Appendix C: 2022 Site Investigation

Site Layout Plan
Trial Pit logs

KEY:

Trial Pits

Notes:

Locations indicative only.

CC Ground Investigations Ltd

Site Layout Plan

Brislington Meadows

Campbell Reith (Bristol)

Figure 1

Contract No: C7505

Drawn by:	Scale:
MM	NTS

CC Ground Investigations Ltd

TRIAL PIT LOG

Telephone: 01452 739165, Fax: 01452 739220, Email: info@ccground.co.uk

Pit No **TP01**

Sheet 1 of 1

Project Name: Brislington Meadows	Project No: **C7505**	Co-ords: E N Level: mAOD	Date 27/01/2022
Location: Bristol		Dimensions: 1.50m, Depth 0.75m, 0.60m	Scale 1 : 18.75
Client: Campbell Reith			Logged By MM

(m)	Water Levels	Samples & In Situ Testing No/Type	Depth (m)	Result	Description	Depth (m)	Level (mAD)	Legend
					Grass over reddish brown slightly gravelly clayey SAND. Gravel is sub angular to sub rounded fine to coarse of siliceous material.	(0.30)		
					Soft light brown slightly sandy gravelly CLAY. Gravel is angular to sub angular fine to coarse of sandstone	0.30		
						(0.45)		
					0.75m 1No ceramic field drain with water flowing from crack.	0.75		
					Trial pit completed at 0.75m			
1								
2								
3								

EQUIPMENT: JCB 3CX Mechanical Excavator.

METHOD: Trial pits excavated using 0.60m bucket.

GROUNDWATER: None encountered.

STABILITY: Trial pit generally stable.

BACKFILL: Trial pit backfilled with arisings and compacted with excavator bucket.

REMARKS: No samples taken. Water ingress from land drain. Trial pit terminated as per client request.

CC Ground Investigations Ltd

TRIAL PIT LOG

Telephone: 01452 739165, Fax: 01452 739220, Email: info@ccground.co.uk

Pit No **TP02**

Sheet 1 of 1

Project Name: Brislington Meadows	Project No: **C7505**	Co-ords: E N Level: mAOD	Date 27/01/2022
Location: Bristol		Dimensions: 4.90m Depth 1.05m 0.60m	Scale 1 : 18.75
Client: Campbell Reith			Logged By MM

(m)	Water Levels	Samples & In Situ Testing No/Type	Depth (m)	Result	Description	Depth (m)	Level (mAD)	Legend
					MADE GROUND: Grass over reddish brown slightly gravelly clayey SAND. Gravel is sub angular to sub rounded fine to coarse of siliceous material.	(0.40)		
					MADE GROUND: Dark greyish brown very gravelly clayey SAND. Gravel is angular to sub rounded fine to coarse of sandstone, coal and clinker.	0.40 (0.65)		
1					Trial pit completed at 1.05m	1.05		
2								
3								

EQUIPMENT: JCB 3CX Mechanical Excavator.

METHOD: Trial pits excavated using 0.60m bucket.

GROUNDWATER: None encountered.

STABILITY: Trial pit generally stable.

BACKFILL: Trial pit backfilled with arisings and compacted with excavator bucket.

REMARKS: No samples taken. Trial pit terminated as per client request.

CC Ground Investigations Ltd

TRIAL PIT LOG

Telephone: 01452 739165, Fax: 01452 739220, Email: info@ccground.co.uk

Pit No **TP03**

Sheet 1 of 1

Project Name: Brislington Meadows	Project No: **C7505**	Co-ords: E N Level: mAOD	Date 27/01/2022
Location: Bristol		Dimensions: 2.50m Depth 0.70m 0.60m	Scale 1 : 18.75
Client: Campbell Reith			Logged By MM

(m)	Water Levels	Samples & In Situ Testing No/Type	Depth (m)	Result	Description	Depth (m)	Level (mAD)	Legend
		EW	0.00		Grass over reddish brown slightly gravelly clayey SAND. Gravel is sub angular to sub rounded fine to coarse of siliceous material.	(0.30)		
					Soft light brown slightly sandy gravelly CLAY. Gravel is angular to sub angular fine to coarse of sandstone.	0.30 (0.40)		
					0.70m: 1No. Land drain. Trial pit completed at 0.70m	0.70		

EQUIPMENT: JCB 3CX Mechanical Excavator.

METHOD: Trial pits excavated using 0.60m bucket.

GROUNDWATER: None encountered.

STABILITY: Trial pit generally stable.

BACKFILL: Trial pit backfilled with arisings and compacted with excavator bucket.

REMARKS: Water sample taken at 0.00m from standing surface water. Water ingress from land drain. Trial pit terminated as per client request.

CC Ground Investigations Ltd

TRIAL PIT LOG

Telephone: 01452 739165, Fax: 01452 739220, Email: info@ccground.co.uk

Pit No **TP04**

Sheet 1 of 1

Project Name: Brislington Meadows	Project No: **C7505**	Co-ords: E N Level: mAOD	Date 27/01/2022
Location: Bristol		Dimensions: 2.00m Depth 0.70m 0.60m	Scale 1 : 18.75
Client: Campbell Reith			Logged By MM

(m)	Water Levels	Samples & In Situ Testing No/Type	Depth (m)	Result	Description	Depth (m)	Level (mAD)	Legend
					Grass over reddish brown slightly gravelly clayey SAND. Gravel is sub angular to sub rounded fine to coarse of siliceous material.	(0.30)		
					Soft light brown slightly sandy gravelly CLAY. Gravel is angular to sub angular fine to coarse of sandstone.	0.30 (0.40)		
					0.70m: 1No. Land drain cracked and silted up. Trial pit completed at 0.70m	0.70		
1								
2								
3								

EQUIPMENT: JCB 3CX Mechanical Excavator.

METHOD: Trial pits excavated using 0.60m bucket.

GROUNDWATER: None encountered.

STABILITY: Trial pit generally stable.

BACKFILL: Trial pit backfilled with arisings and compacted with excavator bucket.

REMARKS: No samples taken. Trial pit terminated as per client request. Land drain silted up.

Appendix D: UXO Site Investigation

Explosive Ordnance Desk Top Study of Brislington Meadows, EOD Contracts Ltd September 2019 (Report ref. EOD/1/1481/9DTS/Brislington Meadows, Bristol)

Non-Intrusive UXO Survey Report, Brimstone Site Investigation, April 2021 (Report ref. 20210421-NIREP-CAMP11)

Target Investigation Report, Brimstone Site Investigation, December 2021 (Report ref. 20211206-TIREP-CAMP13)

EOD Contracts Ltd

International Unexploded Ordnance Risk Mitigation

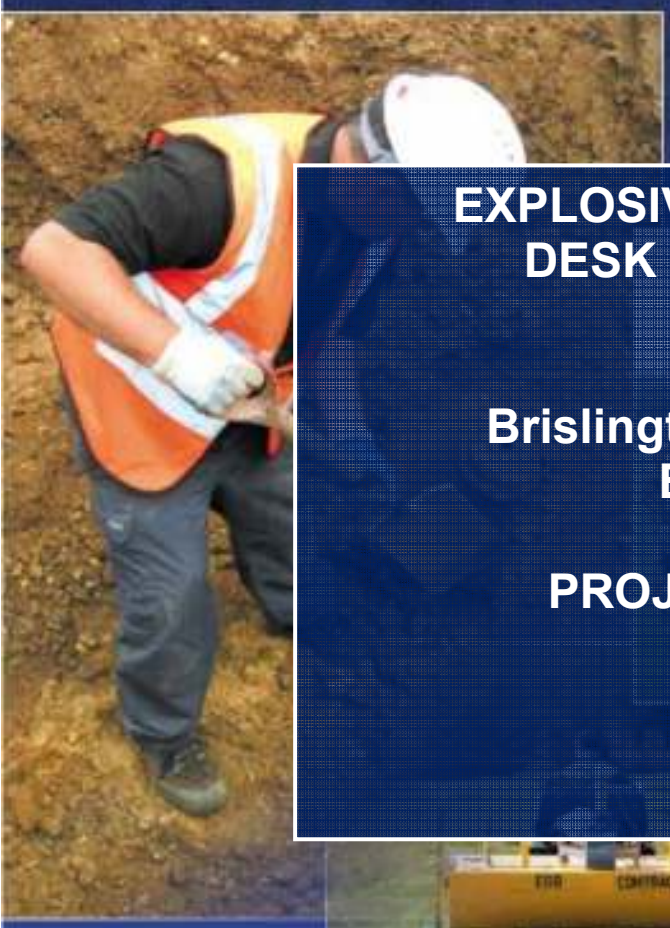
Many People... ...One Aim

EXPLOSIVE ORDNANCE DESK TOP STUDY FOR:

Brislington Meadows, Bristol

PROJECT 19481

WSP



Institute of Explosives Engineers
VOICE OF THE EXPLOSIVES INDUSTRIES

www.eodcontractsltd.com | Tel: 01926 485708

EXPLOSIVE ORDNANCE DESK TOP STUDY

Of

Brislington Meadows, Bristol

Conducted by EOD Contracts Limited

On behalf of

WSP

Conditions of Release

Document Control & Enquiries

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Alternatively; the persons named above can be reached at the above address.

CONTENTS

TERMS AND DEFINITIONS

Anti Aircraft Shells (AA)

Small High Explosive Shells (HE) shells ranging up to 100mm in diameter.

Air Raid Precautions (ARP)

An organisation in the United Kingdom set up in 1937 dedicated to the protection of civilians from the danger of air raids. It included the Raid Wardens' Service that was to report on bombing incidents.

Battlefield Area Clearance (BAC)

The systematic clearance of munitions from military property or old battle sites e.g. ranges, airfields etc.

Borehole Search

The placing of boreholes in a set pattern, then using a magnetometer to take readings at specific depths along each borehole. When used with a geophysical survey system this will give a magnetic signature of the area. The depth of the borehole and the pattern will depend upon the type of Unexploded Bombs (UXB) and the geology of the ground.

Doodle Bug (See Pilotless Aircraft)

Explosive Ordnance (EO)

All munitions containing explosives, nuclear fission/fusion materials and or biological and chemical agents. This includes bombs and warheads; guided and ballistic missiles; artillery, mortar, rocket and Small Arms Ammunition (SAA); all mines, torpedoes and depth charges; pyrotechnics; clusters and dispensers; cartridge and propellant actuated devices; electro-explosive devices; clandestine and improvised explosive devices (IED); and all similar or related items or components explosive in nature.

Explosive Ordnance Clearance (EOC)

See BAC.

Explosive Ordnance Disposal (EOD)

The detection, identification, field evaluation, render safe, recovery and disposal of **UXO**.

Geophysical Survey

The survey of an area using a Magnetometer and geophysical gathering device, after interpretation, this will produce a geophysical map and an object list for any metallic anomalies.

High Explosive (HE)

High explosives burn/detonate at rates of up to 9,000 m/per second.

Incendiary Bomb (IB)

Incendiary bombs ranged from 1kg in size to 500kg the larger sizes were sometimes called Oil Bombs. Fills range from thermite mixtures, phosphorus to kerosene.

Intrusive Survey

The use of a cone penetrometer (MagCone) or drilled boreholes (MagDrill) to take magnetometer test in a set pattern (see borehole search), or to prove pile positions.

Land Service Ammunition (LSA)

LSA is defined as “All items containing explosives or pyrotechnic compounds which are placed, thrown or projected so as to cause damage to men and equipment during land warfare.

Long Range Rocket (LRR)

The long range rocket sometimes codenamed Big Ben is the V2 rocket designed to deliver an approximate payload of 1000 kg.

Oil Bomb (OB)

A bomb containing a flammable liquid, normally the KC 250 Flam or the C 500 flam.

Pilot less Aircraft (PAC)

A flying bomb (Fly) or doodlebug is the V1 rocket or predecessors designed to deliver an explosive payload of approximately 500kg - 800kg.

Parachute Mine (PM)

Air dropped mine may have been used as a blast effect bomb maximum explosive content 1600lb always fitted with anti-handling and anti-stripping equipment.

Unexploded Bomb (UXB)

Any air dropped bomb that has failed to operate.

Unexploded Ordnance (UXO)

Explosive ordnance that has been primed, fused, armed or otherwise prepared for use or used. It may have been fired, dropped, launched or projected yet remains unexploded either through malfunction or design or for any other cause.

Vengeance Weapons (V)

V1 see Pilot less Aircraft.
V2 see Long Range Rocket.

