

NAVIGATOR QUARTER, LAND ADJACENT TO SOUTHAMPTON AIRPORT

PRELIMINARY SOURCES STUDY REPORT (inc. UXO Report)

HYBRID PLANNING APPLICATION

MARCH 2025

blocwork (Eastleigh) LLP
&
Southampton International Airport Ltd

NAVIGATOR QUARTER

Intelligent Ground Solutions

Preliminary Sources Study Report

Navigator Quarter, Southampton
Mitchell Way, SO50 5QJ

For Blocwork (Eastleigh) LLP and AGS Airports Group Limited

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1.0 Introduction

Geo^2 Limited were commissioned by Blocwork (Eastleigh) LLP and AGS Airports Group Limited to conduct a Preliminary Sources Study Report of a site known as Navigator Quarter, Southampton located off Mitchell Way, SO50 5QJ. The site is approximately 32.62 hectares in area and located at grid reference 445940, 117680.

The study was undertaken prior to proposed redevelopment of a new access road into the site area for a commercial/light industrial end use.

A proposed development of the access road is presented in Appendix A.

1.1 Context and Purpose

The objective of this report is to present geotechnical information with interpretation in accordance with current design standards. This assessment has been completed in accordance with CD622 "Managing Geotechnical Risk".

1.2 Proposed Development

The site currently comprises an access road and disused car parking associated with Southampton International Airport in the west, fallow grassland in the east and northeast separated by a historical railway embankment which is densely vegetated. The area of the project includes the northern most area from Mitchell Way in the west to the central area and is understood to comprise a new access road to the wider site to form a commercial development. The site boundary and scheme development is presented as Drawing 1 within Appendix A.

1.3 Previous Reports

No previous reports are listed on the HAGDMS as the site does not lie within the National Highways boundary.

Geo^2 have produced the following report for the project and proposed wider scheme;

- Preliminary Risk Assessment, Navigator Quarter, Southampton, Ref. 25/4362.A.1, dated 27th February 2025.

In addition, the following third-party report has been obtained from planning records/provided to Geo^2 by the Client for review:

- Geo-Environmental Preliminary Risk Assessment, Southampton Airport, Eastleigh, by WSP, Project No. 70048854, dated August 2019 *[report relates to the site and wider airport];*
- Generic Quantitative Risk Assessment, Southampton Airport, Eastleigh, by WSP, Project No. 70048854, dated September 2019 [*this report relates to land adjacent to the northern area and the central northern area of the site];*

- Environmental Statement Chapter 12: Ground Conditions, Southampton International Airport Eastleigh, by Savills dated July 2020 *[report relates to the site and wider airport];*
- Factual Ground Investigation Report, Southampton International Airport Runway Extension, by Southern Testing, Ref. J14044, dated May 2020, Issue No. 7 *[this report relates to land adjacent to the northern area and the central northern area of the site];*
- Groundwater Monitoring Results January 2015 to September *2023 [relates to water monitoring in the central northern area of the site]*; and
- Phase II Land Quality Assessment for runway extension, Southampton Airport, by H Fraser Consulting, Ref. 30691R2, dated January 2023 *[this report relates to land adjacent to the northern area and the central northern area of the site].*

1.4 Limitations

The assessment is limited to the issues agreed within the proposal for the works. General notes on limitations associated with this assessment are provided in Appendix F.

Given the adjacent international airport here are a number of working restrictions which will affect the scheme and proposed ground investigation. In addition, limitations including the presence of a high-pressure gas main through the northern area and the dense vegetation and trees.

1.5 Geotechnical Category of Project

Using the guidance in standard CD622 and standard BS EN 1997-1:2014+A1:2013, the scheme has been assigned to Geotechnical Category 2. This is due to the potential for earthworks and slopes/retaining features likely to be required given the existing airport constraints. Some information exists for ground conditions in the area of the project, however, it is not available along the full route of the proposed highway.

2.0 Sources of Information

2.1 Sources of Information

The information sources and documents consulted in the preparation of this Preliminary Sources Study Report are summarised in the table below:

Information Type	Title/ Source	Comments (if relevant)
Geological	British Geological Survey	BGS Borehole Viewer – Borehole scans of previous ground investigations. BGS Onshore Geoindex– Digital map viewer of digitised geological mapping (various scales). BGS Geological Memoirs; - Geological history of the region, and information regarding geological units.
Environment	Environment Agency https://environment.data.gov.uk/appgallery https://magic.defra.gov.uk/MagicMap.html Envirocheck Environmental Database	Online data of environmental data for the project including landfills, flooding and environmental designations such as Sites of Special Scientific Interest (SSSI's), Areas of Outstanding Natural Beauty (AONB).
Historical Information	Historic England https://historicengland.org.uk/listing/the-list/map-search?clearresults=true Envirocheck Environmental Database	Online data for any historical information that may impact the project. Review of historical maps for the site.
Mining	Mining Remediation Authority https://datamine-cauk.hub.arcgis.com/ Envirocheck Environmental Database	Online data of any mining issues that may impact the project. A specific mining search report may be acquired if necessary. BGS onshore Geoindex also consulted for other forms of mining/quarrying which may affect the site.
GIS	Google Maps/ Google Earth https://maps.app.goo.gl/kRMDJruJjFyjE32W6	Shows current and past visual assessment of the project location

GIS	HAGDMS GDMS	Geotechnical Asset Data – Information regarding any earthworks affected by the scheme. Geosure layers – Data regarding geohazards such as shrink-swell, high plasticity soils, dissolution features.
Reports	Previous Geo² and 3rd Party Reports	Previous reports listed in Section 1.3.
Utilities	Lineseachbeforeudig https://lsbud.co.uk/	Online information on utilities that may impact the project.

2.2 Site Information

Information Type	Discussion
Site Address and Location	Navigator Quarter, Southampton located off Mitchell Way, SO50 5QJ. Google Maps Link A Site Location Map is included as Appendix A. The site is located approximately 6 km north of Southampton city centre.
Coordinates and area	The site is approximately 32.62 hectares in area and located at grid reference 445368, 117814 to 446238, 117811.
Site Description	The site currently comprises an access road and disused car parking associated with Southampton International Airport in the west, fallow grassland in the east and northeast separated by a historical railway embankment which is densely vegetated. Infrastructure (blast barriers and approach lighting) associated with the adjacent runway are present in the north and southeast of the site. The site is access through the car parking in the northwest and via a bridge beneath the railway line along the northeastern boundary.
Description of Adjacent and Surrounding Land	A rail yard, commercial properties and residential housing to the northwest. Sewage treatment works to the northwest and agricultural land beyond in the north. River Itchen and Itchen Valley Country Park in the east. Southampton airport to the southwest. Itchen Valley Country Park and the River Itchen to the southeast. Residential properties beyond the A335 west of the site.

Information Type	Discussion
Aerial Photography	 Plate 1: Site Location Plan. Site boundary in red Contains © Crown Copyright and Database Right 2024

2.3 Physical Setting

Information Type	Discussion
Topography	The site's topography is relatively flat between 10.00 and 15.00 m AOD. A vegetated embankment is located in the central area running in an east and west orientation which is approximately 3.0 m higher than the surrounding fields.
Published Geology	British Geological Survey (BGS) data indicates that the site is underlain by superficial River Terrace Deposits (Clay and Silt) followed by bedrock of the London Clay Formation in the east and the Wittering Formation in the west. Artificial ground is mapped along the northeast of the site, likely associated with the raised railway embankment along the site boundary in this area. Superficial Alluvium is mapped to the east of the site associated with the River Itchen, which may encroach onto site.
Site Specific Geology	BGS boreholes Ref. SU41NE230 is located along the western boundary of the site, drilled in 1969. The ground conditions recorded comprised superficial clay, sand and gravel to c. 5.30 m bgl followed by clay and sand of the London Clay Formation to completion at 30.50 m bgl. Resting groundwater was identified at c. 3.00 m bgl. There are two further BGS boreholes (Ref. SU41NE277 and SU41NE109) located <50.00 m from the southeastern boundary of the site. The ground conditions in these locations includes soft clay and peat at shallow depths (<2.00 m) followed by gravel and sand to c. 4.50 m bgl and firm to stiff bedrock clay below. The geological map (1:10,000 scale) shows the inferred boundary line between the London Clay Formation and the Wittering Formation through the centre of the site in a north to south direction. This map is shown in Plate 2 below.

Information Type	Discussion
	 Plate 2: BGS Geological Map SU41NE (1:10,000 scale). Site boundary in red.
Hydrology	Drainage ditches are present along the northern central boundary and along the southern boundary. In the wider area there are several tributaries of the River Itchen located to the east and south of the site. At its closest the river is approximately 170 m east. According to the Envirocheck Report there are three licensed abstractions from surface waters located approximately 50 m east relating to abstraction for use in transport. The Environment Agency Flood Map for Planning shows the entire site to be within Zone 1 and has a low probability of flooding from rivers and the sea.
Hydrogeology	The Environment Agency (EA) classify the superficial River Terrace Deposits as a Secondary (Undifferentiated) Aquifer and the Wittering Formation and Alluvium as Secondary A Aquifers. The London Clay Formation is classified as Unproductive Strata. The site is not located within a groundwater source protection zone (SPZ). According to the Envirocheck Report there are no licensed groundwater abstractions within 1 km of the site.
Groundwater levels	Historic intrusive logs from previous report by Southern Testing (Ref.J14044), dated May 2020, recorded groundwater during drilling at depths ranging between 4.00 and 5.00 m bgl with subsequent groundwater monitoring over the following year at depths ranging between 3.47 and 4.24 m bgl (10.26 and 9.49 m AOD).
Mining and Quarrying	There are two BGS Recorded Mineral Sites located in the northwest and southeast corner of the site. Both entries related to opencast quarrying of superficial sand and gravel and the operations are noted as ceased. The northwestern quarry is known to be infilled. The site is not within an area which may be affected by coal or other forms of mining activity, therefore the risk to the proposed development from shallow underground mining is considered to be Low.

Information Type	Discussion
Ground Stability Hazard	The Envirocheck report shows the site has the following risk ratings associated with these ground stability hazards: • Collapsible ground stability – *low to very low risk;* • Compressible ground stability – *moderate to very low risk;* • Ground dissolution – *very low risk;* • Landslide ground stability hazard – *very low risk;* • Running sands stability hazard – *low to very low risk; and,* • Shrinking or swelling clay stability hazard – *moderate to very low risk*. The BGS GeoClimateUKCP09 data indicate that it is 'improbable' that foundations will be affected by increased clay shrink-swell due to climate change for 2030, 2050 and 2080. The wider area of the site is classed as possible and probable.
Drainage	The anticipated ground model at the site comprises granular River Terrace Deposits which includes lenses of cohesive strata, which in turn are underlain by bedrock of the London Clay Formation and the Wittering Formation. Granular River Terrace Deposits are typically a suitable receptor for infiltration-based methodologies of drainage. However, the presence and extent of cohesive strata, shallow groundwater and depth of bedrock may locally affect the feasibility of infiltration-based drainage.
Archaeology	Historic England Records (historicengland.org.uk) indicate that no areas of designated heritage interest are located on or adjacent to the site.

2.4 Historical Development

2.4.1 Approach

The historical development of the site and surrounding area has been assessed through a review of available historical maps, aerial photographs, internet sources, previous reports and Google Earth historical satellite imagery. A summary of the key historical site uses and developments in the surrounding area is presented below. A copy of the historical maps is presented in Appendix D.

2.4.2 Historical Information Review

From the earliest map edition dated 1871 the majority of the site comprised undeveloped agricultural land. North Stoneham Farm comprising numerous buildings is mapped in the southern corner of the site. A railway line was also present along the northeastern boundary. Allotment gardens are mapped in the northwestern corner from 1896. By the 1911 map edition two gravel pits are shown, one in the northwest and the other adjacent to the farm in the south. A railway line is also mapped along the northeastern boundary and dissecting through the northern area of the site in an east-west orientation. The railway line is noted on a raised embankment. Further development of the railway is noted in the 1931 map edition in the form of a spur in the northeast. Further allotment gardens are shown in the central northern area

adjacent to the railway embankment from the 1951 to 1968 map editions. The railway line is also noted to be disused by the 1963 map edition.

Development of North Stoneham Farm including a number of huts is shown in the 1931 map edition, aerial imagery dated 1947 and 1963. From readily available online information it is understood that the wider area has been in use as an airfield/airport since 1910, originally known as Eastleigh Airfield. The area was then used by the United States during WWI and by the RAF in WWII with the area known as RAF Eastleigh before becoming RAF Southampton and later RNAS Eastleigh (HMS Raven) as a training ground form the Royal Navy. The buildings shown in the 1930-60's mapping are considered to relate to the airfield use, likely huts/barracks for housing military personal. The buildings are no longer shown by the 1963 map edition and the original buildings associated with North Stoneham Farm remain until their demolition in the early 1990's.

Airport infrastructure comprising approach lights in the northwest and a tower in the southeast are shown in then 1991 and 1992 map editions. Modern development comprising present day car parks in the northwest are shown by the 1995 map edition and 2005 aerial imagery. No further significant changes are noted.

Within the surrounding 250 m potential contaminative land uses include;

- Railway lines to the west and north from the earliest map edition dated 1871 until present. Further sidings, a rail yard and running shed are noted directly north by the 1911 map edition with further development noted in the early 1930's and late 1960's. A series of tanks are noted approximately 30 m north of the site in the central northern area associated with the rail yard in the 1972 map edition;
- A sewage works located approximately 200 m north from the 1887;
- A series of gravel and clay pits in the surrounding area to the northeast and northwest in early 1900 map editions;
- Allotment gardens to the north from 1909 until present and northwest from 1963 until no longer mapped in 1983; and,
- Southampton airport mapped from 1963 onwards with the runway noted within 250 m of the site in 1983 mapping.

2.5 Services

A package of service plans has been provided by the Client for review and obtained from Linesearch which are included in Appendix E, a summary of the utility review can be seen below:

Provider	Present on Site/Comments
Scottish & Southern Electricity Networks	Fibre optic cables are present in the northeastern area of the site in a west to east direction. A low voltage main is also present from the northern boundary of site that runs towards the radar point located in the eastern area of the site.
Southern Water	A clean water main is located in the northeastern area. A rising foul main also runs through the northwestern area of the site. It is understood that as part of the runway extension the foul main was diverted and now runs below the access road to the north of the runway before rejoining the original pipe which exits the site in the central northern area.
SGN	A high-pressure gas main runs through the central area of the site adjacent to the embankment and then cuts across the western area. This gas main will require diverting as part of the proposed scheme.
BT Openreach	Telecoms cuts through the site in the northwestern area through the car park towards the runway and a further cable runs from the central north to the radar tower in the east.
Private Services	The Client has provided a utilities survey for the site which includes the presence of surface water drainage in the northwest and electrical services in the northern area of the site relating to runway approach lighting.

2.6 Existing Information

The following reports have been made available, as summarised in the table below:

Title	Type	Publication Date	Author
Provided by the client			
Factual Ground Investigation Report, Southampton International Airport Runway Extension	Report	May 2020	Southern Testing

Groundwater Monitoring Results	Data	January 2015 to September 2023	Ricardo Energy and Environment
Preliminary Risk Assessment	Report	February 2025	Geo^2
Third-party reports associated with planning reference F/19/86707			
Geo-Environmental Preliminary Risk Assessment, Southampton Airport, Eastleigh	Report	August 2019	WSP
Generic Quantitative Risk Assessment, Southampton Airport, Eastleigh	Report	September 2019	WSP
Environmental Statement Chapter 12: Ground Conditions, Southampton International Airport, Eastleigh	Statement	July 2020	Savills
Phase ll Land Quality Assessment for runway extension, Southampton Airport	Report	January 2023	H Fraser Consulting

Further third-party reports are referenced within the WSP Preliminary Risk Assessment and Environmental Statement Chapter, however, these reports have not been made available to Geo^2. A review of the available third-party reports is provided for information purposes only.

A review of the National Highways GDMS online portal has not highlighted any reports or data on site or within the vicinity of the site.

2.6.1 Report Review

Geo-Environmental Preliminary Risk Assessment, WSP, August 2019

WSP undertook a Preliminary Risk Assessment for Southampton Airport in 2019 to support a runway extension in the north. The red line boundary includes the majority of the current target site with the exception of the northeastern field. Pertinent information related to the target site is included below.

Within this report, reference is made to the previous ground investigation by WSP in February 2004 (*Geo^2 has not been provided with a copy of this report for review).* The following information from the WSP summary of this reports is provided. The ground investigation was undertaken in the northeast corner of the site. The geology encountered comprised brickearth (soft to firm, light brown, slightly sandy clay to a maximum depth of 1.70 m bgl underlain by the River Terrace Deposits (medium-dense, fine to coarse, sandy and occasional clayey flint

and chalk gravels) to a maximum depth of 5.00 m bgl, underlain by the bedrock of the Wittering Formation (soft to firm, dark grey sandy clay). The depth of the Wittering Formation was not proven.

No geotechnical hazards were identified within the report. However, it was recommended characterisation of ground material should be undertaken within proposed development areas for material disposal design. Groundwater levels may be shallower nearer the eastern site boundary and should be considered during geotechnical design.

Generic Quantitative Risk Assessment Report, WSP, dated September 2019 & Factual Ground Investigation Report, Southern Testing, May 2020

WSP undertook a Generic Quantitative Risk Assessment utilising initial data from the Southern Testing Ground Investigation (dated June 2019 at the time of the report preparation). *These reports relate to the land adjacent to the northern area and central northern area of the site.* The ground investigation works comprised the advancement of 8 No. trial pits, 3 No. BRE365 tests and 2 No. cable percussion boreholes. The works were undertaken airside to the north and east of the runway.

The ground conditions comprised a limited thickness of topsoil followed by firm to stiff silty sandy clays becoming gravelly with depth to c. 1.90 m bgl followed by medium dense gravelly sands/sandy gravels to c. 3.70 m bgl and fissured sandy silty clays of the London Clay Formation at depth. Groundwater strikes were identified at depth in the London Clay within the boreholes and standing water at c. 4.00 – 5.00 m bgl at the start of each shift. Return groundwater monitoring over the following year recorded groundwater at depths between 3.47 m bgl and 4.24 m bgl (10.26 m AOD to 9.49 m AOD).

The granular River Terrace Deposits recorded corrected SPT N values between 15 and 46 representing medium-dense and dense soils and the London Clay Formation recorded corrected SPT N_{60} values between 19 and 56 representing firm to stiff soils.

The undrained shear strength values ranged between 26 and 203 kPa at depths between 6.50 and 19.50 within the London Clay Formation. Hand Shear vanes were recorded that ranged between 55 and 135 kPa at depths between 0.30 and 1.00 m bgl within the cohesive River Terrace Deposits.

Southern Testing recorded a mean soil infiltration test as 3.02×10^{-4} m/s within the granular River Terrace Deposits. The CBR values ranged between 1.7 and 3.6 % within the River Terrace Deposits at 1.00 m bgl.

From review of the geochemical results of water-soluble sulphate, pH and total sulphur within each soil sample, testing has indicated a Design Sulphate Class of DS-1 and an Aggressive Chemical Environment for Concrete (ACEC) Classification of AC-1 would be appropriate for all buried concrete structures within the River Terrace Deposits.

Environmental Statement: Chapter 12: Ground Conditions, Savills, July 2020

The Environmental Statement uses the previous WSP reports to provide the baseline conditions for the site and assess the impacts and effects from the development. Given significant contamination was not identified during the ground investigation and the proposed development comprised a runway extension only, the potential impacts to ground conditions were considered to be negligible with consideration to the embedded mitigation measures as part of current best practice.

Phase II Land Quality Assessment for runway extension, H Fraser Consulting, January 2023

H Fraser Consulting undertook a further ground investigation along the northern runway area in 2022 to support the planning application for the runway extension. The ground investigation comprised the advancement of 10 No. shallow boreholes to depths between 3.00 – 4.00 m bgl and 9 No. shallow hand dug pits to a maximum depth of 1.00 m bgl.

The ground conditions generally composed a limited thickness of topsoil followed by a sandy gravelly clays and gravel at depth. Groundwater was identified during drilling between 3.00 - 3.50 m bgl. However, the wells were all noted to be dry upon return monitoring. A strong hydrocarbon odour was noted in the northeastern area (BH208) between 2.70 m bgl and 3.00 m bgl.

The cohesive River Terrace Deposits recorded SPT N values between 3 and 21 representing soft and firm soils and the granular River Terrace Deposits recorded SPT N values between 16 and 86 representing medium-dense and very dense soils.

Groundwater Monitoring Results January 2015 to September 2023

The Client has provided monitoring data for the central northern area of the site, undertaken by Ricardo Energy and Environment from January 2015 to September 2023. There is limited information available, however, the boreholes are understood to be in use for the monitoring of hydrocarbon contamination known to be migrating from the adjacent rail yard.

Groundwater has been recorded at depths between 0.772 m bgl and 4.825 m bgl (3.163m AOD to 10.770 m AOD). No logs or geotechnical testing data is provided.

Most recent monitoring results from March and September 2023 indicate the presence of free product (up to 15 mm in thickness in borehole F2 close to the northwestern corner of the northeastern field) and elevated Total TPH concentrations at a maximum of 1,244,385 µg/l in F2 from groundwater collected using disposable bailers. The locations of the boreholes and photographs of the groundwater sampled from these locations is shown below in Figure B:



Figure B: Image sent to the Client by Ricardo Energy and Environment

2.6.2 As-built Drawings

As built drawings have been made available for the diverted foul main sewer in the northwestern area of the site. No further as-built drawings are available.

2.7 Man-made Features

In addition to the existing car parking, highway (Mitchell Way), former rail embankment and underground services, runway approach lights are present along the northern boundary of the site and a radar tower is present in the east.

2.8 Contaminated land/Other Statutory Consultations

From information within the previous Geo^2 report, a historical landfill is present in the northwestern area associated with the backfilling of the former gravel pit. Details indicate that the licence was held by British Rail and deposited waste included household materials. No further pertinent information is supplied.

An area of Special Scientific Interest is listed on-site, however, is considered to relate to the River Itchen and surrounding land which is also classified as a Special Area of Conservation.

The Contaminated Land Officer (CLO) was contacted to enquire into information on the site and immediate surrounding area as well as enquiring into whether the site is on their list for inspection on the basis of the historical use of the site. The response confirms that the site nor any property /land adjoining has been classified as Contaminated Land under Part 2A.

2.9 Unexploded Ordnance

A review of Zetica online risk mapping for the area indicates that the site is located in a Moderate risk area, with Southampton Airport listed as a Luftwaffe target.

A Detailed Explosive Ordnance Risk Assessment has been undertaken for the site by Impartial Assessments which concludes that Explosive Ordnance poses a Low Risk and a Moderate Risk in the northern and northeastern area of the site to proposed ground investigation and the development. A copy of the Detailed Explosive Risk Assessment is presented as Appendix B.

3.0 Site Reconnaissance

3.1 Description of Site Walkover

Geo^2 undertook a site walkover on 16th January 2025, with a photographic survey included in Appendix C. The site walkover findings are detailed below.

The site is accessed via Mitchell Way in the northwestern corner. Mitchel Way leads to a tarmac car park and a mixed gravel and tarmac car park in the most northwest corner of the site. An area of disused grass land was also noted adjacent to the car parks with sporadic fragments of concrete and metal noted on the surface.

The site wraps around the northern extent of Southampton Airport runway comprising a gravel track and densely vegetated bund. Runway approach lights were noted adjacent to the site in this area. The site is separated from the runway and associated areas by a c. 2.50 m metal wire fence.

The majority of the site comprised vacant grassland separated by a densely vegetated embankment in the central area running in an east to west orientation. This embankment is considered to represent the former railway line. Concrete blocks and metal fragments were noted in the material of the embankment where bare ground could be seen. Access to the northeastern field was via foot over the embankment or via a metal gate along the northern boundary. The northern access was noted to be flooded at the time of the walkover by c. 0.4 m of water. The track off-site to the north passed beneath the railway line via a brick tunnel.

Further airport infrastructure was noted in the larger southern field comprising a radar station and windsock flagpoles. In addition, a series of third-party boreholes were noted in the northern central area, which are understood to relate to the investigation of off-site hydrocarbon migration from the adjacent railway yard.

The remains of former buildings could be seen in the most southern area of the site comprising remnant brick walls and concrete floors with rubble, engines, metal and corrugated sheeting. No evidence of asbestos containing materials was noted, however, the area was densely vegetated as such, the potential cannot be discounted.

An above ground storage tank was noted off-site adjacent to the central northern area of the site.

The site was bounded by the airport in the east and largely by vegetation, hedgerow and trees along the eastern and northern boundaries.

3.2 Recent Geotechnical Data

No quantitative geotechnical data directly relevant to the proposed development is available.

3.3 Other Field Surveys

The client has provided archaeological and ecological reports relating to the runway extension adjacent to the north. No reports have been made available to Geo^2 for the current site boundary.

4.0 Ground Conditions

4.1 Introduction

The following ground conditions have been assessed utilising available information within the previous third-party reports. Although there are a number of boreholes located on-site in the central northern area for groundwater monitoring, no borehole data has been made available.

4.2 Ground Model

The ground conditions underlying the proposed development area have been recorded by the BGS as superficial River Terrace Deposits (clay, silt, sand and gravel) which directly overlie solid bedrock geology of the London Clay Formation (clay, silt and sand) in the east and the Wittering Formation (clay, silt and sand) in the west.

No other linear features such as faults, artificial ground, mass movement or active mining works have been identified within the vicinity of the site.

Based upon desk-based research and historical ground investigation data where appropriate, the following preliminary ground model has been compiled:

Stratum	Typical Description	Depth to Base (m bgl)	Max. Thickness (m)	Comments (If relevant)
Topsoil	Sandy silt/clay.	Unknown – anticipated to be limited in thickness		-
Made Ground	Unknown	Unknown		*No data known – assumed to be present in developed areas and within former rail embankment.*
River Terrace Deposits	Soft to firm sandy/gravelly clays and silt	0.70 – 1.80	~1.70	*Observed in third-party reports*
	Clayey gravel becoming sandy gravel with depth	~5.30	>2.60	*Observed in BGS historic borehole (Ref. SU41NE230) and third-party reports*
Wittering Formation	Clay and sands.	Unknown	*Unknown*	*Observed BGS maps and previous third-party report. Mapped across the eastern*

	Soft to firm dark grey sandy clay.			*area only, overlying the London Clay.*
London Clay Formation	Firm becoming stiff fissure clay.	>30.50	*Not proven*	*Observed in the BGS historical borehole (Ref. SU41NE230) along the western boundary of the site.*

4.3 Contaminated Land and Ground Gas Assessment

Potential sources of contamination have been identified associated with the historical use of the site as an airfield, the adjacent rail depot and siding across the central area and the known hydrocarbon contamination migrating from the north onto site via groundwater. No recent ground gas data is available.

5.0 Preliminary Engineering Assessment

5.1 Design Implications of Each Soil Type

The design implications of soil compositions most likely to be encountered across the proposed development area have been summarised below. Topsoil has been omitted from the assessment below given its likely unsuitability as an engineering material.

5.1.1 Made Ground

The site comprises a road and car parking area in the northwestern area of the site. Subsequently, there is likely macadam surfacing, subgrade and reworked/engineered natural soils present placed to form the current landform. A historic gravel quarry is also mapped in the northwestern area of the site known to have been used as a historical landfill.

The former rail embankment across the central area is noted to be c. 3.00 m in height and comprised of unknown fill materials.

Made Ground is typically variable in nature and strength with a potentially low bearing capacity, high compressibility and unacceptable levels of total/differential settlement may occur under load.

5.1.2 River Terrace Deposits

The natural superficial materials have been identified within third-party reports and BGS boreholes in the wider area. The materials are generally initially soft and cohesive in nature with SPT N values of <10. The materials become more granular with depth grading to gravels at c. 2.50 m bgl.

Sands and gravels may offer favourable geotechnical properties regarding bearing capacity, though this will ultimately depend on the density profile of the stratum. Previous third-party results adjacent to the northern area of the site recorded SPT N values between 15 and 46 within the granular materials and undrained shear strengths (using hand vanes) of between 55 and 135 kPa at depths between 0.30 and 1.00 m bgl within the cohesive materials. As such, it would be anticipated that the granular materials would provide sufficient bearing capacity for sub-structures. Settlement is also likely to be immediate within the granular materials, however, will be dependent on the depth to the London Clay below in conjunction with any earthworks cut or fill.

Given the granular nature of the formation the materials may also be suitable as a drainage stratum.

5.1.3 London Clay Formation

Clay, silt and sand associated with the London Clay Formation are mapped in the western area of the site and are likely to be variable in strength depending on their weathering

status. At shallower depths there may be increased weathering whereby the deposits behave as a medium strength clay with associated increased volume change potential. Previous third-party reports adjacent to the north of the site recorded SPT N values between 19 and 56 within the London Clay Formation. Moreover, the report recorded undrained shear strength values ranged between 26 and 203 kPa at depths between 6.50 and 19.50 m bgl.

The generally cohesive nature of the materials would likely not be suitable for use as a drainage stratum.

5.1.4 Wittering Formation

Clay, silt and sand associated with the Wittering Formation are mapped in the eastern area of the site. As above, the strength of the material is likely dependent on the weathering status. The Wittering Formation is noted to lie above the London Clay Formation stratigraphically, as such, may be limited in thickness and difficult to identify given the proximity of the boundary and similarity in composition (clay, silt and sand).

The generally cohesive nature of the materials would likely not be suitable for use as a drainage stratum.

5.2 Groundwater

Based on previous third-party report by WSP dated 2019 (Ref. 70048854), groundwater strikes were identified at depth in the London Clay within the boreholes and standing water at c. 4.00 – 5.00 m bgl at the start of each shift. Return groundwater monitoring over the following year recorded groundwater at depths between 3.47 m bgl and 4.24 m bgl (10.26 m AOD to 9.49 m AOD) within the River Terrace Deposits.

Furthermore, the Phase ll report by H Fraser Consulting, dated 2023 (Ref. 30681R2) recorded groundwater during drilling between 3.00 - 3.50 m bgl. However, the wells were all noted to be dry upon return monitoring.

A comprehensive period of monitoring is required to assess the groundwater levels at the site.

5.3 Earthworks

It is anticipated that some degree of excavation will be required as part of the proposed development although significant earthworks for large scale cut/fill operations are not anticipated. No information such as a specification or geometry of proposed earthworks has been provided/is available at this stage though it is understood levels will be decreased in the proximity of the end of the airport runway so the proposed access road is appropriate for height restrictions. The proposed access road is located across the existing embankment in the northeastern area of the site therefore, a cut of the embankment would be anticipated as part of the proposed development.

5.4 Cuttings & Embankments

As above, due to the proposed access road bending across the embankment some degree of cutting would be anticipated with associate slopes and/or retaining structures required. A ground investigation would be required to assess the ground conditions within the embankment and the suitability for engineering re-use on site.

5.5 Subgrade

A detailed ground investigation will be required to determine the subgrade characteristics for use in design. Should the strata be unsuitable for use as subgrade materials an imported capping layer would be required.

5.6 Geochemistry

No site-specific geochemical data has been found or made available. An environmental investigation will be required to assess the potential for aggressive ground conditions.

5.7 Existing Geotechnical Risk

Below is a summary of geotechnical risks that have been identified relevant to the Site and project:

- Utility Services – There are high pressure gas main, foul, electric and telecom utilities are present on site. This will need to be taken in to account during the design of the new highways infrastructure.
- Contamination – Potential sources of on-site contamination have been identified associated with historical mineral extraction and subsequent landfilling in the northwest, the historical farm, mineral extraction and RAF/military use of the southern area of the site, railway embankment in the central area and development of airport infrastructure including car parks, radar towers and blast screens. Hydrocarbons are known to be present in groundwater in the central north migrating from the rail yard to the north. The project will also require the removal of former rail embankments, the contents of which are unknown;
- Ground and groundwater conditions – Whilst previous desk studies and site investigations has been carried out across parts of the site, it is not specific to the proposed development therefore gaps in the data may exist. Using out of date or incomplete information may result in inappropriate design;
- Earthworks, slopes and soil retention– No information regarding the geometry of the proposed earthworks is currently available, however, given the varying site levels and height restrictions associated with the runway, it is anticipated that excavation and filling works potentially including slopes and soil retention will be required to suit the new road alignment;

- Quarrying: A former pit is noted on historical mapping in the northwest area of the site. The northwestern pit is recorded to have been landfilled. Fill materials are typically variable in nature and strength with a potentially low bearing capacity and unacceptable levels of total/differential settlement may occur;
- Unexploded Ordnance – A Detailed Unexploded Ordnance Assessment has been undertaken for the site which indicates that the project crosses areas of low to moderate risk. Remedial health and safety measures will be required during construction; and
- Ecological Constraints – It is unclear at this stage whether any burrows, nests or significant trees and their root system are present at the project location. Appropriate ecological surveys should be carried out to identify any potential ecological risks.

