A Model for Recovery: Predicting the Location of Human Remains on WWII Bombardment and Cargo Aircraft Crash Sites

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Abstract

The United States government makes a solemn promise to the men and women of the armed forces that if they fall on the field of battle their remains will be returned home. Americans demand that this occur in order for the individual to be properly honored. This commitment and corresponding expectation applies to both current and past conflicts. The Joint Prisoner of War/Missing in Action Accounting Command (JPAC) is responsible for locating, recovering, and identifying the approximately 90,000 American military personnel who remain missing from the beginning of World War II through to the end of the Vietnam War. To help increase the rate of identifications, this thesis builds a model that predicts where human remains will be found within WWII bombardment and cargo aircraft crash sites based upon each individual duty station. The JPAC's previously resolved loss incidents were critically examined, working through the identification process in reverse. This allowed for the determination of where each crew member was recovered from within their respective crash sites in relation to the corresponding wreckage. Hypotheses are developed for each crew position within the aircraft based upon the patterns observed. The validity of these predictions is then tested against an additional case for each category of aircraft. Results show that bombardment aircraft crew members will be found within approximately 8 m of their assigned duty station and that the distribution of all cargo aircraft personnel mirrors that of the cockpit wreckage. For the cases in this thesis, it is determined that the physics of the crash, not the actions of the crew or subsequent erosion, that primarily dictates where individuals will be found within a crash site. This research is contextualized within archaeology as a discipline, the broader conversation of conflict archaeology by filling a gap in the current historical and archaeological literature, evaluating JPAC's impact on the heritage of material culture, and this type of research can provide temporal and cross-cultural insight into people's interactions with the battlefields and crash sites. Finally, weak points within the JPAC's identification processes are highlighted and recommended solutions provided.

Table of Contents

List of Tables

List of Figures

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Author’s Declaration

I declare that, except where explicit reference is made to the contribution of others, that this thesis 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.

Owen Luck O’Leary

Definitions/Abbreviations

ABMC	American Battle Monuments Commission
ADF-FRT	Australian Defense Force Forensic Recovery Team
AFDIL	Armed Forces DNA Identification Laboratory
AGRC	American Graves Registration Command
AGRS	American Graves Registration Service
ATC	Air Transport Command
AWOL	Absent without leave
BNR	Body not recovered
BuNo	A unique serial number given to U.S. Navy and Marine Corps aircraft
CBI	China-Burma-India theater of operations during WWII
CIL	Central Identification Laboratory: the JPAC department for scientific affairs
CIU	Central Identification Unit
CILHI	Central Identification Laboratory, Hawaii (Merged with JTF-FA in October 2003 to form JPAC)
CILTHAI	Central Identification Laboratory, Thailand
CIP	Central Identification Point
CNAC	China National Aviation Corporation
CONUS	Contiguous United States
CPOA	Central Pacific Ocean Area
DoD	Department of Defense
DNA	Deoxyribonucleic acid
DNAC	DNA Coordinator
DPMO	Defense Prisoner of War Missing Personnel Office
EGISD	Enterprise Geographic Information System Database
EOD	Explosive ordnance disposal
ESR	Excavation summary report
Evidentiary materials	Collective term for the three categories of evidence used by the CIL and is comprised of osseous remains, personal effects, and life support equipment
FAR	Forensic anthropology report
FOR	Forensic odontology report
FPJMT	Four Party Joint Military Team
GRS	Graves Registration Service
Hump, The	The euphemism used to refer to flying over the eastern portion of the Himalaya Mountains between India, Burma and China during WWII.
IDPF	Individual Deceased Personnel File
IRM	Incident related material
J1	JPAC department for administration and personnel
J3	JPAC department for planning
J4	JPAC department for logistics and supply
J5	JPAC department for foreign policy and negotiation
J6	JPAC department for information technology
JBPH-H	Joint Base Pearl Harbor – Hickam
JCA	JPAC CONUS Annex
JCRC	Joint Casualty Resolution Center
JPAC	Joint POW-MIA Accounting Command (stood up on 1 October 2003)

JPRC	Joint Personnel Recovery Center
JSARC	Joint Search and Recovery Center
JTF-FA	Joint Task Force – Full Accounting (Merged with CIL-HI in October 2003 to form the JPAC)
KIA	Killed in action
LKA	Last known alive
LPP	Liberator production pool
LSE	Life support equipment
LSEL	Life Sciences Equipment Laboratory
LSI	Life support investigator
MACR	Missing Aircrew Report
MDSU	Mobile diving salvage unit
ME	Material evidence (e.g. identification tags, rings, watches, keys, glasses, etc…)
MER	Material evidence report
MIA	Missing in action
MNI	Minimum number of individuals
mtDNA	Mitochondrial DNA
NARA	National Archives and Records Administration
NDAA	National Defense Authorization Act
Oss	Osseous remains
PAO	Public Affair Office
PHR	Possible human remains
PNG	Papua New Guinea
POR	Possible osseous remains
POW	Prisoner of war
QBC	Quartermaster Burial Corps
R&A	Research and Analysis. The JPAC department for intelligence, historical research, investigations, and records
RAAF	Royal Australian Air Force
RAF	Royal Air Force (British)
RAN	Royal Australian Navy
SAR	Search and recovery report
SWPA	Southwest Pacific Area
UK	United Kingdom of Great Britain and Northern Ireland
USAAF	United States Army Air Forces
USAMAA-E	United States Army Memorial Affairs Activity – Europe
USPACOM	United States Pacific Command
UXO	Unexploded ordnance

1 Introduction

The mission of the Joint Prisoner of War/Missing in Action (POW/MIA) Accounting Command (JPAC) is to secures access to applicable countries to conduct global search, recovery, and laboratory operations in order to identify individuals missing as a result of past conflicts in accordance with the Department of Defense's (DoD) fullest possible accounting policy. The Command is headquartered at Joint Base Pearl Harbor – Hickam (JBPH-H) on the Island of Oahu, Hawaii and consists of uniformed service members from the Army, Navy, Marine Corps, and Air Force, as well as federal civilian employees. They comprise the staff of nine different directorates, each with specific tasks that contribute to the overall goal. One of these departments is the Central Identification Laboratory (CIL), which is responsible for directing field investigation and excavation of all types of loss locations as well as the laboratory analysis necessary for the identifications. The objective is to recover as much as possible of each missing service member and to identify them through multiple independent lines of established forensic evidence. This can include antemortem – postmortem dental comparison, mitochondrial deoxyribonucleic acid (mtDNA) matching, determination of biological profiles from skeletal remains, radiographic matching, and analysis of personal effects.

Ultimately, the JPAC is seeking to substantially increase its total number of identifications per year. As a result of both external and internal pressures, which are described in detail below, the organization is currently undergoing numerous changes. There has been a rebalancing of the time, energy, and money amongst the various 20th Century conflicts in which the U.S. Military has been involved, with an increased emphasis being placed on World War II (WWII). Approximately 78,000 service personnel are missing from WWII, but due to losses in extreme ocean depths, only 26,000 have been deemed recoverable. This provides enormous potential for future identifications. The large number of unrecovered persons reflects the vast geographic expanse over which the conflict was fought and the corresponding necessary manpower to do so. One component of the global mobilization was the extensive use of bombardment and transport aircraft. These included the Consolidated B-24 Liberator, North American B-25 Mitchell, Curtiss-Wright C-46 Commando, and Douglas C-47 Dakota.

For the JPAC's purposes of recovery and identification there are two primary benefits of choosing these types of aircraft. First, they are large and thus relatively easy to find in comparison to solitary battlefield losses. Second, they are frequently manned by crews numbering between 5 and 12 personnel. Therefore, the loss of one of these types of aircraft isolates multiple individuals to a single location. While they do have this advantage, there are two fundamental sets of challenges in recovering and identifying human remains from large aircraft crash sites.

The first is that by their nature these crash sites are frequently large, complex, very challenging, and often require several missions to complete an excavation. Due to weather concerns, recovery operations can often be limited to once per year. Thus, any effort to reduce the number of times a site has to be excavated saves considerable resource of manpower, time, and money. When on site, archaeologists use crew compartment wreckage to help indicate those locations within a debris field where excavation is likely to recover human remains. Each duty station aboard the aircraft has diagnostic components including, for example, the navigator's table and seat, bomb sight, cockpit instrument panel, and gunners' turrets. In addition, there is life support related equipment, which are those items that are either on or around a crew member that keep them alive both during the flight, during a bail out, and after a crash. Examples include oxygen systems, cold weather clothing, flak vests, parachute components, and survival kits. However, aircraft crashes are inherently violent events, which lead to the principal question of how far human remains are dispersed from these types of parts and equipment.

