APPENDIX 2

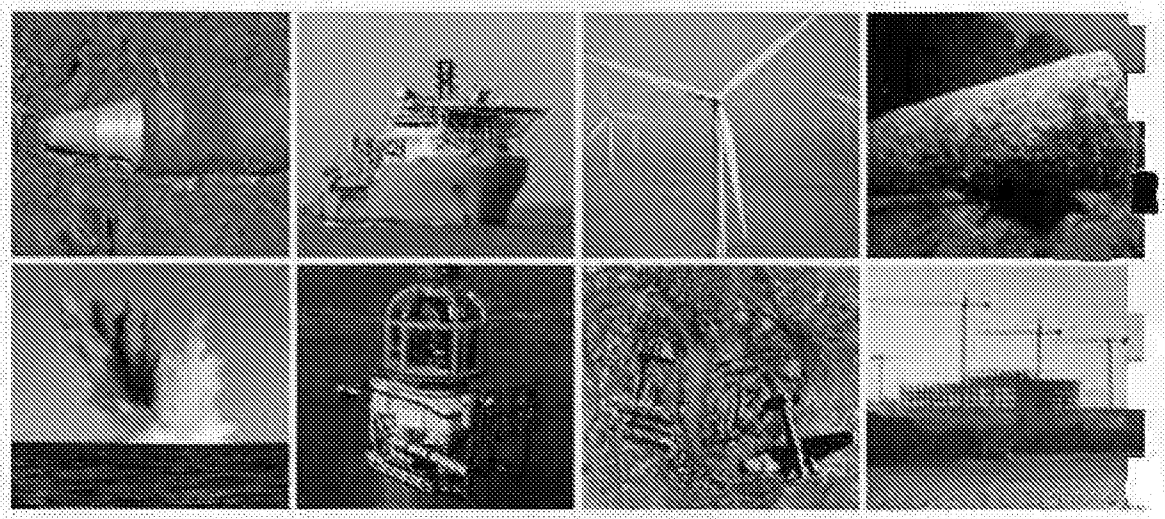
DETAILED UNEXPLODED ORDNANCE RISK ASSESSMENT ASSESSMENT (RSK, JULY 2018)

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Detailed Unexploded Ordnance Risk Assessment

(In Accordance with CIRIA Report C681)

FIL Reference: 2078

Client: RSK Environmental Ltd

Project: Ford Airfield

Site Location: Ford Road, Ford, Arundel, BN18 0FL

Date: 13th July 2018

www.fellowsint.com

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Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery
AP	Armour Piercing
AP	Anti-Personnel
ARP	Air Raid Precaution (Wardens)
BD	Bombing Density
BGL	Below Ground Level
BGS	British Geological Survey (UK)
BH	Borehole
CDM	Construction (Design and Management) Regulations 2015 (UK)
CIRIA	Construction Industry Research and Information Association
CPT	Cone Penetrometer Test
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
ERP	Emergency Response Plan
ERW	Explosive Remnants of War
FFE	Free From Explosives
GI	Ground Investigation
GPS	Global Positioning System
HE	High Explosive
HSE	Health and Safety Executive
HSWA	Health and Safety at Work Act 1974
IB	Incendiary Bomb
JSEODOC	Joint Services Explosive Ordnance Disposal Operations Centre (UK)
LE	Low Explosive
LM	Luftmine (Germany)
LSA	Land Service Ammunition
MOD	Ministry of Defence (UK)
NEQ	Net Explosive Quantity
RAF	Royal Air Force
RN	Royal Navy
ROF	Royal Ordnance Factory
SAA	Small Arms Ammunition
SAP	Semi-Armour-Piercing
SI	Site Investigation
SIP	Self-Igniting Phosphorous
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V1	Vengeance Weapon 1 - Flying bombs or doodlebugs
V2	Vengeance Weapon 2 - Long range rocket
WW	World War

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1. Executive Summary

Site details

The site is the former RAF and Royal Navy airfield known as RAF FORD or RNAS PEREGRINE. It is situated immediately adjacent to the village of Yapton, approximately 3.8km west of Littlehampton.

Risk Assessment

Unexploded Ordnance (UXO) risk at the site is assessed as:

UXO	*RISK*
German air dropped weapons	Medium
British Anti-Air defensive munitions	Low Risk
Other (Land service Ammunition / Historic (Home Guard) / Military Training)	Low Risk

Full detail of the UXO risk and the risk assessment process including site zoning is within section 11.

UXO Risk

The primary UXO risk associated with this site is considered to be deep buried aerial dropped bombs. There is also a risk of encountering shallow buried anti-aircraft munitions and other aerial or land service ordnance which may have been dumped or buried in caches.

Summary of findings

The site, a former Royal Navy Fleet Air Arm and RAF aerodrome has seen significant military usage throughout the 20th Century. Constructed in 1917, the airfield saw a variety of aircraft ranging from the biplanes of the early 20's to the jet powered aircraft of the 50's.

The site was heavily bombed and nearly destroyed on the 18th August 1940 while it was under the control of the Fleet Air Arm. Following this, the RAF took over and used the site as both a training centre and a variety of mixed roles, from Intruder Squadrons to night bombing.

Following the end of WWII, the site was utilised once again by the Fleet Air Arm but the station eventually closed. Following this, parts of the land were used as an Open Prison and other parts were given over to agriculture. There has been some recent construction with the Ford Trading Estate.

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UXO Risk management recommendations

For all works within the site area:

A UXO Awareness Brief (UXOAB) be delivered to all site personnel. This can also include a site safety walk-through and provision of a UXO Emergency Response Plan for inclusion into the site HSE documentation.

Ground Investigation (GI) works:

Provision of a UXO Engineer to oversee intrusive GI works to include the use of a magnetometer (downhole scanning) to determine the presence or otherwise, of possible Unexploded Ordnance (UXO) contamination that could compromise any intrusive ground investigation works.

Excavations and shallow intrusive works within the site area:

Provision of an UXO Engineer to oversee shallow intrusive excavation works will reduce the risk of a UXO incident occurring. The UXO Engineer can be on-site to identify any items uncovered during excavation. This can reduce down-time and improve site efficiency.

Piling or deep excavations:

Due to the risk from German aerial bombs at the site, an intrusive magnetometer survey is recommended to assure safety of personnel and equipment during the piling works. This can be in the form of or Cone Penetration Testing (CPT) where load bearing or contiguous piling is planned.

For deep piling, CPT probing should take place to a minimum probe depth of 10m bgl.

Fellows International Limited (Fellows) can provide all of the above services and would be pleased to provide a proposal accordingly.

For further information, or to discuss requirements, please get in touch.

Web - www.fellowsint.com

Tel - 01243 551025

Email – research@fellowsint.com

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2. Report Methodology

The aim of this report is to conduct a comprehensive assessment of the potential risk from UXO at the site as described by the client.

Every reasonable effort has been made to ensure that all available historical information has been accessed and checked. Where possible, evidence has been included in the report to enable the client to understand the basis of the risk assessment. Fellows cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date. The accuracy of wartime records is frequently difficult to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance threat can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. Fellows cannot be held responsible for inaccuracies or gaps in the available historical information. All sources are referenced at Section 13.

The report recommends appropriate site and work-specific risk mitigation measures to reduce the risk from explosive ordnance during the envisaged works to a level that is as low as reasonably practicable (ALARP).

This report follows the guidelines outlined in CIRIA Report C681, 'Unexploded Ordnance (UXO) A Guide for the Construction Industry'.

