole and as such is likely to have gone unnoticed amongst the disturbed ground.

In London and south-east England, the German V1 Flying Bomb and V2 Long Range Rocket campaigns caused widespread devastation. However, as these weapons began to be utilised after the final significant Luftwaffe air raids had occurred, any serious damage caused by such weapons does not necessarily indicate an increased risk of Luftwaffe freefall UXB contamination. However, it is quite possible that serious damage inflicted during the 1940-1944 campaigns by Luftwaffe freefall bombs could have been erased by a subsequent V Weapon strike.

8.6.3 Frequency of Access

A UXB strike at a site where human access was infrequent would have had a lower chance of being observed, reported and recorded compared to a site which was developed and subject to regular access. UXB strikes during night time raids (when German planes could more easily evade anti-aircraft defences) are also more likely to have fallen unobserved than ones dropped during a daylight attack.

In frequently bombed cities / towns, ARP Wardens were tasked with carrying out searches for UXBs within recently bombed residential areas and schools. Similarly, many important home front facilities (factories, gas works, power stations, docks etc.) had their own dedicated ARP teams or Fire Watchers tasked with observing local air raids. Fire Watchers were mainly responsible for extinguishing 1kg incendiary bombs as well as reporting any UXB strikes. Anecdotal evidence however indicates that Fire Watchers did not always turn up for their shifts and therefore such UXB mitigating activities should not be assumed in the absence of site-specific evidence. Less important buildings sustaining bomb damage would have been abandoned until after the German bombing campaign in that area had ceased and repairs could be made, greatly decreasing the level of access to that site.

Schools closed due to the evacuation of children were often requisitioned by the Civil Defence authorities to be utilised as night time First Aid posts and reception centres (providing emergency accommodation for bombed out civilians). Therefore, an increased level of access is likely at these locations.

8.6.4 Ground Cover

The entry hole of a 50kg UXB (the most commonly deployed German HE bomb) could have been as little as 20cm in diameter. Wartime records also confirm that small German Incendiary Bombs, weighing just 1kg, were capable of significant penetration into soil, resulting in very small entry holes (5cm) or complete burial.

The quantity and type of ground cover present on a site during WWII would have had a significant effect, at ground level, on the visual evidence of buried UXO.

Evidence of UXO could be obscured in dense vegetation, soft ground, rubble, railway ballast or amongst stockpiled material (such as aggregate, coal or refuse heaps). A UXB strike to waterlogged ground or open water would have been immediately obscured from view beneath the waterline. Had such an incident occurred within a tidal mudflat or river bank, the resulting entry hole will have remained only temporarily, before becoming in-filled by water and sediment. Any HE UXB strike to elevated risk ground cover could potentially have come to rest beneath neighbouring undamaged buildings or hard-standing due to the 'J-Curve' Effect.

UXB strikes to undamaged/superficially damaged buildings and hard-surfaced ground will still have caused substantial damage or an easily identifiable and persistent entry hole. Similarly, it is unlikely that an HE UXB entry hole on well-maintained / manicured lawns (tennis courts, bowling greens, golf course fairways / greens, gardens in affluent areas etc), would have been overlooked. Such incidents would have been reported and the UXB subsequently removed.

8.6.5 German Air-Delivered Ordnance Failure Rate

Based on empirical evidence, it is generally accepted that 10% of the German HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuze or gaine malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude. Most likely if the bomber was under attack or crashing.

War Office Statistics document that a daily average of 84 bombs which failed to function were dropped on civilian targets in Great Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these (probably mostly fitted with time delay fuzes) exploded sometime after they fell; the remainder were unintentional failures.

From 1940 to 1945 bomb disposal teams dealt with a total of 50,000 explosive items of 50kg and over (i.e. German bombs), 7,000 AAA shells and 300,000 beach mines. These operations resulted in the deaths of 394 officers and men. However, UXO is still regularly encountered across the UK.

Note, due to manufacturing fault or failure of the bomber crew to correctly arm their munitions, whole bomb loads often failed to detonate. Therefore, the presence of reported UXBs increases the likelihood of an additional unrecorded UXB in the vicinity.

8.6.6 Site Specific Analysis

The following table will place the site in context with these factors, in order to assess the likelihood of post-raid UXO detection within the project site.

Likelihood of Post Raid UXO Detection on Site			
Site-Specific Factors			**Additional Comments**
Density of Bombing Assessment	Based on wartime records or secondary source information, what was the bombing density over the site?	Low	
	Was the site ever subjected to one or more large-scale (>100 tons of ordnance) night time Blitz raids?	✘	
	Were any HE bomb strikes recorded on site?	✘	
	What is the distance between the site boundary and the closest recorded large bomb strike?	n/k	No German bombing was recorded over Skye during WWII.
	How many HE, Parachute Mine, Oil Incendiary, Phosphorus Incendiary or Fire Pot bombs (large bombs) were recorded within a 300m radius of the site?	0	
	Were any nearby sticks of large bombs recorded in line with the site?	✘	
	Were any 1kg incendiary bomb showers recorded over the site?	✘	
Bomb Damage Assessment	A comparison of the historical records confirms that buildings within the site boundary sustained serious bomb damage.	n/a	
	Direct or indirect evidence of HE bomb craters in open ground (within the site boundary) has been found.	✘	
	Buildings on site were seriously damaged by a V1 and / or V2 strike.	n/a	

	Buildings on site could have been seriously damaged prior to the nearby V1 or V2 strike?	n/a	
Frequency of Access Assessment	The site was situated in a densely populated urban area during WWII and therefore would have been accessed at the outbreak of WWII.	✘	
	The site was exclusively or partially developed during WWII.	✘	
	Buildings on site survived WWII intact and therefore likely remained inhabited or in use, suggesting these localities and their immediate environs were accessed throughout the war.	n/a	
	The site was crossed by roads / pavements or footpaths which would have been regularly used / subject to daily footfall.	✘	
	The site was occupied by small residential back yards / gardens, likely to have been put to use for cultivation as a result of the government's Dig for Victory Campaign.	✘	
	The site was occupied by a school during WWII.	✘	
	Part of the site is likely to have been subject to post-raid searches for UXO.	✘	
	Buildings on site sustained serious bomb damage and as a result were likely abandoned (along with any associated gardens / open ground) for the remainder of the war.	n/a	
	The site was occupied by peripheral open ground / wasteland, with no apparent use, which may have been neglected.	✓	
	The site may have been occupied by recreational land / sports fields which may have only experienced seasonal access.	✘	
	The site was occupied by a graveyard which would have experienced limited access.	✘	
	The site was occupied by agricultural land, rural countryside or woodland which would not have been accessed in full, either regularly or frequently.	✓	

	The site was occupied by railway sidings which may not have been as regularly checked for buckling as mainline railway tracks.	✖	
	The site was occupied by soft railway embankments which are likely to have been neglected during the war.	✖	
Ground Cover Assessment	The site was partially or entirely abandoned, due to bomb damage, resulting in associated open ground likely becoming overgrown.	✖	
	The site was occupied by dense, inaccessible vegetation during WWII.	✓	
	The site may have been susceptible to waterlogged conditions during WWII.	✖	
	The site was occupied by (possibly) unmaintained grass field during WWII.	✓	
	The site was part occupied by a canal, river, dock basin, lake or reservoir during WWII.	✖	
	The site was occupied by tidal mud or marshland during WWII.	✓	
	The site was occupied by railway tracks crossing soft ground during WWII.	✖	
	The site was occupied by stockpiled material during WWII.	✖	
	The site was occupied by buildings, hard-standing or other manmade structures that did not sustain any degree of bomb damage.	n/a	
	A comparison of the historical records confirms that buildings on site sustained inconsequential minor / moderate damage.	n/a	
	The site was occupied by well-maintained, manicured lawn during WWII.	✖	
	Undamaged, developed parts of the site would have been vulnerable to the J-Curve Effect.	✓	

Bomb Failure Rate Assessment	Evidence has been found which suggests that the bomb failure rate in the vicinity of the site would have been different from the "approximately 10%" figure normally used.	✗	

9 The Threat from Allied Military Ordnance

The following potential historical and modern sources of UXO contamination on site or in the surrounding area have been considered:

Potential Source of Contamination on Site	
Army, Navy and RAF Bases / Installations	✗
Military Training Areas / Weapons Ranges	✗
Ordnance / Explosives Factories and Storage Depots	✗
Sites Requisitioned for Military Use	✓
Sites Used or Occupied by the Home Guard	✓
Military Fortifications and Coastal Defences	✗
Locations of Army Explosive Ordnance Clearance Tasks	✗
WWII Anti-Aircraft Batteries	✓
WWII Pipe Mined Locations and Beach Minefields	✗

The risk of contamination from Allied UXO on site is discussed below.

9.1 Home Guard Activity

The Home Guard (HG) was a defence organisation of the British Army, operational between 1940 and 1944. It comprised 1.5 million local volunteers, otherwise ineligible for military service and acted as a secondary defence force in case of enemy invasion. The HG guarded the coastal areas of Britain and other important facilities such as airfields, factories and explosives stores. They were also active in county towns and cities.

Official records were rarely kept by the HG and therefore any present-day evidence is usually anecdotal. However, it is known that HG personnel often carried out training (including weapons training) in open countryside on the outskirts of cities / towns. Today, items of ordnance related to the HG are occasionally encountered by members of the public and the construction industry in the British countryside. This suggests a culture of ill-discipline regarding live ammunition within HG units.

HG personnel are known to have purposefully buried caches of ammunition and weapons in tactical positions, to be exhumed and used in case of invasion. Records of such caches were not rigorously kept, and some were therefore forgotten about. This is substantiated by several HG UXO finds over recent years. The below table shows just a handful of examples:[1]

[1] Various News Sources

Home Guard UXO Finds:	
	Unexploded Spigot Mortar Round, used by the Home Guard in WWII, found and disposed of in Hayle, Cornwall – January 2021
	24 x WWII grenades found buried in a field in Sibton, Suffolk – May 2019
	A cache of 80 phosphorous grenades buried by the Home Guard found in Eastbourne – September 2015
	Home Guard Phosphorous Grenades found buried beneath a bridge in Herne Bay – July 2015

9.2 Anti-Aircraft Gun Batteries

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) and Light Anti-Aircraft Artillery (LAA). The LAA batteries were intended to engage fast low flying aircraft and were typically deployed around airfields or strategic installations. These batteries were mobile and could be moved to new positions with relative ease when required. With four guns per battery firing several rounds per minute, AA batteries could expel numerous shells in even the shortest engagements. Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

The maximum ceiling height of fire at that time was around 11,000m however, as the war progressed, improved variants of the 3.7" gun were introduced and, from 1942, large 5.25-inch weapons were brought into service. These had significantly improved ceiling heights of fire reaching over 18,000m.

When the supply of clockwork fuses from Switzerland was cut off, Britain was forced to make its own. After four years of war, the country still lacked the engineering skills to produce a reliable fuse. This resulted in a considerable number of AA projectiles exploding prematurely, killing the gunners or failing to explode at all and falling to the ground as UXBs. In January 1944, more people in London were killed by HAA shells than by German bombs.

9.3 Site-Specific Threat from Allied Military Ordnance

The following table identifies the potential threat to the site of contamination from British / Allied UXO.

Potential Source	Details
Home Guard Activity on site	• Minutes from a session of parliament in December 1940 imply that a Home Guard unit was stationed on the island and may have suffered a lack of serious organisation and training due to a lack of nearby military personnel. [2] • Sections of the site were occupied by undeveloped open ground during WWII, suitable for training exercises. However, no evidence has been discovered to infer that such activities took place within the vicinity of the route.
Military Activity on site	• Whilst no designated military camp has been recorded on the Isle of Skye, units of commandos, based at their headquarters in Lochailhort (31km south) would take part in training exercises on the island. The account below details one such exercise. *"We were taken at dusk one evening in assault boats from Inverailort across to Skye. We landed on the west coast of Skye, blew a gap in barbed wire with Bangalore torpedoes, and then crossed and attacked Portree we advanced down Skye attacking various places along the way, eventually attacking Broadford and ending up near the Kyle* (15km north) *where we got on a destroyer and were brought back to Inverailort and landed on the jetty".*[3] • Whilst this exercise took place a significant distance from the site, it is important to note the large area of the island covered during this drill. It is possible that similar activities could have taken place in the vicinity of the site, however no evidence for this was obtained during the timeframe of this report.

[2] https://api.parliament.uk/historic-hansard/commons/1940/nov/19/home-guard
[3] Allan, S., *Commando Country*. (NMS Enterprises Ltd 2007). Page 41.

Naval Activity on site	• During both world wars, the waters and lochs off the western coast of Scotland were used by German U-boats to conceal themselves from Allied air-patrol. This is illustrated by the anti-submarine nets at Loch Hourn, approximately 6km south-east of the site.[4] • Additional evidence for this can be seen on the northern coast of the island, approximately 50km north-west of the study area. A Royal Naval seaplane was noted to have dropped depth charges into Loch Greshornish to destroy a U-boat taking refuge there.[5] • While the presence of U-Boats was likely in the waters surrounding the site, the lower water level and narrow channel of the study area meant that a U-boat would have been unable to access this area. Therefore, the presence of anti-submarine munitions having been dropped on site is minimal.
Defensive features within the vicinity	No defensive emplacements located within a 1km radius of the site.
Threat to the site from unexploded AA shells	• No heavy anti-aircraft batteries were located within 15km of the site. • The nearest HAA battery was situated in the vicinity of Kyle of Lochalsh.

9.4 Generic Types of WWII British / Allied Unexploded Ordnance

9.4.1 Land Service Ammunition (LSA)

9.4.1.1 General

The term Land Service Ammunition covers all items of ordnance that are propelled, placed or thrown during land warfare. They may be filled or charged with explosives, smoke, incendiary or pyrotechnics. They can be broken into five main groups:

a. Mortars
b. Grenades
c. Projectiles
d. Rockets
e. Landmines

Unexploded or partially unexploded Mortars and Grenades are among the most common items of UXO encountered in the UK. They are commonly encountered in areas used by the military for training and are often found discarded on or near historic military bases.

Examples of the most commonly used British / Allied Land Service Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

[4] NOSAS: Archeological Survey of Outer Loch Hourn (2009).
[5] Swire, O., *Skye: The Island and its Legends*. (2006). Page 114.

9.4.1.2 Mortars

A mortar bomb is a fin-stabilised munition, normally nose-fuzed and fitted with its own propelling charge (primary cartridge). Range is increased by adding extra propellant (augmenting charges). They are either HE or Carrier and generally identified by their tear-dropped shape (older variants however are parallel sided) and a finned 'spigot tube' screwed or welded to the rear end of the body housing the propellant charge.

A mortar relies on a striker hitting a detonator for explosion to occur. It is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Discarded augmenting charges are often encountered around mortar firing areas/bases.

9.4.1.3 Grenades

A grenade is a short-range weapon which may be thrown by hand, fired from the end of a rifle or projected/propelled from a special purpose grenade launcher. They are divided into two categories; HE and Carrier (generally smoke). As with mortars, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension, and therefore shock may cause it to function. A grenade can have an explosive range of 15-20m. Common older variants have a classic 'pineapple' shape; modern grenades tend to be smooth-sided.

9.4.2 Small Arms Ammunition (SAA)

The most likely type of ordnance to be encountered on site are items of SAA (bullets), especially .303" ammunition which was the standard British and Commonwealth military cartridge from 1889 until the 1950s.

However even if an item such as this functioned, the explosion would not be contained within a barrel and detonation would only result in local overpressure and very minor fragmentation from the cartridge case.

Some LAA guns and RAF fighter cannons in use with British forces during WWII utilised the 20mm round. These bullets had a small fuse and a ~4gram HE or incendiary charge. Although small, this fill quantity still has the potential to cause serious injury.

Examples of the most commonly used British / Allied Small Arms Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

9.4.3 Anti-Aircraft Shells

At the start of the war two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA) using large calibre weapons such as the 3.7" QF (Quick Firing) gun and Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons such as 40mm Bofors gun which could fire up to 120 x 40mm HE shells per minute to over 1,800m. During the early war period there was a severe shortage of AAA so older WWI 3" and modified naval 4.5" guns were also deployed.

These shells are frequently mistakenly identified as small German air-delivered bombs but are differentiated by the copper driving band found in front of the base. Although the larger unexploded projectiles could enter the ground, they did not have great penetration ability and are therefore likely to be found close to WWII ground level. With a HE fill and fragmentation hazard these items of UXO also present a significant risk if encountered.

The smaller 40mm projectiles are similar in appearance and effect to small arms ammunition and, although still dangerous, present a lower risk. Details of the most commonly deployed WWII AAA projectiles are shown below:

Gun type	Calibre	Shell Dimensions	Shell Weight	HE Fill Weight
3.7 Inch	94mm	94mm x 438mm	12.7kg	1.1kg
4.5 Inch	114mm	114mm x 578mm	24.7kg	1.7kg
40mm	40mm	40mm x 311mm	0.84kg	70g

Examples of the most commonly used British / Allied Anti-Aircraft Ammunition types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

10 Explosive Ordnance in the Marine and Inter-Tidal Environment

10.1 Naval Mines

10.1.1 General

A naval mine is a self-contained explosive device placed in water to destroy ships and/or submarines. Like land mines, they are weapons laid and left until they are triggered by the approach of an enemy ship. Naval mines can be used offensively, to hamper enemy shipping and lock it into its harbour, or defensively, to protect friendly shipping and create "safe" zones.

Although attempts were made to remove all the mines from the sea following WWI and WWII some sources state that up to 70% of sea mines were not recovered. Consequently, the possibility of encountering a British or German sea mine in the area of the proposed works cannot be discounted and would cause considerable damage if such a device functioned.

The North Sea is known to have been mined during both WWI and WWII by the UK, however it is also known that unrecorded German mine laying operations also took place in the shallow, coastal areas of the English Channel and the Solent. The primary targets of German mining in both wars were the coastal traffic and merchant convoys delivering to and moving supplies around Britain. Many of the Lochs on the western coast of Scotland were mined by the Allies in an attempt to thwart the U-boat menace in the area.

A 2009 NATO mine assessment concluded there could be some 80,000 mines from both world wars in the English Channel, North Sea, and Baltic Sea.

10.1.2 Mining off Skye – WWII

Whilst no recorded minefields were present off the coast of Skye during WWII, a number of secondary sources have recorded incidents within the surrounding area. One such occasion was mentioned in a 1948 newspaper article, where two mines were discovered in the channel off Kyle of Lochalsh (14.5km north).[6] The most noteworthy incident occurred during November 1940, when the Minelayer HMS Port Napier, moored at Kyle of Lochalsh with the rest of the minelaying squadron caught fire whilst refuelling. Over 500 mines fitted with detonators were aboard, and while the crew

[6] https://www.britishnewspaperarchive.co.uk/viewer/bl/0000578/19480302/053/0004

managed to remove a large number of them before the ship foundered, many were jettisoned fully armed.[7]

Clearance operations took place post of the war, with unexploded mines and 4-inch ammunition recovered during the 1950s. However, it is possible in this area that some unrecorded mines may still be present in the area. This area is now registered as a chartered munitions dump.

10.1.3 Generic Types of Mines

A wide range of different types of sea-mines were deployed by German and Allied Forces. Mines can be broadly categorised into four classes – ground, moored, control and drifting, with the main initiation mechanisms being impact and influence.

The impact/contact mines contained a fuzing system which was activated by direct contact with the hull of a vessel. Influence mines were detonated by detecting changes in the earth's magnetic field, noise or sea-water pressure effects caused by the passage of a vessel. Some mines were also fitted with timed fuzes. It should be noted that WWI contact mines were very similar in appearance and design to their WWII successors.

- Contact Mines: These came in a number of different designs but mostly were initiated by "Hertz horns", comprising a soft lead tube containing a glass vial of electrolyte which broke when the horn was bent by contact. The electrolyte completed an electrical circuit which detonated the device. Others used a switch system initiated by direct contact or via a snag-line. Explosive charges were up to 300kg. When deployed the mines floated (on the surface or at depth) in position on a cable or chain attached to a sinker.
- Influence Mines: Again there were a number of variants of these mines which were laid on the sea-bed and activated by the passage of a vessel. They were typically larger than the contact variety with high explosive charge weights of up to 900kg.
- The "mine-bomb": This device was designed by the Luftwaffe due to the difficulty in the precise delivery of parachute mines. It had a robust influence mechanism which could withstand the impact of being dropped in water without retardation but could also be fitted with an impact fuze for use against shipping – in this configuration it functioned as a conventional high explosive bomb. Charge weight was 725kg.
- Also deployed in the Channel were thousands of Anti-Sweep devices. These were sometimes attached to the mooring lines themselves. When a submarine or any mine-sweeping equipment touched and pulled the mooring wire, the trigger moved upwards and closed an electric circuit which detonated the mine. Others were fitted with switches which would detonate a small charge severing the sweep cable.

Contact and influence mines were deployed in lines by various navies. The mines were designed to float at varying depths and thus create complex curtains. While records of mine lays were generally kept, they are now incomplete and cannot be relied upon. Nevertheless, they serve to provide a guide to areas of elevated risk.

Examples of the most commonly used naval mine types are presented in the *Ordnance Specifications and Information* appendices, at the end of this document.

[7] https://www.britishnewspaperarchive.co.uk/viewer/bl/0000540/19450726/074/0003

10.1.4 Site-Specific Threat from Mines

Whilst the possibility of encountering naval mines in the surrounding area cannot be fully ruled out, the significant distance of known incidents / areas of operation in relation to the site means that the likelihood of contamination from this source remains low.