WWI

World War 1 (1914 – 1918)

WWII

World War 2 (1939 – 1945)

EXECUTIVE SUMMARY

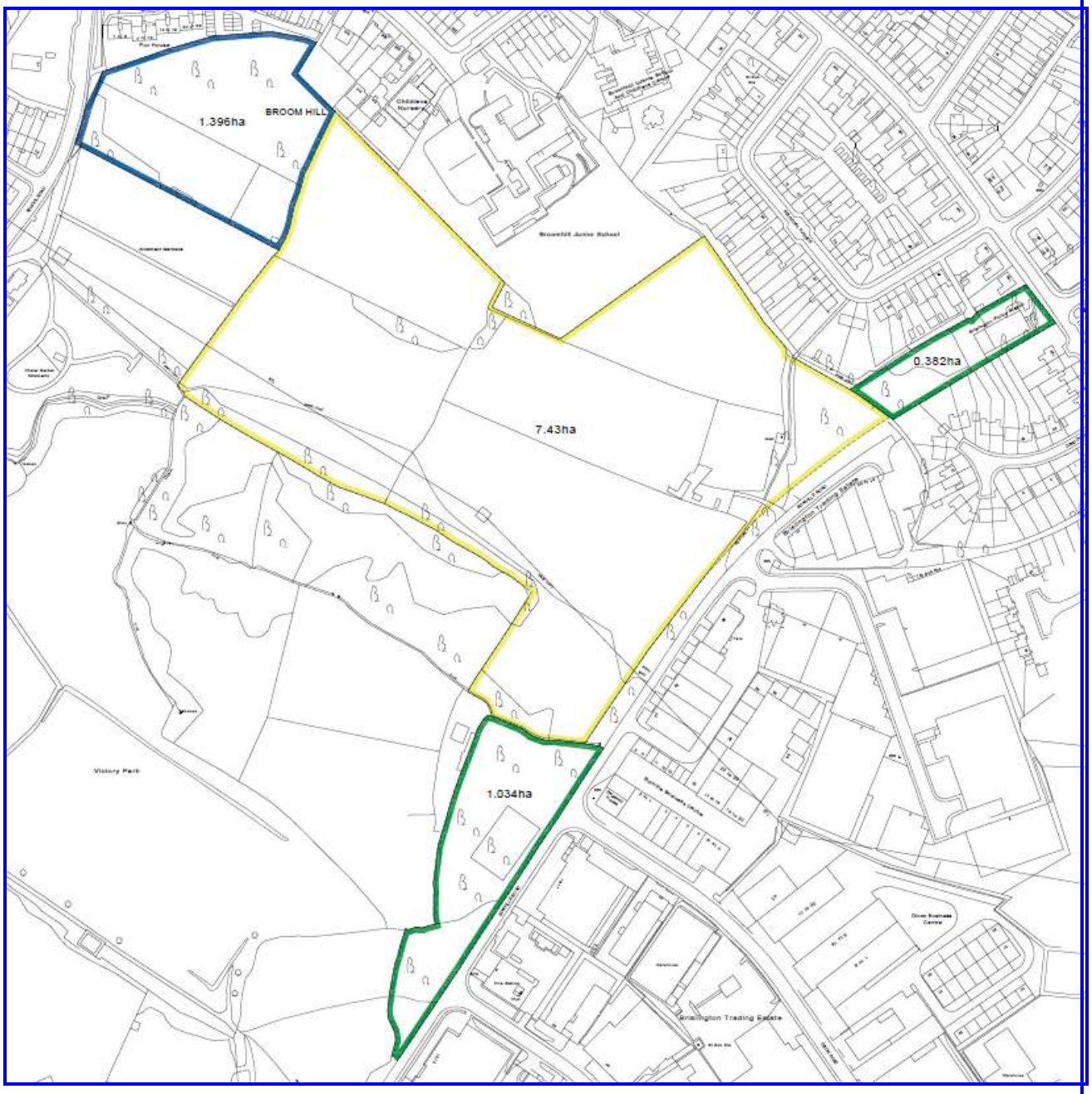
INSTRUCTION

EOD Contracts Ltd, have been commissioned by WSP to undertake a desktop study for potential historic Unexploded Ordnance (UXO) contamination for the future works at Brislington Meadows, Bristol (The Site).

Scope of Work

The scope of this EO Risk Assessment/Desk Study is to assess the likelihood of buried EO/UXO within the environs of The Site (See Figure 1.1), in view of further development. A further aim was to evaluate the implication from UXO contamination during any future intrusive land use.

Figure 1**:** Clients Supplied Site Diagram, This DTS will be covering all areas shown within the Boundaries.



LOCATION

The site is located within Brislington an area in the south east of the city of Bristol. During WWII the site was located within the Air Raid Precautions reporting area Region (7) South Western Region HQ Bristol.

Table 1 Site Location

Title	Description (Centre of Site)
Address	Brislington Meadows, Bristol
Post Code	BS4 4NZ (Nearest)
Grid Reference	ST6268171168
OS (X)	362681
OS (Y)	171168

SOURCES OF UXO CONTAMINATION

The main sources of UXO contamination that have been researched and are deemed a threat to the site are:

- Air delivered ordnance bombs and sub-munitions/incendiaries
- Anti Aircraft Ammunition (AA)
- Military Usage

KEY FINDINGS

Based on the information researched by EOD Contracts Ltd for the proposed scope of works being carried out within the given site area, the following conclusions have been reached:

Historical UXO Contamination

The indications of UXO contamination are:

Bomb Strikes	The area has bombs on and in close proximity to the site
Bomb Damage	Possible bomb craters shown in aerial photographs
Reconstruction	No development
Military Usage	None recorded

Risk Level

The overall risk has been determined to apply to all ground works within the site footprint.

Risk Level	The risk level on site is **HIGH** and given that some UXO retains the potential to detonate if disturbed with possible severe consequences, it is concluded that it would be prudent to ensure that basic precautions are taken to ensure that the project can proceed in the safest possible manner and that any residual risk posed by UXO is as low as it is reasonably practical to achieve (ALARP).
Risk Depth	The expected bomb depth is 8m below 1939 ground level.

RECOMMENDATIONS

It is recommended that the following risk mitigation strategy is executed during all Phases of the project:

Communicating the risks, all stakeholders should be made aware of the UXO situation on the site and the possible impact it may have on the project works and day to day running of the district. Clients have a legal duty under the Construction Design & Management Regulations (CDM) and Health & Safety at Work legislation to provide Designers and Contractors with project specific information needed to identify hazards and risks associated with the design and construction work. The possibility that UXO may be encountered on site falls within the category of a significant risk and as such it should be addressed as early as possible in the lifecycle of the project.

Further planning; the risks posed by UXO should be brought to the attention of the Project Principal Designers and other individuals with a responsibility for project safety and operations at the site. The matter of UXO should be considered critical to project safety and one requiring high priority action.

UXO safety awareness training should be given at all levels of site personnel and selected individuals on the project staff with relevant responsibilities. A competent person as part of the project safety induction course should provide the awareness training. It should be reinforced with specific safety briefings and toolbox talks to individuals involved in conducting intrusive earthworks.

Project overview and the responsibilities of those working on site with regard to duty of care and public safety.

UXO recognition and safety procedures to be followed on discovery of a suspicious object or the alarm being sounded.

Emergency procedures to be followed in the event of an explosion. Evacuation routes, muster stations and accounting for personnel.

Work permits, works methodology and specific UXO risk mitigation methods. Post-incident inspections and returning to normal works.

Prior to any intrusive piling or drilling commencing, UXO safety testing and appropriate clearance certification into the ground to sufficient depth to provide clearance from UXO. This can be done using a progressive drilling process or (where large numbers of piles are to be placed and ground permitting) using a vehicle borne hydraulic system to push a magnetometer into the ground to test for the presence of UXO prior to piling.

UXO safety monitoring of all “at risk” excavations, including geotechnical or archaeological trial pits to be conducted during the project. This should be provided by a UK Home Office Authorised EOD/UXO Contractor using qualified EOD Engineer with specialist locators and detectors to scan the ground ahead of the excavation wherever possible.

Specifically

- Geotechnical investigations, percussive drilling/trial pits/window/samples, require an EOD Engineer over watch

- This site would warrant a Non-Intrusive Magnetometer surveys and post analysis excavation of anomalies

- New foundations with piling could be mitigated by the insertion of a magnetometer to encompass the pile position, this would be carried out using a CPT rig (magcone), the expected radius of the magcone is 1.5m therefore multiple piles could be checked

EOD Contracts Ltd can supply a turnkey solution to your UXO requirements. Therefore, the following mitigation strategies can be supplied for land or water based operations:

Intrusive survey using CPT *(Cone Pressure Testing)* or borehole equipment, *supplying risk mitigation to all Borehole and Pile locations, down to a maximum bomb penetration depth determined within this document.*

Non-Intrusive Survey using multiple array system with DGPS *(Differential Global Positioning System).*

Offshore, near-shore, estuarine and freshwater water environments magnetic, side scan and bathymetric supported by state of the art DGPS.

The aforementioned surveys are supported with post processing of data and intrusive investigations if required.

EOD Engineer over watch using Suitably Qualified and Experienced Personnel, normally former British Army, Navy or RAF Bomb Disposal specialists.

Explosive Ordnance Safety Presentations.

PART 1: INTRODUCTION

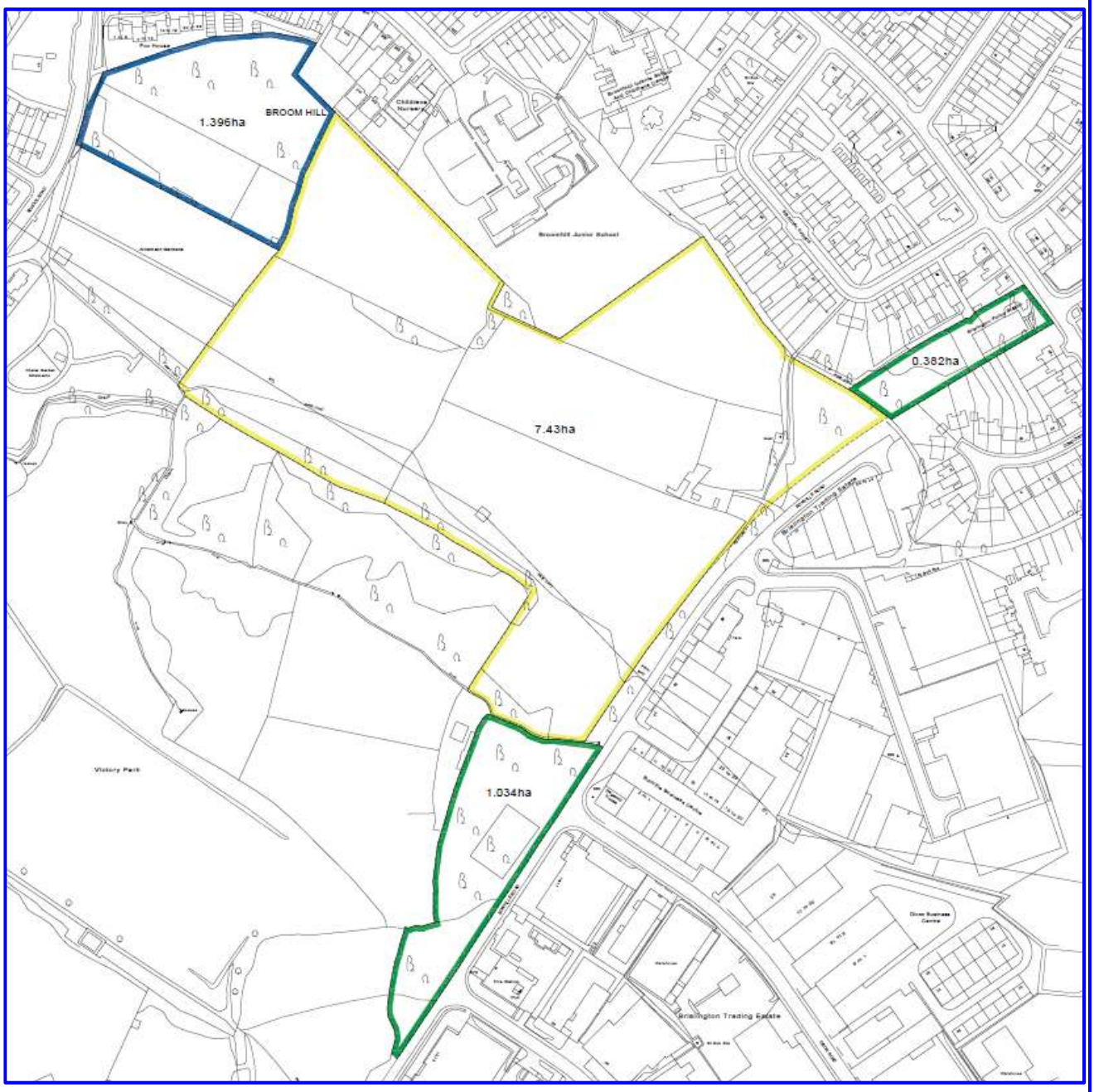
Instruction

EOD Contracts Ltd, have been commissioned by WSP to undertake a desktop study for potential historic Unexploded Ordnance (UXO) contamination for the future works at Brislington Meadows, Bristol (The Site).

Scope of Work

The scope of this EO Risk Assessment/Desk Study is to assess the likelihood of buried EO/UXO within the environs of The Site (See Figure 1.1), in view of further development. A further aim was to evaluate the implication from UXO contamination during any future intrusive land use.

Figure 1.1**:** Clients Supplied Site Diagram, This DTS will be covering all areas shown within the Boundaries.



Restrictions

It must be emphasized that a desk study can only indicate the potential for UXO to be present on the site.

This study was written with the site conditions prevailing at the time of the study and no liability can be accepted for any change in the condition of the area.

Please note that our appraisal relies on the accuracy of the information contained in the documents consulted and that EOD Contacts Ltd will in no circumstances be held responsible for the accuracy of such information or data supplied.

Sensitive Documentation

Information may be classified, restricted or deemed to be confidential in nature to EOD Contracts Limited, where such material has been gained a summary of the documentation has been approved.

Objective

The objective of this document is to define the UXO contamination routes as defined in Unexploded ordnance (UXO) A guide for the construction industry (C681) dated July 2009 and offer remediation methodologies if required.

CIRIA Frame Work

The CIRIA report is intended to provide good practice guidance (code of practice) on how to identify whether a site is likely to be at significant risk of UXO encounter and, if so, to set-out a process that will allow this risk to be managed. To be effective this process must start early in the life of the project (usually before intrusive works commence) and have involved Clients, Advisors and Principle Contractors. Therefore, the ground contractor should be provided with a systematic appraisal of the UXO risk when they become involved. The CIRIA report recommends the following stages be undertaken as part of the risk management process:

- Phase 1 Preliminary Risk Assessment
- Phase 2 Detailed Risk Assessment (Completed and updated in this document)
- Phase 3 Risk Mitigation (The act of ameliorating the risk, the clearance methodology)
- Phase 4 The UXO Risk Management and Implementation Plan

PART 2: SOURCES OF INFORMATION

Research of the site's history, with regard to military usage, bombing raids and bomb impacts has been undertaken to establish the following:

- Frequency and intensity of enemy bombing raids for the site and immediate vicinity up to 500m.
- Bomb impacts and associated damage on the Site and in the immediate vicinity.
- The potential for UXO to remain on the Site and in the vicinity.
- Records of UXO removal activities for the Site and immediate vicinity.
- The main sources of information consulted include:
- EOD Contracts Ltd company records
- Ministry of Defence records
- Central and Local Government Records
- Public Records Office (Kew)
- Historic Maps and Air Photography
- Open Source information (Internet)

Ministry of Defence (MOD) Records

33 Engineer Regiment (Explosive Ordnance Disposal) Royal Engineers is the unit responsible for maintaining the records concerning conventional Bomb incidents, reports, clearances and related UXO matters. These records are known to be incomplete and are no longer supplied. Based on in-house information released by the MOD previously, it is considered unlikely that any information released will have any significant impact on the findings of this study.

