Phased Aviation Archaeology Research [PAAR]: Development and application of a standardised methodology to Second World War aircraft sites in Scotland

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Abstract

Past research has focused on aircraft wreck sites as historic entities with characteristics similar to any other archaeological site. The Phased Aviation Archaeology Research [PAAR] Methodology is the first study to examine historic aircraft wreck sites as unique, self-contained data sets. With a production total of nearly 500,000 units, combat aircraft represent one of the largest composite artefact classifications of the Second World War. Despite the vast production quantities, the number of archaeologically secure specimens has been drastically reduced by salvage, corrosion/decay and haphazard research. Improper research and conservation practices, usually employed by the enthusiastic but inexpert avocational aviation archaeology community, are responsible for much of the site attrition since the 1960s/1970s. Sites in close proximity to areas of human habitation have drawn thousands of hill walkers who encounter, handle and re-deposit aircraft wreck site artefacts. When combined with the media attention which often accompanies excavation of aircraft wrecks, the perceived ease of artefact identification in the internet age emboldens history enthusiasts to acquire aircraft debris without regard to the contextual integrity of air wreck sites.

This dissertation addresses the lack of methodological rigour in the aviation archaeology sub-discipline through the development and application of the Phased Aviation Archaeology Research [PAAR] Methodology. Following a discussion of statutory protections for aircraft wreck sites in the United Kingdom, the practices and procedures of both avocational and professional organisations involved in aviation wreck investigations are examined. Taking into account the best practices of each of these communities, the proposed PAAR Methodology enhances standard archaeological methodology by establishing a systematic approach uniquely appropriate for the study of aircraft wrecks. By combining historical primary sources and modern archaeological and air crash investigative techniques to examine Second World War aircraft wreck sites, the PAAR Methodology both compensates for tourism induced site modification and provides a template for future resource management. Field surveys of eight Second World War wreck sites, including excavation of de Havilland Mosquito MM244 and Consolidated LB-30A AM261, assess the effectiveness of the PAAR Methodology.

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Glossary

42-41030	Serial Number of a USAAF Consolidated B-24D aircraft which impacted Beinn Nuis, Isle of Arran on 20 August 1943; see Chapter 7, Section 7.4
42-97286	Serial Number of a USAAF Boeing B-17G aircraft which impacted Beinn Nuis, Isle of Arran on 10 December 1944; see Chapter 7, Section 7.3
44-83325	Serial Number of a USAAF Boeing B-17G aircraft which impacted Beinn Edra, Isle of Skye on 3 March 1945; see Chapter 7, Section 7.2
AAIB	Air Accidents Investigation Branch (UK)
AAF Form 14	*Report of Major Accident* (USAAF)
AAR	Aircraft Accident Report
ADS	Archaeology Data Service
AFHRA	Air Force Historical Research Agency (US)
AJMRC	Arran Junior Mountain Rescue Club
Allies, Allied Powers	For this thesis, the original 26 signatorees to the *Declaration of United Nations* (aka the *Atlantic Charter*)
AM261	Serial Number of an RAF Consolidated LB-30A aircraft which impacted North Goatfell, Isle of Arran on 10 August 1941; see Chapter 9
AMAAA 1979	*Ancient Monuments and Archaeological Areas Act 1979*
AMA 1931	*Ancient Monuments Act 1931*
AMCAA 1913	*Ancient Monuments Consolidation and Amendment Act 1913*
AM Form 1180	*Accident Record Card* (RAF)
AMPA 1882	*Ancient Monuments Protection Act 1882*
AMPA 1900	*Ancient Monuments Protection Act 1900*
AMPA 1910	*Ancient Monuments Protection Act 1910*
AOS	Air Observer School (RAF)
ARGOS	Aircraft Research Group Orkney and Shetland
ATC	Air traffic control
Avocational archaeology	For this thesis, a person or persons engaged in archaeological research but who lack formal, university training in archaeology and are not employed in the discipline

Axis, Axis Powers .... For this thesis, the original signatories of the 1936 *Agreement Guarding Against the Communistic International* (aka the *Anti-Comintern Pact*), the 1939 *Pact of Friendship and Alliance between Germany and Italy* (aka the *Pact of Steel*) and the 1940 *Tri-Partite Pact Between Germany, Italy, and Japan*

B-17 .... Model designator for the Boeing B-17 Flying Fortress; one of two heavy bombers used by the USAAF in the Second World War

B-24 .... Model designator for the Consolidated B-24 Liberator; one of two heavy bombers used by the USAAF in the Second World War

BAAC .... British Aviation Archaeological Council

CBA .... Council for British Archaeology

CHAPG .... Chiltern Historical Aircraft Preservation Group

CIL .... Central Identification Laboratory for the JPAC

CWGC .... Commonwealth War Graves Commission

DD753 .... Serial Number of an RAF de Havilland DH.98 NFII aircraft which impacted The Curr, Scottish Borders on 12 December 1944; see Chapter 6, Section 6.3

DD795 .... Serial Number of an RAF de Havilland DH.98 NFII aircraft which impacted the Corserine, Dumfries and Galloway on 20/21 January 1944; see Chapter 6, Section 6.2

DGPS .... Differential GPS

DH.95 .... Model designator for the de Havilland Flamingo aircraft; passenger airliner used by the RAF as a general purpose aircraft during the Second World War

DH.98 .... Model designator for the de Havilland Mosquito aircraft

DoA .... Department of Agriculture (US)

EAARG .... East Anglian Aircraft Research Group

EDM .... Electronic distance meter

EGNOS .... European Geostationary Navigation Overlay Service; a satellite-based augmentation system, similar to WAAS, developed by the European Space Agency, the European Commission and Eurocontrol to improve the accuracy and coverage of the US Global Positioning System

ETO .... European Theatre of Operations

FAA .... Federal Aviation Administration (US)

FC-S .... Forestry Commission–Scotland

FL 455 Z9-A	Serial Number of an RAF Boeing B-17E aircraft which crashed in the RSPB Forsinard Flows Reserve, Caithness on 31 January 1945; see Chapter 7, Section 7.5
FS #	Field Specimen Number
GNSS	Global navigation satellite system; general term for a satellite navigation system with world-wide coverage
GPS	Global Positioning System; in this thesis the use of GPS refers specifically to the satellite navigation system created and maintained by the US Department of Defense
HBAMA 1953	*Historic Buildings and Ancient Monuments Act 1953*
HC	House of Commons
He 177	Model designator for the Heinkel He 177 Greif (Griffin); the only operational long-range bomber to be used by the *Luftwaffe* during the Second World War
HER	Historic Environment Record
HL	House of Lords
HRC	Human Resources Command, US Army
HS	Historic Scotland
ICAO	International Civil Aviation Organization
ICON	Institute of Conservation
IDPF	Individual Deceased Personnel File
IfA	Institute for Archaeologists
IWM	Imperial War Museum
JCCC	Joint Casualty and Compassionate Centre (MoD)
JPAC	Joint POW-MIA Accounting Command (US)
LAIT	Lancashire Aircraft Investigation Team
LARG	Lincolnshire Aircraft Recovery Group
LB-30A	Model designator given to the initial production run of Consolidated B-24 aircraft which were subsequently sold to the RAF
MACR	Missing Aircrew Report
MAS	Marches Aviation Society
MD #	Metal Detection Finds Number
MHAS	Macclesfield Historical Aviation Society

MM244 .... Serial Number of an RAF de Havilland DH.98 P.R. Mk. IX aircraft which crashed within a FC-S tree plantation near Corryfoyness, Highlands on 25 November 1943; see Chapter 8

MoD .... Ministry of Defence (UK)

MTO .... Mediterranean Theatre of Operations

MU .... Maintenance Unit (RAF)

NAVEX .... Navigation Exercise

NF .... Nondiagnostic fragment

NGF .... Nondiagnostic glass fragment

NGO .... Non-governmental organisation

NMF .... Nondiagnostic metal fragment

NMR .... National Monuments Record

Nondiagnostic(diagnostic) .... An artefact, while is not currently identified, but retains unique features which may allow for positive identification in future

NSA .... National Scenic Areas

NTS .... National Trust for Scotland

NTSB .... National Transportation Safety Board (US)

NWF .... Nondiagnostic wood fragment

OS .... Ordnance Survey

OTU .... Operational Training Unit (RAF)

P-51 .... North American P-51 Mustang; one of the USAAF's main fighter aircraft during the Second World War

PAAR Methodology .... Phased Aviation Archaeology Research Methodology; the methodology developed in this thesis for the archaeological investigation of historical aircraft wreck sites

PDAAR .... Peak District Air Accident Research

PMRA 1986 .... *Protection of Military Remains Act 1986*

RAAF .... Royal Australian Air Force

RAF .... Royal Air Force

RAF Form 540 .... *Squadron Operations Record Books-Summary of Events* (RAF)

RAF Form 541 .... *Squadron Operations Record Books-Detail of Work Carried Out* (RAF)

RAFVR .... Royal Air Force Volunteer Reserve

RCAF .... Royal Canadian Air Force

RSAFB .... Royal Swedish Air Force Board

RCAHMS .... Royal Commission on the Ancient and Historical Monuments of Scotland

RCAHMW .... Royal Commission on the Ancient and Historical Monuments of Wales

RL/A .... Recovery Leader/Anthropologist (specifically in reference to the JPAC)

RSPB .... Royal Society for the Protection of Birds

RSPM .... Recovery scene plan map

SAC .... Special Area of Conservation

SAR Report .... Search and Recovery Report

SOP .... Standard operating procedure

SPA .... Special Protection Area

SS # .... Soil Sample Number

SSSI .... Sites of Special Scientific Interest

STP .... Shovel test probe

SWHAPS .... South Wales Historic Aircraft Preservation Society

TIGHAR .... The International Group for Historic Aircraft Recovery

UK .... United Kingdom of Great Britain and Northern Ireland

UN .... United Nations

US .... United States of America

USAF .... United States Air Force

USAAF .... United States Army Air Forces

USNSC-AD .... US Naval Safety Center-Aeromedical Division

WAAS .... Wide Area Augmentation System; a satellite-based augmentation system developed by the FAA to improve the accuracy and coverage of the GPS

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This thesis is the product of long days and hard labour by volunteers who gave up their weekends, weekdays and sometimes whole weeks to assist me in visiting remote wreck sites. Trekking many miles over rough terrain and overcoming challenging conditions, the field volunteers made data collection possible. I am indebted to Patrick Callaghan and Hamish McArthur for being the first volunteers to visit wreck sites with me. Your willingness to explore more modern archaeology and your suggestions were, and are, very much appreciated. I appreciate Dr. Natasha Ferguson, Kevin Grant and Martin Crawford braving the midges and mud in order to tackle the first excavation. Martin, the enthusiasm displayed on your first excavation even though you had a largely sterile unit and your early identification of de Havilland Mosquito parts made a decided difference. Kevin, I am grateful for your willingness to walk in the rain for hours trying to find a Wellington bomber (to no avail) and your enduring optimism on site. Thank you, Natasha, for driving to Drumnadrochit and to the MM244 wreck site each day. I can only offer repeated apologies for getting you stuck in that man's driveway high on the slopes above Loch Ness and offer frequent praises to your ability to extricate the van safely.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Signature: ____

Printed Name: Terence Alexander Christian

Part 1: Development of the Phased Aviation Archaeology Research [PAAR] Methodology

1 Introduction: Relics of the Recent Past

1.1 Introduction

Iconic photographs of airplanes and their crews fill family albums across the globe; aged pictures capture cigar smoking pilots in bomber jackets standing with their aircrew and oily, jumpsuit-clad crew chiefs. Photos of crew members posed in front of aircraft commemorate a mission about to begin or a mission survived. The men in the photographs know their future is uncertain. Any number of events could turn their plane into a fiery ball of molten metal hurtling toward the ground, destroying both plane and crew.

Figure 1-1: The author's grandfather, Leslie Alsager (second from left), and his aircrew (Alsager n.d.). In 1944, Alsager's crew would be killed in a plane crash in England.

Almost since the beginning of air conflict, an aura of daring and danger has inspired interest in the aviation wreckage of modern warfare. Multitudes of history enthusiasts seek out historic air crash sites. However, nearly all academic research into the role, deployment and current disposition of historic aircraft and aircraft remains relies exclusively on historical and archival material. Professional study of historic aircraft and aircraft wrecks from an archaeological perspective is sorely lacking. Indeed, while 20th century battlefields and defensive emplacements frequently are professionally excavated in order to provide new insight into the military decisions of the warring powers, the scientific excavation of historic aircraft wrecks is rare.

1.2 Purpose of Research

1.2.1 Objectives

It is the goal of this thesis to provide a phased investigatory methodology, deployable by both avocational[1] and professional archaeologists, for the investigation of historic aircraft wreck sites. Currently, no such standard methodology exists. As such, methods differ between groups (see Chapter 3 Sections 3.2 and Chapter 4 Sections 4.2 and 4.3 for discussion of current practices). Because no standardised methodology exists for studying historic air crashes, the extent of the unique information which archaeological investigation of aviation wreck sites can supply to the archaeological discipline, cultural resource managers and the wider historical community is ill-defined. Imperative to a discussion of archaeology's place in historic aviation research are three practical, methodological queries. Firstly, what legal protections are afforded air crash sites as cultural and spiritual resources? Included in any answer to this question must be a discussion of the legal requirements for artefact removal from historic air crash sites. Secondly, how have people/organisations/disciplines investigated aircraft wreck sites and are there methodological differences between avocational aviation archaeologists' practices and the procedures utilised by the professional archaeological community? If there is a difference, can modern archaeology provide the framework for a methodology uniquely designed for the discovery, investigation, excavation and analysis of aviation wrecks? Finally, can expansion and management of the sub-discipline's objectives, methods and ethics stimulate development of statutory protections uniquely devoted to cultural heritage and aircraft wreck sites?

Addressing these questions necessitates developing and field-trialling a phased methodology within a topographically, climatically and historically diverse environment. Reflecting the need to promote methodological and informational parity between professional and avocational aviation archaeologists, the methodology created is named the Phased Aviation Archaeology Research [PAAR] Methodology. Expanding on accepted archaeological research methods, the PAAR Methodology includes five distinct research phases. While this work references aircraft investigations from across the United Kingdom

[1] For the purposes of this thesis, "avocational archaeology" (and its derivative forms) is defined as persons engaged in archaeological research but who lack formal, university training in archaeology and are not employed in the discipline as their primary means of income (see Frison 1984 for discussion on the same).

and the United States, case studies implementing the PAAR Methodology are limited to Scotland.

Scotland was not in the thick of the fight during the Battle of Britain, nor did it experience the terrors of aerial bombardment on the scale of England. As such, Scotland missed many of the most militarily trying times of Britain at war. Yet, upon closer examination, Scotland is an ideal nation in which to study historic Second World War aircraft wrecks. Fielding a large variety of aircraft types during the Second World War, airbases in Scotland supported combat air patrol missions for the Royal Navy base at Scapa Flow as well as bombing, target marking, reconnaissance, strike and close air support missions over Europe, the North Sea and the Atlantic Ocean. Indeed, Scotland's wartime history included experience with counter-bombing raid defensive flights, training schools, anti-submarine patrols, material ferrying flights and bomber sorties to enemy occupied Europe. In contrast to England's close proximity to the European mainland, Scotland's distance from Germany and occupied Europe provided an ideal end location for aerial convoy routes ferrying men and aircraft from training camps in North America. This location resulted in Scotland hosting one of the largest assortments of aircraft types and aircrews of various skill levels in all of Allied Europe. Many of the planes operating in Scotland were of new design and unexpected technological malfunctions caused non-combat related crashes.

The Allied force build-up included newly trained aircrew who were unfamiliar with Scotland's varied terrain and weather. An environment ranging from anaerobic peat bogs on outer sea islands to steep mountains slopes in excess of 3,000 ft above sea level created a setting primed for accidental crashes. Indeed, Scotland's weather, topography and demography allow for a uniquely inclusive archaeological analysis of aircraft wreck site deposition, decomposition, and attrition. Scotland's wet climate and topography create microclimates which produce unsuitable flying conditions (such as low visibility cloud cover and icing) and/or sudden flying hazards (such as mountains rendered barely visible in fog). Furthermore, the wet soil and peat bogs of Scotland create anaerobic sub-surface environments which preserve organic remains extremely well. As much of Scotland is sparsely populated, a substantial percentage of wreck sites can be expected to have not been removed or damaged by urban expansion. For these reasons, Scotland offers an excellent laboratory for assessing the degradation of historic aircraft crash sites and for testing methodological practise.

Due to the potential inventory of Scottish sites which could be researched using the PAAR Methodology, three primary criteria were used to determine which air crash sites would be studied and to what level of the methodology. As the research objectives dictate the examination of sites through an archaeological methodology, the first criteria was that all sites studied should have encountered little alteration since the end of the war. Based on the first criteria, eight sites were identified. Of these sites, six sites did not meet the second criterion: compliance with the *Protection of Military Remains Act 1986* [*PMRA 1986*]. As artefacts on these sites could not be handled or excavated, research was halted early in the investigative process. However, the site surveys of DH.98s DD795 (Corserine, Dumfries and Galloway) and DD753 (The Curr, Scottish Borders), B-17s 44-83325 (Beinn Edra, Isle of Skye), 42-97286 (Beinn Nuis, Isle of Arran) and FL455 Z9-A (Forsinard Flows, Caithness), and B-24 42-41030 (Beinn Nuis, Isle of Arran) provide explanatory information about air crash sites which potentially contain human remains and unexploded ordnance.

Two sites met both of the first two criteria and were selected for excavation; in specific, the de Havilland Mosquito DH.98 MM244 and Consolidated Liberator LB-30A AM261 were selected for detailed study. Both sites are located in primarily rural, difficult to access areas. DH.98 MM244 is located deep on Forestry Commission-Scotland land near Corryfoyness, Highlands and the shores of Loch Ness. Its location off the main Great Glen hiking trail renders it relatively hidden to all but the most dedicated searchers. Located on the slopes of North Goatfell (*Coire Lan*), Isle of Arran, LB-30A AM261 is similarly difficult to reach. While a hiking path follows the *Coire Lan* west of the crash site, a difficult gradient and a location 100 metres off the trail limits access to the site.

Secondly, both sites conform to the Ministry of Defence's permit application standards as established by the *PMRA 1986*. Neither the DH.98 MM244 site nor the LB-30A AM261 site contain known human remains or unexploded ordnance. DH.98 MM244 was a photo-reconnaissance aircraft from which both crewmen successfully parachuted. LB-30A AM261 was on a return ferry flight from RAF Ayr to Gander on Canada's east coast when it crashed into North Goatfell. Offensive weapons were removed from the Consolidated LB-30A in order to maximise its cargo capacity and range. While the crew perished in the crash, their remains were recovered in 1941 and buried either in the Kilbride Old Churchyard, Isle of Arran or Brookwood Military Cemetery, Surrey (CWGC 2013).

The third criterion used in selecting two sites for complete field testing of the PAAR Methodology was that one aircraft be wood skinned and one aircraft be metal skinned. These aircraft fabrication methods cover the two major construction styles of aircraft during the Second World War. DH.98 MM244 fulfilled the wood and canvas construction criterion while LB-30A AM261 fulfilled the metal construction criterion.

1.2.2 Purpose of Excavation and Research Designs

Though the Second World War was heavily documented both deliberately (using embedded journalists, photographers, artists and historians) and incidentally (primarily via the accumulation of war-related paper archives), the archaeological investigation of the Second World War is a critical tool by which to both preserve and reappraise the history of this global conflagration. The primary link to the conflict, the veterans themselves and the oral history they retain, is fast disappearing. According to US Department of Veterans Affairs' estimates, there will be no surviving US Second World War veterans by approximately 2040 (US Department of Veterans Affairs 2012a, 2012b); a similar timeline, based upon the age of Second World War combatants, is likely for the other warring nations. Without the first-hand testimony of veterans, Second World War scholarship will be entirely reliant on historical and archaeological research. Excavation, the technique most associated with archaeology by the public, is but one of many techniques which can be used to investigate historic aircraft wreck sites. When applied as part of a defined research programme, excavation can result in productive data which informs on both known and unknown aspects of the war.

Invasive recovery of artefacts is too often the first or only technique used to investigate aircraft wreck sites (see discussion in Chapter 3 Section 3.2.2.3). The lack of proficient excavations is alarming considering that airplanes potentially represent the single largest intact composite artefact assemblages associated with modern warfare. During the Second World War, the warring powers produced over 500,000 combat aircraft (Harrison 1998: 15-16, Table 1.6). Scotland alone has over 5,200 known aircraft wreck sites spanning 1913 to present.[2]

[2] A privately compiled and maintained database of aircraft wrecks, produced by Alan Thomson and Alan Leishman of the Dumfries and Galloway Aviation Museum, contains information on Scottish aircraft accidents involving over 5,200 aircraft from 1913-present (Thomson 2011). A separate, privately maintained database, compiled by Jim Corbett of the Air Crash Investigation and Archaeology Group, contains around 5,000 entries (Corbett 2013). Access to both databases was requested but not received.

Unfortunately, unscientific souvenir hunts dominate the aircraft excavations occurring in Scotland and the wider United Kingdom. The primary objective underlying many non-professional investigations is the securing of so-called high-value artefact types. High-value artefact types consist of aircraft cockpit equipment, engines and propellers, weaponry, painted aircraft skin components, crewmembers' personal items, and artefacts associated with historically important individuals. That this selective artefact retrieval often is at the expense of information available from significant but less recognisable artefact types displays a lack of appreciation as to how methodological rigour can enhance the understanding of past events. As such, an irreplaceable data set is under threat of premature eradication.

Critical to reversing the trend of unscientific invasive research is the universal employment of project research designs. Reflecting archaeology's academic pedigree, research designs have been mandatory for academic and commercial projects for many decades. Unfortunately, much of avocational aircraft archaeology has not followed the precedence set by professional archaeology projects. Writing in *Aviation Archaeologist*, Alan Clark (n.d.) of Peak District Air Accident Research bemoans the lack of research designs within avocational aviation archaeology (see Chapter 3 Section 3.2). The MoD's own aviation archaeology excavation license programme does little to encourage the use of research designs as a means to justify and focus invasive investigatory techniques. The MoD JCCC's most recent licensure requirements do not mandate submission of a research design when applying for an excavation license (UK Ministry of Defence 2011). While still not commonplace within avocational aviation archaeology, any recognition that research designs can focus historic aircraft wreck investigations (e.g., Clark n.d.), even possibly helping to limit the level of disturbance, is positive. It is the position of this thesis that excavation of aircraft wreck sites should be undertaken as part of a fuller research programme. Such a programme should include background research (Chapter 5 Section 5.2.1) and intensive pre-excavation surveys (Chapter 5 Sections 5.2.2 and 5.2.3) and should be guided by research designs detailing specific investigatory questions only answerable through invasive techniques.

1.2.3 Methods of Discovery and Investigation

Currently, archaeological study of historic aircraft can be partitioned into three categories: accidental discovery, avocational excavations and professional projects. Accidental discovery is the usual means by which the limited professional archaeological study of historic aircraft wrecks occurs. Although covering a multitude of situations in which professional archaeologists encounter aircraft wrecks, the majority of accidental discoveries occur during new construction or infrastructure improvement activities. Located by Jakub Perka while prospecting for oil in the Western Sahara, Curtiss P-40 ET574 is representative of infrastructure-related accidental discoveries (Alleyne 2012a, 2012b). A smaller percentage of accidental discoveries are by individuals or groups pursuing recreational activities. The discovery of the Harlech, Gwynned Lockheed P-38 (presumed serial number 41-7677) on 31 July 2007 typifies recreational discoveries. The intact aircraft was found eroding out of a coastline by a family spending the day at the beach. The submerged P-38's discovery came to the attention of a local aviation enthusiast who, recognising the aircraft's shape from books, reported the find to The International Group for Historic Aircraft Recovery [TIGHAR] (Pyle 2007; Quigg and King 2007a). While not undertaken by an archaeological team that purposely set out to locate, study and excavate a given aircraft based upon its own historical merit, efforts resulting from accidental discovery have provided opportunities for aircraft preservation and scientific excavation. The release of accidentally discovered sites to, and the subsequent management by, professional archaeologists results in the use of standard archaeological field methodology developed for the excavation of multi-period sites. Using methodology created and deployed in the excavation of entirely unrelated ancient and post-medieval sites, project leaders often are untrained in the specific idiosyncrasies of aircraft sites.

Far more deleterious to the study of historic aircraft wrecks is the removal of artefacts or whole airframes by individual members of the public and by avocational groups. As of 2011, there are over 30 societies in the United Kingdom dedicated to the unearthing of historic aircraft wrecks. However, none of these groups adheres to a standardised archaeological methodology. In fact, each group's methodology often differs from site to site. Photographs and site plans either exhibit very little accuracy or are non-existent. No standards for post-excavation artefact analysis and stabilisation exist. Often the excavated artefacts eventually reside in public or private curiosity cabinets. In one known instance, a recovered machine gun ended its career exposed to the elements as a garden ornament (A. MacLeod 2011; R. MacLeod 2011). The publication history of non-professional groups' activities varies widely. Very few reports meet Institute for Archaeologists [IfA] archaeological standards.

Targeted, professional research into aircraft archaeology occurs with less frequency than avocational projects. Research by Time Team/Wessex Archaeology (e.g., Time Team 1998, Ely 2005; see Chapter 4 Section 4.2.2) demonstrates the depth of data which can be obtained from professional aircraft archaeology. Utilising general, standard archaeological practises common on multi-period sites, these professional archaeology units currently provide the best archaeological practise within aviation archaeology. However, the generalised focus of most professional archaeologists' training does not include the specialised, aircraft-specific knowledge base found in avocational aviation groups.

1.2.4 Formation Processes: Identifying the boundaries of crash sites

Regardless of the means of discovery, one of the first tasks is to identify the crash site boundaries. Critical factors dictating the relative boundaries of a military aircraft crash site include the (1) soil composition, (2) angle of impact, (3) velocity of impact, (4) aircraft attitude (degree of pitch, roll and yaw),[3] (5) terrain of impact and (6) weapons on board the aircraft at the time of the crash. Determining site boundaries requires exploring these factors in relation to one another.

Impact site soil composition significantly influences crash site boundaries. The deposition and stratification of soil through natural and anthropogenic factors has been discussed at length within archaeology and earth sciences. For a discussion of general soil/artefact deposition and stratification see Johnson 1990, Johnson *et al.* 2005 and Hupy and Schaetzl 2006. Though the long-term formation and movement of aircraft wreck site soils and artefacts follow standard depositional models, the immediate depth and spread of aircraft wreck sites is influenced by the other critical factors.

Four disparate crash site patterns result from the interrelationship of angle and velocity of impact (Figure 1-2). A low speed, high angle impact produces the familiar wreckage pattern of a circular crater containing the plane's wreckage within its boundaries. The self-contained nature of this pattern is due to the inertial break-up of the plane on impact. A low velocity, low angle impact results in an oval-shaped, shallow crater that may, or may not, have ground scars leading to the point of impact. In this latter crash, the airframe

[3] Pitch is defined as an object's movement around the lateral (x) axis while roll and yaw are defined as motion about the longitudinal (y) and vertical (z) axes (Russell 1996: 72; Matthews 2002: 66-68; Hull 2007: 2, 4).

usually breaks apart into its primary structures with little extraneous artefact scatter (US Air Force Civil Engineer Support Agency 2006: 153).

High velocity crashes produce their own unique patterns. A high angle, high velocity impact generates a deep crater with a short, but wide, artefact scatter fanning outward from the point of impact. A high speed, low angle impact creates a shallow, elongated trench. Because the aircraft involved in a high speed, low angle crash tends to skip along the ground, the heaviest artefacts settle furthest from the initial point of contact. Heavier artefacts are found further down range as the high velocity and low angle of impact propels them at high speed along low, flat trajectories (US Air Force Civil Engineer Support Agency 2006: 153; Cutnell and Johnson 2010: 88-91).

Figure 1-2: Four disparate crash site patterns resulting from the interrelationship of angle and velocity of impact: (1) high velocity, high angle impact; (2) high velocity, low angle impact; (3) low velocity, high angle impact; and (4) low velocity, low angle impact (Figure redrawn from US Air Force Civil Engineer Support Agency 2006: 153).

Allowances for the terrain of the crash site add complexity to artefact scatter assumptions. Indeed, the four simple, generalised patterns presented rely on hypothetical modelling which assumes a completely flat, or planar, surface. Real world topography rarely meets this planar condition; thus, actual aircraft artefact scatters are considerably more varied (Hasbrook and Petry 1951: 25-26). For example, a high speed aircraft crashing into a cliff face at 90 degrees, by definition, experiences a high speed, high angle impact. However, the artefact scatter produced by such a crash defies the generalised pattern. Due to the steep cliff face, the scatter is relatively isolated, forming mostly along the uneven, rock strewn side of the cliff (the scree slope) and at the cliff base (Figure 1-3). Similarly, an aircraft hitting a 45 degree slope at low speed and high angle may generate an artefact scatter which spreads far beyond the point of impact due to down-slope migration (Figure 1-4). This pattern differs vastly from the self-contained circular pattern predicted by the speed/angle models. In addition, seemingly incidental contact can cause an aircraft to crash and generate unexpected artefact scatters. Striking terrain or other aircraft, such as a wing clip, can cause the loss of control surfaces and lead to catastrophic airframe or system failure. The resulting crash event produces a cascading debris pattern in the direction of movement (Figure 1-5).

Further, the presence of munitions on board an ill-fated aircraft complicates artefact scatters. Indeed, munitions that explode at the time of the airplane's impact entirely transform the artefact scatter. The resultant scatter pattern from both impact and explosive deposition is a consistent and archaeologically recognisable phenomenon known as bombturbation. Bombturbation is the term introduced in 2006 by Joseph Hupy and Randall Schaetzl to define "the cratering of the soil surface and mixing of the soil by explosive munitions…and the phenomenon of explosive artefact scatter and ground disturbance" (825-826). An example of the bombturbation phenomenon impacting the archaeology of aircraft crash sites is Lancaster HK594. Lancaster HK594 crashed at low speed and low angle in Svenskop, Sweden while carrying a full bomb load. The on-board bombs detonated on impact. Sixty-eight years later, local townsfolk reported to the archaeologists excavating the aircraft that plane parts had been recovered as much as two kilometres from the point of impact and detonation (Knarrström 2011). This scatter pattern contrasts markedly with the hypothetical oval-shaped, shallow crater expected from a low speed, low angle crash. The Svenskop townsfolk's oral testimony reveals a dramatic incidence of ordnance-detonation altering expected patterns.

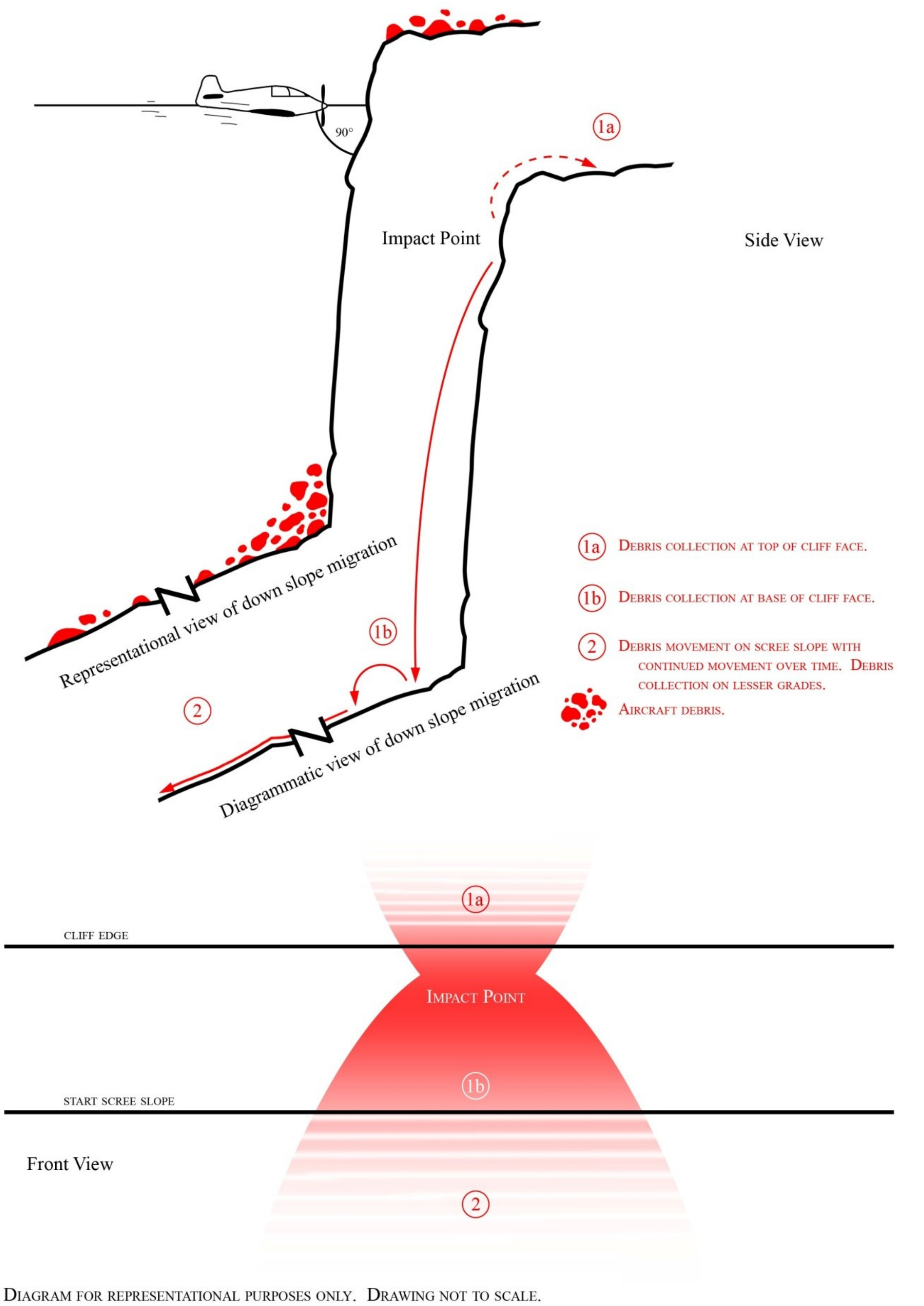


Figure 1-3: Unorthodox artefact patterning in high velocity, high angle impact due to unique terrain factors (Author).

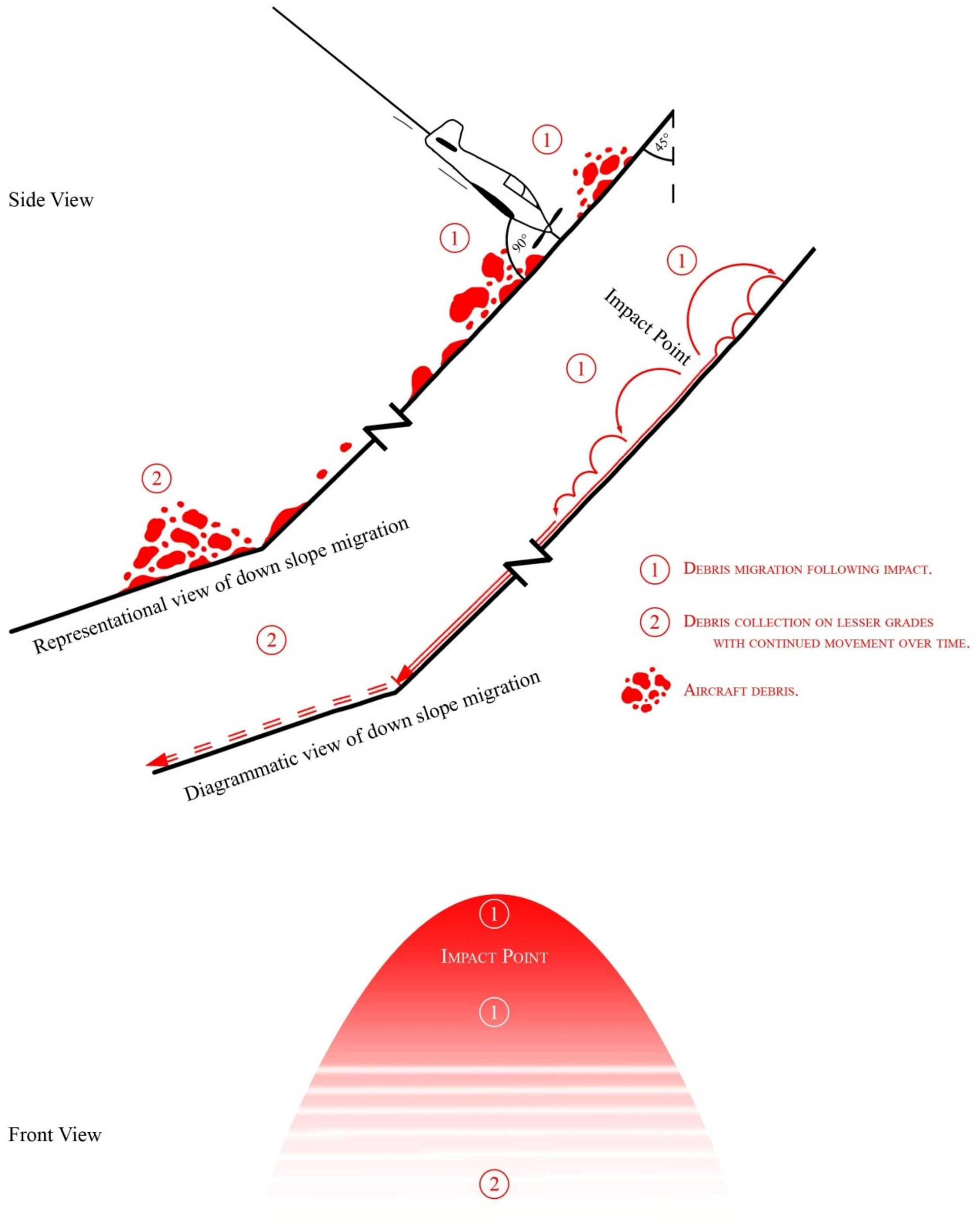


Diagram for representational purposes only. Drawing not to scale.

Figure 1-4: Unorthodox artefact patterning in low speed, high angle impact due to unique terrain factors (Author).

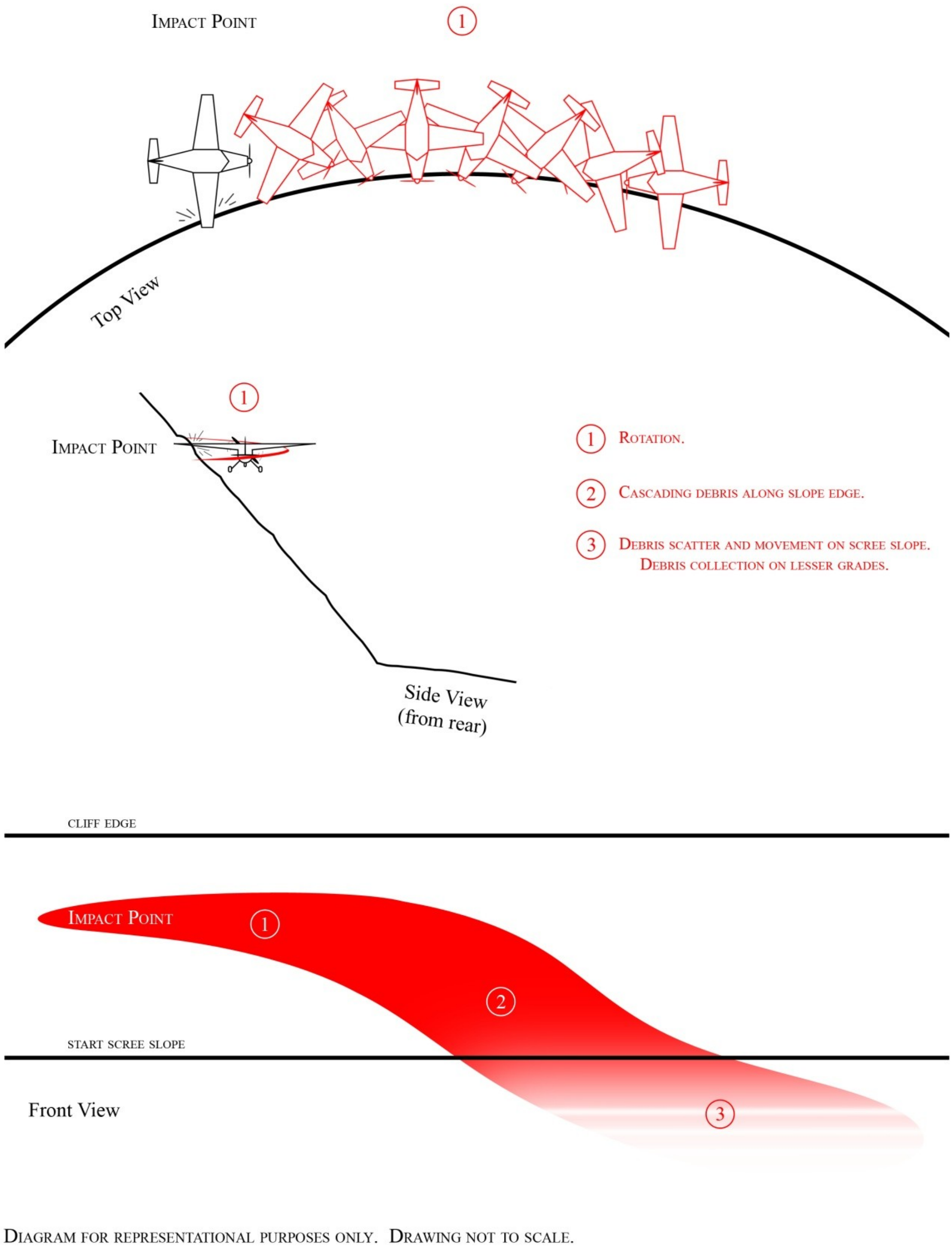


Figure 1-5: Unorthodox artefact patterning due to post-impact tumbling (Author).

1.2.5 Relevance of Forensic Anthropology

Amongst the various subfields of anthropology, physical and forensic anthropology have the largest roles to play in the investigation of historic aircraft wrecks. Traditionally, physical anthropology has focused on determining the biological characteristics of skeletal remains (sex, race, age and stature). During the last quarter of the 20th century, anthropology expanded and now analyses the full range of human existence including the recently deceased. This expanded focus, including "fleshed, decomposing, burnt and dismembered remains" (Simmons and Haglund 2005: 159), provides forensic anthropology with relevant expertise critical to the investigation of aircraft wreck-related human remains. Reflecting the medico-legal origins of forensic anthropology (Simmons and Haglund 2005: 159), the initial application of physical and forensic anthropology to historic aircraft wreck scholarship is a direct result of aviation archaeology's professional relationship with military repatriation efforts and civil aviation search and recovery operations (see Chapter 4 Section 4.3). The integration of established forensic anthropology search, recovery and identification methodologies with the PAAR Methodology is of critical importance to the respectful and productive investigation of aircraft wreck-based human remains.

Though each investigation is different, forensic anthropology investigations generally employ search, recovery and identification procedures similar to those utilised in archaeological research (Hunter *et al.* 2013: 15). Forensic anthropology investigations commonly utilise a phased research design incorporating desk-based assessments, field surveys and invasive actions (Hunter *et al.* 2013: 13, 15, 77-80, 88). The phased progression from desk-based assessments through non-invasive searches and, ultimately, invasive search and recovery operations reflects forensic anthropology's intent to minimise the loss and/or corruption of critical evidence (Hunter *et al.* 2013: 13), a concept paralleled in the PAAR Methodology. Established forensic anthropology methodologies have been detailed by other texts (Stewart 1979; Hunter and Cox 2005; Dupras *et al.* 2006; Pickering and Bachman 2009; Hunter *et al.* 2013; Christensen *et al.* 2014) and, as such, will not be enumerated here; the similarities between forensic anthropology procedures (Dupras *et al.* 2006: 23-28, 44-64, 81-102, 114-128; Hunter *et al.* 2013: 15, 77, 79; Christensen *et al.* 2014: 149-178) and the PAAR Methodology, however, show the proposed aviation archaeology methodology to be procedurally sound.

While forensic anthropology, archaeology and the PAAR Methodology utilise parallel desk-based, search and recovery strategies, the positive identification of human remains differs. Archaeology, being focused on the more distant past, is often satisfied with a more general characterisation of the deceased. Forensic anthropology's medico-legal requirements often necessitate a more definite identification be made. Aircraft archaeology, working on the cusp of history and living memory, may align with either outlook depending upon the investigatory organisation, the site examined and the research questions posed. While professional aviation archaeology organisations have established procedures for the confirmation of personal identification (e.g., Lee 2006: 60-70; JPAC 2010: 36-37 (Annex F), 47 (Enclosure 1); FAA 2011: 4-8; ICAO n.d.: 18.5.2), the concept is little discussed within avocational archaeology. Should aviation archaeology expand to encompass sites retaining human remains, as this thesis advocates (see Chapter 10, Section 10.1.3.1), forensic anthropology can provide proven guidance on the establishment of personal identification.

Personal identification of human remains can be classified as either presumptive or positive. Presumptive identification predominantly is established using multiple lines of evidence; ante- and peri-mortem information (such as trauma and pathology) and personal effects are the lines of evidence most commonly used (Simmons and Haglund 2005: 166-167). While the singular reliance on presumptive identification for the establishment of personal identity may be sensible in specific circumstances (see Simmons and Haglund 2005: 169-170 for two scenarios abstractly similar to those encountered in aircraft wreck sites), presumptive identification cannot provide positive identification and, therefore, should not be used for definitive confirmation of personal identity. As positive identification only requires a single line of evidence due to a reliance upon an individual's unique characteristics (DNA, fingerprints, dental records and/or medical imaging), positive identification is often preferred over presumptive identification, especially in cases where remains are degraded to the point that visual identification is impossible or in mass fatality events (Simmons and Haglund 2005: 169-170).

On aircraft wreck sites with a known or supposed crew manifest, presumptive identification can be used to tentatively identify individuals while concurrently reducing the size of the unidentified victim pool. Taken with new research into the distribution of human remains on historic aircraft wreck sites (O'Leary 2014), early presumptive identification of victims can be used to direct aircraft wreck site-associated human remains search programmes with positive identification completed prior to next-of-kin notification.

This thesis does not undertake the study of aircraft wreck-based human remains due to the *PMRA 1986*'s extra-legal prohibition on the excavation of human remains. While the PAAR Methodology has not been trialled on sites containing human remains, new scholarship (O'Leary 2014) has shown that the PAAR Methodology's proposed research programme may be applied with little alteration. O'Leary's research demonstrates a positive relationship between crew duty station artefacts and the discovery of human remains. The identified relationship creates exciting opportunities for archaeologists. Where probable impact sites have been determined, O'Leary's observation could be used to consciously avoid human remains during further invasive research while still allowing critical research to progress. The use of O'Leary's research to avoid human remains may well assist in lessening the *PMRA 1986*'s extra-legal prohibition on the excavation of human remains.

1.3 Thesis Structure

This thesis is structured as a template for avocational and professional archaeologists undertaking aviation focused archaeological research. As such, the thesis explores previous research and investigatory practices before introducing the PAAR Methodology. This work first considers the legal and moral ramifications of past governmental policy on air crash excavations (Chapter 2). The evaluation of statutory protection for aircraft wreck sites includes an examination of the management of historic aircraft wrecks as cultural resources. An important consideration for the proper excavation of air crash sites is the current government policy as it relates to possibly extant Allied and Axis human remains. The traumatic nature of air wrecks means that fragmentary human remains may be on site. Such a possibility demands that air crash sites with known casualties be treated with the respect due a war grave and only excavated by professionals with specialised training.

Next this thesis reviews previous examples of wreck site exploration with specific emphasis on the methods employed by both professional and avocational crash site investigators (Chapters 3 and 4, respectively). Since the Second World War, governments, non-governmental organisations [NGOs] and non-professional organisations have utilised a variety of methodologies to investigate aircraft wrecks. In the United States alone, there are at least eight professional agencies and organisations that deal with aircraft wreck investigations. Similarly, the United Kingdom has over 30 avocational organisations dedicated to wreck recovery. The current thesis will compare governmental, NGO and non-professional organisation procedures to established archaeological methodology.

Following the review of current practises, a comprehensive, standardised field methodology for researching historic air crash sites is developed (Chapter 5). The inadequacies inherent in previous excavations, both professional and avocational, reveal that generalised, non-aircraft specific excavations threaten the continued existence of air crash sites as cultural and spiritual resources. The establishment of a standardised, phased methodology directing the user's actions from initial survey through artefact stabilisation is long overdue. The PAAR Methodology developed in this thesis provides a comprehensive, five phase methodology utilising an increasing scale of professional expertise, monetary investment, and expected results:

- Phase I: Historical Survey (basic site identification; site visit and basic artefact retention assessment without site modification)

- Phase IIa: General Data Survey (archival data collection and analysis conducted to refine crash scenario; unsystematic pedestrian and metal detector surveys completed to provide maximum site boundaries)

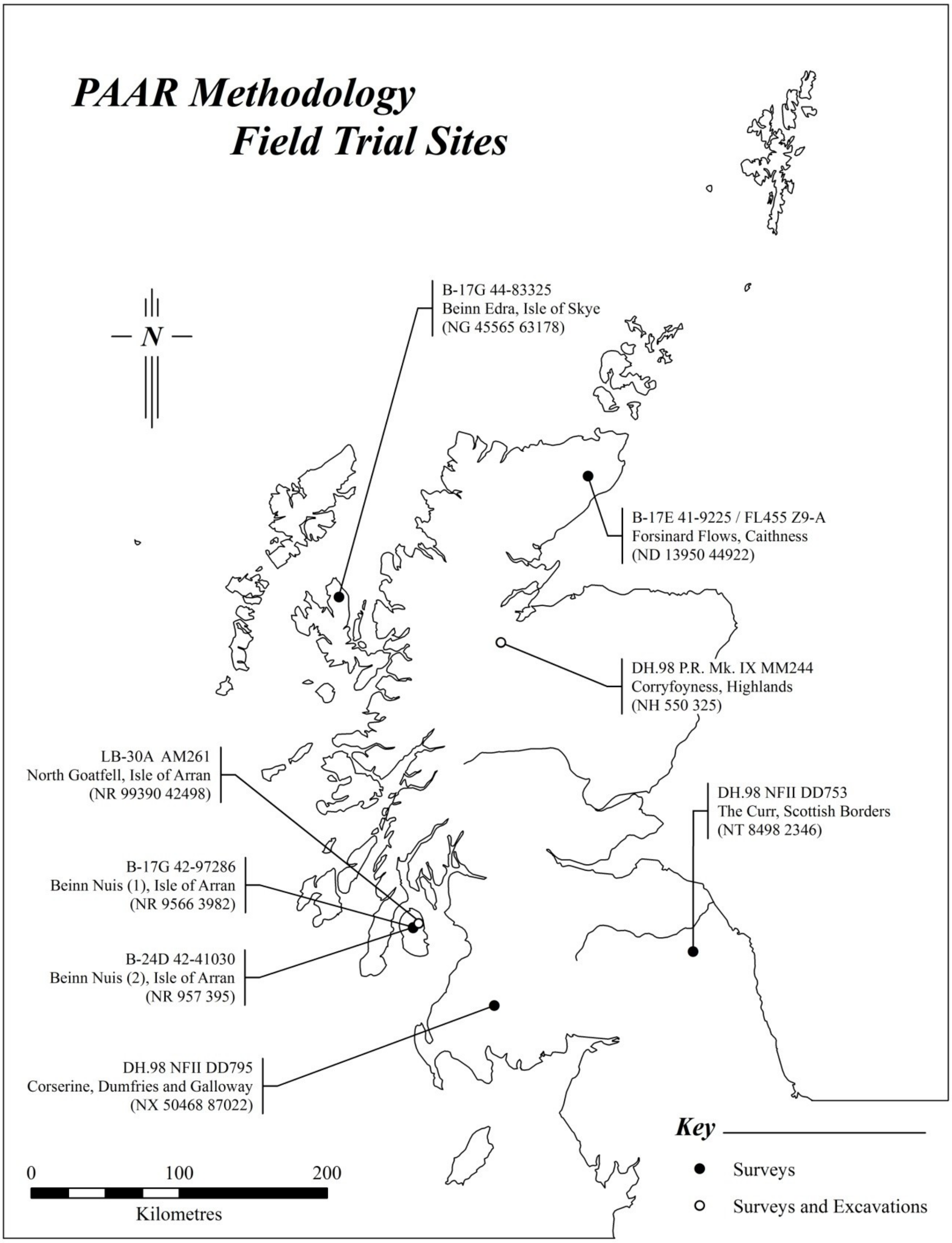
- Phase IIb: Detailed Data Survey (systematic pedestrian, metal detector and shovel test probe surveys completed to refine site boundaries, identify archaeologically sensitive areas and focus Phase IIIa/IIIb recoveries)

- Phase IIIa: Exploratory Excavations (test units and test trenches excavated to assess subsurface artefact retention and impact-related soil stratigraphy)

- Phase IIIb: Full Data Recovery (excavation of all aircraft-associated material; extremely invasive archaeologically, requiring a specialised skill-set).

The splitting of the industry standard Phase II and Phase III (Greene and Moore 2010: 106-107; Neumann and Sanford 2010: 5; Neumann *et al.* 2010: 2) into four phases (Phases IIa/IIb and Phases IIIa/IIIb) results in five phases overall and enables increased investigatory flexibility while maintaining phase terminology correspondent with the larger archaeological discipline.

Lastly, the usefulness of the PAAR Methodology is field trialled at sites varying in terrain, elevation and aircraft types (see Map 1-1 and Chapters 6-9). Successes and areas for future development are identified and critically evaluated (Chapter 10).



Map 1-1: PAAR Methodology field trial site locations (Author).

2 The Legal Protection of Military Aircraft Wrecks and Wreck Sites

2.1 Introduction

Limited political will exists to police military air crash sites whether or not the sites contain human remains; as such, the legal protection of such sites is wholly inadequate. Indeed, there exists minimal codified international understanding as to what constitutes "archaeology" as concerns crash sites. Within the United Kingdom, the foundation of heritage law is the preservation of shared cultural history and material culture for the benefit of future generations. While UK heritage law provides Government ministers and heritage organisations with a wide remit to both preserve shared history and prosecute those who would destroy it, the implementation of pecuniary punishments and jail sentences under the law is severely lacking. This chapter briefly discusses legal efforts to protect military crash sites within the United Kingdom and the uneven enforcement of relevant national laws.

2.2 Legal Precedence in the United Kingdom

Only four acts protect military wreck sites within the United Kingdom: the *Protection of Wrecks Act 1973*; the *Ancient Monuments and Archaeological Areas Act 1979*; the *Protection of Military Remains Act 1986*; and the *Marine and Coastal Access Act 2009* (and its Scottish corollary, the *Marine (Scotland) Act 2010*). While all these Acts provide legal protection either for military wreck sites specifically or cultural heritage in general, the *Protection of Wrecks Act 1973*, the *Marine and Coastal Access Act 2009* and the *Marine (Scotland) Act 2010* will not be discussed as these three Acts specifically apply to marine wrecks and, therefore, are outside the scope of the current terrestrial study (Dromgoole 1996: 24-29; *Marine and Coastal Access Act 2009*: Chapter 1 Part 4 Section 115(2), Chapter 1 Part 5 Section 117(8) and Section 147(1)(b); *Marine (Scotland) Act 2010*: Part 5 Section 73). The sequence of relevant terrestrial heritage law discussed in this chapter is summarised in Figure 2-1.

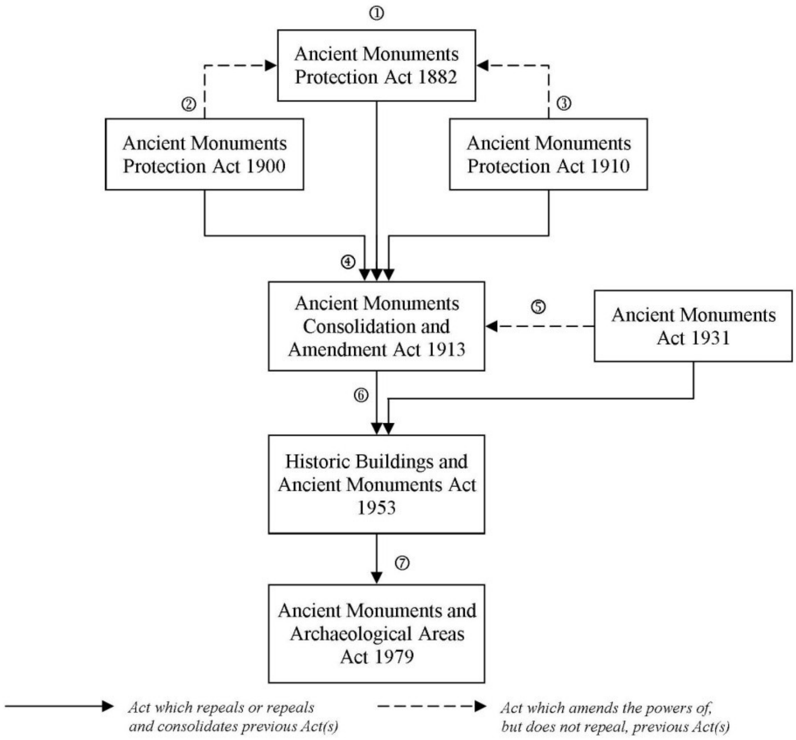


Figure 2-1: History of terrestrial heritage law in the United Kingdom (Author).

2.2.1 *Ancient Monuments and Archaeological Areas Act 1979* and its Predecessors

The origins of the *Ancient Monuments and Archaeological Areas Act 1979* [*AMAAA 1979*] can be traced to the *Ancient Monuments Protection Act 1882* [*AMPA 1882*]. The first of its kind, the *AMPA 1882* provided a system of State protection for terrestrial ancient monuments through the appointment of Inspectors of Ancient Monuments. The *Ancient Monuments Protection Act 1900* and *Ancient Monuments Protection Act 1910* [*AMPA 1900* and *AMPA 1910*, respectively] expanded the *AMPA 1882*'s original powers. Important for the legal protection of modern heritage, the Acts broadened the definition of "monument" to include more than just "ancient monuments" as defined by the *AMPA 1882* (*AMPA 1900*: Section 6; *AMPA 1910*: Section 1; Mynors 2006:8-9). In 1913, all three *Ancient Monuments Protection Acts* were repealed and a new system introduced under the *Ancient Monuments Consolidation and Amendment Act 1913* [*AMCAA 1913*]. Significantly, the *AMCAA 1913* allowed for the extension of the term "monument" to include areas surrounding the physical structure (Section 22). The addition of a buffer zone around ancient monuments proved instrumental in promoting both public access and physical preservation. The *Ancient Monuments Act 1931* [*AMA 1931*] expanded the term "monument" to include sub-surface features (Section 15). This inclusion offered the first legal precedence for the future protection of buried aircraft. The subsequent *Historic*

Buildings and Ancient Monuments Act 1953 [*HBAMA 1953*] unified the *AMCAA 1913* and the *AMA 1931* (Mynors 2006: 12-13) but did little to expand the Acts' protective powers.

A milestone for the protection of archaeological heritage as a whole, the *AMAAA 1979* was the first Act explicitly offering protection to aircraft wreck sites. Like its antecedents, the *AMAAA 1979* seeks to preserve areas of archaeological importance from unlawful tampering by legally excluding designated "ancient monuments" from unauthorised interference (*AMAAA 1979*: Sections 1(3), 2, Section 61(7) and 61(12); Dromgoole 1996: 38). Referencing the expanded definition of "monuments," as defined by the preceding Acts, Section 61(7)(c) and 61(7)(d) of the *AMAAA 1979* provides historic aircraft, aircraft wreck sites, and aircraft wreck site assemblages the same legal protection, should they be deemed "of national importance," as older structures. To aid in the selection of sites of "national importance," a series of non-statutory criteria were established in 1983; revised criteria were published by the Department for Culture, Media and Sport [DCMS] and Historic Scotland in March 2010 and July 2009, respectively. Aircraft wreck sites can be seen to fit a number of these criteria including DCMS's *period*, *rarity*, *documentation*, *survival/condition*, *diversity* and *potential* (DCMS 2010: 18-19) and Historic Scotland's *a*, *b*, *d* and *e* criteria (Historic Scotland 2009: 65). Unfortunately, while the *AMAAA 1979* provides theoretical protection to designated aircraft wreck sites, no historic aircraft wreck sites have been afforded scheduling protection despite the threat to many important wreck sites and airframe models (Holyoak and Schofield 2002).

2.2.2 *Protection of Military Remains Act 1986*

The *Protection of Military Remains Act 1986* [*PMRA 1986*] provides wreck sites with protective mechanisms and licensure processes similar to that afforded scheduled monuments by the *AMAAA 1979* though with specific consideration for military wreck sites as a historical group unto themselves. The *PMRA 1986* provides protection for aircraft in both terrestrial and marine environments (Section 1(6), 2(3) and 2(7)).

While the *PMRA 1986* is useful in supplying general protection to aircraft wreck sites, the Act limits exploratory excavations of suspected aircraft wreck sites (Section 2(3)(c)). Particularly problematic is that the Act fails to divine when an unknown site becomes an aircraft wreck site. Moreover, the *PMRA 1986* does not directly distinguish between wrecks with human remains and those without human remains (*PMRA 1986*: Section 9(1); Dromgoole 1996: 33-34). To be sure, the only means to identify an artefact scatter as aircraft debris is to locate a diagnostic part, aircraft serial number or identifiable human remains. The necessity of a diagnostic part and/or serial number to denote a site as an aircraft crash site introduces a large amount of individual professional and legal ethics. Should a site be declared an unknown aircraft wreck site based upon erroneous artefact identifications, further work to overturn incorrect conclusions is barred. Alternatively, an archaeologist requiring confirmation beyond diagnostic parts and seeking confirmation via the aircraft's serial number, nose art or other unique identifier (so as to apply for an excavation license) is in violation while awaiting identification. Thus the goal of the *PMRA 1986* in relation to exploratory excavations and human remains is admirable but misguided. If the excavation of unconfirmed sites and sites containing human remains were governed by the same licensure procedure as known wreck sites, their inclusion would allow for the expansion of a historic aircraft wreck site gazetteer and reduce the potential for accidental violation of the Act.

2.3 Enforcement of UK Heritage Law with Regards to Military Aircraft Wrecks and Wreck Sites

No long-term, systematic study pertaining to the removal of material from historic aircraft wreck sites exists. Past and current levels of cultural material theft must be assessed using a corollary data set. Appropriate corollary data sets for examining cultural material (i.e., ones with the same high profile and legal protections as historic military aircraft) are the CBA-English Heritage and English Heritage-Oxford Archaeology unauthorised metal detecting/excavation studies (Dobinson and Denison 1995; Oxford Archaeology 2009).

The 1995 CBA-English Heritage study revealed illicit metal detecting to be extensive and prosecutions for unauthorised metal detection uncommon (Dobinson and Denison 1995: 54). Despite this dedicated study on illicit metal detecting, quantifying the extent of unauthorised metal detecting remains difficult. Home Office records regarding convictions under the *Theft Act 1968* and the *Ancient Monuments and Archaeological Areas Act 1979* exclude the precise nature of offences. Additionally, as a matter for local jurisdictions, no central record regarding trespass prosecutions exists (Dobinson and Denison 1995: 59).

A revised study on the extent and effects of unauthorised metal detecting/excavation was commissioned by English Heritage and conducted by Oxford Archaeology from 2007-2008. Oxford Archaeology found unauthorised metal detecting caused serious harm to the preservation of UK cultural heritage. Rather than concentrating solely on England, the

Oxford Archaeology study sought to assess the extent of unauthorised metal detection activity and, by extension, public compliance with heritage law throughout the whole of the UK and Crown dependent territories. Similarly, the Oxford Archaeology study expanded its focus beyond scheduled monuments and active archaeological sites by including private land. The data collected during the study demonstrated a continued problem with the unlawful metal detecting of both scheduled and non-scheduled archaeological sites as well as varying and unpredictable levels of prosecution for illicit metal detecting (Oxford Archaeology 2009: 37, 49-51, 74).

Like more general heritage crime convictions (Oxford Archaeology 2009: 49-52, 58, 68), data relating to prosecutions under the *PMRA 1986* is limited. What data is available shows the *PMRA 1986* to be little enforced. Despite recognising cases as heritage crimes, successful prosecutions have failed to elicit pecuniary punishments. In total, only three aircraft cases prosecuted under the *PMRA 1986* have been discovered with one successful conviction (Times 1994, 1996; Daily Post 1996; Birmingham Post 2002).

While the number of cases discovered may seem inaccurately low, consultation of the House of Commons and House of Lords written answers for 26 and 5 June 2000 show the numbers to be reasonably correct (HL Deb 5 June 2000, vol. 613, col. WA130; HC Deb 26 June 2000, vol. l cols. 352, 414-416W). A 26 June 2000 House of Commons query as to those charged and successfully prosecuted under the *PMRA 1986* relates that "Ministry of Defence Police investigations have resulted in one individual being charged with theft from a sunken military vessel. The individual accepted an official police caution. There have been other prosecutions…for offences relating to aircraft" (HC Deb 26 June 2000, vol. l col. 352W). A House of Lords response to a similar query (HL Deb 5 June 2000, vol. 613, col. WA130) provides more specific prosecution numbers. Lady Symons reports that: "There have been two successful prosecutions against individuals who have committed offences under the Act" (HL Deb 5 June 2000, vol. 613, col. WA130). While the media, House of Commons' and House of Lords' data is limited by the reporting standards of heritage crime prosecutions, the available data demonstrates the *PMRA 1986*'s historically low prosecution rate. Considering the number of wreck sites, the number of hill walkers, the low prosecution numbers and the lack of annual wreck site damage inspections, the un-catalogued obliteration of historic wreck sites due to illicit artefact recovery is of considerable concern.

Current legislation as embodied by the *AMAAA 1979* and the *PMRA 1986*, while arguably sufficient for the protection and preservation of heritage in the UK, is not enforced to its fullest extent. Increasing law enforcements' awareness and application of heritage laws, while possibly not increasing successful prosecutions, may increase public awareness of heritage laws as well as limit new infractions.

3 Evaluation of Past Work: Avocational Aviation Archaeology Groups

3.1 Introduction

A wide range of groups with differing interests currently practice aviation archaeology, the specific archaeology of aircraft. For nearly 50 years, archival and field historians eager to locate and record the sites of aircraft crashes worldwide have dominated the field. While those participating in the identification and exhumation of aircraft wreck sites self-identify as "amateur archaeologists" conducting "aircraft archaeology," their lack of scientific rigor and controlled excavation makes much of their work akin to hobbyist recoveries rather than archaeology (Gould 1980: 230).

Although avocational aviation archaeology involves groups and crash sites worldwide, the current study focuses on Britain. Aircraft archaeology began in Britain during the 1960s. A template for the archaeological study of aircraft for much of the world, British excavations demonstrate aircraft archaeology investigations at their most well-organised. Unfortunately, British aircraft archaeology also demonstrates the defects inherent in investigations which cobble together various practices without following a uniform, standardised methodology.

Indeed, the use of atypical methodological practises, different from those expected of the established archaeological discipline, characterises much of avocational aviation archaeology. Avocational aviation archaeologists consistently do not (1) georeference finds, features and trenches, (2) employ standard methodological procedures including the use of vertical and horizontal controls, or (3) produce a record of work undertaken. In addition, the lack of avocational-professional methodological synthesis currently limits collaborative productivity as well as the completeness of archaeological data gained from avocational research.

A logical means by which to assess current research practices is through the critical examination of select case studies. In the current study, three active avocational aviation archaeology groups, selected from across Britain, are used to demonstrate the methodological, archival and publication practices within current, avocational aircraft archaeology. A review of commercial literature where avocational groups frequently publish narratives of their excavations ends the chapter.

3.2 Avocational Groups

Drawing its popularity from a deep interest in past conflicts and human flight, avocational archaeology has been at the vanguard of the study of historic aircraft wrecks. Avocational archaeologists show great enthusiasm for the sub-discipline. Their dedication to cataloguing wreck sites provides information valuable to both avocational and professional archaeologists. While the practitioners' enthusiasm is commendable, much of avocational field research is diluted through a focus on physical excavation at the expense of establishing appropriately focused research questions and methodical recording practises. In addition, background research and surveys conducted by avocational groups too often focus on targeting areas for excavation without first determining whether a viable site should be excavated or the best means for protecting archaeologically sensitive areas.

Utilising the four main archaeological phases—background research, survey, excavation and stabilisation (Greene and Moore 2010: 106-107; Neumann and Sanford 2010: 5; Neumann *et al.* 2010: 2)—as a critical framework, the standard field procedures currently used by avocational aviation archaeology groups will be assessed. The Aviation Research Group Orkney and Shetland [ARGOS], Peak District Air Accident Research [PDAAR] and the Lancashire Aircraft Investigation Team [LAIT] were selected as avocational sample groups because (1) they involve some of the most active names in current avocational aircraft archaeology, (2) their collective work demonstrates the best of current avocational aircraft archaeology and (3) they frequently publish information on their activities.

3.2.1 Organisation Histories

ARGOS was established in 2009 "to document all aspects of aviation history on and around the Orkney and Shetland Isles" including "Recording and documenting Aircraft crash sites both on land and underwater; Documenting sites of airstrips and air bases from both the RAF and FAA; Research and document Balloon Barrage sites, Anti Aircraft gun sites and search light stations" (ARGOS 2010a). ARGOS's current methodology and depth of historical research demonstrates avocational group aircraft archaeology with a high level of sophistication. Their interest in the subject matter is obvious. However, a lack of basic archaeological methodology and formal publication diminishes data integrity and removes the associated provenance from recovered artefacts.

Both PDAAR and LAIT preceded ARGOS and each has conducted numerous investigations. PDAAR was formed when core members Alan Clark and Mark Sheldon combined with associated groups and local research partners in 2004. The aims and field methodologies of the PDAAR group restrict most work to archival research and non-invasive site visits (Clark 2012a). As such, PDAAR presents one of the most archaeologically sympathetic remits in the avocational community. In the Peak District alone, Clark and Sheldon researched and visited 178 sites, providing detailed information for 153 sites (Clark 2012b). LAIT, one of the most active avocational aviation archaeology groups in the UK, has conducted 48 total investigations; 24 sites included some form of field work in the investigatory process (Wotherspoon 2011a).

All three of these avocational archaeology groups belong to the British Aviation Archaeological Council [BAAC]. Founded in the late 1970s, BAAC is self-described as "the official national body in the United Kingdom for aviation archaeologists and researchers of historic aircraft crashes" (BAAC n.d.a). Similar to the Council for British Archaeology [CBA], the BAAC is a charity which lacks any official government support. The BAAC embraces various organised aviation archaeology clubs throughout Britain. Currently numbering 35 member clubs, seven individual research members and five associate members outside the United Kingdom, the BAAC proclaims a five-fold purpose: "1. To establish and maintain ethical standards; 2. To provide a forum for discussion; 3. To provide advice for member groups; 4. To liaise with national and international bodies; 5. To promote the preservation of aircraft relics and relevant historical documents" (BAAC n.d.a). Unlike the CBA, which conforms to IfA standards (indeed the CBA and IfA collaborate on research, publications and grant schemes), BAAC documents reveal support of ethical standards that are in contrast to mainstream archaeology. Despite its professed goal "to establish and maintain ethical standards" (BAAC 2000a), consultation of the BAAC *Code of Conduct* reveals a document which advises actions which irreparably destroy archaeological information. In addition, the BAAC's ineffectiveness as a unifying organisation is evident in the methodological problems observed in avocational research, many of which are due to a lack of strict accountability to, and a lack of guidance from, a larger archaeological organisation. One area, however, where the BAAC guidelines parallel professional archaeology is in the recommendation that pre-field investigation archival research be undertaken (BAAC 2000a: Section 2.1). This emphasis reflects the popularity of aviation history within the sub-discipline.

3.2.2 Investigative Procedures

3.2.2.1 Background Research

Avocational groups excel in conducting background research. The collation and publication of historical research, via organisations' websites, online forums, popular publications and books provide aviation archaeology with data sets often beyond the scope of professional projects and budgets. Many organisations focus on a specific locale and maintain databases and dossiers for wreck sites in the surrounding region. Conscientious avocational groups, including ARGOS, PDAAR and LAIT, provide detailed historical narratives for each crash visited. PDAAR, for example, has established research aims which purposefully confine most work to archival research and non-invasive site visits (Clark 2012a). Indeed, their communicated focus on the creation of historical dossiers for each site visited conforms to the background research/site visit phase common in professional archaeology. Though separate from local Historic Environment Records [HER] and nationwide National Monuments Records [NMR], the avocational databases often provide access to both archival and new data as well as informed historical analysis.

3.2.2.2 Survey

Examination of avocational aviation archaeology groups, including ARGOS, PDAAR and LAIT, demonstrate that avocational practitioners understand the value of surveys but do not make full use of the technique. As with much of the methodological deficiencies observed, the lack of a preliminary field survey, and the resultant lack of recorded results, does not appear to be a wilful disregard of proven archaeological practice. When preliminary surveys are undertaken, the departure from proven survey methodologies appears to stem from a lack of procedural specification and training. For example, the BAAC guidelines recommend that groups conduct pre-excavation surface, topographic and flora-damage surveys (Section 2.2). However, Section 2.2 provides incomplete and inaccurate advice on the completion of archaeological surveys. Beyond the initial statement that surveys should be undertaken, Section 2.2 provides little guidance on how to conduct archaeological surveys. The onus for researching, designing and completing the site survey is left to the avocational archaeologist. Stating that the distribution of surface material need not be georeferenced and plotted as it is likely to have been moved in the past, Section 2.2 of the BAAC guidelines merely advises either that photographs be taken or that the number of artefacts recovered per quadrant be given (BAAC 2000a). While artefacts may have been subjected to post-depositional forces, the argument that such movement disqualifies the artefact scatter from proper recording goes against basic archaeological field craft. In order to preserve artefact context, all available data should be collected during investigation/excavation even if the collected data is later confirmed to include post-depositional errors. If the BAAC member groups' investigations did not involve collecting artefacts, quadrant counts could be considered useful and even prudent. Indeed, quadrant counts are an established methodology in prehistoric pottery and lithic scatter analysis (e.g., Given and Knapp 2003: 35). However, the BAAC document directly references the collection of artefacts without establishing protections for context integrity.

Not all surveys undertaken by avocational groups contain gross deficiencies. Some surveys appear to have been well designed and executed with only limited shortcomings. ARGOS, for example, has undertaken three terrestrial invasive investigations (Martlets FN284 & FN288, B-24H 42-50331, and Seafire MB369) as well as non-invasive site histories and location identifications. Analysis of the ARGOS site reports demonstrates not only the organisation's effective use of surveys to locate sites but also the unfortunate consequences of the BAAC's georeference/distribution plot advice. The report on ARGOS's B-24H 42-50331 field research, while brief, describes the use of metal detector survey to establish the location of impact:

> *In June following permission from landowners ARGOS surveyed the site of the B-24 for any signs of aircraft with view to obtaining a license should any significant readings be detected, however although the site revealed a few small pieces, it looks like the salvage team did a very thorough clean up and a license will not be applied for, the survey at least confirmed that we had found the spot where the B-24 came to grief (ARGOS 2010b).*

Visual material accompanying the research narrative further demonstrates ARGOS's use of a survey for site identification. The single photograph included seems to show transects either 5 or 10 metres wide. It is unclear from the report or photograph whether finds were georeferenced prior to collection (no artefact markers are observed in Figure 3-1). Given the reported results, the survey results and the plans for further research including "the site revealed a few small pieces" and "a license will not be applied for" as well as "the survey at least confirmed that we had found the spot where the B-24 came to grief" (ARGOS 2010b), the recording of artefact locations and publication of an artefact distribution plot would have created a more instructive document.

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Figure 3-1: Field work photograph, 2 June 2011 (Earl 2011a).

In addition to standard metal detector surveys, ARGOS has made use of a metal detector data logger with promising results. The only published results, from the survey of Supermarine Seafire MB369, show the production of a basic geophysical survey map using the obtained survey data (Figure 3-2). Like the B-24H 42-50331 finds, however, the Seafire MB369 metal detector data logger derived data was not georeferenced. Moreover, the lack of axis labels precludes the identification of units. Therefore the derived data's usefulness for archaeological study is diminished (ARGOS 2010c).

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Figure 3-2: Mini Geo metal detector data logger results for Supermarine Seafire MB369 (ARGOS 2010c).

The PDAAR site reports display similar understanding of the importance of surveys. Much of PDAAR's research, as expressed by their research aims, is restricted to archival research and non-invasive site visits (Clark 2012a). Like ARGOS, PDAAR utilises a loosely archaeological approach, completing site identification, survey and excavation in stages. The investigation of Vampire VV602 best displays PDAAR's segmented field methodology. Though substantial methodological details are not provided, the PDAAR site report states that an initial site visit was conducted in September 2007 with a pre-excavation site survey completed nine months later (Clark 2012c). It is unclear how the survey was conducted, though it is reported that the PDAAR team did not geo-reference anomalies to a fixed site datum (Clark 2011: 11) and that an initial walk-over survey was not completed "as the site has never been ploughed" (Clark 2011: 10). Similar in deficiencies to ARGOS's B-24H and Seafire published survey results, PDAAR's publications demonstrate an understanding of survey usefulness but do not indicate progress beyond the survey into the recording of artefact/anomaly locations. This lack of recording precludes post-survey distribution analysis of VV602-associated artefacts. In addition, PDAAR's assumption that only ploughed fields yield aircraft-related artefacts during walkover surveys is misguided. While current land use may influence walk-over survey productivity, local soil morphology and geology also affect survey site conditions (Wood and Johnson 1978; Schiffer 1983, 1987; Dunnell 1990; Paton *et al.* 1995; Balek 2002; Hupy and Schaetzl 2006).

LAIT also builds upon historical background research through the use of surveys. However, the same recording deficiency identified in ARGOS and PDAAR surveys hinder LAIT's survey methodology. LAIT's search protocol for P-51B 43-6635 (a 4 June 1944 air crash) shows that the organisation understands effective survey procedures. The site report relates that, after locating the approximate site using historical research and two extant copses of trees, LAIT initially conducted the survey using wide transects to cover the large search area. Upon finding aircraft-associated debris, the LAIT team narrowed their transect intervals in order to focus their efforts and to reduce the possibility of omitting contacts. The readjustment of transect intervals proved productive as crash-associated finds were soon located. While LAIT's effective use of systematic search patterns is effectively demonstrated by the location and recovery of artefacts from P-51B 43-6635, LAIT seems not to have georeferenced the identified artefact scatter (Wotherspoon 2010a). Similar recording problems plague LAIT's survey of Spitfire BL585. The initial grid metal detector search locating the impact point and using upstanding pegs as markers is quite similar to the methodology used by professional archaeologists. However, LAIT does not seem to have georeferenced the staked finds or subsequently produced a distribution plot (Wotherspoon 2010b). The limited finds stand as the only archaeological testament to the P-51B 43-6635's and Spitfire BL585's points of impact. The georeferencing of finds, and the pre-excavation production of a distribution plot, would have enhanced LAIT's operational methodology and secured the archaeological context of the artefacts recovered.

The avocational community, as demonstrated by ARGOS, PDAAR and LAIT, appears to understand the value of surveys in identifying crash sites. While the method and technology employed attempts to simulate standard archaeological practice, the apparent reticence to georeference surface finds and metal detector contacts lessens the surveys' informational use. Indeed, the regular addition of site visits, transect or grid surveys, and the georeferencing of finds/contacts would increase the information available to the avocational groups planning excavations and contribute valuable data to the larger archaeological community.

3.2.2.3 Excavation

The surveys undertaken by avocational archaeologists often replicate many of the techniques used by the professional community but the surveys command little attention outside the archaeological community. Excavation remains the most visible activity. Even though excavation is the most obvious and most archaeologically destructive of field research techniques, only limited published recommendations guide avocational archaeologists in its implementation. Indeed, BAAC's guidance on excavation methodology and techniques is less detailed than that offered for pre-excavation surveys. No mention is made concerning how excavations should proceed. In addressing the recording of artefacts and archaeological features, the BAAC *Code of Conduct* states that

> *Sufficient photographs will be taken to create a record of the relative positions and depths of artefacts that are buried in the ground. Information that can be inferred, such as the direction of impact and inclination to the surface, will be recorded (2000a: 2.3).*

Even within this recommendation, the BAAC *Code of Conduct* lacks clarification concerning what it considers a proper record of direction and inclination of impact and lacks any discussion concerning site or trench plans beyond indicating the supply of "sufficient photographs" (2000a: 2.3). While photographs certainly are integral to a properly documented site, the creation of site and trench plans is imperative for site interpretation and information preservation.

Even more disconcerting is that the methodological means by which BAAC members dig wreck sites is contrary to established archaeological procedure. Indeed, the lack of established protocols not only damages the sites themselves but also works in opposition to the establishment of a recognised archaeological sub-discipline. Six of the current 35 BAAC member groups were established during the early period of aviation archaeology (1960s-1970s). Although describing themselves as amateur archaeologists, the operational methodology established by these early groups was not then, nor is now, aligned with professional archaeological standards. An example of nonstandard excavation methodology is illustrated by the 1975 Supermarine Spitfire Mk. IX PT766 excavation undertaken by the now defunct South Wales Historic Aircraft Preservation Society [SWHAPS]. A subsequent investigation and recovery effort in 2009 by the Marches Aviation Society [MAS][1] revealed that SWHAPS excavated the wreck site with a view only to recovering the engine. The remainder of aircraft parts were removed and, once the engine was recovered, re-interred during backfill. It was reported by one of the SWHAPS dig participants that a wing leading edge needed to be forcibly pushed down during the backfill so that it did not continue to pop up. Neither the SWHAPS nor the MAS excavation was systematic or methodical. Indeed, in an ominous harbinger of future standard practice, the SWHAPS excavation utilised a mechanical excavator to unearth the crash site and engine (Parry n.d.). A photograph taken during the removal of PT766's engine, Figure 3-3, clearly demonstrates the crater effect wrought by the unsystematic use of a mechanical excavator.

[1] The Marches Aviation Society began in the 1960s and is still active at present (BAAC n.d.b).

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Figure 3-3: South Wales Historic Aircraft Preservation Society excavates Supermarine Spitfire PT766's Merlin engine in 1975 (Parry n.d.).

Unfortunately, the SWHAPS excavation was far from unique in its use of a destructive tool during excavation. Other groups routinely have dug bowl-shaped holes into wreck sites using mechanical excavators. Chiltern Historical Aircraft Preservation Group's [CHAPG] Autumn 1972 excavation of Hawker Hurricane Z7010 utilised a mechanical excavator-based uncontrolled excavation methodology. Figure 3-4 shows the bowl shaped pit characteristic of aviation archaeology accomplished through mechanical excavation (King and Mason 2010).

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Figure 3-4: Excavation of Hawker Hurricane Z7010 by CHAPG in autumn 1971 (King and Mason 2010).
Note the rounded edge of the bowl-shaped excavation hole.

While ARGOS performs non-invasive site histories and location identifications, it also has conducted three terrestrial invasive investigations: Martlets FN284 & FN288, B-24H 42-

50331, and Seafire MB369. The photographs provided in the Martlet FN284 excavation report (Figure 3-5 and Figure 3-6) demonstrate a site without systematic control.

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Figure 3-5: Excavation of Martlet FN288 at Symilders, 22 May 2011 (Ramsey 2011).

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Figure 3-6: Excavation of Martlet FN284, May 2011 (Earl 2011b).

Similar evidence for uncontrolled excavation is observed in the ARGOS excavation of Supermarine Seafire MB369. Site photographs show the site to be lacking in both vertical and horizontal control (Figure 3-7 and Figure 3-8). While the three separate pits are labelled as trenches and, at least in the case of Trenches 2 and 3, are separated by secondary balks, the slopping sides, collapsed trench edges and uneven floors show the working teams only to be mimicking accepted excavation methodologies.

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Figure 3-7: "Trenches 2 & 3 showing (A) the port side 20mm Hispano cannon, (B) the starboard Hispano cannon, (C) the top of the engine casing and (D) the internal parts of the engine with three of the twelve cylinders" (K. Heath 2010).

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Figure 3-8: Trench 3 being dug in background with Trench 2 and Hispano Cannon A (as seen in Figure 3-7) in foreground (L. Heath 2010).

It is important to note that not all of ARGOS's methodology is poorly executed. Though on-site artefact photography lacks scales (Figure 3-9), the single post-excavation artefact photograph from Supermarine Seafire MB369 makes use of a clearly labelled and proportionate scale (Figure 3-10). Unfortunately, no finds number is present which could tie the artefact to a specific location.

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Figure 3-9: The ends of two 20mm Hispano cannons from Supermarine Seafire MB369 without included scales (ARGOS 2010c).

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Figure 3-10: Post-excavation photograph of a diagnostic artefact with included scale (K. Heath n.d.).

Within the avocational community, some groups seem to grasp the destructive nature of irresponsible excavation. The PDAAR group's general site methodology makes use of GPS for site identification and of digital photography for site recording. The resultant lack of a heavy archaeological footprint both corresponds to the group's stated objectives—"we prefer to see the vast majority of crash sites left as they are, even though corrosion will eventually destroy almost all wreckage" (Clark 2012a)—and assures the continued survival of archaeological material either *in situ* or near the location of original deposition. This is not to say that PDAAR investigations completely avoid archaeological impact. Indeed, several photographs released by PDAAR show associated individuals lifting wreckage. While PDAAR's historical research and site visitation procedures basically demonstrate good practise, methodological inadequacies similar to those observed with ARGOS plague PDAAR excavation and recording practices. Indeed, the excavations of Albemarle V1604 and Vampire VV602 demonstrate PDAAR's use of an unsystematic excavation methodology. For example, photographs of PDAAR's Albemarle V1604 excavation show the excavated trenches to be without any defined edges, walls or floor (Figure 3-11 and Figure 3-12).

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Figure 3-11: Lifting Albemarle V1604's propeller and boss (Clark 2012d).

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Figure 3-12: Albemarle V1604's propeller and boss (Clark 2012d).

Similar methodological deficiencies are evident in PDAAR's excavation of de Havilland Vampire VV602. PDAAR, following an initial site visit and survey, undertook excavation of Vampire VV602 on 28 June 2008. As with SWHAPS, CHAPS and ARGOS excavations, PDAAR's excavation made use of a mechanical excavator as the primary form of excavation (Clark 2012c). However, unlike the Albemarle V1604 report, the VV602 report indicates that shovels and hand excavation, when required to define and recover smaller artefacts, complemented the use of the mechanical excavator. The use of a mechanical excavator paralleled the method used to unearth Albemarle V1604. A stripping of the topsoil exposed aluminium corrosion product (Clark 2012c). The PDAAR short narrative states:

> *More soil was then cleared with the machine which again struck something substantial....At this point the shovels moved in and began clearing this item to find its edges, and then we used the digger, this time with a narrow bucket, to clear soil out from around it....Attempts were made to shift it by hand but it was too heavy so the machine was brought in again with a lifting strop to haul it out....*
>
> *Once we had the large piece of engine out we continued to clear the crater with the digger, pausing every so often to lift out pieces which were spotted....The digging then continued solely by hand to uncover as many small items as possible....*
>
> *Just to one side of the crater we found a large magnetometer contact during our previous visit to the site, after having concluded that no more big items were going to come from the hole a couple of the group set about finding this once more. It did not take long as the digger having rolled across the area had flattened to the soil just enough for the top of the item to be showing above the surface. This was then dug out by hand, at first it was thought it looked like a 20mm cannon, but then it was so twisted we thought it couldn't be one and was possibly an undercarriage leg. Once more of it was clear it was obvious to those of us who had been on digs before that the first guess was correct. A strop was put round it and it was then lifted clear of the ground by the digger. We were amazed by the level of damage that it had suffered, on occasions the barrel may be bent but this cannon had been literally bent in half and the breach was completely smashed with almost all of the internal workings missing.*
>
> *The excavation was brought to a close once all of the more substantial magnetometer and deep seeker contacts had been explained and the site was covered over again. The recovered parts have been removed for cleaning and sorting (Clark 2012c).*

The longer narrative contains the same general information (Clark 2011: 12; 2012e).

The methodological failings afflicting the Albemarle V1604 excavation persist in the Vampire VV602 excavation. PDAAR's lack of defined, squared trenches (Figure 3-13, Figure 3-14 and Figure 3-15) and stratigraphic excavation makes horizontal and vertical control of the excavation difficult to maintain, as well as hindering the accurate measurement and recording of trench depth, artefact orientation and distribution, and trench stratigraphy.

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Figure 3-13: General view of PDAAR's Vampire VV602 excavation (Clark 2012c).

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Figure 3-14: Exposure of Vampire VV602 by the PDAAR (Clark 2012c).

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Figure 3-15: Uncontrolled hand excavation of Vampire VV602 (Clark 2012c).

Additionally, PDAAR does not explicitly state whether excavated artefacts were recorded *in situ* at either the Albemarle or Vampire excavation sites. Although PDAAR provides valuable connections between artefact orientation and the larger historical narrative—such as the conclusion that the Vampire's Goblin engine pipe was thrown into the burial pit during the crash clean-up due to its inverted orientation (Clark 2012c)—the lack of a photographic or drawn record of the artefacts in place detracts from the overall quality of the field work. The implementation of squared-off trenches and detailed recording procedures—including the location of trench corners and artefacts as well as basic measured and drawn stratigraphic profiles—would enhance PDAAR's useful historical dossiers through the inclusion of valuable archaeological data. The PDAAR's adoption of established excavation and recording methodologies would complement their existing, site protection-focused research objectives.

LAIT excavations evidence a similar use of nonconforming excavation methods. Indeed, the substandard horizontal and vertical controls—exacerbated by the uncontrolled use of a mechanical excavator—previously identified in ARGOS and PDAAR excavations are apparent. Using a combination of hand tools and a mechanical excavator, the excavation of Spitfire BL585 seemingly represents LAIT's excavation methodology. Following identification of the main crash site, excavation of BL585 was undertaken using hand tools. This process proved slower than anticipated; the team had only budgeted two days for excavation. Transitioning to a small excavator on the second day (Wotherspoon 2010b) expedited the excavation process greatly but, as seen in Figure 3-16, Figure 3-17 and Figure 3-18, magnified excavation control problems.

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Figure 3-16: General view of working trench, LAIT Spitfire BL585 (Wotherspoon 2010b).

In addition, the unsuitable artefact removal procedure utilised by PDAAR is employed by LAIT. Important artefacts are not excavated fully before removal but are rather wrenched free using lifting straps and the mechanical excavator. The recovery of BL585's two 20mm Hispano cannons demonstrates the artefact removal methodology employed by LAIT. The team reportedly worried that the guns could not be recovered as the trench was already 12 feet deep and the cannons, unbent, eight feet long. Instead of undertaking one of the two archaeologically preferred options—stepping the trench in order to excavate the weapons using controlled, stratigraphic procedures or recording the cannons' presence and backfilling the trench—the LAIT team elected to use lifting straps (Wotherspoon 2010b).

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Figure 3-17: Removal of still buried Hispano cannon using lifting straps and mechanical excavator (Wotherspoon 2010b).

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Figure 3-18: Spitfire BL585's Hispano cannon pulled free from the working trench (Wotherspoon 2010b).

Moreover, the cannons were not easily dislodged. The LAIT report specifically mentions that "everyone kept well back, in case the strain proved too much and snapped the straps…Progress was painfully slow….Slowly and almost imperceptibly at first, the clay released its grip and then without warning the eight and a half foot long cannon hung in the air, the barrel perfectly straight" (Wotherspoon 2010b). The forcible removal of artefacts from the surrounding matrix not only jeopardises the artefacts' condition but also risks physically damaging surrounding artefacts and artefact-artefact, artefact-level associations. This decision to prematurely and forcibly remove the cannons reinforces the impression that avocational groups' excavation objectives and methodologies often are at odds with established archaeological practice.

The inclusion of professional excavation methodologies by avocational groups would increase the amount of artefacts recovered, protect the condition of the recovered artefacts and enhance the level of data recorded. Indeed, the use of established archaeological procedures would allow for the recording of artefact-artefact and artefact-feature relationships, relationships which too often are ignored in avocational investigations. Moreover, the adoption of a methodical process of excavation by the avocational community would bring them in line with the mainstream discipline and enable an open exchange of data between professional and avocational archaeologists.

3.2.2.4 Stabilisation and Storage

Artefact stabilisation and storage techniques are the least publicised of the avocational archaeologists' pursuits. The guidance offered by the BAAC is quite general and the published practises by avocational organisations are brief. Sections 2.4, 3.2 and 3.3 of the BAAC *Code of Conduct* (2000a), for example, require all susceptible parts be properly conserved. However, the BAAC does not provide any information as to what it considers proper conservation. The alarmingly basic requirements for the labelling of long term artefact storage containers detailed in Section 3.3 (only the aircraft's identity—usually the serial number—need be included) calls into question the competency of conservation activities employed by BAAC members. The lack of specifics provided by the BAAC contrast unfavourably with the IfA which states that it adheres to Institute of Conservation [ICON] conservation standards (IfA 2008: 2).

In their site-specific narratives, neither ARGOS nor LAIT provide information detailing stabilisation and storage practices. However, stabilisation and storage programmes, similar in detail to the BAAC recommendations, are evident in the PDAAR Vampire VV602 report. The PDAAR excavation of Vampire VV602 recounts reburial at the bottom of the excavated hole (approximately 2 metres deep) of artefacts too corroded to have survived cleaning. Artefacts without useful information about the aircraft were reburied alongside the corroded material (Clark 2011: 16). The report also details the artefact cleaning process, explaining that all initial cleaning employed a domestic pressure washer to remove loose dirt, while final cleaning utilised "varying grades of brushes to reveal their [the artefacts'] original surfaces" (Clark 2011: 17-18). As demonstrated by Hobbs *et al.* (2002: 59-61, 65-70, plate 25), employing inappropriate brushes and cleaning techniques can have deleterious effects on artefacts composed of various metal alloys. Indeed, Hobbs *et al.* specifically argue against the vigorous use of wire brushes as they can scratch the surface of metal alloy artefacts (2002: 66, plate 25).

The lack of published stabilisation and storage programmes is worrisome. It is known that ferrous, cupreous and aluminium-alloy artefacts can degrade rapidly when excavated. Effective artefact stabilisation and storage programmes are critical to both short- and long-term artefact preservation and collections management. As much of conservation literature does not directly address archaeological aircraft debris (see Chapter 5 Section 5.2.7), the publication of successful and unsuccessful stabilisation methodologies and techniques utilised by the avocational community would have immediate effect upon the wider discipline. Additionally, the design, implementation and publication of transparent artefact and data storage systems would greatly assist in mitigating data loss from collection amalgamation and/or organisations' disbandment.

3.2.3 Reporting and Archiving

The quantity and quality of publications produced by avocational aviation archaeologists restricts the archaeological value of excavated sites, a sentiment already identified within the avocational community (Clark n.d.). Avocational aviation archaeologists offer the archaeological community a specialised skill set with which to explore historic aircraft wreck sites. The skill sets represented by the avocation archaeology community, often the result of individuals' occupational histories and/or extensive experience within the sub-discipline, are not currently being capitalised upon due to the lack of publication and data dissemination. Indeed, the lack of emphasis on publications separates avocational aviation archaeologists from mainstream archaeologists almost as much as their disparate research methodologies. Encouraging avocational archaeologists both to archive collected data with HERs/NMRs and to publish research reports will not only secure critical archaeological data but will enable the identification of developmental areas. Specific guidance on report submission timelines and report contents by the BAAC, as the parent organisation, would enhance report quality. The standardisation of report layout and the encouragement of submissions from HER/NMR officers would increase the quantity of submitted reports.

Unfortunately, current BAAC publication standards are disadvantageous to aviation archaeology. Sections 3-5 of the BAAC *Code of Conduct* (2000a) require that groups submit a finds form to the BAAC within one year of completing work and a full report within three years of completing work. In an attempt to standardise the process of report submission, the BAAC created a *Site Report* template that creates a comprehensive site investigation record through seven sub-headings: (1) Information known prior to site investigation, (2) Local investigations prior to site work, (3) Site work, (4) Information learnt from site investigation, (5) Information learnt after the site investigation, (6) References, (7) Appendix (BAAC 2000b). Unfortunately, the BAAC *Site Report* (2000b) only requires data readily available from archival sources. Sections 4 and 5, "Information learnt from site investigation" and "Information learnt after the site investigation," are particularly problematic; these sections request readily available archival material be included in site report sub-sections specifically dedicated to information obtained from excavation. Indeed, Sections 4 and 5 request identification of:

1. *Aircraft type serial number(s)*
2. *Engine(s) fitted at time of loss*
3. *Unit and base at time of loss*
4. *Coding and stencilling at time of loss*
5. *Camouflage at time of loss*
6. *Date and time of loss*
7. *Location of loss*
8. *Crew and fate*
9. *Heading of the aircraft and its inclination to the ground prior to crashing*
10. *Speed of the aircraft on impact, or the height from which it fell*
11. *Circumstances of the loss from gauges and indicators*
12. *Equipment carried by the aircraft*
13. *Type of guns and ammunition carried by the aircraft and dates of ammunition*
14. *Construction and modification of the airframe*
15. *Modification standard of the cockpit*
16. *Location(s) where the aircraft was built and inspected*
17. *Equipment carried or worn by the crew of the aircraft*
18. *Documentary evidence relevant to the aircraft, crew, mission or unit*
19. *Information to create or complement period construction drawings*
20. *Aircraft type and serial (BAAC Site Report Section 5 only)*
21. *Items found.*

(BAAC 2000b)

Because of the specificity included in the BAAC *Site Report* (2000b) template, the lack of sub-headings dedicated to the investigatory methodology used and to site/trench plans implies that the creation and inclusion of these items is superfluous.

BAAC members are required to register their activities with the applicable National Monument Record within one year of completion of work. Using ARGOS, PDAAR and LAIT as archetypal avocational aviation archaeology organisations, a search of the relevant HERs/NMRs was made in order to establish the quantity of report submission. Unfortunately, of the 218 aircraft sites surveyed and/or excavated by ARGOS, PDAAR and LAIT only five (less than 17%) are entered into English Heritage's or the Royal Commission on the Ancient and Historical Monuments of Scotland's [RCAHMS] databases. All five of the sites included in the English Heritage NMR were investigated by LAIT. No sites investigated by ARGOS or PDAAR were included in the English Heritage or RCAHMS NMRs. Only one of the three sites (North American P-51 Mustang KH838) included in the NMR referenced any archaeological investigations having taken place (English Heritage 2010; Wotherspoon 2011b). The information regarding the other two sites—Bell P-39 Airacobra BX195 (English Heritage 2006; Wotherspoon 2010c) and North American P-51 Mustang SR411 (English Heritage 2005; Wotherspoon 2010d)—is taken from guidebooks on the location of aircraft wreck sites. This makes the percentage of sites included in the NMR by the three surveyed BAAC member groups a dismal three percent. Even in the areas where the BAAC *Code of Conduct* (2000a) demonstrates competence, the Council's lack of specificity or enforcement degrades the quality and quantity of artefacts recovered and information reported.

Individual organisations' publication standards, echoing BAAC publication insufficiencies, undersupply in quantity and/or detail. Similar to those of other avocational groups, ARGOS' excavation reports lack expected elements. Indeed, each report regarding field procedures and finds during the Martlet and B-24H excavations is only two sentences long. Concerning the Martlets excavation procedures and finds, the report simply states

> *In May 2011, the group having obtained the necessary License and permission from landowners, excavated the two Martlet sites at Stymilders and Harray, very little remained at the two sites but among the finds were the engine data plate and ignition lead from FN284 at the Harray site, battery data plate, instrument panel (Minus instruments) fuel tank access door and some inspection covers, one unidentified data plate from a motor, and a piece of alloy poss [sic] cowl with the serial number FN288. All will be cleaned and stored…(ARGOS 2010d).*

The B-24H report is similarly brief:

> *In June following permission from landowners ARGOS surveyed the site of the B-24 for any signs of aircraft with view to obtaining a license should any significant readings be detected, however although the site revealed a few small pieces, it looks like the salvage team did a very thorough clean up and a license will not be applied for, the survey at least confirmed that we had found the spot where the B-24 came to grief (ARGOS 2010b).*

In neither investigation do ARGOS members relate where, how, and with what equipment they conducted their surface and metal detector surveys or their excavations. Indeed, the only evidence provided for their methodological practise is the included photographs. The Martlet excavation report, encompassing two excavations, only provides one general photograph of FN288 and one photograph of work in progress at FN284 (Figure 3-19 and Figure 3-20).

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Figure 3-19: Excavation of Martlet FN288 at Symilders, 22 May 2011 (Ramsey 2011).

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Figure 3-20: Excavation of Martlet FN284, May 2011 (Earl 2011b).

The photographs provided for the Martlet excavation report either provide no useful site information (in the case of the FN288) or seem to demonstrate deficient horizontal/vertical control (in the case of FN284). No mention of investigatory procedure is made or shown. The B-24H excavation report includes only two general site location photographs (Figure 3-21 and Figure 3-22) and one fieldwork photograph (Figure 3-23).

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Figure 3-21: General site photograph (Earl n.d.).

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Figure 3-22: General site photograph (Shearer 2011).

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due to copyright restrictions.

Figure 3-23: Field work photograph, 2 June 2011 (Earl 2011a).

While the general site photographs allow for basic location comparison, no National Grid Reference or Latitude/Longitude coordinates are provided. Similarly lacking in clarity is the means by which the B-24H survey was conducted. The single fieldwork photograph seems to show transects either 5 or 10 metres wide (Figure 3-23). It is not clear, however, how many times the site was surveyed and in what orientation or whether finds were georeferenced prior to collection (no artefact markers are observed in Figure 3-23). Indeed, the lack of a published investigation report hinders comprehension of utilised methods. The publication of a detailed site report with HERs/NMRs would greatly enhance the transparency of the project's methodology and results.

ARGOS's more extensive treatment of the Supermarine Seafire MB369 contains little additional information relating to investigatory procedures or information recovered. The ARGOS report spends a relatively considerable amount of time (four paragraphs) detailing a basic history of the group's search for the site and includes a recounting of two failed attempts. Indeed, following the extensive recitation of where the site was not located, the ARGOS report only expends two sentences on the actual excavation

> *So armed with this new knowledge along with fresh information from another witness Ivy Ballantyne of Sunnybrae Farm, a new search was conducted on 27 July 2009 by Kevin Heath and William Shearer and this time one small piece of stainless steel was found on the surface of the field in a disturbed area, this piece fortunately contained a set of numbers confirming the aircraft type and with further detector readings and what were almost certain to be the two 20mm Hispano canon protruding out of the ground.*
>
> *At last the aircraft had been found and an MoD licence could be applied for, though due to the aircraft being on an exercise over a bombing range which was actually out to sea, this took a year to obtain (ARGOS 2010c).*

with a further three sentences describing analysis (ARGOS 2010c). Any remaining methodological information contained within the report must be extracted from the accompanying 12 photographs and 3 figures.

Image removed

due to copyright restrictions.

Figure 3-24: Panoramic view of the excavation site (Winkler 2010).

The single diagnostic artefact published (Figure 3-10) conforms to expected artefact photography except that it lacks relevant artefact/site information. Without the accompanying site name and field specimen number, the contextual information which can be gained from the artefact is severely limited.

A search of the Highland Council HER, RCAHMS Canmore NMR, the ADS database and the BAAC project report record show that no project report has been logged and, as such, there is no publically available excavation report to supplement the online narrative. Not only does the lack of a submitted data structure report [DSR] endanger the information gained from excavation, the lack of a published DSR directly opposes ARGOS's responsibilities as a BAAC member-group.

Reflecting many avocational aviation archaeologists' interest in site histories, PDAAR reports provide detailed site information—including circumstances of crash, crew names and burial locations, contemporaneous and current photographs, and previous excavations if known—for each wreck visited. PDAAR's site specific data is complemented by the inclusion of crash distribution maps. While not based upon an Ordnance Survey [OS] base map, the basic maps supplied by PDAAR nonetheless show the regional distribution of crash sites (Figure 3-25) (Clark 2012e) and the location of specific wreck sites (Figure 3-26) (Clark 2012f). Indeed, while Figure 3-25 is unlabeled, it is complimented by Figure 3-26 which is an interactive map supplying the air force of ownership or occupational designation, the model and number, and the location nearest impact.

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Figure 3-25: Regional distribution of crash site locations identified by PDAAR (Clark 2012e).

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due to copyright restrictions.

Figure 3-26: Interactive map of specific crash site locations identified by PDAAR (Clark 2012f).

Because PDAAR focuses on site identification and documentation, the group has not produced similar site-specific artefact distribution maps. An inclusion of detailed distribution maps would not contravene PDAAR's stated aim to leave a light footprint and the production of site plans and artefact distribution plots would enhance the group's already valuable data.

PDAAR's site reports include basic information—how the site came to be found, how the site was excavated and what artefacts were recovered—but specific information on methodology and techniques used remains absent. For example, the PDAAR report on the excavation of Albemarle Mk.II V1604 (Clark 2012d) provides basic information without critical detail. Information published in the report includes statements that: the wreck site was first investigated by PDAAR in 2004 using a standard metal detector; the generation of a large contact during the initial survey prompted further investigation; further investigation, using a detailed metal detector survey using a deep seeking metal detector, confirmed the anomaly; an MoD excavation license was granted; the excavation took place over one day in early March 2005 using a mechanical excavator; the anomaly discovered during the initial surveys was, as hypothesised, a propeller boss; following the extraction of the propeller boss and attached reduction gear, additional excavation revealed a layer of burnt material covering apparently sterile clay; the nose wheel oleo and "a large quantity of smaller items (including stainless steel frame work from around the cockpit) were recovered" in the clay layer following impact with the mechanical excavator (Clark 2012d).

From the material recovered, PDAAR inferred that (1) the recovered propeller had either not been turning or was turning at very low speed when the aircraft impacted the ground as the propeller was still straight, and (2) the wreck site had been the subject of an extensive clean-up following the crash as reported in the archival material (Clark 2012d). While all the information supplied is useful, there is no reporting on other specific archaeologically critical data such as how the two surveys were undertaken, how many other contacts were located/recovered, the site and excavated trench locations and dimensions, or the total number and fundamental characteristics (such as total weight) of artefacts excavated.

Similar methodological deficiencies are observed in PDAAR's excavation of de Havilland Vampire VV602. PDAAR provides two reports for the excavation. The publicly available copy, accessible via the PDAAR website, is of limited length and detail (Clark 2012c). Although a longer, more complete site report was produced, the more comprehensive report has not been filed with either the Cheshire HER or the English Heritage NMR and no mention is made of its existence on the PDAAR website. Indeed, the only discovered reference to the longer, more complete site report is as a final sentence in Alan Clark's *Aviation Archaeologist* article in which he offers the VV602 report for use as a formatting and content example (Clark n.d.). The following exploration of PDAAR's excavation of Vampire VV602 utilises both reports and compares their content.

The Vampire VV602 short report, at 644 words, provides information similar to that included in the Albemarle Mk.II V1604 report. The longer narrative provides the same general information with added specificity. Both the short and long reports describe the basic excavation methodology (topsoil stripping followed by mechanical excavation) (Clark 2011: 12; 2012e) and the artefacts recovered (engine cone, engine blades, 20mm Hispano cannon, a lead counterweight, gun camera film, and small airframe and cockpit fragments) (Clark 2011: 13-14, 16-22; 2012e). The long report provides greater detail for certain portions of the excavation narrative and includes discussion of the site survey, the soil types encountered and the depth of artefacts (Clark 2011: 5, 12-16). The long report discloses that the PDAAR team did not georeference anomalies to a fixed site datum (Clark 2011: 11).

In addition, the long report provides information not reported in the short narrative. For example, the long report relates previous archaeological work conducted on VV602 (Clark 2011: 6-7), provides information on the disposition of artefacts and details the artefact cleaning process. Moreover, the long report clarifies information regarding artefact location and stratigraphy. For instance, while the short report only relates that artefacts were first encountered "within a couple of feet" (Clark 2012c), the long report details that "From the start parts of the aircraft were being found" with the first large piece located at approximately 60cm depth (Clark 2011: 12-13). Similarly, the long report offers unique information on the presence of fuel and its localised, correlative effect on inhibiting artefact oxidation (Clark 2011: 16).

The comprehensive information on recovered individual diagnostic artefacts supplied by the long report expands the basic information supplied by the short report. Foremost amongst the additions is the inclusion of artefact photographs. Though the long report does not contain photographs of all material recovered, the inclusion of specific artefact photographs provides additional, concrete information unobtainable in the short narrative. The long report also includes observed part numbers as well as a partial reconstruction of the pilot's seat back armour. Accompanying the recitation of part numbers are specific, artefact-based conclusions. For example, the long report contends—based on the stamped reference number prefix *6A/* —that the single lever recovered from the site was from the cockpit instrument panel. The ability to place the lever on the instrument panel is significant as it accounts for the only piece of instrumentation recovered from VV602 (Clark 2011: 21). Historical investigation into VV602 showed that neither the post-crash MoD recovery team nor the 1988 MHAS excavation recovered instrumentation (Clark 2011: 21; 2012e).

The long PDAAR report is not without problems, however. Though PDAAR provides one map in each report on the Vampire, neither are detailed site plans (Clark 2011: 3; 2012e). The short report map shows the aircraft's final flight path (Clark 2012c) and the long report map shows the site location on a 1:50000 OS map (Clark 2011: 3). One key piece of methodological practice included in the short report but omitted from the long report cited removal of the Goblin engine through use of a lifting strap wrapped around the artefact which was then prised free of the soil using the mechanical excavator (Clark 2012c). The long report also fails to detail conservation methods used to stabilise artefacts recovered from the site. Although supplying a basic explanation of artefact cleaning, the report provides little information on the conservation of sensitive items uncovered during the PDAAR Vampire excavation. For example, the PDAAR report states that the group recovered gun camera film still in its case. Despite detailing a large gouge observed on the exterior of the gun film cassette, the report does not indicate whether PDAAR sought to conserve the artefact and, if so, using what techniques (Clark 2011: 21).

Moreover, while the PDAAR website provides access to a large quantity of researched historical data, excavation reports for neither the Albemarle nor the Vampire excavation are on file with the Cheshire HER or the English Heritage NMR. The formal archiving of PDAAR field work results with HERs/NMRs would both guarantee the long-term information security of data gained from PDAAR fieldwork and improve general public access.

Similar to ARGOS and PDAAR reports in its disproportionate reliance on historical and narrative content versus archaeological methodology, LAIT's P-51B 43-6635 site report demonstrates the inclusion of basic methodological practise but omits desired specifics. While LAIT's effective use of systematic search patterns is effectively demonstrated by the location and recovery of artefacts from P-51B 43-6635, a lack of reporting on the search area location, specific transect intervals, the location of individual artefacts and the distribution of finds dilutes LAIT's methodology and restricts the value of the derived data.

Similar methodological and artefact distribution reporting omissions are observed in the B-24H 42-7467 (Gaskell and Wotherspoon 2001) and Hawker Hurricane V6811 (Wotherspoon 2010e), respectively.

Compounding individual report's content deficiencies, a lack of project archiving with HERs/NMRs, similar to the lack observed with ARGOS and PDAAR sites, characterises LAIT excavations. A detailed search of the Lancashire HER undertaken by Ken Davies (HER Officer, Lancashire HER) returned no project report for Spitfire BL585 and only one report for all other LAIT projects (Davies 2012). A wider search of the English Heritage NMR returned similarly negative results. *Aviation Archaeologist* records several of the recoveries recounted on the LAIT website but provides extremely limited detail. Thus, as with ARGOS and PDAAR, LAIT's online narratives provide the primary public record of work undertaken and artefacts recovered for 22 of 24 sites which LAIT invasively investigated.

Thus the lack of an accessible, central archive for aircraft archaeology reports compounds the lack of methodology reported in group narratives. While the BAAC collects reports on excavations from member organisations, copies are not obtainable from the BAAC directly (BAAC n.d.c). A recurrent theme of aircraft archaeology is the disbanding of avocational groups after a few years of activity. The disbanding of avocational groups often presages the total loss of their recovered artefacts and excavation archives. The disbanding of the South Wales Historic Aircraft Preservation Society, active from the 1970s to late 1990s, and subsequent dispersal or loss of SWHAPS-associated artefacts and records demonstrates the detrimental effect occasioned by the lack of a central repository (Bishop 2009; ian_ 2009; Parry n.d.; Providence 200 n.d.).

To be sure, the inconsistency in report content, detail, and quantity seems due to a lack of training in, and motivation for, published results rather than wilful negligence. Avocational aviation archaeologists' great enthusiasm for the subject is evidenced by their desk-based historical research, collation of regional databases and willingness to conduct field research. As with the inconsistencies in methodology, the dearth of detailed field investigation reports completed to the standard required in professional archaeology should not be considered a reflection of the avocational community's disinterest or inability. Rather, the disparities in methodology and publication result from an unintended division between avocational aviation archaeology and professional archaeologists who irregularly excavate aircraft wreck sites. As such, a standard format for the researching and reporting of aviation archaeology investigations would aid in communication between two communities with similar interests.

3.3 Commercial Publications

The avocational community relies on commercial publications to disseminate information about historic aircraft investigations. One popular publication, the magazine *Britain at War*, features historical reports on aviation wreck sites as well as other wartime subjects. A less general magazine, *Aviation Archaeologist*, self-identifies as an archaeological journal which publishes articles on aviation archaeology, general aviation and wreck site history and aircraft recovery. Published by the BAAC, *Aviation Archaeologist* is written and edited by volunteers and does not adhere to the publication requirements of Section 4 of the BAAC *Code of Conduct* (2000a).

In order to evaluate the effectiveness of *Aviation Archaeologist* and *Britain at War* for disseminating appropriate standards and procedures relevant to aviation archaeology, sections of articles specifically discussing the survey, excavation or recovery of artefacts from aircraft wreck sites were analysed. The chosen sections were given three scores:

1. Passage Length Score [PLS]. The PLS counted the number of sentences (up to a maximum score of five) devoted to the discussion of the survey methodology employed, the excavation methodology utilised, or the artefacts recovered.

2. Passage Subject Score [PSS]. The PSS awarded a maximum of three points based on the content of the section. One point was conferred for brief discussion of either the survey/excavation methodology or a description of artefacts recovered. Two points were awarded if the passage supplied brief discussions of both the survey/excavation methodology and a description of artefacts recovered. Three points signified that the passage provided a highly detailed discussion of both the survey/excavation methodology utilised and a description of artefacts recovered.

3. Passage Compound Score [PCS]. The PSC was computed by multiplying the PLS and the PSS. The PCS allows for the general comparison of passages without bias to specific length or information content.

3.3.1 *Aviation Archaeologist*

Examination of *Aviation Archaeologist* reveals a publication more historical in focus than archaeological. Where archaeological investigations are included, the articles lack detailed discussion of site-specific research questions, methodologies, techniques and artefacts recovered. The points-based scoring system applied across 22 issues of *Aviation Archaeologist* corroborated this assertion. Of the 22 issues analysed for this thesis, a full 65.6 percent of reports on surveys or excavations devote four or less sentences (Figure 3-27) to discussing the field methodology employed or the artefacts recovered.

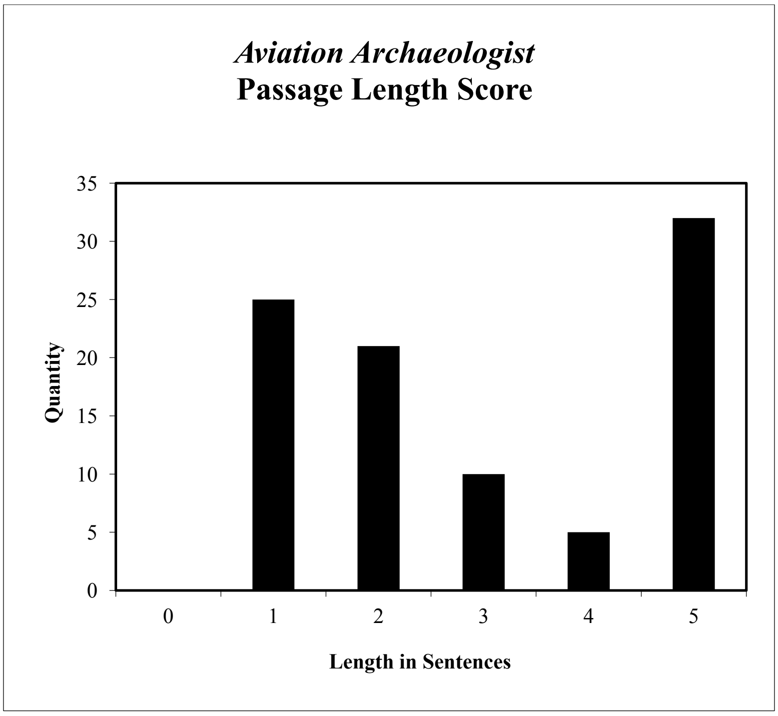

Figure 3-27: *Aviation Archaeologist* Passage Length Score totals (Author).

A diminutive passage is exemplified by the article, "Loss of Whitely T4163," from Series 2, Number 40 (Jones 2003). Though the article devotes 1.5 pages to discussing the historical background of the wreck site, the author only allots two sentences for discussion on field practice and artefacts recovered:

> *With the help of Arthur Evans, after hours of searching among the dunes of Kenfig Sands, the last few remaining parts of the aircraft were recently found. The type was confirmed by the discovery of fragments bearing the Whitley's component number prefix, 'SP' (Jones 2003: 19).*

No reference explains how the search for Whitley T4163's impact point was conducted or whether specialised equipment (metal detectors, magnetometers, ground penetrating radar, etc.) was employed in locating "the last remaining parts of the aircraft" (Jones 2003: 19).

The "Loss of Whitely T4163" is the primary record for Jones and Evans's investigation and recovery of material at the Whitely T4163 site. No report has been submitted to the BAAC, in contravention of the Section 4 of the BAAC *Code of Conduct* (2000a), and no record of Jones and Evans's investigation is recorded in the Royal Commission on Ancient and Historical Monuments of Wales [RCAHMW] catalogue. As the RCAHMW catalogue record for Whitely T4163 contains only a basic historical background on the aircraft—"This Whitely was assigned to 7 BGS. The aircraft crashed after take-off from Stormy Down at Kenfig Sands on 15 June 1941" (Halley 1981: 24; RCAHMW 2011)—and the location qualification that the aircraft wreck site has "not [been] precisely located" (RCAHMW 2011), any submission by Jones and Evans would enhance the RCAHMW catalogue's site record.

In addition, the lack of an investigation report submitted to either the BAAC or RCAHMW demonstrates the lack of data security inherent in avocational aviation archaeology. The two succinct sentences comprise the only publicly available record regarding Jones and Evan's work at the Whitely T4163 site. Given the fact that the artefacts recovered were, by the article author's own admission, "the last few remaining parts of the aircraft" (Jones 2003: 19) from a site which, according to RCAHMW, has "not [been] precisely located" (RCAHMW 2011), the lack of a site report impairs collective understanding of the historical environment.

A similar lack of detail characterises *Aviation Archaeologist* discussions of methodology and artefacts. A majority of passages (56 percent) provide only basic descriptions of utilised methodology or artefacts (Figure 3-28). Only 25 percent of passages include brief discussions of both methodology and artefacts. Of the remainder of passages, 9.7 percent discuss either methodologies employed and/or artefacts recovered in substantial detail; 3.2 percent completely neglect any discussion of methodology or artefacts recovered.