10.2 Shipwrecks

10.2.1 General

Over 1,000 vessels (both military and merchant navy) were sunk within the British Isles during both World Wars, predominantly as a result of offensive submarine activity, aerial bombardment and within naval minefields.

Many vessels, particularly those in use by the military and responsible for the transportation of ordnance and live explosives, can still pose a threat to modern-day intrusive works.

In general, the risk of munitions contamination is somewhat less in the vicinity of military related wrecks than for dump sites and weapons ranges, since the munitions tend to be enclosed and immobile within the wrecks, and typically unfuzed during transportation.

Furthermore, weapons stored in ships' magazines which have not been through the firing sequence are inherently safer than those which have been fired but failed to detonate. It is possible that some munitions would have been thrown clear of the vessel as it sank, or they may have become exposed as the wrecks gradually break up.

Shipwrecks (even those of a commercial nature) are indicative of military activity in the area. The method in which these ships were sunk, for example by aerial bombing or torpedoes, illustrate the types of weapons expelled in that area. Had any of these weapons missed the target or landed in the sea unexploded, they could still remain on the sea floor. In addition to this, most merchant vessels were equipped with some form of provision for protection against enemy attack.

10.2.2 HMS Embrace

Approximately 650m north of the site, in the vicinity of Duisdealmor lies the wreck of the HMS Embrace, a 94 tonne trawler requisitioned for naval use as a harbour defence patrol craft. Records indicate that the ship went aground on the 2nd August 1940 (location presented in **Annex D**). In addition, a dive at the site in 2005 indicated that ammunition still lay within the wreckage.[8] The types of ammunition present within the wreck of the Embrace is not confirmed; however, due to the size of the vessel and its purpose as a harbour patrol craft, it is likely to include small arms ammunition.

10.2.3 Site-Specific Threat from Shipwrecks

Whilst the possibility of encountering ammunition deposits from the nearby shipwreck cannot be fully ruled out, the significant distance of the HMS Embrace in relation to the site means that the likelihood of contamination from this source remains low.

[8] https://www.wrecksite.eu/ukhoDetails.aspx?1964

10.3 Modern Training Areas[9]

A number of sources have been reviewed to identify the locations of naval training areas within proximity to the site route. The following features have been recorded:

10.3.1 Submarine Practice Area

The site route lies adjacent to a designated Submarine Exercise area, running through the channel between the south-east coast of Skye and the mainland. Due to the sheltered nature of the site route, in addition to the shallow water level surrounding the site, the exercise area is unlikely to present an elevated risk of ordnance contamination.

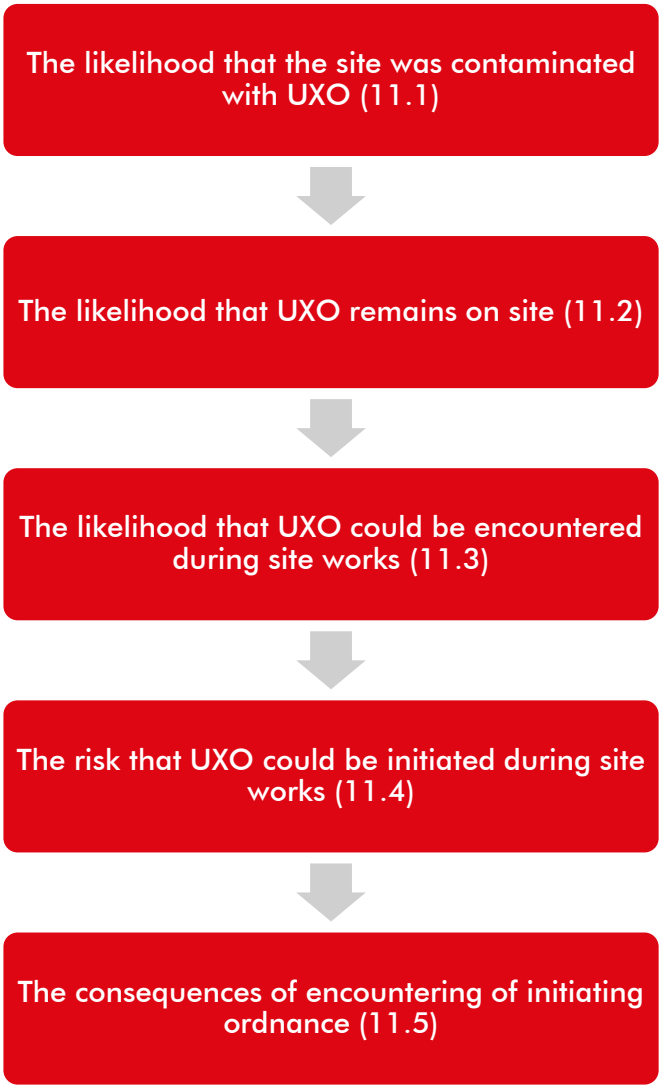
10.3.2 Mine Warfare Activity

A modern mine-warfare practice area, designated 6G can be identified approximately 5.5km south-east of the site, in the vicinity of Mallaig. Due to the significant distance of this practice area to the site, it is unlikely to present an elevated risk of ordnance contamination and will not be further addressed in this report.

[9] http://www.scottishcreelfishermensfederation.co.uk/20160322%20JW161%20Brief%20for%20fishing%20vessels%20and%20ferries-U-SOSM%20V1.pdf

11 The Overall Unexploded Ordnance Risk Assessment Methodology

Taking into account the quality of the historical evidence, the assessment of the overall risk to any intrusive works from UXO must evaluate the following factors:



Each of these steps will be evaluated in the following sections in order to conclude the total risk from UXO to the proposed works to be undertaken within the project site.

11.1 The Likelihood that the Site was Contaminated with Unexploded Ordnance

11.1.1 General

The below is a generalised table of factors used to determine the likelihood that the site was contaminated with unexploded ordnance. Note that additional site-specific information can adjust UXO risk beyond these criteria:

Low Likelihood	Medium Likelihood	High Likelihood
German Air-Delivered Ordnance / Allied Anti-Aircraft Shells		
No evidence of bombing / bomb damage on site coupled with low local bombing density.	Moderate to High local bombing density or evidence of bombing / bomb damage on or close to the site.	High local bombing density or evidence of bombing /bomb damage on or adjacent to the site. Confirmed finds of WWII UXB.
Ground conditions that would prevent UXB penetration or lead to easily identifiable entry holes.	Ground conditions that allow for bomb penetration.	Ground conditions that would have immediately and completely obscured the existence of UXB.
Site was occupied and accessed fully throughout the bombing campaign.	Site located in an area that was infrequently observed or accessed, with a low likelihood that a UXB strike would have been noticed.	Site may be completely obscured from view or subject to very infrequent access.
British / Allied Ordnance		
No evidence of Allied military activity on or near the site. Or Military sites which have been cleared / redeveloped since their use Or Military-owned sites which have not been used for training with live munitions.	Clear evidence of military training activity on site involving live ammunition / munitions. Military sites which have not undergone clearance operations or redevelopment since use. Evidence of weapons storage on site.	Evidence of weapons testing or disposal on or adjacent to the site.
Developed areas that are unlikely to have been used for military exercises.	Open or unmaintained ground that may have been used for disposal or caching of munitions.	Evidence of UXO finds on or in the vicinity of the site.

The following sections assess the likelihood of contamination from German UXO and British / Allied UXO, based on the evidence discussed in the previous sections.

11.1.2 Likelihood of Contamination from German UXO

The following table discusses the overall likelihood of contamination from German UXO, based on the evidence discussed in Section 8.

Overview of the Potential Sources of German Air-Delivered UXO	
Bombing density	• No bombing activity recorded over the Isle of Skye.
Bomb Damage	• No signs of bomb damage on site or in the surrounding area.
Ground Conditions	• Soft vegetation in the western and eastern extent. • Sand and shingle present at the sites centre.
Frequency of Access	• Site unlikely to have seen regular access.
J-Curve Effect	• Had any UXB landed within the soft ground or tidal mud on site, it could have come to rest beneath the study area.
Other considerations	• n/a
Overall Likelihood of Contamination	**Low**

11.1.3 Likelihood of Contamination from British / Allied UXO

The following table discusses the overall likelihood of contamination from British / Allied UXO, based on the evidence discussed in Section 9.

Overview of the Potential Sources of British / Allied UXO	
Land Service Ammunition / Small Arms Ammunition	• Whilst no designated military camp has been recorded on the Isle of Skye, units of commandos would take part in training exercises on the island. • No evidence has been found to suggest that the site formerly had any British / Allied military occupation or usage that could have led to contamination with items of UXO.
Anti-Aircraft Projectiles	• The nearest recorded HAA battery to the site was located approximately 15km to the north.
Overall Likelihood of Contamination	**Low**

11.1.4 Likelihood of Contamination from Naval Explosive Ordnance

The following table discusses the overall likelihood of contamination from Marine and Inter-Tidal UXO, based on the evidence discussed in Section 10.

Overview of the Potential Sources of Marine and Inter-Tidal UXO	
Naval / Airdropped Mines	• Records indicate that several mines were jettisoned / disposed of in the channel of Kyle of Lochalsh, approximately 14.5km north of the site. • In addition, it is possible the German U-Boats may have laid mines in the surrounding lochs and waterways. • Whilst the possibility of encountering naval mines in the surrounding area cannot be fully ruled out, the significant distance of known incidents / areas of operation in relation to the site means that the likelihood of contamination from this source remains low.
Shipwrecks	• HMS Embrace, a naval trawler ran aground at Duisdealmor, approximately 650m north-west of the site. • Reports indicate that the vessel had ammunition stored onboard. • The significant distance of the HMS Embrace in relation to the site means that the likelihood of contamination from this source remains low.
Naval Ordnance	• Secondary evidence indicates that Lochs and waterways around Skye would have been subjected to anti-submarine warfare activity, including depth charges and anti-sub netting. • While the presence of U-Boats was likely in the waters surrounding the site, the lower water level and narrow channel of the study area meant that a U-boat would have been unable to access this area. Therefore, the presence of anti-submarine munitions having been dropped on site is minimal.
Overall Likelihood of Contamination	**Low**

11.2 The Likelihood that Unexploded Ordnance Remains on Site

11.2.1 General

The extent to which any ordnance clearance activities have taken place on site or extensive ground works have occurred is relevant since they may indicate previous ordnance contamination but also may have reduced the risk that ordnance remains undiscovered.

11.2.2 EOD Bomb Disposal and Clearance Tasks

SafeLane Global holds a number of official records of explosive ordnance disposal operations during and following WWII, obtained from the Explosive Ordnance Disposal (EOD) Archive Information Office at 33 Engineer Regiment (EOD), British Army.

Potential Source	Details
Records of Army EOD tasks having taken place on site or in the vicinity	None
Local ordnance finds	OSPAR Find: 17/03/2005 – One item of Conventional Ordnance discovered on the shore at Sconser, approximately 26km north-west of the site.
Local tasks undertaken by SafeLane Global	None

11.2.3 Post War Redevelopment

The nature of post-WWII ground works, redevelopment and construction has been considered. Significant structural redevelopment on site can, in some cases, provide a level of mitigation, particularly from shallow buried items. However, if a site has not undergone any extent of redevelopment, the likelihood of UXO remaining within its boundaries can remain.

The site has been redeveloped post-WWII	✘
Further Details	No signs of significant development appear to have taken place within the study area post-WWII.

11.2.4 Site-Specific Analysis

The following table discusses the likelihood that UXO could remain on site, following any post-WWII activity.

Mitigating factors during post-WWII period	The site has remained undeveloped since the end of WWII.

Further comments	The threat of UXO contaminating the site has been assessed as minimal and therefore the likelihood of UXO remaining on site is also minimal.

11.3 The Likelihood that Ordnance may be Encountered during the Works

The following table discusses the likelihood that UXO could be encountered on site during the proposed works.

At-Risk Scenarios	The most likely scenarios under which a UXO could be encountered during construction works is during piling, drilling operations or bulk excavations for basement levels. The overall risk will depend on the extent of the works, such as the numbers of boreholes/piles (if required) and the volume of the excavations. Since an air-dropped bomb may come to rest at any depth between just below ground level and its approximate penetration depth there is also a chance that such an item could be encountered during shallow excavations (for services or site investigations) into the original WWII ground level. If the proposed works are due to be undertaken within post war fill material / made ground, the risk of encountering WWII UXBs is low. However, if works are to be undertaken below WWII ground level this risk is significantly higher.
Likelihood of UXO being encountered during the proposed works	The threat from UXO remaining on site has been assessed as minimal and therefore the risk of UXO being encountered during the proposed work is also minimal.

11.4 The Risk that Ordnance may be Initiated

Items of ordnance do not become inert or lose their effectiveness with age. Time can indeed cause items to become more sensitive and less stable. This applies equally to items submerged in water or embedded in silts, clays or similar materials. The greatest risk occurs when an item of ordnance is struck or interfered with. This is likely to occur when mechanical equipment is used or when unqualified personnel pick up munitions.

11.4.1 Initiation of Unexploded Bombs

In the case of unexploded German bombs discovered within the construction site environment, there are a number of potential initiation mechanisms:

Direct Impact onto the main body of the bomb	Unless the fuze or fuze pocket is struck, there needs to be a significant impact to initiate a buried iron bomb.
Re-starting the clock timer in the fuze	Only a small proportion of German WWII bombs employed clockwork fuzes. It is probable that significant corrosion has taken place within the fuze since the end of WWII that would prevent clockwork mechanisms from functioning, nevertheless it was reported that the fuze in a UXB dealt with by 33 EOD Regiment in Surrey in 2002 did recommence.

Induction of a static charge, causing a current in an electric fuze	The majority of German WWII bombs employed electric fuzes. It is probable that significant corrosion has taken place within the fuze mechanism since the end of WWII such that the fuze circuit could not be activated.
Friction impact initiating the (shock-sensitive) fuze explosive	This is the most likely scenario resulting in the bomb detonating.

11.4.2 Activities that may Result in the Initiation of Unexploded Ordnance

Unexploded bombs do not spontaneously explode. All high explosive requires significant energy to create the conditions for detonation to occur. The risk that UXO could be initiated if encountered will depend on its condition, how it is found and the energy with which it is struck. However certain activities pose a greater risk than others.

Percussive piling or deep mechanical excavations	The most violent activity on most construction sites is percussive piling or deep mechanical excavations. If an item is struck with a significant enough impact, be it direct or through friction/vibration, it risks detonation.
Shallow excavation	Soil levelling and shallow excavation such as trial pits can pose a similar risk to deeper excavations, since UXO can be found at any depth between ground level and the maximum bomb penetration depth. In addition to risk of initiation by violent impact or vibration, detonation can also occur if discovered items are mishandled by unqualified personnel. This is particularly common when onsite personnel are not trained in the recognition of ordnance.
Non-intrusive works	In the case of non-intrusive planned works, little risk is posed by items of UXO that are buried beneath the ground. However, risk can arise from unburied munitions, particularly items of ordnance discarded in periphery areas of military sites. These items are frequently discovered by onsite personnel and remain live and liable to activate if mishandled.

11.5 The Consequences of Encountering or Initiating Ordnance

Clearly the consequences of an inadvertent detonation of UXO during construction operations would be catastrophic with a serious risk to life, damage to plant and a total site shutdown during follow-up investigations.

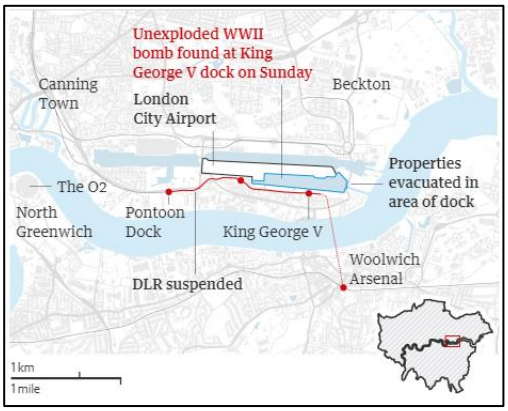
Since the risk of initiating ordnance is significantly reduced if appropriate mitigation measures are undertaken, the most important consequence of the discovery of ordnance will be economic. This would be particularly so in the case of high-profile locations and could involve the evacuation of the public.

The unexpected discovery of ordnance may require the closing of the site for any time between a few hours and a week with a potentially significant cost in lost time. Note also that the suspected find of ordnance, if handled solely through the authorities, may also involve loss of production since the first action of the Police in most cases will be to isolate the locale whilst awaiting military assistance, even if this turns out to have been unnecessary.

The following tables review a number of finds over recent years both in the UK and overseas that have seen large-scale disruptions, damage and injury/death:

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
 RESCUE workers search for survivors after a Second World War bomb exploded at a building site in Berlin, killing three people and injuring at least eight others. A fire brigade spokesman said he feared the final death toll could be higher. One worker was still missing, believed to be trapped under a machine. "We've found human remains 100 metres away but we can't tell if they belong to the dead already found," the spokesman said. The blast, set off by drilling work on Frankfurter Allee, one of east Berlin's busiest avenues, trapped workers under building machinery and sent huge chunks of concrete tumbling through the air. A large office block was being built on the site of the explosion which sent shoppers scrambling for shelter and paralysed dense afternoon traffic. One eyewitness said: "There was a bang, then silence, and then it started raining stones and dirt." Dozens of cars within a 250-metre radius were wrecked and the top two floors of a nearby apartment block caved in. Radio reports claimed that the total number of injured stood at 14. **Blown up by history**	A WWII bomb killed 3 and injured 8 in Berlin - 1994
	WWII bomb killed 3 in Goettingen, Germany – 2010.
	Excavator operator killed by WWII bomb in Euskirchen, Germany – 2014. A WWII bomb exploded at a construction site near a west German town, killing a man and injuring 8 others. The explosion occurred with a digger accidently struck the device during excavation works.

UXB Incidents where intrusive works have caused detonation, resulting in death, injury and damage to plant	
	A highway construction worker in Germany accidentally struck a WWII bomb, killing himself and wrecking several passing cars – 2006.
	Destroyed piling rig and dump truck after detonation of WWII UXB in Austria – 2006.
	WWII bomb injures 17 at construction site in Hattingen, Germany – 2008.
	A buried WWII-era bomb exploded during construction works in Bandar Malaysia, Kuala Lumpur – 2017.

UXB Incidents in the UK, resulting in delays, site shutdowns, evacuations, and disruptions	
	London City Airport shut: Flights cancelled after WWII bomb found in River Thames dock. London City Airport was closed after the discovery of a 250kg WWII German bomb, affecting tens of thousands of passengers. All flights into and out of the airport were stopped after the device was found by SafeLane Global in the nearby King George V dock. A 700ft exclusion zone was put in place and people living nearby were evacuated.
	Unexploded WWII 1000kg HE bomb found in Exeter, causing a construction site and the surrounding area to be evacuated. The subsequent detonation caused substantial damage to nearby buildings.
	A WWII UXB was found near to the Aston Expressway, leading to the evacuation of around 200 residents and a 500m cordon. Following the discovery, the weapon was safely detonated by the Army. However, although the M6 was reopened after the blast, the key Aston Expressway stayed shut until 6pm, extending traffic disruption. All nearby rail services and other roads were also disrupted.
	Up to 1000 homes were evacuated and a 300m exclusion zone was put in place following the discovery of a WWII UXB in Lansdown Road, Bath. The 500lb bomb was found just a meter beneath a playground at the former Royal High Junior School.

12 SafeLane Global's Risk Assessment

The Risk Assessment made by SafeLane Global for the site is based upon the likelihood that the site was contaminated, the risk of the contaminant item remaining, and the likelihood of, and potential consequences, should the item be struck during the proposed works. The following section discusses the risk that each ordnance type presents to the scope of works for the project site.

12.1 Conclusions

Taking into consideration the findings of this study, SafeLane Global considers the UXO risk at the site to be **Low.**

Type of Ordnance	Likelihood of Contamination	Likelihood of UXO remaining	Likelihood of encounter	Potential Consequence	Overall Risk level
German High Explosive Bombs	Low	Low	Low	Severe	**Low**
German 1kg Incendiary Bombs	Low	Low	Low	Severe	**Low**
Allied Anti-Aircraft Shells	Low	Low	Low	Minor	**Low**
British / Allied Small Arms	Low	Low	Low	Not Significant	**Low**
Land Service Ammunition	Low	Low	Low	Moderate	**Low**
Naval Ordnance	Low	Low	Low	Severe	**Low**

13 Proposed Risk Mitigation Strategy

Although the site has been assessed as Low Risk, the risk of encountering UXO during the proposed works cannot be completely ruled out and therefore SafeLane Global recommends the following minimum risk mitigation measures be deployed to support the proposed ground works at the site.

13.1 Summary

Based on the findings of the report, the following mitigation measures have been recommended for the proposed works on the site. Further detail on each method is presented in **Section 12.2**.