Attack Record Keeping

In general, the quality and accuracy of bombing and shelling records prior to 1942 varied greatly from one region to another. Records relating to the limited air attacks on the United Kingdom are considered to be sufficiently accurate in urban areas to provide a reasonable level of confidence in determining the likelihood that an area was or was not bombed during this period. Wartime records, maps etc held within the civil archives are considerably more comprehensive than those still in existence within the MOD, where it is acknowledged that large numbers of records have been disposed of since 1945. Records from some areas, particularly rural districts or near large bodies of water should still be regarded as an incomplete picture of the extent and effect of the bombing campaign.

Attack Record Accuracy

While an Air Raid was in progress it was inevitable that mistakes would be made in the transcription of rushed verbal reports into the written records. Discrepancies did occur between the total of bombs dropped against detonations witnessed. In some cases records were made several hours after the event and mistakes were inevitable. Some reports were drafted before the full extent of the raid had been determined which has led to significant omissions in the records. Reports of raids on rural

areas were often witnessed and submitted by untrained individuals and passed through third parties before being recorded. Suspect UXBs occasionally went unreported by local farmers and freeholders who saw the event as insignificant, or were reluctant to report their findings for fear of valuable land or crops being destroyed by the authorities in their attempts to find the UXB. It should also be noted that bomb strikes in water were notoriously difficult to spot, particularly if the bomb had failed to detonate. As a result bomb record accuracy in areas containing large bodies of water or marshland is considered to be questionable.

Errors and Omissions

The accuracy of bombing records has been shown to vary greatly; this may have been a result of the individual record keeper's expertise. Additionally, in some cases, errors occurred as a result of poor or incomplete transcription and copying. Some "errors and omissions" were intentional, designed to serve as dis-information to confuse German intelligence. So long after the event, official verification of such incidents has often proven to be impossible to obtain. At present, UXBs are found on construction sites and other locations where there had been no documentary evidence to suggest their presence. These events, although infrequent, do serve as confirmation that records cannot be considered definitive.

Bibliography

The significant published documents referred to during this study are listed below:

- HO 193 series from National Archives
- HO 198 series from National Archives
- The Blitz Then and Now Volumes 1 to 3
- AA Command Colin Dobinson
- German Air Raids on Britain 1914-1918
- Bristol Blitz Diary John Dike
- A Chronology Of The Air War Over The County Of Avon 1939 – 1944 John Penny

PART 3: SITE DESCRIPTION AND DETAILS

Location

The site is located within Brislington an area in the south east of the city of Bristol. During WWII the site was located within the Air Raid Precautions reporting area Region (7) South Western Region HQ Bristol.

Table 3.1 Site Location

Title	Description (Centre of Site)
Address	Brislington Meadows, Bristol
Post Code	BS4 4NZ (Nearest)
Grid Reference	ST6268171168
OS (X)	362681
OS (Y)	171168

Description and Current Usage

The site is 10.25 hectares with irregular boundaries, therefore the outside boundaries are to the west is the rear of the properties on School Road, to the south is open pastureland to the east is Bonville Road and an industrial estate and to the north is Broomhill School and housing estate. At present the site is open pastureland.

Geology

BGS (British Geological Survey) nearest borehole see Figure 3.1 indicates the following geology:

Table 3.2 Geology

Geological Unit Description	Anticipated Thickness (m)	Anticipated Depth (m bgl)
Top Soil	0.2	0.2
Sand	1.2	1.4
Sandstone	8.6	10 end of log

Figure 3.1 Borehole Location

Future Works

At the time of writing this report it is understood that the site will be redeveloped (the exact scope of works is not known at this time). Therefore, it is assumed that the following intrusive construction works will be carried out:

- Geotechnical investigations, percussive drilling/trial pits/window/samples
- Foundations with possible piling
- Services trenching
- Open Excavations

PART 4: HISTORICAL REVIEW

Historical Mapping and Aerial Photography

The air photograph and historical maps in Annex B have been reviewed and a brief synopsis is in Table 4.1:

Table 4.1 Aerial Photograph and Historical Map Synopsis

Date	Scale	Description/Remarks
1938	NA	Aerial Photograph Oblique: Site appears to be open pastureland with allotments in the west, the pastureland is divided by hedgerows and trees.
1938	1:10,560	Site appears to be open pastureland
1946	1:10,560	Site appears to be open pastureland and allotments; bomb damage would not be obvious
1946		Aerial Photograph: Site appears to be open pastureland with allotments in the west, the pastureland is divided by hedgerows and trees. A large crater plus secondary craters are to the south and west as is an area that appears to be heavily tracked, minor scoring can be seen on the site, possibly indicative of bomb damage
1972	1:10,000	Shows present configuration of surrounding buildings and usage

WWI

Although many people associate wartime bombing with The Blitz during World War II, the first airborne terror campaign in Britain took place during the First World War. Air raids in World War One caused significant damage and took many lives. German raids on Britain, for example, caused 1,413 deaths and 3,409 injuries.

Site Specific Bombing Information

The map shown in Annex C indicates the Site was not the subject of bombardment during WWI.

WWII

Bombing started as early as October 1939, by the end of the WWII the Luftwaffe had dropped approximately 50,000tonnes of high explosive bombs and 110,000 tonnes of incendiary bombs, this caused over 40,000 UXBs, killed 43,000 people and over 250,000 homes were destroyed.

Bristol in the Blitz

Bristol was the fifth most heavily bombed British city of World War II. The presence of Bristol Harbour and the Bristol Aeroplane Company made it a target for bombing by the Nazi German Luftwaffe who were able to trace a course up the River Avon from Avonmouth using reflected moonlight on the waters into the heart of the city.

Between 24 November 1940 and 11 April 1941 there were six major bombing raids. In total Bristol received 548 air raid alerts and 77 air raids with:

- 919 tons of high-explosive bombs and myriad incendiary bombs
- 1299 people killed, 1303 seriously injured, 697 rescued from debris
- 89,080 buildings damaged including 81,830 houses destroyed and over 3000 later demolished.

Site Specific Bombing Information

Record of air raids on and in the vicinity of the site have been scrutinized, bomb impact maps are attached in Annex D, the mapping indicates 3 x HE bombs were dropped on the site and 9 x 50kg HE and 2 x UXBs in close proximity.

Abandoned Bombs/UXO

EOD Contracts records could find no evidence of any abandoned Bombs in or around the subject site, however 2 x UXBs were noted in close proximity to the site.

Anti-Aircraft Artillery

The nearest recorded location of heavy anti-aircraft gun (HAA) position is 700m from the site.

Military Usage

The area is open pastureland, no recorded military usage was noted.

Prior Clearance Operations

EOD Contracts could find no evidence to suggest that there have been any prior UXO clearance operations in or around the site footprint.

PART 5: SOURCES OF UXO CONTAMINATION

The main sources of UXO contamination that have been researched for the site are:

- Air delivered ordnance bombs and sub-munitions/incendiaries
- Anti Aircraft Ammunition (AA)
- Military Usage

General

Due to the fact that there is UXO contamination pathways from:

- Air delivered ordnance bombs and sub-munitions/incendiaries

UXOs are essentially dangerous; therefore, further information on UXO and Safety is detailed in Annex E.

Bomb Penetration Depths

The expected bomb depths for the site assuming the following criteria:

- 15,000 feet, the vast majority of bombs were dropped from height to avoid AA fire and balloons
- General Purpose Bombs of 50kg to 1000kg
- Near Vertical impact 80 to 90 degrees
- Surface geotechnical conditions are made ground
- Subsurface geotechnical conditions are as per Paragraph 3

Therefore, the expected depths for Air dropped UXBs on site are indicated in **RED** in the following table:

Table 5.1: Bomb Penetration Depths

	Bomb Weights			
Sub Soil Type	50kg	250kg	500kg	1000kg
Soft Rock	**2.442**	**5.016**	**6.006**	**7.062**
Gravel	2.442	5.016	6.006	7.062
Sand	**2.442**	5.016	6.006	7.062
Chalk	3.7	7.6	9.1	10.7
Shingle	3.7	7.6	9.1	10.7
Dry Clay	3.7	7.6	9.1	10.7
Wet Sand	5.55	11.4	13.65	16.05
Wet Clay	5.55	11.4	13.65	16.05
Average Offset (m)	0.8-1.6	1.6-3.7	3-4.5	3.4-5.3

***** Empirical data taken from 1,000 bombs dropped during WWII, strata and depth from operational excavations.

Bombs on penetration of the surface do not follow a straight-line trajectory they can and do curve; this is called a “J” curve where the bomb’s path bends back towards the surface. This gives what is known as the Offset, which may place a bomb under a structure and at a shallow depth.

Further information on bomb depths and J Curves is in Annex E.

PART 6: RISK ASSESSMENT

Risk Assessment

Assessing both the likelihood of occurrence and the consequences of the encounter has derived the overall risk for the site from unexploded ordnance. Review of the site's history and geographic location can provide an overall likelihood of encounter factor, which is used in the subsequent determination of a risk level when a Figure can be determined for the consequence.

Likelihood of Encounter

Given the study findings and other criteria (See Annex F Tables) it is considered that there is a **HIGH** risk of encountering UXO within the site footprint. This finding is based on assessment of all of the available information and taking account of the following factors:

- It is a matter of historic record that the area was subjected to enemy attack. For the most part, the records provide relatively accurate numbers of strikes however are limited in their precise locations.
- The area has not been developed since WW2.

Encounters of UXO are not uncommon, recent UXO finds are in Annex G.

Consequence of Encounter

The consequence see Annex E of an uncontrolled encounter with UXO, given its lethal design and its unpredictable nature could be catastrophic and warrants a high severity factor. With regards to the consequences, the following factors were considered:

The project works may make use of a number of common ground investigation and construction techniques in its methodology during the project. Any intrusive groundwork has the potential to encounter UXO.

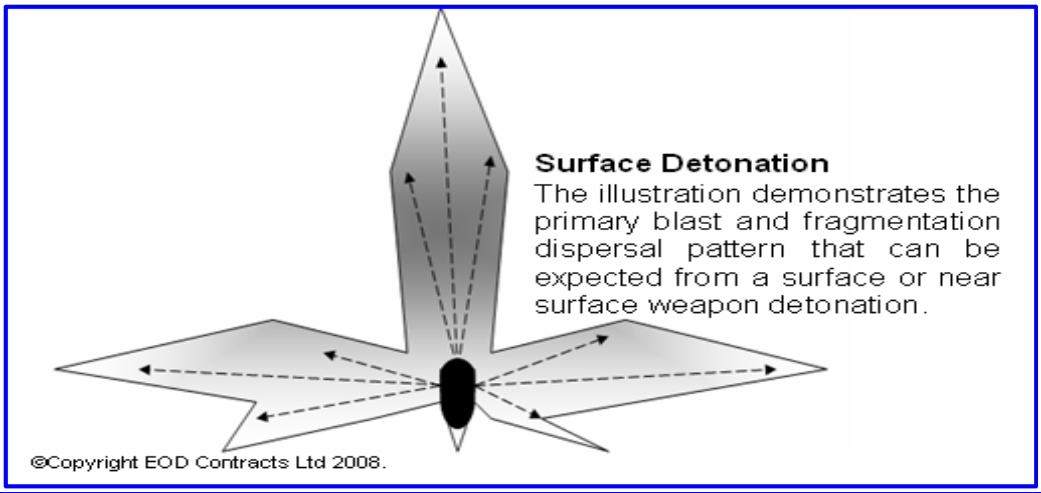
Intrusive earthwork, piling driving and dynamic ground compaction are by nature, aggressive, significant force (kN) is often required to achieve the desired results. As a precaution it is prudent to assume that any external stimulus, no matter how slight, may result in an unstable weapon detonating.

Records of encounters with UXO, particularly where plant machinery has been involved have resulted in detonations of the items with varying degrees of consequence; ranging from slight injuries sustained to piling contractors when a bomb detonated at 6.0m bgl to fatal injuries sustained to a construction worker while conducting near surface machine works on a motorway.

Detonation on land; the effects of a detonation at depth will be more localised and less destructive than one occurring on the surface. Figure 6.1 shows an illustration of the primary blast and fragmentation dispersal from explosive ordnance when it detonates on the surface. The weapon's design, and other key factors such as the ratio of explosive charge weight to total weapon weight (CWR) and the Net Explosive Quantity (NEQ) will determine the size and effects of a blast. The effects will also be enhanced or reduced by a number of factors including, the presence of other energetic materials in close proximity to the blast or if the weapon is buried or exposed on the surface. As a guide Annex E Table 1 gives an indication of the likely blast radius for common types of UXO.

Figure 6.1: Primary Blast & Fragmentation on Land

Blast and fragmentation dispersal.



In addition to the dangers of explosion, many common chemicals used in the manufacture of explosive ordnance fillings are; in sufficient quantity, and level of exposure, toxic or poisonous. Although it is unlikely that such chemicals would be encountered in significant quantity to represent a significant risk to personnel, leakage or venting could pose a risk to the local marine environment. In addition to heavy metals; copper, lead, zinc etc used in the weapon body and fuze, hydrocarbon propellants such as Kerosene may also be present.

Risk Level

The overall risk has been determined to apply to all of the ground within the site footprint. The prevailing risk level has been determined to be **HIGH**. The risk from UXO is considered to exist to a maximum depth of 8 metres below the 1939 ground levels.

Encounter Consequences

It is acknowledged that when viewed from a "likelihood versus consequence" scenario; the consequences of an explosion may have the potential to include:

- Multiple casualties or fatalities.
- Extensive damage to high value private and public assets and property.
- Significant delays to the construction project.

Those at Risk

The risk is considered to have the potential to pose a direct and indirect threat to a wide range of individuals and facilities. While the impact on fixed assets can be estimated based on the asset's proximity to the seat of the explosion. The impact to transient assets and people will, for the most part, be the result of both; proximity to the explosion and the time at which the event occurs. The overall impact therefore has the potential to range from little more than a minor localised event to a level, which may be considered to be a more widespread major incident involving some or all of the following:

- Construction and other specialist personnel carrying out the work.