The author of this report visited West Sussex Records Office to obtain local information pertaining to this site.

Fellows has been supporting the UK construction industry with UXO Risk Management measures for over 2 decades and offer the complete UXO risk management process from the preliminary and detailed desk study though to the physical site survey and finally, the identification and removal or disposal of an item, either in house or in liaison with military disposal assets. Our desk top studies enable our clients to accurately assess the UXO risk and take proportionate, cost effective action to manage the risk posed by unexploded aerial bombs and other munitions.

As one of the first companies to offer this service in the UK, Fellows have unrivalled experience delivering the UXO Risk Management process and are proud of our reputation for quality and cost-effective delivery, gained from our years of experience. Fellows can support you through the whole risk management process from project start to final delivery.

While Fellows is mainly active in the UK, we also have a long history of operating overseas on projects all over the globe. We are proud to support both the construction and offshore industries with the right experience, people, qualifications and equipment to best identify, quantify and mitigate the UXO risk wherever it may be.

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3. Requirement for UXO Risk Assessment

Background

There is no formal obligation requiring a UXO risk assessment to be undertaken for construction or development projects in the UK, nor is there any specific legislation stipulating the management or mitigation of UXO risk. However, the legislation outlined below makes very clear that those responsible for intrusive works (archaeology, site investigation, drilling, piling, excavation etc.) should undertake a comprehensive and robust assessment of the potential risks to employees and that mitigation measures are implemented to address any identified hazards.

CDM Regulations 2015

The Construction (Design and Management) Regulations 2015 (CDM 2015) defines the responsibilities of parties involved in the construction of temporary or permanent structures. CDM 2015 establishes a duty of care extending from clients, principle co-ordinators, designers, and contractors to those working on, or affected by, a project. Those responsible for construction projects may therefore be accountable for the personal or proprietary loss of third parties if correct health and safety procedure has not been applied.

Although CDM 2015 does not specifically reference UXO, the risk presented by such items is both within the scope and purpose of the legislation. It is therefore implied that there is an obligation on parties to:

- Provide or obtain an appropriate assessment of potential UXO risks at the site
- Emplace appropriate risk mitigation measures if necessary
- Supply all parties with relevant risk information
- Prepare a suitably robust emergency response plan.

Other legislation

The 1974 Health and Safety at Work Act

All employers have a responsibility under the Health and Safety at Work Act 1974 and the Management of Health and Safety at Work Regulations 1999, to ensure the health and safety of their employees and third parties, so far as is reasonably practicable.

4. Site Description (Current)

Site location

The site is located on the former Ford Airfield in West Sussex. The site is approximately 3.8km west of Littlehampton, 4.8km southwest of Arundel and 6.9km northeast of Bognor Regis. The area is predominantly comprised of agricultural land, with some recent developments of commercial and retail properties within the site boundaries.

Mapping / aerial photography



Figure 1. Showing aerial photography of the approximate site boundaries outlined in red. (Google Earth Pro, 2018)

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5. Site History

Ford Aerodrome (HMS PEREGRINE, RAF FORD)

Ford airfield was originally opened in March 1918 by German POWs for use by RAF and USAAFn squadrons. Due to the late construction of the airfield, it was never utilised for its original purpose of being a "jumping off" point for France by the American troops. The airfield fell into disuse and was closed in 1920.

The airfield re-opened to civilian pilots in the next decade. During this time, experiments with in-air refueling were conducted from this airfield by the Ford Motor Company. Ford intended to fly the Ford Tri-motor Passenger aircraft commercially from this location, but it was not given an air worthy license by the government. Ford vacated the hangers and local flying clubs utilised these for private flying before finally being given over to the military again in 1937.

The Fleet Air Arm renamed the airfield HMS PEREGRINE and training units were stationed there at the beginning of WWII. Despite having little considerable involvement with the Battle of Britain, the Luftwaffe considered the airfield as strategically important. The airfield was bombed and heavily damaged by Luftwaffe Junkers Ju 87 aircraft on 18th August 1940. This was one of the the worst raids against airfield targets due to the extent of damage caused. This raid claimed 28 lives and destroyed the main airfield buildings and runway. 1946 RAF aerial photography shows some damage that has been repaired or buildings demolished and can be seen in figures 2 - 4.

Following this raid, the RAF quickly repaired and reused the airfield for counter attacks against Germany by Fighter-Bomber "Intruder squadrons". These squadrons were tasked with roaming German occupied territories and attacking targets at will. This was further amalgamated into fighter-bomber sorties throughout D-Day preparations and commencement. The airfield was also utilised by the RAF Aerial Photography School with the purpose of training photographers in both reconnaissance and post-raid photograph interpretation. Fighters, night fighters, bombers and fighter-bombers were based here and played an important role in the Dieppe and D-Day operations. There are several recorded allied and enemy aircraft crashes recorded near Ford Aerodrome. These can be seen in Table 1. Other aircraft crashes in the county were found to have live UXO on board which was subsequently buried by soft mud and not discovered until years later.

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Date	Aircraft	Location
24/10/42	Lancaster	Wicks Farm, Ford
20/06/42	Hurricane	Little Harn Farm, Ford
25/03/42	Hurricane	West of Ford
19/02/43	Beaufighter	Ford
12/06/43	Mosquito	Near Ford Airfield
10/09/43	Messerschmitt 108	Ford Airfield
19/11/1943	Halifax	Near Ford
24/11/1943	Spitfire	Yapton
30/01/44	Mosquito	Bilsham Corner, Yapton
23/05/44	Fortress B17	Ford Aerodrome
09/06/44	Mosquito	Ford Aerodrome
22/06/44	Marauder B26	Yapton
30/06/44	Lancaster	Ford Aerodrome
18/07/44	Spitfire	Bilsham Farm, Yapton
01/08/44	Mosquito	Ford Aerodrome
22/10/44	Mosquito	Ford Aerodrome
19/12/44	Halifax	Ford Airfield