Risk Level	Planned Site Activity	Recommendations
Low	All	• UXO Safety & Awareness Briefing (Toolbox Brief, TBB) • Site Specific Safety Instructions (SSSIs) Training Course

13.2 Additional Notes

Risk Mitigation Measures – Further Detail	
Site Specific Explosive Ordnance Safety and Awareness Briefings (UXO Toolbox Briefing) to all personnel conducting intrusive works	These briefings are intended to make site operatives aware of the nature of explosive ordnance that may be encountered on their project site. • Delivered by a specialist Explosive Ordnance Disposal Engineer. • Provides information on the site-specific explosive ordnance risk • Basic ordnance identification. • What to do in the event of an encounter with a suspicious object. Provide UXO response procedures.
Site Specific Safety Instruction (SSSI)	For longer term projects that require Explosive Ordnance Safety and Awareness Briefings as part of the Explosive Ordnance Risk Mitigation measures for the project, SSSIs can be provided to allow nominated site representatives to deliver these briefings after initial training. • 2/3-hour presentation and training course. • Delivered by a fully qualified senior EOD Engineer. • Suitable for Project Site Manager HSE representative and supervisors. • Includes briefing pack. This provides a cost-effective solution to ensure that the Explosive Ordnance Safety and Awareness Briefings can be delivered effectively and efficiently to the required standard.

Explosive Ordnance Disposal (EOD) Engineer On-Site Support	In areas where the risk posed by the potential presence of explosive ordnance is low or where the conditions are not suitable for pro-active survey, EOD On-Site Support can provide a reactive response to any suspicious object that may be encountered during open excavation works. The presence of the EOD Engineer (sometimes referred to as 'high risk dig wardens') on-site in support of shallow intrusive work allows for a direct monitoring of works using visual recognition and instrumentation and provides an immediate response to reports of suspicious objects or suspected items of ordnance that have been recovered by ground workers. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings (UXO TBB) to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential incident management which would involve liaison with the local authorities and police should ordnance that presents an explosive hazard be identified. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all excavations. • Provides safety and awareness briefings to construction personnel as required. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO.
Explosive Ordnance Disposal (EOD) Engineer to support site investigation works	For cost effective Explosive Ordnance Risk Mitigation for site investigation work, the EOD Engineer can survey ahead of trial pits, monitor excavations when the ground conditions are not suitable for a pro-active survey and conduct intrusive surveys for borehole and window sample locations working in conjunction with the site investigation team. The On-Site Support will also provide a reactive response to any suspicious object that may be encountered during open excavation works. SafeLane Global EOD personnel on-site also have the additional benefit of providing Explosive Ordnance Safety and Awareness briefings to any staff that have not received them earlier and can advise staff of the need to modify working practices to take account of the ordnance threat. The EOD Engineer will also aid potential Incident Management which would involve liaison with the local authorities and police should ordnance be identified and present an explosive hazard. • Specialist Explosive Ordnance Disposal Engineer. • Maintains a watching brief over all trial pit excavations. • Provides safety and awareness briefings to construction personnel as required.

	• Works in conjunction with the drilling team to survey all borehole and window sample locations in real-time using a staged drilling and magnetometer survey procedure. • Provides immediate identification of any suspicious item that is encountered. • Identifies whether any UXO item is live or inert. • Provides liaison assistance with the relevant authorities when dealing with any live UXO. • Avoids on site delays which can be caused by the incorrect identification of a suspect item being potential UXO. *Technical Information* 1. In optimum ground conditions each survey using the borehole technique will have a 1 metre look ahead capability. 2. Any steel casing used for borehole surveys will need to be retracted by 3 metres to allow the magnetometer survey to be conducted. Non-ferrous pipe will be required to support the borehole during the survey minimum diameter 60mm (to be supplied by the client).
Search & Clear	Where a non-intrusive magnetometer survey is not possible (e.g. wooded areas) SafeLane Global can deploy a two-man Explosive Ordnance Disposal Engineer team using handheld magnetometer equipment who will proactively survey either in search lanes or boxes, investigating each reading with the support of an operated excavator. The survey is suited to detecting suspicious ferro-magnetic buried objects that may be munitions and/or explosive ordnance related. All SafeLane Global personnel involved with the Search and Clearance Works will be former military personnel who have gained formal NATO Military Explosive Ordnance Disposal Qualifications, having completed training at the Defence Explosive Ordnance Disposal School (DEODS) Chattenden, Kent or similar establishment throughout their military service. The client will be responsible for: • Demarcating the areas to be searched. • Providing services clearance and permit to dig. • Providing operated excavator to access deeper targets if required (SafeLane Global can provide this service at additional cost). • Providing coordinates of positions where debris have been identified (if information required in report). • Providing storage for recovered debris. Output will depend upon terrain and contamination (number of readings to be investigated).
Non-Intrusive Magnetometer Survey and Target Investigation (greenfield land only)	**Non-Intrusive Survey** This survey type is designed for use on magnetically 'clean' land commonly referred to as 'greenfield'. Brownfield land is often described as that which has had previous industrial or commercial use. In this context it specifically encompasses sites with are underlain by 'made ground' which may contain

	metallic contamination. Non-intrusive magnetometry or electromagnetic equipment which is used in the search for buried UXO relies upon the detection of small changes between clear ground and that containing UXO. The technique operates very successfully in environments where there is minimal ground contamination from other sources such as fired bricks, reinforced concrete, discarded scrap metal and buried services. There are also man-made ambient effects on magnetic and electromagnetic non-intrusive survey systems which include moving plant vehicles, power cables, electric trains etc. Non-Intrusive survey is carried out using either total-field or gradiometer magnetometry, dependent upon site conditions. Data is recorded and then interpreted using advanced AGSPRoc software in order to map magnetic fields and model discrete magnetic anomalies (variations in the Earth's magnetic field caused by ferro-magnetic objects electrical fields or geology). The location of such anomalies is determined, and mathematical modelling used to estimate their mass and depth. The survey will also locate any buried services with a magnetic signature and indicate any areas of gross magnetic "contamination" which may indicate the presence of unknown obstructions. Additionally, the survey can provide information on archaeological features. The system can detect the magnetic field from a 50kg WWII air-dropped bomb at a depth of 4m and smaller items such as Land Service Ammunition to depths of up to 1.5m in ground with a low ambient magnetic field. In the case of soft geology, it should be noted that a 50kg high explosive bomb may be buried greater than 4 metres below ground level and therefore may not be detected by the survey. In this instance intrusive surveys may be required. The non-intrusive survey system will be deployed utilising the pedestrian survey frame. The output for the pedestrian frame is estimated at up to 2Ha per day. *Technical information:* • Client to clearly demarcate area to be surveyed prior to start and highlight any known services/underground obstructions. • Ground must be level, free of obstacles / obstructions and clear of undergrowth. Height of any crops should be no more than 400mm and where crops are present SafeLane Global would require written approval from the landowner or client to walk over the site area. • When working adjacent to existing infrastructure the survey may be ineffective due to the ferro magnetic interference caused by passing vehicles and the presence of underground buried services. A site visit may be recommended prior to commencement. • Note: the survey will be ineffective on Brownfield sites due to the magnetic nature of building rubble, which typically masks the weaker magnetic signatures of buried objects. If parts of the site are contaminated, then alternative risk mitigation measures may need to be considered. **Target Investigation** If a buried anomaly is detected that cannot be discounted as a potential UXO / UXB then the object will need to be investigated to positively identify the item. The process will include; • Specialist two-man Explosive Ordnance Disposal Team. • Combination of manual and mechanical excavation techniques.

	• Excavator shafting, shoring and dewatering equipment can be provided by SafeLane Global if required. • Excavation techniques will be defined and agreed prior to the commence. A factual report with clearance certificate will be issued on completion of the investigation.
Intrusive Magnetometer Survey of all pile locations down to the maximum bomb penetration depth	SafeLane Global can deploy a range of intrusive magnetometry techniques to clear ahead of all the pile locations. The appropriate technique is governed by a number of factors, but most importantly the site's ground conditions. The appropriate survey methodology would be confirmed once the enabling works have been completed. A site meeting would be required between SafeLane Global and the client to determine the methodology suitable for this site. Target investigation or avoidance will be recommended as appropriate.

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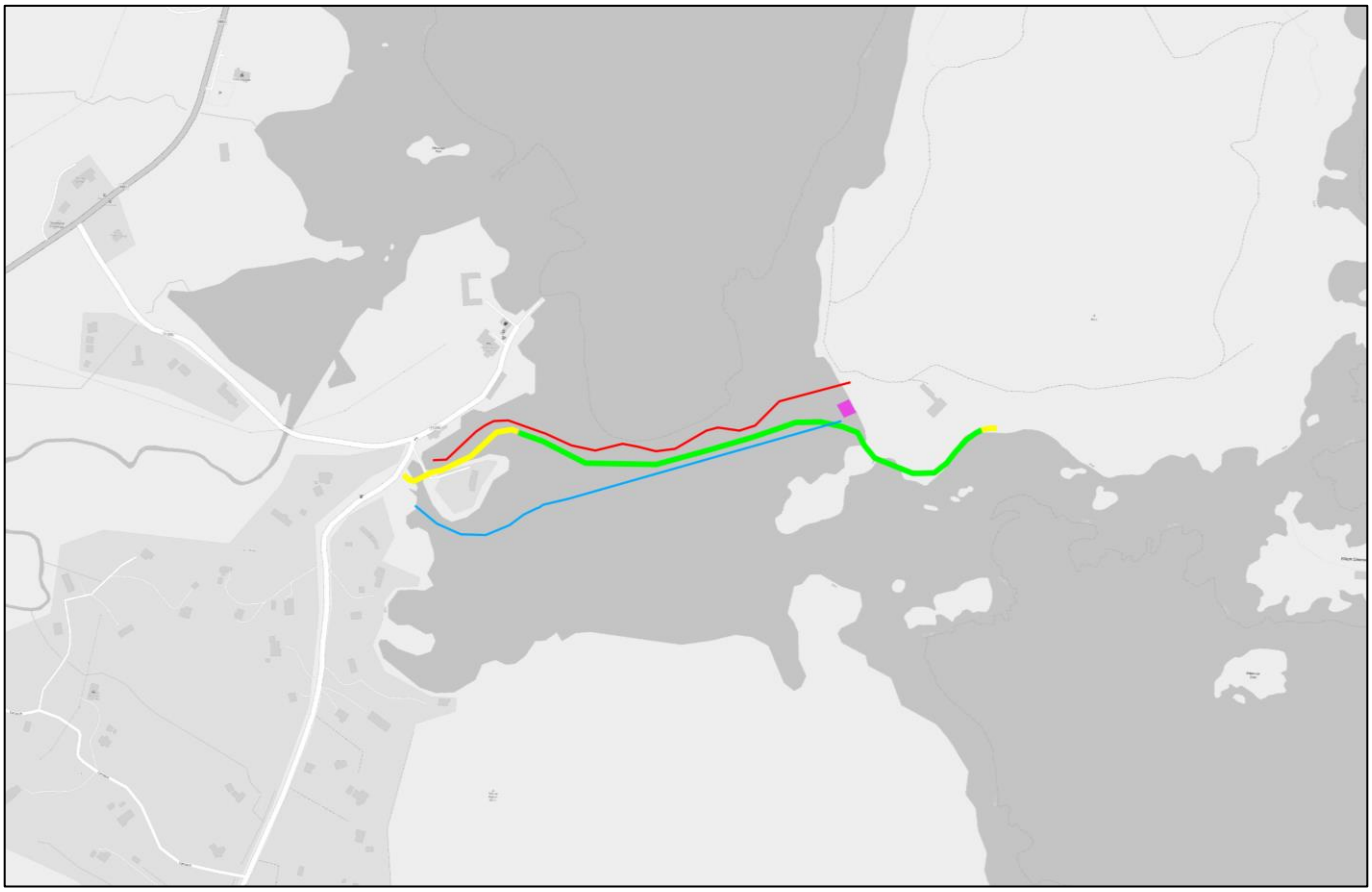

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Recent Aerial Photograph

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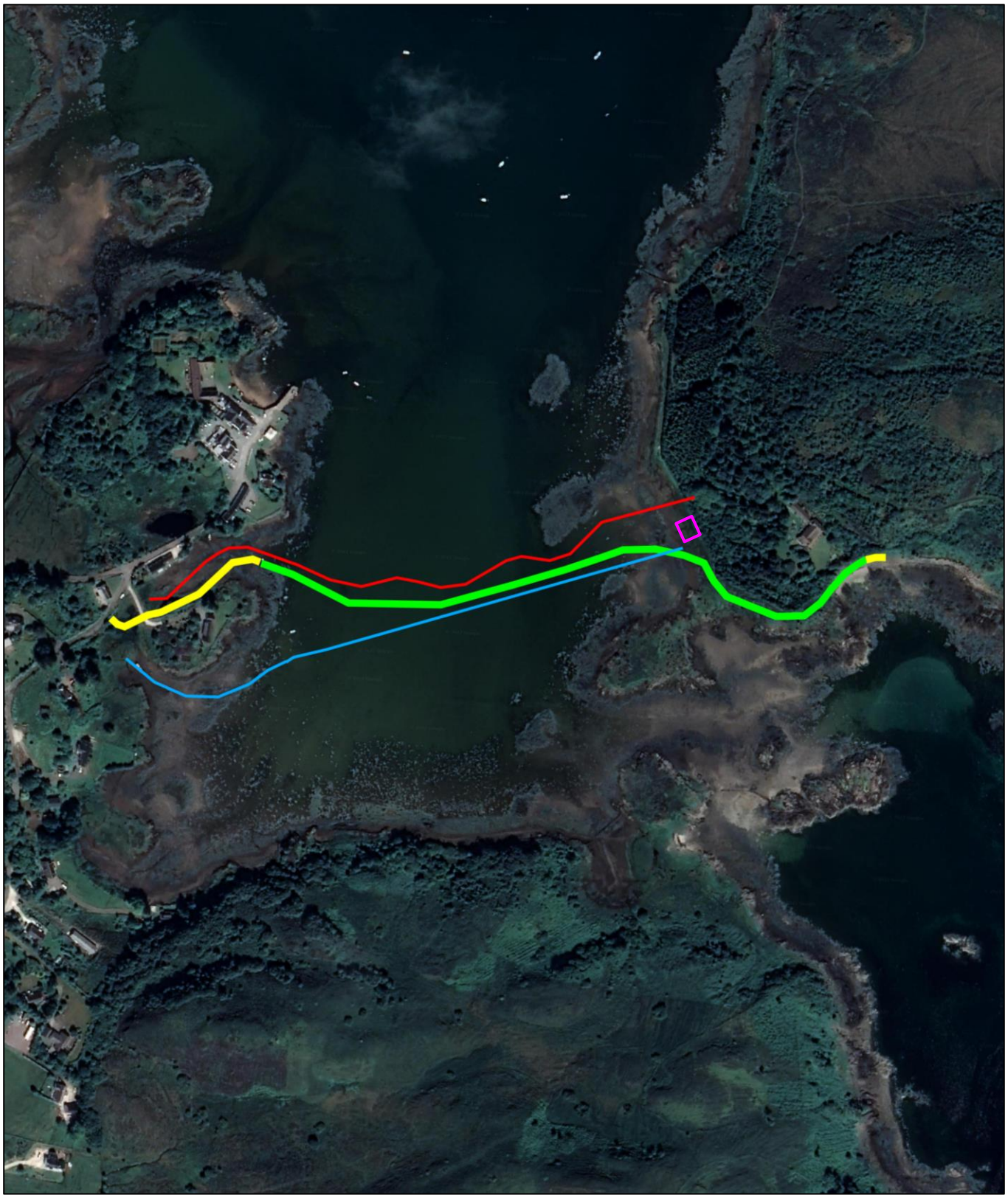
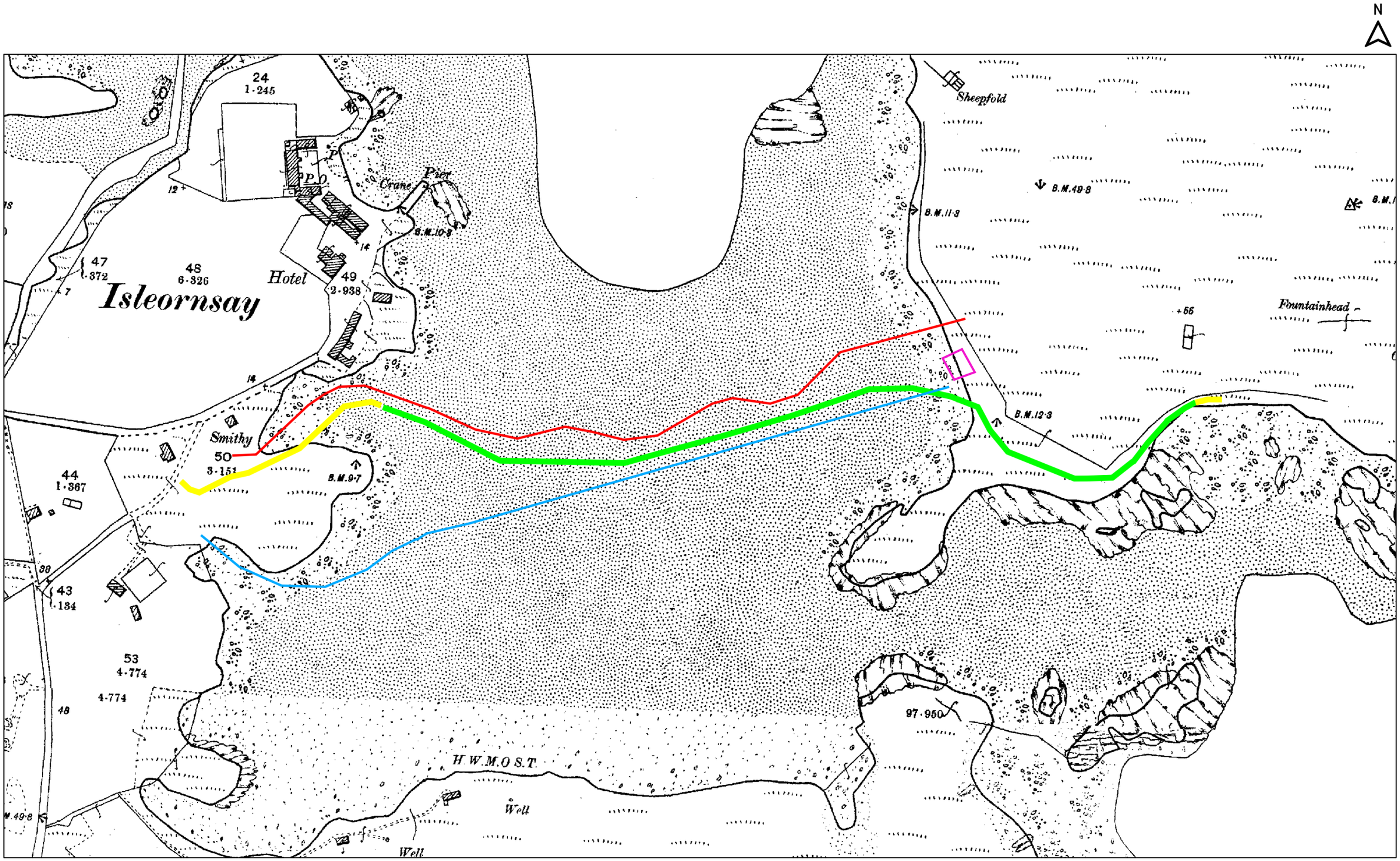


Approximate site boundary

Google Earth™ Mapping Services



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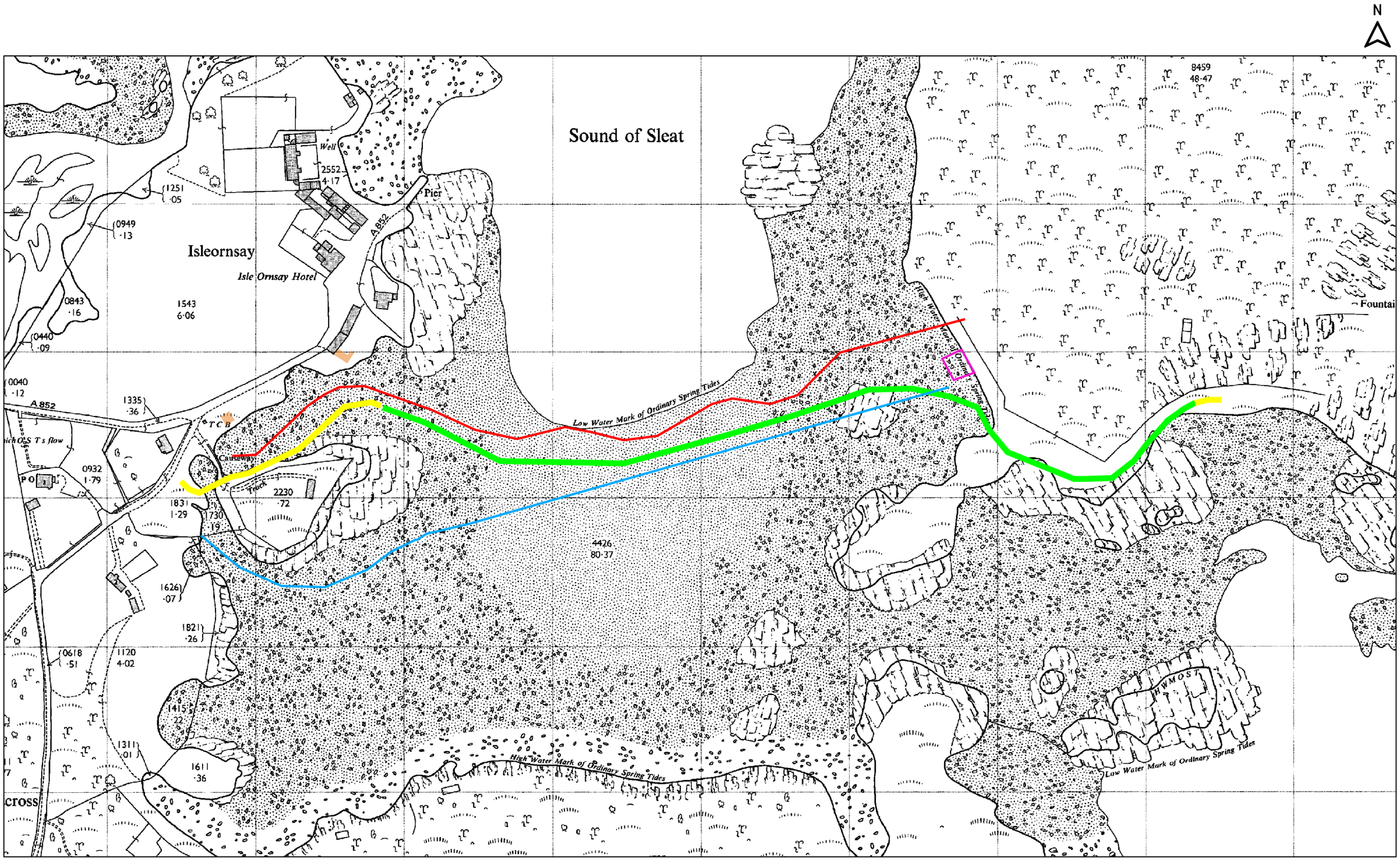