5.8 Effects of Man-Made Obstructions/ Mining/ Site History

There are two BGS Recorded Mineral Sites located in the northwest and southeast corner of the site. Both entries related to opencast quarrying of superficial sand and gravel and the operations are noted as ceased. The quarry in the northwest is known to have been backfilled as a landfill.

The site is not within an area which may be affected by coal mining or other underground mineral extraction activity, therefore the risk to the proposed development from shallow mining is considered to be Low.

Underground services are known to be present in the area of the proposed new highway, most notably a high-pressure gas main. It is understood that the gas main will require diverting as part of the works.

6.0 Comparison of Project Options and Risks

6.1 Factors Likely to Influence the Project

Based on the information reviewed in the PSSR, the factors that are likely to influence the project from a geotechnical perspective are listed in the table below.

Item	Factor	Impact
Ground Conditions	No site-specific data is available. Third-party reports are localised to the central area only.	A lack of confidence in the ground conditions beneath site, specific geotechnical data is not available and thus creates uncertainty in design suitability
Earthworks, slopes and soil retention	Existing materials may be unsuitable for re-use.	Ground investigation and material testing may be required to assess suitability for subgrade and/or re-use. Import/export of material may be required to facilitate development levels.
Contamination	Potential sources of contamination have been identified associated with the rail yard to the north and the wider airport. Hydrocarbon contamination is known to be migrating onto site from the rail yard.	Contamination may have health and safety implications for construction workers. An environmental investigation will be required to assess the groundwater quality beneath the site and the risk to future site users and controlled waters, and determine if remediation is required.
Sulphates	No site-specific test data is currently available to determine the ground geochemistry.	Inadequate design sulphate class may lead to attack on buried concrete and deterioration of foundations. Sulphates may also affect the type of ground stabilisation methods used, if required. Ground investigation is required to obtain site specific geochemical data to determine assumptions from the surrounding area.
Groundwater	Historic intrusive logs from previous report by Southern Testing (Ref.J14044), dated May 2020, recorded groundwater during drilling at depths ranging between 4.00 and 5.00 m bgl	May lead to lowering of geotechnical parameters if encountered along with groundwater control measures being required for temporary works. A high groundwater table

	with subsequent groundwater monitoring over the following year at depths ranging between 3.47 and 4.24 m bgl (10.26 and 9.49 m AOD).	may preclude the option for infiltration based drainage.
Existing services	Existing services including high pressure gas main, telecoms, fibre optic, low voltage main and water & foul mains have been identified provided by the client. Residual risk of otherwise undetected below ground utilities.	May present significant constraint to the design/construction and may need to be relocated.
Ecological Constraints	Existing trees and wildlife may be present on the Site.	Potential damage to the environment. Site specific assessment will be required.
UXO	Potential for unexploded ordnance to be identified.	Health and safety risk. Recommendations within the Detailed UXO Risk Assessment should be followed.

6.2 Geotechnical Risk Register

The following scoring system used in the risk register is provided in the tables below.

Probability	**(P)**		**Impact**	**(I)**		**(R)**	**Risk**	**Risk Rating**
Almost Certain	5		Catastrophic	5		20-25	Severe	Critical. Risk must be addressed.
Extremely Likely	4	X	Major	4	=	25-19	Substantial	Intolerable and work must not start on the project until risk has been reduced, project should not proceed.
Likely	3		Serious	3		10-14	Moderate	Substantial and work must not start until risk has been reduced.

Unlikely	2	Moderate	2	5-9	Minor	Significant but tolerable. Must consider improvements.
Extremely Unlikely	1	Minor	1	1-4	Negligible	Trivial, but no action required.

Navigator Quarter, Southampton: Preliminary Sources Study Report

Hazard	Risk Description	Consequence	Risk Rating Before Control			Risk Management Measures	Risk Rating After Control		
			P	I	R		P	I	R
Ground Model	Ground conditions not as anticipated from review of BGS boreholes and previous reports.	Destabilise earthworks, inadequate foundation/pavement design. Risks to cost & programme	3	3	9	Undertake ground investigation to confirm ground model, Use of moderately conservative values in design. Use site specific data in design of geotechnical structures.	3	2	6
	Soft compressible materials associated within infilled pit in the northwestern area.	Potential for poor ground conditions to be encountered and to change over relatively short distances.	3	3	9	Undertake ground investigation at sufficient spacing to assess potential variability of soils to confirm ground model along the alignment of the scheme. Use site specific data in design of geotechnical structures.	3	2	6
Changes in level	Potential requirement for soil removal along the northern boundary of the site.	Need for removal of soils for the proposed access road. Risks to cost, programme and health and safety (unknown material composition)	3	3	9	To be assessed through a ground investigation.	3	2	6

Hazard	Risk Description	Consequence	Risk Rating Before Control			Risk Management Measures	Risk Rating After Control		
			P	I	R		P	I	R
	Requirement for soil retention or slopes may be required.	Slope/Retaining structures may be required. Structures will require appropriate design.	3	3	9	Review final earthworks levels when known to determine if slopes/retaining features are required. Any required Earthworks/slopes will be designed at initial 1:3 gradients. Exact nature of the earthworks proposed will require review with the wider project team prior to the scoping of ground investigation. Detailed design of slopes, earthworks and retaining structures required to be based on available ground investigation.	3	2	6
Utilities	Several third-party utilities have been identified on site including a high pressure gas main, electric, telecoms and sewerage.	Utilities require identifying prior to ground investigation. Risk to cost and project timescales if utilities require diversion.	5	5	25	Utilities plans to be reviewed prior to any intrusive investigation. Detailed utilities survey to be undertaken prior to breaking ground. Design to account for diversion and protection of utilities as required.	3	2	6
Contaminated land	Hydrocarbons in the groundwater in the northern central area associated with the off-site migration from rail yard.	Risk of ill health to workers and buried concrete. Risk to costs if sulphate resistant concrete required for substructures. Risk to groundwater and surface waters to the east	3	4	12	Risk to be determined through ground investigation. Remedial measures may be required for soil and or groundwater. Good hygiene practices to be observed during construction	3	2	6
	Aggressive in ground geo-chemistry	Risk to costs if sulphate resistant concrete required for substructures.	3	2	6	To be assessed as part of future ground investigation to determine a suitable concrete grade and classifications	2	2	4

Hazard	Risk Description	Consequence	Risk Rating Before Control			Risk Management Measures	Risk Rating After Control		
			P	I	R		P	I	R
Groundwater	Depth to groundwater may be within excavation depth of earthworks or foundations	Additional costs of project due to foundation depth, earthworks, temporary works or inadequate design. Time delays	2	4	8	Complete ground investigation to understand groundwater conditions.	2	2	4
Drainage	Risk of unsuitable soils and/or high groundwater table precluding the use of drainage to land	Additional costs of project due to drainage design	3	2	6	Complete ground investigation to understand ground and groundwater conditions.	2	2	4
Ecology/ Environmental Issues	Vegetation clearance may be required prior to ground investigation or any construction phase works	Delays to project if ecological works required. Possible impact on foundation design if trees remain/removed or new planting proposed	2	4	8	Environmental considerations already discussed in wider project team reports. Recommendations detail in reports to be followed prior to and during construction. Ground investigation designed accordingly	2	2	4

6.3 Preferred Routes/Options

At the time of writing, other route options were not made available for Geo^2.

7.0 Ground Investigation Scope Report

7.1 Objectives

The objective of the proposed ground investigation is to provide contamination and geotechnical information to inform design criteria. The scope of the intrusive investigation has been specified by the Clients Engineer and revised following a walkover and liaison with the airport to understand site constraints;

- Confirm the anticipated ground model beneath site, particularly regarding the depth to bedrock and presence of any soft/loose materials within the River Terrace Deposits. *Given constraints associated with the adjacent runway, no boreholes could be advanced in the area of the former gravel pit in the northwest*;
- To determine the groundwater regime at the site;
- Confirm whether any contamination is present at the site. *The assessment and monitoring of the known hydrocarbon contamination in the northern area of the site is being undertaken by a third-party and is currently outside the scope of the highways investigation;*
- To obtain representative soil samples for subsequent geochemical and geotechnical laboratory analysis to inform design; and,
- To allow in-situ testing in underlying strata to derive geotechnical design parameters including infiltration testing for drainage design.

7.2 Proposed Investigation

7.2.1 Fieldwork

The below table summarised the proposed ground investigation programme of works to be undertaken at the site:

Item	Method	Rationale
Drilling of up to 4 no. cable percussive (CP) boreholes to a maximum depth of 10.00 m bgl	Cable percussive drilling rig.	To allow logging of the underlying ground conditions beneath the site to enable refinement of the ground model.
Excavation of up to 12 no. machine excavated trial pits to a maximum depth of 3.50 m bgl.	JCB 3CX	
Excavation of up to 7 no. hand dug pits to a maximum depth of 1.20 m bgl.	Hand digging with insulated hand tools.	

Installation of up to 4 no. CP boreholes up to approximately 6.00 m bgl.	Cable percussive drilling rig. Slotted/plain 50 mm pipe with gravel/bentonite.	To enable a combined monitoring and assessment of potential ground gas and groundwater regime at the site
Up to 3. No trial pits to be converted into BRE365 soakaway tests.	JCB 3CX Slotted/plain 50 mm pipe with gravel/	To derive preliminary soil infiltration rates for use in drainage design.

Post works monitoring of installation wells to be undertaken on a monthly basis for a period of 6 months to measure ground gas and groundwater levels. All borehole installations will be finished with a protective raised cover.

7.2.2 Laboratory Analysis

The below table summarised the proposed laboratory testing to be undertaken as part of the ground investigation programme:

Item	Rationale
A selection of samples schedule for soil analytical testing- including Total Organic Carbon (TOC), heavy metals, pH, sulphate (water soluble 2:1 extract), speciated Polycyclic Aromatic Hydrocarbons (sPAH), Total Petroleum Hydrocarbon (TPH), TPH tested to the Criteria Working Group method (TPHCWG), BTEX (benzene, toluene, ethylbenzene and xylene), MTBE and asbestos screen/ID.	To assess the potential for contamination to be present and the risk to groundworkers.
Waste Acceptance Criteria	To assist in determining preliminary off-site disposal routes.
A selection of samples schedule for geochemical BRE SD1 Greenfield Suite.	To assess sulphate concentrations within the underlying strata in general accordance with BRE Special Digest 1 to determine suitability for earthworks and ensure suitability of design for buried concrete. Should potentially pyritic conditions arise, a suitable brownfield suite may be adopted for selected samples.
A selection of samples schedule for geotechnical classification testing including moisture content, Atterberg limits, CBR and particle size distribution.	To allow characteristic geotechnical parameters to be determined for the underlying strata and assess the potential for re-use in earthworks.
A selection of samples schedule for Optimum Moisture Content (OMC) &	To allow the compaction characteristics of soils to be assessed for use along particle size density classification. The data will inform any

Maximum Dry Density (MDD) 2.5kg compaction testing	required treatment and stabilisation works prior to the placement of fill.
A selection of samples scheduled for Quick Undrained Triaxial, hand shear vanes and oedometer testing.	To inform the undrained shear strength (cu) of cohesive soils and coefficient of compressibility/consolidation for use in geotechnical design.

7.3 Site and Working Restrictions

Given the active nature of Southampton Airport there will be several working restrictions in place. Most notably no works to be undertaken to the north of the runway during plane take off/landing and no works at any time of the day which extend above the runway fence line. As such, in height restriction areas the works are limited to hand dug pits only. Furthermore, contractors and operatives should have appropriate competencies and personal protective equipment (PPE) to perform the ground investigation. Safe working environments including temporary fencing and adequate welfare facilities will be required throughout the works.

Information from Statutory Undertakers and the airport regarding private services will be provided to Geo^2 for review and passed onto the relevant sub-contractor who will carry out utility avoidance surveying to locate existing known services in advance of intrusive fieldwork; hand excavated inspection pits will be excavated to confirm presence/ absence of services at borehole locations. SGN will also attend site to trace the existing high-pressure gas main.

7.4 Specialist Consultation

The Detailed Explosive Ordnance Risk Assessment concluded two areas of moderate risk in the northern and northeastern area on site. The following relevant recommendations were made:

- Explosive Ordnance Safety & Awareness Briefing and Site Safety Instructions (both in the GI works and build phase works); and,
- Non-Intrusive Magnetometer Survey (prior to build-phase for mechanical excavations).

7.5 Programme

The following timescale is indicative. Geo^2 would maintain in contact with the project team throughout the works and where necessary can provide informal updates as required at key stages (e.g. draft records following completion of on-Site excavation).

The following timescales are indicative:

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14-31	32
Mobilisation															

Intrusive Works															
Laboratory testing															
Post works monitoring															
PRA/ PSSR Reporting & Preliminary GEA/GI Reporting															
Final Reporting (on completion of 6 month monitoring period)															

Appendix A - Figures



Site Boundary

0 300 600 900 1,200 1,500 1,800 2,100 m

N

DO NOT SCALE. NOT FOR CONSTRUCTION

Figure: Site Location Plan		
Job: Navigator Quarter, Southampton		
Client: Blocwork (Eastleigh) LLP and AGS Airports Group Limited		
Figure No.: 1	Revision: 1	Date: 07 February 2025
Drawn by: JCR	Checked by: TH	Scale: 1:15,000
Job No.: 4362		

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Geo2

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SITE AREAS

Road area	2.40 Ha / 5.92 Acres
Total Planning Redline	32.05 Ha / 79.19 Acres

1 LOCATION PLAN
1:2500

REV	DATE	NOTES	DRAWN	CHECKED
A1	DD/MM/YY	First Issue	AA	BB

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MSA JOB No. **31794**

CLIENT
BLOCKWORK (EASTLEIGH) LLP & SIAL

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Appendix B – UXO Report

Stage 2 Detailed Explosive Ordnance Risk Assessment

Project: Navigator Quarter, Southampton | **Client:** Geo2



The Client
Geo2 Limited

Project
Navigator Quarter, Southampton

Report Reference Number
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As detailed a search for pertinent information as possible within the stated timeframe and budget has been conducted. Although unlikely, additional significant information (e.g. local anecdotal accounts) may exist, however future emergence of such evidence would not constitute a failure of this risk assessment.

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EXECUTIVE SUMMARY

Conclusion	Explosive ordnance (EO) poses an elevated risk to some of the proposed ground works. Three risk zones have been identified: **Low Risk** | **Low-to-Moderate Risk** | **Moderate Risk**
Recommendation(s)	► **Explosive Ordnance Safety & Awareness Briefing** to all Site personnel prior to breaking ground anywhere on Site (both the GI works and build phase works). ► **Explosive Ordnance Site Safety Instructions** to be held on Site for the duration of both the GI works and the build phase works ► **Explosive Ordnance Disposal (EOD) Engineer:** remote consultancy / on-call service providing remote consultancy and immediate deployment to Site if necessary, in support of the build phase mechanical excavations within the Low-to-Moderate Risk Zone only. ► **Explosive Ordnance Disposal (EOD) Engineer** carrying out a handheld magnetometer survey of all / any GI boreholes (down to the maximum bomb penetration depth) within the Moderate Risk Zone only. ► **Non-Intrusive Magnetometer Survey:** prior to build-phase mechanical excavations within the Moderate Risk Zone only. ► **Intrusive Magnetometer Probe Survey** of any pile locations, down to the maximum bomb penetration depth, within the Moderate Risk Zone only. Note, depending on the scope / extent of the finalised redevelopment / build phase ground works, these mitigation measures may require modifying.
The Site	Site Address: Campbell Road, Newtown, Eastleigh, Hampshire, SO50 5AE. The Site is centred on the approximate National Grid Ref: SU 45960 17665. The Site is occupied by two grass fields, peripheral unmaintained vegetation, a post-WW2 constructed hard surfaced access road (west extent) and the Southampton VOR-DME (airport radio beacon). The Site abuts Southampton Airport (to the west and south) and Eastleigh (railway) Works to the north.
Proposed works	It is understood that the Site will be redeveloped for commercial use, comprising multiple medium and large warehouse type units with associated service yards, vehicle parks, access, and peripheral soft landscaping. A new access road will be built along the northern Site boundary. At this stage, specific details regarding the required ground works were unavailable, however various shallow mechanical excavations can be assumed and the potential requirement for piling works cannot be discounted. Prior to development, a GI will be undertaken, comprising 14No. trial pits and 7No. cable percussive boreholes up to 10.0m bgl within the proposed access road area. Note however, this is the first phase of GI. Subsequent phase(s) will be required, comprising trial pits and boreholes (shallow and deep) throughout the Site.
Risk Assessment - Key Findings	
Historic Site occupancy	During WW2, the Site was occupied by farmland crossed by a railway line, allotment gardens, peripheral vegetation and the northern extent of a military airfield, Royal Naval Air Station (RNAS) Eastleigh. Note, HMS Raven was the Royal Navy camp immediately south of the Site.

Likelihood of EO contamination:

British / Allied EO:

- The RNAS was temporarily extended north into the Site (requisitioning a farmstead and its grounds) during WW2. Evidence of defensive earthworks, hardened fortifications and perimeter barbed wire has been identified in this section of the Site. Therefore, it is likely that small arms ammunition (SAA) and land service ammunition (LSA) were handled here. Mock battles (training exercises testing the Royal Marines defence force) probably took place here, potentially involving the use of blank SAA and battle simulants (e.g. smoke grenades and pyrotechnics). Note, such items do not pose a significant EO hazard if encountered today.
- Numerous post-war EO finds in England confirm that there is an increased likelihood of British ammunition contamination of shallow level soil in locations of WW2 invasion defences and associated activity. There are three main pathways to such contamination - intentional burial of ammunition caches at defended positions (subsequently forgotten), accidental loss, and unauthorised disposal (intentional burial). The former pathway could have occurred within the south of the Site and, due to the presence in the south of a small gravel pit and possible former / overgrown orchard, the latter pathway is also a possibility here.
- That said, experience shows that British / Allied ammunition can be unearthed in unexpected places in and around WW2-era military airfields and sometimes historic records cannot explain why such EO came to be buried there. As some EO finds are probably attributable to the unpredictable behaviour of individuals several decades ago, the possibility cannot be completed discounted that items of British EO were dropped / discarded within soft ground beyond the airfield perimeter.
- British air-delivered bombs (live and practice) are unlikely to have been required at the RNAS. Furthermore, any such munitions are highly unlikely to have been brought into the requisitioned farmstead area of the Site.
- Although the neighbouring railway works was categorised as a vulnerable point (VP) - defended by a Home Guard (HG) platoon of employee volunteers - a significant defensive effort around its perimeter does not appear to have occurred. It is considered unlikely that these HG troops, potentially active in the vicinity of the northern Site boudnary, had access to significant quantities of effective LSA and caused associated EO contamination of the Site.
- Although a significant number of heavy anti-aircraft (AA) guns were deployed within firing range of the Site during WW2 and the Luftwaffe were frequently active in the region, only three unexploded AA shell strikes were recorded in Eastleigh Borough. The UXO strike density does not appear to have been significantly elevated and therefore the likelihood of such a strike within the Site boundary is low. Note, most or all light AA guns deployed within firing range of the Site were machine guns firing SAA (no associated UXO hazard).
- Although the RNAS was pipe mined during WW2, British Army records confirm that all mining occurred within the landing ground area, to the southwest of the Site, as expected. Due to the presence of military structures. the requisitioned farmstead in the south of the Site would not have been pipe mined.

German Unexploded Bombs (UXBs):

- During four (and possibly two further) air raids, the likelihood that an aircraft flew over the Site during its bombing run and released a UXB that fell within the Site boundary, is elevated.
- As three of the four of these potentially significant air raids occurred during the hours of darkness, the potential for any UXBs to fall within the Site boundary unwitnessed is greater. However, armed guards / sentries are known to have been posted to perimeter locations (probably including within the southern part of the Site) around the clock, and throughout the

conflict. The two RAF barrage balloon sites within and adjacent to the Site boundary (as well as a third within the railway works) are known to have been established prior to the first air raid. These sites will have been manned around the clock up until at least March 1942. It is also known that the neighbouring railway works had a team of fire watchers. These roof-top observers will likely have been deployed during most, if not all of the potentially significant air raids.

- During the two, three or four significant / potentially significant single aircraft sortie raids, the Site would have been under observation by multiple personnel (LAA gunners, armed guards, barrage balloon operators, and fire watchers). As these raids were of the lowest possible intensity, any high explosive (HE) UXB strike to the Site will likely have been witnessed, reported and subsequently investigated.
- German UXBs have been unearthed in recent years at some former RAF airfields. However, these three airfields experienced one or more large-scale concentrated air raids (each resulting in >150No. HE bombs dropped in a small area), which appear to have overwhelmed the defences / ground personnel. Each of the two medium scale air raids affecting the wider study area, resulted in far fewer bomb strikes.
- The 22nd June 1942 raid appears to have been spread out, affecting the aircraft factories in the south of the RNAS, the southern extent of the Site (northern extent of the RNAS) and the southern extent of the railway works. Furthermore, it is reported that the RNAS / HMS Raven received adequate early warning of this medium scale air raid, indicating that LAA gunners (and possibly barrage balloon operators) would have manned their sites in preparation, reducing the risk of UXBs falling unwitnessed.
- The other medium scale air raid (8th October 1940) occurred during the period of imminent invasion threat, when the defences at RNAS / HMS Raven will have been on high alert throughout the day and night. And an anecdotal account states that early warning of this raid was again received. The resulting 19No. UXBs reported at the RNAS suggests that specific searches for UXBs were carried out. Note, at RAF airfields it was standard procedure to search the alignment of all 'sticks' of bomb craters up to the airfield perimeter for UXB entry holes, so the same may have occurred in the south of the Site, in and around the requisitioned farmstead.
- Evidence of any HE bomb craters (fresh or infilled) occurring during the first four (August to October 1940) local air raids on these unworked, apparently unused fields would be visible on the September and November 1940 aerial photographs. The lack of any such evidence (also within multiple fields to the east and southeast of the Site) indicates that the vast majority of the 38No. HE bombs recorded within the RNAS perimeter during the 8th October raid, will not have fallen close to this area of the Site. Indeed, the November 1940 aerial photograph exhibits a few infilled crater marks on the airfield's landing ground, between 750m and 1km of the Site's southern extent.
- However, two HE UXBs were discovered within 100m of the north Site boundary (in the railways works) several months and a few years after their occurrence (8th October 1940). They appear to have been overlooked immediately following the air raid, due to risk elevating ground conditions. It is conceivable therefore that another unnoticed UXB struck the Site's agricultural fields, allotments gardens or small sections of unmaintained vegetation and was not immediately detected and reported.
- The fields in the west and northeast appear to have been arable use. Any UXB entry hole is more likely to have been overlooked on such land, its entry hole obscured by dense / tall crop growth or ploughed up soil. And the same can be said for the small sections of unmaintained grassland that bordered the railway lines in the east of the Site.

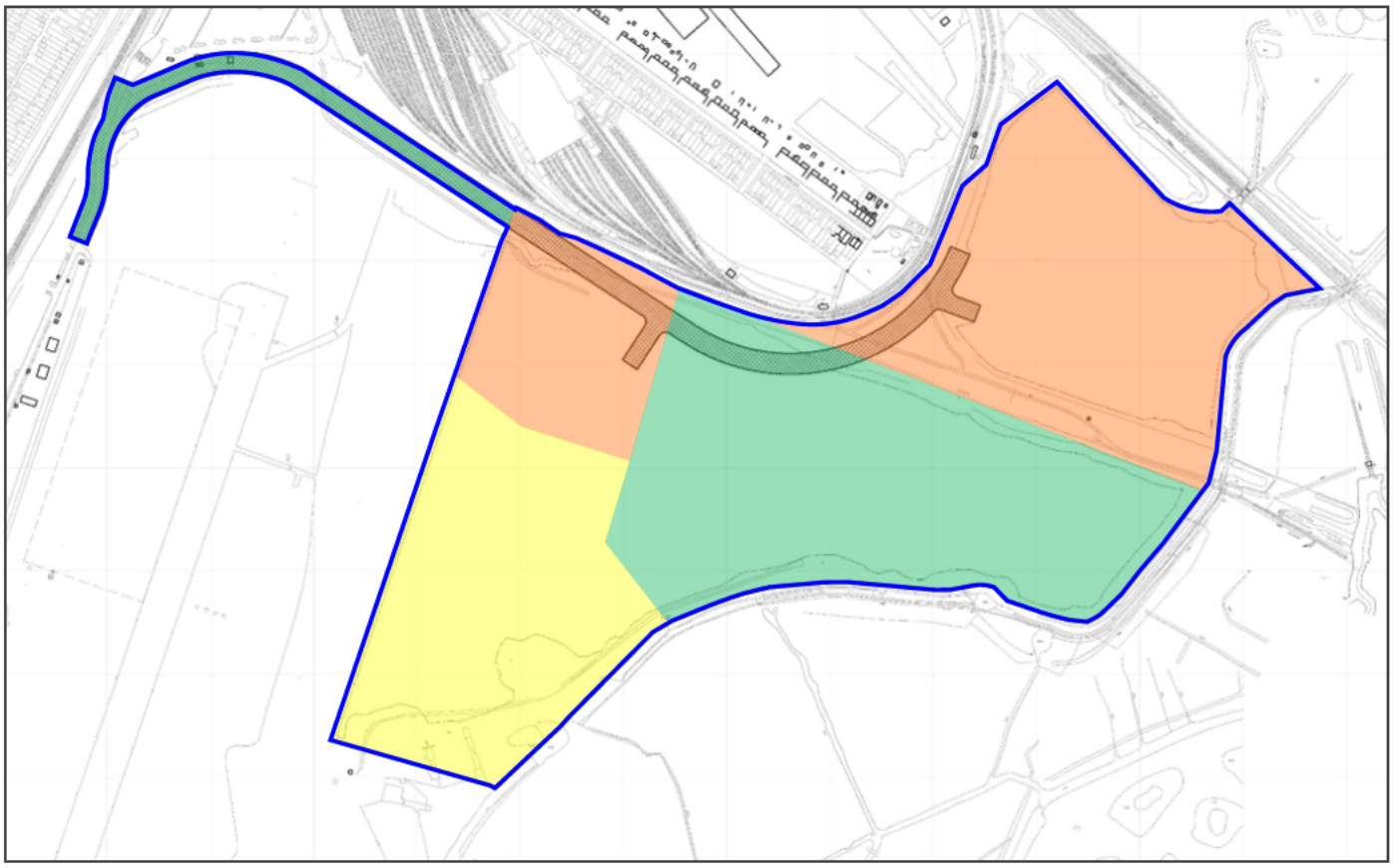
	► The government's nationwide 'Dig for Victory' campaign saw an explosion in the number of, and use of existing, allotment gardens for growing food, due to wartime rationing. It's highly likely therefore that each allotment garden on Site was in use throughout the war. Each gardener is unlikely to have overlooked the entry hole of even the smallest / lightest German HE UXB (20 / 30cm diameter) within their small plot of land. ► The appearance of two fields in the centre and east of the Site is consistently uniform throughout the conflict (during 1940, 1942, 1943 and 1946). These grass fields do not appear to have had any arable use and may have only been used as grazing pasture, although several wartime aerial photographs do not show any livestock here. The entry hole of any German HE UXB on this land may not have been immediately noticed, however it is unlikely to have remained undetected throughout the conflict and into the post-war period.
Likelihood of EO remaining	► The risk mitigating effect of post-war agricultural ploughing is not well understood. Although such works could have unearthed small items of very shallow buried EO depositing them on the surface, such items could also have been reburied / obscured from view. The risk associated with any such EO will have been partly mitigated across most of the Site area. ► As the vast majority of the Site has not experienced disturbance of soil below ~0.5m bgl, the risk associated with any German UXBs or British heavy AA shells likely remains unmitigated.
Likelihood of EO encounter and initiation	► Areas of potential concern (where there is an elevated likelihood of EO remaining in-situ today) have been identified. As some of the future GI works almost certainly will, and some of the subsequent build phase works will occur within these areas of potential concern, risk pathways will be created exposing each intrusion / excavation to a potential EO encounter. ► Any UXB contamination of the Site resulting from the heaviest air raid will be a 50kg HE bomb at shallow depth (<3.0m bgl). Therefore, even shallow mechanical excavations of any UXB impact site would likely encounter such UXO. Note, any HE UXB contamination of the Site resulting from the second heaviest air raid would probably be encountered at greater depth. ► The zone of potential EO contamination (ZPC) within the southern portion of the Site, occupying the WW2-era military requisitioned land, is associated with shallow buried British LSA. Any intrusions in this area beyond ~2.0m bgl are unlikely to encounter EO. ► As only small-scale GI works and very shallow mechanical excavations appear to be planned for the northwestern section of the Site (proposed access road), the likelihood of encountering EO here is not significantly elevated. Furthermore, the likelihood of very shallow buried EO remaining in this area is not significantly elevated. ► Although the likelihood of an EO encounter during the GI works is lower compared to the subsequent large-scale build phase ground works, this is offset by the significantly elevated likelihood EO remaining in some areas and the 'blind' nature of the planned borehole works, increasing the likelihood of aggressively striking buried EO. ► If the build phase works involve large-scale piling, the likelihood of aggressively striking buried EO will be significantly elevated. ► As a high force intrusive methodology (percussive boreholes) is planned, the likelihood of initiating a German HE UXB is especially elevated during these specific works. And the same could be said regarding the build phase works, if piling is required on a large-scale. ► The likelihood of initiating some types of LSA would be significantly elevated during the planned mechanical excavations.

That is, those WW2-era British grenades that feature glass in their construction. However, generally speaking the likelihood of detonating most types of hazard item at the Site is lower during mechanical excavations (especially when utilising toothless / bladed excavator buckets) when compared to 'blind' percussive boreholes and piling.

- That said, the smallest very shallow buried EO devices are more likely to be pushed aside (glancing blow) by a drill / pile head in soft soil, reducing the likelihood of detonation.

The executive summary covers the key points only. The main body of this report contains the majority of the Site-specific detail and the limitations of the assessment. Should the proposed works be significantly modified or additional works be considered, IAL should be contacted as a reassessment of EO risk may be required.