Table 1. Showing aircraft crashes on or near Ford Aerodrome

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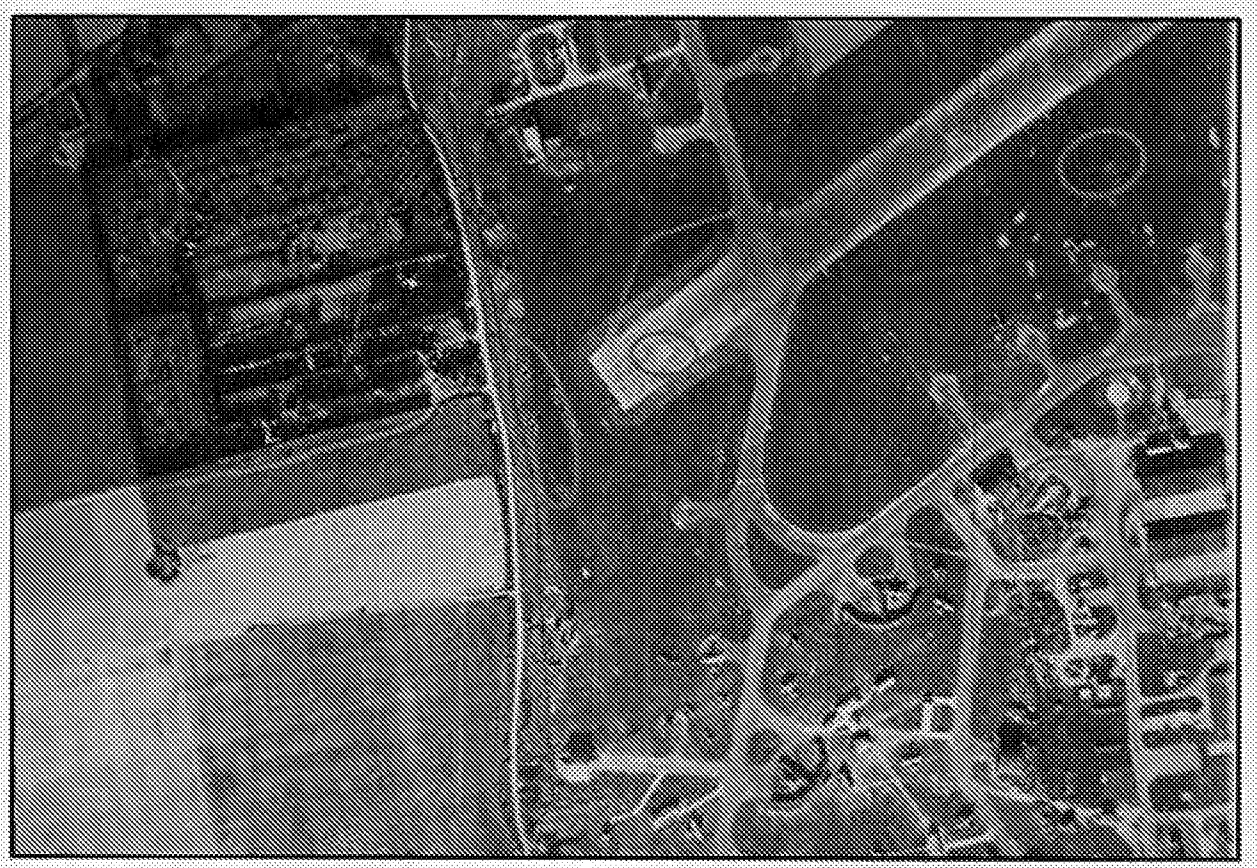


Figure 2. Showing post war bomb damage. Craters are visible and have been circled in red.

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Figure 3. Showing further bomb damage to areas near hangers.

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Figure 4. Showing further craters in the fields and buildings adjacent to one of the runways.

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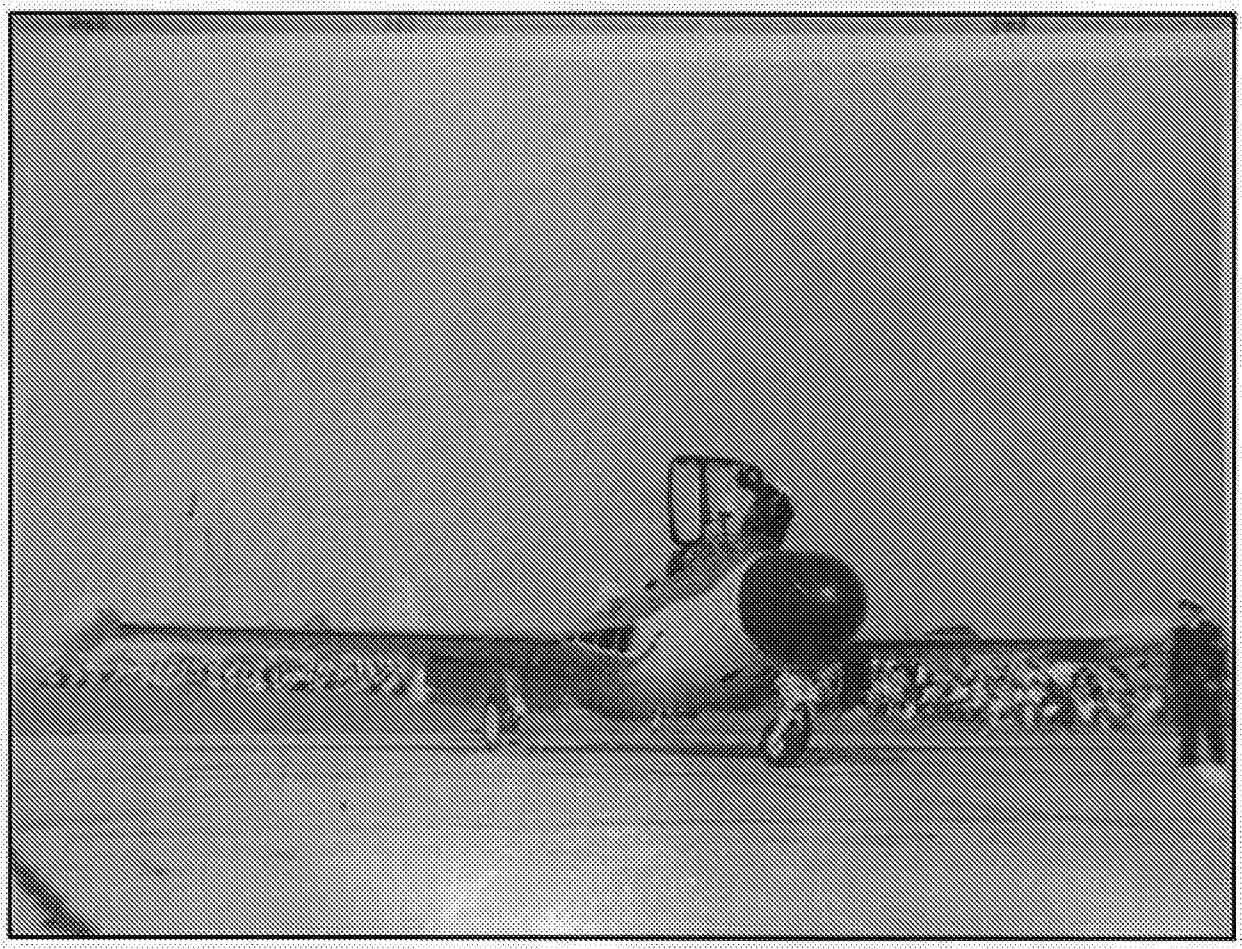


Figure 5. Showing a de Havilland Venom circa 1950's during the RNAS PEREGRINE open day [The Aviation Forum, n.d.].

Arundel Municipal District

Despite the close proximity of Tangmere and Ford airfields and the number of missiles and HE bombs dropped on the borough, none of Arundel's citizens are on the War Dead Roll for the entirety of the war.

On 13th August 1940, a Junkers Ju 88 bomber crashed into Swanbourne lake after being shot down by Tangmere based Hurricanes. The plane tore itself apart after striking the Beech trees on the west side of the lake. Much of the wreckage fell into the lake with the evidence becoming apparent after the drying of the lake in 1989 when an unexploded 50kg bomb was found on the mud. In the early part of 1990, further UXBs were found at the site, a single SC50kg and two SC250s. These were defused and removed for disposal.

On 2nd May 1941, the borough received 5 HE bombs to the east of London Road causing some slight damage to the roof of Green Lodge, Arundel Park, but no casualties.

It is assessed that this was an act of Tip and Run.

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Chichester Rural District

With its proximity to military targets, the district saw its fair share of fighting. Twenty three enemy aircraft came down in 1940 alone. Despite the cost to the Luftwaffe, there were relatively few injuries or fatalities. On 19th August there were 3 civilian casualties at Broadreads Holiday Camp in Selsey.