Approximate site boundary

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HMS Embrace – Wreck Location

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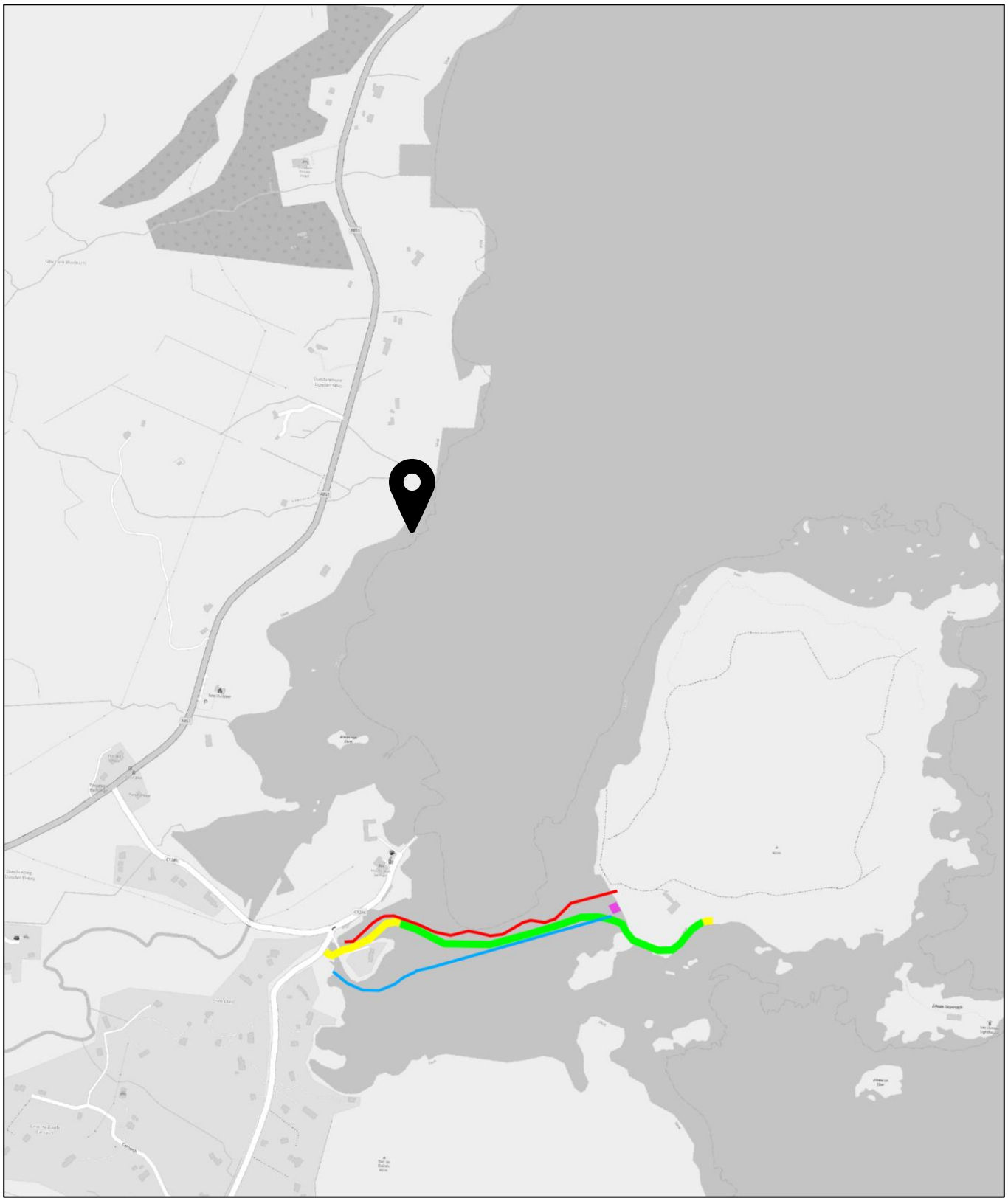

Approximate wreck location

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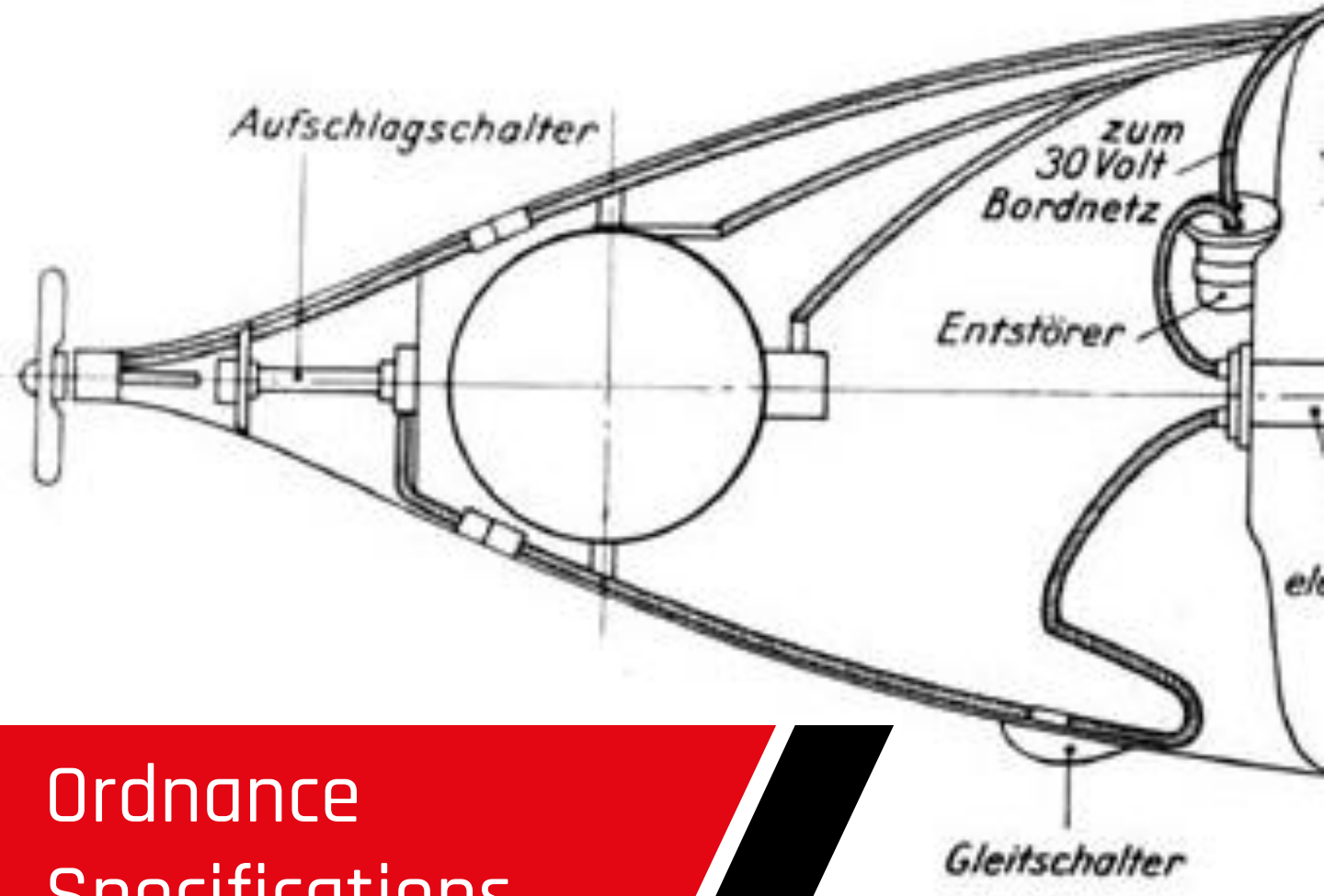
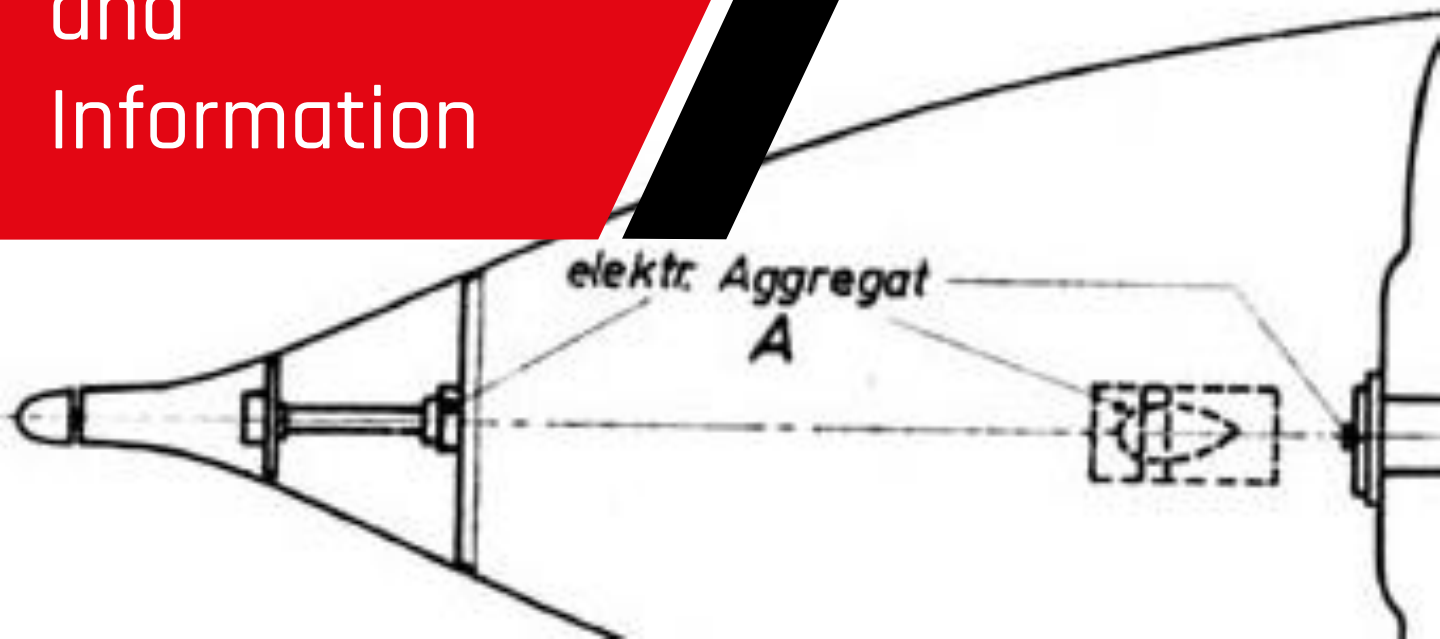
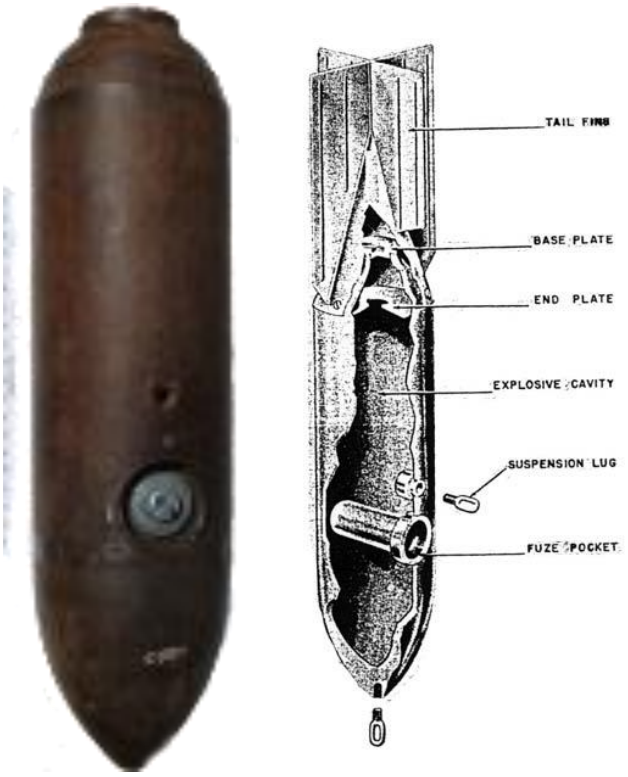


Ordnance Specifications and Information



German Ordnance

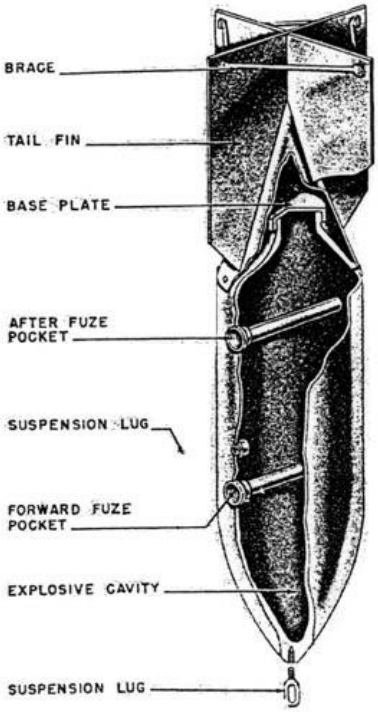


Sprengbombe Cylindrisch 50

Bomb weight: 40-54kg
Fuze Type: Impact fuze / electro-mechanical time delay fuze
Bomb Dimensions: 1090 x 280mm
Body Diameter: 200mm
Use: Used against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to 3-storeys.
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.

SC50 found on site

In May 2015, an SC50 was found at a building site on Empire Way, Wembley, London. (*Image source: The Guardian*)

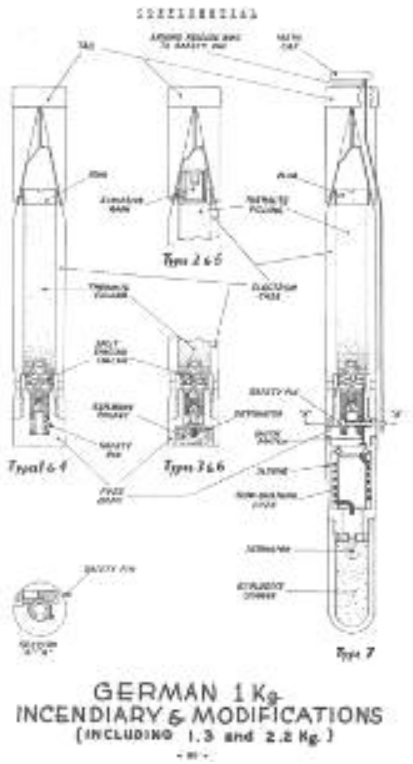


Sprengbombe Cylindrisch 250

Bomb weight: 245-256k
Explosive Weight: 125-130kg
Fuze Type: Electrical impact / mechanical time delay fuze
Bomb Dimensions: 1640x512mm
Body Diameter: 368mm
Use: Used against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.

SC250 found on site

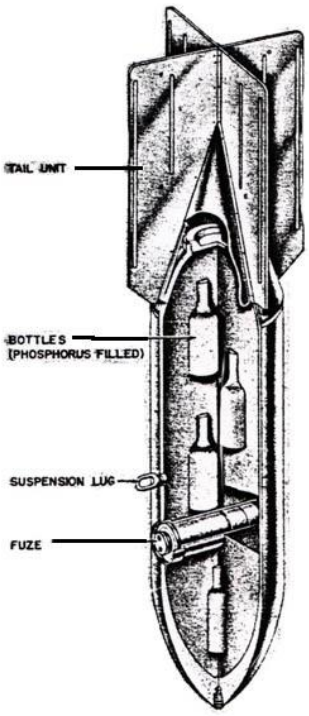
In the year 2000, SafeLane Global discovered an SC250 whilst supervising construction work at Hawkinge, Kent.

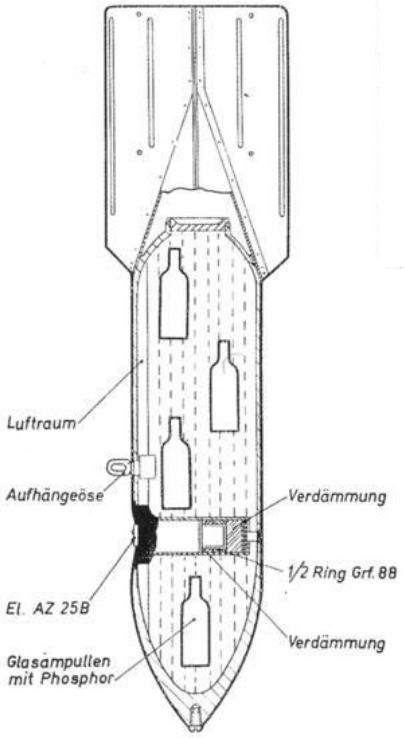


Above: Left – ordinary scaffold pipe, centre - 1kg incendiary bomb, right - incendiary bomb recently found on site in UK

1kg Incendiary Bomb (IB)

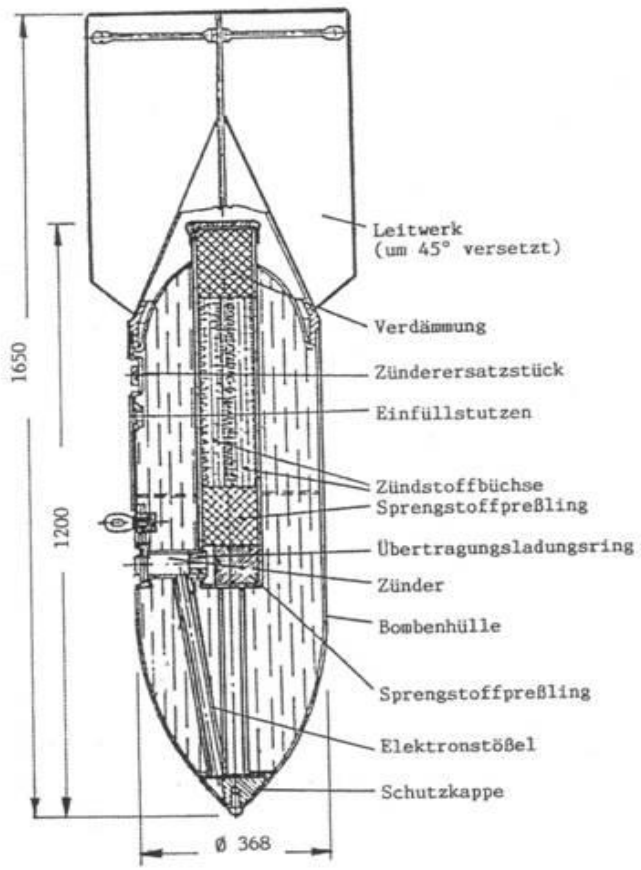
Bomb weight: 1.0 & 1.3kg
Filling: 680g Thermite
Fuze Type: Impact fuze
Body Dimensions: 350x50mm
Body Diameter: 50mm
Use: As incendiary – dropped in clusters against towns and industrial complexes
Remarks: Jettisoned from air-dropped containers. Magnesium alloy case. Sometimes filled with high explosive charge.