- General public in open spaces, at their places of work and transient population on foot or road users in proximity to the construction work.
- Public services including; transport, water, gas and electricity supplies.
- Public facilities, including; buildings, vehicles, other high value assets and equipment.
- Private business property including construction equipment.
- Private residential property in proximity to the work.

At Risk Activities

Based on our understanding of the scope of the most common construction projects, it is considered that a wide range of intrusive processes may be required to complete the project. Any intrusive groundworks has the potential to encounter UXO and each activity therefore has a degree of risk attached to it. The severity or level of the risk is derived as a consequence of activity's; location, methodology and volume or quantity of risk material to be worked, at risk activities are considered to include:

- Site preparation and levelling.
- Intrusive geotechnical and archaeological investigations including drilling and pitting.
- Foundation construction, trenching and other excavations.
- Intrusive construction works, which may include piling.

PART 7: CONCLUSIONS

Based on the information researched by EOD Contracts Ltd for the proposed scope of works being carried out within the given site area, the following conclusions have been reached:

Historical UXO Contamination

The indications of UXO contamination are:

Bomb Strikes	The area has bombs on and in close proximity to the site
Bomb Damage	Possible bomb craters shown in aerial photographs
Reconstruction	No development
Military Usage	None recorded

Risk Level

The overall risk has been determined to apply to all ground works within the site footprint.

Risk Level	The risk level on site is **HIGH** and given that some UXO retains the potential to detonate if disturbed with possible severe consequences, it is concluded that it would be prudent to ensure that basic precautions are taken to ensure that the project can proceed in the safest possible manner and that any residual risk posed by UXO is as low as it is reasonably practical to achieve (ALARP).
Risk Depth	The expected bomb depth is 8m below 1939 ground level.

PART 8: RECOMMENDATIONS

Communicating the risks, all stakeholders should be made aware of the UXO situation on the site and the possible impact it may have on the project works and day to day running of the district. Clients have a legal duty under the Construction Design & Management Regulations (CDM) and Health & Safety at Work legislation to provide Designers and Contractors with project specific information needed to identify hazards and risks associated with the design and construction work. The possibility that UXO may be encountered on site falls within the category of a significant risk and as such it should be addressed as early as possible in the lifecycle of the project.

Further Planning; the risks posed by UXO should be brought to the attention of the Project Principal Designers and other individuals with a responsibility for project safety and operations at the site. The matter of UXO should be considered critical to project safety and one requiring high priority action.

Safety Training; UXO safety awareness training should be given at all levels of site personnel and selected individuals on the project staff with relevant responsibilities. The training should be provided by a competent person as part of the project safety induction course. It should be reinforced with specific safety briefings and tool box talks to individuals involved in conducting intrusive earthworks. The training should cover the following topics to a level commensurate with the audience's responsibilities and duties:

- Project overview and the responsibilities of those working on site with regard to duty of care and public safety
- UXO recognition and safety procedures to be followed on discovery of a suspicious object or the alarm being sounded
- Emergency procedures to be followed in the event of an explosion. Evacuation routes, muster stations and accounting for personnel
- Work permits, works methodology and specific UXO risk mitigation methods. Post incident inspections and returning to normal works

Prior to any intrusive piling or drilling commencing, UXO safety testing and appropriate clearance certification into the ground to sufficient depth to provide clearance from UXO. This can be done using a progressive drilling process or (where large numbers of piles are to be placed and ground permitting) using a vehicle borne hydraulic system to push a magnetometer into the ground to test for the presence of UXO prior to piling.

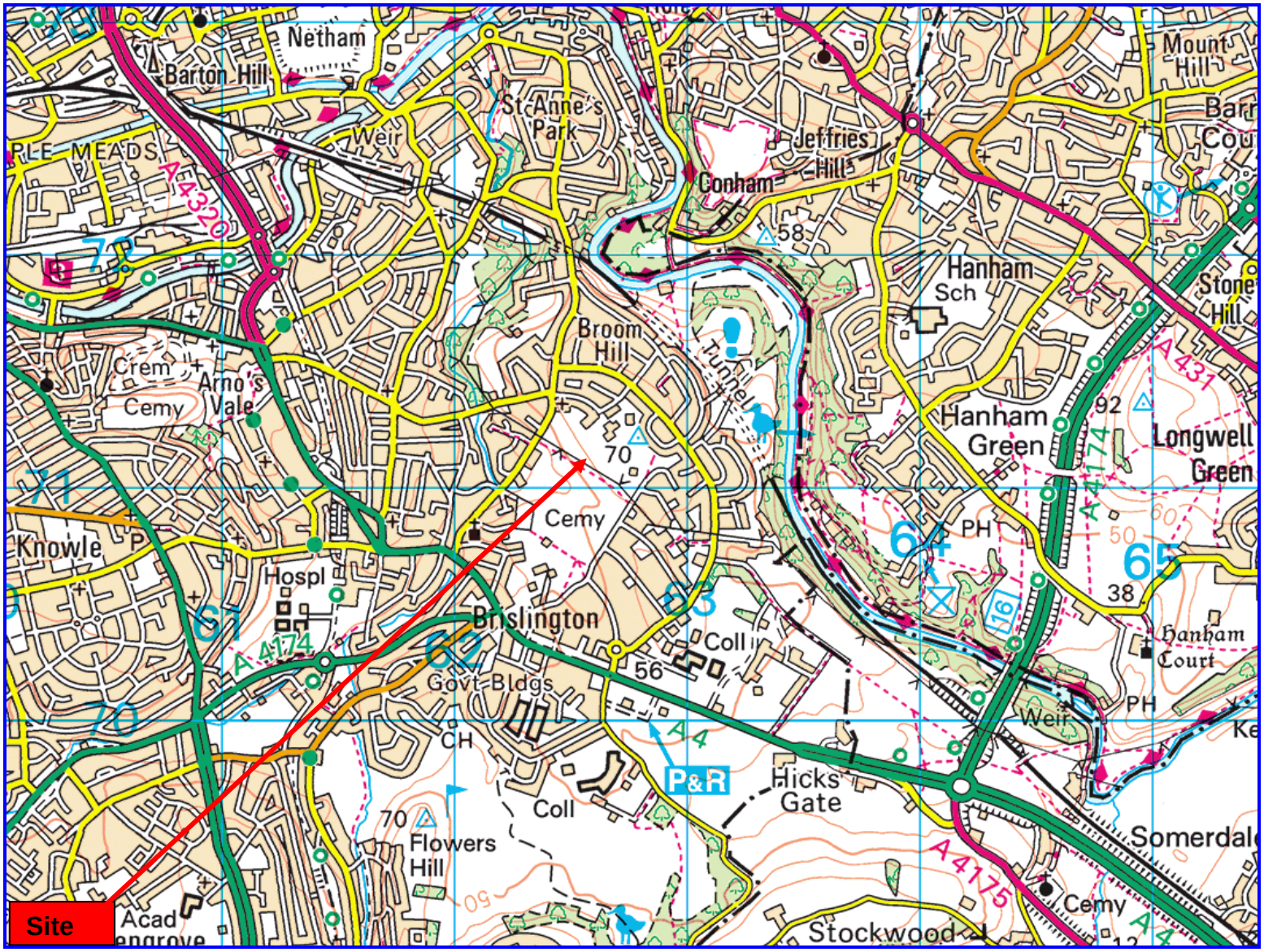
UXO safety monitoring of all "at risk" excavations, including geotechnical or archaeological trial pits to be conducted during the project. This should be provided by a UK Home Office Authorised EOD/UXO Contractor using qualified EOD Engineer with specialist locators and detectors to scan the ground ahead of the excavation wherever possible.

Specifically

- Geotechnical investigations, percussive drilling/trial pits/window/samples, require an EOD Engineer over watch
- This site would warrant a Non-Intrusive Magnetometer surveys and post analysis excavation of anomalies
- New foundations with piling could be mitigated by the insertion of a magnetometer to encompass the pile position, this would be carried out using a CPT rig (magcone), the expected radius of the magcone is 1.5m therefore multiple piles could be checked

Annex A

SITE LOCATION



Annex B

HISTORIC AERIAL PHOTOGRAPHS AND MAPS

Index of Historical Maps

Page No.	Date	Scale	Description/Remarks
B-2	NA	1:10,000 and 1:10,560	Historical Mapping Legends
B-3	1938	NA	Aerial Photograph Oblique: Site appears to be open pastureland with allotments in the west, the pastureland is divided by hedgerows and trees.
B-4	1938	1:10,560	Site appears to be open pastureland
B-5	1946	1:10,560	Site appears to be open pastureland and allotments; bomb damage would not be obvious
B-6	1946		Aerial Photograph: Site appears to be open pastureland with allotments in the west, the pastureland is divided by hedgerows and trees. A large crater plus secondary craters are to the south and west as is an area that appears to be heavily tracked, minor scoring can be seen on the site, possibly indicative of bomb damage
B-7	1972	1:10,000	Shows present configuration of surrounding buildings and usage

Historical Mapping Legends

Ordnance Survey County Series 1:10,560

Gravel Pit
Sand Pit
Other Pits
Quarry
Shingle
Orchard
Osiers
Reeds
Marsh
Mixed Wood
Deciduous
Brushwood
Fir
Furze
Rough Pasture
Arrow denotes flow of water
Trigonometrical Station
Site of Antiquities
Bench Mark
Pump, Guide Post, Signal Post
Well, Spring, Boundary Post
•285 Surface Level
Sketched Contour
Instrumental Contour
Main Roads
Fenced
Un-Fenced
Minor Roads
Fenced
Un-Fenced
Sunken Road
Raised Road
Road over Railway
Railway over River
Railway over Road
Level Crossing
Road over River or Canal
Road over Stream
Road over Stream
County Boundary (Geographical)
County & Civil Parish Boundary
Administrative County & Civil Parish Boundary
Co. Boro. Bdy. County Borough Boundary (England)
Co. Burgh Bdy. County Burgh Boundary (Scotland)
R.D. Bdy. Rural District Boundary
Civil Parish Boundary

Ordnance Survey Plan 1:10,000

Chalk Pit, Clay Pit or Quarry
Gravel Pit
Sand Pit
Disused Pit or Quarry
Refuse or Slag Heap
Lake, Loch or Pond
Dunes
Boulders
Coniferous Trees
Non-Coniferous Trees
Orchard
Scrub
Coppice
Bracken
Heath
Rough Grassland
Marsh
Reeds
Saltings
Building
Direction of Flow of Water
Shingle
Sand
Glasshouse
Pylon
Sloping Masonry
Electricity Transmission Line
Pole
Cutting
Embankment
Standard Gauge Multiple Track
Road Under
Road Over
Level Crossing
Foot Bridge
Standard Gauge Single Track
Siding, Tramway or Mineral Line
Narrow Gauge
Geographical County
Administrative County, County Borough or County of City
Municipal Borough, Urban or Rural District, Burgh or District Council
Borough, Burgh or County Constituency
Shown only when not coincident with other boundaries
Civil Parish
Shown alternately when coincidence of boundaries occurs

BP, BS	Boundary Post or Stone	Pol Sta	Police Station
Ch	Church	PO	Post Office
CH	Club House	PC	Public Convenience
F E Sta	Fire Engine Station	PH	Public House
FB	Foot Bridge	SB	Signal Box
Fn	Fountain	Spr	Spring
GP	Guide Post	TCB	Telephone Call Box
MP	Mile Post	TCP	Telephone Call Post
MS	Mile Stone	W	Well

1:10,000 Raster Mapping

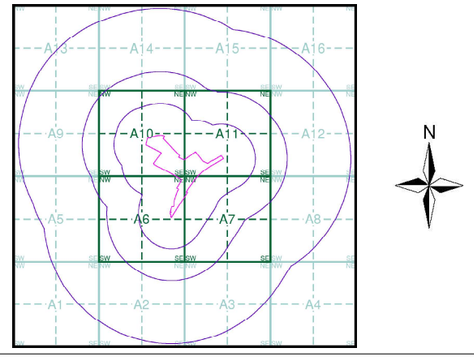
Gravel Pit
Refuse tip or slag heap
Rock
Rock (scattered)
Boulders
Boulders (scattered)
Shingle
Mud
Sand
Sand Pit
Slopes
Top of cliff
General detail
Underground detail
Overhead detail
Narrow gauge railway
Multi-track railway
Single track railway
County boundary (England only)
Civil, parish or community boundary
District, Unitary, Metropolitan, London Borough boundary
Constituency boundary
Area of wooded vegetation
Non-coniferous trees
Non-coniferous trees (scattered)
Coniferous trees
Coniferous trees (scattered)
Positioned tree
Orchard
Coppice or Osiers
Rough Grassland
Heath
Scrub
Marsh, Salt Marsh or Reeds
Water feature
Flow arrows
MHW(S) Mean high water (springs)
MLW(S) Mean low water (springs)
Telephone line (where shown)
Electricity transmission line (with poles)
BM 123.45 m Bench mark (where shown)
Triangulation station
Point feature (e.g. Guide Post or Mile Stone)
Pylon, flare stack or lighting tower
Site of (antiquity)
Glasshouse
General Building
Important Building

EOD Contracts Ltd

Historical Mapping & Photography included:

Mapping Type	Scale	Date	Pg
Somerset	1:10,560	1884	3
Gloucestershire	1:10,560	1887	4
Somerset	1:10,560	1904 - 1905	5
Gloucestershire	1:10,560	1904	6
Gloucestershire	1:10,560	1920	7
Somerset	1:10,560	1921 - 1932	8
Somerset	1:10,560	1932 - 1933	9
Gloucestershire	1:10,560	1938	10
Somerset	1:10,560	1938	11
Gloucestershire	1:10,560	1938	12
Somerset	1:10,560	1938	13
Gloucestershire	1:10,560	1946	14
Ordnance Survey Plan	1:10,000	1955	15
Ordnance Survey Plan	1:10,000	1965 - 1967	16
Ordnance Survey Plan	1:10,000	1972 - 1973	17
Bristol	1:10,000	1972	18
Ordnance Survey Plan	1:10,000	1982 - 1988	19
10K Raster Mapping	1:10,000	1999	20
10K Raster Mapping	1:10,000	2006	21
VectorMap Local	1:10,000	2019	22