The second challenge to large WWII aircraft losses are commingled remains (i.e. when the skeletal elements from multiple individuals are intermixed), which are present in 11 of the 14 cases included in this study. Commingling is the result of four primary factors: the crash itself, subsequent erosion, post-depositional disturbance by local residents, and possibly even the excavation of the site. The violent nature of an aircraft crash often tears bodies apart and separates the various pieces. The 60 to 65 years between the loss of the aircraft and the excavation provides ample time for erosion to redistribute skeletal elements within the sites. Finally, the style of excavation conducted by JPAC teams in the field may be failing to recognize articulated skeletons, or parts thereof, and thus contributing to the overall level of commingling. While the first two are out of the CIL's control, the third is most certainly not and excavations will be evaluated to determine if current practices are sufficient. Reducing the overall level of commingling can decrease the time and costs of laboratory analysis.

This comes about in the way commingling is resolved. A small fragment cut from each of the major bones is sent to the Armed Forces DNA Identification Laboratory (AFDIL) for mitochondrial DNA (mtDNA) amplification and sequencing. The archaeologically recovered sequences are then compared to those obtained from family reference samples. When that process is completed, and the results are confirmed, a forensic anthropologist begins the process of individualizing each skeletal fragment and conducting skeletal analyses. The entire mtDNA process, not including the skeletal analysis itself, can take anywhere from several months to more than a year to complete depending on the total number of samples that are selected for a case. Thus, any effort that can be made in the field to recognize articulated remains and excavate and document them as such can potentially reduce the level of commingling which could in turn prove helpful in reducing laboratory time and cost.

1.1 Institutional Constraints

In addition to the inherent challenges that accompany large WWII aircraft losses described above, there are two substantial, institutional level constrains that currently affect the JPAC. One of these is the parameters recently established by the U.S. Congress (Congress) and the other pertains to the current experience level of the CIL's staff.

1.1.1 National Defense Authorization Act for 2010

Passed by Congress in October 2009, the NDAA 2010 directly addressed those organizations within the U.S. DoD that are responsible for recovering and identifying missing in action service members from past wars. These organizations, collectively known as the accounting community, include: the Defense Prisoner of War/Missing Personnel Office (DPMO), the Joint POW/MIA Accounting Command (JPAC), the Armed Forces DNA Identification Laboratory (AFDIL), and the Life Sciences Equipment Laboratory of the Air Force (LSEL). Also included are the casualty and mortuary affairs offices of the Army, Navy, Marine Corps, and Air Force. Specifically, NDAA 2010 it established several guidelines for the accounting community:

1. The community is responsible for those service members who went missing in all conflicts between the outset of World War II December 7, 1941 and the conclusion of the Persian Gulf War on February 28, 1991.
2. All missing members of the armed forces shall be given an equal level of priority by the accounting community.
3. Each unaccounted for individual shall be treated as a missing person.
4. The community must have the capability and capacity, beginning in fiscal year 2015, to account for at least 200 missing persons per year.

5. A missing person can only be accounted for by being returned to U.S. control alive, or identified through established forensic methods (House 2009, 107-110).

While some of these directives seem rather obvious, many of them, such as numbers 1 and 2, had never been officially codified prior to the passage of NDAA 2010. The two methods of accounting for a missing person was also a new protocol. However, number 4 has had the greatest impact on the accounting community. The 200 identifications per year is the first time that a quota has ever been established. Of the eight organizations listed above, only JPAC establishes forensic identifications. In addition, because there is no credible evidence of POWs from the time period listed above, the majority of the burden of reaching the goal of 200 identifications falls to JPAC. The 5-year running average from calendar years 2009 through 2013 is 75 identifications. This figure needs to increase by approximately 267% in order to meet the standard established by Congress.

1.1.2 Staff Experience Levels

With the JPAC's increased budget came new scientific staff billets for more archaeologists and forensic anthropologists, who are collectively referred to as deploying staff, or recovery leaders, because both groups direct excavations in the field. With only a portion of the new billets being filled to date, it has resulted in the CIL being staffed with a higher proportion of inexperienced recovery leaders. The CIL currently has 33 deployable recovery leaders and the number of missions they have completed ranges from 2 to 65 with a mean of 14.4 (Figure 1). The distribution exhibits a positive skew with the average being raised because of the small number of individuals who have been with the CIL for many years. At present, 23 of the recovery leaders have fewer missions than the average. Furthermore, a hiring freeze on federal civilian employees has been in effect across the U.S. Government for more than a year. This has prevented the CIL from filling all of the newly created positions and when it is eventually allowed to begin hiring again, the average level of experience will decrease even further.

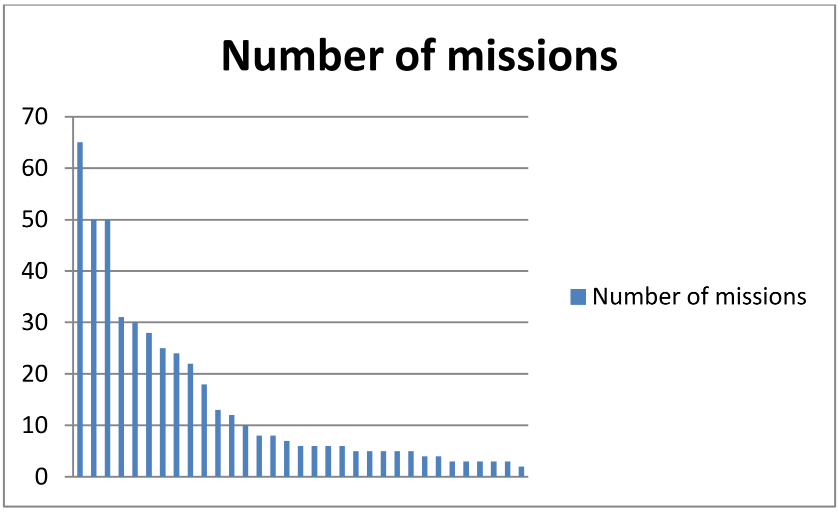

Figure 1. The number of missions that each of the recovery leaders at the CIL have completed as of February 2014. Each column represents a single individual.

While new employees are experienced within their respective disciplines, they often have little familiarity with conflict, and more specifically, aircraft crash archaeology. Recovery leaders are mentored by a senior, veteran staff member for their first field mission and then continue to work in Southeast Asia and as their experience level grows they are assigned to sites with increasing levels of difficulty. The large WWII aircraft crash sites discussed in this thesis are among the most challenging, and typically necessitate an archaeologist or anthropologist to have completed between 6 and 8 missions. However, it can take several years for new staff members to complete this many deployments and become ready for the task. This is due to laboratory duties, the types of cases slated for excavation, other scheduling conflicts, and events in their personal lives.

There has also been a marked decrease in the CIL's experience level and institutional knowledge regarding the excavation and analysis of large WWII aircraft crashes. Ten of the 19 recovery leaders (53%) who participated in the excavation of at least one of the cases included in this thesis are no longer with the CIL. Of the nine who are still with the CIL, only three people have excavated more than one crash site. Likewise, 17 of the 33 CIL's staff (52%) who participated in some aspect of the cases are no longer with the CIL. A complete listing of the CIL staff who have worked on the field and laboratory aspects of the 14 cases included in this thesis are listed below in Table 1.

Table 1. List of CIL personnel who worked on each case included in this thesis. Individuals listed in italics are no longer with the CIL.

Case	Search and Recovery	Forensic Anthropology	Forensic Odontology	Material Evidence
Bombardment				
10020	*Dennis Danielson*	*James Pokines*	*Kenneth Dunn*	Alexander Christensen
0963	*Andrew Tyrrell*	*Kelly Burke*, *James Pokines*, Hugh Tuller, Allysha Winburn,	*Lisa Franklin*	Owen O'Leary
15092	*Elizabeth Goodman*, *Andrew Tyrrell*, *Jeff Loyd-Jones*	*Matthew Rhode*	*Kevin Torske*	Gregory Fox
1069	Alexander Christensen	Gregory Berg, *Christian Crowder*, *Elizabeth Goodman*, Hugh Tuller	Mark Gleisner, *Kevin Torske*	*Samuel Connell*, *Jay Silverstein*
1459	*Dennis Danielson*, *Jay Silverstein*	Gregory Berg	*Gregory Silver*	Alexander Christensen
4497	*Andrew Tyrrell*, *Eric Emery*, *Christopher Monahan*	*James Pokines*	*Kevin Torske*	*Franklin Damann*
8641	*Eric Emery*	Denise To	*Lisa Franklin*	*Jay Siverstein*
4512	*Gwendolyn Haugen*, Bradley Sturm	John Byrd, Paul Emanovsky	*Kevin Torske*	*Dennis Danielson*
Cargo				
3282	*James Pokines*	Paul Emanovsky	Mark Gleisner	William Belcher
4441	*James Pokines*	*Joan Baker*, *Kelly Burke*	Calvin Shiroma	*Dennis Danielson*
0222	Derek Benedix, *Christopher Monahan*, Owen O'Leary, Mary Megyesi, Alexander Christensen, *Hedy Justus*	Joseph Hefner	*Bradley Jones*	Andrew Pietruszka, Gregory Fox
14302	*Jay Silverstein*	Alexander Christensen	*Kevin Torske*	*Andrew Tyrrell*
Test cases				
BTC	Kelley Esh, *Cullen Black*	Megan Ingvoldstad	Calvin Shiroma	Kelley Esh

Case	Search and Recovery	Forensic Anthropology	Forensic Odontology	Material Evidence
CTC	Mary Megyesi, Denise To, Kelley Esh, Megan Ingvoldstad, Owen O'Leary	Excavation of the site has not been completed, thus CIL staff have not been assigned to the various laboratory analyses.		