The first Luftwaffe loss was a Heinkal HE111 shot down onto East Beach at Selsey on 11th July 1940 by Hurricanes of 145 Sqn from Westhampnett. Two crew were killed, three taken as POWs.

On the 21st July 1940, a Messershmitt 110 was forced down almost in one piece onto Home Farm, Goodwood. The aircraft was repaired and test flown by the RAF.

The constant downing of German planes came to a head in the region on the 16th August. Five German planes and two British planes were shot down over the county and Tangmere airfield was heavily bombed. A crippled Hurricane landed in flames at the height of the bombing raid on Tangmere. The pilot later died in hospital. Later that day a Messerschmitt was shot town at Shopwyke House.

Two days later on the 18thAugust, the Stuka bombers returned and attacked Thorney Island, Poling and Ford airfield. Downed Stukas were found at Cut Mill in West Ashling, North Barn at Chidham and in Fishbourne Creek. The bomber in Fishbourne Creek had not jettisoned its bomb load, and these were thought to have been recovered more recently.

26th August saw heavy aerial fighting with a Heinkel He111 shot down at Bracklesham Bay, West Wittering. This plane was intact and slowly sank into the sands. It is now completely covered. Another bomber was shot down at Stansted House, Stoughton. The bombs of this exploded, taking the lives of all 5 crew and mortally wounding an RAF Pilot Officer who was billeted here.

29th August saw a Hurricane shot down in the sea by Selsey Bill. A rare Messerschmitt 109 was also shot down at Mapsons Farm, Sidlesham.

As night raids became more common, several more aircraft were shot down at Stocks Lane, East Wittering on 20th November.

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Historical Developments

Military occupied areas were frequently not mapped until such time that the land became available for public use. During the war period, much of the land has not been mapped to protect the information.

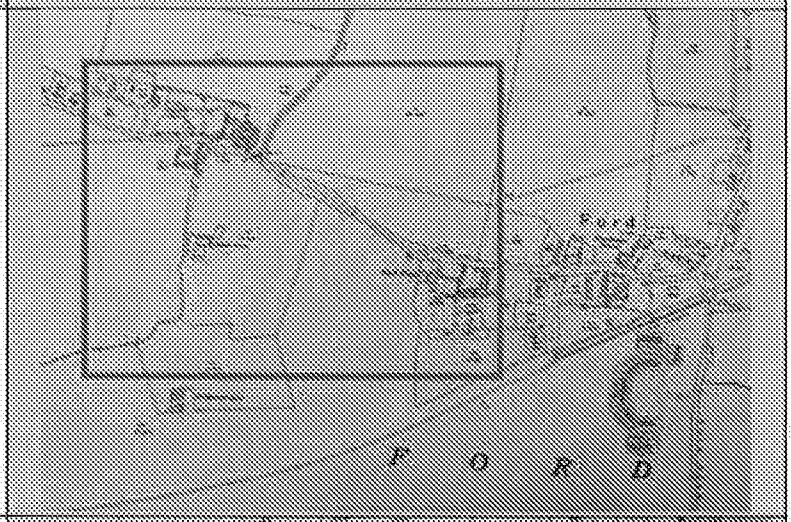
Data	Description	Map
1939	1939 revision of the OS map of the area. The airfield is not shown on this map, despite being constructed long before this. Military presence was not shown.	
1962	1962 revision of the OS map shows the airfield, but the majority of the aircraft pens and structures are still not shown. Much of the land was given over to agriculture at this point in time.	

Table 2. Summary table of the develop and demolition works which have taken place in the site before and after WWII (Ordnance Survey, 1939 – 1962).

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Recent developments.

At the end of WWII, the airfield was returned to the Fleet Air Arm. At this point, the airfield was closed to make essential improvements. The runways were extended and reconstructed using concrete to accommodate newer jet powered aircraft.

In August 1951 the airfield was the site of the first Naval jet fighter unit comprised of Supermarine Attackers. Military occupation of the airfield ceased in 1958 and control was once again given over to civilian flights. Flying by civilians stopped in 1980.

The site was returned to agricultural use and some of the buildings used as an open prison. The majority of the aircraft hangers and pens were removed around this time.

The site is mostly agricultural with some newer sections of industrial and commercial properties. The Ford Trading Estate and Water Treatment plant are both examples of the change, both built close to the original runways. Part of the site has been utilized by the local Rifle club and on Sundays it is used for car boot sales and markets.

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6. Site Environment

Proposed scope of works

There are mixed developments proposed in various sections of the site. This ranges from residential dwellings to areas designated for employment purposes (commercial, most likely). There is likely to be areas of piling. The map in figure 6 and aerial photography in figure 7 show the extent of different types of development.

Ground conditions

There is expected to be up to 5m of alluvial soils present across much of the site. Beneath this, it is expected that it will be chalk bedrock of varying strata and hardness.

Site geological conditions

The site sits on superficial River Terrace deposits which is comprised of sand, silts and clays. These are fluvial in origin and undifferentiated.

Bedrock geology in the area is of the Lewes Nodular Chalk, Newhaven Chalk, Seaford Chalk, Culver Chalk and Portsdown Chalk formations. These formations are undifferentiated and are shallow marine in origin. These are carbonate material lain in distinctive beds over time.

Local Borehole information

Borehole / Trial pit reference	Date	Location	Hole Depth	Strata (Thickness)
SU90SE2	n.d.	On site	20'3"	1'0" Soil 15'0" Sandy Clay 4'3" Chalk

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Borehole / Trial pit reference	Date	Location	Hole Depth	Strata (Thickness)
SU90SE3	n.d.	On site	20'0"	1'0" Soil 16'0" Sandy Clay 3'0" Chalk
SU90SE4	n.d.	On site	20'0"	1'0" Soil 14'0" Sandy Clay 5'0" Chalk

Table 3. Showing historic borehole logs in the vicinity of the site.

