## Unexploded ordnance (UXO)

**A guide for the construction industry**

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<td>S Cooke</td>
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<td>L Gooderham</td>
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Unexploded ordnance (UXO). A guide for the construction industry

Stone, K, Murray, A, Cooke, S, Foran, J, Gooderham, L

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The guide was written by Kevin Stone, Allen Murray (WorleyParsons), Simon Cooke, John Foran and Lee Gooderham (6 Alpha Associates) under contract to CIRIA.

Authors

Kevin Stone BSc (Hons) MIEnv

Kevin Stone is senior remediation engineer at WorleyParsons. Kevin has 10 years of experience in the design, management and supervision of contaminated land investigation, risk assessment and remediation projects. Kevin has been responsible for the design, management and reporting of numerous research projects.

Allen Murray Eur Ing BSc (Hons) PGDip Arch Consv CEng CEnv FICE FInstuctE

Allen Murray is director of engineering, Europe, at WorleyParsons. Allen has 30 years of engineering experience, working on numerous remediation, civil, structural and marine projects, involving assessment, design and supervision in the UK.

Simon Cooke BSc MA MBA MAPM MIExpE MASC

Simon Cooke is managing director of 6 Alpha Associates. Simon qualified by degree as a quantity surveyor before serving for 17 years with the Corps of Royal Engineers. He is qualified as an advanced army bomb disposal officer. Simon has a blend of operational and commercial explosive ordnance disposal experience gained in places such as Afghanistan, Australia, Canada, Cyprus, China, Bosnia, Kosovo, Macedonia, the Middle East, Japan, as well as the UK (including Northern Ireland).

John Foran MM

John Foran (Military Medal) is a leading explosive ordnance disposal risk consultant for 6 Alpha Associates. He joined the company on retirement from the British Army, in the rank of Major in 2006. John served for almost 30 years with the Corps of Royal Engineers and is qualified as an advanced army bomb disposal officer.

Lee Gooderham BSc (Hons) FGS

Lee Gooderham heads the Explosive Remnants of War/Unexploded Ordnance Sector of 6 Alpha Associates. He has obtained a balance of academic training and practical experience across the disciplines of explosive ordnance disposal (EOD) and geophysics. Lee has worked for nine years in the commercial EOD sector most notably in Iran, Holland, Belgium, Kazakhstan, Libya, Poland and Canada. Importantly to date he has been involved with UXO assessment/mitigation of hundreds of sites within the UK.

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Patrick Cox
Claire Dickinson (chair)
Derek Egan
Alastair Forbes
Digby Harman
Paul Harris
Kevin Kneebone
Ursula Lawrence
Donald Lamont
Jonquil Maudlin
John Morrison
Andy O’Dea
Steve Poulter
Margaret Sackey
Mike Sainsbury
Keith Swarbrick
Sarah Terry
Roger Tollervey
Mike Wilson

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Foreword

One unintended outcome from construction activity is that unexploded ordnance (UXO) is occasionally discovered. When it is, it usually generates considerable media interest and causes major disruption to the public. Fortunately experience shows that the risk of casualties has been very low. However as it is a high consequence but low probability event, appropriate allowance should be made at the design stage for assessing the risk of encountering UXO on-site and for mitigating that risk if significant.

UXO arises from both hostile and defensive military activity often related to World Wars I and II. Many parts of the country, both urban and rural are affected.

There has long been uncertainty over the extent to which designers and others should undertake investigatory work to establish if a potential development site is free of the presence of UXO and how that risk should best be mitigated. This guide aims to help end this uncertainty. It is the work of a very enthusiastic and experienced group of people and HSE supports and welcomes its publication.

Dr Donald Lamont
HM principal specialist inspector (construction engineering)
Health and Safety Executive
Executive summary

The legacy of unexploded explosive ordnance (UXO) has caused many problems for construction projects throughout the UK. Invariably these problems have led to delays and an associated increase in costs, especially during the site investigation and groundwork phases of construction. In many cases these problems could have been avoided if an appropriate risk management procedure had been carried out at the initial stages of the project design process.

Clients have a legal duty under CDM2007 to provide designers and contractors with project specific health and safety information needed to identify hazards and risks associated with the design and construction work. The possibility of UXO being encountered on a site falls within the category of a potentially significant risk, and it should be addressed as early as possible in the lifecycle of a project.

Recommendations for good practice

The principal purpose of this document is to provide the UK construction industry with a set and defined process for the management of risks associated with UXO from WWI and WWII aerial bombardment. Also it will be broadly applicable to the risks from other forms of UXO that might be encountered.