However, despite the hopefully short-term slowdown, simply expanding the number of personnel, field missions, and laboratory floor space will not be sufficient. In order to achieve the new requirement of 200 identifications per year the JPAC, and the CIL in particular, must critically examine their practices and find ways of becoming more effective and efficient. Specifically, the CIL needs to revaluate how WWII bombardment and cargo aircraft crash sites are excavated and the recovered human remains are analyzed in the laboratory so that the potential of these types of cases can be maximized. These examinations also need to take into account the relative inexperience of the current CIL staff.

1.2 Aims and Objectives

The goal of this thesis is to develop a model that predicts where a crew member's remains will be found within a WWII bombardment or cargo crash site based upon their assigned duty station within the aircraft. Contributing towards this goal this study seeks to answer several questions. Is duty station wreckage a good indicator of the presence of human remains? Is that wreckage a good indicator that the individual assigned to that particular station will be found in close proximity? Where in the crash scene are each crew member's remains found in relation to their duty station wreckage? For example, are the pilot's remains always found amongst the cockpit wreckage or are they predominantly found next to the radio operator station wreckage? What is the maximum distance that remains associated with each crew position are found from the appropriate corresponding wreckage? What is the maximum distance that remains associated with each crew position are going to be spread across a site?

Answering these questions necessitates working backwards through the identification process for each of 12 case studies, which are bombardment and cargo aircraft losses that have already been resolved by the JPAC. Running the identification process in reverse, starting with identified individuals, and determining where they were found within a crash scene is not a required step within the CIL's Standard Operating Procedures (SOP) and is something that has never before been undertaken by the CIL. Within the 12 case studies, as many skeletal elements and fragments as possible from each individually identified crew member aboard the aircraft are plotted onto a map redrafted from the one made by the recovery leader(s) when they were excavating the site. This metaphorically involves taking a finished puzzle apart that has been assembled through mtDNA analysis, refitting, re-articulation, and pair matching and determining where the individual pieces came from. Material evidence, which can also be referred to as personal effects or identification media, such as identification tags, identification cards, or other items with a person's name or initials on them are also plotted onto the site map. This provides a visual depiction of the crew's dispersal within the crash scene. The locations of the remains and artifacts are then compared to each other and the pertinent portions of the aircraft wreckage that were recorded in the field.

During the excavation of a site, the location that human remains and other evidence are recovered are recorded on the site map, but at that point in time, the archaeologist does not know who to whom a particular skeletal element belongs. However, because identification is unidirectional, at no point in the CIL's analytical process is it required for either the anthropologist conducting the skeletal analysis or the archaeologist examining the material evidence to complete the process described in the paragraph above. The only mandatory step which is somewhat similar is for the personal effects to be associated with an individual when possible. These findings are provided in the Material Evidence Report (MER) for the case and it is to ensure that the appropriate artifacts are returned to the family along with the remains. As a result, this thesis is the first time that the identification process is being run in reverse in a systematic and comprehensive fashion.

Determining where as many individuals as possible from each loss incident were recovered from within their respective crash sites allows for the creation of hypotheses for each duty station and the aircraft types as a whole that are then tested against two additional, previously un-reviewed cases. The overall results indicate that duty station wreckage does serve as a strong indicator of where remains will be found within a crash site. For the most part, in bombardment aircraft crash sites crew members can be expected to be found within approximately 8 m of their corresponding duty station wreckage. For several crew positions the distance is much lower. The exception to this trend appears to be in cases where the aircraft began to break up in mid-air and impacted the ground at a low angle. In these situations, the personnel in the aft portion of the aircraft can be separated from their positions by more than 30 m. The remains and personal effects of cargo aircraft crew, including those in the cargo compartment, reflect the distribution of the cockpit wreckage. When the cockpit components were largely intact within a tight cluster the remains were in a similar condition. However, when the same wreckage was extremely fragmented and widely dispersed over a very large area, the remains were as well.

These determinations, and the analytical process that led to them, provide the CIL and its recovery leaders, with valuable information concerning their excavation methodologies and subsequent laboratory analyses of the recovered evidentiary materials. Somewhat unsurprisingly, the vast majority of the methods and techniques in the SOPs utilized by the CIL appropriately address and balance the constraints described above. For example, the protocol of extending an excavation to the geographic and stratigraphic extent of evidentiary materials ensures that as much osseous material is recovered as possible. Additionally, it simultaneously helps to make sure that crash sites are not over excavated, thus avoiding unnecessary time in the field. This is valuable because each additional mission to a site adds both a substantial costs and, in some cases, an additional year to the overall time it takes to resolve a case. Another finding is that excavating a site using a grid with large, 4-x-4 m excavation units does not inhibit the recovery of articulated remains.

The recovery of articulated skeletal elements offers an area for potential improvement for the CIL in regards to large crash sites involving multiple individuals. There is no formal guidance or structure for insuring that those spatial contexts observed in the field within a set of remains are transferred to the forensic anthropologist in a manner that they can utilize at the outset of their analysis. At present, these types of contexts are documented in the search and recovery report (SAR) written for the fieldwork, but because the determination of a biological profile is conducted in the “blind”, the analysts are not allowed to read the SAR prior to the completion of their analysis. A set of practices needs to be developed that ensures that the contextual information from the field is provided to the skeletal analyst in a manner that does not introduce bias into the process.

Knowledge of relationships between osseous elements affects the mtDNA sampling process. For example, if it is known that a left, lower limb was found in articulated contexts it may be possible for the DNA coordinator (DNAC) only to have to cut one sample from amongst the elements as opposed to sampling each major bone. This is another aspect of the identification process where both time and money can be saved. The analysis of the 14 cases included in this thesis indicates that for the most part articulated sets of remains were not oversampled. There are a few instances amongst the cases where it appears more samples may have been cut than were necessary. However, due to the need for certainty in all JPAC identifications there is a limit to the extent that it is prudent to reduce the overall level of sampling. Furthermore, second and third rounds of sampling are sometimes undertaken in hopes of finding an element from an individual who had not previously been located within the assemblage.

The area within the current CIL SOP that has the most room for improvement is in relation to maintaining provenience through the DNA sampling process. At the present time there is no requirement for the DNAC or skeletal analysts to ensure that the provenience of each sample taken is recorded in either paper or electronic format. The inclusion of this step has the potential to impact the identification process through prompting skeletal analysts to pay more attention to provenience as they work to determine the biological profiles of the crew members associated with a loss incident. Additionally, the failure to complete this step was the single greatest factor is eliminating potential case studies from this study. While it did not prove to be an insurmountable obstacle to the completion of this study, it could potentially prevent future studies along similar lines from being undertaken on different aircraft types from both WWII and other conflicts.

A substantial benefit of this study is that it increases recovery leaders' preparedness for working large WWII bombardment and cargo aircraft crash sites. It provides a strong basis of knowledge and can serve as a guide to help them decide where to begin and how far they are likely to need to expand their excavation. It can aid in helping to predict how long it will take to complete the recovery effort on a site. This can provide additional information for longer range planning for future missions in upcoming years. However, this value added to the field component of the identification process is based upon a recovery leader's ability to recognize and correctly identify the various duty station wreckage components found throughout the aircraft. In order to ensure that more inexperienced CIL personnel are as familiar as possible with the pertinent portions of the aircraft future work will need to be undertaken to build a searchable, photographic database that can be taken into field and consulted as necessary.

Two substantial methodological contributions are made to the field of archaeology as a whole. First, Chapter 4 provides a detailed description of techniques that are appropriate for addressing large, complex archaeological sites. These methods have been established through extensive iterative testing and experimentation in the field in a variety of environments. Their implementation by other archaeologists will allow them to work at a greater pace and scale than they have before while still maintaining scientific integrity. Second, this thesis demonstrates how predictive models can be built from the archaeological record and then implemented to aid in future work. As it is not possible to include everything of interest to a researcher in any thesis, a more extensive discussion of specific examples of applicability are not provided. Readers are encouraged to think critically about the methodological topics presented below, adjust them to their specific needs, and implement them when appropriate.