Risk Map



Low Risk

Low-to-Moderate Risk posed by British LSA

Moderate Risk posed by German HE UXBs

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Glossary

AA	Anti-Aircraft
AAA	Anti-Aircraft Artillery
ALARP	As Low As Reasonably Practicable
AP	Anti-Personnel
ARP	Air Raid Precautions
AT	Anti-Tank
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
bgl	below ground level
BGS	British Geological Survey
BPD	Bomb Penetration Depth
CIRIA	Construction Industry Research & Information Association
DA	Delayed Action (bomb type)
EO	Explosive Ordnance (UXO and AXO)
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
FAA	Fleet Air Arm (Royal Navy)
FP	Fire Pot (WW2 German bomb)
GP	General Purpose (bomb type)
ha	hectare(s)
HAA	Heavy Anti-Aircraft (gun)
HC	High Capacity (bomb type)
HE	High Explosive
HMNB	Her/His Majety's Naval Base
HMS	Her/His Majesty's Service (shore establishment)
HO	Home Office
HQ	Headquarters
HSE	Health & Safety Executive
IB	Incendiary Bomb
kg	kilogram(s)
km	kilometre(s)
LAA	Light Anti-Aircraft (gun)
LM	Land Mine
LRRB	Long Range Rocket Bomb (V2 rocket)
LSA	Land Service Ammunition
m	metre(s)
MC	Medium Capacity (bomb type)
mm	millimetre(s)
MOD	Ministry of Defence
MU	Maintenance Unit
NEQ	Net Explosive Quantity
NFF	National Filling Factory
NGR	National Grid Reference
OB	Oil Bomb
OS	Ordnance Survey
PAC	Pilotless Aircraft (V1 missile)
PB	Phosphorus Bomb
PM	Parachute Mine (bomb type)
POW	Prisoner of War
RADAR	Radio Detection And Ranging
RAF	Royal Air Force
RDX	Research Department Explosive
REF	Royal Explosive Factory
RFC	Royal Flying Corps (1912-1918)
RN	Royal Navy
RNAD	Royal Naval Armaments Depot
RNAS	Royal Naval Air Station
ROF	Royal Ordnance Factory
SAA	Small Arms Ammunition
SI	Site Investigation
SIP	Self-Igniting Phosphorus (grenade type)
TA	Territorial Army
TNT	Trinitrotoluene (explosive)
UK	United Kingdom
UN	United Nations
UP	Unrotating Projectile (AA rocket)
USAAF	United States Army Air Force (1941-1947)
USAF	United States Air Force (since 1947)
UX	Unexploded
UX AA	Unexploded Anti-Aircraft (projectile)
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V1	Vergeltungswaffe 1 (German cruise missile)
V2	Vergeltungswaffe 2 (German ballistic missile)
WAAF	Women's Auxiliary Air Force (1939-1949)
WO	War Office (1857-1964)
WW1	World War One (1914-1918)
WW2	World War Two (1939-1945)

1 Introduction

1.1 Instruction

Geo2 (referred to hereon in as the Client) has commissioned Impartial Assessments Limited (referred to hereon in as IAL) to carry out a Stage 2 Detailed EO Risk Assessment of the proposed works at the Navigator Quarter, Southampton site (referred to hereon in as the Site).

1.2 Objective

The objective of this report is to assess the likelihood of encountering buried explosive ordnance (EO) during intrusive ground works and to assess the consequences of any such encounter. If an intolerable risk level is identified, risk mitigation measures will be recommended.

1.3 Using This Report

In the UK, EO risk is not always considered or fully understood and is often misunderstood. This report aims to provide a comprehensive and coherent account, including introductory text and details on location-specific types of EO. We believe it is important to provide sufficient information to allow the layman to form a good understanding of the potential EO risks.

However, we also appreciate that some readers will not require the full contextual information and therefore the report is structured with this in mind. From **Chapters 3 to 13**, all Site-specific text that affects the outcome of this risk assessment can be found under the highlighted Site-Specific subheadings.

1.4 Explosive Ordnance Risk in the UK

The term EO describes both unexploded ordnance (UXO) and abandoned explosive ordnance (AXO). The former describes devices and projectiles that have been armed (and in some cases fired, dropped, placed, etc) yet failed to function. The latter describes devices and projectiles that have simply been abandoned (discarded or buried).

Fortunately, inadvertent EO initiations (detonations) in the UK are very rare, however, buried EO can cause significant delays to construction projects with associated increases in costs. The origin of UK EO can be broadly categorised as such:

- **Enemy Action (UXO):** the German air force bombed targets throughout the UK during WW1 and WW2. The German Navy bombarded coastal targets in eastern England during WW1 and German long-range artillery bombarded Kent during WW2.
- **Allied Military Activity (UXO and AXO):** several Allied nations used the UK as a staging area for military action in the European theatre of conflict (most notably the US and Canada) during WW1 and WW2.
- **UK Military Activity (UXO and AXO):** domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities as well as anti-aircraft (AA) weapons used during WW1 and WW2.

1.5 Guidelines for Risk Assessment

1.5.1 CIRIA

This assessment has been designed and written in accordance with the relevant Construction Industry Research and Information Association (CIRIA) guidelines: **C681** 'Unexploded Ordnance - A Guide for the Construction Industry' (published 2009) and **C785** 'Unexploded Ordnance Risk Management Guide for Land-Based Projects' (published 2019). C681 and C785 were written (with the support of the UK Health and Safety Executive) to provide the construction industry with accurate and authoritative information regarding matters of onshore EO risk in the UK.

1.5.2 Legislation

There is no specific UK legislation covering the assessment and management of EO risk. However, there is legislation that more broadly covers the consideration of EO hazards:

- Health & Safety at Work Act (1974) and Management of Health & Safety at Work Regulations 1999
- Construction (Design & Management) Regulations (CDM) 2015
- Corporate Manslaughter and Corporate Homicide Act 2007

1.5.3 MOD

EO finds in the UK are handled by the MOD's Joint Service Explosive Ordnance Disposal Operations Centre (JSEODOC). At any site where an identifiable EO risk was not highlighted at project design stage, JSEODOC will not provide EOD services for frequent callouts to EO encounters. Instead, the client will be required to employ the services of a commercial EO risk management contractor to manage the ongoing EO risk.

The delay caused by retrospectively carrying out a risk assessment can have significant cost implications as site works are halted. Therefore, it is essential that EO risk is considered at the earliest possible stage, ideally through the commissioning of a Stage 1 or Stage 2 EO risk assessment.

1.6 Assessment Methodology

1.6.1 Introduction

This report is based on a traditional source-pathway-receptor-consequence (SPRC) assessment methodology and semi-quantitative risk model. The following subheadings describe how this risk assessment structure is applied to buried EO risk (in the UK).

1.6.2 Source

In the UK there are numerous sources of potential EO contamination. Three main factors govern the likelihood of buried EO being present at a given site today:

- **Contamination:** The likelihood that EO came to be buried at a site.
- **Subsequent Detection:** The likelihood that EO (chiefly UXO) contamination went unobserved and reported.
- **Degree of (any) Risk Mitigation:** Could subsequent earthworks or Explosive Ordnance Clearance (EOC) activities have mitigated the buried EO risk?

1.6.3 Pathway

The activities that could result in the EO hazard reaching sensitive receptors and the specific type of EO hazard.

- **Encounter:** The likelihood of buried EO being encountered during the proposed works depends on the total volume of soil disturbed and the type(s) of intrusion methodology. Note, site-specific bomb penetration depth (BPD) calculations must be conducted where appropriate.
- **Initiation:** The likelihood that an encounter results in the EO initiating.

1.6.4 Receptor

The number and sensitivity of receptors will vary from site to site. In the context of an EO initiation, the receptors present at the time of the event will almost always include the most sensitive category; human health.

1.6.5 Consequence

The consequences of an inadvertent EO initiation event vary from none to catastrophic. However, the likelihood of initiating EO is far lower than that of encountering EO. The negative consequences of an EO encounter are much more likely to be financial, resulting from project delays.

1.6.6 Semi-Quantitative Risk Calculation

Once all project-specific factors have been assessed, a semi-quantitative risk assessment (likelihood versus consequence risk matrix) will be carried out or multiple calculations will be carried out if the factors described above vary considerably across the site. In the latter scenario, a risk map will be drawn to illustrate the differing risk zones.

1.6.7 Recommendations

If a significantly elevated risk level(s) is concluded, industry standard risk mitigation measures (appropriate to the project specific intrusive methodologies) will be recommended to reduce the elevated risk level(s) to as low as reasonably practicable (ALARP) level.

1.7 Information Sources

To guarantee a robust assessment of risk, primary source records form the basis of this report. The following information types and information sources were accessed / contacted during the research process:

- The National Archives, Hampshire Archive, Southampton Library, Eastleigh Museum, The RAF Museum, The National Museum of the Royal Navy, the MoD, Historic England, Council for British Archaeology, Hampshire Historic Environment Record, British Geological Society, the local authority, the Client.
- Historic OS mapping, historic aerial photography and various web resources.
- Our PIEO (potential indicators of explosive ordnance) GIS map and our physical library. Note, PIEO is the result of over fourteen years of research and is constantly growing.

1.8 Reporting Conditions

The accuracy of original records relating to bombing is difficult to verify. Wartime bombing records were only as detailed and accurate as the availability of time, personnel, and ease of access to information would allow. The conditions under which information was gathered in many urban locations, i.e. intense aerial bombardment, will not have been conducive to accurate record keeping. Air raids within sparsely populated locations are less likely to have been witnessed, limiting the accuracy of any corresponding records. Furthermore, such records were often based on unverifiable second-hand eyewitness accounts.

Many records of historic military activity have not survived and some of those that have are only declassified and released into the public domain decades after their creation. Consequently, pertinent records can be inaccessible at the time of requirement. Impartial Assessments cannot accept liability for any missing historic records, inaccuracies or omissions within the available historic records.

It is never possible to accurately determine, through desktop study alone, the precise location, type and condition of buried EO at a given site. Furthermore, some factors (human behavioural) make assessment of EO risk partly subjective.

2 The Site

2.1 Location

Site Address: Campbell Road, Newtown, Eastleigh, Hampshire, SO50 5AE.

The Site is centred on the approximate National Grid Ref: SU 45960 17665.

Site location maps and recent aerial photography are displayed at **FIGURE 1**.

2.2 Description

The Site is occupied by two grass fields, peripheral unmaintained vegetation, a post-WW2 constructed hard surfaced access road (west extent) and the Southampton VOR-DME (airport radio beacon). The Site abuts Southampton Airport (to the west and south) and Eastleigh (railway) Works to the north.

2.3 Proposed Works

It is understood that the Site will be redeveloped for commercial use, comprising multiple medium and large warehouse type units with associated service yards, vehicle parks, access, and peripheral soft landscaping. A new access road will be built along the northern Site boundary. At this stage, specific details regarding the required ground works were unavailable, however various shallow mechanical excavations can be assumed and the potential requirement for piling works cannot be discounted.

Prior to development, a GI will be undertaken, comprising 14No. trial pits and 7No. cable percussive boreholes up to 10.0m bgl within the proposed access road area. Note however, this is the first phase of GI. Subsequent phase(s) will be required, comprising trial pits and boreholes (shallow and deep) throughout the Site.

An existing Site plan, a proposed Phase I GI positions plan and the proposed development plan are displayed at **FIGURE 2**.

3 Site History Assessment

3.1 OS Mapping

3.1.1 Introduction

Bomb damage to structures, resulting from enemy action can be identified by comparing pre and post conflict OS maps. These maps can also help identify historic military activity, as 19th / 20th Century military structures had a typical shape and were distributed in typical patterns. Note however, the process adopted in generating these maps (mapping intervals, scale, exclusion of some features, e.g. military, in the interests of national security, etc), may result in an incomplete account of a site's history.

Those available historic OS maps covering the Site (between 1:1,056 and 1:10,560 scale) have been assessed, with relevant observations detailed in the table below.

The latest pre-WW2 OS map is displayed at **FIGURE 3**.

3.1.2 Site-Specific

	Maps	Observations	
Pre-WW1	1868 1896 1909	Site occupancy?	Mainly farmland crossed by a railway line. A farmstead (North Stoneham Farm) in the south comprises buildings, a small orchard and a small gravel pit. A second small old gravel pit encroaches into the northwest part of the Site.
		Evidence of local military activity?	None.
		Other significant observations?	None.
Pre-WW2	1931 1938	Site occupancy?	Extension of the farmstead further into the Site. The northwest extent passes through an area of allotment gardens
		Evidence of local military activity?	None.
		Evidence of WW1 German bombing?	None.
		Other significant observations?	None.
Post-WW2	1946 1951 1971 1991	Site occupancy?	No significant changes. Farmstead demolished.
		Evidence of local military activity?	Yes. Southampton (Eastleigh) Airport - military use during WW2 - apparently abutting the southwest Site boundary immediately post-war.
		Evidence of WW2 German bombing?	Possibly. A pair of Southampton Road terraced houses (~60m west of the Site) demolished soon after WW2.
		Other significant observations?	None.

TABLE 1: Historical OS Mapping Review

3.2 Military Plans

3.2.1 Introduction

The three branches of the UK armed forces all produced various different types of plans of their bases / facilities historically. These plans vary in their scale and level of detail. Most plans are indexed with accompanied keys / legends identifying the various structures. Not all 19th and 20th Century dated plans have survived to the present-day.

Original plans of Eastleigh Aerodrome / Southampton Airport were sought and two were obtained - displayed at **FIGURE 4**.

3.2.2 Site-Specific

	Date	Scale	Observations
WW2	1944	1:10,560	The Site appears to be situated immediately beyond (north of) the airfield's wartime perimeter. The cluster of buildings immediately south of the Site although unlabelled, is known to be the WW2-era HMS Raven, a Fleet Air Arm (Royal Navy) shore establishment. Note, this plan has no corresponding key identifying individual military-use buildings. A large building (probable aircraft hangar) further south of the Site is labelled 'RNAS' (Royal Naval Air Station), confirming the airport's at least partial wartime use as Royal Navy (RN) airfield, as opposed to a Royal Air Force (RAF) airfield. One of the airport's grass runways aligns with the west extent of the Site, like today.
Post-WW2	1954	1:2,500	This plan includes a corresponding key identifying individual military-use buildings. The key states that North Stoneham Farm (occupying the south of the Site) is 'occupied by the camp commandment', i.e. requisitioned by the military. The associated buildings are all labelled as agricultural use, however one 'block house' (a military fortification) is labelled immediately adjacent to the south Site boundary. Note, this is an Air Ministry (RAF) station plan, not a station plan produced by the RN. An archive collection of historic RN plans was closed to the public throughout the timeframe of this project and therefore no original WW2-era plan(s) of RNAS Eastleigh were available.

TABLE 2: Historical Military Plan(s) Review

3.3 Aerial Photography

3.3.1 Introduction

Historical aerial photography is often key in identifying temporary wartime activity. As well as clarifying historic site occupancy, aerial photographs can elucidate the degree of bomb damage to structures and show the locations of German high explosive (HE) bomb craters. Note, the latter usually only persisted for a short time.

WW2-era aerial photography is displayed at **FIGURE 5**.

3.3.2 Site-Specific

	Date	Type	Observations	
WW2	27th Sep 1940	Vertical. Moderate resolution	Timing?	During the initial 'Battle of Britain' bombing campaign.
			Site occupancy?	Generally as per the 1946 OS mapping. A footpath connects the farm buildings in the south of the Site with military features immediately west.
			Site ground cover type(s)?	The northwest allotment gardens are visible. and the old gravel pit here is occupied by unmaintained mixed vegetation. The railway junction in the east is bordered by / encompasses unmaintained grassland. Some of the farmland may be grazing pasture.
			Evidence of WW2 bombing? (ruins, clearance, craters)	No obvious evidence.
			Evidence of potentially significant military activity?	Two grounded RAF barrage balloons, one at North Stoneham Farm and one within the neighbouring Eastleigh (railway) Works, where a possible infantry trench is also visible. Two likely light anti-aircraft (LAA) gun sites just west of the Site. Also, various unidentifiable military activity in and around North Stoneham Farm.
			Other significant observations?	None.
	27th Nov 1940	Vertical. Moderate resolution	Timing?	During the nine month 'Blitz' bombing campaign.
			Site occupancy?	No significant changes.
			Site ground cover type(s)?	No significant changes.
			Evidence of WW2 bombing? (ruins, clearance, craters)	No obvious evidence.
			Evidence of potentially significant military activity?	A likely barbed wire perimeter line passes through the Site, encompassing the WW2-era military activity visible on the requisitioned farmland. Just inside this line and served by a footpath is a feature that could be an LAA gun site / fortified position.
			Other significant observations?	None.

Post-WW2	21st Sep 1946	Vertical. Moderate resolution	Timing?	Approx. 17No. months after the cessation of hostilities in Europe.
			Site occupancy?	The military structures and footpaths in around the farm have been removed.
			Site ground cover type(s)?	Unchanged. Note, the two fields in centre and southeast parts of the Site have remained unchanged (probably grazing pasture).
			Evidence of WW2 bombing? (ruins, clearance, craters)	The aforementioned pair of demolished houses have indeed been cleared. A farm building straddling the southern Site boundary has been cleared.
			Evidence of potentially significant military activity?	No obvious evidence in the immediate vicinity.
			Other significant observations?	At the northern extent of the farm there is an area comprising unmaintained vegetation, small huts, and strewn objects, one of which may be a small aircraft. This could be a waste processing / scrapping / disposal site.

TABLE 3: Historical Aerial Photography Review

Note, additional aerial photographs of the Site dated 24th September 1940, March 1942, October 1942 and February 1943 do not exhibit any significant observations.

3.4 Southampton Airport

At the end of WW1, in 1918, Eastleigh Aerodrome became operational. It was built for the United States Naval Air Force (USNAF) and was situated ~600m southwest of the Site. After the war, the aerodrome became a municipal / civil airport.

In the early 1930s, an area in the northeast corner of the aerodrome (immediately south of the Site) was leased to the Air Ministry and used as an RAF reconditioning base called RAF Eastleigh. This was renamed RAF Southampton in August 1936 and later, in July 1939, it was transferred to the Admiralty to become the Royal Navy Fleet Air Arm shore establishment HMS Raven.

HMS Raven covered some ten acres, comprising wooden hutted accommodation for up to 885No. personnel (all ranks), eight Bessaneaux wooden framed canvas covered aircraft hangars of WW1 vintage, and multiple other support buildings / facilities. During WW2, it was home to the Air Medical School, Safety Equipment School, Observer Training Course Part I, (non-flying), Fire Fighting School, Aircraft Handling School, and Naval Fighter School - 759 Squadron. Multiple RN flying squadrons were also temporarily housed at HMS Raven during WW2, mostly torpedo spotter reconnaissance squadrons, flying Swordfish aircraft.

Prior to and during WW2, three aircraft factories were built in the west and southwest of the aerodrome, the Cunliffe-Owen works, Supermarine works, and Vickers Armstrong works. All of which assembled and / or produced parts for military aircraft during the conflict.

At the start of WW2 the municipal airport ceased all operations and the airfield was requisitioned by the Admiralty, becoming known as RNAS Eastleigh. And it was not until a year after the war ended (April 1946) that it was released and returned to civilian use. HMS Raven was surplus to requirements by May 1946 and as a result was placed in care and maintenance status, eventually closing for good a year later.

4 Domestic Military Activity Assessment

4.1 Sources of Potential Explosive Ordnance Contamination

The table below lists all the modern and historical sites and activities that could have potentially resulted in British / Allied UXO and AXO contamination in the UK.

Source of EO	Examples	Associated EO Hazard Items	Relevance
Military Bases and Installations	Army camps, RAF, RN or USAAF airfields, RN shore establishments, signals or communications installations, military training centres, etc.	Various conventional and chemical EO. The types of EO will depend on the type of site and branch of the military utilising it. Plus AXO (SAA, LSA and AA ammunition) for WW2 site defence, if applicable.	**POTENTIALLY SIGNIFICANT**
Military Training Areas and Weapons Ranges	Inland and costal RAF and USAAF bombing ranges. Army / Royal Marines / RAF Regiment etc weapons ranges.	Various conventional and chemical EO. The types of EO will depend on the type of range / training area and branch of the military utilising it.	**UNLIKELY**
Munitions and Explosives Factories	Royal Ordnance Factories, National Filling Factories, National Explosives Factories, Royal Naval Cordite Factories, etc.	Various conventional and chemical EO. The types of EO and explosives contamination will depend on the type of factory. Potentially plus AXO (SAA, LSA and AA ammunition) for WW2 defence.	INSIGNIFICANT
Munitions Storage Depots	Royal Naval Armaments Depot, Royal Naval Ordnance Depots, RAF Ammunition Depots, Air Ammunition Parks, Reserve / Forward Ammunition Depots, Central Ammunition Depots, etc	Various conventional and chemical EO. The types of EO potentially present will depend on the branch of the military utilising it. Potentially plus AXO (SAA, LSA and AA ammunition) for WW2 defence.	INSIGNIFICANT
Fortifications and Defence Measures	Pillboxes, fortified houses, various earthworks (e.g. trenches) etc at: Nodal Points, Stop-Lines, VPs, etc.	SAA, regular army LSA, AA ammunition, Flame Fougasse, and Home Guard-specific weapons / ammunition.	**POTENTIALLY SIGNIFICANT**
Military Requisitioned Sites: WW1 and WW2	During WW1 and WW2 many private properties were requisitioned by the War Office for military use, including training.	SAA, regular army LSA and Home Guard specific weapons / ammunition.	**POTENTIALLY SIGNIFICANT**
Pipe Mines and Conventional Minefields: WW2	Pipe mines and improvised mines at military bases. Conventional minefields at beaches and some Nodal Points.	Canadian pipe mines, various British landmines (AT and AP) and IEDs.	**POTENTIALLY SIGNIFICANT**
RAF and USAAF Crash Sites	Numerous British and American aircraft crashed in the UK, chiefly during WW2. Munitions and ammunition not always fully recovered.	Various conventional air-delivered ordnance (bombs and rockets) and machine gun / autocannon ammunition.	**POTENTIALLY SIGNIFICANT**
Home Guard Activity: WW2	Volunteer army tasked with home defence during WW2. An armed branch of the British Army. Battalions were active in all British counties.	SAA, regular army LSA, Home Guard specific ammunition e.g. 29mm Spigot Mortar, 3-inch Smith Gun, No.73, No.74, No.75 and No.76 grenades, etc.	**POTENTIALLY SIGNIFICANT**
Anti-Aircraft Weaponry: WW1 and WW2	Light AA (machine gun and autocannon), Heavy AA (QF guns), and ZAA (rocket projectors).	SAA, autocannon shells (20mm, 37mm, 40mm), QF shells (3, 3.7, 4.5-inch), UP rockets (2 and 3-inch).	**POTENTIALLY SIGNIFICANT**

TABLE 4: Sources of Potential Domestic Explosive Ordnance

4.2 Military Airfield Activities - Introduction

There are multiple potential sources of EO contamination associated with British WW2-era military airfields and activities that occurred there historically. There is a generally increased likelihood of EO contamination at historic military airfield sites, via a number of different pathways. This is evidenced by the regularity of EO finds (of WW2 vintage) by the public and the construction industry. Those potential sources of EO relevant to the Site, are discussed under the following subheadings.

The intensity and frequency of combat operations during WW2, coupled with the armed forces' less stringent health and safety policies of the time resulted in isolated instances of EO contamination. Then in the immediate aftermath of WW2, vast quantities of surplus equipment and ammunition led to a culture of burial as a means of quick / convenient disposal. This 'out of sight out of mind' attitude has created a legacy of EO contamination at numerous wartime military sites. Note, experience shows that peacetime military activities at military airfields are far less likely to have resulted in live hazardous devices contaminating soil.

4.3 Airfield Defence Activities

4.3.1 Introduction

Most British military airfields operational prior to or during the first three years of WW2 had an airfield specific defence scheme. RAF airfield defence squadrons and local army unit detachments were tasked with executing defence schemes. They constructed / maintained defensive positions (fortifications and earthworks), took part in defence exercises and trained non-combat airfield personnel. Defence forces would have held stocks of ammunition at the airfield.

Defence measures varied with airfield location, size and function. They included pillboxes (hardened weapons positions), battle headquarters, trenches, weapons pits, sandbag machine gun nests, improvised explosive devices (mines) and pipe mines. Post-war EO finds indicate that small caches of ammunition were occasionally buried at individual defence positions, to be utilised in the event of an attack.

Airfield defence exercises were frequently conducted at airfields. Army and Home Guard (HG) units often visited airfields, providing an attacking force for mock battles, to test the defence scheme. Blank small arms ammunition (SAA), drill devices (inert / practice) and battle simulants (pyrotechnics and smoke generators) were usually used to create realistic battle conditions. Live ammunition was rarely used for obvious reasons.

Complete or partially expended hazardous (non-lethal) battle simulant devices could have been discarded during training.

4.3.2 Site-Specific

As the original WW2 RNAS Eastleigh / HMS Raven defence scheme document and any WW2-dated RN plans / drawings of HMS Raven are unavailable, commentary on local invasion defence preparations is limited. It can be said however that the military airfield was established prior to the period of highest invasion threat (late 1940) and therefore defensive preparations will have been made.

As well as the aforementioned block house (a Type 22 pillbox) immediately adjacent to the southern Site boundary, secondary source research (e.g. wartime aerial photography, local historic environment record, relevant publications, internet resources) has highlighted a second pillbox ~50m south of the southern extent of the Site, a third pillbox straddling the southern Site boundary, a weapons pit just outside the southern Site boundary and two RAF barrage balloon mooring sites within / near the southern Site boundary, see images displayed at **FIGURE 6**. Note, the No.294 Balloon Squadron (RAF) was deployed to defend the RNAS from June 1940.

Furthermore, IAL's aerial photography analysis highlights two circular features (likely sandbagged machine gun nests) just west of the Site and a third potential fortification straddling another part of the Site boundary just north of the farm.

Official records state that military airfields comprised inner / within the perimeter defended localities (DLs) and outer DLs, beyond the airfield perimeter covering the main approach roads. As no approach roads passed through the Site and the aerial photography provides good wartime coverage (1940, 1942, and 1943) with no evidence of defence measures (earthworks or hardened fortifications) visible in other parts of the Site, it can be confidentially assumed that no outer airfield DLs occupied other parts of the Site.

Official records confirm that RNAS Eastleigh was a vital point (VP) garrisoned / defended by a Royal Marines unit, not a British Army unit. However, no original Royal Marines records have been found identifying the specific unit(s) deployed to fortify and defend the airfield.

IAL's research experience indicates an almost certainty that training exercises to test the airfield defence measures and defenders will have been carried out on a number of occasions (no specific evidence found). Such exercises could conceivably have seen a visiting unit (potentially Home Guard or Army) passing through the Site to execute a mock attack of the airfield's northern perimeter. Any such scenario could have seen training aids / battle simulants and blank ammunition carried into and expended within the Site boundary.

As the aerodrome was situated within 10 miles of the coast, a military guard force was mandated, as per official defence policy. This was an anti-sabotage policy, separate to invasion defence measures and would have remained in place throughout the conflict, i.e. after the threat of invasion had subsided. Therefore, it can be assumed that the southern part of the Site was accessed by armed sentries and / or perimeter armed patrols between 1940 and 1945.

4.4 Airfield Defensive Mines - Pipe Mines

4.4.1 Brief Overview

Canadian pipe mines were long steel pipes (50-70mm diameter) containing Gelignite explosive, inserted into the ground to depths between 1.8m and 4.0m bgl. They were laid in a grid pattern under the landing grounds of the most vulnerable military airfields in England during 1940. They were to be detonated remotely in the event of an invasion.

It is estimated that over 40,000ft of pipe mine were installed in Britain, at key points as well as airfields. During the war some pipe mines were made safe and removed due to deterioration of Gelignite, however most were left in-situ. After the war, Canadian engineers were tasked with the removal of all pipe mines, however this was not completed in full.

In the 1980s a British Army EOD unit was tasked with the clearance of all remaining airfield pipe mines in the UK (Operation Crabstick). As part of the research carried out for this EOC task, the Army found that the original wartime EOC records did not record the number of pipe mines removed / cleared at each airfield during and immediately post-war.

Recent (post-Crabstick) pipe mine finds and re-investigation by Army EOD units at some former airfields have found that Operation Crabstick did not provide comprehensive clearance at some airfields, whilst at some sites, more pipe mines were placed than were recorded in the original wartime installation plans, and some were also encountered in the wrong place (compared to wartime records). The largest such discrepancy was at RAF Lympne where 186No. mines were recorded as having been laid, however 305No. were recovered.

During WW2, a pipe mine clearance effort at an unknown airfield resulted in an inadvertent explosion and the death of a Ukrainian worker. Then in 1962, an EOD engineer was killed at the former RAF Lympne site, when a pipe mine detonated. This engineer had been working on a different EOC task and was not expecting to encounter a pipe mine. During Operation Crabstick, two pipe mines were inadvertently detonated however as remote-control excavators were used, no injuries were sustained.

4.4.2 Case Study - RAF Manston

Records confirm that RAF Manston was pipe-mined during WW2 and the airfield was given a Class I Clearance Certificate after WW2, confirming that all mines were accounted for (removed) during the 1940s. However, during Operation Crabstick, 34No. pipe mines were found and removed at the airfield.

Then subsequently, between April and August 2001, four filled pipe mines and three empty pipe mines were recovered during two separate Army EOD tasks at the airfield. It is understood that these were not planned EOD tasks but reactive tasks. Furthermore, in March 2019 pipe mines were again unearthed at Manston Airport. This confirms that Operation Crabstick did not provide complete clearance of all pipe mines at the WW2 airfield site. Note, it is not known whether these recent pipe mines were known to Operation Crabstick and inaccessible at the time or whether they were missed during Operation Crabstick.

4.4.3 Case Study - HMS Daedalus

The original pipe mine plan for this airfield recorded 265No. mines laid out in 13No. rows. During Operation Crabstick, the Royal Engineers cleared a total of 14No. pipe mines, nine of which matched the original map layout. The other five were unexpected / unrecorded.

A subsequent army EOD operation carried out between September and October 2006 identified a further 20No. pipe mines, four of which did not correspond to the original plan either. Some were still live and had to be destroyed in-situ. Anecdotal wartime evidence suggests that a second team of Canadian engineers may have been tasked with filling in any gaps left in the original layout during WW2, but the plan was not updated to take account of these additional mines.

Then in November 2017 another pipe mine was discovered by a contractor during construction works on a new substation at Swordfish Business Park within the perimeter of the former airfield.

4.4.4 Case Study - RAF Hawkinge

Operation Crabstick documents confirm that this airfield was also given a Class I Clearance Certificate after WW2, confirming that all mines were accounted for (removed) during the 1940s. However, Operation Crabstick located and destroyed one additional pipe mine at the former airfield site.

Then in November 2000, a commercial UXO risk management company were contracted to provide EOD support to construction works at a site within the former RAF perimeter. During these works a number of additional pipe mines were unearthed.

4.4.5 Site-Specific

Documentation relating to Operation Crabstick's Southampton Airport task was accessed, however it is understood that the available documentation is incomplete.

These records state that the original WW2-era clearance document for RNAS Eastleigh lists 233No. mines laid under the airfield, with 233No. mines later recovered (presumably during the mid / late 1940s).

Southampton Airport was originally recced by the army on the 5th September 1983, however surface searches in specific locations were not carried out until 1989.

A detailed account written by one of the EOD engineers involved in the Southampton Airport task was accessed. The author states that 18No. mines, each ~40-ft long were identified for removal / clearance during a February 1990 task that required the temporary closure of Southampton Airport, the adjacent A road and railway line.

This task appears to have been largely successful, however a September 1992 update (Operation Crabstick report) states that four possible pipe mines under the hard surfaced runway were detected during the February 1990 EOC task but cannot yet be confirmed or cleared. The recommendation was to enquire with the airport's owner (BAA) as to when the runway is due for refurbishment, with a view to investigating these possible mines during those ground works.

The northern section of the Army's plan of RNAS Eastleigh plotting the pipe mine matrix is displayed at **FIGURE 7**. The nearest pipe mine is located ~150m southwest of the nearest Site boundary. As expected, the northern edge of this plotted mine grid corresponds to the known WW2-era northern extent of RNAS Eastleigh. It is considered highly unlikely that any mines were buried beyond this airfield perimeter. The four remaining (possible) mines beneath the hard surfaced runway are highly unlikely therefore to have been identified beneath the northern section of runway just west and south of the Site boundary.

4.5 Airfield Defensive Mines - Improvised

4.5.1 Brief Overview

Other post-war EO finds indicate that RAF personnel may have occasionally placed improvised mines or actual AP or AT mines in / around airfield perimeters. Note, any such activity is highly unlikely to have been widely adopted at the UK's many WW2-era military airfields.

This could have involved deliberately burying HE devices (e.g. air-delivered bombs) at strategic locations around the airfield perimeter. In the event of a German ground attack, the bombs could be remotely detonated from a sheltered position, using a long detonation cord. One such possible example was encountered post-WW2 at RAF Oakington. Similarly, a WW1-era British AP mine (chemical-fill) was recently unearthed near the perimeter of RAF Horsham St. Faith.

4.5.2 Site-Specific

No evidence of small-scale improvised mining of the airfield perimeter has been found. As the extended wartime airfield perimeter passed through the Site any such activity could conceivably have affected the southern part of the Site, immediately north of the requisitioned North Stoneham Farm. However, the likelihood of Royal Marines sewing land mines or improvised land mines at RNAS Eastleigh, is considered to be low.