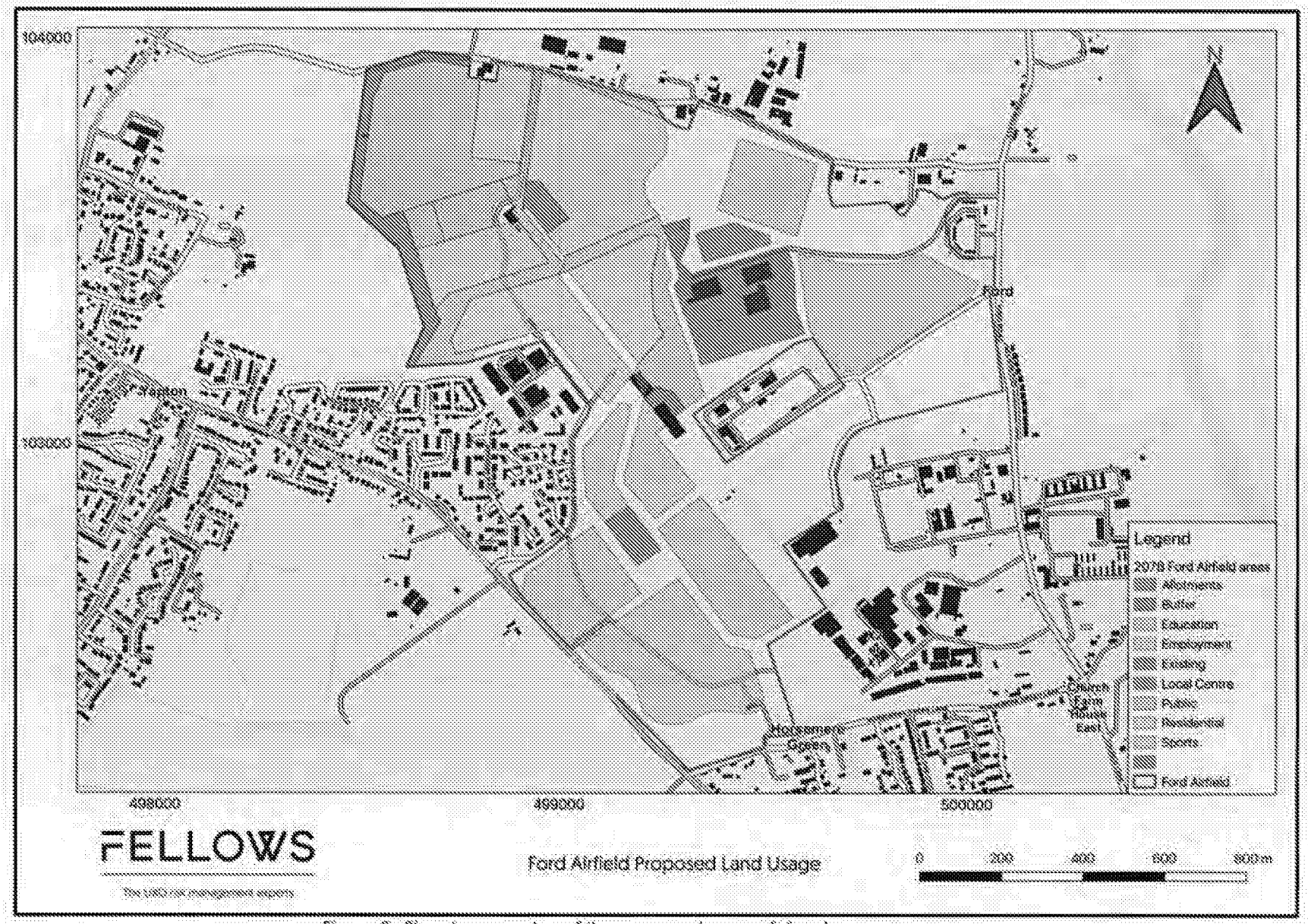


Figure 6. Showing mapping of the proposed areas of development areas.

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Figure 7. Showing aerial photography with proposed development are

7. Sources of Potential Unexploded Ordnance

UXO found at construction and development sites in the UK originates from three principal sources:

- **Munitions deposited as part of military training or exercises.**

  In the UK, this can be historical from WWI or before but also more recent, especially as land reserved for military use is released for development.

- **Dumping**

  Munitions abandoned or dumped, either deliberately post war, accidentally lost in transit or due to ineffective working practices during manufacture, storage and transportation.

- **Wartime activity (including aerial bombing)**

  This includes ordnance resulting from wartime activities including enemy bombing, long range shelling, area or site denial weapons (mine fields or airfield pipe mines) and munitions from defensive activity such as anti-aircraft batteries or pre-invasion measures.

Other factors which may increase UXO risk

Transportation of aggregates containing munitions to an area that was previously free of UXO has led to small munitions contaminating a previously low risk site. This is usually related to construction activities employing material dredged from a contaminated offshore borrow site although the use of explosive contaminated soil or fill from higher risk areas should also be considered.

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8. Aerial Bombing

General

During WWI and WWII, many towns and cities across the UK were subjected to bombing which often resulted in extensive damage to city centres, docks, rail infrastructure and industrial areas. In addition to raids which concentrated on specific targets, indiscriminate bombing of large areas also took place, notably the London 'Blitz', but bombing also affected many other towns and cities including Portsmouth and Southampton.

Approximately 10% of the bombs dropped on the UK did not detonate as designed. Although extensive efforts were made to locate and deal with these UXBs at the time, many still remain buried and can present a potential risk to construction projects.

The main focus of research for this report concerns German air-delivered ordnance dropped during WWII, although other forms of explosive contamination will also be considered.

The most common type of UXO discovered today is the aircraft delivered high explosive (HE) bomb. These are comparatively thick-skinned and dropped from enemy aircraft. If the bomb did not detonate when it was dropped, the force of impact enabled the bomb to penetrate the ground, often leaving behind it an entry hole. These entry holes were not always apparent, and some went unreported, leaving the bomb buried and unrecorded. The bomb then became an Unexploded Bomb or UXB.

Additional forms of German aerial UXO will be considered including WWII 'Vengeance' weapons (V1 and V2 rockets), small Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets.

World War One aerial bombing

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress.

Only limited information is available of WWI attacks and targeting and there is nothing to suggest that the site area suffered serious WWI aerial attack. The threat from WWI German UXBs is therefore considered to be very low and will not be considered further in this report.

World War Two aerial bombing

Targeting

Although the Luftwaffe had designated primary bombing targets across the UK, their high-altitude night bombing was not accurate. As a result, thousands of buildings were damaged and civilian fatalities were common. Bombs were also jettisoned over opportunistic targets and residential areas were sometimes struck.

When Luftwaffe aircraft wished to scape due to interception by fighter aircraft or anti-aircraft fire they would jettison their bomb-load to increase speed and manoeuvrability. This is commonly referred to as tip and run and it has resulted in bombs being found in unexpected locations.

Decoy sites

RAF and Royal Navy decoy sites were constructed in the vicinity of legitimate targets to deceive and decoy enemy bombers. For obvious reasons, such sites were often built in remote and uninhabited areas. Some were more successful than others and received relatively high bombing rates.

There were no decoy sites within 5km of the site boundaries. The area surrounding the site was predominantly rural, with two nearby coastal towns (Bognor Regis and Littlehampton).

Aerial bombs

The most commonly dropped German aerial weapon was the SC50 (50Kg). The next largest weapon is the SC250 (250Kg bomb HE bomb. These were dropped primarily against soft targets such as gas and electricity installations, factories, housing and transport infra-structure.

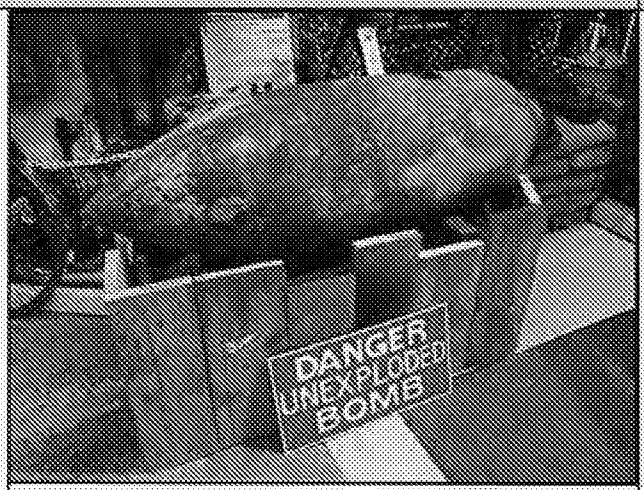
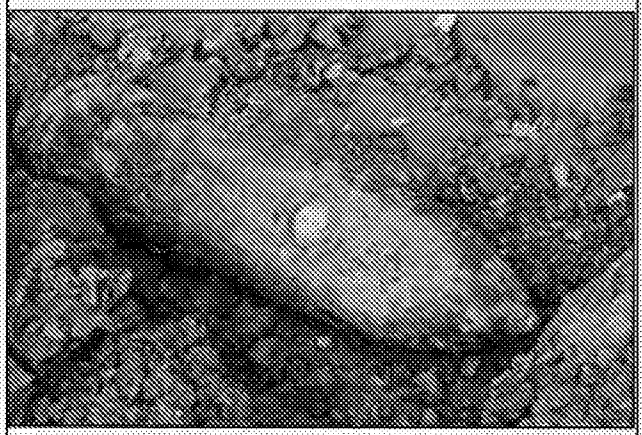
Although the Luftwaffe deployed larger bombs in the area, their deployment was infrequent, the majority of bombs dropped were SC50 (50kg) and SC250 (250kg) HE bombs.