This thesis also seeks to contribute to the larger body of literature on conflict history and archaeology. It fills a gap that has, to this point, not been address, and that is the crash. Extensive work has been done on the macro, theater-level air campaigns in WWII, the detailed minutia of the planes themselves, and human remains recovery after the war. However, none of these cover the actual crashes themselves. Additionally, this thesis goes beyond the mechanics of aircraft crashes to evaluate those factors that may contribute to where human remains eventually come to rest in a site. This includes air crew behavior within the aircraft in those instances when they know that the plane is going to crash. Examination of this period of a crash provides insight to the nature of war and the men who were fighting it. The JPAC's work also has substantial impact on the material heritage of WWII and often leaves it mostly destroyed, with the documentation largely out of reach of the general public. Finally, the thesis examines another line of potential future research that could focus on learning about how people who live near crash sites and battlefields interact with and perceive them. There are numerous possibilities for investigation such as how views of battlefield sites have changed over time, shifted across generations, as well as cross culturally around the world. Unfortunately, despite being a fascinating aspect of this research, only a very cursory overview is provided because an entire thesis would be needed to properly address the topic.

1.3 Thesis Structure

A two-chapter background section is included in the thesis to provide an in-depth contextual framework. Chapter 2 briefly discusses the work undertaken by other countries to recover their missing service members as a comparison to the U.S. It also details the history of America's repatriation efforts beginning with the Seminole Indian Wars in the early 1800s. As the majority of the cases included in this thesis are from WWII, special attention is given to recovery activities both during and after the conflict. The Korean and

Vietnam Wars are also covered. The numerous organizational developments and scientific advancements aiding in the identification of the fallen that occurred throughout the 20th Century are highlighted throughout the chapter. The second half of Chapter 2 is devoted to the modern effort to recover and identify the county's members of the armed forces. The organizations that were established at the end of the Vietnam War, how they evolved, and their subsequent iterations leading up to the founding of JPAC in 2003 is also presented. Finally, the current organizational structure of JPAC, new developments, and recent mission levels are provided.

The second half of the background, Chapter 3, focuses specifically on the Pacific and China/Burma/India Theaters of WWII. Fourteen of the 16 cases included in this thesis were lost in these two areas. The other two, both C-47 cargo aircraft, crashed in Laos during the Vietnam War. While each of the two theaters could fill a multiple volume treatise, this thesis specifically examines the aspects of the theaters that are pertinent to the research being conducted. A history of the development and a detailed description, paying particular attention to each duty station, is included for the four types of aircraft included in this thesis: the Consolidated B-24 Liberator, North American B-25 Mitchell, Curtiss-Wright C-46 Commando, and Douglas C-47 Dakota.

An in depth discussion of two of the two major categories of methods that are pertinent to this thesis are provided in Chapter 4. The first is an overview of the CIL's standard operating procedures regarding remote operations. This consists of investigation and survey of sites as well as their excavation of sites, which is also frequently referred to as recovery operations. Typical mission team size, composition, and roles and responsibilities are explained as well as the unique excavation techniques that are necessary for the remote and challenging environments often faced by CIL recovery leaders. Documentation procedures such as field notes, map making, and chain of custody procedures are detailed. The second half of the chapter is dedicated to providing a thorough explanation of the methods utilized this study including the selection criteria for case studies, how they are analyzed, and the steps used to develop the hypotheses and then subsequently test them with the test cases.

Chapters 5 through 7 present the 12 case study loss incidents. There are eight bombardment aircraft, seven B-24 Liberators and one B-25 Mitchell. The four smaller crash sites in terms of overall size of their debris fields are covered in Chapter 5, while the cases with the four larger sites are in Chapter 6. Chapter 7 addresses the four cargo aircraft, one Curtiss C-46 and three Douglas C-47s. Like the bombardment aircraft, they are presented from smallest to largest. Each case study includes background information about the loss and how the site was found as well as a description of the site environment, wreckage pattern, excavation, analyses of recovered evidentiary materials, mtDNA results, distribution of remains, identification, and notable conclusions.

Chapter 8 shifts the focus from looking at each case study in isolation to examining the duty stations within both categories of aircraft. For example, the patterns and trends within the pilot remains across all the sites are evaluated separately from every other crew position. This is undertaken for each station aboard the bombardment and cargo aircrafts. Two principal measurements are provided. The first is the maximum distance that remains were found from the corresponding duty station wreckage and the second is the maximum distance that an individual's remains were spread out across the site. A hypothesis is presented for each duty station stating within what distance that individual's remains should be expected to be found during an excavation. An additional, summary hypothesis is given for both bombardment and cargo aircrafts as a whole.

Chapter 9 presents the bombardment and cargo test cases in the same format as the 12 case studies in Chapters 5 through 7. The bombardment test case is a B-24 Liberator that crashed in Papua New Guinea during WWII and the cargo test case is an AC-47D Dakota that crashed in Laos during the Vietnam War. Chapter 10 compares the findings of the test cases in Chapter 9 against the hypotheses developed from the case studies in Chapter 8. Those duty stations where a comparison was possible are addressed in turn along with the various crew compartments within the bombardment aircraft. Summary assessments of bombardment and cargo aircraft as a whole are also discussed. Additional results based upon all 14 cases covers excavation practices, the impacts of erosion, mtDNA sampling procedures, and maintaining provenience through DNA and laboratory analyses. The impacts of the thesis beyond crash site dynamics are included in Chapter 10 as well. This includes crew behavior, affects to material heritage, and contributions to the literatures of conflict archaeology and history.

Finally, Chapter 11 compares the findings and discussions in Chapter 10 to the original objectives outlined above in this chapter. Furthermore, future avenues of research are outlined and recommendations for improvements in the CIL SOPs are provided.

2 Background –The Recovery Efforts

The work currently undertaken by the JPAC is part of a long tradition. It is simply the most recent manifestation of the United States Government's history of taking actions that are consistent with American cultural traditions surrounding the nation's fallen service members. In this chapter the history of America's efforts to recover and repatriate its war dead is discussed including its origins in the early 19th century and continued developments through to the Vietnam War. From this conflict, and the unaccounted-for service members associated with it, grew the modern effort to find the missing. This has included the conflict in Southeast Asia as well as the prior wars of the 20th century. The various iterations of military organizations from the Joint Casualty Resolution Center (JCRC) to the JPAC that have been responsible for accomplishing this task since 1973 are also covered.

2.1 History of Body Recovery

There are numerous reasons for the removal of bodies from the field of battle including morale, health, forensic, political, family, and moral. Service members who fight next to – and rely upon – each other through situations and conditions that were, and still are, beyond what the imagination can conjure, form an especially strong bond between them. This bond persists when one of them has fallen. Sledge (2005, 15-21) details several examples of service members showing great care for their fallen comrades and even sacrificing their own lives in attempts to retrieve their remains. These incidents span from WWII to the infamous "Blackhawk Down" incident in Mogadishu, Somalia on October 3, 1993. One poignant example recounted by Sledge (2005, 59) reportedly took place during the Vietnam War. An American medical evacuation helicopter crew trained their loaded weapons on friendly hospital staff that were roughly unloading the bodies that they were delivering to the medical facility. The recovery and appropriate handling of fallen comrades allows some small preservation of morale within the remaining service members, thus allowing them to more effectively continue their roles ongoing conflict.

While decreases in morale due to the loss of fellow service members can impact the fighting ability of a nation's armed forces, the remains of the dead, if left on a battlefield, can have a significant impact in terms of health. Dead bodies, if unattended, can become a breeding ground for a variety of insects, parasites and diseases (e.g. Healing, et al. 1995; Morgan 2004). Examination of soldiers' bodies after their death can also determine the type of wounds that killed them. Differentiating between injuries sustained during open combat and other circumstances can provide the grounding for proving that war crimes have occurred. Forensic methods have been used by the United States to document war crimes from WWII to the present conflict in Iraq (Sledge 2005, 9-13; Steere and Boardman 1957, 185).

Governments also have an interest in the proper recovery and repatriation of service members killed in action. A member of the Armed Forces is the front line embodiment of a nation's policies, ideology and culture and the treatment of the physical body in some ways represents the government's commitment to the living. The American public became outraged when they viewed photographs in Time Magazine's October 18, 1993 issue (Church, et al. 1993) of the naked bodies of two service members being dragged through the streets of Mogadishu, Somalia (Ayres 1993). The nation's overwhelming opinion was that if the government could not prevent this type of event that the military should not be in Somalia. Unable to achieve their aims, the American government, desiring to remain in favour with the public, removed all military forces from the country by early spring 2004.

On a more personal level, the families of a fallen loved one are forced to deal with the violent loss of a young person in the prime of their life that they cared very deeply for. Mourning of a lost family member is challenging enough, but it becomes even more difficult when there is no body, as is the case with individuals who are MIA or KIA/BNR. The lack of a body can often times prevent a family from accepting that a death has taken place and will result in them holding out hope, sometimes for decades, that their loved one could still be alive (Boss 2000, 2006). Lastly, within the socio-political ideology of the United States it is widely held there is a moral duty to care for those persons who have volunteered and unfortunately given their lives for the nation. The viewpoint is such a part of the cultural landscape that it is practically inconceivable to most Americans that we would not make every effort to ensure that out fallen are returned home.