This publication is a construction industry guide. It focuses on the needs of the construction professional if there is a suspected UXO on site and covers issues such as what to expect from an UXO specialist. However the guide is not intended to give details guidance for the EOD contractors or contracting practices.

In many cases, an important question for construction clients is whether and when UXO specialist advice is needed. A UXO specialist adds more value where the project and/or degree of UXO contamination and its associated risk is very high but less when the risk posed by UXO is relatively benign and straightforward to deal with.

To help the client to decide when will be the appropriate time to seek such advice, it is important to understand and follow a risk management process that is divided into the following four distinct stages:

1 Preliminary risk assessment. The purpose of the preliminary risk assessment is to enable the non-UXO specialist to place a site in context with the potential risk from UXO and to identify whether more detailed assessment is required. The assessment is based on data obtained from a desktop review of historical information regarding site location, previous site development, wartime bombing records etc.

It is anticipated that the majority of sites in the UK will be identified as having a low probability of a UXO hazard to take place and would be excluded from further consideration following the completion of the preliminary risk assessment. However this is an important initial step to help construction professionals to assess sites with potential UXO risk.

If a potential UXO risk is identified at the preliminary risk assessment, it is important that a UXO specialist is commissioned by the client. This should take place during the initial stages of the project planning and ideally before the start of
any detailed design. This early involvement may also enable the project team to identify appropriate techniques to reduce potential risks through considered design, without the need for UXO specific mitigation methods.

2 **Detailed risk assessment.** This assessment enables an estimate to be made of the likelihood of creating a UXO hazard on a site, giving due consideration to the development type and construction methods to be employed.

3 **Risk mitigation.** The purpose of risk mitigation is to eliminate risk or reduce it to an acceptable level. The risk mitigation process provides a framework that identifies appropriate mitigation methods for the various risk scenarios that may be identified by the detailed risk assessment. Identified options are then assessed to ensure that an efficient and cost effective risk mitigation programme is selected.

4 **Implementation.** The final phase of the risk management process is to ensure that the selected risk mitigation plan is carried out correctly and efficiently during the construction phase of the development works and that the works are verified as having been completed to a satisfactory level.

Details of these four stages are given in Figure 4.1.

For sites where there is the possibility of a UXO hazard, there should be an emergency response plan in place. The plan should provide clear and precise guidance on what to do should a UXO be encountered, and/or initiated as part of the site works, with accompanying emergency management team roles and responsibilities. This should be included in the health and safety plan for the proposed works and should be communicated to the work force at the operational level, typically as part of a tool box brief.