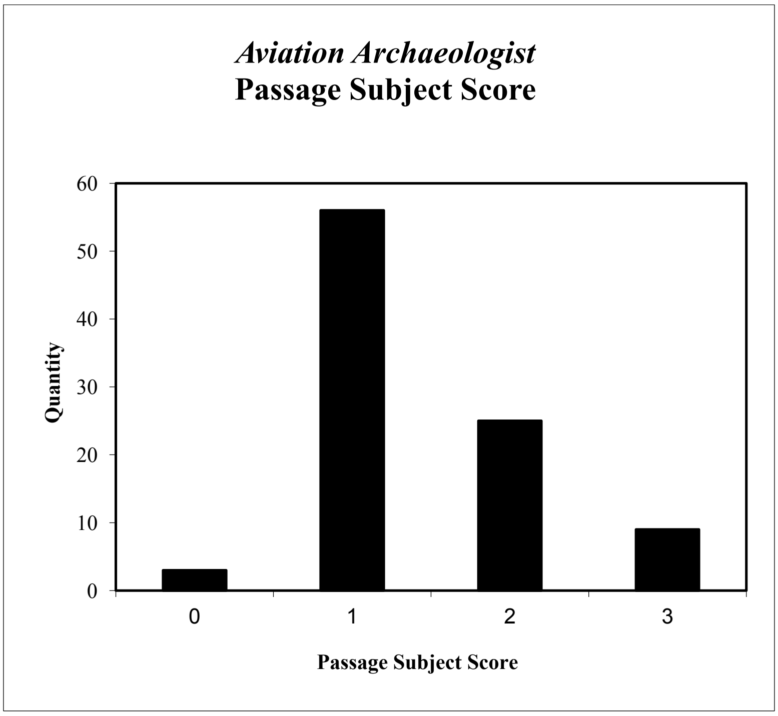

Figure 3-28: ***Aviation Archaeologist*** **Passage Subject Score totals (Author).**

The excavation of de Havilland Mosquito NF11 DD602 [DH.NF11 DD602] provides an illustrative example of articles which contain only basic discussions of field methodology. Reported in Series 3, Number 2 of *Aviation Archaeologist*, the DH.NF11 DD602 article states "The site [of DH.NF11 DD602] had been discovered a few days earlier when an earth moving vehicle had burst a tyre on a protruding propeller blade tip....A nearly complete Merlin, parts of the undercarriage and propeller were amongst the items recovered" (Stansfield n.d.: 4). The *Aviation Archaeologist* report culminates with the declaration that "It is hoped to have a feature on this recovery in the next AA" (Stansfield n.d.: 4). Additional, basic information relating to the excavation's field methodology—namely the use of a mechanical excavator on the DD602 site—is reported by the *Milton Keynes Citizen* on 3 January 2007 (Larner 2007). However no project report has ever been filed with the BAAC, the Buckinghamshire HER or the English Heritage NMR, nor has any follow-up article been published in *Aviation Archaeologist*. Therefore, the single *Aviation Archaeologist* article serves as the primary public record for the excavation of DH.NF11 DD602. Fortunately, a lengthy discussion of artefacts recovered at least provides the archaeological community with a general finds record.

The Series 3, Number 10 report on the Spitfire N3238 excavation takes a minimalist approach to both methodology and finds reporting. In presenting basic, abbreviated information on the field methodology utilised, the pertinent passage for Spitfire N3238 informs that:

> *already it seems to have been a Spitfire year with two being dug on within sight of former Warmwell aerodrome on the high ground to the South. [Spitfire] N3238 piloted by Sgt Feary of 609 Squadron came down at Watercombe Farm....This was a shallow hand dig in dry flinty soil but a careful search amongst the 'daz' revealed a number of trinkets (Wheeler n.d.: 14).*

The notation that trinkets were revealed furnishes extremely limited information about the artefacts recovered. No work or finds report has been filed with the BAAC or the Republic of Ireland National Monuments Service. That the author of the Spitfire article, Philippa Wheeler, is considered an experienced and respected air crash hunter by the avocational aviation archaeology community renders these exclusions all the more alarming.

The lack of specifics in the DD602 and N3238 articles reflects the general composition of articles contained in *Aviation Archaeologist*. Focusing on historical background and eyewitness accounts, the articles attempt only abbreviated discussions of field methodology and artefacts recovered. The amount of specific information is minimally enhanced by increased passage length. The PCS (Figure 3-29) provides insight into the correlation of passage length and level of detailed discussion.

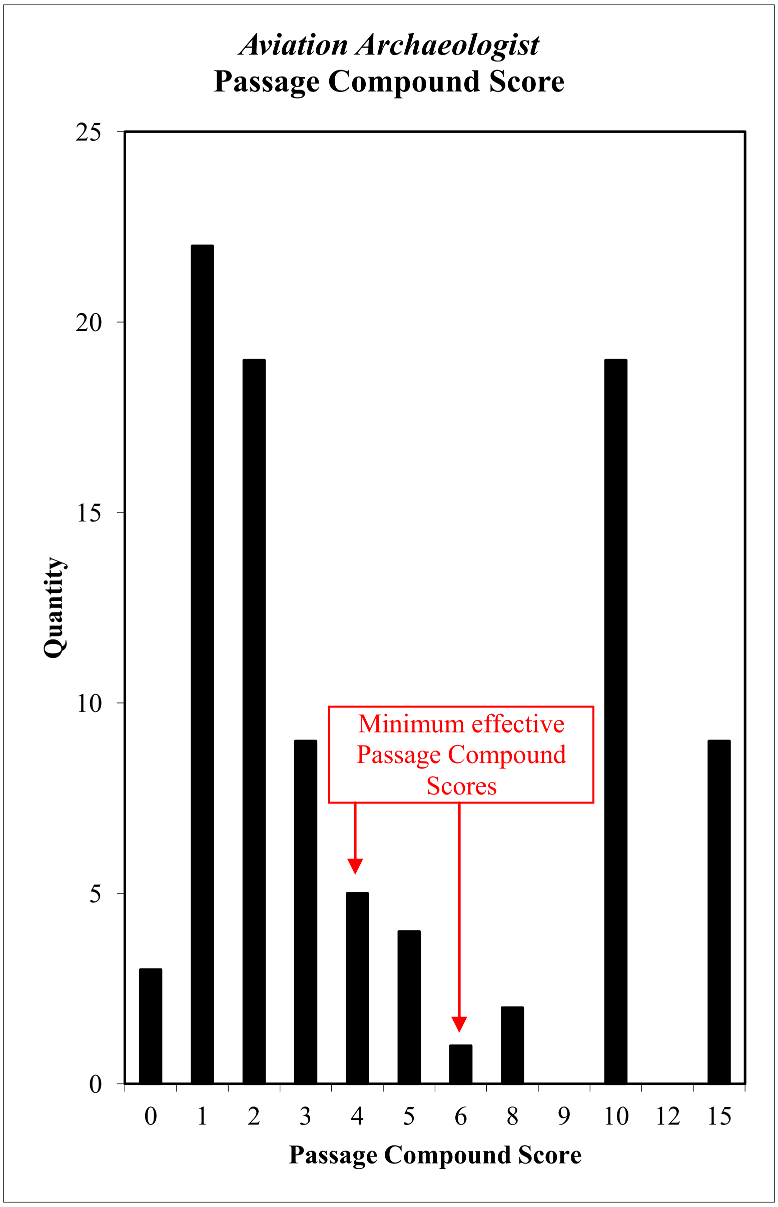

Figure 3-29: *Aviation Archaeologist* Passage Compound Score totals and minimum effective PCS (Author).

As is to be expected, the shorter passages (1-2 sentences) provide substantially less detail than the longer passages (≥5 sentences). The minimum PCS values which effectively discuss both the methodology employed and the artefacts recovered are four and six points.[2] When compared to the overall distribution of scores, the minimum effective PCS is dwarfed by PCS derived from low PSS/low PLS combinations (PCS=1 to 3) and low PSS/high PLS combinations (PCS=10 to 15). Not only do authors use minimal sentences to discuss the methodologies employed and artefacts recovered but the few sentences frequently are ineffective.

[2] A PCS of four points is achieved by using one sentence to report the basic methodoloy employed and another sentence to enumerate the significant artefacts recovered (PSS: 2 points and PLS: 2 points). A highly detailed discussion of methodology and artefacts recovered can achieve a minimum PCS of six points (PSS: 3 points and PLS: 2 points).

Because publishers of general audience magazines may believe that the use of accompanying photographs compensates for the lack of written discussion regarding methodological practice or artefacts recovered, the number of associated photographs was compared to the PCS (Figure 3-30). Results indicate that the longer the passage, the greater the number of relevant photographs. Thus, photographs are more often used to augment detailed articles than to supplement imprecise articles.

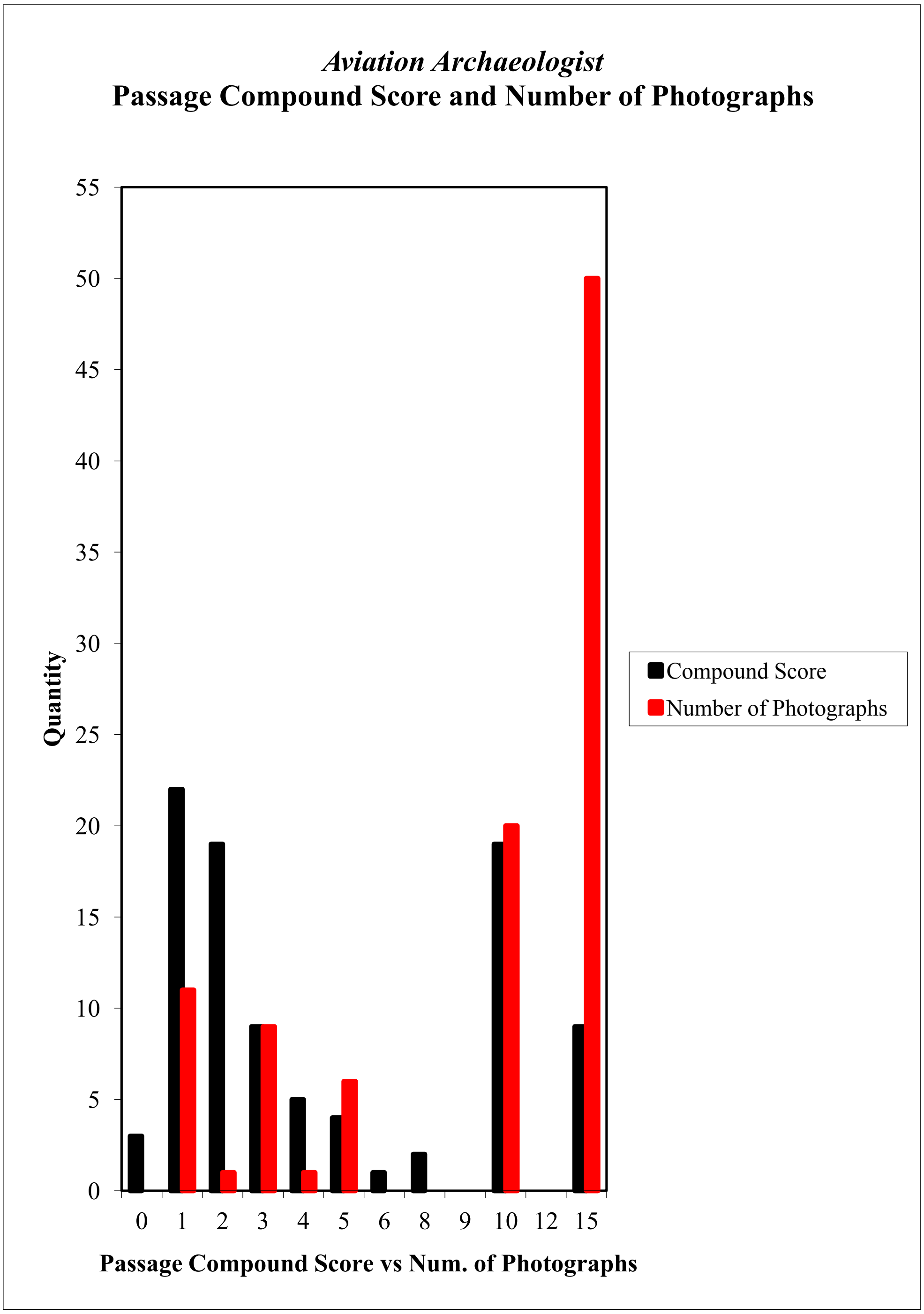

Figure 3-30: ***Aviation Archaeologist*** **Passage Compound Scores compared to number of photographs (Author).**

Though a decided minority at 9.7 percent, articles scoring the maximum PCS of 15 points provide detailed discussions of both the methodologies employed and the artefacts recovered. However, these articles still lack vital information such as survey and excavation locations and dimensions. An example of an adequate discussion (PCS: 15 points) is "The Faldingworth Halifax" from *Aviation Archaeologist* Series 3, Number 9. "The Faldingworth Halifax" article provides requisite methodology details including that the survey used "standard metal detectors" and "deep search metal detectors, [and] magnetometers" with deep anomalies marked using white pegs (Stubley *et al.* n.d.: 14). Additionally, the Stubley/LARG article provides detailed information on excavation procedures, recording that a mechanical excavator was utilised and that topsoil was stripped to a depth of 24 inches before work "commenced on the areas around each marker" (Stubley *et al.* n.d.: 15). The artefacts recovered, the positional relationship between key artefacts, and the condition of key artefacts are discussed in the article. Unfortunately, the article fails to clarify critical information regarding the dimensions of the excavation area, including the total area stripped of top soil and the areas exposed around each marker.

Eight photographs are included with the Stubley/LARG article. However, only two photographs are annotated with adequate methodological information. The figure described as "Crash site marked" shows the white marker stakes in place but shows the site with top soil intact (Stubley *et al.* n.d.: 14). As such, the full dimensions of the area stripped of top soil remain unknown. Similarly, the figure captioned as "Port inner propeller boss" shows the artefact *in situ* but it is so closely cropped that its relative location to the white marker stake and location within the larger site is unknown (Stubley *et al.* n.d.: 15). Even with these report shortcomings, the Stubley/LARG article shows that valuable information can be gained from aircraft excavation if field teams note the location and orientation of artefacts. Indeed, Stubley/LARG conclude that

> *The position of the two propeller bosses found indicate that the aircraft hit the ground at a fairly shallow angle and so did not penetrate the hard ground too much. Parts of the bombsite, which is situated in the nose of the aircraft, were found around the area of the port inner engine, so explaining that the nose may have broken off to the left side (Stubley et al. n.d.: 16).*

Additionally, Stubley/LARG hypothesise that the attachment of engine casting remains to a propeller boss demonstrates "that the engine had been dragged backwards away from the boss whilst wartime recovery took place" (Stubley *et al.* n.d.: 16).

In contrast to all other *Aviation Archaeology* articles reviewed, the published article on the recovery of Wellington Z1206 best exemplifies a project which was carefully thought out prior to breaking ground. Mark Evans's article relates that the 2002 beach-site excavation proceeded using a mechanical excavator to open "a hole fifteen metres long, five metres wide and a metre deep" (2003: 13-14). Excavation then proceeded by hand with the assistance of a water jet. Once the fuselage was exposed, "a scaffolding frame was rigged around the fuselage to support it" (Evans 2003: 14). The supported structure was lifted on 2 July 2002 using lifting straps connected to the mechanical excavator. During the fuselage lift, the team recovered a variety of artefacts including the rear fuselage section with radio operator and navigator's positions, the cockpit with control columns and throttles, the bombardier's equipment, the gun turret's leather seat and a black rubber floatation bag (Evans 2003: 14). Additional artefacts were recovered following the fuselage lift, including the port engine and nacelle (Evans 2003: 15). While a finds list should have been submitted to the MoD in fulfilment of license requirements, no complete list of recovered material has been widely published either in *Aviation Archaeologist* or with HERs/NMRs. A site report was filed with the Western Isles Archaeological Service but was not made available for scrutiny (Western Isles Archaeology Service n.d.). While an unquantifiable factor, the on-site presence of an English Heritage archaeologist, Dr. Vincent Holyoak, probably contributed to the detailed record of activity supplied to both *Aviation Archaeologist* and the Western Isles SMR.

3.3.2 *Britain at War*

Analysis of a second publication popular with aviation historians was undertaken to determine whether the lack of specifics in *Aviation Archaeologist* was due to editors' preference or symptomatic of a wider deficit in the understanding and the reporting of archaeological practice. The chosen magazine, *Britain at War*, often publishes historical reports on aviation wreck sites. A total of 14 passages from 13 individual articles published during a 24 month period (April 2011-April 2013) were discovered to report methodologies employed or artefacts recovered.

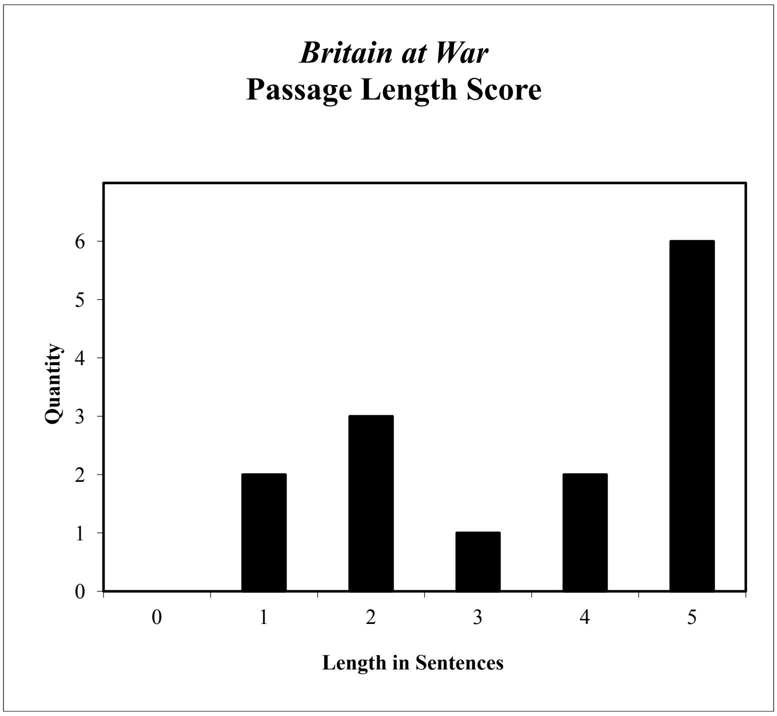

Figure 3-31: ***Britain at War Magazine*** **Passage Length Score totals (Author).**

Once again, the passages discussing survey/excavation methodologies and artefacts recovered were consistently short. In fact, 57.1 percent of all *Britain at War* passages were four sentence or less (Figure 3-31). This trend mirrors the 65.6 percent of four sentence or less passages seen in *Aviation Archaeologist*. Thus, a popular, general subject publication and the self-appointed sub-discipline's main journal share a similarly low level of engagement with, and reporting of, field methodologies and finds recovered.

"Secret War Flight Disaster Remembered" (Lumley 2011) typifies passages found in *Britain at War*. The passage, quoted below, recounts Richard Allenby *et al.*'s search for the remains of de Havilland DH.95 Flamingo R2764.

> *Through the testimony of the eyewitnesses, official reports and contemporary photographs, Richard Allenby and his colleagues [Ken Reast, Albert Prichard and Eric Barton] were able to locate the crash site. With the permission of the landowners, a number of small fragments of the aircraft were located (Lumley 2011: 12).*

While Lumley indicates that work was carried out on the DH.95 R2764 site and that some "small fragments" were recovered, he fails to detail how the artefacts were located (survey methodology) or what types of fragments were located (engine casting, fuselage, equipment, etc.).

A majority of *Britain at War* passages present only basic information related to field methodologies utilised or artefacts recovered. More than half of passages scored (57.1 percent) achieved only one point or less on the PSS (Figure 3-32). Of the rest of the passages, 35.7 and 7.1 percent scored two and three points, respectively.

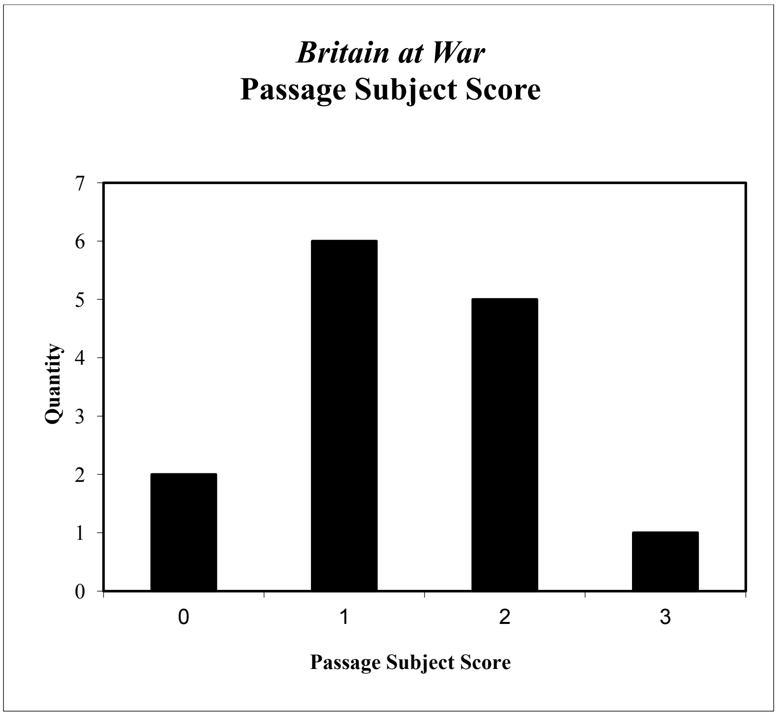

Figure 3-32: ***Britain at War Magazine*** **Passage Subject Score totals (Author).**

An example of this limited discussion of field methodologies and finds is illustrated by Mark Khan's March 2012 article titled "Pilot's Lighter Uncovered at Crash Site." In one of the longer passages (11 sentences) analysed, Khan details few of the items recovered from the excavation. Primary attention is paid to "the S.U. fuel injection system that had been fitted to the Merlin engine" as the author relates that it is to be returned to Rolls-Royce for restoration and display (Khan 2012: 12). Less attention is paid to the "other artefacts [that] were recovered" (Khan 2012: 12). Indeed, Khan only mentions one of these artefacts in the article: "a personal possession of Flying Officer Hollick—his engraved Ronson Lighter" (Khan 2012: 12).

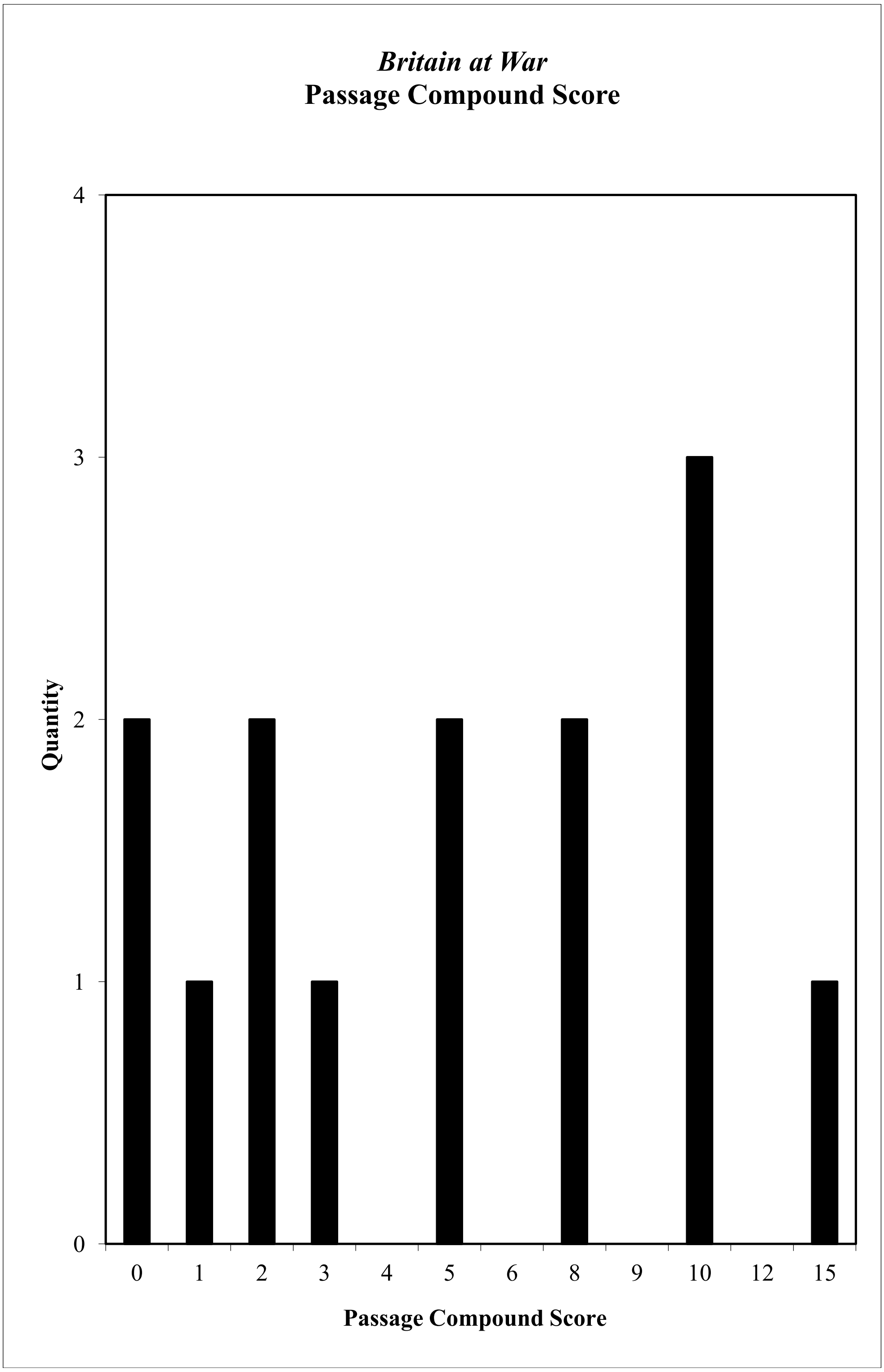

Figure 3-33: ***Britain at War Magazine*** **Passage Compound Score totals (Author).**

The PCSs for *Britain at War* (Figure 3-33) correlate with data obtained from the study of *Aviation Archaeologist*. Once again, the lack of high scoring passages is a reflection of both diminutive passage lengths and limited informational content. Only the article quoted below, representing 7.1 percent of the total data set, achieved a full score of 15.

A mechanical digger began to scrape away the top soil layer and, apart from a few off corroded fragments of airframe and remains of once molten metal and steel components, little was located. A trench two yards wide was then dug from south to north in the marked-out quadrant, starting in an area where metal detection had revealed a concentration of metal targets. The excavated soil was placed to the west of the first trench and was carefully sorted through by metal detecting and visual appreciation.

Other areas of the site were then investigated and towards the southern section of the original trench, at a depth of ten inches, clear evidence of burning was seen with vitrified clay and carbon inclusions. Taking this trench deeper into the subsoil clay revealed evidence of impact in the form of ash, blue crystalline aluminium oxide and several pieces of Plexiglas….A small sondage, or test pit, was opened and revealed a large piece of Plexiglas and some small electrical components, initial checks revealed airframe and fragments going downwards (Evan-Hart 2011: 37).

While the description of trenches placed in a St. Andrew's cross layout is certainly not a standard archaeological description of trench placement, the design is evident. Although the inclusion of a site plan and a survey finds distribution map would have clarified the project's methodologies and discoveries greatly, the written description is so complete that a non-georeferenced site plan can be deduced.

Britain at War articles suffer from many of the same defects in artefact reporting and discovery as those found in *Aviation Archaeologist*. Evan-Hart bucks the prevailing trends by extensively detailing the finds recovered at the Heinkel He 177 6N+AK site. The artefacts recovered at the Heinkel He 177 6N+AK project included "nine corroded 13mm cannon shells and…many broken (exploded in heat) badly corroded 13mm casings that were made of steel" (Evan-Hart 2011: 37). Airframe components located included: "an eight-inch riveted strip of allow still bearing…coarse granular matt black distemper paint"; "Several Bakelite control cable trim wheels…two with company logo and serial number"; and " a large section of once molten engine casing" (Evan-Hart 2011: 37-38).

The completeness of "What a Place to Die" is unique for an article in a commercial publication. While no site plan or map of the Heinkel He 177 6N+AK site are supplied, the author's detailed description of the site, the finds and the relationship between finds allows for reconstruction of a large portion of the excavation specifics. Unfortunately, no report has been filed with the Essex County Council HER or with the English Heritage NMR.

Britain at War provides a larger number of photographs both per article and overall than *Aviation Archaeologist* (Figure 3-34). The inclusion of more accompanying, effective photographs likely relates to the publication's general readership. Nonetheless, their presence improves overall methodological clarity in both low and high scoring passages.

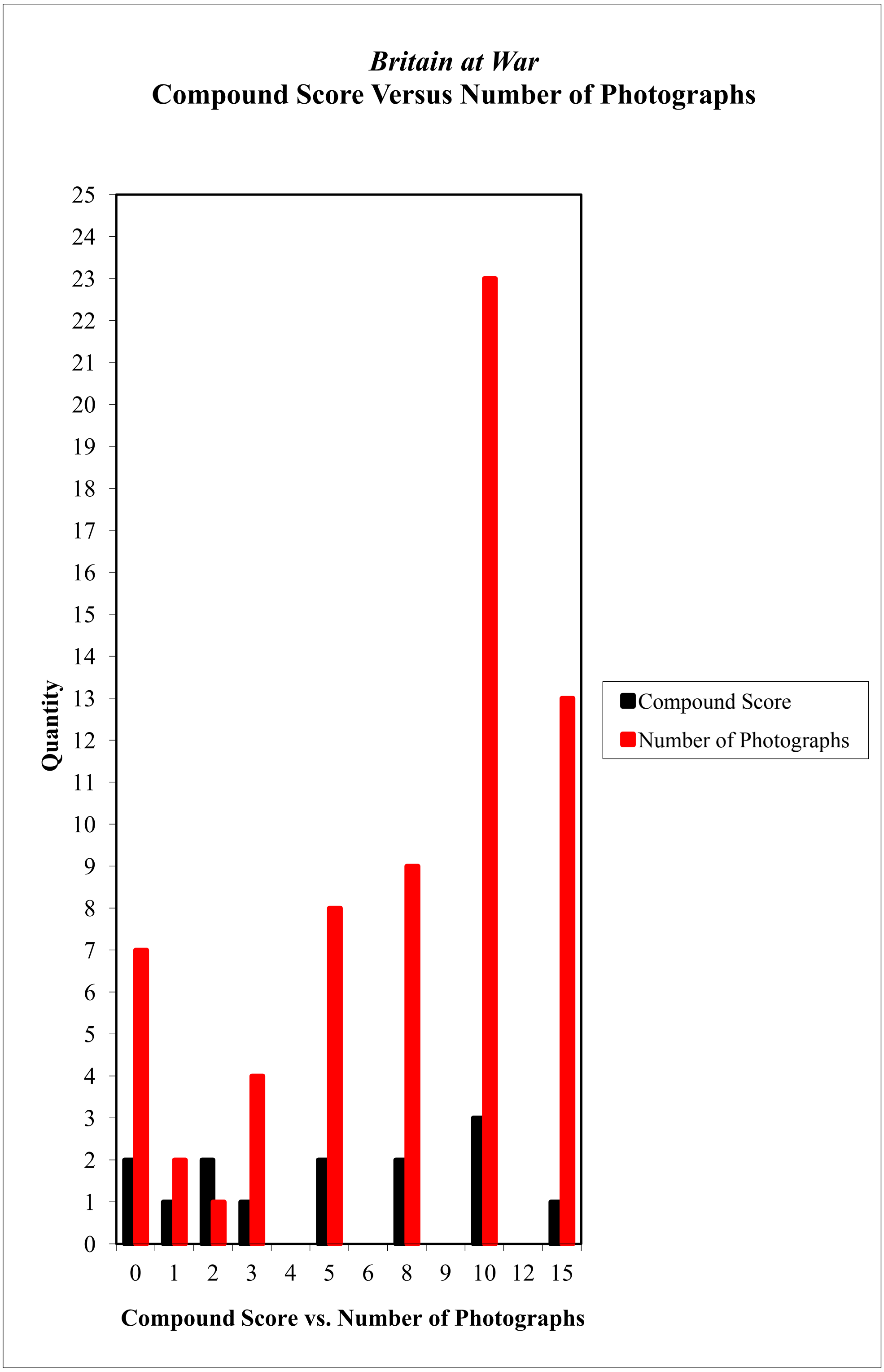

Figure 3-34: *Britain at War* Passage Compound Scores compared to number of photographs (Author).

Effective photographs are particularly informative in the limited instances where they pair with low PCS articles. In low PCS articles, the photographs provide otherwise lacking information on the field methodologies employed and/or artefacts recovered. In the case of "Pilot's Lighter Uncovered at Crash Site," the article includes four colour photographs providing substantial detail about how the excavation was conducted (including both the position of the site within the landscape as well as the placement of excavation debris on site). Two additional photographs show the artefacts recovered (the S.U. fuel injector and lighter) (Khan 2012: 11-12).

It is worth highlighting that it is *Britain at War*, and not *Aviation Archaeologist*, which includes the most complete recitation of aircraft survey, excavation and finds reporting encountered. Still, neither *Aviation Archaeologist* nor *Britain at War* routinely provides sufficient information on the archaeological practices of avocational groups to guide other aviation enthusiasts. The lack of methodological and small finds discussion in both publications seemingly suggests a lack of interest on the part of the avocational authors and/or readership. However, this lack may be more accurately blamed on an aviation archaeology-wide naiveté to the benefits of applying an organised methodology to aviation crash sites.

3.4 Conclusion

Due to the lack of specific guidance on the proper application of professional archaeological practices to air crash sites, excavations of aircraft wreck sites by avocational groups have left much to be desired. Failure of avocational units to meet basic methodological requirements deletes archaeological data due to the wide-spread use of large scale, destructive excavation methods and a failure to publish findings. Given the limited nature of sites available for archaeological excavation, this destruction of artefacts and lack of published results is tragic indeed.

Undeniably limited, the archaeological data concerning powered human flight spans only around 100 years of human history. The period of military aviation, with which this study is concerned, is even shorter. Safety concerns, technological advances and the supremacy of modern aviation means that accidents and downings rarely occur. On the rare occasions that accidents and downings do occur, national security, public safety and cost dictate that airframes be quickly recovered for accident or intelligence analysis by either friendly or hostile governments. Indeed, the last major conflict involving substantial aerial combat—

the 1982 Falklands conflict—witnessed what may be the last great aerial contest resulting in enduring crash sites. In essence, the restricted antiquity of human flight juxtaposed with the cost of modern aircraft limits the available archaeological data set to that contained within a time period of approximately 79 years (1903-1982). As new aircraft crash sites are no longer being generated in quantity, the available data set is more akin in scarcity to ancient remains than to artefacts of the modern era.

The scarcity of historic air crash sites necessitates development of a comprehensive methodology which secures and manages the sites as cultural resources, increases the data set available to air crash researchers and establishes reporting procedures which increase avocational-professional collaboration. Modern air crash investigators have developed methodologies for use in the assessment sites of modern accidents and downings. In addition, professional archaeologists working with avocational groups have introduced archaeological standards on some historic air crash sites. The following chapter evaluates the standards and procedures employed by professional archaeological units when assessing air crash sites.

4 Evaluation of Past Work: Professional Archaeology and Forensic Investigation Units

4.1 Introduction

A review of the methodologies employed by professional archaeological units engaging with aviation wreck sites and of the methodologies used by agencies and organisations with a judicial remit demonstrates the applicability of standardised practices to aviation archaeology. Time Team/Wessex Archaeology's highly publicised Reedham and Warton Marsh excavations employed distinguished archaeologists; thus, those investigations will serve as cases studies for evaluating professional archaeological methods applied to air crash sites. The methodology utilised by the Joint PoW/MIA Accounting Command, US Navy [JPAC] will be discussed in the context of an archaeologically-focused agency with a judicial remit. By focusing on forensics, the JPAC's mission "to achieve the fullest possible accounting of all Americans missing as a result of the nation's past conflicts" (JPAC n.d.a) and the JPAC's Central Identification Laboratory's [CIL] mission "to search for, recover, and identify U.S. personnel missing from past military conflicts" (JPAC n.d.b) separate JPAC/CIL from other professional archaeology ventures. A consistent emphasis on Second World War, Korean War and Vietnam War casualties (JPAC n.d.c) makes aircraft wreck sites a recurring research subject for the JPAC. Non-archaeological agencies and organisations with a judicial remit and a focus on modern aircraft safety include the UN International Civil Aviation Organization, the US National Transportation Safety Board, the US Federal Aviation Administration, the US Navy, the US Department of Agriculture and the Ellis manual.

4.2 Professional Archaeological Units

4.2.1 The International Group for Historic Aircraft Recovery

US-based avocational aviation archaeology groups exhibit variations in objectives and methodologies similar to the differences between UK-based organisations. Most US groups are dedicated to the hobby of wreck chasing (akin to Phase I: Background Research and site visit) rather than traditional archaeological survey and/or excavation (e.g., Arizona Wrecks, Nebraska Air Crash, Oklahoma Wreckchasing, The X-Hunters Aerospace Archaeology Team, etc.). However, amongst the US based groups are a few who practice more systematic aircraft archaeology. The International Group for Historic Aircraft Recovery [TIGHAR] is widely considered the leading US-based organisation. TIGHAR was founded by a former air crash investigator (TIGHAR 2013a) and focuses its efforts on submerged aircraft and on recovering intact wrecks. A non-profit organisation, TIGHAR makes use of both corporate support and professional archaeologist and non-archaeologist volunteers. Indeed, TIGHAR's use of professional archaeologists and volunteers bridges the gap between avocational and professional archaeological organisations. The 2010 Nikumaroro Expedition, for example, was headed by associate Dr. Tom King (U.C. Riverside), employed two additional archaeologists and included twelve volunteers (TIGHAR 2013b). Though TIGHAR utilises crash investigation techniques as the primary discovery and survey methodology, the organisation employs standard archaeological methodologies during intensive surveys and excavations.

TIGHAR has developed its own rapid recording methodology which it uses as its primary discovery and survey technique (Quigg and King 2007a, 2007b, 2007c). Identical to established aircraft crash investigation methodologies, and reflecting its founder's previous occupation as an air crash investigator (TIGHAR 2013a), the TIGHAR rapid recording methodology is a five step process:

1. *Locate the wreck site.*

2. *Establish a control or datum point close to but outside the boundaries of the wreckage distribution.*

3. *Run a tape from the control point on any compass heading that transects the wreckage, or the part of the wreckage closest to the control point.*

4. *Record the locations of key wreckage elements, other features, and significant observations, photographs, sample recoveries, or tests, with reference to the tape.*

5. *If necessary, reorient and/or relocate the tape and repeat the process with each part of the wreckage distribution (Quigg and King 2007a).*

TIGHAR reports that its rapid recording system enables it to complete a terrestrial wreck site survey in 8-12 hours (Quigg and King 2007a). Though TIGHAR's rapid recording methodology is a step in the right direction, the resulting distribution maps are not as precise as GPS or total station-recorded distributions which require similar amounts of time to complete (Figure 4-1, Figure 4-2 and Figure 4-3).

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due to copyright restrictions.

Figure 4-1: Site Map of Lockheed Electra 10A #1024 Crash Site (Quigg and King 2007b). No primary datum is provided by which to position the five spot elevations recorded.

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due to copyright restrictions.

Figure 4-2: Lockheed Electra 10B (USDA 49-KET-00910) Crash Site (Quigg and King 2007c). No primary datum is documented on the site map. While a geographic coordinate appears to have been recorded, withholding the information prevents the wreck site map from being contextualised within the larger landscape.

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due to copyright restrictions.

Figure 4-3: Site Map, Site #1, Old Airstrip Vicinity, Colonia Airport, Yap (FSM) (Quigg and King 2007c).

The methodologies TIGHAR utilises during intensive survey/excavation projects yield more nuanced data than that collected through its rapid recording methodology. An example of the informational dichotomy between the rapid recording methodology and that utilised on intensive survey/excavation projects is found in reports from TIGHAR's 2010 Nikumaroro Expedition. Appendix A, for example, provides details on the discovery and recording methodologies employed. Discovery techniques included GPR surveys, UV surveys, metal detector surveys, transect excavation to a depth of 10cm, shovel test probes and two units excavated (one 2x2 metre and one 1x2 metre). Recording of artefact and transect/survey grid/unit locations was completed using a total station (King 2011; TIGHAR 2013c). Appendices D-H demonstrate the employment of professional resources with substantial post-excavation artefact analysis completed by TIGHAR volunteers or contracted subject matter experts (Amesbury and Szabó 2011; Collins 2011; Cunnar 2011; Jones 2011; Lewis 2011). Although TIGHAR's role in the project was to supervise a for profit organisation mainly focused on submerged wrecks, TIGHAR's leadership occasioned the use of standard archaeological methodologies.

4.2.2 Time Team

While the number of organised aircraft wreck site investigations conducted by avocational groups falls in the double digits and the number of unorganised avocational aircraft wreck site recoveries well in the triple digits, the number of professional, terrestrial aircraft excavations in Britain is extremely small. Indeed, the only unit substantively experienced in aircraft wreck site investigation is the Time Team production crew and their collaborative colleagues at Wessex Archaeology. Since 1999, the Time Team/Wessex Archaeology team has carried out three aircraft excavations (two in the UK and one in France). At both UK sites, Time Team looked at midair collisions involving two aircraft. Interestingly, and with perhaps some forethought as to the sizable nature of aircraft wreck sites, the Time Team/Wessex Archaeology staff decided to focus attention on excavating only one of the aircraft. The first site on which the Time Team focused was the B-17 wreckage located in Reedham Marsh, Norfolk. The 1999 excavation, taking place over three days, sought to explain the aircrafts' sudden mid-air collision which occurred while the planes were in formation. Time Team/Wessex Archaeology published both a formal report on the site and a more informal eight page account in *Time Team 99: The site reports*. While the Time Team/Wessex Archaeology report constitutes the primary record, considerable information can be obtained from the brief, eight page site report. The excavation utilised three trenches, two of which were extended several times (Taylor 1999:

61-65). Although the single map provided shows the approximate location of the crash site in relation to the surrounding area, no site plans or section drawings are supplied (Taylor 1999: 59). However, site dimensions and coordinates are given (Taylor 1999: 60-61, 64).

The formal excavation report submitted to the Norfolk County HER includes a detailed account of the geophysical survey results (Time Team 1998: 5). Additional information regarding methodology and excavation procedures also is supplied. Overburden was removed using a mechanical excavator and toothless grading bucket and the subsequently exposed soil scanned with a metal detector. If no anomalies were located in the exposed area, excavation was abandoned. Located anomalies were cleaned by hand and their location georeferenced using a total station. Each bucket of spoil was scanned with a metal detector to recover as many small finds as possible (Time Team 1998: 6). Time Team did not undertake sieving of spoil. All geophysical survey areas and excavation trenches were integrated into the OS National Grid using a total station (Time Team 1998: 5). While Time Team had hoped to document and georeference all artefacts recovered, the number of pieces encountered and the ground conditions meant that documentation and georeferencing was abandoned as the trench became deeper.

It is worth noting that Time Team's interactions with avocational aviation researchers were not without discord. *Time Team 99* relates a methodological disagreement between the Time Team archaeologists and avocational volunteers, writing:

> *Stewart [Ainsworth] was convinced that the same investigation processes that normally applied to discovering archaeological sites could be applied to air crash sites. He walked around the surrounding area, looking to see if there were any marks to show where the plane might have skidded before crashing, as some witnesses had insisted, and whether any trees showed signs of having been damaged by the crash and then regrown. In the end, he found a small crater-like depression along the edge of the dyke to the east of Decoy Carr, which corresponded with a fresh impact crater visible on air photography taken in 1946…*
>
> *Already the differences in working methods between the aviation excavators and TIME TEAM archaeologists were beginning to clash. Although the strangest things can happen to aircraft after a crash, the fact that we had found what was apparently part of the bottom of the plane at the top of our trench seemed to prove to some of those on site—and particularly the aviation excavators—that these pieces of the plane had been pulled apart by the American team who had recovered the bodies and then simply piled the wreckage back into the hole and covered it up (There were also mutterings among the TIME TEAM diggers that they may have been part of the backfill from the excavators' 1976 dig.)*

> *In any event, these finds did not represent significant stratigraphy in any archaeological sense, and so to the excavators, it made no sense to dig carefully around the remains with small trowels or to records each layer carefully as the archaeologists, led by Phil [Harding], were doing. At this rate, they said, we would find nothing significant in the three days available—a sad waste of an opportunity and, more to the point, of the availability of the large machines on site, which could move mountains and were being required to move spadefuls.*
>
> *The archaeologists disputed this, saying that there was no way of knowing what had been found so far. The fact that the enthusiast had done so many other excavations of aircraft did not really prove anything because that had always tackled their sites so roughly. If they had used archaeological methods, they might have drawn different conclusions. It was important to discover the context of what we had found so far and only then decide what to do next.*
>
> *Despite the archaeologists' best intentions, some shortcuts were being made by those working on the site (Taylor 1999: 61).*

Time Team's conclusions regarding the Reedham Marshes B-17s both describe the current status of aircraft wreck sites and reflect upon the positive role mainstream archaeology can play in recording and excavating aircraft wreck sites. The realisation that "the lack of wreckage seems to be more a product of what has happened to the site after the crash, rather than a failure on the part of Time Team to locate the main crash site" characterises many accessible and/or known wreck sites (Time Team 1998: 11). Although Time Team's report acknowledges the recovery of a smaller than expected quantity of debris, the systematic nature of the investigation showed that geophysical survey could be used to locate major aircraft components on flat ground (Time Team 1998: 11). Furthermore, the specification that the project's paper archive will be deposited with the Norfolk Museums Service and that the majority of debris will be given to the Norfolk and Suffolk Aviation Museum or the 8th Air Force Museum provides a valuable example for transparent specification of archive and artefact repositories.

In its 2004 project, Time Team/Wessex Archaeology focused attention on the excavation of two Douglas A-26B Invaders (43-22336 and 43-22298) from USAAF BAD2 at Warton. Pre-excavation site mapping was accomplished by LAIT and GSB Prospection [GSBP] using a combination of low-penetration and high-penetration metal detectors and a gradiometer (Ely 2005: 11; Wotherspoon 2008). The successful identification of aircraft-related, metallic sub-surface anomalies on the Warton Marsh site using geophysical survey further demonstrates the effectiveness of methodical survey and recording procedures (Ely 2005: 11-12).

A mechanical excavator was used to remove overlying soil. Once aircraft debris was encountered, the team commenced excavation by hand (Figure 4-4) (Ely 2005: 13).

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Figure 4-4: Excavation of A-26B Invader 43-22336 engine (photographer unknown) (Wotherspoon 2008).

Photographs from the project show the excavation of the engine to be typical of avocational excavations. However, the remainder of the excavation seems to be more in line with Time Team's usual archaeological rigour. Though a little messy owing to the marsh's high water table, the presence of squared off trenches (Figure 4-5) and a fully excavated rear fuselage (Figure 4-6) demonstrates Time Team's adherence to established open area excavation techniques.

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Figure 4-5: General view of Douglas A-28B Invader 43-22298 site (photographer unknown) (Wotherspoon 2008).
Note the squared off trenches. This level of site control is rarely seen in aircraft archaeology and is the product of Time Team/Wessex Archaeology supervision.

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due to copyright restrictions.

Figure 4-6: The fully excavated tail section of Douglas A-26B Invader 43-22298 (photographer unknown) (Wotherspoon 2008).

The Time Team excavation report further demonstrates the successful application of professional archaeological methods to a modern crash site. As with Time Team's excavation of the Reedham Marsh B-17s, the Warton Marsh report includes (1) critical records including past excavation work (Ely 2005: 9), (2) trench, survey and diagnostic artefact coordinates (Ely 2005: 20), (3) a geophysical survey results plan (Ely 2005: 21) and (4) a posited crash scenario diagram (Ely 2005: 22). Additionally, the Warton Marsh report uses the plotted debris scatter to confirm eyewitness accounts of the accident and to posit an evidenced-based crash scenario (Ely 2005: 16). Echoing the importance of controlled excavation and artefact recording, the Warton Marsh report concludes with a general observation which, while referencing Time Team's own methodology, is almost assuredly aimed at convincing the avocational aviation archaeology community of the benefits of standard methodological procedures:

> *The recovery of crashed aircraft using archaeological techniques follows very closely the methods and practices used by the Accident Investigation Teams, whereby the smallest correctly plotted and recovered part could provide the answer as to why the plane(s) crashed. As with any excavation of any period it is the detail of recording and care that provides the most valuable evidence, therefore to obtain the most from a crash site an archaeological approach is a sound route to take especially if human remains are to be expected or doubt surrounds the circumstances of the crash (Ely 2005: 17).*

An additional asset of Time Team aircraft wreck site excavations is the publication of site reports. Due to their adherence to archaeological standards, professional units' published results provide information often overlooked by avocational groups. A detailed report on the A-26B Invaders was archived in the Lancashire HER. The cataloguing of the Time Team site report is of critical importance not just for data archiving but because the GSBP geophysical survey results account for one of only a few terrestrial geophysical surveys ever conducted on aircraft wreck sites.

The Time Team/Wessex Archaeology excavations demonstrate the benefits of archaeological science. The discord between Time Team/Wessex Archaeology archaeologists and avocational aviation researchers over the use of non-standard archaeological recovery procedures demonstrates the critical need for phased, standard operating procedures in aviation archaeology. Indeed, the televised excavations undertaken by Time Team/Wessex Archaeology on the Reedham and Warton Marshes effectively demonstrate to avocational groups the results obtainable using standard archaeological methods. The standards employed and the published technical reports on the Reedham and Warton Marsh excavations adds urgently needed methodological precedence to the archaeological record and challenges aviation archaeology's standing as solely an avocational pursuit. Indeed, Time Team utilised the Reedham and Warton Marsh excavations to demonstrate that utilising established archaeological procedures enhances aviation archaeology.

4.3 Forensic Investigation Units

4.3.1 Joint POW/MIA Accounting Command, United States Pacific Command

Unlike Time Team/Wessex Archaeology, which specialises in general and commercial archaeology, the US Joint POW/MIA Accounting Command [JPAC] and its associated Central Identification Laboratory [CIL] are not archaeologically focused but rather are forensic science units operating within an archaeological environment. JPAP/CIL's mission, "to search for, recover, and identify U.S. personnel missing from past military conflicts" (JPAC n.d.b), reflects its focus. Indeed, while avocational aviation archaeologists and Time Team/Wessex Archaeology are focused on the archaeology of an aircraft wreck site as a holistic event, the JPAC is focused on the archaeology as a means to complete its mission directive. As such, the archaeology of the site is considered important so long as it assists JPAC recovery teams in locating, confirming the identity and repatriating US military personnel remains. Indeed, the JPAC's remit and methodological practises can be viewed as the link between aviation archaeology and the evidentiary focused crash investigations of transportation safety boards; the JPAC is a little of both, but neither one completely.

Tasked with the complete recovery of missing and deceased US service personnel from various theatres and conflicts, a large percentage of JPAC investigations centre upon the identification and recovery of pilots lost during the Korean and Vietnam conflicts. With its stated objective that "Recovery scenes will be processed in an organized manner conducive to the replication and verification of the work performed," *SOP 2.0: Recovery Scene Processing* represents the primary source of guidance for JPAC field teams (JPAC 2010: 1). Though the JPAC/CIL's *SOP 2.0: Recovery Scene Processing* serves as a manual used to investigate aircraft wreck sites, its need to be generally applicable to the varying sites which the JPAC investigates underlies its less than perfect fit as an aviation archaeology-specific methodological manual. Reflecting the mission with which it is tasked, the JPAC has developed—and continues to revise—its own field methodology specific to the forensic investigation of conflict sites. The methodology developed by the JPAC reflects the organisation's mission and, as such, focuses upon the recovery of US military personnel remains. The recording of aircraft or wreck site features is usually only undertaken in support of the forensic recovery mission. Nonetheless, *SOP 2.0: Recovery Scene Processing* provides a forensic archaeology perspective frequently missing in aircraft investigation-focused manuals.

Four of seven chapters within *SOP 2.0: Recovery Scene Processing* directly relate to the construction of a standardised methodology for the investigation of aircraft wreck sites. Developed for the JPAC's work in forensic science and the judicial system, Chapter One stipulates precision of field and laboratory procedures as well as standardisation of mission aims and recovery goals declaring that "Derivations and exclusions from, and/or additions to, this SOP are permitted in exceptional circumstances and, if applicable, only when technically justified, authorized, and accepted by Laboratory Management" (JPAC 2010: 1). *SOP 2.0: Recovery Scene Processing* thus provides for fixed field procedures except under extraordinary situations. The codification of field procedures generates recoveries that are both resource-effective and, more importantly, "scientifically sound, legally defensible, and ethically above reproach" (JPAC 2010: 1). In support of its goal to produce scientifically sound and legally defensible evidence, the JPAC scene processing manual dictates six recovery operation goals.

1. *To select a recovery strategy that maximizes data recorded and physical evidence recovered from a scene in order to minimize the loss of physical evidence and other pertinent data.*

2. *To establish and fully document the context in which all evidence is found. The recording of all spatial and contextual associations should be such that any subsequent identification process will not be hindered or compromised.*

3. *To recover all relevant evidence from the recovery scene.*

4. *To secure, store and stabilize evidence from the point of its recovery to its accession to the CIL.*

5. *To maintain a chain of custody through documentary and photographic records that links the recovered evidence to the recovery scene.*

6. *To ensure that the evidence is safely and securely transported to the CIL (JPAC 2010: 2).*

The first three operation goals relate directly to aviation archaeology field investigations. The establishment of specific research objectives which require the recovery of physical evidence and data without loss, as well as the transport and secure storage of the same, represents a substantial difference between the JPAC/mainstream archaeology and avocational aviation archaeology. Slightly modified for non-forensic application, the adoption of the primary JPAC recovery goals within the aviation archaeology sub-discipline would provide much needed methodological guidance and focus.

Chapter 4, "Recovery Scene Processing," details the JPAC's field methodology, parts of which directly correspond to that seen in non-forensic aircraft archaeology. As acknowledged in *SOP 2.0: Recovery Scene Processing*, many JPAC sites are decades old. The JPAC's field investigations begin with a detailed background research assessment. Background research not only supplies information on the deceased individual(s) and their associated equipment but also directs the creation of excavation strategies including a list of projected equipment, labour and special training required (JPAC 2010: 4-5).

Following completion of background research, identified sites are further assessed using a variety of survey techniques appropriate for surface and subsurface surveying. The JPAC utilises a systematic transect survey with a line-abreast formation to ensure full coverage of the survey area. It is during the surface survey stage that JPAC field teams usually establish the site boundary. While the JPAC surface survey mirrors that used in non-forensic archaeology, the JPAC's field processing SOP introduces the often atypical concept of *limited-collection*. The JPAC's limited-collection policy stipulates that no evidence should be recovered during surface surveys unless it is in danger of being lost or damaged between initial observation and further investigatory stages (2010: 7). The position of any evidence recovered during the surface survey is plotted on a map for future consultation. The addition of a similar limited-collection policy to a standard aviation archaeology investigatory methodology would work to effectively reverse the current trend toward undocumented full data recovery excavations in avocational aviation archaeology.

Unlike traditional archaeology which conducts sub-surface surveys in concert with surface reconnaissance, a sub-surface survey is authorised for a JPAC investigation only if the survey can "provide supplementary information to support the results of the surface survey" (such as the determination of the site boundary) or if additional data is required in order to accurately "assess stratigraphy and other aspects of recovery scene soils and sediments and formation and disturbance processes;…determine the nature and distribution of evidence;…[or] develop an assessment of the recovery scene conditions, contents, and any intrasite patterning" (JPAC 2010: 8). Sub-surface surveys incorporate a range of technologies and techniques not uncommon in non-forensic conflict archaeology (Connor and Scott 1998; Scott *et al.* 2000; Banks 2007; Pollard and Banks 2007; Gaffney 2008; Pollard 2009; Sutherland 2009; Scott and McFeaters 2011). The techniques and technologies utilised (e.g., metal-detectors, remote sensing equipment, soil probes and augers, and test pits) are portable, inexpensive and provide accurate sub-surface survey results (JPAC 2010: 8).

Recovery excavations employ block excavation to artefact-sterile soil (JPAC 2010: 10). Hand excavation is used in situations where small amounts of soils are to be excavated and where "there is a strong a priori suspicion that evidence will be encountered" (JPAC 2010: 10). Although indicating a preference for hand excavation, the JPAC acknowledges that mechanical excavation may be necessary or useful in particular scenarios. In contrast to the avocational aviation archaeology excavations which freely utilise uncontrolled mechanical excavation to remove aircraft-associated material, the JPAC stipulates that mechanical excavation be utilised only under tightly controlled conditions.

In specific, the JPAC disallows the use of mechanical excavators for the recovery of "surface remains, small crash sites, or small features" (JPAC 2010: 33). However, the

JPAC acknowledges that sites which have limited human labour available but which require deep stratigraphic assessment or encompass large areas may necessitate controlled mechanical excavation (JPAC 2010: 33). The JPAC stresses the maintenance of horizontal, vertical and provenance controls when using either hand or mechanical excavation. When archaeological material is discovered, mechanical excavation ceases, hand excavation commences and the ensuing removed soil is screened (JPAC 2010: 34).

The JPAC's evidence recovery framework reflects its forensic, rather than archaeological, focus. Only evidence beneficial to the identification process is retained by the JPAC team. Material not beneficial to the identification process (non-evidentiary, nondiagnostic parts, UMF, etc.) can be photographed as part of site documentation, but are not retained. The process and location of non-evidentiary material disposal is recorded to mitigate future, re-excavation confusion. Excavation ceases only when the RL/A decides that "the likelihood of recovering additional evidence pertinent to support the identification(s) is minimal" (JPAC 2010: 12). To this end, recovery efforts usually terminate only after a 2-4 metre extended margin from the last relevant item recovered returns null results. Recording the location of finds, features and reburial sites is accomplished using either a datum and site grid or a global navigation satellite system [GNSS] receiver. In accord with archaeological convention, the JPAC dictates that the site grid origin and individual unit datums be located at the southwest corner of the site/unit. Where possible, however, the JPAC georeferences site positions using GPS receivers and the WGS-84 datum in place of manual offset measurements (JPAC 2010: 9).

In addition to georeferencing specific units and finds, the JPAC utilises a variety of plans and catalogues to document work undertaken. The smallest scale map produced for recovery scenes—the Recovery Scene Plan Map [RSPM]—includes plans drawn to a scale commensurate with a single page of the field notebook (or one sheet of graph paper). The RSPM shows information relevant to locating the recovery scene and work undertaken. To this end, the RSPM includes two classes of information: recovery related information and geographic information. Recovery related information shown on the RSPM should include:

- *location of the site perimeter*
- *the location and orientation of the survey/excavation grid*
- *the location of observed and/or recovered evidence*
- *the horizontal and vertical location of burials and wreckage*
- *the location of temporary benchmarks and datums*
- *the location of submaps or stratigraphic section drawings*

(JPAC 2010: 14).

Geographic information included on the RSPM relates the site plan to the surrounding built and natural environment. Geographic information shown on the RPSM should include:

- *Relevant man-made features on the landscape (trails, roads, buildings, etc.)*
- *Relevant natural features on the landscape (large boulders, trees, streams, etc.)*
- *Elevations*
- *North arrow and bearing of recovery scene excavation grid base lines if they deviate from true or magnetic north*
- *Map key*

(JPAC 2010: 14).

Specific information in the RPSM key, as dictated by the JPAC SOP manual, should include:

- *Case number/REFNO*
- *Map scale*
- *Date map completed (date ranges are permissible)*
- *Person who created map*
- *Symbol key (if needed)*
- *Map scale*
- *Grid origin/site datum location*

(JPAC 2010: 14).

Several larger scale maps and plans are also used to record excavations undertaken and data recovered. The two primary drawings accompanying the RSPM are section and feature drawings. The execution of section and feature drawings matches the techniques employed by professional archaeologists. Utilising standard archaeological convention, information identical to that included in the RSPM is also included on the section and feature drawings.

A standard practice in mainstream archaeological practise, but atypical for aircraft archaeology, the compilation of evidence, feature and photography logs is required by the JPAC. Logs are usually entered into a reserved section of the field notebook to ensure data security; especially large logs can be entered into dedicated notebooks. The JPAC logs are similar to their archaeological counterparts. The evidence log lists each piece of evidence collected as well as its provenance. The feature catalogue lists "the type of feature, vertical and horizontal dimensions, contents, grid coordinates, and depth of initial discovery below surface" (JPAC 2010: 15). Photography logs include the "memory card or CD number, the file name or number, view (in terms of cardinal directions) and [a] short description of the subject of the photograph" (JPAC 2010: 38).

The JPAC SOP expends little effort dictating photography procedures (JPAC 2010: 39). The JPAC does not require the use of information boards showing site-, unit- and photograph-specific information during photographic documentation. Instead, the JPAC methodology relies upon the integrity and security of the photography catalogue. The non-use of photography information boards during photographic documentation discloses a decided flaw in the JPAC methodology. The reliance on photography logs alone risks the possible loss of critical information either through weather, misplacement or computer data corruption. The use of photography information boards guarantees data redundancy through the inclusion of basic photographic information in frame.

The JPAC search and recovery [SAR] report format is strictly controlled. The imposed structure allows for the consistent presentation of data across different site reports. JPAC SAR reports are divided into three categories. Search and Recovery reports are produced for recovery scenes which were opened and terminated during the same mission. All JPAC SAR Reports require usage of a consistently formatted title block. The JPAC SAR Report title block includes the unique investigation-specific CIL number (the site number), the type of site (such as aircraft crash), identification of site (such as aircraft type), location of site, dates of field investigation, author's name, organisation undertaking the investigation and date the report was written. An example SAR Report title block is depicted below:

(Final/Interim) Search and Recovery Report CIL 2006-055, an F-4C Aircraft Crash Site Associated with REFNO 0727, Bo Trach District, Quang Binh Province, Socialist Republic of Vietnam, 6 through 25 September 2006

(JPAC 2010: 41-42)

In addition to a consistently structured title block, the JPAC SOP dictates the SAR Report contents. The SAR Report includes:

- *Introduction*
- *Background*
- *Recovery Scene Location*
- *Description of the Recovery Scene*
- *Field Methods*
- *Archaeological Findings*
- *Conclusions and Recommendations*
- *Signature Block*
- *References*
- *Tables*
- *Figures*

(JPAC 2010: 42).

Information included in the SAR Report (Introduction, Background, Recovery Scene Location and Description of the Recovery Scene) frequently matches that found in any archaeological report. Indeed, much of the information included in the Field Methods section also accompanies standard archaeological reports. JPAC investigations require recounting and justification of site boundary determination and of any deviations from established JPAC SOPs. The introduction of methodological standardisation, as exemplified by the JPAC report structure, would have a positive effect on aviation archaeology. By dictating the basic information required, a standardised report format would improve the quantity of publications. Even groups with little formal archaeological training could effectively 'fill in the blanks' and create documents beneficial to the advancement of the air crash database.

4.3.2 Air Crash Investigation Operating Procedures

Orville and Wilbur Wright's recording of their first flights at Kitty Hawk, North Carolina and of their concomitant first air crashes represent the earliest entries in a continuously expanding trove of written and artefactual material related to the scientific investigation of aircraft wrecks. The non-archaeology specific literature generated across diverse disciplines, from aeronautics to history, provides critical interdisciplinary guidance for the formation of aviation archaeology-specific objectives and methodologies. An effective standard methodology for the investigation of historic aircraft wreck sites requires the marrying of established archaeological practise with appropriate accident investigation methodologies. This section discusses current modern aviation incident investigation procedures and historic aviation cultural resource management. Included in the section will be general crash investigation recommendations and procedures of three leading national aviation investigation agencies (the UN International Civil Aviation Organization/the UK Air Accident Investigation Branch, the US National Transportation Safety Board, and the US Federal Aviation Administration), two non-aviation investigation agencies (the US Navy and US Department of Agriculture) and a manual on crash investigation written for the privately employed aircraft investigator (the Ellis manual). For the sake of clarity, the current discussion of aviation investigation methodologies will proceed through the individual steps of crash investigation thematically rather than by individual manual. As most investigation manuals are similar in general methodological practice, this thematic organisation allows for the direct comparison of individual agencies' particular methodological phases and/or techniques.

4.3.2.1 Background Research

The researcher of historic aircraft wreck sites cannot presume the ready availability of reliable information about the aircraft or the particulars of its mission. However, the background materials required for a modern air crash investigation differ little from that required for historic crashes. Though modern air crash investigation is safety focused while aviation archaeology is historically focused, both rely on the same background data to understand possible crash causes and debris distribution dimensions. As such, the strategies established for modern air accident sites provide some guidelines for creating a standard checklist of air crash background information. While research will not provide information of every background type for every aviation incident, using such a checklist provides the researcher with a basic framework for use in developing a research plan.

The *Manual of Aircraft Accident and Incident Investigation* provides a particularly good summary of actions which should be taken prior to arriving at a modern accident site. Much of the background information essential to a modern, ICAO-based investigation is readily available including maintenance, aircraft operator and crew logs, aircraft engineering plans and associated technical materials. Similarly, relevant air traffic control, localised meteorological data and fuel stock samples can be collected and securely stored immediately following the incident in preparation for specialist analysis (ICAO 2000: 3.5). The FAA's *Order 8020.11C Aircraft Accident and Incident Notification, Investigation, and Reporting* and the *National Transportation Safety Board Aviation Investigation Manual—Major Team Investigations*, as well as documents prepared by the US Department of

Agriculture-Forest Service, assume access to readily available background material similar to that specified by the ICAO manuals (NTSB 2002: 2-26; Whitlock 2003: 1-18; FAA 2011: 4-1 - 4-11).

US DoA background research focuses on the accident sequence. The accident sequence records the total accident event, ideally noting (1) events that occurred before the accident, (2) the accident, (3) events occurring after the accident, (4) injuries and treatment received, and (5) damage to the aircraft and local property. The recitation of events preceding the accident satisfies the basic questions of who, what, when, where and how. Specific conditions relating to the incident, such as "urgency, weather, equipment condition, or terrain," are noted in detail (Whitlock 2003: 16). While specific detail undoubtedly will be added to the accident sequence once the site survey is underway, early adoption of the accident sequence approach provides the investigatory team with a basic chain of events which can be expanded as information becomes available.

In order to condense the abundant background research material relevant to modern aircraft accidents/incidents readily available from cooperating governments and corporations into a workable document, the ICAO created a single page document for the notification of an aviation incident (Document 4-1) (2000: I-4-4; 2006). As the level of informational detail included in final reports often varies between countries, the *ICAO Initial Notification Document* provides a single, standardised source relaying the most immediately relevant information relating to a specific accident/incident. In addition, this distillation of relevant background information into a single, standardised document focuses data collection and facilitates comparison across air crash investigations. The inclusion of a modified *ICAO Initial Notification Document* in all professional and avocational aircraft archaeology reports would both increase the readily accessible, site-specific information and enable quick cross-referencing between sites. A proposal for the use of such a document is further advanced in Chapter 5, Section 5.2.

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due to copyright restrictions.

Document 4-1: Example of the *ICAO Initial Notification Document* (ICAO 2006).
The *PAAR Aircraft Incident Record* form is derived from the *ICAO Initial Notification Document* and modified for the characteristics of historic aviation wrecks.

Compliance records for modern aviation accident investigations differ from those submitted for most historic aircraft crashes. Modern aircraft investigations aspire toward understanding whether “deviations from policies, procedures, practices, and contract specifications” contributed to the accident (Whitlock 2003: 16). While modern civil aviation investigations require scrutiny of the level of adherence to standard manufacturing protocols and flight procedures, historic military aircraft crashes require enquiry into combat procedures and corollary issues. Such analysis implies study of records establishing whether the aircraft was properly maintained and flown along with records which establish whether the crew followed the prescribed combat standard operating procedures. Basic information on aircraft maintenance procedures and, provided the crew survived, combat flight operations can be gained from official histories. Unfortunately, observers’ reports, official accident reports or the interview of witnesses must suffice in those instances where the crew is lost in flight. Because they are government records, observers’ reports and official accident reports usually are housed within a country’s national or military archives. Witness interviews can be found in variety of locations including associated official and popular histories as well as personal interviews, news media and diary-type documents.

Identification and assessment of the equipment involved in the crash requires collection of relevant user manuals, as well as maintenance and servicing records. The ICAO/AAIB, NTSB and US DoA and the Ellis Manual recommend the collection of aircraft service and ownership records as these documents provide critical information regarding an aircraft’s current and past airworthiness status as well as any repairs it has undergone. Current aircraft ownership records facilitate the search for current and past aircraft service records, as well as help in the recovery of related material such as past owners, flight plans and incident reports (Ellis 1984: 36-37). In the case of historic military aircraft, aircraft-specific movement cards may supplant lost aircraft-specific service records as aircraft movement cards often provide the same basic information in relation to ownership and major service overhauls. The recording of restraint system(s), emergency systems and safety equipment built into the aircraft, a focus in modern investigations (Whitlock 2003: 17), is largely inapplicable to historic aviation archaeology. However, the discovery of specific activated emergency systems, opened escape hatches and/or used safety equipment which may indicate crew actions during the accident sequence is equally important to both.

Weather and terrain documents required by the environmental component of the US DoA investigation process are similar to those described by the ICAO/AAIB and NTSB manuals. Paramount to full completion of site-specific background research, verification of weather conditions should include the evaluation of any conditions potentially influencing the accident (before, during and after the accident), as well as the study of detailed and general maps of the appropriate area (Whitlock 2003: 17).

When available, the local Air Traffic Control [ATC] Report provides, in one file, some of the most important data relating to an air crash. As such, acquiring a copy of the ATC Report, or a secondary report which contains the relevant data as extracted from the ATC Report, is critical to complete and accurate background research (Ellis 1984: 38-39). ATC reports may vary in format, content and quantity of information based upon age. In an ATC or Accident Report for aircraft crashes from the Second World War, an exact reconstructed radar track usually is not available. Rather, a written description and/or map of the aircraft's observed radar track or radio transponder contacts are included in the Aircraft Accident Report. The data supplied is comparatively identical but the means of recording differ.

While all Government/NGO manuals (ICAO/AAIB, NTSB, US DoA and Ellis) provide recommendations for pre-scene arrival background research, the rapid decay of physical evidence dictates that these manuals/agencies place a larger emphasis on the collection of background research after initial crash scene processing. This post-collection background research and analysis is in direct opposition to the order of analysis undertaken in archaeological investigations. Indeed, initiating on-site investigations after completing the analysis of background research material often decreases the instances of damage to the archaeological site under investigation. Moreover, the focusing of field work, in turn, can maximise the amount and quality of data recovered while minimising time, personnel and financial requirements.

While the ICAO/AAIB, NTSB, US DoA and Ellis manuals generally agree on what information should be collected early in the investigation process, the manuals differ in their proposed level of detail and method for site processing. Furthermore, not all of the information found in non-archaeological publications directly applies to archaeological fieldwork. Both the age of the historic aircraft wreck sites as well as existence of appropriate, proven field methodologies of archaeological research necessitate that the current Government/NGO air crash investigation manuals and their recommendations function as guidelines for the study of historic aircraft wreck sites, not as methodologies sufficient for the discipline.

4.3.2.2 Site Survey

Following background research, the expeditious processing of a modern aircraft crash scene claims foremost priority. The ICAO/AAIB, NTSB, US DoA and Ellis manuals provide varying recommendations for processing air crash sites. The ICAO recommendations provide appropriate, general direction in this matter. While not so detailed as to impair site-specific implementation, the ICAO recommendations specify techniques and procedures which greatly enhance both site processing speed and data redundancy. The ICAO recommends that crash site processing be undertaken in three sub-phases: walkover survey and general photography, evidence staking, and recording of wreckage distribution (ICAO n.d.: 2.3-2.3.4).

Processing a crash site using the ICAO's recommendations begins with a site walkover. The site walkover affords the investigatory team time to familiarise themselves with the site's contents and size. Confirming the presence of all major aircraft components is integral to the successful investigation of modern air crashes. As such, the ICAO recommends that the walkover survey be used to confirm the presence of all major aircraft structures (ICAO n.d.: 2.3). In order to ease identification and confirmation of major structures and critical components, the ICAO recommends the distribution of a general aircraft diagram. As individual investigators identify major structures and critical components, each investigator colours in the appropriate section on a simplified aircraft diagram. Following the completion of the walkover survey, all investigators' aircraft plans are compared and a master plan is generated. This master plan confirms or refutes the presence of all major structures and critical components and directs future work. Should investigators not have located all major structures and critical components, effort must be made to locate the missing pieces (ICAO n.d.: 2.3). If missing components need to be found, the survey team breaks into two sub-teams—one sub-team continuing to process the confirmed debris field whilst the other sub-team continues searching for the missing components.

In addition to the basic inventory confirming or refuting the presence of all major structures and critical components, the ICAO directs that the immediate determination of site boundaries is essential to both organisational control and effective site processing. In order to determine the site's boundaries, the ICAO recommends that investigators first locate the point of impact. On most fresh wreck sites this is easily determined due to ground cratering or scarring and ploughed dirt. From the point of impact, investigators determine the direction of primary break-up and begin to walk a line of best fit. A notation of whether parts are along the line, to the right or to the left as well as the creation of a "preliminary sketch" without strict adherence to scale assists in establishing basic site length (ICAO n.d.: 2.3). The ICAO emphasises, however, that investigators must continue to walk some distance beyond the last observed piece of wreckage. Walking beyond the last observed piece of debris ensures that all outlying pieces have been located. Indeed, heavy items possessing greater inertia may have travelled further than the immediately apparent debris concentration(s) (ICAO n.d.: 2.3).

General photographs of the site should be taken during this phase. The ICAO recommends general site photography "from all cardinal and intermediate compass points" with the qualification that: "If the wreckage is spread out over a large area, it may not be practical to photograph the whole scene. In this case, photograph each significant piece or group of pieces of wreckage" (ICAO n.d.: 2.2.4.4). The ICAO's *Manual of Aircraft Accident and Incident Investigation* correctly concludes that site photography should not be limited to one or two exposures per subject but rather that a multitude of exposures should be taken to ensure that all observed information, of both current and future use, is recorded (ICAO n.d.: 2.2.4.5).

After investigators have confirmed the presence of major structures and critical components, established the site's boundaries and taken opening photographs, the investigative procedure moves to staking wreckage. Staking the wreckage involves placing a stake in immediate proximity to each piece of identified wreckage. The ICAO recommends that, as stakes are placed, each stake is assigned a "unique identification number" which is noted on both sides of the stake as well as in a separate log. A master log with pre-determined number strings can be used on larger sites where a number of sub-teams are operating simultaneously. The use of pre-determined number strings entails assigning each individual or sub-team a set of numbers different from other individuals/sub-teams. For example, one investigator/sub-team would receive numbers 1-99, another individual/sub-team 100-199 and yet another individual/sub-team 200-299. This system could be extended to provide a unique identifier for each piece of debris encountered. In addition to a unique identifying number, stakes can also record a description of the associated artefact should it be seen as useful to the larger investigation. Concurrent to individual stake notation, the ICAO recommends that investigation teams "Take photos that illustrate damage to the components, fracture surfaces, and witness marks….evidence of fire, heat discoloration of structures, structural fractures, switch positions, and circuit breakers" as well as "Anything found in the wreckage that should not be there [or] anything that has a critical component missing" (ICAO n.d.: 2.2.4.4). Additionally, the ICAO advises that a photograph showing the stake, written information on the stake and the associated artefact be taken as this may prove useful during the post-field survey portion of the investigation (ICAO n.d.: 2.3.2). The ICAO further recommends photographing evidence beyond debris. Observed ground or foliage damage can provide information relating to flight vector, altitude and speed (ICAO n.d.: 2.2.4.4).

No matter the number of photographs taken, all photographs should be logged using both in-frame references and a photography log book. Photography log books should contain enough additional information about the photograph so as to enable post-field investigation, photograph identification and significance (ICAO n.d.: 2.2.4.5). While the exposure, notation and publication of large quantities of constructive site and artefact photographs is not a novel technique to introduce to mainstream archaeology, the introduction of such a technique would readily improve the quality of the vast majority of aviation archaeology investigations. Indeed, as discussed in the previous chapter, aviation archaeology reports often lack sufficient documentation of site methodology, topography, stratigraphy and recovered artefacts. While some professional units and avocational groups, such as the JPAC and the Peak District Air Accident Research respectively, have produced photographic records which are useful in conveying their methodological technique and documenting the artefacts observed, adherence to the ICAO's photographic procedures and standards would expand and refine the performance of less sophisticated practitioners.

Following debris identification and photography, the mapping of scatter is required. Plotting the precise location of individual pieces of debris is accomplished using either a flexible measuring tape or measuring wheel and a compass or a GPS receiver. The ICAO recommends two predominant chart and measuring systems. For small area scatters, the location of individual pieces of debris can be measured from the centre impact point (which doubles as the site datum) using a tape measure and compass while more dispersed sites can use either a linear or Cartesian grid system (ICAO n.d.: 2.3.4; Appendix 4 to

Chapter 2). The scatter map should include all relevant data including "the locations of all major components, parts and accessories, freight, and the locations at which the accident victims were found, or survivors located, and if available, their identities" as well as "The initial contact markings and other ground markings" (ICAO n.d.: 2.3.4). The inclusion of terrain features which may have influenced the crash or scatter pattern should also be included in the scatter map. While not obligatory, the addition of dimensions, notes, and the location/direction of photographs may add to the fullness of the map as a reference document (ICAO n.d.: 2.3.4).

The NTSB does not go into great detail regarding site processing. However, the FAA, the NTSB's partner agency, provides relevant information in *Order 8020.11C*. The FAA recommends techniques that are similar to those provided by the ICAO. Concerning general site photographs, *Order 8020.11C* advocates that the photographs be taken by "'walking around the clock' in a circular fashion to ensure that a 360-degree view of the main wreckage site is completed with a series of six photographs; i.e., 12, 2, 4, 6, 8, 10 o'clock positions" (FAA 2011: 4-8 – 4-9). While this clock pattern differs from the ICAO recommended technique—taking photographs "from all cardinal and intermediate compass points" (ICAO n.d.: 2.2.4.4)—the product is nominally the same. However, the FAA clock-face technique does not provide the user with guidance on what 12 o'clock represents (i.e., whether or not 12 o'clock is equivalent to north or the direction of flight) nor on how to determine the required irregular angles for the 2, 4, 8 and 10 o'clock positions. In contrast, the ICAO technique of utilising compass directions is easily reproduced and anchors photographs to specific geographic directions.

In addition to general site photographs, *Order 8020.11C* directs field investigators to take photographs of major structural components, component details and features, and surrounding terrain (FAA 2011: 4-9). *Order 8020.11C*'s list of items requiring photography is more extensive than the ICAO document but lacks guidance for investigators' photographic technique and makes no mention of linking the wreckage photographs with specific, unique finds numbers.

The final section in an FAA field survey is documentation. Documentation covers a range of activities including part specific notes, site measurements and wreckage distribution plots. *Order 8020.11C* provides a list of "suggested documentation subjects" valid for modern and historic air crash sites alike (FAA 2011: 4-9 - 4-10). However, little specific direction is provided on how documentation is to be accomplished. Indeed, *Order 8020.11C* does not identify the need for unique finds numbers nor does it specify what constitutes the “main wreckage” (FAA 2011: 4-10). The assertion that “the GPS coordinates of the main wreckage should be documented” fails to clarify the number and precise placement of georeferenced points (FAA 2011: 4-10). Thus, suggested documentation directives could easily be misinterpreted to mean that a single point sufficiently georeferences the whole of the impact point and/or the main debris field. Due to the complexity and often extensive geographic spread of impact points and debris fields, *Order 8020.11C*’s possibly unintended proposition that a single point can reference the whole of an impact point and/or debris field is unconsidered.

In addition to specific debris documentation problems, there is no mention in *Order 8020.11C* (FAA 2011) of how debris distribution documentation should be linked with the photographic record. *Order 8020.11C*’s failure to elucidate this process unintentionally suggests a limited georeferencing of debris and the separation of the photographic and debris distribution records. The potential separation of the photographic record and debris distribution can produce artefact and photograph location problems during post-survey analyses.

Unlike the ICAO and the FAA manuals, the US DoA manual does not provide extensive direction on how to process an accident scene. Indeed, the US DoA manual only makes three brief references to site surveying. The first mention of site processing comes from the US DoA manual’s chapter 4 section 4.2, sub-section b.5. Under the site inventory photographic guidance there is a single sentence related to distribution mapping: “The location of each item may be plotted on a scaled map using a fixed point of reference” (Whitlock 2003: 35). While only a brief statement of fact, the suggestion that individual debris should be documented on an appropriately scaled map and referenced based upon a permanent datum is significant. Section 9.9.d.2 contains the second mention of US DoA site survey procedure, specifying in part that investigators should “gather accident photography and location map information” (Whitlock 2003: 70). The third example of US DoA site processing, under *Exhibit 9-1: Aviation Report Formatting Guidelines*, provides a series of bullet points from which processing objectives can be extracted (Whitlock 2003: 72). While only brief descriptions, the understanding that the bulleted descriptions are end products allows for the assumption of causal actions. For example, it can be inferred from the broad directive that on-site investigations should include an

"Accident scene or aerial photo identifying important features" (Whitlock 2003: 70) that some form of walk-over survey, debris identification and distribution analysis, even if only on a broad scale, need be undertaken.

The US DoA manual provides specifics on site photography by dividing accident site photography into ten photograph categories. Nine of the ten categories are directly relevant to most aircraft wreck sites (Whitlock 2003: 34-35). The nine relevant US DoA manual photography categories are: perishable evidence, aerial views, overviews of the scene, significant scene elements, site inventory, close-ups, documents, witnesses' views, and exemplars (Whitlock 2003: 34-35). The US DoA's list of perishable evidence includes critical evidence such as switches, gauges, and radio positions as well as fire damage and ground scars (Whitlock 2003: 34).

The scene overviews, significant scene elements, site inventory and close-ups categories identified by the US DoA manual provide information similar to that acquired using site photography procedures advised by the ICAO and FAA. Indeed, the scene overview recommendations provide an identical process for general site photographs as that suggested by the ICAO. However, expounding upon the primary and secondary compass bearing technique, the US DoA counsels that several overlapping photographs can be stitched together to form a panoramic image if the accident scene is extremely large. As with similar suggested categories found in the ICAO and FAA manual, the significant scene elements category highlights the importance of terrain in the investigation process by directing the investigator(s) to "establish the terrain gradient through photographs" (Whitlock 2003: 34). The site inventory photographs are, it seems, assumed to be self-explanatory. No detailed discussion is made on how to photograph individual debris or whole debris fields. Nonetheless, the US DoA manual makes the critical connection between evidence photography and debris distribution plots, writing that

> *The camera can help inventory the accident site and document personal protective clothing, equipment and other safety equipment, including the victim's personal effects and clothing. The location of each item may be plotted on a scaled map using a fixed point of reference (Whitlock 2003: 35).*

Unfortunately, the close-ups category does not make the same astute connections between the identification of specific evidence using general photography and the detailed data gained from evidence photography. Instead, the close-ups section provides a very basic explanation of photo bracketing (taking of photographs at varying exposure settings to ensure that at least one exposure is clear and, at a more complex level, stitch exposures together to provide a composite photograph lacking shadows or out of focus regions) (Whitlock 2003: 35). While bracketing is a useful technique in site and evidence photography, it is ancillary to site processing. Clarification on how close-up photography in the field can aid an investigation would have proved more useful.

An interesting and astute addition to the US DoA manual not found in the ICAO and FAA manuals is the recommendation that investigators take witness view photographs. Witness view photographs do not provide evidentiary content beyond seeking to "document the witnesses' views of the accident" (Whitlock 2003: 35). This witness view technique is akin to map regression and terrain matching exercises, a commonplace methodology for site identification in battlefield and conflict archaeology (e.g., *After the Battle*).

While the US Naval Safety Center-Aeromedical Division [USNSC-AD] manual does not supply any recommendations relating to general pre-site arrival background research, it does supply information relating to the field survey and processing of accident sites. In order to adequately cover all the necessary material, the USNSC-AD manual supplies twenty-three general bullet points with further direction on important tasks provided separately. Much of the USNSC-AD manual's bulleted general recommendations are similar to those supplied by the ICAO, FAA and US DoA (Lee 2006: 46-47). In addition, the USNSC-AD manual provides two new and significant suggestions relating to initial site walkover surveys. First, the USNSC-AD manual advises that the initial walkover survey "should be with hands in pockets" calling it "a reconnaissance" (Lee 2006: 46). Secondly, the USNSC-AD manual calls for the debris to "not be moved or disturbed for the first 24 hours" so as "to allow investigators to assess, plan, then proceed deliberately" (Lee 2006: 46).

Along with very good, if brief, information on wreck scene processing, the USNSC-AD manual devotes three lengthy sections to site photography, human remains survey and recovery, and wreck site distribution plotting. The photography section provides much of the same information as the ICAO, FAA, US DoA manuals (Lee 2006: 52). However, Appendix S of the USNSC-AD manual provides additional information on the survey and recovery of human remains. As the USNSC-AD manual is primarily concerned with the medical trauma of aircraft incidents, the survey and recovery of human remains as recommended in the USNSC-AD manual is equivalent to the recovery of aircraft debris in the ICAO, FAA and US DoA manuals.

The USNSC-AD manual recommends that surveys for remains be carried out using a parallel search line. On uneven, vertical ground the parallel search line can be modified to a contour search pattern (e.g., where all members of the survey team are aligned along a common contour). Because the survey team moves in unison across the site searching only the area immediately surrounding the individual survey team member, the USNSC-AD search method is identical to transect and grid surveys utilised in archaeology. When remains are discovered, an upstanding visible marker is placed at the site with the remains left untouched. Once the first survey is complete, the survey team completes a second survey perpendicular to the first (Lee 2006: 149). Following the completion of the two perpendicular surveys, each identified fragment is photographed, tagged and placed in an evidence bag, its original position marked with a find number-labelled stake and the position plotted on the distribution diagram. Echoing the ICAO manual recommendations, the labelled upstanding marker should be visible in the discovery photographs (Lee 2006: 150).

While the ICAO, FAA and US DoA identify the need to locate and georeference debris to varying degrees of comprehensiveness and accuracy, the USNSC-AD manual's recommendations on debris mapping are original in detail. At its most basic, the USNSC-AD manual qualifies the technology used to georeference debris locations. On small sites, tape measures are advised. The USNSC-AD manual recommends on larger sites, however, the use of GPS units. Additionally, the USNSC-AD manual discusses plot diagram formats. The USNSC-AD manual, like the ICAO manual, provides three plot diagram formats: polar, linear and grid. The polar format is most appropriate for crash sites where the debris is dispersed around the central impact point. The centre of the polar diagram equates to the centre of the impact point and measurements are recorded via degree off north and distance from the centre. Linear diagrams are recommended for debris fields arrayed along a single, long axis. In a linear diagram, a centreline is laid down along the axis of break-up and debris distance from the centreline is measured at 90-degrees (Lee 2006: 54). Grid diagrams, widely used in archaeology, can be seen as the most multi-purpose diagram format and are suitable for wreckage with a wide dispersal. Additionally, the USNSC-AD manual recommends that a terrain cross-section be recorded for sites with vertical obstructions (Lee 2006: 55).

It is no coincidence, due to the author's government training and experience, that the Ellis manual provides similar site processing recommendations as the ICAO, the FAA, the US DoA and the USNSC-AD. The Ellis manual recommends that the first priorities of site processing should be the securing of the site followed by an initial walkover survey to establish the presence of all major aircraft components and the preservation of perishable evidence (1984: 23-24). In agreement with the USNSC-AD manual, the Ellis manual cautions that the initial site walkover should be conducted without detailed examination. Writing that "The general state of the wreckage should be taken into account at this time….but the wreckage should not be moved or disturbed" (Ellis 1984: 23), Ellis contends that the initial site walkover survey should attempt to provide the investigatory team with a clear understanding of the site's orientation, size and contents. To this end, the manual directs that special attention be paid to locating the point of impact, ground or object scaring as well as "establishing the probable flight path, impact angle, impact speeds, whether or not the aircraft may have been under control, and if structural failure occurred prior to impact" (Ellis 1984: 23).

Following the initial site walkover, the Ellis manual suggests the commencement of site and debris photography. As with the ICAO, FAA and US DoA manuals, the Ellis manual dictates that photography should begin with general, perimeter site photographs. Oddly, the Ellis manual's method of perimeter site photographs combines the ICAO and US DoA compass degree technique with the FAA clock-based technique. The Ellis technique starts photography oriented north and then moves around the perimeter of the wreck site taking photographs every 30 degrees (Ellis 1984: 25). While the Ellis method is certainly a replicable technique that exposes the site to more viewing angles, it lacks the inherent mental orientation of the ICAO/US DoA method. Most people, professionals and avocational enthusiasts alike, can mentally orient themselves northwest or southeast. It may prove difficult to provide the same level of immediate clarity using degree angles to determine photograph positions.

The Ellis manual provides a unique method for the mapping of wreckage in a variety of terrain. With non-airfield accidents, the point of "initial touchdown…ground roll track, stopping point and debris scatter" are all noted (Ellis 1984: 26). Larger scatter patterns require a more flexible distribution system which allows for the concurrent use of both large and small scale maps. In the case of large scale scatters, the Ellis manual recommends that the wreck site be divided into smaller regions using found terrain features and/or natural datums. Each small region is given a letter designation and a series of finds numbers. The letter “A” represents the area of first debris impact. Subsequent regions are given sequential letter designations. In addition to a reference letter, each region is also assigned a series of finds numbers. The span of finds numbers assigned to a region is subjective and based upon the number of individual debris pieces expected. For example, the region of initial impact could be assigned the letter designation and finds numbers A: 0-99, the second region B: 100-199, the third region C: 200-299 are so forth (Ellis 1984: 26). The Ellis system of site division allows more than one investigative team to operate on the site without confusion over the ground covered or duplication of debris finds numbers. Furthermore, the designation of letters for regions of the crash site allows for the quick approximation of specific debris location within the larger scatter (Ellis 1984: 27).

Unfortunately, the Ellis manual does not provide any substantial directions on how to map the location of individual pieces of debris. Indeed, the Ellis manual only advises that “you [the investigator] should determine the distances from the point of initial impact, the place where the major part of the aircraft came to rest, to the point to which the parts travelled after they separated from the aircraft” (Ellis 1984: 27). The measuring of an artefact’s distance from the point of impact and angle off north is completed using a “one-hundred-foot flexible measuring tape” and a compass (Ellis 1984: 27).

As with other archaeological sites, the identification of site size, direction of scatter and the distribution of finds are integral to the effective survey of an air crash site. Though the ICAO, FAA, US DoA, USNSC-AD and Ellis manuals cover similar themes regarding site processing, the variation in specific operational procedures and occasional deficiency in methodological detail shows them to be incomplete, individually, as models for the archaeological field survey of historic aircraft wreck sites.

4.3.2.3 Evidence Recovery

Following completion of the site survey and photography, evidence must be collected and stored. Proper collection and storage ensures that the valuable physical data gained during the site survey and post-survey analysis is not corrupted or lost. To this end, the ICAO recommends that no artefact be removed from its original position before it is confirmed that “(a) its [the artefact’s] position is recorded; (b) an identification number is painted on it in an undamaged area, or in the case of small portions, a label attached; and (c) notes are made of the manner in which the piece struck the ground, what the nature of the ground was, and whether it hit trees or buildings, etc., prior to this" (ICAO n.d.: 2.4). Following confirmation of conditions A-C, artefacts are collected for post-survey analysis. Beyond directing that submerged debris recovered from salt water be hosed with fresh water followed by either the application of water displacement fluid and oil or inhibited lanolin (for metallic debris without organic deposits) or dried and sealed in a plastic bag with an inert desiccant (for metallic debris with organic deposits), the ICAO manual does not provide information on physically stabilising aircraft wreckage (ICAO 2000: 5.6.4.1-5.6.4.4). The lack of conservation guidance in the ICAO manual is likely a result of the ICAO's experience with recent sites which suffer little artefact degradation and where there is an expectation of on-site specialist assistance. Nonetheless, the omission of additional conservation advice renders the ICAO manual only partially useful in managing evidence recovery, conservation and storage at historic crash sites.

The NTSB *Aviation Investigation Manual-Major Team Investigations* manual (2002) lacks discussion of evidence recovery. Like the NTSB manual, neither FAA *Order 8020.11C* (2011), the US DoA manual (Whitlock 2003), or the USNSC-AD manual (Lee 2006) contain evidence removal procedures beyond the recommendations provided during site survey. The Ellis manual, however, provides a level of procedural detail equivalent to the ICAO manual. Foremost, the Ellis manual cautions that debris should not be removed from the site "until all possible field analysis and assessment of damage have been accomplished, as premature removal methods may obscure or obliterate valuable evidence" (1984: 30).

4.3.2.4 Chain of Evidence or Provenance Security

Of the documents surveyed, only the ICAO's Document 9756c (ICAO n.d.) discusses post-artefact collection evidence data security. However, even the ICAO's discussion is limited to a brief paragraph on the creation of a site-specific database. While certainly a useful recommendation, the ICAO proposal that

> *Of primary importance is noting the geographic location where the particular wreckage was recovered by reference to a wreckage map grid, latitude and longitude, or other appropriate reference system. A brief summary of any significant evidence, such as fire damage or sooting, corrosion, pre-existing cracking, etc. should also be included. Reference to photographs or sketches might also be recorded in the wreckage catalog. Additional information, such as when the item was recovered and by whom, may also be appropriate (ICAO n.d.: 8.7.1).*

cannot be considered a fully developed system of evidence security. The lack of discussion on chain of evidence protocols in the FAA, NTSB, US DoA, USNSC-AD and Ellis manuals is surprising. Ensuring proper protocol for the movement of evidence between individuals, facilities and organisations is imperative to both the physical retention of all evidence as well as to maintaining evidence integrity.

4.4 Reason for the Proposed PAAR Methodology

While manuals dedicated to the investigation of modern aircraft incidents provide guidance on the current procedures and methodologies for investigating air crashes, modern manuals do not offer insight into the archaeological and historical importance of older aircraft crash sites. Recognising that aircraft wrecks represent important, physical artefacts of England's experience during the Second World War (most notably the Battle of Britain), the executive non-departmental public body English Heritage published a 2002 guidance note: *Military Aircraft Crash Sites: Archaeological guidance on their significance and future management* (Holyoak and Schofield 2002). The primary purpose of the guidance note is to argue for the historical importance and proper management of aircraft wreck sites. The first—and currently only—document of its kind, English Heritage's guidance note provides key information related to (1) the importance of aircraft wreck sites as archaeologically valuable source material, (2) historical trends in public interest in aircraft wreck sites, (3) areas of likely aircraft preservation and expected datasets, (4) criteria for selection as an important site, and (5) methodological guidance for professional and avocational investigations.

Military Aircraft Crash Sites: Archaeological guidance on their significance and future management advocates that all crash sites be considered of historic significance and that the information they contain not be needlessly destroyed or removed without adequate record (Holyoak and Schofield 2002: 2). Further arguing for the importance of aircraft wreck sites as an invaluable resource, the guidance document notes that crash sites are the most probable repository for twenty-one of the ninety extinct aircraft types (22 percent) which operated in UK airspace during the Second World War. Pre-Second World War numbers are even higher with UK crash sites representing 67 of 93 aircraft models (72 percent) for which there is no surviving example (Holyoak and Schofield 2002: 5). The methodological choices in aircraft wreck site excavations can thus either preserve or destroy up to 88 extinct pre-1945 aircraft models. In order to simultaneously preserve this finite resource for future generations whilst exploiting the information it contains, a new aviation specific archaeological methodology needs devising, disseminating and implementing. This study proposes such a methodology.

5 Phased Aviation Archaeology Research [PAAR] Methodology

5.1 Introduction

A diverse number of interrelated factors contribute to the configuration of historic aircraft wrecks. Primary factors can be separated into three main categories: environmental, mechanical and human. Primary environmental factors are relatively limited, consisting predominantly of terrain and weather. Mechanical factors include air frame construction and maintenance. Human factors are more diverse and often intersect with environmental and mechanical factors. Predominant human factors include air speed, altitude, attitude, flight plan, loading and crew experience. Boeing B-17G 42-97286 (see Chapter 7 for additional information), for example, exemplifies the interconnected causal factors related to a crash as its crash narrative combines human error, environmental factors and mechanical operating limits (Figure 5-1).

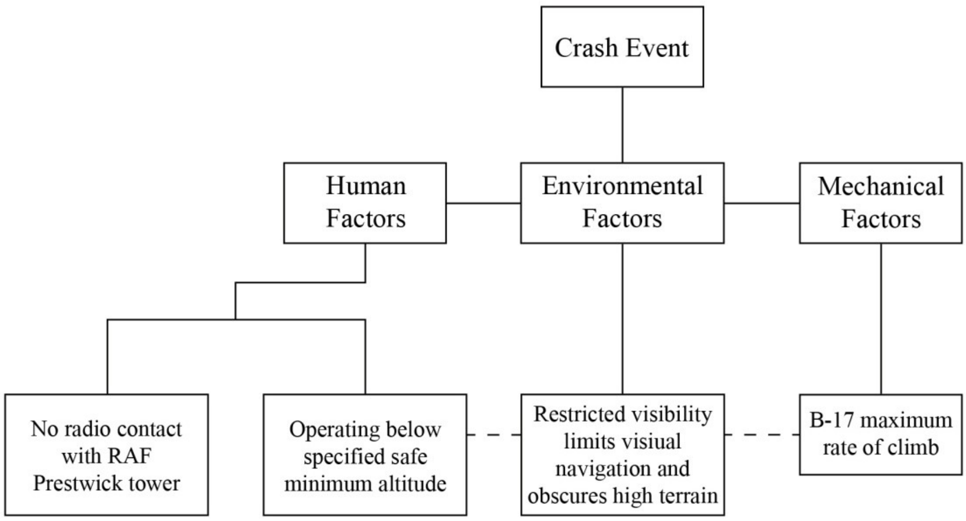

Figure 5-1: Interrelated factors which contributed to the configuration of the B-17G 42-97286 crash and wreck site (Author).

In order to archaeologically identify the numerous factors contributing to the formation of aircraft wreck sites, a phased investigatory approach is proposed. As with all archaeological investigations, the planned methodology and the methodology deployed for a specific site may differ slightly as a result of the specific site's characteristics. The following methodology was field-trialled on the sites discussed in Chapters 6, 7, 8 and 9. Widespread use of the proposed standardised, phased methodology would provide cost-benefit flexibility to the investigative team and allow for cross-site and cross-team comparisons.

5.2 Phased Methodology

Normal archaeological practice dictates the use of a three phase methodology. These three phases are background research, survey and excavation (Greene and Moore 2010: 106-107; Neumann and Sanford 2010: 5; Neumann *et al.* 2010: 2). However, the variable size and complexity of historic aircraft wreck sites requires the splitting of Phases II and III into two sub-sections each. The proposed aircraft archaeology methodology thus contains:

- Phase I Historical Survey
- Phase IIa General Data Survey
- Phase IIb Detailed Data Survey
- Phase IIIa Exploratory Excavation
- Phase IIIb Full Data Recovery Excavation

As these phases grow in complexity, increasing levels of expertise, time and financial investment are required. In each phase, a *PAAR Aircraft Incident Record* form is completed the format of which is based on the ICAO *Initial Notification Document* (ICAO 2006).

5.2.1 Phase I: Historical Survey

A baseline survey, Phase I establishes the basic historical background of a potential wreck site as well as the general presence, condition and geographic boundaries of material anticipated on the potential site. A Phase I survey begins with the construction of a wreck dossier detailing basic information (the journalistic four W's of who, what, when, where). Added to this data is any information regarding previous enquiries or excavations. Previous work on the site will dictate, should investigation continue into Phases IIa/b or IIIa/b, where work will be focused and what areas are deemed archaeologically compromised or sterile. Historic pictures and information from hill walkers, the local population and enthusiasts aid in establishing expectations of artefact survivability. However, a Phase I historical survey does not critique the data collected or assess previous activity on the potential site. A Phase I historical survey simply establishes past contacts, be they human or natural, with the potential site.

A site visit may follow completion of the basic desk assessment. A Phase I site visit identifies, photographs and georeferences surface wreck debris concentrations. Additionally, the site panorama is photographed both from a distance (180 degree coverage) and from the point of impact/primary points of debris concentration (360 degree coverage) to produce a visual record of the site within the larger landscape. This 180°/360° site-landscape photography is repeated with each additional phase. Witness views, if known, are similarly recorded at this stage. Subsequent plotting of the GNSS data produces a rough scatter plot which allows the investigative team to loosely bound the site geographically as well as to hypothesise the aircraft's wreck patterning and final disposition. Surface diagnostic artefact concentrations should be noted and photographed as the presence (or absence) of surface diagnostic artefacts allows for the establishment of surface artefact survivability, the visual assessment of approximate site boundary and the recommendation of continued work to Phase IIa.

5.2.2 Phase IIa General Data Survey

5.2.2.1 Continued Historical Research

Should a Phase I historical survey confirm a potential site as (1) being a historic aircraft wreck site and (2) having sufficient archaeological survivability to warrant further investigation, a Phase IIa general data survey is initiated. A Phase IIa general data survey seeks to go beyond the basic historical background of the now confirmed site by establishing a detailed wreck dossier which includes relevant airframe service forms, official histories, oral testimony, weather conditions, crew personnel forms, maps and crash/missing aircrew forms. While a Phase I survey reflects the very cursory 'who, what, when, where' of a doomed flight, the Phase IIa survey provides all other accessible historical information including suspected causes of the crash. The assessment of historical source material against known crash site dynamics and formation processes guides the Phase IIa unsystematic surveys by identifying/refining the suspected site location and hypothesising the extent of scatter distributions. The derived scatter distribution hypothesis is then used, with an added appropriately wide buffer, to establish the Phase IIa survey boundary. Much of the information critical to a complete historical assessment of both the wreck site and the recoverable archaeology is included in the US

MACR files, official accident reports, the *AM Form 1180*, historic land titles, Squadron Record Books and official histories, crew personnel records and historic weather records.

5.2.2.2 Unsystematic Pedestrian Survey

A Phase IIa general data survey does not simply expand upon the historical information established previously, it also expands upon data collected during the Phase I site visit by introducing an unsystematic pedestrian survey and an unsystematic metal detector survey. An extremely important component at this point in the investigative process, the pedestrian survey physically establishes both the actual types and specific quantity of extant material. While the Phase I site visit provides a cursory look at what, if any, diagnostic artefact concentrations are extant on the surface, the Phase IIa unsystematic pedestrian survey seeks to record observed surface diagnostics as well as artefact groups, suspected burial areas and suspected crash scars. Similar to the process utilised in the Phase I site visit, the site panorama is photographed and surface diagnostics are georeferenced and photographed. Artefact groups, suspected burial areas and suspected crash scars are photographed. Following photography, their circumferences are either mapped with a GNSS receiver or planned by hand. The data gained from the unsystematic pedestrian survey is then used in the recommendation, planning and execution of Phase IIb field work.

5.2.2.3 Unsystematic Metal Detector Survey

An unsystematic metal detector survey is undertaken during Phase IIa in order to define basic subsurface anomaly patterns. A full, systematic metal detector survey is not necessary at this time (this should be completed in Phase IIb); a sweeping of the periphery of grouped surface deposits and suspected burial sites/suspected crash scars so as to establish the presence or absence of subsurface artefacts comprises the objective for the Phase IIa metal detector survey. Grouped surface deposits and suspected burial sites/suspected crash scars are swept along their periphery to a sterile buffer of 2-4 metres minimum (the standard JPAC sterile buffer zone) (JPAC 2010: 12). Individual returns should be georeferenced using the same technique as the pedestrian survey while individually indistinguishable, contiguous returns should have their circumference mapped; a single Metal Detection Finds [MD] Number can be applied to these individually indistinguishable, contiguous returns. The survey of artefact groups and suspected burial sites/suspected crash scar interiors should tune out the smaller artefact sizes (i.e., screws and small nondiagnostic metal fragments [NMFs]) in order to bias the detector toward larger artefacts. The interior returns should, again, be georeferenced as per the pedestrian survey (if individual anomalies) or along their circumference (if individually indistinguishable, contiguous returns).

5.2.2.4 Field Team and Assignments

Practice has shown that a carefully organised field team will return the best results in the shortest amount of time, thereby expediting collection of field data while maximising time and financial resources. Real-world field trials have distilled the basic survey team into three assignments: beating, georeferencing and photography. As in grouse hunting, the beaters' job is to move ahead of the two other assignments identifying the objective in the low foliage for the benefit of the latter. The beaters drive the survey's direction and must, therefore, have a good knowledge of the terrain, the site, and the project objectives. In a Phase IIa survey, the beaters move from observed artefact to observed artefact and mark diagnostic artefacts, artefact groups, suspected burial areas and/or suspected crash scars with pin flags for the follow-on teams. Concurrently, the beaters complete the unsystematic metal detector survey, marking identified subsurface anomalies with pin flags. Beaters are invaluable to the expeditious completion of the Phase IIa unsystematic surveys as they can move freely across the terrain unencumbered by the need to record and photograph artefacts' locations.

In order to make the survey assignment system function well, beaters must make the location of artefacts easily discoverable for follow-on georeferencing and photography teams. The easiest means to mark artefact locations is to use surveyors' pin flags in a bright colour. Pin flags with metallic shafts should be avoided, where possible, as their metal content can mask the electromagnetic response from artefacts in close proximity to the pin flag shaft or induce false positives on their own (Connor and Scott 1998: 82). While the placement of information on pin flags can vary according to project requirements, it has been found that a standardised method of coding works extremely well. Figure 5-2 shows the method of coding developed by this thesis. The proposed standard format allows for rapid consultation of the pin flags based on the standardised placement of information.

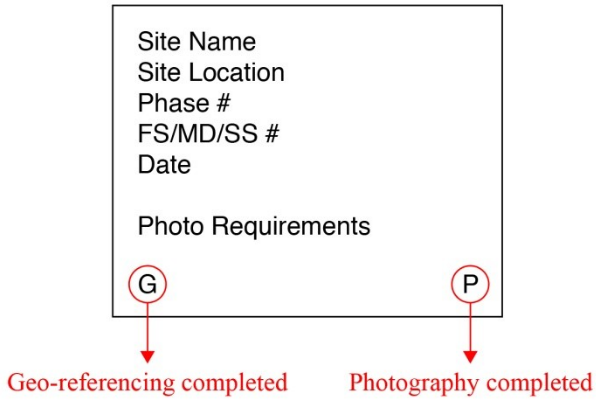

Figure 5-2: Artefact-specific information included on pin flag during Phases IIa and IIb (Author). The standardised format provides quick evaluation of artefact-specific information which, when expanded across all artefacts observed, assists in expediting site surveys. See Section 5.2.2.5 for the use of FS/MD/SS numbers.

The georeferencing team follows close behind the beaters and records individual artefact locations using both the GNSS unit's internal memory and a paper log. The duplication of location recording ensures redundancy of the georeferencing data. Additionally, the georeferencing team conducts an abbreviated analysis of the artefact for any visible part number, manufacturers' stamps, or component which will need to be photographed, noting special instructions on the pin flag. Pin flag instructions should not be overly detailed; the objective is to make follow on teams aware of artefacts' attributes using unambiguous abbreviations. Writing *Fire Dmg* or *Part Stamps*, for example, notifies the georeferencing and photography teams that evidence of fire damage or more than one part stamp can be seen on the artefact. Alerted by the notations on the flags, the follow on teams know that those features should be located and photographed prior to moving on. The simple absence of notation can indicate that no additional characteristics are evident; however, the use of a null return abbreviation can greatly minimise misinterpretations. This thesis used *NAC* on the flags to indicate that no additional characteristics were observed. Artefacts should not be lifted if legal permission to do so has not been obtained. If artefacts are lifted, care should be taken to replace them 'as found' for subsequent photography. Especially important artefacts, in the georeferencing team's judgment, should be left *in situ* for photography and recording. Finally, the georeferencing team should write the assigned artefact Field Specimen [FS] Number on the pin flag. Writing the artefact's FS Number and associated photography requirements on the pin flag allows for non-line-of-sight communication between the georeferencing and photography teams.

The photography teams are the last to move through the survey area. Consulting the pin flag, the photography teams take photographs of each artefact showing its most important characteristics. At minimum, a photograph of the artefact accompanied by a completed photo board,[1] north arrow, scale and the relevant pin flag should be taken but additional photographs are recommended as additional photographs can be useful in post-survey analyses. Additional photographs usually include locating photographs showing the artefact in the wider landscape, a general photograph of the artefact without the photo board, photography of all four sides of the artefact and a vertical or near-vertical photograph. The vertical/near-vertical photograph can be taken with the initial photo board image. Additional photographs of attributes (part numbers, manufacturers' stamps, wear marks, attachment points, evidence of fire or post-depositional tampering, corrosion, etc.) identified by the beater or georeferencing teams are then photographed. All photographs, regardless of whether they include the photo board, should be accompanied by an appropriately sized scale. Before moving to the next artefact/pin flag, the photography teams mark on the pin flag that artefact photography was completed. If a pin flag collection team is in operation, the photography teams may leave the pin flags in place. If no flag collection team is being used, the photography teams can collect an artefact's pin flag after completing photography or the whole field team can collect the pin flags following the completion of the surveys.

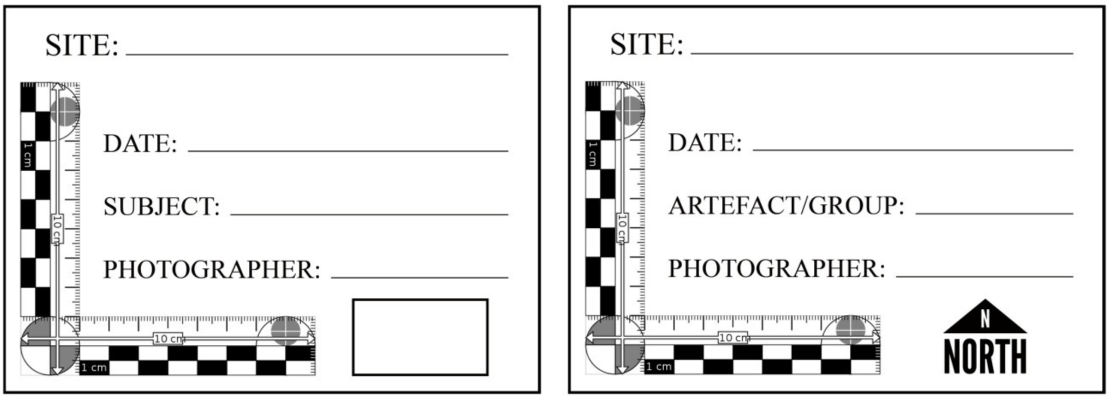

Figure 5-3: Example of the A5 size PAAR Methodology disposable photo boards (Author). When printed on waterproof paper, disposable photo boards provide a lightweight, smear-proof, scale-ready photo board which performs extremely well. The site name, which includes the phase number, are usually completed prior to undertaking a survey as they normally will not change in the field. Extra, blank boards are always taken as a back-up/extra supply.

[1] While push letter or slate photo boards, as used by much of the archaeological community are acceptable, the large number of artefacts located at aircraft crash sites (necessitating the changing or erasure of letters/numbers), the difficult terrain (where their bulk/weight can be tiresome), and inclement weather (which may smear chalk/dry erase markers) can make their repetitive use wearisome. It is recommended that disposable photo boards, a technique employed by forensic technicians (e.g., Gardner 2012: 149), be utilised instead. Figure 5-3 is an example of the disposable photo board created for this thesis.

The use of an aircraft cutaway diagram to record identified aircraft components in real time is not critical but may be useful on larger sites where understanding the distribution of material is helpful to establishing preliminary site boundaries. The aircraft diagram can be given to any member of the field team. Completion of the diagram does not require the labelling of individual components with specific FS Numbers. As proven by the ICAO, the simple shading of positively and provisionally identified parts is sufficient (ICAO n.d.: 2.3).

The proposed survey methodology can be successfully employed using an absolute minimum of two or three people but a working minimum of six people (2 per assignment) is preferred.

5.2.2.5 Field Specimen [FS] and Metal Detector [MD] Contact Numbering

The numbering of artefacts is critical to maintaining archaeological records both in the field and during subsequent analysis. A unique identifier (FS for Field Specimen and MD for Metal Detector) is assigned to each artefact. It is proposed that FS/MD Numbering be assigned based on the number of georeferencing teams in operation. Projects utilising a single georeferencing team begin artefact numbering with FS 001.01 or MD 001.01, increasing numbers as required. Individual artefacts within artefact groups are identified using the numbers to the right of the decimal. An artefact group with 10 artefacts is thus numbered FS/MD 001.01- 001.10. With two or more georeferencing teams in operation, FS/MD numbering must be allocated so as to not create record confusion through duplicate numbering. It is suggested that FS/MD Numbers be allocated in blocks of 250 as the large allocation enables georeferencing teams to move across the site without having to repeatedly return to the site office for additional allocations. Under the proposed allocation system, for example, two georeferencing teams would be allocated the following FS/MD Numbers: Georeferencing Team 1 would be allocated FS Numbers 001.01-250.01 and MD Numbers 001.01-250.01 while Geo-referencing Team 2 would be allocated FS Numbers 251.01-500.01 and MD Numbers 251.01-500.01. Should a team exhaust their initial allocation, an additional 250 number block would be allocated. In this case, the next block allocated would be FS 501.01-750.01 and MD 501.01-750.01. All initial and subsequent allocations are noted in the site FS/MD log.

5.2.2.6 Artefact Classification

In the proposed PAAR Methodology, artefacts are sorted into three general groups: diagnostic, nondiagnostic(diagnostic) and nondiagnostic. While every effort should be made to identify all artefacts, the use of the three groups allows for rapid sorting of artefacts both in the field and during post-field analysis. Diagnostic artefacts are artefacts which are confirmed as specific parts. Nondiagnostic(diagnostic) artefacts are artefacts which, although currently unidentified, retain specific characteristics which are expected to yield positive identification in the future. Nondiagnostic artefacts are unidentified artefacts which retain few unique characteristics to aid identification and, therefore, are unlikely to be identified in the future. The designation given to an artefact in the field or laboratory is not permanent and can be revised as research progresses or as a site/project is revisited. Indeed, the three classifications reflect the wealth of primary documents available to archaeologists researching 20th century sites. The use of a three level identification system provides greater flexibility than the diagnostic/nondiagnostic system regularly employed in archaeological analysis (e.g., lithics and ceramic analysis) and is reflective of the potential for post-recovery artefact identification through the use of manufacturer and operator catalogues.

5.2.2.7 Site Datums and Georeferencing

The georeferencing of surface scatter, subsurface anomalies and excavated material comprises one of the most important aspects of data management. Indeed, removing an artefact from its context without recording its specific provenance results in the loss of significant information. Initial attempts to utilise a physical site grid and baseline survey (such as that utilised by TIGHAR) were unsuccessful. The expansive boundaries of aircraft wreck sites surveyed during Phase IIa/b (sometimes over 0.5 kilometres along one axis alone) made ensuring grid line accuracy and tension unfeasible. Base line surveys were similarly problematic as the large site size magnified variance errors over distance (parallax errors and bearing drift), thereby increasing the potential for inaccurate measurements. Therefore, a wholly digital methodology was employed for Phase IIa/b with site boundaries, transects and grids loaded onto handheld GNSS receivers using ArcMap (though the same effect could be completed using open source GIS or mapping applications such as Google Earth). The abandonment of a physical datum and transects/grid not only expedited the recording of sites but provided positioning data equal to that gained during an initial trial using physical recording strategies.

To assure that the proposed PAAR Methodology could be widely understandable and deployable by both professional and avocational archaeologists, the World Geodetic System 1984 [WGS84] and the UK OS National Grid systems were used to record artefacts, features and sites. The use of a metric cartographic standard (instead of degree-based latitudinal and longitudinal measures) allows for the easy subdivision of the site as well as the application of easting and northing values to all finds and features. In countries where no metric national grid is in regular use, the site boundary can be integrated with the WGS84 system.

While cost-efficient and easily acquired, handheld personal GNSS units vary in accuracy depending upon current atmospheric and topographic conditions as well the brand in use. Atmospheric interference can generate erroneously long data transmission times which distort the satellite-to-handheld unit clock comparisons and, thus, shift the unit’s perceived location. However, experience on case study crash sites has shown current, more sophisticated handheld GNSS units produce satisfactory results provided they come equipped with basic differential GPS [DGPS] such as the US WAAS or EU EGNOS systems.

No matter the system in use, handheld GNSS receivers produce less accurate results than do professional grade GNSS receivers and EDMs (Ainsworth and Thomason 2003: 8-11, 17). English Heritage contends that handheld GNSS receivers cannot be expected to achieve better than 10 metre accuracy (Ainsworth and Thomason 2003: 3, 8-13). However, extensive field trial experience has shown that current, higher-end navigation receivers generally receive a location accuracy error of less than eight metres. An open horizon, such as that observed on a flat plane or on a hill/mountain summit consistently boosts accuracy to less than three metres. Surveys conducted in the course of this thesis using a Garmin Dakota 20 receiver (operating system software version 4.00, GPS software version 4.52) and an open horizon resulted in readings with independent error radii well below the 8 metre upper average. It is essential to note that independent navigation-grade GNSS readings do not experience consistent error radii from point to point and cannot be simultaneously adjusted, as a group, to fit existing map locations. Therefore it is essential that each point have its independent error recorded.

5.2.2.8 Data Management (including phase databases)

Methodological information relating to the processing and storage of Phase IIa field data is discussed in detail in Section 5.2.6.

5.2.3 Phase IIb Detailed Data Survey

A Phase IIb detailed data survey is the closest one can get to the excavation of an aircraft without opening test units/trenches. A basic Phase IIb detailed data survey encompasses a systematic pedestrian survey, a systematic metal detector survey and a shovel test probe survey (if excavation is legally possible). All of these archaeological tools work towards the generation of map overlays to locate archaeologically sensitive areas and focus Phase IIIa/IIIb recoveries.

In order to accomplish a Phase IIb survey, the construction of a preliminary site grid is required. Though the preliminary grid will be further refined for use in Phase IIIa/IIIb recommendations and/or work, its establishment is critical to full area coverage during Phase IIb surveys.

5.2.3.1 Grid Setup

While investigations may occur on terrain and sites of varying complexity and size, the core aspects of surveys remain consistent for airplane crash site studies. First, the boundaries of the site are established. As stated previously, a site's boundaries are established through Phase IIa pedestrian and metal detector surveys. The unified scatter plot rendered from the survey data is bounded by a maximum boundary and a best fit rectangle (Figure 5-4).