Historical Map - Slice A



Order Details

Order Number: 217804183_1_1
Customer Ref: 19481 Brislington Park WSP
National Grid Reference: 362660, 171050
Slice: A
Site Area (Ha): 10.27
Search Buffer (m): 1000

Site Details

Brislington Park, BRISTOL, BS4 4NZ

Landmark INFORMATION GROUP
Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

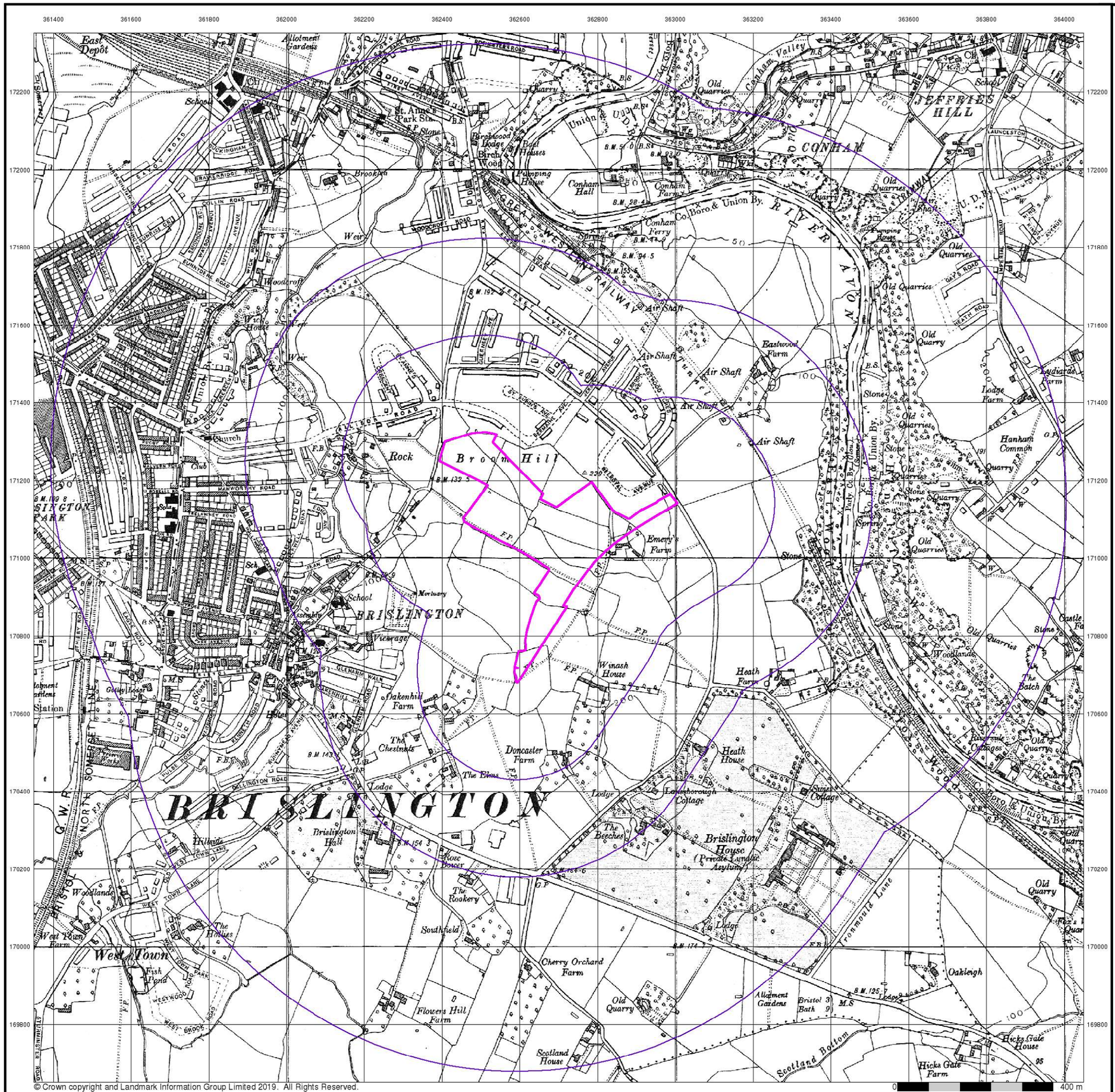
Description/Remarks

AERIAL PHOTOGRAPH
Oblique

Site appears to be open pasture land with allotments in the west, the pasture land is divided by hedgerows and trees.

Date

1938



EOD Contracts Ltd

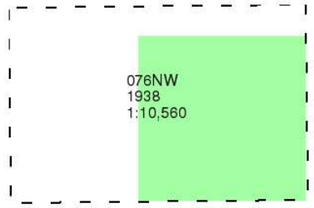
Gloucestershire

Published 1938

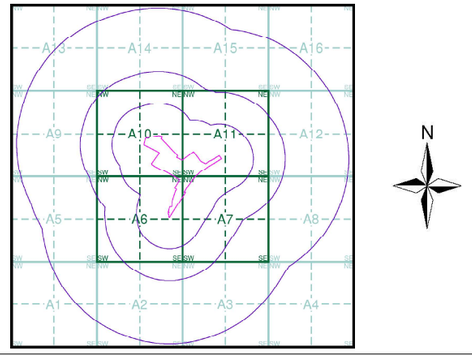
Source map scale - 1:10,560

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840`s. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940`s, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)



Historical Map - Slice A



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National Grid Reference:	362660, 171050
Slice:	A
Site Area (Ha):	10.27
Search Buffer (m):	1000

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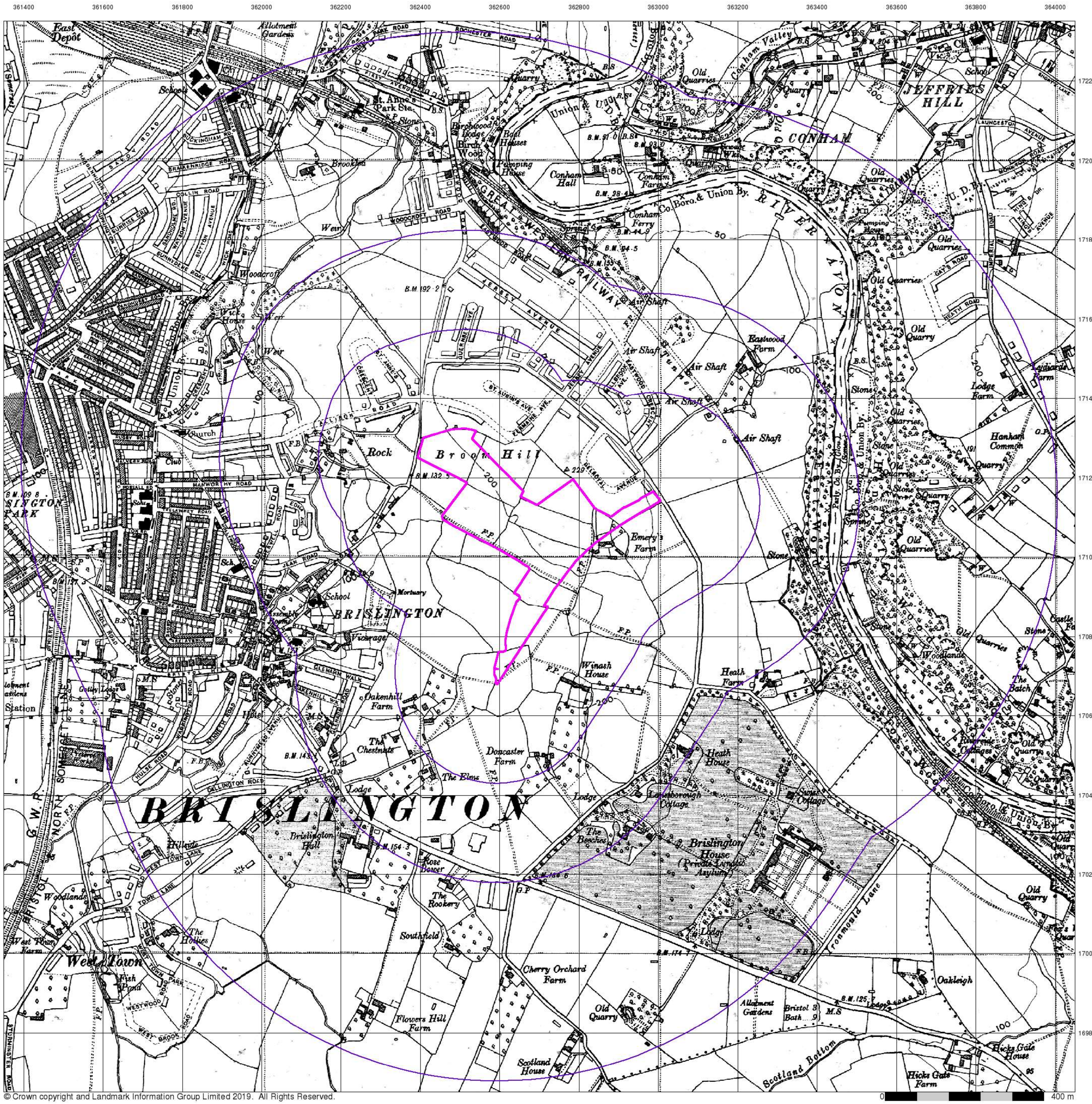


EOD Contracts Ltd

Gloucestershire

Published 1946

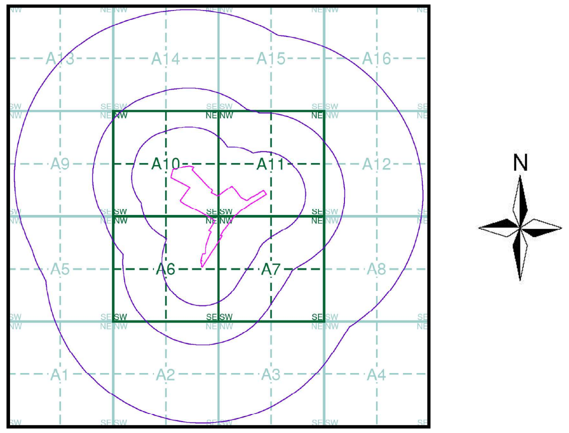
Source map scale - 1:10,560

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840`s. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940`s, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)

076NW
1946
1:10,560

Historical Map - Slice A



Order Details

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National Grid Reference:	362660, 171050
Slice:	A
Site Area (Ha):	10.27
Search Buffer (m):	1000

Site Details

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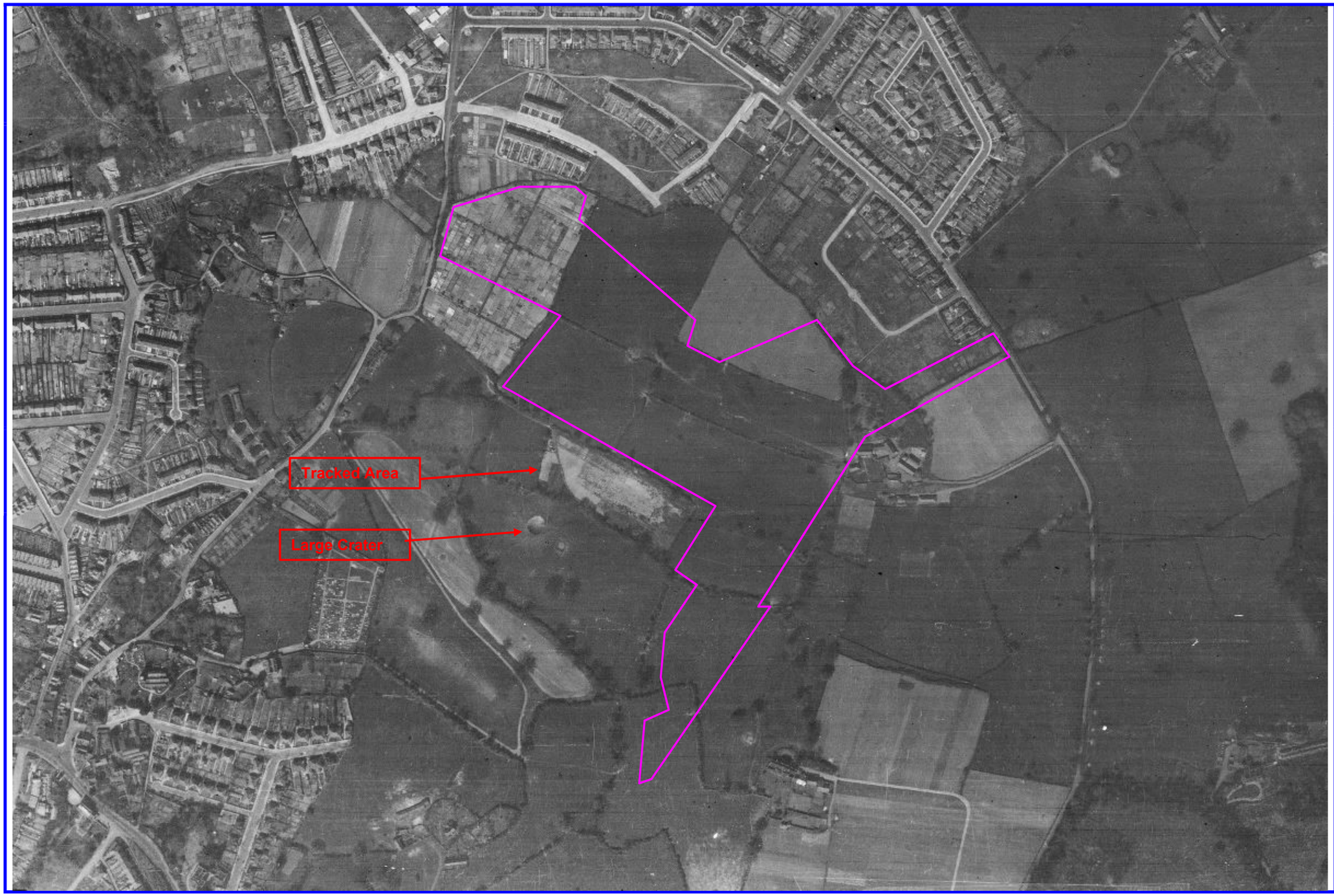


Description/Remarks

AERIAL PHOTOGRAPH

Site appears to be open pastureland with allotments in the west, the pastureland is divided by hedgerows and trees.