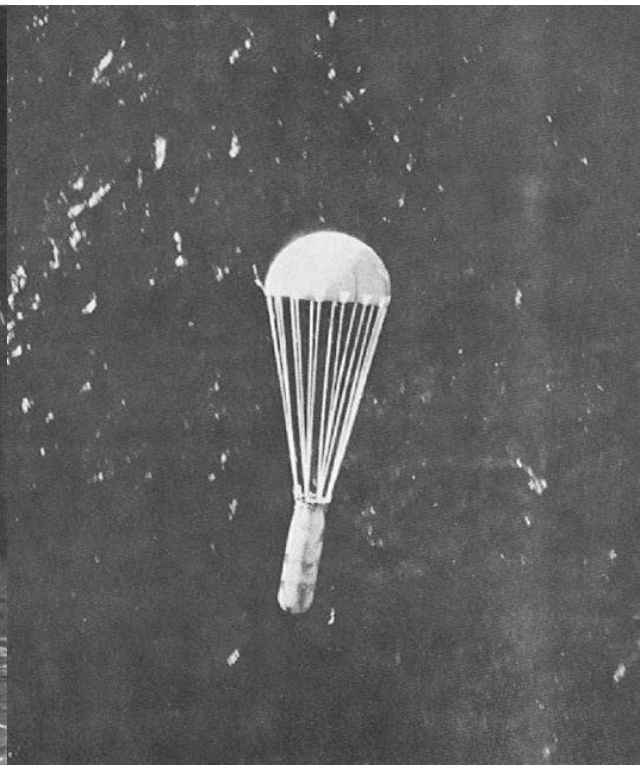
C-50 A Phosphorus Bomb

Bomb Weight: c.41kg
Explosive Weight: 0.03kg
Incendiary Filling: 12kg liquid filling with phosphor igniters in glass phials
Fuze Type: Electrical impact fuze
Bomb Dimensions: 1100x2800mm
Body Diameter: 200mm
Use: Against all targets where an incendiary effect is to be expected
Remarks: Early fill was a phosphorus / carbon disulphide incendiary mixture



Flam C-250 'Oil Bomb'

Bomb Weight: 125kg
Explosive Weight: 1kg
Flammable Weight: 74kg
Filling: Mixture of 30% petrol and 70% crude oil
Fuze Type: Super-fast electrical impact fuze
Bomb Dimensions: 1650 x 512.2mm
Body Diameter: 368mm
Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations
Remarks: Thin casing – not designed for ground penetration



Luftmine A/B 'Parachute Mine'

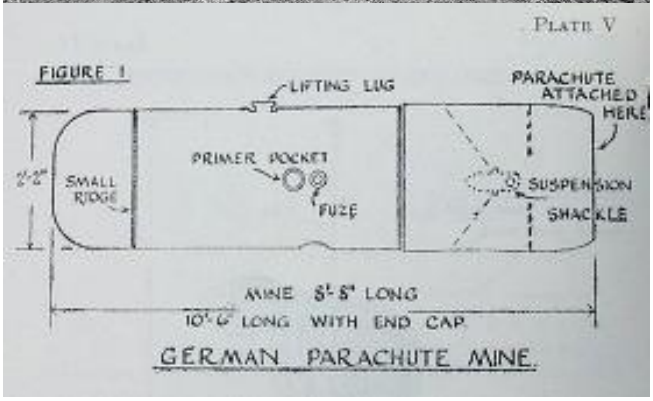
Bomb Weight: A- 500kg, B – 1000kg

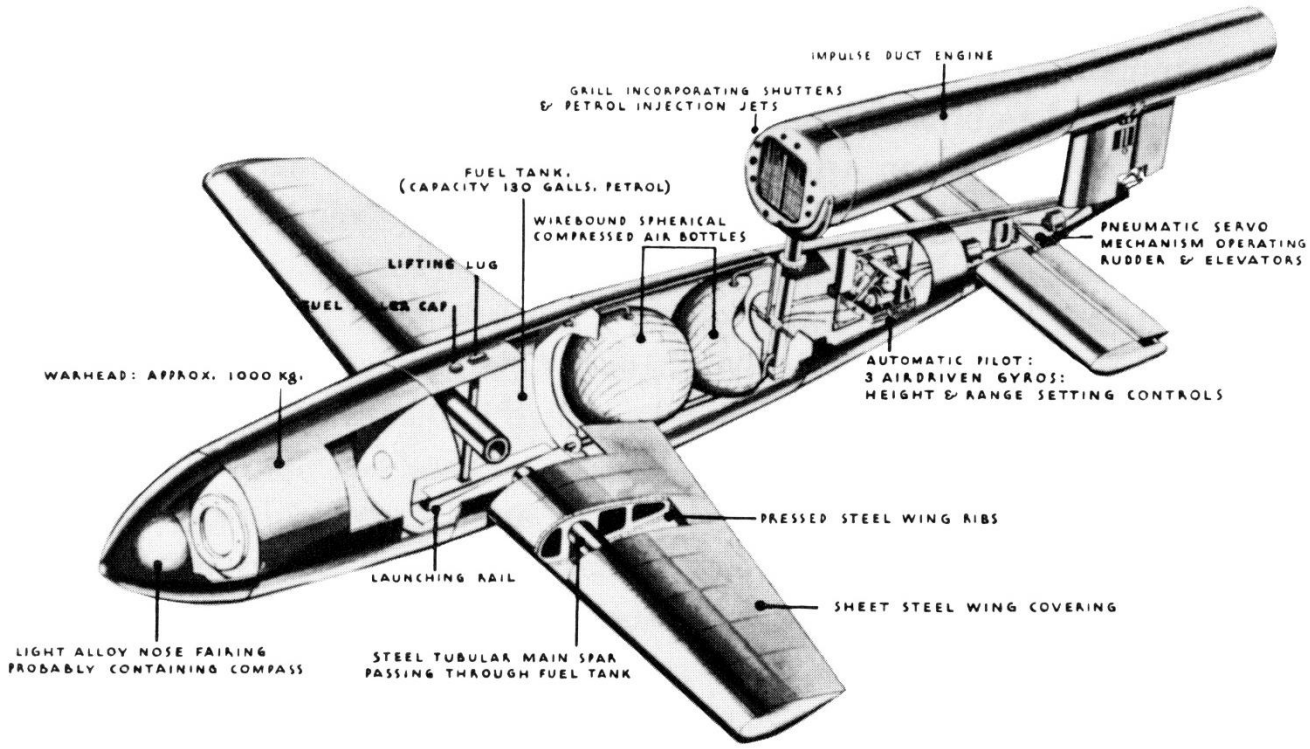
Fuze Type: Mechanical clockwork fuze

Bomb Dimensions: A – 1768mm, B – 2682mm

Use: Capable of creating severe blast damage in built-up areas.

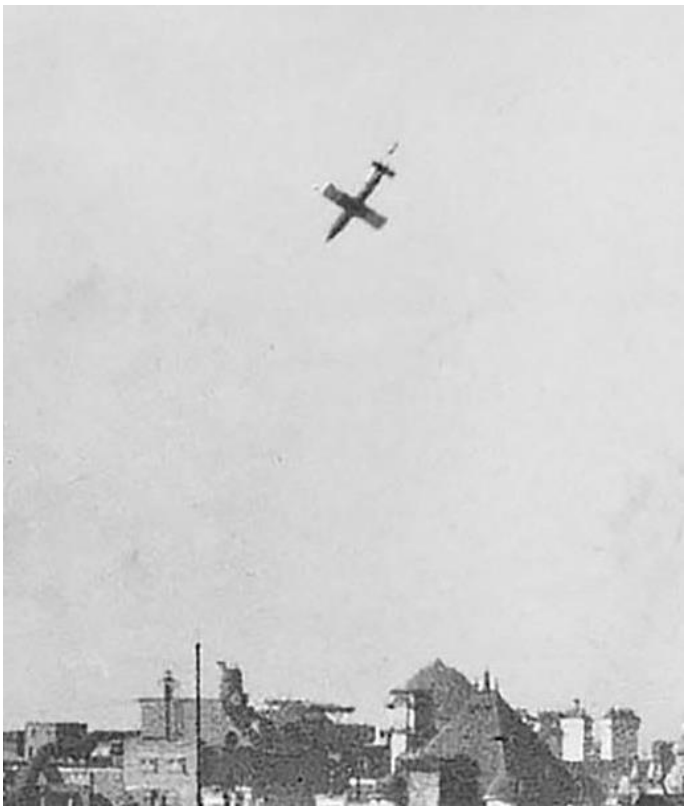
Remarks: Parachute mines were standard German sea mines fitted with a suitable detonator. They were widely used against British cities.



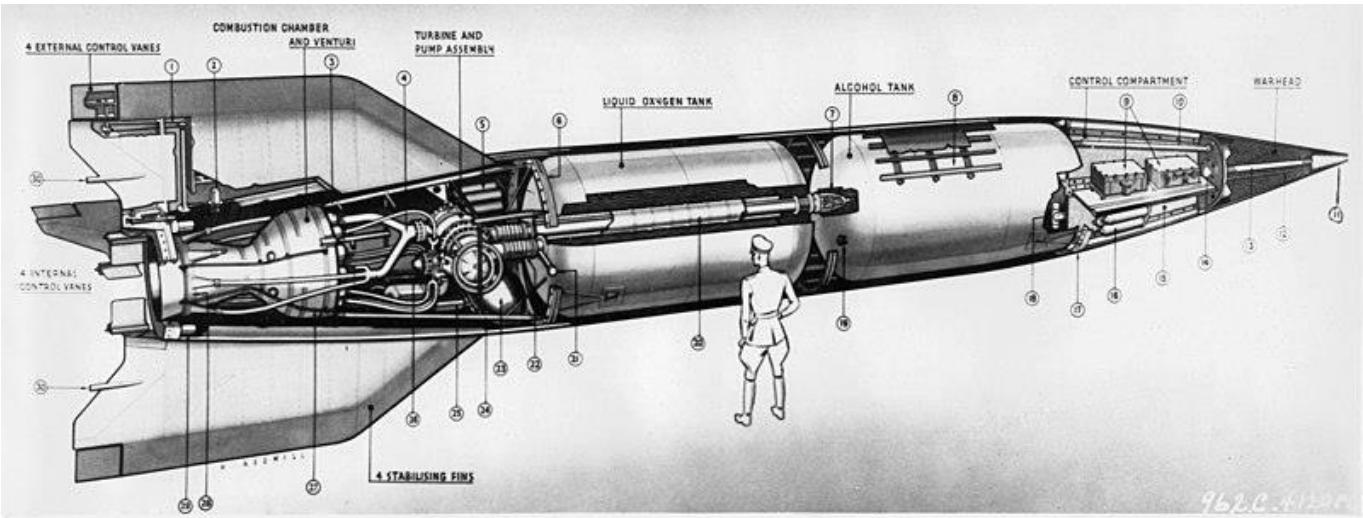


Vergeltungswaffe 1 (V-1) 'Fly' Bomb

Missile Weight: 2,150kg
Fuze Type: Electric Impact Fuze
Missile Length: 8.32m
Width: 5.37m
Range: 250km
Use: Pulsejet-powered guided cruise missile, designed to attack Allied cities.
Remarks: Armed with an 850kg warhead, around 10,000 V-1 flying bombs were fired at England, causing significant damage and killing approximately 6,000 people . There is a negligible risk from unexploded V-1s today, since the remains would have left incontrovertible evidence of the impact.



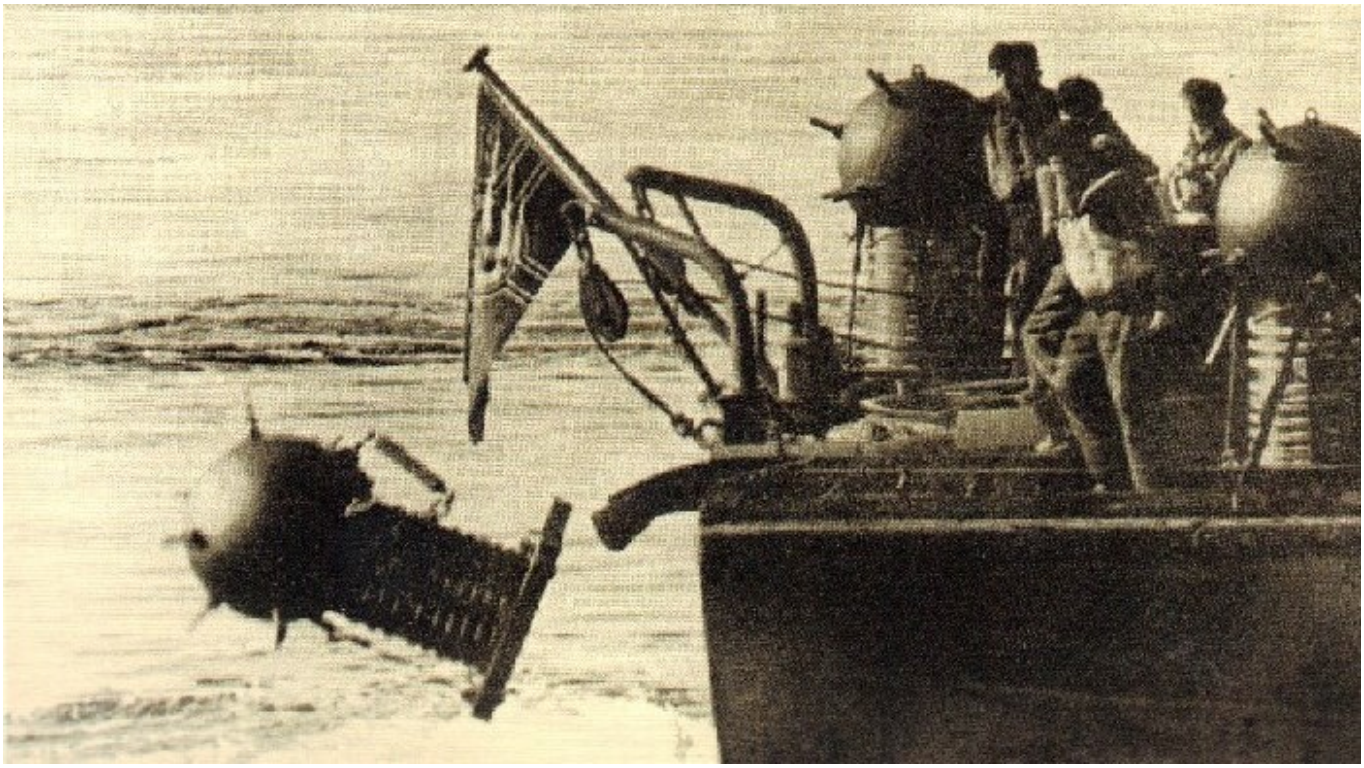
A V-1 'Fly' Bomb, captured over London seconds before impacting



1 CHAIN DRIVE TO EXTERNAL CONTROL VALVE
2 ELECTRIC MOTOR
3 BURNER CUPS
4 ALCHOL SUPPLY FROM PUMP
5 AIR BOTTLES
6 REAR JOINT RING AND STRONG POINT FOR TRANSPORT
7 SERVO-OPERATED ALCOHOL CUTLET VALVE
8 ROCKET SHELL
9 RADIO EQUIPMENT
10 PIPE LEADING FROM ALCOHOL TANK TO WARHEAD
11 NOSE PROBABLY FITTED WITH NOSE SWITCH, OR OTHER DEVICE FOR OPERATING WARHEAD FUZE
12 CONDUIT CARRYING WIRES TO NOSE OF WARHEAD
13 CENTRAL EXPLODER TUBE
14 ELECTRIC FUZE FOR WARHEAD
15 PLYWOOD FRAME
16 NITROGEN BOTTLES
17 FRONT JOINT RING AND STRONG POINT FOR TRANSPORT
18 PITCH AND AZIMUTH GYROS
19 ALOCHOL FILLING POINT
20 DOUBLE WALLED ALCOHOL DELIVERY PIPE TO PUMP
21 OXYGEN FILLING POINT
22 CONCERTINA CONNECTIONS
23 HYDROGEN PEROXIDE TANK
24 TUBULAR FRAME HOLDING TURBINE AND PUMP ASSEMBLY
25 PERMANGANATE TANK (GAS GENERATOR UNIT BEHIND THIS TANK)
26 OXYGEN DISTRIBUTOR FROM PUMP
27 ALCOHOL PIPES FOR SUBSIDIARY COOLING
28 ALCOHOL INLET TO DOUBLE WALL
29 ELECTRO-HYDRAULIC SERVO MOTORS
30 AERIAL LEADS

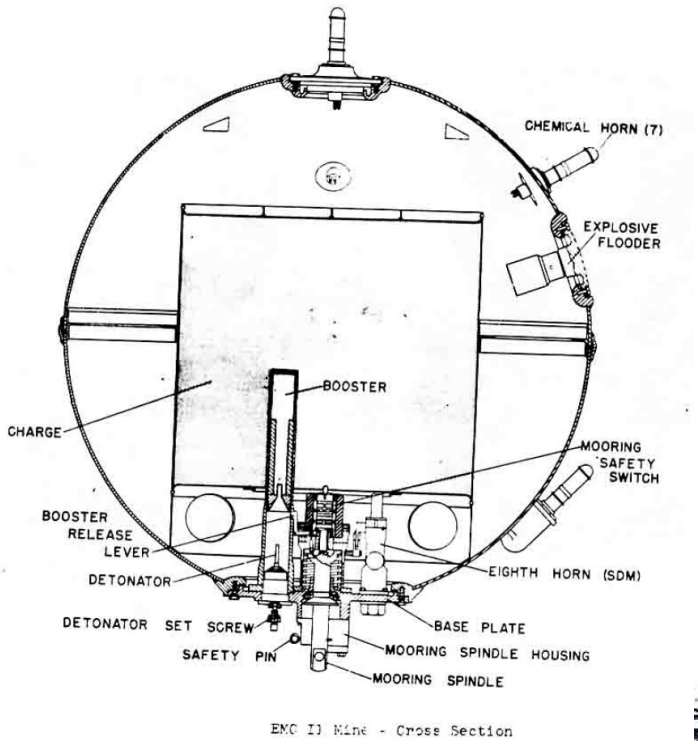
Vergeltungswaffe 2 (V-2) Rocket

Rocket Weight: 12,500kg
Fuze Type: Electric Impact Fuze
Rocket Length: 14m
Body Diameter: 1.65m
Range: 320km
Use: Long-range ballistic missile, designed to attack Allied cities.
Remarks: Armed with a 975kg warhead and travelling at three times the speed of sound, the V-2 could cause widespread destruction. There is a negligible risk from unexploded V-2s today, since the remains would have left incontrovertible evidence of the impact.

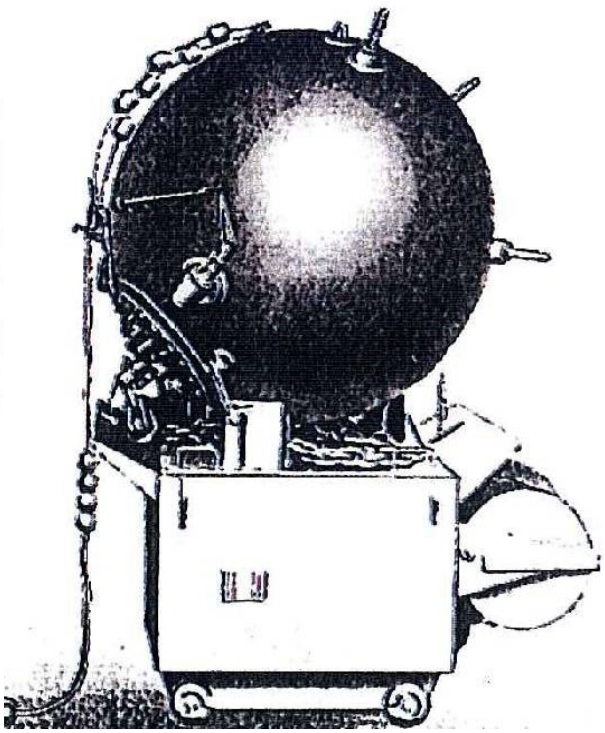


Contact Mine. Code EMA/EMB

British Designation: GU
Type: Moored contact
Shape: Ovoid
Dimensions: EMA – 1.6x0.8m, EMB – smaller, 0.9m high
Charge Weight: EMA – 220kg, EMB – 150kg
Delivered By: Surface craft
First Deployed: 1939
Remarks: Could be moored in waters of 100 or 150m depth. Equipped with five Hertz Horns.