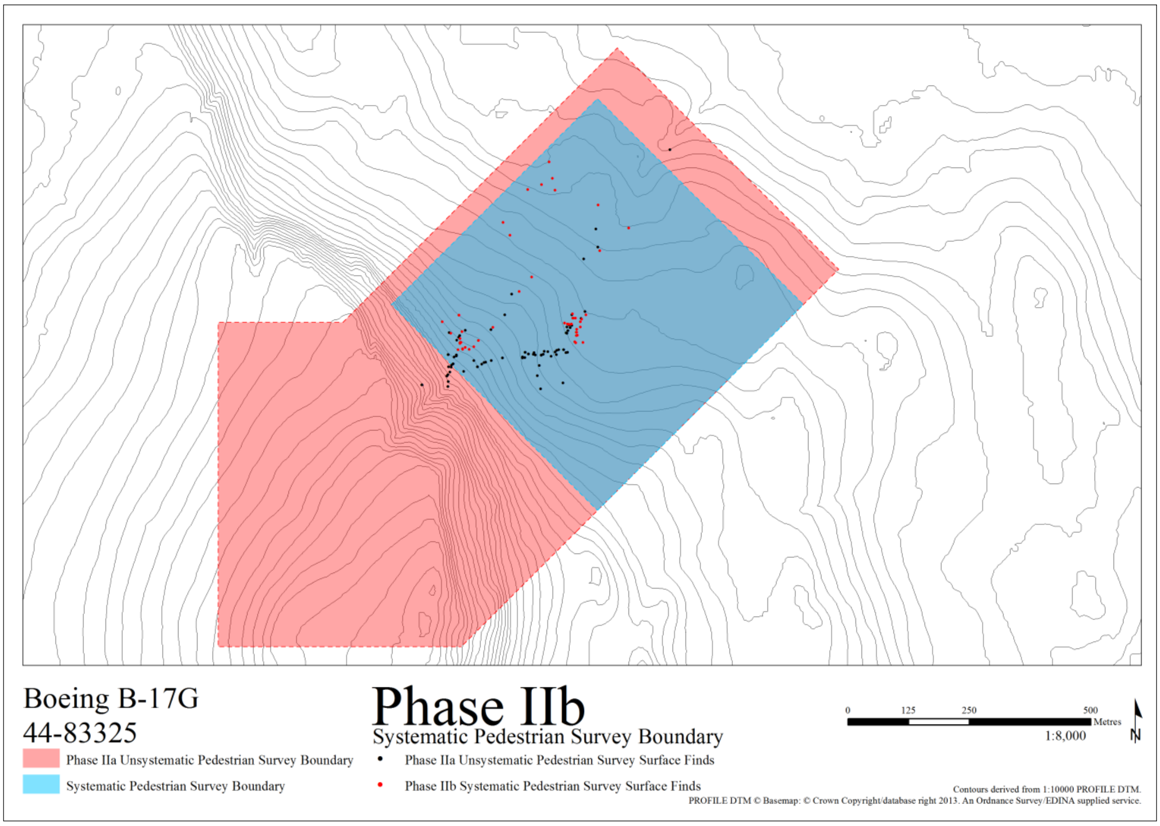

**Figure 5-4: Example of a Phase IIa-derived maximum boundary and best fit rectangle (Crown Copyright/database right OS 2013a; Author).
This particular example is of B-17G 44-83325 (Isle of Skye).**

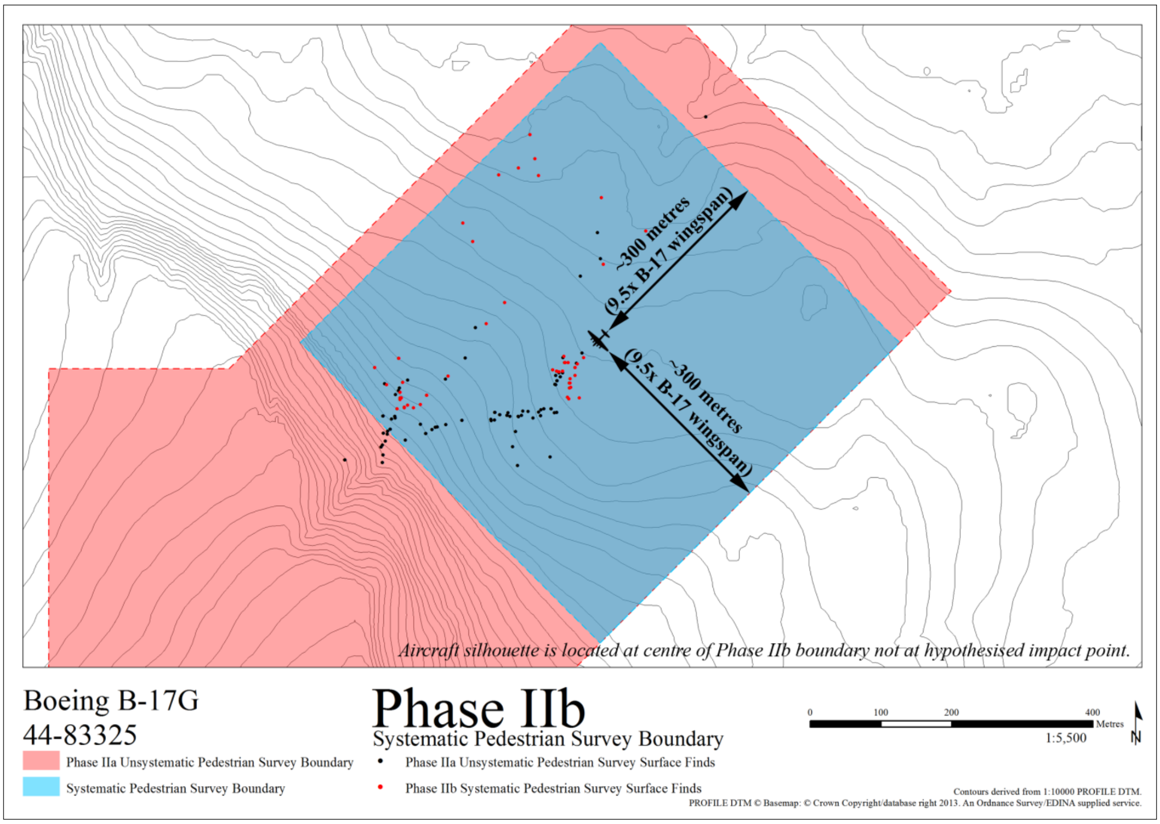

**Figure 5-5: Example of minimum Phase IIa-derived best fit boundary dimensions in practise (Crown Copyright/database right OS 2013a; Author).
This example, the survey of B-17G 44-83325 (Isle of Skye), utilised dimensions well beyond the minimum recommended.**

While the imposed maximum site boundary varies in size according to the aircraft involved, the boundary should be at least twice the size as the targeted aircraft's maximum dimensions.[2] Making the site dimensions twice the dimensions of the wrecked aircraft site boundary provides appropriate minimal coverage as well as a comfortable buffer zone (Figure 5-5).

Once the point of initial impact has been geospatially located and marked, the survey is divided equally into smaller squares. The smaller squares can vary in size according to the complexity and size of the site. However, the grid squares should be no larger than 10 metres by 10 metres and no smaller than 1 metre by 1 metre. The 10 metre maximum and 1 metre minimum square size limits the grid's complexity, utilises the established 10 metre transect interval (used during Phase IIb surveys), aligns with the STP interval, integrates well with varying international excavation unit sizes (McMillon 1991: 48; Carmichael *et al.* 2003: 51-52; Drewett 2011: 88), and is easily used as the base excavation grid for test unit and test trench investigations. The individual squares are identified by their respective southwest corner.

5.2.3.2 Systematic Pedestrian Survey

As with the Phase IIa unsystematic pedestrian and metal detector surveys, the field team is divided into three groups: beating, georeferencing and photography. The beater again moves in the forefront, marking the location of surface artefacts and subsurface anomalies using pin flags. Due to Phase IIb utilising a systematic survey methodology, as opposed to the unstructured survey technique utilised in Phase IIa, the Phase IIb survey begins in one corner with the field team covering each transect in a serpentine fashion (Figure 5-6). The serpentine pattern, as opposed to a single direction or circular patterns, ensures full coverage with a minimum of time and energy expenditure (Banning 2002: 89-92).

The pedestrian survey and metal detector surveys are conducted using 10 metre wide transects. While any appropriate width between 3 and 30 metres is viable, a width of between 3 and 10 metres is more practical and productive (Banning 2002: 41, 198). The 10 metre distance was selected as it allows for focused coverage of a given swath while simultaneously decreasing the number of working transects and easily integrating with survey and excavation techniques. If finances and scheduling allow, a second transect

[2] An aircraft's maximum dimension is the larger of the calculated distances when an aircraft is measured from nose to tail and wingtip to wingtip.

survey perpendicular to the first is recommended. The perpendicular survey allows the field team to observe the site at two distinct angles and may yield artefacts not visible during the first pass (Pollard 2009: 191-192; Pratt 2009: 7; Drewett 2011: 43).

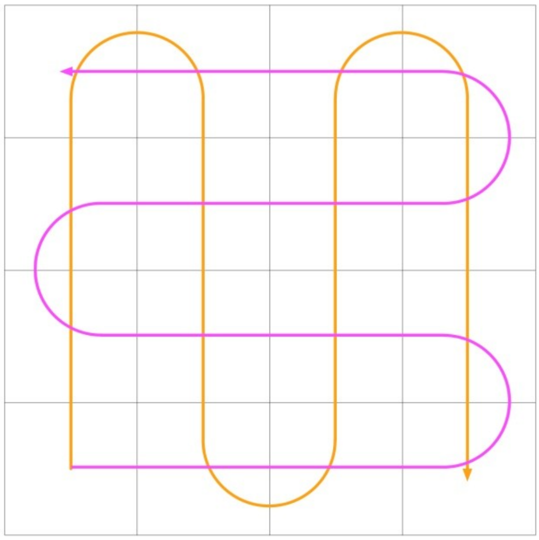

Figure 5-6: Serpentine survey methodology starting in the SW corner (Author). The overlapping 2-2-90 methodology ensures full coverage of the area surveyed.

5.2.3.3 Systematic Metal Detection Survey

The modern metal detector is extremely useful for identifying metallurgical sub-surface anomalies at aircraft wreck sites. Metal detectors provide the investigative team a highly mobile geophysical survey technique with real-time results. Such results focus an investigation's efforts on valid targets and identify artefact-sterile locations.

Metal detectors come in a variety of sensitivities. Most commercially available metal detectors come with a general purpose, medium coil (7-9 inches or 18-23 centimetres in diameter) which proves adequate for identification of most average sized, medium depth targets. The substitution of the general purpose coil for a larger variant (10-18 inches or 25-45 centimetres in diameter) allows for the detection of deeper targets. While the larger coil identifies artefacts to a greater depth, it excludes smaller artefact returns, considering them to be background noise. Conversely, smaller metal artefacts are more readily identified using a small coil (approximately 5 inches or 12 centimetres in diameter), however depth of penetration is less than with a larger head (Cheetham 2005: 83-84; Dupras *et al.* 2006: 62). Indeed, signal strength varies inversely to depth; this inverse relationship renders the ability to discriminate between deep, large objects and shallow, small objects difficult (Cheetham 2005: 83-84; Albright 2012: 100).

Unfortunately, recent forensic research indicates that the ability of medium coil metal detectors to located buried metallic artefacts is limited to rather shallow depths. Research carried out by the University of Central Florida and the Orange County Sherriff's Office, Florida using three material classes (firearms, miscellaneous weapons and scrap metal) demonstrates key problems with metal detector reliance. For their two year study, Rezos *et al.* selected 16 firearms (ranging in size from 119-1067mm in length), 10 miscellaneous weapons (ranging in size from 11.6-81mm in length) and 6 pieces of scrap metal (ranging in size from 47.7-68.5mm in length) (2010: 122-124). A strong correlation existed between the size of a firearm and the maximum depth detected. Interestingly, neither the miscellaneous weapons nor the scrap metal showed the same correlation. Indeed, small and medium miscellaneous weapons, such as a police baton and a claw hammer, were detected at 45cm and 35cm maximum depth, respectively. Larger miscellaneous items, such as a Phillip's head screwdriver, were only detected at the rather shallow depth of 20cm. Perhaps most important for the study of aircraft wreck sites, the scrap metal displayed no size-to-depth correlation. Indeed, medium and small artefacts were identified at the greatest depth (40-45cm maximum depth) while the largest and smallest scrap metal specimens were the shallowest detected objects (25-30 cm). While the study shows that metallic composition does not adversely affect detection, the study found that surface area, not size, impacted the depth of detection (Rezos *et al.* 2010: 125-126). As such, investigators of aircraft wreck sites who utilise metal detectors as a primary geophysical tool must be aware that a medium coil only detects metallic objects to a depth of 10-55 cm (depending upon the programmed sensitivity) and favours large surface area objects (Cheetham 2005: 83-84; Rezos *et al.* 2010: 125-126).

Overcoming the established drawbacks of metal detector use requires a proven, systematic methodology. A modified version of Richard Green's (Historic Archaeological Research) 2-2-90 metal detection methodology (Pratt 2009: 8) is appropriate for use in aircraft wreck site investigation. Dr. Michael Pratt describes Green as having refined "detection methodology in an effort to develop a standardised, intensive approach which permits comparisons among diverse areas of a battlefield and between battlefields" (2009: 7). In developing a standardised methodology for the use of metal detectors on large scale battlefield sites, Green deployed his methodology on three battlefield surveys with positive results (Pratt 2009: 7). In his 2-2-90 methodology, Green dictates that 15 x 15 metre survey squares be established in areas of interest. Metal detector sweeps are conducted along overlapping transects to ensure full coverage. Following completion of the first survey, a second operator, using a different metal detector, re-surveys the same grid at 90-degrees to the first survey. In this manner, the survey grid is effectively covered "by two operators using two different metal detectors and at a 90-degree angle of approach" (Pratt 2009: 8).

While Green presents an ideal methodology (Pratt 2009: 7-8), the dimensions of many aircraft archaeological surveys involve areas much larger than 15 metres x 15 metres. Similarly, archaeological projects with limited financial resources may not be able to employ more than one metal detector. As such, a modified version of Green's methodology is suggested. It is recommended that the metal detector survey be conducted by beaters using transects and the serpentine pattern established for the pedestrian survey. The systematic metal detector survey can be conducted concurrently with the pedestrian survey if scheduling and/or budgetary considerations require. The area surveyed often will be substantially larger than the 15 metre x 15 metre survey units proposed by Green. Nonetheless, the same methodological practises apply, just in an enlarged form. Following completion of the first metal detector survey, a second operator (when available) should re-survey perpendicular to the original transects with a second metal detector (where available). For crash sites located in remote environments, it can be presumed that all metallic returns received during metal detection are aircraft-related. Naturally, this assumption proves false in direct relation to the amount of modern detritus commingling with site debris. Even so, these false positives should not affect the larger image generated by artefact scatter analysis as their numbers usually are limited.

5.2.3.4 FS and MD Numbering

All surface artefacts and metal detector returns should be marked with a pin flag. Field testing has shown that continuation of the Phase IIa pin flag labelling methodology is useful during Phase IIb. As with Phase IIa, FS and MD numbers are allocated to field teams in blocks of 250.

5.2.3.5 Artefact Collection

If legally permissible, peripheral or isolated artefacts can be collected during the survey (along with the pin flags) by a dedicated pin flag team or the photography team. Alternatively, the recorded artefacts can be collected after the survey is completed during removal of the pin flags. Such recovery accomplishes two goals. Firstly, it allows for classification of the metal detecting returns and possible identification of the airframe's orientation prior to more thorough investigation. Secondly, limiting artefact recovery to peripheral and isolated artefacts/returns leaves more concentrated artefact scatters *in situ* for controlled excavation. Where practically feasible, artefacts should be stratigraphically excavated with the artefacts photographed *in situ* and their angle and position in the ground recorded via drawn plans. It is imperative to add a depth measurement to the already mapped coordinate data prior to back filling. Failure to provide depth information, like failure to georeference the artefact's location, will limit its informative potential. In many instances the artefacts recovered will be of small enough size that they will come away with the removed soil. This does not pose a methodological problem as the primary concern for the survey of aircraft wreck sites is the overall distribution pattern. Like the analysis of bullet casing scatters (e.g., Scott *et al.* 2000), it is not the orientation of the artefact when recovered that is of primary significance but rather its make, its model and its relationship to other finds that provides a clearer understanding of site dynamics. Artefacts not to be transported for study in the laboratory should be photographed and weighed in the field. The weighing of non-transported artefacts is instrumental in establishing how much of the plane has been recovered. Due to the violence of aircraft impacts, many artefacts are disfigured to the point that refitting is impossible. As such, the total weight of artefacts, as established via field and laboratory analysis, is one of the only means by which to establish the percentage of the aircraft recovered. If the artefact's condition or composition necessitates, stabilisation should begin immediately (see section 5.2.7).

5.2.3.6 Photography Requirements and the Use of Aircraft Cutaway Diagrams

The individual photography requirements are identical to that employed during Phase IIa. Phase IIb field teams may find aircraft cutaway diagrams, as utilised during Phase IIa, to be equally beneficial during Phase IIb surveys. For specific information related to photography recommendations and the use of aircraft cutaway diagrams to ascertain and record component installation location see *Phase IIa: Field Team and Assignments*.

5.2.3.7 Artefact Bag Labelling System

A standardised artefact bag labelling system is suggested in order to maintain data integrity during artefact collection and storage. The proposed methodology labels artefact finds bags using the method shown in Figure 5-7.

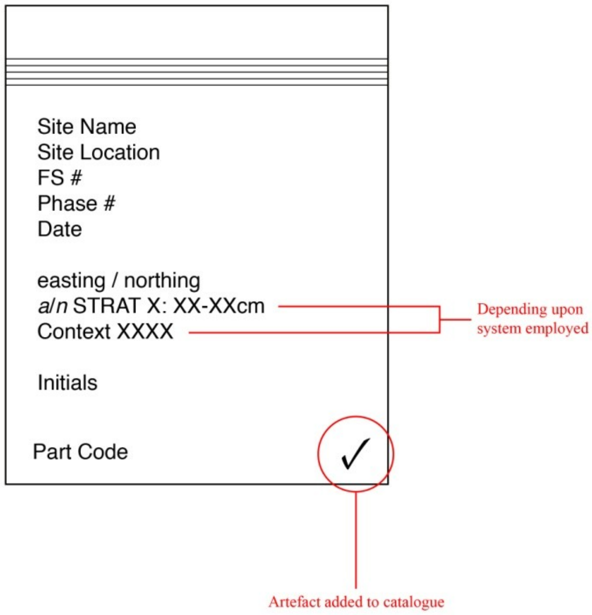

Figure 5-7: Bag labelling standard utilised for PAAR Methodology (Author).

5.2.3.8 Shovel Test Probes

Shovel test probes [STPs] can only be undertaken if it is legal to excavate. Archaeologically, STPs are seen as a site surveying technique (Roskams 2001: 48-49; Neumann and Sanford 2010: 149; Neumann *et al.* 2010: 105-107). However, the act of breaking ground is legally indistinguishable from excavation (Neumann and Sanford 2010: 149) in UK-based aviation archaeology (*Protection of Military Remains Act 1986*; UK Ministry of Defence 2011: 2). If it is legal to undertake STPs, the results can be extremely beneficial for mapping basic sub-surface strata and artefact distributions (Greene and Moore 2010: 57-58; Neumann and Sanford 2010: 134; Renfrew and Bahn 2012: 95). Should they be carried out, STPs can be placed at any fixed interval (Neumann and Sanford 2010: 134, 149-150; Neumann *et al.* 2010: 105, 121-122); this thesis advocates a minimum of 50 metre intervals and a maximum of 10 metre intervals in order to provide both low and high resolution options. STPs are usually no more than one metre square (Renfrew and Bahn 2012: 95) with most approximately one-quarter metre by one-quarter metre in dimension (Roskams 2001: 49; Carmichael *et al.* 2003: 51; Neumann and Sanford 2010: 149). Any STP which contains relevant artefacts should be noted. If deemed advantageous, radial investigations [RI] are undertaken through placing further STPs in each of the cardinal directions a limited distance away from the positive STP (Neumann and Sanford 2010: 151; Neumann *et al.* 2010: 123) (Figure 5-8). The use or disuse of RIs should be decided prior to conducting the survey, applied to the whole of the phase and the decision substantiated in site reports. The STP survey methodology applies to any RI undertaken. Each RI should be given a unique STP number, photographed, georeferenced and any artefacts recovered given a unique FS number.

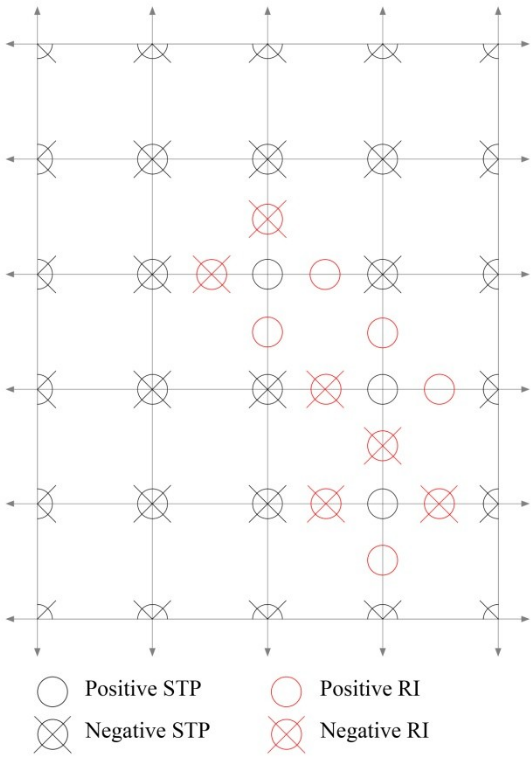

Figure 5-8: Phase IIb STPs, if legally permissible, can help further define archaeologically sensitive areas (Author).

5.2.3.9 Excavation Forms

When stratigraphic excavation is undertaken during Phase IIb, such as during metal detecting and STPs, the proposed methodology advises the recording of observed contexts and completed units/STPs using standard recording sheets. Current field-trial surveys and excavations utilised University of Glasgow Archaeology recording sheets; however, equivalent versions would fulfil much the same role.

5.2.4 Phase IIIa Exploratory Excavation

Should a Phase IIb detailed data survey show a crash site to be of sufficient interest to warrant further investigation, a Phase IIIa exploratory excavation is undertaken. While standard stratigraphic excavation practise is generally well defined within the archaeological profession—indeed it is one of the first chapters covered in almost every general archaeology textbook (Barker 1993: 110-112; Greene and Moore 2010: 89-147;

Drewett 2011: 8-12, 99-118; Renfrew and Bahn 2012: 104-120)—the use of stratigraphic excavation in avocational aircraft archaeology is consistently absent.

The excavation of an aircraft is a complex operation which, if undertaken in an unsystematic manner, provides an overwhelmingly large artefact assemblage. An example of the potential for site-assemblage obfuscation is illustrated by the supercharger for a Rolls Royce Merlin engine. This single part, depending upon the variables surrounding the airframe's impact, can be encountered as differing orders of artefact. On the one hand, the supercharger unit is one complete artefact with a specific manufacturer/military part number and installation location. However, the supercharger unit contains many thousands of individual parts each with its own part identification number and installation location and, thus, potential identification as an individual artefact. Component rupture may split the supercharger into individual artefacts or artefact fragments. Investigators who ignore the information gleaned from artefact-artefact and artefact-stratigraphy associations omit critical evidence. Modern archaeological excavation practises must be modified and standardised specifically for use on aircraft sites. A specific event chain, readily deployable by all investigation teams (professional and non-professional alike) yet able to generate information of such high quality as to be useful to governments, NGOs and professional researchers must be developed. In order to produce the most informational and financially effective scaled methodology, standard archaeological practise has been synthesised with proven air accident investigation methodologies to produce an aircraft specific, Phase IIIa/b excavation methodology.

5.2.4.1 Test Units and Test Trenches

Although involving physical excavation, appropriate Phase IIIa exploratory excavations attempt to limit site disturbance as much as possible. To this end, a Phase IIIa exploratory excavation should only sample areas suspected to be crew duty stations and/or engine nacelles. Crew duty stations and engine nacelles are targeted as they provide a concentration of prospective diagnostic artefacts whose locations can assist in orienting the aircraft within the larger landscape. The proposed Phase IIIa exploratory excavation methodology uses one metre by one metre units to systematically or judgmentally sample archaeologically sensitive areas, suspected crew duty stations and suspected engine nacelles as located through the pedestrian surveys, non-invasive investigations and STPs. Additionally, judgmental sampling using test trenches can be deployed in areas already confirmed to be crew duty stations or engine nacelles to conduct limited assessments on artefact survivability. Using metre units and test trenches maximises data recovery while limiting the amount of the wreck site exposed and/or altered.

Test trenches are long narrow trenches which allow archaeologists access to a cross-section of a given site in order to make note of its stratigraphy, archaeological features and archaeological deposits (Joukowsky 1980: 146; Barker 1993: 70-71). The use of test trenches limits wreck site disturbance while maintaining associations between sub-surface artefacts. The test trench must be placed judiciously and should only be placed on engine nacelles and/or crew duty stations when they are directly related to valid research questions. Use of small test trenches, such as 2x5 metre or 2x10 metre trenches, limits wreck site disturbance. The 2x5 and 2x10 metre advised dimensions are not arbitrary but are selected so as to allow the extension of Phase IIIa one metre by one metre test units into Phase IIIa test trenches, and Phase IIIa test trenches into the internationally standardised 5x5 metre or 10x10 metre excavation units used in Phase IIIb.

Once an area has been confirmed to be a crew duty station and/or engine nacelle, that portion of the Phase IIIa excavation is closed so as to preserve as much of the wreck site as possible for future research. It is essential that Phase IIIa excavation work be meticulously planned prior to its commencement. For the most part, buried artefacts have established a corrosion equilibrium with their surrounding soil environment. Therefore, great care must be taken to limit the amount of material exposed. Once the excavation unit is opened, archaeologists have disrupted the natural artefact-soil environment equilibrium and expedited artefact decay becomes an ever present issue (Florian 1987: 23; Sease 1987: 1-2; Hobbs *et al.* 2002: 9).

Once a test trench is opened, the trench should be dug using both horizontal and vertical controls. Horizontal control, on the small scale, is manifest in the division of trenches into one metre by one metre squares. Complying with standard archaeological practise, the trench datum is located in the SW corner (Figure 5-9). Finds, contexts and features either can be georeferenced using a survey-grade GNSS receiver or associated with the trench datum using offset measurements. The integration of trenches into the Phase IIb site grid provides larger horizontal control (Joukowsky 1980: 139).

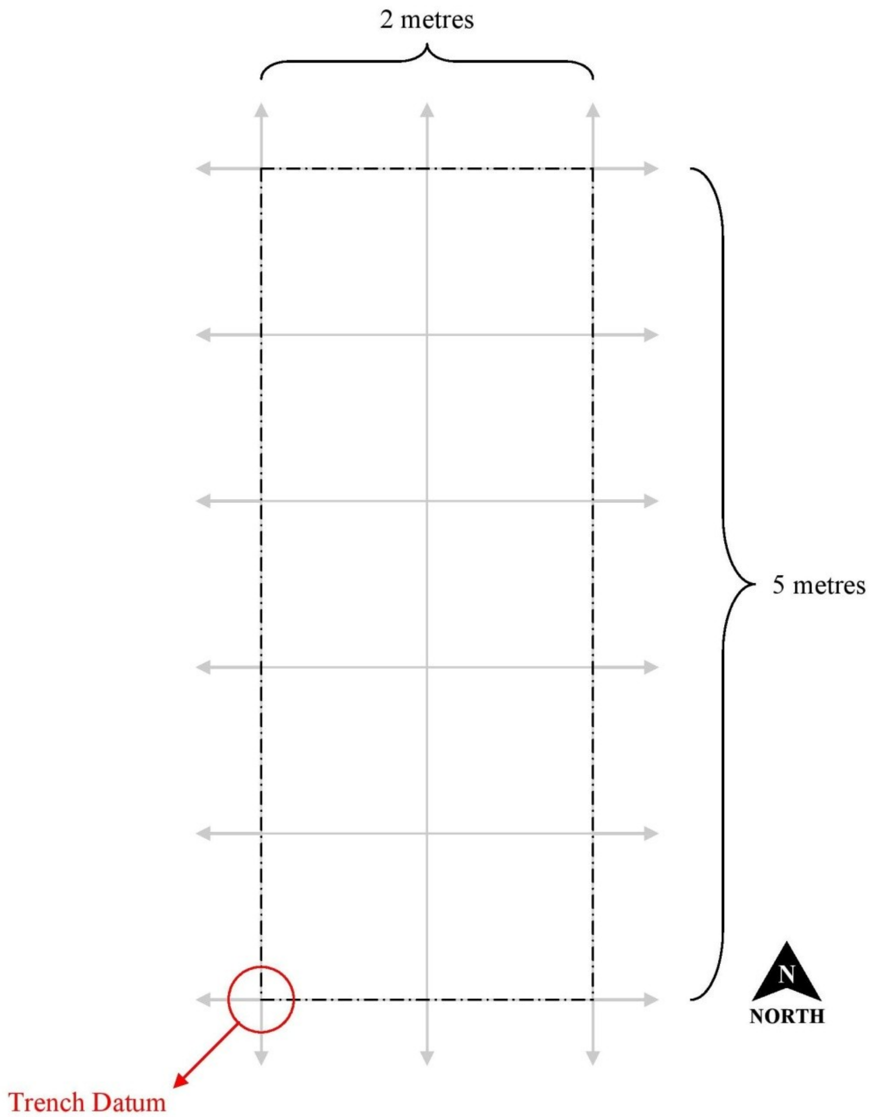

Figure 5-9: The standard use of a SW datum allows for trench finds to be integrated into the larger site grid (Author).

Vertical control is implemented via the stratigraphic method using both natural or arbitrary strata and single context recording (Carmichael *et al.* 2003: 53; Balme and Paterson 2006: 104). Natural strata should follow the natural contours of sub-surface soil topography with a unique number attached to each discrete context encountered. Arbitrary strata are set based upon the particulars of the site (such as the depth of homogenous soil) and can vary depending upon soil depth and excavation objectives (Roskams 2001: 213-214; Carmichael *et al.* 2003: 53, 55; Balme and Paterson 2006: 104). The measuring, drawing and photographing of the trench floor and associated artefacts (where methodologically and topographically feasible) should be conducted when either a new arbitrary or natural strata is uncovered (Carmichael *et al.* 2003: 55-56; Balme and Paterson 2006: 104).

Due to the topography of certain aircraft wreck sites (in particular, mountain tops/slopes and low-lying terrain), strict vertical control may not be feasible. The scree fields associated with mountain slopes are often a surface indicator of shallow soil beds. Rocky and/or shallow soil beds limit aircraft penetration and enhance soil erosion. As such, deep excavation into scree field bedrock is usually archaeologically unproductive. Similarly, excavation in low-lying terrain frequently uncovers boggy ground caused by a naturally low water table and/or surface water pooling. Boggy ground creates soil lacking structural stability. A trench which is structurally non-self-supporting creates a variety of problems, including recurrent sloughing (the continual backfilling of the working area via wall sliding) and quick/boiling condition on the trench floor (quick/boiling condition can vary widely from soupy soil to thicker paste-like qualities) (Richardson 2010: 29-31, 45-47; Hayslip 2013: 173). Continuous backfill and quick/boiling condition obscure both the artefact targets and the natural strata.

In locations with either shallow or extremely fluid soil the use of vertical control becomes unproductive, serving only to create crater-like holes rather than defined units/trenches. In these unfavourable conditions the investigator must rely upon either the use of boards and water pumps to shore up unit and trench walls and keep the working area free of standing water or use horizontal control to retain and reconstruct generated data (Roskams 2001: 104-105, 107). As there is no reliable manner when not using shoring in which to absolutely measure artefact depths due to rock and/or soil shift, artefacts must be removed individually and sequentially; excavation square and order of removal must be recorded for each artefact. Relative artefact depths are recorded and reconstructed using the artefact-to-artefact super-positional data. While not as accurate as the carefully measured vertical control processes, the horizontal control's relative super-positional process provides some useful data.

5.2.4.2 FS and MD Numbering

As with Phase IIa/b, FS and MD numbering continues to be allocated to field teams in 250 number blocks during Phase IIIa.

5.2.4.3 Field Team Assignments

Field team assignments during Phase IIIa differ from Phase IIa/b and are closely related to those utilised on most archaeological sites. There are a number of ways to structure field team assignments during Phase IIIa/b (Collis 2001: 44-45). The hierarchical design used in this thesis is similar to Collis's Structure D, a system commonly in use at archaeological sites (Collis 2001: 45). Each test unit or test trench is overseen by a trench supervisor. The trench supervisor may direct one or more archaeologists working on a unit/trench. A grouping of test units/trenches is overseen by a site supervisor. Depending upon the size of the site and the number of test units/trenches opened, there may be one or several site supervisors on site. The entirety of the site is overseen by the site director. The entirety of the project is directed by the principal investigator (also commonly called the project manager). While there may be several site managers on larger projects, the author acted as both site director and principal investigator for all sites discussed in this thesis.

5.2.4.4 Photography

Phase IIIa follows standard archaeological photographic procedure. Opening photographs of the trench site should be taken prior to soil penetration. During excavation, photographs are taken to document each successive natural or arbitrary strata. Photographs are also used to record individual features, contexts and artefacts as they are uncovered. Following completion of the test unit or test trench, closing photographs are taken of the clean floor and all trench walls. As in Phase IIa/b, photographs are taken both with and without photo boards. An appropriately sized scale and north arrow are present in all photographs. Additional working shots can be taken to document terrain and excavation practice.

5.2.5 Phase IIIb Full Data Recovery Excavation

A Phase IIIb excavation exemplifies the project phase most closely associated with archaeology by the general public. A full data recovery phase, Phase IIIb necessitates a comprehensive excavation of a wreck site. The methodologies employed for Phases I-IIIa are paralleled in Phase IIIb but on a larger scale; test units/trenches are expanded into area excavation allowing for the identification, recording and recovery of all aircraft-related artefacts and features. Mechanical excavators may be useful for stripping overburden (JPAC 2010: 8, 34; Neumann *et al.* 2010: 156). However, it is argued that their use should be strictly controlled, be in line with existing archaeological practice and cease once trenches/area excavations are at a level likely to be associated with aircraft remains.

The most archaeologically destructive of all the phases, a Phase IIIb excavation should only be conducted if the wreck site cannot be avoided (Neumann and Sanford 2010;

Neumann *et al.* 2010: 45, 175) or if specific research objectives do not allow for the survey and sampling of the wreck site alone. This condition applies, for example, to the JPAC (JPAC 2010: 36-37) though recent research has sought to limit even the JPAC's archaeological footprint (O'Leary 2014). As the site is destroyed through excavation, a Phase IIIb full data recovery should only be conducted under the direction of one or more trained archaeologists (Joukowsky 1980: 159-160) and should continue to make use of standard stratigraphic excavation practises.

5.2.6 Data Management

The lack of a consistent artefact identification system for airplane wreckage inevitably means the loss of basic information through mismanagement of collected artefacts by enthusiast groups. As stated previously (see Phase IIa recording procedures), optimum preservation of archaeological data requires thoughtful and deliberate recording of finds, along with standardised data archive numbering and terminology. The system usually employed to identify and record artefact provenience is the FS Number. Assigning each artefact a different and unique FS Number establishes recovery location within the site plan. Further identification of individual artefacts by using unique assigned suffixes distinguishes each artefact within the larger Field Specimen group. Normally, FS numbers begin with number one and count upwards until artefacts are exhausted (Joukowsky 1980: 201-204; Neumann and Sanford 2010: 160-161; Drewett 2011: 133-135). Numbers of similar format attached to metal detection finds and soil samples carry the labels MD and SS, respectively. Soil sample and artefact labels additionally contain a level measurement, the geodetic coordinate using easting and northing, the feature from which the material was removed, the date of placement in the finds bag and the initials of the archaeologist who permanently sealed the bag in the field (Joukowsky 1980: 201-204; Neumann and Sanford 2010: 160-161; Drewett 2011: 133-135). Additional entries made during analysis include textual and numeric descriptions and codes describing individual artefact's characteristics including material, method of construction and dimensions.

All archaeological data labelling associated with excavated material entails repeating textual and alphanumeric entries. Integral to successful data archiving either on a personal computer or within a larger data archive service like national heritage bodies (e.g., English Heritage, Historic Scotland/RCAHMS, RCAHMW, Cadw) or the Archaeology Data Service, the construction of a field-oriented database constitutes a primary concern for data management. Uniquely useful in identifying aircraft artefacts are the aircraft-specific parts catalogue codes.

The aircraft-specific spare parts catalogue allows for detailed identification of all parts associated with a specific airframe type. Indeed, all aircraft have parts that are uniquely designed for them alone. The use of the aircraft-specific parts catalogues takes advantage of this fact by adopting these unique coding structures as one of wreck sites' specific artefact descriptive codes. Thus, the use of aircraft-specific spare parts catalogues allows for specific part comparison amongst various sites involving similar airframe types.

Based on the forgoing considerations of standard archaeological excavation methods and airplane specifics, a comprehensive *field-oriented artefact database* can be developed. Such a database lists the following characteristics: site name, the aircraft serial number, primary datum location, secondary datum location (if used), site phase, FS/MD/SS number, FS/MD/SS-referencing datum, easting, northing, the context/feature from which the material was removed, strata and level measurements, the date of placement in the finds bag, and the archaeologist's initials. In addition, the following should be noted in a standardised manner: OS Grid map grid reference/WGS84 coordinate, transect number, unit number, and/or trench number. Following post-survey artefact analysis, the following entries should be added: aircraft-specific spare parts identification code, NTSB part identification code, x-y-z dimensions, weight and artefact descriptions. This wider reaching database constitutes a *unified site database*. Any portion of the field data identification string possessing a null value should be written as XXXX to avoid confusion with existing database code numeration. Consistent use of identification codes preserves historical and geospatial information. Figure 5-10, the field-oriented artefact database table, demonstrates the layout of the proposed database. The *unified site database* is visually similar with additional data added into the column categories supplied.

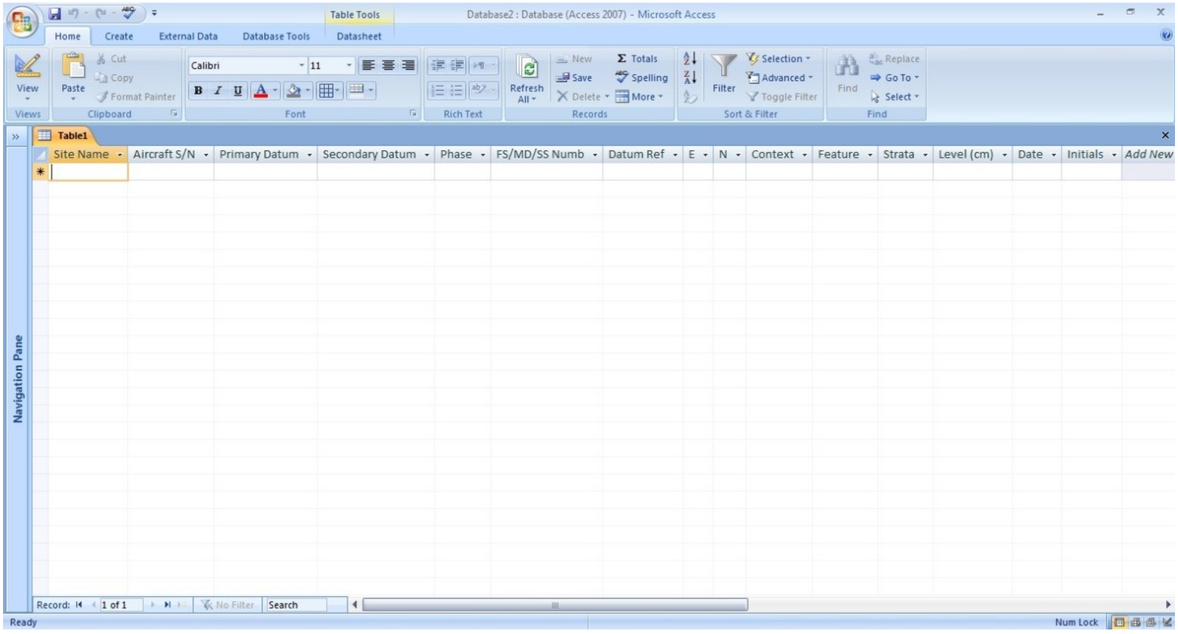

Figure 5-10: Sample field-oriented artefact database table (Author).
Post-excavation data is entered into the visually similar *unified site database*.

Similarly, the completion of written site reports describing the work undertaken, the artefacts/features recorded, the artefacts removed, and site recommendations are critical to documenting aviation archaeological research and managing aviation archaeology wreck sites as cultural resources. Chapters 6, 7, 8 and 9 provide a basic template for aviation archaeology reports. Additional information and/or sections can be added to the basic template, as required.

5.2.7 Artefact Preservation

Aircraft wreck associated artefacts can be conserved using a wide variety of methods depending upon the environment from which the artefact was recovered, the available budget and the degree of expertise available. The objective of this work is to offer a cost-effective means for artefact excavation and short-term preservation. A full recitation of conservation methodologies is inappropriate as many require purpose-built equipment, specialised skill, prolonged processing and the use of caustic substances (e.g., Bryce 1979: 21; Grattan 1982: 127-129; North 1987: 222-227; Cronyn 1990: 80, 258-259, 261, 274; Hamilton 1999: 26-28, 50-52, 57-70; Abadin 2006 *et al.*: 5; Cameron *et al.* 2006: 247-248).

The most fundamental consideration for the effective preservation of artefacts is the storage environment (Knight 1982: 51; Cronyn 1990: 196; Calnan 1991: 49; Canadian Conservation Institute 1992: 1-2; Selwyn 2004: 296; Staniforth 2005:105; Cameron *et al.*

2006: 251, 253, 260). Controlling relative humidity [RH] and temperature of smaller artefact groups has been shown to have a positive effect on artefact longevity and requires only limited financial commitment (Weisser 1987; Knight 1990: 41-42; Selwyn 2004: 297 citing Turgoose 1982; Watkinson and Lewis 2005: 9-10; Scott and Eggert 2009: 142). To this end, this study promotes a low-temperature, low-RH and low-light environment (passive preservation) for short-term artefact storage. The use of passive preservation as a protective method is well documented for most of the artefact types (metals, plastics, glass, rubber, and leather) encountered in historic air crash sites (e.g., Knight 1982; Blank 1988; Cronyn 1990: 196-197; Knight 1990; Adams and Hallam 1991: 283; Calnan 1991: 49; Fenn 1991; Green and Thickett 1991: 263; Haines 1991: 27; Loadman 1991: 72-73; Morgan 1991; Shashoua and Thomsen 1991; Canadian Conservation Institute 1992: 1-2; Williams 1997; Hamilton 1999: 31-32; Lantry 2001; Janaway 2002: 395; Selwyn 2004: 297; Watkinson and Lewis 2005; Cameron *et al.* 2006: 251, 253, 260; Scott and Eggert 2009: 142; Karsten, Graham, Goodman *et al.* 2012: 596-598, 600-603; Karsten, Graham, Jones *et al.* 2012: 9).

The life of aircraft wreck site-associated artefacts can be prolonged by employing a relatively unobtrusive, multi-stage process to care for the artefacts prior to conservation by a trained professional. Following excavation, stable artefacts are gently washed with a slightly damp, soft brush to remove remaining soil. Unstable artefacts are delicately cleaned using a dry soft brush. Following cleaning, the artefacts are air dried at room temperature for a minimum of 48 hours. After an artefact is confirmed to be dry, the artefact is wrapped in unbuffered tissue paper and placed within a pre-labelled polythene bag. Artefacts with an olfactory quality (such as plastics) should be separated from other artefacts and be well ventilated as off-gassing volatile compounds can cause harm to the artefact of origin or artefacts in the same storage environment (Blank 1988: 81; Williams 1997: 2-3). Bagged silica gel is added to the polythene bag; a 1:1 artefact-to-silica gel weight ratio is used to determine the amount of silica gel added. Finally, a humidity indicator card [HIC] displaying 5%, 10% and 15% RH levels is added to the artefact bag (Knight 1990: 42; Scott and Eggert 2009: 142). The bag is sealed and placed within an airtight black plastic box in order to inhibit light penetration and to provide a secondary desiccated environment, for protective redundancy, in case an artefact punctures the polythene bag. The HIC card is checked daily for the first week, weekly for weeks 2-4 and monthly thereafter. Corrosion is only inhibited if the RH is 20 percent or lower (Cronyn 1990: 196; Knight 1990: 41; Selwyn 2004: 297; Watkinson and Lewis 2005: 3); a RH below 12-15 percent is preferred for surety (Cronyn 1990: 75; Knight 1990: 41-42; Selwyn 2004: 297; Watkinson and Lewis 2005: 3, 9-10; Scott and Eggert 2009: 142). If the HIC card indicates a RH above 10 percent, both the silica gel and HIC card are replaced. Once a RH of below 10 percent is achieved, and provided the bag retains airtight integrity, the desiccated environment should last for an extended time (Knight 1990: 42).

Wet leather artefact preservation varies slightly from the normal processing procedures. Following cleaning, the leather artefact is placed into a drying press. The drying press is constructed from two elevated glass or acrylic sheets with lint-free paper towels lining the interior faces. Weight is added to the top of the drying press after the artefacts are in place. The paper towels are changed once the first day and daily thereafter. Tests undertaken as part of this thesis showed that leather should remain in the press for a minimum of four weeks before being removed for further work. Following final removal from the drying press, the leather artefact is wrapped and stored like other artefact classes but with a RH of 45-65 percent (Calnan 1991: 49; Canadian Conservation Institute 1992: 1-2; Hamilton 1999: 31-32; Cameron *et al.* 2006: 260; Karsten, Graham, Goodman *et al.* 2012: 596-598, 600-603). A RH of 45-65 percent keeps the leather from drying out and cracking (≤30 percent) while simultaneously preventing mould growth (which occurs at approximately ≥65 percent) (Canadian Conservation Institute 1992: 1-2).

The process of wood preservation requires more specialised processes than the passive preservation promoted for other aircraft artefacts and is a topic often revisited within the discipline due to wood's unique informational content and often delicate condition (e.g., Mühlethaler 1973: 11-64; Grattan 1982; Grattan 1987: 55-67; Grattan and Clarke 1987: 164-206; Cronyn 1990: 246-263; Rowell and Barbour 1990; Hamilton 1999: 22-29; Unger *et al.* 2001; Graves 2004; Karsten, Graham, Goodman *et al.* 2012; Karsten, Graham, Jones *et al.* 2012). Techniques to preserve natural wood artefacts centre on replacing an artefact's water content with a bulking agent. Polyethylene glycol [PEG] bulking, historically one of the most widespread and economical methods of archaeological wood preservation (e.g., Grattan 1982: 129-131; Grattan and Clarke 1987: 166; 169-184; Barbour 1990: 186-190; Cronyn 1990: 257-259, 261; Florian 1990: 21-25; Håfors 1990: 195-200; Peterson 1990: 443-444; Hamilton 1999: 25-26; Unger *et al.* 2001: 405-427, 501-502; Graves 2004: 13-14; Brunning and Watson 2010: 30; Karsten, Graham, Goodman *et al.* 2012: 21, 23-24, 26; Karsten, Graham, Jones *et al.* 2012: 595), is an easily performed technique which simultaneously removes and replaces the water, which supports the artefact's cellular walls, with PEG. Sometimes requiring extended treatment times, based upon artefact/sample sizes, the general PEG treatment methodology (Hamilton 1999: 25; Unger *et al.* 2001: 501; Graves 2004: 14) can be altered to fulfil specific research objectives.

Due to the variety in size and vast number of wood artefacts excavated from aircraft wreck sites, only the method for preserving wood samples will be discussed in this thesis. The wood samples are immersed in an initial concentration of 1 percent PEG 540 Blend-ethanol solution, the individual containers are placed into a larger 1L beaker, and the temperature is slowly elevated to 60°C. No additional PEG is added to the solution during treatment. The 60°C solution temperature is maintained until the wood samples achieve the minimum required 70 percent saturation. Solvent evaporation can economically and rapidly lower the PEG-solvent ratio (increasing PEG concentration).

Although standard conservation practices exist which are applicable to older natural wood artefacts, wood recovered from terrestrial Second World War wreck sites may be quite different than that usually encountered by an archaeological conservator. Wood used on aircraft often is not old enough to have lost all interior cellular integrity (Forest Products Laboratory 1941: 2-3; Perry 1941; Perry 1948: 43, 282-296 contra Grattan 1987: 59-63; Cronyn 1990: 250). No studies have been located which assess either the need to conserve engineered aircraft archaeological wood or the means by which to complete conservation. Procedures for the conservation of engineered aircraft archaeological wood are very much needed by aircraft archaeology.

5.2.8 Conclusion

The PAAR Methodology developed in this thesis fulfils an urgent requirement within aviation archaeology. The lack of a consistent methodology for the investigation of historic aircraft wreck sites has led to a diversification of methodological standards which, it is argued, poses a danger to the continued management of historic aircraft wreck sites as important cultural resources. The PAAR Methodology synthesises accepted archaeological practises, air crash investigation procedures and innovative aviation archaeology-specific techniques to provide a base standard, acceptable to professional and avocational archaeologists alike, which can be tailored in response both to individual site characteristics and to the time, human and financial resources available. Field-trialled on eight sites across Scotland, the merits of a consistently executed methodological standard, scalable to individual site qualities and available resources, is demonstrable through an examination of individual case studies.

Part 2: Application of the Phased Aviation Archaeology Research [PAAR] Methodology to Second World War aircraft sites in Scotland

6 Survey Sites: Wooden Airframes

6.1 Introduction

In order to field test the proposed PAAR Methodology, crash sites drawn from various elevations across Scotland were investigated. Both wooden framed and metal skinned aircraft wreck sites were examined. In total, three wooden airframe de Havilland DH.98, three metal skinned Boeing B-17 and two metal skinned Consolidated B-24 crash sites were investigated.

Each air crash site presented with a unique combination of available primary and secondary sources; researchers encountered a variety of site and resource restrictions. Map regression analyses were conducted for each site. However, analysis of historic OS maps (1904, 1912, 1929, 1947, 1961, 2007a, 2007b) showed no natural or anthropogenic changes to the landscape which would have significantly altered the terrain or distribution pattern of any of the aircraft wreck sites. The identification of consistent landscape topography eases recognition of long-term routes of artefact migration and, consequently, the identification of less mobile outlier artefacts still located near their point of initial deposition. Due to the consistency of results, site-specific discussion of map regression analyses will not be undertaken.

Two of the de Havilland DH.98 studies terminated with Phase IIa. The current chapter provides results and analysis from these two site surveys. These analyses demonstrate the significant information obtainable from even a limited study of historic wreck sites provided a systematic research methodology is employed.

6.2 de Havilland DH.98 NFII DD795 (Corserine, Dumfries and Galloway)

6.2.1 Overview

6.2.1.1 Site Background

On 20 August 2011, a non-invasive survey of DH.98 DD795 (Figure 6-1) was conducted. Located at NX 50468 87022, approximately 780 metres asl (Map 6-1), DD795 was selected due to its crash environment. Impacting the 814 metre asl Corserine near Scar of the Folk (near St. John’s Town of Dalry, Dumfries and Galloway) on 20/21 January 1944, the DD795's location typifies high ground wreck sites and is the highest elevation of the three DH.98 crash sites investigated.

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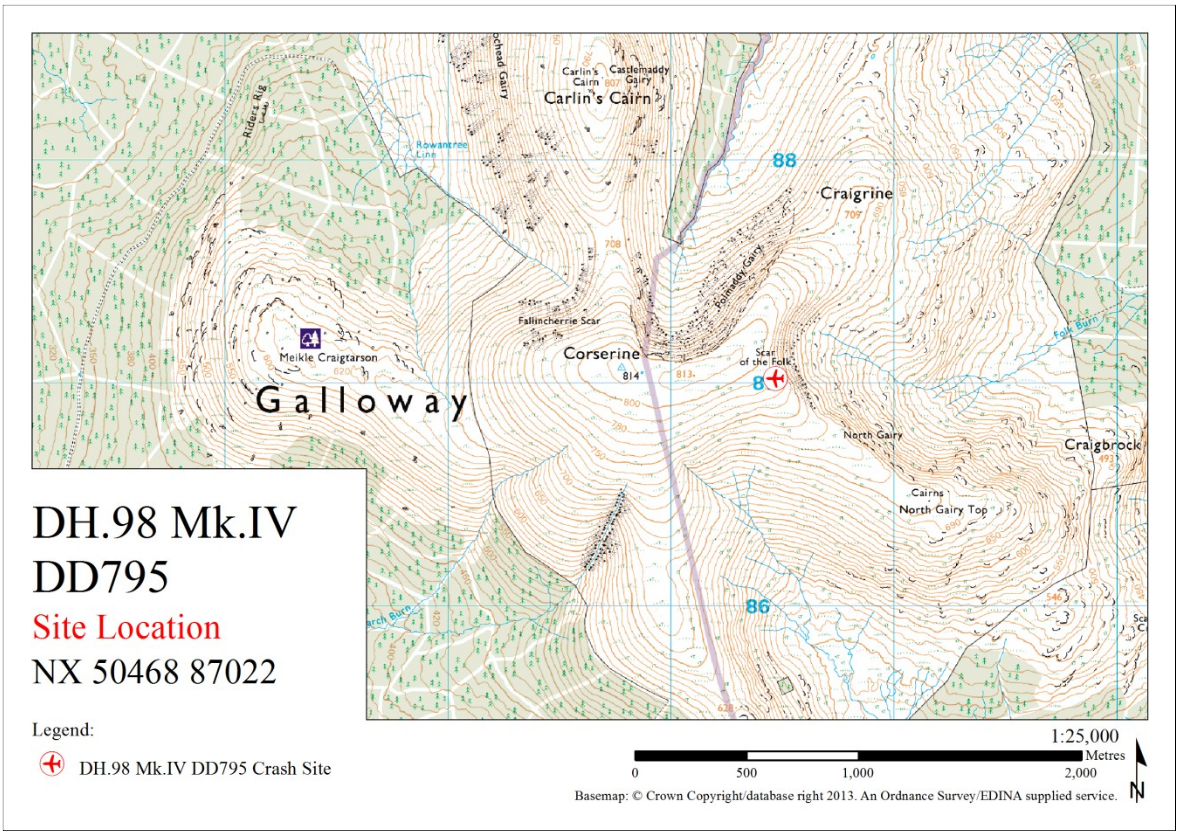
Figure 6-1: An identical airframe model as DD795, de Havilland DH.98 NFII W4092 of No 157 Squadron, RAF (IWM c1939-1945).



Map 6-1: Location of de Havilland Mosquito Mk.IV DD795 crash site (Crown Copyright/database right OS 2013b; Author).
DH.98 Mk.IV DD795 impacted the Corserine at approximately 780 metres asl.

6.2.1.2 Investigation Summary

The crash site area is protected both as part of the Merrick Kells Site of Special Scientific Significance [SSSI] and as part of the Merrick Kells Special Area of Conservation [SAC] (SNH 2012), work licensure of which is managed by Scottish Natural Heritage [SNH]. The survey of DH.98 DD795 utilised an early version of the PAAR Methodology and employed a variety of non-technical and technical archaeological methods and procedures including pedestrian, metal detector, topographic and photographic surveys terminating with Phase IIa. Excavation was not undertaken at this time but is legally feasible as the two crewmen's remains were recovered and interred post-crash. The proposed research plan was limited to one basic research aim: the unsystematic pedestrian and metal detector surveys of the suspected crash site in order to establish the distribution, character and quantity of extant diagnostic archaeological material (Phase IIa). The four research objectives underlying this basic research aim are:

1. To provide a distribution map of extant artefactual material including a separation of diagnostic and nondiagnostic material.

2. To establish DD795's final vector and point of impact through the plotting and analysis of *in situ* artefactual material.

3. To establish the extent of aircraft artefacts remaining on site in relation to the amount removed over the previous 60+ years.

4. To report on the site's status and provide recommendations for its management into the future.

Recent photographs discovered during the Phase I historical survey showed the site to be appropriate for at least a Phase IIa investigation. Thus, no Phase I site visit was necessary. The Phase IIa site survey was undertaken on 20 August 2011. The results returned during the Phase IIa investigation identified substantial small artefact scatters centred on three main ground scars (Areas 1-3) (Map 6-2 and Map 6-5). Primarily consisting of NMF and metal wood screws, the concentrated scatters in Areas 2 and 3 also contained melted aluminium fragments evidencing a hot but short ground fire. No aluminium fragments showed the filamenting characteristic of a fire in flight; the lack of aluminium fragments with filament edges is consistent with the records which relate that the impact of DD795 occurred whilst the aircraft was in full flight. Larger diagnostic artefacts, consisting primarily of main undercarriage components, were observed in Area 1.

The Phase IIa survey located no substantial artefact groupings beyond the three scars identified. A metal detector survey of the area returned seven results within the ground scars (Map 6-6 and Map 6-7). Tuning out smaller artefact signatures (i.e., small nondiagnostic metal fragments [NMFs], wood screws, etc.) resulted in no additional metal detector indicators of substantial-size, buried anomalies.

While the survey of the DD795 wreck site did not display any buried anomalies indicative of diagnostic components, a future Phase IIIa investigation of DD795 would certainly prove useful. Quantification and classification of the numerous extant wood screws would allow for the characterisation of the three ground scars, post-depositional practices, and site attrition.

6.2.2 Airframe Construction

A recitation on the wooden, metal and Perspex components of DH.98 aircraft will not be undertaken in this section as a detailed discussion is offered in Chapter 8, Section 8.2.

6.2.3 Archaeological Investigation

6.2.3.1 Phase I Historical Survey

Consistent with all investigations utilising the PAAR Methodology, the Phase I historical survey undertaken in early June 2011 was dedicated to generating the information necessary to complete the *PAAR Aircraft Incident Record* form (Document 6-1). The Phase I historical survey identified the two deceased crewmen as Flight Sergeant Kenneth Mitchell RAFVR (pilot) and Flight Sergeant John Jeffrey Aylott RAFVR (navigator) both of No. 60 OTU (Appendix Table 11-1). Secondary sources (e.g., Wotherspoon *et al.* 2009: 244) identified the aircraft as having been on a night NAVEX from RAF High Ercall on 20/21 January 1944 when it impacted the south-eastern side of the Corserine. No site visit was undertaken during Phase I as recent photographs and hikers' accounts demonstrated the crash site to have sufficient *in situ* wreckage to warrant a Phase IIa investigation.

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Document 6-1: Phase I *PAAR Aircraft Incident Record* form for DH.98 DD795 (ICAO 2006; Author).

6.2.3.2 Phase IIa General Data Survey

Background Research:

Primary Source Accounts:

Primary source accounts by DD795's aircrew, recovery crews or local residents were not located despite an extensive search. Indeed, the only primary records located that relate to the crash of DD795 are No. 60 OTU's Operational Record Book (Royal Air Force 1943-1945a), No. 1 AOS's Operational Record Book (Royal Air Force 1943-1945b) and *Air Ministry Form 1180* (UK Air Ministry 1944a).

The most comprehensive account of the DD795 crash and subsequent remains recovery is described in the No. 60 OTU (Royal Air Force 1943-1945a) and No. 1 AOS Operational Record Books (Royal Air Force 1943-1945b). On the night of 20/21 January 1944, Mitchell and Aylott-both of No. 9 Course, No. 60 OTU-were tasked with a night NAVEX from RAF High Ercall. Though a four ship flight from No. 60 OTU searched for DD795 the following day using the NAVEX flight path, DD795 was not seen again until the wreckage was identified on 11 February 1944. A 50 man team from No. 1 AOS, stationed at RAF Wigtown, recovered the physical remains of Mitchell and Aylott on 12 February 1944. Observations by the recovery team noted evidence of a brief but extensive fire with the wreck site most likely covered by snow soon after the crash. It was speculated that the crash occurred during the northern leg of the designated NAVEX flight plan.

Aircraft History:

No records relating to RAF High Ercall for the period post-December 1943 could be obtained from The National Archives (Royal Air Force 1941-1943). As such, it is unknown whether base records offer more detail on the operational history, maintenance record or crash of DD795.

Crew Personnel Files:

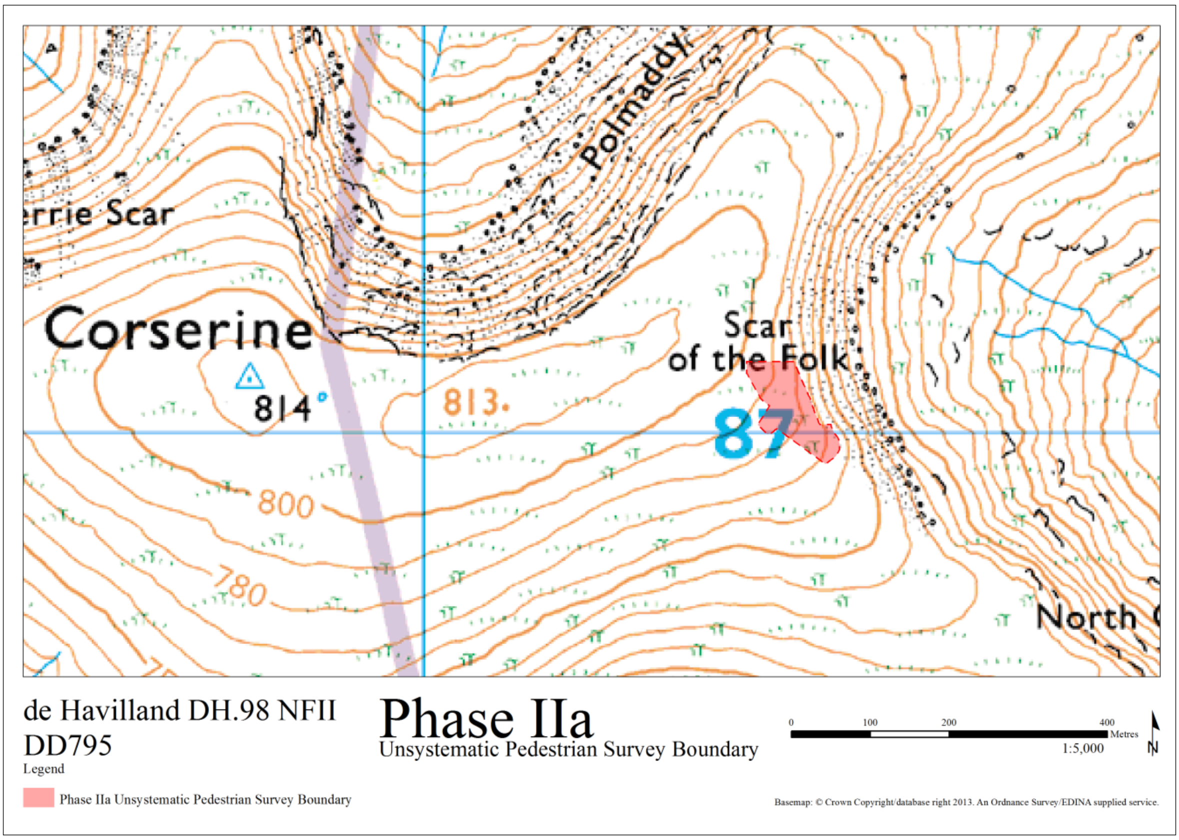
Crew personnel files are currently unavailable to non-next-of-kin. The process for transferring personnel crash dossiers and associated personnel records to The National Archives and organising their subsequent release was begun in January 2013 and is expected to take several years to complete. The National Archives has stated that records will be accessioned and released in chronological order. As such, access to the DD795 crash dossier and Mitchell and Aylott's respective personnel records will not be possible for some years.

Field Survey:

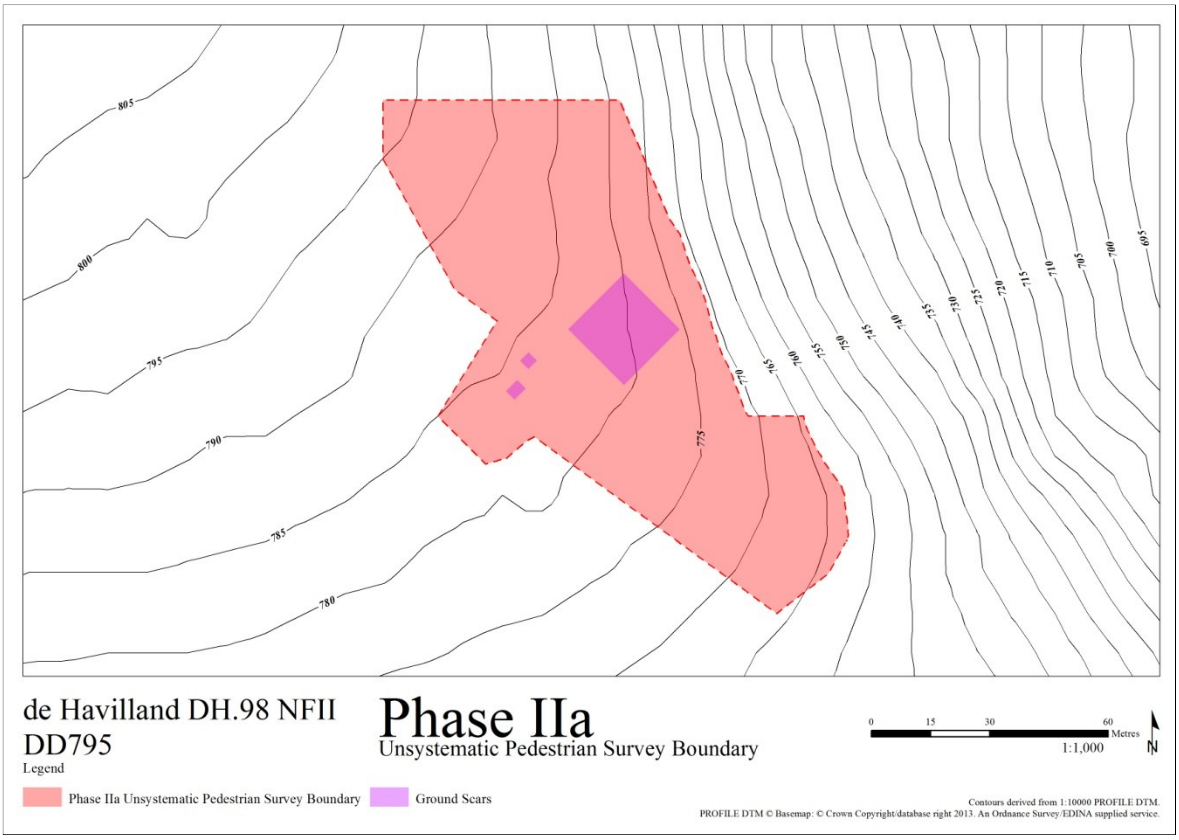
Unsystematic pedestrian and metal detector surveys were conducted on 20 August 2011. The unsystematic surveys were designed to identify the quantity and disposition of surface diagnostic artefacts, to establish the presence of sub-surface anomalies of interest and to provide site dimensions should a Phase IIb detailed site survey proceed.

Unsystematic Pedestrian Survey:

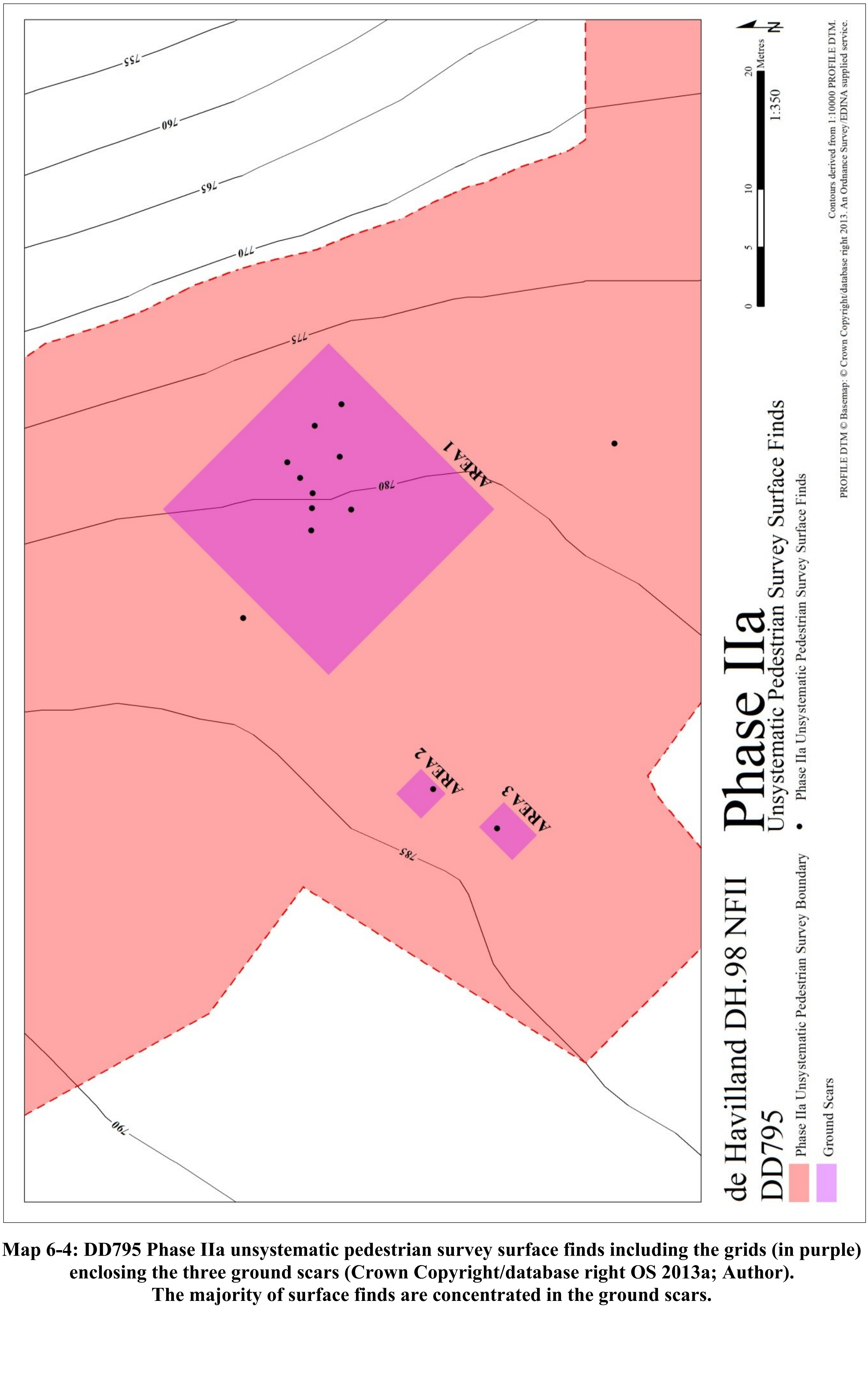
The Phase IIa unsystematic pedestrian survey focused attention on three prominent ground scars barren of vegetation (Map 6-2 and Map 6-3). All three ground scars included possible major and fragmentary aircraft components including undercarriage support structures. While not utilising specific transects, the unsystematic pedestrian survey proceeded along a SW-NW axis which correlated to the axis of ground scarring. The unsystematic pedestrian survey returned eight comingled artefact groups (FS 004-011) and five individual artefacts (FS 001-003, 012 and 013) (Map 6-4 and Map 6-5). All artefact groups were concentrated in the observed ground scars except FS 004 which was approximately 2 metres outside the main ground scar.



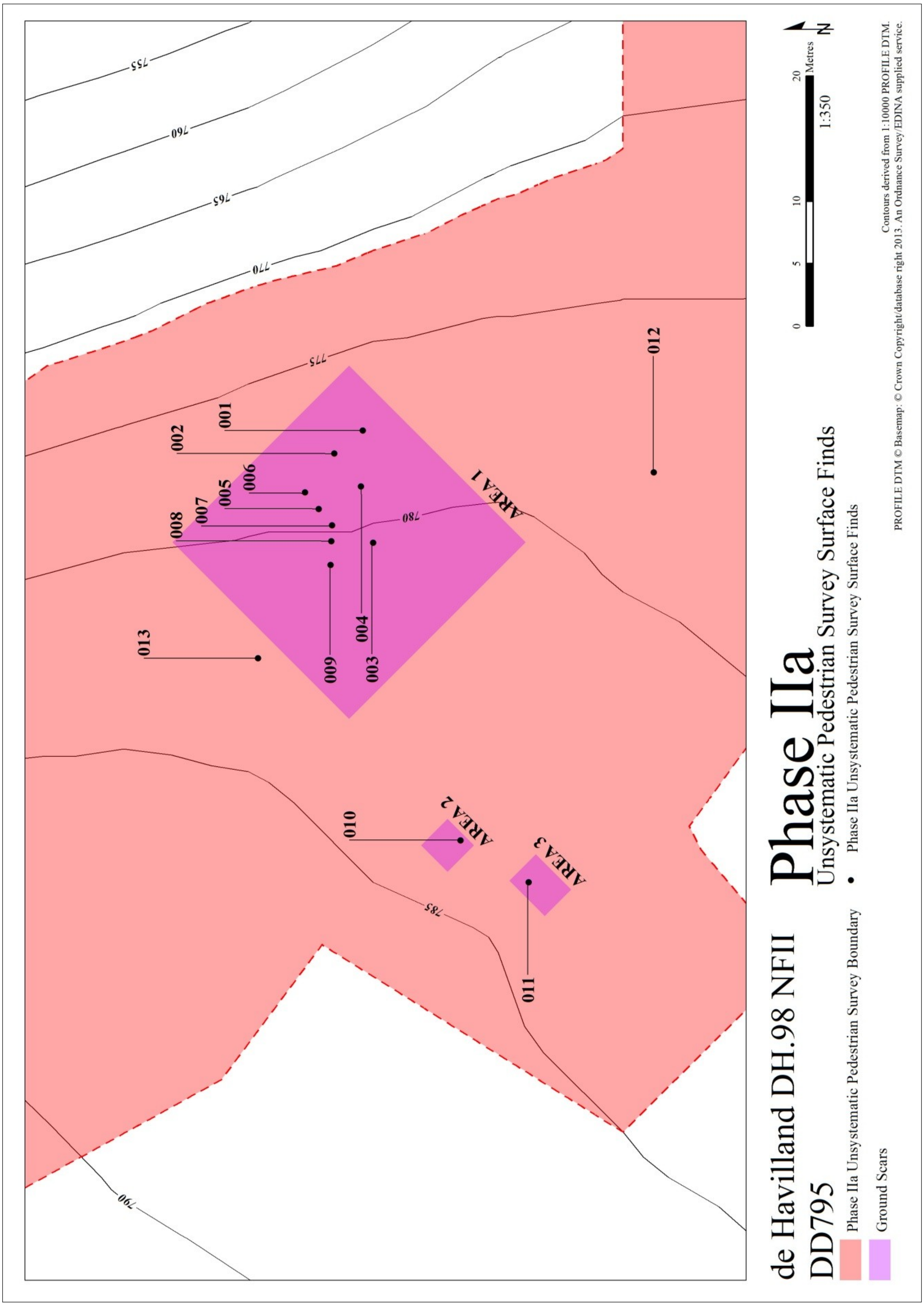
Map 6-2: DD795 Phase IIa survey boundary focusing on the southern half of the Scar of the Folk (Crown Copyright/database right OS 2013b; Author).



Map 6-3: DD795 Phase IIa unsystematic pedestrian survey boundary and ground scars (Crown Copyright/database right OS 2013a; Author).
The Scar of the Folk is the eastern slope while the summit of the Corserine is to the northwest.



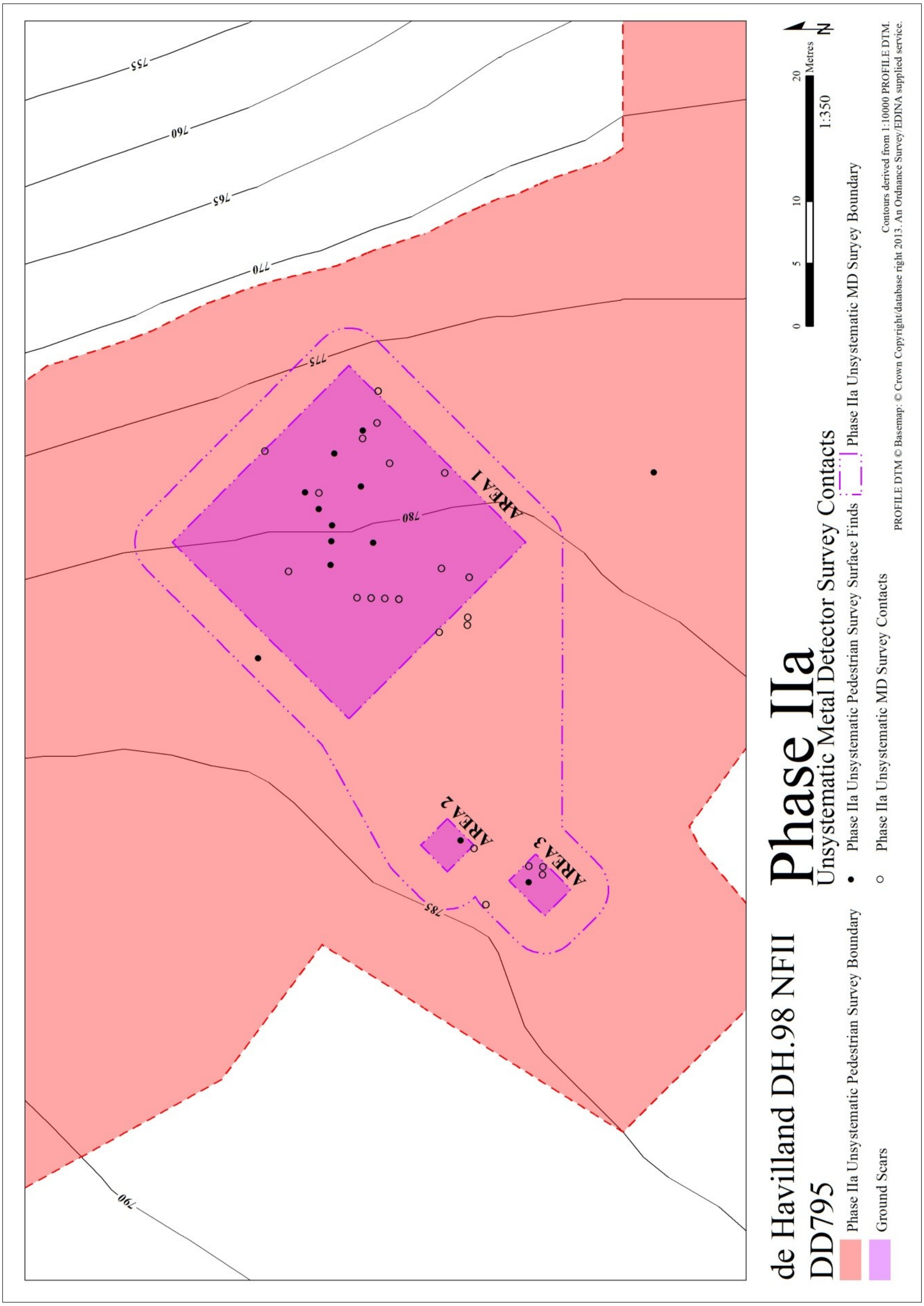
Map 6-4: DD795 Phase IIa unsystematic pedestrian survey surface finds including the grids (in purple) enclosing the three ground scars (Crown Copyright/database right OS 2013a; Author). The majority of surface finds are concentrated in the ground scars.



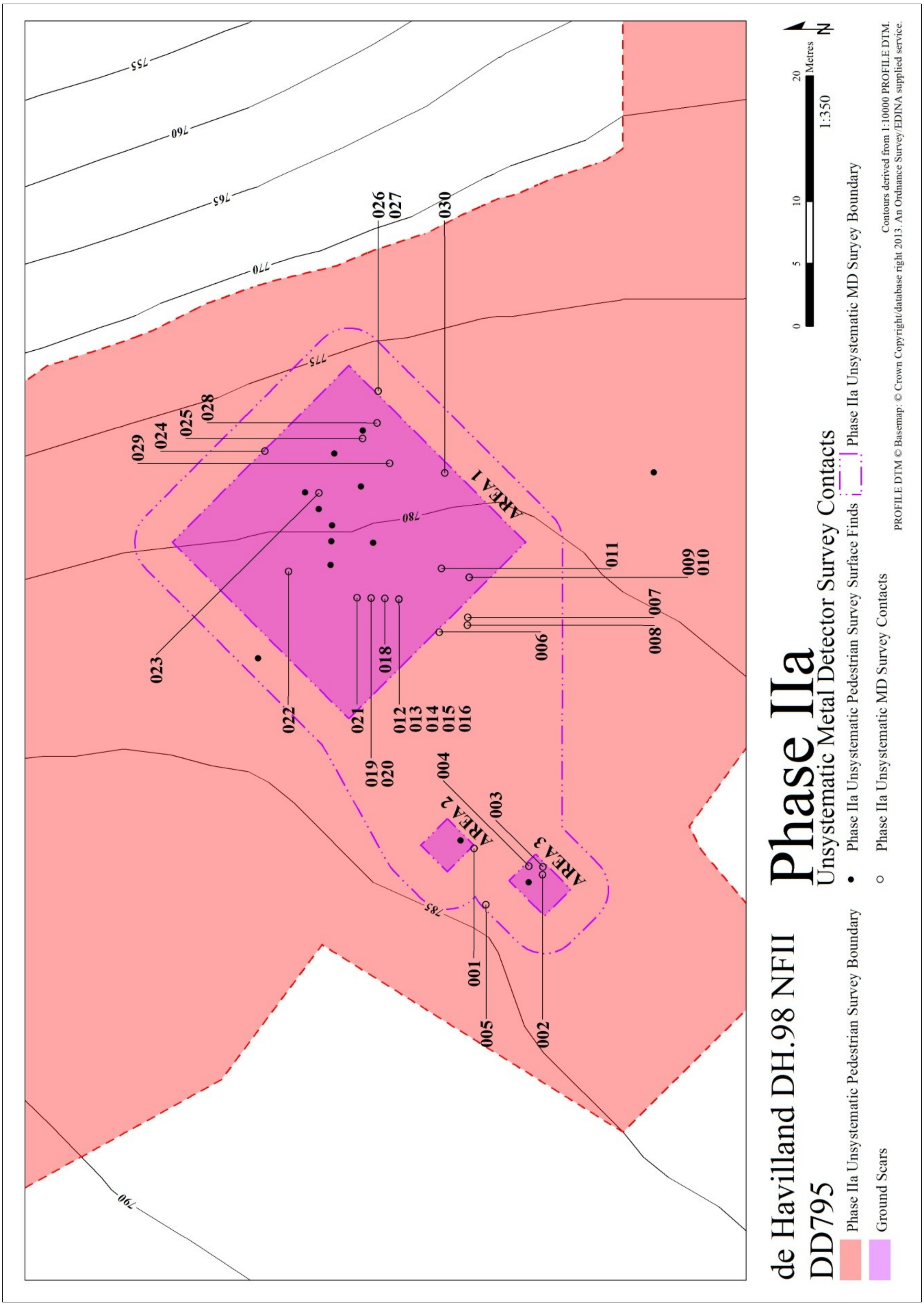
Map 6-5: Annotated distribution of DD795 Phase IIa surface finds (Crown Copyright/database right OS 2013a; Author).

Unsystematic Metal Detector Survey:

Tasked with identifying any sub-surface contacts which may show more substantial aircraft wreckage than that observed on the surface, the unsystematic metal detector survey was conducted in two stages. The first stage mirrored the Phase IIa unsystematic pedestrian survey's SW-NW axis of movement. The interior of the three ground scars was surveyed during the first stage and included both normal tuning, as used throughout the site, and a second sweep that tuned out smaller artefacts (screws, small NMFs, etc.) which may have provided false positives during the first sweep. The second stage, a follow-on sweep of the periphery of the three observed ground scars, utilised a three metre sterile buffer to identify any continuation of observed surface wreckage into the soil matrix or the possible presence of substantial sub-surface anomalies. Thirty discreet metal detector contacts were located during the Phase IIa unsystematic metal detector survey. Oddly, no sub-surface contacts were recorded in the western corner of Area 1 or in the region between Area 1 and Areas 2 and 3 (Map 6-6 and Map 6-7). As will be discussed in further detail in Section 6.2.4, the absence of sub-surface contacts in this region may be explained by the aircraft's final vector, final attitude and the slope of the localised terrain. Indeed, it is believed that Area 1 represents the primary impact point while Areas 2 and 3 are the depositional position of the aircraft's two engines.



Map 6-6: DD795 Phase IIa unsystematic pedestrian survey surface finds and unsystematic metal detector survey contacts (Crown Copyright/database right OS 2013a; Author).
No metal detector contacts were recorded between Area 1 and Area 2. The absence of metal detector contacts may indicate Areas 2 and 3 as the final impact site of DD795's engines. Alternatively, the absence of metal detector contacts may be a false negative with DD795-related artefacts buried too deep to register with the metal detector used.



Map 6-7: Annotated distribution of DD795 Phase IIa metal detector contacts (Crown Copyright/database right OS 2013a; Author).

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Document 6-2: Phase IIa *PAAR Aircraft Incident Record* form for DH.98 DD795 (ICAO 2006; Author).

Artefact Analysis:

Eighteen confirmed diagnostic artefacts were located during the Phase IIa unsystematic pedestrian survey. While all of the artefact groups contain additional material potentially identifiable during subsequent Phase IIb research, the material identified during the Phase IIa unsystematic survey is adequate for drawing corroborated conclusions about DD795's final moments and intra-site artefact mobility.

FS 001.01-001.12 are critical to understanding the impact and potential artefact spread of DD795. FS 001.01-001.12 are the shattered remnants of one of DD795's two sets of main undercarriage shock absorbers and a fragmentary piece of the joining wheel cross-bracing. Easily identifiable due to their size and unique shape, FS 001.01 and 001.02 are the exterior reinforcement (DHA-G. 9865A) for the assembled shock absorber (DHA-G.983A) (Figure 6-2). An exterior support plate and mounting point for hinged bracing, FS 001.01 is not a component of the compound shock absorber piston but rather is bolted to it using four substantial bolt assemblies approximately ½" OD (BSS A16Y/GT, DHA-G.98417, AGS 784.3, DHA-G.98418, BSS A16Y/GS, BSS A16Y/GP). FS 001.03 and FS 001.07—corroded fragments of the exterior shock absorber jacket (DGA-G.98118A/2)—similarly retain their installed bolts assemblies (DHA-G.98101 Mk1-Mk3 and BSS A16Y/ET) (RSAFB[1] n.d.a: 8-10). A critical core component, FS 001.06 (a Bakelite piston) (Figure 6-2), was discovered outside the working chamber (Tanner 1977: 184; RSAFB n.d.b: 8-10). The presence of intact bolt assemblies on the shock absorber reinforcement plates and on the exterior jacket, proximate to disarticulated interior shock absorber components, indicates that post-crash dismantlement of the shock absorber assembly is unlikely. Rupture of the core piston assembly likely occurred due to high speed impact.

Additional evidence of a high speed, full flight impact is observed in FS 001.04-001.05 and FS 001.08-001.12 (Figure 6-2). In all seven examples, the solid structural rods (RSAFB n.d.b: 4-6, 8-10) experienced shearing forces sufficient to tear the undercarriage support structures. FS 001.12, a section of the cross-bracing which spans the distance between the two shock absorbers (RSAFB n.d.b: 4-6), shows termini which have been

[1] The Royal Swedish Air Force Board [RSAFB] published the spare parts catalogue for the de Havilland Mosquito aircraft purchased by the Swedish armed services. An RSAFB spare parts catalogue, owned by the Swedish Flygvapenmuseum (Godfurnon 2011), is the only known de Havilland Mosquito spare parts catalogue in existence. References to the RSAFB spare parts catalogue, and similar Technical Orders for B-24/LB-30A and B-17 aircraft, positively identify artefacts and artefact assemblies as well as their installation location.

sheared away from extant cross bracing connections (FS 001.09 and FS 001.11: DHA-G.986A) (RSAFB n.d.b: 4-6) and spacers (FS 001.08 and FS 001.10: DHA-G.9866 and DHA-G.9864) (RSAFB n.d.b: 8-10) which are still attached to the shock absorber jacket and reinforcement plate (Figure 6-2). The seemingly crash-induced angled terminus of a sheared cross bracing fragment is clearly visible on FS 001.09 (Appendix Figure 11-1). The close proximity of shock absorber components and main gear structural components offers compelling evidence that the general area of scatter represents the impact point of one of the main land gear assemblies, engine and wing.

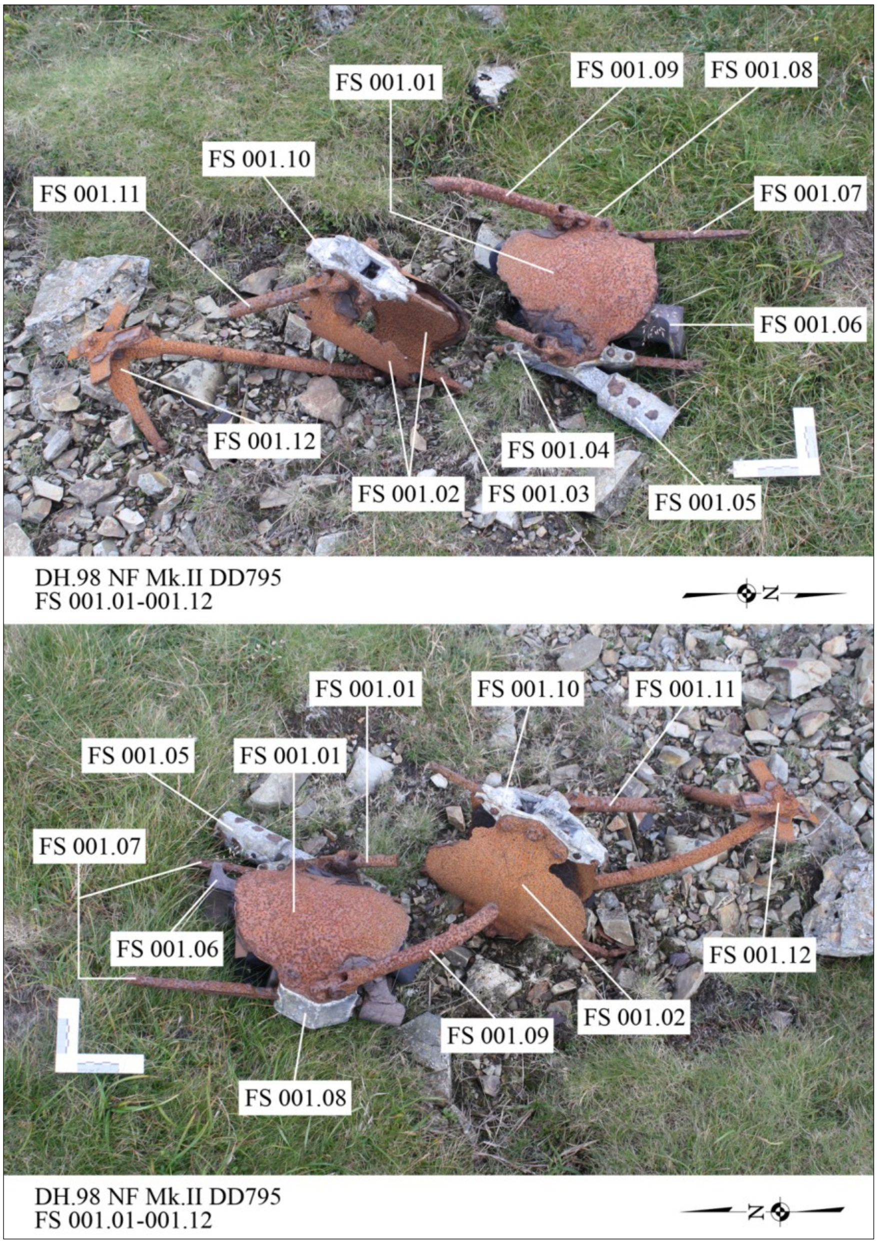

Figure 6-2: DH.98 DD795 Artefact Group FS 001, a ruptured main landing gear shock absorber (Author).
The proximity and traumatic disassembly of the exterior reinforcement plates (FS 001.01 and FS 001.02), the exterior shock absorber jacket fragments (FS 001.03 and 001.07), Bakelite piston (FS 001.06) and main landing gear bracing (FS 001.08-001.12) provide compelling evidence that FS 001 is the impact point of one of the main landing gear assemblies, engine and wing.

Additional evidence of a full flight impact is observed in artefacts FS 004.01-004.05 which are the remains of a main landing gear and an engine. FS 004 predominantly contains parts of the engine mounting brackets (Figure 6-3). FS 004.01 and 004.02 (Appendix Figure 11-2) are back portions of two of the four total engine mounting brackets installed on DH.98 models (RSAFB n.d.c: 24-27). Mounted on the main spar at wing ribs three and four, the DHA-G.98110 assemblage is the backing plate for the parts which receive the engine mounting cradle (Tanner 1977: 239-240, 304; RSAFB n.d.c: 20-21). When built, FS 004.01 and 004.02 were separated by approximately one metre; their continued co-mingled association at the DD795 wreck site suggests their current position as the likely area of original deposition. Moreover, their location relative to other artefacts—such as FS 004.03 (suspected electrical generator/motor casing) and FS 004.05 (a DHA-E.98451A or DHA-E.98452A bracket joining DHA-D.9873A Mk1-Mk2 or DHA-F.98443A engine cradle mount brackets to the underside of the main spar) (RSAFB n.d.c: 24-27)—provides the FS 004 artefact group with additional context from which to deduce that FS 004 is the other wheel/engine structure impact point.

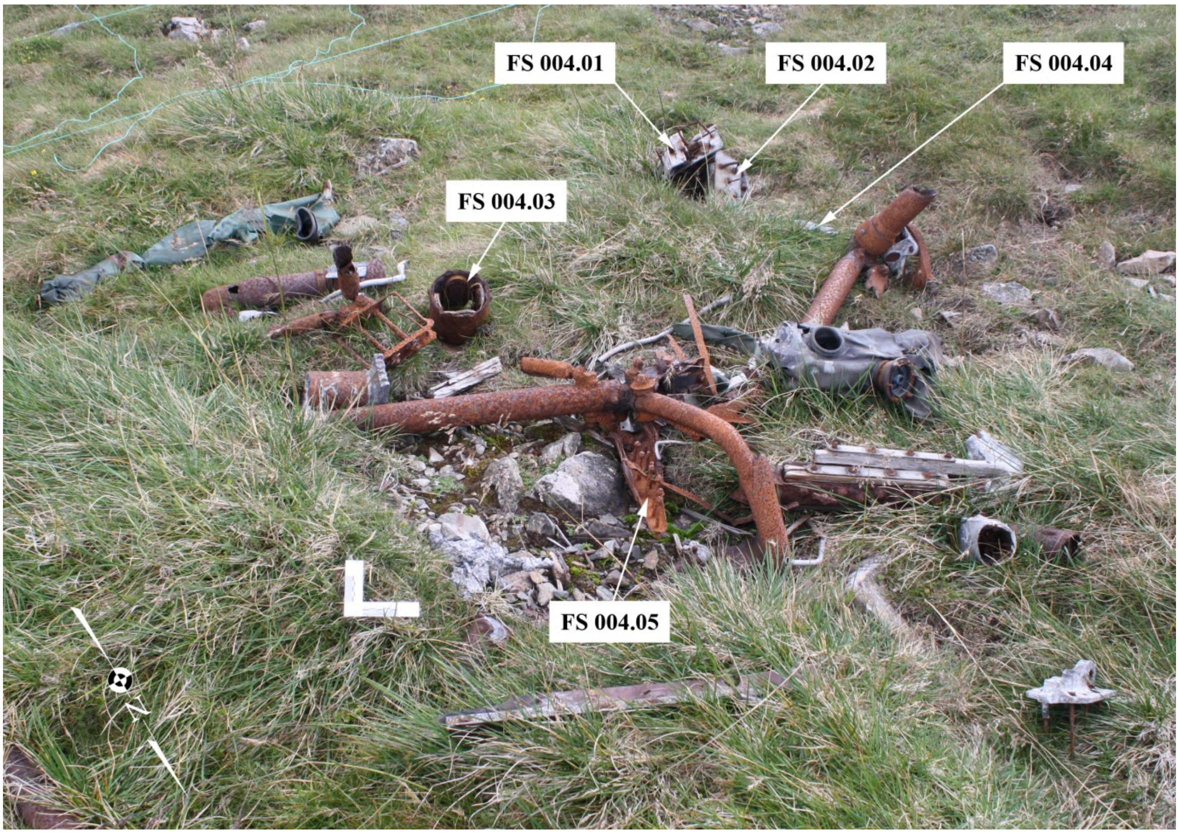

Figure 6-3: General view of FS 004 scatter (Author).

While the additional two shock absorber reinforcement plates identified in FS 001 were not found, FS 004.04 provides evidence of similar shock absorber disarticulation as that hypothesised for FS 001. Indeed, FS 004.04 (Appendix Figure 11-3) is one of 22 metal spacers (DHA-G.98133) separating 12 rubber blocks (Tanner 1977: 284). The distance between FS 004.04 and the major shock absorber components of FS 001 either demonstrates the original presence, and now absence, of a second shock absorber set or the post-crash transfer of FS 004.04 away from its original deposition with FS 001. The absence of any other shock absorber components in the proximity of FS 004 makes the survival, and post-crash removal, of the second shock absorber set seem likely.

FS 007 contains artefacts of similar type as those observed in FS 004 (Appendix Figure 11-4). Located only two metres from FS 004, FS 007 potentially represents a continuation of the parts scatter recorded in FS 004. Indeed, FS 007.04 (DHA-E.98451A or DHA-E.98452A) is identical to FS 004.05 (RSAFB n.d.c: 24-27). Further supporting the claim that FS 004 and FS 007 represent a secondary, high speed engine impact point are FS 007.01-007.03. FS 007.01 is the front spar engine mounting bracket (DHA-D.9873A Mk1-Mk2 or DHA-F.98443A) which connects to FS 004.01, 004.02 and 004.05 (RSAFB n.d.c: 20-21, 24-27). Attached to FS 007.01 are FS 007.02 and 007.03 which are the front undercarriage attachment arm and the upper engine cradle mount arm, respectively (RSAFB n.d.b: 4-6, 18-19; RSAFB n.d.d: 3-4). Supporting contemporary claims of a full flight impact are the sheared termini of FS 007.02 and 007.03, similar to those observed in FS 001.08-001.12. The additional rod welded to FS 007.03 to form the opposite side of the engine cradle has been torn free cleanly at the weld seam. Further evidence that the area around FS 007 comprises the second main gear/engine impact point is the proximity of FS 008.01. FS 008.01 (Appendix Figure 11-5 and Appendix Figure 11-6) lies approximately 0.5 metres NE of FS 007.03 and is a connection bracket for the inboard, upper rear landing gear strut (DHA-G.98108A) and the inboard, rear undercarriage well (RSAFB n.d.c: 28-29). Additionally, FS 008 contains a large ingot of melted aluminium (FS 008.02) (Appendix Figure 11-5 and Appendix Figure 11-6), evidence of a post-crash fire. Taken together, FS 004, FS 007 and FS 008 represent the major structural components for one of the main landing gear units and the engine installation fittings.

As with FS 007, FS 005 (Figure 6-4) contains portions of undercarriage structures. For example, FS 005.02 is the upper undercarriage strut (DHA-G.9857A) and engine mount (DHA-G.9811) (RSAFB n.d.b: 4-5, 18-19). Integral to a full understanding of DD795's attitude at impact is the deformation pattern of the upper engine cradle mount spars (DHA-L.981878A/1, DHA-L.981880A/1, DHA-L.981877A/1, or DHA-L.981879A/1).

Originally installed at approximately -20 degrees off horizontal (Tanner 1977: 239; RSAFB n.d.d: 4-6), the double bend of the upper engine cradle mount spars are indicative of compression forces along the axis of the pipe. When combined with the bending and partial to full wall collapse of FS 005.01 and FS 005.03, the deformation of FS 005 shows DD795 to have experienced a zero or near zero degree attitude of impact.

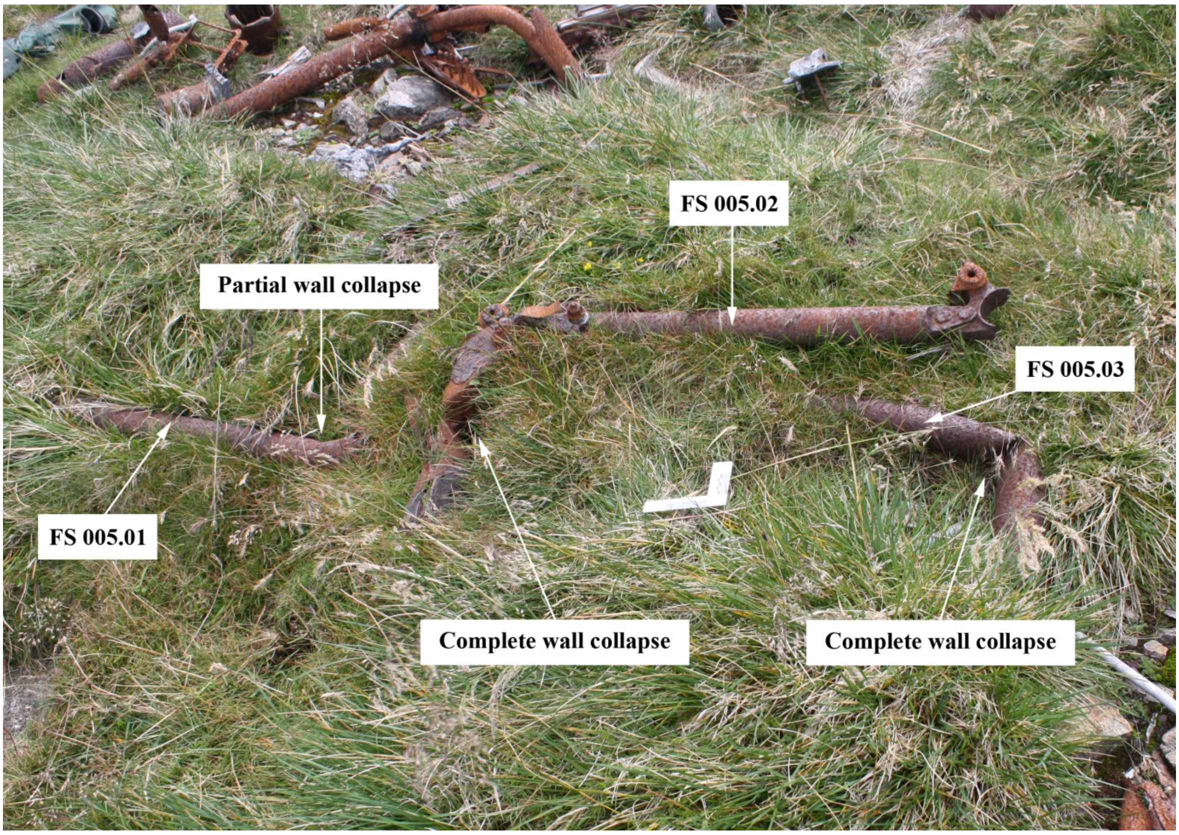

Figure 6-4: Location of DD795 FS 005 (Author).
FS 005 contains portions of undercarriage structures including the upper undercarriage strut (FS 005.02: DHA-G.9857A) and engine mount (FS 005.02: DHA-G.9811). The double bend of the upper engine cradle mount spars are indicative of compression forces along the axis of the pipe and show DD795 to have experienced a zero or near zero degree attitude of impact.

Further reinforcing the hypothesis that the positions of FS 004-005 and FS 007-008 reflect the point of impact for one of the two main gear/engine sections are the contents of FS 006 (Figure 6-5). As confirmed by fittings DHA-Q.981835 and DHA-Q.981836, FS 006.01 is the bottom section of the undercarriage jack actuating cylinder (RSAFB n.d.e: 20-21). Identified by the presence of a bolt head marked AIR 11158 on the south easterly facing end and the presence of an identical connection to that observed on FS 006.01 (Appendix Figure 11-8), FS 006.06 is a near complete undercarriage jack actuating cylinder (RSAFB n.d.e: 20-23). Undercarriage jack actuating cylinders (DHA-Q.982127A) are installed onto the rear inboard landing gear struts and represent one of the main linkages between the front and rear of each main gear assembly (Tanner 1977: 324; RSAFB n.d.b: 4-6).

Identifiable by their termini, FS 006.02 is the upper, rear connection joint of main gear strut DHA-G.9841A (RSAFB n.d.b: 12-13, 4-6) while FS 006.03 is the upper terminus of strut DHA-G.98106A (Tanner 1977: 324; RSAFB n.d.b: 4-6, 14-16). FS 006.03 retains part DHA-G.9888, its unique pivot joint. The presence of FS 006.01-006.03 and 006.06 in close proximity to other main gear and engine mount assemblies reinforces the previously posited hypothesis that intra-site artefact mobility, while taking place, does not preclude the generation of supported conclusions regarding the orientation of DD795 within the larger landscape.

Identification of artefacts FS 006.04 and 006.07 is not possible at this time. Though a unique part, FS 006.04 could not be located in the DH.98 or Rolls Royce Merlin parts manuals and, as such, is classified as nondiagnostic(diagnostic) NMF. Future continuation of research into Phase IIb or Phase IIIa/b may yield identification of FS 006.04. FS 006.07 is currently classified as NMF, however its diameter makes it likely that FS 006.07 is a wall fragment from FS 006.01 (RSAFB n.d.e: 20-21). An additional NMF, FS 006.05, is a melted aluminium ingot. Though its context is not secure as it is a surface NMF which does not benefit from part-to-part associations of diagnostic artefacts such as FS 006.01-006.03 and FS006.06, FS 006.05 does reinforce the hypothesised occurrence of a post-crash ground fire.

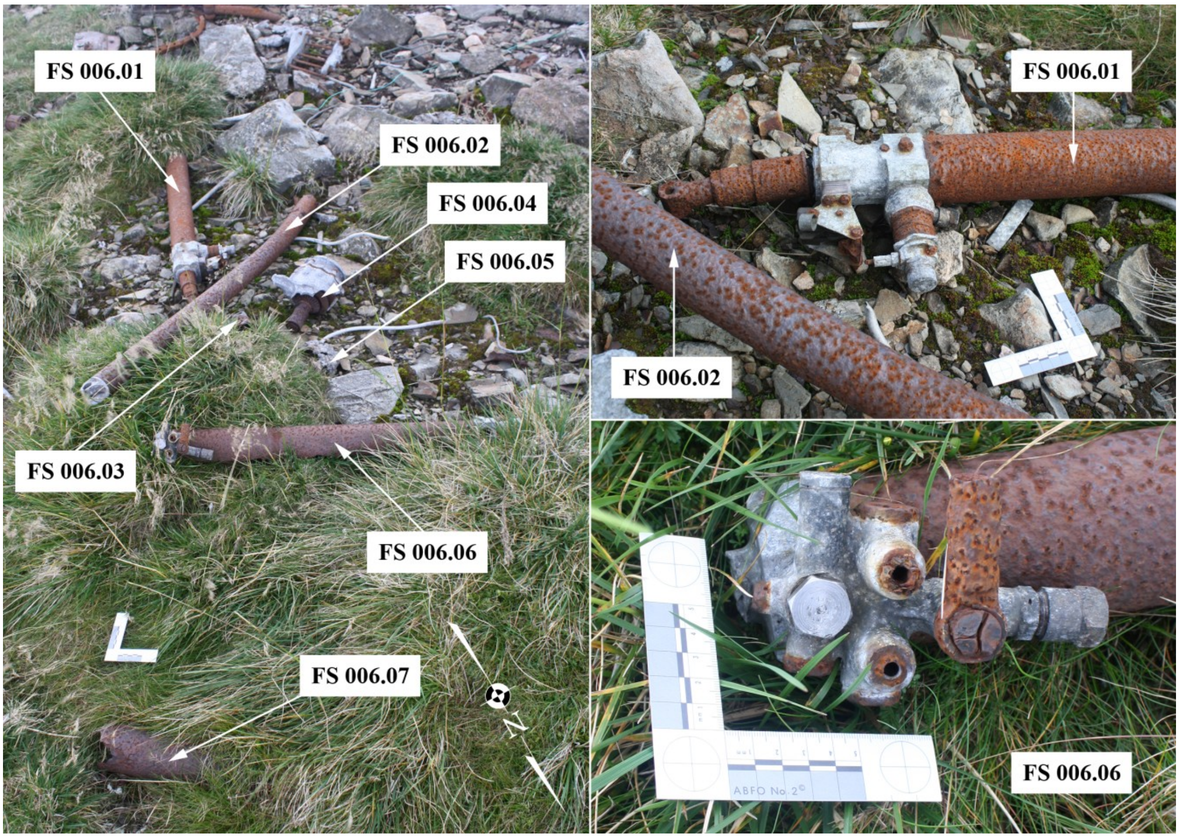

Figure 6-5: Location of DD795 FS 006 (Author).
FS 006 contains main landing gear components including undercarriage jack actuating cylinders (FS 006.01 and FS 006.06) and sections of main gear struts (FS 006.02 and FS 006.03).

Although differing in total content, both FS 010 (representative of Area 2) (Figure 6-6 and Figure 6-7) and FS 011 (representative of Area 3) (Figure 6-8 and Figure 6-9) contain melted aluminium ingots similar to those observed in FS 006.05 and 007.04. FS 010 contains several hundred wood screws and almost no structural plates and fittings (Figure 6-7). The wood screws are of varying sizes and distortion with most showing some evidence of having been burned. Several screws have similar, unusual curvatures suggesting that the screws come from a single section of aircraft and suffered similar impact forces. In contrast, FS 011 contains large quantities of bolt assemblies, plates and fittings but few wood screws (Figure 6-9). A metal detector sweep of Area 2 and Area 3, tuning out small metallic artefacts so as to bias the survey towards larger sub-surface material, generated few contacts and none of substantial size. While the difference in specific contents between FS 010 and FS 011 is curious, the dearth of sub-surface contacts in either area suggests that Area 2 and Area 3 are the impact points for DD795's engines. Comparing the lack of sub-surface contacts in Areas 2 and 3 with the multitude of sub-surface contacts recorded in Area 1 indicates that the site was not entirely sanitised. Rather, only large debris was removed from Areas 2 and 3. Such large-item removal is consistent with war time practice to recover the engines whenever possible. Additionally, the holes in close proximity to the recovery effort might indicate an area where No. 1 AOS disposed of large wooden sections which hindered recovery of crew remains. As a bonus, burning the large wooden sections would have provided warmth during the cold February task. Thus, it is hypothesised that No. 1 AOS personnel, in the process of recovering the crew, sanitised the crash site by moving wooden sections to Areas 2 and 3 for disposal by burning. The clearance and burning of the main impact site, necessary in order to access the crews' remains and sanitise the crash site so as to limit duplicate reports of a downed aircraft, would have created scatters identical to that observed: no sub-surface contacts (due to engine removal) and, resting on the surface, a large quantity of charred wood screws and burnt out wood fittings all suffering from varying degrees of impact deformation.

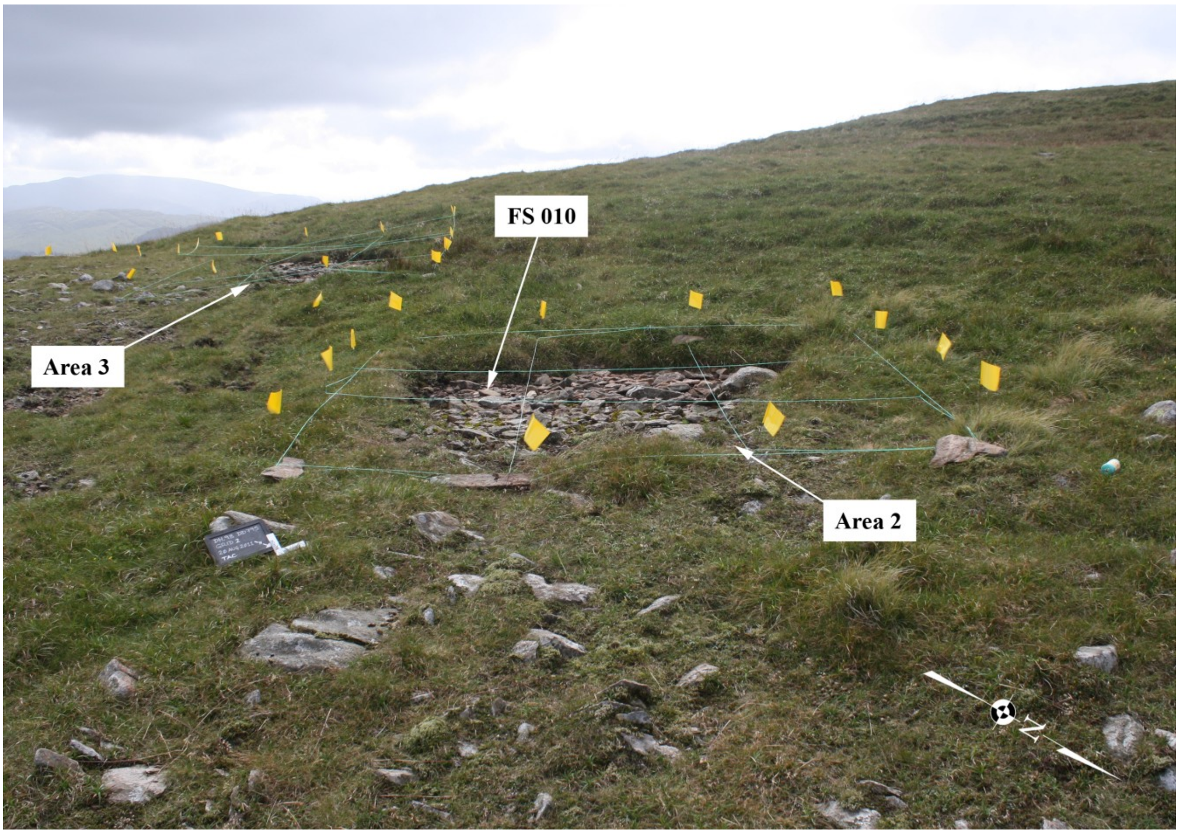

Figure 6-6: Location of DD795 FS 010 (Author).
FS 010, containing a large quantity of screws and melted aluminium, is representative of Area 2's surface scatter.

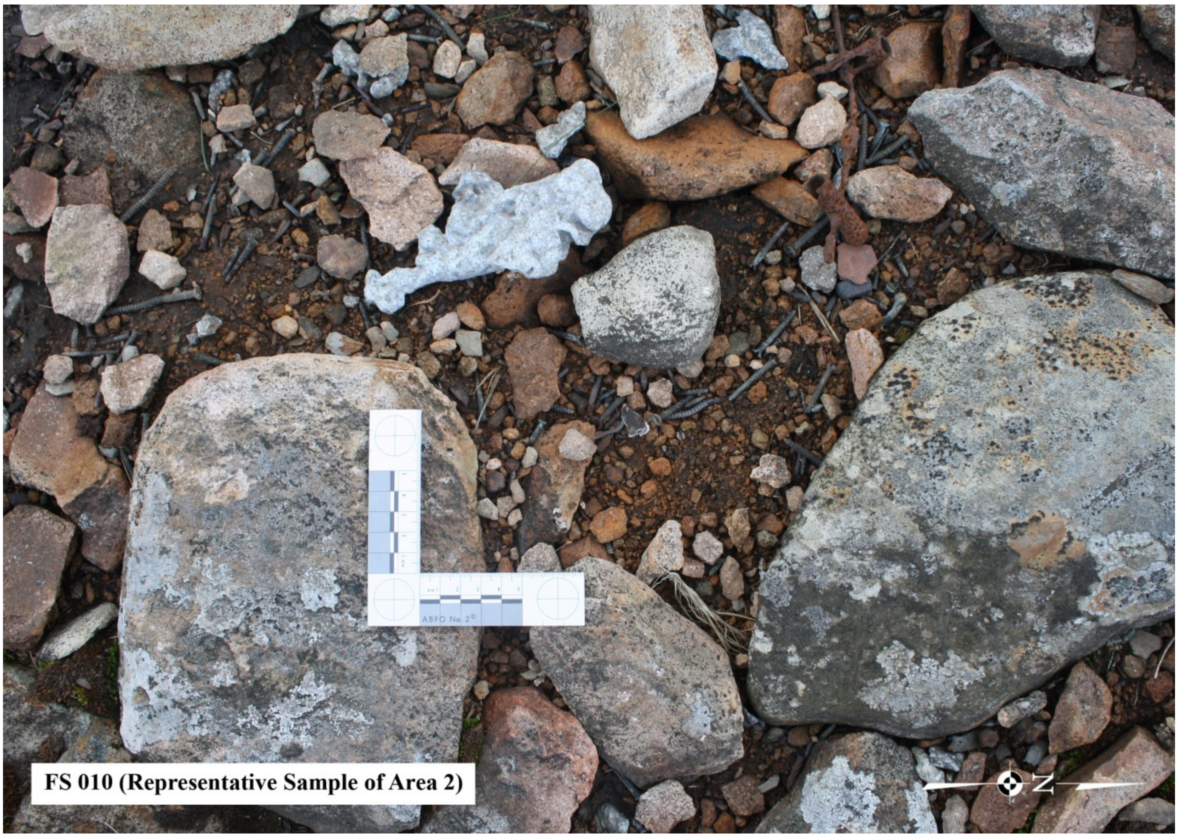

Figure 6-7: FS 010, a representative sample of Area 2, contains a large quantity of screws and melted aluminium indicative of an extensive, post-crash fire (Author).

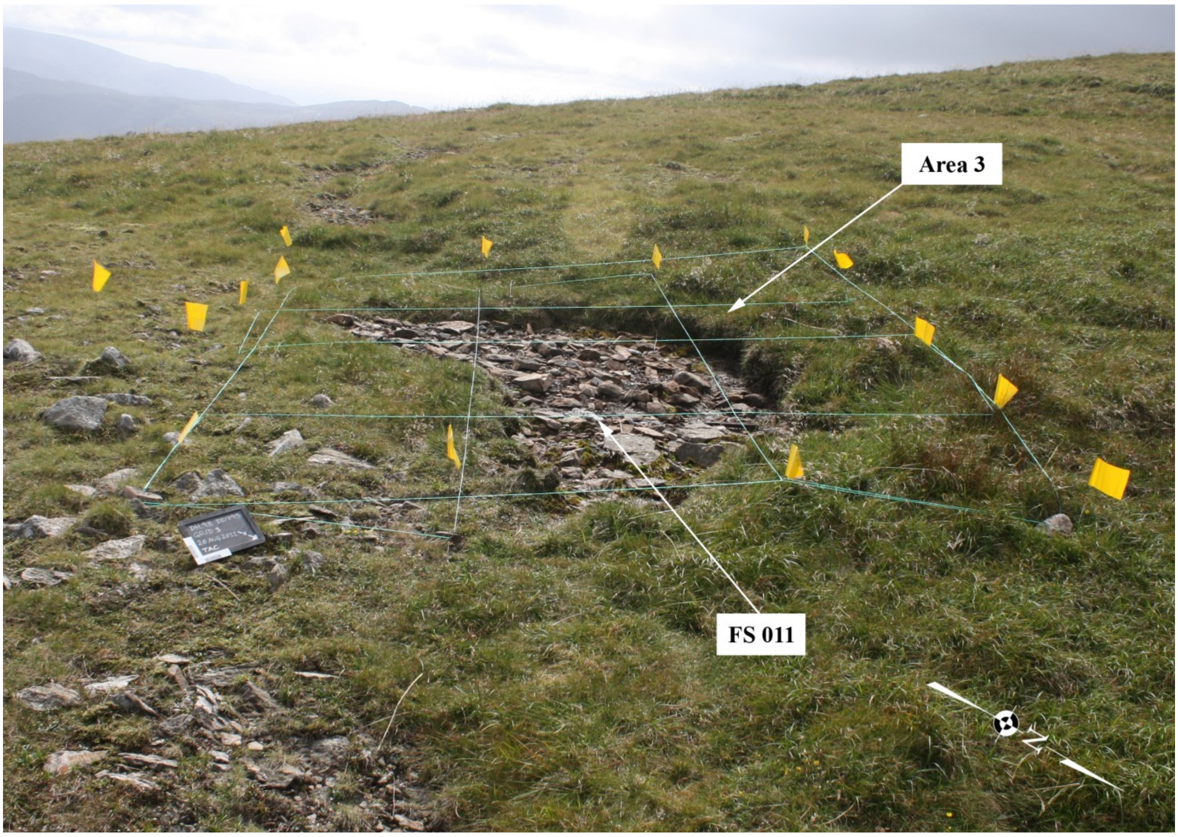

Figure 6-8: Location of DD795 FS 011 (Author).
FS 011 is representative of Area 3's surface scatter. FS 011, containing bolts, plates and brackets, lacks the extensive scatter of wood screws observed in FS 010.