On completion of each work stage the UXO specialist should produce a report detailing the nature of the work done. Also, on completion of the final stage of risk mitigation, the UXO contractor should produce a verification report detailing all the works undertaken with specific reference as to how the individual risks identified as part of the risk assessment process have been addressed.
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<tr>
<td>Abandoned bomb</td>
<td>UXB that was abandoned during WWII rather than being dealt with at the time by bomb disposal teams due to benign position, difficulty of access, or a lack of resources.</td>
</tr>
<tr>
<td>Abandoned bomb register</td>
<td>Official and current records of abandoned bombs held and updated by central government (not local authorities).</td>
</tr>
<tr>
<td>Aerial delivered ordnance</td>
<td>Ordnance used by air forces. In the UK, most likely to be German aerial delivered bombs.</td>
</tr>
<tr>
<td>Alienated site</td>
<td>Ex MoD land that has been returned to non-military use.</td>
</tr>
<tr>
<td>Ammunition</td>
<td>A complete device charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological or chemical material for use in military operations, including demolitions.</td>
</tr>
<tr>
<td>Anecdotal evidence</td>
<td>Evidence of potential UXO from sources such as local newspaper records, local historical groups and local residents.</td>
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<tr>
<td>Anti-personnel bomb</td>
<td>Aerial delivered bombs containing small quantities of high explosive. Often booby-trapped and designed to be triggered by individuals.</td>
</tr>
<tr>
<td>Anti-personnel mine</td>
<td>A landmine designed to injure or kill one or more persons. Usually detonated when they are stepped on or when a tripwire is disturbed, also set off by the passage of time or by controlled means.</td>
</tr>
<tr>
<td>Anti-tank mine (also known as anti-vehicle mine)</td>
<td>A landmine designed to disable or destroy vehicles, including tanks. Can be detonated by pressure (though normally significantly more than required to activate an anti-personnel mine) or remote control, as well as by magnetic influence or through the disturbance of a tilt rod (a sort of vertical tripwire).</td>
</tr>
<tr>
<td>Artillery</td>
<td>Guns of larger calibre than machine guns, equipment, supplies and ammunition.</td>
</tr>
<tr>
<td>Bedrock</td>
<td>The natural consolidated rock underlying a site.</td>
</tr>
<tr>
<td>Benign UXO related items</td>
<td>UXO related items Free From Explosives, generally comprising empty cartridge cases, inert/expended ordnance etc.</td>
</tr>
<tr>
<td>Bomb Census</td>
<td>Census undertaken by the Ministry of Home Security during the war to provide intelligence relating to bombing raid patterns, types of ordnance used and consequent damage. Held at the National Archives.</td>
</tr>
<tr>
<td>Bomb damage maps</td>
<td>Maps maintained by many local authorities during WWII that provided a record of bomb damage sustained.</td>
</tr>
<tr>
<td>Bomb penetration assessment</td>
<td>Assessment of the likely maximum depth of burial of aerial delivered ordnance.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
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</tr>
<tr>
<td>Bombing density</td>
<td>Number of bombs per hectare.</td>
</tr>
<tr>
<td>Booster</td>
<td>A separate (intermediate stage) component and placed next to the high explosives – it is activated by the fuse and/or primer. It initiates the HE.</td>
</tr>
<tr>
<td>Brownfield</td>
<td>As opposed to a greenfield site, a brownfield site is a generic term for land used previously for an industrial, residential or commercial purpose, being available for redevelopment towards new industrial, commercial or residential use.</td>
</tr>
<tr>
<td>Caesium vapour</td>
<td>Instrument that measures the Earth’s total magnetic field at a point in space. Items high in ferrous or ferric components will cause significant changes in the fields. They are manufactured in sealed units, which consist of four elements:</td>
</tr>
<tr>
<td>magnetometer</td>
<td>1 A caesium light (i.e. photon) emitter.</td>
</tr>
<tr>
<td></td>
<td>2 An absorption chamber (containing optically pumped caesium vapour).</td>
</tr>
<tr>
<td></td>
<td>3 A buffer gas (that emitted photons pass through).</td>
</tr>
<tr>
<td></td>
<td>4 A photon detector.</td>
</tr>
<tr>
<td>CDM co-ordinator</td>
<td>For projects to be notified to the Health and Safety Executives or ORR under the Construction (Design and Management) Regulations 2007 a person appointed to advise the client on the health and safety risks associated with the project including the potential presence of UXO. The CDM co-ordinator must seek specialist advice and must be satisfied that the sources are suitable. If requested, the CDM co-ordinator must advise the client on the competence that is needed by the designer, principal contractor and other contractors. If the CDM co-ordinator does not have relevant expertise themselves, they are required to identify the need for a UXO specialist to provide advice on potential risks from UXO and advise the client on their competency needed.</td>
</tr>
<tr>
<td>Charge</td>
<td>A bagged, wrapped or cased quantity of explosive without its own integral means of ignition.</td>
</tr>
<tr>
<td>Clearance certificate</td>
<td>A clearance certification is issued by the MoD and other organisations. The level of clearance will also depend on the available technology, resources and practices of the day. The existence of a clearance certificate does not provide a 100 per cent guarantee that UXO will not be encountered later, but rather that trained staff using the best available technology of the time have been applied to reducing the potential risk from residual items of ordnance (see Section 7.11.2).</td>
</tr>
<tr>
<td>Clearance report</td>
<td>A report issued by UXO contractor following the completion of the risk mitigation works at a site detailing all the works undertaken to date and any residual risk.</td>
</tr>
<tr>
<td>Cleared area/cleared land</td>
<td>An area that has been physically and systematically processed by an UXO contractor to ensure the removal/clearance and/or destruction of all mine and UXO to a specified depth.</td>
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Collateral damage  Unintentional damage or incidental damage affecting facilities, equipment or staff.

Competence  An individual’s demonstrated capacity to perform, ie the possession of appropriate knowledge and skills to enable an individual to effectively perform a specific role.

Cone Penetration Test (CPT) rig  Device by which a cone is pushed into the ground at a constant rate and to which a magnetometer may be attached to give continuous measurements.

Construction (Design and Management) Regulations 2007 (CDM)  Regulations carried out under the Health and Safety at Work etc Act 1974 and setting out duties in respect of the planning, management and monitoring of health, safety and welfare in construction projects, and of the co-ordination of performing these duties by duty holders. Duties applicable to all projects, including those of clients, designers and contractors.

Crash landing  A forced emergency landing of an aircraft.

Decommissioning  The process of taking plant, equipment and buildings out of normal use and leaving in a safe condition.