Larger incendiary or 'Flam' bombs were also known to have been dropped in the area. Outwardly similar to the SC250, these contained flammable mixed oil and a small HE bursting charge and were designed to shower burning oil over softer, flammable targets.

UXB risk of encounter has been assessed by using the SC50 and SC250 as the primary risk weapon.

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WWII German aerial Ordnance

Type		Description
High Explosive (HE) Bombs	 German SC250 (recovered casing)	The SC series of HE Bombs were a thin cased general-purpose bomb used as general demolition bombs. Most bombs were 50kg, 250kg or 500kg, although larger bombs of up to 1,800kg were also used. About half the weight of these HE bombs comprised of explosive fill. The SC50 had a one-piece drawn steel body and its total weight was 48 to 55 kg.[1] It was dropped on targets across the UK. The SD series of bombs were thicker cased, with a lower charge weight used against hardened targets.
	 German SC50 (London 2015)	

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Type		Description
Incendiary bombs	 1Kg Incendiary Bomb	The 1 kg BIE incendiary bomb consisted of a cylinder of magnesium alloy, with an incendiary filling of thermite. Rivetted to the body was a steel tail with three fins. These bombs did not explode but were ignited by a small percussion charge, fired upon impact. They were dropped in a variety of containers. Later an explosive head was incorporated into the IB.

Type		Description
Anti-Personnel [AP] bombs	 SD2 'Butterfly' Bomb [Armed status]	A Butterfly Bomb [or *Sprengbombe Dickwandig* 2 kg or SD2] was a German 2 kilogram anti-personnel sub munition used by the Luftwaffe during the Second World War. It was so named because the thin cylindrical metal outer shell which hinged open when the bomblet deployed gave it the superficial appearance of a large butterfly. The design was very distinctive and easy to recognise. SD2 bomblets were not dropped individually but were packed into containers holding between 6 and 108 sub munitions. These broke open in air and scattered the sub-munitions.

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UXB Initiation

Unexploded ordnance does not spontaneously explode. Military high explosive is generally reasonably stable and requires significant energy, normally via a fuze and initiation system for detonation to occur. In the case of unexploded German bombs discovered within the construction site environment, there are a number of other potential initiation mechanisms.

Direct impact

Unless the fuze or fuze pocket is struck, there needs to be a significant impact e.g. from piling machinery or large and violent mechanical excavation, onto the main body of the weapon to initiate a buried iron bomb. Such violent action could cause a bomb to detonate.

Fuzes

Most German bomb and mine fuzes were electric and were highly engineered compared to their British equivalents. A small proportion of German WWII bombs employed clockwork fuzes. It is probable that clockwork or mechanical fuze mechanisms would have corroded since WWII and this will generally prevent them from functioning.

Friction impact

Impact from construction machinery or processes could initiate the shock-sensitive fuze explosive. The effects of chemical breakdown of explosive fill and general degradation over time can cause explosive compounds to crystallise and extrude out from the main body of the bomb. It may only require a limited amount of energy to initiate the extruded explosive around the fuze pocket which could detonate the main charge.

Consequence of interaction

When considering the potential consequences of a detonation, it is necessary to identify who may be affected. These will vary depending on the site-specific conditions but can be summarised as:

- People – site workers, local residents and general public.
- Plant and equipment – construction plant on site.
- Services – subsurface gas, electricity, telecommunications.
- Structures – not only visible damage to above ground buildings, but potentially damage to foundations and the weakening of support structures.
- Environment – introduction of potentially contaminating materials.

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Failure Rate of German air-delivered ordnance

It has been estimated that 10% of the German HE bombs dropped during WWII failed to explode as designed. There are a number of reasons why an air-delivered weapon might fail to function as designed:

- Malfunction of the fuze or initiation mechanism (either electric or clockwork)
- Failure of the bomber aircraft to arm bombs correctly
- Jettisoning of the bomb before it was armed or from a very low altitude. Likely if the bomber was under attack or attempting a forced landing due to damage.

Unexploded ordnance is still regularly encountered across the UK and is dealt with on a routine basis by military and commercial Bomb Disposal teams.

Bomb penetration

An important consideration when assessing the risk from a UXB is the likely maximum depth of penetration. There are several factors which determine the depth that an unexploded bomb will penetrate to:

- Size and shape of bomb
- Height of release
- Velocity and angle of bomb
- Nature of the ground cover
- Underlying geology

Geology is perhaps the most important variable. If the ground is soft, there is a greater potential of deeper penetration. For example, peat and alluvial deposits are easier to penetrate than gravel and sand. Layers of hard strata will significantly retard and may stop the trajectory of a UXB.

Impact angle and velocity

It is assessed that bombs struck at an angle 80-85° from vertical and at c. 270 metres per second. These are standard figures used for bomb release from an aircraft at normal altitude. Other factors such as low speed or altitude of the bombing aircraft may alter these figures, but no records are available to suggest any low level raids or incidents.

Buried bombs

When bombs strike but do not detonate, they can easily remain undetected. Note that the entry hole of an SC50 (the most commonly deployed German HE bomb) could have been as small as 20cm in diameter and therefore easily obscured within dense crops, or unmaintained vegetation, rough soil or rubble from previous damage.

The J-Curve Effect

J-curve is the term used to describe the characteristic curve commonly followed by an air-delivered bomb dropped from height after it penetrates the ground. Typically, as the bomb is slowed by its passage through underlying soils, its trajectory curves towards the surface.

Many UXBs are found with their nose cone pointing upwards as a result of this effect. More importantly however is the resulting horizontal offset from the point of entry. This is typically a distance of about one third of the bomb's penetration depth but can be up to 15m leading to bombs settling underneath undamaged buildings.

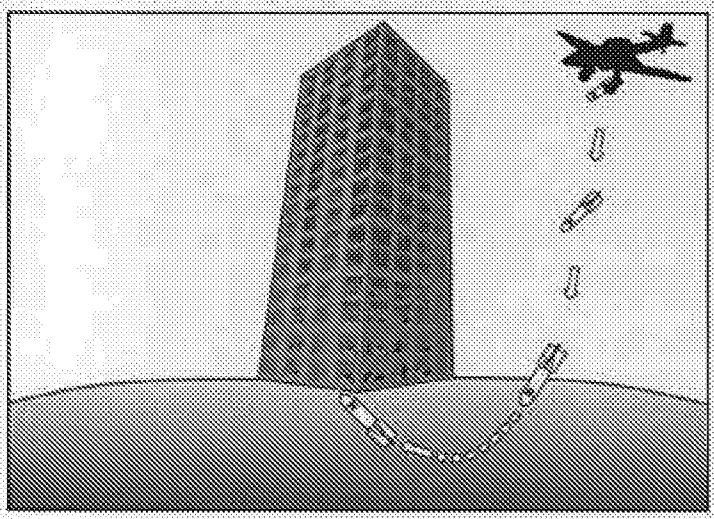


Figure 8. Demonstrating the J-Curve

Abandoned bombs

Research did not indicate the presence of any abandoned bombs within the site boundary.