Figure 6-9: FS 011 is a representative sample of Area 3 (Author).
Though not containing an extensive screw scatter like FS 010, FS 011 similarly shows evidence of an extensive, post-crash fire.

6.2.4 Comprehensive Site Analysis

Analysis of FS 005.02 suggests that DD795 was in level or near level flight at the time of impact. The absence of substantial wreckage in Areas 2 and 3, as well as the absence of DD795's engines, provides further evidence that DD795 impacted Scar of the Folk in level and full flight. Under that scenario, the engines broke free from their mounts and continued to travel forward until impacting the ground some 20-30 metres beyond the point of initial impact. The height at which DD795 impacted Scar of the Folk (approximately 780 metres asl) and the artefact evidence suggesting an impact during level, full flight is consistent with navigational error. Mitchell and Aylott, undertaking a night NAVEX, most likely planned to fly over the Corserine's summit. Flying just 35 metres asl too low, the plane impacted just below the ridge.

While the observed artefact distribution certainly supports the hypothesis that DD795 experienced a near-zero degree attitude impact and that, during the crash, its engines separated from their mounts and were deposited 20-30 meters away from the core impact site, the artefact distribution also corroborates the theory that the decades since the crash have experienced at least minor intra-site artefact movement. Indeed, the comingling of

FS 006.01 and FS 006.06 (the two undercarriage jack actuating cylinders) indicate artefact movement. Similarly, the absence of any other shock absorber components in the vicinity of FS 004.04 (shock absorber spacer) demonstrates either the movement of FS 004.04 from FS 001 or the removal of associated artefacts proximal to FS 004.04's current location. In either case, the minor modification or deletion of artefacts from sections of the site is seemingly confirmed; enough artefacts, however, have retained their original spatial relationship to provide data useful in understanding the crash of DH.98 DD795.

6.3 de Havilland DH.98 NFII DD753 (The Curr, Scottish Borders)

6.3.1 Overview

6.3.1.1 Site Background

Conducted on 23 August 2011, a non-invasive survey of DH.98 DD753 (located at NT 8498 2346) provides insight into crash site and artefact survivability. On 12 December 1944 DH.98 DD75 impacted The Curr (near Kirk Yetholm, Scottish Borders) at 535 metres asl, an elevation median to the three DH.98 crash sites investigated. As the site evidences subsequent artefact displacement, DD753's current condition facilitates understanding of anthropogenic and natural artefact mobility (see Figure 6-1 for an exemplar of the DH.98 NFII airframe).

6.3.1.2 Investigation Summary

The land upon which the aircraft wreck site resides is not subject to SSSI or other environmental protections. The closest protected area is the Rowhope Burn section of the River Tweed SSSI and SAC (SNH 2012). The survey of DH.98 DD753 utilised a modified version of the PAAR Methodology, and employed a variety of non-technical and technical archaeological methods and procedures including pedestrian, metal detector, topographic and photographic surveys terminating with Phase IIa. Although excavation was not undertaken at this time, such research is legally feasible as both crewmen were recovered and interred post-crash. The proposed research aim and its related four objectives are identical to those reported in section 6.2.1.2.

As recent photographs of the area show sufficient artefacts to recommend immediate continuation to Phase IIa, a Phase I site visit was not conducted for DD753. Undertaken on 23 August 2011, the Phase IIa investigation identified extensive and significant artefact scatters centred on a single ground scar with two extending sections. The two extended sections, sloping downhill, contain significant portions of hinged sheet metal believed to be remnants of the main landing gear doors. Additionally, discovery of melted aluminium ingots provide evidence of a post-crash fire. The discovered aluminium fragments did not display filament edges consistent with an in-flight fire; this lack of aluminium fragments with filament edges corroborates records indicating that DD795 burned following impact and did not experience an engine fire whilst in full flight. An unexpected hack saw blade fragment also was identified. Considering both the condition of the blade fragment and the fact that DH.98 aircraft were not equipped with an emergency hack saw—escape access was gained via an emergency axe—the hack saw blade fragment presumably was left by post-crash wreck hunters intent on salvaging souvenirs.

In addition to identifying 66 surface artefacts and artefact groups, the Phase IIa survey located 38 unique metallic sub-surface anomalies. Five of the 38 unique contacts (MD 001.01, 002.02, 004.01, 030.01 and 031.01) were obtained after tuning out smaller artefact signatures (i.e., small NMF, wood screws, etc.) and re-surveying the interior of the crash scar. The identification of substantial surface components and the likelihood of numerous sub-surface artefacts with secure contexts makes DD753 a good candidate for future Phase IIIa investigations.

Evidence of recent and substantial artefact removal makes the progression of research on DD753 into Phase IIb and possible Phase IIIa/b time sensitive. Continuation of research into Phase IIb and possibly Phase IIIa/b would allow for the detailed analysis of the numerous extant screws, bolts and NMF. Furthermore, progression into Phase IIb would advance characterisation of the two ground scar extensions and the central scar, potentially answering whether (1) the extensions are impact scars or merely the cuts, and ensuing artefact movement, produced by 70+ years of run-off, or (2) the engines were exploded in the central scar by recovery crews and whether there is archaeological evidence of the detonation.

6.3.2 Airframe Construction

A recitation on the wooden, metal and Perspex components of DH.98 aircraft will not be undertaken in this section as a detailed discussion is offered in Chapter 8, Section 8.2.

6.3.3 Archaeological Investigation

6.3.3.1 Phase I Historical Survey

A Phase I historical survey undertaken in late June 2011 included completion of the *PAAR Aircraft Incident Record* form (Document 6-3) and provided incentive for continued research into Phase IIa. The two deceased crewmen were identified as Flight Lieutenant Henry John Medcalf RAFVR (pilot) and Flying Officer Ronald Edward Bellamy RAFVR (navigator) both of No. 54 OTU (Appendix Table 11-2). Primary sources (UK Air Ministry 1944b) identify the aircraft as having been on a night NAVEX from RAF Charterhall on 12 December 1944 when the aircraft impacted the north north-west side of The Curr.

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Document 6-3: Phase I *PAAR Aircraft Incident Record* form for DH.98 DD753 (ICAO 2006; Author).

6.3.3.2 Phase IIa General Data Survey

Background Research:

Primary Source Accounts:

As to be expected from a crash involving the death of the two crewmen, no primary source accounts by Medcalf and Bellamy were located. Consultation of secondary source material provides little supplementary explanation for the cause or circumstances surrounding the wreck. Information provided is limited to the re-statement of the primary texts' descriptions: "Flew into high ground at Altonburn, near Yetholm, while on night flight from Charterhall. Cause unknown. F/L Metcalf (P) and F/O Bellamy (N/R) both killed. Aircraft destroyed" (Thompson 1995: 135) and

> *A second fatal Mosquito accident occurred on the twelfth, when Mk II, DD753, flew into high ground at Altonburn, near Yetholm, whilst on a flight from Charterhall. The Mosquito was burned out and the crew, Flight Lieutenant Metcalf and his N/R, Flying Officer Bellamy, were killed. The cause of the accident was not ascertained (Thompson 1995: 61).*

It has been reported by a local farmer that the recovery teams explosively destroyed the engines on site and that two extant craters and associated debris scatters are the result of this post-crash recovery activity (Corbett 2013). Neither of these speculative claims is confirmed by the consulted primary source material.

AM Form 1180 discloses that Medcalf and Bellamy were conducting a solo night NAVEX and had only completed 20 minutes flying time when they struck The Curr at 22:10 hrs. Further information regarding the conditions and time of the crash are recorded in *AM Form 1180*'s brief description of the crash scenario: "Accident – due [unintelligible] lapse of pilot regarding his position in relation to base, because he apparently remained below cloud and was still below cloud when he struck" and "a/c flying below cloud which had base of 1400" (UK Air Ministry 1944b). Additionally, *AM Form 1180* confirms that the "a/c burned after crash" (UK Air Ministry 1944b).

Aircraft History:

No. 141 took charge of DD753 in October 1943 while based at RAF Wittering where it was used in night intruder operations supporting Bomber Command (Royal Air Force

1943a, 1944a). In May 1944 DD753 was transferred to No. 54 OTU based at RAF Charterhall (Royal Air Force 1944a, 1944b). DD753 remained with No. 54 OTU until the crash of 12 December 1944 (Royal Air Force 1944b).

Crew Personnel Files:

Crew personnel files are currently unavailable to non-next-of-kin. For detailed explanation of current MoD policy regarding military personnel files, see section 6.2.3.2, *Crew Personnel Files*.

AM Form 1180, while not providing a complete record of the aircrew's progression through familiarisation training, provides basic information relating to Medcalf's familiarity with the DH.98 aircraft. *AM Form 1180* records that, at the time of the crash, Medcalf had a total of 1011 hours solo (of which 178 had been completed at night) and 20 hours solo in a DH.98 (of which 7 had been completed at night) (UK Air Ministry 1944b).

Field Survey:

In compliance with the proposed PAAR Methodology, Phase IIa involved the survey of the DD753 crash site using both unsystematic pedestrian and unsystematic metal detector surveys. Conducted on 23 August 2011, the Phase IIa surveys were tasked with:

1. Identifying the quantity, distribution and condition of surface diagnostic artefacts (and any nondiagnostic artefacts in immediate proximity to identified surface diagnostic artefacts).

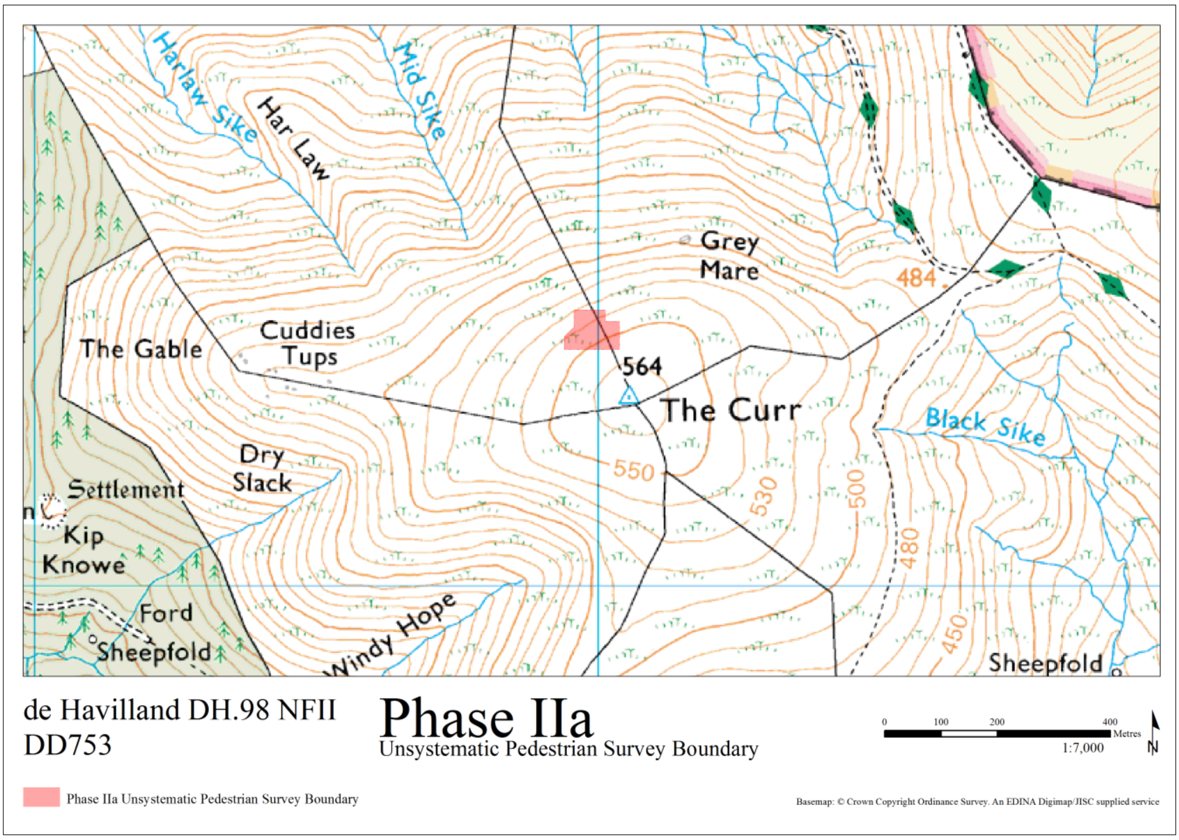
2. Ascertaining the presence, location and quantity of sub-surface anomalies.

3. Providing a site boundary should a Phase IIb detailed site survey proceed.

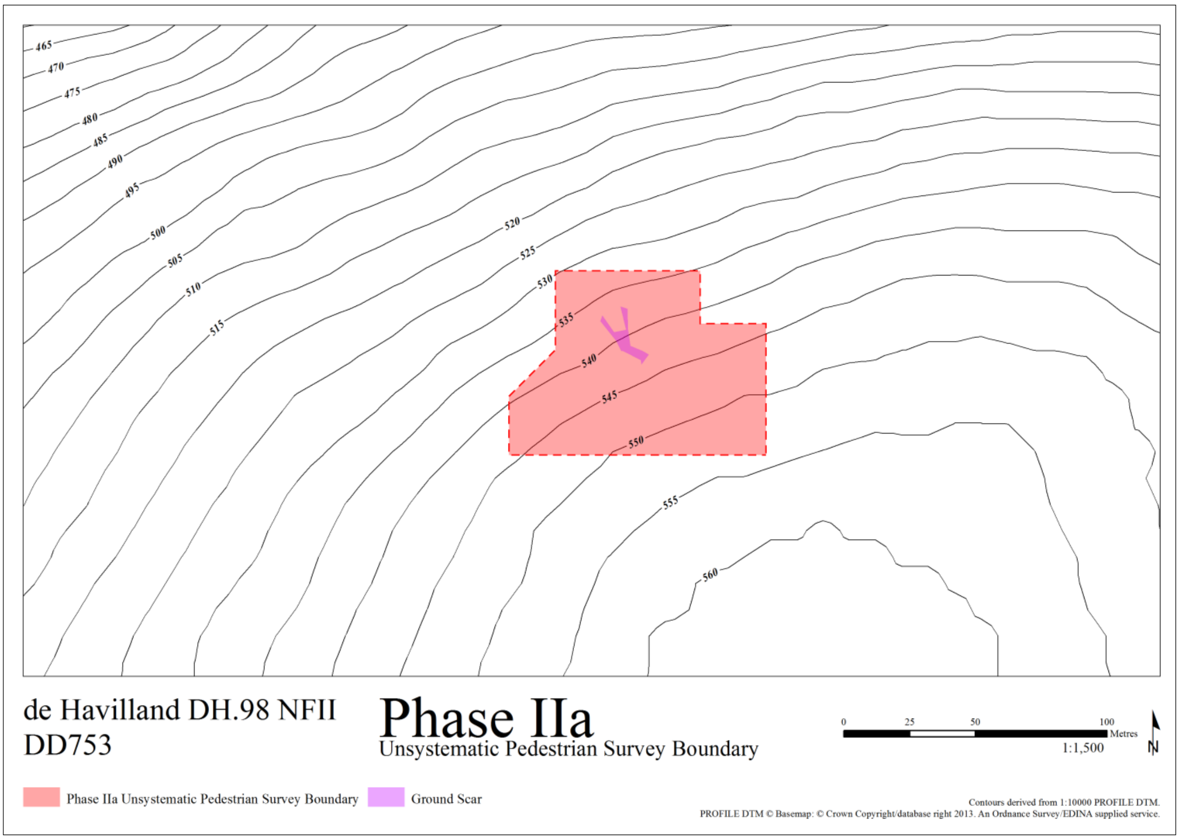
Unsystematic Pedestrian Survey:

Due to the concentration of wreckage in its vicinity, the large ground scar with two down-slope cuts constituted the primary area of focus for the unsystematic pedestrian survey (Map 6-8 and Map 6-9). Observed within the central scar were suspected fragments of the undercarriage and engine assemblies (Figure 6-10, Figure 6-11 and Figure 6-14).

Additionally, several pieces of sheet metal were located within the two down-slope cuts (Figure 6-12 and Figure 6-13). The pieces of sheet metal were identified as pieces of the engine cowling and main landing gear doors. Defined transects were not employed in the Phase IIa survey. Due to the concentration of wreckage and lack of immediately perceived axis of deposition, the unsystematic pedestrian survey was conducted along an SE-NW axis, perpendicular to the terrain contours. Sixty-six individual artefacts/artefact groups were identified during the unsystematic pedestrian survey (Map 6-10 and Map 6-11). Thirty-one artefact groups/artefacts were located in the observed ground scar, two in the down-slope cuts and thirty-three outside the ground scar.



Map 6-8: DD753 Phase IIa survey boundary focusing on the north-northwest slope of The Curr (Crown Copyright/database right OS 2013b; Author).



Map 6-9: DD753 Phase IIa unsystematic pedestrian survey boundary and ground scar (Crown Copyright/database right OS 2013a; Author).
The summit of The Curr is the high ground southeast of the Phase IIa unsystematic pedestrian survey boundary.

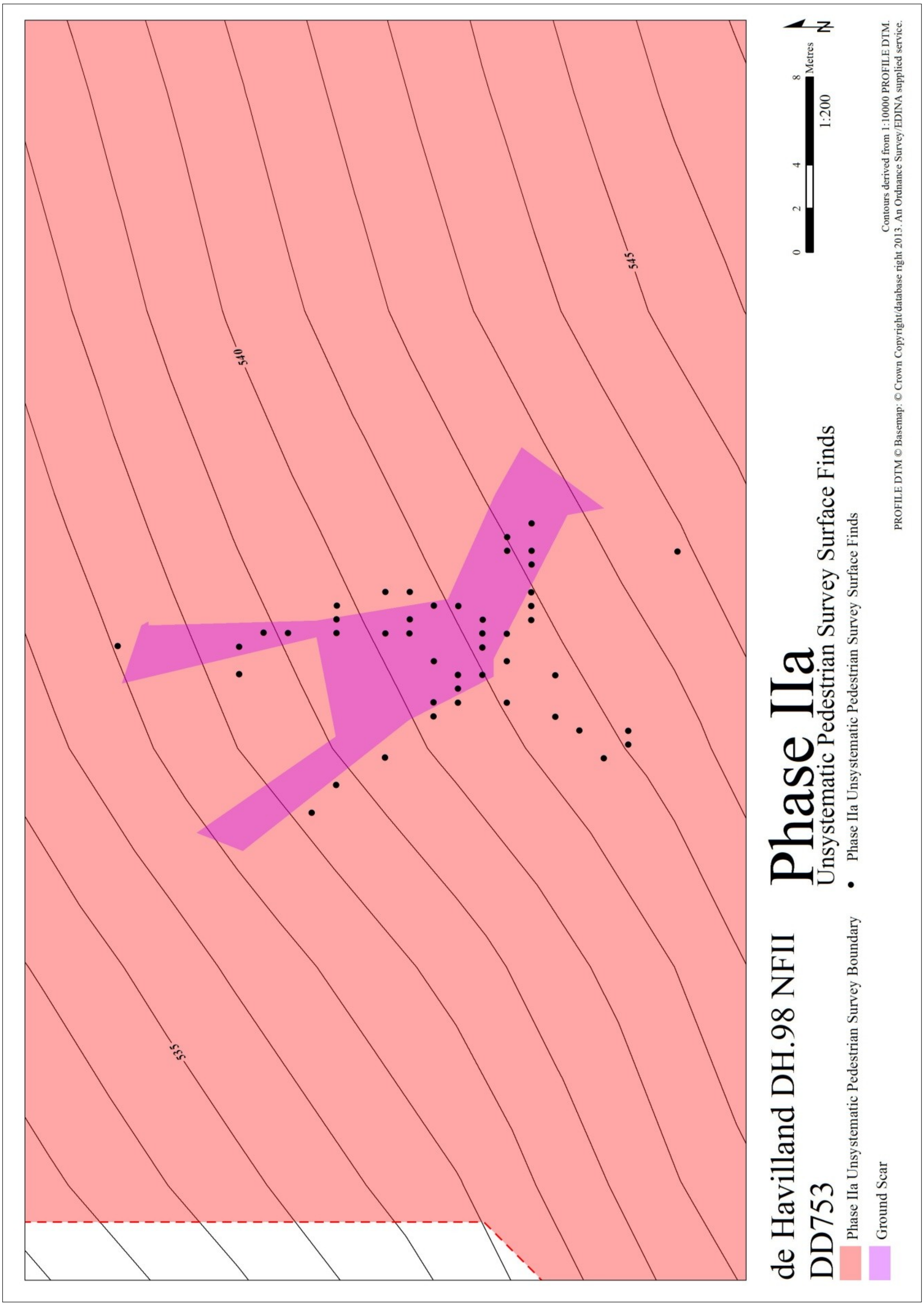
Figure 6-10: General view of the DD753 crash site facing north (Author).
The rising east and west flanks are exaggerated by lens and post-processing distortions. The actual gradient is more uniform. The wreck site has an approximate grade of 26 percent while the flanking high ground has an approximate grade of 32 percent.

Figure 6-11: The DD753 wreck site centre ground scar facing north (Author). The photograph was taken at the southern edge of the centre ground scar.

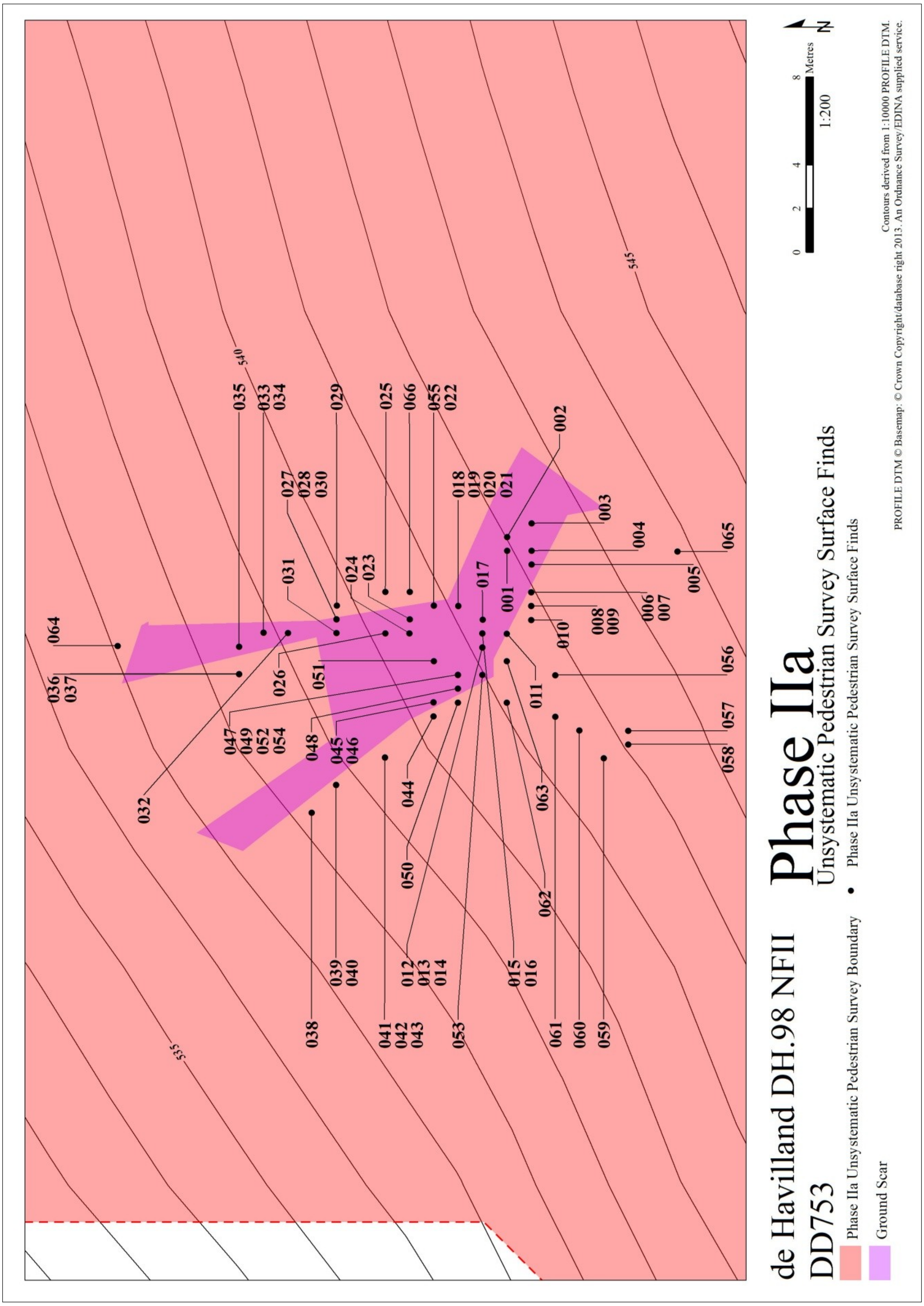
Figure 6-12: North-facing view of western down-slope cut (Author).
Photograph was taken at the northern edge of the main, centre crash scar.

**Figure 6-13: North-facing view of eastern down-slope cut (Author).
Photograph was taken at the northern edge of the main, centre crash scar.**

Figure 6-14: South-facing view of southern ground scar (Author).
Photograph was taken at the southern edge of the main, centre crash scar.



Map 6-10: DD753 Phase IIa unsystematic pedestrian survey surface finds (Crown Copyright/database right OS 2013a; Author).

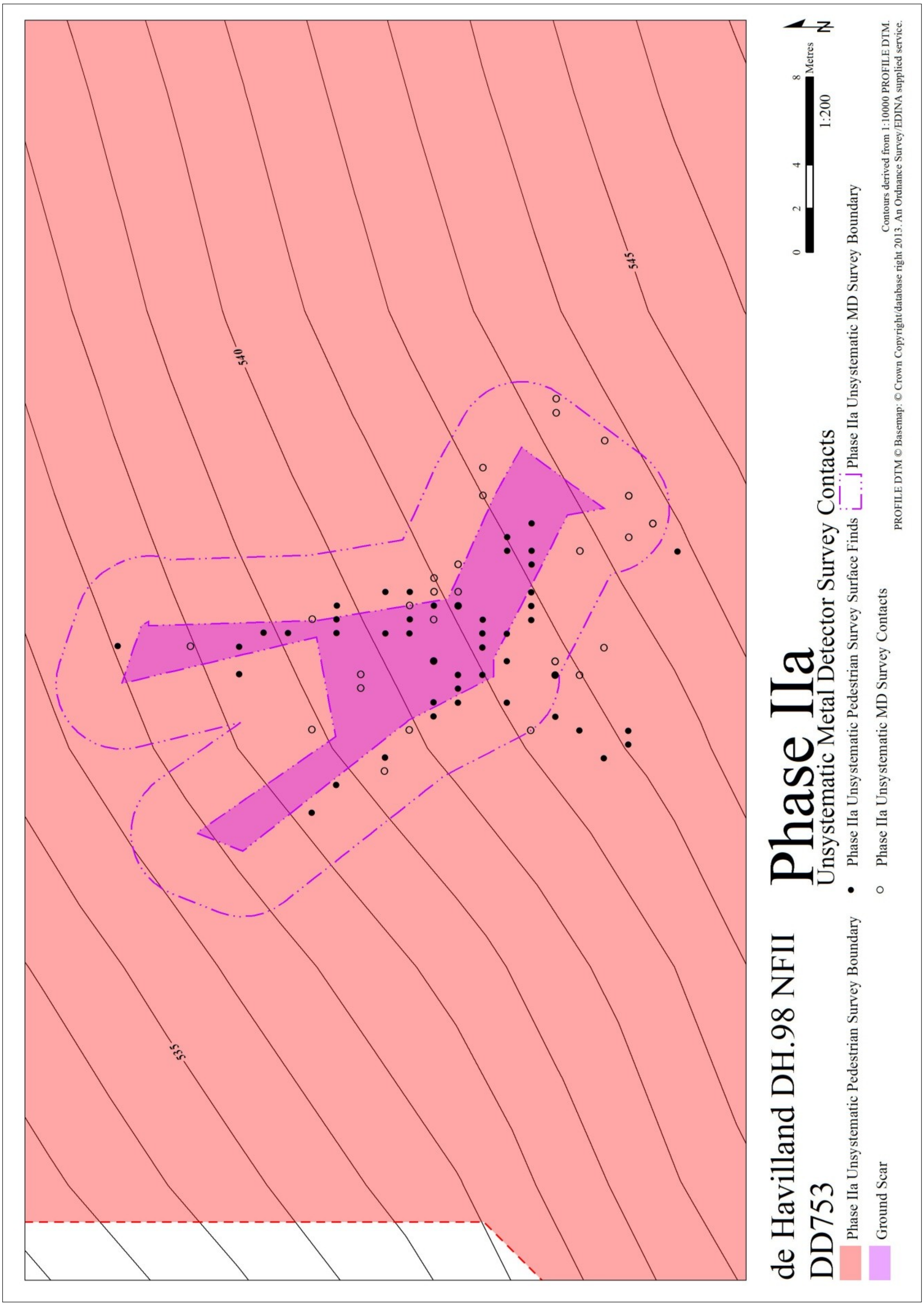


Map 6-11: Annotated distribution of DD753 Phase IIa surface finds (Crown Copyright/database right OS 2013a; Author).

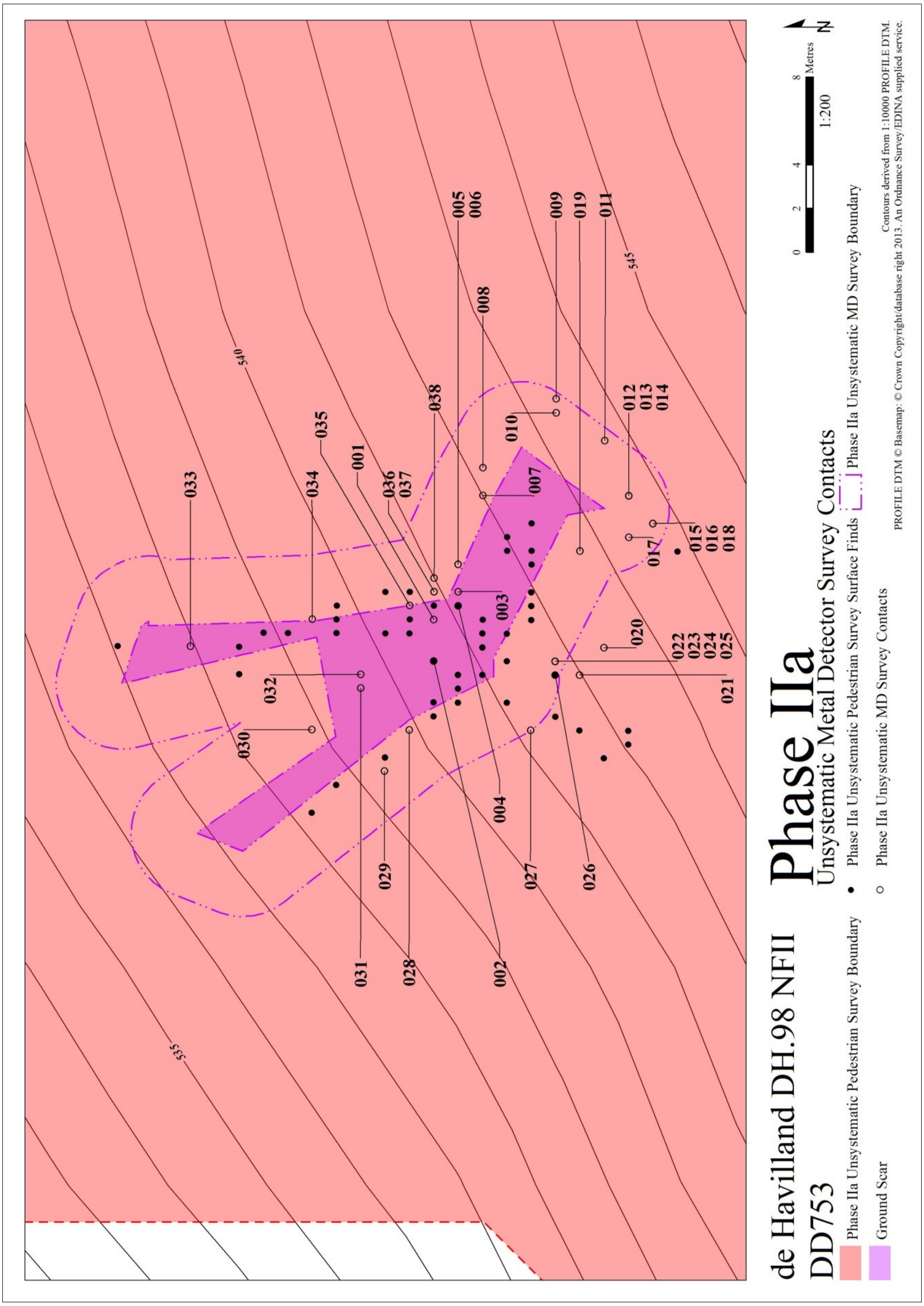
Unsystematic Metal Detector Survey:

The unsystematic metal detector survey was completed in two stages. The initial stage focused on identifying any substantial subsurface anomalies within the ground scar. The first survey was conducted without adjusting the metal detector's sensitivity to exclude surface artefacts. A second survey of the ground scar was completed with the smaller surface artefacts tuned out. While no defined transects were utilised, the survey generally moved on an SE-NW axis. The second stage of the unsystematic metal detector survey scrutinised the periphery of the ground scar utilising a 3 metre sterile buffer as well as sweeping the interior and periphery (3 metre buffer) of the down-slope cuts. The buffer zone was enlarged from the original 1.5 metres as a result of continued metal detector contacts. Thirty-eight individual sub-surface anomalies were recorded during the Phase IIa unsystematic metal detector survey. Twelve of the thirty-eight total sub-surface anomalies recorded were discovered within the ground scar and down-slope cuts (Map 6-12 and Map 6-13).

The lack of surface artefacts and sub-surface anomalies noted between the two down-slope cuts commands particular attention in resolving DD753's final vector, attitude and current site boundaries. Only one sub-surface anomaly was recorded between the down-slope cuts and only one additional sub-surface contact was recorded within either of the down-slope cuts. The lack of substantial surface artefacts and sub-surface contacts within and between the two down-slope cuts show the cuts to be a secondary feature of the crash site. Indeed, the presence of the cuts may be due simply to natural erosion and artefact wash-out caused by rainwater run-off in the devegetated main crash site.



Map 6-12: DD753 Phase IIa unsystematic pedestrian survey surface finds and unsystematic metal detector survey contacts (Crown Copyright/database right OS 2013a; Author).



Map 6-13: Annotated distribution of DD753 Phase IIa metal detector contacts (Crown Copyright/database right OS 2013a; Author).

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Document 6-4: Phase IIa *PAAR Aircraft Incident Record* form for DH.98 DD753 (ICAO 2006; Author).

Artefact Analysis:

The DD753 crash site contains considerable observable surface material. Phase IIa identified 37 diagnostic and critical nondiagnostic(diagnostic) artefacts. While additional NMF, NWF, and NGF were recorded, the Phase IIa artefact record is not exhaustive. Numerous additional NF were unrecorded as they were not in close proximity to diagnostic material and should be subject to scrutiny during any future Phase IIb investigation. The recorded diagnostic and critical NF material identified during the Phase IIa unsystematic survey allows for plotting the orientation of DD753 within the landscape, provides a boundary for the crash site, and clarifies the post-crash sequence of events. In addition, a detailing of critical diagnostic material is prerequisite for comprehending the deposition process, the aircraft's orientation, and the post-crash *inter alia* tampering within the wreck site. Given the number of artefacts surveyed, the following discussion encompasses only those artefacts significant to these research objectives.

FS 005.01 (Figure 6-15 and Appendix Figure 11-9), while missing its characteristic end cap fitting, is most likely the lower terminus of upper main landing gear support (DHA-G.98107A or DHA-G.98108A). It appears that the aluminium end fitting (DHA-G.9890 or DHA-G.9887) has corroded away as the attachment pins (DHS 91/243 or DHS 91/268) remain protruding from the side of the main tube (RSAFB n.d.b: 4-6, 14-16). The protrusion of the pins is significant to parts identification as DHA-G.9890/DHA-G.9887 is the only section of the main landing gear assembly which has pins oriented in a staggered perpendicular format (RSAFB n.d.b). Additionally, only three pins (two on one side and one on another) remain visible. It is not clear from the artefact's terminus whether the missing two pins, which should be present below the corroded end, were sheared off in the crash or whether they corroded away afterward. The lack of the aluminium end fitting, however, supports the hypothesis that the missing pins and tube section corroded away in the decades since the crash.

Figure 6-15: FS 005.01 (centre) and FS 006.01 (upper right) (Author).
FS 005.01 is most likely the lower terminus of upper main landing gear support (DHA-G.98107A or DHA-G.98108A).

In close proximity to FS 005.01, FS 007.01 (Figure 6-16 and Appendix Figure 11-10) is the lower portion of the undercarriage jack actuating cylinder, retracted piston and valve lock (DHA-Q.98850A/3) (RSAFB n.d.e: 20-24). The upper section, including the attached valve, is missing from FS 007.01. Apparently, the upper section broke free during the crash or during the alleged detonation of the engines during salvage. While the upper portion could not be located, thus preventing confirmation of its detachment during the crash or during salvage, the retracted piston rod shows evidence of having been bent during the crash (Appendix Figure 11-11). The 23 degree bend towards the fuselage, perpendicular to the retracted axis of installation, provides compelling evidence that the aircraft impacted the hillside front on with the ground sloping slightly upwards (as opposed to a zero degree angle of impact). While the bend to the piston rod indicates that one engine impacted the hillside prior to the other, the lack of a readable part number on the assembly components precludes specific identification of the first engine to impact the hillside. Consistent with the extent of corrosion found on most aluminium and/or steel materials on site, the aluminium end piece (DHA-Q.98852) and steel cylinder (DHA-Q.98677A/ND) suffer from severe intergranular corrosion (Appendix Figure 11-12). The aluminium end piece is corroded such that recessed nut DHA-Q.9823 is nearly fully exposed. The presence of severe corrosion on FS 007.01 suggests a total corrosion of the FS 005.01 end fitting.

Figure 6-16: General view of FS 007.01 (Author).
FS 005.01 and FS 006.01 are seen in the low grass at top left and top right, respectively.

Complementing the undercarriage assembly represented by FS 005.01 and FS 007.01, FS 024.01 (Figure 6-17) is the upper terminus of the upper landing gear support (DHA-G.98107A or DHA-G.98108A) (RSAFB n.d.b: 4-6, 14-16). It is unclear whether FS 024.01 is associated with FS 005.01 or FS 046.01/047.01. Its location on the eastern side of the ground scar and the presence of similarly advanced stages of intergranular corrosion—FS 047.01 shows minor aluminium corrosion including surface oxidation, pitting and early stage intergranular corrosion of attached parts—favours association with FS 005. However, its distance from FS 005.01 and FS 007.01 and its location in line with the eastern down-slope cut makes it feasible that FS 024.01 has been transported from its original context by rain run-off. Similar run-off induced transport is inferred to have relocated FS 026.01 (Figure 6-18 and Appendix Figure 11-13), a probable section of strut tubing similar to that observed in FS 024.01 (RSAFB n.d.b: 4-6, 14-16).

Figure 6-17: FS 024.01, the upper terminus of the upper landing gear support (Author). FS 024.01 may either be associated with FS 005.01 or may have been relocated by run-off within the eastern down-slope cut.

**Figure 6-18: FS 026.01, a probable section of strut tubing similar to that observed in FS 024.01 (Author).
It is believed run-off has caused the relocation of FS 026.01 from its original point of deposition.**

Expanding the assemblage beyond undercarriage components, FS 031.01 (Figure 6-19 and Appendix Figure 11-14) is one of only two extant wing section surface fragments observed. A section of the aileron, FS 031.01 consists of the pushrod assembly (DHA-D.98527A) and aileron pushrod connection (G3.U1.S5.45-64) as well as ribs 6A and 6B (DHA-D.98481/DHA-D.98482 and DHA-D.98483/DHA-D.98485) (Appendix Figure 11-15) (RSAFB n.d.a: 4-6, 8). Located further down slope than FS 024.01 and FS 026.01, FS 031.01's approximate location represents the back edge of DD753's wing section. No evidence of the aileron centre hinge pulley connection, Stub B (DHA-D.98407) (Tanner 1977: 177; RSAFB n.d.c: 46-48, 50), was found in the immediate vicinity. This deficit may indicate either that FS 031.01 has been transported from the site of original deposition or that the main wing section was removed from the area during the post-crash site recovery process.

Figure 6-19: FS 031.01 with FS 032.01, 034.01 and 035.01 in the background (Author). All five artefacts are located within the eastern down-slope cut.

FS 032.01, 034.01 and 035.01 are the main undercarriage door panels. FS 032.01 (Figure 6-20) and 034.01 (Figure 6-21) are left covers (DHA-L.981515A) while FS 035.01 (Figure 6-22) is a right side panel (DHA-L.981516A) (RSAFB n.d.d: 10-12). The left covers are identifiable by the door hinge part numbers (L.98295A) (Appendix Figure 11-16 and Appendix Figure 11-17). The right doors do not retain hinge part numbers but are identifiable by process of elimination and similar shape to confirmed artefacts FS 032.01 and 034.01. FS 034.01 has an additional stamp impressed onto the front left door hinge. Faintly visible, its meaning could not be ascertained.

All of the doors have accordion deformation on their leading edge with no substantial deformation to the trailing section. The similar deformation pattern observed on the leading edges of FS 032.01, 034.01 and 035.01 (Figure 6-20, Figure 6-21 and Figure 6-22) conforms to the near zero-degree attitude impact scenario proposed by the bend in FS 007.01.

Figure 6-20: FS 032.01 is one of two left side main undercarriage door panels recorded (Author).

Figure 6-21: The second left undercarriage door cover, FS 034.01, rests only metres from FS 032.01 (Author).

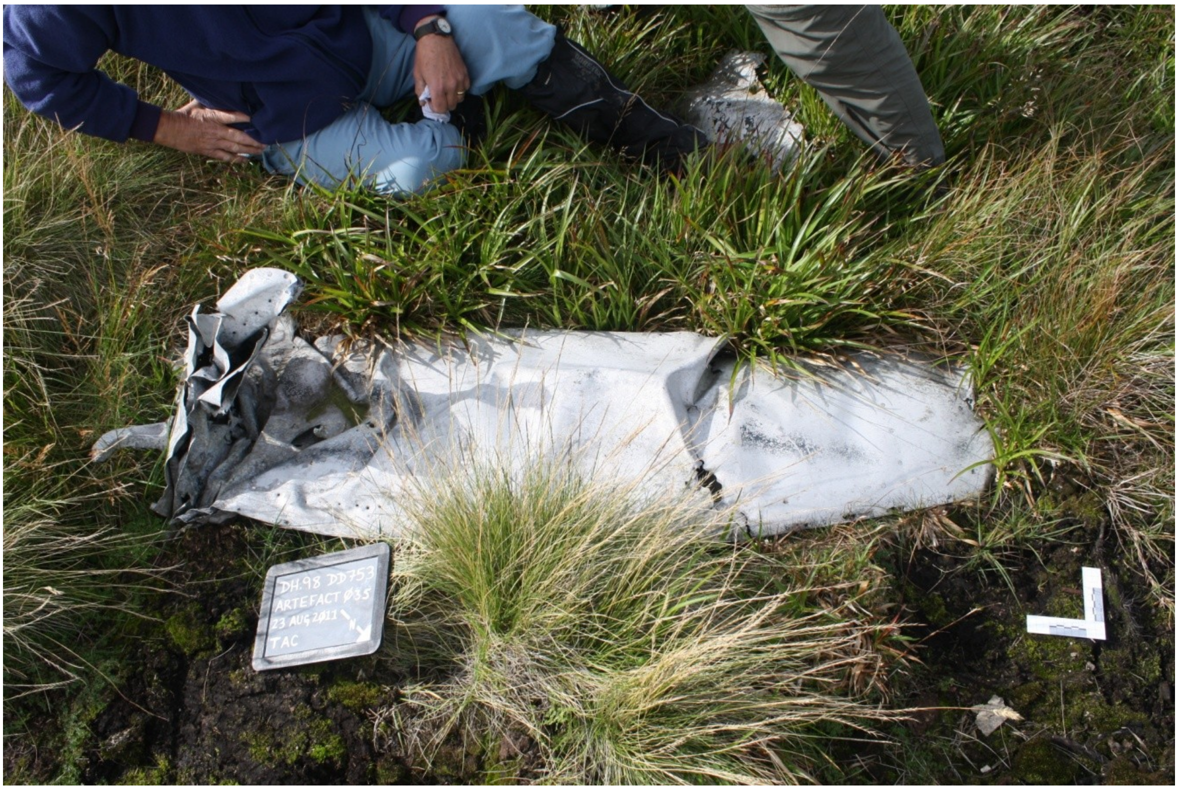


Figure 6-22: FS 035.01 is the only confirmed right undercarriage door cover located (Author). The second right undercarriage door cover is believed to be FS 033.01.

FS 033.01 (Appendix Figure 11-18) appears to be the missing main undercarriage panel as its shape resembles that of FS 032.01, 034.01 and 035.01 as well as the diagram given in the parts manual (RSAFB n.d.d: 10-12). Additionally, FS 033.01's close proximity to FS 035.01 (similar distances are observed between FS 032.01/034.01 and FS 033.01/035.01) makes its identification as the missing right side panel plausible. However, the lack of a stamped part number precludes confirmation of FS 033.01 as a right side main landing gear door.

Probably not directly associated with DD753's airframe, FS 036.01—a hack saw blade fragment (Figure 6-23 and Appendix Figure 11-19)—may represent either post-crash recovery activity or the removal of artefacts in the decades following impact. Relative dating of FS 036.01 is not possible as a type catalogue of hack saws does not exist at this time.

Figure 6-23: FS 036.01, a hack saw blade fragment, is either associated with post-crash salvage or with later site tampering (Author).
While it is not possible to date the hack saw blade fragment, its presence at the DD753 crash site supports the dismemberment and movement of surface artefacts.

FS 041.01 and 042.01 are the only sections of the engine cowling located. FS 041.01 (Appendix Figure 11-20) encloses the exhaust ports (DHA-L. 986257/2 or DHA-L.985878/2, DHA-L.988127A/2 or DHA-L.985880A/2). FS 042.01 (Appendix Figure 11-21) covers the area near the supercharger intake on the underside of the engine (DHA-

L.987819A or DHA-L.987819A) (RSAFB n.d.d: 22-23). Part numbers are only observed on FS 041.01:

684000
L982158A2
SI654

Complementing main landing gear components FS 005.01, FS 007.01 and FS 024.01, FS 046.01 (Figure 6-24) is the complete undercarriage top structure (DHA-G.98172A, DHA-G.985A) including the vertical struts (DHA-G.9856A and DHA-G.9857A) (RSAFB n.d.b: 4-6, 19-22) and main spar attachments (DHA-D.9873 and DHA-F.98443 A) (RSAFB n.d.c: 20-21, 24-27). FS 046.01 suffers from substantial corrosion including partial mineralisation of the adjustable struts. Although corroded, FS 046.01 appears unbent and thus reinforces the hypothesis that DD753 impacted with the main landing gear retracted. Any impact with the main landing gear down and locked would produce some deformation of FS 046.01 when the main gear top structure struck the ground prior to the fuselage's impact.

Figure 6-24: One complete main landing gear top structure (FS 046.01) as seen facing north (Author). The second main landing gear top structure has broken up into smaller pieces.

FS 047.01, the main landing gear upper brace strut to rear spar attachment bracket (DHA-D.98240 A and DHA-E.98463, DHA-E.98464, DHA-E. 98459 A or DHA-E.98460 A) Appendix Figure 11-22) (RSAFB n.d.c: 28-31, 34-36), rests atop FS 046.01 but is not attached to it (Appendix Figure 11-23). As additional sections of the main landing gear, FS 046.01 and 047.01's immediate proximity supports an assertion that FS 046.01/047.01 represents the impact point for one of the two main landing gear assemblies. FS 047.01, unlike FS 046.01, retains its wood attachment and its placement on top of FS 046.01 may demonstrate the post-crash relocation of FS 047.01. However, it is equally plausible that FS 046.01 was wrenched from the main spar during the crash and that the lack of any observable wood fragments is inconsequential to the larger artefact patterning.

The second of two wing components observed at the DD753 crash site, FS 048.01 (Appendix Figure 11-24) is one-half of the port flap torque tube (DHA-E.98359A/1, DHA-E.98360A/1, DHA-E.98367 or DHA-E.98272) (Tanner 1977: 244; RSAFB n.d.a: 10-14). The centre hinge of the main torque tube has a single part stamp (AUUDNO 300). The centre hinge support adjustable struts have been sheared off prior to the threaded end connections (DHA-D.98377 A / DHA-D.98378 A and DHA-D.98380 A) (Appendix Figure 11-25) (RSAFB n.d.c: 34-36). The position of FS 048.01 amongst undercarriage components supports the hypothesis that the area and the artefacts surrounding FS 048.01 are remnants of the port wing, engine and undercarriage.

FS 049.01 consists of two adjacent artefacts. Though FS 049.02 would normally be considered NMF, its relative location, similar diameter and comparable condition makes it likely that FS 049.02 is a fragment of the missing port flap torque tube (Appendix Figure 11-26) (Tanner 1977: 244; RSAFB n.d.a: 10-14). FS 049.01 is the outboard main undercarriage radius rod upper fixing assembly (DHA-D.98124, DHA-D.98125 A, and DHA-D.98360 A) and the undercarriage strut attachment brackets on the rear spar (DHA-E.98459 A and DHA-E.98460 A) (Appendix Figure 11-26) (Tanner 1977: 171; RSAFB n.d.a: 30-31). The undercarriage strut attachments are fragmentary with the upper portions of DHA-E.98459 A and DHA-E.98460 A missing. Additionally, the wood spar between DHA-D.98124 and DHA-E.98459 A / DHA-E.98460 A is considerably charred (Appendix Figure 11-27). It is unclear whether the upper sections of DHA-E.98459 A and DHA-E.98460 A are missing due to corrosion or due to impact-induced breakage. A detachment of DHA-E.98459 A and DHA-E.98460 A due to breakage would correspond with a low angle impact which shears the undercarriage away from the rear spar at the weakest bracket (DHA-E.98459 A and DHA-E.98460 A). The charring of the internal wood spar, due to the proximity of like components, is probably the result of the post-crash fire rather than debris burning during salvage operations.

FS 053 similarly demonstrates the proximate impact of an engine/main landing gear section. FS 053.01 is the main spar brackets for the main landing gear and engine cradle (Appendix Figure 11-28). FS 053.01 is identical to the two brackets observed in FS 046.01 and is the attachment point for the second engine (DHA-D.9873 or DHA-F.98443 A) (RSAFB n.d.c: 20-21, 24-27). The presence of the jacking attachment (DHA-G.98125 or DHA-G.98126), only installed on one side, indicates that the FS 053.01 are outboard brackets (Tanner 1977: 324; RSAFB n.d.b: 4-6). No fragments of the landing gear struts were observed attached to FS 053.01. FS 053.02 is a wing-fuselage connection (DHA-B.98323) installed in the same area as FS 049.01 (Appendix Figure 11-28) (RSAFB n.d.c: 34-36). FS 053.03 is the undercarriage jack piston (DHA-Q.98850A/3) missing from FS 005.01 and is identifiable by down stop lever bracket (DHA-G.9885) and ram stop sleeve (DHA-Q.9844) at one end (Appendix Figure 11-28) (Tanner 1977: 171, 182; RSAFB n.d.b: 14-16; RSAFB n.d.e: 20-24). Originally attached to FS 005.01, the position of FS 053.03 away from FS 005.01 may demonstrate minor artefact mobility.

Adjoining FS 053, FS 054 provides additional evidence that this immediate location served as impact point for one of the two main landing gear and engine/engine cradle assemblies. FS 054.1 is the inboard main undercarriage radius rod upper fixing and the undercarriage strut attachment bracket assemblies on the rear spar (DHA-D.98129 A or DHA-D.98130 A and DHA-D.98131) (Appendix Figure 11-29 and Appendix Figure 11-30) (RSAFB n.d.c: 28-29). Taken together, FS 054.01 and FS 049.01 provide the two rear-spar attachment points for the main undercarriage upper radius rods. Additional evidence for establishing this area as the impact point for the inboard wing section is demonstrated by FS 054.02. Although fragmentary, the recessed construction of the cover plate and the 10 securing bolts (only seven of which survive) indicate that FS 054.02 probably is an inspection cover from one of the eight wing petrol tanks (DHA-P.98229A, DHA-P.98231A, DHA-P.98911A or DHA-P.98887A Mk 2) (Appendix Figure 11-29 and Appendix Figure 11-30) (RSAFB n.d.f: 2-3, 4-18) or from the right side Number 10 tank (DHA-P.98368A) (RSAFB n.d.f: 2-3, 22-23). FS 054.02 is the only confirmed, surviving example of petrol tanks extant at the DD753 crash site. As the DH.98’s petrol tanks flank the engine nacelle/landing gear-wing connection, the location of FS 054.02 supports the hypothesis that this area of the wreck site was the site of a wing impact.

FS 055.01 and FS 055.02 are the exterior reinforcement (DHA-G. 9865A) for the assembled shock absorber (DHA-G.983A) and the mounting point for hinged bracing. Badly corroded, FS 055.01 and 055.02 retain fragments of the shock absorber jacket (DHA-G.98118A/2) and the undercarriage cross-bracing (DHA-G.9881A and DHA-G.9882A) (Appendix Figure 11-31 and Appendix Figure 11-32) (Tanner 1977: 184; RSAFB n.d.b: 4-6, 8-10). No portion of the shock absorber assembly beyond the exterior reinforcement plate was observed in the immediate vicinity. The presence of intact bolt assemblies on the shock absorber reinforcement plates (BSS A16Y/GT, DHA-G.98417, AGS 784.3, DHA-G.98418, BSS A16Y/GS, BSS A16Y/GP) and on the exterior jacket (DHA-G.98118A/2, DHA-G.9869, AGS 249/13) (RSAFB n.d.b: 8-10) connotes that the two shock absorber pistons associated with FS 055.1 and 055.2 were not systematically disassembled following the crash.

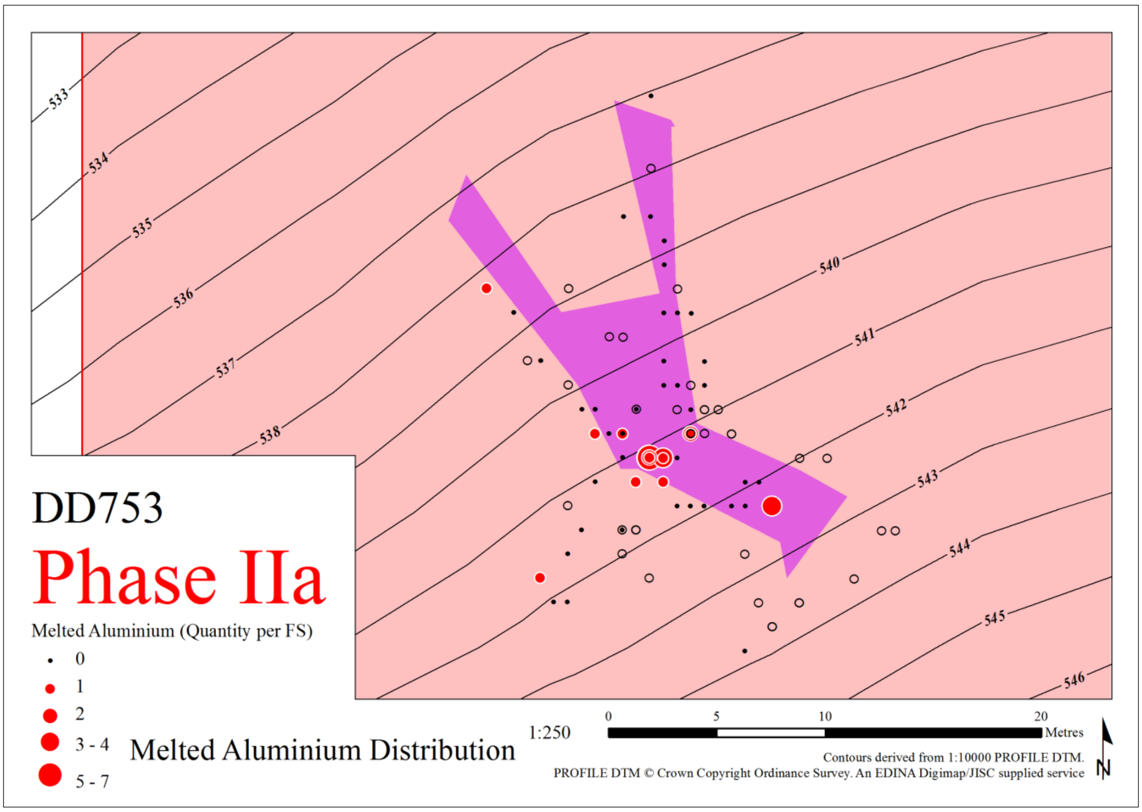
FS 056.01 offers tantalising but currently unconfirmed evidence regarding the circumstances surrounding the crash of DD753. A section of the exterior engine cradle mounting struts extending from the top joint of the undercarriage top structure (DHA-L.981878A/1, DHA-L.981880A/1, DHA-L.981877A/1 or DHA-L.981879A/1) (Figure 6-25) (Tanner 1977: 239; RSAFB n.d.d: 4-6), FS 056.01 demonstrates a confirmed weld failure at the eastern end (Appendix Figure 11-33) and a possible weld failure at the western terminus. Additionally, FS 056.01 shows a 28 degree bend which feasibly occurred during the crash (Figure 6-25). It is unknown whether FS 056.01 comes from the number one or number two engine or, if the engine was known, whether it is the port or starboard side exterior cradle strut. The lack of confirmation on FS 056.01's positioning is due to the legal restrictions placed on aircraft excavations in the UK (see Chapter 2 Section 2.2.2). The ability to handle FS 056.01 and examine the termini and bend in more detail would undoubtedly provide additional information on FS 056.01's placement within the airframe and, therefore, additional evidence on DD753's attitude at the time of the crash.

Figure 6-25: FS 056.01, a section of the exterior engine cradle mounting struts extending from the top joint of the undercarriage top structure, shows weld failures suggestive of a high speed impact (Author).

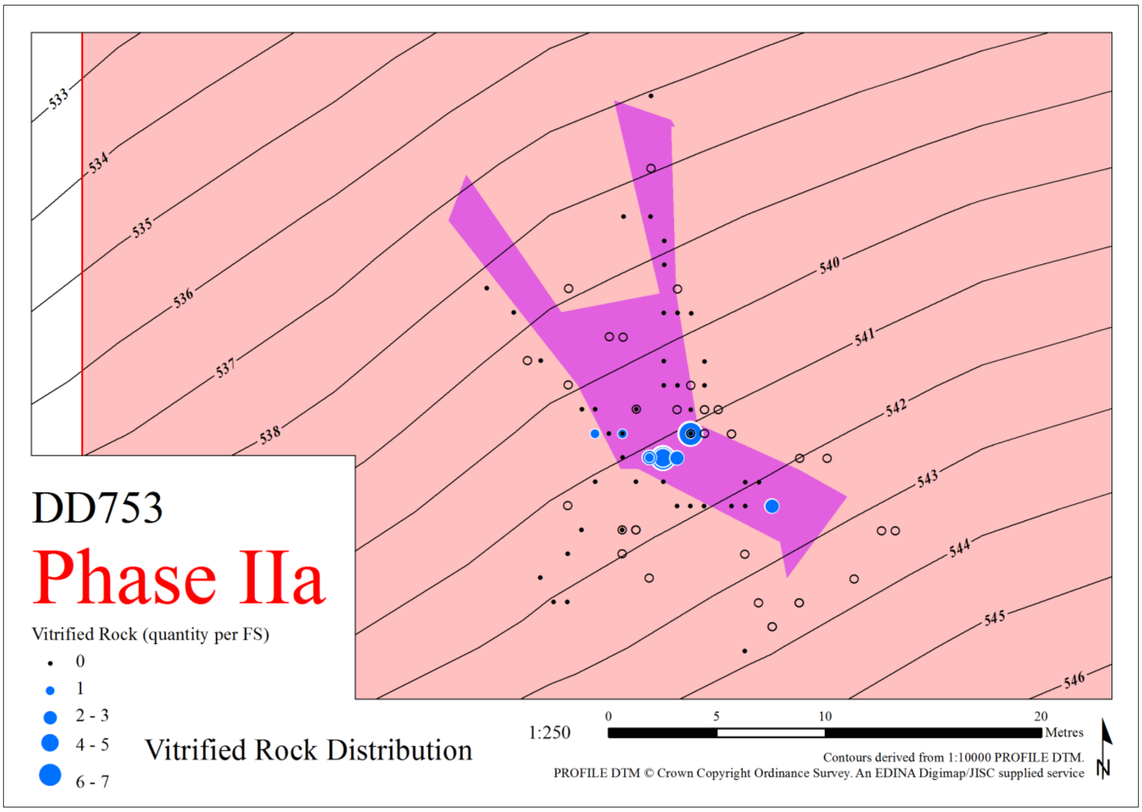
A substantial quantity of melted aluminium fragments were observed both within and beyond the ground scar. Though three melted aluminium fragments were discovered outside of the ground scar, the vast majority (a total of 26 fragments) were discovered within the ground scar. Varying in size from only a few centimetres to approximately 20 centimetres maximum diameter (Figure 6-26), the predominant location of most melted aluminium fragments within the southern constriction of the ground scar (Map 6-14) further supports the conjecture that the central portion of the crash scar was shaped by the crash event. Furthermore, the observed aluminium fragments cluster in two areas on opposing edges of the central ground scar. Separated by approximately four metres, the distance between the two concentrations of melted aluminium fragments correspond to the distance between DD753's two engine/main gear wing sections. Indeed, the presence of the undercarriage, wing and engine components proximate to melted aluminium concentrations (for example FS 046-049, 052 and 055) further substantiates the claim that this melted aluminium is associated with DD753's main landing gear, wings and engines.

In addition to melted aluminium, vitrified rock is present both inside and outside the ground scar. The majority of the vitrified rock (FS 029.01) is located inside the ground scar and is concentrated on the eastern edge of the central scar in largely the same artefact locations as the melted aluminium (Map 6-15). It is not surprising that the observed vitrified rock locations correlate with the melted aluminium locations as both materials require prolonged high temperatures to deform from their native state (Map 6-16). The adjacent grouping of undercarriage, wing, engine and fuel tank assemblies (FS 047-049, 052 and 055) would have provided substantial quantities of aviation petrol capable of fuelling a post-impact fire and, thus, of raising the temperature sufficiently to deform both aluminium parts and surface rock.

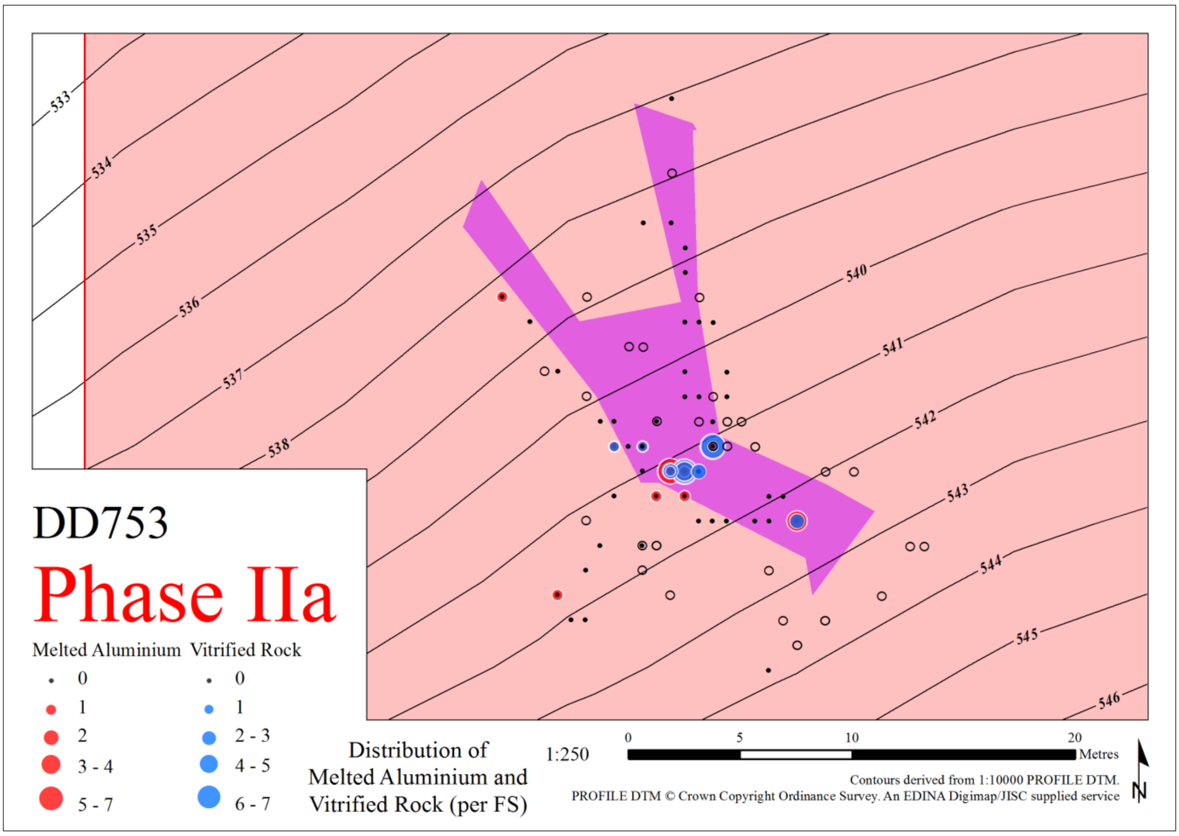
Figure 6-26: The FS 020 concentration exemplifies the melted aluminium-vitrified rock correlation (Author).



Map 6-14: The distribution of melted aluminium (Crown Copyright/database right OS 2013a; Author).
The predominant location of most melted aluminium fragments within the southern constriction of the ground scar further supports the conjecture that the central portion of the crash scar was shaped by the crash event



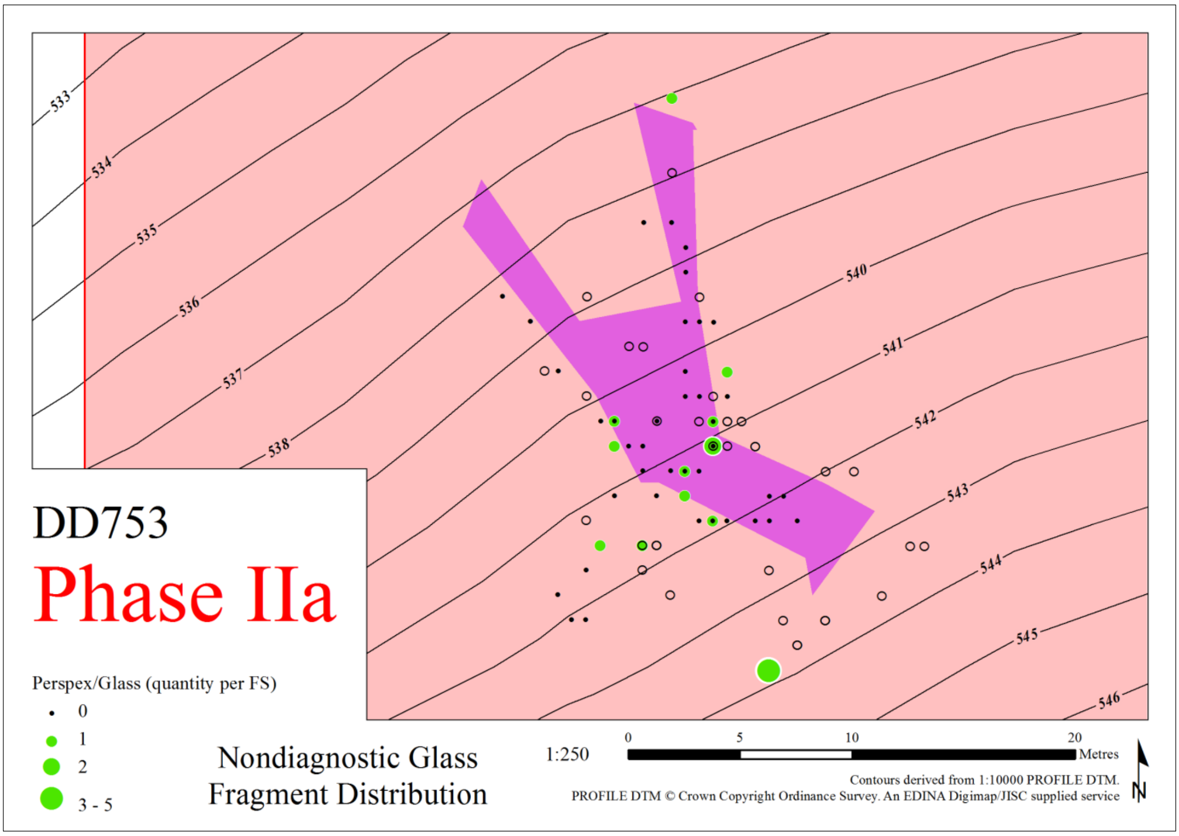
Map 6-15: The distribution of vitrified rock (Crown Copyright/database right OS 2013a; Author).
The majority of the vitrified rock is located inside the ground scar and is concentrated on the eastern edge of the central scar in largely the same artefact locations as the melted aluminium.



Map 6-16: The distribution of melted aluminium and vitrified rock (Crown Copyright/database right OS 2013a; Author).
The observed vitrified rock locations correlate with the melted aluminium locations as both materials require prolonged high temperatures to deform from their native state. It is believed that the aviation petrol-based post-crash fire generated the extreme temperature elevation required.

Small quantities of nondiagnostic glass or Perspex fragments [NGF] span the southern edge of the central ground scar (Figure 6-27, Appendix Figure 11-34 and Map 6-17). While the NGF distribution conforms to the general trend observed in the melted aluminium and vitrified rock distributions, no concrete deductions regarding individual fragments' installation could be obtained without handling the artefacts. Nonetheless, the linear trend of the NGF distribution probably represents a linear distribution of glass and Perspex across the leading edge of the aircraft including the Perspex lamp covers and cockpit windscreen.

Figure 6-27: FS 022.01, a small fragment of Perspex, is a typical NGF observed on the DD753 wreck site (Author).

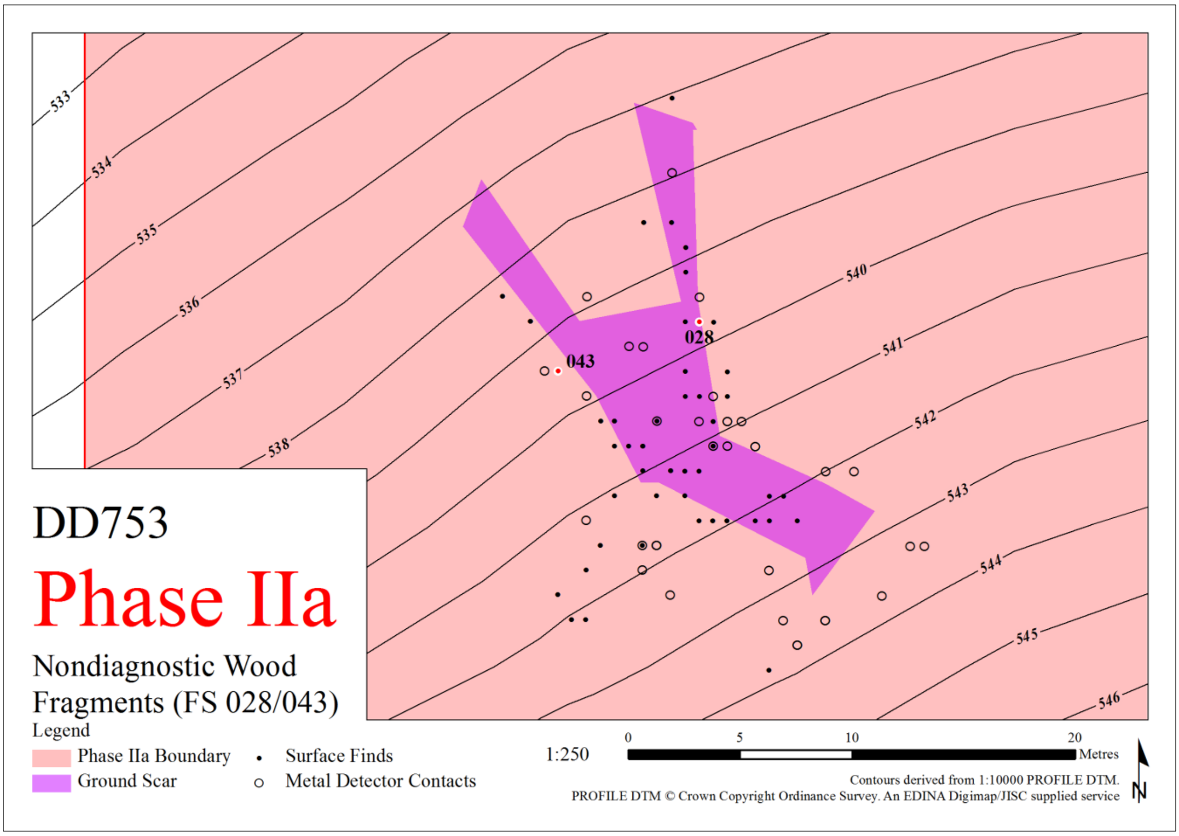


Map 6-17: The distribution of nondiagnostic glass fragments (Crown Copyright/database right OS 2013a; Author).
The linear trend of the NGF distribution probably represents a linear distribution of glass and Perspex across the leading edge of the aircraft

Only two wood artefacts were discovered during the Phase IIa survey. FS 028.01 is a plywood fragment with a single slotted screw attached (Figure 6-28). FS 043.01 is a single specie wood fragment approximately 4.4-5cm wide and 1.5-1.9cm thick with at least 13 slotted screws installed (Figure 6-29). Located on either side of the central ground scar, no concrete conclusion can be drawn from FS 028.01's and FS 043.01's location within the larger artefact distribution at this time (Map 6-18). Further research including the recovery of artefacts may allow for the speciation, and thus the approximate installation location, of FS 028.01 and 043.01.

Figure 6-28: FS 028.01, a plywood fragment with a single slotted screw attached, is one of only two nondiagnostic wood fragments observed (Author).

Figure 6-29: FS 043.01, the second of only two nondiagnostic wood fragments observed (Author). FS 041.01 and FS 042.01 are partially visible on the right side of the frame.



Map 6-18: Distribution of nondiagnostic wood fragments (Crown Copyright/database right OS 2013a; Author).
Located on opposing sides of the main scar, the limited number and distribution of NWF fragments does not allow for the generation of concrete conclusions.

6.3.4 Comprehensive Site Analysis

DD753 impacted The Curr during a challenging night NAVEX training operation. Deposited on The Curr at 535 metres asl, the observed artefact evidence indicates that impact occurred during an attempt to aggressively gain altitude. No evidence was located to show a mechanical malfunction or in-flight fire as the cause of the crash. Indeed, evidence supports the hypothesis that DD753 came to grief as a result of navigational error. Flying below the maximum altitude required for the NAVEX flight plan, DD753 was unable to gain altitude fast enough to clear The Curr.

Analysis of FS 007.01, 032.01, 034.01, 035.01 and 046.01 shows recurring evidence of compression forces along the longitudinal axis which are consistent with an impact near zero angle. There is substantial evidence that DD753 experienced positive pitch input prior to impact. The 23 degree bend observed on FS 007.01 provides evidence consistent with a scenario in which the pilot attempted to drastically gain altitude immediately prior to impact. While the observed bends in FS 007.01 and 056.01 suggest that one engine impacted the ground just prior to the other, the staggered impact is not believed to be the result of a banking turn or off-zero heading. The observed bends are consistent only with zero degree bank and heading angles. Peri-impact roll or yaw inputs, if performed, would be reflected in the different correlative bend angles observed on FS 007.01 and 056.01. The accordion deformation of FS 032.01, 034.01 and 035.01 indicate that the retracted landing gear experienced an impact similar to that shown by FS 007.01 and 056.01. Rather than a banked turn or off-zero degree heading, the best explanation for the staggered engine impact is the variation in terrain slope across the impact site.

The extant scatter of DD753 is not without evidence of tampering. Indeed, (1) the presence of a hack saw blade fragment (FS 036.01), (2) the lack of associated wing components in proximity to FS 031.01, (3) the comingling of FS 032.01, 034.01 and 035.01, and (4) the hypothesised movement of FS 024.01 and 026.01 away from FS 005.01 and 007.01 establishes that natural artefact mobility and/or anthropogenic tampering occurred at the DD753 crash site. However, neither the natural nor man-made adulterations of the site affect the larger conclusions concerning the circumstances surrounding impact and the current boundaries of the site.

6.4 Conclusion

The two surveys of de Havilland DH.98 aircraft wreck sites demonstrate positive aspects of the proposed PAAR Methodology as applied to crash sites involving wood framed aircraft. In specific, the surveys demonstrated (1) the viability of an archaeology-specific, phased standard operating procedure, and (2) the significant data derived from a non-invasive approach to aircraft wreck site investigation. The division of research into multiple phases allowed the investigation to intensify based upon both the data returns and the available resources. Indeed, the Phase IIa surveys provided detailed historical research as well as the exploration of the sites without the commitment of considerable resources.

7 Survey Sites: Metal Skinned Aircraft

7.1 Introduction

Three Boeing B-17 and two B-24 crash sites were investigated using the PAAR Methodology. Surveys of four of the sites terminated at Phase IIa or IIb. The results and analysis of the data returned at those four sites are explored in the current chapter. As in the previous chapter, site-specific discussion of map regression analysis will not be detailed as analysis of historic OS maps (1904, 1912, 1929, 1947, 1961, 2007a, 2007b) revealed no evidence of natural or anthropogenic changes to the landscape which would have altered the terrains or artefact distribution patterns of any of the wreck sites.

7.2 Boeing B-17G 44-83325 (Beinn Edra, Isle of Skye)

7.2.1 Overview

7.2.1.1 Site Background

Impacting the eastern face of Beinn Edra (Isle of Skye) on 3 March 1945 at 550 metres asl (NG 45565 63178), the environment of the 44-83325 wreck site (Map 7-1) is the second lowest elevation of the five metal B-17 (Figure 7-1) and B-24 crash sites investigated. A Phase IIa non-invasive survey of 44-83325, conducted from 7-8 August 2011, confirmed extensive site survivability and the presence of large scale artefact scatter including numerous diagnostic artefacts. The Phase IIa survey resulted in a recommendation that the investigation continue to at least a Phase IIb and, if excellent data continued to be collected, possibly a Phase IIIa targeted excavation. Unfortunately, the investigation of Boeing B-17G 44-83325 was terminated at Phase IIb due to legal restrictions imposed by the *PMRA 1986*.

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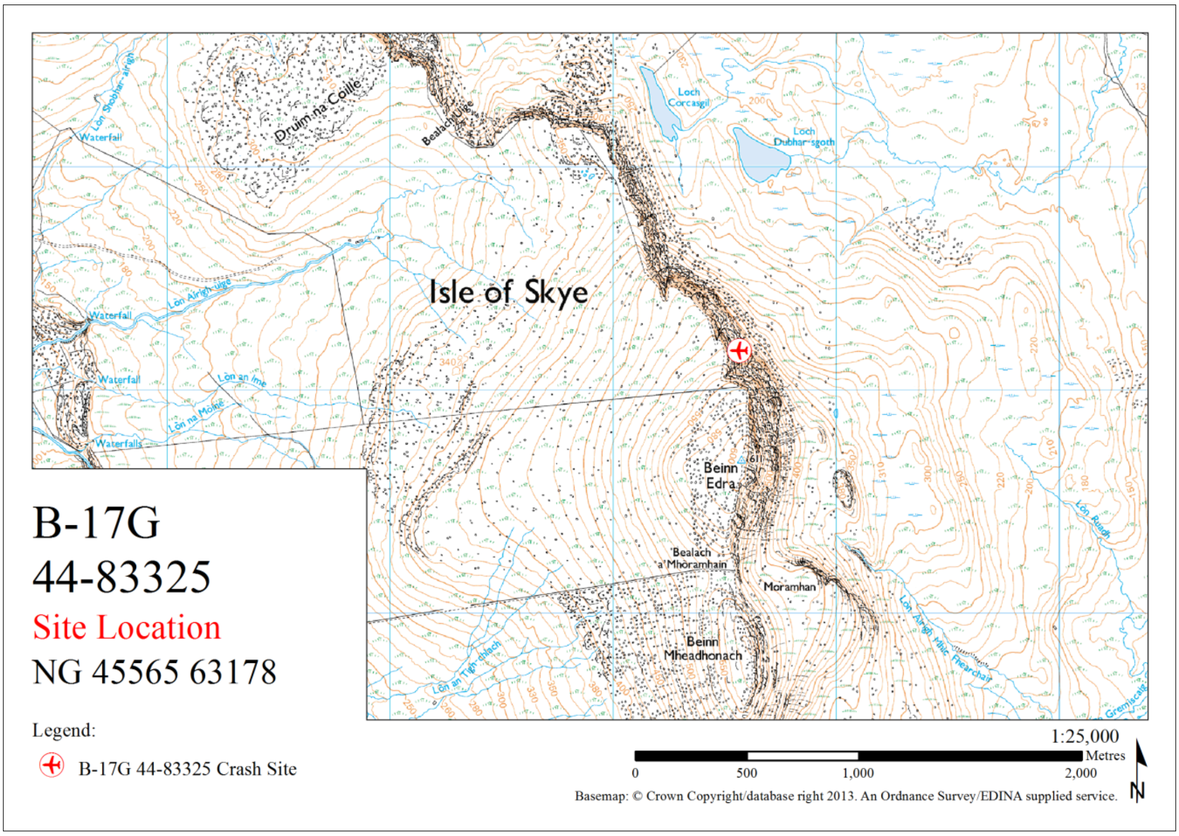
Figure 7-1: A formation flight of B-17Gs, similar to 44-83325, from the 532nd Bomb Squadron, 381st Bomb Group (US Air Force c1944-1945).



Map 7-1: Location of the Boeing B-17G 44-83325 crash site (Crown Copyright/database right OS 2013b; Author).
B-17G 44-83325 impacted Beinn Edra at approximately 550 metres asl.

7.2.1.2 Investigation Summary

The proposed research aim and its related four objectives are identical to those reported in Chapter 6 Section 6.2.1.2. The land upon which the aircraft wreck site resides, currently in the ownership of the Scottish Ministers as part of the Kilmuir Estate, is subject to SSSI, SAC and NSA protections (SNH 2012). A Phase I site visit was conducted 15 May 2011 and established that no artefacts are extant on the cliff tops; all artefacts are situated on the eastern side of Beinn Edra. Additionally, Phase I verified the presence of sufficient artefacts to recommend continuation to Phase IIa.

Undertaken on 7-8 August 2011, the Phase IIa investigation identified extensive and significant artefact scatters contained within the main gully scar and scree slope. A total of 163 artefacts and artefact groups were recorded. The identification of major aircraft components including engines, superchargers, landing gear struts and a machine gun allowed for the establishment of both the site's maximum and core boundaries. Additionally, the location of diagnostic artefacts including armour plate, oxygen bottles, a leather boot upper and a snap closure allowed assessment of the aircraft's final vector and impact point. Background information obtained during a Phase IIa consultation with Roderick Macleod (*Tigh an Duin*, Clachan, Isle of Skye), whose father was part of the first group on scene attempting rescue, allowed the gathered archaeological material to be examined in conjunction with primary source memory.

Capitalising on the data gained from the Phase IIa unsystematic surveys, a Phase IIb systematic pedestrian survey was undertaken from 27 July-2 August 2012. The Phase IIb systematic pedestrian survey focused on the archaeologically sensitive areas and unsurveyed portions of the site identified during Phase IIa analysis. An additional 86 artefacts beyond the 163 identified during Phase IIa were recorded. As a result of the additional artefacts recorded, the corridors of artefact movement postulated during Phase IIa were confirmed and better defined. The absence of aircraft-related artefacts on the Trotternish Ridge/Beinn Edra summit first noted during Phase I was verified.

The Phase IIa survey of B-17G 44-83325 utilised one of the earliest versions of the PAAR Methodology including an attempt at a physical string grid. Neither the Phase IIa nor IIb surveys incorporated a metal detector survey component as the site terrain slope was too extreme for safe handling. Although research into 44-83325 did not progress to Phase IIIa at this time due to a MoD ruling on human remains (see Section 7.2.3.4), future Phase IIIa research may be legally feasible should 44-83325's protection under *PMRA 1986* be resolved. Indeed, should progression to Phase IIIa become possible in the future, it is recommended that 44-83325 receive immediate attention.

7.2.2 Airframe Construction

While the B-17 and the B-24 are two different aircraft models developed by two different companies (Boeing Aircraft Corporation and Consolidated Aircraft, respectively), the method and materials of construction, outfitting and operation are similar. Discussion of the assemblies and components anticipated on metal-skinned aircraft wreck sites is discussed in detail in Chapter 9 Section 9.2. While Section 9.2 specifically relates to the B-24 aircraft, the information included in the summery is applicable and transferrable to the B-17 as well.

7.2.3 Archaeological Investigation

7.2.3.1 Phase I Historical Survey

The Phase I historical survey, undertaken in March 2011, located the current resting place of all aircrew (Appendix Table 11-3) as well as a tasking summary compatible with PMRA 1986. A *PAAR Aircraft Incident Record* form (Document 7-1) subsequently was completed. Primary sources identify 44-83325's final mission as a 3 March 1945 ferry delivery flight from Meeks Field, Iceland to RAF Valley, Wales before final delivery to the American Air Force in Gioia, Italy. No site visit was undertaken during Phase I as recent photographs and hikers' accounts demonstrate the crash site to have sufficient *in situ* wreckage to warrant a Phase IIa investigation.

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Document 7-1: Phase I *PAAR Aircraft Incident Record* form for Boeing B-17G 44-83325 (ICAO 2006; Author).

7.2.3.2 Phase IIa General Data Survey

Background Research:

Primary Source Accounts:

Written primary source accounts regarding 44-83325's final flight detail the crash sequence and the post-crash recovery operation. Significant historical detail regarding the crash of 44-83325 is gained from MACR 15492 and the official accident report. Both MACR 15492 (US Army Air Force 1945a) and the official accident report (US Army Air Force 1945b) record 44-83325 as being in transit from Meeks Field to RAF Valley via Stornoway. The official accident report includes the filed flight plan and provides all expected course changes (Appendix Table 11-4).

The MACR lists the nine airmen on board, provides their assigned positions and relays a brief crash narrative: "Circumstances: Killed on the Isle of Skye, Scotland in an airplane crash (orders found at scene of accident listing nine crew members) Plane crashed & burned" (US Army Air Force 1945a).

The official accident report contains a more detailed accident narrative:

> *On March 3rd, 1945, at about 1345 GMT, B17 #44-83325 was observed flying contact below an 800 ft. ceiling with visibility of about 5 miles. He approached the north-east end of the Isle of Skye and followed the shore for a short distance. A very few seconds later there was a load explosion and fire was observed to roll down the mountain-side. The ground at the point where the aircraft turned inland is extremely precipitous, rising to 2000 ft. in roughly three miles. This mountain at the time was obscured by low cloud. Upon arrival, the rescue party found that while in cloud the aircraft had struck the top of a steep rocky cliff at an altitude of 2000 ft. The aircraft was completely demolished and had burned. The bodies of all nine crew members were recovered.*
>
> *The cause of this accident is attributed to the pilot flying below a minimum safe altitude in mountainous country. There was no indication that the aircraft was in any difficulties. The pilot had checked in a few minutes before at Stornoway and eye witness [sic] have testified that all four engines were performing properly as he flew down the shore of the Isle of Skye (US Army Air Force 1945b).*

While not acknowledged in the official accident report, the report dossier includes a cover letter from Major Thomas Shallcross, Headquarters, 1403rd AAF Base Unit. Written to the relevant ferry, safety and operational commands concerned with 44-83325, the letter explains that: “There are no pictures taken of this crash because of the extremely poor visibility prevalent in this area at all times, never better than 10 (ten) yards” (US Army Air Force 1945b). As such, the disposition of the wreckage with regards to the scatter on the east and/or western slopes of Beinn Edra/the Trotternish Ridge is unconfirmed.

The official accident report states that Lt. Overfield had 105h40m and 28h20m total hours as first pilot on the B-17 airframe and B-17G model, respectively, with an additional 248h45m and 80h00m total hours as secondary pilot on the B-17 airframe and B-17G model, respectively. While a new pilot, Lt. Overfield’s experience with the B-17G aircraft cannot be seen as a contributing factor. Indeed, the official accident report claims the cause of the accident lies with Lt. Overfield’s decision to proceed below the safe altitude limit of 2,000ft asl in order to maintain heading using visual navigation (US Army Air Force 1945b).

Supporting the official crash scenario is an account provided by secondary witness Roderick MacLeod. MacLeod’s uncle lived in the village of Clachan at the base of Beinn Edra, was one of the first people at the crash site, and is likely one of the witnesses cited by the official accident report. In recounting the accident, MacLeod states that the aircraft flew over Flodigarry Island and Staffin Bay before overflying the fields of Clachan at only a couple hundred feet and impacting the brae of Beinn Edra. Upon impact, the plane flipped over onto the Uig side of the Trotternish Ridge and burned. The locals, though aware of the crash, were not able to reach the wreck site until the next day as the heat and exploding ammunition from the burning aircraft, fuelled by the ruptured petrol tanks, kept them at bay. Once able to reach the wreck site on 4 March 1945, the locals discovered that the entire aircrew was deceased and their bodies heavily burned. A single individual whom MacLeod remembers having red hair was discovered to be without substantial exterior trauma and lying on a rock. It took two days to remove the aircrew from what was left of the twisted and melted aircraft. According to MacLeod, the recovered bodies were taken to Uig and buried in Portree before being repatriated at the end of the war (A. MacLeod 2011; R. MacLeod 2011).

MacLeod claims that the locals managed to salvage two or three US military bicycles from the wreckage. He remembers his uncle claiming that the Home Guard threw the debris over the cliff face and then buried the substantial pieces to keep the Germans from seeing the downed aircraft (A. MacLeod 2011; R. MacLeod 2011). This popular explanation for the burial of debris differs from the standard military reason for burying debris which is to keep a known, recovered aircraft wreck site from being reported as a new crash site.

MacLeod states that he encountered a multitude of aircraft related debris and aircrew personal affects in the 1950s including seats, aircraft dials/instruments, machine guns, oxygen tanks, boots and toothbrushes. Recollections of visits included consistent memories of aircraft related debris and positioning. Both MacLeod and his son, Alan, recall a concentration of material within the *bealach*[1] (to the north of Beinn Edra's eastern summit. In addition, McLeod admits that cockpit instrument panels and equipment were removed from the site by himself, his children and local youths (A. MacLeod 2011; R. MacLeod 2011).

The MacLeods, serving as intermediaries, arranged for a viewing of materials held by local inhabitants Nambi, Iain Campbell and Norma MacLean Linicro. Only a few pieces of Nambi's collection, removed from the site when he was a young man, have survived. The two artefacts available for assessment were a nondiagnostic metal bar and a US standard issue spoon. In addition to the two artefacts, Nambi claims to have taken a .50 calibre machine gun from 44-83325. The machine gun was stolen from Nambi's garden where it had been mounted on a wooden pole (Figure 7-2) (Campbell n.d.). Fortunately, Nambi took a photograph of the gun prior to removing it from the crash site (Figure 7-3) (Nambi n.d.). As such, the location from which the gun was recovered can be assessed based on the relationship between the scree slope, Loch Corcasgil and Loch Dubhar-sgoth. The written recollections of Iain Campbell of Riverside, Stenscholl provide additional information on how Nambi acquired the machine gun as well as its subsequent theft:

> *After a few visits to Beinn Edra, he had gathered a few items of interest. Especially a .50 Heavy Browning Machine Gun which would have been positioned on th [sic] of the bomber and was known as a waste [sic] gun. Iain cut off gun from its broken mounting and made for home. Such was the weight of the gun he could only take it was far as Loch Cleop above Stenscholl. He went back up the next day and with the aid of some webbing took it home. He had it in his outdoor shed for years and eventually mounted it on a tree in the garden. It stayed there here for about fifteen years (Campbell n.d.).*

Local resident Norma MacLean Linicro's written statement on post-crash activities provides further insight into post-crash activities:

[1] *Bealach* (Scottish, noun): "a narrow mountain pass" (Stevenson 2010: 142).

I remember being at school in Portree and much fuss and activity happening in and around the village. We had heard earlier in the day of many corpses from the accident. Later that day two U.S. army trucks passed Elgin Hostel en-route to Uig. They were empty with the canvas flaps at the rear all rolled up. The next day the trucks passed the school again with the canvas all pulled down and secure and would have been heading to Kyle. The secure loads gave way to much mystery and rumours as to what was in the trucks (Linicro n.d.).

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due to copyright restrictions.

Figure 7-2: Staffin, Isle of Skye resident Nambi with the B-17G 44-83325 Browning machine gun mounted in his garden (Photographer unknown; Provided by R. MacLeod and A. MacLeod).

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due to copyright restrictions.

Figure 7-3: The photograph taken by Nambi recording the position of his machine gun prior to removal (Nambi n.d.).

Aircraft History:

A review of the 44-83325's Individual Aircraft Record Card shows the aircraft was accepted by the US Government from the Douglas Aircraft Corporation factory in Long Beach, California on 5 February 1945. The aircraft moved across the US in preparation for its departure to the MTO via the Northern Atlantic Route on 19 February 1945 (US Army Air Force 1945c). Being a new aircraft, 44-83325 did not receive any combat-related repairs that could assist in identifying nondiagnostic component fragments. A Freedom of Information Act request filed with the Air Force Historical Research Agency, Department of the Air Force [AFHRA] returned only the AAR and MACR files.

Crew Personnel Files:

Each decedent's Individual Deceased Personnel Files [IDPF] was requested from the US Army Human Resources Command [HRC]. IDPFs were obtained for six of nine crewmen aboard 44-83325. According to HRC, "The IDPFs for Carter D. Wilkinson, John H. Vaughan, and Leroy E. Cagle could not be found" although HRC's records indicate that they exist (Alton 2013). The IDPF files focus on (1) the identification and burial of the deceased, (2) the informing of the next of kin of the individual's death, and (3) where appropriate, the arrangements for the repatriation and reburial of the deceased in the United States. Of specific relevance to the archaeological investigation of aviation wreck sites in which crewmen perished is the documentation of general and specific peri-mortem trauma. All six assessed IDPFs contained at least one description of observed peri-mortem trauma. The most common description—"Partial Decapitation. Extreme Mutilation of Trunk and Extremities. Remains Mutilated."—appears in all six IDPFs (US Army Air Force 1945-1949a-f) and is most likely a standard description for impact events. Casualty specific trauma descriptions are provided for Overfield, Kopp, Jeanblanc, Fahselt and Blue (US Army Air Force 1945-1949b-f).

The information presented by the IDPFs indicates that the wreck site of 44-83325 likely contains human remains. The systematic wreck site surveys advanced in the current thesis can provide insight into the distribution of the crew's remains within the larger crash site boundary. As the crash site of 44-83325 could still be classified as a war grave, proper bounding is critical to its current and future preservation.

Field Survey:

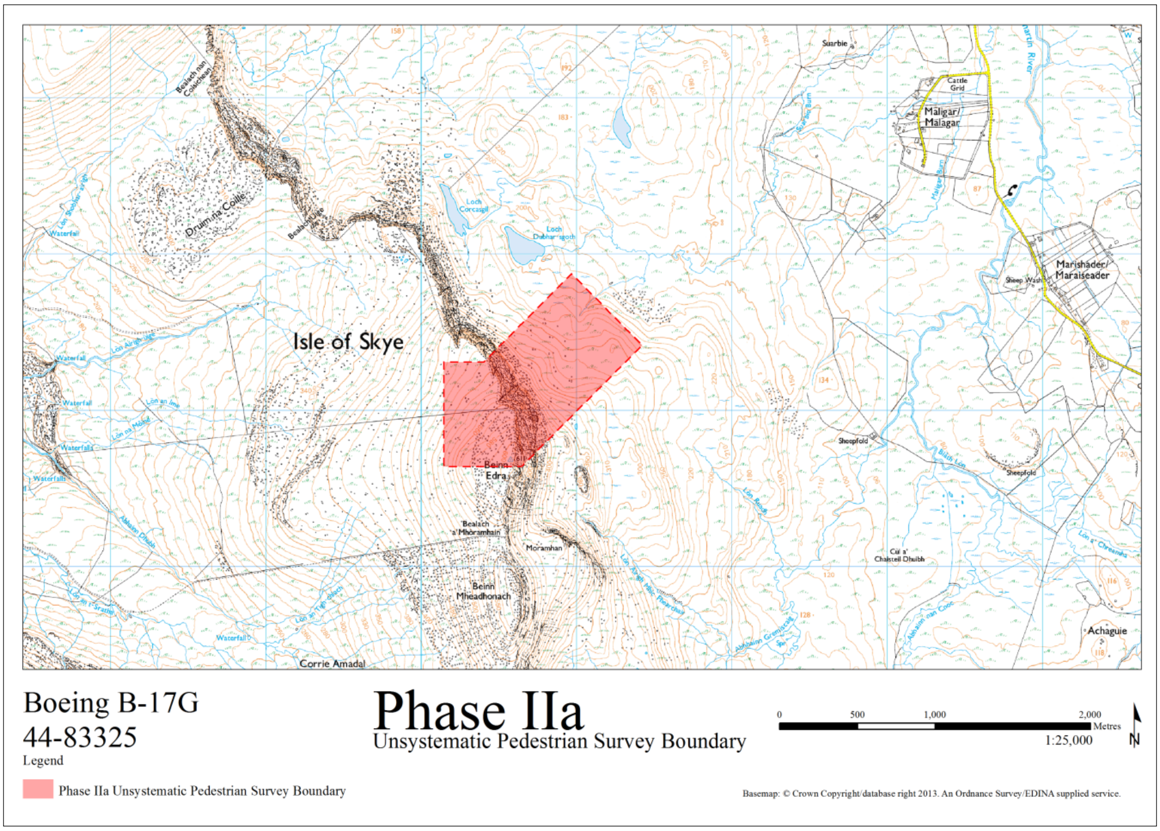
An unsystematic pedestrian survey was conducted. An unsystematic metal detector survey was begun but was terminated early on day one due to health and safety concerns. The Phase IIa surveys sought to identify the quantity, distribution and condition of surface diagnostic artefacts and of any nondiagnostic artefacts immediately proximal to identified surface diagnostic artefacts, as well as to provide a site boundary should investigation continue into Phase IIb.

Unsystematic Pedestrian Survey:

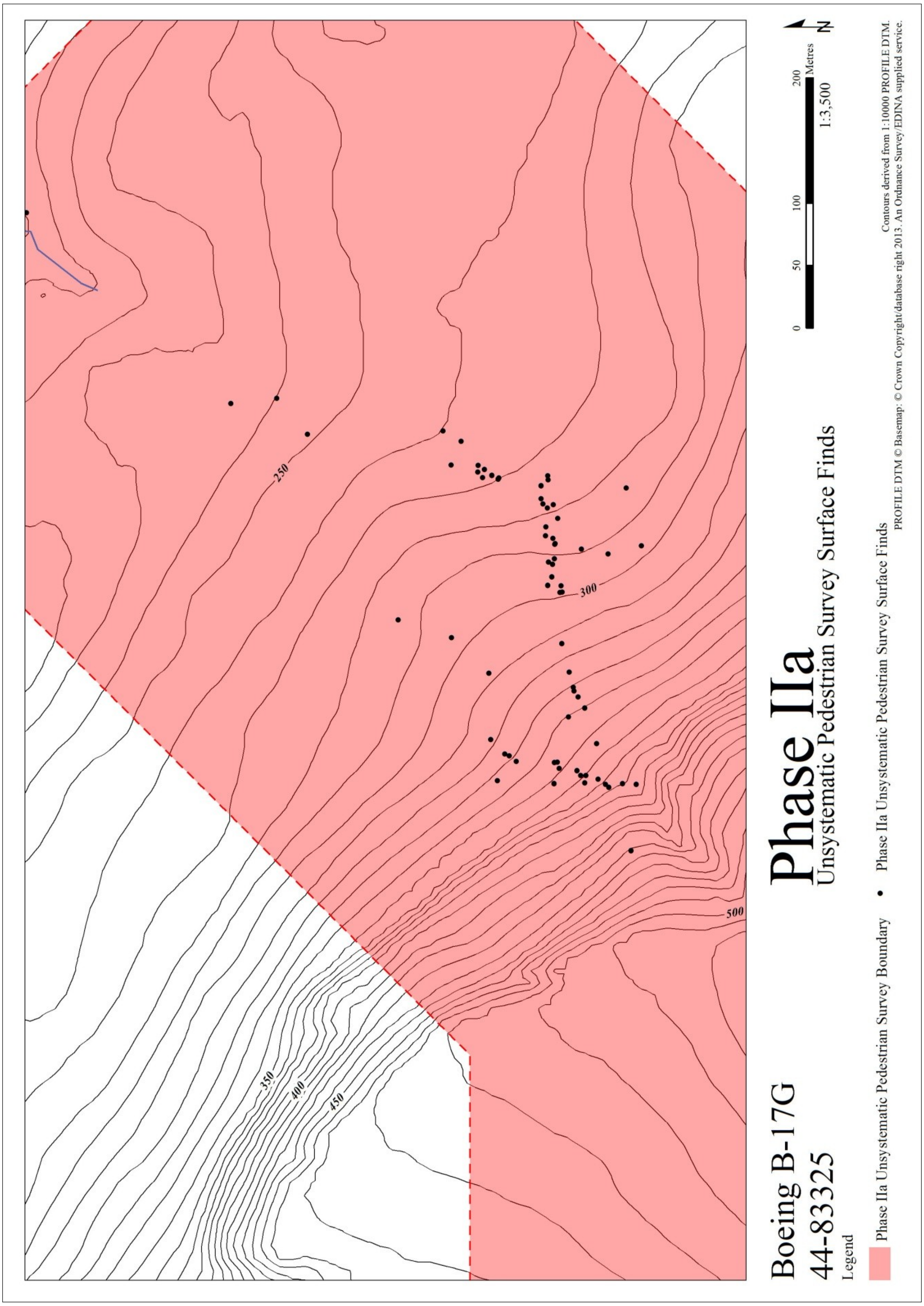
The 44-83325 Phase IIa unsystematic pedestrian survey was conducted from 7-8 August 2011. Utilising archival material and secondary testimony derived from the early stages of Phase IIa, the survey area centred upon the *bealach* of Beinn Edra (Figure 7-4, Figure 7-5 and Map 7-2). The two visible plateaus below the *bealach* (Map 7-5) retain many large pieces of wreckage including portions of the engines and wing spar fragments. The unsystematic pedestrian survey progressed from observed surface artefact to observed surface artefact in a roughly NE-SW direction. Nondiagnostic artefacts were ignored unless they were in immediate proximity to diagnostic or nondiagnostic(diagnostic) artefacts. One hundred sixty-three individual artefacts/artefact groups were recorded during the unsystematic pedestrian survey, 61 of which are confirmed diagnostic artefacts (Map 7-3 and Map 7-4). While no axis of deposition was visible on site, post-survey distribution analysis identified two axes of artefact distribution (Map 7-6). An analysis of the identified distribution axes is offered in Section 0: Artefact Analysis.

Figure 7-4: View of the B-17G 44-83325 crash site facing west (Author).
The gully, at the centre of the Beinn Edra cliff face, is the proposed site of primary impact. The summit of Beinn Edra is the high ground left of the gully.

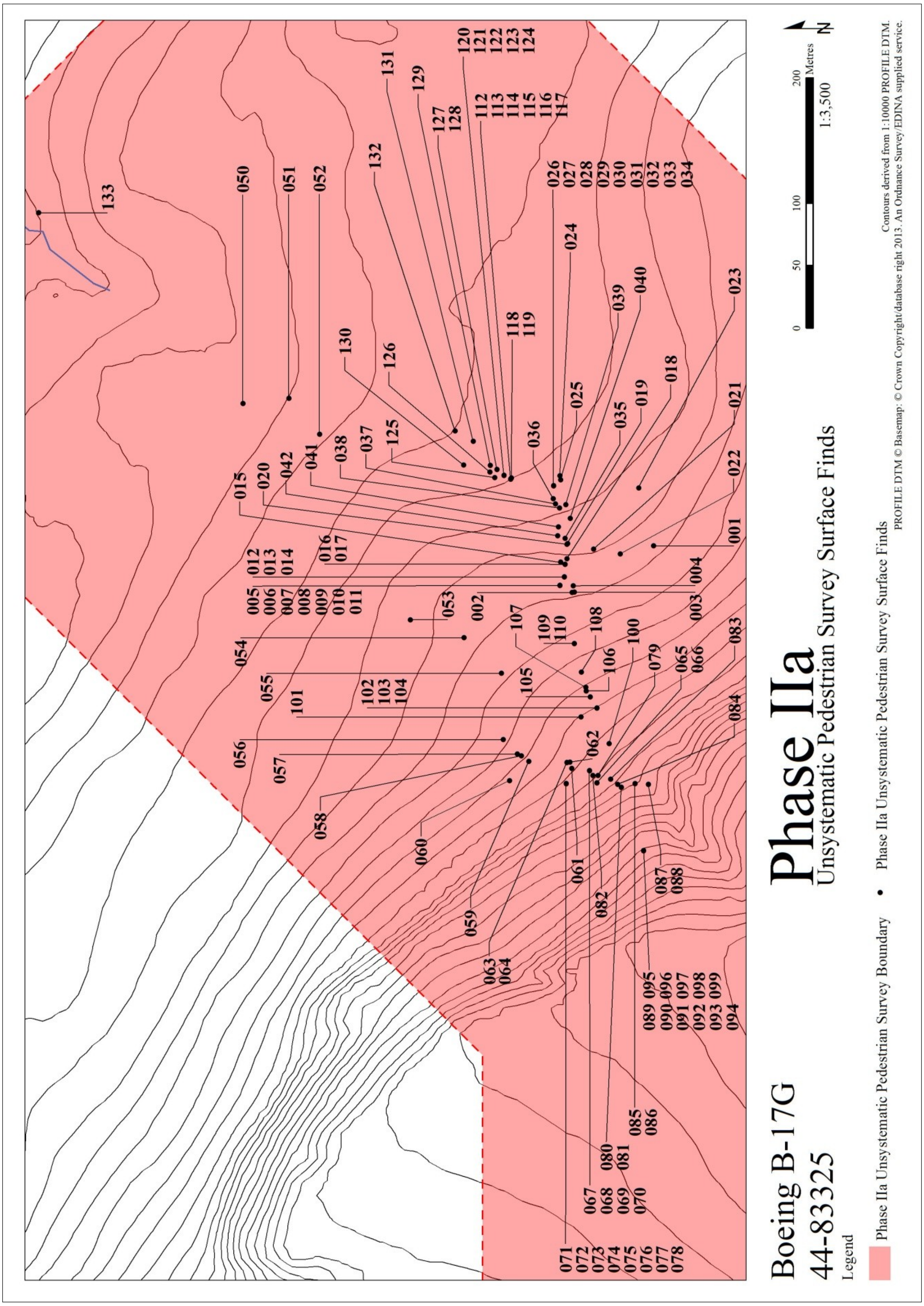
Figure 7-5: B-17G 44-83325's crash site (Author).
The primary point of impact is the gully at centre with debris distributed across the scree slope and flats. Plateau 2 is partially visible on the right.



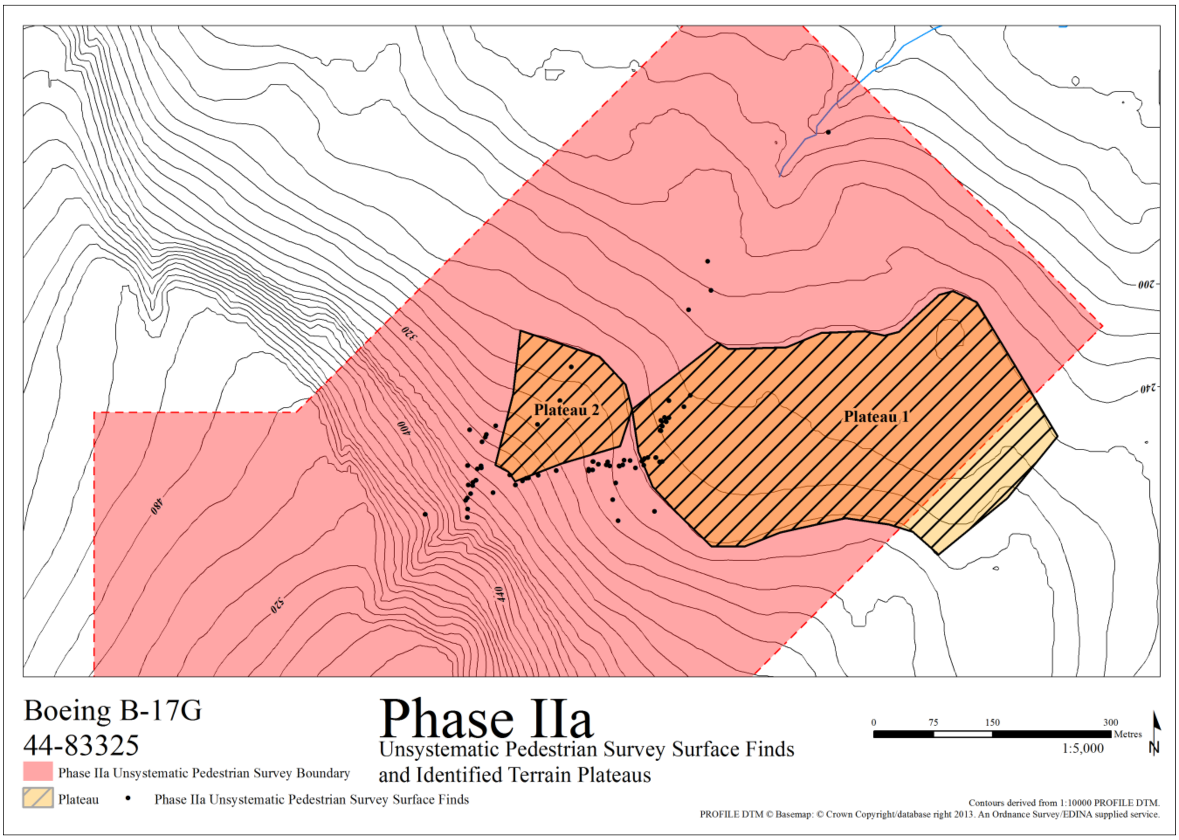
Map 7-2: 44-83325 Phase IIa survey boundary encompassing Beinn Edra's heights, scree slopes and lower plateaus (Crown Copyright/database right OS 2013b; Author).



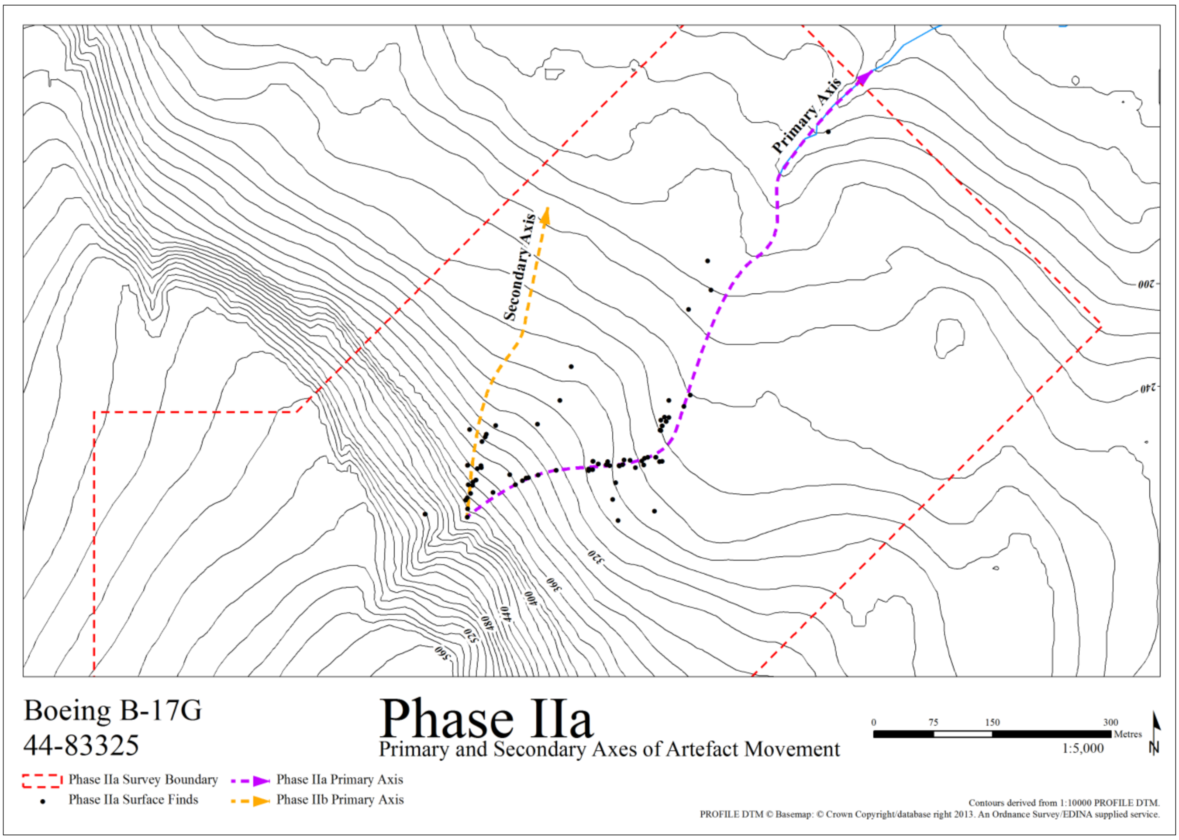
Map 7-3: 44-83325 Phase IIa unsystematic pedestrian survey surface finds (Crown Copyright/database right OS 2013a; Author).
Though note readily apparent at the site, post-survey distribution analysis shows 44-83325 artefacts to be deposited along two axes.



Map 7-4: Annotated distribution of 44-83325 Phase IIa surface finds (Crown Copyright/database right OS 2013a; Author).



Map 7-5: The two observed plateaus below Beinn Edra which retain many larger portions of wreckage associated with B-17G 44-83325 (Crown Copyright/database right OS 2013a; Author).



Map 7-6: 44-83325 Phase IIa primary and secondary axes of artefact distribution and probable movement (Crown Copyright/database right OS 2013a; Author).

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Document 7-2: Phase IIa *PAAR Aircraft Incident Record* form for Boeing B-17G 44-83325 (ICAO 2006; Author).

Unsystematic Metal Detector Survey:

An unsystematic metal detector survey was begun on 7 August 2011 but was terminated due to health and safety concerns. The extremely steep gradient requires use of both hands; the use of the full size metal detector was considered a health and safety hazard. If metal detecting is to be utilised in a future Phase IIb and/or Phase IIIa, it is recommended that an excavation license be obtained prior to undertaking the survey so that crews need only complete the survey once, thereby limiting crew exposure to health and safety risks. Additionally, it is recommended that any Phase IIb and/or Phase IIIa metal detector surveys be limited to a small area of scrutiny and that appropriately sized metal detectors be employed (hand-held wands would be most effective considering the terrain).

Artefact Analysis:

The Phase IIa unsystematic pedestrian survey identified, photographed and geo-referenced 61 confirmed diagnostic artefacts, 32 nondiagnostic(diagnostic) artefacts and 70 nondiagnostic artefacts. While the entire artefact spread is critical to effectively identifying the site's boundaries, the 61 confirmed diagnostic artefacts provide significant information relating to the aircraft's final vector, eventual point of impact and subsequent deposition across the site. Of primary interest are landing gear, engine and propellers/propeller hubs; being some of the heaviest components, these artefacts are less likely to experience natural or human-induced post-deposition movement. The main landing gear components (FS 004.01-004.02, 076.01, 101.02 and 108.01) are widely distributed across the site with their general distribution conforming to the larger distribution axes (Appendix Figure 11-35 — Appendix Figure 11-40). The confusing distribution of the main landing gear components may be due to down slope wash of lighter parts. A reappraisal of the distribution, removing the broken up retracting screw (FS 004.01: 48-591-401; FS 004.02: 3-15118) (Appendix Figure 11-35) (US Army Air Force 1944a: 85, 151; US Air Force 1949a: 274-275) and complete retracting screw (FS 076: 64-1498-504 or 64-1498-505) (US Army Air Force 1944a: 83, 85; US Air Force 1949a: 270-271, 274-275) (Appendix Figure 11-36 and Appendix Figure 11-37) assemblies in favour of the heavier main struts and oleos (FS 101.02: 15-10414-5 or 15-10414-6; FS 108.01: 15-10414-5 or 15-10414-6) (US Army Air Force 1944a: 83; US Air Force 1949a: 270-271, 272-273) shows the heavier main gear components to be concentrated in the upper end of the primary distribution axis near the confluence of the primary and secondary axes. The addition of the tail landing gear treadle assembly (FS 101.01: B.A.C. No. 15-7389; FS 101.03: B.A.C. No. 15-7378; FS 101.05: B.A.C. No. 55-7622) (US Army Air Force 1944a: 97; US Air Force 1949a: 280-281) (Appendix Figure 11-38 and Appendix Figure 11-39) into the Phase IIa artefact spatial analysis confuses the distribution a bit. Indeed, the treadle assembly is co-located with the one of the main gear strut and oleo assemblies (FS 101.02) (Appendix Figure 11-39). It is unlikely that the main gear was ripped free and embedded in the same spot as the treadle assembly as the main gear is offset from the aircraft's centre line by 119.64 inches and is approximately 540 inches forward of the tail landing gear when both are retracted (US Army Air Force 1944a: 1-2). The deposition of additional tail landing gear components (FS 101.03 and 101.05) in close proximity to the treadle assembly (FS 101.01) lends credence to the hypothesis that FS 101.02 was transported from its original point of impact to its current location. Based upon installation offsets and the distribution of FS 004.01, 004.02, 101.03, 101.05 and 108.01, it is likely that FS 101.02 was originally deposited nearer to the FS 076.01.