4.6 Handling of Ammunition and Munitions at Airfields

4.6.1 Introduction

A wide range of ammunition and munitions was stored, handled and (sometimes) disposed of at military airfields. Most airfields had designated ammunition, pyrotechnics and dispersed bomb storage facilities. Post-war EO finds confirm a higher likelihood of EO contamination, as well as other EO-related items (fuzes, detonators, bomb pistols etc) within the soil around such stores. Note, due to their size / weight it is unlikely that large bombs, air-dropped (naval) mines, depth charges or torpedoes will remain buried at a former military airfield site today.

Some military airfields designated specific locations for the disposal of hazardous items (including EO). These burning / demolition pits were usually established in peripheral locations, away from day-to-day activities. EO was not always destroyed but often simply buried at such locations.

Random (likely unauthorised) small-scale disposal of EO appears to have also occurred at airfield sites. A soldier or airman discarding a small quantity of EO, or a single item, is difficult to predict, in terms of location. However, post-war EO finds indicate that unused peripheral / isolated land (e.g. near the perimeter fence) and perhaps densely vegetated locations (for concealment) are more likely to have experienced such contamination.

The arming and disarming of combat aircraft often took place at aircraft dispersals (pens, loops and pan hardstands) situated throughout an airfield site. Ground crews under time pressure appear to have (occasionally) discarded small items on adjacent grass. Such small items may not have been subsequently collected and properly disposed of. Any bombs returned to the airfield with unremovable antihandling mechanisms fitted could conceivably have been placed on grass adjacent to aircraft dispersals, awaiting EOD removal. Anecdotal evidence indicates that ammunition / ordnance was sometimes stored in small huts adjacent to dispersals, to maximise ground crew efficiency.

In mid-1945 the RAF and USAAF were left with vast quantities of surplus munitions and ammunition. Several RAF maintenance units specialising in weapons servicing were tasked with their long-term storage and eventual disposal. Bombs and ammunition were stacked up on runways and in spare buildings at a number of British military airfields.

Although the quantities were vast, these large-scale storage activities are unlikely to have resulted in EO contamination, partly due to the secure nature of the dumps and also due to the size of most of the stored items, being large individual bombs and crates of SAA and sub-munitions / bomblets.

4.6.2 Site-Specific

- RNAS Eastleigh was not home to front line RAF combat squadrons. As a Fleet Air Arm base associated with aircraft carrier operations, no combat sorties were flown directly from the airfield. Consequently, it did not have a large bomb storage compound.
- As no WW2-era plans of the RNAS are available, the locations of any ammunition storage buildings are unknown. It is considered unlikely however that any such buildings would have been erected on the requisitioned farmstead and adjacent ground. Indeed, wartime aerial photorgaophy does not exhibit any earth-bunded (blast protected) explosives storage buildings within or near the Site boundary.
- Various EO items would have been stored / handled at RNAS Eastleigh, including:
  - LSA (chiefly grenades) for the airfield defence force.
  - SAA (for LAA machine guns, rifles and sidearms).
  - Pyrotechnics (distress flares, battle simulants) and smoke grenades / canisters (battle simulants).
  - Although no specific evidence has been found, 20mm or 40mm calibre autocannon ammunition (for LAA guns) could conceivably have been stored at the RNAS.
  - Live and practice air-delivered bombs are unlikely to have been stored locally, although this cannot be ruled out.
- As no aircraft dispersal points / hardstands were positioned nearby, aircraft arming / disarming can be discounted as a potential EO contamination source.
- The 1946 aerial photograph shows evidence of possible waste processing / disposal on Site, with the potential for small-scale aircraft breaking. Recent EO finds in around WW2-era military airfields confirm that mass burial of surplus / unwanted equipment and hazardous items was not uncommon. It is not inconceivable therefore that such activity (potentially including the burial of ammunition) occurred here. Note, the appearance of this site (and presence of buildings) is not consistent with that of an official / authorised ammunition burning and demolition ground.
- The old gravel pit within the farmstead may have provided adequate conditions for the concealed / unauthorised small-scale disposal or a hazardous device(s) by an individual.

4.7 Weapons Ranges

4.7.1 Introduction

Most military airfields had small arms firing ranges (for pistol and rifle target practice) and aircraft gun test butts (for calibrating aircraft mounted guns). Some airfields made provision for airfield defence soldiers to practice live grenade throwing.

Some airfields utilised unused ground within or requisitioned land near the airfield perimeter for low altitude gunnery and bombing practice, the latter utilising small (typically <20lb), relatively low hazard practice bombs. The ‘A’ shaped runway layout, typical of WW2-era military airfields, created a central triangle of unused grass and a highly visible target marker. Such areas were therefore perfect for aircraft target practice. Note, such target practice was undertaken by a wide variety of flying units / aircraft, not just heavy bomber squadrons.

Potential contamination in and around these ranges would include partially expended or dud practice bombs, SAA (solid shot), live / fuzed rounds (>20mm calibre), heavy metals (Lead, Antimony, Barium, Copper), explosive propellant residues and possibly other devices. The RAF's standard practice bombs were small, cheap and therefore any that did not function as designed (penetrating soft ground) are unlikely to have been retrieved.

4.7.2 Site-Specific

No small arms (pistol, rifle, machine gun) firing range or RNAS aircraft weapons shooting-in-butt was established on Site and no evidence (written or visual) of a temporary grenade throwing range associated with the RNAS has been found.

Official records do not list USNAF Eastleigh / RAF Eastleigh / RNAS Eastleigh as an airfield that featured its own onsite practice bombing or aircraft gunnery firing range.

4.8 Aircraft Crash Sites

4.8.1 Brief Overview

WW2 necessitated a significant reduction in the length of pilot training programs, inevitably resulting in a higher frequency of accidents. For bomber aircraft especially, very heavy weapon and fuel loads greatly hampered take-off (the most dangerous manoeuvre), resulting in many crashes. Additionally, the Allied bombing campaign of occupied Europe saw numerous aircraft return with damage from German AA defences, frequently ending in crash landings.

High-speed ground impacts resulted in high density objects (engines and bombs) becoming buried in the soil. Complete salvage of the bombload would not necessarily have been a priority following such incidents, especially in isolated areas. This is evidenced by recent UXB and ammunition finds at wartime aircraft crash sites.

4.8.2 Site-Specific

Searches of primary source / official and secondary source records have found no evidence confirming or indicating a significant British / Allied-nation aircraft crash scenario within the Site boundary. That is, a 'bombed-up' military aircraft impacting the ground at high angle and high speed, or a midair collision over the Site involving a 'bombed-up' military aircraft.

4.9 Mustard Gas

4.9.1 Introduction

In the lead up to (and during) WW2 Britain stockpiled many tens of thousands of tonnes of mustard gas. >60No. RAF and USAAF bases were used as storage (and occasionally disposal) sites. Some sites declared as clear / safe by the MOD have since yielded mustard gas filled containers (storage canisters and artillery shells). Note, the highly sensitive nature of Britain's former chemical warfare capability hampers present day research.

Ineffective attempts were made to clean up the former airfield sites over the past 40No. years, leaving significant amounts of this chemical agent in the soil. Furthermore, some original records appear to have been lost.

At WW2 RAF airfields, Station Gas Exercises were frequent. They involved the use of real mustard gas to simulate a chemical attack on the base. Weapons, vehicles, and buildings would be deliberately contaminated so RAF personnel could practice their response.

4.9.2 Site-Specific

RNAS Eastleigh was not one of the airfields used for large-scale mustard gas storage and / or disposal.

4.10 Invasion Defensive Activities - Civilian Land

4.10.1 Brief Overview - WW2

From mid-1940, the threat of imminent German invasion resulted in the fortification of many coastlines, cities and towns in Britain. Army units were concentrated in the most vulnerable / most likely invasion areas and local Home Guard (HG) battalions were raised throughout the country.

At first, the strategy called for largely static defences focused on the coastline (the coastal crust) and a series of inland anti-tank (AT) stop-lines. The stop-lines varied in their length, strength and complexity with the General Headquarters Line (GHQ Line) being the most important. Stop-lines mostly comprised pillbox fortifications and AT trenches, where possible built / dug along natural barriers to armoured vehicles, for example rivers. Similarly, major cities (including London) were ringed with inner and outer stop-lines.

By July 1940 however, the plan had changed. Coastal crust defences and 'nodal points' were prioritised over stop-lines. Nodal points (also known as AT islands or fortress towns), were strategic focal points expected to hold out against attack for up to seven days.

The HG comprised men either too old or young, or in reserved occupations. Almost all populated areas in Britain stood up a HG battalion and some organisations (infrastructure organisations and large industrial works) created their own private units. HG platoons were sometimes detached to military related sites for training and to provide guards for sentry duty.

By mid-1940, over one million had signed up to the HG. Initially, only basic and improvised weapons were available, however by mid WW2, weapons specifically designed for the HG (e.g. SIP grenades and the Blacker Bombard spigot mortar) as well as conventional weapons, were widely deployed.

Historically, an 'out of sight out of mind' culture (with regards to ammunition disposal) has been widespread in the British armed forces. This is evidenced by numerous post-war AXO finds in the UK. Troops appear to have discarded unwanted or faulty items (including surplus ammunition) on civilian land, most likely when the threat from invasion had passed or when the HG was disbanded in 1944. Ammunition caches are also believed to have been buried at defended positions, for quick / easy access in the event of an invasion. Inevitably some were forgotten and can therefore remain in-situ today.

4.10.2 Site-Specific

From September 1940, Eastleigh town was categorised as a divisional anti-tank island (fortified urban area) under the responsibility of the British Army's 4th Division. No official records detailing the associated defence works were however available. It can be said that no fortified stop-lines were built through the Site.

The portion of the Site beyond the wartime RNAS perimeter will have been the responsibility of the local Home Guard (HG) unit - the 11th Hampshire (Eastleigh) HG Battalion, headquartered at Woodside House, Woodside Lane, Eastleigh. Although, as Southern Rail's Eastleigh Works (immediately north of the Site) was categorised as a vulnerable point (VP) requiring its own 'inhouse' HG platoon, 11th Hampshire Battalion soldiers may not have accessed the farmland on Site. Note, the HG platoon deployed to defend this railway works was part of the 21st Hampshire (4 Southern Rail) Battalion.

Although HG troops would have been active locally, the original operational records (including defence schemes and operational orders) of these units are not held by the relevant archives and therefore significant details regarding the activities of these soldiers relative to the Site is unclear. Note, no secondary source / indirect evidence of defence measures (earthworks or hardened fortifications) at the railway works' southern perimeter has been found.

It can be said however, that Southern Rail HG troops (sentries and patrols) may have accessed the northern peripheries of the Site. However, such activity would have required small arms only (rifles and sidearms), with small arms ammunition (SAA) being a low hazard form of EO. It is unlikely that this South Rail HG unit (not a high priority unit) would have had access to adequate LSA during the period of highest invasion threat (1940) when such ammunition was in short supply.

4.11 Anti-Aircraft Weaponry

4.11.1 WW1

AA artillery was in its infancy during WW1 and therefore British AA gun deployments were on a far smaller scale than during WW2. Initial activity saw guns installed on top of some buildings and at other key facilities in London and Kent during 1914.

London was the most heavily defended region. Other cities and towns throughout Britain were defended, however Kent had the most AA batteries outside of the capital. Note, many of Britain's AA guns were not static. Single guns were mounted on trucks and moved around. RN installations also received protection. At the beginning of the conflict, 58No. guns were distributed between naval facilities at Dover, Harwich, Liverpool, the Tyne and the Humber.

The 3-inch QF gun was the mainstay of British AA artillery. UX 3-inch shells typically landed between 8km and 10km away. The smaller calibre 1-Pounder QF autocannon was also used in the LAA role, however it proved to be ineffective.

4.11.2 WW2

During WW2, the British Army's AA Command utilised three types of AA weapon for home defence: heavy AA (HAA) guns, light AA (LAA) guns, and Unrotated Projectile (UP) rocket projectors. From 1940 to 1945, BD units dealt with approximately 7,000No. UXAA projectiles in the UK, however such UXO is still unearthed today.

- **HAA Guns:** The vast majority of HAA guns (3.7 and 4.5-inch calibre) were deployed in static batteries of between four and eight guns. HAA batteries were used to engage bombers at high altitudes and were the main constituent of most city's (and some town's) Gun Defence Area (GDA). Mobile gun mounts were also available for temporary deployments to key military and civilian targets. Note, a very small number of British 5.25-inch guns were deployed from 1942 onwards, as well as batteries of US Army 90mm guns during 1944.

  Some 2,000No. of these guns were available during the 1940 / 1941 Blitz. GDAs could expend vast quantities of ammunition during each engagement. The most numerous 3.7-inch gun variant had a firing ceiling of approximately 9km. Although a number of factors will have affected the range of falling UX shells, most typically landed 10km to 15km away. Note, greater distances were achievable.

- **LAA Guns:** Smaller calibre guns (machine guns, 20mm and 40mm autocannon) were used for point (individual target) defence of strategic targets / vulnerable points (VPs). At the time, government policy mandated that (where possible) every VP should be protected, however in reality, a chronic shortage of effective LAA guns (autocannon) during the early years meant that only priority VPs received adequate protection.

  These smaller guns were easily transportable, and LAA regiment deployments were often temporary. British WW2 40mm guns had a firing ceiling of approximately 7.1km. Although a number of factors will have affected the range of falling UX shells, most typically landed <10km away.

- **ZAA Rockets:** A ZAA battery comprised a grid of typically 64No. UP rocket projectors firing single and (later) multiple 2-inch (UP-2) and 3-inch (UP-3) rockets in a volley, creating a 'box of effect' at preselected altitudes. Although a number of factors will have affected the range of falling UX rockets, they typically landed within 10km of the battery.

  Prototype ZAA weapons were fielded in late 1940 and deployed in cities around Britain from 1941. However, they were only deployed in significant numbers after the initial nine-month Blitz campaign had ended. Consequently, ZAA batteries saw far less action than AA guns. By the end of the war, >50No. ZAA batteries were operational across Britain.

4.11.3 AA Defence of Airfields

During the early stages of WW2, most airfields' ground defence positions armed with machine guns doubled up as LAA positions. The much more effective autocannons (in short supply) were distributed amongst the most important and vulnerable airfields only. As the war progressed, these 20mm and 40mm calibre guns became more readily available and dedicated RAF Regiment LAA units were formed to provide protection for more RAF airfields. Note, the RN's equivalent to the RAF Regiment was the Royal Marines, who will have manned LAA guns at RNASs.

LAA gun positions were not always static. They were dispersed around airfields and were sometimes moved to hinder Luftwaffe pilot planning. AA gunners may have discarded any faulty or jammed ammunition close to their firing positions. Most UX shells fired from these guns however, would have fallen far from the airfield.

4.11.4 Site-Specific

- Two static AA gun batteries (each armed with a single 18-pounder gun) were active within firing range of the Site during WW1 and there is an elevated likelihood of mobile AA gun deployments to the wider area (to defend RN sites). However, as no German aircraft were active locally, WW1-era UX AA projectiles can be discounted as a source of potential UXO contamination.
- 17No. static HAA gun batteries (totalling at least 68No. gun emplacements) were built within firing range of the Site prior to / during WW2. Note, some emplacements may not have been constantly armed with an artillery gun throughout the local bombing campaign.
- One U.P rocket projector (ZAA) battery and possibly a second (RN experimental) U.P rocket projector battery was / were active within firing range of the Site during WW2. This is an insignificant number of weapons. The likelihood of associated UXO striking the Site is low.
- Evidence of one Royal Artillery (army) LAA gun site within autocannon firing range of the Site has been found. Anecdotal evidence of three further possible LAA gun sites within 2km of the Site has been found.
- RNAS Eastleigh's LAA gun sites will have comprised machine guns from 1940. No evidence has been found indicating autocannon deployments (e.g. the RN's Oerlikon 20mm calibre) at the airfield during WW2.
- No RAF Regiment LAA squadron deployments to defend RAF sites within firing range of the Site appear to have occurred.
- An official record states that by the 6th June 1944, Eastleigh was defended by a total of 17No. LAA gun sites, nine of which were operated by local HG troops.
- As WW2 Luftwaffe activity in the region was moderate frequency and low to high intensity, these AA weapons may have expended a significant quantity of ammunition. However, as only three such UXO strikes (see below) are recorded in the borough, the UXO strike density does not appear to have been significantly elevated.
- An original WW2 Eastleigh council record of wartime incidents includes three such incidents in the borough:
  - 19th / 20th January 1941 - an unexploded AA shell fell at No.184 Manket Street, Eastleigh. Reported to police and bomb disposal squad.
  - 17th April 1942 - an unexploded AA shell was discovered near the Southern Railway Locomotive works, adjacent to the boiler supply building.
  - 19th September 1943 - at 11:05hrs, an unexploded AA shell struck No.26 Doncaster Road, causing damage to the roof, ceiling, staircase and flooring.

4.12 Explosive Ordnance Hazards Overview

4.12.1 Introduction

The following subheadings detail the EO hazards most likely to be relevant to the study area. Note, this is not an exhaustive list of potential EO contaminates.

4.12.2 Artillery Projectiles: Anti-Armour and Anti-Aircraft

AT guns, AA guns, and howitzers have been in use with the British Army for over a hundred years and from 1942 / 1943, many HG units were armed with a variety of small calibre AT guns. AT gun calibres ranged from the Ordnance QF 2 Pounder (40mm) to the Ordnance QF 17 Pounder (76mm). Howitzers ranged from the Ordnance QF 25 Pounder (87.6mm) to the BL 60 Pounder (127mm). HAA gun calibres were medium.

A wide variety of artillery projectiles have been deployed in the UK historically, by British and allied nation armies. In general, projectiles fall into two categories; shot and shell. The former are inert; solid metal projectiles containing no hazardous element, whereas the latter are hollow (like bombs), containing a variety of potentially hazardous fills.

Solid shot falls into four categories, mainly for gun proofing, target practice, and AT use, however as they are inert they are relatively irrelevant with regards to present day UXO risk. Historically, there were three types of WW2-era British artillery shell:

- **Bursting Type** - The filling (or part of it) caused the shell to burst. The most common filling was HE where the shell caused damage to material by the force of the burst or to personnel and aircraft by fragmentation of the shell casing producing shrapnel. WW2 HAA shells were of the bursting type. Note, bursting shells were also used with chemical fillings.
- **Shrapnel Type** - These usually burst in the air and projected their 'payload' forwards acting like a shotgun. The usual payload was shrapnel bullets however Thermite 'pots' were used during WW1. By the start of WW2 shrapnel shells were obsolete for field artillery.
- **Carrier Type** - These also burst in the air, however ejected their payload backwards after blowing the base plate off the shell. The most common fills used were smoke, star and flare shells. The latter two being designed to illuminate an area or target. Smoke shells were used to produce smoke screens and used various fillings (the most common being white Phosphorus).

Artillery projectiles were always painted, this protected the steel from rust but was also used to indicate the nature of the ammunition. The basic body colours for artillery were; Yellow (HE), Light Green (smoke), Black (Flare / Star) and Grey (chemical). Note, artillery shell fuzes found on their own can also represent a hazard. Although small, such items can contain enough HE to cause serious injury if mishandled.

With regards to HAA shells, British mechanical time-delay and barometric pressure fuzes of WW2 were poorly designed, resulting in high HAA ammunition failure rates (around 30%) during 1940 and 1941. By 1944 however, new fuzes had reduced the rate to approximately 2%.

Unlike bombs, AA shells were not designed to strike the ground nose first and therefore UX AA shell strikes on soft ground did not always create recognisable circular entry holes. This, combined with their lower mass (compared to a UXB) resulted in shallower ground penetration depths, typically <1.0m bgl in soil. Although, in very soft / saturated ground, UX HAA shells were observed to penetrate to >1.5m bgl.

Data sheets detailing examples of field gun and AA projectiles are displayed at **APPENDICES 1** and **2**.

4.12.3 Grenades

Grenades are the most commonly encountered type of WW2-era British LSA in the UK. Other types of LSA include mortars, artillery projectiles (e.g. AT guns), infantry rocket systems and mines (AP and AT).

Hand grenades and rifle (projected) grenades are small devices with a delay fuze that detonates three to five seconds after initiation / launch. They are divided into two categories, explosive (fragmentation or blast) and carrier. The latter are used for signalling (smoke) and incendiary (chiefly white phosphorus for AP and AT use).

A wide variety of grenades have been deployed in the UK historically. The first modern British fragmentation grenade (the Mills Bomb) was used from 1915 onwards, with later models used well into the post-WW2 period. Consequently, this model accounts for the majority of UX grenade finds in Britain. A Mills Bomb (the No.36 grenade in British service) is approximately 95mm x 61mm and contains approximately 71g of HE.

Another common UK grenade find is the No.76 Self-Igniting Phosphorus (SIP) grenade. These cheap and simple devices comprised a glass bottle (152mm x 63mm) containing a composition that reacts with air (when broken) creating an intense white phosphorus incendiary effect (burns hazard). They equipped most HG units during WW2.

A data sheet detailing some of the grenades (and other LSA items) most commonly deployed in the UK historically is displayed at **APPENDIX 2**.

4.12.4 Mortars

A mortar is a compact infantry support weapon that fires a projectile (mortar bomb) in a high-arcing ballistic trajectory, at low velocity. The first British mortars were used during WW1.

A mortar bomb / round is usually tear-drop shaped or cylindrical, nosed-fused and fitted with its own propelling charge. A small tail fin assembly stabilises the round in flight and a ‘spigot tube’ containing the propellant charge is screwed or welded to the base of the round.

During WW2, the 2-inch and 3-inch calibre mortars were the most commonly used by the British Army. These systems utilised several different types of ammunition (HE, smoke, illumination, signal, chemical and drill). The most commonly deployed round (the 2-inch HE variant) weighed approximately 1kg, 200g of which was the HE bursting charge. As such, mortars pose a hazard similar to grenades.

Data sheets detailing examples of this EO type are displayed at **APPENDIX 2**.

4.12.5 Autocannon (LAA) Shells

In Britain, two types of autocannons were used in the LAA home defence role by the Royal Artillery and later the RAF Regiment, the Hispano (20mm calibre) and Bofors (40mm calibre). These guns are similar to machine guns, however fire larger calibre rounds at a lower rate of fire (<750 rounds / min and 120 rounds / min, respectively).

Although cannon ammunition looks similar to SAA, these larger projectiles incorporate a small, simple impact fuse and hazardous charge. 20mm projectiles were typically 41mm in length and included a 6g - 11g HE and / or incendiary composition charge. 40mm projectiles were typically 130mm in length and included a 70g HE charge. Although small, when compared to artillery shells, each projectile still has the potential to cause serious injury.

Most WW2 autocannon ammunition incorporated a self-destruct mechanism, detonating the projectile after five seconds if no impact occurred. This resulted in less collateral damage and far less unexploded shells falling back to earth. If this mechanism failed, a UXO strike would occur at ground level.

Data sheets detailing examples of field gun and AA projectiles are displayed at **APPENDIX 2**.

4.12.6 Small Arms Ammunition

SAA (or bullets colloquially) is primarily cartridge-type ammunition with a calibre of <20mm. Each 'round' comprises a cartridge case, projectile (bullet), propellant and primer. Side arms (pistols), rifles and light to heavy machine guns utilise SAA.

Generally, SAA poses a relatively low EO hazard due to the small amount of explosive contained within the cartridge case and the low sensitivity / stable nature of the complete round. Although a cache of unspent rounds subjected to high temperatures (e.g. fire) could function and create a hazard.

Expended SAA (the projectile) is almost always solid shot, i.e. inert. Note, During WW1, experimental incendiary and explosive .303-inch SAA saw limited use with the Royal Flying Core and the RAF. Consequently, such SAA encounters today are very rare.

In the UK, the most commonly encountered historic SAA is .303-inch calibre. This was the standard cartridge used by British and Commonwealth armed forces from 1889 until the 1950s. However, many other calibres have been deployed in the UK by British and Allied forces.

4.12.7 Miscellaneous

Aside from live ammunition / munitions, a wide variety of potentially hazardous devices were handled at WW2-era military airfields.

- **Battle simulants / Training Aids**: during the 20th Century the British armed forces utilised a variety of devices during training exercises to simulate battle conditions. One of the first such devices, the WW2 ‘Thunder Flash’ was designed to mimic a grenade detonation and therefore is akin to a loud firework. Battle simulants do not contain HE and are not lethal, however they do contain a small charge or hazardous fill (usually a smoke producing composition). As such, they have the potential to cause injury if mishandled.
- **Fuzes and Detonators**: Detonators and fuzes are small components of individual rounds of ammunition / munitions. All detonators and some fuzes contain primary explosive, in relatively small quantities. These devices can be very small and are therefore more likely to persist at a site, long after military activity has ceased.
- **Drill / Training Ammunition**: Drill versions of numerous live ammunition types have been utilised by the British armed forces over the years. However, as drill ammunition / devices do not contain a hazardous fill element, they are inert (harmless). Drill devices are the same size, shape and often weight as their live counterparts, chiefly because they must be fired from the same weapon. They are also very similar in appearance to their live counterparts, although usually painted grey or blue and marked ‘drill’ or ‘inert’. It should be noted however that examples of historic drill ammunition found today are usually so heavily corroded, they are indistinguishable from their live counterparts.

5 WW2 Enemy Action Assessment: Aerial Bombing

5.1 German bombing during WW2

Between 1939 and 1945, the German air force (the Luftwaffe) dropped approximately 75,000 tonnes of HE bombs and over two million incendiary bombs (IBs) on the four nations of the UK. Almost all counties were affected to some degree.

At the time, bombing was still in its infancy. Testing showed that the accuracy of daylight, level flight bombardment would put 50% of the bombload within 91m of the centre of the target from an altitude of 3,000m. At double this altitude the error exceeded 400m. In poor visibility and at night, the error could increase by >250%.

Furthermore, these tests were conducted within an uncontested environment. The various British AA defences and navigational countermeasures greatly hindered bombing. Luftwaffe aircraft frequently abandoned their intended target and jettisoned their bombloads indiscriminately. Consequently, numerous bombing incidents occurred in open countryside throughout the UK, many miles from intended targets.

Bombs were only rarely dropped individually. The normal procedure was to drop an internally carried bombload in a single sequence, with release spacings pre-set from 10m to 100m. 20No. 50kg bombs (the most numerous HE bombload) could thus extend in a line (called a bomb-stick) varying between 200m and 2km in length. These patterns (when accurately plotted) can aid in locating unreported UXBs. It should be noted however that externally carried bombs could be released individually, creating uneven bomb-stick patterns or solitary bomb strikes.

For other types of commonly deployed ordnance, inaccuracy was inherent. 1kg / 2kg IBs and parachute retarded mines (high-capacity blast bombs) were easily blown off course by the wind.

5.2 Explosive Ordnance Hazards Overview

5.2.1 Introduction

During WW2 the Luftwaffe deployed a variety of ordnance against the UK. The most frequently deployed large bombs achieved significant ground penetration due to their ‘thick-skinned’ steel construction and are therefore more likely to remain buried in the ground today. These HE (and some incendiary type) bombs are termed ‘iron’ bombs. The 50kg and 250kg ‘iron’ bombs accounted for approximately 93% of ‘iron’ bombs dropped on the UK.

Descriptions of these different bomb types are presented below. Data sheets detailing those bombs most likely to be encountered today are displayed at **APPENDIX 3**.

Note, the Italian Air Force participated in a small number of air raids in Essex and Kent during 1940. The Italian bombs were comparable to German general purpose ‘iron’ bombs, however any UXB find would be extremely rare.

5.2.2 More Likely to be Unearthed in the UK Today

- **High Explosive ‘iron’ bombs - General Purpose:** The SC series accounted for the majority of HE bombs dropped on the UK. This design had a moderate charge to weight ratio, approximately 50% charge. The most common weights were 50kg (SC50), 250kg (SC250) and 500kg (SC500). 6No. additional models (1,000kg, 1,200kg, 1,400kg, 1,800kg, 2,000kg and 2,500kg) were deployed in much smaller numbers.
- **High Explosive ‘iron’ bombs - Semi Armour Piercing:** The SD series were very similar in appearance to the SC bombs but had lower charge to weight ratios, approximately 30% charge. The casing was thicker, allowing for greater penetration through structures. There were six ‘iron’ bombs models ranging from 50kg to 1,700kg.
- **Incendiary ‘iron’ bombs:** The Brand C50A used a SC50 type casing but contained a mixture of incendiary liquids (including phosphorus) that ignited on contact with the air. The C50B was the same size but mostly phosphorus filled. The Sprengbrand C50 (Firepot) also utilised a thick ‘iron’ bomb casing, however contained both Thermite incendiary containers and a 7kg HE charge. These bombs weighed approximately 41kg and 50kg respectively and were introduced later in the war.

- **Incendiary Sub-Munitions:** The 1kg B1E IB was the most frequently dropped German bomb. Up to 620No. B1Es could be packed into a sub-munition canister, which opened at a pre-determined height, scattering the IBs over a wide area. The Thermite fill burns at extremely high temperature. The longer 2kg B2E model incorporated a small HE charge with delay fuze. The B2E is therefore more hazardous than the B1E, however was dropped in smaller numbers. Although light weight, both had the potential to fully penetrate soft ground.

5.2.3 Less Likely to be Unearthed in the UK Today

- **High Explosive 'iron' bombs - Armour Piercing:** The PC series (four models between 500kg and 1,600kg) were used against reinforced military structures and warships. Consequently, they were not commonly used against the UK mainland. Charge to weight ratios were low, approximately 15% charge.
- **High Explosive Blast Bombs - Parachute Mines:** Converted naval influence mines were dropped on urban targets. Their thin steel bodies allowed for very high charge to weight ratios, approximately 73% charge. Luftmine A (LMA) and Luftmine B (LMB) weighed 500kg and 1,000kg respectively. Each was parachute retarded, enabling detonation at ground level and therefore no ground penetration. Consequently, the only unexploded parachute mines found today, wash up along the coastline or remain on river or lake beds.
- **Oil Incendiary Bombs:** The Flam 250 and Flam 500 bombs contained a mixture of benzine and petroleum, ignited by a small HE charge. They were constructed of thin metal which broke up on impact, spreading the incendiary mixture across an area. As such they are unlikely to remain buried in the UK today. The bombs proved unreliable, often failing to ignite, and consequently were withdrawn from service in 1941.
- **Anti-Personnel (AP) Sub-Munitions:** The 2kg SD2 'Butterfly' bomb was dropped on several British cities and towns. It was a nuisance weapon incorporating both time-delay and anti-handling fuzes. It contained a small 225g HE charge, however had no ground penetration ability. A sub-munition canister could hold up to 108No. SD2s. The SD10 was a larger (10kg) AP bomb. It could achieve full penetration, however this model was dropped in very small numbers on the UK. A sub-munition canister could hold 17No. SD10s.
- **Miscellaneous:** The Luftwaffe dropped various other devices on the UK. Flares (for target illumination) were by far the most numerous, however had no ground penetration potential. Photoflash bombs (to aid reconnaissance photography) are similar in appearance to 50kg bombs. Inert concrete-filled bombs were dropped to cause disruption and unnecessarily tie up bomb disposal (BD) resources.

5.2.4 'Iron' Bomb Penetration Depths

The Research & Experiments Department of the Ministry of Home Security (MoHS) used BD records to study German HE UXB penetration depths, publishing their findings in 1949. The British Army's BD headquarters provided details of 1,304 UXB recoveries. In addition, the ministry carried out their own tests, involving 24No. bombs dropped into Chalk under controlled conditions.

The average penetration depth of 430No. 50kg bombs (the most commonly dropped HE bomb) in London Clay was 4.6m and 6.1m for the 250kg model. Note, these bombs landed in open ground and were therefore unaffected by structures or hardstanding. Once the distribution of bomb weights against penetration depths was plotted, the mean line was extrapolated for each bomb weight to produce probable maximum depth figures.

For each bomb weight, the mean average of all observed penetration depths was calculated for each geology. The resulting figures, plus the observed minimum penetration depths, are presented in the table below. Note, bombs weighing >1,000kg have been omitted from the table as only several such UXBs were recovered during WW2.