Designer (CDM)  Under CDM, designers are those who are involved in preparing designs for construction work, including variations. This includes preparing drawings, design details, specifications, bills of quantities and the specification (or prohibition) of articles and substances, as well as all the related analysis, calculations, and preparatory work or arranging for their employees or other people under their control to prepare designs relating to a structure or part of a structure. It does not matter whether the design is recorded (for example on paper or a computer) or not (for example it is only communicated orally).

Destroy/destruction  The destruction of any item of ordnance by explosives in situ or blow in situ without moving the item from where it was found, normally by placing an explosive charge alongside. Also known as a controlled explosion.

Detection  The discovery by any means of the presence of UXO.

Detonation  A violent chemical reaction due to heat and pressure. A detonation is a reaction that proceeds through the reacted material toward the un-reacted material. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium, forming a propagating shock wave that originally is of supersonic velocity. When the material is located on or near the surface of the ground, a crater normally characterises a detonation.

Detonation pathway  The mechanism that may cause a UXO to detonate. This is the second component of risk. The first component of risk is the presence of UXO.

Detonator  The component within an explosives train that, when initiated, detonates a less sensitive but larger high explosive charge (usually the booster), or when containing its own primer initiates the detonation.
**Disarm**  
The act of making safe by removing the fuse or igniters. The procedure normally removes one or more links from the firing chain.

**Emergency management team**  
Multi-disciplinary team usually consisting of senior management staff. Established to carry out and control a suitable response to an emergency situation.

**Explosive ordnance**  
All munitions containing explosives, nuclear fission or fusion materials and biological and chemical agents, this includes bombs and warheads, guided and ballistic missiles, artillery, mortar, rocket and small arms ammunition, all mines, torpedoes and depth charges, demolition stores, pyrotechnics, clusters and dispensers, cartridges and propellant actuated devices, electro explosive devices, clandestine and improvised explosive devices and all similar or related items or components explosive in nature.

**Explosive ordnance disposal (EOD)**  
The detection, identification, evaluation, rendering safe, recovery and disposal of UXO.

**Explosive**  
A substance or mixture of substances that, under external influences, is capable of rapidly releasing energy in the form of gases and heat.

**Exudation**  
The process in which a chemical reaction occurs over a period of time within an explosive compound. Mainly generated by organic impurities melting and exuding from the main body of an unexploded bomb around the fuze pocket. This can make an UXB extremely sensitive to shock and/or friction. The main visual signs are:
- white or dirty white encrustations
- brownish viscous substance
- yellowish liquid
- coloured crystals.

**Failure rate**  
The proportion of aerially delivered bombs and other explosive ordnance that fail to detonate as intended.

**Fluxgate magnetometer**  
Instrument that measure variations in the Earth’s magnetic fields. They are manufactured in sealed units, which consist of a small (magnetically susceptible) core, wrapped by two coils of wire. See also Gradiometer.

**Free From Explosive (FFE)**  
Term used to signify that an item that may have been associated with UXO has been assessed by a qualified EOD engineer and identified as no longer containing any explosive substances.

**Fuze**  
A designed and manufactured mechanism to activate a mine or munitions. It can be designed for use by electrical, chemical or mechanical systems, by push, pull, pressure, release and time activation, singly or in combination. Usually consists of an igniter and detonator.

**Geophysical survey techniques**  
Methods of investigating the spatial distribution of physical characteristics of the subsurface methods. These can be classified into two distinct types:
1 **Passive:** those that detect variations within the Earth (e.g., gravitational, magnetic).

2 **Active:** those in which artificially generated signals are transmitted into the ground (e.g., electrical and electromagnetic fields).

**Gradiometer**
Instrument that measures changes in the magnetic field of the Earth at a known distance apart allowing a gradient to be derived.

**Greenfield**
Land that has never been built upon.

**Grenade**
A small explosive bomb hand thrown or projected from a rifle or purpose built grenade launcher.

**Ground penetrating radar (GPR)**
Instrument used in non-intrusive surveys that emits short pulses of radio-frequency electromagnetic energy into the subsurface from a transmitting antenna. It produces a visual representation of the subsurface. See also *Bomb penetration assessment*.

**Ground penetration capacity**
The extent an item of ordnance can potentially penetrate below ground level.

**Hazard**
Anything with the potential for harmful effects.

**Hazard assessment (UXO)**
An assessment of the potential for a UXO hazard to exist at a site. The assessment is based on data obtained from a desktop review of historical information regarding site location, previous site development, wartime bombing records etc.

**Hazard characterisation (UXO)**
Assessment of the potential for a UXO hazard to:
- detonate
- cause harm.

The assessment is based on data obtained from a desktop review of historical information regarding the UXO type, geology, proposed construction and the construction methods.