Distribution analysis of the engines and propellers indicates 44-83325's orientation at the base of Beinn Edra. The engines can be broken down into four components: the propeller, the engine, the engine mount and the super turbocharger. The propeller hub, in which the propeller blades are installed and to which the engine attaches, is a component readily identifiable to the layman. As such, propeller hubs can experience a high degree of mobility across a wreck site as successive visitors manipulate and/or attempt to recover the readily identifiable parts. Natural or human-induced artefact movement seems to have impacted the propeller hubs (FS 040.01, 106.01 and 109.01) (US Army Air Force 1946: 103-106; US Air Force 1949a: 286-287) as their distribution is in line with the primary deposition axis. FS 040.01 and 106.01 do not retain their propeller blades (Figure 7-6, Figure 7-7 and Appendix Figure 11-41). The blades seem to have been torn free from the mounts on impact. FS 109.01 is missing only two of its blades; the third blade, while fragmentary, represents a large, identifiable section (Figure 7-8 and Appendix Figure 11-42). Human tampering with the 44-83325 propeller hubs is evident by the long, straight cut to the front of FS 109.01's remaining blade fragment (Figure 7-8 and Figure 7-9). While the removal of the blade fragment is incomplete, the movement of the entire propeller hub in the attempt to recover the blade fragment cannot be discounted.

Figure 7-6: FS 040.01, one of three propeller hubs located during the 44-83325 Phase IIa unsystematic pedestrian survey (Author).

Figure 7-7: FS 106.01, the second propeller hub located during the Phase IIa survey of 44-83325 (Author).

FS 106.02, right adjacent to FS 106.01, is believed to be a fragment of a propeller paddle. The inability to obtain an excavation license for 44-83325, and the resulting prohibition on handling artefacts, did not allow for confirmation.

Figure 7-8: FS 109.01 retains a fragment of one propeller though an obvious cut mark evidences attempts at post-crash removal (Author).
Like FS 040.01 and 106.01, FS 109.01 shows substantial damage to the front of the propeller hub.

Figure 7-9: The cut mark on the front of FS 109.01's propeller paddle (Author). According to Roderick and Alan Macleod, the cut mark is a more recent attempt to remove the propeller fragment and evidences the ongoing tampering threat that faces historic aircraft wreck sites.

Similar inconclusive distributions are observed in the locations of two intact engines, FS 103.01 and 110.01 (R1820-97) (US Army Air Force 1946; US Air Force 1949a: 286-287) (Figure 7-10 and Figure 7-11), and probable pieces of other engines. Three cylinder head fragments are located in two concentrations: FS 016.01/017.02 (Figure 7-12, Figure 7-13 and Appendix Figure 11-45) and 037.01 (112096) (US Army Air Force 1946: 113-116) (Figure 7-14 and Appendix Figure 11-46). The two concentrations, located approximately 48 metres apart, could represent one of three possibilities: they could be down slope wash from the two intact engines (FS 103.01 and 110.01), they could mark the location of a removed engine, or they could be the down slope wash or location of an *in situ* but unobserved engine. The distribution of the engine mounts provides limited clarity. All four Dynafocal engine mounts (55-6185, 289000) (US Army Air Force 1944a: 139-140; US Air Force 1949a: 291, 293) are visible (FS 064.01, 114.01, 124.01 and 128.01) (Figure 7-15 — Figure 7-18 and Appendix Figure 11-47). However, three of the engine mounts (FS 114.01, 124.01 and 128.01) reside in a series of cut depressions at the lowest extreme of the primary distribution axis 235 metres NE of FS 064.01. While the incongruity of engine mount distribution may be the result of the human manipulation (i.e., collection of debris in the lower basin for burial), the movement of such heavy objects renders this unlikely. The most likely explanation is that a majority of the engines and engine mounts travelled down slope immediately following the impact event and collected in the lower basin where natural forces including water flow and sheep grazing created a series of natural depressions. The parts which were not deposited onto the eastern portion of the *bealach* did not migrate down to the basin but retained their original linear alignment having found their momentum expended upon reaching the upper plateau. A similar patterning is observed with the superchargers (FS 055.01, 121.01 and 132.01) (4868827, WW8456556 or 4868827, WW8456556) (Figure 7-19 — Figure 7-21, Appendix Figure 11-48 — Appendix Figure 11-50) (US Air Force 1949a: 62-65). Two of the turbo superchargers (FS 121.01 and 132.01) are located in the same series of natural depressions as the Dynafocal engine mounts (FS 114.01, 124.01 and 128.01) while the third supercharger is located on the upper plateau directly below the fourth engine mount (FS 064.01).

Figure 7-10: FS 103.01, one of 44-83325's four engines, half buried under tumbled scree rock (Author).

Figure 7-11: FS 110.01, the second of two engines discovered, is largely obscured by soil and rock (Author).
It is believed FS 110.01, given its weight, location and buried condition, is still located at the point of initial deposition.

Figure 7-12: FS 016.01, one of three cylinder head fragments (Author).
The distribution of cylinder head fragments could result from down slope wash from the two intact engines; could mark the location of a removed engine or; could be the down slope wash or location of an *in situ* but unobserved engine.

Figure 7-13: FS 017.01 and 017.02 (Author).
The cast ridges on FS 017.02 identify it as a cylinder head fragment. Both FS 017.01 and 017.02, an exhaust collector tailpipe section and a cylinder head fragment respectively, were installed in 44-83325's four engines.

Figure 7-14: FS 037.01, the third cylinder head fragment located (Author).

Figure 7-15: FS 064.01, a Dynafocal engine mount with cowling attached (Author).

Figure 7-16: One of 44-83325's Dynafocal engine mounts (FS 114.01) (Author).

Figure 7-17: FS 124.01, a fragment of Dynafocal engine mount (Author).

Figure 7-18: FS 128.01, one of four Dynafocal engine mount installed on 44-83325 (Author).

Figure 7-19: One of three turbo superchargers located, FS 055.01 has been recently turned onto its side (Author).
It is unknown whether the upturning of FS 055.01 was the result of human or animal movement. Both are equally likely as the site has experience known visitation and the Author, during the Phase IIa survey, witnessed sheep pushing against similarly large artefacts.

Figure 7-20: A turbo supercharger and engine impeller (FS 121.01) and an oxygen bottle (FS 121.02) (Author).

Figure 7-21: FS 132.01, a turbo supercharger and exposed engine impeller (Author).

Two other engine components seem to confirm the hypothesis of artefact down slope migration. The engine connecting rod assembly through gear-reduction driving (FS 027.01) (Figure 7-22) (US Army Air Force 1946: 8-9, 79-80, 102-113) and the engine diffugal plate, impeller and impeller shaft from the engine supercharger (FS 120.01: 4868827, WW8456556 or 4868827, WW8456556; 68585) (Figure 7-23) (US Army Air Force 1946: 56-58; US Air Force 1949a: 62-65) are internal engine components which would only be deposited separate from the rest of the engine should the engine casing break apart. Their distribution between the engines/propeller hubs and the engine mounts, but in line with the primary axis of deposition, seems to suggest engine break up and mass artefact migration immediately following the impact event.

Figure 7-22: FS 027.01, engine connecting rod assembly through gear-reduction driving (Author).

Figure 7-23: The diffugal plate, impeller and impeller shaft from the engine supercharger (FS 120.01) (Author).
This component is only encountered as an single artefact when an engine casing has broken apart.

The hypothesis of primary and secondary axes of artefact movement, as first demonstrated by the distribution of propulsion components, is reflected in the distribution of engine exhaust assemblies and wing support truss fragments and wing skin fragments. The observed pattern demonstrates a similar migratory pattern as the propeller/engine distribution.

The similar patterning—the primary axis of down slope movement—allows the seemingly out of context engines to be traced back to a possible point of impact. A secondary axis of movement is confirmed by comparing the identified diagnostic material with the overall distribution of artefacts (Map 7-6). The secondary axis of artefact movement is made up of mostly nondiagnostic artefacts (80 percent). Comparison of the secondary movement axis allows for the identification of the point of primary and secondary axis intersection and, thus, the likely site of impact.

This hypothesised site of impact correlates well with diagnostic material that seems to have experienced little movement. For example, one magneto (FS 115.01: 114076N1 or 114077N1, MJR9A307 or MJR9A309), identified by the unique triangular installation plate (US Army Air Force 1946: 171-173) (Appendix Figure 11-51), has collected in the same depression as three engine mounts (FS 114.01, 124.01 and 128.01). A single red ceramic fragment (FS 032.01) (Appendix Figure 11-52) is located 35 metres south of FS 115.01 and, given the shattered casing of FS 115.01, is most likely a fragment of the same. The only other magneto located (FS 090.01: 114076N1 or 114077N1, MJR9A307 or MJR9A309) (Appendix Figure 11-53, Appendix Figure 11-54 and Appendix Figure 11-55) (US Army Air Force 1946: 171-173) is located 316 metres WSW of the FS 115.01. FS 090.01 is associated with a single red ceramic fragment (FS 095.01) characteristic of a magneto's interior components (Appendix Figure 11-56) (US Army Air Force 1946: 171-173). While the overall patterning of the observed magnetos does not resolve the crash and post-crash narrative entirely, the location of FS 090.01 and 095.01 at the confluence of the primary and secondary axes suggests that FS 090.01 and 095.01 have not migrated far from the site of original deposition. Conversely, the location of FS 032.01 and 115.01 further down slope from FS 090.01 and 095.01 suggests an episode or episodes of post-impact artefact movement.

The wing spars and carry-through members (constructed from 24ST and heat treated square steel tubing respectively) (Beall 1945: 133) seem to have remained fixed over the years. Their location reinforces the crash/post-crash narrative indicated by the location of the recorded magnetos and magneto fragments. Both upper wing spar and carry-through termini were located (FS 079.01 and 081.01) (Figure 7-24 — Figure 7-26 and Appendix Figure 11-57) (US Air Force 1949a: 22-23) as were three of the four lower wing spar and bulkhead 4 and 5 carry-through termini (FS 100.01 and 102.01) (Figure 7-27, Figure 7-28 and Appendix Figure 11-58 — Appendix Figure 11-61) (Beall 1945: 125, 133, 137; US Air Force 1949a: 22-23). All of the observed termini and associated spars were contained within a rectangle approximately 15 metres x 66 metres. The collection of the termini within such a small area correlates well with the hypothesised primary and secondary axes of movement. This concentration demonstrates a lack of individual artefact mobility for FS 079.01, 081.01, 100.01 and 102.01, thereby substantiating the gulley north of Beinn Edra as the likely site of impact.

Figure 7-24: FS 079.01, as upper wing spar and attached carry-through member (Author). The bottom of the wing spar is on the left; the top on the right. The fuselage carry-through member is the corroded tubing in the back right.

Figure 7-25: At centre is the connection between the wing spar and the fuselage. The upper carry-through member is the corroded square tube (centre right) (Author).

Figure 7-26: FS 081.01, an upper wing spar to carry-through member attachment (Author). The upper wing spar attachment terminus is at the bottom while the carry-through end attachment is at the top. The upper wing spar and upper carry-through member terminals are in the centre between the two corroded aluminium fixtures.

Figure 7-27: FS 100.01, the lower carry-through member and lower terminal (Author).

Figure 7-28: FS 102.01, a fragment of a lower wing spar and terminal (Author).

Two pieces of armour plate were located during Phase IIa: FS 099.01 (Plate-Top Gunner Armour: 3-15152 OR 3-15152-1) (Figure 7-29) and FS 111.01 (Armour Assembly-Waist Gun Armour: 15-11926-8 OR 15-11927-7) (Figure 7-30) (US Army Air Force 1944a: 380-381, 398; US Air Force 1949a: 266-267). Armour plate is a diagnostic artefact class likely to retain a near original deposition location due to its size, weight and lack of aesthetic value. FS 099.01 was originally installed on the aft side of the Bulkhead 4 as protection for the top turret gunner (US Army Air Force 1944a: 380, 398; US Air Force 1949a: 266-267). Located within the gulley, FS 099.01 is associated with the wing spars, spar terminals, carry-through members and personal effects. FS 111.01 is the waist gun armour installed in the fuselage directly below the waist gunners' windows (US Army Air Force 1944a: 381, 398; US Air Force 1949a: 266-267). Dead vegetation to the north of FS 111.01 shows the armour plate to have been flipped relatively recently. Located at the start of plateau 2's eastern slope, FS 111.01 is grouped along the primary axis though its isolated position may make it an outlying artefact either originally deposited in its current location or transported at some point in the decades since the crash.

Figure 7-29: FS 099.01, one of two pieces of armour plate fitted the aft side of the Bulkhead 4 as protection for the top turret gunner (Author).

Figure 7-30: FS 111.01, a section of waist armour installed in the fuselage directly below the waist gunners' windows (Author).

Three artefacts were identified as being personal items of the aircrew. FS 080.01, the contorted remnants of a US military bicycle main sprocket and pedal cranks, contains a unique sprocket pattern developed by Westfield Columbia for the US military (Figure 7-31 and Appendix Figure 11-62) (US Army Air Force 1942). The identification of the bicycle drive fragment confirms the oral testimony given by Roderick MacLeod that the locals discovered and recovered several US military bicycles from the wreck site. Additional personal effects identified include a snap fastener (FS 093.01) (Figure 7-32) and a leather boot upper (FS 094.01) (Figure 7-33). A comparison of the snap fastener's overall dimensions and design indicates that it is a fastening device used on a diverse array of military clothing and equipment. The leather boot upper discovered half-buried in close proximity to FS 093.01 is not standard flight equipment and, therefore, is likely to have been part of the crew's packed clothing. As FS 094.01 is the whole of the boot upper, it may be possible to identify the boot's size. Currently, however, identification of the boot size would be of limited use as not all aircrew personnel files report shoe size. Without invasive work in the area of FS 093.01 and 094.01, no additional specific information about these personal items can be determined.

Figure 7-31: FS 080.01, the contorted remains of a Westfield Columbia US military bicycle main sprocket and pedal cranks, confirms MacLeod's account of local inhabitants salvaging bicycles post-crash (Author).

Figure 7-32: FS 093.01, a snap fastener (Author).
The snap fastener's dimensions and design indicates that it is a fastening device used on a diverse array of military clothing and equipment.

Figure 7-33: FS 094.01, the leather boot upper discovered half-buried in close proximity to FS 093.01, is not standard flight equipment and, therefore, is likely to have been part of the crew's packed clothing (Author).
It may be possible to determine the boot's size. However, determining the boot's owner would require a complete set of crew shoe size data; not all crew shoe sizes were discovered during Phase IIa historical research.

Figure 7-34: Interior of the Beinn Edra gully, the proposed impact site (Author).
The photograph is taken up the gully, toward the southwest, at the FS 093.01/094.01 discovery location.

The close proximity of FS 090.01 and 095.01 to the confluence of the primary and secondary axes coupled with the historical documentation and secondary testimony regarding 44-83325's flight path indicates that FS 090.01 and 095.01 mark the approximate location where the right engines impacted the cliff face. The clustering of the upper and lower wing spar and bulkhead 4 and 5 carry-through terminals (FS 079.01, 081.01, 100.01 and 102.01) around the gulley opening supports the hypothesis that the gulley is the point of impact. Similarly, the observation of personal effects within the gulley itself correlates well with the hypothesis that the gulley is the confluence of the primary and secondary axes of movement and, therefore, the point of impact.

7.2.3.3 Phase IIb Detailed Site Survey

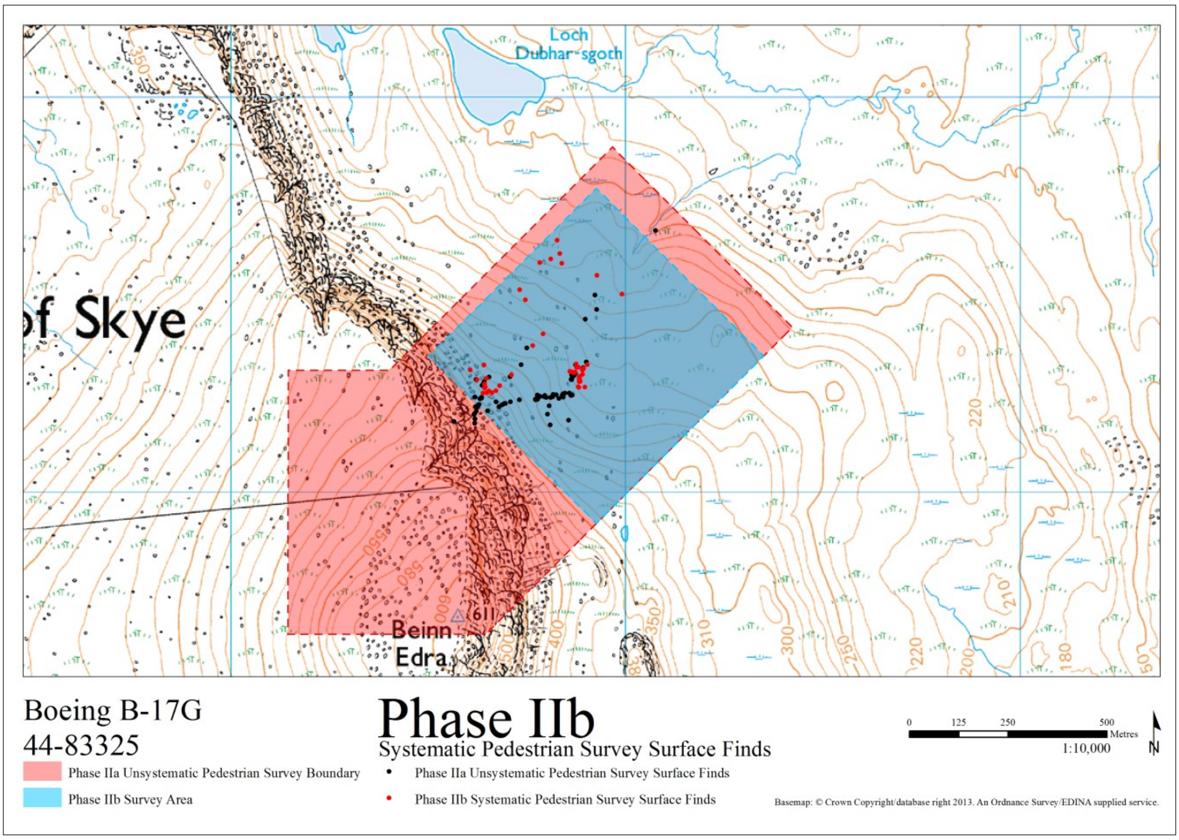
Undertaken from July 2012 to February 2013, the Phase IIb detailed site survey utilised a systematic pedestrian survey to assess the archaeological content and integrity of both the archaeologically sensitive areas identified during Phase IIa and the areas of the proposed site boundary not surveyed during Phase IIa. Primary focus was devoted to the top and eastern slope of Beinn Edra. Although the data acquired during Phase IIb resulted in the widening of the corridors of movement, Phase IIb generally confirmed the primary and secondary axes of movement first identified as a result of the Phase IIa non-systematic pedestrian survey. Additionally, the complete absence of wreckage on the Trotternish Ridge, first noted during the zero visibility Phase I site visit, was confirmed.

Systematic Pedestrian Survey:

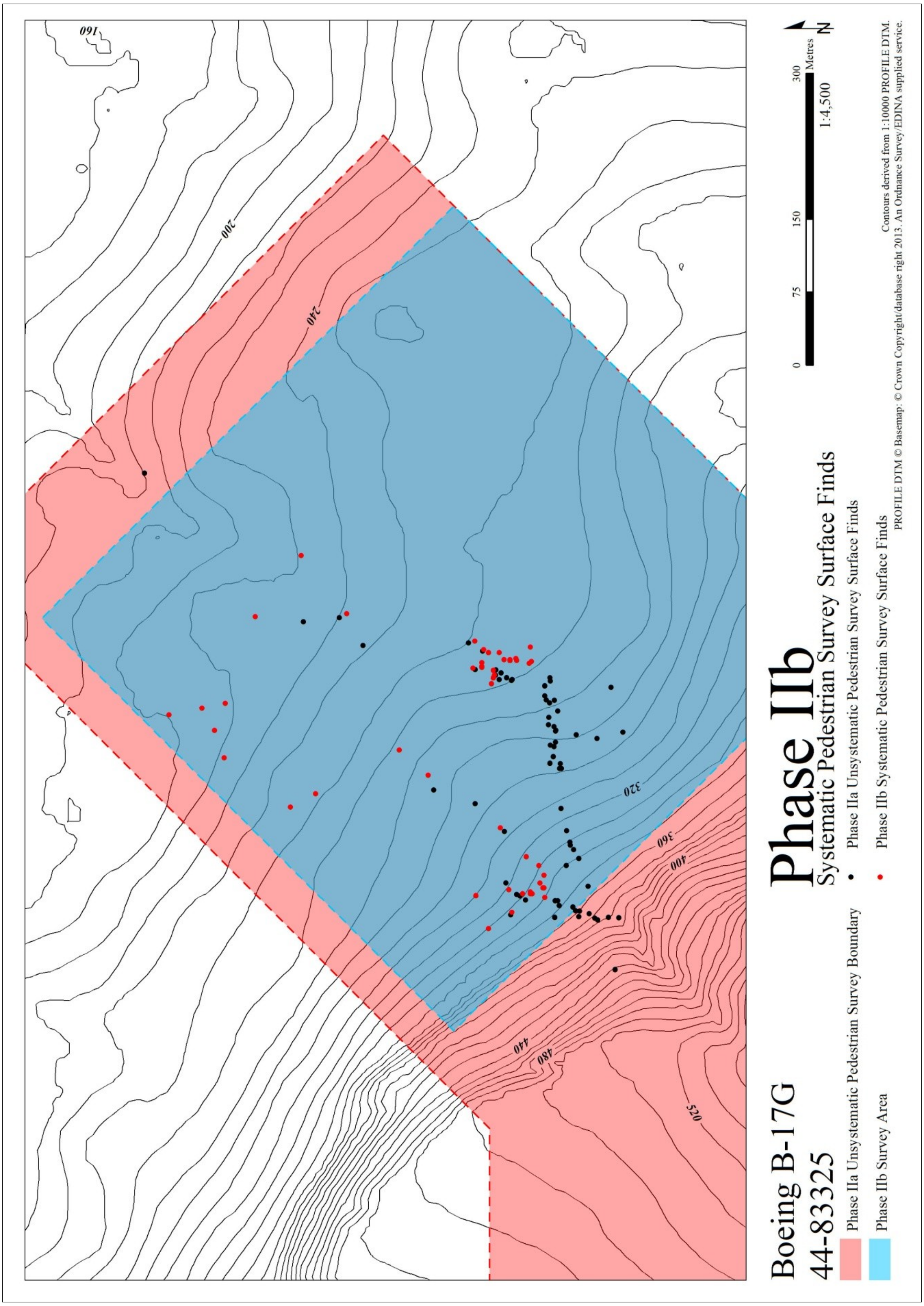
Due to health, safety and legal requirements which precluded metal detector and invasive surveys, Phase IIb data collection was limited to a systematic pedestrian survey. The historical and artefact data produced by the Phase IIa detailed historical survey shows 44-83325 to have crashed into Beinn Edra in full flight. The amount of additional surface scatter observed during Phase IIb was minimal. To preclude omission of artefacts not previously identified during Phase IIa and to ensure uniform coverage, a systematic pedestrian survey of the crash site was undertaken at ten metre intervals.

The Phase IIa and Phase IIb data were pooled and an artefact density analysis performed. The artefact density analysis showed the site boundaries first generated in Phase I and revised during Phase IIa to be substantially correct. In addition, data from Phase IIb confirmed and widened the axes of movement identified during Phase IIa (Map 7-7 to Map

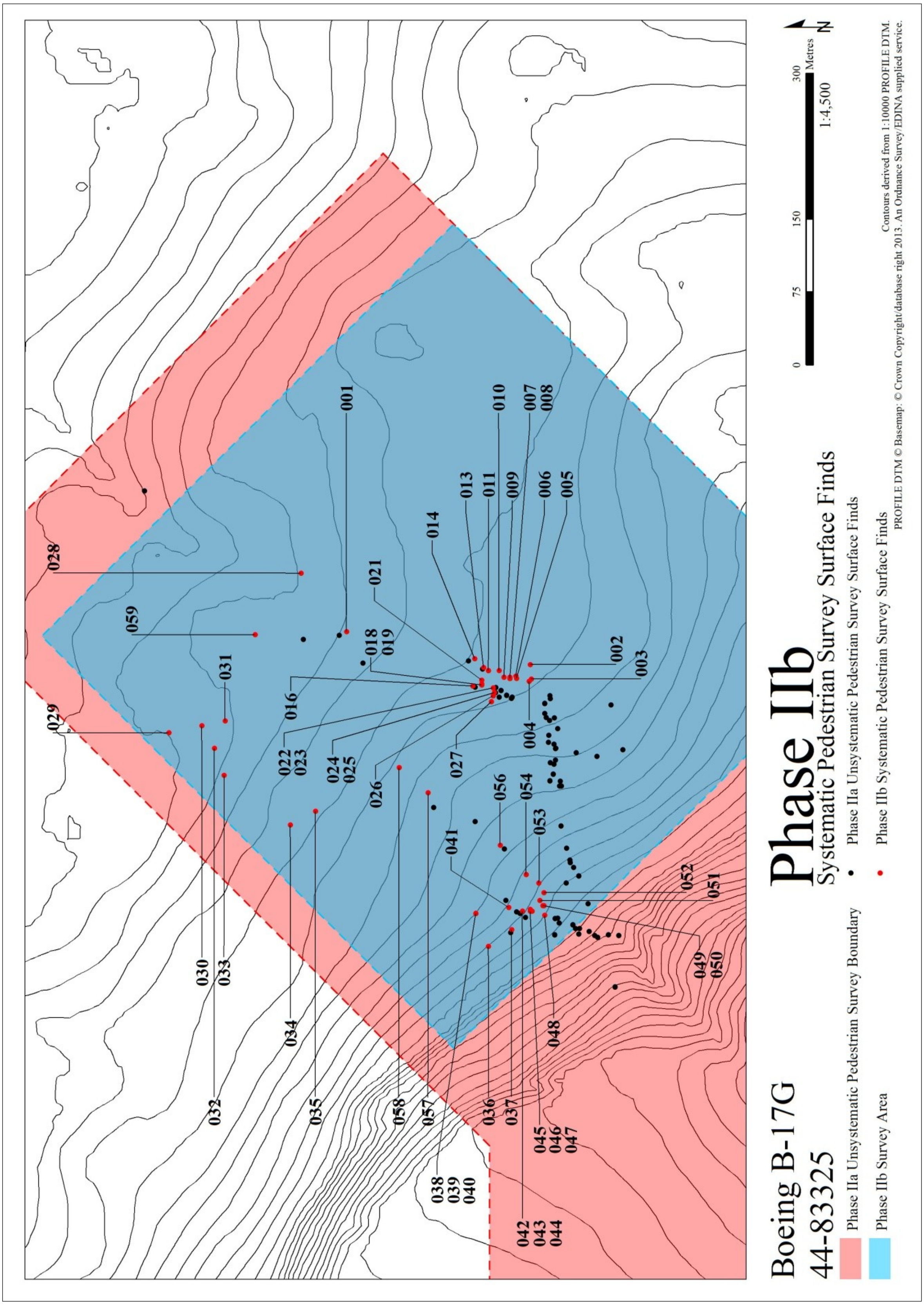
7-10) as well as confirmed individual artefact mobility during the 12 months between surveys (see Phase IIb FS 015.01/017.01 (Phase IIa 130.02/130.01) in Section 0: Artefact Analysis and Section 7.2.3.3: Artefact Analysis for specific detail). It is unclear whether the artefacts were moved due to human, animal or weather forces. Given the differing size and weights of individual artefacts, it is unlikely that a single force altered the location/orientation of all artefacts concerned; different forces or combinations of forces probably altered the disposition of discrete artefacts.



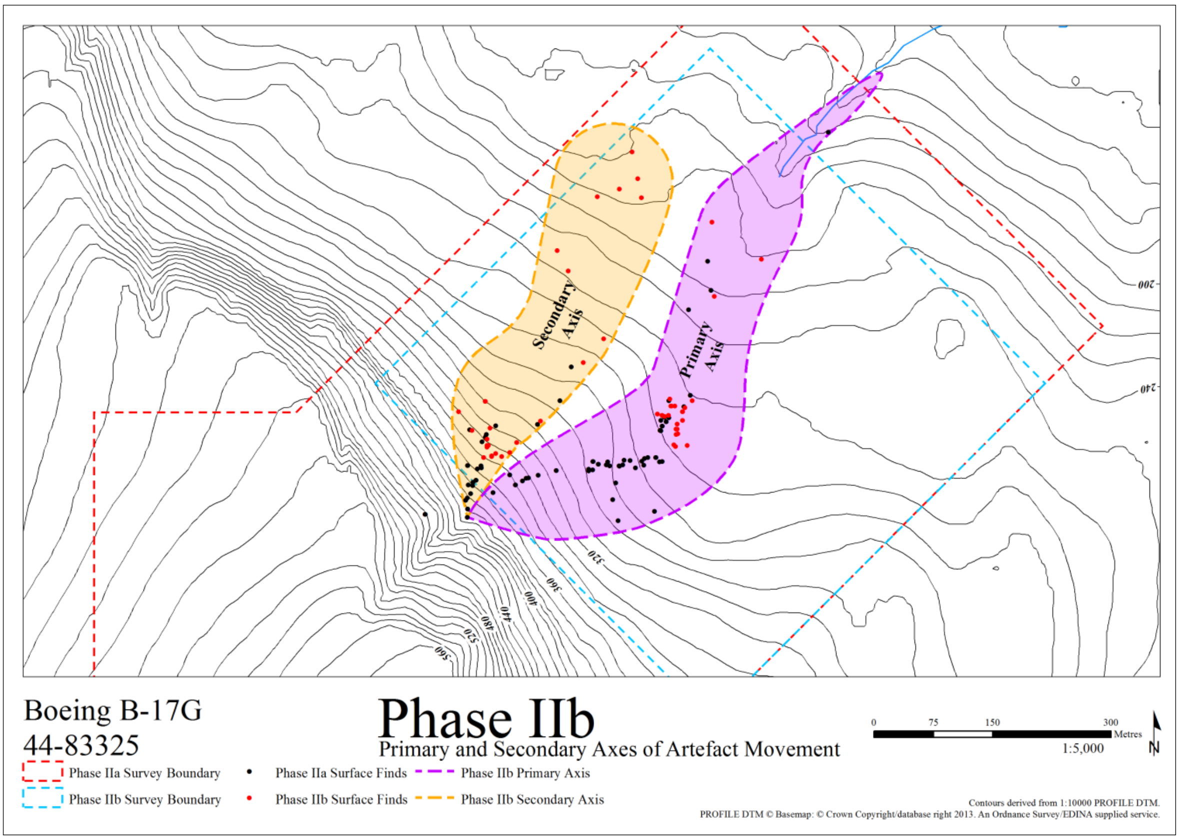
Map 7-7: 44-83325 Phase IIb unsystematic pedestrian survey boundary (blue) and new surface finds (red) (Crown Copyright/database right OS 2013b; Author).
Surface artefacts first recorded during Phase IIa are shown in black.



Map 7-8: Surface finds new to the 44-83325 Phase IIb unsystematic pedestrian survey (red) and surface finds first recorded during Phase IIa (black) (Crown Copyright/database right OS 2013a; Author).



Map 7-9: Annotated distribution of surface finds new to the 44-83325 Phase IIb unsystematic pedestrian survey (Crown Copyright/database right OS 2013a; Author).



Map 7-10: 44-83325 Phase IIb primary and secondary axes of artefact distribution and probable movement (Crown Copyright/database right OS 2013a; Author).
The primary and secondary axes of artefact movement first proposed during Phase IIa are generally confirmed, though widened, as a result of Phase IIb data.

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due to copyright restrictions.

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due to copyright restrictions.

Document 7-3: Phase IIb *PAAR Aircraft Incident Record* form for Boeing B-17G 44-83325 (ICAO 2006; Author).

Artefact Analysis:

The Phase IIb systematic pedestrian survey recorded 86 artefacts in addition to the 163 artefacts recorded during Phase IIa. The additional artefacts were located predominantly in the east-northeast depressions identified during Phase IIa and in the southern portion of the secondary axis (north-to-north northeast of the hypothesised impact point). As new, Phase IIb recorded artefact classes are near evenly split between the two concentrations, data will be discussed by class rather than by location.

The first class of artefacts are similar to those encountered during Phase IIa. FS 053.01, the outstanding propeller hub (Figure 7-35 and Appendix Figure 11-63) (US Army Air Force 1946: 103-106; US Air Force 1949a: 286-287), is situated on the western plateau along the fringe of the main secondary axis distribution. Situated on relatively flat ground, FS 053.01 probably has been relatively stable, experiencing little water and/or gravity-born transport. Its position, approximately 38.5 metres north-northwest of Phase IIa FS 106.01, is not isolated. While unconfirmed due to a lack of serial number, FS 053.01 likely is the number four engine (outboard starboard).

Additional engine assemblies were identified and recorded during Phase IIb. FS 008.01 is a single dynamic suspension bracket assembly (215827) (Appendix Figure 11-64) (US Air Force 1949a: 291) located one metre from FS 007.01 (Phase IIa FS 128.01—Engine Dynafocal Mount Assembly, Cowling Flap Level/Link). Based on their proximity, FS 008.01 probably was originally a part of FS 007.01. FS 014.01 is the outstanding turbo supercharger (4868827, WW8456556 or 4868827, WW8456556) (Figure 7-36) (US Air Force 1949a: 62-65); the other three turbo superchargers were recorded during Phase IIa as FS 055.01, 121.01 and 132.01. The turbo supercharger patterning is comparable to the propeller hub and engine mount distributions. One turbo supercharger is located within plateau 2 along the secondary axis (Phase IIa FS 055.01) and three turbo superchargers have collected alongside many other artefacts in depressions on the western edge of plateau 1. The similar distribution of the propeller hubs, turbo superchargers and engine mounts provides strong evidence for an off-centre collision with a majority of the aircraft (engine numbers 1-3) impacting the south-eastern half of the gulley rather than the north-western half.

Figure 7-35: FS 053.01, the fourth propeller hub, in context (Author). The gulley impact site is at the upper left immediately out of frame.

Figure 7-36: FS 014.01 is the outstanding turbo supercharger (Author).
The other three turbo superchargers were recorded during Phase IIa as FS 055.01, 121.01 and 132.01.

A single engine mount fragment, attached to the nacelle wall, also was located. Located approximately halfway down plateau 2 on the eastern edge of the secondary axis, FS 056.01 is the only engine mount-nacelle connection (85-4805, 85-4805-1, 85-4806 or 85-4806-1; 55-6185) (Figure 7-37) (US Air Force 1949a: 20-21, 28-29, 291) located in Phase IIb. While other engine mounts were recorded during Phase IIa (FS 064.01, 114.01, 124.01 and 128.01), FS 056.01 differs in that it retains an engine mount foot which connects the engine mount to the engine mount pillars/nacelle wall. The 94 metres separation of Phase IIa FS 064.01 (engine Dynafocal mount assembly, cowl assembly) and Phase IIb FS 056.01 indicates that the two engine mount fragments were likely once part of the same engine mount assembly. Additionally, the grouping of FS 056.01 with Phase IIa FS 055.01 (turbo supercharger), Phase IIa FS 064.01 (engine Dynafocal mount assembly, cowl assembly), and Phase IIb FS 053.01 (propeller hub) provides strong evidence for the deposition of a single engine along the secondary axis.

Figure 7-37: FS 056.01 is the only engine mount-nacelle connection located in Phase IIb (Author). While other engine mounts were recorded during Phase IIa (FS 064.01, 114.01, 124.01 and 128.01), FS 056.01 differs in that it retains an engine mount foot which connects the engine mount to the engine mount pillars/nacelle wall.

The three additional oxygen bottles recorded during Phase IIb (FS 007.17, 009.02 and 054.01) (Appendix Figure 11-65, Appendix Figure 11-66 and Appendix Figure 11-67) show similar patterning to the four bottles recorded during Phase IIa (FS 108.02, 121.02, 127.01 and 129.01). FS 007.17 (Appendix Figure 11-65) and 009.02 (Appendix Figure 11-66) are clustered in the same series of depressions as Phase IIa FS 121.02, 127.01 and 129.01. The similar location is unsurprising as most oxygen bottles were installed in the fuselage section (US Air Force 1949a: 218-219). The two oxygen bottles located outside the cluster, Phase IIa FS 108.02 and Phase IIb FS 054.01 (Appendix Figure 11-67), are likely not located at the point of initial impact/deposition but rather have migrated down the primary and secondary axes of movement, respectively. Exhaust tailpipe assemblies show patterning similar to that of the oxygen bottles, conforming to the biaxial movement theory. Artefacts recorded during Phase IIb cluster in the same western depressions of plateau 1 with FS 049.01 (Exhaust Ball Assembly-Flexible Joint), the lone isolate, centrally located within the secondary axis (Appendix Figure 11-68). The presence of three exhaust tailpipe assemblies and nacelle shrouds (Phase IIa FS 023.01 and 127.02 and Phase IIb FS 009.01) along the primary axis and a single exhaust tailpipe assembly along the secondary axis (Phase IIa FS 062.01) parallels the distribution of propeller hubs.

The wing truss, corrugated under skinning and exterior skin fragments recorded during Phase IIb, while less numerous than those identified in Phase IIa, corroborate the biaxial artefact movement hypothesis by filling in some of the gaps in the artefact distribution. Two new wing assembly artefacts were recorded along the primary axis during Phase IIb. FS 026.04 is a wing truss fragment (Figure 7-38 and Figure 7-39) (Beall 1945: 133), the specific installation of which is not currently known due to a lack of unique connection joints and/or observed part stamps. Located within the same cluster of artefacts as Phase IIb FS 007.17 and 009.02, FS 026.04 bridges Phase IIa FS 112.1 and 160.01 and provides directionality to the lower half of the primary axis. FS 028.01 (a nondiagnostic(diagnostic) metal fragment currently unclassified but probably from the exterior of the wing or fuselage) (Appendix Figure 11-69) and FS 059.01 (probable wing top skin and corrugated under skin) (Appendix Figure 11-70) are useful in understanding the flow dynamic of the primary axis. Prior to the discovery of FS 028.01 and 059.01, there was little to link Phase IIa FS 050.01 with Phase IIa FS 133.00. Indeed, the working hypothesis for the isolation of Phase IIa FS 133 was that it was transported into the burn by humans and then discarded as too large for easy recovery. The location of FS 028.01 and 059.01 offer a different, equally plausible alternative by linking the primary axis of movement, otherwise terminating with Phase IIa FS 050.01, with Phase IIa FS 133.01. The single Phase IIb unique confirmed artefact within the secondary flow, FS 057.01 (a fragment of corrugated wing under skin) is the lowest wing assembly fragment located along the secondary axis (Appendix Figure 11-71). An additional eight nondiagnostic and nondiagnostic(diagnostic) artefacts (FS 029-035, 058) were recorded further north of FS 057.01 but their character and position within the aircraft cannot be definitively determined at this time. Nonetheless, the presence of FS 029-035, 057-058 indicates that the wing and fuselage structure of 44-83325 did not break up exclusively to the east of plateau 2.

Figure 7-38: Facing south, the FS 026 scatter (Author).
FS 026.04, a fragment of wing truss, is located in the background behind the photo board.

Figure 7-39: Close up of FS 026.04, a wing truss fragment (Author).

Of particular importance in supporting the hypothesised 44-83325 crash scenario and post-impact depositional forces are FS 007.11, 026.05, 027.01 and 027.02 (Rail Assemblies-Internal Bomb Rack) (Appendix Figure 11-72 — Appendix Figure 11-78) (US Air Force 1949a: 262-265). FS 026.05 and 027.02 are the only bomb rack rail assemblies whose location can be positively identified. FS 026.05, identified by the unique space between the five upper bomb rack hook assemblies (1-17847 or 1-17847-1) and the lower three bomb rack hook assemblies (1-17847 or 1-17847-1), is the lower portion of the upper five, right hand outboard bomb rack rail and hook assemblies (15-7953-10, 15-7953-14, 15-7953-50) (Appendix Figure 11-74 and Appendix Figure 11-75) (US Air Force 1949a: 262-263). FS 027.02 appears to retain none of its bomb rack hook assemblies (Appendix Figure 11-76); however, it is confirmed to be an outboard bomb rack rail terminus due to the retention of the outboard bomb rack bracket assembly (6-10108) and a fragment of the body compression strut (85-3445; strut -701 or -703) to which the outboard bomb rack was affixed (Appendix Figure 11-78) (US Air Force 1949a: 126, 262-263). Lying approximately 0.5 metres east of FS 027.02, FS 027.01 retains three intact bomb rack hook assemblies (1-17847 or 1-17847-1) (US Air Force 1949a: 262-265) with a fourth bomb rack hook assembly having become detached and lying immediately beside FS 027.01 (Appendix Figure 11-77). The installation location of FS 027.01 cannot be determined at this time as one-half of the artefact is obscured by long grass. FS 007.11 is similarly unidentifiable as it retains three evenly spaced bomb rack hook assemblies and is broken off at one end with the other end buried in the ground surrounded by FS 007.12-007.15, 007.19 and 007.20 (Appendix Figure 11-72 and Appendix Figure 11-73). This configuration prevents bomb rack hook assembly spacing comparisons and/or continuations. The absence of bomb rack rail assemblies along the secondary axis and the collection of the recorded bomb rack rail assemblies in proximity to other quantities of fuselage-related artefacts (such as oxygen bottles) supports the hypothesis of an off-centre impact. The bomb rack rail assemblies are located well away from most of the recorded wing spars, spar terminals and carry-through members, the closest of which is Phase IIa FS 038.01 (a carry-through member fragment) approximately 60 metres southwest of Phase IIb FS 007.11. However, the presence of the bomb rack rail assemblies away from the wing spars, spar terminals and carry-through members is not surprising. B-17G 44-83325 was not carrying a bomb load at the time of impact and, thus, was not encumbered by additional weight. Bomb rack rail assemblies were constructed from thinner, lighter aluminium than the SF27 and steel of the wing spars, spar terminals and carry-through members. Therefore, the significant movement of FS 007.11, 026.05, 027.01 and 027.02 down slope—either via natural forces or human relocation immediately following the crash or in the ensuing years—and the retention of the heavier wing spars, spar terminals and carry-through members in the area around the impact site are expected phenomena for the hypothesised crash scenario.

FS 047.01, a single piece of black rubberised nylon fabric with grommets stamped “UNITED” [lower word is illegible due to corrosion but most likely “STATES”], was located in the south-western end of the secondary axis (Appendix Figure 11-79 and Appendix Figure 11-80). As FS 047.01 was half-buried, any identification at this time would be pure conjecture. Due to the artefact’s uniqueness within the larger assembly, extension of research into Phase IIIa should include targeted excavation of FS 047.01. Targeted excavation and conservation of FS 047.01 would not only classify and stabilise a possibly endangered artefact but also, depending upon FS 047.01’s identity, better refine the crash scenario and the resultant site boundaries.

Several artefacts recorded during Phase IIb provide data demonstrating artefact movement on both small and large scales from August 2011-August 2012. Lighter artefacts are more susceptible to relocation as their weight allows them to be more easily moved by natural and human influence. For example, Phase IIa recorded FS 129.01 as an oxygen bottle with no evidence of movement since initial deposition (Figure 7-40). During Phase IIb, the same artefact was observed to have moved some 0.3-0.4 metres east and rotated 180 degrees about the y-axis (Figure 7-41). If the 0.3-0.4 metres per year movement is considered average, FS 129.01/FS 020.01 could have moved 20.1-26.8 metres in the previous 67 years. While conjecture, the hypothetical 26.8 metre movement of FS 129.01/FS 20.01 demonstrates that artefacts' current locations may differ markedly from their point of original deposition.

Figure 7-40: Phase IIa FS 129.01 as observed on 8 August 2011 (Author).
FS 129.01 was disturbed between August 2011 and August 2012.

Figure 7-41: Phase IIb FS 020.01 as observed on 29 July 2012 (Author).
FS 020.01 has moved some 0.3-0.4 metres east and rotated 180 degrees about the y-axis in approximately 12 months. Dead vegetation, marking FS 020.01's former location, is seen in the upper right.

Similar localised movement is observed in artefacts with greater size and/or mass. Having obviously been moved quite recently, as evidenced by the dead grass to the south side, Phase IIa FS 055.01 (a turbo supercharger) was observed during Phase IIa to be resting on its side (Figure 7-42). A year later, during the Phase IIb survey, Phase IIa FS 055.01/Phase IIb 055.01 was observed to be resting on its base (Figure 7-43). While the artefact has not moved from the position recorded during Phase IIa, the substantial weight/size of the turbo supercharger and the alteration of its resting orientation show the 44-83325 crash site to experience *inter alia* tampering. While the positioning of FS 111.01 (Armor Assembly 15-11926-8 or 15-11927-7) (Figure 7-44) did not change from August 2011 to July/August 2012, dead vegetation of identical size and shape to FS 111.01 was noted during Phase IIa. As with FS 055.01, the weight/size of FS 111.01 precludes FS 111.01 from being flipped by anything other than humans. While Phase IIa/Phase IIb FS 055.01 and Phase IIa FS 111.01 demonstrate the localised movement of artefacts which do not adversely affect overall distribution patterns, the migration of artefacts over larger distances also was recorded. On 8 August 2011, Phase IIa FS 130.01 and 130.02 (an exhaust tailpipe/exhaust shroud assembly and a probable wing leading edge) were separated by less than 50 centimetres (Figure 7-45). A year later, Phase IIa FS 130.01 and FS 130.02 (Phase IIb FS 017.01 and 015.01) were recorded with a gap of 8.6 metres (Figure 7-46). The location of two artefacts, whether in close proximity or far apart, has the potential to alter the interpretation of the site. In close proximity, Phase IIa FS 130.01 and FS 130.02 represent the union of an engine nacelle and the main wing. Their close association specifically marks a potential area where one of the engine nacelles or the wing came to rest and, more generally, a compact site. Separated, Phase IIb FS 017.01 and 015.01 represent a more dispersed site with larger boundaries and, potentially, a more violent airframe breakup.

Figure 7-42: Phase IIa FS 055.01, on 8 August 2011, viewed facing northeast (Author).

Figure 7-43: Phase IIb FS 055.01, on 1 August 2012, viewed facing east (Author).

Figure 7-44: Phase IIa FS 111.01, a section of armour plate from the waist gunner stations (Author). The dead vegetation suggests FS 111.01 has been flipped recently. The plate's size and weight make human manipulation the only possible method of movement.

Figure 7-45: Phase IIa FS 130.01 (right) and 130.02 (left), a probable wing leading edge and an exhaust tailpipe/exhaust shroud assembly, were separated by less than 50 centimetres on 8 August 2011 (Author).

Figure 7-46: Phase IIb FS 015.01 (foreground) and FS 017.01 (background) on 29 July 2012 (Author). The artefacts are now separated by 8.6 metres.

7.2.3.4 Phase IIIa Targeted Excavation

A permit request to excavate Boeing B-17G 44-83325 was submitted to the MoD JCCC on 3 July 2012. Due to concern over the incomplete recovery of human remains, namely the comingled remains of Aldrich, Fahselt, Vaughan and Wilkinson buried as a group in Jefferson Barracks National Cemetery (US Department of Veterans Affairs 2012c), the MoD JCCC denied the permit request. Should future research demonstrate complete recovery of Aldrich, Fahselt, Vaughan and Wilkinson, the MoD JCCC has confirmed that it would grant an excavation license. The MoD JCCC position is unfortunate for professional—and specifically academic—research as it bars professional archaeologists from excavating any site which may contain human remains. Professional archaeology has a positive reputation for excavating and studying human remains with the utmost care and respect to the deceased. As excavation of 44-83325 is not allowed under current MoD policy, the site will continue to have its artefacts slowly removed from the landscape by weather, corrosion and ill-informed hill walkers/enthusiasts.

7.2.4 Comprehensive Site Analysis

Documentary source material was unable to clarify why 44-83325 deviated from the filed flight plan and began to fly over the Trotternish Peninsula. Because the USAAF did not take crash scene photographs at the time of personnel recovery, the final vector and impact point of 44-83325 is unknown. Surveys conducted during Phase IIa and Phase IIb identified wing spar, carry-through members, and spar and carry-through member terminals near the opening of the gulley. Armour plate was located in the same area. Additionally, personal effects (snap fastener, boot upper and bicycle main sprocket) were discovered within the gulley. The positioning of personal effects, heavy wing-to-fuselage assembly components and armour plate within and adjacent to the gulley indicates that the gulley was the impact area.

Analysis of the surface artefact positions yielded two distinct artefact scatters branching east-northeast and north-northeast from the suspected impact point. The two scatters seemingly resulted from the movement of artefacts down slope both during and subsequent to the crash event. The east-northeast and north-northeast scatters were termed the primary and secondary axes of artefact movement, respectively, due to the relative quantity of artefacts recorded along each axis. An uneven distribution of power plant assemblies (propeller hub, engine, engine mount and turbo supercharger) was noted with three power plant assemblies located along the primary axis and one recorded along the secondary axis.

That the available data positions the impact point so close to the summit of Beinn Edra supports the hypothesis that 44-83325 attempted to descend below cloud cover and use Beinn Edra as a visual waypoint in order to fix a compass bearing. The recorded local weather conditions for 3 March 1945 suggest that the summit of Beinn Edra was obscured. In order to make a bearing correction, the pilot/co-pilot of 44-83325 may have focused on the gulley as a visual landmark readily identifiable on his chart. Instead of maintaining a safe altitude and completing the course correction, 44-83325 impacted the ridgeline with parts tumbling down the east slope in a ball of fire.

Oral testimony by Roderick and Alan MacLeod confirm the site has been subject to artefact removal since the accident. Likewise, movement of artefacts was observed between the Phase IIa and Phase IIb surveys. Though neither the source of the recent movement nor its relevance as evidence of widespread artefact relocation over the past decades is known, the observed movement qualifies the location of specific artefacts. At this time, however, the limited movement observed with Phase IIa FS 055 (Phase IIb FS 055), Phase IIa FS 111, Phase IIa FS 129 (Phase IIb FS 020), Phase IIa FS 130.01 (Phase IIb FS 017) and Phase IIa FS 130.02 (Phase IIb FS 015) does not impact the larger scatter pattern.

The identification of substantial surface components (including organic artefact survival) and the likelihood of numerous sub-surface artefacts probably with secure contexts (as evidence by extremely heavy, half-buried artefacts) makes 44-83325 an excellent candidate for future Phase IIIa investigations should legal constraints allow. A limited metal detector survey in proximity to key artefacts/artefact concentrations, excavation of archaeologically promising deposits and a detailed analysis of the cliff gully would greatly enhance understanding of the plight of 44-83325. Evidence of recent and destructive tampering at the site makes such research highly time sensitive.

7.3 Boeing B-17G 42-97286 (Beinn Nuis, Isle of Arran)

7.3.1 Overview

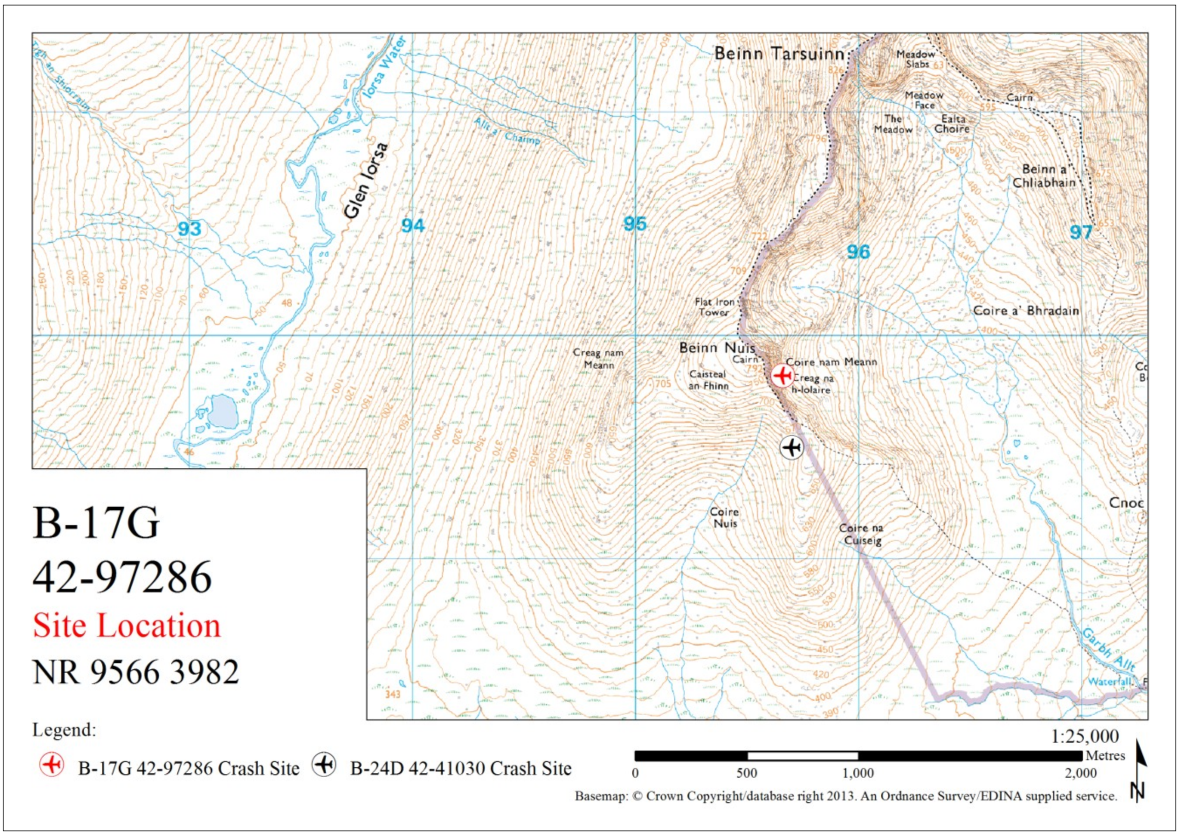
7.3.1.1 Site Background

Boeing B-17G 42-97286, "Skipper an' the Kids," of 560th Bombardment Squadron, 388th Bombardment Group, United States 8th Air Force (see Figure 7-1 for an exemplar of the B-17G airframe), crashed on 10 December 1944 while on a NAVEX/aircraft re-certification flight from RAF Knettishall, Suffolk (then USAAF Station No. 136) to RAF Prestwick, Ayrshire. Impacting the eastern side of Beinn Nuis (Isle of Arran) in the vicinity of NR 9566 3982 (the high ground between the *Coire nam Meann* and the *Creag na h-lolaire*), 655 metres asl, 42-97286's crash location provides additional artefact-altitude survivability data relative to crash heights.[2] The topography of the crash site (the eastern face of Beinn Nuis) is similar to that observed on the scree slopes at 44-83325 and AM261. The observed soil and hydrologic conditions at the 42-97286 wreck site, however, are substantially wetter due to the abundance of burns and the presence of boggy ground on the lower slopes. Based upon the historical and archaeological data collected, the impact dynamics of 42-97286 evoke those detected at 44-83325.

A Phase IIa survey of 42-97286 conducted on 17-19 July 2012 confirmed site survivability, the presence of a diagnostic artefact clustering near the cliff face, the probable preservation of substantial buried archaeology, and the co-mingling of 42-97286 and 42-41030 artefacts on the western boundary of the 42-97286 site. Results of the Phase IIa survey oblige continuation of enquiry to at least a Phase IIb if a MoD JCCC excavation license becomes obtainable. A license would be required to process the site further as the overgrown site vegetation and the boggy ground half buried artefacts and obscured diagnostic features. Were a license to be obtained, specific, important artefacts (including at least one crew-associated organic artefact) could be handled. The NTS granted permission for work to continue into Phase IIb but the MoD JCCC rejected the permit application based upon the group burial of Littlejohn, Rosebasky and Merkely (Site 1175, Section 4, Fort McPherson National Cemetery, Nebraska, United States) (US Department

[2] FL455 Z9-A (Forsinard Flows, Caithness): 140m asl, MM244 (Corryfoyness, Highlands): 340m asl, DD753 (The Curr, Scottish Borders): 535m asl, 44-83325 (Beinn Edra, Isle of Skye): 550m asl, 42-41030 (Beinn Nuis, Isle of Arran): 640m asl, AM261 (North Goatfell, Isle of Arran): 700m asl and DD795 (Corserine, Dumfries and Galloway): 760m asl.

of Veterans Affairs 2012c) and a concern for the possible presence of human remains on site.



Map 7-11: Location of the Boeing B-17G 42-97286 crash site (Crown Copyright/database right OS 2013b; Author).
B-17G 42-97286 impacted high on the east face of Beinn Nuis at approximately 655 metres asl.

7.3.1.2 Investigation Summary

Located within the confines of the Brodick and Goatfell holdings, National Trust for Scotland, the wreck site of B-17G 42-97286 is located within the Arran Northern Mountains SSSI and the North Arran NSA areas (SNH 2012). The proposed research aim and objectives for the study of B-17G 42-97286 were the same as other for other wreck sites investigated.

Phase I background research was completed in January 2010. No Phase I site visit was completed as aircraft-related artefacts were confirmed by hill walkers and by recent photographs. The reporting of substantial surface debris in secondary source material provided sufficient data to recommend continuation to Phase IIa.

A Phase IIa survey, undertaken from January 2010—May 2012, identified primary source documentation, information reporting past excavation results and the presence of an extensive artefact scatter with significant clustering in proximity to the reported point of impact. Central to the Phase IIa detailed historical survey were the MACR and AAR files and the diary entries of Verner Small, the man who located the wreck site on 3 March 1945. Individual Deceased Personnel Files, obtained for a percentage of the aircrew, provide information as to the nature of impact and recovery operations. Attainable secondary source material detailing past excavations is limited in quantity and detail.

The Phase IIa survey did not utilise a metal detector survey as the terrain slope and wet conditions did not allow for safe handling. However, the Phase IIa unsystematic pedestrian survey was extremely productive. Recorded diagnostic artefacts, including one of four engines, one of two main landing gear, and several main spar fragments, enabled the generation of maximum and core boundaries. Moreover, the unsystematic survey confirmed 42-97286 scatter co-mingling with 42-41030 scatter on the 42-97286 western periphery. The deep vegetation and wet conditions of the site make 42-97286 a constructive case study to progress to at least Phase IIb as the topography, vegetation and hydrologic characteristics of the site obscure artefacts easily. Similar conditions previously have yielded excellent artefact survivability. The wet vegetation conceals artefacts from visitors and the wet, boggy climate retards oxidation. While previous, possibly extensive excavations may compromise artefact recovery, the presence of at least one crew-associated surface artefact makes the exploration of the site beyond Phase IIa a tantalizing objective. Although the MoD JCCC would not grant an excavation permit for the current research, confirmation of full body recovery and/or the employment of forensic anthropologists on site may alter the JCCC's decision. As such, the future progression of 42-97286 research into Phase IIb or Phase IIIa should not be eschewed.

7.3.2 Airframe Construction

Discussion of the assemblies and components anticipated on metal-skinned aircraft wreck sites is discussed in detail in Chapter 9 Section 9.2. While Section 9.2 specifically relates to the Consolidated B-24, the construction methods discussed are also applicable to the Boeing B-17.

7.3.3 Archaeological Investigation

7.3.3.1 Phase I Historical Survey

A Phase I historical survey was undertaken in January 2010. Eleven deceased crew were identified (Appendix Table 11-5) along with a mission profile complying with *PMRA 1986* licensure requirements. Primary sources state 42-97286 was on a 10 December 1944 NAVEX and transition flight from RAF Knettishall to RAF Prestwick when the aircraft impacted Beinn Nuis, Isle of Arran. While official documentation records 42-97286 on a NAVEX and transition flight, unproven claims imply that 42-97286 was unofficially flying to RAF Prestwick to purchase whisky for the Officers Mess Christmas party (McLachlan 1989: 11). Based on this information, a *PAAR Aircraft Incident Record* form (Document 7-4) was completed and investigation into Phase IIa recommended.

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Document 7-4: Phase I *PAAR Aircraft Incident Record* form for Boeing B-17G 42-97286 (ICAO 2006; Author).

7.3.3.2 Phase IIa General Data Survey

Background Research:

Primary Source Accounts:

The Phase IIa detailed historical survey identified a range of material regarding the 42-97286 crash narrative and post-depositional site activity. Central to the planning and execution of the unsystematic survey was assessment of the Missing Air Crew Report [MACR] and the Aircraft Accident Report [AAR]. The 42-97286 MACR, located during Phase I, provides a brief account of the suspected crash circumstances:

> *Aircraft No. 42-97286 was cleared from Knettishall, Suffolk, England on a routine flight to Prestwick, Scotland. The Prestwick radio range was never contacted but their radar listening set picked up a plane on its approach. However, the radar set became inoperative and the aircraft could not be followed. A farmer on the Isle of Aaran [sic] reported hearing a plane (believed to be aircraft number 42-97286) and seeing one fly directly overhead heading for a glen. Weather was very bad and the tops of the hills in that locality were in the clouds. Air craft [sic] number 42-97286 is believed to have crashed into the mountains (US Army Air Force 1944b).*

The MACR, filed once an aircraft was officially overdue, does not provide a full accounting of the crash nor of the recovery operations. Indeed, the initial MACR narrative finishes by reporting on the initiation and progress of search operations. Following the discovery of the crash on 3 May 1945, MACR 1133 was amended with an account of the discovery and recovery operations:

> *c. On March 3rd, 1945, the police of Arran called Prestwick and stated that a crashed aircraft had been located in a small narrow gorge on that island. On the arrival of a part from Prestwick, it was discovered that the aircraft had flown into a rocky cliff at the end of a narrow gorge approximately 1000 ft. above sea level. The aircraft struck with such force that the wreckage was unrecognisable and was spread over an area of one quarter mile. The only piece of wreckage that was recognizable as a B-17 was the vertical stabilizer which was in good condition with the aircraft number clearly visible (US Army Air Force 1944b).*

Unfortunately, the AAR does not provide any additional crash narrative. The post-recovery information added to the MACR file is duplicated in the AAR as the *Description of Accident*. That said, the AAR does provide supplementary historical data. Two flight paths were uncovered during Phase IIa. The flight path listed in Missing Air Crew Report

1133 indicates that the aircraft would fly northwest over Thorpe Fell (SD 993588) and the Solway Firth (approximate southeast seafall at Silloth, approximate northwest landfall at Kirkconnell) before arriving at RAF Prestwick, Ayrshire (US Army Air Force 1944b). The AAR-reported flight path shows the B-17 flying up the east coast of Britain and then heading west at Masham (US Army Air Force 1945d). Study of the two flight paths shows a strong correlation—Masham is only 24 km (at a 90 degree bearing) from the MACR flight path—and demonstrates a planned easterly approach to RAF Prestwick.

The AAR includes forecasted weather conditions along the filed flight path. Departing RAF Knettishall, the crew of 42-97286 would have experienced no low cloud with 7 9/10[3] middle cloud between 15,000 and 18,000 feet asl. The visibility would degrade over the Midlands to 3 4/10 low cloud at 2,500 feet asl and 7 9/10 low cloud between 900-1,200 feet asl over RAF Prestwick. Higher cloud bases were expected to worsen similarly. The low and middle cloud layers encountered over the Midlands were predicted to become multi-layer over RAF Prestwick to a height of 18,000 feet asl. In addition to cloud cover decreasing visibility around RAF Prestwick, light rain was forecast between 900-1,200 feet asl with light rime ice[4] in clouds above 3,000 feet asl. Winds, at 2,000 feet asl, were forecast to be 22 knots at 280 degrees becoming 25 knots at 345 degrees over RAF Prestwick (US Army Air Force 1945d). Unfortunately, the actual conditions over RAF Prestwick were very different from that originally forecast. MACR 1133 indicates that observed conditions at RAF Prestwick were "Light rain and snow. Visibility 4 to 6 miles. Ceiling variable, nine-tenths at 2000 ft. to ten-tenths at 1500 feet. Some low cloud present. Wind east 13 to 18 miles per hour" (US Army Air Force 1944b). The cloud cover was heavier than expected and would have required the crew to rely on dead reckoning navigation alone. If the crew did not compensate for the change in wind direction, the actual weather conditions would have both accelerated the flight time and pushed 42-97286 off course. In all likelihood, the weather-altered course, cloud conditions, and flying altitude resulted in collision with the high peaks of Arran (McLachlan 2004: 127-128).

[3] The first digit is the okta value. An okta is a unit of measurement used to describe the amount of cloud cover. The fraction following the okta value is the same measurement given in tenths (Ahrens *et al.* 2012: 151-152).

[4] Rime ice is caused by supercooled water droplets freezing on contact with the aircraft. While usually less dangerous than glaze ice, which migrates across the aircraft surfaces usually covering a larger, more unprotected surfaces, if left uncorrected excessive rime icing can cause dangerous drag (Politovich 2003: 69-70).

Four photographs are included in the AAR. Two of the photographs are unintelligible due to poor contemporary duplication. Figure 7-47 is not definitive and provides little geographical information but appears to show the remains of one of the crew as largely intact (Figure 7-48, Figure 7-49 and Figure 7-50 identify diagnostic D-rings). In contrast to the lack of geographical information in Figure 7-47, Figure 7-51 provides strong identification as to the location of the crash site centre. Indeed, the rock wall where Payne's dog tag and a propeller hub were located by the Arran Junior Mountain Rescue Club appears to be shown in the photograph (Figure 7-52, Figure 7-53 and Figure 7-54).

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Figure 7-47: AAR photograph believed to show human remains (US Army Air Force 1945d).

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due to copyright restrictions.

Figure 7-48: Annotated Figure 7-47 identifying personnel equipment (US Army Air Force 1945d; Author).
The red areas are believed to be the back and hip parachute harness straps while the fittings marked (B) are the parachute harness's hip D-rings.

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due to copyright restrictions.

Figure 7-49: D-ring of the type fitted to A-3 and B-8 parachute harnesses and believed to be present in the proposed AAR human remains photograph (Figure 7-48) (US Army Air Force 1943a: 14).

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due to copyright restrictions.

Figure 7-50: Example of an A-3 parachute harness (Nored 2010).
The hip D-rings are seen on the exterior of the lower, outer straps.

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due to copyright restrictions.

Figure 7-51: Original AAR photograph showing hypothesised primary impact scatter at the cliff face (US Army Air Force 1945d).

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due to copyright restrictions.

Figure 7-52: Annotated AAR photograph showing hypothesised primary impact scatter at the cliff face (US Army Air Force 1945d; Author).
The rising ground, demarcated in yellow, and rock marked (A) also appear in the Arran Junior Mountain Rescue Club photographs.

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due to copyright restrictions.

Figure 7-53: Arran Junior Mountain Rescue Club photographs showing a similar area as the AAR photograph (AJMRC n.d.).

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due to copyright restrictions.

Figure 7-54: The Arran Junior Mountain Rescue Club photographs annotated to show terrain similarities with the AAR photograph (AJMRC n.d.; Author).
The rock marked (A) is visible in all three photographs and confirms their association.

Additional primary source material specifies that it was Verner Small, a local resident and guide, who located 42-97286 in March 1945. Small's diary entries, obtained from the Arran Heritage Museum Archives, offer a flight narrative similar to that stated in the official accident report and provide further detail on the site discovery and subsequent recovery operation:

> *Sat. March 3rd.*
>
> *Went for a climb in afternoon, up Beinn Nuis. It was a lovely day, warm and sunny (my nose is quite sunburned), but it was might [sic] cold on top. On way down, I looked over the edge of the precipice and beheld a place where there wasn't no plane before, so scrambled down to investigate. It was a new crash all right, as there was at least one body. I didn't examine him to [sic] closely, but he was humming [Scots slang: smelling] quite a bit, poor devil. It was mighty eerie, as the icicles were falling from the cliff and rattling onto the wreckage; it sounded like someone raking around. The number was H297289 and the map reference of the place (foot of Beinn Nuis Chimney) was 451629. I think it is an Auster. I hurried home and reported the find to the Brodick Policeman (P.C. Archie Galbraith) who phoned me back later to say that a squad of Naval ratings, under a Chief Petty Officer were going up to the crash site the following morning, and could I lead them to the place.*
>
> *Sun. March 4th.*
>
> *Very wet, with low clouds in morning cleared about 13.00 hrs. and bright sun thereafter. Set off with Naval party at 9.45 hrs. Top of String, 10.45 hrs. Pouring like blazes and fairly strong wind. Headed for top of Gleann Easbuig, crossed it and hit Beinn Nuis on S.E. shoulder. Clouds very thick and had a terrible job to find plane. Eventually reached it about 13.00 hrs. Turned out to be one of the Flying Forts missing since November, so no wonder the body was stinking. Found another 6, so there will probably be 3 more underneath. I have to go up again with the Yanks. Arrived home about 16.30 (16.00 hrs. at String, where we got a cup of tea from the W.V.S (Small n.d.).*

Consultation of contemporary newspaper articles did not reveal additional information. However, an abbreviated and unconfirmed description of 42-97286's impact point was located in *The Scots Magazine* March 1989. The article *Wrecked on Arran* states that 42-97286

> *had flown straight into the cliff face, leaving fragments embedded and then falling to the rocks below. There is a well-known rock climb here called Beinn Nuis Chimney, and a mountaineering guide published about 20 years ago stated rather callously that the crash had ruined a good climbing route!...Such was the force of the impact that the sole remaining engine has been smashed in half (Smith 1989: 650-651).*

Identification of which climbing guide provided this information or the information's source was unattainable.

Ian McLachlan's book *Eighth Air Force Bomber Stories* (2004) provides an in-depth recitation of the persons and events surrounding the 42-97286 accident. By McLachlan's own admission, most of his information is taken from research conducted by Graham

Herbertson (East Anglian Aviation Research Group) and cannot be confirmed due to the complete absence of source references. However, taken with appropriate caution, McLachlan's book provides additional information on 42-97286 not contained within the MACR or AAR. *Skipper an' the Kids* was perceived to be a 'lucky ship' having survived over 60 missions despite participating in some of the most dangerous sorties of the war (including the June 1944 raid on Poltava, Ukraine and 28 September 1944 raid on the IG Farbenindustrie oil refinery, Merseburg, Germany) (McLachlan 2004: 109, 110). By December 1944, McLachlan states that pilots described 42-97286 as being a "war-weary old clunker" and "a dog" (2004: 111). McLachlan does not name the commenting pilots, specify whether they had flown 42-97286 or indicate whether they were just other pilots in the squadron. Nonetheless, the sentiment that McLachlan portrays is that, having returned safely on so many dangerous missions and having the damage repair patches to show for it, 42-97286 was to fly to Prestwick on a proving flight in preparation for her return to active service. Concurrent with the return to duty test flight, McLachlan indicates that the Knettishall-Prestwick flight was to be used to train a recently arrive 'rookie' crew. Second Lieutenant Jack Merkley's crew had trained on B-24s in the US and, upon arriving in the ETO, were informed they would be transitioning to B-17s. The flight to Prestwick was to be one of many conversion flights they would undertake prior to operational readiness (McLachlan 2004: 111-112).

In addition to the test flight and conversion training, McLachlan states that the flight included the transportation of Master Sergeant Brown (who was headed to Scotland on a five-day pass to see his Scottish girlfriend) and Major Bell (who had five days temporary duty in Prestwick and was utilising 42-97286 instead of Air Transport Command so as to log flying hours) (2004: 111, 114-115). More exciting than a conversion training, personnel transport or test-flight, are persistent rumours which question whether the mission description actually concealed the purchase and transport of Scotch whisky for the Officers Mess Christmas party (McLachlan 1989: 11; 2004: 111). While neither the MACR nor the AAR provide explicit evidence to support this claim, circumstantial evidence allows for its possibility. Navigator Lt August Bolino, also of the 388th Bombardment Group, remembers:

> *One mission turned out to be comical. We were told one day we were going to make a secret mission to Scotland. And we got into our Fortress and started flying towards Prestwick. We were, of course, very fascinated by this. What could be our secret mission? When the Fortress landed, there on the flying field was a supply of Scotch whisky, which we loaded in the waist and brought back to the field. It seems that every few months somebody was assigned to go up to Scotland to get Scotch for the weekend parties (MacLachlan 2004: 111).*

McLachlan's account of the accident provides little additional information to that located in the MACR, AAR and Verner Small's diary entries. The only piece of additional information—a description of a crew member's remains

> *The body he [Small] found was lying face down in full flying kit including a leather helmet. One leg was drawn up and the arms stretched out in front and it looked to Verner as if the poor soul had been alive following the crash and was attempting to crawl away from the wreck (McLachlan 2004: 118)*

—may match the photograph of the suspected airman filed with the AAR. The lack of source attribution makes the account difficult to confirm. Indeed, there is at least one discovery story, found in the Arran Heritage Museum Archives, which has been presented as accurate but which is denied by Small as fiction. The absence of source attribution and the lack of description regarding physical features or deceased's location do not allow the AAR photograph to be definitively linked to the body description.

While McLachlan's post-crash narrative relies heavily on Small's diary, McLachlan does provide some additional information. McLachlan reports that 10 caskets were loaded onto an RAF launch in Brodick because insufficient remains were recovered to fill all eleven. Indeed, local legend says that so little was recovered that rocks were placed in the caskets to make up for their diminutive weight (McLachlan 2004: 119). Additionally, McLachlan reports that the aircraft was broken apart and buried in order to keep the wreck site from being reported again (2004: 120).

Introducing a new appraisal of the accident scenario and cause, McLachlan references his suspected source, Graham Herbertson of the EAARG, in a 10 page quote (2004: 120-129). While much of Herbertson's account focuses on why the aircraft ended up on the Isle of Arran well long and east of its intended destination and, thus, is not relevant to the archaeological survey of 42-97286, Herbertson provides a possible flight vector for 42-97286. Calculating known weather against that given to the crew of 42-97286 prior to departure, Herbertson calculates a heading of 307 degrees from Masham. The Herbertson bearing is approximately 3 degrees east of the planned 310 degree heading (McLachlan 2004: 127-128).

Research into past excavation activity revealed few specifics. Consultation of the MoD JCCC revealed “licences having been issued in the late 80s/early 90s” (Morgan 2012). The earliest record of an organised excavation at the 42-97286 wreck site is the 1986 excavation by the Arran Junior Mountain Rescue Club [AJMRC]. The AJMRC located and recovered a propeller hub and single dog tag at the base of the Beinn Nuis cliff face. The propeller hub retains a single blade and shows partial scrapping damage to one side of the nose cone. The dog tag, identified as belonging to Joseph Payne, was given to the AJMRC by the Office of the Defense Attache, US Embassy. Its current location is unknown. Photographs of the recovery site (Figure 7-52, Figure 7-53 and Figure 7-54), however, allow its original location to be positioned within the site (NR 9566 3982) and correlate to the coordinate data supplied by Small’s diary entries.

The second excavation conducted into B-17G 42-97286 was completed by EAARG on Boxing Day 1988. An account of EAARG’s excavation, with an accompanying photograph showing an apparently uncontrolled excavation in progress, is reported in the June 1989 edition of *FlyPast Magazine* (McLachlan 1989). Much of the *FlyPast* article information is repeated nearly word-for-word in *Eight Air Force Bomber Stories* (McLachlan 2004).

A larger recovery undertaken in 1989-1990 by Peter Stanley uncovered “parachutes, a waist-mounted machine gun, the star and bar insignia from the fuselage and wing,...[and] a fully inflated tail wheel” as well as a propeller hub, two horizontal stabilisers, and “many other artefacts” (McLachlan 2004: 131). The propeller hub and horizontal stabilisers were left on site for recovery at a later time. Unfortunately, much of the material was stolen from the site prior to removal by Stanley. Though a large portion of artefacts dug out in May 1990 were subsequently recovered by the police, Stanley was notified by NTS Head Ranger Derrick Warner that “somebody had been unlawfully digging huge holes and scattering wreckage everywhere” (McLachlan 2004: 131).

Extending his discourse beyond the historiography of the 42-97286 accident, McLachlan in his 2004 account provides detailed information on the 26 December 1988 EAARG and 1989-1990 Peter Stanley excavations.

> *First evidence of the tragedy appeared lower down the mountainside when we found water-tumbled fragments wedged between rocks in numerous rivulets rushing to the brook below. Strangely, parts of the B-17 had merged with pieces of Liberator washed from another nearby wreck....large sections of the lost Boeing became apparent. Chunks of structure, a smashed Cyclone engine and a machine gun still clutched in a rock-face crevice; parts of the ball turret strewn on the grass below – an eerily quiet battlefield shrouded in mist. Digging in one of the trenches, EAARG members were jubilant to discover remains of the tail fin spotted by Verner Small. Numerous flak patches testified to the Skipper's battle days, but the shiny aluminium skin was as bright as the day Alcan made it. The short December day limited time but, by 2 p.m., the group had several trophies light enough to transport and they began their journey to Norfolk being manhandled down the hillside (McLachlan 2004: 130).*

Accompanying McLachlan's chapter on 42-97286 are two photographs of note. The first photograph shows the site as observed on Boxing Day 1989 (2004: 130). The large quantity of aircraft-associated artefacts is evident. The second photograph shows the propeller hub uncovered by Stanley in 1990. Like the *FlyPast Magazine* photograph, the Stanley photograph demonstrates the use of an uncontrolled excavation methodology.

Although he does not provide specific location details or an exact accounting of artefacts removed by the December 1988 EAARG or May 1990 Stanley excavations, McLachlan does confirm the presence of more than one lawful recovery and at least one act of unlawful tampering. In addition, McLachlan references Stanley in stating that subsequent inspection of the site revealed unsettling site conditions:

> *the [propeller] blades had been re-dug out of the hole and were missing. Also missing was the more complete of the two stabilizers. A rusty, vandilized propeller boss was found a little way down the hill, scattered around it were broken hacksaw blade...the propellers had been removed by hacksawing through the prop ring (McLachlan 2004: 131).*

Aircraft History:

Boeing B-17G 42-97286 was accepted by the US Government from the Boeing Aircraft Company factory in Seattle, Washington on 15 February 1944. B-17G 42-97286 subsequently was moved around the United States for post-production modification from 15 February until 4 March 1944. Specific modifications are not recorded. Given that 42-97286 was initially transferred to the Cheyenne Modification Center (15-19 February 1944) (US Army Air Force 1944c), the modifications would most likely have involved the installation of G model components. On 10 March 1944, 42-97286 arrived at Grenier

Army Airfield, New Hampshire for departure on 11 March to the ETO (US Army Air Force 1944c). No further maintenance records were located, though it is reported that 42-97286 completed 60+ missions, incurring damage during its flight service (McLachlan 2004: 109, 111). Indeed, secondary sources state that the doomed NAVEX mission had three reasons for being undertaken, one of which was to certify the aircraft following battle-damage repair (McLachlan 2004: 111).

Crew Personnel Files:

Records relating to 42-97286 air crew remains are contained in the IDPFs. All IDPFs include brief descriptions on the condition of personnel remains as observed during disinterment/reburial. While individual trauma varies between sets of remains, all air crew remains generally display multiple fractures of the entire body with varying degrees of skull fracture. Appendix Table 11-6 records the description of remains for each man as well as the method of identification. Individual identification of Littlejohn's, Merkley's and Rosebasky's comingled remains (X-56ABC) could not be made as the report states "all major bones fractured and/or missing" (US Army Air Force 1944-1949a-c). The IDPF provides a processed weight for each of the sets of segregated remains (X-56A: 60lbs, X-56B: 30lbs, X-56C: 25lbs) which, while taken more than three years after initial burial, exemplifies the low percentage of human remains able to be recovered from the wreck site. Additionally, the X-56ABC records indicate that no teeth were recovered (US Army Air Force 1944-1949a-c).

Accompanying the remains were clothing fragments, insignia and equipment. Included were remnants of officers' rank (one 1/LT bar, one 2/LT bar, and two Captains' bars), three service shoes (one size 9D and two size 9C), the remnants of a parachute harness, and three identification tags. Only the location of discovery for the officers' insignia is recorded. The 1/Lt and Captain's bars were still attached to uniform blouses while the 2/Lt bar was discovered in the debris. The three identification tags similarly were found in the debris (US Army Air Force 1944-1949a-c).

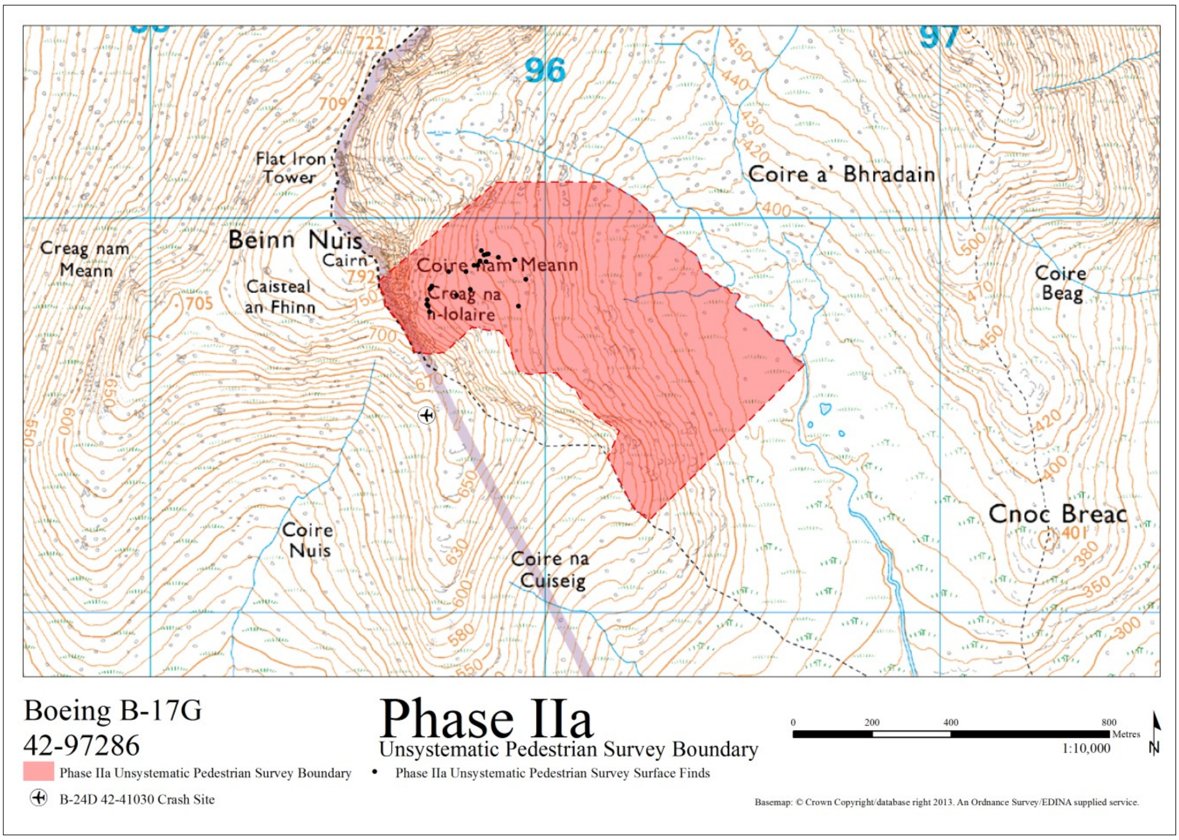
The condition of the crew's remains and the methods of identification make a large scale on-site presence of human remains and personal effects improbable. However, evidence collected during Phase IIa negates any correlative supposition that the length of time since the accident renders the surface scatter sterile of human remains or personal effects. Indeed, both this survey and the AJMRC have discovered personal effects proximal to the point of impact. In 1986, the AJRMC discovered the second of Payne's identification tags (AJMRC n.d.) and this survey located a rubber overshoe in the same general area. The mortuary evidence for numerous skeletal fractures, missing bones and limited recovery of clothing/personal effects associated with the remains makes the possible discovery of human remains and personal effects near the point of impact highly likely. The screening of spoil is essential should invasive work be undertaken in the future.

Field Survey:

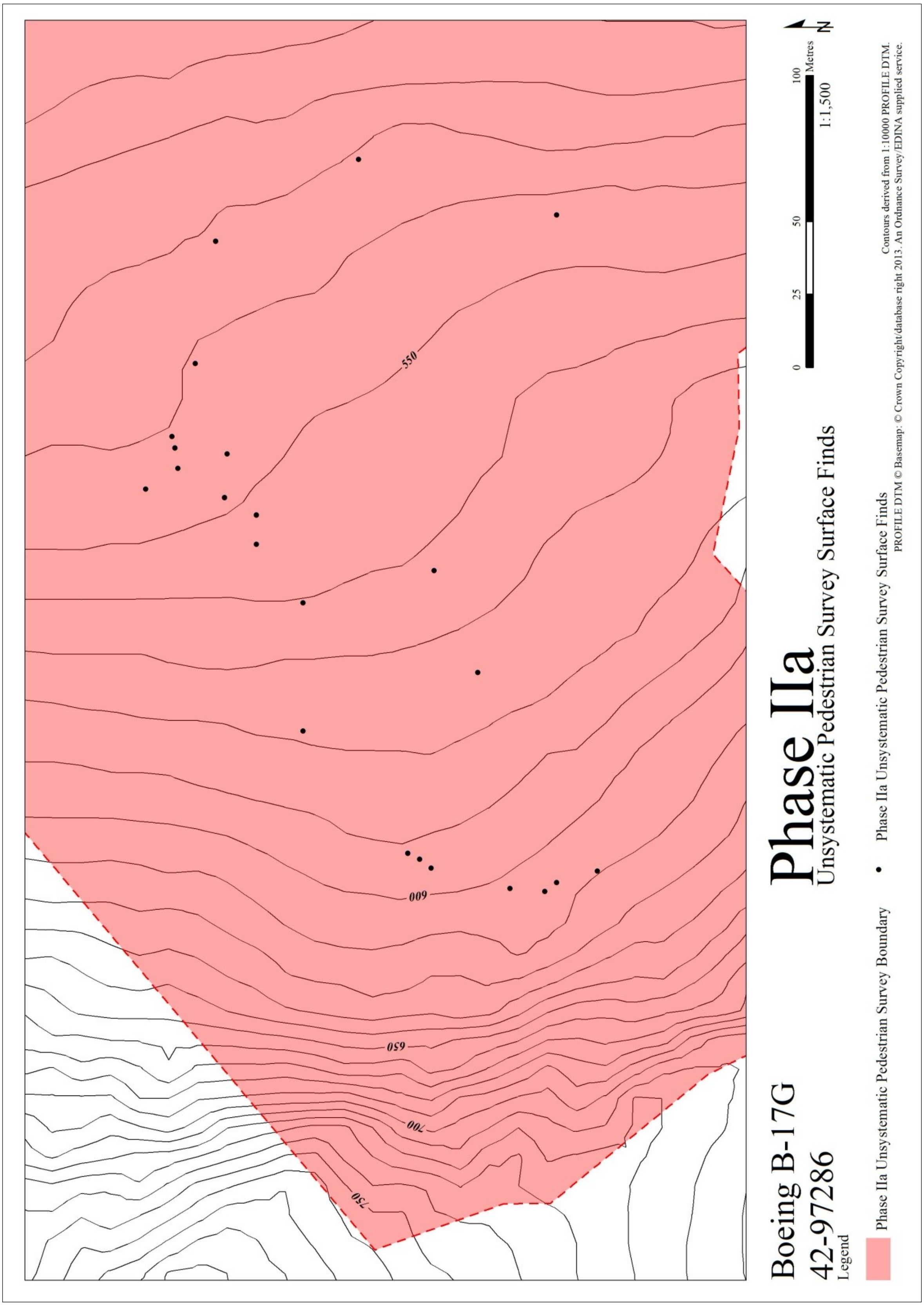
Unsystematic Pedestrian Survey:

The suspected co-mingling of the 42-97286 and 42-41030 wreck sites (Figure 7-55, Map 7-12, Map 7-13 and Map 7-14) required the processing of the two sites in succession. The Phase IIa surveys were undertaken following completion of the 42-41030 Phase IIa surveys (Document 7-5). Transition from 42-41030 was made via FS 060.01-063.01. From FS 064.01, the unsystematic survey continued rapidly along the subsequently defined southwest-northeast axis. Seventy-five individual artefacts/artefact groups were identified during the unsystematic pedestrian survey. Post-survey analysis shows only FS 060.01 to be within the likely area of co-mingling.

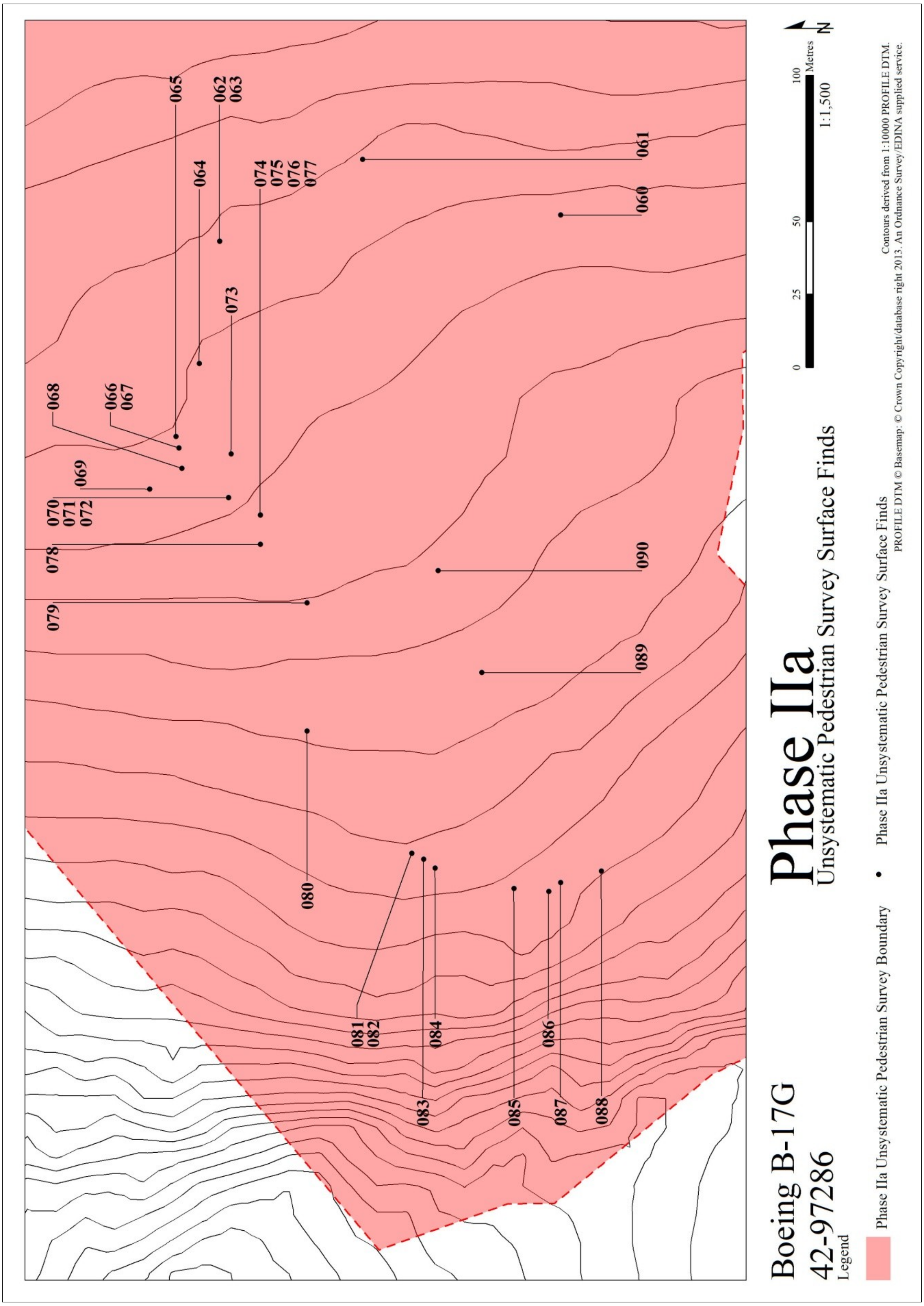
Figure 7-55: The crash sites of B-17G 42-97286 (background) and B-24D 42-41030 (middle ground) facing approximately northwest (Author).
B-17G 42-97286 impacted Beinn Nuis (centre background) from the east.



Map 7-12: 42-97286 Phase IIa survey boundary encompassing Beinn Nuis's east and southeast scree slopes and lower plateaus (Crown Copyright/database right OS 2013b; Author). Phase IIa unsystematic pedestrian survey surface finds are shown in black.



Map 7-13: 42-97286 Phase IIa unsystematic pedestrian survey surface finds (Crown Copyright/database right OS 2013a; Author).
The summit of Beinn Nuis is the high ground to the northwest.



Map 7-14: Annotated distribution of 42-97286 Phase IIa surface finds (Crown Copyright/database right OS 2013a; Author).

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Document 7-5: Phase IIa *PAAR Aircraft Incident Record* form for Boeing B-17G 42-97286 (ICAO 2006; Author).

Unsystematic Metal Detector Survey:

The unsystematic metal detector survey of the 42-97286 crash site was planned but not undertaken due to mechanical instrument failure and unsafe conditions. The wet weather conditions and the extremely steep slopes of the Beinn Nuis approach—the combination of the two required use of both hands to climb—would have made a metal detector survey difficult to accomplish. If future work is undertaken, it is recommended that an unsystematic metal detector survey be located in the vicinity of NR 95625 39805 (FS 082-088 and the unrecorded, cliff-face Perspex fragments) as their location's less extreme topography would mitigate the health and safety risk associated with steeper portions of the site.

It is further recommended that no excavation/artefact removal of the proposed metal detection sites be undertaken in Phase IIb if positive returns are identified as these areas may be considered archaeologically sensitive. Subsequent investigation during Phase IIIa may yield useful information which could be compromised by early recovery of metal detection anomalies. Given the remote nature of the site, the metal detection anomalies should be considered positively-associated aircraft debris within a critical portion of the site and maintained as archaeologically sensitive areas without invasive exploration undertaken.

Artefact Analysis:

Scatter analysis proved useful in providing an archaeological data set independent of the historical sources. Seventy-five surface artefacts were located. The recorded scatter is aligned along a southwest-northeast axis and is 125-250 metres wide. The initial scatter correlates well with the terrain. As such, it is hypothesised that deposition and post-deposition migration occurred along a similar axis and that the scatter represents the vector at which 42-97286 was flying when it impacted the Beinn Nuis range. The scatter terminus, however, appears to turn south and follow the natural contours of the landscape. The location of these artefacts is believed to be resultant from weather and/or human induced post-deposition migration. The recorded diagnostic and critical NF material enables the generation of a final vector hypothesis, maximum and best fit boundaries, and a limited post-crash event sequence.

The diagnostic and critical nondiagnostic(diagnostic) artefacts are geographically segregated into three concentrations: southwest, central and northeast. The northeast concentration, located approximately 250 metres down slope from the identified point of impact, is likely not positioned at the point of initial deposition. Indeed, the nature of the artefacts located within the northeast concentration indicates that their current location resulted from movement via wind and water. The four artefacts which make up the northeast concentration—FS 066.01, 070.01, 074.01, and 074.02—are all main wing associated components. FS 066.01 (Figure 7-56 and Appendix Figure 11-81) and FS 070.01 (Figure 7-57 and Appendix Figure 11-82), two trailing edge ribs (64-1490), constitute only a small portion of the total 10 installed on the left and right wings with flap support tube assemblies (64-1490-411, 64-1490-412, 64-1490-15, 64-1490-16, 64-1490-19, 64-1490-20, 64-1490-21, 64-1490-22, 64-1490-27, 64-1490-28) (US Air Force 1949a: 27-28). FS 074.02 is not a wing component but the fixed cowl installed behind the engines' hinged cowlings (55-7672-400 or 15-7672-5, 55-7672-1 or 15-7672-1) (Figure 7-58) (US Air Force 1949a: 296-297). Geographically associated with FS 074.02, FS 074.01 is a nondiagnostic(diagnostic) NMF which retains a continuous hinge on one edge (Figure 7-58). Curiously, the underside of FS 074.02 retains a webbing strap with snap fastener and a fragment of cotton cord. As the survey did not have a JCCC permit, the artefact was not flipped in order to gain more information on the webbing/snap fastener and cotton cord. However, the presence of organic components on FS 074.02 demonstrates the viability of non-metallic artefact survivability on the lower slopes. Taken together, the relatively small size and estimated weight of FS 066.01, 070.01, 074.01, and 074.02 makes the current location of the northeast concentration artefacts explainable as wind/water runoff, post-depositional transport.

Figure 7-56: FS 066.01, as viewed from the southeast, showing the profile characteristic of the trailing edge ribs (Author).

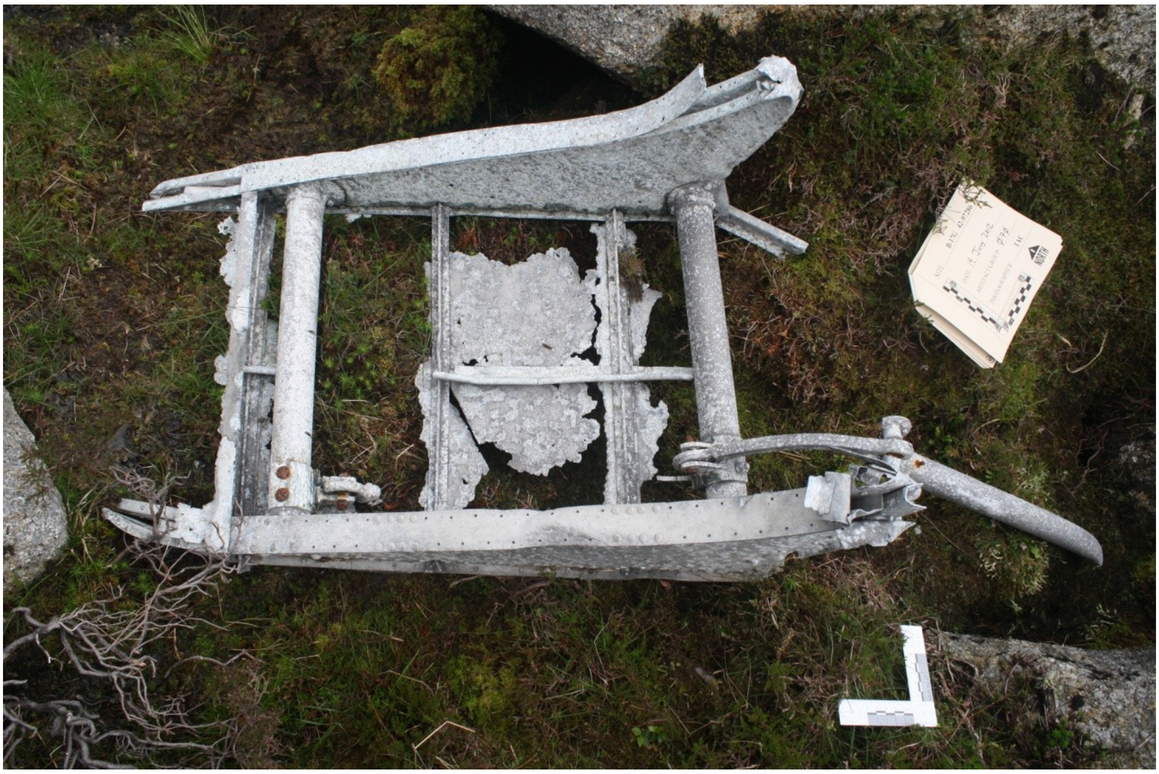

Figure 7-57: FS 070.01, the second of two trailing edge ribs located during Phase IIa (Author).

Figure 7-58: FS 074.02 (bottom) is a section of the fixed cowl installed behind the engines' hinged cowlings (Author).
FS 074.01 (top) is a nondiagnostic(diagnostic) NMF which retains a continuous hinge on one edge.

The central concentration appears to be the result of both natural and human-induced artefact movement. FS 090.01, for example, is the remains of a propeller hub (Figure 7-59) (US Army Air Force 1946: 103-106; US Air Force 1949a: 286-287). Completely stripped of its propeller shafts, a rarity considering most propeller hubs suffering violent impacts will still retain some evidence of the blades, FS 090.01's location and condition match that described by Stanley in 1990: "A rusty, vandilized propeller boss was found a little way down the hill, scattered around it were broken hacksaw blade...the propellers had been removed by hacksawing through the prop ring" (McLachlan 2004: 131). Further evidence of human movement is seemingly manifested by FS 089.20, a section of armour plate from the Sperry (ball) Turret (Figure 7-60 and Appendix Figure 11-83) (US Air Force 1949b: 70). In his description of the EAARG Boxing Day 1988 excavation, McLachlan describes "parts of the ball turret strewn on the grass below [the cliff face]" (McLachlan 2004: 130). It is hard to believe that a single large section of armour plate, which is at least as heavy as the components McLachlan places at the cliff face, was naturally deposited further down slope. Furthermore, the artefacts close to FS 089.20 do not appear to be ball turret components but are rather sections of the engines (Figure 7-61). Based on these observations, it is hypothesised that FS 089.20's current location is the result of individuals attempting to remove the armour plate and either abandoning it due to its size/weight or caching it in a debris field for easy rediscovery and not subsequently removing it.

Figure 7-59: FS 090.01, the remains of a propeller hub completely stripped of its propeller shafts, matches a propeller hub described by Stanley in 1990 (McLachlan 2004: 131; Author).

Figure 7-60: FS 089.20, a section of armour plate from the Sperry (ball) Turret (Author). FS 089.20's position lower down the slope than that described by Stanley in 1990 (McLachlan 2004: 130) demonstrates long term tampering with the crash site.

FS 089.19 and 089.21, and the associated artefact group (Figure 7-61), have more secure contexts. While the suspected tampering of the propeller hub and the addition of the ball turret armour adds suspicion to the whole of the central scatter, FS 089.19 and 089.21 were co-located on the intact aircraft. FS 089.19 is a fragment of an engine (Figure 7-62 and Figure 7-63) (US Army Air Force 1946: 10, 12, 114-115) while FS 089.21 is a ruptured intercooler (Figure 7-64) (1E7654, 1E7654-1, 58-1077 or 58-1077-1 (US Air Force 1949a: 62-67). Both components were originally installed behind and below one of the four engines. While further work—specifically the ability to lift and manipulate the rest of the FS 089 artefact group—would be needed to confirm that the majority of the scatter is associated with the engines, the seemingly consistent artefact installation location points to FS 089 being (1) the location of initial deposition, (2) the result of group migration, or (3) the breaking apart of a larger component during down slope movement.

Figure 7-61: FS 089 scatter facing north (Author).
FS 089.19, a fragment of engine or turbo supercharger, is located just above the photo board. FS 089.21, the ruptured intercooler, is the back most artefact.

Figure 7-62: FS 089.19 retains a supercharger diffuser plate (top) indicative of an engine fragment (Author).

Figure 7-63: The characteristic cylinder head ridges confirm FS 089.19 as an engine fragment (Author).

Figure 7-64: FS 089.21, a ruptured intercooler once part of an engine assembly (Author). Artefact viewed facing north.

The southwest concentration is believed to be more contextually secure than the northeast and central concentrations. Indeed, the varied artefact content and its proximity to the supposed point of impact demonstrate the southwest artefacts/artefact groups to be the location of initial deposition. The southwest concentration is further divided into two discernible artefact groups. The northern group contains FS 082.01, 083.07 and 083.08 while the southern group contains FS 085.01, 086.01, 087.01 and 088.01. FS 082.01 is one of two protective armour plates installed in front of the top turret (Figure 7-65) (US Army Air Force 1944a: 380; US Air Force 1949a: 266-267). No additional components associated with the top turret armour, including the matching piece of identical armour, were observed. Given the weight of FS 082.01 and its current location, it is unlikely that FS 082.01 was transported far from the point of initial deposition. It is hypothesised, therefore, that the associated components are probably buried in the soft ground upon which the southwest concentration rests and could be readily located during a Phase IIb survey. Artefact group FS 083, of which FS 083.07 and 083.08 are a part, is a collection of nondiagnostic, nondiagnostic(diagnostic) and diagnostic artefacts (Figure 7-66). While much of FS 083 cannot be currently examined as this would require the legal permission to lift artefacts, the identifiable artefacts show FS 083 to be associated with one of 42-97286's four engines. Indeed, FS 083.08 is the half-buried crankcase main section and cylinder heads of one such engine (US Army Air Force 1946: 8-9, 114-115; US Air Force

1949a: 286-287). FS 083.07, a currently unidentified motor or generator, was most probably installed on FS 083.08 (US Air Force 1949a: 286-287, 302-303) prior to impact tearing it free.

Figure 7-65: FS 082.01, viewed facing south, is one of two protective armour plates installed in front of the top turret (Author).
No additional components associated with the top turret armour, including the matching piece of identical armour, were observed.

Figure 7-66: FS 083 scatter (Author).
FS 083.07 (right) is a half buried engine main crankcase and cylinder heads. FS 083.08 (centre) is a currently unidentified motor or generator most probably installed on FS 083.08.

In close proximity to artefact group FS 083, FS 084.01 is either a USAAF Type A-6/A-6A Flight Boot or a Glove Brand rubber overshoe (Figure 7-67 and Appendix Figure 11-84). The Type A-6 Flight Boot was used by American forces throughout World War II and the rubber sole tread and toe design are similar to Type A-6 boot designs (Appendix Figure 11-84 and Appendix Figure 11-85). Thus it is plausible that FS 084.01 is a boot's remaining portion, the leather upper having decayed. Equally plausible is that FS 084.01 is a rubber overshoe. The Glove Brand, produced by the Goodyear Corporation, was a popular brand of overshoe from about 1920 to the late 1940s-early 1950s. It is tempting to assign an overshoe popular with the US civilian market to either Major Bell or M/Sgt Brown, as they both would be staying in Scotland for five days and may have packed for wet weather. However, the lack of available specific information on Glove Brand overshoes, the similarity of FS 084.01 to Type A-6 Flight Boots and the known shoe sizes of only three of the crew (Littlejohn, Merkely and Rosebasky) currently makes definitive classification and/or ownership purely conjecture.

Figure 7-67: FS 084.01, a Glove Brand rubber overshoe (galosh) in size 8.5 (Author). The owner of FS 084.01 cannot be determined with certainty due to incomplete crew shoe size records.

The southern grouping of the southwest concentration, FS 085.01, 086.01, 087.01 and 088.01, is made up almost exclusively of wing trusses and bulkhead carry-through members. Wing trusses FS 086.01 (Figure 7-68) and 087.01 (Figure 7-69) are half-buried; specification on their installation location and completeness, as such, is not possible. FS 088.01, however, is known to be the main wing truss as it is observed to still be connected to bulkhead 4 or 5 carry-through members (Figure 7-70). The carry-through members extend below the ground surface and, as such, it cannot currently be said whether the adjoining main wing truss is attached (Beall 1945: 125, 133, 137; US Air Force 1949a: 20-23). Further reinforcing the southwest grouping as an area of initial deposition is FS 088.02, a wing skin fragment (Figure 7-70). FS 088.02's position underneath FS 088.01, but not attached to it, associates an otherwise nondiagnostic(diagnostic) artefact with the main wing truss connection and provides tantalising evidence that more of the wing structure may be buried nearby. Straight cuts were noted at all three wing truss locations. For example, a rectangular trench approximately 2 metres by 20 metres was observed around FS 088. Additionally, the grade of the terrain and the artefacts exposed show a similarity to one of the photographs accompanying the June 1988 *Flypast* article. It is, therefore, believed that the exposed components and cuts observed at FS 086.01, 087.01 and 088 were initially the result of the EAARG excavation. It is not currently possible to determine if the suspected EAARG trenches have been re-dug.

Figure 7-68: FS 086.01 (left) is a section of wing truss (Author).

Figure 7-69: FS 087.01, a section of wing truss viewed facing northeast (Author).

Figure 7-70: FS 088.01 as viewed facing east. FS 088.01, still connected to bulkhead 4 or 5 carry-through members, is confirmed to be a main wing truss (Author).
It cannot currently be said whether the adjoining main wing truss is also attached as the carry-through members extend below the ground surface. FS 088.02 (back right) is a wing skin fragment.

Perhaps as important as the main truss and carry-through members to establishing the southwest concentration as the point of initial impact is FS 085.01. One of the two main landing gear (15-10414-27 or 15-10414-28) (US Air Force 1949a: 270-273), FS 085.01 not only retains an intact main strut but also the wheel rim (Figure 7-71). Its position near the wing trusses and carry-through members correlates well with its installed location behind engines two and three.

Figure 7-71: FS 085.01, one of the two main landing gear (Author).

Additional fragmentary evidence, mostly NGF Perspex fragments, was located along the cliff face in the area shown in the AAR and AJMRC photographs. The evidence was dismissed by the beater with its existence only reported following the completion of the survey. While the evidence came from a known location, and as such did not skew the larger scatter distribution patterning, future work on the 42-97286 wreck site should understand this evidence to exist and make its recording a priority. If continued work is undertaken, it is recommended that the unrecorded cliff face artefacts are recorded during subsequent Phase IIa/b work while unrecorded NF artefacts are recorded during Phase IIb as normal procedure dictates.

7.3.4 Comprehensive Site Analysis

Analysis of the historical and artefactual data from Phase IIa provides an understanding of the crash dynamics, artefactually sensitive areas and post-deposition site alteration. The crash dynamics of 42-97286 are born out through combined analysis of historical and artefactal evidence. Herbertson's calculations regarding 42-97286's course drift, when extended to the aircraft's final moments, give insight into the aircrafts attitude at impact. Flying with a ground speed of 221mph, the B-17 could cover one mile in approximately 16 seconds. This means that 42-97286 could cover 4 miles in approximately 65 seconds and 6 miles in approximately 98 seconds. Using the B-17s maximum rate of climb (900 ft/m), the estimated cloud cover over RAF Prestwick (9/10 at 2,000ft asl), the known visibility (4-6 miles), the known impact altitude (approximately 2,150ft asl), and assuming the crew attempted to climb over Beinn Nuis as soon as it became visible, it can be estimated that 42-97286 had a flying altitude of between 975ft asl and 1,466ft asl prior to initiating an emergency climb. The known maximum summit height around the Glenn Rosa (excluding the Beinn Nuis range) is 1,315-1,325ft asl. The drastic increase in altitude (the emergency climb) correlates with both historical and archaeological evidence.

While Herbertson argues that the comingled remains of Littlejohn, Merkely and Rosebasky are the result of Littlejohn and Rosebasky attempting to ascertain their current location (Littlejohn assuming command and Rosebasky attempting to make use of the maps stored in the cockpit) before impacting Beinn Nuis in cloud (McLachlan 2004: 115-116), this thesis maintains that the archaeological evidence points to a more harrowing reason for the trauma observed in the crew's remains. Indeed, the comingled remains of Littlejohn (Pilot-Instructor), Merkely (Pilot undertaking conversion training) and Rosbasky (Navigator-Instructor) are explained by the dynamics of a non-fly-by-wire emergency climb. It is hypothesised that, upon seeing the cliff-face, Rosbasky either joined or was called to join his crew's captain (Littlejohn) in the cockpit in order to assist Merkely and Littlejohn in the climb. Three people were in the cockpit at impact as the three men were desperately trying to fight increased wind resistance while moving/holding the hydraulic flight controls at an extreme angle. Additional evidence for a climb-induced, angled impact is recorded within Rosbasky's IDPF. The comingling of remains necessitated the group burial of Littlejohn, Merkley and Rosbasky. The successful identification of the remainder of the crew lends weight to the hypothesis of an emergency climb. Having observed the quickly closing high ground, Littlejohn would have most likely ordered the crew to evacuate the nose of the aircraft. The areas of initial impact, unlike the cockpit, are without the comingled remains expected from having two student navigators and one bombardier (serving as a radio operator) on board. Moreover, the scraping evidence observed on the propeller boss uncovered in 1988 by the AJMRC correlates with the hypothesised scenario. As discussed in Section 0, the propeller boss was found near Payne's identification tag and in the area which Verner Small identified as the primary point of impact. This area is known as The Chimney. The propeller boss lacks head-on deformation typically expected from a horizontal (high-angle) impact. Instead, scraping is only located on one-half of the propeller boss while the whole of the boss is deformed in one direction. It is hypothesised that the propeller boss deformation, mounted in its current orientation not as representative of its original installation but in order to have the remaining propeller upright, demonstrates an upward angle of flight at the time of impact; the underside of the propeller boss thus impacting the cliff face prior to the remainder of the engine nacelle.

The upward angle of climb would generate a rather compact wreck site such as that observed in the contemporary photograph and the Phase IIa survey distribution plot (Map 7-3 and Map 7-4). The discovery of the numerous and varied diagnostic artefacts—including three propeller hubs, vertical stabilisers, a waist machine gun, ball turret fragments, tail wheel, an engine, an identification tag, and a rubber overshoe—in the vicinity of The Chimney shows the area to be the point of initial impact, as referred to by Small, and the current resting place of a portion of the aircraft. It is believed, based upon the distribution of the southwest concentration (FS 082-088), that the primary point of impact is located at NR 95625 39805 with a possible 25 metre margin of error to the NW, W and SW. Locating the point of initial impact at NR 95625 39805 conforms to historical photographs and documentation as well as explaining the splitting of the southwest concentration into two groups; the presence of a slightly higher ground would naturally divide cascading debris to the north and south.

The site has not escaped alteration. Weather has caused artefacts to wash down slope, at least two licensed excavations have legally removed artefacts, and one illegal excavation is known to have redistributed buried material across the site. The suspected contents and alteration of the site, especially the archaeologically sensitive area around The Chimney, limits the area of interest for further research to targeted areas. The half-buried nature of 42-97286 associated artefacts makes both the identification and the detailed field analysis of artefacts difficult without the use of invasive methods. It is thus recommended that the archaeologically sensitive area near The Chimney be the focus of NTS site preservation management. Reflecting the likely presence of human remains on site, it is further recommended that additional research should only progress into Phase IIb if an excavation license is obtained. Any soil excavated from MD anomalies or STPs should be screened in order to collect any previously unrecovered human remains.

7.4 Consolidated B-24D 42-41030 (Beinn Nuis, Isle of Arran)

7.4.1 Overview

7.4.1.1 Site Background

Consolidated B-24D 42-41030 (Figure 7-72) crashed 20 August 1943 on the west slope of Beinn Nuis (Isle of Arran) near the end of a Gander-Prestwick trans-Atlantic transfer flight. All 10 crew on board 42-41030 perished in the crash. Following the crash, the aircraft was cut into smaller pieces by No. 63 Maintenance Unit and parts reburied either within the impact scar or close nearby. It appears the No. 63 MU burials remain archaeologically undisturbed. A partial Phase IIa survey, focused on the eastern slope of Beinn Nuis, was undertaken on 17 July 2012. The purpose of the Phase IIa unsystematic survey of 42-41030 was to support the 42-97286 surveys and to analyse the level of artefact comingling between 42-41030 and 42-97286. The impact point, at NR 957 395 (640m asl on the western slope of Beinn Nuis) (Map 7-15), is far from the scatter investigated during the current partial Phase IIa survey. The presence of a large artefact scatter on the eastern slope of Beinn Nuis correlates well with photographs showing the terrain at the point of impact and the apparent rising ground near the ridge line. The combination of the location of impact, the terrain at the point of impact, and the scatter recorded on the eastern slope of Beinn Nuis is consistent with a full and level flight ground impact which hurled debris forward, over the ridge line and onto the opposite slopes. Confirmation of this deduction would necessitate completion of a Phase IIa survey with a specific focus on the upper ridge line and western slope of Beinn Nuis (the supposed point of impact). Initial results indicate that the continuation of study into, and completion of, a Phase IIa study may show the comingling of debris to be less extensive than previously suspected.

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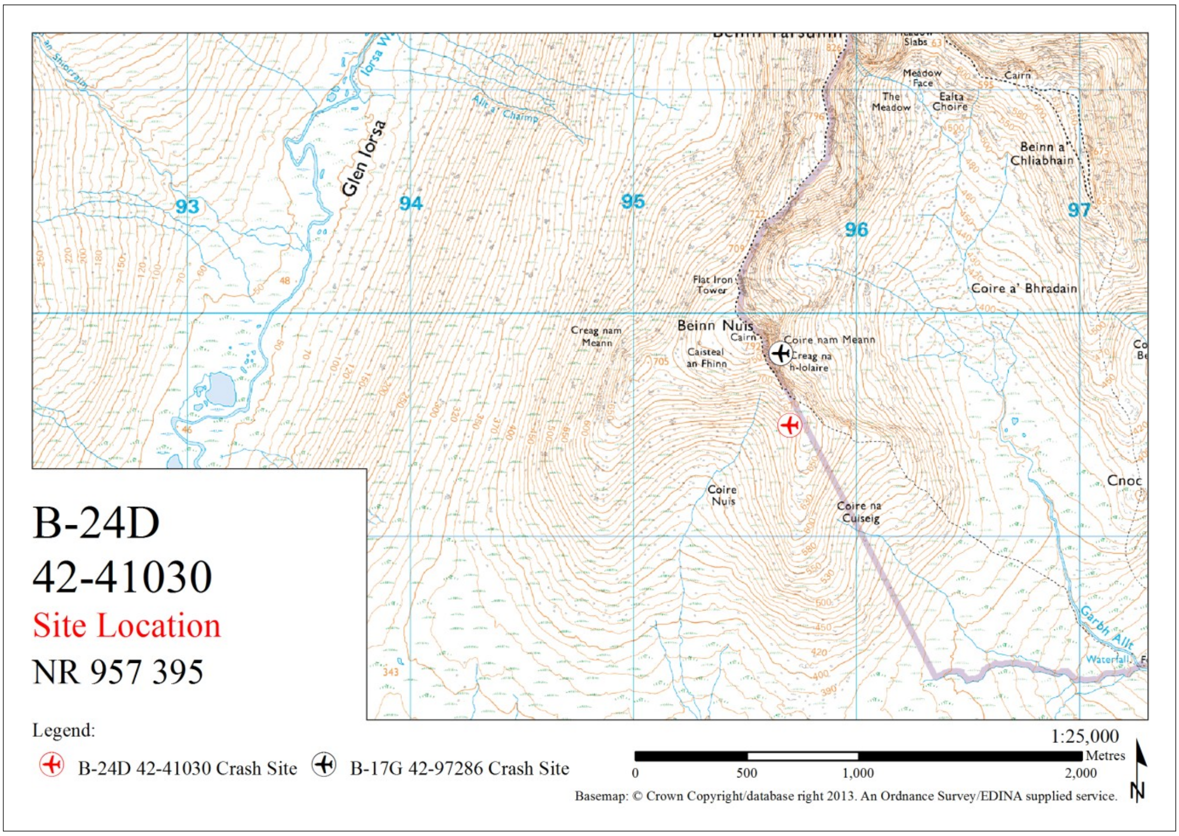
Figure 7-72: A formation flight of B-24Ds, similar to 42-41030, from the 93rd Bomb Group (US Air Force c1943).