Bomb (Kg)	Clay			Chalk			Gravel			Sand			Sandstone		
	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)	Min (m)	Average (m)	Max (m)
50	0.7	4.0	9.1	1.0	3.5	7.7	1.0	2.8	7.8	1.0	2.8	7.8	1.8	2.7	6.0
250	1.5	6.8	15.8	1.0	6.0	13.1	0.7	4.8	13.7	1.8	4.8	13.7	2.5	4.6	10.3
500	3.8	8.7	19.8	4.0	7.6	16.4	2.5	6.0	17.3	3.0	6.0	17.3	-	5.8	13.1
1,000	4.8	10.9	24.9	4.2	9.6	20.7	2.0	7.6	21.9	6.8	7.6	21.9	-	7.3	16.4

TABLE 5: WW2 German UXB Penetration Depths Data

Although most German HE UXBs came to rest after several metres travel through the ground, these weapons can be encountered at any depth between just below WW2 ground level and the maximum BPD. There are three reasons why heavy bombs might be found at surprisingly shallow depths:

- **Low Altitude Release:** Some Luftwaffe raids (particularly those involving fast fighter-bombers) were executed at very low altitudes, to avoid RADAR detection. Bombs released over soft ground from very low altitude would impact at a shallower angle, resulting in extreme J-Curve Effect (see below).
- **Deflection:** 'iron' bombs had conical nosecones and were therefore susceptible to deflection. A bomb striking a structure (above or below ground), could deflect and come to rest at a shallower depth.
- **Aircraft Crash Site:** For several reasons, a pilot may not have been able to dump his bombload before impacting the ground. Any internally or externally fitted bombs could have become shallow buried on impact.

5.2.5 'Iron' Bomb J-Curve Effect

WW2 BD units reported that most deep buried German HE UXBs were observed in a horizontal or up-turned orientation. As a HE UXB penetrates the ground at an angle slightly offset from the vertical, it begins to turn, creating a curved passage through the soil.

This phenomenon can be significant when assessing the risk of UXO as the J-Curve Effect results in a horizontal offset from the point of UXB entry. A HE UXB could impact soft ground adjacent to a building and then come to rest beneath that building. The degree of lateral offset is typically one third (approximately) of the bomb's ultimate penetration depth. Therefore, for locations which experienced high-altitude bombing raids, J-Curve offsets will typically be between 2.0m and 4.0m. In extreme conditions, a low altitude attack resulting in a low angle UXB strike could produce even greater horizontal offset, up to 15.0m.

5.3 British Records of Bombing

5.3.1 Official Records

The Bomb Census was undertaken by the MoHS. The Bomb Census was compiled using information primarily gathered by ARP (Air Raid Precautions) wardens. Standardised forms were used to keep a written record of each incident. In many areas, these reports were used to create bomb plot maps. The Ministry also calculated bombing density statistics for every administrative area and created Daily Intelligence Reports, recording the date and location of every single air raid.

The Bomb Census commenced in September 1940, more than three months after the German bombing campaign commenced. Initially, only information relating to London, Birmingham and Liverpool was collated. It was not until September 1941 that the Bomb Census was extended to cover the entire UK. Consequently, many pre-September 1941 records were not standardised and, in some cases, were poor quality.

The level of detail varied greatly with location. Furthermore, the Bomb Census did not cover air raids on military property. The armed forces had no formal process for recording air raids and processing associated records.

As well as bombing incident records, some local authorities produced war damage maps. Council engineers carried out street by street surveys to create a record of the varying degrees of damage sustained by buildings.

Today, many original (archived) bombing records are incomplete, some collections are missing altogether and in some cases, entire records were destroyed at the time by German bombs.

5.3.2 Unofficial Records

In some parts of the UK where official bombing records are incomplete or missing, historic eyewitness accounts, newspaper articles, aerial photographs, etc can be used to build up a picture of WW2 air raids. The credibility of any such information, however, must be addressed and assessed.

5.4 Luftwaffe Targets

5.4.1 Brief Overview

The Luftwaffe carried out reconnaissance flights over the UK. Numerous aerial photographs were taken with subsequent German annotations earmarking various facilities for attack. Luftwaffe crews were also given British OS maps with German annotations highlighting their target area. In the absence of detailed bombing records, the presence of a known target increases the likelihood that bombs fell locally.

Although official German doctrine did not specifically target civilian residential areas, the Blitz raids on individual targets were gradually replaced by what was, for all intents and purposes, unrestricted indiscriminate bombing. This was due to the effectiveness of British countermeasures. The Luftwaffe identified city centre aiming points for some attacks, as well as identifying individual targets. Typical types of target:

- **Common Primary (strategic) Targets:** RAF airfields, Royal Navy bases, commercial docks, weapons (chiefly aircraft) factories and RADAR installations.
- **Common Secondary Targets:** engineering works, steel works, factories, depots, railway marshalling yards, gasworks, power stations, army camps / barracks, AA artillery batteries, coastal gun batteries etc.

Note, the inherent inaccuracies in WW2-era aerial bombardment resulted in many wayward bomb strikes in areas surrounding targeted facilities.

5.4.2 Site-Specific

Original Luftwaffe target mapping and target reconnaissance photography of the wider region was accessed. One such photograph is displayed at **FIGURE 8**.

Target Category	Relevance and Approx. Proximity to the Site
Confirmed primary aiming point (indiscriminate bombing)	Southampton city centre (~6km away)
Closest confirmed primary individual target(s)	None within 2km
Confirmed secondary individual target(s)	Eastleigh Railway Works (immediately north) Sewage treatment works (~100m north)
Unconfirmed but potential target(s)	RNAS Eastleigh / HMS Raven (immediately south) Three aircraft factories (600m - 1.2km south)

TABLE 6: WW2 Bombing Targets

5.5 Bombing Decoy Installations

5.5.1 Brief Overview

British decoys were intended to draw enemy bombers away from the true targets. 839No. decoys were built at 602No. sites in England, with approximately 200No. more established in Wales, Scotland and Northern Ireland. Although success rates varied greatly, the confirmed presence of a bombing decoy significantly increases the likelihood that bombs fell near or on that location. 5No. types were fielded:

- **'K' and 'Q' Sites - Dummy Aerodromes**. 230No. were established. 'K' decoys (landing field, mock-up buildings, and inflatable aircraft) were for daylight use. 'Q' decoys used lights to create a flarepath simulating a runway at night.
- **'QL' Sites - Urban Lighting**. Electric lights were used to simulate poorly implemented blackout procedures. As a bomber force approached, the lights would be extinguished erratically.
- **'SF' and 'QF' Sites - Diversionary Fires**. The largest and most sophisticated decoys. When lit, 'Starfish' sites gave the impression of an urban area set alight by incendiary bombing. They were installed near cities. Similar to, however smaller than 'SF' decoys, 'QF's were installed near and for the protection of specific vulnerable points (VPs) such as factories, military sites, oil storage tank farms, etc. Some 100No. 'QF' sites were established in England.
- **'M' and 'C' Sites - Dummy Factories and AA Batteries**. The former comprised a scale model of a specific factory, vital to the war effort. They were made from wood and canvas and had other features, such as access roads and equipment.
- **ASQL - Assault.** During August and September 1943, 18No 'QL' sites were installed along the south coast of England during a deception operation. These temporary decoys received very little attention.

Between 1942 and 1943, most 'K' sites were dismantled, however many of the other decoys were used up until late 1944 when Luftwaffe activity over the UK had all but ceased. By the end of 1941, the airfield decoys had received 359No. attacks compared with 358No. raids carried out against the real airfields. By June 1944, approximately 730No. attacks had been recorded on all decoy types. At least 5% of the total weight of German bombs dropped are estimated to have been aimed at Britain's decoy sites.

5.5.2 Site-Specific

No bombing decoys were installed locally. The closest was ~5.9km west of the Site.

5.6 Local Air Raids Information

5.6.1 Brief Summary

During the Battle of Britain in 1940, the Luftwaffe carried out targeted air raids against RNAS Eastleigh, its aircraft factories and the neighbouring railway works, although the airfield was never the subject of a large-scale raid, the likes of which were experienced by the RAF's front line Fighter Command airfields.

Furthermore, Eastleigh was located relatively close to the tenth most heavily bombed British urban area – Southampton. This increases the likelihood that some Luftwaffe bombers involved in the large-scale air raids on this city (during late 1940 and 1941) found themselves inadvertently passing over the town.

Between August 1940 and May 1943, Eastleigh experienced some 14No. small and medium-scale air raids.

5.6.2 Bombing Density

The table below records the MoHS' bombing density calculations for the Municipal Borough of Eastleigh and Winchester Rural District. Note, the Site is located within the former, however just 150m west of the border with the latter. It gives a breakdown of the number of large Luftwaffe bombs reported within the administrative area. The adjacent table displays IAL's bombing density parameters.

Administrative Area	E.MB	W.RD
Administrative Area Size (Acres)	6,269	110,432
HE 'iron' bombs (all types)	160	795
HE Parachute Mines	10	19
'Flam' Oil IBs	3	26
Phosphorus IBs	0	0
'Fire Pot' Phosphorus IBs	0	0
V1 Flying Bomb	5	13
V2 Long Range Rocket	0	0
Total (excluding V Weapons)	173	840
Bombs Per 1,000 Acres (405ha)	**27.5**	**7.6**

Qualitative	Quantitative
Very Low	<5 bombs per 1,000 acres (405ha)
Low	5 to 15 bombs per 405ha
Low to Moderate	15 to 30 bombs per 405ha
Moderate	30 to 75 bombs per 405ha
Moderate to High	75 to 150 bombs per 405ha
High	150 to 300 bombs per 405ha
Very High	>300 bombs per 405ha

TABLE 7: Bombing Statistics and Parameters - National Source

Note, these figures do not include UXBs, 1kg / 2kg IBs, or 2kg AP bombs. An incomplete Hampshire ARP record lists 100No. lightweight IBs falling on Eastleigh Borough between 1941 and 1945.

5.6.3 Site-Specific

The bombing density figure for a whole administrative area is not always a good indication of the bombing density over a specific site. Within larger districts, particularly rural districts, bombing density figures may be skewered by the presence of a heavily bombed target.

The rural district was a very large administrative area, reducing the accuracy of the bombing density figure when applied to constituent parishes (i.e. West End Parish immediately east of the Site). According to the bombing density calculation above, the Site occupied a wider area that experienced a low-to-moderate bombing density. Further research however suggests that **the study area experienced a moderate bombing density**.

5.7 Bomb Failure Rate

5.7.1 Brief Overview

There are three reasons why German 'iron' bombs dropped during WW2 failed to function as designed:

- **Human Error:** failure of the aircraft's crew to charge the electrical condenser in the fuze.
- **Very Low Altitude Release:** the fuze would not have enough time to arm itself before impact.
- **Faulty Fuze:** inadvertently during manufacture or sabotage by POWs working in German factories.

The Bomb Census recorded a daily average of 84No. German 'iron' bomb UXBs dropped on civilian targets throughout Britain, between 21st September 1940 and 5th July 1941. 8.5% of these were Delayed Action (DA) bombs (time bombs) which exploded sometime later. The remainder were unintentional 'duds' (UXBs).

By the end of WW2, the MoHS calculated a total figure of 200,195No. HE bombs recorded as exploded in Britain. An additional 25,195No. HE UXBs were recorded, giving a HE bomb failure rate of 12.6%.

The Luftwaffe figure for the total number of bombs dropped on the UK was approximately 11% higher than the number observed and reported by UK authorities. This suggests that the total number of UXBs remaining buried in the UK today is greater. However, anecdotal evidence suggests that German sources overstated their bombing statistics for propaganda reasons.

The average HE bomb failure rate of all boroughs and districts making up the London Civil Defence Region (the most heavily bombed part of the UK) was calculated as 10%, with rates ranging from 6% to 15%. Note, those areas of the capital that suffered the most damage, had the most ruins into which subsequent UXBs could fall unnoticed / go unrecorded. This limits the accuracy of the observed failure rates in those areas.

The discrepancy between the British and German records combined with the fact that HE UXBs are still consistently being discovered in the UK today (averaging five per year), confirms that the UK's 12.6% rate is inaccurate and is in fact higher. As rates of 15% were observed in some areas, this is considered to be a more accurate estimate of the true failure rate.

5.7.2 Site-Specific

No evidence has been found to suggest that the local HE bomb failure rate differs significantly from the national average.

5.8 Site-Specific Bombing Incident Records

5.8.1 RAF Records - Bomb Record Cards

Many RAF airfields operational during WW2 produced a specific record of German bombing incidents - the bomb record card. These records tend to include little detail, especially with regards to bomb strike locations. Although the airfield was chiefly a RNAS during WW2, an RAF bomb record card was still produced (displayed at **FIGURE 9**).

- Seven bombing raids are listed, during 1940 and 1941.
- Six resulted in HE bomb strikes only, with the seventh resulting in IB strikes only.
- At least three were single aircraft sortie raids.
- As one of the small-scale air raids (21st August 1940) resulted in bomb craters at the southern end of the landing ground (>900m south of the Site - a significant distance away) this raid can be discounted as almost certainly insignificant.

5.8.2 RAF Records - Official Campaign Diary

The RAF's original / official campaign diary for the Battle of Britain (July 1940 - October 1940) was searched. This record includes details on air raids sustained by RAF and RN airfields during this period. One entry relating to the study area was included:

- **11th September 1940** - Eastleigh. Enemy aircraft made a dive-bombing attack on Eastleigh Naval Air Station at about 16:13hrs without causing any damage, but the Cunliffe Owen Aircraft Factory nearby was hit and a fire was started. This was soon under control but many casualties were caused by a direct hit on a shelter.

5.8.3 RN Records - Official War Diary

Official / original monthly war diaries detailing all RN / RN-related activities and incidents throughout the UK, produced by the Admiralty during the conflict, were accessed. Note, the October 1940 diary is missing from the collection. These records include details relating to enemy action against all RN sites and assets throughout WW2. Relevant excerpts are displayed at **FIGURE 10**.

- Four air raids on RNAS Eastleigh are reported. One of these (22nd June 1942) is missing from the RAF bomb record card. Therefore, four raids are missing from the war diary.
- The **11th September 1940** raid involved 12No. enemy aircraft. HMS Raven (immediately south of the Site) did not sustain any bomb damage, however bomb strikes and damage was reported to a factory >1.1km southwest of the Site (a significant distance away). As a daylight dive-bombing raid (high accuracy) with aircraft flying east to west, it can be confidently assumed that none of the raiders flew over the study area. This raid can be discounted as almost certainly insignificant.

- The **23rd November 1940** single aircraft sortie raid resulted in seven HE bomb strikes, a one strike discrepancy with the RAF bomb record card. All bombs fell on the west side of the RNAS, between ~350m and ~1.2km from the southern Site boundary.
- The **22nd June 1942** raid appears to have been medium-scale. Reported damage to two wardroom blocks likely indicates a bombing incident(s) within the northern half of HMS Raven (within 350m of the southern Site boundary).

  Note, wartime aerial photography records the destruction of a farm buildings straddling the southern Site boundary at some point between March 1942 and February 1943. This is almost certainly evidence of bomb damage sustained during the 22nd June 1942 raid.

5.8.4 Hampshire ARP - Incidents Charts

An original record of all bombing incidents recorded within the Hampshire ARP Control area was accessed. The level of detail varies from incident to incident, however, generally includes, date, time, type, and general location. Some reports include details on damage sustained and some include grid references (GR) for individual bomb strike locations. As a handwritten record, text is illegible in places. Those incidents confirmed as, or potentially occurring within the wider study area (and some other relevant incidents) are summarised below:

- **21st August 1940** - at 17:25hrs, eight HE bombs fell on Eastleigh Airport. No damage or casualties reported.
- **11th September 1940** - at 16:20hrs an unrecorded number of HE bombs fell on the Cuncliffe Owens factory on Southampton Aerodrome. HMS Raven requested an ambulance from Eastleigh, and two casualties were taken to hospital. No damage recorded.
- **8th October 1940** - at 18:40hrs, three Junkers Ju 88 medium bomber aircraft flew across Eastleigh. An unrecorded number of HE bombs fell on the Southern Railway Works (between 10m and 1.2km of the north Site boundary), killing two people and injuring a further two. Three UXBs were recorded as having fallen at the Southern Railway Running Sheds (between 70m and 200m north of the Site). Further bombs were recorded as having fallen on the carpenter's store.

  Across the town, nine UXBs were reported, with a further 19No. being recorded at the airport. An additional three bombs fell on the Perilli Cable Works in the centre of the town, with areas of the borough also subject to machine-gunning. Collectively, across the borough, four people were killed and a further 19No. people were injured. Note, this incident record is partially illegible.

  Note, the 19No. UXBs is a large discrepancy with the RAF bomb record card (three HE bombs).
- **23rd November 1940** - during the night, time not reported. 11No. HE bombs (including a UXB) fell on the RNAS. No damage or casualties recorded. A RN bomb disposal squad was reported as having dealt with the UXB. One HE bomb reported on open ground, Doncaster Drive (between 500m and 1.1km west of the Site). Four UXBs fell in marshy ground at the sewage farm (between 160m and 570m north of the Site), believed to have sunk to great depth.

  Note, this is three and four more reported HE bombs, compared to the official RAF and RN records.
- **24th November 1940** - unknown number of UXBs reported at Eastleigh Airport (report time 01:55hrs). Note, these likely fell during the previous night's raid.
- **1st December 1940** - at 20:09hrs, four HE bombs fell in open country, Eastleigh. No damage or casualties reported. This incident is highly unlikely to have occurred within the wider study area.
- **18th January 1941** - at 20:43hrs, one HE bomb was recorded as having fallen in the Eastleigh area, no further details. This incident is highly unlikely to have occurred within the wider study area.

- **19th January 1941** - at 20:42hrs, a stick of HE bombs (four or five) fell on the Southern Railway Works (between 10m and 1.2km of the north Site boundary). Administrative offices and paint shops damaged, five people killed. On Southampton Road, 800m south of Eastleigh Station, two further HE bombs fell blocking the road (~260m north of the Site). Gas and water mains and several houses were reported as damaged. On the Southern Railway line 400m north of Eastleigh Station one HE bomb was reported as blocking the line. Two UXBs were also reported on the gangway between the workshops of the Southern Railway Company.
- **8th February 1941** - time not reported. One 50kg HE UXB was discovered in a coal stack at the Southern Railway Running Sheds (between 70m and 200m north of the Site). 22nd Bomb Disposal Company, Royal Engineers removed / disposed of the UXB four days later.
- **22nd April 1941** - at 18:27hrs, the crater of a small HE bomb was discovered in the southeast corner of Eastleigh Aerodrome (>1km south of the Site).

  Note, this probably resulted from the IBs raid of the 18th April 1941 (RAF bomb record card). This single aircraft sortie bombload almost certainly fell outside the wider study area and therefore this raid can probably be discounted as almost certainly insignificant.
- **26th June 1941** - at 01:59hrs, two parachute mines fell on a military camp at the south end of town. At least one soldier was killed, and others were reported as injured. Note, this is unlikely to refer to HMS Raven.
- **22nd June 1942** - at 01:16hrs, multiple small IBs then HE bombs were dropped in and around the Pirelli Factory (>960m northwest of the Site).
- **11th April 1945** - a second UXB was discovered in the Southern Railway Running Sheds coal stack, reportedly from an air raid on the 8th October 1940, at GR: 893 380 (80m north of the Site).

5.8.5 Hampshire ARP - UXBs Register

An original register detailing all German UXB and British unexploded AA projectile finds and disposals in the county was accessed. This extensive record appears to be comprehensive. Some incidents include grid references. Those incidents confirmed as, or potentially occurring within the wider study area are summarised listed below:

- **8th October 1940** - 10No. UXBs in Eastleigh Borough, no grid refs listed. All disposal priority category ‘C’. All disposed of by 9th October 1940.
- **9th October 1940** - 3No. UXBs at Southern Railway Works running sheds, no grid refs listed (between 70m and 200m north of the Site). All disposal priority category ‘C’. All disposed of by 9th October 1940.
- **9th October 1940** - 19No. UXBs at Eastleigh Airport, no grid refs listed (possibly within the wider study area). All disposal priority category ‘C’. All disposed of by 9th October 1940.
- **19th November 1940** - 1No. Parachute mine 80-yards from Southern Railway line, no grid ref listed (possibly within the wider study area). Disposal priority category ‘A’. Disposed of 19th November 1940.
- **25th November 1940** - 4No. UXBs in deep marshy water at Eastleigh sewage farm, no grid refs listed (between 160m and 570m north of the Site).
- **20th January 1941** - 1No. 50kg HE UXB at Southern Rail workshops, no grid ref listed (between 840m and 1.2km north of the Site). Disposal priority category ‘A’. Disposed of 21st January 1941.
- **12th February 1941** - 1No. HE UXB at Southern Rail running shed, no grid ref listed (between 70m and 200m north of the Site). Disposal priority category ‘A’. Disposed of 12th February 1941.
- **22nd April 1942** - 1No. HE UXB near Eastleigh Aerodrome, GR: 892 367 (~640m south of the Site). Disposal priority category ‘D’. Disposed of 23rd April 1942.
- **7th May 1944** - 4No. unexploded cannon shells in southeast Eastleigh district, GR: 904 378 (~320m east of the Site). Awaiting collection from Police Station.
- **11th April 1945** - 1No. 50kg HE UXB at Southern Rail Works, GR: 893 380 (~80m north of the Site). Disposal priority category ‘B’. Disposed of 12th April 1945.

5.8.6 Bomb Census - Incident Reports

Several collections containing different types of written MoHS record that could potentially include relevant details of local bombing, were accessed. Note, some of these collections are incomplete, only recording a fraction of the total incidents in the region (after late 1941).

Searches of these collections located cursory mentions of some of the local air raids only. No additional relevant details were available.

5.8.7 Bomb Census - Incident Plot Maps

Collections of original MoHS bomb census maps and trace plot maps for the region were searched. For the majority of Britain, such maps were only produced from late 1941 onwards and they only record HE bomb strikes (not IBs). Therefore, bomb census maps do not represent a complete picture of local bombing.

No such maps covering the study area were available.

5.8.8 Anecdotal and Secondary Source Evidence

A search of online resources and local history publications was carried out with the intention of locating any relevant anecdotal / eyewitness accounts or secondary source information relating to local bombing incidents. Several publications and websites including written histories of RNAS Eastleigh were accessed / searched and relevant details are summarised below:

- Andrews D *et al*. 1990:
  - **21st August 1940** - A German raider dropped eight HE bombs on the southern perimeter of the airfield (>1.1km south of the Site).
  - **11th September 1940** - 16No. German aircraft dropped 16No. HE bombs, nine of which were direct strikes on the Cunliffe-Owen Aircraft Factory (>1.2km south of the Site). The Supermarine Aircraft Factory 100m to the north of this factory sustained no damage.
  - **8th October 1940** - at 18:50hrs, three Heinkel He.III medium bombers approached RNAS Eastleigh from the north, machine gun strafed the Fleet Air Arm camp HMS Raven and dropped a total of 38No. 50kg HE bombs within the airfield perimeter. Three HE bombs fell within the railway works (hitting locomotive sheds and a canteen) and the aircraft also bombed Eastleigh town.
  - **22nd June 1942** - German aircraft attacked HMS Raven, dropping HE bombs and IBs, causing considerable damage and two fatalities (naval ratings).
- Paper No.67: The Bombing of The Railway Works - Eastleigh & District Local History Society:
  - **8th October 1940** - low flying machines in a southeastern direction passed over Eastleigh town and bombed the railway works. Two men were killed and two others wounded when a HE bomb exploded in the running sheds (70m to 200m north of the Site). Subsequently some UXBs were found.
  - **19th January 1941** at 20:45hrs, aircraft flying in a northern direction dropped 16No. bombs in the area. The carriage works was bombed. Southampton Road and rail tracks alongside was bombed, resulting in the destruction of dwellings No. 370 and 372 (~60m west of the Site). Bomb damage within the railway works was reported at the paint shop, office and clock tower (~1.1km north of the Site), lifting shop and smithy (~960m north of the Site), yard south of lifting shop (~760m north of the Site), and the boiler house (~360m north of the Site).
  - **10th April 1945** - a UXB was found in the coal stack at the railway works running shed, presumably dropped during the October 1940 raid.
- Lee D W. 2009:
  - **8th October 1940** - Three He.III bombers swept low over the airfield [RNAS Eastleigh] dropping 38No. 50kg HE bombs within its perimeter.

- **17th April 1941** - An incendiary attack just missed HMS Raven.

  Note, as a HE bomb crater likely resulting from this raid occurred >1km south of the Site, these IBs likely fell to the south of HMS Raven (>400m south of the Site).

► Brooks R J. 1996:

- **11th September 1940** - So much damage was caused to the Cunliffe-Owen factory and airfield during this air raid, that all four Fleet Air Arm squadrons of aircraft based at the RNAS were moved to other airfields, between the 16th September and the 15th October, leaving the RNAS temporarily deserted. It then became a training base. Note, the airfield's defence personnel are known to have remained.

► An anecdotal account [1] states that, quote 'Two men lost their lives on 22nd June 1942 as German bombers attacked [RNAS Eastleigh]. Timely air raid warnings prevented a much higher loss of life'.

► An anecdotal account [2] states that, quote 'On the 22 June 1942 two men were killed and considerable damage was done to the factories on the site; the air raid warnings however had prevented further loss of life'.

► An anecdotal account [3] states that, quote 'The airport was bombed ten times by the Luftwaffe, with considerable damage to the factories and buildings in a raid of June 1942'.

5.9 Abandoned Bombs

5.9.1 Brief Overview

When a WW2 BD team arrived at the scene of a confirmed UXO strike, they would classify the incident by its potential hazard, Categories A, B, C and D, with A the highest priority for immediate removal and disposal. Occasionally, BD engineers could not find or recover the UXO and its location was simply recorded as an 'abandoned bomb'. The reasons for abandonment could be inaccessibility, extremely soft ground (extreme burial depth) or simply a harmless location (e.g. an isolated field). Note, BD teams in heavily bombed areas were constantly overstretched due to the sheer number of UXBs reported.

The archive office of the British Army's 29 EOD&S Group holds an Abandoned Bomb Register for Britain, as does the Ministry of Housing, Communities & Local Government. The registers lack detail, particularly with regards to locations. A general address rather than a precise position (grid refence) is usually given. Some of the abandoned bombs are likely to have been subsequently recovered or discredited, however remain on the register.

5.9.2 Site-Specific

One abandoned bomb incident (a pair of German 250kg HE bombs) is listed at Southampton Airport. However, the grid reference included plots these UXBs 930m southwest of the Site.

5.9.3 WW2 Bombing Incident Records Conclusion

► **Number and intensity of local air raids**: Most of the available bombing incident records do not contain the level of detail required to confirm precise strike positions. However, it can be said that four air raids are confirmed as affecting the wider study area (within 500m of the Site boundary); 8th October 1940 (medium-scale raid), 23rd November 1940 (small-scale / single aircraft sortie), 19th January 1941 (small-scale / single aircraft sortie), and 22nd June 1942 (medium-scale raid).

Two further air raids (almost certainly small-scale / single aircraft sorties) could have affected the wider study area; 19th / 20th November 1940 and 14th / 15th March 1941.

[1] https://archives.wartimeni.com/location/royal-naval-air-station-eastleigh-hampshire/
[2] https://h2g2.com/entry/A61820048
[3] http://sotonopedia.wikidot.com/page-browse:southampton-airport

Note, three local air raids (almost certainly small-scale / single aircraft sorties) have been discounted as almost certainly insignificant.

- **Number of local bombing incidents**: The available bombing incident records do not contain the level of detail required to precisely calculate the total number of bomb strikes within 500m of the Site boundary.

  Those UXO strikes reported in the wider study area are mapped at **FIGURE 11**.

- **Local bomb-stick orientations**: Most of the available bombing incident records do not contain the level of detail required to identify the linear bomb-stick orientations (flight paths) of those aircraft that bombed the wider study area.

  Between one and three aircraft appear to have flown over the Site during the 8th October 1940 raid, dropping HE bombs to the north of the Site (on the railway works) and to the south of the Site (the RNAS). This raises the possibility of a UXB(s) release (unreported) over the Site.

  The 23rd November 1940 raider dropped bombs to the southwest of the Site and to the north of the eastern extent of the Site, confirming that it flew over the Site during its bombing run, raising the possibility of a UXB release (unreported) over the Site.

  As the 19th January 1941 raider is reported to have been flying in a northerly direction when it bombed the railway works, this aircraft probably flew over the Site, raising the possibility of a UXB release (unreported) over the Site.

  As the 22nd June 1942 raid appears to have resulted in some bomb damage to HMS Raven and a farm building on Site, one or more of these multiple aircraft (which also bombed a factory to the northwest, in central Eastleigh) probably flew over the Site. Note, anecdotal accounts state that significant damage was caused to the aircraft factories in the west and south of the RNAS (>600m from the Site).

  It is not known whether the 19th / 20th November 1940 or the 14th / 15th March 1941 raiders flew over the Site.

5.10 Aircraft Crash Sites

5.10.1 Brief Overview

Numerous German aircraft came down over the UK during WW2. In most cases, the pilot was able to jettison any remaining bombload prior to impact or the aircraft belly-landed resulting in only superficial damage to the fuselage. However, in some cases, mechanical malfunction and / or crew injury meant bombs were not released. If the aircraft struck the ground at a steep angle and at high velocity, high density objects (engines and bombs) became buried, sometimes to significant depths.

5.10.2 Site-Specific

No Luftwaffe aircraft crashed within the Site boundary.

6 WW2 Enemy Action Assessment: Other

6.1 V Weapons

6.1.1 Brief Overview

In mid-1944 Germany launched the V1 Flying Bomb campaign. The V1 was a primitive cruise missile carrying an 848kg HE warhead. Between 13th June 1944 and 29th March 1945, V1s were launched from static sites in France and Belgium. 5,823No. missiles landed in England, 2,419No. of which reached London, their intended target.

Not long after, Germany launched the V2 Rocket campaign. The V2 was a primitive ballistic missile carrying a slightly smaller HE warhead (735kg). Between 8th September 1944 and 27th March 1945, V2s were launched from static and mobile sites in Holland. 1,102No. rockets landed in England, 516No. of which hit London, the initial target area. Later on, Norwich was targeted, sustaining 43No. strikes.

Both weapons were constructed of thin sheet steel and consequently had very limited ground penetration ability, if they failed to function. Therefore, V Weapons do not themselves pose a UXO risk, however the damage they caused can hamper the accurate assessment of Luftwaffe UXB risk.

6.1.2 Site-Specific

Five V1 Bombs fell in Eastleigh Borough during WW2, the closest strike occurring on the 15th July 1944 at 04:00hrs in water meadows near Allington Lane, to the southeast of RNAS Eastleigh (>1.3km from the Site). This strike density is only slightly elevated (low to moderate) and furthermore, due to the Site's wartime ground cover, V Weapons themselves do not represent a significant direct UXO contamination risk. The significant distance between the Site and the nearest V1 strike, also means V Weapons do not represent an indirect EO risk factor.

6.2 Artillery Bombardment

6.2.1 Brief Overview

Six German Navy artillery batteries (comprising 20No. guns of between 21cm and 40.6cm calibre) were established in the German occupied Pas-de-Calais area from July 1940. In addition, the German army brought railway-mounted guns to this area of France, seven of which (six 28.0cm calibre guns and one 21.0cm gun) were capable of striking inland targets in Kent.

The first shells were fired at Kent on the 12th August 1940 with frequent attacks occurring during each of the next four years until the final bombardment on the 26th September 1944. In all, at least 1,000No. attacks (each involving multiple projectiles fired) were recorded, an average of one every two days. The towns of Folkestone, Deal and Dover were targeted, however many shells landed in the surrounding countryside. UXO finds of this type are rare.

6.2.2 Site-Specific

Eastleigh was located well beyond the range of the German cross-channel artillery batteries.