**Health and Safety at Work etc Act 1974**
Regulations stating every employer must ensure so far as is reasonably practicable the health and safety of their employees and that of other persons who are affected by their work activity.

**High explosive (HE)**
An explosive that normally detonates rather than burns, i.e., the rate of detonation exceeds the velocity of sound.

**High explosive (HE) bombs**
Aerial delivered ordnance containing high explosives generally with sufficient mass, velocity and suitably streamlined shape to enable them to easily penetrate the ground if they failed to explode on the surface.

**High risk UXO**
Large bombs that are dangerous because of the presence of a potentially unstable fuze charge within the mass of high explosive.

**His Majesty’s factory**
WWI explosive manufacturing factories.

**Home Guard**
This was the organisation active in Britain during WWII to help defend the country against ground invasion. It comprised of local volunteers otherwise ineligible for...
military service, usually owing to age. The Home Guard protected main coastal areas of Britain and other important sites such as factories and explosives stores. They were armed with basic munitions and weapons, however due to shortages of conventional weapons, many improvised devices were developed, eg Molotov Cocktails.

ICE Conditions of Contract for ground investigation works

ICE Conditions of Contract for minor works

Implementation

Improvised explosive device (IED)

Incendiary

Incendiary bombs

Inert ordnance

Initiation

International Mine Action Standards (IMAS)

Intrusive survey

J-curve

Lithology
### Acronyms and abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>AAA</td>
<td>Anti-aircraft artillery</td>
</tr>
<tr>
<td>ACE</td>
<td>Association for Consultancy and Engineering</td>
</tr>
<tr>
<td>ACoP</td>
<td>Approved code of practice</td>
</tr>
<tr>
<td>AP</td>
<td>Anti-personnel</td>
</tr>
<tr>
<td>APM</td>
<td>Association of Project Management</td>
</tr>
<tr>
<td>ARP</td>
<td>Air raid precaution (wardens)</td>
</tr>
<tr>
<td>BH</td>
<td>Borehole</td>
</tr>
<tr>
<td>BD</td>
<td>Bombing density</td>
</tr>
<tr>
<td>BDO</td>
<td>Bomb disposal officer</td>
</tr>
<tr>
<td>BGS</td>
<td>British Geological Survey</td>
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<tr>
<td>CBI</td>
<td>Confederation of British Industry</td>
</tr>
<tr>
<td>CDM</td>
<td>Construction (Design and Management) Regulations (2007)</td>
</tr>
<tr>
<td>CIRIA</td>
<td>Construction Industry Research and Information Association</td>
</tr>
<tr>
<td>CPT</td>
<td>Cone Penetration Test</td>
</tr>
<tr>
<td>DE &amp; S</td>
<td>MoD's Defence Equipment and Services</td>
</tr>
<tr>
<td>DEOADS</td>
<td>Defence Explosive Ordnance Disposal School</td>
</tr>
<tr>
<td>DEMSS</td>
<td>Defence Explosives, Munitions and Search School</td>
</tr>
<tr>
<td>DGPS</td>
<td>Differential global positioning system</td>
</tr>
<tr>
<td>EMT</td>
<td>Emergency management team</td>
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<tr>
<td>EOC</td>
<td>Explosive ordnance clearance</td>
</tr>
<tr>
<td>EOD</td>
<td>Explosive ordnance disposal (engineer)</td>
</tr>
<tr>
<td>ESG</td>
<td>MoD DE &amp; S Environmental Science Group</td>
</tr>
<tr>
<td>FDEM</td>
<td>Frequency domain electromagnetic</td>
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<tr>
<td>FFE</td>
<td>Free From Explosives</td>
</tr>
<tr>
<td>FR</td>
<td>Failure rate</td>
</tr>
<tr>
<td>GPS</td>
<td>Global positioning system</td>
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<tr>
<td>HE</td>
<td>High explosive</td>
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<tr>
<td>HMF</td>
<td>His Majesty's Factories</td>
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<tr>
<td>HSE</td>
<td>Health &amp; Safety Executive</td>
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<tr>
<td>HSW</td>
<td>Health and Safety at Work etc Act 1974</td>
</tr>
<tr>
<td>IB</td>
<td>Incendiary bomb</td>
</tr>
<tr>
<td>ICE</td>
<td>Institution of Civil Engineers</td>
</tr>
<tr>
<td>IED</td>
<td>Improvised explosive devices</td>
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<tr>
<td>IMAS</td>
<td>International Mine Action Standards</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<td>-----------</td>
<td>-----------------------------------------------------------------------------</td>
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<tr>
<td>ITT</td>
<td>Invitations to Tender</td>
</tr>
<tr>
<td>JSEODOC</td>
<td>Joint Services Explosive Ordnance Disposal Operations Centre</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardisation</td>
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<tr>
<td>LSA</td>
<td>Land service ammunition</td>
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<tr>
<td>MHSWR</td>
<td>Management of Health and Safety at Work Regulations (1999)</td>
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<tr>
<td>MICE</td>
<td>Member of the Institution of Civil Engineers</td>
</tr>
<tr>
<td>MIExpE</td>
<td>Member of the Institute of Explosives Engineers</td>
</tr>
<tr>
<td>MoD DE &amp; S</td>
<td>Environmental Science Group MoD Defence Equipment and Support</td>
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<tr>
<td>MoD</td>
<td>Ministry of Defence</td>
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<tr>
<td>NFF</td>
<td>National Filling Factory</td>
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<tr>
<td>NVQ</td>
<td>National Vocational Qualification</td>
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<tr>
<td>ORR</td>
<td>Office of Rail Regulation</td>
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<tr>
<td>PI</td>
<td>Professional indemnity</td>
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<tr>
<td>PVC</td>
<td>Polyvinyl chloride</td>
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<tr>
<td>QA</td>
<td>Quality assurance</td>
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<tr>
<td>QC</td>
<td>Quality control</td>
</tr>
<tr>
<td>RAF</td>
<td>Royal Air Force</td>
</tr>
<tr>
<td>RIBA</td>
<td>Royal Institute of British Architects</td>
</tr>
<tr>
<td>RICS</td>
<td>Royal Institute of Chartered Surveyors</td>
</tr>
<tr>
<td>ROF</td>
<td>Royal Ordnance Factory</td>
</tr>
<tr>
<td>SAA</td>
<td>Small arms ammunition</td>
</tr>
<tr>
<td>SI</td>
<td>Site investigation</td>
</tr>
<tr>
<td>SIP</td>
<td>Self igniting phosphorous</td>
</tr>
<tr>
<td>TDEM</td>
<td>Time domain electromagnetic</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>UXB</td>
<td>Unexploded aerial delivered bombs</td>
</tr>
<tr>
<td>UXO</td>
<td>Unexploded explosive ordnance</td>
</tr>
<tr>
<td>WWI</td>
<td>World War One</td>
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<tr>
<td>WWII</td>
<td>World War Two</td>
</tr>
<tr>
<td>V1</td>
<td>Flying bombs or doodlebugs</td>
</tr>
<tr>
<td>V2</td>
<td>Long range rockets</td>
</tr>
</tbody>
</table>
1 UXO and the construction industry