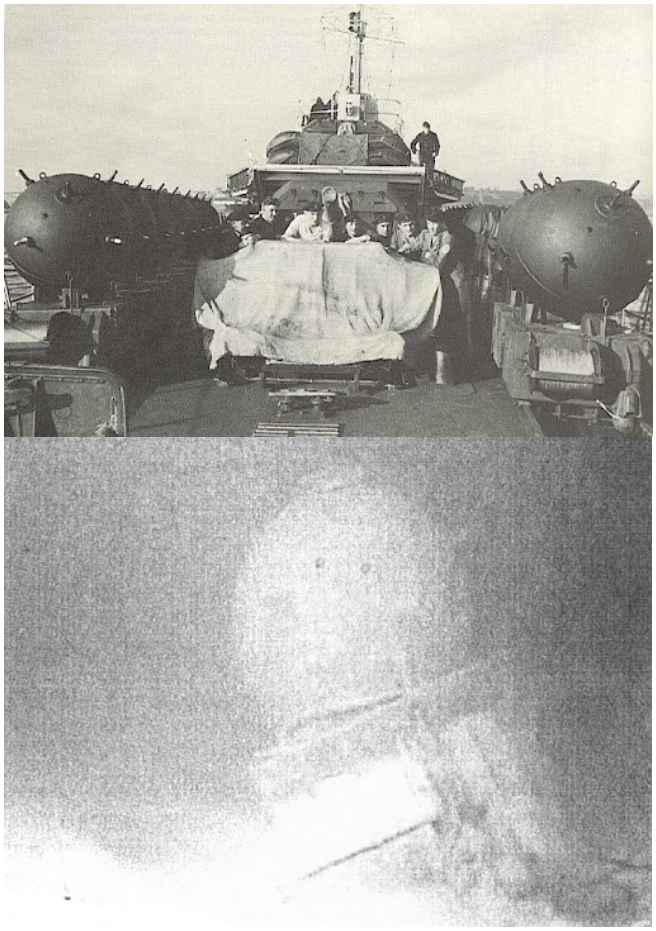


EMC II Mine - Cross Section



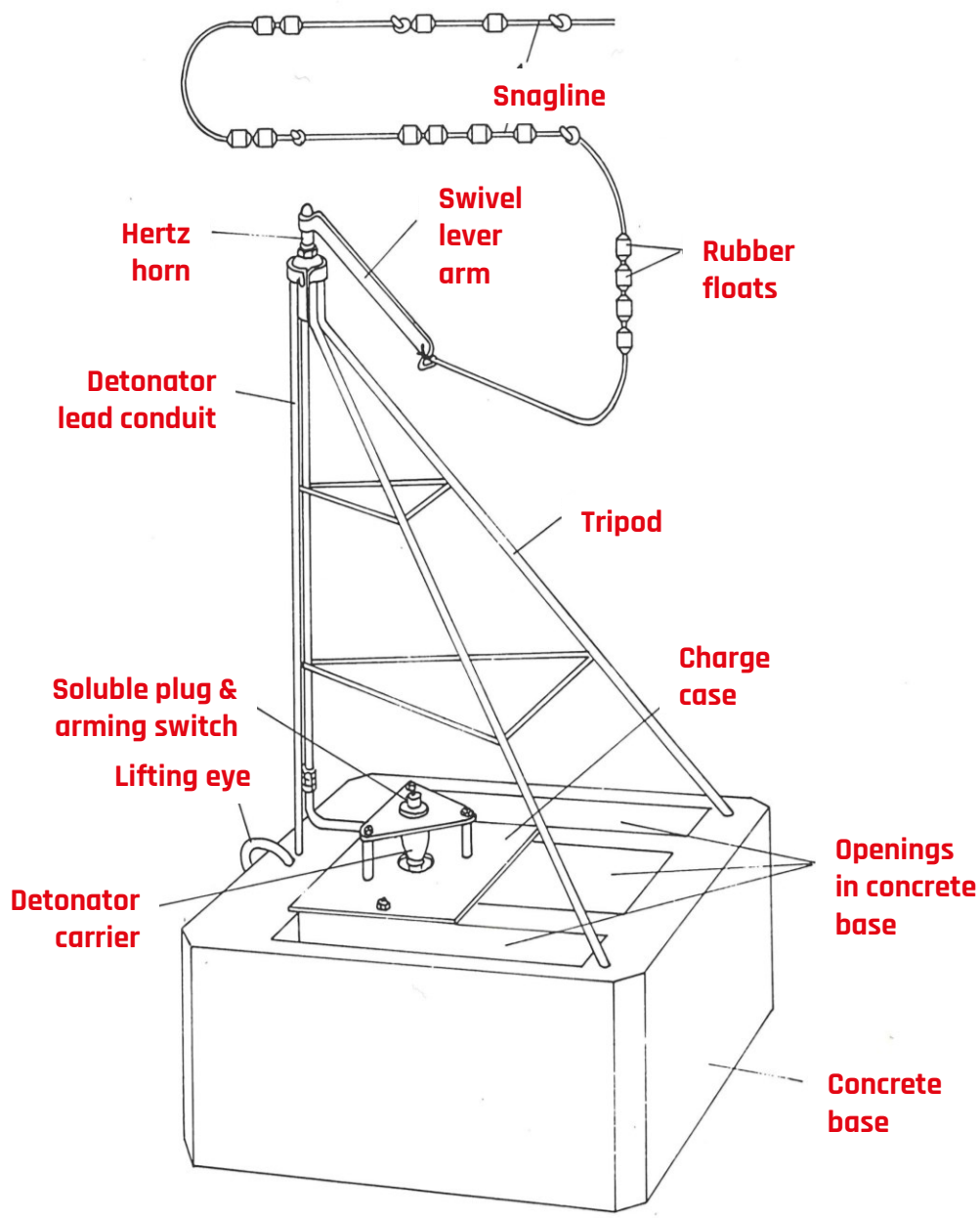
Contact Mine. Code EMC

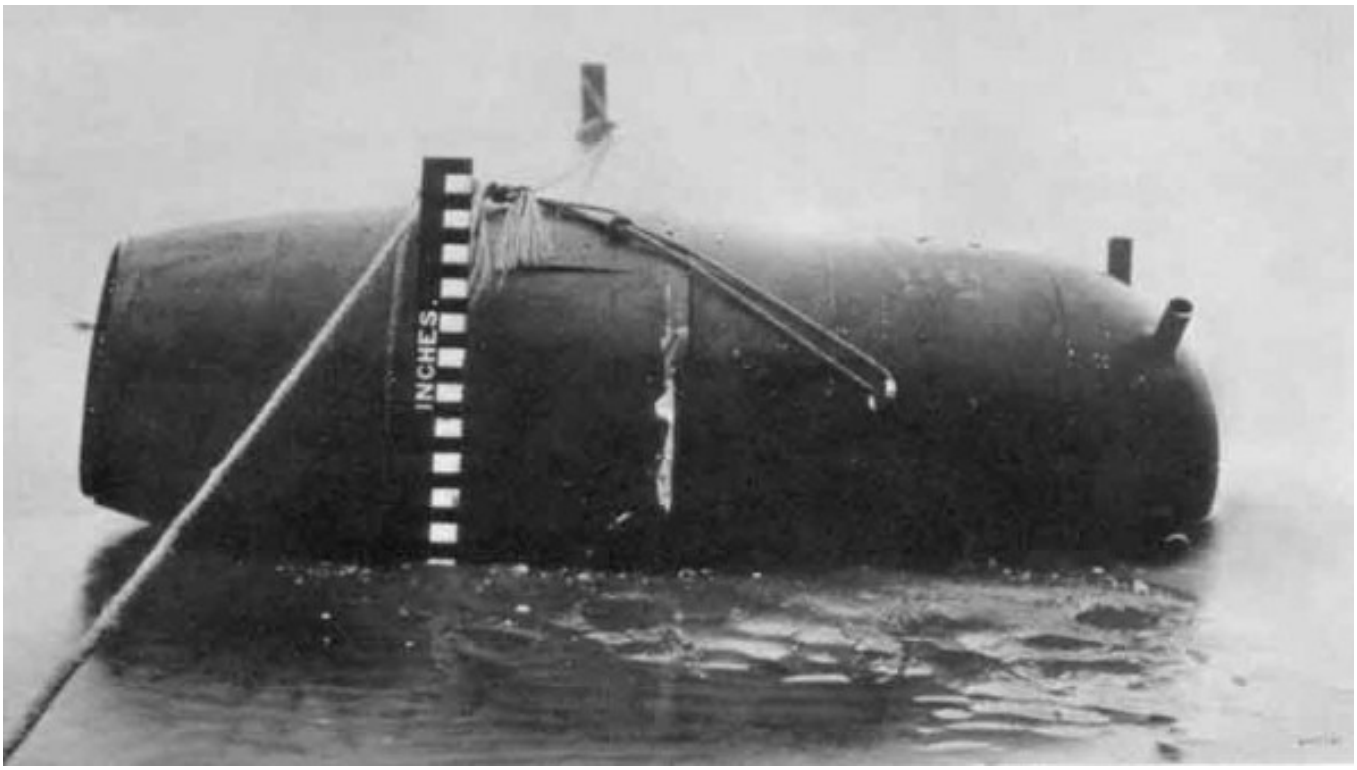
British Designation: GY
Type: Moored contact
Shape: Spherical
Dimensions: 1.12m diameter
Charge Weight: 300kg
Delivered By: Surface craft
First Deployed: September 1939
Remarks: Equipped with seven Hertz Horns. There were a number of variants with different charge weights, horns and chain & snag line devices.
Bottom Image: An EMC mine pictured on the seabed, 2008.



Contact Mine. Code KMA

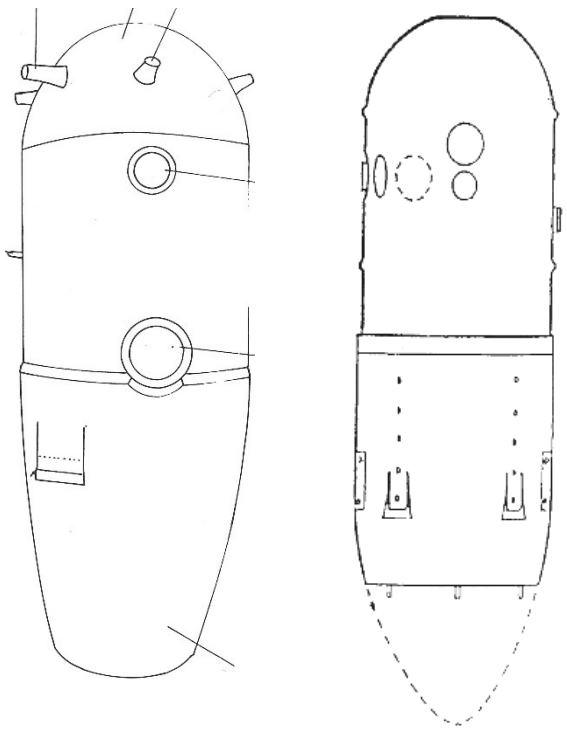
British Designation: GJ
Type: Moored contact
Shape: Spherical
Dimensions: 0.38m diameter
Charge Weight: 12kg
Delivered By: Surface craft
First Deployed: September 1939
Remarks: Equipped with a single Hertz Horn. Used as an anti-invasion, coastal mine.





Influence Mine. Code LMA

British Designation: GA / GD
Type: Ground, Magnetic
Shape: Cylindrical with Hemispherical Nose
Dimensions: 1.8m x 0.66m
Charge Weight: 300kg
Delivered By: Aircraft, retarded by Parachute
First Deployed: September 1939
Remarks: The early GA version was equipped with six anti-rolling horns. A later version, designated GD in Britain, was later also equipped with acoustic detectors. It did not have anti-rolling horns

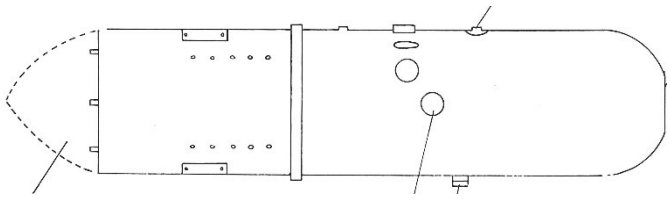


A comparison between the early-war 'GA' (left) and late war 'GD' mines (right)

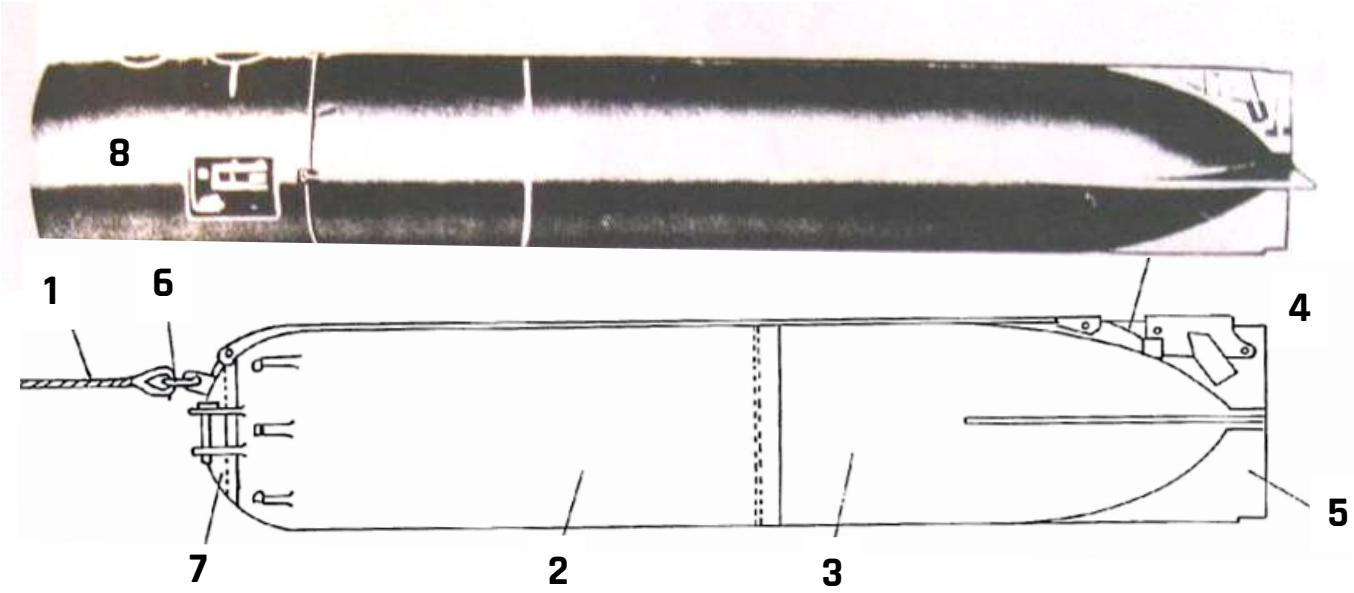
Influence Mine. Code LMB

British Designation: GB / GC
Type: Ground, Magnetic
Shape: Cylindrical with Hemispherical Nose
Dimensions: 3.2m x 0.66m
Charge Weight: 705kg
Delivered By: Aircraft, retarded by Parachute
First Deployed: September 1939
Remarks: The early GB version was equipped with six anti-rolling horns, the GC used acoustic detectors. This mine was also used over land, equipped with an impact fuze and known as a 'Parachute Mine'

May 2018: a LMB parachute mine washed up on the shores of Bognor Regis *(The Sun)*



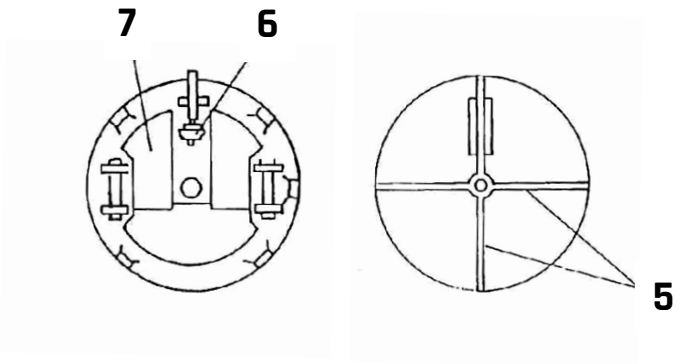
An example of the later 'GC' specification mine

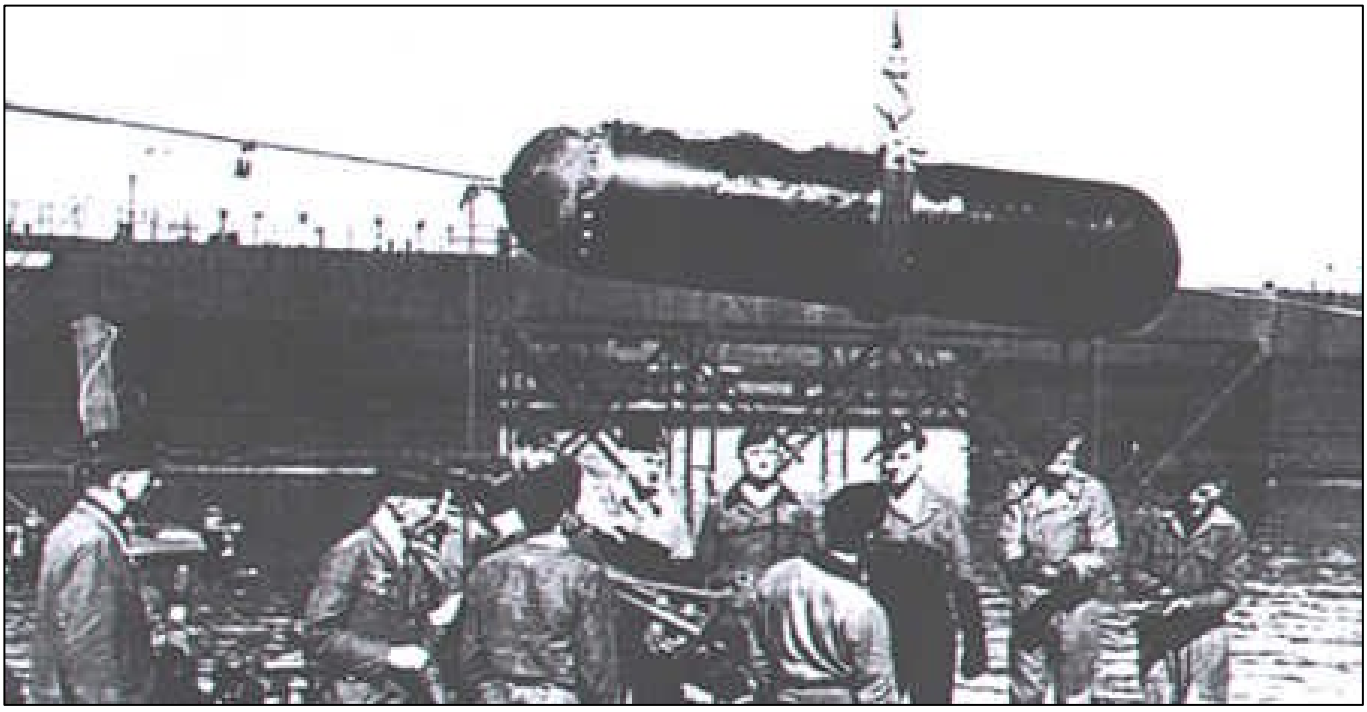


1: Mooring rope, 2: Buoyancy Chamber, 3: Charge, 4: Bowden wire, 5: Fins, 6: Mooring Shackle, 7: Mechanism (covered by light casing, 8: Anchor system (before deployment).

Influence Mine. Code LMF

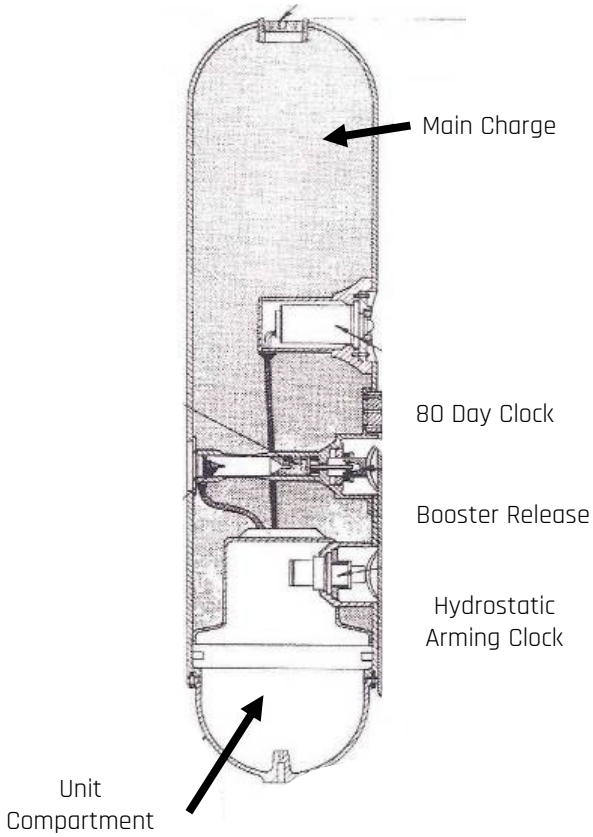
British Designation: GT
Type: Moored, Magnetic
Shape: Cylindrical, finned
Dimensions: 2.7m x 0.53m
Charge Weight: 230kg
Delivered By: Surface Craft, U-Boats and Floatplanes
Remarks: Used between depths of 150 – 270m , this design proved to be unreliable and was withdrawn in 1941

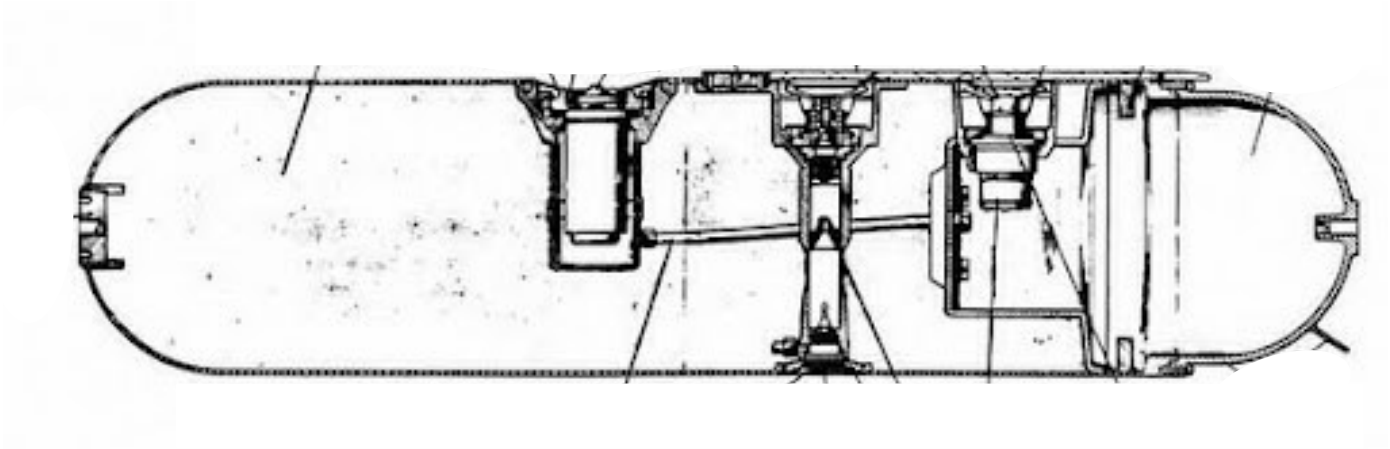




Influence Mine. Code TMB

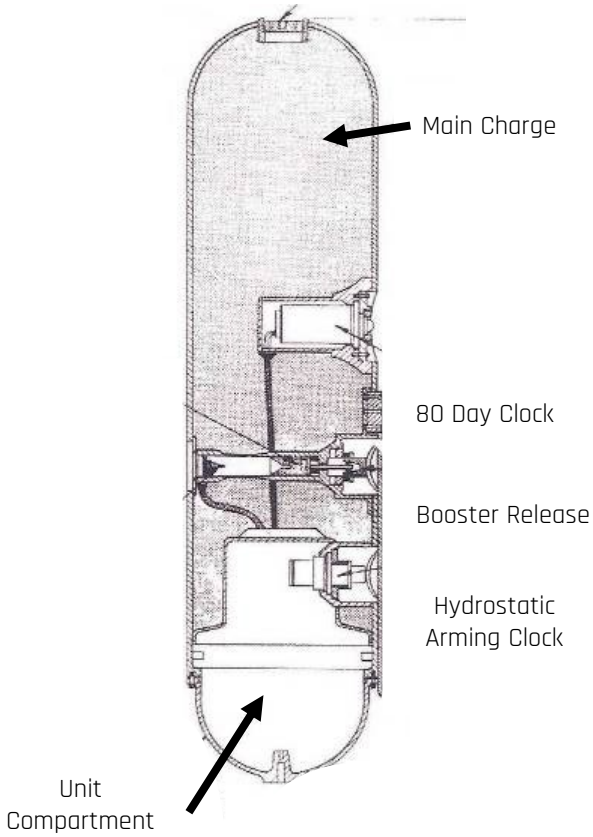
British Designation: GS
Type: Ground, Magnetic
Shape: Cylindrical with Hemispherical ends
Dimensions: 2.3m x 0.53m
Charge Weight: 420 to 560kg
Delivered By: Submarines
First Deployed: 1939
Remarks: Normally laid at a depth of around 22 to 27 meters, The cylindrical shell was said to lay badly on the seabed, leading to its withdrawal from service in 1941.