Map 7-15: Location of the Consolidated B-24D 42-41030 crash site (Crown Copyright/database right OS 2013b; Author).
B-24D 42-41030 impacted the west slope of the Beinn Nuis range (640m asl) with debris cascading onto the east slope.

7.4.1.2 Investigation Summary

The wreck of B-24D 42-41030 lies across a large area within the Arran Northern Mountains SSSI and the North Arran NSA areas (SNH 2012). The partial Phase IIa unsystematic pedestrian survey focused on establishing the level of 42-41030 and 42-97286 scatter comingling. As with the Phase IIa survey of B-17G 42-97286, no unsystematic metal detector survey was undertaken due to health and safety concerns; the saturated conditions and steep terrain required both hands to be freely available at all times. The proposed research aims were threefold:

1. Estimate the amount of material associated with 42-41030 located on the eastern slope of Beinn Nuis.

2. Establish a debris corridor so as to determine an approximate angle of impact. This debris corridor can be used to establish a comprehensive site boundary during future work targeting the western slope of Beinn Nuis.

3. Investigate the level of artefact comingling between the B-17G 42-97286 and the B-24D 42-41030 scatters.

Phase I background research was completed in January 2010 at the same time as the Phase I background research for B-17G 42-97286. No site visit was conducted as B-24D 42-41030 (1) was not a primary research target and (2) recent accounts by enthusiasts and hill walkers indicate that the wreck site contains explicatory scatter. Based upon Phase I data and objectives, continuation to a partial Phase IIa—in support of B-17G 42-97286 research—was undertaken.

As the focus of the B-24D 42-41030 research was to analyse site overlap, no expanded data trawl was undertaken. Should research on this site progress in the future, an expanded Phase IIa data trawl would be a priority. The Phase IIa unsystematic pedestrian survey undertaken in support of B-17G 42-97286 on 17 July 2012 provided excellent data. Recorded artefacts allowed for the establishment of a debris corridor as well as the quantification of site overlap. Contrary to expectations of artefact site overlap, only one recorded artefact (FS 060.01) was shown to be within the intersection of the 42-41030 and 42-97286 debris corridors.

It appears that, although visited by hill walkers/enthusiasts over the years, 42-41030's point of impact and the eastern slope remain archaeologically secure. Indeed, secondary sources judge the main aircraft burial pit, on the western slope of Beinn Nuis, to be undisturbed. As such, a future Phase IIb study seems indicated. However, the progression to Phase IIIa may prove difficult to accomplish given the uncertain burial location of three deceased crewmen.

7.4.2 Airframe Construction

The assemblies and components characteristic of the Consolidated B-24 aircraft are discussed in detail in Chapter 9 Section 9.2.

7.4.3 Archaeological Investigation

7.4.3.1 Phase I Historical Survey

The Phase I historical survey, completed in January 2010 in tandem with B-17G 42-97286, established B-24D 42-41030's 20 August 1943 flight profile as a Gander-Prestwick trans-Atlantic transfer flight which ended with ground collision on the west slope of Beinn Nuis (Isle of Arran). In total, 10 deceased crew members were identified (Appendix Table 11-7).

Though no MACR was created at the time for B-24D 42-41030, the Phase I historical survey returned other information allowing completion of a *PAAR Aircraft Incident Record* form (Document 7-6). Recommendation was made to continue field work into Phase IIa in support of work on B-17G 42-97286. As B-24D 42-41030 was not deemed a primary research site, a Phase IIa full data trawl and western slope survey was rejected in favour of combining the analysis of the AAR, the eastern slope scatter, and the relationship of the eastern slope scatter with that of the B-17G 42-97286 wreck site nearby.

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Document 7-6: Phase I *PAAR Aircraft Incident Record* form for Consolidated B-24D 42-41030 (ICAO 2006; Author).

7.4.3.2 Phase IIa General Data Survey

Background Research:

Primary Source Accounts:

Two primary source crash narratives, one brief and one extended, were located. Filed within the AAR, both narratives provide the same basic information. The short narrative provided by AP12225 Gander, Newfoundland recounts:

> *B-24D, No. 42-41030, departed this station [AP12225 Gander, Newfoundland] at 1946 GMT, August 19, 1943 with twenty-three other aircraft. Prestwick Control had last radio contact with this plane at 0718 GMT, August 20, 1943. No further contacts were had with this plane. Air/Sea search was conducted by Prestwick with the finding of aircraft on ARRAN. The position was 5536"N, 0515"W five miles NW of BRODICK. The crew was killed...The weather was good, and all conditions for safe flight were above average. It would seem that the pilot of this aircraft was making a letdown when not on a leg of the Prestwick radio range (US Army Air Force 1943b).*

The *AAF Form 14* filed by AP12225 Gander, Newfoundland further specifies the local Prestwick weather as "high overcast lower broken [cloud] at 3000' visibility 12 [miles] with light rain...Wind from SE-18 [knots]" (US Army Air Force 1943b).

The extended narrative provides additional information on the sequence and location of the crash. Indeed, the extended narrative states that:

> *At 0634Z the aircraft operating on a callsign of Foolish V contacted Dogwatch [Prestwick tower] giving a position of 10 miles N at 4500 ft....At 0640Z Dogwatch advised Foolish V to hold altitude until advised. No further contacts were established with this aircraft. The weather at 0800Z at Preswick was ceiling 3000 ft., moderate rain, visibility 12 miles. It was established through contact with various people on the Isle of Arran that Beinn Nuis mountain was in cloud coverage during the morning of 20th August, 1943. On the afternoon of 23rd August, this aircraft was located by a shepherd on Beinn Nuis mountain, Isle of Arran, 100 ft. from the top....The aircraft collided with the side of the mountain in normal flight and apparently at normal cruising speed. All four engines were apparently functioning normally. The accident occurred at 0810Z GMT, this time being established by clock recovered from wreckage [sic]. Altimeter indicated 2520 ft...*
>
> *Results – complete destruction of aircraft; fatalities, entire crew; some salvage of parts and equipment (US Army Air Force 1943b).*

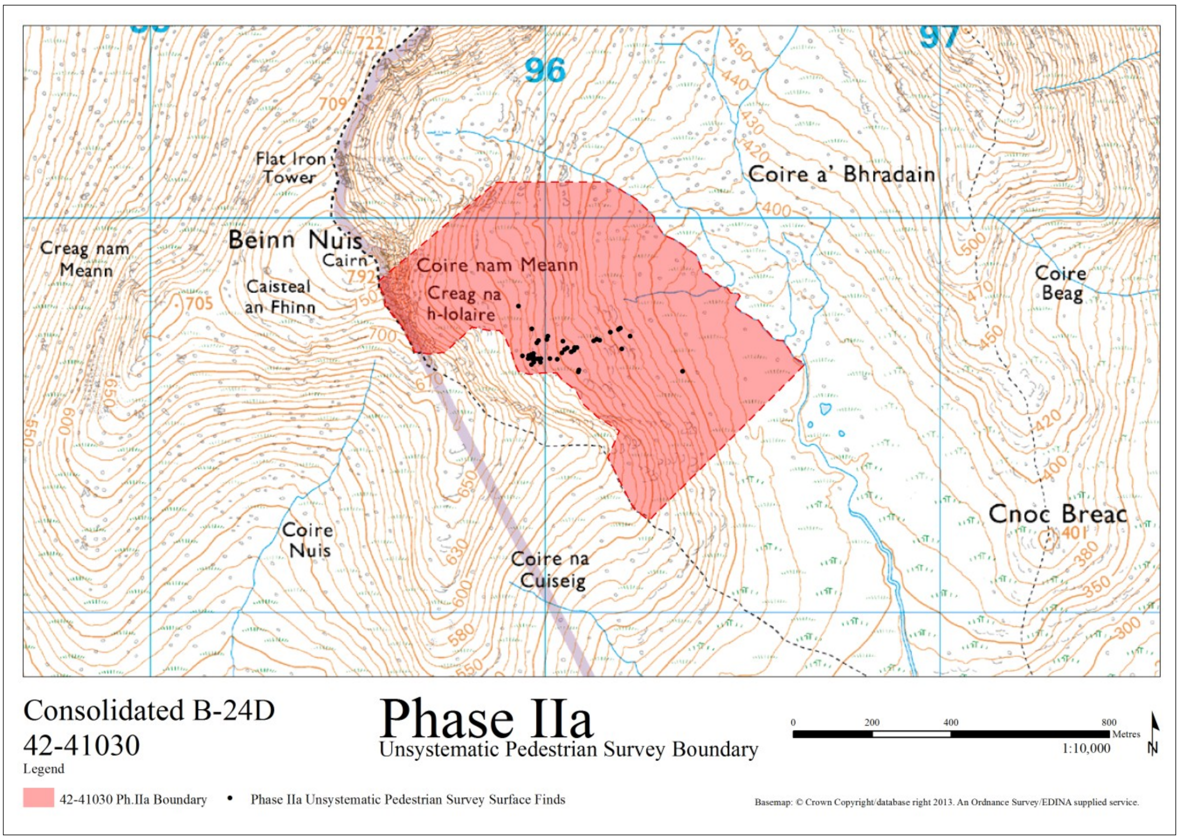
In addition to the Gander and Prestwick *AAF Form 14*s, 18 photographs taken by the response and salvage team are present within the AAR. The photographs confirm 42-41030's position near the western ridge of Beinn Nuis as well as the aircraft's destruction. No photographs show activity on the eastern slope of Beinn Nuis (US Army Air Force 1943b). The positioning of the aircraft on the western slope, its apparent impact in full flight at a shallow angle and the breakup attested to by the Prestwick *AAF Form 14* and accompanying photographs provide excellent documentary evidence for the probable deposition of debris on the eastern slope of Beinn Nuis.

Field Survey:

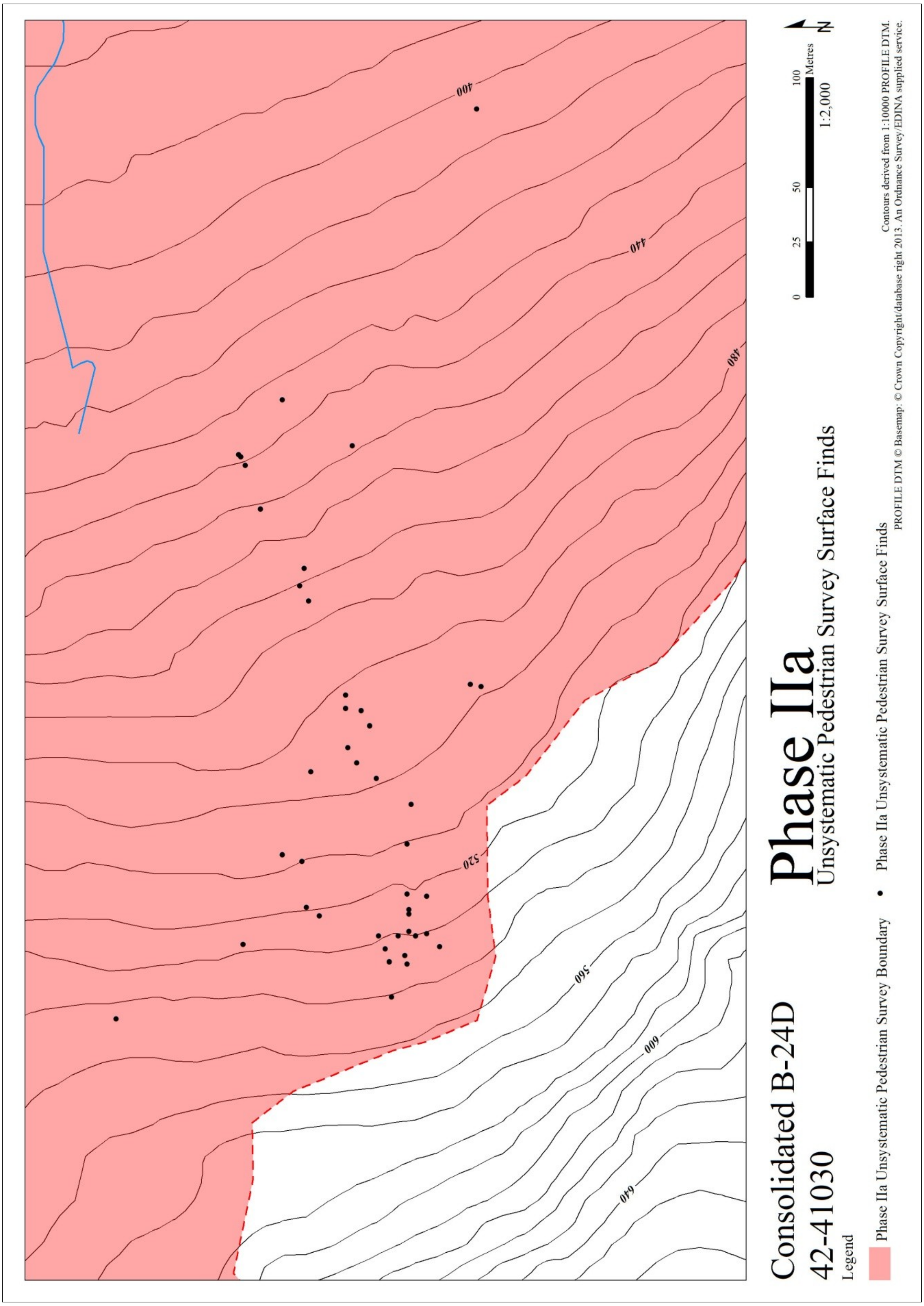
Unsystematic Pedestrian Survey:

As the 42-41030 Phase IIa survey was carried out in support of the 42-97286 Phase IIa research, only the east slope of Beinn Nuis was surveyed. The suspected comingling of B-24D 42-41030 and B-17G 42-97286, as reported in secondary source material, necessitated the undertaking of a limited Phase IIa survey of 42-41030. The limited, east slope unsystematic pedestrian survey recorded 90 artefacts/artefact groups. An approximately linear distribution, along a 72 degree bearing, was noted. Little evidence for the comingling of the 42-41030 and 42-97286 sites was observed with only FS 060.01 recorded within the debris corridors' intersection.

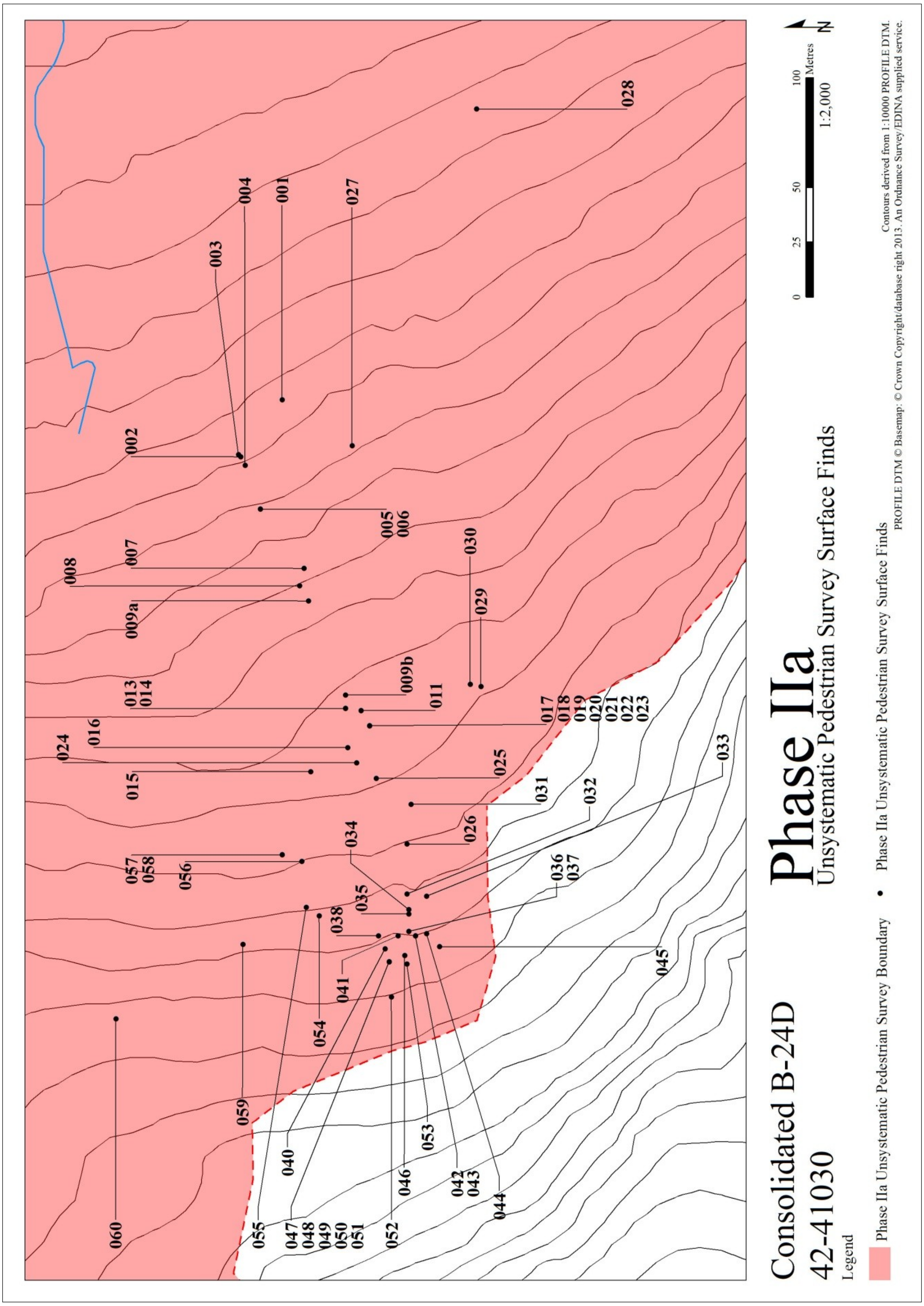
Figure 7-73: The crash sites of B-17G 42-97286 (background) and B-24D 42-41030 (middle ground) facing approximately northwest (Author).
B-17G 42-97286 impacted Beinn Nuis (centre background) from the east.



Map 7-16: 42-41030 Phase IIa survey boundary encompassing Beinn Nuis's east and southeast scree slopes and lower plateaus (Crown Copyright/database right OS 2013b; Author). Phase IIa unsystematic pedestrian survey surface finds are shown in black.



Map 7-17: 42-41030 Phase IIa unsystematic pedestrian survey surface finds (Crown Copyright/database right OS 2013a; Author).
The Beinn Nuis ridgeline is the rising ground to the west and southwest.



Map 7-18: Annotated distribution of 42-41030 Phase IIa surface finds (Crown Copyright/database right OS 2013a; Author).

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Document 7-7: Phase IIa *PAAR Aircraft Incident Record* form for Consolidated B-24D 42-41030 (ICAO 2006; Author).

Unsystematic Metal Detector Survey:

No unsystematic metal detector survey was undertaken due to the health and safety factors which influenced the same decision for B-17G 42-97286. If a fuller Phase IIa and/or Phase IIb survey is undertaken in the future, initial focus should be given to plateaus 1 and 2. The concentration of diagnostic artefacts around plateaus 1 and 2, as well as the plateaus' flat terrains, may provide valuable quantification and distribution data without compromising health and safety.

Artefact Analysis:

In line with expected crash dynamics, no artefacts were observed near the ridgeline (approximately 550-650 metres asl). The artefacts observed on the eastern slope of Beinn Nuis cluster around 530 metres asl with further distribution up slope to 540 metres asl and down slope to between 400 and 430 metres asl. In total, 89 artefacts/artefact groups were recorded; only eight artefacts, however, could be positively identified. An additional 25 artefacts/artefact groups were classified as nondiagnostic(diagnostic) as they retain a part number and/or unique characteristics which may yield identification in the future but their identities could not be confirmed at present. The remaining 56 artefacts/artefact groups could not be identified as they had no unique characteristics or were partially buried. The total artefact distribution provides sufficient data to establish a debris corridor, while the eight confirmed artefacts enable the development of a more refined crash narrative than that posited by secondary sources. The eight confirmed artefacts are divided into two clusters and a single artefact.

The primary cluster of artefacts, located 520-540 metres asl, provides support for the deposition and rupture of an engine at approximately 195968E/639645N. FS 039.01 is a flexible cowl flap panel assembly (32P1003-3) (Figure 7-74 and Appendix Figure 11-86) while FS 043.01 is an upper fixed cowl flap panel assembly (32D1046-7R) (Figure 7-75 and Appendix Figure 11-87) (US Army Air Force 1944d: 78-81; 1944e: 17). Both FS 039.01 and 043.01 are installed around the engine nacelle. FS 053.01, a propeller feather pump (EA75226) formerly installed between each engine and each engine oil tank (Figure 7-76, Appendix Figure 11-88 and Appendix Figure 11-89) (US Army Air Force 1944d: 102-104; 1944e: 89), is located less than 15 metres west northwest of FS 039.01 and 043.01.

Figure 7-74: FS 039.01, a flexible cowl flap panel assembly installed around the engine nacelle (Author).

Figure 7-75: FS 043.01, an upper fixed cowl flap panel assembly (Author). Like FS 039.01, FS 043.01 was installed around the engine nacelle.

Figure 7-76: FS 053.01, a propeller feather pump formerly installed between each engine and each engine oil tank, now resides between two boulders (viewed facing west) (Author).

The secondary cluster (FS 011.01, 019.01, 022.01 and 024.01) is located in the centre of the linear scatter between 490-500 metres asl. This cluster consists primarily of engine nacelle components. FS 024.01 is the door and duct assembly for the main air duct shutoff (32P1453-3 or 32P1543-4) (Figure 7-77 and Appendix Figure 11-90). The air intake assembly, of which FS 024.01 forms a part, is positioned to one side of the engine and feeds air into the turbo supercharger (US Army Air Force 1944d: 83-85; 1944e: 93). It is not possible to identify from which engine FS 024.01 originated as all four engines contain identical ducting. FS 022.01 may relate to FS 024.01 though identification is uncertain. FS 022.01 is currently identified as the front exhaust shroud assembly (32P1070-6 or 32P1070-25) (Figure 7-78) (US Army Air Force 1944d: 83-85; 1944e: 93). Due to its crushed condition, however, this qualified identification can only be confirmed by lifting/handling the artefact. FS 019.01 is one of four exhaust shroud and exhaust collector pipe assemblies (32P1070 and 32P1009-5) installed on B-24D Liberators (Figure 7-79) (US Army Air Force 1944d: 81-83; 1944e: 17, 19). FS 011.01 is not an engine nacelle component. Identified via part stamp and design features, FS 011.01 is an aileron gear unit assembly (32C1505) (Figure 7-80 and Appendix Figure 11-91) (US Army Air Force 1944d: 136-139). Installed in the wings, FS 011.01 is the furthest aft artefact positively identified. The fact that no components from the wing section to the tail were identified on the eastern slope suggests that the eastern slope debris is only from the front half of 42-

41030. Moreover, the close proximity of all four components (FS 011.01, 019.01, 022.01 and 024.01) indicates that an engine nacelle was either deposited at NR 96062 39666 following impact or that the NR 96062 39666 cluster represents down slope artefact migration from an initial, higher point of deposition. Due to the artefacts' position on a small plateau, it is difficult to determine which scenario is more accurate. The clustering of artefacts at NR 95968 39645 provides support for the initial scenario (deposition of an engine at NR 95968 39645 with subsequent artefact wash to the NR 96062 39666 cluster) however further investigation into the NR 96062 39666 artefact cluster would be necessary in order to clarify the circumstances responsible for the locations of FS 011.01, 019.01, 022.01, 024.01 and 039.01.

Figure 7-77: FS 024.01, the door and duct assembly for the main air duct shutoff (Author). The air intake assembly, of which FS 024.01 forms a part, is positioned to one side of the engine and feeds air into the turbo supercharger.

Figure 7-78: FS 022.01, currently identified as the front exhaust shroud assembly (Author). FS 022.01 would have been installed directly below FS 024.01.

Figure 7-79: One of four exhaust shroud and exhaust collector pipe assemblies installed on B-24D Liberators, FS 019.01 would have been fitted in the bottom of the engine nacelle aft of FS 022.01 and 024.01 (Author).

Figure 7-80: FS 011.01 is an aileron gear unit assembly and the furthest aft artefact positively identified (Author).

The isolate, FS 059.01, is an exhaust collector or turbo supercharger pipe (32P1009, 32P1441, or 32P1442) (Figure 7-81) (US Army Air Force 1944d: 80-83, 88-89; 1944e: 19, 93). While an outlier from the rest of the distribution, FS 059.01's installation location directly behind or below the engine corroborates the east slope engine deposition hypothesis previously posited. Moreover, the location of FS 059.01 further suggests the continued widening of the debris field via natural or human artefact movement and/or the presence of additional, buried artefacts north of the observed debris field. Additional work is needed in order to understand whether FS 059.01 is truly an isolate or whether its location is indicative of a wider, buried debris corridor.

Figure 7-81: FS 059.01, the 42-41030 scatter isolate, is an exhaust collector or turbo supercharger pipe (Author).
The location of FS 059.01 corroborates the hypothesis that an engine was jettisoned over the ridge line. Moreover, the isolation of FS 059.01 suggests the continued widening of the debris field via natural or human artefact movement and/or the presence of additional, buried artefacts north of the observed debris field.

7.4.4 Comprehensive Site Analysis

The limited Phase IIa survey returned data suggesting that B-24D 42-41030 may be one of the more archaeologically intact aircraft wreck sites in Scotland. This archaeological stability conceivably is due to the proximity and publicity of B-17G 42-97286 as well as a misinterpretation of the crash site by secondary sources. The known crash location and flight plan intersect with expected crash dynamics to produce an expected debris scatter extremely similar to the observed artefact scatter. For example, the lack of debris recorded near the ridgeline may be due to the purposeful or natural post-impact burial of debris. However, crash factors may provide an even more plausible explanation for the lack of debris nearer the ridgeline. Given the high speed, low angle ridgeline impact, the absence of debris is not unexpected. In a high speed, low angle ridgeline impact, debris deposition is anticipated at the point of impact with additional debris thrown over the ridgeline onto the opposing slope. The natural defilade created by the ridgeline generates a debris-sterile area. The linear distribution of observed debris, aligned along the same bearing as the proposed point of impact, further substantiates the over-ridgeline debris hypothesis.

The quantity of debris observed on the east slope may only be a fraction of extant artefacts. The wet soil of the eastern slope may have buried many of the heavier artefacts. At least one engine, as suggested by seven (of eight) confirmed diagnostic artefacts, is believed to have been thrown over the ridgeline and deposited on the eastern slope. It is hypothesised that the engine, which was not located during the Phase IIa survey, has sunk into the soft soil. The single recorded engine from B-17G 42-97286, located approximately 300 metres northwest and half-buried in more solid soil, demonstrates the possibility of total engine burial given soft soil conditions. Though unlikely given the outwardly intact, west slope impact site, the limited diagnostic debris on the eastern slope may indicate post-depositional removal. The most unexpected aspect of the limited Phase IIa survey is the absence of substantial artefact comingling between 42-41030 and 42-97286. Despite secondary source claims of comingled debris, current examination shows the sites to be largely separate.

While the Phase IIa survey of 42-41030's eastern scatter was only meant to establish the level of comingling with 42-97286, the results of the targeted survey show the 42-41030 wreck site to be worthy of future study. Unlike 42-97286, it appears that 42-41030 has not experienced past excavations and remains largely intact. Future completion of the Phase IIa survey and possible continuation to Phase IIb could (1) provide the additional data required to refine the site boundary, (2) characterise the extent of post-depositional artefact migration, (3) quantify the amount of buried material in proximity of diagnostic and artefact groups, and (4) establish the archaeological integrity of the western slope impact. As part of this further research, a limited metal detector survey of plateaus 1 and 2 would provide useful data potentially corroborating the presence of an east slope engine as well as detailing the quantity of sub-surface artefacts on the east slope.

7.5 Boeing B-17E FL455 Z9-A (Forsinard Flows, Caithness)

7.5.1 Overview

7.5.1.1 Site Background

Based out of RAF Wick, Caithness and tasked with conducting weather reconnaissance flights, B-17E FL455 Z9-A was assigned to RAF No. 519 Squadron. Very little information regarding FL455 Z9-A is available from usual sources. This lack of available information and the crash site's remote location likely are the primary reasons for the amount of material still on site. Available sources state that, on 31 January 1945, B-17E FL455 Z9-A impacted the ground at ND 13950 44922 (140m asl in the Forsinard Flows RSPB Reserve, Caithness) in poor weather conditions whilst returning from a sortie over the North Sea. Three airmen survived the crash; the four deceased crewmen are buried in known locations (Stitt 2010: 128-129; CWGC 2013). The site conformed to *PMRA 1986* requirements as the deceased crewmen have known graves. The site was visited as part of a Phase I investigation in order to confirm the site's size and archaeological integrity. An extensive debris concentration was noted and a crash pattern hypothesis developed. A *PAAR Aircraft Incident Record* form was completed.

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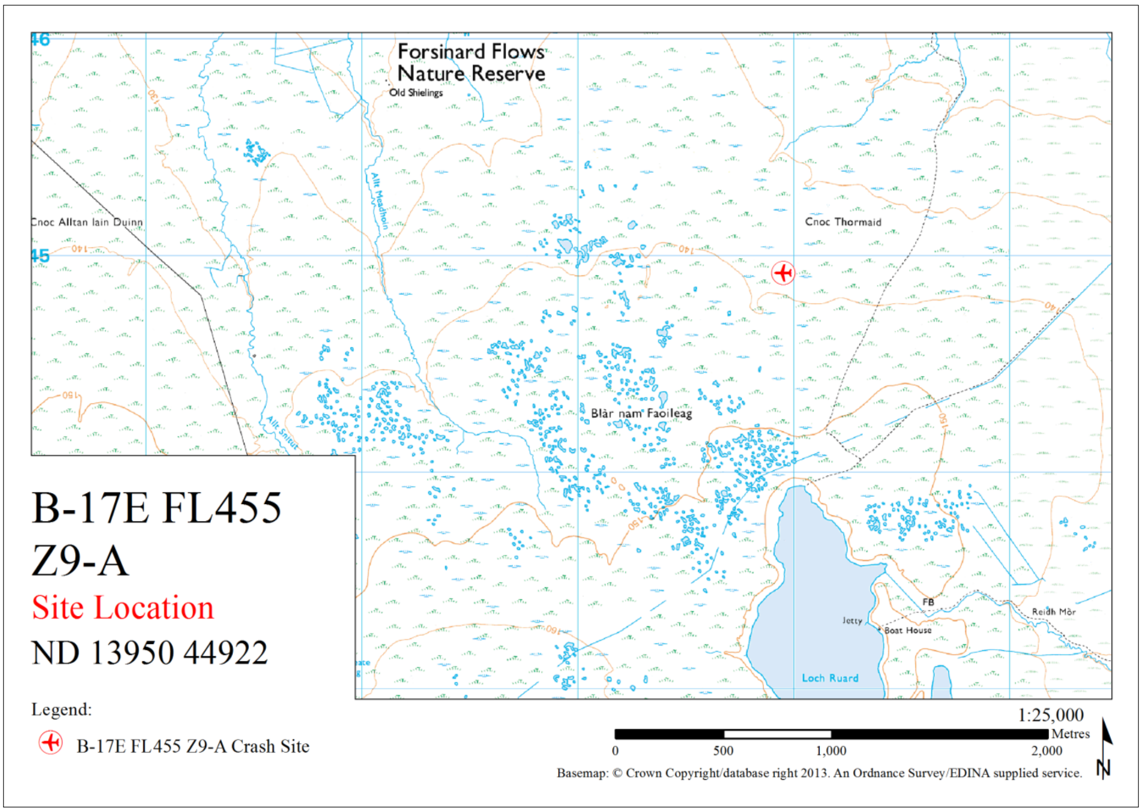
Figure 7-82: Boeing B-17E FK186, similar to FL455 Z9-A, of No 220 Squadron (IWM 1943).



Map 7-19: Location of the Boeing B-17E FL455 Z9-A crash site (Crown Copyright/database right OS 2013b; Author).

7.5.1.2 Investigation Summary

The B-17E FL455 Z9-A crash site is located on the Royal Society for the Protection of Birds Forsinard Flows Nature Reserve. Phase I background research was completed August 2011 with a Phase I site visit on 27 November 2011. A Phase I site visit was deemed necessary as secondary sources provide insufficient data to confirm an intact debris field. The Phase I site visit was completed on 27 November 2011. A dense scatter was observed measuring approximately 200 metres by 125 metres. The centre of the debris field, site of the majority of the wreckage, is approximately 50 metres across. Both metallic and organic artefacts, including large wood artefacts and cordage, were observed on the surface. Continued research into Phase IIa was planned; however, investigation into FL455 Z9-A was eventually limited to Phase I due to environmental protections, environmental damage mitigation requirements, and limited human resources.

7.5.2 Airframe Construction

Discussion of the assemblies and components anticipated on metal-skinned aircraft wreck sites is discussed in detail in Chapter 9 Section 9.2. While Section 9.2 specifically relates to the Consolidated B-24, the construction methods discussed are also applicable to the Boeing B-17.

7.5.3 Archaeological Investigation

7.5.3.1 Phase I Historical Survey

The Phase I historical survey was completed in August 2011. An accident card located for FL455 Z9-A provided little information about the actual crash and little is known about the post-impact recovery efforts. Secondary sources provide operational details of meteorological flights from RAF Wick. The projected flight plan, code-named RECIPE, dictated that B-17E FL455 Z9-A embark from RAF Wick on 31 January 1945 and fly an ascent course east north-east to 59°15'N 00°25'W before continuing north north-east to approximately 67°10'N 04°30'E. From here, the flight was projected to turn onto a west south-west bearing for high altitude flight with further turning points at 65°50'N 05°30'W and Noup Head. The final leg would take the flight south, to the west of the Orkney Isles, on a descent back to RAF Wick (Stitt 2010: 125, 128-129, 197). Boeing B-17E FL455 Z9-A successfully completed most of the proposed RECIPE flight plan, impacting the ground between Loch Ruard and the Blàr nam Faoileag while on the final leg to RAF Wick. Four of the crew perished in the crash (Appendix Table 11-8); all four bodies were immediately recovered by military recovery teams (Stitt 2010: 128-129).

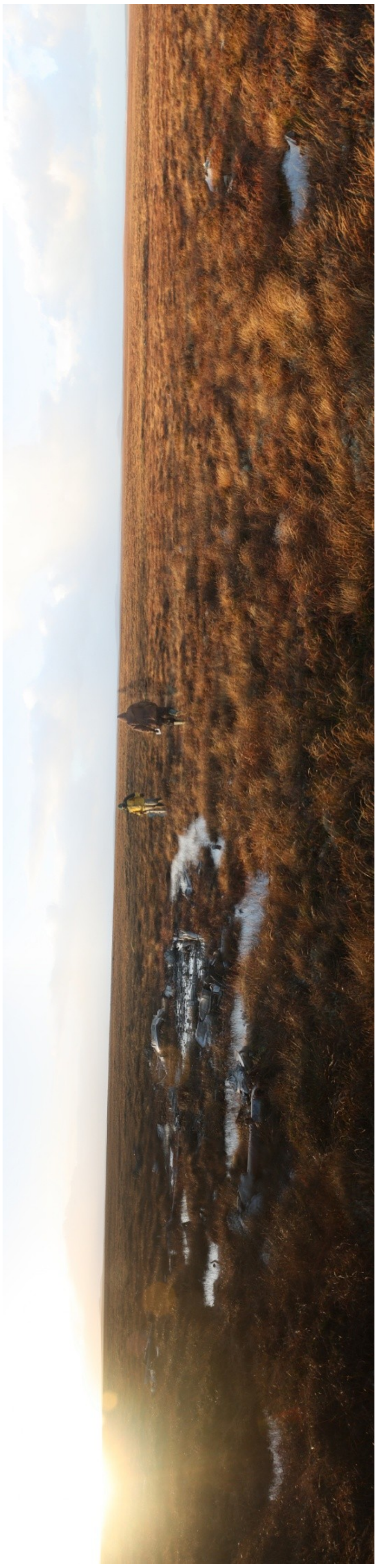


Figure 7-83: B-17G FL455 Z9-A primary crash site (Author).
The main artefact scatter is left of centre.

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due to copyright restrictions.

Document 7-8: Phase I *PAAR Aircraft Incident Record* form for Boeing B-17E FL455 Z9-A (ICAO 2006; Author).

7.5.4 Comprehensive Site Analysis

B-17E FL455 Z9 benefits from its remote location within the RSPB Forsinard Flows Nature Reserve. An important ecosystem which includes an extensive coverage of Blanket Bog, for which the Forsinard Flows Nature Reserve area is provided SSSI (*Blar nam Faoileag*); SAC (Caithness and Sutherland Peatlands); SPA (Caithness and Sutherland Peatlands) and Ramsar (Caithness and Sutherland Peatlands) protections (SNH 2012), makes the removal of large objects difficult. The RSPB's resistance to extensive invasive work within the Reserve provides additional, non-legal protections against excavation. Indeed, the FL455 Z9-A site has experienced minimal artefact relocation and modification and, seemingly, retains much of its original content and distribution.

Figure 7-84: The FL455 Z9-A crash site from a distance (Author).
The crash site is the low silver streak at centre. Its remoteness and location within RSPB reserve, SSSI, SAC, SPA and Ramsar sites make the removal of large objects difficult and preserves much of the wreckage.

It is believed that artefacts are buried below ground. For example, the ground underneath much of the central scatter feels hollow under foot. When walked upon, the ground flexes and then springs back. Such springy ground can be indicative of buried-airframe structures creating an artificial void. If true in this instance, much of the material below ground could be in excellent condition due to (1) the wet, boggy conditions creating an environment which slows oxidation and (2) the lack of invasive crash site tampering.

The discovered ground level artefacts are not without damage. Several artefacts with surviving paint have had names and messages scratched into the surface (Figure 7-85 and Appendix Figure 11-92). At least one artefact, an engine cowl, shows shotgun damage from the interior to the exterior (Figure 7-86 and Appendix Figure 11-93). Moreover, while the site is difficult to locate due to the flat terrain, it has been visibly marked by the post-crash placement of two artefacts. Stuck into the ground upright (Figure 7-87 and Figure 7-88), the artefacts are the only markers which make the site visible from a distance.

Figure 7-85: One of many artefacts on site with scratched-in personal information (Author). This section of fuselage or engine nacelle is located near the tail wheel debris deposit.

Figure 7-86: An engine cowling was discovered to have shotgun blast damage (Author). While the site appears to be largely intact, the presence of damage to the cowling and other artefacts demonstrates past and ongoing site tampering.

Figure 7-87: One of two upright pieces of debris at the B-17E FL455 Z9-A crash site (Author).

Figure 7-88: The second of two upright pieces of debris located 240 metres at 125 degrees from the main impact scar/debris field (Author).

Despite these evidences of tampering, the B-17E FL455 Z9-A site is not in imminent danger of exploitation as its remote location and landowner vigilance provide a modicum of protection. Given its relatively pristine state, future excavations likely would yield well preserved artefacts and excellent aircraft-specific data.

7.6 Conclusion

The survey sites completed as case studies for this thesis demonstrate both positive and negative aspects of the proposed PAAR Methodology. On the positive side, the survey sites demonstrate that:

1. An aviation archaeology-specific, phased standard operating procedure provides a viable field methodology.

2. A non-invasive approach to aircraft wreck site investigation returns significant useful data.

3. A standardised archaeological approach can ameliorate the negative effects of decades of site modification and artefact movement, thereby producing a historical narrative supported by physical evidence.

By substantiating the proposed phased field methodology specific to the eccentricities of historic aircraft wreck sites, the survey sites demonstrate not only the viability of the proposed methodology but, indeed, its success. A phased methodology, which increases in financial, time, human and knowledge resources required, allows a full range of participants (from avocational enthusiasts to professional archaeologist) to engage with and contribute to the larger archaeological discourse. For example, investigations terminating at Phase I, such as B-17E FL455 Z9-A, can be undertaken by both archaeologically and non-archaeologically trained individuals. Hill walkers who seek out or accidentally discover a wreck site may not wish to research the site in detail but may be interested to the point of discovering basic journalistic W's (who, what, when and where). The largely desk-based nature of Phase I provides access to the field of aviation archaeology at an introductory level to avocational historians, local heritage organisations and the general public.

Requiring more in-depth research and more financial outlay than Phase I, PAAR Methodology Phase IIa procedures bridge the gap between site identification and dedicated archaeological survey. In applying accepted multi-disciplinary survey recording practises, Phase IIa generates a data set from which nuanced crash narratives, site health observations, and site management recommendations can be made. For example, Beinn Nuis 1 (Isle of Arran) and Beinn Nuis 2 (Isle of Arran) each required only a single day survey. The objective of these surveys was to understand the quantity and distribution of extant artefacts at each site. An archaeologically significant result derived from the single day survey; to wit, the recorded artefact scatter suggests that the sites are not, in fact, as comingled as previously thought. Furthermore, the combination of historical research and archaeological survey allowed for a reappraisal of the crash narrative. In the case of Beinn

Nuis 1 (Isle of Arran), the revision of the crash scenario re-humanises the deceased, bringing their final actions and fears to light for the first time in over 65 years.

Phase IIb surveys, the phase most similar to standard archaeological surveys, provides avocational communities a procedural choice. If there is considerable interest in a site, continuation of research into Phase IIb can provide a more detailed data set from which avocational individuals/groups and heritage managers can choose to refine Phase IIa hypotheses and plan long-term site management. Conversely, if there is interest in a wider region or aircraft wrecks as a general subject, then the Phase IIa-Phase IIb divide can provide avocational individuals/groups with a natural termination point without endangering or altering the wreck site investigated. The more detailed survey techniques practiced in Phase IIb investigations allow for the refinement of archaeological discovery. In the government/NGO domain, the refined archaeologically sensitive boundaries enable more focused site management and better use of financial and human resources. In the avocational community, Phase IIb surveys can help refine areas of interest such that sites can either be left undisturbed (if not of further interest) or undergo focused, non-destructive excavations should work proceed to invasive exploration. B-17G 44-83325 on the Isle of Skye is archetypal of the Phase IIb terminus. Utilising both historical and archaeological data, Phase IIa initially bounded the site at some 645 metres by 800 metres, identified an archaeologically sensitive core of 400 metres by 450 metres and confirmed extensive debris concentrations within the central gorge. Phase IIb refined the archaeologically sensitive area to a rectangle 125 metres by 250 metres and confirmed the Phase IIa crash narrative without utilising invasive techniques.

In addition to providing proof-of-concept data, the constructive data gained from the six survey sites supports the hypothesis that archaeological methods can be used to study sites which have experienced post-depositional movement. Based upon observed artefact patterning, all six sites evidenced some degree of natural and human-induced post-depositional artefact movement. While observing artefacts on site may provide explicit evidence for post-crash tampering—the cut marks on B-17G 44-83325's propeller hub (FS 109.01) and the hack saw blade (FS 036.01) at DD753 for example—it is usually less clear whether artefacts currently reside in their original location. The scatter distributions provided by Phase IIa and IIb artefact geo-referencing allow for the observation of site wide patterns of movement less readily apparent at ground level. Beinn Nuis 1 (Isle of

Arran) provides an excellent example of how, even though individual artefacts may have been moved locally, the inter-artefact spatial distribution remains largely secure.

While the legal inability to pick-up and manipulate artefacts did not have a debilitating effect on the success of the proposed methodology, the inability to fully examine artefacts did produce site databases with an unexpected number of nondiagnostic and nondiagnostic(diagnostic) artefacts. Half-buried artefacts with seemingly unique characteristics had to be classified as nondiagnostic(diagnostic) as their form or part number could not be determined without physical manipulation. As such, Phase IIa surveys and beyond would benefit, where possible, from an excavation license. While the 'no artefact removal' advice built into Phase IIa and parts of Phase IIb protects sites' long-term survivability, the ability to pick-up and/or flip artefacts in order to inspect and photograph all sides would increase the percentage of positively identified artefacts. If an excavation license is procured, replacement of artefacts 'as found' in order to retain as much of the original artefact orientation and scatter distribution as possible is advised. Chapters 8 and 9 demonstrate the continuance of the PAAR Methodology into Phase IIIa and provide further evidence of its merit.

8 de Havilland Mosquito P.R. Mk. IX MM244 (Corryfoyness, Highlands)

8.1 Overview

Historic airframes segregate into two major categories—wooden framed and metal skinned. Because it is a predominantly wooden framed airplane, the de Havilland Mosquito (Figure 8-1) provides an excellent resource through which to definitively test not only the proposed methodology but also the survival of engineered and natural woods in the archaeological environment.

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Figure 8-1: An identical airframe model as MM244, de Havilland DH.98 P.R. Mk. IX LR432 (IWM c1943-1945).
The two aircraft were assigned to the same unit, No 544 Squadron RAF.

8.1.1 Site Background

The crash site was investigated to assure that it satisfied the MoD JCCC licensure requirements and procedures (see Chapter 2 Section 2.2.2). A photo-reconnaissance aircraft type, DH.98 P.R. Mk.IX MM244 relied upon impressive speed, rather than firepower, to escape attack. Thus, the De Havilland Mosquito MM244 flew without offensive armament. The two crew members, Flight Lieutenant Joe Burfield DFC (then Flying Officer Burfield) and Flying Officer Alexander Barron DFM (then Sergeant Barron), parachuted to safety before the crash (Royal Air Force 1943b). Hence, neither munitions nor human remains were anticipated on site. The crash site of de Havilland Mosquito MM244 met the licensure requirements.

At the time of the crash, DH.98 P.R. Mk.IX MM244 was assigned to No. 544 Squadron.[1] On 25 November 1943, Mosquito MM244 lifted off from RAF Benson on a high-level training mission accompanied by six other Mosquito crews. The proposed flight plan dictated that the seven aircraft fly northwest over the Scottish coastline and, after circling a particular (but unrecorded) coastal rock island, return to base. Upon reaching operational altitude, Fl/Lt Burfield discovered that the plane suffered from petrol injection problems. As a result, both engines were lost sequentially. Descending to 12,000 feet in order to determine their location, Burfield encountered a dense blanket of low-level clouds. Upon requesting a Directional Finder bearing from RAF Dalcross (now Inverness Airport), Fl/Lt Burfield ascertained that he was over highland Scotland. First ordering navigator F/O Barron to abandon the aircraft, Fl/Lt Burfield followed closely thereafter. The men parachuted to safety on the east and west sides of Loch Ness, respectively (Royal Air Force 1943b; Foster 2004: 35-36; Barron 2013).

Mosquito MM244 continued to glide for a period of time before ultimately crashing just above the western coast of Loch Ness near Corryfoyness, Highlands. After the crash, recovery crews removed the plane’s two Rolls-Royce Merlin 72 power plants and buried the remaining wreckage in an unmarked pit (Royal Air Force 1943b; Barron 2013). The wreck resides within the confines of a 780 acre wooded region managed by the Forestry Commission-Scotland. Contained within a small area, the wreck site sits within a shallow forest clearing with the impact point marked by a small amount of standing water and young pine growth.

8.1.2 Investigation Summary

A Phase I historical survey conducted from October 2009-December 2009 established the site’s feasibility for possible in-depth investigation and/or excavation. A Phase IIa detailed historical survey, undertaken from December 2009-April 2010, confirmed the site’s

[1] No. 544 Squadron began its operational career at RAF Benson on 19 October 1942 flying the diverse mixture of planes previously assigned to the Photographic Reconnaissance Unit. This variety, though, was quickly reduced when the Spitfires of B Flight were detached and then formally transferred to No. 541 Squadron at Gibraltar. De Havilland Mosquitoes became the squadron’s sole aircraft type when, in March 1943, No. 544 Squadron received the first operational Mosquito variant (the P.R. Mk. IX). The Squadron flew photographic reconnaissance missions throughout the war (Jefford 2001).

archaeological integrity, verified the site's feasibility for an archaeological investigation, and generated the information required for a successful MoD JCCC permit application.

The excavation of DH.98 P.R. Mk.IX MM244 was undertaken 7-12 July 2010. Prior to physical excavation, Phase IIa unsystematic and Phase IIb systematic pedestrian and metal detector surveys were conducted. All material identified during the Phase IIb surveys was georeferenced, recovered and bagged separately. After processing the Phase IIb data, a limited Phase IIIa investigation commenced. A single trench, two metres by five metres, was opened across an area of visible artefact clustering. All artefacts exposed in the course of the Phase IIIa excavation were bagged and labelled according to their respective one meter grid square. The excavation team recovered all artefacts encountered in order to provide the necessary materials with which to statistically analyse the prevalence of diagnostic parts verses unidentifiable fragments.

8.2 Airframe Construction

8.2.1 Wooden Components

War time necessity forced de Havilland engineers to modify production of aircraft structural components. With metal reserves in short supply and much of it allocated to the production of existing airframe types, de Havilland designers turned to engineered wood (constructed from natural wood and plywood bounded together with Casein glue and, later, formaldehyde resins) for producing the Mosquitoes' major components (Friedman 1943: 100, 102-103; *Popular Mechanics* 1943: 160; Thirsk 2006: 43, 242). Some 50,000 small, brass wood screws were used to further reinforce the fuselage, wing section and tail (RAAF Museum Point Cook n.d.). The Mosquito can be divided into three distinct pieces: the fuselage, wing and tail sections. The fuselage was constructed of plywood moulded on mahogany or concrete forms (Howe 1999: 9; Thirsk 2006: 40; RAAF Museum Point Cook n.d.). The nose section was constructed from plywood made of spruce skins and a balsa wood planking core. The remainder of the fuselage section was constructed from plywood made out of 1.5mm and 2.0mm three ply birch plywood skins with an identical balsa wood planking core (Howe 1999: 9; Thirsk 2006: 40).

Using the term plywood to describe the fuselage's construction might be confusing from a modern perspective. The plywood used for the fuselage was not constructed from a single birch skinned and plywood core sheet which was then moulded to the correct shape.

Rather, a three ply birch plywood skin was moulded first. The core spruce supports were cemented to the moulded inner skin after which a balsa wood core was attached. The balsa wood core was laid down in strips approximately 3/8" thick. The fuselage was clamped to ensure a good bound between the inner skin and the balsa wood core. Following the release of the clamps, the balsa wood core was smoothed to the desired contours. Only after the interior skin and balsa wood core were complete was the exterior three ply birch plywood outer skin placed on top and moulded to the final shape using flexible steel clamps (Howe 1999: 9; Thirsk 2006: 40).

After being released from the moulds, the fuselage halves were fitted with over 60 percent of the requisite internal equipment. Following equipment installation, the two fuselage halves were joined through a process called "buttoning-up" to form the monocoque (Tanner 1977: 300; Howe 1999: 9-10; Thirsk 2006: 41-42). The entire fuselage, except for the wing's leading edges and top surface, was then covered in madapolam. A cotton fabric woven in a linen weave using fine yarns with a dense pick, madapolam's equal warp and weft provided a tensile strength, shrinkage and absorbency of equal value in any two directions at ninety degrees (British Standards Institution 1975, 1995). The wing's edges and top surface received a coating of Irish Linen fabric. Aircraft grade Irish Linen fabric is similar to madapolam in that it has equal warp and weft. Thus, when aircraft dope was applied to stiffen the fabric skin, engineers knew how the fabrics would respond and care could be taken not to contort the airframe's alignment. The fabric covering was stiffened with two coats of either red or clear-coloured aircraft dope, four coats of aluminium dope and a final paint finish (Tanner 1977: 300; Howe 1999: 17; Thirsk 2006: 42).

A marvel of craftsmanship, the wing section was constructed using four large sub-sections: the main wing structure, the detachable wing tips, the leading edges outboard of the engines and the ailerons. The main wing structure was "a one-piece, wooden cantilever structure tapering in plan form and thickness, comprising two box spars which extend over the full span, with wooden ribs and stressed plywood covering top and bottom" (Tanner 1977: 302). The main wing structure's top skin was made from fifteen spruce stringers running the length of the wing sandwiched between two pieces of birch plywood with a balsa wood core. With only one sheet of the birch-balsa plywood glued and screwed directly to the 16 ribs and 15 spruce stringers, the bottom sheet was less substantial than the joined top sheets (Tanner 1977: 302).

The Mosquitoes' internal ribs consisted of a spruce structure with a single birch-balsa plywood facing. Light ribs out-board of the engines did not have additional reinforcement. Engine ribs, however, were faced with birch-balsa plywood on both sides and buttressed a reinforced base constructed from a composite material of plywood with a Bakelite core. The flaps were constructed in an identical fashion to the main wing structure and leading edge (Tanner 1977: 303-307).

Made from the same birch-balsa plywood, the detachable wing tips attached to the spruce pre-form and laminated edge using glue and screws. The wing's leading edge was constructed of 16 spruce rib noses covered with a single, pre-moulded birch-balsa plywood skin (Tanner 1977: 302, 304). Specific connection points incorporated plywood-faced Bakelite and/or ash reinforcing members (Tanner 1977; 302-303).

The tail section fin was "a symmetrical sectioned wooden cantilever structure, comprising two box spars, spruce and plywood ribs and plywood covering" (Tanner 1977: 309). The tail fin ribs and plywood web were constructed using the same method as that employed in the manufacture of the main wing section (Tanner 1977: 309; Thirsk 2006: 46).

8.2.2 Metal Components

As befitting its nickname, the Wooden Wonder contained only four major metal sections. The main wing section ailerons were formed from a light alloy and then skinned using light alloy sheets (Tanner 1977: 303). The leading edge of the wing between the engine nacelles and the fuselage was made from Alclad. Trademarked by Alcoa Incorporated, Alclad combined aluminium, copper, manganese, magnesium and silicon. A ground-breaking alloy, Alclad combined the surface corrosion resistance of pure aluminium with the strength of an alloy core (Aluminum Company of America 1931, 1932). Alclad's combination of corrosion resistance and strength made it increasingly common in aircraft after 1932 (Aluminum Company of America 1931, 1932; Henthorne 1972: 122, 143; Anderson 2003: 261).

The tail section elevators, rudder and trim tabs also were made from Alclad. Though early model Mosquitoes used cloth covered elevators, most Mosquitoes' elevators were constructed using "pressed alclad ribs riveted to alclad spars and covered with metal [Alclad]" (Tanner 1977: 309). The trim tabs were built using the same Alclad ribs, spars and metal covering as later model elevators (Tanner 1977: 309-310; Thirsk 2006: 21). The rudder used the same style of Alclad ribs but had a fabric covering which was stretched over the Alcad ribs. To provide sufficient rigidity, the stretch rubber fabric was doped using the same two and four dope coat process as utilised in constructing the aircraft's main body (Tanner 1977: 309; Thirsk 2006: 50). To ensure accurate artefact interpretation, it is important to note that the Mosquito's elevators are interchangeable. As such, if the elevators are divorced from the larger tail structure, positive identification of the elevator's port or starboard position becomes largely impossible. The rudder, being a unique part, does not suffer from this identification problem.

8.2.3 Perspex Components

Perspex provided the transparency required in key areas of the airframe including the cockpit canopy. Constructed from welded steel tubes, the cockpit canopy was bolted to the plywood fuselage. The entirety of the canopy glass was constructed from Perspex except for the forward windscreen; this later structure was made from bullet-proof glass. Constructed from spruce-balsa plywood, the nose section was physically separated from the rest of the fuselage by an armour plate bulkhead. The armour plate provided the crew with minimal protection from frontal attacks (Tanner 1977: 300). On photoreconnaissance and dedicated bomber variants of the Mosquito, a frontal observation nose made of Perspex was installed in place of the aircraft's usual offensive armament package. In addition, Perspex formed the covers for the navigation, formation and landing lights located on the wings and tail.

8.3 Archaeological Investigation

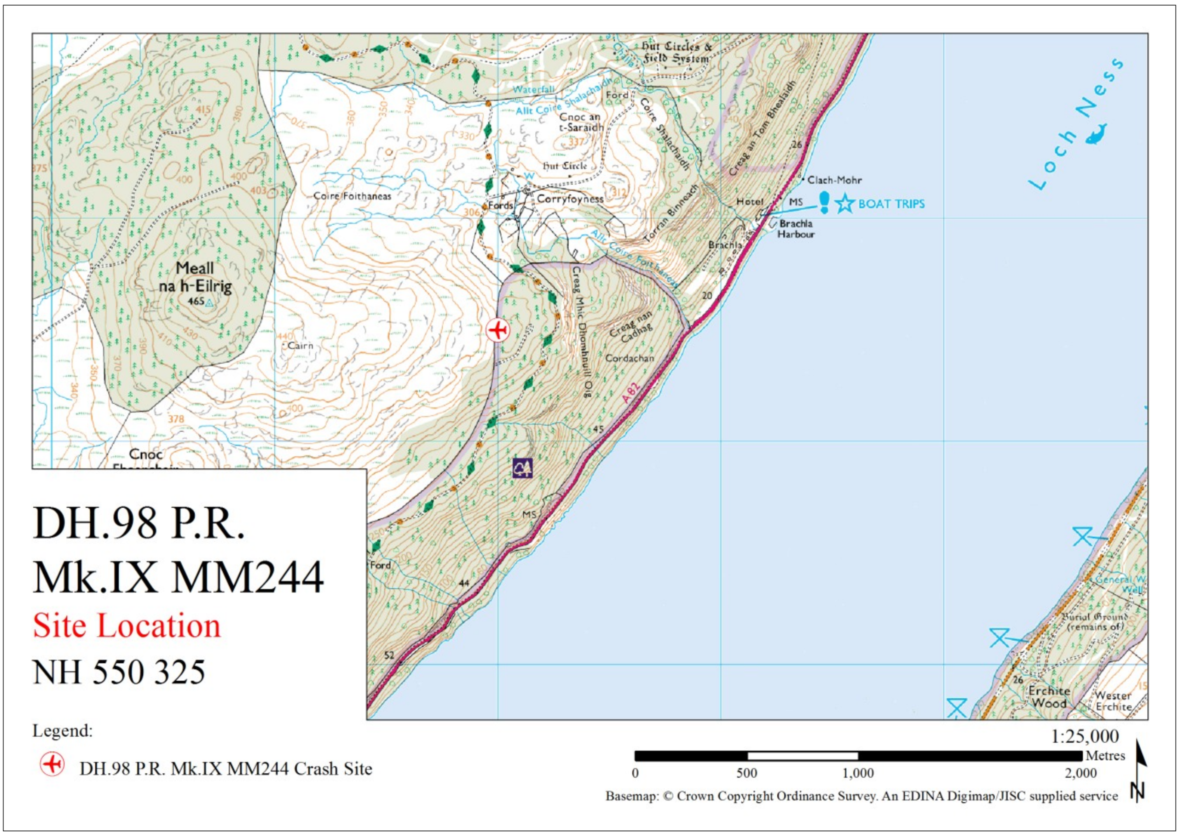
8.3.1 Phase I Historical Survey

A Phase I historical survey conducted from October 2009-April 2010 explored the suitability of DH.98 P.R. Mk.IX MM244 as a viable case study. The Phase I historical survey focused upon the establishment of basic site information including: (1) type of aircraft, (2) when and where the crash occurred, (3) number, names and disposition of the crew on board, (4) approximate location of the wreck site, and (5) current land ownership. Additional information, including records of previous investigations and old photographs/plans of the site—whether scientific or tourist in origin—also was sought.

The Phase I historical survey established that DH.98 P.R. Mk.IX MM244 was a photoreconnaissance de Havilland Mosquito which crashed into a Forestry Commission-Scotland tree plantation (NH 550 325) on 25 November 1943 (Map 8-1). A standard crew of two airmen were on board: Flying Officer Alexander Barron DFM and Flight Lieutenant Joe Burfield DFC (Appendix Table 11-9). Both men parachuted to safety prior to the aircraft's impact (Royal Air Force 1943b; Barron 2013).

A small number of hill walker and enthusiast photographs identified during the Phase I survey provided additional information about the site. A single hill walker (Jones 2008) provided the majority of the photographs showing areas of the site as it existed in 1990s. One image shows an elongated depression filled with standing water, while another includes a small pile of wreckage located just in front of the artefact cluster later partially excavated during Phase IIIa.

The Phase I survey established that the site contained wreckage of an aircraft which both complied with MoD JCCC license procedure and met the experimental requirements of this thesis (Document 8-1). As such, a Phase IIa detailed historical survey of the site was undertaken.



Map 8-1: Location of DH.98 P.R. Mk. IX MM244 (Crown Copyright/database right OS 201ba; Author).

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Document 8-1: Phase I *PAAR Aircraft Incident Record* form for DH.98 MM244 (ICAO 2006; Author).

8.3.2 Phase IIa General Data Survey

The Phase IIa survey undertaken from 10 May to 8 July 2010 focused upon establishing a detailed history of the physical site, the aircraft, and the crew (Document 8-2). The Phase IIa detailed historical survey included a detailed map regression analysis. Map regression analysis was conducted in order to ascertain the site's original topography and to identify significant post-1943 changes to the local topography. Of particular interest was whether the current forestry plantation was newer than, contemporaneous with, or older than the Mosquito wreck site. The historical terrain and the age of the forestry plantation directly affect artefact distribution. Ordnance Survey (1904, 1912, 1929, 1947, 1961, 2007a, 2007b) and Bartholomew and Sons (1934, 1943, 1963, 1975) maps dating from 1904-2007 were used for the map regression analysis.

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Document 8-2: Phase IIa *PAAR Aircraft Incident Record* form for DH.98 MM244 (ICAO 2006; Author).

Background Research:

Primary Source Accounts:

Two primary source accounts of the wreck were discovered during the Phase IIa detailed historical survey. The first account, related by Flying Officer Alexander Barron, provides an interesting account of the flight and the bailout.

> *There were one or two training flights during the first couple of months. On one of these I had my second occasion to bale out. This happened on a flight from Benson routed around the North of Scotland. Three or four aircraft were routed round roughly the same course. The weather was very cold and at 30,000ft the temperature was just about as low as you could find it. I think it was something like -50 degrees Centigrade. Two of the other aircraft had to land about half way round due to fuel problems which were later found to be associated with the extreme cold. Unfortunately, we didn't have any fuel feed problems until we were at the furthest point of the trip over the Outer Hebrides. The engines coughed and spluttered and finally cut out entirely. It is quite frightening to experience the eerie silence with no engines. In order to retain sufficient speed to remain airborne we had to lose height pretty rapidly and the prospect of reaching an aerodrome and effecting a landing was beyond our capacity. Joe, the pilot tried for some time to restart the engine without success. We were losing height at quite a pace and he made the decision that we had no alternative but to abandon the aircraft. The Mosquito cockpit is a pretty cramped affair and getting out of the thing was not a particularly easy matter. By the time we took the decision to go we were below the need for oxygen so that the masks could be discarded. I had to take off my helmet after disconnecting oxygen and intercom and open the inner door and jettison the outer door by kicking the release mechanism. I then had to turn round to go out backwards feet first. This was accomplished by sitting on the floor and sticking my legs through the hole. Care had to be taken not to get caught up on anything sticking out of the wall since a parachute harness with a parachute on front took up quite a lot of room.*
>
> *When it got my legs through the hole the slipstream was so powerful that my legs got pushed up and jammed against the underside of the plane. Added to that, the shaft of the trailing aerial was also jammed against my leg. The cold was severe and I was still suffering from lack of oxygen. I guess my movements were pretty slow because Joe told me I took a long time to get out. It's not surprising since, if I didn't get out, neither would he: However, I was suddenly sucked out like a cork from a bottle and found myself sailing through the air. I grabbed frantically for the ripcord and wrenched it out. I was arrested with such a jerk that I felt I'd been cut in half. My intense relief was incredible and I hung there talking out loud to myself thanking everyone I could think of for my deliverance.*
>
> *The cold was intense. I don't think I saw the aircraft but I was too busy with my own position. What actually happened after I left was that Joe had the*

> *difficult job of coming out of his seat; holding the control column turning round and stepping through the hole hoping that he didn't get tangled on anything on the way. He made it anyway. I must honestly say that as I dangled on the end of this chute for what seemed ages I never gave him a thought. The concealed terror that I experienced gradually subsided at the realisation that I was alive and the parachute seemed to be holding up well. Nevertheless, I was frightened to move in case all the air spilled out and I came to sticky end.*
>
> *My next problem was the hills and forests and lochs which spread below me as I drifted in complete and utter silence. Loch Ness dominated the vista and it looked as though my progress in this direction was inevitable....As luck would have it I was blown over the loch and landed on a hillside after crashing through some trees. There was nothing calculated about my para-landings—just crash bang wallop hope for the best (Barron 2013).*

Unfortunately, F/O Barron's account does not provide detail on the aircraft's final altitude, attitude or vector. Even so, Barron's account provides a possible cause for the aircraft's loss of power. In his account, Barron infers that the high altitude fuel injection problems which caused the other two Mosquitoes to turn back also caused MM244 to lose power and ultimately crash.

A second account, offering substantially less detail, is related by Ft/Lt Ronald Foster in his memoir *Focus on Europe: A photo-reconnaissance Mosquito pilot at war, 1943-1945*. During the war, Foster shared a room with Burfield and another Mosquito pilot, Harold Vickers. As a de Havilland Mosquito carried only a crew of two, Burfield, Foster, Vickers and their attached navigators became fast friends nicknaming themselves the "six musketeers" (Foster 2004: 105). As such, Foster's account constitutes a well-informed, primary account of MM244's last moments.

> *In fact when we returned to [RAF] Benson the next day we learned that four of the seven aircraft had not got back to base the previous day. To cap it all, Joe and his young Scottish navigator, Alec Barron, had lost both their engines and had had to bale out over Loch Ness. Joe said the water had looked softer, though he landed on terra firma....*
>
> *During that period we had a great deal of trouble with fuel of inferior octane, which caused the Rolls-Royce Merlin engines to cut out. It was unpleasant and occurred without warning, and Mosquitos were lost because of this fault. At Benson a conference was held to discuss the troubles, and we completed lengthy reports (2004: 35-36).*

While offering a humorous account of a serious situation, Foster confirms the cause of crash as a loss of fuel injection and subsequent engine failure. In addition, Foster's account confirms that bail out occurred over Loch Ness.

Map Regression:

The *1904 Ordnance Survey 2nd Edition 25-Inch Map* is the first map to show the forested area at its basic modern boundary. While the map shows relative stability in forest boundaries for over 20 years, select deforestation between 1912 and 1929 is observed on the *Ordnance Survey One-Inch "Popular" Edition of 1921-1930*. The deforested areas show a continued presence on *Sheet 20: Central Ross* of *Bartholomew and Sons Half-Inch to the Mile Map of Scotland, 1926-1935* and the *Ordnance Survey One-Inch "Popular" Edition, 1945-1947*. The continued presence of a mostly forested area with select deforestation in the vicinity of the suspected crash site is noteworthy. Indeed, the existence of similar forest boundaries in 1929, 1934 and 1947 demonstrates the presence of an established forest at the time of de Havilland Mosquito MM244's crash landing.

The *Ordnance Survey 1961 7th Edition One-Inch Map* shows the complete deforestation of both the suspected crash site as well as the wider area. The likelihood that the absence of forests on Loch Ness's western shore was a cartographic error is quite low. The Loch's opposite bank, continuously shown as forested since the *Ordnance Survey 1st Edition, Scotland, 1843-1882*, remains forested. As such, the idea must be entertained that the area was clear cut sometime between 1947 and 1961.

Bartholomew's 1:100,000 Map of Britain, 1975-1978, while not as finely detailed or contoured as previous examined maps, displays important alterations to the forested environment from 1961 to 1978. The forested area's northern and eastern borders once again align with the *Allt Coire Foithaneas* while the forested region merges with usually separate *Balnacraig* forest. Both the re-extension of the forested region's borders and the merger with the *Balnacraig* forest are possibly due to the map's scale and purposefully generalised detail. Even with the small scale and generalised detail, increased forestation is shown extending north from the burn head at NH 547579 318792. The presence of the new forest growth indicates either natural or manmade forestation occurring on a relatively large scale after the de Havilland Mosquito MM244 crash.

The modern *Ordnance Survey Landranger (1:50,000) C2 Edition Map* was revised in 1999 with selective changes made in 2002 and 2007. The increase in forest cover provides the most striking change evident on these newer maps. Indeed, while the modern forestry commission landholding boundaries still conform to the 1904 map, the overall forest coverage extends up the banks of the *Allt Coire Foithaneas* and Corryfoyness. New to the

1999 Ordnance Survey Landranger (1:50,000) C2 Edition Map is the Great Glen Way trail/access road. The Great Glen Way trail/access road currently circumvents the suspected wreck site to the east (approximately 300 meters north, 275 meters northeast and 250 meters east). The proximity of an established trail allows for increased access to, and interaction with, the suspected wreck site by the public. The ease of access may, in turn, have detrimental effects on artefact survivability.

The area around the suspected crash site has had rather stable land use patterns. The HLA shows the Forestry Commission-Scotland plantation directly associated with the suspected crash site as having no observable relict land use. The HLA further records the FC-S land to be a coniferous plantation dating to the 20th Century with the associated forested region surrounding the FC-S plantation described as being managed woodland and/or woodland plantation dating from the 18th-20th centuries (RCAHMS n.d.).

Aircraft History:

Unfortunately, post-war demobilisation procedures did not include retention of aircraft specific records. Indeed, the most useful of records—Aircrews' Flying Log Books (*RAF Form 414* and *RAF Form 1767*), Aircraft Log (*RAF Form 700*) and Message Form (*RAF Form 96/96A*)—are believed to have been destroyed either after the specific aircraft was struck off charge or following the Particular Instance Paper Committee's 1959 recommendation on unclaimed log books. This recommendation initiated the post-15 September 1960 destruction of 6,400 linear feet of log books (The National Archives n.d.).[2]

The *Squadron Operations Record Books-Summary of Events* (*RAF Form 540*), the A*ccident Record Cards* (*AM Form 1180*) and the *Squadron Operations Record Books-Detail of Work Carried Out* (*RAF Form 541*) are available and provide useful information. No. 544 Squadron's *Operations Books-Summary of Events* (*RAF Form 540*) for November 1943 provides confirmation of F/O Barron and F/Lt Foster's accounts (Royal Air Force 1943b). Although *RAF Form 540* neither mentions the planned flight path for the seven Mosquitoes nor provides specific detail as to the events surrounding the actual crash of the aircraft, *RAF Form 540* records that

[2] Log books varied in size but, on average, were approximately one inch thick. Calculated based upon a standard log book's thickness, approximately 76,800 log books were destroyed.

Seven training flights sent out to the North of Scotland at 3000 ft. F/O. N.M. BURFIELD, M.M. 244, had persistent petrol cutting on main tanks. He was unable to cure this and eventually both engines cut out at 12,000 ft. At the same time the aircraft was over 10/10 cloud with a D.R. position over the Scottish Highlands and F/O. N.M. BURFIELD ordered the aircraft to be abandoned. Both the pilot and the navigator, Sgt. A. BARRON, landed safely near LOCH NESS (Royal Air Force 1943b).

RAF Form 540 records that during the 25 November training flight "Three further crews experienced serious petrol failures and landed away from base"; "F/O. N.M. BURFIELD fetched from DALCROSS; Sgt A. BARRON confined to hospital for further day" (Royal Air Force 1943b). Further, *RAF Form 540* states that, on 26 November, "A conference was held in the morning about petrol failure. The cause of the trouble appears to be obscure and it was decided to carry out a series of test on one aeroplane" (Royal Air Force 1943b). *RAF Form 540* confirms fuel injection as the cause of MM244's loss of power as well as confirming the well-being, albeit scrapped and bruised, of Burfield and Barron.

AM Form 1180 states that the crash took place near Corryfoyness, Invernesshire during a training operation with the crash being caused by "Engine failure owing to lack of petrol, believes fault in petrol feed system" (UK Air Ministry 1943). *AM Form 1180* further relates that the "Pilot bailed out. A/C [Aircraft] burnt. Pilot not to blame" (UK Air Ministry 1943). *AM Form 1180* stresses the severity of the fuel injection problem in recording

Drastic measures are necessary to trace and cure petrol feed trouble. AOC [Air Officer Commanding] results of tech [illegible] awaited. AOC in C [Air Officer Commander in Chief] mod. is now being carried out (UK Air Ministry 1943).

In addition to supplying the engine type (Merlin 72) and engine serial numbers (A399276 and A399272), *AM Form 1180* reports de Havilland Mosquito MM244's flight time at approximately three hours and the time of crash at approximately 1445 hours BDST (GMT+0200 hours). Classified as Damage Category E, the aircraft wreckage was considered a write-off, useful neither for component salvage nor for scrap (UK Air Ministry 1943). This classification increases the suitability of the wreckage for archaeological investigation as it indicates that the aircraft was not broken apart and parts salvaged by maintenance units.

Crew Personnel Files:

MoD policy states that "for a period of 25 years following the date of death of the subject and without the consent of the Next of Kin, MOD will disclose only: surname; forename; rank; service number; regiment/corps; place of birth; age; date of birth; date of death where this occurred in service; the date an individual joined the service; the date of leaving; good conduct medals (i.e., Long Service and Good Conduct Medal (LS&GCM)), any orders of chivalry and gallantry medals (decorations of valour) awarded, some of which may have been announced in the London Gazette" (UK Ministry of Defence n.d.). Following the 25 year exclusionary period, the MoD will disclose all of the above information as well as the individual's affiliated units, the dates and locations of service, service rank information and campaign medal details even without next of kin consent. Should the next of kin consent for the immediate release of personnel records, the 25 year exclusionary period does not apply (UK Ministry of Defence n.d.).

Flying Officer Barron's death in 2000 makes this policy applicable to his wartime records. Unfortunately next of kin permission to access Flying Officer Barron's personnel file was unattainable. As such, all information relating to his service in the RAF must be accessed from open source material. The primary sources for information related to F/O Barron's military service are Neil Barron's (F/O Barron's son) contribution to the BBC's WW2 People's War project and Ft/Lt Foster's memoir *Focus on Europe: A photo-reconnaissance Mosquito pilot at war, 1943-1945*.

Born in 1923 in Glasgow, Flying Officer Alexander Barron joined the RAF in 1940/41. Selected for general aircrew due to his aptitude for maths and Morse code, Barron embarked to Canada in 1942 to complete air crew training. During training in Canada, Barron experienced his first aircraft bail out landing in one of only a few scattered trees. He returned to England and, in October 1943, formally reported to No. 544 Squadron at RAF Benson. It was at RAF Benson that Barron joined up with his pilot, Fl/Lt Burfield. In all, Barron completed 70 operational sorties. Throughout his time with No. 544 Squadron, F/O Barron served as Fl/Lt Burfield's navigator (Barron 2005; Barron 2013; Lyons 2013a). As such, while access to Barron's military personnel file was not possible, the operational flying hours listed in Fl/Lt Burfield's file can be considered a close approximation of F/O Barron's own experiences. F/O Barron left the RAF in 1947 (Barron 2005) and died in 2000 (Lyons 2013a).

Unlike F/O Barron, access to Flight Lieutenant Burfield's military records was possible. Under the *Archives Act 1983*, all military records held by the Australian Government are free for public examination once they have entered the open access period. Usually, open access is granted after 30 years.

Born on 5 May 1915 in Broken Hill, New South Wales, Australia to Mr. and Mrs. H. A. Burfield, Norman Milton "Joe" Burfield joined the RAAF on 8 November 1941. Initially sent to No. 4 Initial Training School (Victor Harbour, South Australia), Burfied began military occupation training on 9 March 1942 at No. 11 Elementary Flying Training School (EFTS) in Benalla, Victoria. While attending No. 11 EFTS, Burfield gained 60 hours of basic flight training on the CA-6 Wackett trainer. Showing competence during EFTS, Burfield was graduated to No. 6 Service Flying Training School (SFTS) in Uranquinty, New South Wales (3 May 1942). At No. 6 SFTS, Burfield acquired advanced flight training on the CAC Wirraway, a derivative of the North American NA-16-2 single seat fighter, gaining 120 hours flight time (Department of Air, Central Office, RAAF n.d.).

From No. 6 SFTS, Burfield transferred overseas and, on 2 February 1943, arrived in the United Kingdom. Promoted to Flying officer on 22 April 1943 and temporarily posted to RAF Bridgnorth, Burfield continued his training at No 15 (Pilot) Advanced Flying Unit (AFU) on 16 June 1943. While stationed at RAF Ramsbury, Wiltshire, Burfield acquired a further 40 hours flight time on the Airspeed Oxford twin-engine trainer. Following No. 15 (P) AFU, Burfield was transferred (3 August 1943) to his final flight-training course at No. 8 (Coastal) Operational Training Unit (OTU), located at RAF Dyce (now Aberdeen Airport), Aberdeenshire. At No. 8 (C) OTU Burfield acquired 40 hours on his operational aircraft, the de Havilland Mosquito, as well as mission specific training on aerial photoreconnaissance flying. On 5 October 1943, following completion of No. 8 (C) OTU, Burfield joined No. 544 Squadron (Department of Air, Central Office, RAAF n.d.).

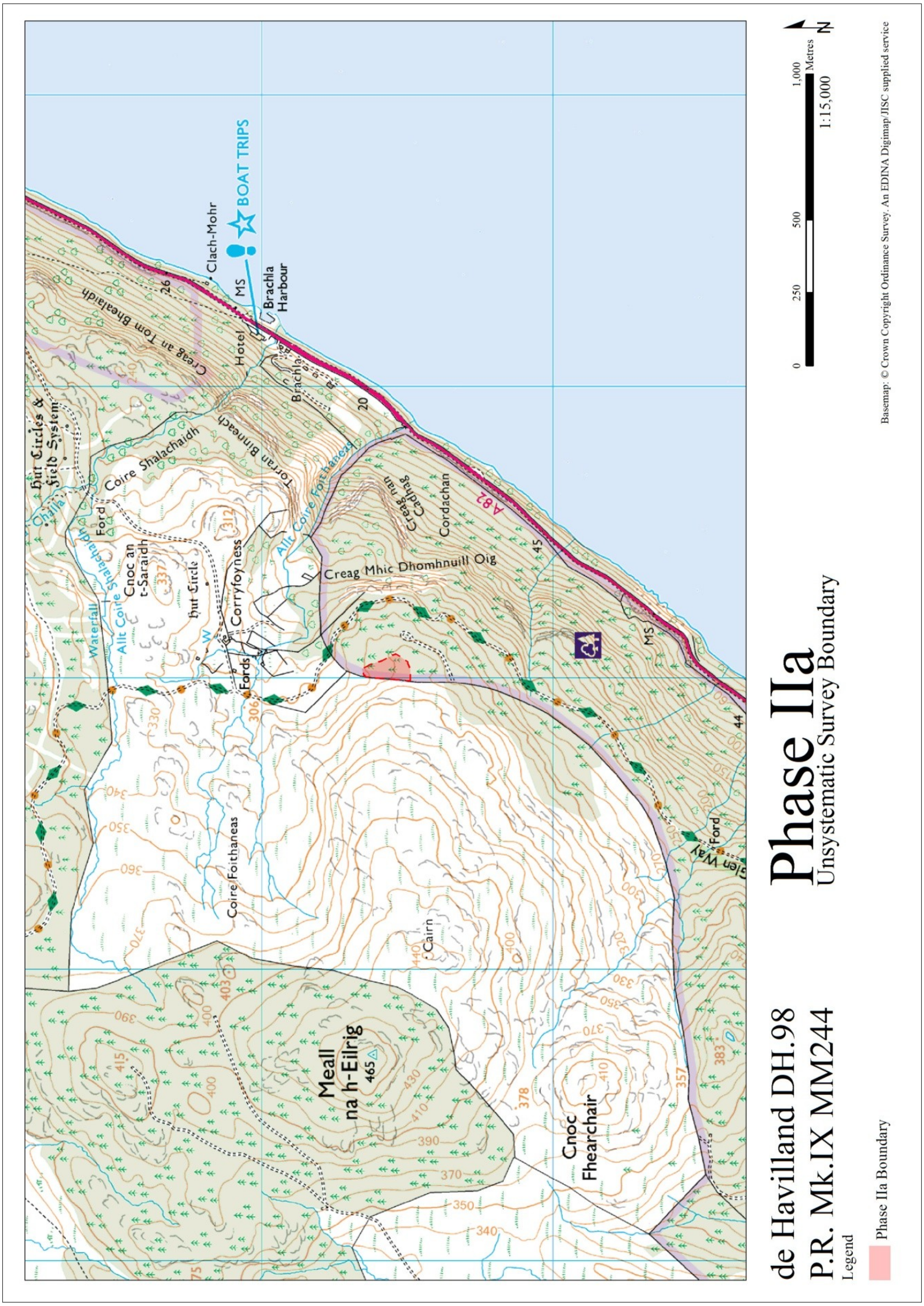
During his tenure with No. 544 Squadron, Burfield flew 71 operational sorties, acquired a further 390 flight hours (290 operation, 100 non-operational) in the Mosquito, achieved promotion to Flight Lieutenant (22 October 1944) and received the Distinguished Flying Cross (9 January 1945). Burfield continued to fly with No. 544 Squadron until 24 February 1945 when he was posted to HQ Transport Command and subsequently, on 4 March 1945, to RAF Northolt (Department of Air, Central Office, RAAF n.d.). RAF Northolt served as home base for Prime Minister Churchill's personal aircraft. Though documentation is inconclusive, it may be that Burfield's transfer to RAF Northolt resulted from his previous service to Churchill during the Yalta conference and the impending Potsdam Conference (Foster 2004: 164; Barron 2005). On 30 July 1945, Burfield transferred to No. 16 Air Crew Holding Unit to begin his repatriation to Australia and eventual discharge. On 30 November 1945, four years and twenty-two days post enlistment, Flight Lieutenant Burfield was discharged from the RAAF having acquired over 780 total hours flying time across five different aircraft (Department of Air, Central Office, RAAF n.d.). Flight Lieutenant Burfield died in 26 April 1995 (Lyons 2013a).

8.3.2.1 Unsystematic Surveys

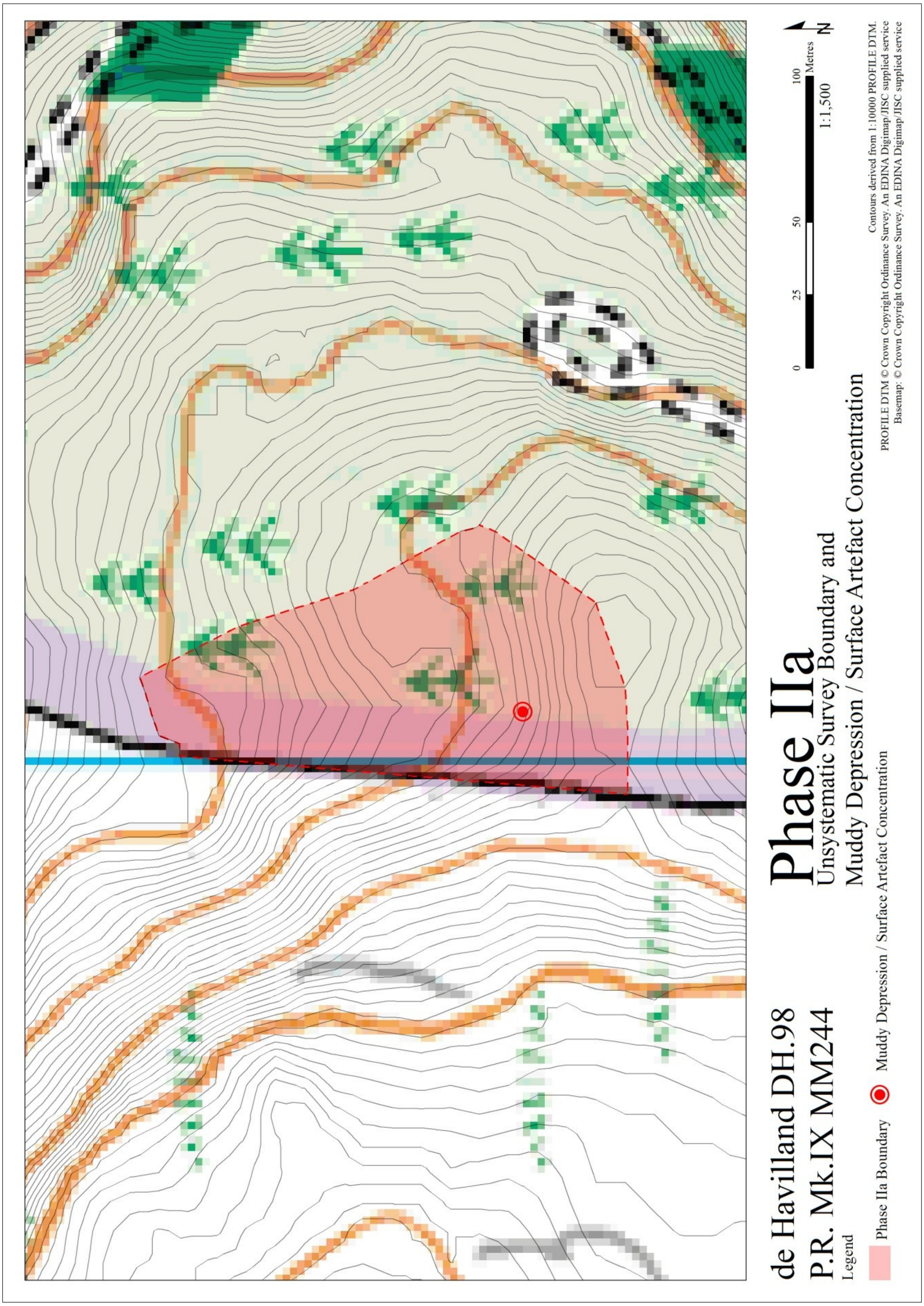
Field Surveys:

Unsystematic Pedestrian Survey:

Begun on the afternoon of 7 July and completed the following morning, the unsystematic pedestrian survey yielded extremely good data from a surprisingly diminutive number of artefacts. An artefact concentration was located in a muddy depression at NH 5501809 3252516 (Map 8-2, Map 8-3, Figure 8-2 and Figure 8-3). Beyond locating this singular concentration, the team observed no further artefacts or artefact concentrations on the surface. Based upon the artefact patterning of similar crashes, the lack of surface scatter most likely evidences contemporary, post-crash debris consolidation or past visitors' removal of artefacts.



Map 8-2: MM244 Phase IIa survey boundary (Crown Copyright/database right OS 2013b; Author). The FC-S land boundary served as the western edge of the MM244 Phase IIa survey boundary.



Map 8-3: Close-up of MM244 Phase IIa survey boundary including the only surface artefact concentration located (the muddy depression/surface artefact concentration located at NH 5501809 3252516) (Crown Copyright/database right OS 2013a, 2013b; Author).

Figure 8-2: The major artefact concentration located during the Phase IIa unsystematic pedestrian survey viewed facing south (Author).
The pink string demarcates the edges of Trench 1 excavated during Phase IIIa.

Figure 8-3: The NH 5501809 3252516 depression viewed facing north (Author).

Unsystematic Metal Detector Survey:

The unsystematic metal detector survey did not include georeferencing of identified debris as georeferenced Phase IIa MD surveys had not yet been added to the PAAR Methodology. The survey team's initial examination of the site's subsurface dimensions located a number of individual contacts as well as a singular, large subsurface anomaly. Located in the same general area as the surface concentration/depression, the subsurface anomaly extended beyond the surface concentration/depression by approximately 2 meters north-east and 0.5-1.0 meters south-west. Attempting to tune out smaller metal fragments yielded no additional information on the depth or dimensions of the subsurface anomaly as the surface scatter was made up of generally large artefacts. The presence of the large surface artefacts effectively shielded the subsurface anomaly from further assessment.

8.3.3 Phase IIb Detailed Data Survey

Field Surveys:

Prior to initiating the Phase IIb field surveys, a north-south oriented site datum was established at NH 5501809 3252916. A physical string grid measuring 20 metres by 30 metres oriented north-south was established. The size of the grid was based upon the outermost Phase IIa surface and subsurface contacts plus a 10 metre margin to the west (Map 8-4). In order to identify whether artefacts were distributed further along the approach vector, the grid's western edge was extended outside the boundaries determined from Phase IIa surveys. Based on the belief that the aircraft's last vector was west-southwest to east-northeast, the extension of the western boarder supported inclusion of a nearby land boundary. The 20 metre by 30 metre grid was subdivided into 10 metre wide reference transects and one meter wide working transects. This divergence from the more standard 10 meter wide working transects reflected the site's diminutive size. The systematic pedestrian and systematic metal detecting surveys were conducted simultaneously. The site was surveyed twice using the 2-2-90 technique. The first survey began in the northeast corner and worked across the grid in a serpentine movement. The second survey was conducted perpendicular to the first using 10 metre wide reference transects and one metre wide working transects. Assuming a metal detector diameter sweep of three meters, this method meant that each transect was effectively surveyed no less than six times at perpendicular angles. Once discovered, a contact was geo-referenced and excavated (if a subsurface contact). All material was bagged and labelled for removal and analysis (Document 8-3).

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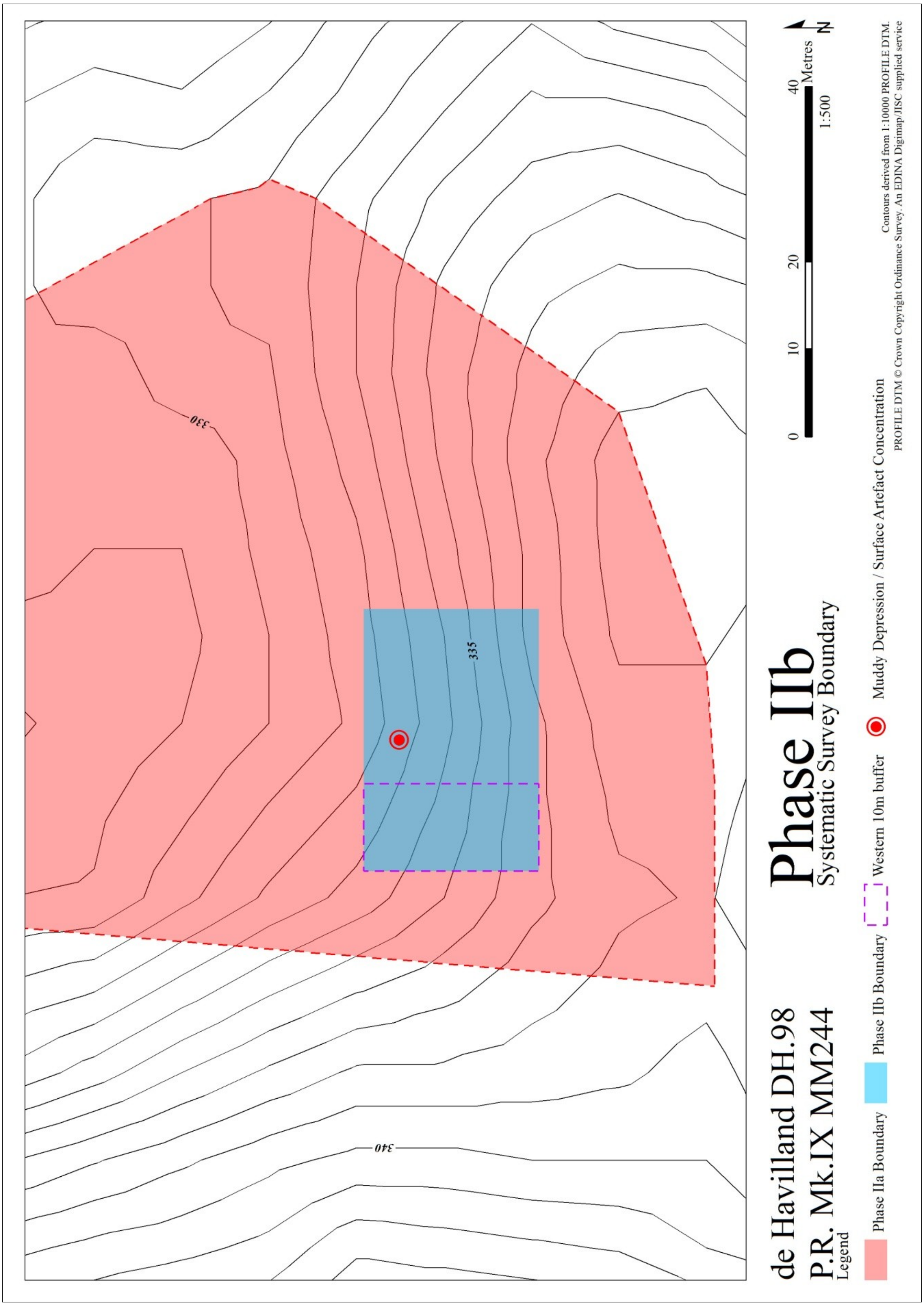
Document 8-3: Phase IIb *PAAR Aircraft Incident Record* form for DH.98 MM244 (ICAO 2006; Author).



Map 8-4: MM244 Phase IIb systematic survey boundary (Crown Copyright/database right OS 2013a; Author).

Systematic Pedestrian Survey:

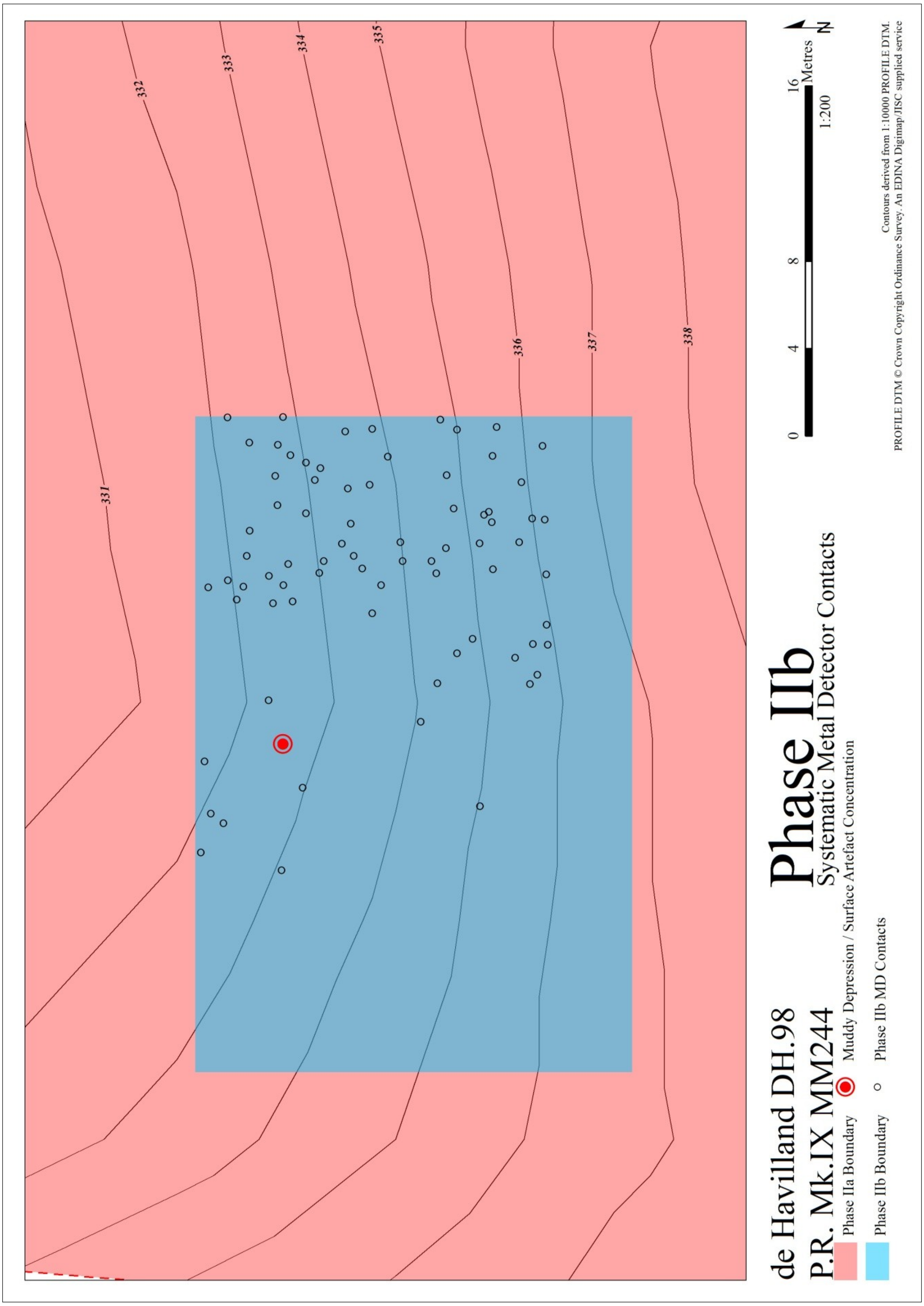
A systematic pedestrian survey of the site was completed 8 July 2010. Beginning in the northeast corner, the systematic pedestrian survey was completed using a standard police line method. Unfortunately, as with the Phase IIa unsystematic pedestrian survey, the Phase IIb systematic pedestrian survey identified no surface finds beyond surface debris located at NH 5501809 3252516. The surface material within the NH 5501809 3252516 depression was left *in situ* as it was only partially exposed.

Figure 8-4: Artefacts visible on the surface of Trench 1 (Author).
More artefacts were visible on the eastern side of Trench 1 (shown) than on the western side.

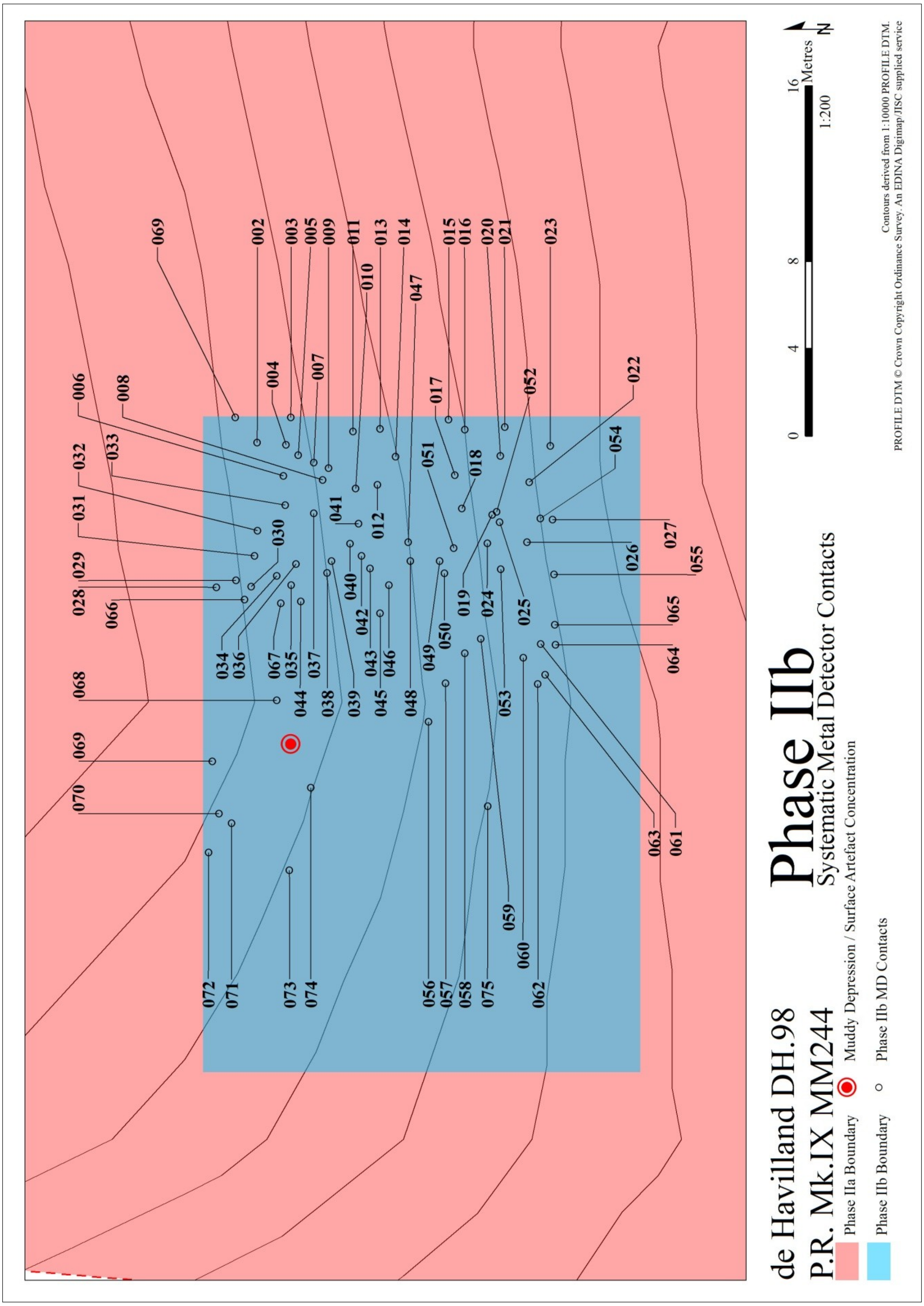
Systematic Metal Detector Survey:

The Phase IIb systematic metal detector survey conducted concurrently with the pedestrian survey returned much better results. The anomalies identified during the metal detecting survey were removed by soil block; the soil block was subsequently broken apart and the anomaly bagged and labelled. The remaining soil was swept for other, unidentified anomalies. All artefacts associated with the same metal detected anomaly were bagged together. The residual, sterile soil was backfilled into the excavated hole and the heather cap replaced.

Seventy-two contacts were identified and excavated during Phase IIb. Amongst the interesting data collected during the Phase IIb metal detector survey was the observed discrepancy in number of artefacts recovered in adjacent transects—fifty-nine artefacts in Transect 1-10, fifteen artefacts in Transect 11-20 and only two artefacts in Transect 21-30 (Map 8-5 and Map 8-6). The NH 5501809 3252516 depression was confirmed to be sizable horizontally and to have irregular boundaries. A decision was made to leave the NH 5501809 3252516 anomaly *in situ* for investigation during Phase IIIa.



Map 8-5: MM244 Phase IIb systematic metal detector survey contacts distribution (Crown Copyright/database right OS 2013a; Author).



Map 8-6: Annotated Phase IIb systematic metal detector survey contacts distribution (Crown Copyright/database right OS 2013a; Author).

Shovel Test Probes:

Based on the information gained in Phase IIa/b pedestrian and metal detector surveys, shovel test probes [STPs] were considered unnecessary for the current site. The decision not to conduct STPs was based on a belief that such probes would not contribute vastly to the understanding of this particular site. While optional under the proposed methodology, the omission of STPs is regrettable as the probes may have provided increased understanding of the southeast corner scatter.

Artefact Analysis:

Artefact distribution analysis revealed two areas of archaeological sensitivity. The NH 5501809 3252516 depression was identified as the primary artefact concentration. A secondary, less concentrated area of archaeological sensitivity was identified east of the NH 5501809 3252516 depression.

8.3.4 Phase IIIa Targeted Excavation

A Phase IIIa excavation focused on resolving the anomaly underneath the NH 5501809 3252516 depression was conducted on 9-12 July 2010. The DH.98 MM244 Phase IIIa investigation utilised an early form of the PAAR Methodology. Judgemental sampling, in the form of a two metre by five metre trench (Trench 1), was the predominant investigative methodology employed. A reference *sondage* (Trench 1.1) was excavated to compare site strata (Map 8-7). Due to the depth and homogeneity of upper soil strata, excavation was initially undertaken using arbitrary excavation procedures before transitioning to natural stratigraphic excavation procedures in archaeologically sensitive strata. Soil consistency did not allow for extensive vertical control in units 1-2, 2-2, 1-3, 2-3, 1-4 and 2-4. Artefacts' superpositional relationships were noted but accurate working depth measurements were impossible to obtain.

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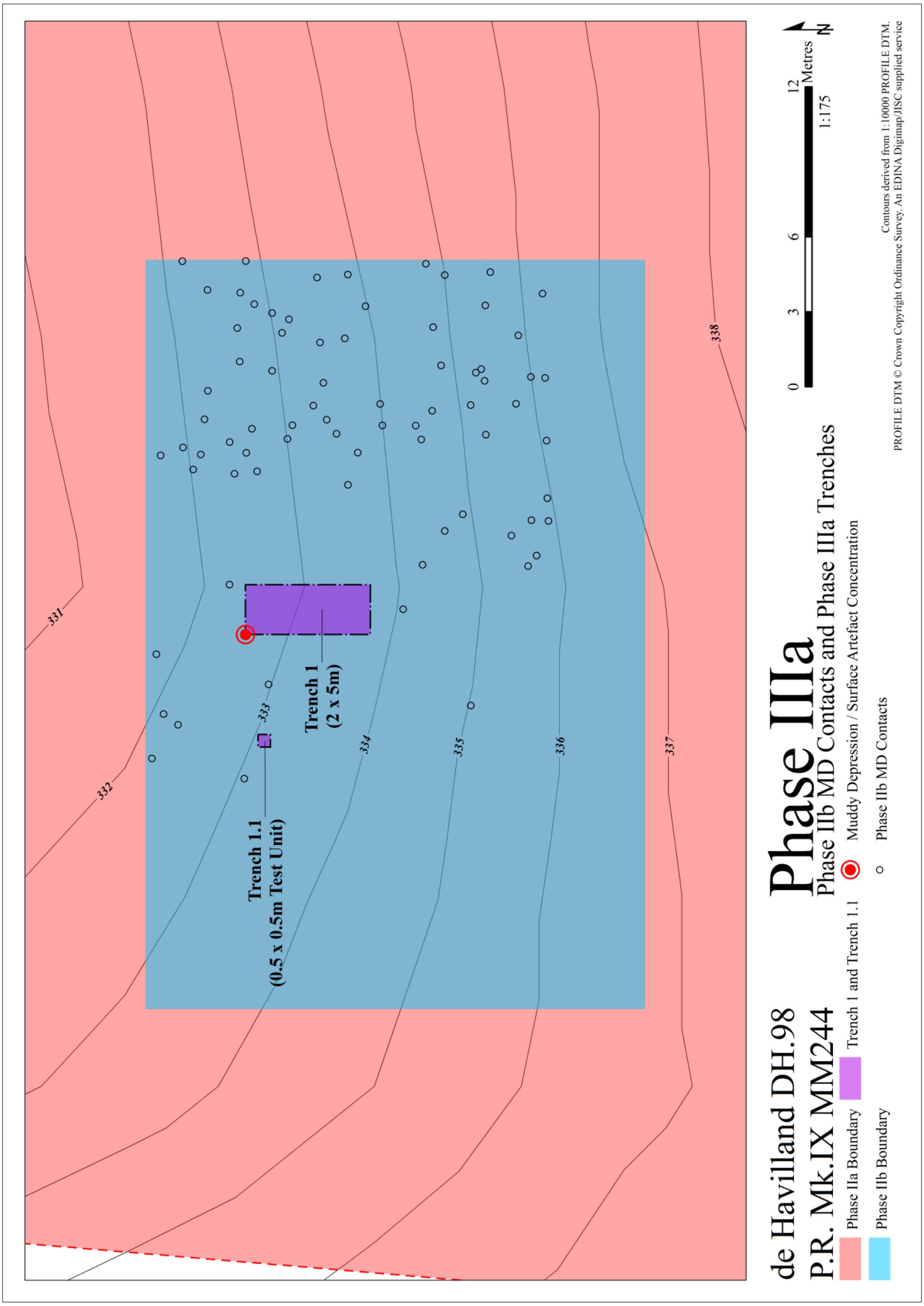
Document 8-4: Phase IIIa *PAAR Aircraft Incident Record* form for DH.98 MM244 (ICAO 2006; Author).



Map 8-7: MM244 Phase IIIa trench locations and Phase IIb metal detector survey contact distribution (Crown Copyright/database right OS 2013a; Author).

Test Trench:

Judgemental sampling of the MM244 site proved extremely productive. Due to focusing crew efforts on a single trench, over 1,050 artefacts (including some 321 organic artefacts) were recovered and the plane's final flight path tentatively plotted.

A single two metre by five metre test trench was placed within Transects 14 and 15 at NH 5501809 3252826 (Figure 8-8 and Figure 8-7). The area selected contained a large concentration of visible debris. A small trench was used as it caused little archaeological damage to the wider site and conformed to Forestry Commission-Scotland stipulations.[3] The expressed goal was to stratigraphically excavate and document both the partially exposed debris and the associated subsurface anomaly identified in the metal detector surveys. The trench was sub-divided into ten, one-meter units in order to provide horizontal control (Figure 8-5 and Figure 8-9).

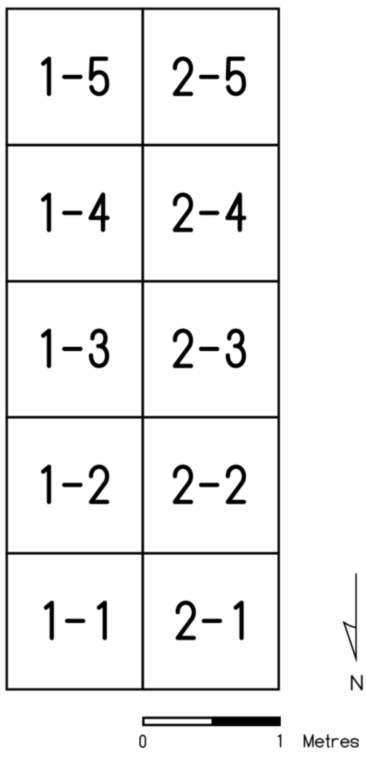


Figure 8-5: The ten, one-meter sub-units of Trench 1 which provided horizontal control (Author). Horizontal control became critical to the excavation of Trench 1 due to the high water table and rain causing soil instability.

[3] As part of granting access for the investigation of de Havilland Mosquito MM244, Forestry Commission-Scotland required that no trees be pruned, temporarily removed and/or cut down. As such, any excavation trenches had to conform to the positions of extant trees.

Excavation began in units 1-1, 2-1, 1-4, 2-4, 1-5 and 2-5 as these units presented the trench's highest points of elevation. The methodological plan anticipated taking units 1-1, 2-1, 1-4, 2-4, 1-5 and 2-5 down by 30 cm arbitrary strata to the same relative height as the centre units in order to establish that associated debris did not extended beyond the centre concentration. The removed bulk was assessed for unobserved metal artefacts via metal detector. Hand excavation was utilised for the remainder of the trench.

Due to recent rainfall, it quickly became apparent that stringent vertical control was not feasible. The combination of a low water table and rain caused the low-lying trench centre to become an unstable muddy quagmire (Figure 8-6). As soon as one area was cleaned, the outlying soupy clay immediately refilled the cleaned region.

Figure 8-6: Trench 1 following overnight rain (Author).
The combination of a low water table and rain caused the low-lying trench centre to become an unstable muddy quagmire.

Although the team prepared to sieve trench spoil, trench spoil was not sieved due to unexpected constraints. First, the soil conditions encountered were not conducive to dry sieving. The soil encountered consisted of a blackish-brown clay overlying a yellow sandy parent strata. The high water table and wet weather rehydrated the clay soil into a consistency somewhere between potter's clay and thick toothpaste. As such, the soil resisted free passage through the sieves. Manually pressing all excavated material through the sieves was rendered unfeasible by the high quantity of unsorted rock inclusions.

Two enacted measures ensured adequate spoil scrutiny, thereby counteracting the possibility of discarding important data contained within the unsieved material. The first measure employed the soil consistency to its advantage. All material excavated was hand sieved through the archaeologists' fingers. The soil consistency was of such liquidity that the act of softly closing one's hand around a fist full of soil—thereby actively squeezing the held dirt through interdigit spaces—left any artefact inclusions within the researcher's palm. This method was particularly successful in the collection of overlooked wood fragments. The second process ameliorating the decision to not sieve excavated spoil necessitated the screening of all spoil using a metal detector. This secondary screening of spoil for metal artefacts proved useful in recovering a few items overlooked during excavation and primary screening.

While small finds were recovered from units 1-1, 2-2, 1-4, 2-4, 1-5 and 2-5, a majority of the large parts recovered were excavated from unit 1-3. In unit 1-3, large nondiagnostic metal fragments (possible engine nacelle cowlings or the leading edges of wings) overlay artefacts associated with the aircrafts internal workings. The layering of outer and inner parts suggests either an in-tact wreck site or a purposeful/controlled disposal of debris following the initial crash. Although evidence of charring existed in unit 1-1, no artefactual evidence for unit 1-1's charring was observed. A strong smell of petrol permeated unit 1-3 at the end of the day.

The Phase IIIa excavation of Trench 1 proceeded with removal of soil from units 1-1, 2-1 and 2-2 but the units yielded no further finds and appeared incident-sterile. As such, focus shifted to the removal of soil in units 1-4, 1-5 and 2-5. Soil removal in these units exposed a large bedrock formation (Figure 8-7 and Figure 8-8). Several pieces of diagnostic artefacts lay in direct contact and close proximity to the protruding bedrock, including engine valve heads, a resin or Bakelite disk and sections of wooden supports (Appendix

Figure 11-94 and Appendix Figure 11-95). Of great interest was the exposure of an incident-sterile gravel and bedrock parent stratum showing a major colour change cross-cutting the trench. A strong petrol smell was extremely evident at the strata change with small oil stains visible under artefacts. The gravel and bedrock parent stratum appears to be the lowest point of contact for aircraft debris and may indicate the original ground surface of aircraft impact.

Units 1-1, 2-2 and 3-3 were sectioned to confirm the continuation of the parent stratum across the whole of the trench (Figure 8-10). A single 0.5 metre by 0.5 metre *sondage* was excavated at approximately NH 5501359 3252466 in order to assess whether Trench 1's parent stratum was an isolated alluvial stratum (and thus associated with an old burn) or a more general stratum running across the site. For clarity, the 0.5 metre x 0.5 metre test unit was demarcated as Trench 1.1. No continuation of Trench 1's yellow sandy parent strata was observed in Trench 1.1.

Figure 8-7: Trench 1 viewed facing south (Author).

Figure 8-8: Trench 1 viewed facing north (Author).

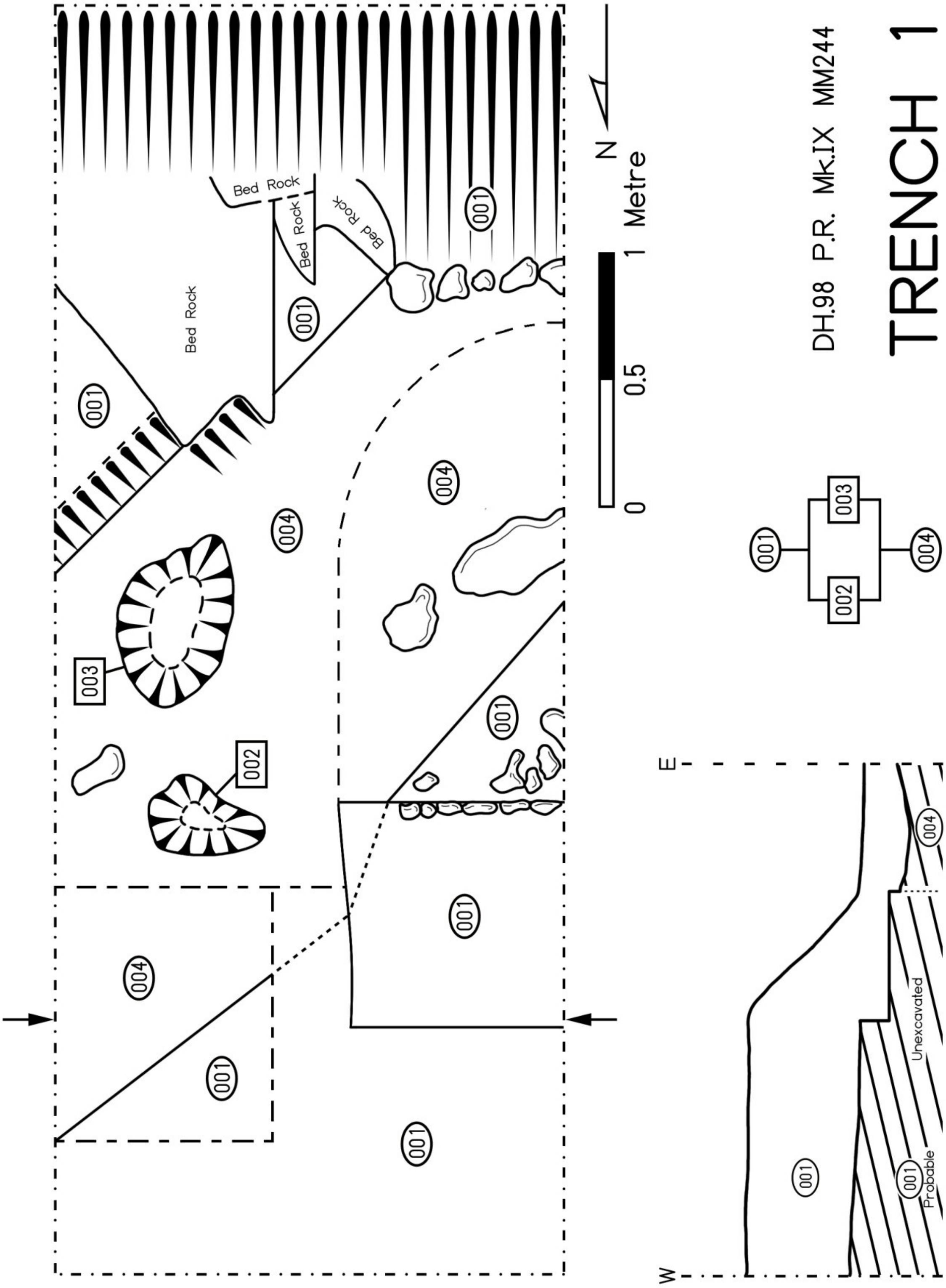


Figure 8-9: Plan and section of Trench 1 (Author).

Figure 8-10: Units 1-1, 2-2 and 3-3 were sectioned to confirm the continuation of the yellow sandy parent soil (context 004) across the whole of the trench (Author).
The isolated alluvial depression cuts diagonally across the trench with the northern edge of the natural cut following the arrow markers (left). The yellow sandy soil visibly contrasts with the topsoil (right).

Test Unit:

A single reference *sondage*, Trench 1.1 (NH 5501359 3252466), was excavated in order to compare the wider site stratigraphy with that observed within Trench 1. Dissimilar stratigraphy to that noted in Trench 1 was observed in Trench 1.1. Indeed, the yellow sandy parent soil (context 004) was not noted in Trench 1.1. The lack of similar parent strata between Trench 1 and 1.1 supports the hypothesis that Trench 1 is arrayed across an older, now covered burn.

Figure 8-11: Trench 1.1, a 0.25 metre by 0.25 metre reference *sondage* excavated to compare stratigraphy with Trench 1 (Author).
Trench 1's yellow sandy parent soil (context 004) is not seen in Trench 1.1.

Following cartographic analysis of the Phase IIb pedestrian and metal detecting surveys, the decision was made to forgo systematic sampling of the small site. This decision allowed the project team to stay within budget, maximise time and human resources, and preserve as much of the site as possible for future research. Judgemental sampling of the site, in the form of a two metre by five metre trench across the NH 5501809 3252516 anomaly/depression, satisfied the aforementioned objectives while positively identifying the NH 5501809 3252516 anomaly.

8.4 Artefact Analysis

Phase IIb and Phase IIIa surveys and excavations provided useful artefactual and stratigraphic data. Out of the 1,219 total artefacts recovered, 48 artefacts were classified as diagnostic and 258 were classified as nondiagnostic(diagnostic). Of the artefacts, 981 were non-wood artefacts; 238 wooden and wood composite artefacts were recovered. Most of the wooden artefacts recovered were too degraded to conduct speciation analysis. Nonetheless, samples were taken and preserved using the PEG methodology described in Chapter 5, Section 5.2.7.