A large crater plus secondary craters are to the south and west as is an area that appears to be heavily tracked, minor scoring can be seen on the site, possibly indicative of bomb damage

Date

1946

EOD Contracts Ltd

Ordnance Survey Plan

Published 1972 - 1973

Source map scale - 1:10,000

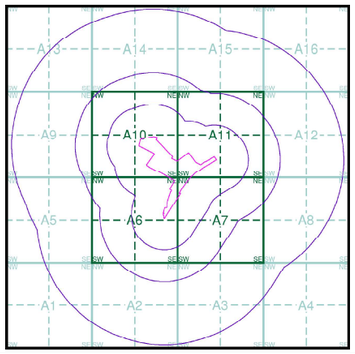
The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840`s. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940`s, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)

ST67SW
1973
1:10,000

ST66NW
1972
1:10,000

Historical Map - Slice A



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Slice:	A
Site Area (Ha):	10.27
Search Buffer (m):	1000

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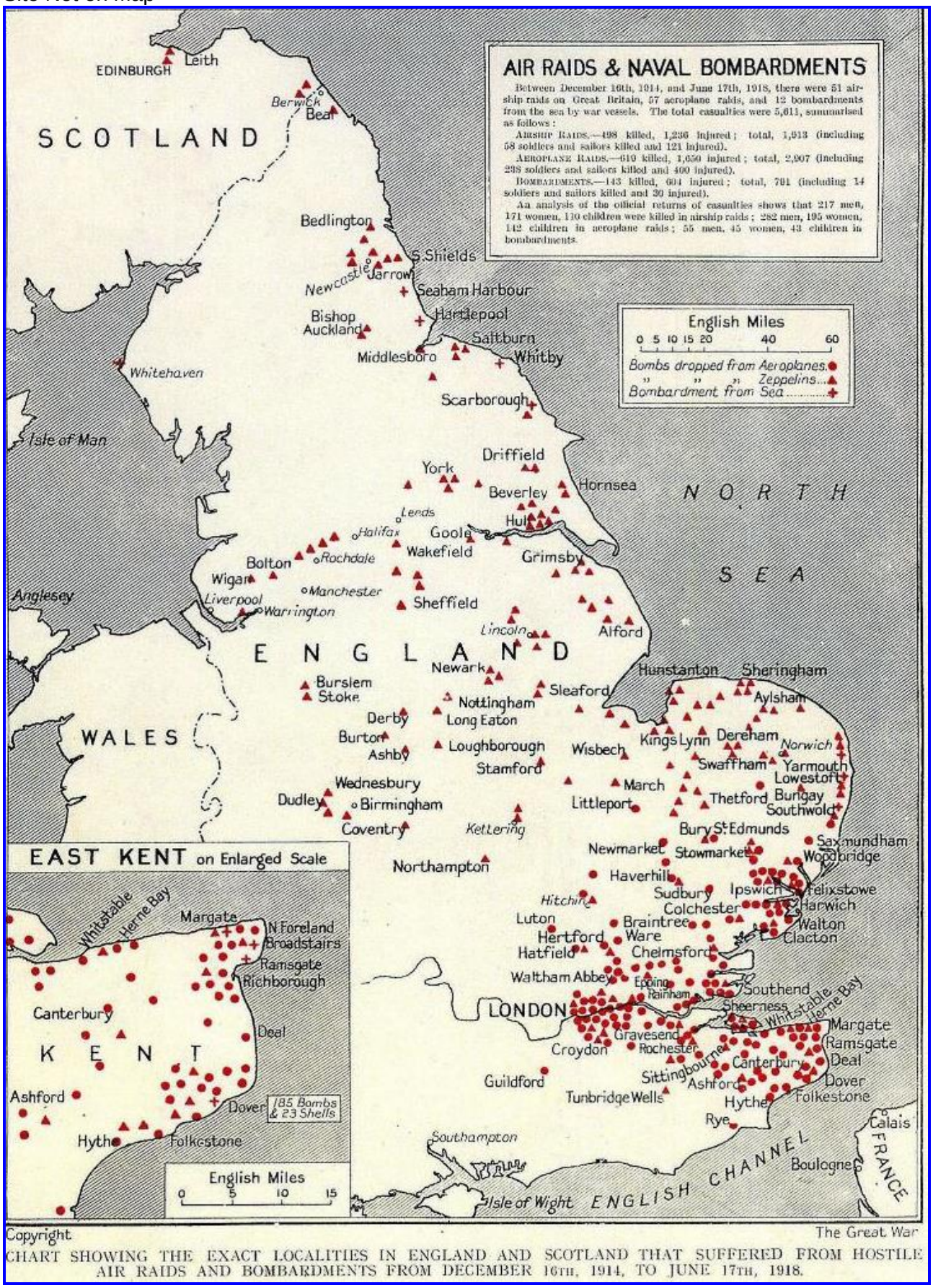
Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

Annex C

BOMB RAIDS WWI

Site Not on Map



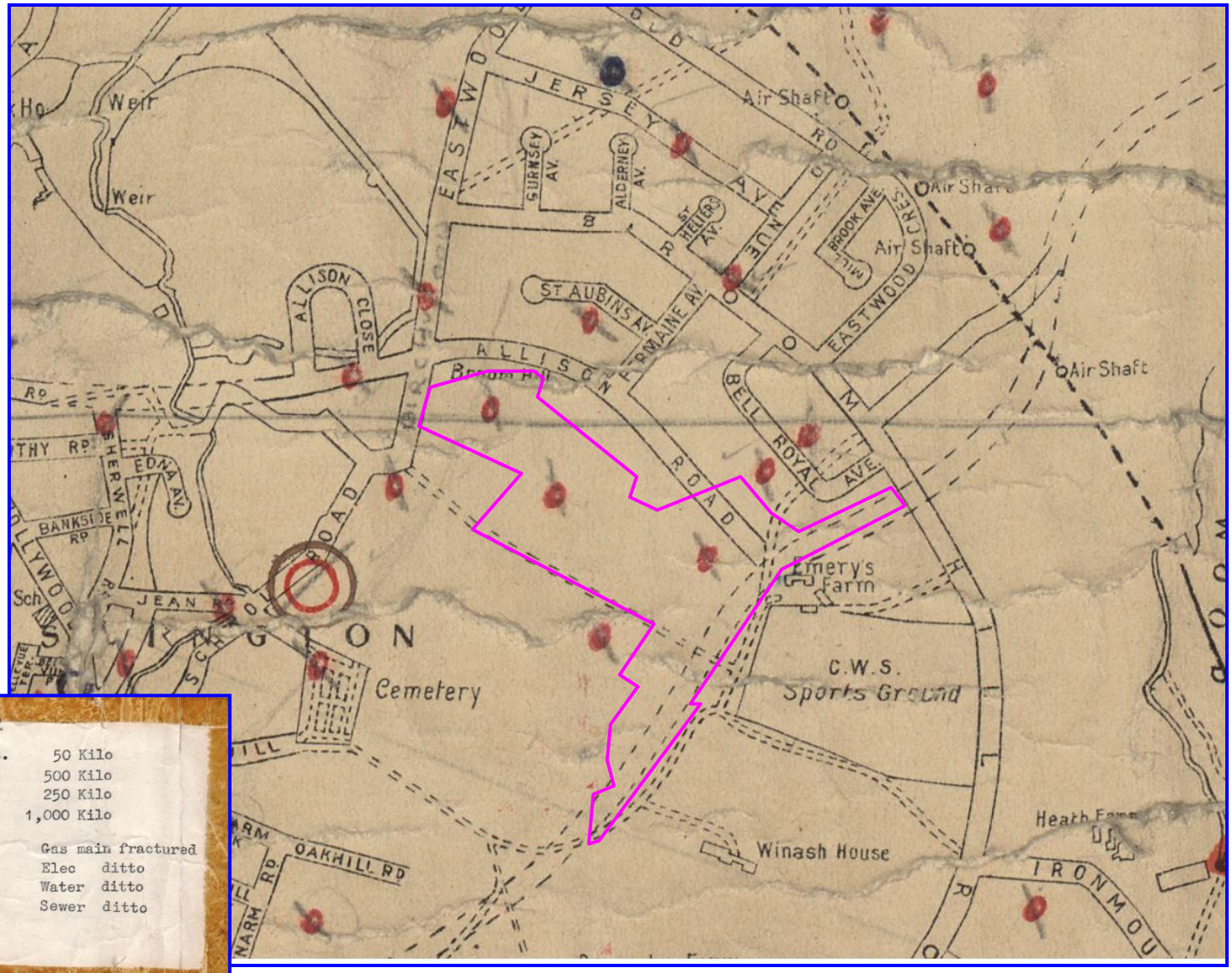
Copyright The Great War

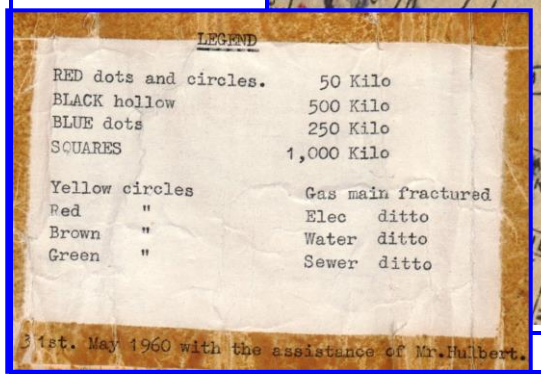
CHART SHOWING THE EXACT LOCALITIES IN ENGLAND AND SCOTLAND THAT SUFFERED FROM HOSTILE AIR RAIDS AND BOMBARDMENTS FROM DECEMBER 16TH, 1914, TO JUNE 17TH, 1918.

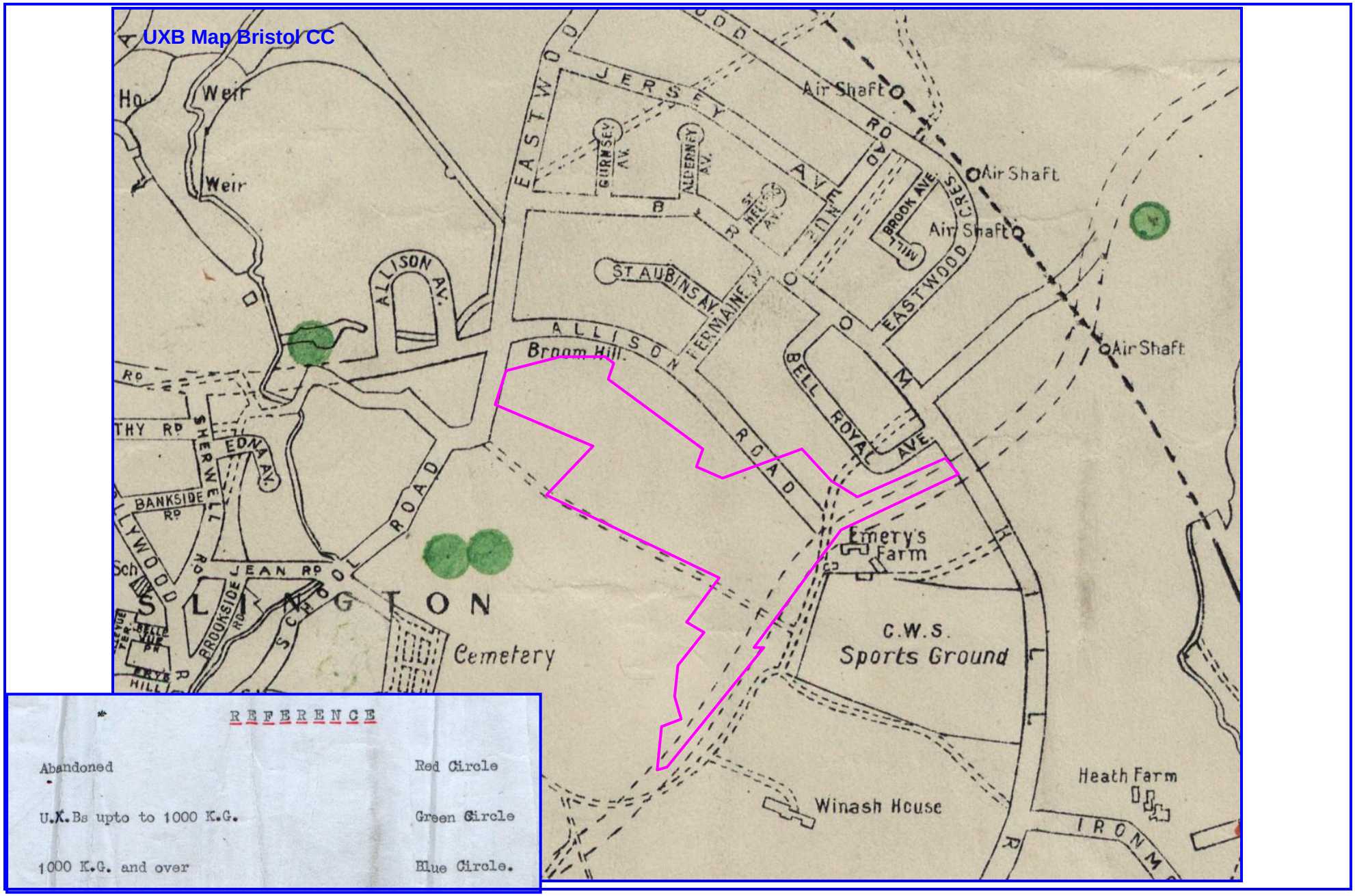
Annex D

UXO CONTAMINATION PATHWAYS (Bomb Maps)

Bomb Map Bristol CC







Map HO 193

Annex E

EXPLOSIVE ORDNANCE SAFETY AND INFORMATION

UNEXPLODED ORDNANCE

Since the end of WWII, there have been a limited number of recorded incidents in the UK where bombs have detonated during engineering works, though a significant number of bombs have been discovered.