There is a concern within the construction industry that advice relating to UXO risks can vary widely depending on the adviser. There is a general desire among construction practitioners for greater transparency in the preparation of UXO risk assessments and for more consistency in approach between UXO specialists. This publication seeks to give clarity to the processes and procedures used for UXO assessments, and provide clients and their professional advisers with the tools to assist them in assessing the suitability of a UXO specialist to undertake the work and to understand the advice being given.

This publication is a construction industry guide. It focuses on the needs of the construction professional if there is a suspected UXO on site and covers issues such as what to expect from an UXO specialist. However the guide is not intended to give details guidance for the EOD contractors or contracting practices.

1.1 WHY BE CONCERNED ABOUT UXO?

In recent decades there have been several incidents in Europe where Allied UXBs have been detonated with at least three being fatal.

The reasons why fatal incidents have not yet occurred in the UK could include:

- the relative scale of German bombing (20 times lower than the Allied bombing of Germany)
- the preferred use of mechanical as opposed to electrical fuses
- good fortune.

There is no available data regarding the number of UXO incidents on construction sites within the UK. To place the potential risk posed by UXO to the UK construction industry into context with other more commonly considered construction risks, estimates have been obtained from UXO specialists. These estimates are based within the UK regarding the occurrence of UXO hazards on UK construction sites for the period 2006 to 2008.

During this period it is estimated that about 15,000 items of ordnance ranging from high explosive aerial delivered German bombs to smaller items such as mortar rounds and grenades (but excluding small arms ammunition) have been removed from UK construction sites. Of these items it is estimated that about five per cent were live, ie still fully functioning. The number of items of small arms ammunition recovered during this period runs into the tens of thousands.