While the United States dedicates the greatest amount of resources to finding its missing service members of any country, it is not the only nation engaged in the pursuit. At least two have created organizations modeled on the JPAC. The Republic of Korea (South Korea) has the second most established effort. Work to recover missing soldiers began in 2000 as a temporary project and the scope of work expanded in 2003 and again in 2005. In 2007 the Korean government created the Ministry of National Defense Agency for Killed in Action Recovery and Identification (MAKRI) (Lee 2009). The Agency's task is to attempt to locate, recover, identify, and return to the family every Korean soldier that could not be accounted for after the signing of the armistice that ended hostilities on the Korean Peninsula on July 27, 1953. At that time there were almost 25,000 missing and over the last ten years the MARKI has recovered the remains of approximately 4,400 soldiers (Na-ri 2010).

Like the JPAC, the MAKRI includes both military personnel and professional civilian scientists who conduct recovery operations between April and November each year at as many as eleven different locations (Na-ri 2010). When skeletal remains are recovered, the MAKRI sends osseous samples to the Defense Scientific Institution for DNA sequencing. The sequences are then compared to over 10,000 family reference samples. The MAKRI is also actively engaged in developing new DNA typing techniques (Lee, et al. 2010)

Additionally, the JPAC and the MAKRI often assist in each other's efforts based upon a memorandum of understanding for bilateral cooperation that was established in 2008 (Na-ri 2010; Sung-ki 2008). While searching for their own troops the MAKRI has located and excavated burials of seven American service members as of 2009 (Lee 2009; Miller 2010), while the JPAC has recovered Korean soldiers as well (Sung-ki 2008). During joint recovery operations the MAKRI provides personnel assistance for the JPAC's teams allowing excavations to be conducted more quickly and efficiently (Chlosta 2009). The Korean laboratory annually sends scientists to Hawaii for training with CIL anthropologists.

The Commonwealth of Australia has also undertaken efforts to recover their MIA service members. At the end of WWII a group from the Royal Australian Air Force spent several months searching for remains in Papua New Guinea, but then very little work was conducted for decades (Griffiths and Duflou 2000, 47-48). Like the United States and Korea, Australia also makes use of both military and civilian personnel to recover their war dead. However, unlike the U.S. and Korea, Australia does not have a single organization. Instead, the Royal Australian Air Force (RAAF), Australian Army, and Royal Australian Navy (RAN) are each responsible for finding their own missing. Additionally, the Australian organizations primarily act in response to notifications about accidental discoveries of Australian loss sites as opposed to actively pursuing cases.

A good example of this is the Australian Defense Force Forensic Recovery Team (ADF-FRT), established by the RAAF in 1994. Working mostly from information provided by expatriates in Papua New Guinea the group recovered 23 individuals over the next five years, 21 of whom proved to be identifiable (Griffiths and Duflou 2000, 48-52). The European theater of WWII has also recently received attention. Based upon the discovery by local residents the Australian team was able to recover a missing pilot (Finan 2010; Finan and Wilkes 2010). The team has also worked throughout Vietnam partially based on information from Veterans groups and has slowly recovered the remains of personnel missing from the conflict in Southeast Asia (Blenkin 2007; News 2009).

Since 2008 the Australian Army's Unrecovered War Casualties unit has worked in conjunction with their counterparts in the British Ministry of Defense, the Commonwealth War Graves Commission, Glasgow University Archaeological Research Division, and Oxford Archaeology to conduct excavations of mass burial pits at Pheasant Wood, Fromelles, France to recover and identify the remains of 250 individuals (C. W. G. Commission 2010; Group 2010; Whitford and Pollard 2009, 224, 226). As is the practice with the members of the Commonwealth War Graves Commission, the Australian government does not return identified remains to Australia, but instead transports them to the closest commonwealth cemetery where they are interred beneath a marked headstone.

The United Kingdom shares a similar outlook as the Australians. For the most part, the British attitude has been that wherever a British service member falls shall forever remain a part of the United Kingdom; at least in spirit. Even though remains were not returned home, efforts were made both during and after wars to recover and identify the dead before interring them into cemeteries (Whitford and Pollard 2009, 207). The one notable exception to this is from after WWI in 1920 (Hawley 2005, 187). A single, randomly selected, unknown British service member was chosen and transported to London. On November 11, 1920, exactly two years to the day from the end of the war, "the body of the unknown warrior was drawn in procession through London" and interred in Westminster Abbey (Cacciottolo 2010). This memorial was the first grave dedicated to an unknown warrior and the practice has been followed by numerous nations including, but not limited to: Australia, Canada, Germany, New Zealand, and the United States (Cacciottolo 2010).

Also during the autumn of 1920, another issue concerning WWI dead was being negotiated that involved Great Britain. The United States' desired to return the remains of some servicemen to their next of kin who resided in the United Kingdom. The British Imperial War Graves Commission was concerned that the press and then the public would raise the issue of the Britain's dead needing to be returned from the continent. The parties involved eventually agreed that bodies could be returned, but that they would have to be transported in a nondescript manner (Sledge 2005, 145).

Today, the UK Ministry of Defence maintains the Joint Casualty and Compassionate Centre (JCCC) whose primary duty is to handle all aspects of current casualties in the British armed forces including repatriation of remains, family notification, funeral arrangements, and the marking of service-funded graves. In addition, a small component of the JCCC known as the Commemoration Team handles the correspondence related to the discovery of a set of remains from WWI or WWII. They conduct research to determine the next-of-kin and contact them to arrange for a proper military funeral (Centre 2011; Saunders 2011, 169-172).

Incorporated within the culture of Japan is a strong sense of duty surrounding honouring ancestors and the dead. However, this reverence is not particularly matched with a commensurate organized national effort. The Japanese government's office responsible for addressing issues surrounding war dead is the Social Welfare and War Victims' Relief Bureau which is part of the Ministry of Health, Labor, and Welfare. Unfortunately, the Bureau is unable to undertake much field work. Their only major recent effort was conducted on Iwo Jima throughout the summer and fall of 2010 (Talmadge 2010). Non profit organizations such as Kuentai, which maintains multiple offices in Japan as well as branch locations throughout the Philippines, have filled in the gap (Kuentai 2010). Supplied with volunteers from the Japan Youth Memorial Association, Kuentai has worked extensively in Papua New Guinea, the Philippines, the Mariana Islands, and Saipan in particular (Bagnol 2011).

2.1.1 Pre World War II

The United States government has been actively engaged in the recovery and interment of the remains of its military service members for over 170 years. Predictably, the first efforts were conducted in a rather crude and disorganized fashion on a very small scale. As additional conflicts occurred, the inevitable need to handle the dead resulted in increased levels of organization, codification of regulations, and advancement of identification methods. However, due to lack of foresight regarding the expansion of the scope and scale of conflicts as well as technological developments, these changes often came during and after wars. This resulted in forces on the ground having to improvise how they handled and processed the deceased as challenges needed to be overcome.

The earliest example of United States' efforts to repatriate fallen soldiers occurred during the Seminole Indian Wars in the early 1800s. The families of a slain officer could request the return of the remains on two conditions. One, that they provide a coffin, and two, they pay the expenses of shipping the body. This practice was the exception at the time as all enlisted men were buried on the field of battle (Sledge 2005, 32). The practice of repatriation expanded during the Mexican-American War of 1846-1847. Despite the dead having been buried on the battlefield, Kentucky, in 1847, at the State's expense recovered 750 sets of remains for burial in an official cemetery. However, none of them were identified (Piehler 1995, 41). This war also saw Congress, for the first time, establish a national cemetery on foreign soil in Mexico City (Steere 1951, 3).

The first federal military regulations were established during the Civil War through two General Orders. The first was Number 75, established on September 11, 1861. It specified that hospitals had to maintain mortuary records and provide headboards to be placed over soldiers' graves. It also stipulated that commanders in the field were responsible for burying the dead and providing proper documentation to the quartermaster's office (Steere 1951, 3-4). Meeting this requirement proved to be difficult because the directive did not provide a means for land acquisition for burials. Order Number 33, which went into effect on April 3 1862, directed field commanders to lay out plots of land adjacent to battlefields and inter the dead (Steere 1951, 4-5). Despite initial difficulties, there were instances where the orders were carried out exceptionally. In July 1864, after a skirmish at Fort Stevens on the northern edge of Washington D.C., Captain James Moore led quartermaster personnel in the recovery of the dead and managed to identify every man (Steere 1951, 7).