The threat to any proposed investigation or development on the site may arise from the effects of a partial or full detonation of a bomb or ordnance item. The major effects usually being shock, blast, heat and shrapnel damage. It should be noted that the detonation of a 50kg buried bomb could damage brick/concrete structures up to 16m away and unprotected personnel on the surface up to 70m away from the blast. Larger ordnance is obviously more destructive. Table 1 denotes recommended safe distance for UXO.

Table 1: Safety Distances for Personnel

UXO (Kg)	Safety Distances (m)			
	Surface UXO		Buried UXO	
	Protected	Unprotected	Protected	Unprotected
2	2O	200	10	20
10	50	400	20	50
50	70	900	40	70
250	185	1100	120	185
500	200	1250	140	200
1000	275	1375	185	275
3000	450	1750	300	450
5000	575	1850	400	575

Explosives rarely become inert or lose effectiveness with age. Over time, fuzing mechanisms can become more sensitive and therefore more prone to detonation.

This applies equally to items that have been submersed in water or embedded in silt, clay, peat or similar materials.

Once initiated, the effects of the detonation of the explosive ordnance such as shells or bombs are usually extremely fast, often catastrophic and invariably traumatic to the personnel involved.

The degradation of a shell or bomb may also offer a source of explosive contamination into the underlying soils. Although this contamination may still present an explosion hazard, it is not generally recognised that explosives offer a significant toxicological risk at concentrations well below that at which a detonation risk exists.

BOMB PENETRATION DEPTHS

Weapons penetrate a significant depth into the ground and other types of ammunition are designed to permit the weapon time to penetrate deeply into the target before detonating a short time after coming to rest or a considerable number of hours afterwards. The second reason is where the weapon has failed to function as designed becoming a UXB. A number of studies have been carried out into weapon penetration and it is an inevitable consequence of a number of variable factors acting on the bombs trajectory that figures can and do differ significantly. Careful consideration must be given to the weapon's velocity, trajectory and shape. Also surface conditions and subsurface geology. The largest of the common German bombs, (500kg) can

penetrate to significant depths given favourable conditions for penetration. In the case of projectiles and shells, the potential for deep penetration is significantly less.

A number of assumptions were used in determining the maximum threat depth within the project footprint, which were;

The penetration of sub-surface bombs will be affected by the following:

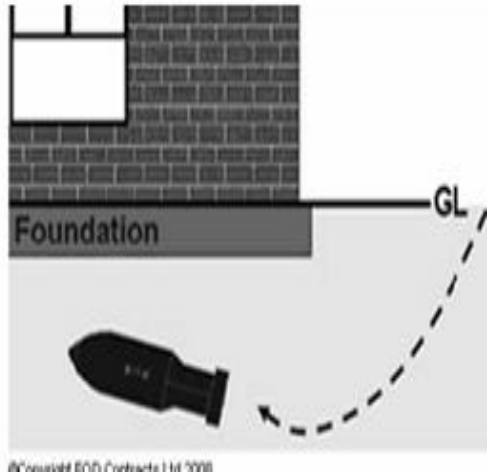
- Height of release
- Weight, shape and design of bomb
- Aerodynamic qualities
- Angle of flight and impact
- Nature of impact surface
- Nature of sub soil

Bombs on penetration of the surface do not follow a straight-line trajectory they can and do curve; this is called a “J” curve where the bomb’s path bends back towards the surface. This gives what is known as the Offset, which may place a bomb under a structure and at a shallow depth.

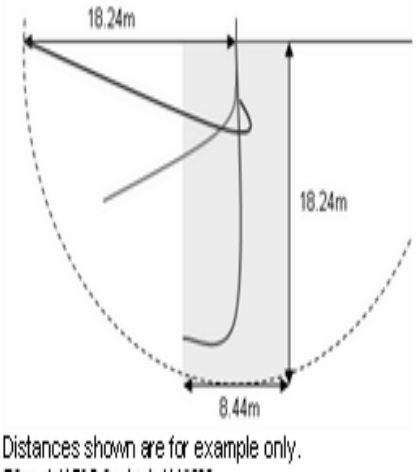
Figure 1*:* Sub-Surface Trajectories & Safety Buffers

Sub Surface Trajectory.

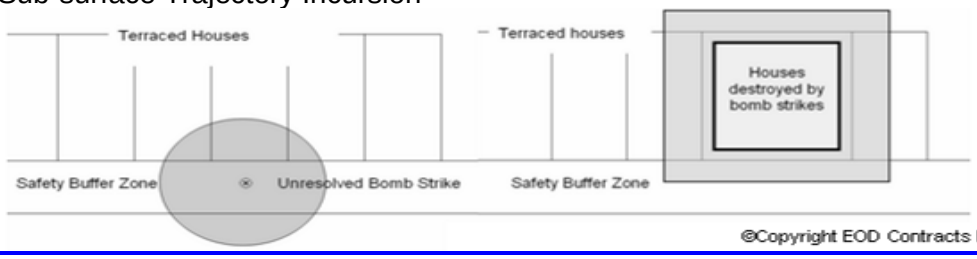
Common Sub-Surface Trajectory [6]



Anomalous Sub-Surface Trajectory [7]



Sub-surface Trajectory Incursion [8]



Note; *the common sub-surface trajectory will follow a path best described as a 'J' curve. The curve can result in a weapon coming to rest some distance from its impact point. The distance from impact point to resting place is referred to as the "Off set Distance and is normally considered to be 1/3 of the depth. This mechanism can permit a weapon to strike outside a building and travel below ground finally coming to rest within the building footprint. Where a strike is known to have occurred close to a building or structure such as a dock wall, a danger zone should be considered to exist around the area of the strike of sufficient size to accommodate the likely sub-surface travel distance for the weapon.*

Note; *the typical offset distance is shown as the shaded area, on rare occasions a near surface deflection of the weapon can occur and the offset distance can be substantially increased up to 5/4 of the penetration depth. This mechanism does however reduce the penetration depth considerably with the net result that while the offset is increased the overall travel distance is for the most part unaffected.*

Note; *scenario 1 shown top left shows a hypothetical bomb strike outside a structure or building. The strike location has been accurately identified and as a consequence; a potential danger zone (circular shaded area) can be placed around the point of impact. Scenario 2 shown top right; depicts a direct HE bomb or Incendiary strike within a building which totally destroyed the building. In circumstances such as this UXB entry the building rubble may have concealed hole and the weapon may still be present within the building footprint or it may have travelled sub-surface and come to rest outside the footprint. Here the danger zone (square shaded Area) extends outwards on all sides of the original building footprint.*

TYPES OF ORDNANCE

German Air Delivered Ordnance. Technical information on the nature and characteristics of the ordnance used by the German Air Force during both world wars has been available for a number of years. Assessment that began during the 1930's has continued to the present day. Experts have conducted research in many countries as part of national research programmes and as individual research projects. Consequently a well-informed assessment of the threat posed by unexploded ordnance, and the hazards that they represent, can be made with a high degree of confidence.

Terminology. It should be noted that two terms used in bomb records can lead to some confusion as to their meaning and therefore significance. The term Unexploded Bomb (UXB) refers to a bomb that has fallen, failed to function and has been subsequently dealt with and removed from the site. The term Abandoned Bomb (A/UXB) refers to a UXB that could not be found or recovered, or the decision was taken not to pursue the matter further. Consequently the unexploded bomb remains where it came to rest when it was dropped or fell to the present day. It should also be noted the word 'bomb' can be used to describe an airdropped bomb or a shell as in some cases no differentiation was made and the term was interchangeable.

Abandoned Bombs. The records of known abandoned unexploded bomb locations in the London area were released in response to a written Parliamentary Question from Simon Hughes. (Hansard: Volume; 282. Dated 15th October 1996). The information was provided by the Ministry of Defence (MOD) and supplied under an indemnity.

Explosive Ordnance Failure Rates. Over the course of both World Wars a considerable quantity of ordnance dropped on UK targets failed to function as designed and subsequently penetrated the ground without exploding. Information gathered during the war by the MOD and its research partners provide typical failure rates for different types of ordnance. Figures significant to this study are:

- 10% of all German airdropped bombs failed to function as intended.

- 30% of all anti-aircraft and other types of shells failed to function as intended.

Deductions & Considerations. The following points were considered as part of the assessment and have been given due consideration:

Records were found that indicated that the general area was subjected to heavy bombing.

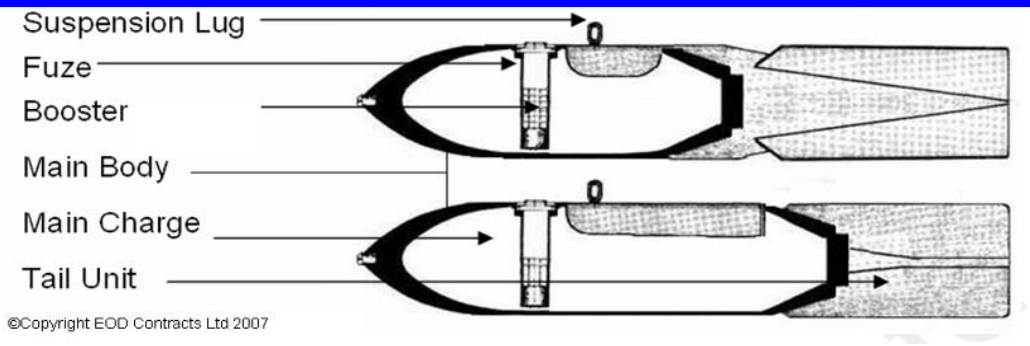
Bombs, which struck previously, hit or burned out targets and did not function; consequently their impact was unseen and therefore no report was ever made.

In all likelihood, the local anti-aircraft battery would have fired a far higher number of shells than the bombers dropped HE bombs. Contamination by anti aircraft shells can not be rules out.

Generic German Bomb Types. The majority of German bombs dropped were 50kg in weight, accounting for approximately 16% of the total bombs dropped. The range of common bombs increased in weight to a maximum of 1700kg. Regardless of size, German bombs were fitted with one or more Electrical Condenser Resistance (ECR) fuzes many of which included a mechanical component. The fuzes were mounted transversely in the bomb body with the booster directly below, and in contact with, the fuze. The booster; sometimes referred to as the Gaine, is composed of a sensitive explosive material (Picric Acid). Picric Acid is known to deteriorate over time becoming increasingly unstable. The internal layout of two common German bombs and a German fuze is shown in Figures 2 & 3.

Figure 2**:** Generic German Bomb Design.

Graphic Cross Section through the most common German bombs (50kg)



Note; the diagram shows that there can be a significant difference in the quantity of High Explosive contained within bombs of similar size and shape; the Grade 1 bomb on the bottom having 30% more HE than the Grade 2 shown at the top. This serves to demonstrate the importance of an accurate identification of any item of UXO.

Figure 3**:** Generic German Bomb Fuze Design.

Graphic Cross Section through a typical German fuze (ECR)

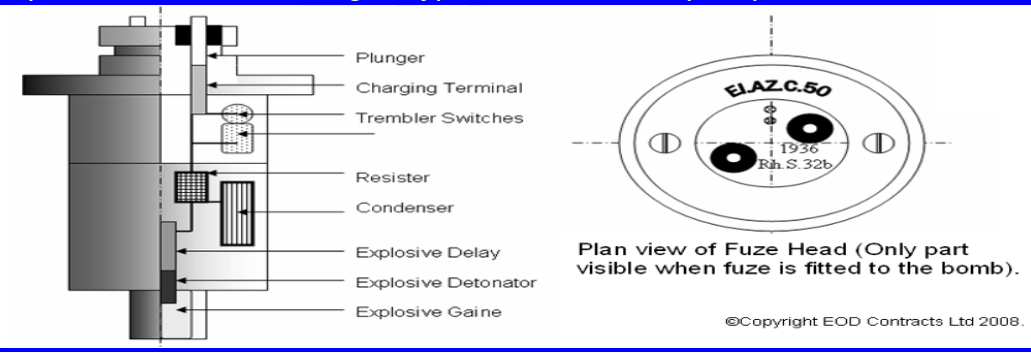


Figure 4**:** Range of HE bombs dropped on the United Kingdom.

German Bombs

NOTE: The smaller sub-munitions (Bomblets) seen to the right, ranged in size between 1 and 3kg, were dropped in large numbers and were intended as incendiary bombs, anti-personnel bombs or as bombs filling both roles. The smaller bomblets were dropped in larger container bombs designed to hold between 360 and 620 of the bomblets. The containers were designed to burst open at a predetermined height above ground level, dispersing the bomblets over a wide area. Air raid damage was far greater by using both incendiary, and HE bombs on a single raid. The fires started by the incendiaries being rapidly spread by the blast waves from the HE bomb. This scenario was shown to devastating effect on the 14th February 1945 in the German city of Dresden. Where fires started and spread by the bombing increased to a point where the oxygen was being sucked into the flames at such a high speed that the fire became a "Fire Storm". At the time the city's population had increased due to a high number of refugees fleeing the Russian advance to the east, the exact civilian death toll from fire and suffocation will never be known, but is considered to be somewhere between 25,000 and 100,000.

High Explosive (HE) Bomb. Some of the most common type of ordnance to be dropped on the United Kingdom, HE bombs are often the type encountered as UXBs. Relatively thick cased, they are still recovered in remarkably good condition. Ranging in size from 50 to 1700 kg, their typical release height (1,500m) allowed them to penetrate deep into the ground as a result of design or flaw. Towards the end of the bombing campaign, as steel became scarce the German Engineers produced a range of bombs that used steel reinforced concrete as the bomb body. Figure 4 shows the range of steel HE bombs dropped on the UK.