Bombing density at Site

The airfield was considered a key target by the Luftwaffe and was subjected to a number of air raids. A large scale raid was conducted in 1940, of which the majority of the airfield was all but destroyed. There is considered to be a high local bombing density on the airfield itself, with a much lower bomb density on the area surrounding the site.

9. UXB Risk at this Site

Local geology

The local geology consists of soft alluvium and chalk, which is considered to be a soft sedimentary rock. As a result of this, and the fact that it is expected to be uniform across the site, the geology is considered to allow bombs to penetrate deep into the ground.

Post war / previous works

As a former airfield, the peripheral areas were covered with hangers, Nissen huts and hard standing structures. The airfield itself had substantial hard standing and not the typical grass runways that smaller airfields usually supported. As a result, there is expected to be some impact on the maximum bomb penetration depth in areas of hard standing.

As there has been significant areas of the site turned over to agriculture, it is unlikely that surface munitions will still be present on the site. As an Open Prison, it is likely that several clearance operations have been conducted post war, although this could not be verified at the time of writing this report.

Bomb penetration

Due to the local geology and the previous usage of the site, the maximum bomb penetration depth for an SC50 (50kg) bomb is expected to be approximately 6m in open ground and 4m in areas of hard standing. An SC250 (250kg) bomb is considered to have a maximum penetration depth of 9m in open ground and 6m in areas of previous buildings and the runway.

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10. Other Military Ordnance

In addition to aerial bombs, there may also be a risk from other items including discarded or forgotten land munitions from both wartime and peacetime military use. Typical military activities may include:

- Former mine-fields; often on beaches on the South and East coasts of England
- Home Guard weapons and munitions
- Anti-Aircraft sites
- Training & firing ranges
- Military bases
- Munitions manufacture and storage sites

During the early years of WWII huge preparations were underway to defend the UK against German attack. This often included the hiding or caching of defensive ordnance at or near to strategically or tactically important locations.

Items may include small arms ammunition, mortar bombs and hand grenades or even crudely manufactured defensive weapons designed for Home Guard use such as the No.76 SIP (Self Igniting Phosphorus) grenades. These items, resembling a milk bottle are frequently found in original crates during shallow excavations or building demolition and although small in size can inflict life-changing injuries if not dealt with correctly.

The potential risk of encountering allied ordnance on construction sites is particularly elevated in areas previously associated with military activity. This includes munitions deposited by military training exercises, dumped as a result of poor working practices, or deliberately placed to prevent adversary occupation.

As the site is a former military establishment, it is not inconceivable that there may be dumped, discarded or buried munitions present within the site boundaries. The area was initially used by the Fleet Air Arm, then given over to the RAF after a period of heavy enemy bombardment. Aircraft munitions and land service munitions would have been present on the site boundary.

Anti-Aircraft Artillery

Urban areas can be at risk from buried unexploded Anti-Aircraft projectiles fired during WWII.

At the onset of WWII two types of Anti-Aircraft Artillery (AAA) guns were deployed:

- Heavy Anti-Aircraft Artillery (HAA), using large calibre weapons, such as the 3.7" QF (Quick Firing) gun. Normally fixed batteries.
- Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons, such as 40mm Bofors gun. Often mobile, vehicle mounted batteries.
-

Type		Description
Anti-Aircraft Shells	 40mm AA Shells found at W Sussex site	Fixed (Heavy) Anti-Aircraft batteries were set up all around the country to defend potential targets from aerial attack. Size of guns and shells ranged from small, quick-firing 40mm Bofors guns to larger 3.7 or 4.5inch guns. 3.7 Inch = 12.7kg 94mm x 438mm 40mm = 0.9kg 40mm x 311mm 4.5 Inch = 24.7kg 114mm x 578mm

LAA batteries were intended to engage fast, low flying aircraft and were typically deployed around military bases, RAF airfields or important installations. These batteries were mobile and could be moved to new positions with relative ease when required. The most numerous of these were the 40mm Bofors gun, which could fire up to 120 x 40mm HE shells per minute to over 1,800m.

HAA projectiles were high explosive shells, usually fitted with a time delay or a barometric pressure fuze to make them explode at a pre-determined height. If they failed to explode or strike an aircraft, they would eventually descend back to earth.

Although the larger unexploded fall-to-earth projectiles could enter beneath the ground surface, they did not have a great penetration ability and are therefore likely to be found close to WWII ground level. If encountered, the high explosive fill and fragmentation hazard of these items of UXO would present a significant risk.

The smaller 40mm projectiles are similar in appearance and effect to SAA and, although still dangerous, present a lower hazard due to its decreased explosive content.

Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

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AAA Emplacements

There were 4 British Anti-Aircraft Artillery emplacements within 5km of the site. These are tabulated below:

Location	Distance from Site
Ford	On site
Fordwych	2.1 km SE
Atherington	2.5 km SE
Toddington	3.5 km E

Table 4 Showing British anti-aircraft emplacements within 5km of the site.

Due to the proximity of the AAA sites, there is a low risk from unexploded fall-to-earth AA projectiles although it is assessed that these would have been discovered and dealt with during rural land use or local redevelopment.

Other munitions

There is evidence that the airfield was mined during the war to prevent enemy forces from using the airfield in the case of a land invasion. Canadian Pipe Mines were used on the majority of southern airfields for this purpose and despite orders to remove these after the war, many remain to this day. Records show that Ford aerodrome had its minefield extended.

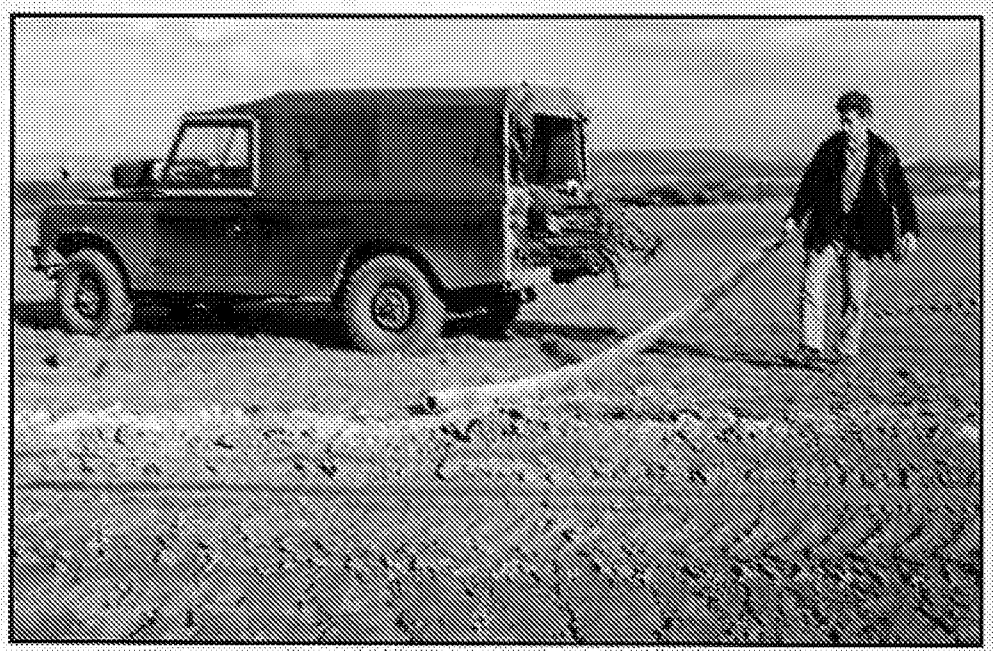
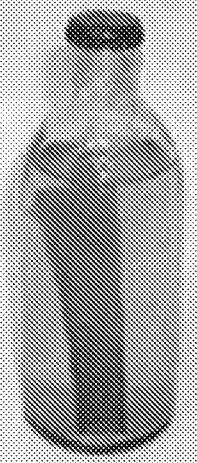


Figure 9. Showing Canadian Pipe Mines.