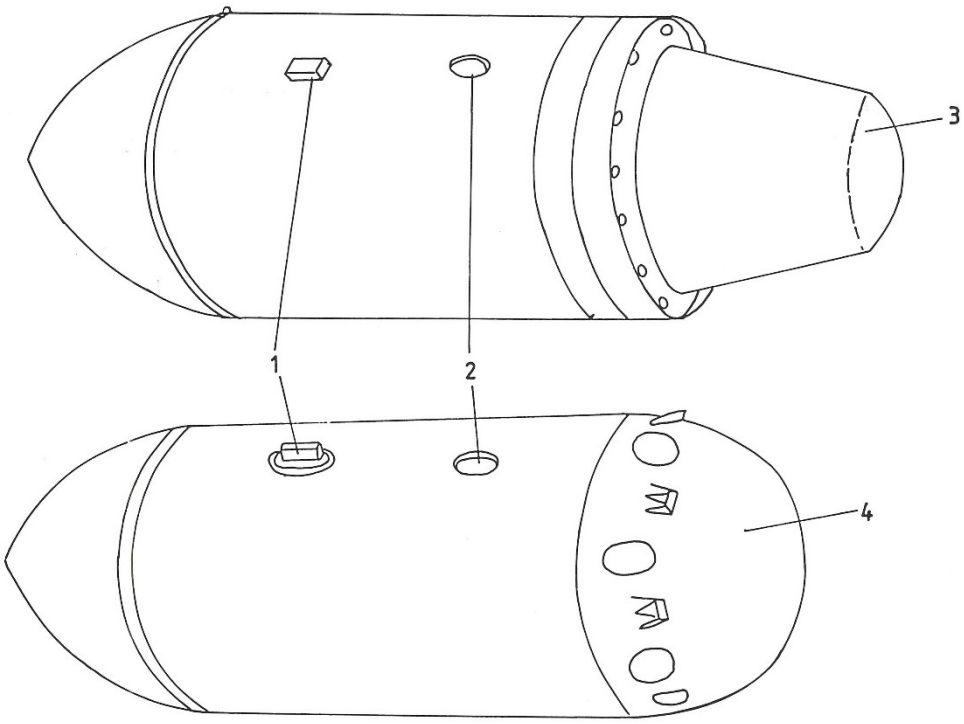




Influence Mine. Code TMC

British Designation: GN
Type: Ground, magnetic (later acoustic/magnetic)
Shape: Cylindrical with Hemispherical ends
Dimensions: 3.1m x 0.53m
Charge Weight: 900kg
Delivered By: Submarines
First Deployed: 1939
Remarks: An enlarged version of the 'TMB' mine, this type would used throughout the war and was laid down to a depth of 37 meters.



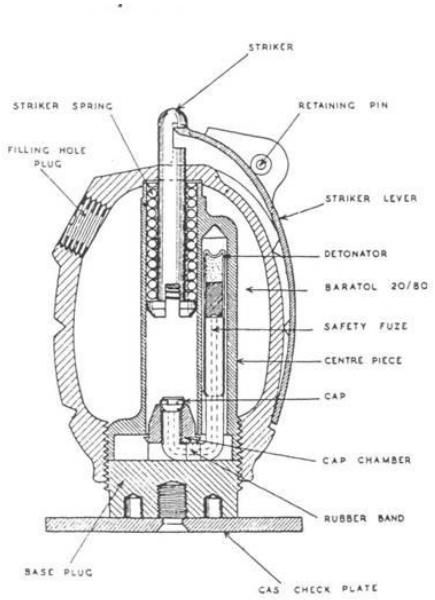


1: Lifting Lug, 2: Bomb Fuze, 3: Magnetic/acoustic tail, 4: Acoustic/magnetic tail

"Mine-bomb". Type BM1000

British Designation: GG
Type: Magnetic and Acoustic
Shape: Cylindrical
Dimensions: Approx. 2.0m x 0.66m
Charge Weight: 725kg
Delivered By: Aircraft, no parachute
First Deployed: May 1941
Remarks: Dropped as a conventional bomb, this Luftwaffe designed mine was designed for more accurate positioning. When deployed against shipping it could be used as an impact bomb or influence mine.

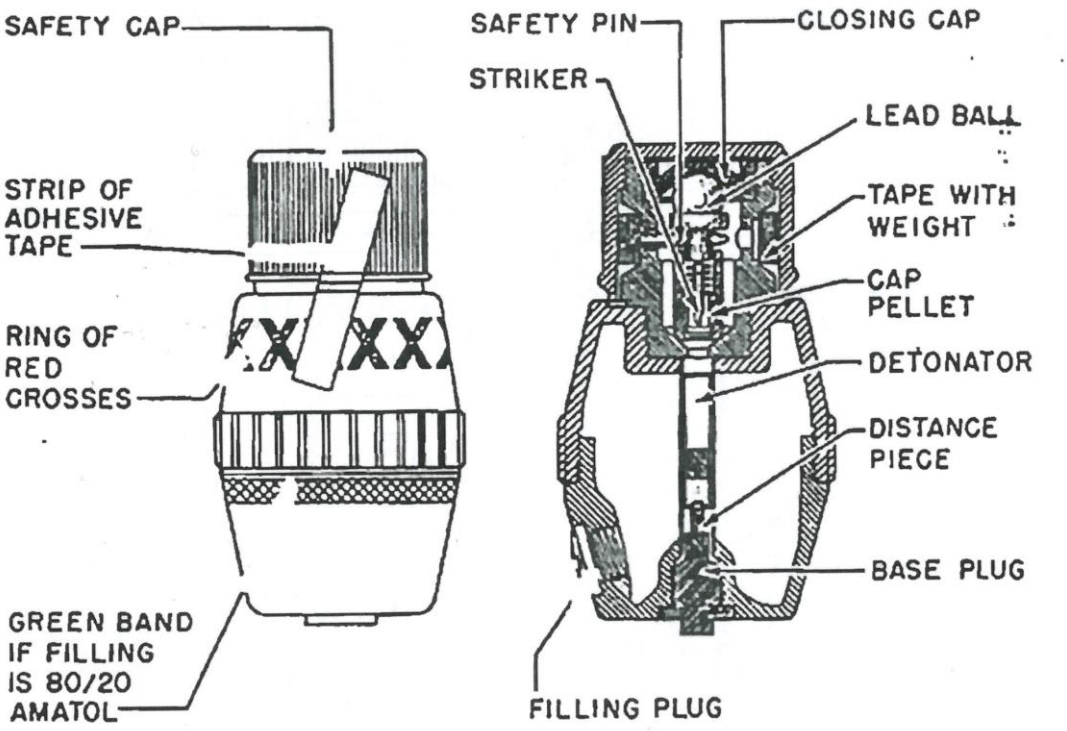
British & Allied Ordnance



Grenade, .303 inch rifle, No. 36M, Mark I.

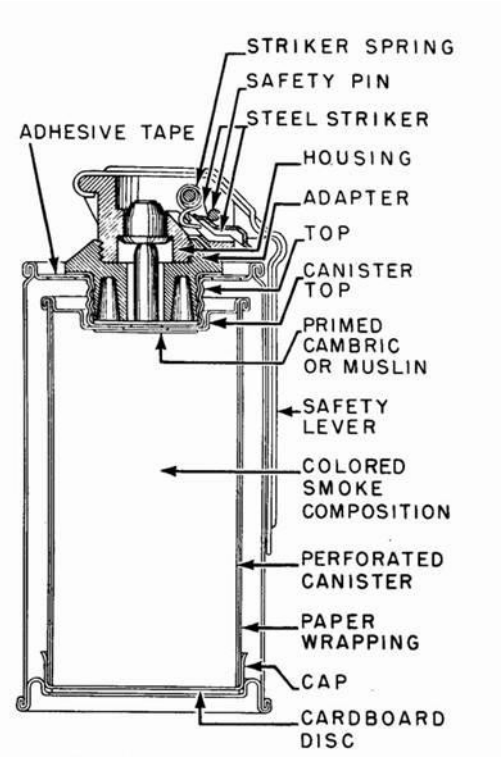
No. 36 "Mills" Grenade

Weight: 0.7kg filled
Type: Hand or discharger, fragmentation
Dimensions: 95 x 61mm
Filling: Alumatol, Amatol 2 or TNT
Remarks: 4 second hand-throwing fuze with approximate range of 30m. First introduced May 1918.



No. 69 Grenade

Weight: 038kg filled
Type: Percussion / Blast
Date Introduced: December 1940
Remarks: Black Bakelite body. Blast rather than fragmentation type. After unscrewing the safety cap, a tape is held when throwing the grenade releasing the safety bolt in the throwing motion. Detection is problematic due to its very low metal content.



Typical Smoke Grenade

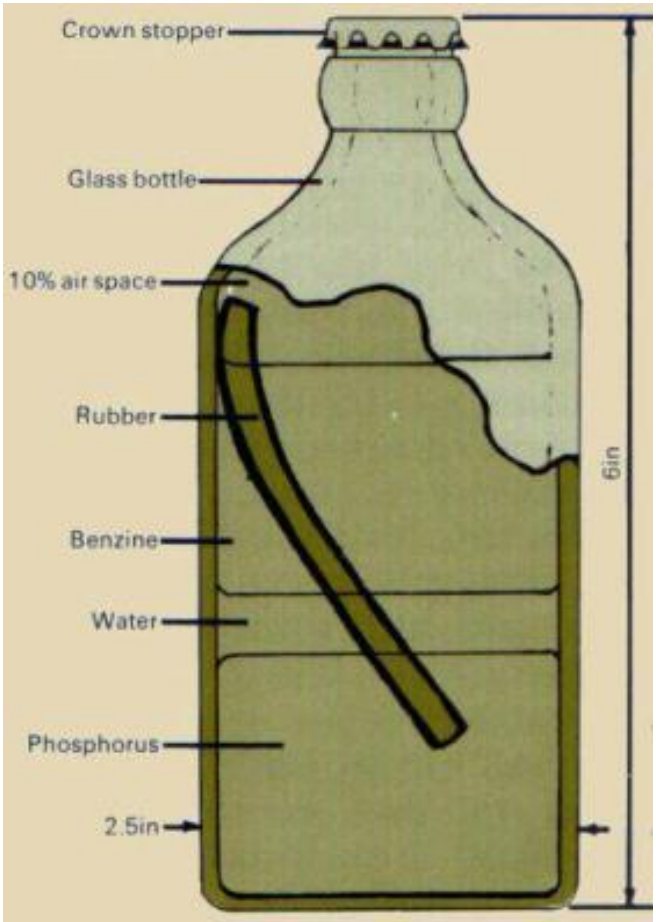
Dimensions: Approx. 65 x 115mm
Type: Smoke
Date Introduced: Current MoD issue
Remarks: Smoke grenades are used as ground-to-ground or ground-to-air signalling devices, target or landing zone marking devices, and screening devices for unit movement.

Self-Igniting Phosphorous (SIP) Grenade

Sometimes called the "A&W (Albright & Wilson)" grenade.

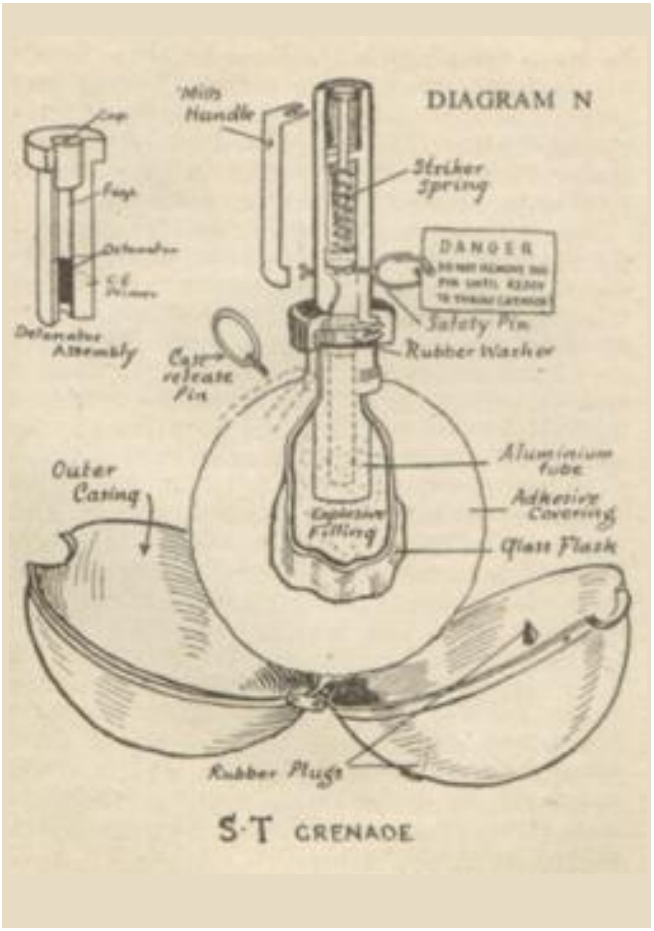
The grenade comprised a glass bottle with a total volume of approximately 1 pint. It was filled with white phosphorous, benzene, a piece of rubber and water. Over time, the rubber dissolved to create a sticky fluid which would self-ignite when the bottle broke.

Fired by hand or Northover Projector.



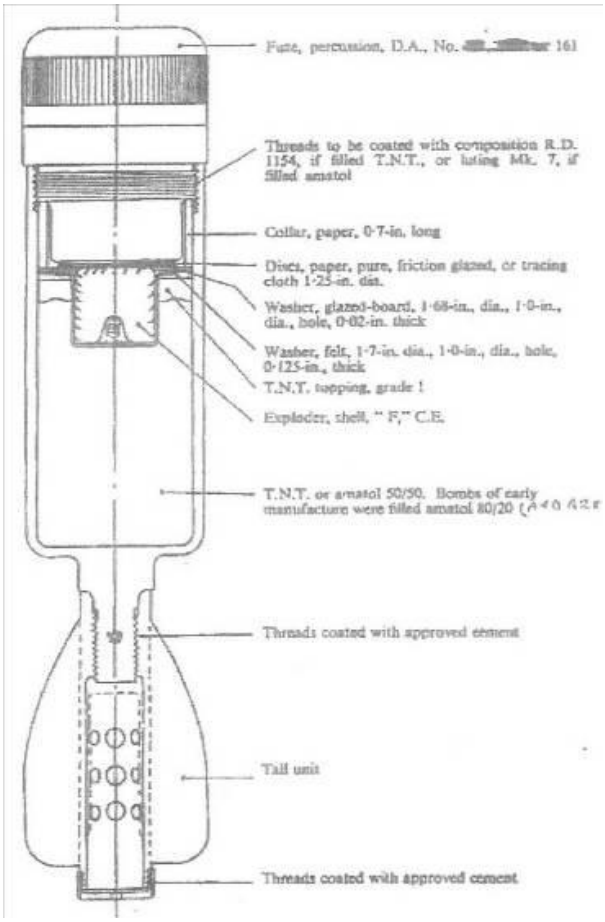
No. 74 Grenade (Sticky Bomb)

Designed as an anti-tank grenade and used by the Home Guard. The grenade consisted of a glass ball on the end of a Bakelite (plastic) handle. Inside the glass ball was an explosive filling whilst on the outside was a very sticky adhesive covering. Until used, this adhesive covering was encased in a metal outer casing.



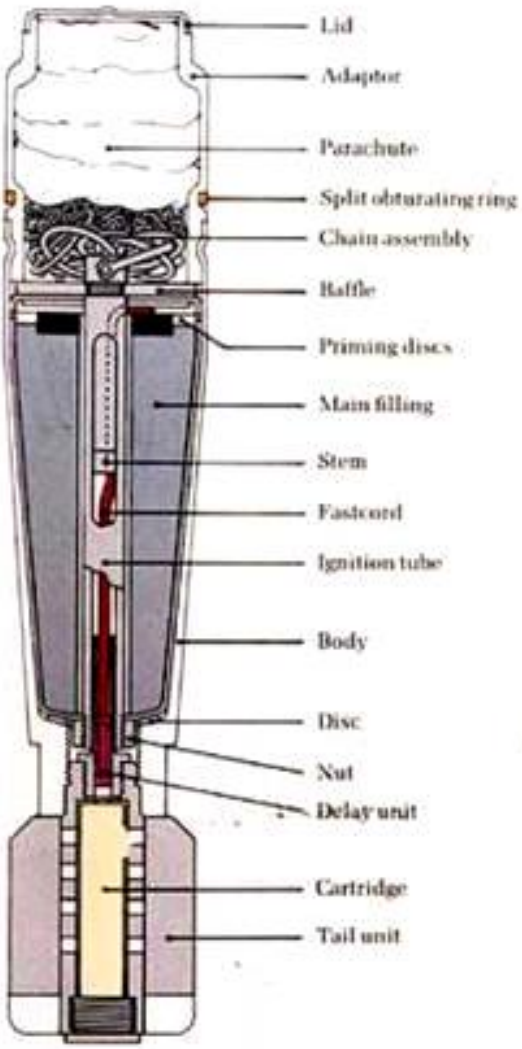
Typical 2" High Explosive Mortar

Bomb weight: 1.02kg
Fuze Type: High Explosive
Bomb Dimensions: 51 x 290mm
Filling: 200g RDX/TNT
Remarks: Fitted with an impact fuze which detonates the fuze booster charge (exploder) and, in turn, the high explosive charge. The main charge shatters the mortar bomb body, producing near optimum fragmentation and blast effect at the target.



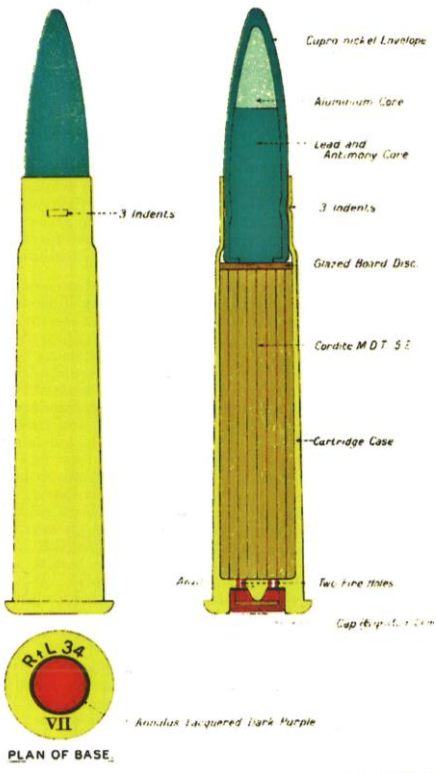
Typical 2" Illuminating Mortar

Fuze Type: Illuminating
Bomb Dimensions: 51 x 290mm
Filling: Various
Remarks: The expulsion charge ignites and ejects the candle assembly. A spring ejects the parachute from the tail cone. The parachute opens, slowing the descent of the burning candle which illuminates the target.



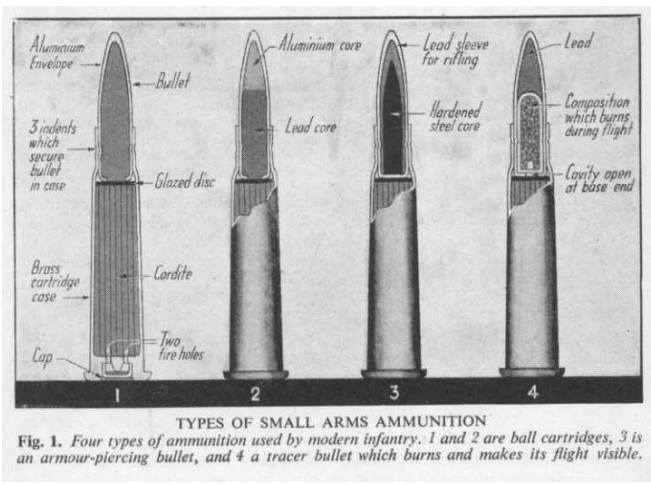
Typical 3" Smoke Mortar

Fuze Type: Smoke
Bomb Dimensions: c.490 x 76mm
Filling: Typically, white phosphorus
Remarks: On impact, the fuze functions and initiates the bursting charge. The bursting charge ruptures the mortar bomb body and disperses the white phosphorous filler. The white phosphorous produces smoke upon exposure to the air.