The necessity of handling war dead during the Civil War resulted in three precedents that can still be observed today. First, was the establishment of national cemeteries when Congress passed an act on July 17, 1862 authorizing the President to purchase land to be used as national cemeteries for those soldiers who died in service to the country (Steere 1951, 4; 1954, 1). Second, by another act of Congress passed on July 4, 1864, was the creation of a specific burial/cemetery section within the quartermaster corps known as the Quartermaster Burial Corps (QBC) (Steere 1951, 6). Despite their creation, the QBC did not receive specific training in the identification of remains. Third was the practice of disinterring remains from battlefields and moving them to the newly created hallowed grounds. After the surrender of the Confederacy at Appomatox, Union forces conducted organized sweeps of battlefields (Sledge 2005, 66) and the surrounding countryside from 1866 to 1870. They located, disinterred, and relocated 299,696 soldiers to the 73 national cemeteries that had been created. Another 13,575 were buried on military posts or in private plots (Steere 1951, 9). By undertaking these efforts the U.S. government had assumed the responsibility to identify and bury the remains of America's war dead in registered graves (Hoshower-Leppo 2002, 80).

The many lessons learned during the Civil War proved to be valuable during the Spanish-American War in 1898. The QBC was able to use its experiences to accomplish tasks that would set new precedents. Subsequent to the cessation of hostilities on August 12, 1898 all American burials were marked. Beginning in February 1899 the QBC began the disinterment of remains in Cuba and Puerto Rico for shipment home. By June 30, 1899 1,222 sets of remains had been repatriated (Steere 1951, 10). Recovery and repatriation operations were then moved to the Philippines. One result of the Spanish American War was the advocacy of adopting identification tags for all service personnel by Chaplain Charles Pierce who had undertaken much of the recovery work in the Philippines (Steere 1951, 11). The Spanish American War was also the first occasion where American war dead were returned to the United States from overseas. This henceforth became standard practice leading up to World War I.

As noted above, the earlier efforts of identification and burial of war dead during the Civil War had established the principle that the government was responsible for this task. This act also began the process of creating a collective idea within the American cultural landscape of expectation that it would to be continued. President McKinley directed that the dead be exhumed and returned to the U.S. from the islands in the Caribbean and sentiment for the justification for the efforts in the Philippines was well stated by the Quartermaster General at the time, Marshal I. Ludington: "...soldiers who, in defense of their country, had given up their lives on a foreign shore, and bring them ... to their native land for their return to their relatives and friends..." (Steere 1951, 11).

World War I proved to be a very different war from those that the United States had previously been engaged in. Prior conflicts, for the most part, witnessed relatively short battles in open areas where the defeated were driven from the field and the victor possessed the ground. In many instances truces were arranged so that the dead could be collected and buried. The advent of trench warfare fundamentally altered military tactics which in turn affected how the war's dead were handled. The protracted fighting from trench lines that advanced and retreated small distances over long periods of time left a no-man's land where men died with each offensive charge. Bodies were often then subjected to additional damage and dismemberment from continued hostilities such as artillery barrages and mortar attacks (Winter 1995, 146). These bodies often had to be collected during heavy fighting to be transported behind friendly lines where they could be identified and interred into temporary cemeteries. Not unexpectedly, mistakes were made in these difficult conditions.

At the end of the conflict the next of kin for each deceased service member had the choice of whether they wanted the remains returned to the United States or not. By the end of May 1921 approximately 46,300 individuals had been transported to the United States, of which 5,800 were buried in national cemeteries. Another 16,675 were interred in permanent overseas cemeteries in Europe (Table 2) (A. B. M. Commission 2010a; Steere 1951, 13; 1953). In total, only 3.5% of the recovered remains were unidentifiable (McDermott 2005a).

Table 2. Permanent U.S. military WWI cemeteries in Europe. (A. B. M. Commission 2010a)

Cemetery Name	Country	Number of Burials
Aisne-Marne	France	2,289
Brookwood	United Kingdom	468
Flanders Field	Belgium	368
Oise Aisne	France	6,012
Somme	France	1,844
St. Mihiel	France	4,153
Suresne	France	1,541
Total number of burials		16,675

Organizational developments occurred during the latter portions of WWI. General Orders 104, August 7, 1917, created the Graves Registration Service (GRS) within the Quartermaster Corps (Steere 1951, 12). The GRS became a specialized section, where, for the first time, the Quartermaster Corps could specifically recruit and train individuals whose sole responsibility was the retrieval, identification, burial, and subsequent repatriation of America's dead. They were charged with six primary tasks.

1. Deploy along battle lines so that identification and burial of bodies could occur quickly.
2. Locate, establish, and maintain any cemeteries that the army may need.
3. Maintain a registry of burials.
4. Assist in identifying the dead all stages of their being moved.
5. Correspond with the family of the deceased.
6. Coordinate with foreign governments regarding mortuary concerns.

Post-WWI Army commanders and American politicians realized that the newly created AGRS was not particularly suited to maintaining the permanent overseas cemeteries. As a result, the American Battle Monuments Commission (ABMC) was created in March, 1923 with Public Law 534, enacted by the 67th Congress (A. B. M. Commission 2010b; Steere 1953). Through the act the ABMC was removed from what was then the War Department by requiring that the President appoint the commissioners. Even though authority over the European cemeteries changed hands repeatedly throughout the late 1920s and early 1930s, jurisdiction finally came to rest with the ABMC on February 26, 1934 as part of Executive Order No.6614 (Steere 1953). The ABMC has designed, constructed, and continues to maintain the permanent American cemeteries and memorials in foreign countries.

2.1.2 World War II

WWII proved to be a phenomenally different type of war than WWI. Where the earlier conflict between the great powers can be characterized by the lack of movement associated with protracted trench warfare, WWII was exactly the opposite. The development of aircraft, throughout the 1920s and 1930s allowed people to move around the globe farther and faster than ever before. This forced the military to develop new techniques for handling war dead.

The efforts undertaken in the European and Pacific theaters during the war will be briefly discussed. Missing Air Crew Reports (MACRs) and other methods of tracking air losses will also be highlighted. For much greater detail on these areas of the world Steere (1951) and Steere and Boardman (1957) are recommended.

2.1.2.1 During the War

Despite the aforementioned increased mobility, the majority of American combat losses, approximately 140,000 (65%), occurred in Europe (Anders 1994; Wood and Stanley 1989, 1365). With the invasion of Normandy on June 6, 1942 the American GRS commenced its assigned duties based upon the lessons learned during WWI. Despite extensive planning, they were woefully unprepared and almost immediately realized that they were not capable of handling the scope or scale of the conflict. Because the European Theater expanded rapidly and armies were so large, there were simply insufficient numbers of GRS personnel within the Quartermaster Corps to collect the dead from the battlefields as they had done during WWI. The situation forced military commanders on the ground to utilize combat troops for the task. It proved too emotionally difficult for combat units to transport their own dead to collection stations and so teams under the supervision of GRS personnel recovered and moved the dead from units other than their own. This meant that GRS personnel were no longer collecting the fallen from battlefields. The GRS took over once the bodies had been brought to the collection points as well as collecting the dead from hospitals. GRS personnel identified each deceased individual and interred them in temporary cemeteries (Table 3). As Allied lines advanced eastward across Europe, new temporary cemeteries were established to reduce the distance remains had to be transported and the amount of time between death and burial. Also, as the war progressed a high level of efficiency was achieved in moving bodies from battlefields to cemeteries (Steere 1951, 102-125; Steere and Boardman 1957, 369). Graves registration personnel also occasionally buried German soldiers. As many as 20,000 were interred after the Battle of the Bulge (Braddock 2003, 52).

Table 3. Temporary U.S. military WWII cemeteries in the European and African Theaters. (Anders 1994)

Country	Number of Cemeteries
France	24
Italy	20
Africa	14
Sicily, Sardinia, Corsica, Malta	10
Greece, Bulgaria, Yugoslavia, Hungary, Romania	7
Belgium	4
Holland	3
United Kingdom	2
Ireland	1
Luxembourg	1
Switzerland	1

The successful completion of the GRS efforts in the Pacific Theater proved to be a much more difficult task than in Europe for several reasons that mostly stemmed from the markedly different geography. While Europe is a large land mass, the Southwest Pacific is comprised of vast archipelagos of small tropical islands. The first, and greatest, difficulty in operating in the Pacific Theater was that numerous individuals aboard ships and aircraft were lost to deep portions of the ocean and will almost certainly never be recovered. Similar to this were remote jungle covered mountains from which crashed airplanes were often never located. These same characteristics also resulted in communication and search and rescue difficulties.

Second, the impossibility of avoiding repeated amphibious assaults meant that the Navy and Marine Corps were needed in addition to the Army. While the Navy and Marine Corps adopted the Army's paper policies for handling the dead, there were distinct departures. The Marine Corps possesses a general attitude that emergency battlefield burials were acceptable as a resting place as opposed to the Army's idea that all of the remains needed to be moved to temporary cemeteries. This, of course, tended to result in more isolated burials which were difficult to locate after the war. Also, when forced to handle its own dead the Navy assigned the task of mortuary practices to medical personnel who did not have specific training in handling large numbers of dead like the GRS.