Other defensive munitions

As the threat of invasion lingered over Britain during WWII, large areas of land were requisitioned for military training and exercises. Thousands of tonnes of munitions including HE bombs, artillery projectiles, Naval shells, bulk explosives and infantry weapons such as grenades and small arms ammunition were used in weapon testing and military training. It has been estimated that at least 20 per cent of the UK's land has been used for military training at some point.

Type		Description
No.76 SIP Grenade		No.76 SIP [Self Igniting Phosphorus] grenades. These items, resembling a milk bottle are frequently found during shallow excavations or building demolition and although small in size can inflict life-changing injuries if not dealt with correctly. Found in wooden crates of 24 items.

Type		Description
Hand Grenades	 British No36 'Mills' grenade	Contains a small amount of High Explosive and a rudimentary time delay fuze. The absence of a pin and fly-off handle indicate the item is potentially live. The distinctive segmented [Pineapple] casing gives the fragmentation effect on detonation.

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Small Arms Ammunition

The most common type of ordnance encountered on land formerly used by the military are items of Small Arms Ammunition (SAA). SAA refers to the complete round or cartridge designed to be used with hand-held infantry weapons such as rifles, machine guns and pistols. SAA can include bullets, cartridge cases and primers/caps. Items of SAA can be accidentally initiated by striking the casing or coming into contact with fire. SAA presents only minimal risk although it must be disposed of correctly if found on-site.

Type		Description
Small Arms Ammunition		Small arms of various sizes from 4 or 5mm calibre (diameter) up to 12 to 13mm. Generally, the head is inert and made of lead or similar dense material. Brass cases without the head pose no risk.

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11. Overall UXO Risk Assessment

In establishing the UXO risk at this site, Fellows take the following factors into account:

- The amount and nature of WWI and WWII German aerial bombing
- The nature and conditions of the site during at the time
- Other military use of the site i.e. AA Gun sites, storage, training
- The extent of post-war development and UXO clearance operations on site
- The scope and nature of the proposed works and assessed bomb penetration depth
- The nature of non-aerial ordnance that may have contaminated the site area

Risk Assessment

The risk assessment matrix below is based upon the chance of encountering items of ordnance and the consequence of interaction with them. This can range from the detonation by design (via fuzing and explosive train) of a large aerial bomb to the accidental breakage of old Home Guard glass bottle grenades.

In accordance with standard UK risk assessment methodologies, the overall risk is gained by multiplying the likelihood (chance of encounter) with the consequence (consequence of interaction) and is graded from negligible to Very High risk.

Descriptors

Chance of encounter

1	2	3	4	5
Very Unlikely	Unlikely	Possible	Likely	Very Likely

Consequence of interaction with munition

1	2	3	4	5
No Injuries	Minor injuries	Severe injuries	Fatalities	Multiple Fatalities

Overall risk calculation (Chance of Encounter X Consequence of interaction)

1-5	6-10	11-15	16-20	21-25
Negligible	Low Risk	Moderate Risk	High Risk	Very High Risk

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Aerial bombs

Due to the extent of bomb damage RAF FORD received, the primary risk to this site is considered to be deep buried aerial bombs. The extent of surface change on the site mitigates the risk of shallower buried and on-surface UXO and practice bombs.

AAA Emplacements

There is a risk of buried AA munitions due to the relative softness of the soil in the area. Again, the surface UXO would have likely been cleared due to the extent of change and agricultural usage of much of the site.

Other (Land service Ammunition etc.)

Buried land service munition caches and dumped RAF munitions may be present on the site due to the extended usage of the site during the war period for both homeland defence and training purposes.

There is considered to be a risk of Canadian Pipe Mines on the site. It is common knowledge that southern airfields were mined to prevent use by invading forces and there is very limited evidence of their removal post-war. Pipe mines have been found on many airfields during recent developments, and no clearance appears to have been conducted on Ford Airfield.

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Overall Risk Assessment

ACTIVITY	THREAT ITEM	CHANCE OF ENCOUNTER	CONSEQUENCE	RISK	JUSTIFICATION
Shallow Excavation (<2m) i.e. Trial Pits	HE Bombs	2	5	10	• Significant military usage throughout WWII and years immediately after for training and night raiders. • Surface and immediate subsurface risk mitigated by agricultural use and historic site change following 1950's. • Possible buried caches due to extended military usage. • Possibility of pipe mines
	AAA Shells / IBs	2	4	8	
	Other munitions	3	4	12	
Window Sampling / shallow Bore-holes	HE Bombs	2	5	10	
	AAA Shells / IBs	2	4	8	
	Other munitions	3	4	12	

ACTIVITY	THREAT ITEM	CHANCE OF ENCOUNTER	CONSEQUENCE	RISK	REASONS
Deeper excavations (>2m) i.e. Basement excavations	HE Bombs	3	5	15	• Historic sources indicate major raid which all but destroyed the airfield. • Soft alluvium and chalk will likely allow deeper bomb penetration
	AAA Shells / IBs	3	4	12	
	Other munitions	2	4	8	

ACTIVITY	THREAT ITEM	CHANCE OF ENCOUNTER	CONSEQUENCE	RISK	REASONS
Piling/deep boreholes	HE Bombs	3	5	15	• Piling will reach bombs buried beyond the scope of previous excavation works. • Geology would allow heavier bombs to bury themselves further.
	AAA Shells / IBs		3		
	Other munitions		2		

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12. Recommendations to Reduce UXO Risk to ALARP

The risk of encountering deep buried HE bombs is assessed as medium. The risk of encountering British anti-aircraft munitions and land service ammunition is considered to be low, but not nil. Due to this, the following risk management options are recommended:

For all works within the site area:

A UXO Awareness Brief (UXOAB) be delivered to all site personnel. This can also include a site safety walk-through and provision of a UXO Emergency Response Plan for inclusion into the site HSE documentation.

Ground Investigation (GI) works:

Provision of a UXO Engineer to oversee intrusive GI works to include the use of a magnetometer (downhole scanning) to determine the presence or otherwise, of possible Unexploded Ordnance (UXO) contamination that could compromise any intrusive ground investigation works.

Excavations and shallow intrusive works within the site area:

Provision of an UXO Engineer to oversee shallow intrusive excavation works will reduce the risk of a UXO incident occurring. The UXO Engineer can be on-site to identify any items uncovered during excavation. This can reduce down-time and improve site efficiency.

Piling and deep excavations:

Due to the risk from German aerial bombs at the site, an intrusive magnetometer survey is recommended to assure safety of personnel and equipment during the piling works. This can be in the form of or Cone Penetration Testing (CPT) where load bearing or contiguous piling is planned.

For deep piling, CPT probing should take place to a minimum probe depth of 10m bgl.

Fellows International Limited (Fellows) can provide all of the above services and would be pleased to provide a proposal accordingly.

For further information, or to discuss requirements, please get in touch.

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