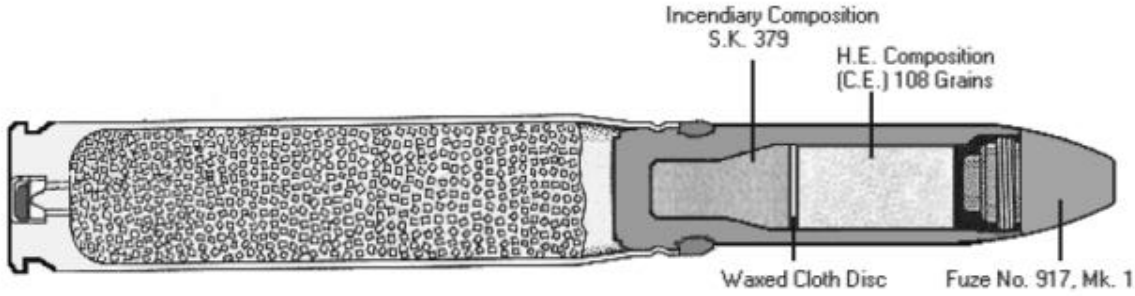
.303" Ammunition

Type: Rifle / machine gun round
Markings: Regular round – none. Tracer round – red primer
Bullet Weight: 150–180g
Dimensions: Total cartridge / projectile length – 182mm
Filling: Regular round – none. Tracer round – small incendiary fill
Threat: Explosive cordite within unspent cartridge
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns, machine guns and rifles. Standard British and Commonwealth military cartridge from 1889 until the end of the 1950s
Remarks: Cartridges are belted or supplied loose in cartons



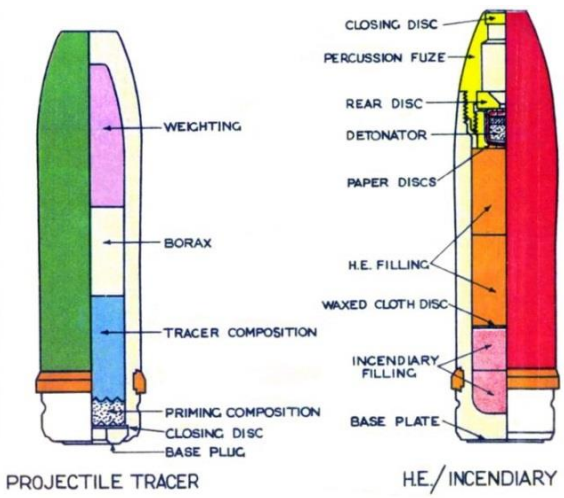
TYPES OF SMALL ARMS AMMUNITION

Fig. 1. *Four types of ammunition used by modern infantry. 1 and 2 are ball cartridges, 3 is an armour-piercing bullet, and 4 a tracer bullet which burns and makes its flight visible.*



20mm Hispano HEI Ammunition

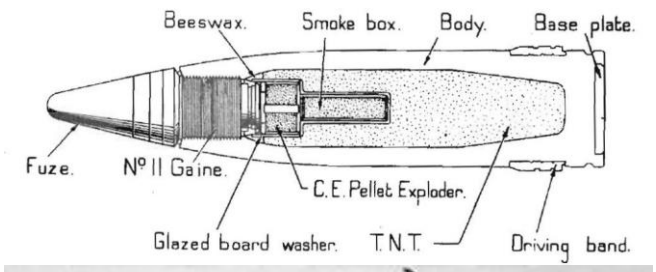
Type: Live cannon round
Markings: Upper half of projectile painted "buff" colour, lower half is red
Cartridge Weight: 256g
Dimensions: Total cartridge / projectile length – 182mm
Fuze: Contact fuze – No. 253, No. 254 or No. 917
Filling: 108g of contact explosive & 68g of SR. 379 incendiary composition
Threat: Explosives within unspent cartridge as well as the projectile
Deployment: Royal Navy, RAF and British Army Light Anti-Aircraft guns. Also RAF aircraft cannons.
Remarks: Cartridges are belted or supplied loose in cartons.



COLOUR IDENTIFICATION		
BRITISH		
NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	

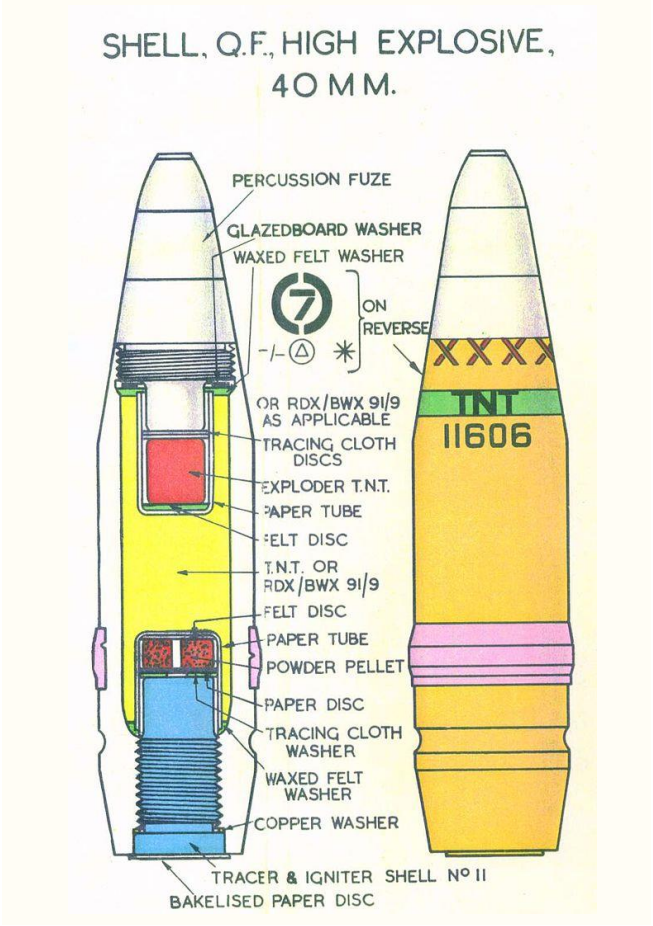
3.7" Anti-Aircraft Projectile

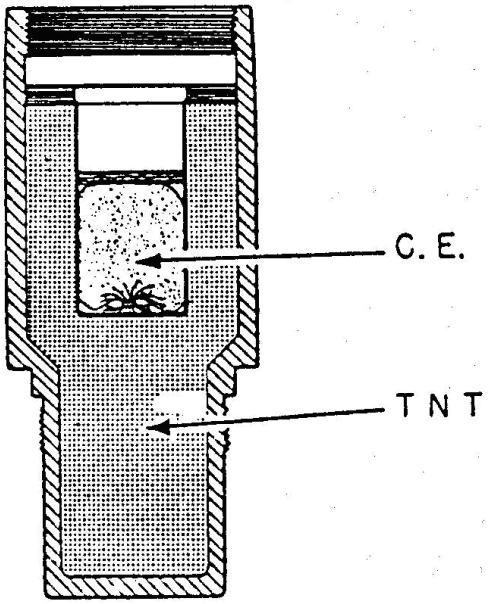
Weight: 12.7kg
Bomb Dimensions: 94 x 360mm
Rate of Fire: 10-20 rounds per minute
Carriage: Typically, white phosphorus
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.



40mm Bofors Gun Projectile

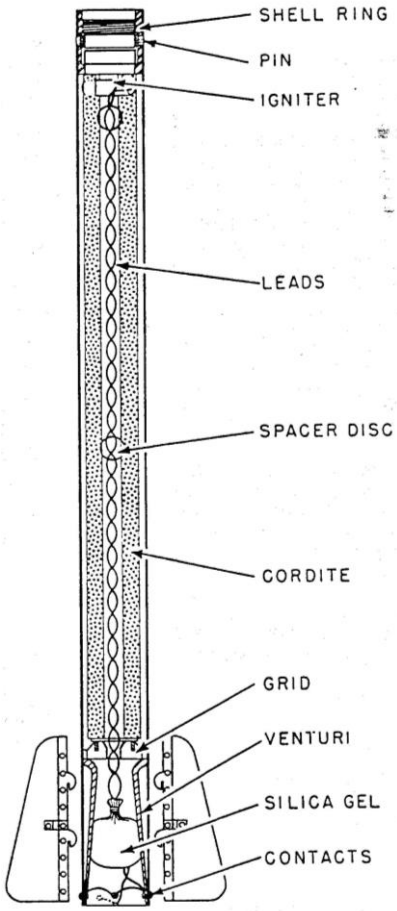
Weight: 0.86kg
Bomb Dimensions: 40mm x 310mm
Rate of Fire: 120 rounds per minute
Ceiling: 7,000m
Muzzle Velocity: 881m/s
Remarks: Mobile batteries – normally few records of where these guns were located.

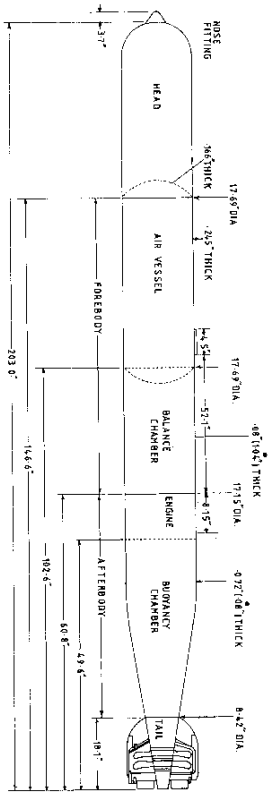




Rockets / Un-rotating Projectiles

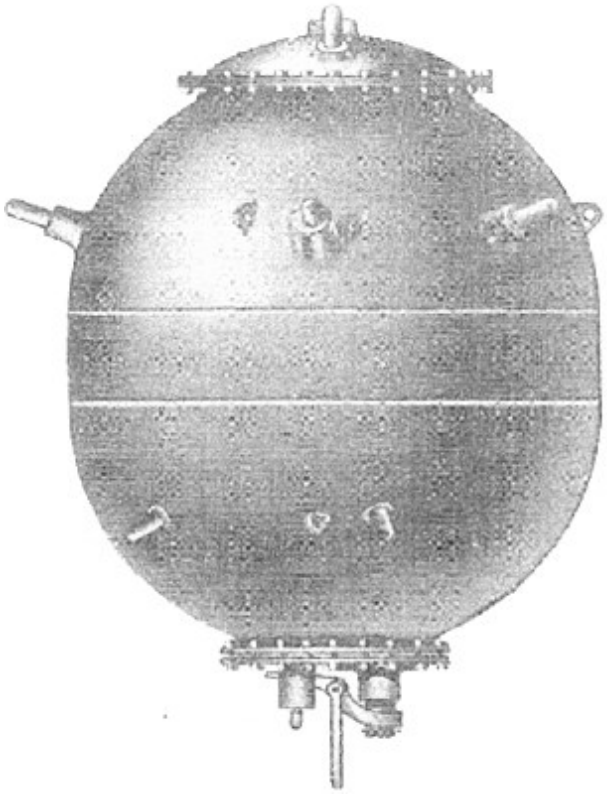
Weight: 24.5kg
Bomb Dimensions: 94 x 360mm
Carriage: Typically, white phosphorus
Rate of Fire: 10-20 rounds per minute
Ceiling: 9,000-18,000m
Muzzle Velocity: 72m/s
Remarks: 4.5" projectiles were also commonly utilized.
Top-left image: Home Guard soldiers load an anti-aircraft rocket at a 'Z' Battery





British 18in Mk XII Torpedo

Weight: 1548lb (702kg)
Length: 16ft 3in (495.3cm)
Charge Weight: 388lb (176kg)
Delivered By: Aircraft, no parachute
First Deployed: May 1941
Remarks: Dropped as a conventional bomb, this Luftwaffe designed mine was designed for more accurate positioning. When deployed against shipping it could be used as an impact bomb or influence mine.

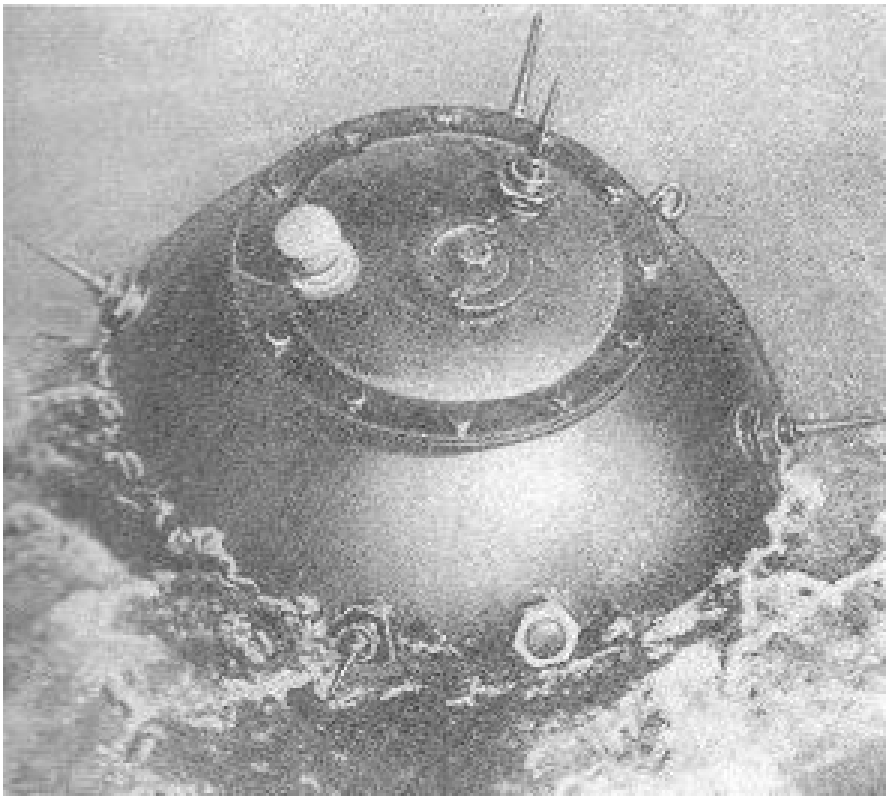


COLOUR: BLACK.
DIAMETER: 40 INCHES.
SHAPE: 2 HEMISPHERES WELDED TO A PARALLEL BELT. WIDTH OF BELT VARIES AS FOLLOWS
MK: 14: 8 INCHES.
MK: 15: 13½ INCHES.

HORNS: MK: 14: 11 IN NO. BRASS.
2 ON TOP COVER PLATE.
5 ON UPPER HEMISPHERE.
4 ON LOWER HEMISPHERE.
MK: 15: 11 IN NO. SWITCH.
2 ON TOP COVER PLATE.
5 ON UPPER HEMISPHERE.
4 ON LOWER HEMISPHERE.

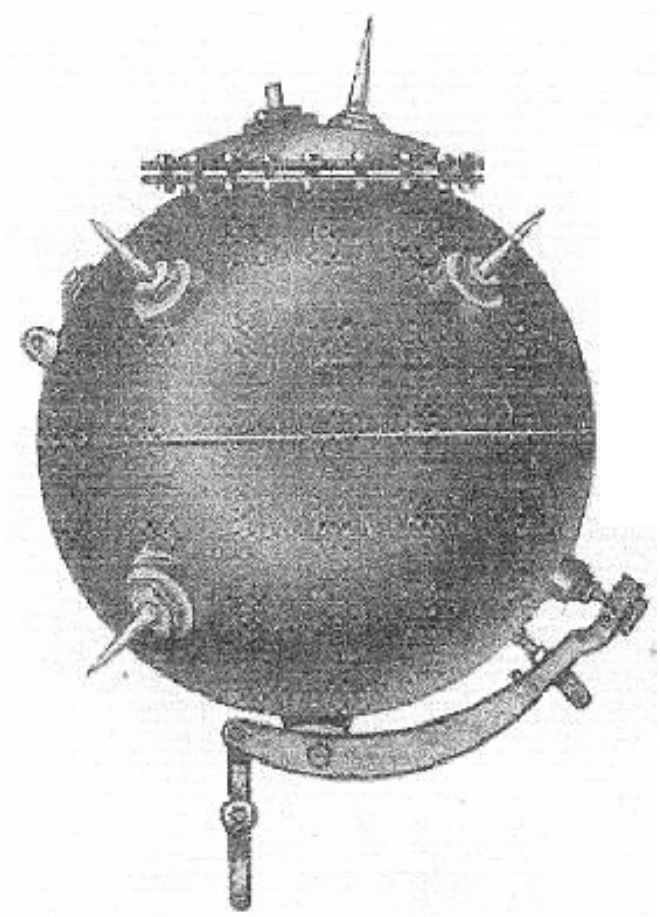
Contact Mine Mk XIV & XV

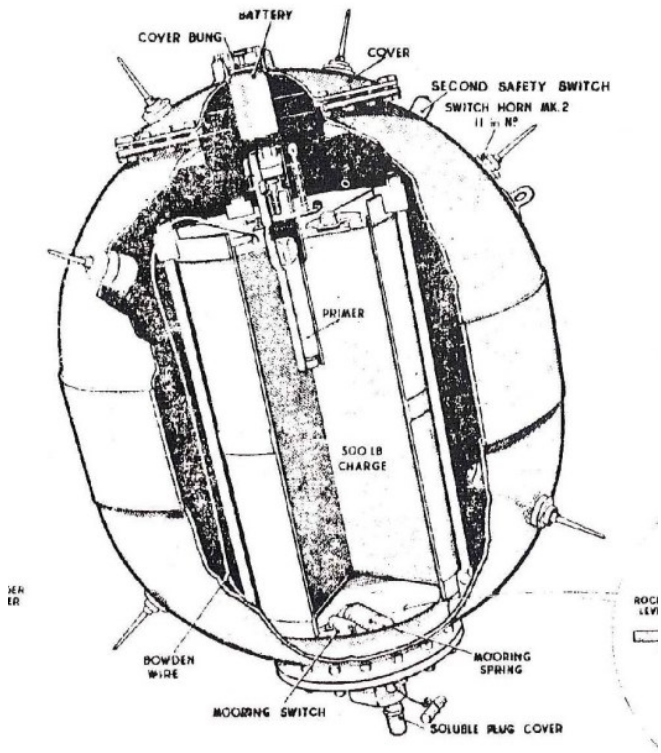
Type: Moored Contact
Shape: Ovoid
Diameter: 40in (101.6cm)
Charge Weight: 145kg or 295kg
Delivered By: Surface Craft
Initiation: 11 Hertz / Switch Horns
First Deployed: 1920s
Remarks: Designed for laying in depths between 365m to 1830, this device was also used as a general purpose mine in tidal waters.

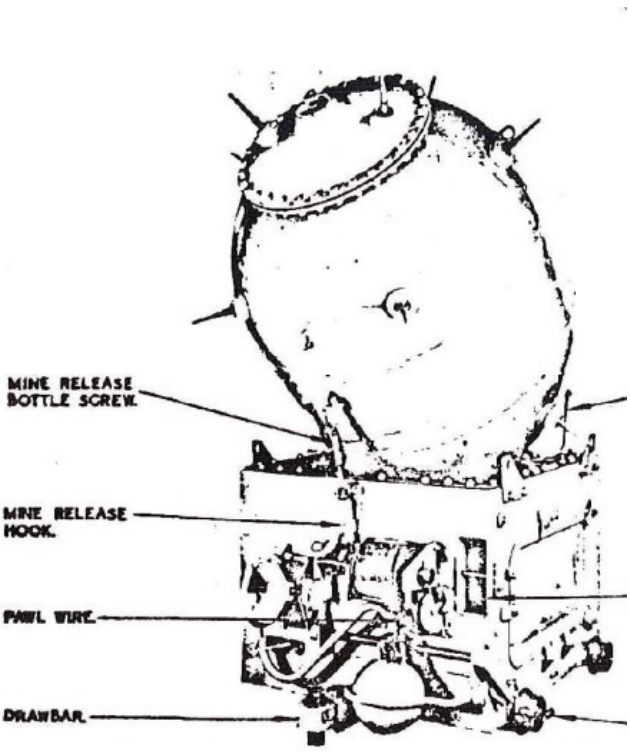


Contact Mine Mk XIX & XIXS

Type: Moored Contact
Shape: Spherical
Diameter: 31in (79cm)
Charge Weight: 45kg
Delivered By: Surface Craft
Initiation: 8 Switch Horns
Remarks: Originally designed to be laid as anti-submarine barrage mines. The "S" variant was for use against shallow draft vessels.







Contact Mine Mk XVII

Type: Moored Contact
Shape: Ovoid
Diameter: 40in (101.6cm)
Charge Weight: 145kg
Delivered By: Surface Craft
Initiation: Switch Horns
First Deployed: Early 1940's
Remarks: The standard British contact mine of WWII. Designed for laying in depths of 925m, there was also an influence (acoustic) version.