1.1.1 Employers responsibilities under health and safety legislation

All employers have a responsibility under the Health and Safety at Work etc Act 1974 and the Management of Health and Safety at Work Regulations 1999, to ensure so far as is reasonably practicable the health and safety of their employees and that of other persons who are affected by their work activity. Construction professionals have further

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Information provided by the UK’s two largest UXO specialist companies. This number would be significantly higher if data from the other UK UXO specialist companies is included.
specific duties under the Construction (Design and Management) Regulations 2007 (CDM2007). Under CDM2007, the client has the legal responsibility for the way that a construction project is managed and run and they are accountable for the health and safety of those working on or affected by the project (see Section 3.1.2).

From 2006 to 2007 the Health and Safety Executive\(^2\) reported a total of 77 fatalities, 3711 major injuries and 7108 injuries resulting in over three days of lost time for workers within the UK construction industry. No reported injuries to construction workers during this period were attributed to incidents involving UXO.

### 1.1.2 Financial implications

Although the likelihood of an inadvertent detonation of an item of UXO is low, the presence of an item of UXO at a site can still have significant implications. If sites with potential UXO risks are not managed efficiently, it can lead to programme delays and an associated increase in project costs (see Case studies 1.1 and 1.2).

Inner city brownfield sites have recently been the subject of development, however many of these areas were heavily targeted during WWII and have remained largely untouched since then. So the likelihood of encountering UXO during the construction phase of projects on these sites is significantly increased.

#### Case study 1.1 The financial implications of the unexpected occurrence of UXO

Construction had just started at the site of major gas pipeline in the UK. During the initial stages of intrusive works, an observant site operative noticed something unusual in the ground. On closer inspection the operative became suspicious that the item might be a UXO, possibly a mortar round. The operative had some military experience and recognised that the item could be ordnance related.

As construction works were already underway, the contractor had mobilised all the required plant, equipment and staff required to undertake the laying and welding of pipes. However, immediately on discovering the suspect item, the whole construction team were stopped from working, removed from the area and put on standing time.

The contractor contacted the police who contacted the Army. A bomb disposal unit was deployed to the site and following careful investigation, the suspect item was confirmed as a mortar round. The mortar round was destroyed \textit{in situ} by the Army and the immediate threat of an uncontrolled explosion averted.

Until this stage the contractor had not considered the potential risk posed by UXO and was naturally concerned when informed by the Army bomb disposal team that, where there is one mortar round, there is a good chance that there are others.

Acting upon this advice, the contractor then brought in a UXO detection and clearance specialist to undertake an assessment and investigation of the pipeline route. This investigation lasted for many weeks and during this period hundreds of UXO and UXO related items were discovered. Each individual item required careful consideration to make safe, involving further time delays. All the while the pipe welding and pipe laying teams remained on standing time.

Ignoring the UXO specialists’ fees, the estimated cost of delay was in excess of £1m. For the next phase of the pipeline construction, the contractor, who was now fully aware of the potential implications of unexpectedly discovering UXO during a construction project, ensured that the rest of pipeline route was assessed, investigated and cleared of any potential UXO by their appointed UXO specialist well in advance of the start of the construction phase of works.

\(2\) For more information visit: <www.hse.gov.uk/>.
While compliance with health and safety legislation may be seen as one of the main aims behind the effective management of UXO risks, in real terms the most likely effects on construction are delays to programme and increased cost.

In the summer of 2008 a high explosive (HE) bomb was discovered during development works for the 2012 Olympics in East London. An exclusion safety zone was established around the UXO, resulting in a site investigation on a nearby site being suspended and workers told to evacuate the area. The UXO was discovered on a Monday morning and it took until the following Friday evening for the bomb to be made safe and the site investigation team to be allowed to return to the site. This inevitably caused significant delay to the site investigation programme and led to a delayed start to the construction phase of works.

The temporary suspension of the site investigation works, with four drilling rigs and associated staff and equipment on standing time for a period of five days, resulted in a significant cost overrun. However, the delays were minimised as the issue of potentially encountering UXO during site works had been taken into consideration by the client’s team at the planning stage of the site investigation works. So the site investigation contractor had only to carry out the mitigation measures already established for such an event. If this had not been the case site investigation works may have been delayed further while the issue of risk was addressed.

### 1.2 LACK OF UK GUIDANCE ON UXO AND THE IMPLICATIONS

There has been UK guidance published regarding the clearing of explosives from sites that were involved in the manufacturing, processing and testing of explosives. However, there is currently little publicly available guidance to specifically assist construction professionals (particularly clients, developers and ground works contractors) in assessing the risks associated with encountering a UXO during the construction phase of a project.

Construction professionals often depend solely on specialist advice to deal with potential UXO risk because there is:

- limited guidance
- lack of direct legislation
- limited knowledge many developers have of the subject.