Third, warfare in the Pacific focused on capturing and securing specific strategic locations, such as airfields, to allow for the continued advancement of allied forces. This frequently meant that Marine assaults would result in fierce battles that lasted only a few days, but leave numerous casualties on beach heads and scattered throughout thick tropical jungles. Field expedient, on-the-spot burials of those bodies that could be located were the norm. The surviving forces would then be pulled out and move on shortly thereafter leaving the dead both buried and unburied. Subsequently, larger Army forces would be positioned on the island to set up airfields and establish a much more robust American presence. The GRS would occasionally accompany the first wave of these forces to establish temporary cemeteries, but more often they would not arrive until a few weeks had passed. The lack of overlap between the personnel who had originally interred the dead and the GRS personnel made it very difficult to account for all of the missing service members (Steere 1951, 133-152).

Fourth, the army groups in Europe and North Africa consistently maintained their internal structure for the duration of the war, while each campaign in the Pacific required a substantial regrouping and reorganization of men, equipment, and channels of authority (Sledge 2005, 74). Without any cohesive unit or organization in the Pacific theater, the few GRS personnel were constantly relocated, reassigned, split-up, and combined. The GRS non-commissioned officers were assigned to combat forces and served as technical advisors. The first GRS commissioned officer did not arrive in theater until January 5, 1943, thirteen months after the outbreak of the war (Steere 1951, 40-41). During campaigns throughout the central Pacific, including the Gilbert and Marshal Islands, the GRS personnel were individuals from an infantry division who had undergone a two week "crash-course" in body recovery and identification while transiting through Honolulu (Steere 1951, 134).

These factors resulted in a very broad distribution of burial places (Steere and Boardman 1957, 369). In total, throughout the course of the war over 80,000 service members gave their lives with 65,000 having been interred into 201 temporary military cemeteries: 133 in the Central and Southwest Pacific Zone, 59 in the India-Burma Zone, and 9 in the China Zone (Anders 1994, 2).

The mobility that came with the ubiquitous use of aircraft in WWII forced the military to address how losses of both machines and men were recorded. Unfortunately no plans were in place prior to the start of the war. Until August of 1942, a full eight months after the attack on Pearl Harbor, the Army Air Forces were still only recording whether "a soldier had been killed, wounded, or was missing in action" (Administration 2005, 1). That month the addition of a soldier's military status, including flight status, was added. In October of 1942 the Statistical Control Division, Office of Management Control, Headquarters, Army Air Forces Service started what would become a seventh month study of how air losses were recorded during WWI, the intervening years, and up to that point of WWII. In May 1943, the recommendation for, and adoption of, Missing Air Crew Reports (MACR) was made. Beginning June 11, 1943, the commanding officer of the last station from which an aircraft had departed was responsible for completing the report and passing it on through proper channels (Administration 2005, 1-2). The commander of the last station of departure was also assigned the task of coordinating the search for the aircraft and reporting the findings. The MACRs were also compiled for aircraft lost prior to June 11, 1943.

A MACR is designed to record all of the salient details surrounding the circumstances of missing air crews. The 16,708 reports on file at the National Archives and Records Administration (NARA) in College Park, Maryland are organized numerically by date of loss. A MACR form includes fields for the following information:

1. The unit the aircraft was assigned to.
2. The aircraft's departure station, intended course, and destination if different than the point of origin.
3. Any known weather in the vicinity of the mission at the time of the loss.
4. The date, time, and last known location of the aircraft.
5. Why the aircraft was believed to have been lost, such as: enemy aircraft, enemy anti-aircraft fire, or other.
6. The aircraft model and serial/tail number.
7. The aircraft's type of engines and their serial numbers.
8. The weapons installed aboard the aircraft (e.g. .50 caliber machine guns) and their serial numbers.

9. Whether the persons aboard the aircraft were a battle or non-battle casualty.
10. The number of people aboard the aircraft, which were separated into to categories: crew and passengers. The following details are provided for each person manifested aboard the aircraft: crew position, name, rank, and serial number.
11. Names of individuals who were known to have had last contact with the flight and what the type of contact was (e.g. radio, last sight, witnessed crash, or saw forced landing).
12. If any individuals were known to have survived (e.g. parachute spotted, walked away from the aircraft, or other).
13. The form also directed that additional materials such as maps, charts, photographs, written statement of extent of search and rescue operations, and witness statements be included.
14. Finally, the rank, name, and serial number of the responsible station officer had to be provided.

Overall, MACRs did, and still do, serve as an invaluable resource in finding missing service members. However, they must be viewed with caution. Not every loss has a MACR and there are MACRs for planes that were never lost such as an aircraft with which radio contact was lost for an extended period of time. Simple unintended human error such as misspelling a name or transposing numbers in a serial number when the form was filled out could, and has, led to additional difficulties. Also, MACRs only covered Army Air Forces losses, not Navy or Marine Corps. The Navy filed Aircraft Accident Reports, utilizing Bureau Numbers (BuNo), which was the aircraft’s factory designated serial number. A major problem with the BuNo reports is that the Navy was primarily concerned with the loss of the plane and not the crew. A more detailed discussion of Navy losses and their recording is forgone here as there are no Navy losses included in the study.

2.1.2.2 After the War

With the cessation of combat in the European Theater and eventually the Pacific Theater, the GRS relinquished the responsibility of recovering, identifying, and repatriating remains to the American Graves Registration Command (AGRC) (Wood and Stanley 1989, 1366). By the end of 1951 over 171,000 sets of remains were returned to the United States from around the world by a combined military and civilian staff, which at its peak was comprised of around 13,000 individuals. Approximately 107,000 were permanently interred in cemeteries around the world (Anders 1994) (Table 4).

Table 4. Permanent U.S. military WWII cemeteries.
(A. B. M. Commission 2010a; Sledge 2005, 210; Steere and Boardman 1957)

Cemetery Name	Country	Number of Burials
Ardennes	Belgium	5,329
Brittany	France	4,410
Cambridge	United Kingdom	3,812
Epinal	France	5,255
Florence	Italy	4,402
Henri-Chapelle	Belgium	7,992
Lorraine	France	10,489
Luxembourg	Luxembourg	5,076
Manila	Philippines	17,202
Netherlands	Netherlands	8,301
Normandy	France	9,387
North Africa	Tunisia	2,841
Punchbowl	U.S.	13,854
Rhone	France	861
Sicily-Rome	Italy	7,861
Total number of burials		107,072

In Europe, search and recovery efforts began as early as 1944 in areas well behind battle lines and rapidly increased after the end of hostilities. The primary method utilized to locate the approximately 25,000 missing were pedestrian line sweeps (Sledge 2005, 69-71). By May of 1946 over 24,000 square miles (62,000 km^2) in Belgium, Netherlands, and Luxembourg had been covered. In addition, 38,000 square miles (98,000 km^2) had been swept in France. The combined area is larger than twice that of Scotland. The effort resulted in the recovery of 1,335 sets of remains (Steere and Boardman 1957, 205). More targeted approaches were undertaken by propaganda, investigation, disinterment, and identification teams. Propaganda teams spread out across Europe announcing through newspapers, radio stations and flyers that they were seeking information concerning American losses. Investigation teams followed up on leads and conducted interviews with community leaders to locate the exact loss locations. The disinterment teams conducted the actual recovery of the remains (Steere and Boardman 1957, 228-232). It was at this stage where a major development occurred in America’s handling of war dead.

For the first time, the United States military employed professionally trained physical anthropologists and anatomists to identify the remains (Hoshower-Leppo 2002, 80). The idea was first put forth by Wilton Krogman (1939) in the FBI Law Enforcement Bulletin, but specific recommendations on how to carry it out were provided by Dr. Harry Shapiro, the Curator of Anthropology at the American Museum of Natural History in New York City, after he toured Europe in the spring of 1946. He evaluated past GRS practices and argued that graveside identifications by untrained personnel could potentially lead to numerous misidentifications and instead advocated the use of modern laboratory settings and trained personnel. The Army's response was the creation of a Central Identification Point (CIP) in Strasbourg, France. The one facility was soon overwhelmed and commanders quickly established multiple CIPs. Remains processing went through several distinct stages. First was removal and a detailed examination of the clothes and other material evidence for any indications that might provide insight into the identity of the individuals. Second, the remains were carefully examined for individuating characteristics along with any signs of trauma. Stature and weight estimates were produced for skeletonized remains. Third, the remains were examined with a fluoroscope to note any internal features or other abnormalities that may have been missed during the anatomic examination. Finally, the remains were prepared for interment into a temporary cemetery (McDermott 2005a).