7 WW1 Enemy Action Assessment

7.1 Aerial Bombing

7.1.1 Brief Overview

Between December 1914 and August 1918, the German navy air wing and army air wing carried out 51No. Zeppelin airship raids and 52No. fixed-wing aircraft raids (involving multiple aircraft) against England and south-east Scotland. Note, many more attacks involving solitary fixed-wing aircraft occurred. An estimated total of 9,000No. HE bombs and IBs were dropped, with London and the east Kent towns experiencing the most raids. During the four years long campaign, Britain suffered 4,820No. casualties.

The German bombing campaign of WW1 was significantly smaller in scale than the WW2 campaign, in terms of the number of raids, number of aircraft per raid, and size of bombloads (for fixed-wing aircraft). As it was the first time Britain had experienced aerial bombardment, the small-scale daytime attacks often attracted spectators, which increased the chance of any UXB being observed and reported. When combined with the fact that most WW1 bombsites have been redeveloped, German WW1 UXB finds are rare.

7.1.2 Site-Specific

No air raids occurred over Eastleigh and the surrounding area during WW1.

7.2 Naval Bombardment

7.2.1 Brief Overview

Several coastal towns in Yorkshire, Norfolk, Suffolk, and Kent were subjected to naval bombardment from German warships during seven raids in 1914, 1916 and 1917. These raids varied in intensity, both in terms of duration (number of shells expended) and calibre of artillery employed. The heaviest attack resulted in >1,000No. shells fired, with the lightest raid expending only several rounds.

The relatively short firing distances during these bombardments resulted in many shells failing to explode, as there was not enough time for some shells to arm themselves before striking the coast. German WW1 UX naval shell finds are extremely rare.

7.2.2 Site-Specific

Eastleigh was not subjected to naval bombardment during WW1.

8 Explosive Ordnance Migration

8.1 Introduction

Any fill material deposited on a site is unlikely to be contaminated with EO, as the material will have experienced excavation, transport, and processing during which any large objects are likely to have been observed and removed. However, EO encounters within such material do occur, confirming that items can be missed.

One known reason is WW2 Blitz rubble. The Blitz resulted in vast quantities of bombsite rubble. This material was put to use in a variety of ways. >750,000No. tonnes of London's rubble were used to build runways for new USAAF airfields in East Anglia and Liverpool's rubble was used to create and maintain flood defences throughout Merseyside. Blitz rubble was also commonly used for smaller scale construction works, immediately following WW2.

In 2010, two German HE UXBs were encountered in, what was later identified as, Blitz rubble at a Plymouth building site. Such incidents are rare however, and such contamination is much more likely to take the form of smaller items e.g. UX AA projectiles or UX 1kg / 2kg German IBs.

8.2 Site-Specific

No evidence found. There is a low likelihood that potentially EO contaminated material was deposited on Site historically.

9 Local Explosive Ordnance Encounters

9.1 Introduction

Even if research does not identify potential sources of EO contamination at a given site, knowledge of a recent EO encounter in the vicinity could indicate an elevated risk at that site. EO encounters on civilian land are often reported in the media and therefore a web search of media outlets was carried out.

9.2 Site-Specific

Aside from the multiple UXB finds made locally during WW2 and the pipe mine clearance task in 1990, no evidence of a recent EO find on or near the Site has been found.

10 Site-Specific Risk Assessment

10.1 Introduction

Two key Site-specific considerations must be assessed, the likelihood of an EO linkage (source-pathway-receptor) becoming complete and the severity of the resulting consequences. The 'likelihood' consideration itself is a function of the likelihood of contamination, the degree of subsequent risk mitigation (if any), the likelihood of encounter and the likelihood of initiation. These factors (in relation to the Site) are assessed at **Headings 10.2 to 10.5**.

10.2 The Likelihood of Contamination

10.2.1 Hazard Items

The table below details the most common EO types encountered in the UK today. The / those EO type(s) relevant to the Site (the Site-specific hazard item / items) are:

- German UXBs
- British AA projectiles
- British LSA and SAA
- British air-delivered bombs

EO Type	NEQ or Incendiary Hazard	Likely Contamination Depth	Hazard Class
German HE 'iron' bombs	25kg to 220kg HE (most common) 530kg to 990kg HE (least common)	Deep (3.0m to 10.0m+)	**Very High**
German 41kg and 50kg Incendiary 'iron' bombs	13kg incendiary composition or 7kg HE	Shallow / Deep (2.0m to 6.0m)	**High**
British HE HAA Shells and Rockets	1.1kg - 2.2kg HE	Shallow (0.5m to 2.0m)	
Some British HE Land Service Ammunition	1 - 2kg HE	Very Shallow (<1.0m)	
Some British HE Land Service Ammunition	<1kg HE	Very Shallow (<1.0m)	**Moderate**
German 2kg Incendiary + HE Bombs	680g thermite (incendiary) + 100g HE	Very Shallow (<1.0m)	
German 1kg Incendiary Bombs	680g thermite	Very Shallow (<1.0m)	**Low to Moderate**
British HE LAA Autocannon Shells	4g to 70g HE and / or incendiary composition	Very Shallow (<0.5m)	
British Small Arms Ammunition	Small quantity of black powder. Inert projectile or <1g incendiary composition	Very Shallow (<0.5m)	**Low**

TABLE 8: Most Common Hazard Items

10.2.2 Subsequent Detection

There are many variables that affect the likelihood that a German UXB or British UX AA projectile strike was detected and reported, either as it fell to the ground or subsequently. Accurately assessing the precise conditions that existed at a given site >75 years ago is problematic. The most pertinent variables are addressed below.

Historic Ground Cover	
Risk Elevating Ground Cover	Site-Specific Comment
Bombsite: a UXO strike to a building in ruin will likely have remained undetected. The entry hole of a UXB will have been easily obscured under the rubble / debris. However, a small UX AA projectile or UX 1kg / 2kg IB may not have achieved ground penetration, instead coming to rest within the rubble.	No evidence found.
Water: UXO landing in a stream, canal, river, pond, lake or the sea would have been immediately lost beneath the waterline and would not have resulted in any persistent evidence of its incidence.	n/a
Soft / Waterlogged / Unconsolidated Ground: a UXO entry hole within marshland, tidal riverbank sediment, tidal coastal sediment / sand dunes, etc will have closed up / collapsed relatively soon after it occurred.	No evidence found.
Dense Vegetation: Peripheral unmaintained vegetation or woodland in an urban location. Or rural forest, heathland, etc. A UXO entry hole within inaccessible vegetation could have been overlooked. Note, WW2-era woodland obscures the view of the ground cover beneath and therefore it must be assumed that vegetation exists beneath the canopy.	Bordering the railway line, occupying two former gravel pits and possibly an unmaintained (former) orchard at the farmstead.
Arable Land: a field under dense crop growth or ploughed soil. A UXO entry hole within this dense foliage or broken soil could have been overlooked.	Yes, some fields on Site.
Risk Reducing Ground Cover	Site-Specific Comment
Undamaged Building / Structures: any UXO strike would have caused substantial damage and incontrovertible evidence of the incident.	Most of the farm buildings on Site.
Undamaged Hardstanding: A UXO strike on historic hard surfacing (roads, pavements, commercial yards, etc) would have created an easily recognisable entry hole.	No significant areas.
Maintained Grass Lawns: a grass lawn known to have been in use throughout WW2 and therefore subject to regular grounds maintenance, e.g playing fields, parkland, sports pitches, golf course fairways. A UXO strike would have created an easily recognisable entry hole.	n/a
Less Easily Assessed Ground Cover Types	Site-Specific Comment
Waste / scrap / aggregate etc storage area: a UXO strike to a heap of unconsolidated material could have collapsed / become obscured. However, if the ground cover beneath was hard surfaced, a large UXB entry hole could have been subsequently observed and reported.	n/a
Wasteland: the ground cover on such land may not be easily identifiable. Weed-covered bare earth or broken up made ground could conceivably obscure a UXO entry hole. Alternatively, a UXO strike to hard unvegetated earth ground could have been recognisable.	n/a
Railway Tracks: a small UXO entry hole within material in between tracks could conceivably have collapsed. Alternatively, a large UXB strike to rail track would have caused obvious damage.	One line passed through the Site. It does not however appear to have occupied a raised embankment.
Quarry: clay pit, gravel pit, etc. The type and condition of the ground cover might not be easily identifiable. Note, disused quarries could easily become flooded.	Two former gravel pits.

TABLE 9: Historic Ground Cover

Historic Site Occupancy and Access	
UXO Observed as it Occurred	**Site-Specific Comment**
Air Raid Timing: If most local air raids occurred during the hours of darkness, there is a greater chance that any UXO fall occurred unobserved. If the study area only experienced daylight attacks, there is a greater chance that any UXO strike was witnessed as it occurred.	Of those raids that definitely affected the wider study area, two occurred during the early hours of the morning, one occurred during the evening hours of darkness and the other was a twilight evening raid. The other two raids that may have affected the wider study area were both night time raids.
Population Density: If the study area was sparsely populated, there is a greater chance that any UXO strike could occur unobserved. Within a densely populated built up area, the opposite is true. Note however, most people would have been sheltering during large scale night raids.	The wider study area was a mixture of sparse (to the east) and moderate (to the west) population. The RNAS will have been operating throughout the night.
Civil Defence and Military Defence: Many vital facilities (factories, dockyards, etc) had their own teams of Fire Watchers tasked with extinguishing small IBs. These observers would have also reported any UXB strikes. AA batteries, searchlight batteries, barrage balloon sites, and Royal Observer Corps posts. Associated personnel would have reported any UXB strikes.	LAA gunners, armed guards / sentries and barrage balloon operators were probably deployed during all local raids. The railway works is known to have had a fire watching team of at least nine men, deployed on roof tops to quickly report IBs for extinguishing.
Civil Defence Requisition: many schools, churches and other public buildings in frequently bombed areas were requisitioned by Civil Defence for use as first aid posts, reception centres and canteens for bombed out civilians. Such buildings were therefore in use during night raids.	n/a
UXO Subsequently Observed	**Site-Specific Comment**
Bomb Damage: If substantial bomb damage occurred, parts or all of a site would have been abandoned for the remainder of the war. Any subsequent evidence of a UXO strike is more likely to have remained unobserved for a significant period.	As the only known bombsite on Site (farm building) occurred during the final local air raid, no subsequent UXB could have struck this location of rubble / debris.
Site Occupancy: If a site was occupied by buildings that survived the war intact, it likely remained inhabited or in use during the bombing campaign. Probably accessed on a daily basis, evidence of a UXO strike is highly unlikely to have gone unreported. Undeveloped sites could have been neglected for significant periods. Any UXO is more likely to have remained unobserved and gone unreported.	Variable. Infrequent / seasonal access to the agricultural fields and allotment gardens. The requisitioned farm and grounds will have been frequently accessed. A few small areas (gravel pits, railway vegetation, possible disused orchard) may have been neglected.
UXB Searches: the Luftwaffe used delayed-action (DA) bombs, designed to detonate up to 72hrs after impact. As a result, ARP wardens, residents and workers often carried out specific searches for DA / UXB entry holes within the environs of their buildings, following local raids. Undeveloped isolated land is unlikely to have been searched.	RAF personnel searched bomb-stick (craters) alignments for UXB entry holes, up to their airfield perimeter, as standard procedure after an air raid. It is not known whether RN personnel did the same at RNASs, however due to the number of UXBs reported at RNAS Eastleigh, it is safe to assume that some post-raid searches occurred at the requisitioned farm and its grounds. The areas of the Site beyond the farm may have been searched (by military personnel and / or ARP wardens) had a suspected UXB been witnessed as falling within this part of the Site.

TABLE 10: Historic Site Occupancy and Access

10.2.3 Site-Specific Conclusion

British / Allied EO:

The RNAS was temporarily extended north into the Site (requisitioning a farmstead and its grounds) during WW2. Evidence of defensive earthworks, hardened fortifications and perimeter barbed wire has been identified in this section of the Site. Therefore, it is likely that SAA and LSA were handled here. Mock battles (training exercises testing the Royal Marines defence force) probably took place here, potentially involving the use of blank SAA and battle simulants (e.g. smoke grenades and pyrotechnics). Note, such items do not pose a significant EO hazard if encountered today.

Numerous post-war EO finds in England confirm that there is an increased likelihood of British ammunition contamination of shallow level soil in locations of WW2 invasion defences and associated activity. There are three main pathways to such contamination - intentional burial of ammunition caches at defended positions (subsequently forgotten), accidental loss, and unauthorised disposal (intentional burial). The former pathway could have occurred within the south of the Site and, due to the presence in the south of a small gravel pit and possible former / overgrown orchard, the latter pathway is also a possibility here.

That said, experience shows that British / Allied ammunition can be unearthed in unexpected places in and around WW2-era military airfields and sometimes historic records cannot explain why such EO came to be buried there. As some EO finds are probably attributable to the unpredictable behaviour of individuals several decades ago, the possibility cannot be completed discounted that items of British EO were dropped / discarded within soft ground beyond the airfield perimeter.

British air-delivered bombs (live and practice) are unlikely to have been required at the RNAS. Furthermore, any such munitions are highly unlikely to have been brought into the requisitioned farmstead area of the Site.

Although the neighbouring railway works was categorised as a VP - defended by a HG platoon (employee volunteers) - a significant defensive effort around its perimeter does not appear to have occurred. It is considered unlikely that these HG troops, potentially active in the vicinity of the northern Site boudnary, had access to significant quantities of effective LSA and caused associated EO contamination of the Site.

Although a significant number of HAA guns were deployed within firing range of the Site during WW2 and the Luftwaffe were frequently active in the region, only three UX AA shell strikes were recorded in Eastleigh Borough. The UXO strike density does not appear to have been significantly elevated and therefore the likelihood of such a strike within the Site boundary is low. Note, most or all LAA guns deployed within firing range of the Site were machine guns firing SAA (no associated UXO hazard).

Although the RNAS was pipe mined during WW2, British Army records confirm that all mining occurred within the landing ground area, to the southwest of the Site, as expected. Due to the presence of military structures. the requisitioned farmstead in the south of the Site would not have been pipe mined.

German UXO:

During four (and possibly two further) air raids, the likelihood that an aircraft flew over the Site during its bombing run and released a UXB that fell within the Site boundary, is elevated.

As three of the four of these potentially significant air raids occurred during the hours of darkness, the potential for any UXBs to fall within the Site boundary unwitnessed is greater. However, armed guards / sentries are known to have been posted to perimeter locations (probably including within the southern part of the Site) around the clock, and throughout the conflict. The two RAF barrage balloon sites within and adjacent to the Site boundary (as well as a third within the railway works) are known to have been established prior to the first air raid. These sites will have been manned around the clock up until at least March 1942. It is also known that the neighbouring railway works had a team of fire watchers. These roof-top observers will likely have been deployed during most, if not all of the potentially significant air raids.

During the two, three or four significant / potentially significant single aircraft sortie raids, the Site would have been under observation by multiple personnel (LAA gunners, armed guards, barrage balloon operators, and fire watchers). As these raids were of the lowest possible intensity, any HE UXB strike to the Site will likely have been witnessed, reported and subsequently investigated.

German UXBs have been unearthed in recent years at some former RAF airfields. However, these three airfields experienced one or more large-scale concentrated air raids (each resulting in >150No. HE bombs dropped in a small area), which appear to have overwhelmed the defences / ground personnel. Each of the two medium scale air raids affecting the wider study area, resulted in far fewer bomb strikes.

The 22nd June 1942 raid appears to have been spread out, affecting the aircraft factories in the south of the RNAS, the southern extent of the Site (northern extent of the RNAS) and the southern extent of the railway works. Furthermore, it is reported that the RNAS / HMS Raven received adequate early warning of this medium scale air raid, indicating that LAA gunners (and possibly barrage balloon operators) would have manned their sites in preparation, reducing the risk of UXBs falling unwitnessed.

The other medium scale air raid (8th October 1940) occurred during the period of imminent invasion threat, when the defences at RNAS / HMS Raven will have been on high alert throughout the day and night. And an anecdotal account states that early warning of this raid was again received. The resulting 19No. UXBs reported at the RNAS suggests that specific searches for UXBs were carried out. Note, at RAF airfields it was standard procedure to search the alignment of all ‘sticks’ of bomb craters up to the airfield perimeter for UXB entry holes, so the same may have occurred in the south of the Site, in and around the requisitioned farmstead.

Evidence of any HE bomb craters (fresh or infilled) occurring during the first four (August to October 1940) local air raids on these unworked, apparently unused fields would be visible on the September and November 1940 aerial photographs. The lack of any such evidence (also within multiple fields to the east and southeast of the Site) indicates that the vast majority of the 38No. HE bombs recorded within the RNAS perimeter during the 8th October raid, will not have fallen close to this area of the Site. Indeed, the November 1940 aerial photograph exhibits a few infilled crater marks on the airfield’s landing ground, between 750m and 1km of the Site’s southern extent.

However, two HE UXBs were discovered within 100m of the north Site boundary (in the railways works) several months and a few years after their occurrence (8th October 1940). They appear to have been overlooked immediately following the air raid, due to risk elevating ground conditions. It is conceivable therefore that another unnoticed UXB struck the Site’s agricultural fields, allotments gardens or small sections of unmaintained vegetation and was not immediately detected and reported.

The fields in the west and northeast appear to have been arable use. Any UXB entry hole is more likely to have been overlooked on such land, its entry hole obscured by dense / tall crop growth or ploughed up soil. And the same can be said for the small sections of unmaintained grassland that bordered the railway lines in the east of the Site.

The government’s nationwide ‘Dig for Victory’ campaign saw an explosion in the number of, and use of existing, allotment gardens for growing food, due to wartime rationing. It’s highly likely therefore that each allotment garden on Site was in use throughout the war. Each gardener is unlikely to have overlooked the entry hole of even the smallest / lightest German HE UXB (20 / 30cm diameter) within their small plot of land.

The appearance of two fields in the centre and east of the Site is consistently uniform throughout the conflict (during 1940, 1942, 1943 and 1946). These grass fields do not appear to have had any arable use and may have only been used as grazing pasture, although several wartime aerial photographs do not show any livestock here. The entry hole of any German HE UXB on this land may not have been immediately noticed, however it is unlikely to have remained undetected throughout the conflict and into the post-war period.

10.3 Degree of Risk Mitigation

10.3.1 Ground Works

Ground works on an EO contaminated site could have resulted in the partial or complete removal of the buried EO threat. If EO was uncovered during intrusive ground works, the incident would have been reported and dealt with by the armed forces. Note, it is usually not possible to accurately determine the volume of soil disturbance associated with historic or even recent ground works at a given site.

10.3.2 Explosive Ordnance Clearance

EOC was not as effective historically as it is today. Surveys were not always undertaken to set parameters and degrees of certainty. Recent EO finds on land known to have been previously surveyed for EO confirm that older detection equipment was ineffective. Furthermore, some EOC tasks did not result in 100% clearance of all EO, by design. Magnetometer surveys can be calibrated to ignore magnetic anomalies that model under a certain mass.

EOC tasks are not conducted on all MOD land prior to disposal / sale. An EOC task will only be carried out on land where there is a known risk of EO contamination, e.g. a former firing range. For example, when numerous WW2-era RAF / Allied airfields were closed down and sold off, they were not automatically subject to site-wide magnetometer surveying for EO. Any EOC activity was usually prioritised for the airfield bomb dump / bomb storage compound, other ammunition stores and any burning / demolition grounds. Due to a lack of capacity, historic RAF EOC activities were largely reactive (not proactive), the result of call outs to EO finds.

EO is occasionally discovered at sites where EOC activities are known to have occurred. The detail and level of survey and targeted investigation undertaken by the military will depend on the former use of the site and purpose of the clearance (i.e. disposal, redevelopment, return to agriculture, etc). The level of clearance will also depend on the available technology, resources and practices of the day. Note, a standard notice accompanying British Army EOC documentation states that 'the presence of EO can never be completely discounted. Although considered unlikely, there still remains the possibility of buried or stray [EO] items.' Therefore, it cannot be assumed that the risk of EO remaining has been completely mitigated, even if EOC tasks have been undertaken.

IAL has access to a database of historic EOC tasks carried out by the British Army's 33 Engineer Regiment EOD (now part of 29 EOD&S Group). However, this database is only complete up until the early 2000s and only provides basic details on each task.

The RAF's recently disbanded EOD unit (No. 5131 Bomb Disposal Squadron) kept records of EOD incidents and EOC tasks at numerous former military airfield sites. However, freedom of information requests confirm that the MOD will routinely not search their collections to supply such records to the public.

10.3.3 Site-Specific Conclusion

Ground Works: Post-WW2 / Post Military Use	Site-Specific Comment
EOC Activity: evidence of EOC task(s) affecting the Site. Or, is there an increased chance that the Site has experienced partial or complete EOC?	No evidence found. Any part of the Site is highly unlikely to have been subject to a proactive post-WW2 EOC survey / search task.
Phases of Development / Redevelopment: How many phases of ground work have affected the Site?	No significant developments. Just minor hard surfacing and airport radio beacon installation.
Greenfield Land: Does the Site contain any significant areas of undisturbed greenfield land?	Almost the entire Site.

Very Shallow Buried EO: Have any parts of the Site experienced very shallow level soil / made ground disturbance? e.g. demolition, soil stripping, site enabling works, minor grading works, agricultural ploughing, etc.	Probably decades of agricultural ploughing in the northwest and northeast. An aerial photograph dated 2015 confirms agricultural ploughing within the central and eastern field. Some small areas of land have likely remained undisturbed.
Shallow Buried EO: Have any parts of the Site experienced shallow level soil disturbance? e.g. grading works, strip / pad foundations, buried services installation (drainage), etc.	No significant areas.
Deep Buried German 'Iron' UXBs: Have any parts of the Site experienced deep level soil disturbance? e.g. bulk excavations (basement levels), dense pile layout, installation of large subsurface tanks, cut and fill, etc.	Highly unlikely.
Conclusion	
The risk mitigating effect of post-war agricultural ploughing is not well understood. Although such works could have unearthed small items of very shallow buried EO depositing them on the surface, such items could also have been reburied / obscured from view. The risk associated with any such EO will have been partly mitigated across most of the Site area. As the vast majority of the Site has not experienced disturbance of soil below ~0.5m bgl, the risk associated with any German UXBs or British HAA shells likely remains unmitigated.	

TABLE 11: The Degree of Risk Mitigation: Site-Specific Comments

10.4 The Likelihood of Encounter

10.4.1 Introduction

The likelihood of an EO encounter at a given site will vary depending on the hazard items, the EO burial depth and the type(s) of intrusive methodology employed. The greater the volume of soil disturbed within the Zone of Potential EO Contamination (ZPC), the greater the likelihood of an EO encounter.

Most domestic AXO and UXO (LSA and SAA), British UXAA projectiles and small (1kg and 2kg) German IBs will typically be encountered at very shallow or shallow burial levels (<1.0m and <2.0m). Whereas heavy German 'iron' bombs will typically be encountered at deeper levels.

The ZPC is defined as the site-specific volume of soil which could contain EO. The size of a ZPC will depend on the history of the site. At a site where the hazard items are German UXBs only, the ZPC will exist between just below WW2 ground level and the maximum BPD. Alternatively, at an active military site where the threat items are known to be British AXO only, the ZPC will exist between just below present-day ground level and approx. 1.0m bgl.

The smaller the mass of the individual EO threat item, the shallower the likely 'as found' depth, generally speaking. There are however some noteworthy exceptions regarding German 'iron' UXBs. In extreme cases, heavy UXBs can be encountered at shallow depths.

10.4.2 Bomb Penetration Depth Calculations

To calculate BPDs for a given site, one must make assumptions based on the most likely bomb impact scenario:

- **Impact Velocity:** The majority of German HE bombs dropped on the UK resulted from large-scale carpet-bombing raids. These attacks were carried out at altitudes exceeding 5,000m which would have resulted in a 500kg HE UXB impacting the ground at approximately 260m/s.

- **Impact Angle:** Luftwaffe high altitude bombing resulted in bomb impact angles of 10 to 15 degrees from the vertical. Note, it will be assumed that the bomb was stable at the point of impact.
- **Bomb Design:** Some larger German bombs had metal 'Kopfrings' fitted around the nose of the bomb to limit ground penetration. It must be assumed that no such retarder units were fitted.

10.4.3 Site-Specific Ground Conditions

	Superficial / Drift	Bedrock
BGS Geological Mapping	River Terrace Deposits (Clay and Silt) throughout the Site.	Most of the Site area underlain by Wittering Formation (Sand, Silt and Clay). Small portion in the west underlain by London Clay Formation (Clay, Silt and Sand).
BGS SI Data	No borehole logs are available for the Site. A log dated 1975 (~60m south of the Site) records the following ground conditions. Note, this log penetrates an area of mapped superficial alluvium deposits, not river terrace gravel. - Topsoil - 1.25m of soft silty clay - 2.75m of gravel and sand in silty clay matrix - 7.6m of firm to stiff clay with thin silty clay bands (London Clay bedrock)	
Site-specific factors	None.	

TABLE 12: Site-Specific Ground Conditions

10.4.4 Site-Specific Maximum Bomb Penetration Depth

During WW2 the Luftwaffe dropped different types of HE bomb on the UK. The SC series accounted for the vast majority, and of this series, the SC 500 variant (weighing 500kg) was the heaviest of the three most deployed types. Therefore, a 500kg bomb will be used as the benchmark weapon for the BPD calculations.

As the Site is largely underlain by superficial geology over bedrock and no borehole log data confirming the thickness and composition of the superficial layer is available, an accurate Site-specific maximum BPD cannot be calculated. Note, the empirical BPD evidence records UXBs travelling through geology of one uniform composition. These lithologies will have had a differing decelerating effect on a UXB, both individually and in combination, complicating the estimation of UXB burial depth.

To calculate an approximate maximum BPD for a 500kg UXB strike, IAL has taken the average of the averages of the two figures (average and maximum) for the most appropriate lithologies (sand and clay) in **TABLE 4**. This gives an average maximum BPD of **13.0m** (rounded up) below WW2 ground level.

Note however, the heaviest local air raid (8th October 1940) involved aircraft flying at very low attitude with bombloads exclusively comprising the smallest model of HE bomb (50kg). Indeed, the extremely low height of release meant that many of the bombs (at least 19No.) failed to arm and detonate. As these relatively lightweight UXBs will have struck the ground at relatively shallow angles, the J-Curve Effect will have been significant, with all UXBs coming to rest at shallow depth.

The HE bombs dropped during the second heaviest raid (22nd June 1942) will likely have been heavier models. Furthermore, as this was a dive-bombing raid, any UXBs will have struck the ground at a steeper angle, increasing burial depth, reducing the 'shallowing' J-Curve Effect.

Note, theoretically a UXB could remain on Site at a depth greater than 13.0m bgl, however MoHS data indicates that only 3% (approximately) of the bombs dropped on the UK weighed over 500kg.

10.4.5 Site-Specific Conclusion

Areas of potential concern (where there is an elevated likelihood of EO remaining in-situ today) have been identified. As some of the future GI works almost certainly will, and some of the subsequent build phase works will occur within these areas of potential concern, risk pathways will be created exposing each intrusion / excavation to a potential EO encounter.

Any UXB contamination of the Site resulting from the heaviest air raid will be a 50kg HE bomb at shallow depth (<3.0m bgl). Therefore, even shallow mechanical excavations of any UXB impact site would likely encounter such UXO. Note, any HE UXB contamination of the Site resulting from the second heaviest air raid would probably be encountered at greater depth.

The ZPC within the southern portion of the Site, occupying the WW2-era military requisitioned land, is associated with shallow buried British LSA. Any intrusions in this area beyond ~2.0m bgl are unlikely to encounter EO.

As only small-scale GI works and very shallow mechanical excavations appear to be planned for the northwestern section of the Site (proposed access road), the likelihood of encountering EO here is not significantly elevated. Furthermore, the likelihood of very shallow buried EO remaining in this area is not significantly elevated.

Although the likelihood of an EO encounter during the GI works is lower compared to the subsequent large-scale build phase ground works, this is offset by the significantly elevated likelihood EO remaining in some areas and the 'blind' nature of the planned borehole works, increasing the likelihood of aggressively striking buried EO.

If the build phase works involve large-scale piling, the likelihood of aggressively striking buried EO will be significantly elevated.

10.5 The Likelihood of Initiation

10.5.1 Introduction

The likelihood of initiating EO depends on the type of EO and how aggressively it is encountered. Various types of EO buried in the UK require an impact, vibration or heat to initiate. Most EO contains a fuze and most fuzes contain a small quantity of shock-sensitive primary explosive. An impact to a fuze can therefore cause it to initiate, in turn detonating the main explosive charge.

German UXBs buried in the UK do not spontaneously self-detonate. The vast majority of German WW2 'iron' bombs contained an electrical fuze. Decades of burial (exposure to environmental conditions) will have caused these fuzes to corrode and lose their electrical charge. Consequently, during any such UXO encounter, it would be almost impossible for the fuze to initiate via its original (electrical) explosive train.

In theory, German UXBs could still initiate if the bomb were impacted with enough force. Percussive piling and bore-holing are engineering works that could impart enough force to detonate the main explosive charge of an EO, without requiring the fuze to function. Furthermore, the 'blind' nature of these intrusions elevates the likelihood of an EO impact.

Excavators and loaders impart less energy via their buckets and site workers might be able to notice a partially unearthed EO and halt works prior to an impact. For these reasons, IAL conducts separate risk rating calculations for different intrusive methodologies.

During WW2, the Allied air forces used mechanical (not electrical) fuzes, which pose a greater long-term UXB hazard on the continent. Furthermore, in Germany, 1No. buried Allied WW2 HE bomb per year (on average) self-detonates due to degradation of the chemical detonator in its time-delay fuze.

Sensitive types of EO include German 2kg (mechanically fuzed) 'Butterfly' bombs, types of British (mechanically fuzed) unexploded LSA ('blind' / 'dud' items), and bombs with chemical time-delay fuzes.

10.5.2 Site-Specific Conclusion

As a high force intrusive methodology (percussive boreholes) is planned, the likelihood of initiating a German HE UXB is especially elevated during these specific works. And the same could be said regarding the build phase works, if piling is required on a large-scale.

The likelihood of initiating some types of LSA would be significantly elevated during the planned mechanical excavations. That is, those WW2-era British grenades that feature glass in their construction. However, generally speaking the likelihood of detonating most types of hazard item at the Site is lower during mechanical excavations (especially when utilising toothless / bladed excavator buckets) when compared to 'blind' percussive boreholes and piling.

That said, the smallest very shallow buried EO devices are more likely to be pushed aside (glancing blow) by a drill / pile head in soft soil, reducing the likelihood of detonation.

11 The Historical Record: Extent and Accuracy

11.1 Introduction

The availability of key documents and data will affect the completeness and accuracy of the Site-specific risk assessment. Furthermore, historical records can sometimes be proven inaccurate, when compared with other records. Some inaccuracies could significantly affect the outcome of a risk assessment and therefore a Site-specific review must be conducted.

11.2 Site-Specific

Several inconsistencies between the available bombing incident records have been highlighted, however none are significant, and the quality of the available historic records (relating to German bombing) is sufficient. Furthermore, as wartime aerial photography coverage is very good, salient factors relate to WW2-era Site occupancy and ground conditions. A risk assessment of German UXO with a sufficient degree of accuracy can be performed.

The quality of the historic record relating to British military activity is moderate. As official defence schemes are missing, assessment of EO contamination relating to invasion defence activities is limited, however those records that are available, combined with IAL's previous research at similar sites, is deemed sufficient.

12 Site-Specific Risk Calculation

12.1 Introduction

The first stage of the semi-quantitative risk model considers potential sources of buried EO on Site. The next stage evaluates the possible linkages, identifying whether significant harm could occur (as a result of the proposed Site works) and the impact of such harm. To provide a numerical evaluation of risk, the two key considerations must be assigned a score and then multiplied together to provide a final risk rating / risk level:

- The likelihood of an EO linkage becoming complete: **FACTOR 3** (= Factors 1 x 2)
- The severity of the consequence(s) resulting from this linkage completion: **FACTOR 6** (= Factors 4 x 5)

12.2 Factor 1 (F1): Explosive Ordnance Presence

The Likelihood of EO contamination of the Site combined with the degree of subsequent risk mitigation. This factor is described and scored in the table below.