Most of the material—diagnostic, nondiagnostic(diagnostic) and nondiagnostic alike—were recovered from the southern segment of Trench 1 in close proximity to an outcrop of bedrock. The violence of impact and/or post-crash recovery and corrosion has made a vast majority of the material unidentifiable. For brevity, the distribution of artefacts from four diagnostic artefact sub-categories, indicative of the larger distribution, will be examined: rocker arms, camshafts, poppet valves and miscellaneous components. The selections reflect not only the larger artefact distribution of Trench 1 (Figure 8-12) (artefacts were observed to follow a distributive alignment across metre units 1-2, 1-3, 2-3 and 2-4), but also are characteristic of the overall components recovered. Indeed, the vast majority of the diagnostic artefacts recovered are either associated with the engines or with the airframe in proximity to the engines.

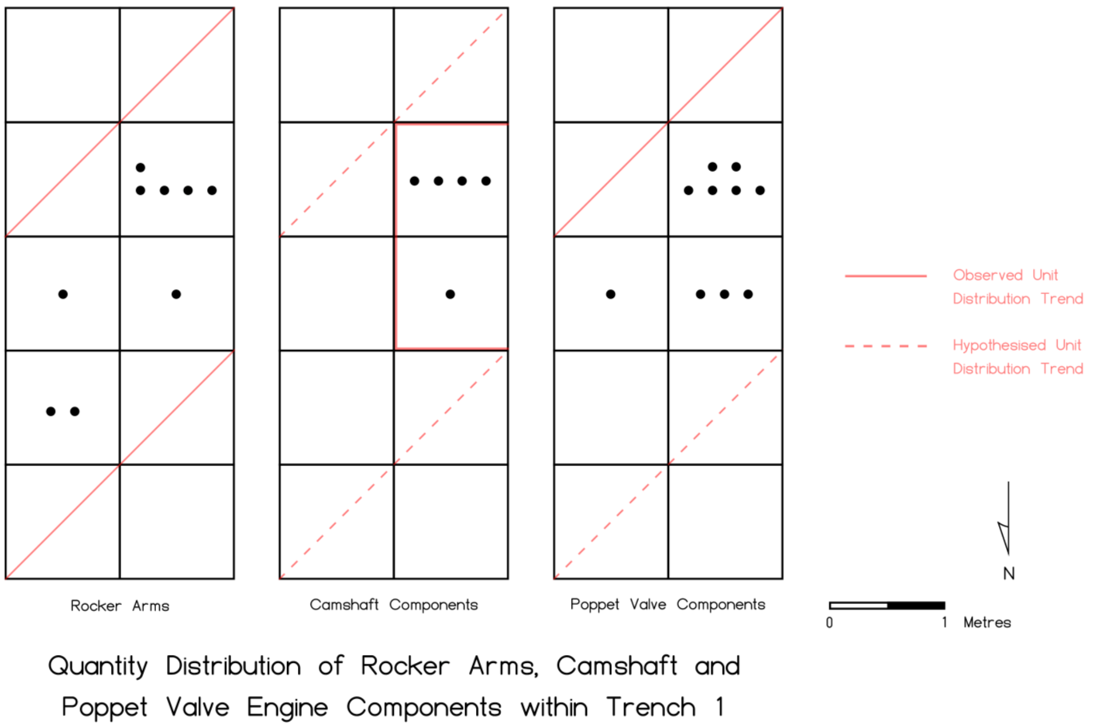


Figure 8-12: Quantity distribution of rocker arms, camshaft and poppet valve engine components within Trench 1 (Author).
Artefacts within Trench 1 were observed to follow a distributive alignment across metre units 1-2, 1-3, 2-3 and 2-4 comparable to the alignment of the yellow sandy parent soil (context 004).

Rocker arms transfer the radial movement of the cam shaft into linear movement which opens the poppet valve. Linking the camshaft and poppet valves, the distribution of detached rocker arms can inform on the manner of engine disassembly. The rocker arms recovered (40305 or 40306) (UK Air Ministry 1940: 14, 63, 158) (FS 017.01, 229.01, 293.01, 513.01, 527.01, 590.01, 739.01, 760.01 and 761.01) have an elevated presence in unit 2-4 (with 5 rocker arms located) but are otherwise relatively evenly distributed across the trench. The second largest concentration, two rocker arms, was located in unit 1-2. Units 1-3 and 2-3 each contained one rocker arm. All rocker arms recovered show evidence of damage. FS 229.01, 513.01, 527.01, 760.01 and 761.01 show destructive terminations before the rocker shaft hole (Figure 8-13). FS 017.01, 293.01, 590.01 and 739.01 retain portions of the rocker shaft hole but show extreme distortion of the rocker arm. Looking down the camshaft, the rocker arm to tappet segment of FS 590.01 is twisted 90 degrees about the y-axis while FS 017.01 has an approximately 45 degree bend along the z-axis (Appendix Figure 11-96). The uneven distribution and disarticulated disposition of the rocker arms evidences peri-crash dismantlement of the engine. It is unclear whether the higher concentration of rocker arms in unit 2-4 is indicative of post-event site sterilisation practices, with the burn used as a convenient depression for debris burial, or if the concentration represents the location of an engine's impact. Indeed, the alignment of the rocker arm distribution with the parent strata can signify either scenario.

Figure 8-13: Rocker arms (40305 or 40306) recovered from MM244 Trench 1 (Author). Top row, left to right: FS 229.01 (Unit 2-4), FS 513.01 (Unit 2-4), FS 527.01 (Unit 2-4); middle row: FS 739.01 (Unit 2-4), FS 760.01 (Unit 2-4), FS 761.01 (Unit 2-4); bottom row: FS 590.01 (Unit 2-3), FS 017.01 (Unit 1-3).

Camshaft components (40229 or 40230; 40250) (UK Air Ministry 1940: 12, 62, 157) (FS 060.01, 098.01, 510.01, 528.01 and 545.01) (Figure 8-14) are more concentrated than the linear distribution observed with the rocker arms. All camshaft components were located in unit 2-4 with the exception of FS 545.01. FS 545.01 was discovered in unit 2-3. The concentration of camshaft components in units 2-3 and 2-4 suggests that all recovered camshaft equipment was originally derived from one engine. FS 510.01, a camshaft cover (40229 or 40230) (UK Air Ministry 1940: 12, 62, 157), has been torn from its securing bolts on one side. FS 545.01 has been ripped diagonally across the shaft. FS 528.01 has a pronounced bend at one end and a broken off opposing end. FS 060.01 shows similar end breakages to that observed on FS 528.01. The most pronounced damage to the camshaft assembly is observed on FS 090.01. Remnants of the camshaft, still mounted in the carrier (40229 or 40230) (UK Air Ministry 1940: 12, 62, 157), have been broken off on each end; the cast metal carrier has a rip approximately three inches across the centre. The damage observed would be consistent with both a violent impact into bedrock and explosive disassembly. All recovered artefacts bear witness to sudden and violent disarticulation and the close proximity of the camshaft components to the bedrock in units 1-5 and 2-5 provides additional evidence for the theory of crash-induced engine rupture.

Figure 8-14: Camshaft components recovered from MM244 Trench 1 (Author). Clockwise from top left: FS 098.01 (Unit 2-4), FS 510.01 (Unit 2-4), FS 545.01 (Unit 2-3), FS 528.01 (Unit 2-4) and FS 060.01 (Unit 2-4).

The distribution of confirmed poppet valve components (44760 or 41700) (UK Air Ministry 1940: 64, 132, 205) (FS 219.01, 233.01, 238.01, 294.01, 301.01, 530.01, 587.01, 588.01, 757.01, 758.01, 759.01 and 770.01) (Figure 8-15) forms a pattern similar to that of the camshaft fragments. Eleven poppet valve components, the majority of sub-assemblage, were recovered from unit 2-4. An additional four poppet valve components were recovered from unit 2-3. Only two poppet valve components were located outside units 2-4 and 2-3. FS 294.01 was discovered in unit 1-3 while MD 071.01 was found in grid 2. All poppet valves show substantial deformation, the most common of which is folding. FS 219.01, 233.01, 238.01 and 789.01 are fragmentary, having been torn across the valve head. Curiously, FS 759.01 shows evidence of metal on metal gouging. The directionality of the gouges (intersecting at 90 degrees) suggests engine break-up on impact. The earlier, lighter and longer gouges hypothetically result from the engine components' momentum causing breakup along the axis of flight while the secondary, deeper and shorter gouges possibly result from weighty engine components settling vertically. The valve stems (FS 035.01, 069.01, 070.01, 251.01, 515.01, 530.01, 770.01 and MD 071.01) show similar peri-crash damage. Indeed, a majority of the identified valve stems (FS 035.01, 069.01, 070.01, 251.01 and 515.01) show truncation of the poppet valve unit prior to the valve head as well as varying degrees of valve stem deformation. The most common valve stem deformation is severe bending. Except for FS 530.01, all poppet valve heads were uncovered in an inverted position (i.e., the piston/cylinder face was oriented up). Given the disarticulated distribution of the valve heads, it is thought that the observed orientation of the valve heads is the result of initial engine dismantlement and subsequent natural soil sorting phenomena.

Figure 8-15: Poppet valve fragments recovered from MM244 Trench 1 (Author).
Top row, left to right: FS 757.01 (Unit 2-4), FS 758.01 (Unit 2-4), FS 759.01 (Unit 2-4), FS 238.01 (Unit 2-4), FS 233.01 (Unit 2-4), FS 219.01 (Unit 2-4); third row: FS 588.01 (Unit 2-3), FS 587.01 (Unit 2-3), FS 530.01 (Unit 2-3); second row: FS 294.01 (Unit 1-3), MD 071.01; bottom row: FS 770.01 (Unit 2-4).

Miscellaneous diagnostic artefacts include a variety of artefact types. MD 054.01, discovered at approximately NH 5501913 3252760, is the only glass/Perspex fragment recovered (Figure 8-16). The photo-reconnaissance variant of the Mosquito only had glass/Perspex installed in the cockpit and nose area (Thirsk 2006: 54). The flat form of MD 054.01 suggests that it is a part of the windscreen/window. The proximity of MD 054.01 to other artefacts further advances the windscreen/window hypothesis. For example, MD 053.01 was discovered only three metres from MD 054.01. MD 053.01 has part stamps, including the known aircraft associated “Serial No” and “DFG No” embossing; the characteristic red doping over the metal structure and the embossed part stamp descriptive fields identifies MD 053.01 as a MM244-related artefact (Figure 8-17 and Appendix Figure 11-97).

Figure 8-16: MD 054.01, the only glass/Perspex fragment recovered (Author).
The flat form of MD 054.01 suggests that it is a part of the windscreen/window.

Figure 8-17: MD 053.01, a nondiagnostic(diagnostic) fitting discovered three metres from MD 054.01 (Author).
The characteristic red doping over the metal structure and the embossed part stamp descriptive fields identifies MD 053.01 as a MM244-related artefact.

Located near the top of the low hill (NH 5501841 3252758) and close to MD 053.01 and 054.01 is MD 061.01. A rescue dinghy CO_2 inflation bottle, MD 061.01 (Figure 8-18) would have been installed in the centre section of the aircraft (behind the cockpit but forward of bulkhead three) (Thirsk 2006: 54). The associated locations of MD 061.01 and

MD 054.01 (the suspected windscreen/window fragment) mark the only areas where cockpit associated components were recovered.

Figure 8-18: MD 061.01, a rescue dinghy CO2 inflation bottle (Author).
The associated locations of MD 061.01 and MD 054.01 (the suspected windscreen/window fragment) mark the only areas where cockpit associated components were recovered.

8.5 Comprehensive Site Analysis

As stated previously, no finds were recovered during the Phase IIb systematic pedestrian survey. This finding is incongruous with expected artefact patterning. Based on accounts given by the crew, MM244 continued on a stable, unpowered glide heading toward Loch Ness following the crew's abandonment. Such a glide predicates a relatively shallow angle, low speed impact. As such, it was hypothesised that the aircraft would have impacted the upstanding trees well before it impacted the hillside. The combination of the plane's suspected glide slope and the presence of heavy foliage should have resulted in major break-up of the wooden plane prior to its impacting solid ground. As such, a majority of parts were hypothesised to have been scattered on the ground surface rather than driven into the loose soil. While a portion of the wood may well have burnt, decayed or been recovered contemporaneous with the crash, the near total absence of material, including the second engine, outside the NH 5501809 3252826 grouping is perplexing.

Though only a limited number of artefacts were confirmed and major components are still unaccounted for, the data gained from the investigation of MM244 using the first attempt at a phased research methodology allows for the deduction of an evidence-based crash narrative. Primary source accounts state that MM244 was last seen in a level glide towards Loch Ness. The disparate scatter observed between transects corroborates the historical documentation. Transects 21-30, having the least number of artefacts recorded, align well with the supposed flight plan; the aircraft would have largely passed over Transects 21-30 with momentum casting artefacts further afield. Transects 1-10 and 11-20, having an increasingly higher number of artefacts recorded, confirm the hypothesis; during break-up, aircraft components initially were cast in an east to northeast direction.

Excavation refines the proposed crash narrative. The concentration of confirmed engine components within Trench 1, especially favouring the southern, bedrock-abutting portion of Trench 1, provides evidence for the violent destruction of at least one of MM244's two engines. Moreover, the location of the hypothesised impact site at the edge of the FC-S plantation would have allowed the aircraft to initially impact the ground largely unhindered by heavy tree growth. It is believed, based upon the stratigraphy observed in Trenches 1 and 1.1, that the yellow parent stratum of Trench 1 was a small burn with partially exposed bedrock at the time of impact. The sudden collision with the bedrock formation broke the port engine apart. The remainder of the aircraft impacted the low hill south and southeast of Trench 1 casting limited debris, including MD 053.01 and 054.01, into Transects 1-10.

8.6 Conclusion

The excavation of MM244 was the earliest of all field investigations. Conducted as an experiment in methodology, the lessons learned from the MM244 excavation were applied to subsequent field work and greatly assisted in the formulation of a comprehensive phased methodology for air crash sites which is both cost and object effective. However, many of the techniques used on the MM244 excavation either were improperly focused or were not fully exploited. While the unsystematic metal detector data returned good inferred data, none of the contacts were recorded or planned. At the time, the PAAR Methodology utilised the unsystematic metal detector survey to gain a feel for the site rather than record contacts identified via unmethodical sweeps. The recording of metal detector contacts, therefore, depended entirely upon the planned systematic metal detector survey. The inability to compare unsystematic and systematic results was identified during post-excavation analysis. Resultant modifications to the PAAR Methodology included the addition of an unsystematic metal detector survey during Phase IIa and the georeferencing of survey contacts.

Moreover, much like avocational aviation archaeology, a heavy emphasis was placed on excavation. The rush to excavate was based upon the lack of available literature to advise on the level of artefact survivability within the specific environment and the still-developing nature of the PAAR Methodology. Nonetheless, the data and material recovered allowed for the generation of a crash site boundary, the designation of archaeologically sensitive areas and a crash narrative hypothesis.

Limited future research, focusing on the subsequently established and field-trialled Phase IIb, is recommended south and east of the survey/excavation established grid. A return to Phase IIb and the use of the fully developed and field-trialled PAAR Methodology would clarify the distribution observed during 2010. For example, following refinement of the PAAR Methodology the post-excavation analysis was revisited and the early termination of the survey grid's eastern boundary scrutinized. The gradual terrain to the east of Transects 1-10 transitions, after some distance, to a steeper slope. The diminutive artefact scatter recorded in 2010 may be (1) due to a considerably longer debris scatter than that originally hypothesised and (2) the post-depositional migration of artefacts down the eastern slope terrain. Returning to a Phase IIb STP survey and Phase IIIa test unit excavation would enable the characterisation of the yellow sandy strata. While current data suggest the yellow sandy soil to be sterile, natural ground, excavating through the layer would resolve post-excavation concern that the strata may be backfill with additional wreckage underneath. Indeed, the use of STPs and/or test units might resolve questions about the deficiency of artefacts beyond northing 83253076.

9 Consolidated LB-30A AM261 (North Goatfell, Isle of Arran)

9.1 Overview

The second site chosen for implementation of Phases I-IIIa of the PAAR Methodology for the archaeological investigation of historic aircraft wreck sites contains a metal framed and metal skinned Consolidated B-24/LB-30A Liberator heavy bombardment aircraft (Figure 9-1). The B-24/LB-30A's primary manufacturing material, large production numbers and widespread adoption by Allied air forces make the aircraft an excellent resource for demonstrating the widespread applicability of the PAAR Methodology and for evaluating the surface and sub-surface endurance of metal aircraft components. Both the potential for site identification and interpretation and the effects of natural and anthropogenic factors on artefact mobility are revealed by the PAAR Methodology directed investigation of the LB-30A AM261 (North Goatfell, Isle of Arran) wreck site.

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Figure 9-1: An LB-30A, believed to be AM258, in flight (Simons 2012: 26).

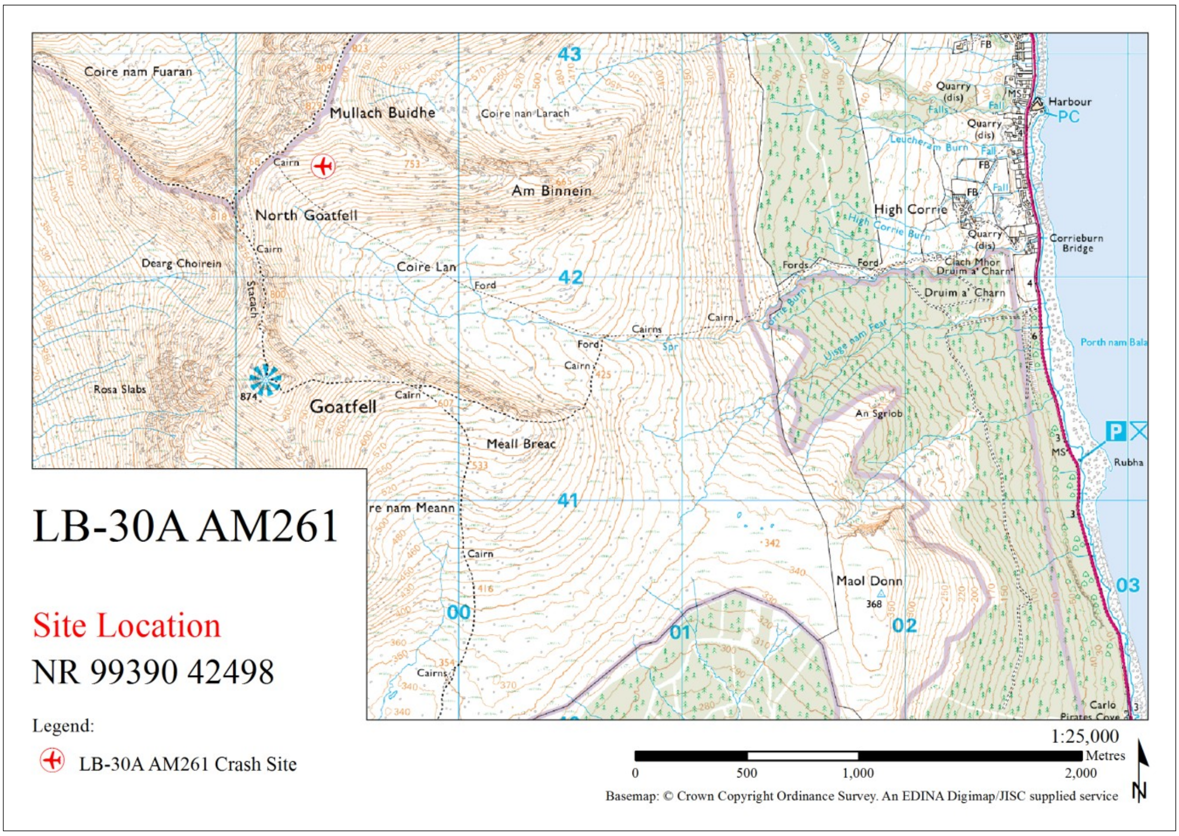
9.1.1 Site Background

On the day of the crash, 10 August 1941, AM261 took off from RAF Ayr to complete a crossing of the North Atlantic Route with eventual arrival at Gander, Newfoundland. The twenty passengers on board would, in turn, ferry additional aircraft from Gander to Britain.

AM261 climbed shallowly away from RAF Ayr on a heading which intersected with the treacherous peaks on the Isle of Arran. Climbing into the low clouds, it was anticipated that the aircrew would gain altitude quickly and avoid the high peaks. This was a well-known route. Just eight days prior the aircraft had successfully evacuated the Duke of Kent and his family across the Atlantic, making them the first members of the Royal family to cross the Atlantic by air. The flight plan proposed that AM261 fly the established path: 273 degrees at 1,000 feet asl for 73 minutes followed by a 300ft/m climb rate for 30 minutes. A cruising attitude of 10,000 feet asl would be maintained until close to Gander, Newfoundland. It was anticipated that AM261 would make land-fall over Arran at Whiting Bay and pass safely overhead at an altitude of 4,000 feet asl. Tragically, AM61 impacted the *Mullach Buidhe* (North Goatfell, Isle of Arran) at 1930Z approximately ten minutes after take-off (Air Historical Branch 1941; Davies 2001a: 14; Davies 2001b: 38, 41) (Map 9-1 and Figure 9-2).

The force of impact was considerable and destructive. The aircraft, laden with enough fuel to reach Canada nonstop, exploded and burned. Small fragments of aircraft were cast across the hillside. Indeed, the only large sections observed at the time appear to have been a section of rear fuselage and the engines. While the rear fuselage section remained near the point of impact, it is reported that the engines were deposited in the *Coire Lan*, a considerable distance from the main crash site (Air Historical Branch 1941; Davies 2001a: 14; Davies 2001b: 39). Officially, the accident was classified as a navigational error. However, at least one subsequent researcher has questioned whether the more northern heading and shallow climb rate indicates instrument failure as the source of the atypical flight pattern taken by the highly experienced pilot (Air Historical Branch 1941; Davies 2001a: 14-15; Davies 2001b: 41).

The aircraft apparently struck high on the hillside with debris and 10 bodies collecting in a narrow gully. George Watson (of Corrie, Isle of Arran) was tending to his flock when he discovered the remnants of the aircraft in a burned out patch of ground. A search was undertaken the following night and day during which the remaining deceased were recovered; some of the bodies were discovered almost 500 yards distant. The deceased were buried in Lamlash Cemetery (then Old Kilbride Churchyard) on 15 August 1941 (Davies 2001a: 15; 2001b: 39). After the war, the site was subject to large scale clean up by a scrap merchant (Smith 1989: 646; Davies 2001a: 15). The site is located within the current confines of the Brodick and Goatfell holdings, National Trust for Scotland on the eastern side of the Goatfell range. The impact point is not readily discernible. Artefact removal, mass wasting and new vegetation have disguised any impact-related ground scar.



Map 9-1: Location of Consolidated LB-30A AM261 crash site (Crown Copyright/database right OS 2013b; Author).
LB-30A AM261 impacted the North Goatfell at approximately 700 metres asl.

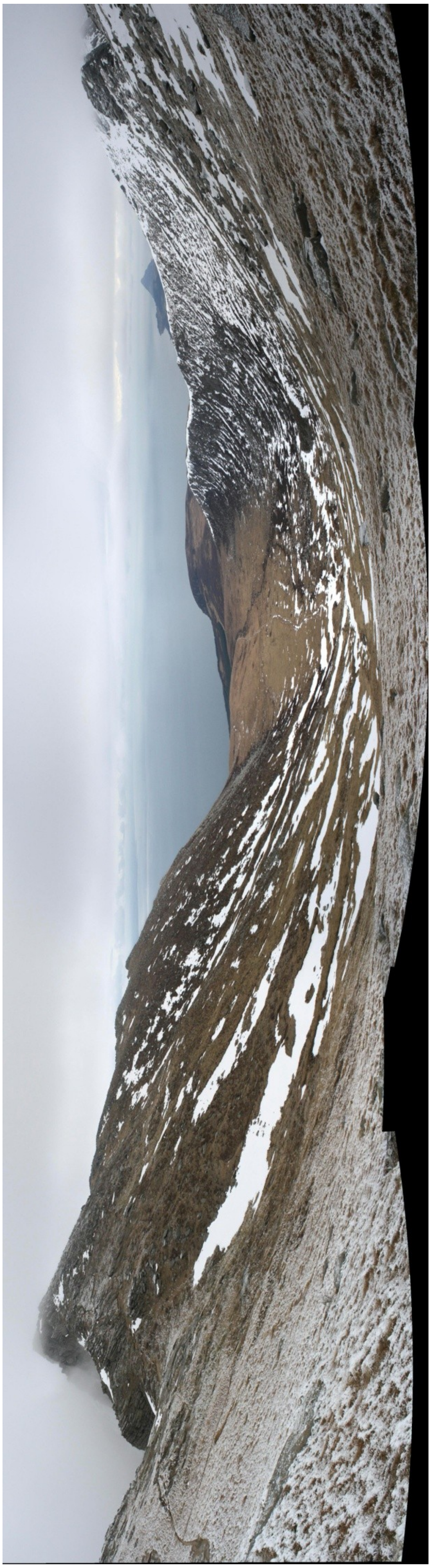


Figure 9-2: The crash site of LB-30A AM261 (Author).
The impact site is the grassy slope centre left.

9.1.2 Investigation Summary

A Phase I historical survey undertaken December 2009-March 2010 identified LB-30A AM261 as compliant with JCCC licensure requirements and, as such, a potential research site. A Phase IIa general data survey was conducted September 2012-April 2013. An unsystematic pedestrian survey was undertaken on 24 February 2013. The unsystematic survey confirmed the presence of a positive debris scatter including the existence of critical diagnostic artefacts such as pressure bottles and engine fragments. Thirty two surface artefacts/artefact groups were recorded along a roughly northwest by north to southeast by south axis. The identified artefact clustering distribution was evaluated against relevant historical documentation to guide the subsequent Phase IIb systematic survey.

A Phase IIb systematic survey was completed on 25 February 2013. The Phase IIb systematic survey focused upon the crowned topography between the *Mullach Buidhe* and the head of the *Coire Lan*. Thirty-eight artefacts/artefact groups not identified during Phase IIa were recorded during Phase IIb. These additional recorded artefacts narrowed the Phase IIa-established primary debris distribution corridor although the diminutive total artefact assemblage undoubtedly reflects post-war debris collection. The systematic survey identified an absence of artefacts above FS 050. The lack of artefacts on the hillside above FS 050 and the presence of an intact tail section, as reported by historical sources, suggests a crash scenario different from that offered in current historical research (e.g., Davies 2001b: 39).

The positive results gained from the Phase IIb survey, the potential for a revised crash scenario and the continued inability to locate the point of impact by survey led to a Phase IIIa targeted excavation of five one-metre test units. Positioned at specific diagnostic artefacts, nondiagnostic(diagnostic) artefacts, heavy artefacts and/or historically identified locations, the test units were chosen in order to determine whether the associated survey artefacts are located at their point of initial deposition or whether their current location is the result of post-deposition artefact relocation. Four of five test units showed the artefacts' current location to be inconsistent with primary deposition. Unit 2 was the only unit with artefacts whose position indicated a long-term presence in their current location. All artefacts exposed during Phase IIIa were georeferenced, photographed, bagged and labelled according to their respective one meter grid square. The excavation team recovered all stable diagnostic and nondiagnostic(diagnostic) artefacts associated with exposed test units. Nondiagnostic parts were placed into their respective test units in a parallel, unidirectional orientation to distinguish their prior excavation from natural deposition should they be re-exposed during future research.

9.2 Airframe Construction

9.2.1 Metal Components

The Consolidated B-24 is an archetype of wartime necessity producing a superior product on a large scale at the cost of aesthetics. Indeed, the B-24 aircraft grew from the personal bravado and genius of Consolidated Aircraft Corporation executives who sought to challenge Boeing's monopoly on heavy bombardment aircraft rather than produce the B-17 on license. When introduced to the Boeing B-17 in 1938, Consolidated's executives believed that their firm could produce a competing aircraft which, though possibly lacking the B-17's sleek lines, could outperform the competition (Simons 2012: 20). While the debate continues to the present day which aircraft was better suited in combat, the design statistics and crew sentiments show the B-24 to be a more than equal match to the much fêted B-17 (Simons 2012: 21, 214-217). The following discussion identifies major design characteristics of the B-24 which may provide critical information during field research. Readers desiring an in depth discussion of design, construction, and manufacturing materials and techniques are referred to the works by W.E. Beall and J.H. Famme, Vice-President in charge of Engineering for Boeing Aircraft Company and Chief Design Engineer-San Diego Division for Consolidated Vultee Aircraft Corporation in 1945, respectively (Beall 1945; Famme 1945).

The first B-24 produced, the prototype Model 32, was a combination of unique design and existing, tested ideas. The characteristic twin tail was taken from the Consolidated Model 31 flying boat (Bowman 1998: 7; Simons 2012: 12, 17, 25). The 'Davis wing' design was licensed by Consolidated from freelance engineer David Davis in 1937 and provided a highly efficient aerofoil that increased operating efficiencies and envelopes (Simons 2012: 22, 24-25). The existing tail and wing designs were mated to a new purpose-designed fuselage that could carry a similar bomb load as the B-17 but had a longer maximum range (Simons 2012: 22). As the British and French were in desperate need of bomber aircraft and the B-24 production design was still being finalised, the US Government released the first six YB-24 aircraft for direct purchase. Originally destined for France, the shipment was redirected to an existing RAF order following the fall of France in June 1940 (Bowman 1998: 7-9, 121; Simons 2012: 27-28). After testing the aircraft, the RAF determined the YB-24 to be insufficient for combat operations. The RAF removed combat related installations and installed equipment for personnel transport. The major structures of the LB-30A, however, remained unchanged (Simons 2012: 29, 32, 231).

The B-24/LB-30A's maximum dimensions are 796 inches long, 1,320 inches wide and 215 inches tall (Figure 9-3) (US Army Air Force 1944e: 1). Recognisable by its flat sided construction, the all metal semimonocoque fuselage is designed to share loads between the stressed skin, the catwalk beam between bulkheads four and six, foreword auxiliary longerons and two aft longerons (Figure 9-4) (US Army Air Force 1941: 4; Consolidated Aircraft Corporation 1942: 61; US Army Air Force 1944e: 1; Famme 1945: 7-8). The centrepieces of the fuselage are the bomb bays. The B-24/LB-30A is designed with two independent bomb bays separated by bulkhead five (US Army Air Force 1944e: 139). Unlike the B-17 which is designed with externally opening bomb bay doors, the B-24/LB-30A uses rolling bomb bay doors which slide vertically along the exterior fuselage walls; the bomb bay doors are outside the aircraft when fully open (US Army Air Force 1944e: 141). The bomb doors are constructed using an aluminium corrugated inner skin and an aluminium smooth outer skin riveted together to produce a strong but flexible structure (Consolidated Aircraft Corporation 1942: 90). In addition to its offensive capabilities, the aircraft is fitted with six gun stations carrying six .50 calibre Browning M2 machine guns and two .30 calibre Browning machine guns (US Army Air Force 1941: 17). In the LB-30A model, the .50 and .30 calibre guns were removed entirely following the LB-30As' pre-operation test flights (Bowman 1998: 121-122; Simons 2012: 32-33, 231).

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Figure 9-3: Dimensions and design of the Consolidated B-24/LB-30A (US Army Air Force 1944e: 2).

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Figure 9-4: Location of Bulkheads 4-6 and twin bomb bays (US Army Air Force 1944d: 6; Author). The catwalk beam between bulkheads four and six, the foreword auxiliary longerons and the two aft longerons are obscured. The catwalk, running between bulkheads four and six, is near number 39. The forward auxiliary longerons are positioned near numbers 14 and 15 while the two rear longerons are aft of number 11.

The B-24/LB-30A wing—composed of a predominantly metal, internally braced, stressed skin design—is characterised by its mid-wing monoplane, tapered full cantilever Davis aerofoil wing (US Army Air Force 1941: 4; 1944e: 1, 114). The 110 foot wing is constructed in three parts: the centre section, the outer section and the wing tips. The centre section is permanently attached to the fuselage in four places. The outer wing section and the wing tips, however, are detachable (Consolidated Aircraft Corporation 1942: 13; US Army Air Force 1944e: 114). The leading and trailing edges are similarly detachable (US Army Air Force 1941: 4; 1944e: 1). In the event of a crash, therefore, the centre section likely will be found in proximity to the fuselage while the outer wing sections may be more widely scattered. The left aileron houses the aileron trim tab (US Army Air Force 1941: 4). The Fowler type flaps, extending from the fuselage to the inboard edge of the ailerons, are controlled via a hydraulic jack on the aircraft's left side. The flaps are covered using an aluminium-alloy sheet riveted to Alclad (US Army Air Force 1941: 4; Consolidated Aircraft Corporation 1942: 15; US Army Air Force 1944e: 115). Rather than being all metal, the ailerons are metal ribbed with fabric covering and an Alclad-reinforced leading edge (US Army Air Force 1941: 4; 1944e: 118). If located at the crash site, the known left side-only installation of the trim tab and aileron control jack may allow for the definitive orientation of observed debris, the aircraft's final vector and/or post-depositional site alterations.

As with the wing, the cantilevered horizontal and vertical stabilisers are predominantly metal. The dual rudders, elevators and rudder/elevator trim tabs are of metal ribbed construction with a fabric covering (US Army Air Force 1941: 4; Consolidated Aircraft Corporation 1942: 27).

Twelve main fuel cells and six auxiliary wing fuel cells are housed within the centre wing section with six on each side of the aircraft's centre line and inboard of engines two and three (Figure 9-5) (US Army Air Force 1941: 259; Consolidated Aircraft Corporation 1942: 141). An additional six auxiliary fuel cells, three per wing, are installed in the outer wing section beginning with B-24 41-23640 (Consolidated Aircraft Corporation 1942: 141). The outer auxiliary fuel cells were not present on LB-30As. The main and auxiliary wing fuel cells are of identical design and, therefore, are of limited use in orienting a confused debris pattern.

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Figure 9-5: Location of fuel tanks within the Consolidated B-24 (US Army Air Force 1944e: 19). The LB-30A variant was not fitted with bomb bay auxiliary tanks (marked as number 4).

The B-24/LB-30A's landing gear is a hydraulically operated tricycle design. This tricycle design landing gear, the first of its kind on a heavy bomber aircraft, consists of two wing-mounted wheels and a nose wheel (US Army Air Force 1941: 4, 6; Consolidated Aircraft Corporation 1942: 217). Unlike the B-17, where the wheels protrude slightly from each wing, the B-24/LB-30A's main landing gear retracts outward and is fully withdrawn into the wing between the engine nacelles. The full encapsulation of the wheel into the wing is the result of the Davis wing's thick cross-section (US Army Air Force 1941: 6). The presence of the landing gear either inside or in proximity to inter-nacelle wing structures may provide data to confirm the position of the landing gear at the time of impact.

The forward landing gear similarly retracts entirely into the aircraft. In flight, the nose gear is covered by nose wheel doors which open and close automatically as part of the landing gear retraction/extension sequence. Additionally, in order to provide "free ground manoeuvrability and stability in a cross wind landing" (US Army Air Force 1941: 6), the nose gear is designed to caster (US Army Air Force 1941: 6; 1944e: 153). As such, the retracted or extended position of the nose wheel may provide some information on the position of the landing gear during the crash sequence. The ability of the nose gear to freely move based upon exterior inputs, however, renders the observed orientation of the nose gear less reliable in determining the angle of impact.

Powering the B-24/LB-30A's are four R-1830 Twin Wasp engines each equipped with a mechanical supercharger (US Army Air Force 1941: 7; 1944e: 221). Installed as blended nacelles into the centre wing section, the engines are affixed via interchangeable welded tubular steel engine mounts bolted to the front spar (US Army Air Force 1941: 118; Consolidated Aircraft Corporation 1942: 15). As with the engine mounts, all nacelle components are interchangeable. As such, the positive identification of individual engines is reliant upon the location of engine serial numbers and the distribution of a majority of engines nacelles; the identification of engine nacelle ancillary components does not provide sufficient documentation to positively identify individual engines.

9.2.2 Plexiglas Components

Unlike many of the aircraft of the period which utilise a combination of Perspex/Plexiglas and glass in windscreen/wind construction, the B-24/LB-30A utilises Plexiglas almost exclusively. Much of the Plexiglas is located forward of bulkhead four in three primary installations: the nose, the observation dome and the pilot/co-pilot windscreen. The observation dome is constructed from one piece of Plexiglas mounted onto an inward opening escape hatch. The nose and flight deck windscreen make use of Plexiglas panels composited in a ribbed frame (US Army Air Force 1944e: 139). A single glass pane, the bombardier's sighting window, is fitted at the centre of the composite nose window. The nose of the B-24/LB-30A was largely constructed from Plexiglas in order to provide the bombardier/nose gunner with an expansive field of view. Unlike later models which fitted an enclosed tail turret with large Plexiglas windows (e.g., US Army Air Force 1944e: 564), the early models of the B-24 lack substantial rear protection with rear visibility (IWM 2013a) (Figure 9-6). If Plexiglas is found in quantity on B-24/LB-30A wreck sites, the predominant installation of Plexiglas within the forward end of the aircraft allows for the relatively sure identification of the cockpit impact site.

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Figure 9-6: The early models of the B-24/LB-30A lack substantial rear protection with rear visibility. This particular aircraft, LB-30A AM259, was one of the original six LB-30A aircraft purchased by the RAF. The shipment of six aircraft also included LB-30A AM261 (IWM 2013a).

9.3 Archaeological Investigation

9.3.1 Phase I Historical Survey

A Phase I historical survey conducted from December 2009-March 2010 confirmed LB-30A AM261 as a viable excavation case study. As prescribed under the proposed PAAR Methodology, the Phase I historical survey was devoted to collating basic site information including: (1) the type of aircraft involved, (2) the data and general location of the incident, (3) the number, names, and disposition of the aircrew and passengers, (4) the specific location of the wreck site as recorded in primary and/or secondary sources, (5) the details of the current land owner, and (6) any supplementary information detailing known post-depositional site interactions and/or previous excavations.

LB-30A AM261 was one of six original Consolidated YB-24 Liberators converted by the RAF to personnel transport use following unsatisfactory combat operation trials. The aircraft crashed into the *Mullach Buidhe* near North Goatfell (NR 993 425) on 10 August 1941 with the loss of all 22 aircrew and passengers (Appendix Table 11-10). Hill walker photographs and commentary (e.g., Smith 1989: 646; Wotherspoon *et al.* 2009: 284; Clark 2012g; Lyons 2013b) classify the site as retaining few pieces of sizeable aircraft remains. Based upon archival reports of extant debris, AM261's compliance with JCCC licensure requirements and the experimental requirements of this thesis, a Phase I *PAAR Aircraft*

Incident Record form (Document 9-1) was generated with research continuing into Phase IIa.

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Document 9-1: Phase I *PAAR Aircraft Incident Record* form for Consolidated LB-30A AM261 (ICAO 2006; Author).

9.3.2 Phase IIa General Data Survey

The Phase IIa general data survey (Document 9-2) conducted from July 2012-March 2013 established a history of the aircraft and aircrew, a basic crash narrative and the existence of post-depositional activity. Analysis of the available historical documentation and debris scatter showed AM261 to be an appropriate case study for trialling the PAAR Methodology at a site with known contemporaneous and long-term artefact attrition. A map regression study from 1904 to 2013 showed no substantial alteration to the site which would impact the spread or quantity of debris. The retention of a linear artefact distribution suggested the core of the site to be relatively well defined and further supported continuation of research to include a systematic pedestrian survey.

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Document 9-2: Phase IIa *PAAR Aircraft Incident Record* form for Consolidated LB-30A AM261 (ICAO 2006; Author).

Background Research:

Primary Source Accounts:

Primary source material available regarding the crash of LB-30A AM261 is limited; however, the *AM Form 1180* provides relevant, if brief, information. *AM Form 1180* confirms that the mission profile was an "E to W atlantic [sic] flight returning aircrew to Canada" and that the time of impact, reported incorrectly, was 2040Z (UK Air Ministry 1941). More critical for the interpretation of debris distribution patterning, the form also provides a brief crash narrative stating that AM261 "Struck mountain in bad viz [visibility] due to errors in navigation (Mountain 25 miles from Ayr & 4 1/2 miles of prescribed track). Reason for errors N/K [not known] Possibly [sic] extraordinary air currents, usually associated with bad weather in Corrie Glen area contributed to actual crash" (UK Air Ministry 1941). Finally, *AM Form 1180* identifies the area of impact as one mile north of Goatfell, Isle of Arran and notes the occurrence of a post-crash fire (UK Air Ministry 1941). In addition to *AM Form 1180*, an accident investigation and official report was generated for AM261. *W-1086a*, the official accident report, includes an additional focus on the event sequence leading up to the crash (Air Historical Branch 1941; UK Air Ministry 1941).

The 10 August 1941 crossing by AM261 was flown by BOAC Pilot Captain E.R.B. White and First Officer/Navigator Captain F.D. Bradbrooke (Air Historical Branch 1941; Davies 2001b: 14). White increased AM261's engines to full power, raced the aircraft down RAF Ayr runway 245 and lifted off into low cloud at 1915Z. Perhaps fatally, the aircrew did not make use of a dedicated navigator; it was believed that White and Bradbrooke were sharing navigational duties. Weather was within flight operation parameters with cloud at 1,200 feet asl, visibility 4 miles and a WSW 10 knot head wind. The aircraft climbed to approximately 800 feet and made a wide left banking turn before departing on a 273 degree initial flight track. The proposed flight plan had AM261 fly the 273 degree initial heading for 73 minutes at 1,000 feet asl. A subsequent 300ft/m climb for 30 minutes followed with the final 10,000 feet asl cruising attitude maintained until close to Gander, Newfoundland. Land-fall over Arran was expected at Whiting Bay at an approximate altitude of 4,000 feet asl, well away and above the hazardous high peaks (Figure 9-7) (Air Historical Branch 1941; Wynn 1944: 51-52; Davies 2001a: 38, 41; Davies 2001b: 14).

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Figure 9-7: Expected flight path (273 degrees) and actual flight path (293-295 degrees) as reported in the AAR (Air Historical Branch 1941).

Unfortunately, it is from this point onwards that details become less clear in both the primary and secondary sources. Witnesses to the initial take-off believed AM261's actual heading to be more northerly than the expected 273 degree bearing. Subsequent analysis of the wreckage location showed AM261 actually flew on a heading of 293-295 degrees, a direct route from RAF Ayr (Air Historical Branch 1941; Davies 2001b: 14). The discrepancy in filed and actual flight path may result from navigational error. AM261 impacted the *Mullach Buidhe* (North Goatfell, Isle of Arran) approximately 15 minutes after take-off at 1930Z. The impact shattered the forward end of the aircraft and scattered debris across the hillside. The fully fuelled aircraft burned on impact. The impact and subsequent fuel explosion cast debris and bodies some 500 yards away (Air Historical Branch 1941).

The force of impact reduced much of the plane to fragments. The only portion of the cockpit control assembly recovered was a single rudder pedal. The cockpit instrument panel, partially damaged after having rolled some 200 yards from the point of impact, enabled limited but critical conclusions regarding the aircraft's instrumentation. Both the directional gyro and artificial horizon were in an uncaged position at the time of impact. Moreover, the altimeter's barometric pressure, set at 29.62", was considered appropriately accurate for the recorded takeoff pressure (29.64"). While the pilot's compass was not found and the navigator's too badly damaged to provide useful information, the investigation concluded that the aircraft's impact was not the result of instrument failure. Analysis of the wreckage provided insight to the crash narrative. The belly of the aircraft had been torn away with most of the remaining aircraft reduced to small fragments. The aft portion of the aircraft was found to be relatively intact while the heavier parts, including the engines, were observed to have rolled a considerable distance down the hillside. The investigation concluded that "Impact with the ground was made while the aircraft was in a climbing attitude and banked to port at an angle corresponding with the slope of the hill" (Air Historical Branch 1941). The climb and bank angles are indicative of evasive action undertaken to avoid collision (Air Historical Branch 1941). The detached fuselage and torn away belly support the investigation's hypothesis of a positive pitch angle during the crash and demonstrate evasive actions in the last moments. The presence of an intact aft fuselage, with torn away underside, is explainable by known LB-30A characteristics and localised terrain features. RAF Coastal Command acceptance trials of the LB-30A design show an "Extreme weakness of the fuselage underbody at the bomb bays" making the underbody prone to "general collapse" (Schoenfield 1995: 189-190). Both *AM Form 1180* and *W-1086a* classify the accident as navigational error with the extraordinary wind currents around the Arran peaks as possible contributing causes and mention the high winds as hampering the investigation as they had scattered components widely (Air Historical Branch 1941; UK Air Ministry 1941).

At least one contemporary, Captain Edgar Wynn, provides a different reasoning for AM261's eventual impact with the high peaks of Arran. Wynn recalls that the actual cloud deck was not the 1,200 feet asl recorded but actually around 900 feet asl (1944: 51). Moreover, Wynn dismisses mechanical malfunction or pilot navigational error as reasons for White's gradual climb. Rather, Wynn sees the flight pattern as characteristic of White's preferred bearing and angle of climb:

> *only two weeks before he [fellow pilot Silverthorn] had asked to be relieved as White's co-pilot on those return trips. He didn't like the way Herb [White] made those gradual climbs toward the mountain....it was simply a characteristic of White's to make that dare of the mountain (Wynn 1944: 54).*

Apparently, one fellow ferry pilot openly questioned White's initial flight track wondering aloud why he did not divert to the less hazardous firth and climb to altitude over water (Wynn 1944: 52).

Recent research has been conducted into the demise of AM261 by avocational historian Ian Davies (Bowden, Cheshire). Unfortunately, Davies's research relies too heavily on conjecture and too little on concrete historical and/or archaeological data. For example, Davies concludes that White's misdirection may have been caused by a fault in the vacuum pumps. Davies claims that an increased vacuum pressure would have indicated a higher rate of climb than that actually experienced and an erroneous compass bearing (2001a: 41). While the increased vacuum pressure could have caused the faults identified by Davies, a faulty vacuum pump is not identified in the accident report maintenance records (Air Historical Branch 1941) nor is it likely that the veteran Pilot and First Officer would have neglected to watch the vacuum pressure gauge during the initial climb.

The uncertainty of the crash sequence after AM261 slipped into the clouds shows a demonstrable need for a revised and unbiased appraisal of the AM261 wreck site. Indeed, the application of methodological research procedures, including archaeological analysis to compliment the limited historical documentation, would help in clarifying the crash sequence, ascertaining the current status of the site and guiding a management plan for the site's future.

Aircraft History:

Early model LB-30A aircraft were the first six Consolidated B-24 aircraft produced. Initially produced as prototype aircraft and designated YB-24, the six hand-built LB-30A aircraft were sold to the RAF in November 1940 with delivery the following month in Montreal. Tested by the RAF and deemed unsuitable for combat operations, the LB-30As were allocated to Ferry Command. Modified in Montreal, the LB-30As were stripped of all armament and refitted with passenger seating, a passenger oxygen system and cabin heating (Bowman 1998: 121-122; Simons 2012: 27-29, 32-33). Following RAF acceptance trials and subsequent dismissal from offensive operations over Europe, all six initial LB-30A were assigned to RAF Ferry Command (Simons 2012: 29, 32).

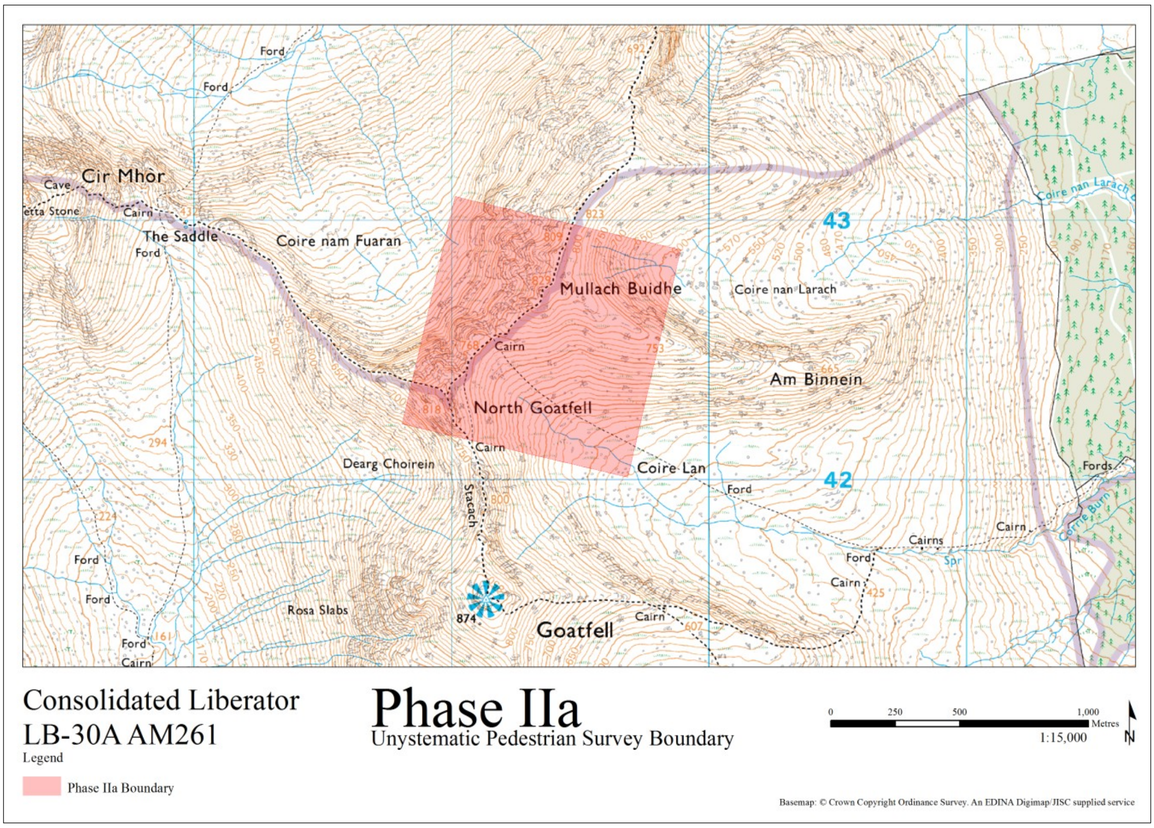
Crew Personnel Files:

BOAC Pilot Captain E.R.B. White and First Officer/Navigator Captain F.D. Bradbrooke had extensive experience. White had accumulated 7,650 hours, 5,635 hours as first pilot, and had completed eight previous Atlantic ferry crossings in Liberators. Bradbrooke was similarly experienced having logged over 1,000 hours, two transatlantic flights as first pilot (albeit not on Liberators), and a further five transatlantic Liberator flights as First Officer/Navigator (Air Historical Branch 1941; Davies 2001a: 40). The proposed route, RAF Ayr to Gander, Newfoundland, was treacherous but by no means unfamiliar. Indeed, BOAC pilots helped pioneer the route in late 1940 (*Atlantic Bridge* 1945: 12-16, 20-25).

Field Surveys:

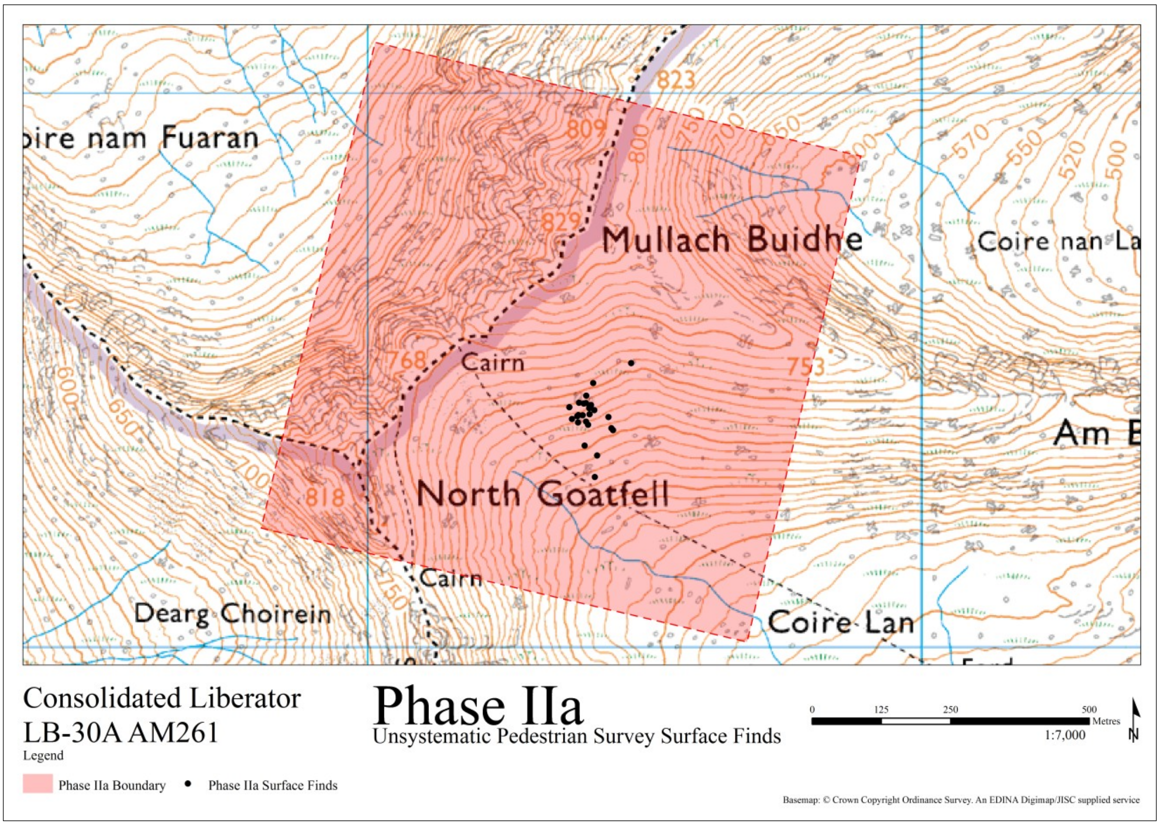
Unsystematic Pedestrian Survey:

An unsystematic pedestrian survey was conducted on 24 February 2013. Utilising Phase IIa-derived archival and secondary material, field research focused on the slopes east of Goatfell between the *Mullach Buidhe* and the *Coire Lan* (Map 9-2).

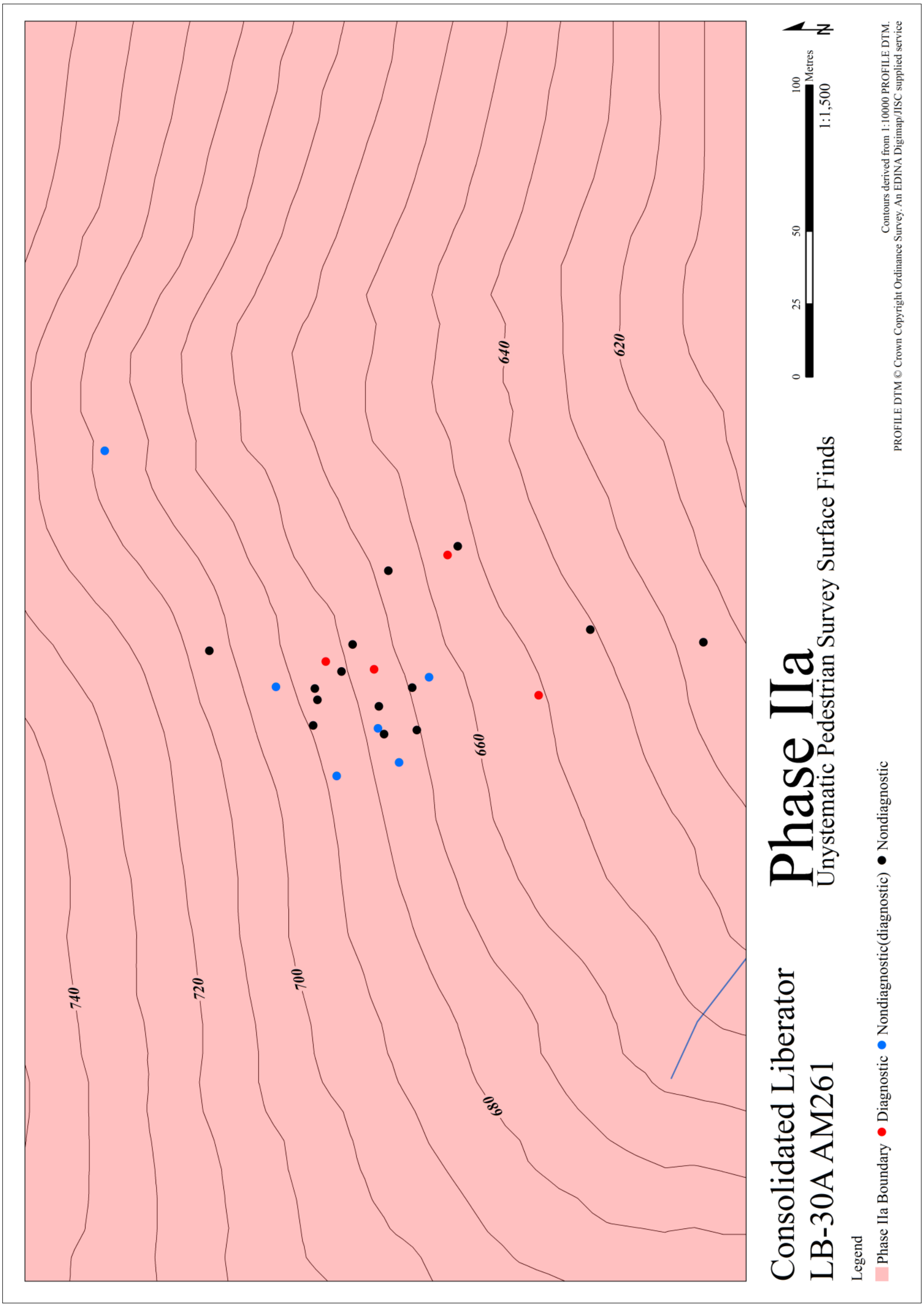


Map 9-2: AM261 Phase IIa survey boundary focusing on the slopes east of Goatfell between the *Mullach Buidhe* and the *Coire Lan* (Crown Copyright/database right OS 2013b; Author).

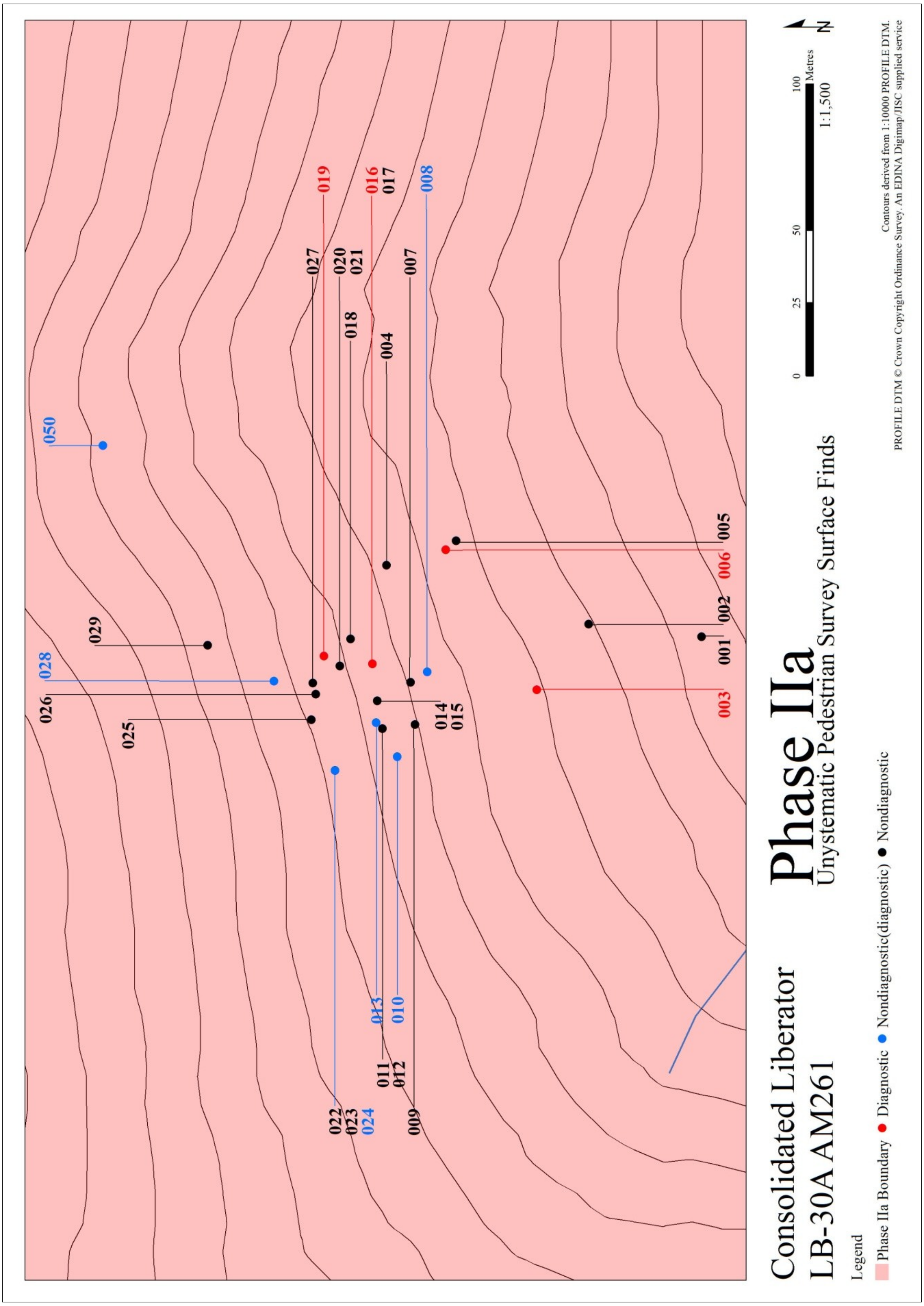
The Phase IIa square search boundary was defined around a circle (r=450 metres). The Phase IIa datum was placed at NR 9968553 4200924 with boundary corners at NR 9968553 4200924, NR 9880924 4221447, NR 9901447 4309076 and NR 9989076 4288553. The unsystematic pedestrian survey started in the southeast corner of the search boundary and progressed from observed surface artefact to observed surface artefact in a roughly NNE-SSW direction. Due to the low number of artefacts identified, the outer search boundary—although seemingly devoid of artefacts for considerable distances—was fully included in the unsystematic pedestrian survey. A total of 32 individual artefacts/artefact groups were located. A general clustering of artefacts was identified at NR 99390 42429. The identified artefacts were observed along a roughly linear pattern on an approximately 0/180 degree bearing (Map 9-3). Four artefacts were identified as diagnostic with a further eight classified as nondiagnostic(diagnostic) (Map 9-4 and Map 9-5). Due to the low number of artefacts observed, all nondiagnostic artefacts encountered were recorded. A similar general concentration of diagnostic artefacts and diagnostic and nondiagnostic(diagnostics) artefacts was observed.



Map 9-3: AM261 Phase IIa overall surface finds distribution (Crown Copyright/database right OS 2013b; Author).
A 0/180 degree scatter orientation is noted.



Map 9-4: AM261 Phase IIb diagnostic, nondiagnostic(diagnostic) and nondiagnostic surface finds (Crown Copyright/database right OS 2013a; Author).



Map 9-5: AM261 Phase IIa annotated diagnostic, nondiagnostic(diagnostic) and nondiagnostic surface finds (Crown Copyright/database right OS 2013a; Author).

Unsystematic Metal Detector Survey:

An unsystematic metal detector survey was planned but was not executed due to health and safety concerns. The proposed AM261 wreck site is situated on an extremely steep gradient. The addition of ice and interspersed snow drifts necessitated the unencumbered use of both hands making the use of the full size metal detector a health and safety hazard. If metal detecting is to be utilised in future research on the AM261 site, it is recommended (1) that an excavation license is obtained prior to the survey so that crews need only complete the survey once and thus limit health and safety risks, (2) that metal detection is focused on smaller areas where more compact metal detectors can be used without drastically reducing crews' mobility and balance (hand-held wands, while not effective for full sites, may be most appropriate in the encountered terrain) and (3) that metal detection focus on the few narrow plateaus encountered as they are the likely location for artefact collection and would allow for the minimisation of terrain-induced health and safety risks.

9.3.3 Phase IIb Detailed Data Survey

Though Phase IIa showed the AM261 crash site to have been subject to contemporary artefact movement (via high winds on site) and post-war artefact attrition (via the collection of debris for scrap), the observed artefact scatter showed AM261 to retain archaeological productivity. The identification of a linear artefact distribution suggests the retention of the site's core and, as such, the possibility of isolating the point of impact. The Phase IIb detailed data survey, undertaken from July 2012-March 2013, further refined the observed debris distribution boundaries and allowed for the identification of archaeologically sensitive areas (Document 9-3).

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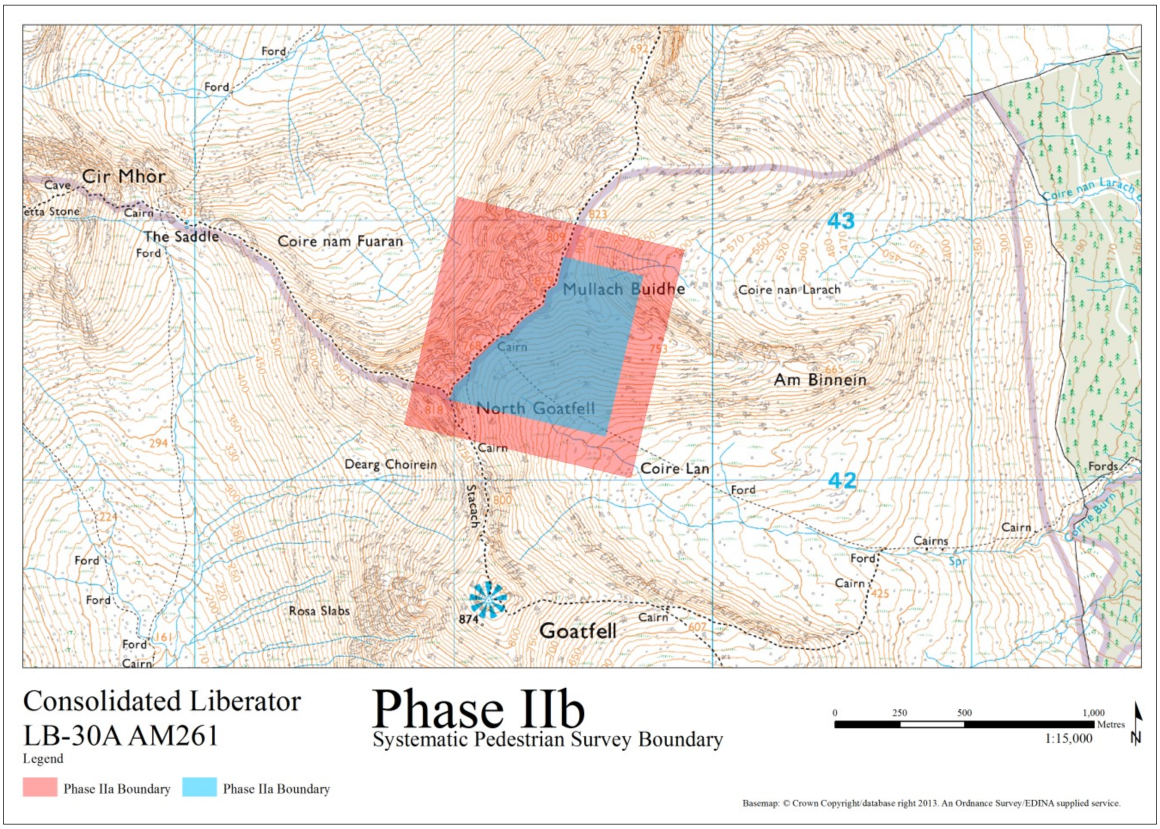
Document 9-3: Phase IIb *PAAR Aircraft Incident Record* form for Consolidated LB-30A AM261 (ICAO 2006; Author).

Field Survey:

The Phase IIb surveys built upon the debris scatter identified during Phase IIa. A refined search area was established using the crash location obtained from primary and secondary sources (NR 99350 42550) and Phase IIa data. The Phase IIb square boundary was established as a square inscribed within a circle (r=450 metres). The Phase IIb datum was established at NR 99587258 42167627. The western and northern survey boundary edges followed the ridge line (which is also the NTS land boundary) (Map 9-6).

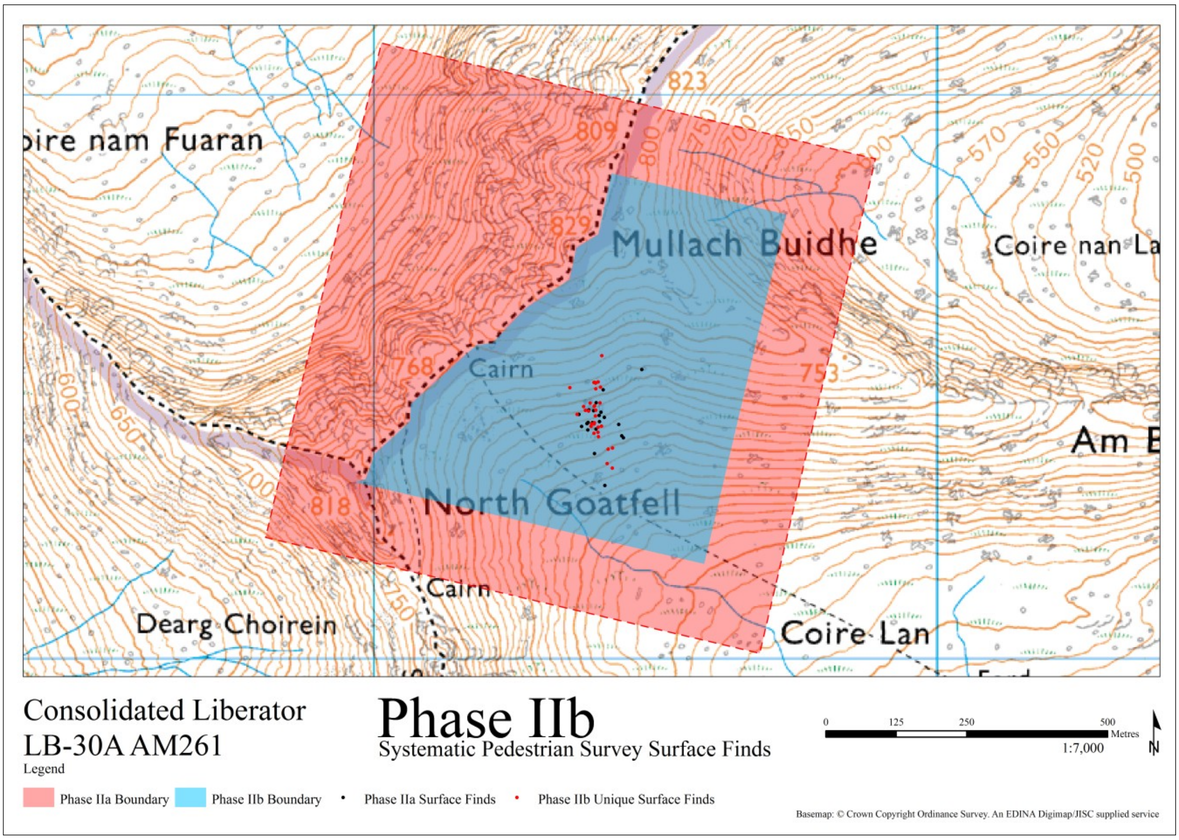


Map 9-6: The Phase IIb refined search area established using the crash location obtained from primary and secondary sources and Phase IIa data (Crown Copyright/database right OS 2013b; Author).

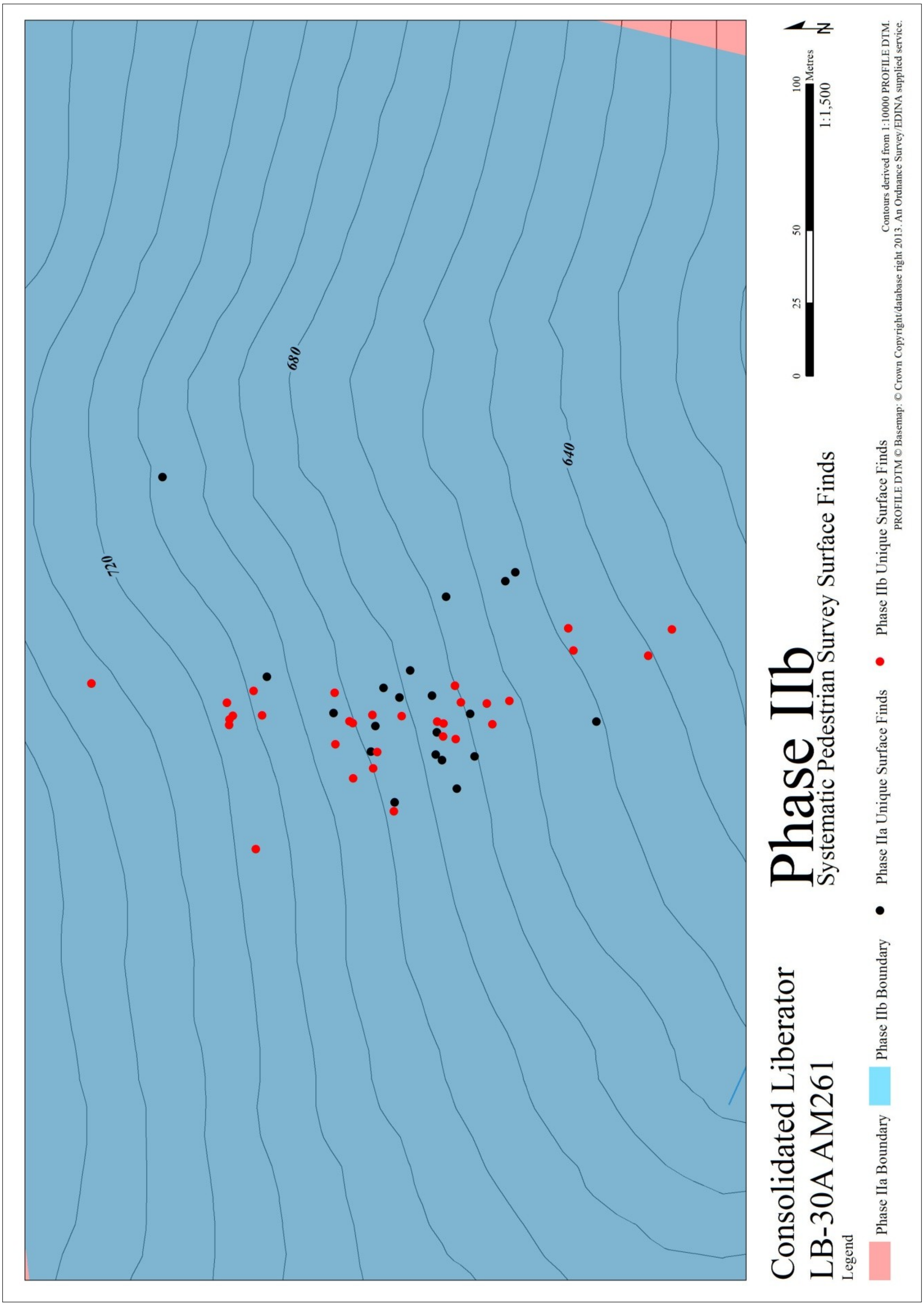
The size of the Phase IIb survey area reflected the absence of artefacts on the outer slopes of the *Mullach Buidhe* and the *Stachach* but took into account the approximately 500 yard dispersal pattern observed during the initial crash response. The opposing ridge face (down to the *Coire nam Fuaran*) was eliminated from the Phase IIb survey due to negative Phase IIa artefact returns near the ridge summit. The site was surveyed twice using the 2-2-90 technique included in the PAAR Methodology. A total of 73 surface artefacts, including 41 unique to Phase IIb, were located.

Systematic Pedestrian Survey:

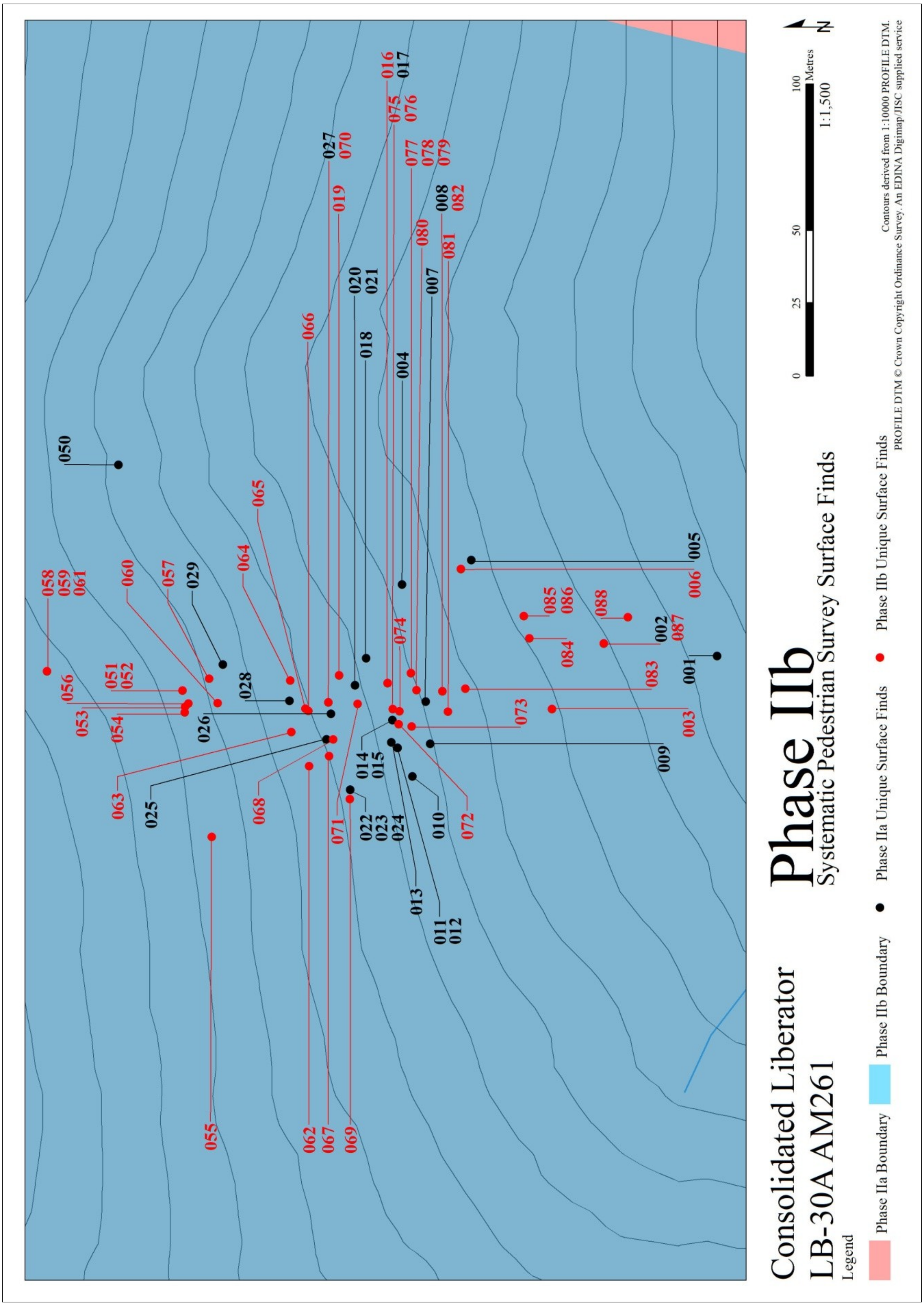
The systematic pedestrian survey of the AM261 crash site was completed on 25 February 2013. Due to health and safety concerns similar to those which prohibited an unsystematic metal detector survey, a systematic metal detector survey was excluded. As such, systematic analysis of the site relied upon the systematic pedestrian survey alone. Maximum ground coverage was achieved through use of the 2-2-90 survey technique and 10 metre transects. The first survey began in the SSE corner (NR 99587258 42167627) and worked in a serpentine pattern along a NNE-SSW axis. A second survey was conducted perpendicular to the first. Again starting at NR 99587258 42167627, the second survey worked along a WNW-ESE axis. Both surveys were completed using 10 metre wide transects. Contacts were marked by the beater using pin flags and subsequently geo-referenced and photographed. As no excavation permit had been obtained, all artefacts were left undisturbed. In addition to the 32 artefacts located during Phase IIa, Phase IIb recorded 41 artefacts including two diagnostic and two nondiagnostic(diagnostic) (Map 9-7, Map 9-8 and Map 9-9).



Map 9-7: AM261 Phase IIb overall surface finds distribution (Crown Copyright/database right OS 2013b; Author).
A 003/183 degree scatter orientation is noted.



Map 9-8: AM261 distribution of artefacts unique to Phase IIa (black) and Phase IIb (red) (Crown Copyright/database right OS 2013a; Author).



Map 9-9: Annotated AM261 distribution of artefacts unique to Phase IIa (black) and Phase IIb (red) (Crown Copyright/database right OS 2013a; Author).

While additional artefacts were located during Phase IIb survey above FS 050, no artefacts were located above FS 058 and 059 (located 75 metres from FS 050). The minimal distance between FS 050 and FS 058/059 and the proximal location of the historically recognised impact point (NR 993 425) (Wotherspoon *et al.* 2009: 285) (60 metres from FS 058/059) provide compelling evidence that minimal archaeological material exists higher on the ridge. Moreover, the previously undetected artefacts identified during Phase IIb refined the axis of artefact distribution with a linear corridor identified on an approximately 003/183 degree bearing (Map 9-7). The core of the linear axis is consistent with the landscape topography and suggests artefact movement down slope. It is unclear, using Phase IIb data alone, whether the intimated down slope movement results from a cascading of material immediately following impact or from natural and/or human induced post-depositional artefact migration.

Artefact Analysis:

The Phase IIa/b pedestrian surveys located, photographed and geo-referenced 5 diagnostic artefacts, 11 nondiagnostic(diagnostic) artefacts and 57 nondiagnostic artefacts. The 16 diagnostic and nondiagnostic(diagnostic) artefacts confirmed the potential existence of an archaeologically productive crash site. While the nondiagnostic(diagnostic) artefacts require excavation for positive identification, the distribution of the five diagnostic artefacts allows for the construction of basic crash site orientation and characterisation.

Only one fragment of AM261's power plants was located during Phase II. FS 016.01, a cylinder head fragment from one of AM261's four Wasp engines (Figure 9-8), was discovered in the centre of the main debris field. The break-up of the substantial and shielded engine cylinder heads, as attested by FS 016.01, demonstrates the violence of AM261's impact. Suffering from surface corrosion and lying unburied beneath larger stones, it appears that the recorded position of FS 016.01 is near the point of original deposition but that the position recorded is not the actual point of original deposition.

Figure 9-8: FS 016.01, a cylinder head fragment from one of AM261's four Wasp engines (Author). The break-up of the substantial and shielded engine cylinder heads demonstrates the violence of AM261's impact

The two A-12 engine fire extinguisher CO_2 tanks (FS 003.01 and 019.01) (Figure 9-9 and Figure 9-10) installed on LB-30A were recorded at disparate locations. FS 019.01 was recorded in the right-centre of the main debris field while FS 003.01 was located approximately 74 metres away and substantially lower on the slopes. Indeed, FS 003.01 is the fourth lowest artefact recorded during Phase II. While heavily corroded, the dimensions, shape and LUX manufacturing stamp on FS 019.01's valve show FS 003.01 and 019.01 to be the two A-12 engine fire extinguisher bottles originally fitted in AM261 (Appendix Figure 11-98 and Appendix Figure 11-99) (Walter Kidde and Company 1924; US Army Air Force 1944e: 515, 517-518). The two A-12 fire extinguisher bottles were installed "on the right side of the fuselage, between the nose wheel well enclosure and the outer skin" (Figure 9-11) (Consolidated Aircraft Corporation 1942: 117-119; US Army Air Force 1944e: 515). In addition to the missing base, it appears the extinguisher has a large dent near the valve head; the extreme degradation of FS 019.01's base may be due to a crash-induced rupture (Figure 9-10 and Appendix Figure 11-98). FS 019.01's position amongst the main debris field higher on the slope provides additional, speculative support to the crash-rupture hypothesis. FS 003.01 lies, apparently intact, lower on the slope and near plateau 1 (Figure 9-9). Its half-buried position precludes further, non-invasive inspection.

Figure 9-9: FS 003.01, one of two engine fire extinguishers installed on AM261 (Author). Originally installed together, the 74 metre separation between FS 003.01 and FS 019.01 is currently unexplained.

Figure 9-10: FS 019.01, the second engine fire extinguisher installed on AM261 (Author). FS 019.01 is located amongst the main debris field 74 metres up slope from FS 003.01.

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Figure 9-11: Installation location of FS 003.01 and 019.01 within B-24/LB-30A aircraft. (Consolidated Aircraft Corporation 1942: 118; US Army Air Force 1944e: 518)

FS 071.02, the artefact perhaps most directly associated with the deceased aircrew/passengers, was discovered in the very centre of the primary debris concentration. Hidden between two rocks and associated with an NMF classified section of piping (FS 071.01), FS 071.02 is the centre locking/release mechanism for the chest/observer type parachute harness worn by RAF bomber crew members (Figure 9-12, Figure 9-13 and Figure 9-14) (Irvin 1932; Wigley and Austing 1933; Irvin 1935; IWM 2013b ; Australian War Memorial n.d.). Corroded almost beyond recognition, FS 071.02 retains the confirmatory part stamp 1340-1 (Figure 9-13) (Australian War Memorial n.d.). Discovered on the surface, it is unlikely that FS 071.02 is located at the point of initial deposition. Given its relationship with the wider scatter, it has probably travelled slightly down slope. More important for the future management of the AM261 wreck site is the uncertainty FS 071.02 brings to the body recovery operation undertaken immediately following the crash. While historical sources claim the bodies were recovered, no information relating to the completeness of the human remains was located. The identification of a harness clasp which would have been strapped to the front of an individual's chest either means the human remains discovered were fragmentary (such as that encountered with B-17Gs 42-97286 and 44-83325) or that the harness was disconnected before the individual's death and/or removal. Given the condition of human remains from similar sites, the presence of fragmentary remains is possible and needs to be considered during any future field research on AM261.

Figure 9-12: FS 071.01 (above scale in rock crevice), identified by its unique shape and part number, is the centre locking/release mechanism for the chest/observer type parachute harness worn by RAF bomber crew members (Author).

Figure 9-13: Beyond just its unique shape, FS 071.01 was confirmed as the centre locking/release mechanism for the chest/observer type parachute harness via the 1340-1 part number stamped on the reverse (Author).
Photographs taken during Phase IIIa.

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Figure 9-14: An example of the chest/observer type parachute harness for which FS 071.01 served as the centre locking/release mechanism (IWM 2013b; Australian War Memorial n.d.). The left is a complete example including back pad (IWM 2013b) while the right example shows the harness straps only (Australian War Memorial n.d.). In the Imperial War Museum specimen, the centre locking/release mechanism is disconnected and lies in the lower left.

The most provocative unconfirmed artefact group located during Phase II is FS 028. FS 028 consists of two small leather fragments (FS 028.01 and 028.02), one large leather fragment (FS 028.03) and a nondiagnostic metal fragment (FS 028.04) wedged between two rocks (Figure 9-15 and Appendix Figure 11-100). While the lack of an excavation license prevented handling of the leather artefacts, an impressed design was noted on the large fragment. All three leather fragments showed evidence of machine stitching (Appendix Figure 11-101). The visual assessment during Phase II showed that the leather matched neither B-24/LB-30A seat designs nor installed equipment covers. As such, it was hypothesised that FS 028.01-028.03 were either personal effects of the crew, equipment left on site by the search parties, or the abandoned and fragmentary belongings of more recent visitors. An adjacent NMF artefact, FS 028.04, may be associated with FS 028.01-028.03. Its wedged position between two large stones did not allow for visual assessment to define whether FS 028.04 was connected to FS 028.03 and/or whether the two artefacts were deposited in the same position simultaneously. Further invasive research to identify FS 028.01-028.03 and to determine how long FS 028 has been in its current position may help define the level of artefact migration which remains largely undefined for the assemblage.

Figure 9-15: FS 028 wedged between two rocks (Author).
The lack of an excavation license prevented handling of the leather artefacts and, therefore, identification. FS 028.04, the unidentifiable metal fragments, are visible in the upper left.

FS 008.01 is characterised by its corrugated aluminium riveted to a smooth aluminium skin (Appendix Figure 11-102). The bomb bay doors, the bomb bay catwalk and the floor walkways made extensive use of mated corrugated and sheet aluminium. Only the catwalk cross-section (Consolidated Aircraft Corporation 1942: 91; Famme 1945: 4, 8) and the flooring (Charette 2011a, 2011b) match FS 008.01's characteristics. Its position and disposition, therefore, is curious. As the second lowest artefact recorded during Phase II, FS 008.01 should be located on or near the ground surface due to consistent down slope migration. Such a location would correspond to patterns found on other sites. The fact that FS 008.01 is half buried and wedged below substantial rocks indicates that FS 008.01 was likely transported down slope in the past. The exact depth of FS 008.01 cannot be determined without excavation. Similarly, the approximate length of time FS 008.01 has remained in its present position is indeterminable without excavation. The positive identification and depth measurement of FS 008.01 as part of future research into the down slope section of the AM261 would enhance understanding of crash and post-depositional sequences.

FS 058.01 was discovered on the ground surface underneath a rock in a position very similar to FS 016.01. One of the two uppermost artefacts identified (the other being FS 059.01, classified NMF), FS 058.01 appears to be armour plate (Appendix Figure 11-103). An apparent anomaly considering the LB-30A's poor initial armouring and subsequent RAF conversion to personnel transport, the legal inability to handle the artefact precluded more secure identification. FS 058.01, as the only artefact hypothesised to be armour plating and a potential anomaly in established LB-30A design, required further analysis in Phase IIIa.

Six additional nondiagnostic(diagnostic) artefacts (FS 006.01, 010.01, 013.01, 024.01, 050.01 and 077.01) were recorded which, if assessed using invasive techniques, could provide increased clarity on aircraft orientation and site dynamics (Figure 9-16). FS 006.01, for example, is believed to be a hinge section from one of the wings or control surfaces (Figure 9-17). While the artefact shows defining characteristics, including a threaded female end which has been broken in half due to external forces, its half-buried position and the resulting inability to examine the obscured section precludes further classification (Figure 9-17 and Appendix Figure 11-104). Identifying FS 006.01, which is situated just below the main debris concentration, and similar nondiagnostic(diagnostic) artefacts would provide better understanding of whether the linear artefact axis identified is related to initial deposition or post-depositional processes.

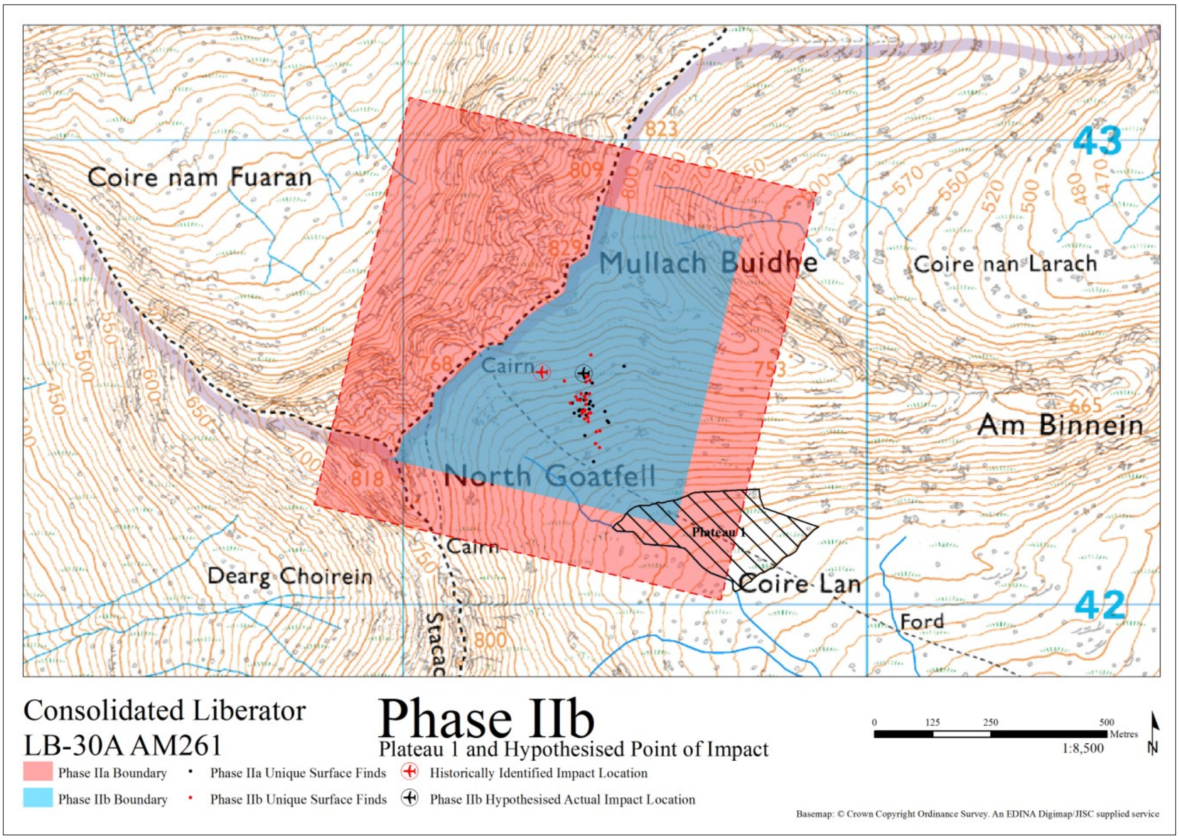
Figure 9-16: The six additional nondiagnostic(diagnostic) artefacts (FS 006.01, 010.01, 013.01, 024.01, 050.01 and 077.01) were recorded which, if assessed using invasive techniques, could provide increased clarity on aircraft orientation and site dynamics (Author).
FS 006.01 (facing northwest), FS 010.01 (facing east), FS 013.01 (facing northwest) (top row, left to right); FS 024.01 (facing north), FS 050.01 (facing south) and FS 077.01 (facing north) (bottom row, left to right).

Figure 9-17: FS 006.01, believed to be a hinge section from one of the wings or control surfaces, shows defining characteristics but its half-buried position precludes further classification (Author). Identifying FS 006.01, and similar nondiagnostic(diagnostic) artefacts, would provide better understanding of whether the linear artefact axis identified is related to initial deposition or post-depositional processes.

While artefacts classified as NMF do not normally contribute significant detailed information to the larger site data assemblage, FS 062.01 is an exception. FS 062.01 is an ingot of melted aluminium (Figure 9-18). The 500°-638°C melting point of 2024T3 aluminium (the modern alloy equivalent of 24ST aluminium) (Davis 1993: 377; Vargel 2004: 42; Polmear 2006: 170-172) is well within the temperatures expected for a post-crash leaded petrol fire (Gordon and McMillan 1963: 8-10). Therefore, it is believed that FS 062.01's deformation resulted from a fire following AM261's impact. Located at the top of the main artefact contribution and approximately 10 metres west of the identified linear axis of distribution, FS 062.01's weight, location and condition—along with the information gained from other artefacts—suggest that the area immediately north of FS 062.01 is the likely point of impact.

Figure 9-18: FS 062.01, the only melted aluminium ingot discovered during Phase IIb (Author).

The location of the observed artefact scatter and the identified 3/183 degree axis of artefact distribution largely confirms the crash site narrative found in historical sources and conforms to the expected axis of movement over the observed topography (Map 9-7). Evidence (e.g., FS 062.01) supports reports of an intense post-crash fire. No evidence was obtained, however, indicating that White attempted evasive manoeuvres prior to impact. Indeed, much of the data recovered demonstrates a high speed, mid angle impact with the mountain side and the subsequent movement of artefacts. A majority of the artefacts reside adjacent to a natural gully, a terrain feature attested to in secondary sources (Davies 2001a: 15). Substantial horizontal wreckage dispersal was minimal. While the distribution axis and the location of the wreckage proximal to the natural gully are largely expected, the absence of artefacts on the flatter terrain below the gully (plateau 1) is surprising (Map 9-10). The engines were likely deposited in this area below the gully and, with the movement of artefacts over time, it is likely that more debris was deposited there as well. Two explanations for the absence of artefacts in plateau 1 have been developed. The post-1980 establishment of a hiking path which cuts across plateau 1 and is within visual range of plateau 1's outer edges may have increased human activity in the area, resulting in increased artefact attrition. A second explanation takes into account the location of plateau 1 on the border of the *Coire Lan*. The related increase in water saturation, and the associated soil erosion and rock movement, may have buried much of the surface artefact assemblage.



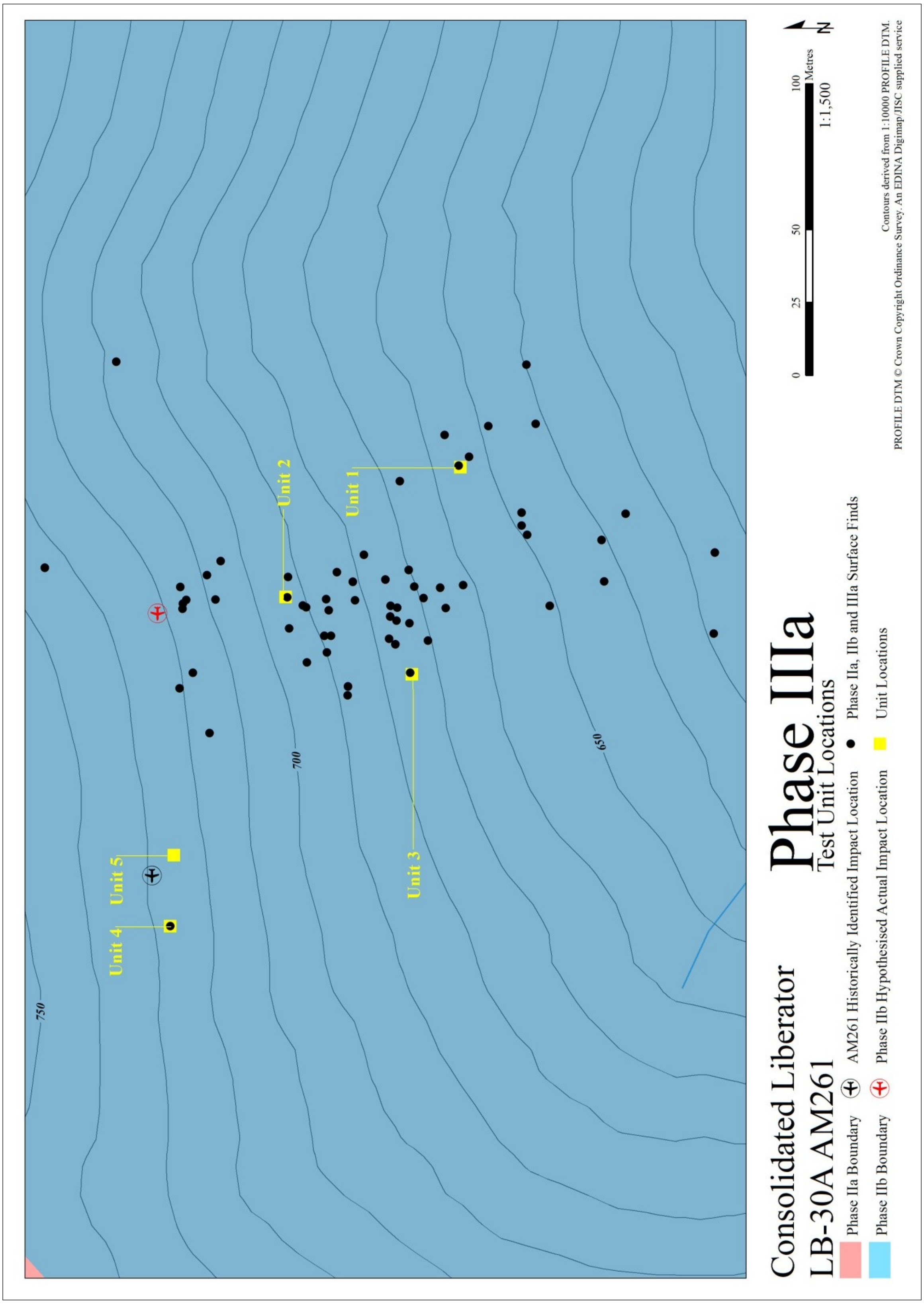
Map 9-10: The recorded Phase IIb surface artefact scatter in relation to plateau 1, the historically identified impact point and the Phase IIb-derived hypothesised point of impact (Crown Copyright/database right OS 2013b; Author).

Given the site attrition which occurred immediately post-war (Smith 1989: 646; Davies 2001b: 15), the proximity of a public hiking path and the observed linear artefact distribution, it is recommended that future research focus on three topics identified during Phase IIb research. The primary focus of future research should be determining whether the artefacts observed west and adjacent to the natural gully are in position at the point of initial deposition or whether the artefacts have moved since 10 August 1941. Should research into the artefacts' present position show that they have been affected by post-depositional movement, attention should be given to surveying and verifying the presence of collected artefacts within plateau 1. In conjunction with the survey of plateau 1, a systematic metal detector survey of the historically recognised impact point should be undertaken. Such a survey of the proposed impact point could verify whether the majority of AM261 debris was removed post-war for scrap or whether, following common practice, the impact point was filled in with debris. Completion of any one of these investigations would provide increased understanding of site contents, artefact movement dynamics and resultant site boundaries.

9.3.4 Phase IIIa Targeted Excavation

Research into LB-30A AM261 continued into Phase IIIa in order to better characterise the artefact scatter and understand post-depositional activity. Phase IIIa research specifically targeted whether the extensive spread down the gully and atypical locations of artefacts reflected the AM261 crash scenario or whether it was the result of natural/anthropogenic-induced artefact movement. A targeted exploratory excavation of five, one metre test units was undertaken (Map 9-11). Completed on 19 May 2013, the Phase IIIa test units were placed on or adjacent to diagnostic or nondiagnostic(diagnostic) artefacts which Phase IIb analysis recommended for further invasive study. These artefacts were believed to have remained stationary for long periods of time and were widely spaced across the site.

Excavations of the five test units revealed a limited soil depth profile that, if indicative of the larger site, would limit artefact penetration into the slope soil. Only one test unit, Unit 2 (centred on Phase II FS 028), showed the associated artefacts to have been stationary for an extended period of time. The remaining test units revealed no subsurface artefacts associated with surface debris. As per the proposed PAAR Methodology, stratigraphic excavation maintained vertical control. Horizontal control was maintained via georeferencing the artefact and test unit locations. All units were drawn and photographed prior to closure in order to maintain a record of research conducted. The artefacts recovered during Phase IIIa were successfully stabilised using the artefact preservation method outlined in Chapter 5, Section 5.2.7.



Map 9-11: Location of five test units relative to Phase IIa, IIb and IIIa surface finds (Crown Copyright/database right OS 2013a; Author).

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Document 9-4: Phase IIIa *PAAR Aircraft Incident Record* form for Consolidated LB-30A AM261 (ICAO 2006; Author).

Artefact Analysis:

Unit 1, Nondiagnostic(diagnostic) hinge fragment (FS 006.01):

Unit 1 (NR 994398 423935) was placed adjacent to FS 006.01 (Figure 9-19) to positively identify the suspected hinge component and to determine whether its present location is a point of long term deposition. Unit 1 was oriented north-south with FS 006.01 located in the SE corner and the one metre test unit fully exposed to an average uniform depth of 28 centimetres. While locating FS 006.01 in the NW corner or centre of the north wall would have been preferred as down slope artefact wash would have been within Unit 2, the presence of immovable stones dictated the unit's orientation relative to FS 006.01 (Figure 9-20). The upper most soil layer (context 001) consisted of compact, black clay across the whole of the unit to a depth of 13-18 centimetres. The east wall, however, had a shallower soil profile with context 001 only 7-10 centimetres deep (Figure 9-21 and Figure 9-22). The underlying stratum (context 006) is similarly consistent across the unit. Context 006 is a light brown loamy gravel with ≈1 mm gravel inclusions. Red speckling was observed across the whole of the unit but showed no discernible pattern and was, therefore, considered natural and unrelated to FS 006.01. Both context 001 and 006 were observed to slope to the SE corner, in the direction of FS 006.01. Large rocks (context 002), believed to be tumbled boulders like those observed on the surface, were observed throughout the unit including one large rock extending from the south wall across the unit (Figure 9-21 and Figure 9-22). No cultural material, aircraft-related or otherwise, was recovered from Unit 1.

The observed soils, stratigraphy and large boulder inclusions are consistent with expected characteristics for the thick and uninterrupted vegetation observed. Indeed, the only soil inconsistency, shallower soil depth recorded on the eastern wall, is likely due to the collection of soil around the large rocks present near the north, south and western walls (Figure 9-21 and Figure 9-22). Moreover, the lack of aircraft-related artefacts within the top 20-28 centimetres, a depth far deeper than the <5 centimetre depth at which FS 006.01 extended, corroborates the observed soil profile. It is concluded that FS 006.01's current location, based upon the data gained from Unit 1, results from a relatively recent down slope migration. The absence of any associated parts or corrosion product within Unit 1 makes it likely FS 006.01 has not been present in its current location for an extended period of time. Moreover, the location of FS 006.01, upslope from the artefact's adjoining rock, is demonstrative of slope wash movement.

Figure 9-19: Four views of nondiagnostic(diagnostic) FS 006.01, the subject of Unit 1 investigations (Author).
A single NMF (bottom right: FS 006.02) was found within, but unattached to, FS 006.01.

Figure 9-20: LB-30A AM261 Phase IIIa Unit 1 pre-excavation showing large, immovable stones surrounding delineated unit (Author).
Phase IIb FS 006.01 is seen in the lower right corner.

Figure 9-21: LB-30A AM261 Phase IIIa Unit 1 (Author).

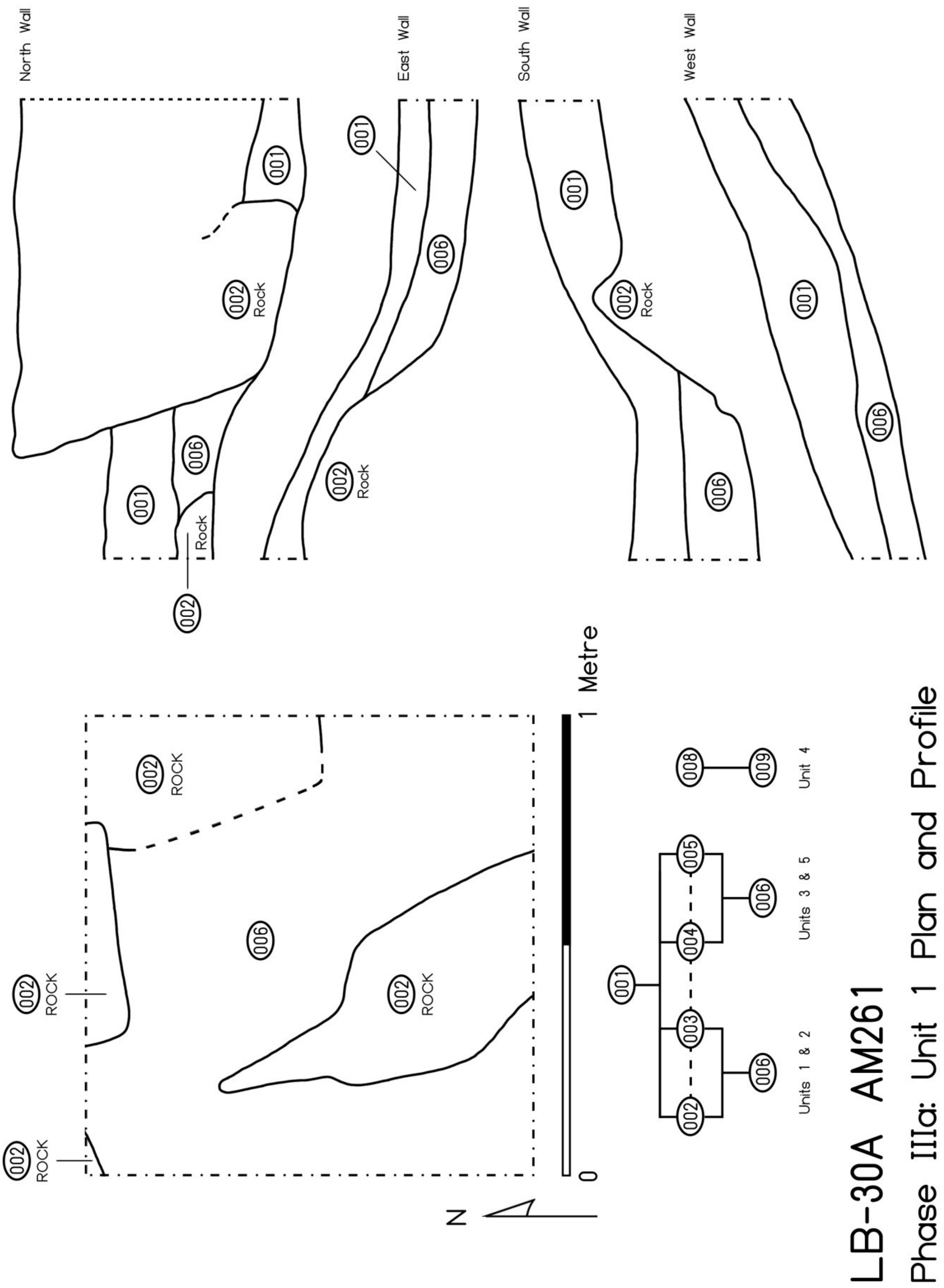


Figure 9-22: Plan and section of AM261 Phase IIIa Unit 1 (Author).

Unit 2, Leather and NMF fragments (FS 028.01-028.04):

Unit 2 (NR 993951 424535) was positioned over Phase II FS 028 in order to clarify (1) how FS 028.01-028.03 were associated with AM261 (clothing, equipment, hikers' equipment, etc.), (2) whether FS 028.04 was attached to FS 028.01-028.03 and, if not, whether it was related to FS 028.01-028.03 or just ended up in the same area and (3) the approximate length of time FS 028 had been in its current position. Unit 2, therefore, was utilised to represent the artefact movement observed on the northern (upper) portion of the site nearest the proposed impact point.

Prior to beginning excavation, the two smaller rocks (A and B) pinning FS 028 to the larger boulder (C) (Figure 9-23) were moved aside with considerable effort in order to expose more of the unit and release FS 028 surface artefacts from their pinched position. A one metre unit was then positioned over FS 028, abutting rock C and oriented NE-SW (Figure 9-24 and Figure 9-25). As with the other four units, Unit 2 was excavated to sterile soil. The topsoil (context 001) was extremely similar to that observed in Unit 1 and consisted of a compact dark brown-black clay 10 centimetres deep. The underlying soil, context 006, was similar to that observed in Unit 1 and consisted of a loose light brown loam with ≈1-2mm gravel inclusions. Both context 001 and 006 sloped to the SW in line with the larger topography. Context 001 was the only context to contain cultural material. Excavated to a maximum depth of 11 centimetres (the lowest depth that could be obtained without undercutting rock C and, in the process, making the site unsafe for hand excavation), cultural material was recovered to a maximum depth of 9 centimetres (Figure 9-24, Figure 9-25 and Figure 9-26). Context 001 contained 7 NMF aircraft components (Appendix Figure 11-105), 37 corroded ferrous fragments (Figure 9-30), 14 leather fragments (including FS 028.01-028.03), 1 McBrine Baggage emblem, numerous small wood fragments and 1 large wood fragment (Appendix Figure 11-106). The wood fragments were not quantified as their instability caused them to crumble when handled. All of the material recovered was exposed on the SW edge adjacent and underneath the large surface rock.

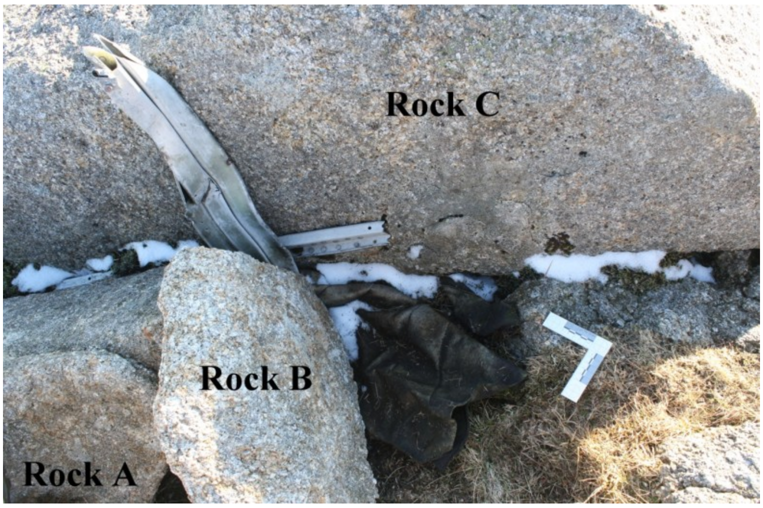


Figure 9-23: Two smaller rocks, labelled A and B, pin FS 028 to a larger boulder (C) (Author). Rocks A and B were moved away from Rock C prior to excavation.

Context 006, excavated to a maximum depth of 20 centimetres, was sterile and dropped off greatly as it approached rock C (context 003) (Figure 9-26). An additional rock (context 003) was uncovered in the eastern corner. No cultural material was recovered in the eastern corner overlying the rock. Excavation further underneath context 003 was not undertaken due to the rock's size and weight and the absence of artefacts at a comparable depth in the productive SW corner. The presence of the material directly beneath FS 028.01-028.03 shows strong correlation between the surface material and the excavated material. Indeed, the leather, manufacturer's plate, ferrous fragments and wood fragments were later observed to be components of a Canadian-manufactured suitcase or hand luggage (Figure 9-27, Figure 9-28, Figure 9-29, Figure 9-30 and Figure 9-31). FS 028.04 was further observed only to consist of the two NMF visible during Phase IIa.

The extensive corrosion and collection of material behind rock B and adjacent/beneath rock C provides compelling evidence that FS 028.01-028.03 has been in its observed position for a considerable length of time. Indeed, if the corrosion and collapse of the McBrine bag had occurred elsewhere, the localised collection of associated wood frame, metal mechanisms and hinges, leather wrapping and name plate is highly unlikely. Moreover, the seven excavated NMF discovered below the leather fragments and at an identical level as the bag's ferrous locking and hinge mechanisms, though unquantifiable, provide additional evidence for Phase II FS 028 having been immobile for considerable time. The mixing of surface and buried debris would only have occurred if the bag and NMF were in the same place as the bag's structure corroded away. Unfortunately, due to the nondiagnostic nature of the NMFs excavated, further association cannot be made between the bag's location on site, the NMFs' locations within the aircraft and the bag's likely location within the aircraft. Perhaps the most important data to be gained from Unit 2 is confirmation of relevant artefacts within the topsoil but not the subsoil. Indeed, the confirmed presence of cultural material within the topsoil demonstrates that at least some of the artefacts on site have been subject to external forces and that large scale mobility of surface artefacts is probable. With artefact movement a known and ongoing affect, the need to find and secure the main impact scar, which is likely to retain deeper, more sheltered artefact deposits, is all the more pressing.

Figure 9-24: LB-30A AM261 Phase IIIa Unit 2 (Author).

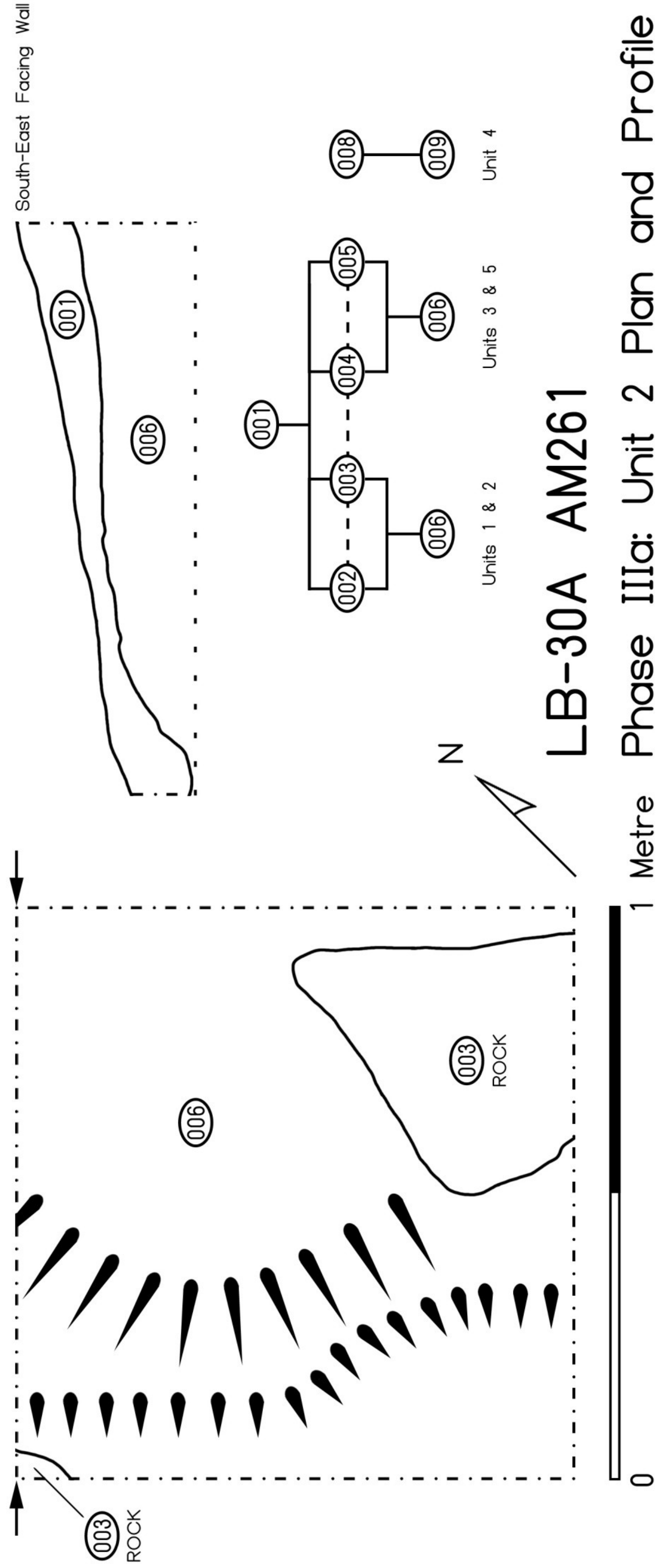


Figure 9-25: Plan and section of AM261 Phase IIIa Unit 2 (Author).

Figure 9-26: LB-30A AM261 Phase IIIa Unit 2 viewed facing west (Author).
The rapid drop off of context 006 is visible in the top third of the unit. Excavation further underneath context 003 was not undertaken due to the rock's size and weight and the absence of artefacts at a comparable depth in the productive SW corner. The limited depth of excavation underneath context 003 (rock C) is evident at the top edge of Unit 2.