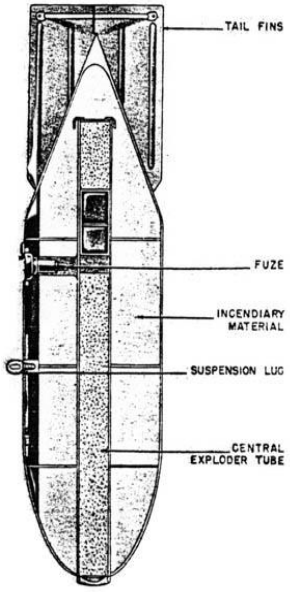
Incendiary Bomb. The larger incendiary bombs, containing bottles of white phosphorus and an incendiary mixture contained within a thin steel case were designed to burst on contact with the ground. A fixed dispenser on the aircraft delivered the smaller type of bomb or 'Bomblet' to the target area in container bombs or; both types of container would open dispersing the smaller Incendiary bombs. Relatively small and light they were unlikely to penetrate the ground to any significant depth. However, once concealed in bomb damage rubble or below water they were easily missed and are still unearthed today from in-fill and drained land. Later versions of the incendiary bomb contained an additional explosive charge used as a short delay "Booby Trap" device that contained a significant amount of high explosive. The Booby Trap component was designed to kill or injure fire fighters and hinder the damage control. See Figure 5.

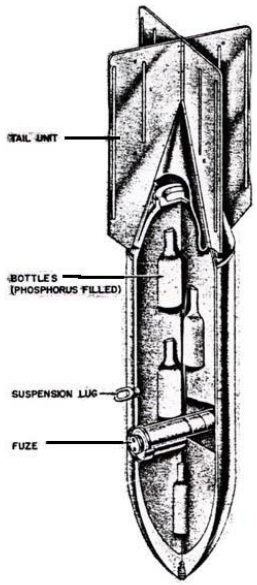
Figure 5**:** Incendiary Bombs.

Common German Incendiary Bombs

250 mm

Above 1kg incendiary bomblet, below left the larger 500kg incendiary bomb Below right a 50kg incendiary bomb containing bottles of white phosphorus.



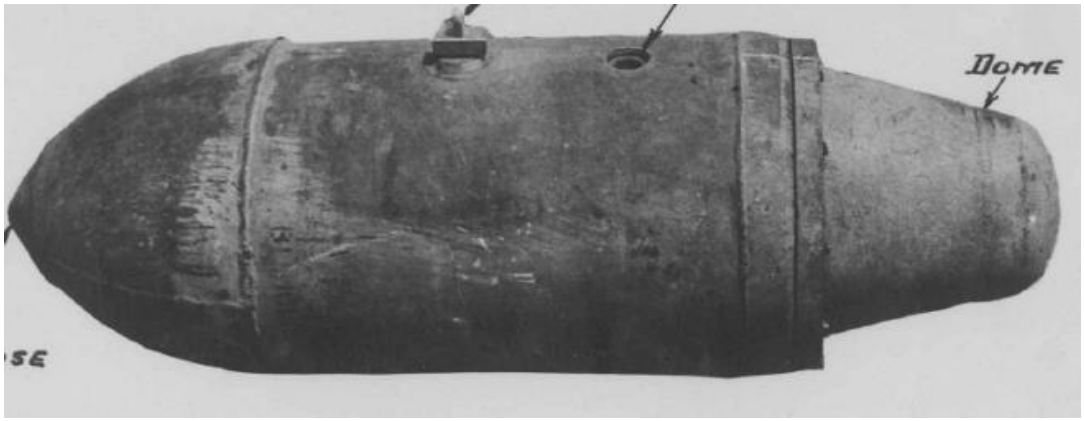


Note; Incendiary bomblets were made of a flammable alloy similar in appearance to aluminium, which resists corrosion well. The tail unit was made of thin tin-plate steel and is more prone to have rusted away. Some Incendiary models were fitted with a High Explosive (HE) steel nose. With the tail and explosive nose attached the bomb was 480mm long.

Blast Bomb / Parachute Mine. The parachute mine was extensively used on land and at sea and was fitted with specialist fuzes designed to trigger the weapon at a predetermined altitude, water depth or to switch on other magnetic influence mechanisms to trigger the weapon when a ship approached (Magnetic or Acoustic influence). While early versions were based on the standard 1000kg SD Bomb case others were specially designed and manufactured with an aluminium body, making them extremely difficult to detect using magnetometers. The thin cased versions would normally disintegrate on impact on land and are normally considered to pose little threat to work on land based projects, but the risk increases significantly on projects over water or in marshland. Thicker cased versions however will survive impact and pose a significant risk regardless of the local ground conditions. (See Figure 6)

Figure 6**:** Common Airdropped Mines.

Parachute & Ground Mines



Note; all mine fuzes were designed to arm after deployment from the ship, submarine or aircraft, some fuze designs incorporated anti-removal booby traps. Unexploded mines found today are the result of a failure within the arming mechanism or procedure whereby the mine never fully armed. Sudden shock or jarring of a weapon in this state has the potential to complete the arming sequence and could result in the mine detonating with lethal consequences.

Non-Steel Cased Bombs. Used primarily in the construction of training or practice bombs, some high explosive variants were introduced towards the end of the war. With resources running scarce, German Engineers produced a small number of blast bombs with a concrete body. The design utilised a steel framework onto which concrete was cast. The explosive filling was also contained within a thin steel container within the bomb body. Very few “concrete” bombs were dropped on the UK. In common with standard steel cased weapons, this type of bomb can be detected using standard magnetometer detection techniques (albeit; providing a smaller ferromagnetic signature than its all steel counterparts). This type of bomb represents a very small percentage of the total number of bombs dropped worldwide and are not considered a significant threat, particularly when viewed from an overall bomb threat in the UK.

Anti-Personnel Bomb. Generally these were small weapons of 1-3 kilograms in weight and are often referred to as ‘Bomblets’ and possessing similar ground penetration ability as the Incendiary Bomblets. They were often located during the post-raid searches. This type of bomb has been recovered within the bomb rubble being cleared or used as in-fill on construction projects and poses the same potential to function as the Incendiary bomb with a greater potential to cause localised casualties.

Specialist Bomb. These types of bombs were designed to meet a specific mission requirement. Typically, this would be a design modification or special fusing to enable the bomb to destroy hardened/armoured targets or deep buried and sub-marine targets. Similar to the more common HE bombs, they differ in that they rarely contain large amounts of high explosive. Therefore the consequence of a detonation is reduced but remains a significant risk, particularly when the detonation occurs on or near the surface.

Depth Bombs & Depth Charges. These types of weapons were designed to meet a specific mission requirement. Typically, the modifications would include the type of explosive filling and special fusing to enable the bomb to penetrate to a significant depth into the ground or water before detonating. Depth bombs intended for maritime attack and sub-marine targets would be fitted with one or more fuzes, one of which would be a hydrostatic fuze designed to detonate the bomb at a predetermined depth. The bomb would be fitted with an anti skip ring to reduce the deflection of the bomb as it entered the water. Similar in many ways to Depth Bombs, Depth Charges were exclusively designed to detonate at a predetermined depth. This was achieved by fitting the Charge with a short time delay or hydrostatic fuze. Depth bombs; having a similar configuration to general purpose bombs had the potential to penetrate deeply into the sea bed where an attack occurred in the relatively shallower water of a dock.

Unmanned Rocket Bombs & Missiles. The most famous in this category of weapons were the V1 (Fi103 flying bomb) commonly known as the Doodlebug and the Larger V2 (A4 missile). Both V1 & V2 with high explosive warheads containing 850kg & 1000kg (respectively) represent some of the largest weapons to land in the United Kingdom. Both types were built in a similar manner to an aircraft and would generally disintegrate on impact even if the warhead failed to detonate. The impact would spread debris over a wide area which was difficult to miss and any resulting unexploded 'V' weapons were comprehensively dealt with at the time. For this reason they are rarely encountered on land. However, where a 'V' weapon landed in water the opportunity for the event to have been missed and/or follow-up action abandoned was greater and they continue to pose a significant risk. Other, less well known rocket bombs were also produced by the Luftwaffe to attack maritime targets. Some were equipped with TV/Radio guidance from the parent bomber. Two of the most common were the Fritz X which consisted of an adapted SD1400kg bomb and the Henschel Hs293 which was based on a smaller 500kg bomb. No record of one having been recovered on land as a UXB can be found but these large HE bombs are considered to pose a significant risk, particularly to maritime projects. No records were found to indicate this type of bomb was ever used on targets in the area.

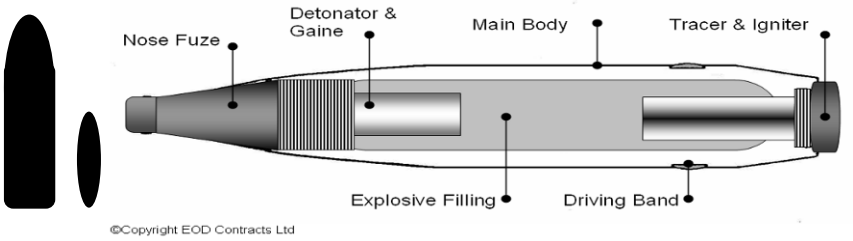
Photoflash Bomb. This type of bomb was dropped by specialist "Pathfinder" aircraft and although this type of bomb can be included with the category of specialist bombs, it is worthy of specific comment due to the danger it may still pose. Photoflash bombs were designed to explode with a blinding flash, rather like a camera flashbulb. They were used to enable photographs to be taken of targets at night and also served to identify ground targets for other aircraft to attack. The speed at which the highly energetic filling detonated, and energy it produced in doing so, was significant. Although these bombs were thin skinned and are prone to corrosion the functioning of one can be compared to a high explosive bomb detonation.

High Explosive Shells & Projectiles. As mentioned previously, one of the most common sources of UXO contamination encountered in the United Kingdom is High Explosive Shells and Projectiles. This is most commonly found to be as the result of firing practice ranges, bombardment and anti-aircraft defence, the latter often positioned to defend Major cities and Strategic installations and ports from German Bombing. Anti Aircraft Shells and projectiles are generally smaller (Up to 4.7" inch diameter) than the airdropped bombs and as a consequence were more easily missed amongst the bomb rubble. However, coastal bombardment guns could fire a shell weighing 1000kg, (larger than most common airdropped bombs) and capable of significant ground penetration. The generic layout of a projectile can be found at Figure 7. It should be noted that the fatal incident on the German autobahn in 2006 was thought to be the result of a shell or projectile detonating, not an airdropped bomb as first reported.

The Fuzes used in Anti-Aircraft Ammunition were designed to ensure the projectile would detonate in contact with the target, or at a pre-set altitude, or in close proximity to the target. The fuzes employed different means to achieve this, including; direct impact, or indirect impact, Barometric, Delay and Electro-magnetic influence. Some were fitted with more than one fuze, which served to reduce the chance of the projectile falling to earth and detonating. Artillery fuzes are activated during the firing process, using the projectile's acceleration or spin within the gun barrel to switch off the safety mechanisms. For this reason, fired projectiles are considered more dangerous than unfired ones.

Figure 7**:** Generic Shell Design

Scale & Graphic Cross Section of a typical High Explosive (HE) Shell



Approximate size of a large shell used by battleships and coastal bombardment guns (Left) and Anti-aircraft shell (Right)

Other Types of Ordnance.

The following additional sources of ordnance types have been considered, and inherent risks taken account of:

Flares and Pyrotechnics. Flares and pyrotechnics were used for a variety of reasons throughout the war and continue to be found today in the most unlikely places. However, due to the thin casings of these weapons a high level of corrosion is likely to have occurred since manufacture. Depending on the specific nature of the weapon, this effectively renders them inert with the exception of any white phosphorous content or explosive gaine.

Land Service Ammunition (LSA). While as the name implies this type of ammunition was designed for use on land, it was also issued to naval personnel for close protection of vessels and their crew and to provide a limited offensive capability even to relatively small craft. This type of ammunition includes some shells and projectiles such as those covered previously. Other natures of LSA range from Small Arms Ammunition (SAA), having little or no high explosive content to Grenades, Mortars and Rockets which may pose a risk of detonation due to their explosive content and the design of their fuzes (impact) which; if subjected to sufficient shock or friction may result in the weapon functioning. (See Figure 8)

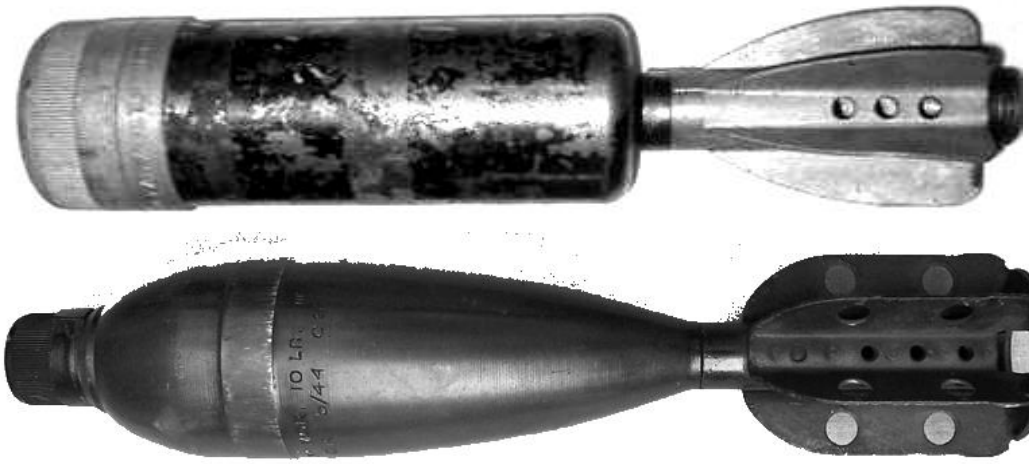
Figure 8: Common Categories of Land Service Ammunition

Land Service Ammunition

Small Arms Ammunition

Grenades

Mortar Bombs



Initiation of Unexploded Ordnance. Explosive Ordnance is highly unlikely to spontaneously explode. The energetic chemical compounds, (Explosives) used in weapon manufacture are chosen to be as stable as possible and they all require a significant application of additional energy to create the right conditions for detonation to occur. If stored correctly, most explosive materials are designed to remain stable for the duration of their expected lifespan (typically 20 years). During this time, the correct functioning of the weapon is achieved by means of the 'Initiation Train' (See Figure 9).

Figure 9: Explosive Ordnance Initiation Train.

Sequence of Initiation