Classification	Example Descriptions	F1 Rating
Impossible	No EO contamination due to complete subsequent excavation / removal of the ZPC.	**0**
Highly Unlikely	EO contamination is highly unlikely to have occurred. Most of the ZPC subsequently excavated or EOC task(s) have been conducted.	**1**
Unlikely	EO contamination is unlikely to have occurred. Part of the ZPC subsequently excavated or EOC task(s) have been conducted.	**2**
Possible	EO contamination could have occurred. Part or none of the ZPC subsequently excavated.	**3**
Likely	EO contamination is likely to have occurred. Only a fraction or none of the ZPC subsequently excavated.	**4**
Almost Certain	EO contamination is almost certain or confirmed evidence of local EO contamination. Greenfield land / ZPC remains undisturbed.	**5**

TABLE 13: Factor 1 Scoring

12.3 Factor 2 (F2): Explosive Ordnance Initiation

The likelihood of encountering EO during the proposed works combined with the likelihood of initiating EO during the proposed works. This factor is described and scored in the table below.

Classification	Example Descriptions	F2 Rating
Impossible	The ZPC will not be disturbed during the proposed ground works.	**0**
Highly Unlikely	Fraction of the ZPC will be intruded / excavated. Hand-dug trial pits. Vegetation clearance / soil stripping. Hazard items include relatively insensitive EO.	**1**
Unlikely	Part of the ZPC will be intruded / excavated. Mechanically excavated trial pits. Shallow excavations for traditional foundations. Piling or boreholes. Hazard items include relatively insensitive EO.	**2**
Possible	Moderate to high intrusion / excavation of the ZPC. Large-scale shallow excavations for traditional foundations. Single basement level construction. Piling or boreholes. Hazard items include relatively insensitive and possibly sensitive EO.	**3**
Likely	Almost the entire ZPC will be excavated. Multi-level basement construction. Large scale piling works (including percussive piling). Hazard items include sensitive EO.	**4**
Almost Certain	The entire ZPC will be excavated. Multi-level basement construction. Large scale piling works (including percussive piling). Hazard items include highly sensitive EO.	**5**

TABLE 14: Factor 2 Scoring

12.4 Factor 3 (F3): Calculating the Likelihood of an Explosive Ordnance Initiation Event

The table below includes the calculations of 'Likelihood' and descriptions of the resulting scores.

F1 x F2 = F3	Classification	Example Descriptions	F3 Rating
F3 = 0	**Impossible**	Confirmed evidence that no EO is present or no pathway to sensitive receptors present.	**0**
F3 = 1 to 4	**Highly Unlikely**	EO is highly unlikely to be present. No pathway to sensitive receptors present. Initiation of EO is highly unlikely.	**1**
F3 = 5 to 8	**Unlikely**	EO is unlikely to be present. There is an established pathway to sensitive receptors. Initiation of EO unlikely.	**2**
F3 = 9 to 13	**Possible**	EO could be present. There is an established pathway to sensitive receptors. Initiation of EO is unlikely but possible.	**3**
F3 = 14 to 20	**Likely**	EO is likely to be present. There is an established pathway to sensitive receptors. Initiation of EO could occur.	**4**
F3 = 21 to 25	**Almost Certain**	Confirmed evidence of EO contamination or almost certainty. There is an established pathway to sensitive receptors. Initiation of EO is likely.	**5**

TABLE 15: Factor 3 Scoring

12.5 Factor 4 (F4): Explosive Ordnance Event Magnitude

The potential hazard associated with each hazard item combined with the likely depth of EO initiation. This factor is described and scored in the table below.

Classification	Example Descriptions	F4 Rating
None	British military training device (inert).	**0**
Very Small	British SAA at depth. 1kg German bomb at depth.	**1**
Small	British LSA or HAA projectile at depth. British LAA projectile near the surface. 2kg German bomb at depth. 1kg German bomb near the surface. British SAA near the surface.	**2**
Medium	British LSA or HAA projectile near the surface. 2kg German bomb near the surface. Medium German 'iron' bombs at depth.	**3**
Large	Large German 'iron' bombs at depth. Medium German 'iron' bombs near the surface.	**4**
Very Large	Large German 'iron' bombs near the surface.	**5**

TABLE 16: Factor 4 Scoring

12.6 Factor 5 (F5): Sensitive Receptors

The presence and sensitivity of receptors in the vicinity at the time of the proposed works. This factor is described and scored in the table below.

Classification	Example Descriptions	F5 Rating
Single	Plant / equipment.	**1**
Few	Human, plant / equipment.	**2**
Medium	Human, plant / equipment, buried services.	**3**

Most	Human, plant / equipment, buried services, buildings.	**4**
All	Human, plant / equipment, buried services, buildings, listed buildings, scheduled ancient monuments, protected environment (e.g. TPO).	**5**

TABLE 17: Factor 5 Scoring

12.7 Factor 6 (F6): Calculating the Consequence of an Explosive Ordnance Initiation Event

The table below includes the calculations of 'Consequence' and descriptions of the resulting scores.

F4 x F5 = F6	Classification	Example Descriptions	F6 Rating
F6 = 0	**None**	Contact with inert military device. No initiation event. No risk to human health or damage sustained.	**0**
F6 = 1 to 4	**Insignificant**	Very small magnitude inadvertent initiation at depth. Possible cosmetic damage to plant. No risk to human health or buildings damaged.	**1**
F6 = 5 to 8	**Mild**	Small magnitude inadvertent initiation. Possible damage to plant. Possible risk to human health (minor first aid injury).	**2**
F6 = 9 to 13	**Moderate**	Medium magnitude inadvertent initiation. Damage to plant. Possible damage to buried services. Possible cosmetic damage to buildings. Possible risk to human health (minor injury).	**3**
F6 = 14 to 20	**Severe**	Large magnitude inadvertent initiation. Severe damage to plant, buried services and buildings. Fatality and / or severe injuries.	**4**
F6 = 21 to 25	**Catastrophic**	Large magnitude inadvertent initiation. Catastrophic damage to plant, buried services and buildings (including listed buildings, scheduled ancient monuments, etc). Multiple fatalities and severe injuries.	**5**

TABLE 18: Factor 6 Scoring

12.8 Calculating the Final Risk Level(s)

The 'Likelihood' and 'Consequence' factors are combined in the risk matrix below to produce a final risk score.

		Consequence (F6)					
		0	1	2	3	4	5
Likelihood (F3)	5	0	5	10	15	20	25
	4	0	4	8	12	16	20
	3	0	3	6	9	12	15
	2	0	2	4	6	8	10
	1	0	1	2	3	4	5
	0	0	0	0	0	0	0

Final Risk Score

Final Risk Rating (score)						
0 - 1	2 - 5	6 - 9	10 - 12	15 - 16	20	25
Very Low	Low	Low-to-Moderate	Moderate	Moderate-to-High	High	Very High
Risk Levels						

TABLE 19: Risk Matrix

12.9 Conceptual Site Model

Risk assessment calculations have identified three risk zones. The conceptual model is displayed in the tables below. With regards to the future build phase works, this risk assessment is only indicative. It is recommended that once the foundations design is finalised, this UXO risk assessment is rerun so as to provide an accurate risk assessment of the ground works that will actually be carried out on Site. Note, the tables below do not include other hazardous military items (e.g. battle simulants, pyrotechnics, etc).

Moderate Risk Table - WW2-era arable farmland beyond the RNAS perimeter

	Hazard Item	Pathway	Receptor	Likelihood (F3)	Consequence (F6)	Final Risk Rating	Risk Level
German	HE and Incendiary 'Iron' Bombs	GI works. Blast + heat + frag.	Human, Plant, Structures.	3 (F1:3 x F2:3)	4 (F4:4 x F5:4)	12 (3 x 4)	Moderate
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	3 (F1:3 x F2:3)	4 (F4:4 x F5:4)	12 (3 x 4)	Moderate
		Piling. Blast + heat + frag.	Human, Plant, Structures.	3 (F1:3 x F2:4)	4 (F4:4 x F5:4)	12 (3 x 4)	Moderate
	1kg Incendiary and 2kg Incendiary (+ HE) Bombs	GI works. Blast + heat.	Human, Plant.	1 (F1:2 x F2:2)	2 (F4:3 x F5:2)	2 (1 x 2)	Low
		Post-GI mech excavations. Blast + heat.	Human, Plant.	2 (F1:2 x F2:3)	2 (F4:3 x F5:2)	4 (2 x 2)	Low
		Piling. Blast + heat.	Human, Plant.	1 (F1:2 x F2:2)	2 (F4:3 x F5:2)	2 (1 x 2)	Low
British / Allied	HE and Incendiary Bombs	GI works. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:2)	4 (F4:5 x F5:4)	4 (1 x 4)	Low
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:2)	4 (F4:5 x F5:4)	4 (1 x 4)	Low
		Piling. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	4 (F4:5 x F5:4)	4 (1 x 4)	Low
	Anti-Aircraft Projectiles (expended UXO)	GI works. Blast + frag.	Human, Plant, Structures.	1 (F1:1 x F2:2)	3 (F4:3 x F5:3)	3 (1 x 3)	Low
		Post-GI mech excavations. Blast + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	3 (F4:3 x F5:3)	3 (1 x 3)	Low
		Piling. Blast + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	3 (F4:3 x F5:3)	3 (1 x 3)	Low
	Land Service Ammunition	GI works. Blast + heat + frag.	Human, Plant, Structures.	2 (F1:2 x F2:3)	3 (F4:3 x F5:3)	6 (2 x 3)	Low-to-Moderate
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	2 (F1:2 x F2:3)	3 (F4:3 x F5:3)	6 (2 x 3)	Low-to-Moderate
		Piling. Blast + heat + frag.	Human, Plant, Structures.	2 (F1:2 x F2:3)	3 (F4:3 x F5:3)	6 (2 x 3)	Low-to-Moderate
	Practice Air-Delivered Bombs	GI works. Burn or smoke.	Human.	1 (F1:1 x F2:1)	1 (F4:2 x F5:2)	2 (2 x 1)	Low
		Post-GI mech excavations. Burn or smoke.	Human.	1 (F1:1 x F2:1)	1 (F4:2 x F5:2)	2 (2 x 1)	Low
		Piling. Burn or smoke.	Human.	1 (F1:1 x F2:2)	1 (F4:2 x F5:2)	2 (2 x 1)	Low
	Small Arms Ammunition	GI works.	Human.	1 (F1:2 x F2:1)	1 (F4:1 x F5:1)	1 (1 x 1)	Very Low
		Post-GI mech excavations.	Human.	1 (F1:2 x F2:1)	1 (F4:1 x F5:1)	1 (1 x 1)	Very Low
		Piling.	Human.	1 (F1:2 x F2:1)	1 (F4:1 x F5:1)	1 (1 x 1)	Very Low

TABLE 20: Moderate Risk Table

Low-to-Moderate Risk Table - within the RNAS perimeter

	Hazard Item	Pathway	Receptor	Likelihood (F3)	Consequence (F6)	Final Risk Rating	Risk Level
German	HE and Incendiary 'Iron' Bombs	GI works. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	4 (F4:4 x F5:4)	4 (1 x 4)	Low
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	4 (F4:4 x F5:4)	4 (1 x 4)	Low
		Piling. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:4)	4 (F4:4 x F5:4)	4 (1 x 4)	Low
	1kg Incendiary and 2kg Incendiary (+ HE) Bombs	GI works. Blast + heat.	Human, Plant.	1 (F1:1 x F2:2)	2 (F4:3 x F5:2)	2 (1 x 2)	Low
		Post-GI mech excavations. Blast + heat.	Human, Plant.	1 (F1:1 x F2:3)	2 (F4:3 x F5:2)	2 (1 x 2)	Low
		Piling. Blast + heat.	Human, Plant.	1 (F1:1 x F2:2)	2 (F4:3 x F5:2)	2 (1 x 2)	Low
British / Allied	HE and Incendiary Bombs	GI works. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:2)	4 (F4:5 x F5:4)	4 (1 x 4)	Low
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:2)	4 (F4:5 x F5:4)	4 (1 x 4)	Low
		Piling. Blast + heat + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	4 (F4:5 x F5:4)	4 (1 x 4)	Low
	Anti-Aircraft Projectiles (expended UXO)	GI works. Blast + frag.	Human, Plant, Structures.	1 (F1:1 x F2:2)	3 (F4:3 x F5:3)	3 (1 x 3)	Low
		Post-GI mech excavations. Blast + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	3 (F4:3 x F5:3)	3 (1 x 3)	Low
		Piling. Blast + frag.	Human, Plant, Structures.	1 (F1:1 x F2:3)	3 (F4:3 x F5:3)	3 (1 x 3)	Low
	Land Service Ammunition	GI works. Blast + heat + frag.	Human, Plant, Structures.	3 (F1:3 x F2:3)	3 (F4:3 x F5:3)	9 (3 x 3)	Low-to-Moderate
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	3 (F1:3 x F2:3)	3 (F4:3 x F5:3)	9 (3 x 3)	Low-to-Moderate
		Piling. Blast + heat + frag.	Human, Plant, Structures.	3 (F1:3 x F2:3)	3 (F4:3 x F5:3)	9 (3 x 3)	Low-to-Moderate
	Practice Air-Delivered Bombs	GI works. Burn or smoke.	Human.	1 (F1:1 x F2:1)	1 (F4:2 x F5:2)	1 (1 x 1)	Very Low
		Post-GI mech excavations. Burn or smoke.	Human.	1 (F1:1 x F2:1)	1 (F4:2 x F5:2)	1 (1 x 1)	Very Low
		Piling. Burn or smoke.	Human.	1 (F1:1 x F2:2)	1 (F4:2 x F5:2)	1 (1 x 1)	Very Low
	Small Arms Ammunition	GI works.	Human.	1 (F1:4 x F2:1)	1 (F4:1 x F5:1)	1 (1 x 1)	Very Low
		Post-GI mech excavations.	Human.	1 (F1:4 x F2:1)	1 (F4:1 x F5:1)	1 (1 x 1)	Very Low
		Piling.	Human.	1 (F1:4 x F2:1)	1 (F4:1 x F5:1)	1 (1 x 1)	Very Low

TABLE 21: Low-to-Moderate Risk Table

	Low Risk Table - WW2-era grass fields beyond the RNAS perimeter						
	Hazard Item	Pathway	Receptor	Likelihood (F3)	Consequence (F6)	Final Risk Rating	Risk Level
German	**HE and Incendiary 'Iron' Bombs**	GI works. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**4** (F4:4 x F5:4)	**4** (1 x 4)	**Low**
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**4** (F4:4 x F5:4)	**4** (1 x 4)	**Low**
		Piling. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:4)	**4** (F4:4 x F5:4)	**4** (1 x 4)	**Low**
	1kg Incendiary and 2kg Incendiary (+ HE) Bombs	GI works. Blast + heat.	Human, Plant.	**1** (F1:1 x F2:2)	**2** (F4:3 x F5:2)	**2** (1 x 2)	**Low**
		Post-GI mech excavations. Blast + heat.	Human, Plant.	**1** (F1:1 x F2:3)	**2** (F4:3 x F5:2)	**2** (1 x 2)	**Low**
		Piling. Blast + heat.	Human, Plant.	**1** (F1:1 x F2:2)	**2** (F4:3 x F5:2)	**2** (1 x 2)	**Low**
British / Allied	**HE and Incendiary Bombs**	GI works. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:2)	**4** (F4:5 x F5:4)	**4** (1 x 4)	**Low**
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:2)	**4** (F4:5 x F5:4)	**4** (1 x 4)	**Low**
		Piling. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**4** (F4:5 x F5:4)	**4** (1 x 4)	**Low**
	Anti-Aircraft Projectiles (expended UXO)	GI works. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:2)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
		Post-GI mech excavations. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
		Piling. Blast + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
	Land Service Ammunition	GI works. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
		Post-GI mech excavations. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
		Piling. Blast + heat + frag.	Human, Plant, Structures.	**1** (F1:1 x F2:3)	**3** (F4:3 x F5:3)	**3** (1 x 3)	**Low**
	Practice Air-Delivered Bombs	GI works. Burn or smoke.	Human.	**1** (F1:1 x F2:1)	**1** (F4:2 x F5:2)	**1** (1 x 1)	**Very Low**
		Post-GI mech excavations. Burn or smoke.	Human.	**1** (F1:1 x F2:1)	**1** (F4:2 x F5:2)	**1** (1 x 1)	**Very Low**
		Piling. Burn or smoke.	Human.	**1** (F1:1 x F2:2)	**1** (F4:2 x F5:2)	**1** (1 x 1)	**Very Low**
	Small Arms Ammunition	GI works.	Human.	**1** (F1:2 x F2:1)	**1** (F4:1 x F5:1)	**1** (1 x 1)	**Very Low**
		Post-GI mech excavations.	Human.	**1** (F1:2 x F2:1)	**1** (F4:1 x F5:1)	**1** (1 x 1)	**Very Low**
		Piling.	Human.	**1** (F1:2 x F2:1)	**1** (F4:1 x F5:1)	**1** (1 x 1)	**Very Low**

TABLE 22: Low Risk Table

13 Risk Mitigation

13.1 ALARP Principle

ALARP is a risk principle associated with the Health and Safety at Work Act 1974. It is used in the regulation and management of construction industry risks and states that risk must be averted unless there is a gross disproportion between the costs and benefits of doing so.

The ALARP principle arises from the fact that infinite time, effort and money could be spent attempting to eliminate a risk entirely. It should not be understood as simply a quantitative measure of benefit against detriment. Instead, a best common practice of judgement, balancing risk and societal benefit.

13.2 Risk Levels and Risk Tolerance

The table below outlines the relationship between final risk scores / levels (the output of the IAL semi-quantitative risk model), risk tolerance and the available industry standard risk mitigation measures. An elevated UXO risk should always be reduced to ALARP level.

Risk Level	IAL Recommendation	Risk Tolerance	Mitigation Measures
Very High	**Proactive** mitigation measures considered essential	Intolerable risk level in all but extreme circumstances.	► EOD Engineer supervision of ground works ► Magnetometer surveying prior to ground works ► Explosive Ordnance Safety & Awareness Briefing(s) ► Explosive Ordnance Site Safety Instructions
High			
Moderate-to-High	**Proactive** mitigation measures recommended	Intolerable level of risk where risk mitigation to ALARP is cost effective. A client may consider the risk tolerable due to impracticability of the available risk mitigation measures or disproportionately high cost of mitigation.	
Moderate		Tolerable risk level providing the recommended mitigation measures have been adopted.	
Low-to-Moderate	**Reactive** mitigation measures recommended	Possibly tolerable risk level, however **reactive** risk mitigation measures would be the prudent course of action. For sensitive, high value sites, a zero-tolerance policy may exist, mandating **proactive** risk mitigation measures.	► Explosive Ordnance Safety & Awareness Briefing(s) ► Explosive Ordnance Site Safety Instructions
Low	**Reactive** mitigation measures considered prudent (not recommended)	Likely to be a tolerable risk level for most clients. However, adoption of the basic precautionary mitigation measure would be the prudent (and very cost effective) course of action, especially for greenfield sites.	► Explosive Ordnance Safety & Awareness Briefing(s) considered prudent ► Explosive Ordnance Site Safety Instructions considered prudent
Very Low	No mitigation measures	N/A	N/A

TABLE 23: Risk Levels and Risk Tolerance

13.3 Site-Specific Recommendation(s)

The following table describes the available industry standard risk mitigation measures and identifies those (if any) that are recommended to reduce an elevated risk to ALARP level.

Mitigation Measure	Appropriate For	Site-Specific
Explosive Ordnance Site Safety Instructions: EO Safety Instructions (compiled by an EO specialist) provide a written record of the key points that make up an EO Safety & Awareness Briefing. Including instructions on making a preliminary suspicious object threat assessment, a visual catalogue of commonly found EO types, and the steps to take in the event of a potential EO find. The instructions should be included within the site-specific Health & Safety Manual.	► Provided to Site personnel prior to commencement of excavations. ► Not appropriate for 'blind' intrusions (e.g. boreholes)	**Recommended** To be held on Site for the duration of both the GI works and the build phase works.
Explosive Ordnance Safety & Awareness Briefings: All personnel conducting ground works on Site should receive this briefing. It should feature as a key element of the CDM Regulations 2015 Health & Safety training package for the site. The briefing should be conducted by a trained EO specialist. Such briefings instruct recipients in the identification of EO hazards and actions to be taken in the event of an EO incident.		**Recommended** To all Site personnel prior to breaking ground anywhere on Site (both the GI works and build phase works).
Explosive Ordnance Disposal (EOD) Engineer: An EOD engineer (banksman) providing an onsite 'watching brief' of mechanical excavations. Or as an on-call service, providing remote consultancy and immediate deployment to a site if necessary. Any suspicious objects will be quickly identified, allowing works to continue if the object is not EO. This reduces the risk of delays to the project. EOD engineers can use portable / handheld magnetometer instruments to scan ground ahead of boreholes.	► SI (including some boreholes) ► Small volume earthworks on greenfield land ► Excavations within made ground	**Recommended** Handheld magnetometer survey of all GI boreholes **within the Moderate Risk Zone only**. **Recommended** Remote consultancy / on-call service in support of the build phase mechanical excavations **within the Low-to-Moderate Risk Zone only**.
Intrusive Magnetometer Probe Survey: A range of intrusive magnetometer methodologies can be deployed. Which equipment is most appropriate will depend upon the ground conditions and site access. This survey will scan the ground down to the maximum bomb penetration depth and therefore is the most appropriate option for clearing pile locations ahead of 'blind' piling works. Multiple overlapping surveys can be conducted, providing matrix clearance of made ground, e.g basement dig.	► Pile locations ► Boreholes ► Large volume earthworks on brownfield land	**Recommended** Of any build-phase pile foundations **within the Moderate Risk Zone only**.
Non-Intrusive Magnetometer Survey: A range of non-intrusive magnetometer survey methodologies can be deployed to survey ground to a limited depth. Such surveys can typically detect a 50kg 'iron' bombs at a depth of 4.5m bgl, providing the ground is 'magnetically clean'. Such surveys are not appropriate for brownfield land where 'magnetic noise' will result in unusable data.	► Large volume earthworks on magnetically clean (greenfield) land	**Recommended** Prior to build-phase mechanical excavations **within the Moderate Risk Zone only**.

TABLE 24: Recommendations for Risk Mitigation

Figures: 1 - 12



Figure: 01.0

Figure Title:
Recent Aerial Photograph

Legend:

Approx. Site boundary

Notes:

Source: Google

N

Project: Navigator Quarter, Southampton

Client: Geo2

Doc Ref: DRA.10210.25 **Version: 1**

IMPARTIAL ASSESSMENTS

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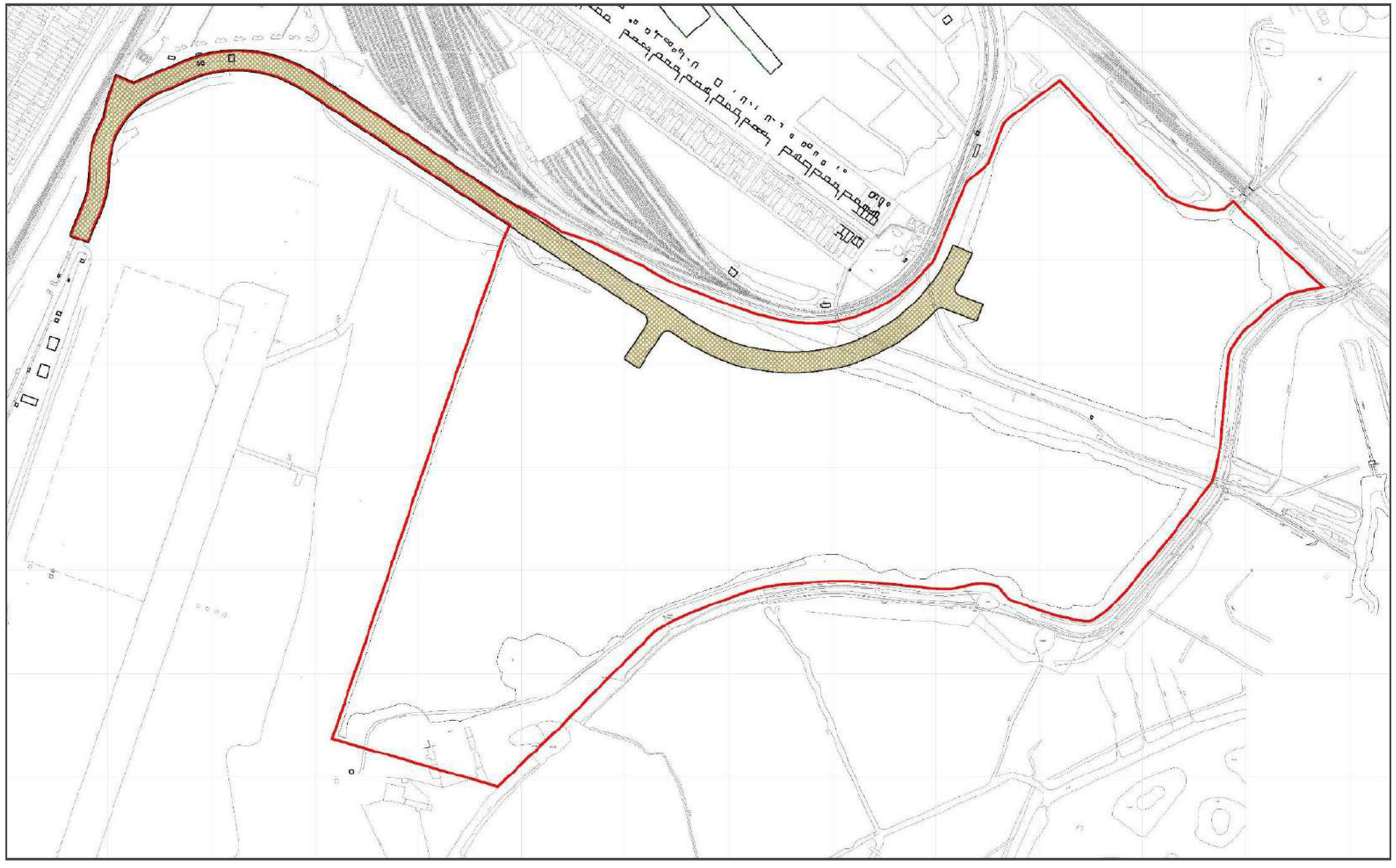


Figure: 02.1

Figure Title:
Existing Site Plan

Legend:

Site boundary

Notes:

Source: Geo2

N

Project: Navigator Quarter, Southampton

Client: Geo2

Doc Ref: DRA.10210.25 **Version: 1**

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Explosive Ordnance Risk Assessments

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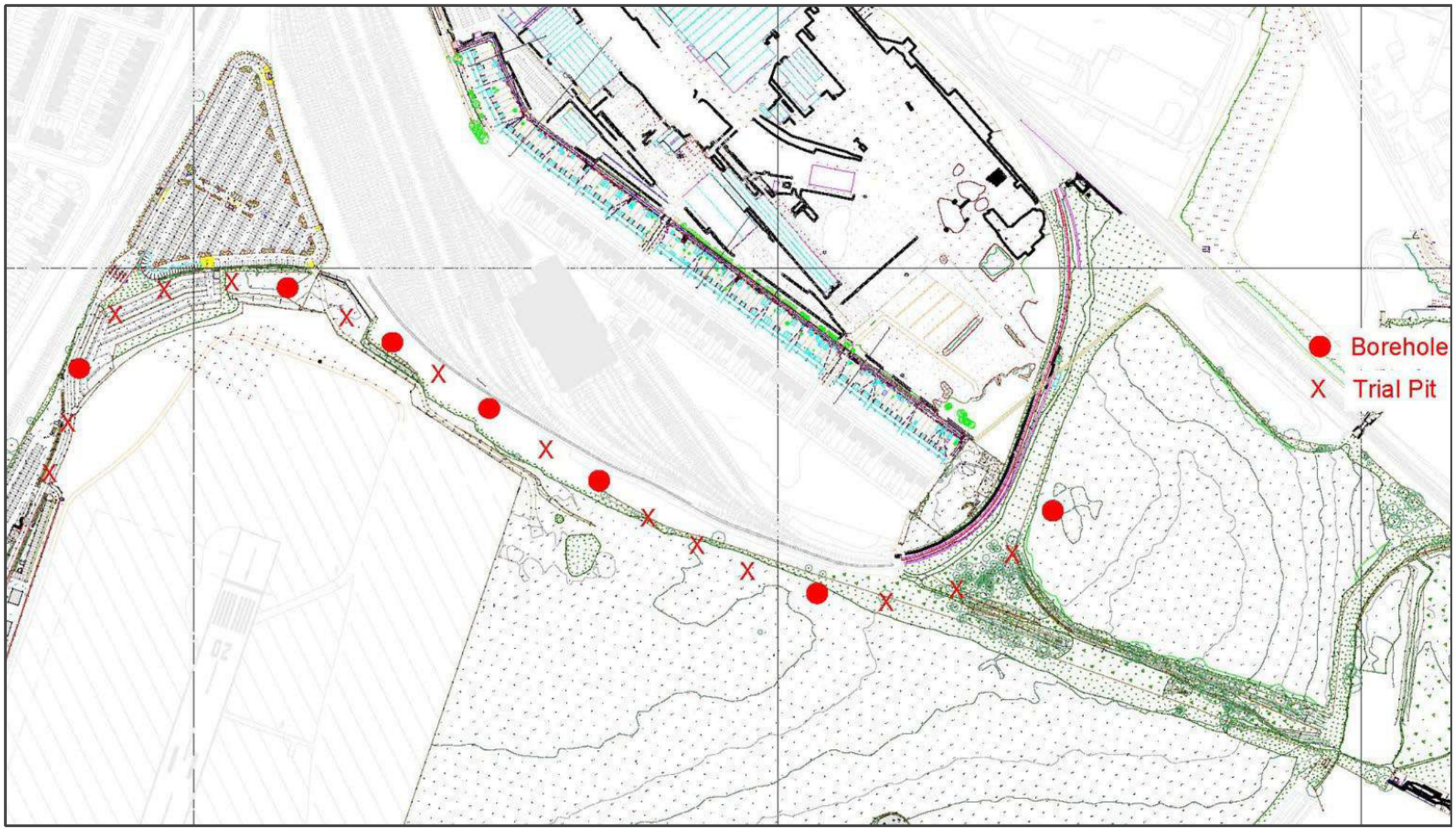


Figure: 02.2

Figure Title:
Proposed Phase I GI Positions Plan

Legend:

Notes:

Source: Geo2

N

Project:	Navigator Quarter, Southampton
Client:	Geo2
Doc Ref:	DRA.10210.25
Version:	1