Figure 9-27: Smaller leather fragments from the fragmented McBrine case (Author).
Top: Strap and hardware fragments from an interior area secured using a belt closure. Middle: Decorative flap, originally sewn next to the handle/main lock, which held the McBrine Baggage emblem; two of four leather corner reinforcements. Bottom: Two of four leather side walls.

Figure 9-28: The two larger McBrine Baggage leather fragments found in AM261 Unit 2 (Author). The top fragment is one of two side panels and shows the seam lines from unique, decorative stitching. The bottom fragment is from the bottom of the bag. The holes and ferrous staining from the six bottom studs are visible in the four corners and centre top and bottom. A stamp just above the tear at the bottom centre reads: 24-5350/5 WARRANTED GENUINE COWHIDE.

Figure 9-29: Diagnostic ferrous artefacts recovered from AM261 Unit 2 (Author).
Top row (left to right): McBrine Baggage emblem, two rounded studs (for bottom of bag) and rounded side hinge cover. Middle row: interior latch connection and exterior latch. Bottom row: main lock.

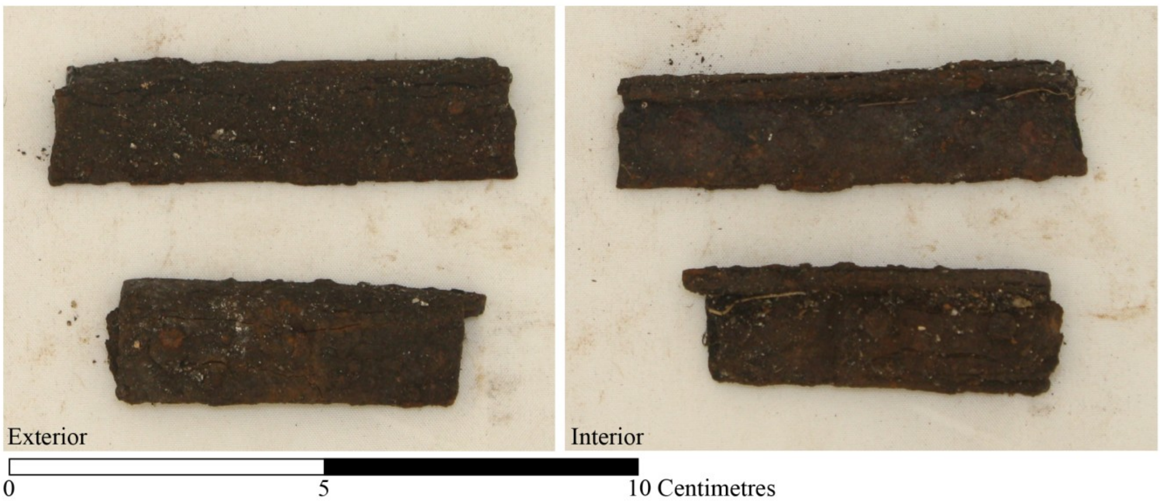


Figure 9-30: Example of ferrous fragments recovered in Unit 2 (Author).
It is believed the 37 ferrous fragments are the remnants of the McBrine bag's metal frame.

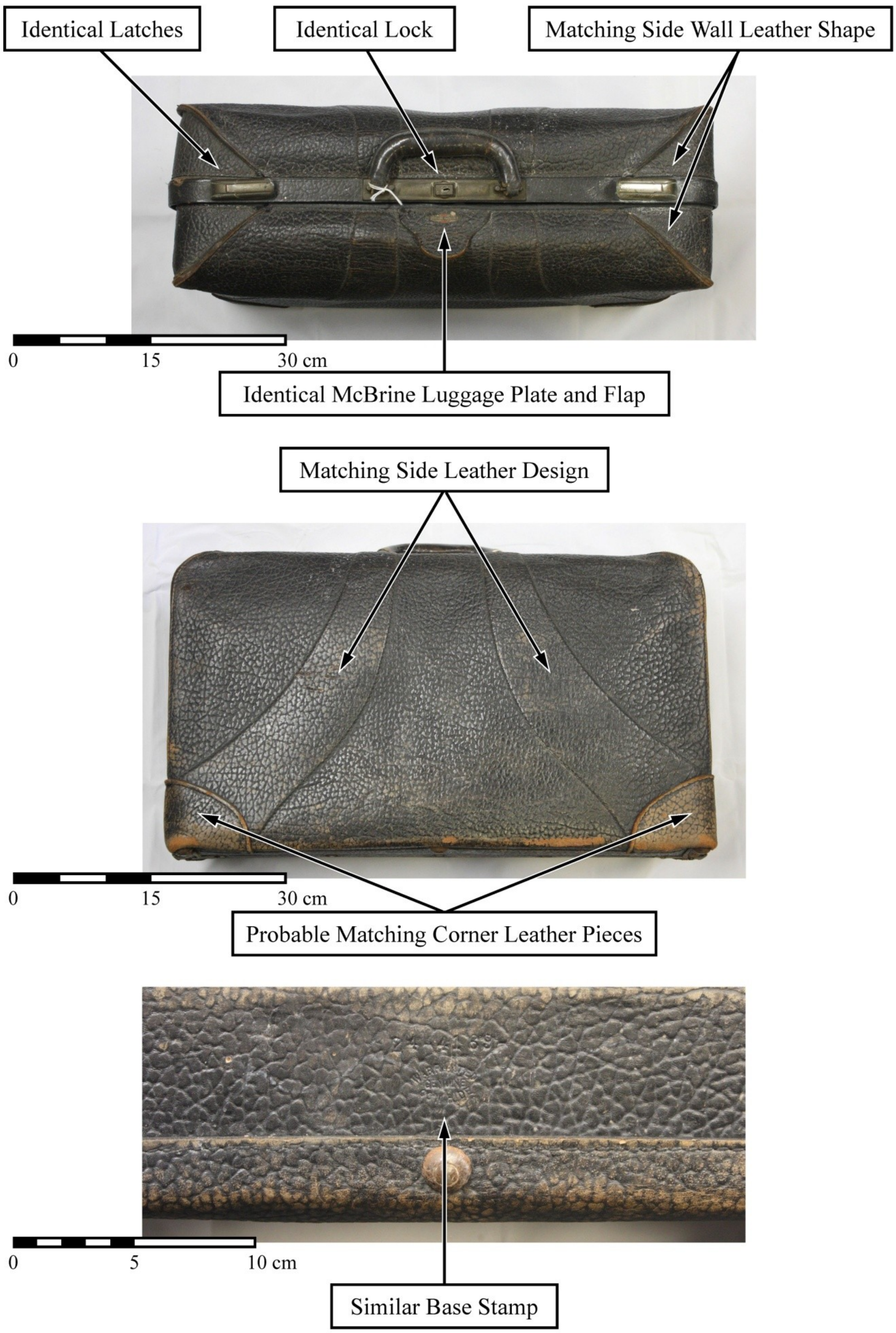


Figure 9-31: Example of McBrine luggage model, from the author's own collection, believed to be identical to the fragmented bag recovered from AM261 Unit 2 (Author).

Unit 3, Unidentified Pump or Generator (FS 010.01):

Unit 3 placement (NR 993687 424102) was selected to determine whether FS 010.01 (Figure 9-32) was located at the point of initial or long-term deposition. Unidentified during Phase II due to a *PMRA 1986*-required prohibition on artefact movement, Phase IIIa provided little more specificity. Currently FS 010.01 is classified as an unidentified pump or generator suffering from heavy corrosion (Figure 9-32). While artefact corrosion is usually detrimental to the productivity of archaeological research, it was anticipated that the advanced active corrosion observed would seed the surrounding soil with corrosion product and/or cause subsidiary components to separate from FS 010.01 over time. The observed presence of substantial corrosion product and/or detached components in the immediate proximity of FS 010.01 would provide compelling data to suggest FS 010.01 had been stationary for an extended period of time. The larger the quantity and density of detached components identified in the soil, the longer FS 010.01 is likely to have remained at its present condition.

Unit 3 was oriented NW-SE and abutted FS 010.01. Placing the unit amongst large rock formations allowed for the excavation of only the western 50cm^2 quadrant to 15 centimetres (Figure 9-33, Figure 9-34 and Figure 9-35). As with Units 1 and 2, two strata were observed. Context 001—a compact, dark black-brown clay with ≈1mm gravel inclusions—is similar to the upper stratum observed in Units 1 and 2. Context 001 extended to a depth of 13 centimetres (Figure 9-34 and Figure 9-35). Context 007, underlying context 001, is a dark brown, friable soil with approximately 40 percent gravel inclusions. While not identical to context 006 in Unit 1, it is similar enough to be considered a natural variation of context 006. Unlike context 001/006, no defined transition between 001 and 007 was observed. Two rocks, context 004, were observed underneath 001. The larger of the two rocks may extend underneath FS 010.01 and, therefore, may limit the deposition of spalling material or components. No cultural material or unnatural soil standing was observed in either context.

The lack of corrosion product or additional aircraft-related material near FS 010.01 and a consistent, natural soil profile provides evidence for secondary deposition. Moreover, the position of FS 010.01 upslope from the rock against which it sat likely makes its observed location the result of natural down slope movement until obstructed. Like FS 006.01, the length of time FS 010.01 has been present at the observed location is not definitively quantifiable.

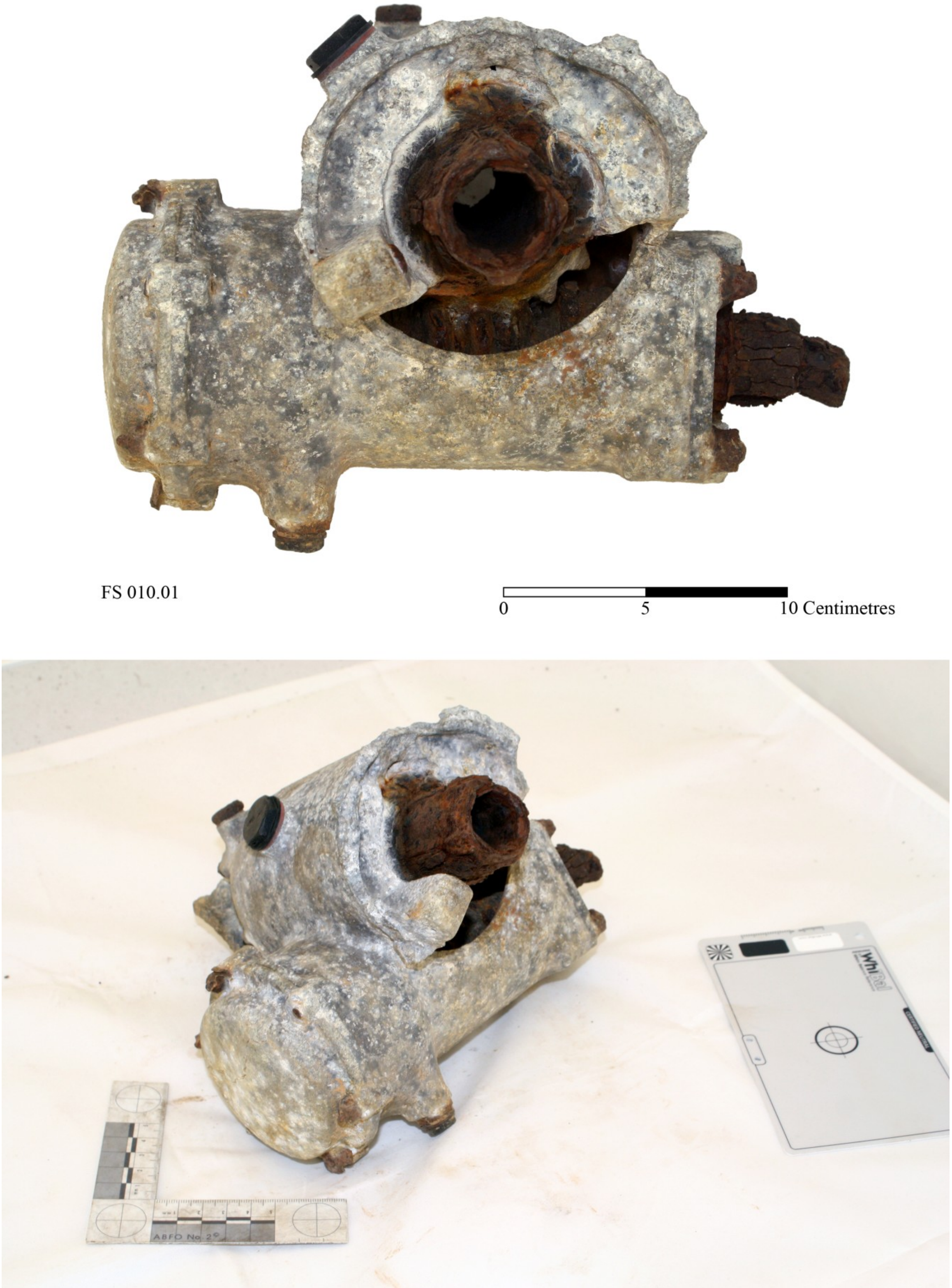


Figure 9-32: AM261 FS 010.01, an unidentified and heavily corroded pump or generator, was the subject of Unit 3 investigations (Author).

Figure 9-33: Positioned to characterise whether FS 010.01 was located at the point of initial or long-term deposition, AM261 Phase IIIa Unit 3's placement amongst large rock formations allowed for the excavation of only the western 50cm^2 quadrant to 15 centimetres (Author).

Figure 9-34: LB-30A AM261 Phase IIIa Unit 3 (Author).

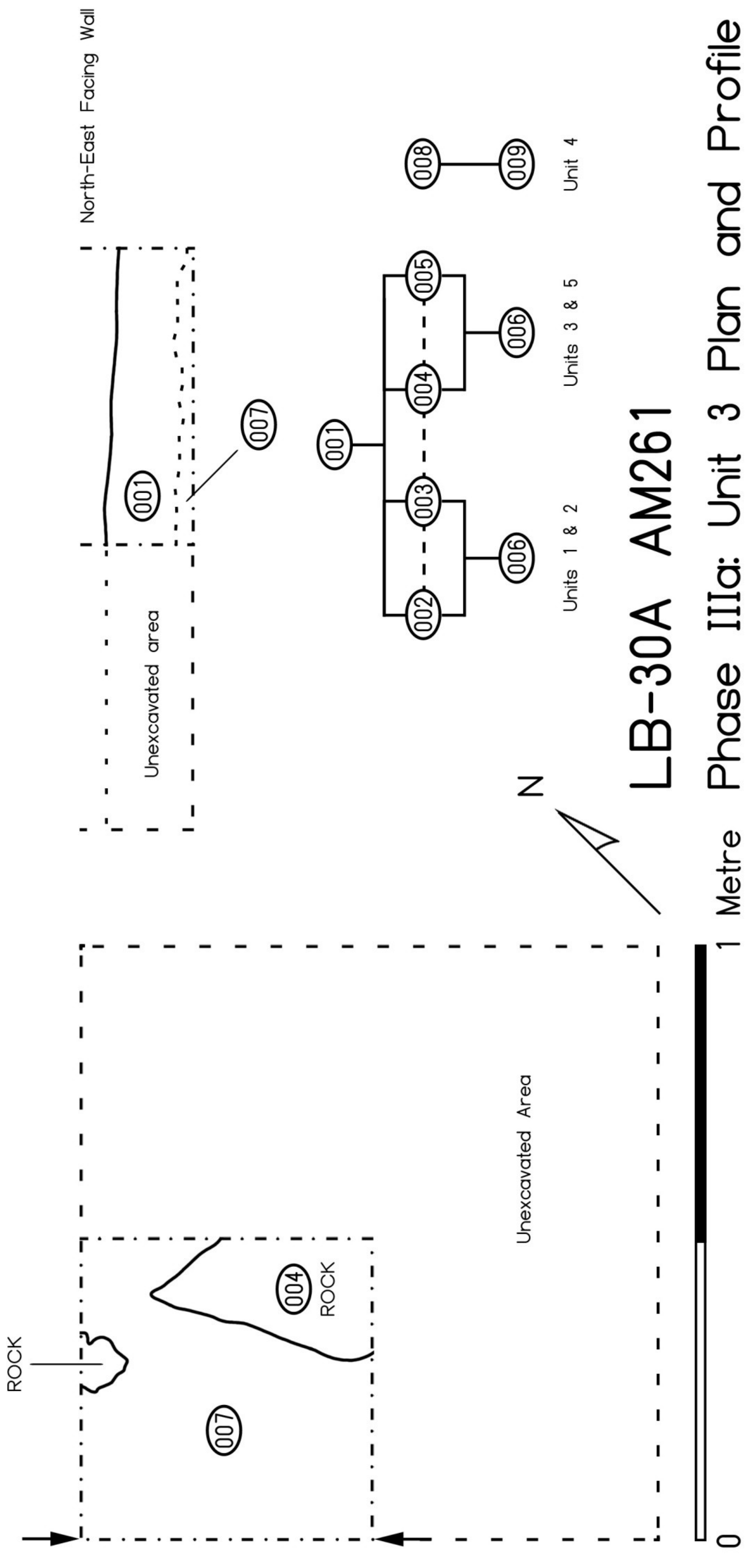


Figure 9-35: Plan and section of AM261 Phase IIIa Unit 3 (Author).

Unit 4, Eastern crash scar surface artefact cache (FS 118.01-118.04):

Units 4 and 5 were opened in order to understand the soil profile on the flat plateau above the Phase II main artefact concentration. Unit 4 (NR 99283 42494) was, therefore, positioned atop a collection of surface debris and adjacent to a large surface rock (Figure 9-36). It was hoped that the surface debris (FS 118)—a fragment of Plexiglas, a possible engine head fragment, and two ferrous NMFs not present during Phase II—was indicative of a larger collection of aircraft-associated material which had been trapped by the adjacent boulder due to down slope movement. Only the SE corner, 50cm^2, of Unit 4 was exposed (Figure 9-37 and Figure 9-38). The remainder of the unit was located underneath the immovable stone and, therefore, inaccessible. Unit 4 revealed an extremely shallow soil profile. The upper strata (context 008) covers the whole of the quadrant and consists of a five centimetre deep, dark black brown, gritty clay/loam soil with approximately 60 percent <5cm gravel inclusions. Context 008 has a slight slope to the NE. As context 008 has such a shallow depth and overlies bedrock conglomerate (context 009), it is believed context 008 is a natural soil deposit accumulated due to slope wash. Moreover, the lack of cultural material discovered within Unit 4, in addition to the observed shallow soil profile and the slight downhill slope of context 011, intimates that the surface artefacts are not the result of natural deposition. Indeed, the odd collection of heavy ferrous/aluminium and light Plexiglas components in one location lends further weight to the argument that FS 118 results from caching activities. While it is unlikely that the plateau upon which FS 118 rested is the primary point of impact (Map 9-10), the caching of material in the area provides the possibility that FS 118 was originally located somewhere nearby. It is not clear, however, if the initial unearthing of FS 118 between February and July 2013 (Phase II to Phase IIIa) was the result of natural forces or human activity. Further research is needed in the area to fully understand FS 118's association with the scatter observed during Phase II and to quantify the amount of material being uncovered due to natural forces.

Figure 9-36: Surface scatter overlying AM261 Phase IIIa Unit 4 (Author).

Figure 9-37: AM261 Phase IIIa Unit 4 (Author).

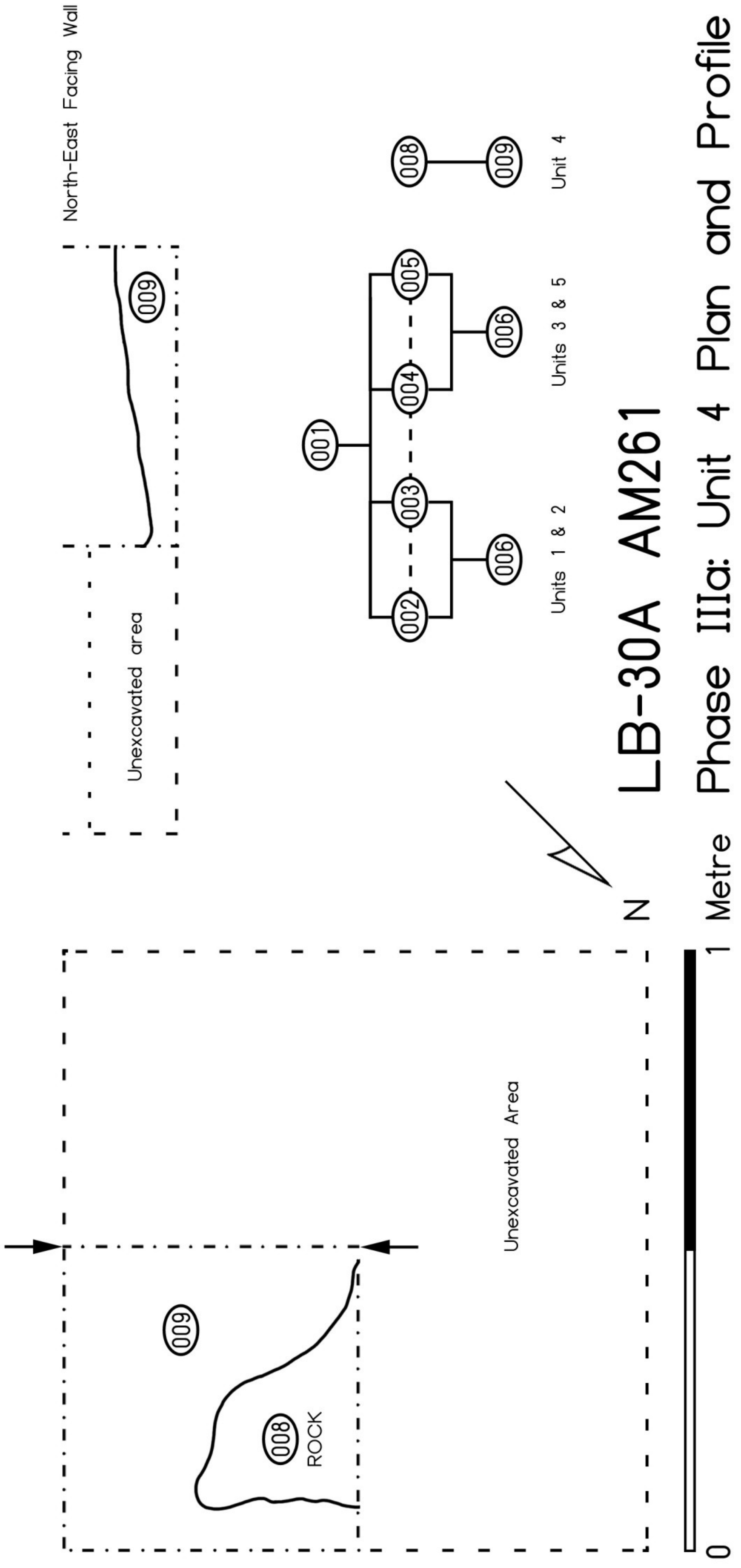


Figure 9-38: Plan and section of AM261 Phase IIIa Unit 4 (Author).

Unit 5, Western crash scar:

The last unit opened, Unit 5 (NR 99307 42493), was positioned to complement Unit 4 and to assess the western edge of the historically-identified crash scar. The eastern 50cm^2 quadrant was excavated (Figure 9-39 and Figure 9-40). As with the previous four units, two strata were observed (context 001 and 007). Unit 5 was excavated to a maximum depth of 30 centimetres with context 001 extending down 10-15 centimetres. Like Unit 3, no defined transition between contexts 001 and 007 was observed and no cultural material discovered. The similar soil stratigraphy observed in Unit 3, a unit placed in an area not usually identified as part of the impact site, makes the plateau less likely to be the area of impact.

Figure 9-39: LB-30A AM261 Phase IIIa Unit 5 (Author).

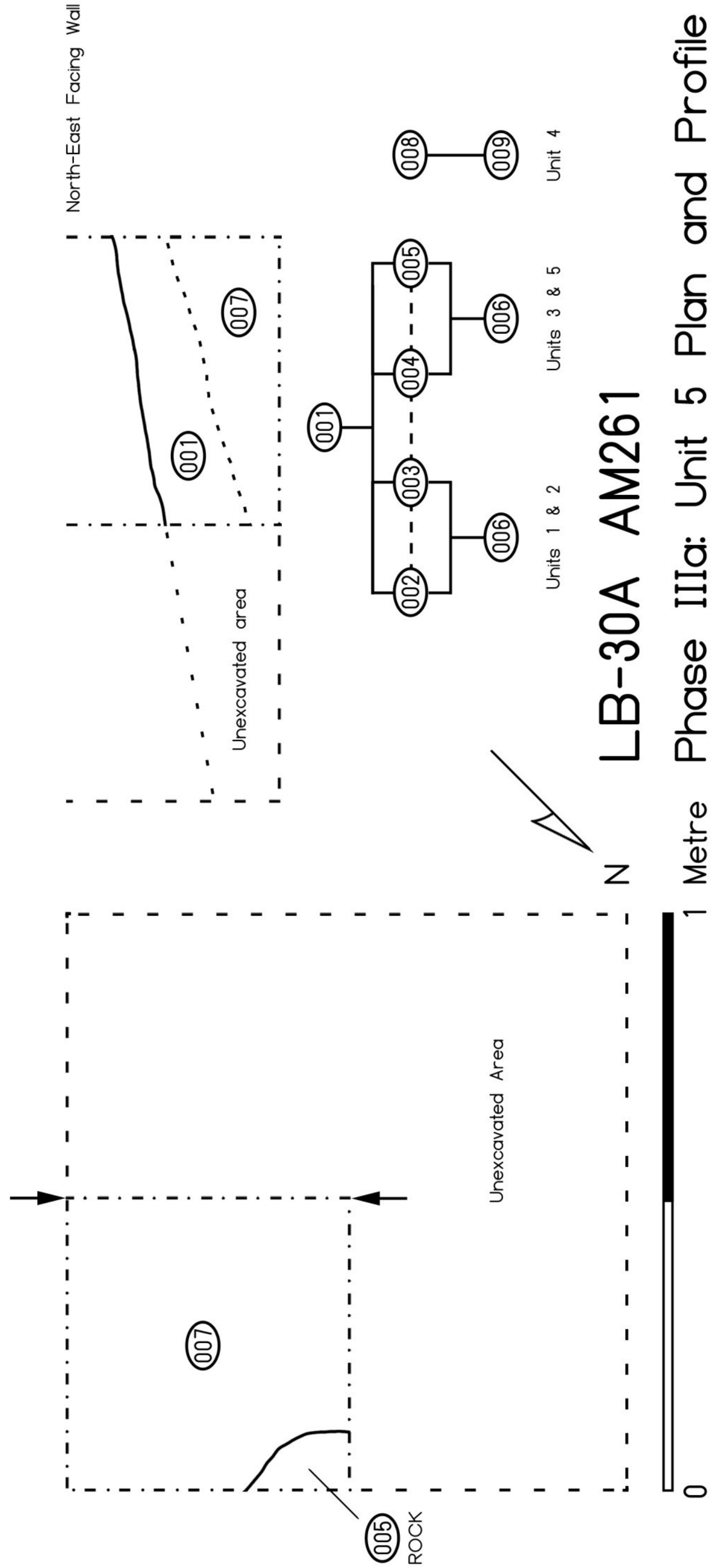
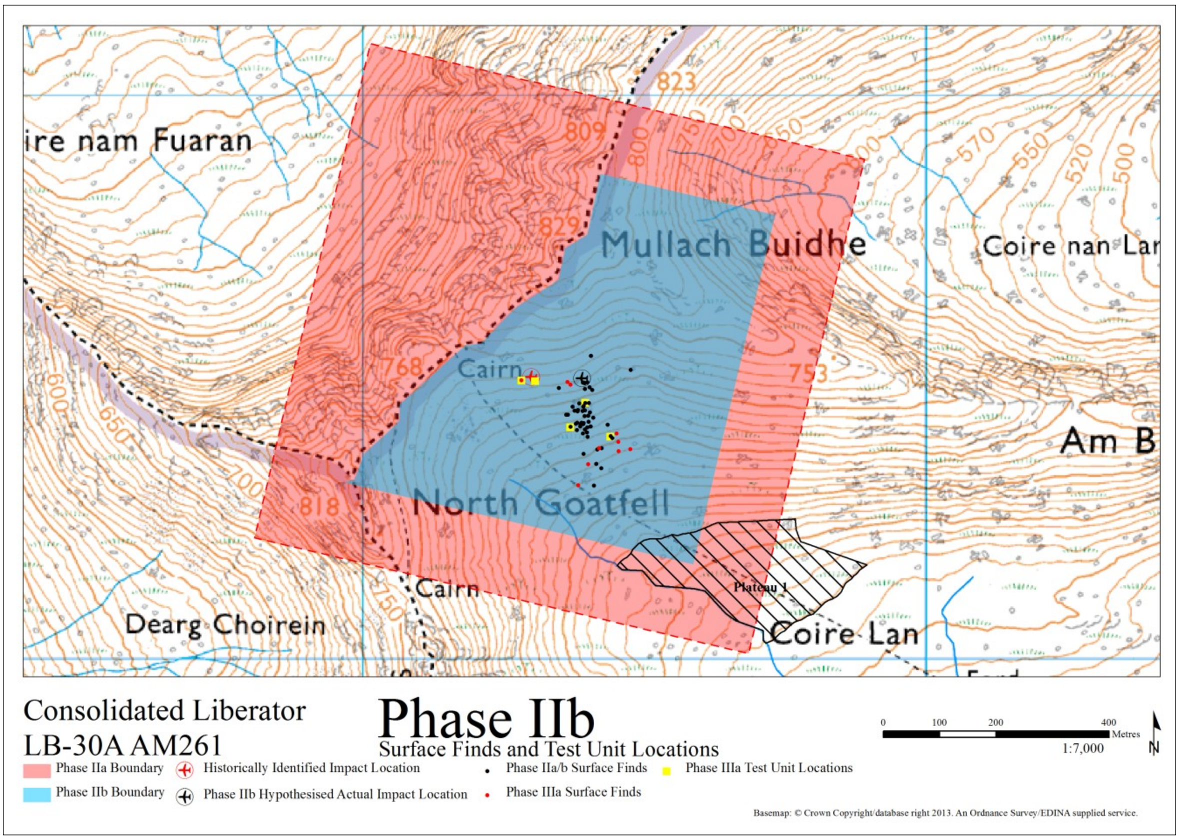


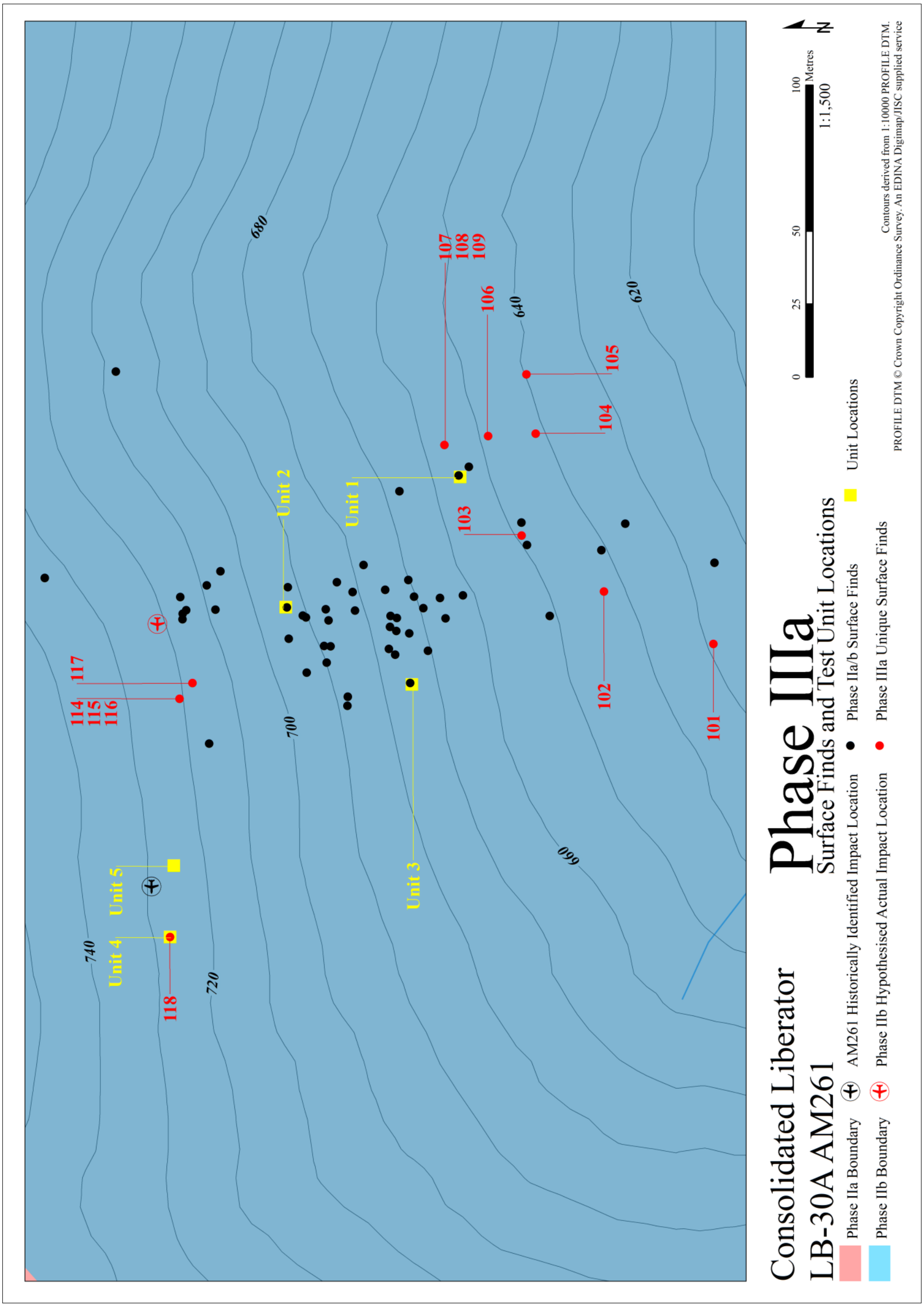
Figure 9-40: Plan and section of AM261 Phase IIIa Unit 5.

Supplementary artefacts recorded during Phase IIIa:

An additional five artefact groups were identified higher on the slope while walking between Phase IIIa units (Map 9-12 and Map 9-13). It is unclear whether these artefacts were dislodged from the ground in the three months between field work or whether they were coincidentally covered by the limited snow patches encountered during Phase II. In either case, the artefacts provide critical data which refines Phase II site interpretations. The majority of identified material, FS 114-116, is comingled. FS 114.01 is a nondiagnostic(diagnostic) metal fragment, FS 115.01 and 115.02 are melted aluminium ingots and FS 116.01 is a melted iron ingot. FS 117.01 is an A-4 parachute riser clip (Figure 9-41, Figure 9-42 and Figure 9-43). The riser clip would have been positioned in front of an airman's shoulders and would secure the parachute pack to the parachute harness (Figure 9-42). When an airman was to bail out, he would clip the parachute pack to the two riser clips, exit the aircraft and pull the D-handle release. The parachute would then unfurl and carry the riser clip above the airmen's head (Figure 9-43). FS 117.01 would have come from the same style harness as FS 071.02 but their significant separation (approximately 61 metres), the presence of 22 such harnesses on board AM261, and the discovery of FS 117.01 on the surface makes a direct association between the FS 117.01 and 071.02 unlikely.



Map 9-12: AM261 Phase IIIa overall surface finds distribution in relation to Phase IIa/b results (Crown Copyright/database right OS 2013b; Author).



Map 9-13: Annotated AM261 distribution of artefacts unique to Phase IIIa (red) and Phase IIIa test units (yellow) (Crown Copyright/database right OS 2013a; Author).

Figure 9-41: FS 117.01, an A-4 parachute riser clip (Author).

Image removed

due to copyright restrictions.

Figure 9-42: FS 117.01, the riser clip from the RAF observer/chest type parachute, would have been positioned in front of an airman's shoulders and would secure the parachute pack to the parachute harness (Hamer 1934; Australian War Memorial n.d.).

Image removed

due to copyright restrictions.

Figure 9-43: The RAF observer/chest type parachute harness and parachute pack opened (Irvin 1935). FS 117.01 is labelled as numbers 27 and 28.

More intriguingly, then, is the location of FS 114-117 in relation to the rest of the recorded site scatter. Indeed, FS 114-117 is directly in line with the westernmost artefact recorded (FS 054.01), the top of the central artefact concentration (buried FS 051-053) and the easternmost artefact recorded (FS 002.01). It is hypothesised that the W-E linear alignment of upper artefacts, including the melted fragments, provides compelling evidence for their locations as either the point of original deposition or indeed very near to it. The presence of a single artefact, buried and rock covered FS 061.01, only 40 metres upslope further supports the position of FS 114-117 as near the original point of impact. Moreover, an atypical cut and eroding section of ground (NR 99390 42498), identified but ignored during Phase IIb/IIIa research due to focus upon the historically recognised impact area, is located some 10 metres away (Map 9-12). The concentration of material in close proximity to the atypical cut, and the possible elimination of the historical crash site based on the results from Units 4 and 5, makes the region around FS 051-053, 061.01 and 114-117 of extreme interest as a possible impact site.

9.4 Comprehensive Site Analysis

The three primary objectives—identifying the point of impact, bounding the site and defining archaeologically sensitive areas—were met. The Phase IIa unsystematic pedestrian survey confirmed the 500 metre artefact spread noted by the contemporary witnesses and investigatory team (Air Historical Branch 1941; Davies 2001a: 15; Davies 2001b: 39). Additionally, a primary axis of artefact distribution was isolated within the 450 metre by 450 metre survey boundary refined for use during Phase IIb. Though the number of artefacts identified was relatively low, the data obtained from their analysis allows for the orientation of AM261 within the landscape. The rejection of the historically recognised impact point in favour of a revised impact point, aligned with the observed scatter, not only adds to the historical record but better correlates with the historical data available. Indeed, though archaeological data has not yet fully resolved the question of why White deviated from established flying procedures, the recorded artefact scatter correlates with historical testimony on White's preferred direction and speed of ascent. It would appear that White was following his preferred flight track and tried to clear the peaks of Arran via the Corrie Glen. Failing to ascend rapidly enough to clear the high slopes, AM261 impacted North Goatfell in full flight just shy of the summit.

The data gained from the excavation of five test units reinforce the revised flight path and point of impact. Four of five test units returned no artefacts or crash-associated soil evidence. Indeed, the test units showed that much of the extant surface artefacts are currently positioned due to down slope migration. FS 028 is the exception. Excavation of Unit 2, and the corroded and decaying interior frame fragments recovered, showed the McBrine luggage (FS 028.01-028.03) had been stationary for some time. While it is not clear whether FS 028.01-028.03 was recovered from the point of initial deposition (its position behind rock C makes this less likely), it is evident from the corroded interior frame that secondary deposition would have likely occurred several decades ago. As resolving the degree of movement of artefacts would require a much longer observational study than that allowed under this assessment of AM261, the specific speed of down slope movement for much of the surface artefacts is currently not quantifiable.

Historical documentation located during Phase IIa noted that the AM261 crash site had been heavily sterilised by a local scrap dealer after the war. The diminutive number of artefacts located, especially nearer to plateau 1, the hiking path and the *Coire Lan*, may be a result of the post-crash scrap collection or the result of artefact collection and burial in alluvial soil (Map 9-12). While the artefact scatter confirmed one aspect of the historical record, it also calls into question hypothesised flight vectors and post-crash recovery activities.

Historical documentation reports that “none of the occupants was wearing a parachute when their bodies were found” (Air Historical Branch 1941) and that all 22 crew members and passengers were recovered and subsequently buried in Lamlash Cemetery (Air Historical Branch 1941; Davies 2001a: 14-15; Davies 2001b: 37, 41; CWGC 2013). The identification of crew-associated equipment (FS 071.02 and 117.01) potentially refutes claims of full remains recovery. FS 071.02 and 117.01, worn on the torso of flying personnel, would need to have been separated from the recovered remains in order to remain on site. Whether the separation of FS 071.02 and 117.01 was the result of the crash event or whether the recovery teams removed the parachute harness prior to departing the site cannot be determined at this time. Indeed, the claim that none of the aircrew or passengers was wearing parachutes when recovered is consistent with FS 071.02 and 117.01. The RAF’s observer/chest type parachute was a two part system, a parachute harness worn by the individual at all times during flight and a separate parachute pack. The parachute pack was clipped onto riser clips (FS 117.01) prior to exiting the aircraft (Figure 9-43: Patent figure 4, numbers 27 and 28; figure 2, notations A and D). The statement that the crew was not wearing parachutes, in light of FS 071.02 and 117.01, is consistent with an accidental and sudden, high speed impact; there would have been no need to affix parachute packs in preparation for bailout as aircraft systems were operating normally and, prior to accidental impact, the crew/passengers would not have had time to affix parachute packs to their harnesses. While the discovery of two parachute harness fixtures 61 metres apart shows possible evidence for the crash-induced mutilation of a maximum two individuals, FS 071.02 and 117.01 alone are not sufficient evidence to identify and confirm two discrete points of human impact.

The perceived level of site disturbance, most notably the wind-induced artefact scattering, the post-war collection of aircraft components for scrap and the hypothesised extensive down slope movement of artefacts, restricts AM261's future archaeological productivity. While post-depositional activity may have affected the quantity of extant artefacts, the general distribution of artefacts and the test units excavated identify features worth additional, focused study. Moreover, like most metal skinned aircraft, the condition of extant artefacts is generally positive. It is advocated that future research focus on the potentially productive areas identified during Phase IIa/b and confirmed during Phase IIIa: the revised point of impact and plateau 1. Confirming whether the proposed crash site and the area of likely artefact collection have elevated artefact densities would help guide NTS site management policy. For example, the site is currently classified as free from human remains. The discovery of parachute harness components reveals that the site may still contain fragmentary human remains. Research into the proposed crash site and/or plateau 1 may provide information that can assist in either substantiating the site as free of human remains or help to reclassify the site as a war grave. Though future research is not particularly time sensitive—the lack of substantial surface debris and the relatively remote location dissuade regular visitation—the earlier research is conducted on plateau 1 and the revised impact site the larger, and potentially more informative, the assemblage expected.

9.5 Conclusion

Phase IIa/b and IIIa utilised the PAAR Methodology to deliver a highly effective research programme using the time, financial and human resources available. Indeed, due to the PAAR Methodology providing clarity of strategy to the background research, field team and post-survey/excavation analyses, the AM261 research project was completed on budget with secure and verifiable data. The use of the PAAR Methodology appropriately focused the majority of research into the survey phases. Additionally, invasive investigation was sufficiently targeted to facilitate the collection of useful data while still preserving the site's extant archaeological integrity. The data and material recovered via the flexible, phased investigatory methodology enabled the establishment of a crash site boundary, the identification of archaeologically sensitive areas and the development of a crash narrative hypothesis based upon both historical and archaeological data.

Future research should prioritise refinement of the hypothesised impact point and evaluation of sub-surface artefact distribution. The employment of metal detector surveys would have generated a complimentary data set characterising the quantity and distribution of subsurface artefacts. Additionally, while exceeding the resources and SNH permissions allocated to the current AM261 research project, the use of a shovel test probe survey would be beneficial. The 50cm^2 units returned largely the same data as full square metre units. The increase in test unit quantity, as embodied by an STP survey, would increase the quantity of data returns at a moderate increase in resources required. Additionally, the implementation of STP surveys would allow for a more complete characterisation of soil stratigraphy including the possible identification of the impact scar. Care, however, would still be required to ensure STP surveys were sufficiently focused to conserve and preserve archaeological resources while simultaneously meeting the projects' research objectives.

10 Conclusion

10.1 Discussion of Work Undertaken

10.1.1 Summary

This thesis effectively merges established archaeological methodology with relevant aspects of forensic aircraft investigation practises. The establishment of a phased methodology which utilises investigatory objectives and techniques requiring increasingly large investments of time, human and financial resources introduces professional rigour to a nascent archaeological sub-discipline popularised by avocational researchers.

The evaluation of current statutory mechanisms confirms the eligibility of aircraft wreck sites within the UK for protection under established heritage laws. Of the current legal regulations, *PMRA 1986* provides the primary protection for aircraft wreck sites. However, the remote location of many crash sites makes general enforcement of *PMRA 1986* and other aircraft-specific legal protections impracticable. As a result, most tampering or vandalism is discovered long after the act. Therefore, the protection and future management of aircraft wreck sites cannot rest entirely with legislation. Instead, a community of interested landowners, aviation enthusiasts and archaeologists must orient the sub-discipline's ethical outlook and operational research objectives toward the safeguarding of air crash sites as cultural resources.

Based on analysis of legal protections, avocational field studies, sub-discipline publication standards and professional field methodologies, this thesis advocates that the focus of current and on-going research must move away from unsystematic and unpublished excavation and towards sustainable, targeted research. In order both to gain acceptance by the wider archaeological discipline and to preserve a finite data set into the future, aviation archaeology must focus on long-term site management. Emphasis should be placed on systematic exploration, increased dissemination of results and safeguarding of sites through persistent vigilance and public education.

The PAAR Methodology developed in this thesis provides deployable procedures which satisfy the requirement for systematic exploration. The proposed methodology's focus on background research (Phase I), unsystematic surveys (Phase IIa) and systematic surveys (Phase IIb) and the eschewal of widespread invasive investigations in favour of targeted sustainable research programmes correlates with the avocational community's stated interests and material strengths. Indeed, avocational communities excel in providing historical data. The PAAR Methodology creates an organizational framework for such data. Demonstrating that excavation need not be central to the investigation of aircraft wreck sites, the field trialling of the PAAR Methodology utilised background research and an increasingly intensive series of archaeological surveys. The study of Boeing B-17G 42-97286 establishes that aircraft archaeological surveys can confirm contemporary testimony as well as signify future research contributions. Phase IIa archival research identified 42-97286's general flight path which was subsequently confirmed by the unsystematic field survey. Data gained from the Phase IIb systematic survey enabled interpretation of the extant debris scatter as well as of the individual artefact deformation. The resulting hypothesis modified the flight path and humanised the tragedy. The crew of B-17G 42-97286 did not simply fly into a cloud-obscured Beinn Nuis, as historical material and secondary sources report, but rather impacted the cliff face after an agonising and prolonged attempt to out-climb disaster. This revised crash narrative, generated from non-invasive techniques only, demonstrates the substantive effect of non-invasive research.

While the survey of 42-97286 demonstrates the usefulness of its two non-invasive phases, the PAAR Methodology does not abandon excavation as a critical archaeological research tool. Phase IIIa targeted excavations resolve specific research questions. The Phase IIIa investigation of LB-30A AM261, for example, confirmed most down slope artefacts to be in their current position due to post-depositional migration. Rather than promoting a freeze on aircraft wreck site excavation, the field trials of the PAAR Methodology indicate that current aircraft archaeology needs to be refocused on Phases I, IIa and IIb with Phases IIIa and IIIb used in specific and/or extraordinary circumstances. The PAAR Methodology's focus on background research and surveys aligns aircraft archaeology with the larger archaeological discipline and helps preserve aircraft wreck sites for future generations.

Increased recognition of the cultural value of aircraft wreck sites is crucial for their preservation. The evaluation of past avocational research and the analysis of PAAR Methodology field trial sites indicate that aircraft wrecks experience tampering and artefact manipulation post initial deposition. Boeing B-17G 44-83325 Phase IIb FS 015.01/017.01 (Phase IIa 130.02/130.01) experienced substantial artefact migration within the three months between surveys. The perpetuation of unmethodical, unrecorded, unpublished and invasive research serves to further cloud and exhaust the archaeological record. Limiting invasive work to targeted excavations (Phase IIIa) enables the collection of crucial archaeological data without the depletion of a site's archaeological potential. Past avocational excavations which focused on removing the entirety of aircraft debris effectively rendered many aircraft wreck sites archaeologically sterile. Because it is a destructive science studying a finite resource, aircraft archaeology must mature in both its research objectives and field methodology. By simultaneously exploring and protecting the finite archaeological resource which it details, the proposed PAAR Methodology balances historical curiosity and site management.

10.1.2 Critique

This thesis's primary objectives of (1) evaluating current statutory protections for historic aircraft wreck sites, (2) developing a standardised, phased methodology adapted to the unique requirements of historic aircraft wreck sites and (3) field trialling the developed methodology were categorically successful. The flexibility of the PAAR Methodology is one of its great strengths; aircraft of different models and/or materials located within disparate terrain were successfully investigated using the standardised operating procedure. As with all research projects, however, unplanned factors revealed methodological omissions which, if corrected, would provide additional and valuable data. In addition, modifications were introduced as the field trialling progressed which resulted in a more robust methodology.

One area of obvious omission is the restriction of field trials to high ground wreck sites. All eight field trial sites (Phase IIa-IIIa) are situated between 340m and 760m asl. The focus on high elevation wreck sites largely was due to Scottish topography. Scotland's high peaks combined with the presence of numerous flight training and ferrying units to create a data set skewed to the upper elevations. In southern England, for example, the data set is reversed due to lower terrain elevations and a higher proportion of combat-related crashes; combat-related crashes are less likely to group around specific terrain features as they are the result of wide-ranging and twisting aerial combat. In addition to the natural grouping of wreck sites on high ground, the remote location of Scottish high ground wrecks assured the retention of surface debris. As this thesis was not focused on locating aircraft wreck sites but rather on their subsequent archaeological investigation, the decision to utilise known, high-ground wreck sites was deemed an acceptable bias. Future field trialling of the PAAR Methodology, therefore, needs to include lower elevation sites.

Due to health and safety concerns, metal detector surveys could not be conducted of B-17G 42-97286, B-17G 44-83325, B-24D 42-41030 and LB-30A AM261. This lack of metal detector surveys almost certainly affected the interpretation of the sites. Surface scatter and subsurface metal detector contacts could not be compared and therefore confirmation of archaeologically sensitive surface areas did not extend into the subsurface strata. If metal detector surveys can be undertaken, correlation of surface and subsurface data may indicate a site with little post-depositional tampering. Conversely, no observed correlation between surface and subsurface data may demonstrate the movement of surface artefacts, the collection and burial of artefacts into subsurface caches, and/or the movement and re-deposition of subsurface contacts due to geologic mass movement. Thus, the development of a method which facilitates use of metal detectors during Phase IIa and IIb on all sites/terrain grades is critical to the universal applicability of the PAAR Methodology.

The proposed shovel test probes [STPs] were omitted due to human, financial and time limitations. While it is known that STPs are an excellent invasive survey technique for large scale, general archaeology sites, STPs have not been successfully trialled on aircraft wreck sites. It is the position of this thesis that the implementation of STPs surveys, where legally possible, would enhance the characterisation of non-metallic, mineralised metal artefact, and/or leached petrol distributions as well as the identification of crash scar stratigraphy. Future field trialling is necessary to determine whether the technique returns data worth the additional resources required or whether pedestrian and metal detector surveys return similar data at lesser expense.

10.1.3 Future Research

The proposed PAAR Methodology is not meant to be static. The methodology was developed with the express desire that it start a conversation between avocational and professional archaeologists. Derived from each groups' specific skill set, field research procedures and research objectives, the methodological synthesis provides a professionally rigorous, historic aircraft-specific archaeological methodology. If employed by both avocational and professional researchers, the evolved methodology would enable the integration of aircraft archaeology into the wider archaeological discipline. As part of the synthesis dialogue, additional research is essential. Two of these research areas have been alluded to previously: high elevation/steep gradient metal detection and shovel test probe techniques. In addition, the PAAR Methodology would benefit from field tests which expand its geographical, chronological and technological parameters.

10.1.3.1 Geographical Expansion

Linking the future research avenues identified as part of the thesis critique with more general future research objectives is the need to expand field trial sites geographically beyond Scottish high ground wrecks. If the PAAR Methodology is to be universally adopted, additional low elevation and non-Scottish sites need to be investigated using the proposed methodology. The most likely initial route for expanded field trialling is to assess lower elevation sites within Scotland. Application to flatter terrain, such as agricultural fields, will further the evolution of the PAAR Methodology. In addition, the expansion of field trial sites to include sites positioned at lower elevations and on lesser grades should alleviate some of the health and safety concerns encountered during the current field trials. Indeed full deployment of the PAAR Methodology was hampered by the inability to use metal detecting on some sites and by the elimination of STP surveys due to resource and time constraints. The immediate limitation to Scottish wreck sites allows for the application of the PAAR Methodology to lower elevation sites without drastically altering factors contributing to sites' survival (e.g., weather, population densities, soil conditions, etc.). Expanding the PAAR Methodology field trials geographically, with the increase in topographical, climatic and population profiles, is critical to the fuller adoption of methodical aviation archaeology research practises. While Scotland provides a moderate climate in which to examine aircraft wreck survivability, the eventual expansion of testing to arctic, desert and tropical climates will require adaptations which will either uphold or evolve the PAAR Methodology.

Should the JCCC revise its interpretation of the *PMRA 1986* and permit the use of trained professional archaeologists on air crash sites where human remains are either known/suspected to be present or encountered during excavation, future research could be expanded to include sites for which excavation licenses currently cannot be obtained. As presently implemented, the *PMRA 1986* prevents professional archaeologists from conducting invasive research on sites where crews have not been recovered or where recovered remains included comingled individuals. Indeed, this interpretation of the *PMRA 1986* by the JCCC resulted in a failure to obtain an excavation license on application for B-17Gs 44-83325 and 42-97286. Specifying only that a license system be implemented as oversight for on-going excavations, the *PMRA 1986* is vague on what sites can and cannot be excavated. However, the JCCC's narrow interpretation of the *PMRA 1986* limits the sites which can be invasively researched. The training, expertise and experience professional archaeologists have in excavating and assessing human remains should allow for the professional archaeological excavation of war graves so long as the research questions are valid, relevant to the public interest and undertaken in a manner befitting the sacrifice of those individuals who are the subject of research. Indeed, these stipulations are no different than those expected of professional archaeologists excavating human remains on non-aircraft wreck sites.

Perhaps most troubling is what the JCCC's narrow interpretation of the *PMRA 1986* means for sites not classified as war graves. As previously stated, the JCCC seems only to bar excavation of sites where the aircrew has no known grave or where the aircrew has a comingled grave. Sites where all aircrew have individual interments are eligible for excavation despite the circumstances of the crash. LB-30A AM261, for example, was eligible for Phase IIIa investigation as all 22 crew and passengers were known to have been buried in individual coffins. However, Phase IIb and IIIa research identified two parachute harness components which were most likely attached to the individual during the crash. Moreover, the known crash dynamics and general body positions suggest that the deceased were likely in a fragmented state at the time of recovery. Based upon the research conducted as part of this thesis, it is believed that AM261 most likely contains substantial, if fragmented, human remains. Under the JCCC's interpretation, AM261 should not have been eligible for an excavation license; a conclusion brought about only through archaeological research. The tautology of AM261's excavation status only serves to reinforce the importance of professional archaeological investigations in identifying and classifying sites. Indeed, a better system would be to classify sites in one of three categories: war graves, probable extant human remains, no human remains present. War graves are sites where the crew have no known graves and would only be eligible for excavation by professional archaeologists. Probable extant human remains would include sites where the crew have known graves but may be interred in a common, comingled grave or sites where the crash dynamics and/or archival material suggests the continued presence of human remains on site. Probable extant human remains would be eligible for excavation by professional archaeologists or avocational archaeologists with suitable professional training and/or professional oversight. Sites with no human remains present would include those crashes where all aircrew survived intact. These sites would be eligible for excavation by all applicants. A more nuanced approach to the issuance of excavation permits is desperately needed. The JCCC's narrow interpretation of the *PMRA 1986* licensure requirements stifles legitimate archaeological research but is frequently flaunted by unethical souvenir hunters due to the remote nature of aircraft wreck sites. Granting excavation permission to professionally trained archaeologists (with specialist training/experience in human remains) would extend research to include previously unavailable sites without dishonouring the dead or the intentions of the *PMRA 1986*. If permission were to be granted for invasive research into sites with known/potential human remains, the PAAR Methodology would need revision to include the professional, respectful treatment due war graves.

10.1.3.2 Chronological Expansion

The PAAR Methodology should also be expanded chronologically. The current study and accompanying field trials are limited to Second World War air wrecks. The decision to limit the current study to the Second World War resulted from Scotland's dominant aircraft wreck site data set as well as from the historical sub-division the Second World War represents in aircraft and world history. If the PAAR Methodology is to be more widely employed, field trialling on both younger and older aircraft wreck sites is required. A focus on First World War aircraft wreck sites fulfils the need to field trial older sites. Younger sites are numerous due to the proxy wars and regional border conflicts which flared up following the end of the Second World War. The assessment of the PAAR Methodology, when applied to non-Second World War wreck sites, will produce methodological revisions and, therefore, a more generally applicable aircraft archaeology-specific methodology.

10.1.3.3 Technological Expansion

The PAAR Methodology should also be expanded technologically. Future research initially should focus on the development of a metal detector survey technique deployable on high elevation, steep grades. The development of this specialised metal detector survey technique is crucial to the general applicability of the proposed PAAR Methodology. The development of a high elevation/steep gradient metal detector methodology will enable comparison of surface scatter and subsurface contacts. Characterising the scale of down slope artefact movement, a phenomenon unique to high ground wreck sites, is only possible via the assessment of surface debris/subsurface contacts. While other geophysical techniques may allow for similar data returns, the metal detector remains one of the most robust and portable techniques for identifying subsurface artefact distribution.

In addition to developing a high elevation/steep gradient metal detector survey technique, the field trialling of STP surveys is paramount to assessing the PAAR Methodology as proposed. Impossible to field trial as part of this thesis due to resources available and legal restrictions on excavation, the proven value of undertaking STP surveys as a discovery technique on large unconfirmed archaeological sites demonstrates the need for future assessment of the quality and relevance of historic aircraft wreck site STP survey data returns.

The introduction of geophysical and geochemical surveys may return data currently unavailable by other means. Remote sensing technologies have been utilised on aircraft sites in the past. Time Team aircraft excavations utilising electro-resistivity, magnetometry and ground penetrating radar obtained positive data returns. Expanding the number of sites surveyed using remote sensing technologies would increase understanding of sites' conditions, enable recurrent examination of sites without requiring invasive work and potentially identify soil features (such as impact scars) which are visually obscured.

In addition to geophysical survey technologies, geochemical surveys may enable the identification of sites with (and without) extensive artefact scatters. Indeed, geochemical surveys may be able to identify artefact corrosion and/or petrol deposits via the leaching of marker elements/molecules in the surrounding soil. As they corrode, aluminium or iron artefacts, for example, leach corrosion product into the surrounding soil. Quantification of the corrosion product versus natural, background quantities may allow for the identification of both extant and fully corroded artefacts.

Trace petrol in the soil may also provide positive aircraft wreck site identification via geochemical analysis. Allied Second World War petrol, AVGAS 100/150, is a blend of 100/130 base stock with additives to improve performance. Though the actual blending agents used to obtain 100/150 fuel varied by date, producer and country, the major blending agents used were aniline, xylidine and tetraethyl lead [TEL]. Allowing for nuanced site analysis are the nation, manufacturer or product-specific additives. During the Second World War, the British usually used 2.5% mono-methyl-aniline [MMA] and 6cc/US gallon TEL to achieve the 100/150 rating. The US, on the other hand, used 3% xylidine and 4.0-4.6cc/US gallon TEL (Heron 1950: 644). A variety of compounds comprised the 100/130 base stock and fuel grade-specific colour dye markers. Much like the identification of a serial number or manufacturer stamp, the identification of base stock, colour dye markers, MMA, xylidine or MMA/xylidine mixed fuel (different manufacturers' fuels were often co-mingled in the aircraft causing wear problems with engine components) may allow for the identification of an aircrafts' national identity and the operational life. More generally, it is hypothesised that the future study of quantification and distribution of aviation petrol base stock and additives will enable characterisation of subsurface boundaries on aircraft wreck sites where deployment of other geophysical survey techniques is impractical (e.g., cliff/scree sites and bog land).

10.1.4 Avocational-Professional Dialogue

Equal in importance to the geographical, chronological and technological expansions of the PAAR Methodology is the need for improved dissemination of research. As discussed in Chapter 3, avocational archaeology and commercial publications largely focus on the history of aircraft wreck sites. The equitable treatment of, or indeed specific focus on, excavation work undertaken is critical to the acceptance of aviation archaeology as a reputable sub-discipline and steward of historical aviation archaeological resources. To this end, the refinement of BAAC archaeological guidance to include more specific advice on excavation methodologies, conservation and publication is believed necessary. The BAAC has an extensive following in the UK and it is thought that abandoning the BAAC in favour of a new organisation would be detrimental to the inclusion of established avocational groups. Collaboration with established archaeological organisations such as the IfA or CBA may provide both the desired avocational-professional dialogue as well as a reorientation of BAAC methods. Additionally, the establishment of a peer-reviewed journal dedicated to aviation archaeology would further the desired avocational-professional collaborative dialogue by promoting a synthesis of mutually acceptable research methodologies and the dissemination of obtained results. A positive tangential result would be the secure archiving of project records.

The UK, having established avocational aircraft archaeology groups as well as active professional archaeology organisations with community archaeology/avocation archaeology outreach, can foster immediate avocational-professional methodological dialogue. The PAAR Methodology's biggest challenge, therefore, is the inclusion of avocational and professional archaeologists as equal stakeholders. The PAAR Methodology is meant to be the start of larger collaboration between the currently separate communities. The failure to embrace a standardised, phased methodology threatens the future of historic aircraft wreck sites as important archaeological resources. Largely the focus of avocational archaeologists, aircraft wreck sites currently are explored, excavated and written about with varying degrees of rigour. The safeguarding, managing and preserving of this finite resource for future generations is critical not only to the survival of the aviation archaeology sub-discipline but to the survival of our archaeological link with man's soaring achievement, human flight.

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11 Appendix: Additional Tables and Figures

11.1 Chapter 6: Wooden Airframe Survey Sites

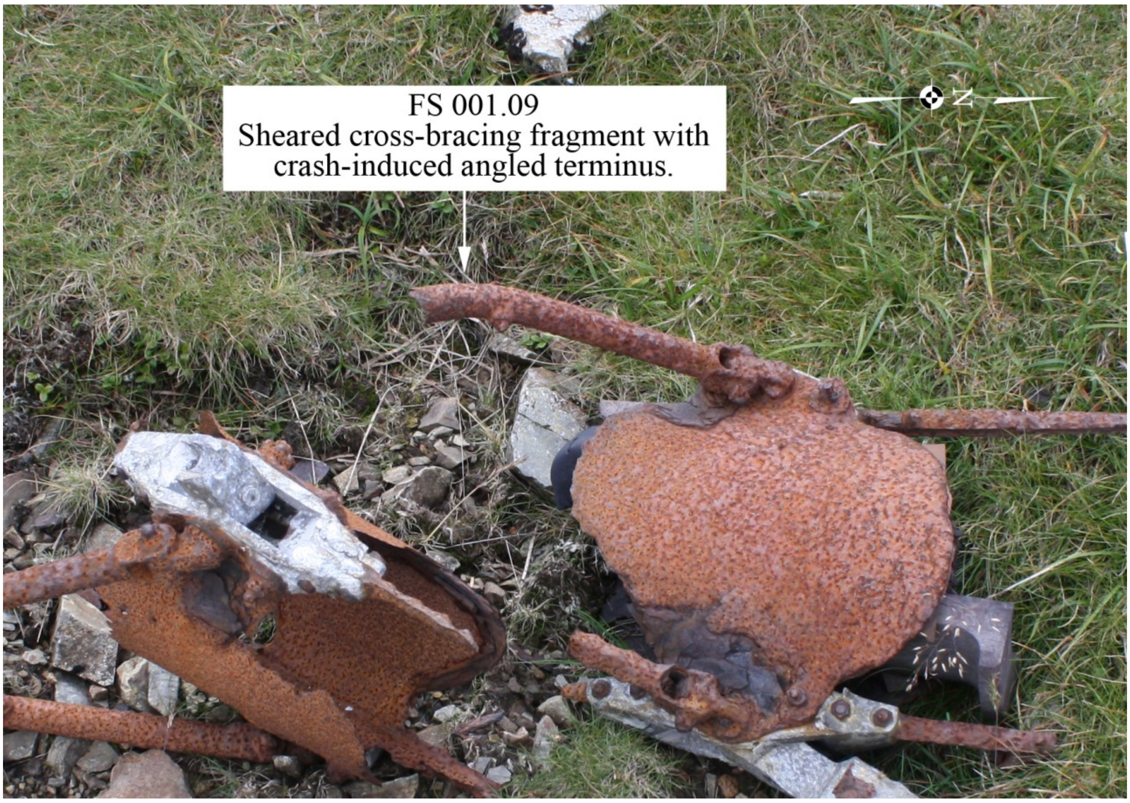
11.1.1 de Havilland DH.98 NFII DD795 (Corserine, Dumfries and Galloway)

11.1.1.1 Phase I Historical Survey

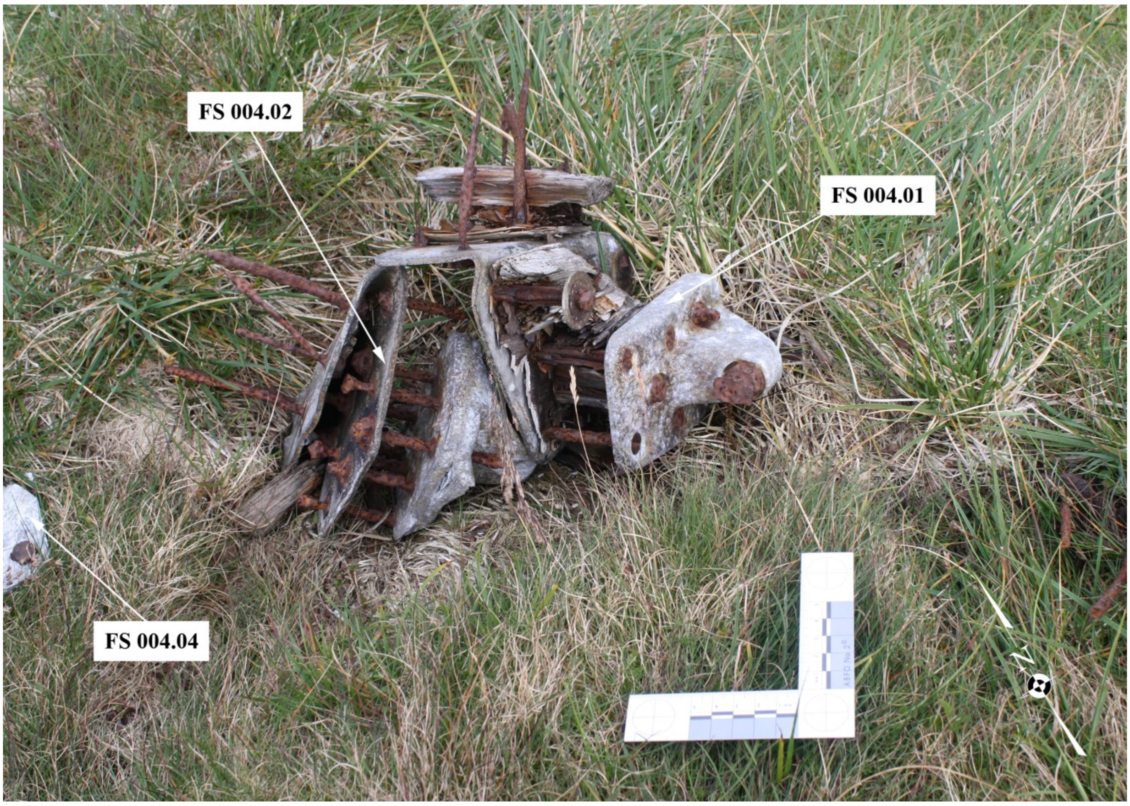
Flight Sergeant Kenneth Mitchell RAFVR	1503624	Grave 5 Division B.C. of E Plot 12 Hartlepool (Stranton) Cemetery, County Durham United Kingdom
Flight Sergeant John Jeffrey Aylott RAFVR	1334222	Grave 625 Section W Barking (Rippleside) Cemetery, Greater London United Kingdom

Appendix Table 11-1: Crew onboard DD795 on 20/21 January 1944 including individual serial numbers and current burial location if known (CWGC 2013).

11.1.1.2 Phase IIa General Data Survey

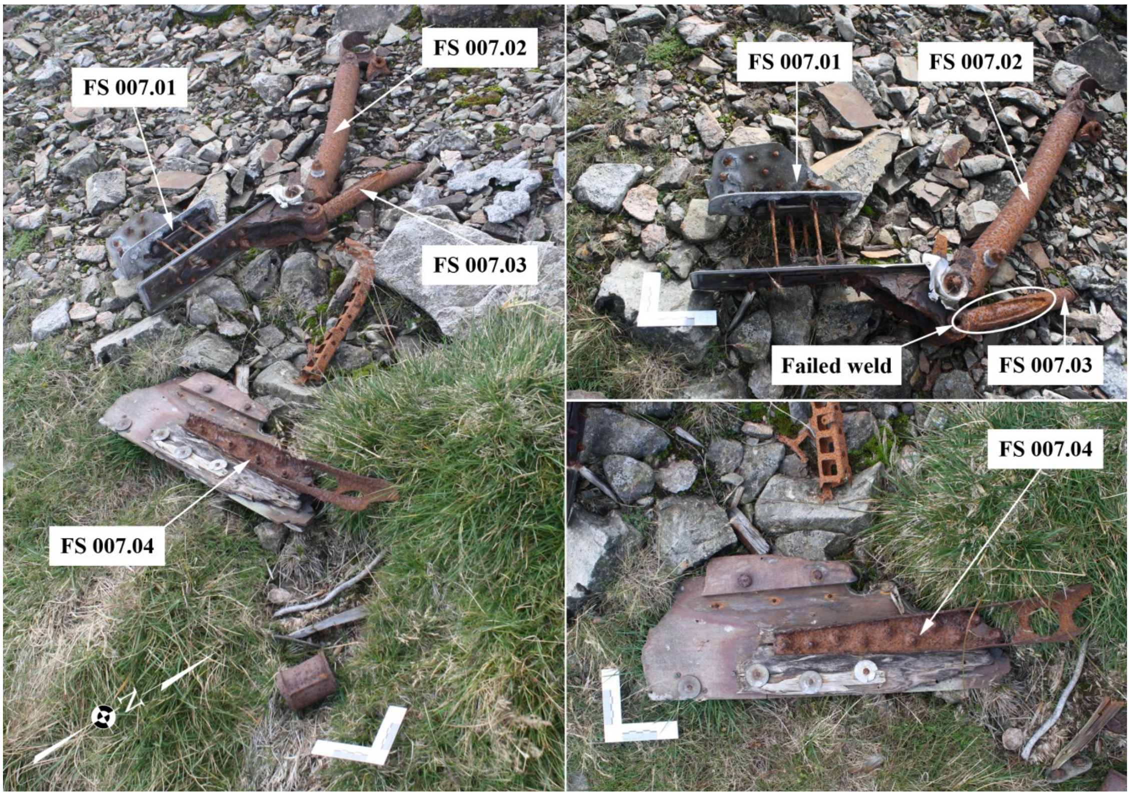


Appendix Figure 11-1: FS 001.09 shows sheared cross-bracing damage consistent with a full flight impact (Author).



Appendix Figure 11-2: FS 004.01 and 004.02 are back portions of two of the four total engine mounting brackets installed on DH.98 models (Author).
Mounted on the main spar at wing ribs three and four, the DHA-G.98110 assemblage is the backing plate for the parts which receive the engine mounting cradle.

Appendix Figure 11-3: FS 004.04—one of 22 metal spacers (DHA-G.98133) separating 12 rubber blocks within the main landing gear shock absorbers (Author).
The proximity of FS 004.04 to FS 001 either demonstrates the original presence, and now absence, of a second shock absorber set or the post-crash transfer of FS 004.04 away from its original deposition with FS 001.



Appendix Figure 11-4: Location of DD795 FS 007 (Author).
FS 007 is likely a continuation of the FS 004 concentration. The sheared termini and failed weld on the engine mount cradle support a high speed impact as recounted in historical documentation.

Appendix Figure 11-5: Location of DD795 FS 008 (Author).
FS 008.01 is a connection bracket for the inboard, upper rear landing gear strut (DHA-G.98108A) and the inboard, rear undercarriage well. FS 008.02 is a large ingot of melted aluminium, evidence of a post-crash fire. The recorded evidence suggests the area around FS 007 and 008 is likely the second main gear/engine impact point.

**Appendix Figure 11-6: FS 008.01 is a connection bracket for the inboard, upper rear landing gear strut (DHA-G.98198A) and the inboard, rear undercarriage well (Author).
FS 008.02 is a large ingot of melted aluminium, evidence of a post-crash fire.**

Appendix Figure 11-7: FS 006.03 retains part DHA-G.9888, its unique pivot joint (Author).

Appendix Figure 11-8: FS 006.06, confirmed by the presence of a bolt head marked AIR 11158, is a near complete undercarriage jack actuating cylinder (Author).
FS 006.01 is the bottom section of the other undercarriage jack actuating cylinder.

11.1.2 de Havilland DH.98 NFII DD753 (The Curr, Scottish Borders)

11.1.2.1 Phase I Historical Survey

Flight Lieutenant Henry John Medcalf RAFVR	131074	Grave 81 Elstead (St. James) Church Cemetery, Surrey United Kingdom
Flying Officer Ronald Edward Bellamy RAFVR	154591	Grave 6252 Section 18 Surbiton Cemetery, Greater London United Kingdom

Appendix Table 11-2: Crew onboard DD753 on 12 December 1944 including individual serial numbers and current burial location if known (CWGC 2013).

11.1.2.2 Phase IIa General Data Survey

Appendix Figure 11-9: Terminus of FS 005.01 (Author).
The aluminium end fitting (DHA-G.9890 or DHA-G.9887) has corroded away leaving the attachment pins (DHS 91/243 or DHS 91/268) protruding from the centre tube.

Appendix Figure 11-10: FS 007.01, the lower portion of the undercarriage jack actuating cylinder, retracted piston and valve lock (DHA-Q.98850A/3) (Author).
The proximity of FS 007.01 to FS 005.01, and the severe intergranular corrosion of aluminium components, provides critical evidence to support the complete corrosion hypothesis of FS 005.01's aluminium missing end cap.

Appendix Figure 11-11: The bent retracted piston and valve lock section of the undercarriage jack actuating cylinder (Author).
The 23 degree bend towards the fuselage, perpendicular to the retracted axis of installation, provides compelling evidence that the aircraft impacted the hillside front on with the ground sloping slightly upwards (as opposed to a zero degree angle of impact).

Appendix Figure 11-12: The valve lock of FS 007.01 shows severe intergranular corrosion (Author). Indeed the aluminium end piece is corroded such that recessed nut DHA-Q.9823 is nearly fully exposed.

Appendix Figure 11-13: Close-up of FS 026.01 (Author).
Similar to FS 005.01, though heavily corroded, three protruding attachment pins are visible on FS 026.01.

Appendix Figure 11-14: FS 031.01, a section of the aileron, consists of the pushrod assembly, the aileron pushrod connection and ribs 6A and 6B (Author).

Appendix Figure 11-15: Side view of FS 031.01 showing the aileron's characteristic aerofoil shape and interior ribs (Author).

Appendix Figure 11-16: The door hinge on FS 032.01, with the cast L.98295A part number, confirms FS 032.01 as a left main undercarriage door cover (Author).

Appendix Figure 11-17: Like FS 032.01, the cast L.98295A part number on one of FS 034.01's hinges positively identifies the artefact as the second, left main undercarriage door cover (Author).

Appendix Figure 11-18: FS 033.01 is believed to be the missing right main landing gear door cover (Author).
The lack of visible part stamps does not currently allow for confirmation.

Appendix Figure 11-19: Close-up view of FS 036.01 (Author).

Appendix Figure 11-20: FS 041.01 is a section of engine cowling which encloses the exhaust ports (Author).
FS 042.01, the only other portion of engine cowling located, is partially visible at the top left.

Appendix Figure 11-21: FS 042.01, the air intake fairing, covers the area near the supercharger intake on the underside of the engine (Author).
FS 041.01 and FS 042.01 are the only sections of engine cowling observed at the DD753 wreck site. FS 041.01 is partially visible at the bottom of the frame.

Appendix Figure 11-22: FS 047.01, the main landing gear upper brace strut to rear spar attachment bracket, rests atop FS 046.01 but is not attached to it (Author).
The two artefacts' immediate proximity supports an assertion that the area around FS 046.01/047.01 represents the impact point for one of the two main landing gear assemblies.

Appendix Figure 11-23: FS 047.01 viewed facing east (Author).
FS 047.01 retention of its wood attachment and its placement on top of FS 046.01 may demonstrate the post-crash relocation of FS 047.01. Alternatively, FS 046.01 may have been wrenched from the main spar during the crash and the absence of expected wood fragments is inconsequential to the larger artefact patterning.

Appendix Figure 11-24: One of two wing flap torque tubes (FS 048.01) installed on DD753 (Author). FS 054.01 and 054.02 are seen (L-R) in the top right of the frame. FS 049.01 is to the left of FS 048.01 while FS 053.03 is to the immediate right. The clustering of undercarriage components supports the hypothesis that the immediate area contains port wing, engine and undercarriage components.

Appendix Figure 11-25: South-facing view of FS 048.01 (Author).
Note the sheared off and bent condition of the centre hinge support adjustable struts. The strut termini do not show visual evidence of having been cut. As such, it is believed their current condition is as a result of the crash.

Appendix Figure 11-26: Missing attachment assemblies from an otherwise intact FS 049.01 (centre) and FS 049.02 (bottom) demonstrate the catastrophic breakup of DD753 during a low angle impact (Author).

Appendix Figure 11-27: The charred wood spar between DHA-D.98124 and DHA-E.98459 A / DHA-E.98460 A (Author).
The charring is likely the result of the post-crash fire.

Appendix Figure 11-28: FS 053.01-053.03 (Author).
FS 053.01, the main spar brackets for the main landing gear and engine cradle, are shown to be the outboard brackets by the retention of the jacking attachment. FS 053.03 03 (an undercarriage jack piston) was part of FS 005.01. The position of FS 053 away from the remainder of the undercarriage jack (FS 005.01) may demonstrate limited artefact mobility.

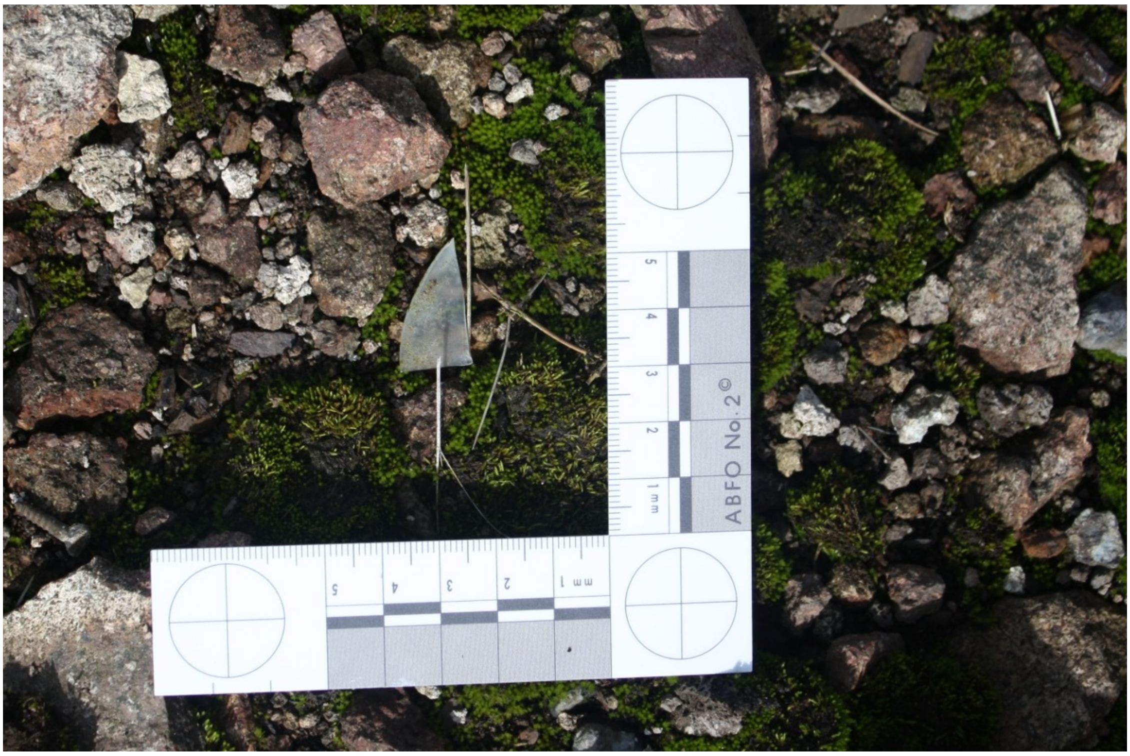
Appendix Figure 11-29: FS 054 includes a rear-spar attachment point for the main undercarriage upper radius rods (FS 054.01 at right) and a wing petrol tank inspection cover (FS 054.02, left of FS 054.01) (Author).
FS 048.01 and FS 053 are partially visible in the top right.

Appendix Figure 11-30: FS 054 viewed facing north-east (Author).
FS 048.01 is partially visible on the left. One of two main landing gear shock absorber exterior reinforcement plates (FS 055.02) is visible at the top of the frame.

Appendix Figure 11-31: General view of FS 055 (Author).
FS 048.01, FS 049.01 and FS 054.01 are partially visible in the upper right.

Appendix Figure 11-32: FS 055 including main landing gear shock absorber exterior reinforcement plates (FS 055.01 and FS 055.02) (Author).
The intact bolt assemblies and broken undercarriage cross-bracing show FS 055.01 and FS 055.02 were not systematically disassembled following the crash.

Appendix Figure 11-33: The eastern terminus of FS 056.01 shows the failure of an angle weld on an exterior engine cradle mount strut (Author).



Appendix Figure 11-34: Close-up of NGF FS 022.01 (Author).

11.2 Chapter 7: Metal Skinned Aircraft Survey Sites

11.2.1 Boeing B-17G 44-83325 (Beinn Edra, Isle of Skye)

11.2.1.1 Phase I Historical Survey

2nd Lieutenant Paul M. Overfield Jr. USAAF	0-836155	Stroudsburg Cemetery Stroudsburg, Pennsylvania United States
2nd Lieutenant Leroy E. Cagle USAAF	0-786238	Grave B, Crypt II Lot 80 Section 1 Dixon Cemetery, California United States
2nd Lieutenant Charles K. Jeanblanc USAAF	0-2075799	Grave 26 Row 2 Plot A Cambridge American Cemetery, Cambridgeshire United Kingdom
Corporal Harold D. Blue USAAF	15341640	Oakwood Cemetery Warsaw, Indiana United States
Corporal Arthur W. Kopp Jr. USAAF	36657982	Site 498 Section C Camp Butler National Cemetery, Illinois United States
Corporal Harold A. Fahselt USAAF	16190036	Site 229 Section 82 Jefferson Barracks National Cemetery, Missouri United States
Corporal John H. Vaughan USAAF	42117158	Site 229 Section 82 Jefferson Barracks National Cemetery, Missouri United States
Corporal George S. Aldrich Jr. USAAF	19192279	Site 229 Section 82 Jefferson Barracks National Cemetery, Missouri United States
Corporal Carter D. Wilkinson USAAF	19073430	Site 229 Section 82 Jefferson Barracks National Cemetery, Missouri United States

Appendix Table 11-3: Crew onboard 44-83325 on 3 March 1945 including individual serial numbers and current burial location (US Department of Veterans Affairs 2012c; American Battle Monuments Commission n.d.).

11.2.1.2 Phase IIa General Data Survey

From	To
Meeks Field	63°19'N 20°00'W
63°19'N 20°00'W	61°48'N 15°00'W
61°48'N 15°00'W	59°55'N 10°00'W
59°55'N 10°00'W	Stornoway
Stornoway	Tiree
Tiree	Rhinns Point
Rhinns Point	West Log PI Range
West Log PI Range	Valley

Appendix Table 11-4: Waypoints filed for 44-83325's flight from Meeks Field, Iceland to RAF Valley, Wales (US Army Air Force 1945a).

Appendix Figure 11-35: Main gear retracting screw components FS 004.01 (left) and FS 004.02 (right) (Author).

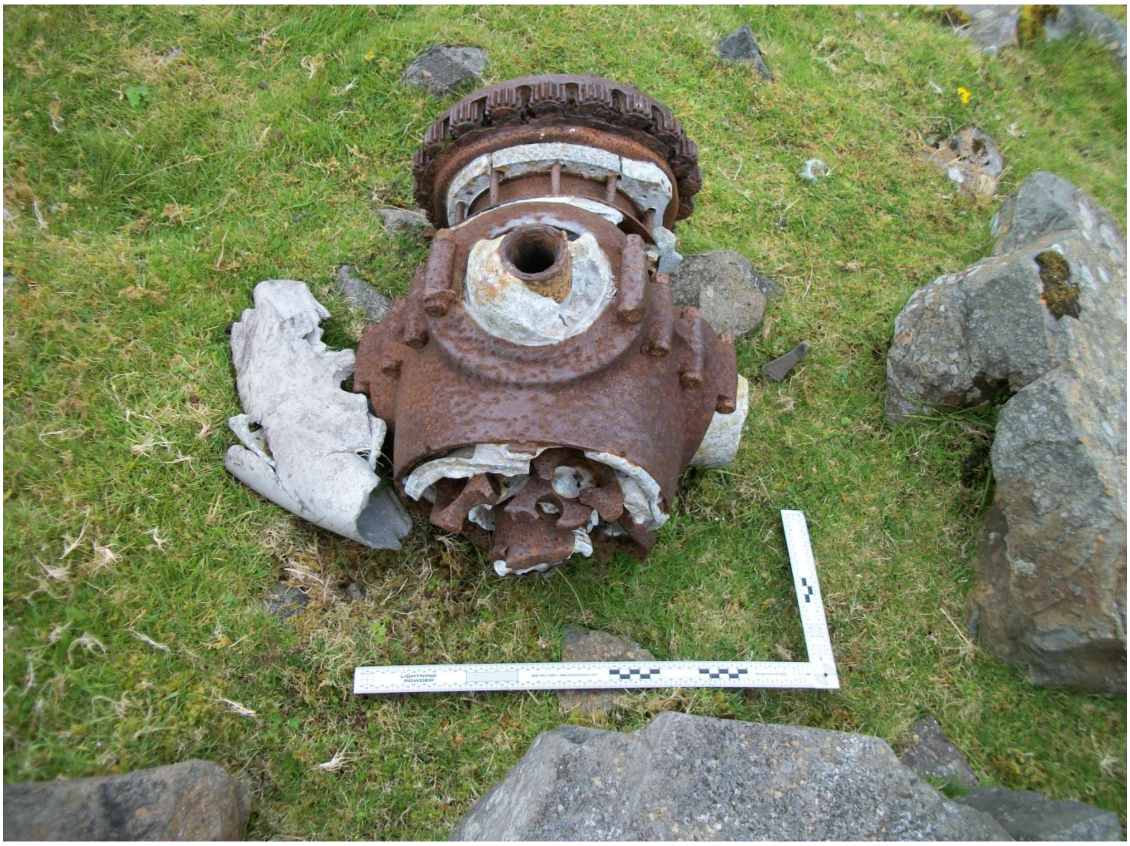
Appendix Figure 11-36: FS 076.01 is the second main gear retracting screw (Author).

Appendix Figure 11-37: Terminus of FS 076.01 showing the lower stop assembly (Author).

Appendix Figure 11-38: General view of FS 101 (Author).
The scree field and cliff face of Beinn Edra is partially visible at the top of the frame.

Appendix Figure 11-39: B-17G 44-83325's tail assembly including FS 101.01 and 101.03 (Author). The tail gear treadle assembly stands upright at centre. FS 101.03, the yoke, is in the foreground on the right. FS 101.02, behind the tail treadle at centre, is the second main gear strut and oleo.

Appendix Figure 11-40: FS 108.01, a main gear strut and oleo assembly (Author). FS 108.02 (oxygen bottle) and FS 108.03 (NMF) are situated beside FS 108.01.



Appendix Figure 11-41: The forward side of the FS 106.01 (Author).
Like FS 040.01, FS 106.01 faces the southwest and shows substantial crash-induced damage to the propeller paddles and leading face.

Appendix Figure 11-42: The front of propeller hub FS 109.01 (Author).
The cut mark is visible at the narrowing section of the propeller paddle.

Appendix Figure 11-43: The cylinder head's unique cast aluminium ridges are clearly visible on FS 016.01 (Author).

Appendix Figure 11-44: The rounded profile of FS 016.01, along with its cast aluminium ridges, confirms FS 016.01 as a cylinder head fragment (Author).

Appendix Figure 11-45: Cylinder head fragment FS 017.02 underlies FS 017.01 (an exhaust collector tailpipe section) (Author).

Appendix Figure 11-46: FS 037.01, as confirmed by the angular arrangement of ridges, is from the lower section of the cylinder head assembly (Author).

Appendix Figure 11-47: Though the most fragmentary piece of Dynafocal engine mounting, FS 124.01's identification is confirmed by the retention of three Dynafocal suspension bracket assemblies (Author).

Appendix Figure 11-48: The northwest side of turbo supercharger FS 055.01 (Author). This side of FS 055.01 would have been installed in the interior of the engine nacelle.

Appendix Figure 11-49: The southeast side of turbo supercharger FS 055.01 (Author). Installed on the underside of the engine nacelle, during its operational life this side was exposed to the elements. The partially crushed exit pipe, on the right of the turbo supercharger housing, was fixed to the trailing edge of the turbo supercharger assembly.

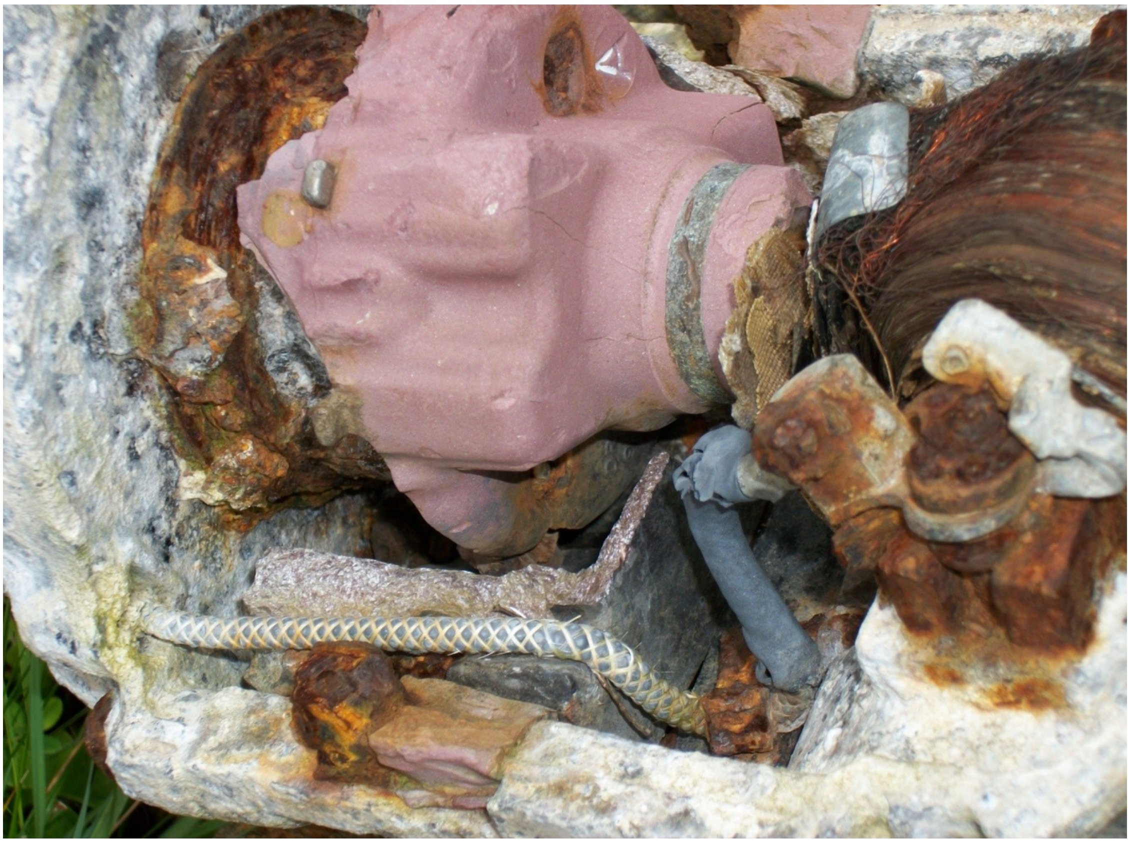
Appendix Figure 11-50: FS 132.01 facing north (Author).
The aft facing turbo supercharger exit pipe is on the right side.

Appendix Figure 11-51: FS 115.01, though extremely damaged is confirmed as a magneto by the Edison-Splitdorf magnetos's unique triangular fitting (Author).

Appendix Figure 11-52: FS 032.01, a fragment from the interior of a magneto, is believed to be from FS 115.01 (Author).

Appendix Figure 11-53: FS 090. FS 090.01 (right) is a broken open magneto while FS 090.02 (left) is a corroded ferrous artefact classified NMF (Author).

Appendix Figure 11-54: Like FS 115.01, the Edison-Splitdorf magnetos's unique triangular fitting is also visible on FS 090.01 (Author).



Appendix Figure 11-55: A close-up view of FS 090.01's fractured ceramic core (left side) (Author). It is believed that FS 032.01 is a piece of red ceramic fractured off this component.

Appendix Figure 11-56: FS 095.0l, a red ceramic fragment (Author).
Like FS 032.01, it is believed FS 095.01 is a fragment from FS 090.01's fractured interior.

Appendix Figure 11-57: Side view of FS 081.01 (Author).

Appendix Figure 11-58: Top view of FS 100.01 showing the unique shape and bolt configuration of the lower terminal to carry-through member joint (Author).

Appendix Figure 11-59: Side view of FS 100.01 showing the unique shape and bolt configuration of the lower terminal to carry-through member joint (Author).

Appendix Figure 11-60: Top view of FS 102.01 showing the unique shape the lower terminal (Author).

Appendix Figure 11-61: Side view (looking southwest) of FS 102.01 showing the unique bolt configuration of the lower terminal (Author).

Appendix Figure 11-62: Side view of FS 080.01, facing southeast, detailing the sprockets unique design. The two pronged spoke design was specifically design by Westfield Columbia for the US military (Author).

11.2.1.3 Phase IIb Detailed Site Survey

Appendix Figure 11-63: Phase IIb FS 053.01 is the fourth propeller hub (Author). The other three propeller hubs were discovered during Phase IIa.

Appendix Figure 11-64: FS 008.01, a single dynamic suspension bracket assembly, was discovered approximately one metre from FS 007.01 (Author).
Based on their proximity, FS 008.01 probably was originally a part of FS 007.01.

Appendix Figure 11-65: FS 007.17, located at the bottom of the frame, is one of three additional oxygen bottles recorded during Phase IIb (Author).
FS 007.17 was discovered partially buried within the same series of depressions as Phase IIa FS 121.02, 127.01 and 129.01.

Appendix Figure 11-66: FS 009.02, in the foreground, was discovered within the same series of depressions as Phase IIb FS 007.17 (Author).

Appendix Figure 11-67: FS 054.01, the third oxygen bottle new to the Phase IIb survey (Author).

Appendix Figure 11-68: FS 049.01, an exhaust ball assembly-flexible joint (Author).

Appendix Figure 11-69: FS 028.01 is currently classified as nondiagnostic(diagnostic) but is probably from the exterior of the wing or fuselage (Author).

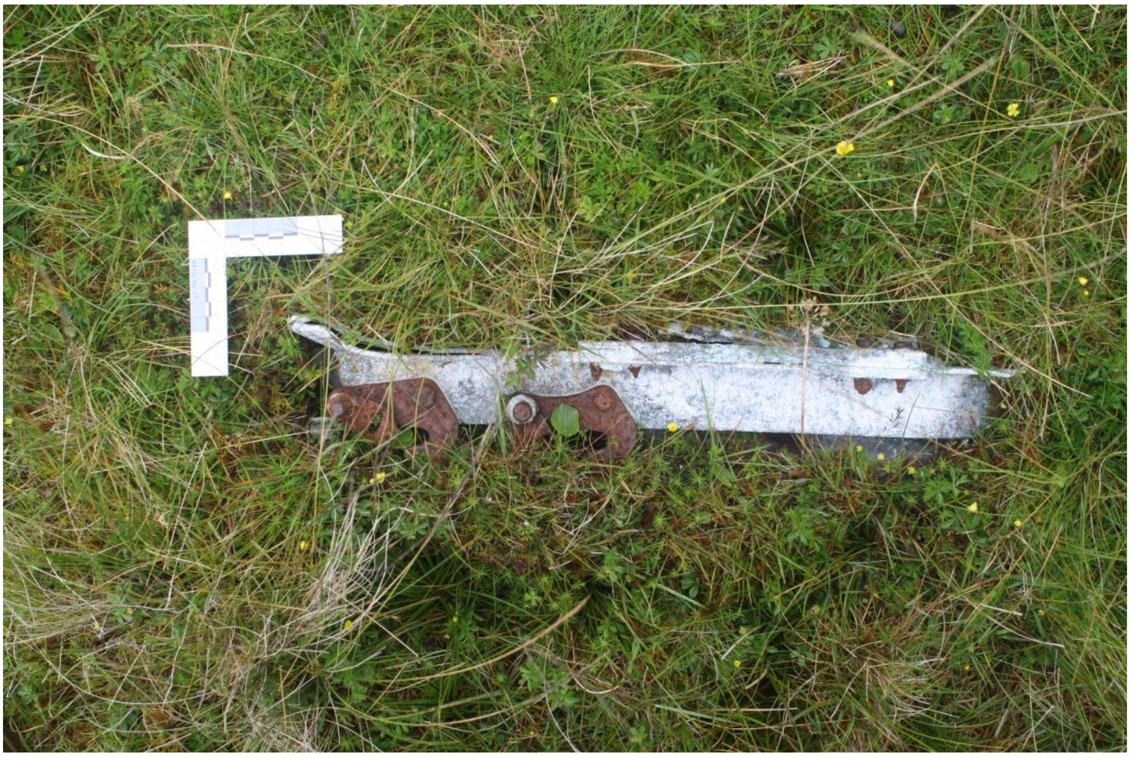
Appendix Figure 11-70: FS 059.01, a probable wing top skin and corrugated under skin (Author).

Appendix Figure 11-71: FS 057.01, a fragment of corrugated wing under skin, is the lowest wing assembly fragment located along the secondary axis (Author).

Appendix Figure 11-72: FS 007 scatter view facing west (Author).
FS 007.11 is located to the left of the scale.

Appendix Figure 11-73: FS 007.11, at centre, retains three evenly spaced bomb rack hook assemblies but is unidentifiable as it is broken off at one end with the other end buried in the ground (Author). This broken and buried termini prevents bomb rack hook assembly spacing comparisons and/or continuations.

Appendix Figure 11-74: General view of FS 026 scatter (foreground) (Author). FS 026.05 is the last artefact in the upper right.



Appendix Figure 11-75: FS 026.05 is the lower portion of the upper five, right hand outboard bomb rack rail and hook assemblies (Author).
FS 026.05 is identified by the unique space between the five upper bomb rack hook assemblies and the lower three bomb rack hook assemblies.

Appendix Figure 11-76: FS 027.01 (left) and 027.02 (right) (Author).
FS 027.01 retains three intact bomb rack hook assemblies with a fourth bomb rack hook assembly having become detached and lying immediately beside FS 027.01. FS 027.02 retains the outboard bomb rack bracket assembly and a fragment of the body compression strut.

Appendix Figure 11-77: FS 027.01, viewed facing northwest, showing the three intact bomb rack hook assemblies (1-17847 or 1-17847-1) and the fourth, detached bomb rack hook assembly (Author). The detached bomb hook assembly is to the immediate upper right of the scale.

Appendix Figure 11-78: Close-up of FS 027.02 showing the outboard bomb rack bracket assembly (bottom) and a fragment of the body compression strut (top) (Author).

Appendix Figure 11-79: FS047.01, a single piece of black rubberised nylon fabric with grommets stamped "UNITED" (Author).
The lower word is illegible due to corrosion but most likely "STATES".

Appendix Figure 11-80: Close-up of the grommet on FS 047.01 (Author).
The upper portion of the grommet is stamped "UNITED" while the lower, unintelligible half is assumed to read "STATES".

11.2.2 Boeing B-17G 42-97286 (Beinn Nuis, Isle of Arran)

11.2.2.1 Phase I Historical Survey

Major James R. Bell USAAF	0-473701	Grave 16 Row 4 Plot A Cambridge American Cemetery, Cambridgeshire United Kingdom
Captain John N. Littlejohn, Jr. USAAF	0-809974	Site 1175 Section F Fort McPherson National Cemetery, Nebraska United States
1st Lieutenant Richard W. Rosebasky USAAF	0-723689	Site 1175 Section F Fort McPherson National Cemetery, Nebraska United States
2nd Lieutenant Jack D. Merkley USAAF	0-719512	Site 1175 Section F Fort McPherson National Cemetery, Nebraska United States
2nd Lieutenant William V. Frey USAAF	0-2068646	Grave 16 Row 1 Plot A Cambridge American Cemetery, Cambridgeshire United Kingdom
2nd Lieutenant Leonard W. Bond USAAF	0-555353	Mount Rest Cemetery Saint Johns, Michigan United States
2nd Lieutenant Robert N. Stoaks USAAF	0-2063886	Grave 43 Row 3 Plot B Cambridge American Cemetery, Cambridgeshire United Kingdom
Master Sergeant Charles S. Brown USAAF	16023651	Grave 16 Row 3 Plot A Cambridge American Cemetery, Cambridgeshire United Kingdom
Staff Sergeant Wade D. Kriner USAAF	33756618	Grave 135 Row 4 Plot F Cambridge American Cemetery, Cambridgeshire United Kingdom
Corporal Albert E. Thomas USAAF	35288004	Maple Grove Cemetery Findlay, Ohio United States
Corporal Joseph A. Payne USAAF	34635346	Grave 61 Row 6 Plot F Cambridge American Cemetery, Cambridgeshire United Kingdom

Appendix Table 11-5: Crew and passengers onboard 42-97286 on 10 December 1944 including individual serial numbers and current burial location (US Department of Veterans Affairs 2012c; American Battle Mounments Commission n.d.).

11.2.2.2 Phase IIa General Data Survey

Name	Condition	Method of Identification
Capt John Littlejohn Jr.	X-56ABC: All major bones fractured and/or missing.	Unidentified. Remains are either X-56X, X-56B or X-56C.
2/Lt Jack Merkley	X-56ABC: All major bones fractured and/or missing.	Unidentified. Remains are either X-56X, X-56B or X-56C.
2/Lt Robert Stoaks	Head crushed. Mass of fractured bones, partially missing. Badly decomposed.	Two (2) identification tags.
2/Lt William Frey	Skull crushed. Multiple fractures of the entire body.	Two (2) identification tags and AGO Card.
1/Lt Richard Rosebasky	X-56ABC: All major bones fractured and/or missing.	Unidentified. Remains are either X-56X, X-56B or X-56C.
2/Lt Leonard Bond	Skull crushed, multiple fractures of entire body. Parts of fractured bones missing of entire skeleton.	Personal letters found on remains.
Corp Albert Thomas	Crushed skull. All major bones fractured. Advanced stage of decomposition.	One (1) identification tag, snapshots, and personal papers.
S/Sgt Wade Kriner	Mass of fractured bones head crushed.	Two (2) identification tags.
Corp Joseph Payne	Mass of fractured bones. Skull crushed.	One (1) identification tag, pay book, immunization record, and personal papers.
M/Sgt Charles Brown	Body intact. Fractured skull. Right and left legs disarticulated below knees.	Two (2) identification tags, pay book, immunization paper, and personal papers.
Maj James Bell	Head crushed. Multiple fractures, badly decomposed.	One (1) identification tag, AGO card, and allied identification papers.

Appendix Table 11-6: Condition and method of identification for the remains of B-17G 42-97286 crew (US Army Air Force 1944-1949a-k).

Appendix Figure 11-81: FS 066.01, one of two trailing edge ribs located during Phase IIa (Author).

Appendix Figure 11-82: FS 070.01 with the Beinn Nuis cliff face, the site of the impact, in the background (Author).

Appendix Figure 11-83: Profile view of FS 089.20 showing the spherical cap indicative of Sperry (ball) turret armour (Author).

Appendix Figure 11-84: The Glove Brand manufacturer's stamp, shoe size and "MADE IN USA" on FS 084.01's bottom arch (Author).
FS 084.01 is likely either a USAAF Type A-6/A-6A Flight Boot or a rubber overshoe.

Appendix Figure 11-85: The unique toe design of FS 084.01 (Author).
The design of FS 084.01 is consistent with both the Type A-6/A-6A Flight Boot and rubber overshoes of the period.

11.2.3 Consolidated B-24D 42-41030 (Beinn Nuis, Isle of Arran)

11.2.3.1 Phase I Historical Survey

2nd Lieutenant William M. Connelly USAAF	O-796314	Site 24 Section A Beverly National Cemetery, New Jersey United States
Flying Officer Francis J. Chew USAAF	T-061004	Site 345 Section 2 Barrancas National Cemetery, Florida United States
2nd Lieutenant Albert T. Spindle USAAF	O-676154	Grave 71 Row 4 Plot E Cambridge American Cemetery, Cambridgeshire United Kingdom
2nd Lieutenant Robert J. Hartl USAAF	O-676481	Currently unknown.
Staff Sergeant Fred W. Brantner USAAF	33066081	Conowingo Cemetery Conowingo, Maryland United States
Staff Sergeant Joseph B. Moore USAAF	13083873	Currently unknown.
Staff Sergeant Chester E. Cislo USAAF	12132284	Probable: South River, New Jersey United States
Sergeant Glenn M. Peyton USAAF	37265096	Site 66 Section B Black Hills National Cemetery, South Dakota United States
Sergeant Robert F. Daud USAAF	35449119	Rush Township Burial Park Rushtown, Ohio United States
Sergeant Louis S. Golis USAAF	33273545	Site 467 Section 2 Gettysburg National Military Park, Pennsylvania United States

Appendix Table 11-7: Crew and passengers onboard 42-41030 on 20 August 1943 including individual serial numbers and current burial location if known (US Department of Veterans Affairs 2012c; American Battle Monuments Commission n.d.).

11.2.3.2 Phase IIa General Data Survey

Appendix Figure 11-86: Close-up of part stamp 32P1003-3 identifying FS 039.01 as a flexible cowl flap panel assembly (Author).

Appendix Figure 11-87: The 32D1046-7R confirming FS 043.01 as an upper fixed cowl flap panel assembly (Author).

Appendix Figure 11-88: Close-up of FS 053.01, a propeller feather pump (Author).

Appendix Figure 11-89: The boulders which hide FS 053.01 (facing north) (Author).
The position of FS 053.01, within the left rock gap, reveals that artefacts may survive in less visible areas.

Appendix Figure 11-90: Profile of FS 024.01, facing northeast, showing the duct's unique clamp assembly and screen (Author).

Appendix Figure 11-91: Side view of FS 011.01 showing the partially fractured aileron gear unit assembly.
The confirmatory part stamp is cast on the side of the hinge arm (Author).

11.2.4 Boeing B-17E FL455 Z9-A (Forsinard Flows, Caithness)

11.2.4.1 Phase I Historical Survey

Flight Lieutenant F.K. Humphries RAAF	Unknown	Survived Crash
Flying Officer G.H. Pullan	Unknown	Survived Crash
Flying Officer T.G. Wrigley	Unknown	Survived Crash
Sergeant A.P. Beatson RAF	823242	Grave 449 Section O Wick Cemetery
Flight Sergeant K.A. Day RAF	1234239	Grave 1434 Wellingborough (Finedon) Cemetery
Flight Sergeant G.A. Panzer RAF	1384480	Grave 162 Section 20 R.C. St. Pancras Cemetery
Flight Sergeant W.H. Payne RAF	1738660	Grave 4201 Row A.H. Section A Kingsway New Cemetery

Appendix Table 11-8: Crew and passengers onboard FL455 Z9-A on 31 January 1945 including individual serial numbers if known and current burial location if relevant (CWGC 2013).

Appendix Figure 11-92: Detail of Figure 7-85 showing the numerous scratch-in names (Author).

Appendix Figure 11-93: Detail of shotgun blast damage observed on the engine cowling (Author).

11.3 Chapter 8: de Havilland Mosquito P.R. Mk. IX MM244 (Corryfoyness, Highlands)

11.3.1 Phase I Historical Survey

Flying Officer Alexander Barron DFM RAAF	Survived war. Died 2000.
Flight Lieutenant Joe Burfield DFC RAF	Survived war. Died 1995.

Appendix Table 11-9: Crew onboard MM244 on 25 November 1943 including individual serial numbers and current burial location if known (Royal Air Force 1943b; Peake 2010; Barron 2013; Lyons 2013a).

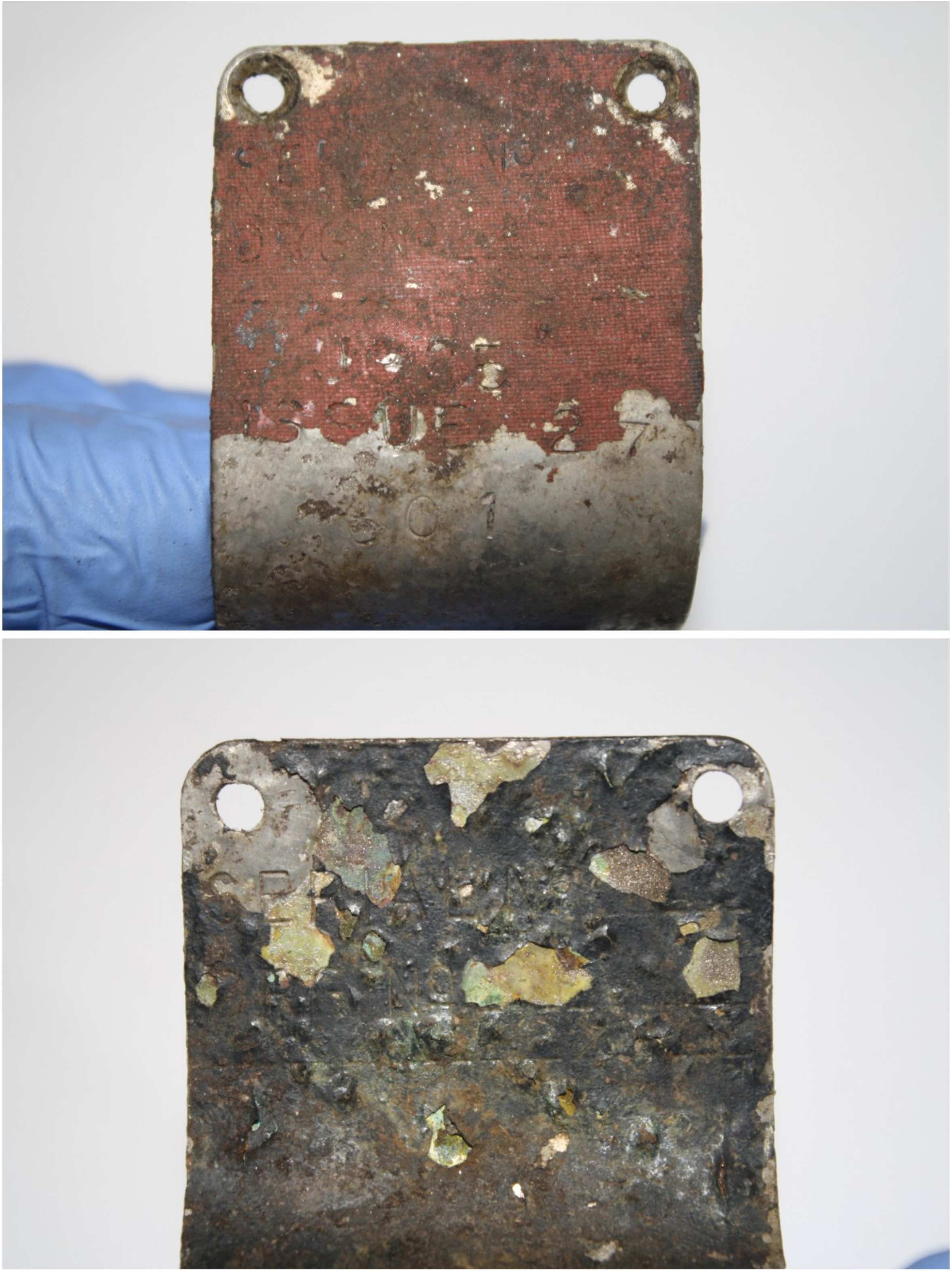
11.3.2 Phase IIIa Targeted Excavation

Appendix Figure 11-94: Numerous engine parts, including poppet valve springs (at intersection of two arrows), were located in close proximity to a large bedrock formation at the southern edge of Trench 1 (Author).

Appendix Figure 11-95: Three of the twelve poppet valves/valve heads located in proximity to the south-edge bedrock formation (Author).

11.3.3 Artefact Analysis

Appendix Figure 11-96: FS 590.01 (Unit 2-3) and FS 017.01 (Unit 1-3) (Author).
The rocker arm to tappet segment of FS 590.01 is twisted 90 degrees about the y-axis while FS 017.01 has an approximately 45 degree bend along the z-axis.



Appendix Figure 11-97: Close-up of the part stamps on MD 053.01 including the known aircraft associated "Serial No" and "DFG No" embossing (Author).

11.4 Chaper 9: Consolidated LB-30A AM261 (North Goatfell, Isle of Arran)

11.4.1 Phase I Historical Survey

Captain Ernest Robert Bristow White * BOAC	Kilbride Old Churchyard Isle of Arran
Captain Francis Delaforce Bradbrooke * ATA	Kilbride Old Churchyard Isle of Arran
Captain James Josiah Anderson RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer Ralph Bruce Brammer RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer John Beatty Drake RAFFC	Kilbride Old Churchyard Isle of Arran
Captain Daniel Joseph Duggan RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer Henry Samuel Green * BOAC	23. C. 13. Brookwood Military Cemetery United Kingdom
Captain George Thomas Harris RAFFC	Kilbride Old Churchyard Isle of Arran
Captain Hoyt Ralph Judy RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer Wilfrid Groves Kennedy RAFFC	Kilbride Old Churchyard Isle of Arran
Captain Watt Miller King * RAFFC	Kilbride Old Churchyard Isle of Arran

Radio Officer George Laing RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer William Kenneth Marks RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer Hugh Cameron McIntosh RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer Albert Alexander Oliver ATA	Kilbride Old Churchyard Isle of Arran
Radio Officer George Herburt Powell ATA	Kilbride Old Churchyard Isle of Arran
Captain John Evan Price RAFFC	Kilbride Old Churchyard Isle of Arran
Radio Officer Herbert David Rees ATA	Kilbride Old Churchyard Isle of Arran
Flight Engineer Ernest George Reeves * RAFFC	Kilbride Old Churchyard Isle of Arran
First Officer John James Rouleston RAFFC	Kilbride Old Churchyard Isle of Arran
Captain Harold Clifford Wesley Smith RAFFC	Kilbride Old Churchyard Isle of Arran
Captain Jack Wixen RAFFC	Kilbride Old Churchyard Isle of Arran

Appendix Table 11-10: Crew and passengers onboard AM261 on 10 August 1941 including current burial location.
The crew are indicated by a star to the left of their name (CWGC 2013).

11.4.2 Phase IIb Detailed Data Survey

Appendix Figure 11-98: FS 019.01, a badly corroded and damaged engine fire extinguisher, is located higher on the slope than its counterpart (Author).
The large dent to the top, the ruptured base and its location amongst the main debris field higher on the slope suggest crash-induced rupture.

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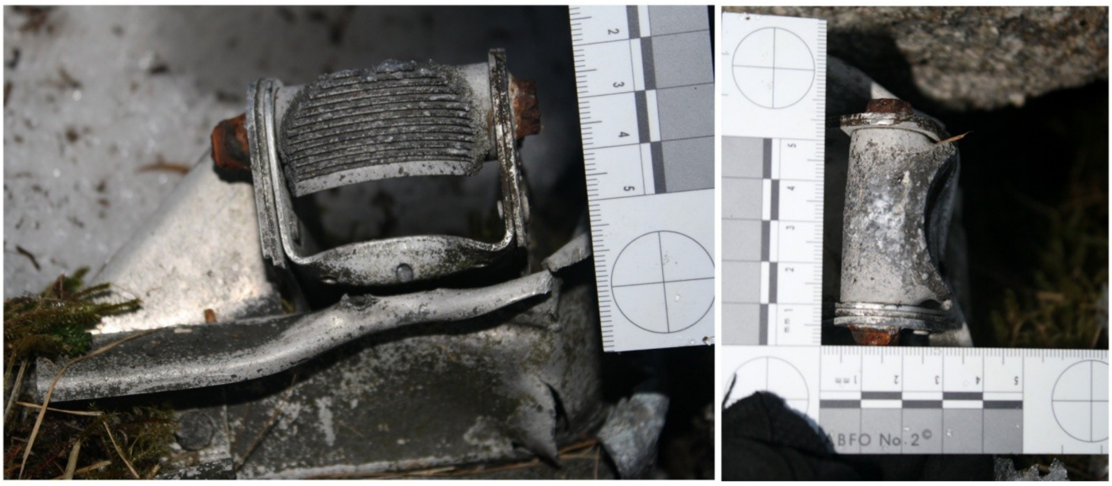
Appendix Figure 11-99: Valve head of FS 019.01 with LUX Trademark stamp confirming it as one of the two engine fire extinguishers (Walker Kidde and Company 1924; Author).

Appendix Figure 11-100: Close-up of FS 028 (Author).
The large leather fragment (FS 028.03) is on top. FS 028.01, one of the two smaller leather fragments, is underneath the left side of FS 028.03. FS 028.02 is on the right of FS 028.03.

Appendix Figure 11-101: Detail of FS 028.01-028.03 (Author).
All three leather fragments (FS 028.01-028.03) showed evidence of machine stitching.

Appendix Figure 11-102: FS 008.01, characterised by its corrugated aluminium riveted to a smooth aluminium skin, matches the construction profiles for the bomb bay catwalk and the floor walkways (Author).

Appendix Figure 11-103: FS 058.01, one of the two uppermost artefacts identified, appears to be armour plate (Author).
A potential design anomaly given LB-30A's limited defensive armour, FS 058.01 would be reassessed during Phase IIIa when an excavation license allowed its removal.



Appendix Figure 11-104: FS 006.01's threaded female end which has been broken in half due to external forces (Author).

11.4.3 Phase IIIa Targeted Excavation

Appendix Figure 11-105: The seven NMF recovered from Phase IIb FS 028.04 (second and third from right) and Phase IIIa (Author).
The large NWF recovered from Unit 2, believed to be a part of the McBrine luggage's leather-wrapped support structure, is visible on the far left.

Appendix Figure 11-106: The single large NWF fragment from AM261 Phase IIIa Unit 2 (Author). The plywood construction and bolts are consistent with both the B-24/LB-30A airframe components and equipment as well as luggage structures. The degraded nature of both the plywood and the bolt assemblies makes definitive assignment difficult. However, the NWF's association with other luggage assemblies adds credibility to the hypothesis that it is a portion of the decayed McBrine luggage.