However in some cases dealing with potential UXO risk at a site or the potential threat from UXO may not be considered at all.

These limitations have resulted in project delays, which often force developers to pay for unnecessary and expensive mitigation measures.

### 1.3 AIMS AND OBJECTIVES OF THIS GUIDE

This publication provides good practice guidance for the management of risks presented by UXO to the construction industry. It is intended to increase the understanding of the subject for the construction industry professional and clarify the benefits and limitations of the services offered by UXO specialists.

The aims of the guide are to explain:

- current good practice methodology for carrying out a tiered risk assessment of encountering and detonating a UXO at both site investigation and construction phases (Chapters 4 to 7)
- how to prepare a transparent and robust risk assessment to provide a clear basis for decision making about the possible need for mitigation measures (Chapters 4 to 8)
how to select specialists to prepare UXO risk assessments for sites at risk (including issues relating to the preparation of specifications for specialists) (Chapter 9)
how to encourage independence of the advice given by UXO risk assessors and detection and clearance professionals (Chapter 9).

This guide is written for use primarily for sites in the UK. The UXO risk and associated legal environment may be different in other countries (though the basic principles of this guide should still be applicable).

1.4 WHO IS THE TARGET AUDIENCE?

The guide is targeted at clients, developers, designers, consultants and contractors dealing with building, civil engineering, geotechnical investigation and remediation works associated with a construction project. It should also be useful to the Health and Safety Executive, Environment Agency, local authorities and other regulators, insurers, investors, landowners and other professionals who are involved in development projects on construction sites.

1.5 WHAT DOES THIS GUIDE COVER?

This guide covers situations arising from conventional military munitions but does not address the discovery of improvised explosive devices (IEDs) with the exception of WWII Home Guard munitions. It also covers land formerly used for defence purposes but now available to the public and commercial sectors.

1.6 WHAT DOES THIS GUIDE NOT COVER?

The guide’s coverage is limited and although the information contained within it is broadly applicable to the investigation and risk management of all UXO, it does not directly address those situations that are already covered under existing guidance and legislation (Table 1.1).

The guidance does not apply to the current Defence Training Estate. The guidance does not address issues regarding the potential toxicological risks associated with the chemical components of UXO or from other materials used in their construction, and their possible effects on human health and the environment.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Existing guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>The occurrence of UXO on current munitions manufacturing and storage sites</td>
<td>Confederation of British Industry (CBI) (1993) Management guidance for the safe decommissioning of explosives sites</td>
</tr>
</tbody>
</table>
1.7 STRUCTURE OF THE GUIDE

The guide is structured to address the objectives as presented in Section 1.3.

Chapter 2 of the guide provides background information on the sources and types of UXO that may be encountered in the UK. The duties and liabilities relating to the management of UXO risks and the responsibilities of various project team members are described in Chapter 3.

The basics of risk management and a framework for good management of UXO risks are described in detail in Chapter 4. Included in Chapter 4 is a risk management flow chart that details the processes to be followed to ensure that the risk at a particular site has been addressed as far as is reasonably practicable. Chapters 5 and 6 describe respectively the processes for undertaking a preliminary UXO risk assessment and detailed UXO risk assessment. Typical risk mitigation strategies are described in Chapter 7 and a suggested emergency response procedure in the event of encountering a suspected UXO is given in Chapter 8.

Chapter 9 provides guidance on how to appoint a suitable UXO specialist including deliverables, contractual arrangements, execution of works, the issuing of verification reports and the provision of risk management plans for end users.

The appendices give further related information to support this publication. Appendix A1 contains a list of information sources. Appendix A2 contains an extract from a government communiqué regarding the failure rate of WWII German aerial delivered bombs. Appendix A3 contains a copy of a written answer to the House of Commons regarding the number and location of abandoned bombs in London. The information within these appendices will assist the non-UXO specialist when undertaking preliminary risk assessments.

Three samples of desk studies and risk assessment reports provided by UXO specialists regarding both aerial delivered UXO and military UXO are included in Appendix A4. These were gathered during the consultation stage of this publication and demonstrate the range of information that can be obtained. In some cases clients may require or prefer an historical perspective particularly in the early stages of planning. Others may prefer a more direct analytical probabilistic approach or indeed a combination of the two.

While these samples provide examples of many of the points raised in this CIRIA guide, they also demonstrate the different styles of presenting the results of desk studies and the different methods of undertaking and presenting the results of a risk assessment.

An overview of UXO survey and investigation techniques is provided in Appendices A5 and A6.

Appendices A7 and A8 contain example verification reports and examples of clearance certificates issued by commercial UXO specialists.