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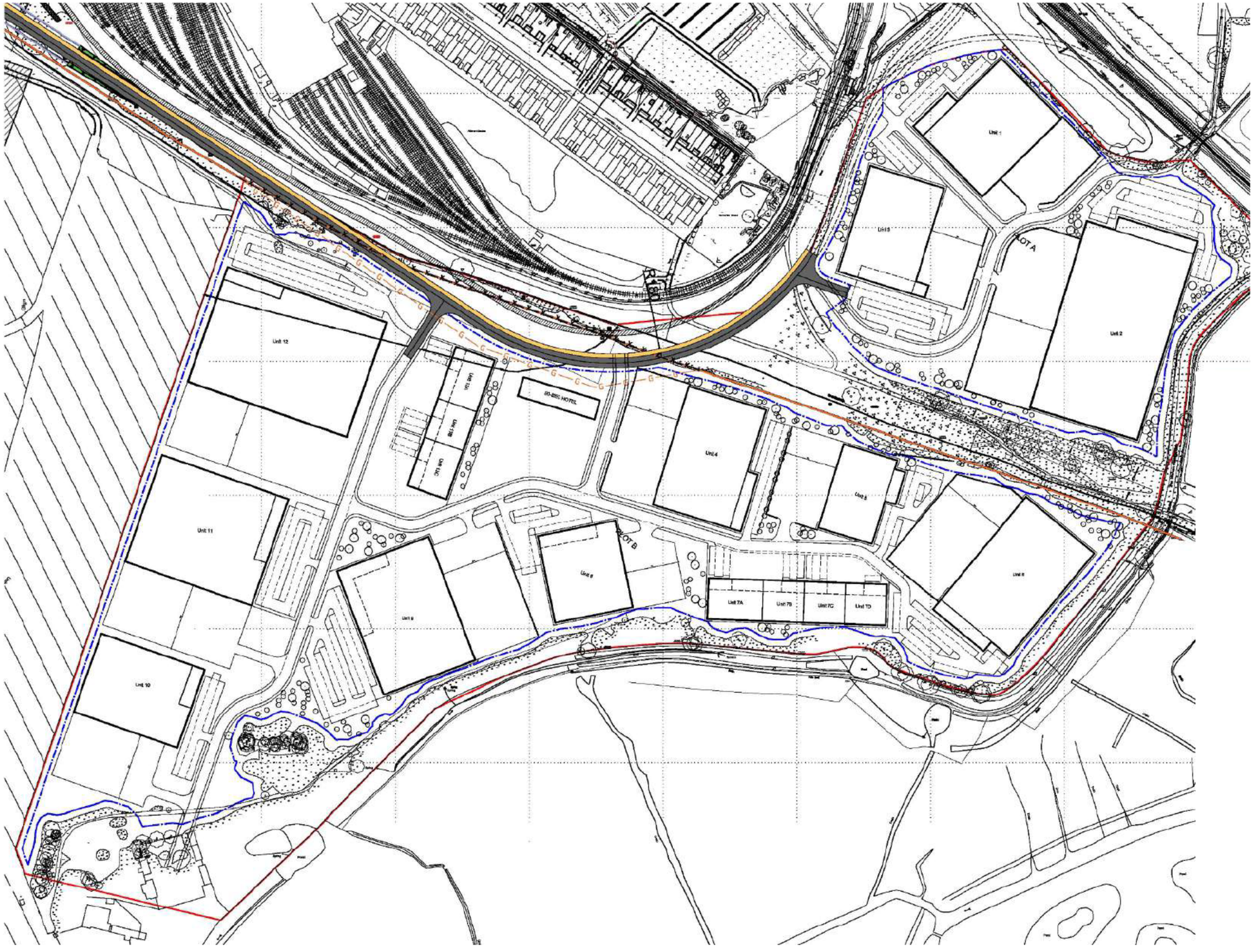


Figure: 02.3

Figure Title:
Proposed Development Plan

Legend:

Notes:

Source: Geo2

N

Project: Navigator Quarter, Southampton

Client: Geo2

Doc Ref: DRA.10210.25 **Version: 1**

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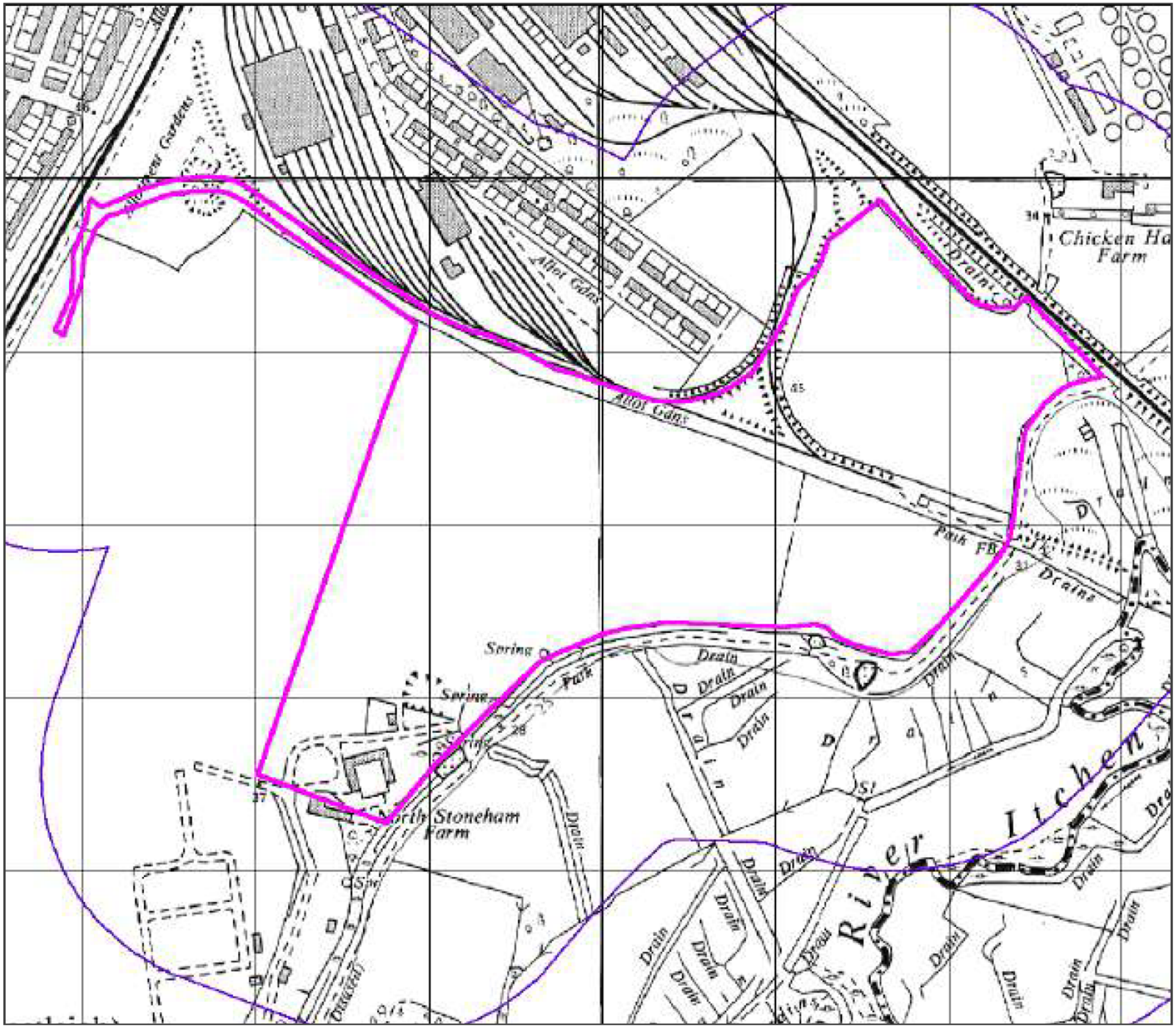


Figure: 03.0

Figure Title:
Historic OS Mapping - 1938

Legend:

Approx. Site boundary

Notes:

Source: Groundsure

N

Project:	Navigator Quarter, Southampton
Client:	Geo2
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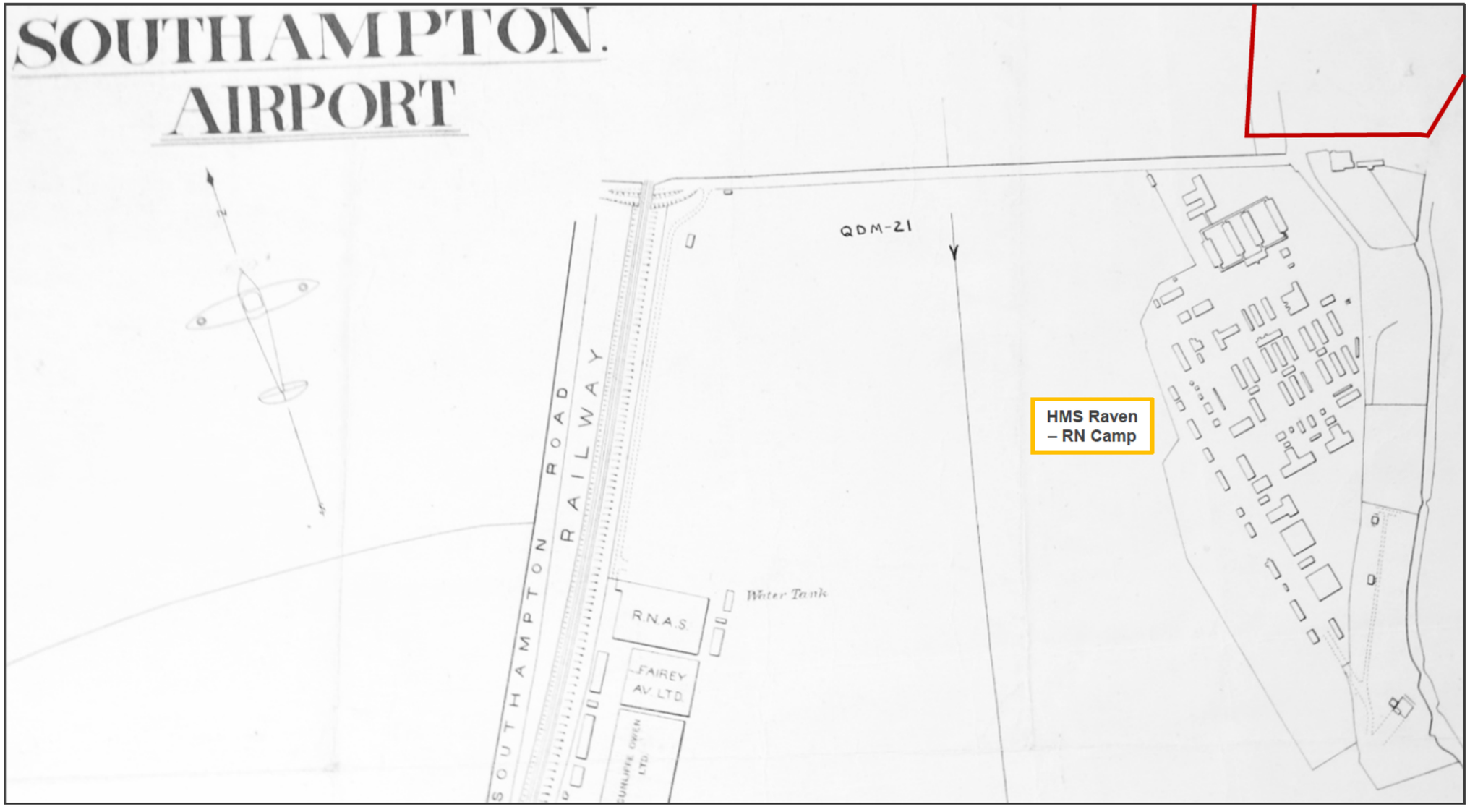


Figure: 04.1

Figure Title:
1944 Borough Engineer & Surveyor Plan - Southampton Airport

Legend:

Approx. Site boundary

Notes:

Source: Hampshire Archive

Project: Navigator Quarter, Southampton

Client: Geo2

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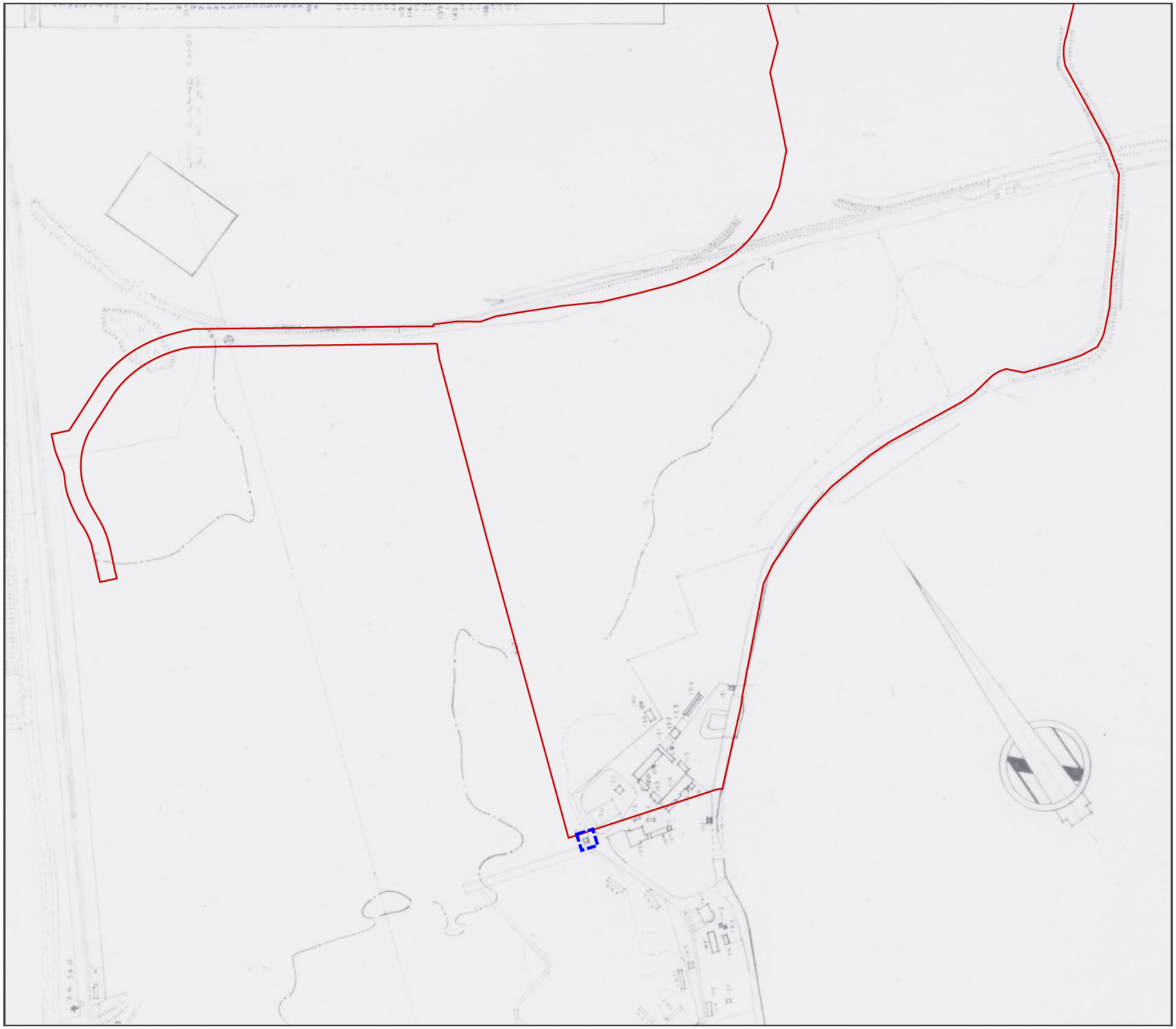


Figure: 04.2

Figure Title:
1954 Air Ministry Plan

Legend:

- Approx. Site boundary
- Block house

Notes:

Source: The RAF Museum

Project: Navigator Quarter, Southampton

Client: Geo2

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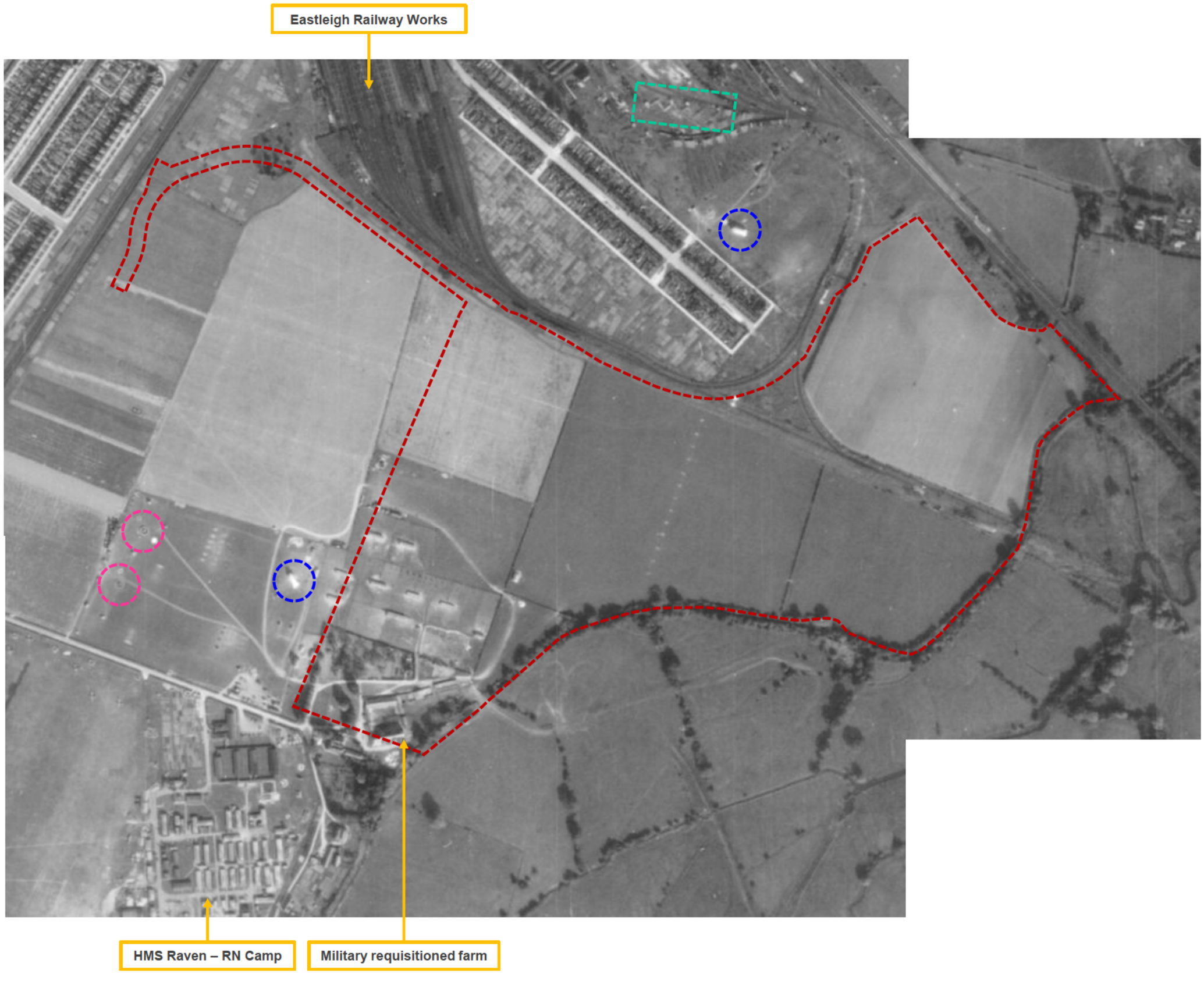


Figure: 05.1

Figure Title:
Historic Aerial Photography:
27th September 1940

Legend:

- Approx. Site boundary
- RAF Barrage Balloon (grounded)
- Probable LAA gun site (sandbag 'nest')
- 'Zig-zag' type infantry trench

Notes:

Source: NARA

N

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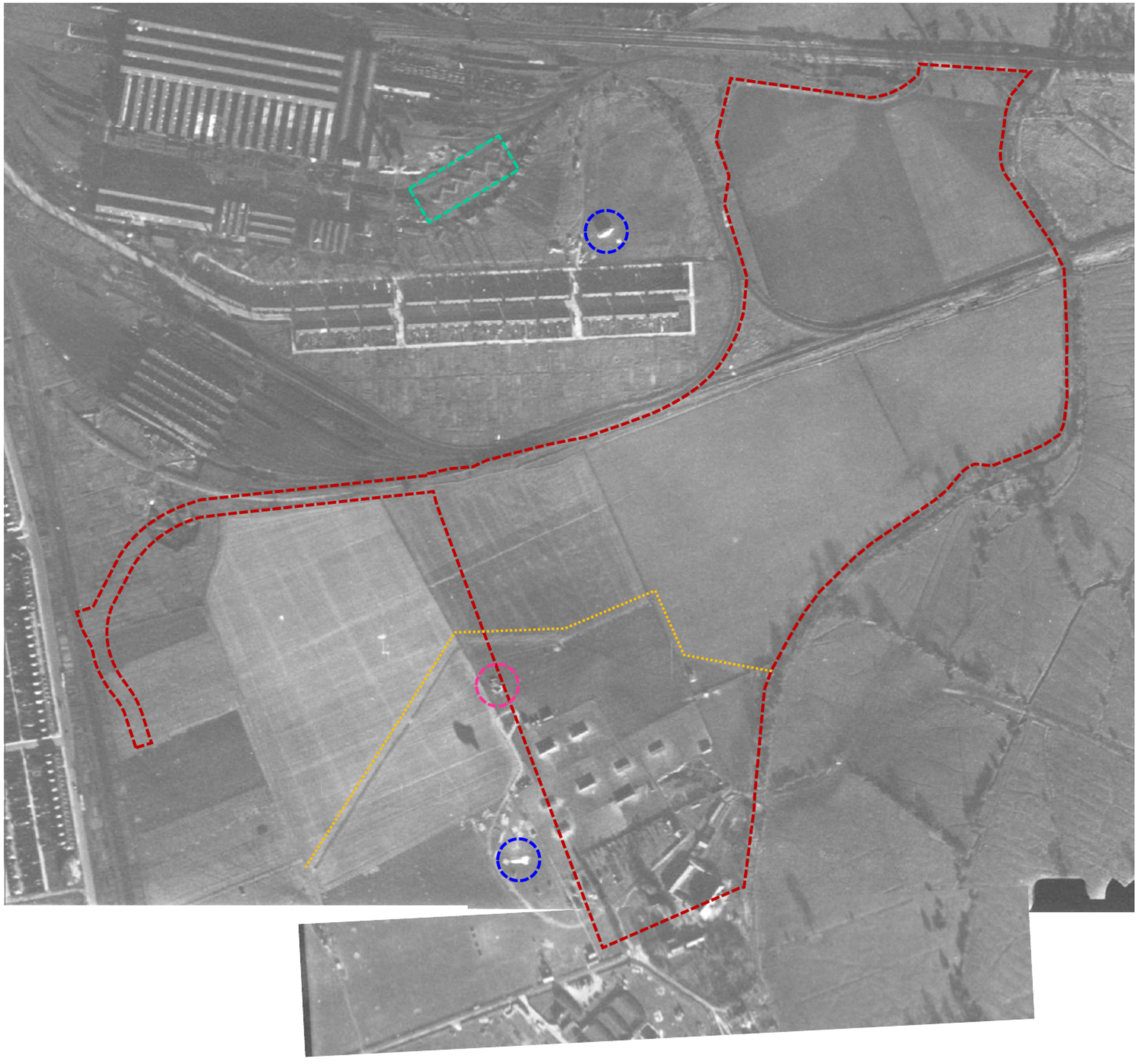


Figure: 05.2

Figure Title:
Historic Aerial Photography:
27th November 1940

Legend:

- Approx. Site boundary
- RAF Barrage Balloon (grounded)
- 'Zig-zag' type infantry trench
- Possible perimeter fortification
- Probable military perimeter (barbed wire)

Notes:

Source: NARA

Project: Navigator Quarter, Southampton

Client: Geo2

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Figure: 05.3

Figure Title:
Historic Aerial Photography:
21st September 1946

Legend:

- Approx. Site boundary
- Demolished buildings
- Possible waste processing / disposal area

Notes:

Source: NARA

N

Project: Navigator Quarter, Southampton

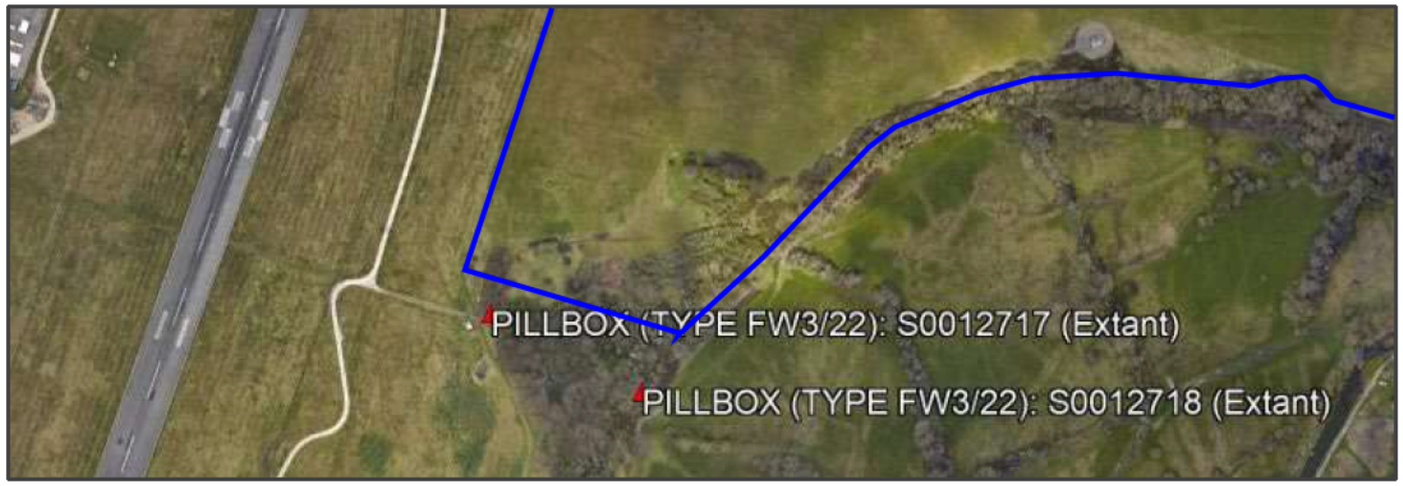
Client: Geo2

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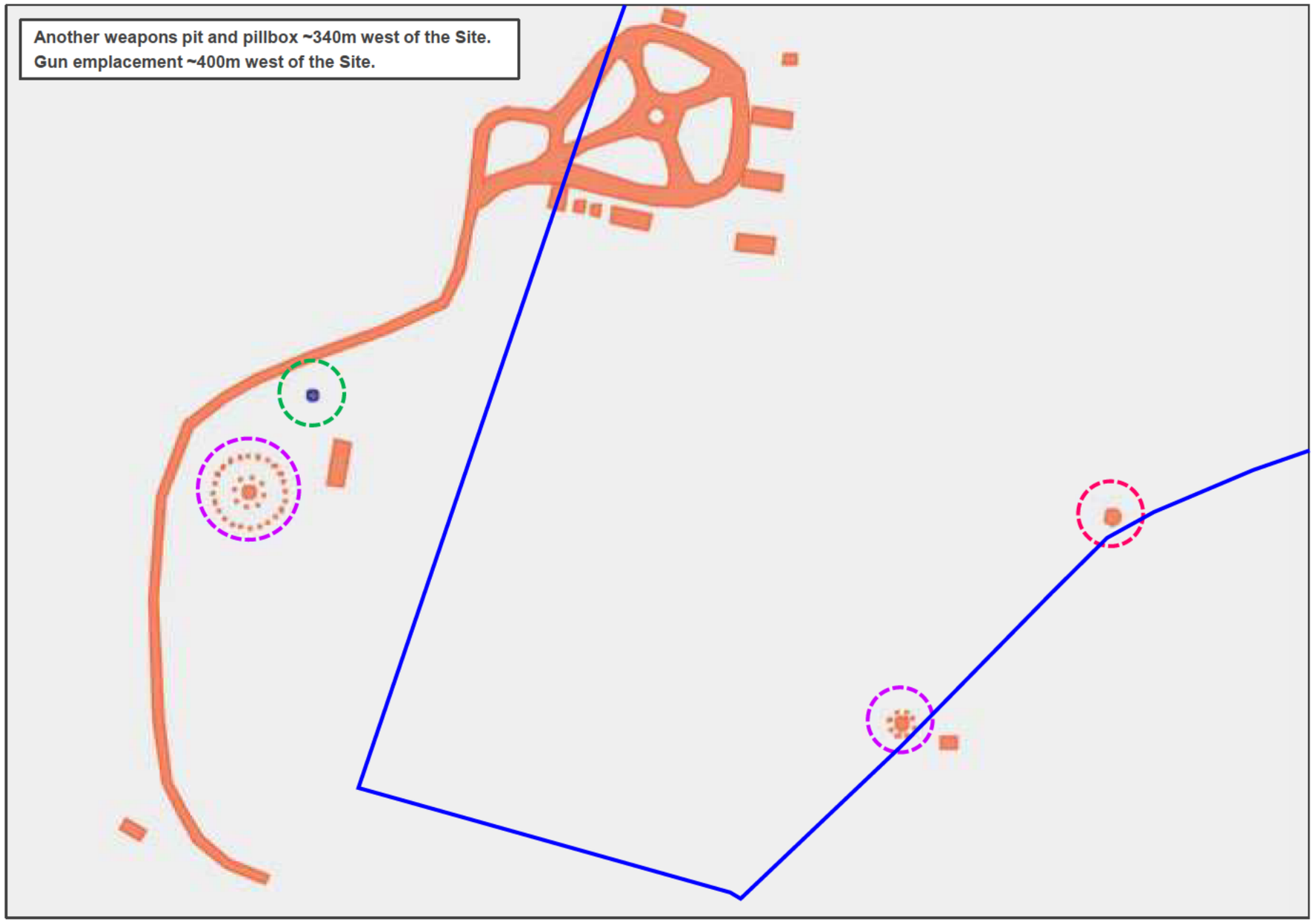


Figure: 06.0

Figure Title:
Historic Environment Record Features Mapped

Legend:

- Approx. Site boundary
- RAF Barrage Balloon mooring site
- Weapons pit
- Pillbox

Notes:

Source: Historic England

N

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Figure: 07.0

Figure Title:
1989 British Army Plan - Southampton Airport Pipe Mines

Legend:

- Approx. Site boundary
- Area containing WW2 recorded pipe mines

Notes:

Source: The National Archives

Project: Navigator Quarter, Southampton

Client: Geo2

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Figure: 08.0

Figure Title:
Luftwaffe Target Reconnaissance Photography - 28th September 1940

Legend:

Approx. Site boundary

Notes:

All red text and red lines are Luftwaffe annotations.

Source: NARA

Project: Navigator Quarter, Southampton

Client: Geo2

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DATE	TIME	REF.	ENEMY AIRCRAFT			BOMBS		M/G	AIRCRAFT CASUALTIES ON GROUND		WARNING	D.G. IN ACTION	DECOY		ENEMY AIRCRAFT CASUALTIES		DAMAGE
			NO.	TYPE	HEIGHT	NO.	TYPE		DEST.	DAMD.			LIT.	ATTD.	DEST.	DAMD.	
1940 AUGUST 21	1728	LREB				8	HE										Craters S. end of L/G
SEPTEMBER 12	1613	DS420			Dive	+	HE										Nil.
OCTOBER 8	1850	RPID	3	E/A	Low	3	HE	+									Canteen demolished.
NOVEMBER 19/20	Night	DS490				1	UXB										Nil.
22/23	0045	SREA	1	E/A		8	HE (7 UX)										Nil.
1941 MARCH 14/15	2340	620				1	HE										Slight to W/T.
APRIL 17/18	0323	758				+	IB										Nil.

Figure: 09.0

Figure Title:
Air Ministry Bomb Record Card

Legend:

Notes:

Source: The MoD

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21st August 1940

Eastleigh aerodrome was bombed but no damage was done.

11th September 1940

Attack on Eastleigh

Aerodrome attacked by 12 hostiles. Dive bombing East to West. No damage to Naval Station or Naval personnel. Cunliffe Owen Factory several hits and casualties. (Eastleigh, 1620/11). Slight damage (S.C.E. Ports. Dkyd., 1216/12).

23rd November 1940

Eastleigh.

At 0045/23, 7 Bombs dropped on West side of Aerodrome. Electric Light cut. No further damage or casualties. (Eastleigh 1020/23 to C. in C. Portsmouth) Estimated Repairs £10 (Supt. C.E. Portsmouth 1130/23 to C.E. in C.)

22nd June 1942

Enemy Air Operations.

Eastleigh Naval Air station bombed.

Air attack 0200, dive-bombing 12 plus aircraft. Casualties 2 Ldg. N.A. killed. 1 Ldg. N.A. seriously injured. Wardroom block 3 and 4 damaged (Eastleigh, 0500/22 to R.A. N.A.S.)
Air raid during night 21/22 caused damage at Eastleigh, Naval Air Station, as follows. Details (S.C.E., Portsmouth, 1500/22).

Figure: 10.0

Figure Title:
Admiralty War Diaries - Excerpts

Legend:

Notes:

Source: Naval Historical Branch

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Client: Geo2

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