The disorganization and ad-hoc handling of the fallen that was pervasive throughout the Pacific Theater during the war continued unabated after the Japanese surrender in Tokyo Bay on September 2, 1945. There was almost no organized plan to search for the approximately 25,000 missing personnel. Furthermore, the manpower shortage that existed amongst the GRS continued with the AGRC. Additional political challenges resulted from both Congress and from within the military itself. Congressionally assigned "special searches" forced the few AGRC personnel that were available to be reassigned for weeks on end to work on cases that turned out to be based on vague or inaccurate information. The investigation of aircraft crashes was also significantly retarded by the failure of the Army Air Forces to provide searchers with sufficient information regarding lost aircraft, namely the MACRs (Steere and Boardman 1957, 447). Despite this, isolated individuals demonstrated initiative and there were successful surveys, recoveries and identifications, including Bataan and Leyte in the Philippines as well as the Bismarck Archipelago and the northern Solomon Islands (Steere and Boardman 1957, 445).

One of the largest tasks undertaken shortly after the end of the war was to consolidate the dead into fewer cemeteries that were closer to larger cities and more accessible to both aircraft and large ocean-going ships. Per the instruction of their next of kin, individuals were either shipped home or eventually moved to one of the two permanent U.S. cemeteries in the Pacific: the National Memorial Cemetery of the Pacific in Honolulu, Hawaii and the Manila American Cemetery and Memorial in the Philippines (Table 4).

While this was being carried out, a somewhat organized effort was slowly coalescing in the form of researchers in Honolulu, Hawaii. They began compiling and sifting through as many loss reports and previous search records as possible from all branches of service throughout the Pacific. By spring of 1947 sufficient information had been compiled to warrant a search and recovery expedition. In July 1947 a specifically tasked ship set out and covered the New Hebrides, Solomon, Loyalty, Caroline, and Marshall-Gilbert Islands. The organizers and planners of the expedition had not previously engaged in graves registration duties in the Pacific, and unsurprisingly, the AGRC personnel who went on the voyage encountered numerous obstacles that had not been foreseen. A second expedition departed Hawaii in June, 1948 and covered areas as far ranging as the Phoenix Islands, Samoa, Fiji, Vanuatu, New Zealand, the Bismarck Archipelago, the Caroline Islands, the New Georgia Group, Guadalcanal, and Australia. Incorporating lessons learned during the first voyage, a greater level of success was achieved. The number of recoveries stemming from both major expeditions totalled 178 (Steere and Boardman 1957, 469-476).

Civilian anthropologists were used in the Pacific in much the same way as in Europe. Dr. Charles Snow helped set up the Central Identification Laboratory on Oahu based upon the laboratory in Strasbourg and worked there for six months from 1947 to 1948 before returning to the University of Kentucky (Holland, et al. 2008, 48). Following on was Mildred Trotter of Washington University, St. Louis who, while identifying the fallen, took the opportunity to collect valuable research data (McDermott 2005a; Pickering and Bachman 2009, 3-4). Her landmark study on the estimation of stature (Trotter and Gleser 1952) would serve a valuable role in the identification of Korean war dead (Coleman 2008, 214). Additional CIPs were located in the Philippines, directed by Dr. Robert Fox and Charles Warren and on Saipan, directed by Thomas McKern. However, Congress had established a fixed five-year time limit on final resolution from the end of the war, and so in 1951 the laboratories in Europe and the Pacific were closed down (Hoshower-Leppo 2002, 80).

2.1.3 Korean War

At the outset of the Korean War the GRS were severely understaffed because most of its companies had been deactivated in 1945 at the end of WWII. Those that did exist had little combat experience and were still operating on principles and practices used during the two World Wars. New and unforeseen developments during the Korean War forced American military, and the GRS specifically, to once again improvise and adapt to the challenging situation at hand.

In the earliest stages of the conflict the United Nations (UN) and American forces were quickly overrun by the North Korean military and they retreated to the vicinity of Pusan in the southeast corner of the Korean peninsula by August of 1950. This did not last long, and following the breakout from the Pusan perimeter in September of the same year many battles were decisively won and American and UN forces who quickly advanced, pushing the North Korean Army northwards well above the 38^{th} parallel. During this major surge the dead were brought to collection points near combat units and then buried in temporary cemeteries behind friendly lines. As was the case during previous conflicts, this was undertaken with the intention of disinterring and repatriating the remains at the end of the war.

When the People's Republic of China (China) entered the conflict in late October 1950 American and UN forces began to lose engagements. When it became apparent that they were going to have to withdraw to the south, Brigadier General Kestler Hastings developed a comprehensive plan for handling the dead. First, because allied forces risked losing control of many temporary cemeteries the GRS exhumed as many of the fallen as they could and moved them to new temporary cemeteries farther south (Coleman 2008, 192; Martz 1954; Sledge 2005, 57). In some cases this process repeated itself several times as the withdrawal continued. Unfortunately, not all of the temporary cemeteries could be emptied and some were lost to the combined North Korean and Chinese forces. Burial grounds remained in this state throughout the relative stalemate that lasted from July 1951 to July 27, 1953. For the first time, at the end of a conflict, the United States did not control large portions of the field of battle upon which it had fought.

Another part of Hastings' plan was an expanded GRS, to include an identification laboratory, that would be able to recover, transport, identify, and repatriate the fallen while the war was ongoing (Coleman 2008, 190). This strategy has been termed concurrent return (Cook 1953) and it provided three major benefits. First, the sooner a set of remains is examined the more likely it is that a positive identification can be made. Second, by using already existing war time logistics infrastructure, the Quartermaster Corps could save money because those transportation networks would not need to be maintained after the war. Third, Hastings rightly argued that the pain and grief of families would be lessened by the rapid return of their loved ones (Coleman 2008, 190-191).

Initially rejecting the plan, leaders in Washington DC finally approved it after they realized the scope of the Chinese involvement. The proposed laboratory was established in Kokura, Kyushu, the southern-most of the four major islands of Japan (Martz 1954). By late December of 1950 the first shipment of remains was on its way from Korea to Japan. The Central Identification Unit (CIU) established at Kokura was modeled on the laboratories from WWII. Its war time commander, Captain Robert Berry managed a staff of approximately 110 personnel that included "chemical experts, clerks, morticians, recorders, photographers, scientists, and x-ray technicians" (Coleman 2008, 199). The unit was swamped with nearly 4,500 sets of remains during its first months of operations and continued to receive hundreds of individuals each month thereafter. Prominent physical and forensic anthropologists included Tadao Furue, Ellis Kerley, Charles Shade, Mildred Trotter, and Charles Warren (Coleman 2008, 200; Pickering and Bachman 2009, 4). Identifications were made through personal effects and material evidence, by comparing antemortem and postmortem medical and dental records, fingerprints, and by eyewitnesses occasionally. The first sets of identified remains left Japan for California on March 1, 1951. As efficiency increased, the bodies of service members killed in battle often arrived back in the U.S. within a month (Coleman 2008, 194). The laboratory remained in operation for three years after the signing of the armistice that ended combat in 1953 until it was eventually closed in 1956 (Hoshower-Leppo 2002, 80).

Three major advancements occurred during the Korean War. First, as part of concurrent return, fallen service members were transported in refrigerated railroad cars (Sledge 2005, 41). Remains were collected near combat units and then loaded into the iced cars for transport south to Pusan where they were refrigerated, until they could be moved onward to Japan aboard naval transport (Coleman 2008, 198; Martz 1954). This prevented decay and the increased level of preservation made identifications easier.

Second was the large scale organized search and recovery efforts in allied held territory while the war was still ongoing. Utilizing detailed reports about prior actions and engagements, specialized teams searched trenches and foxholes and then performed pedestrian line sweeps. Where excavation was necessary, screens were used to ensure that no remains were left behind (Coleman 2008, 197; Martz 1954; Museum 1954b).

Third, the major contributions to forensic identification research. The large number of known individuals passing through the CIU provided an excellent opportunity from which to gather data about the American population. Thomas McKern and T. Dale Stewart

(1957) conducted a comprehensive study on skeletal aging that resulted in a book that detailed "the shape, size, fusion, and ossification of the human skeleton" (Coleman 2008, 215). Mildred Trotter expanded and refined her study on stature estimation, and numerous other studies were undertaken that examined a variety of issues in forensic anthropology (McDermott 2005a).

One component of the armistice signed in June of 1953, ending hostilities on the Korean Peninsula, was the stipulation that the two sides would exchange military war dead. Thirteen months of negotiations ensued with a final agreement that the dead would be swapped from September 1 to October 30, 1954. On the first day North Korea returned 200 sets of remains of deceased UN personnel. Each side passed remains to the other until September 21 when the North Koreans delivered what they said were the final 123 sets of remains. The Allied side continued to pass remains to the North Koreans until October 11. Surprisingly, 78 more bodies were received by UN forces on October 12 and 66 more on November 9. In total, 4,167 UN deceased military personnel were received (Museum 1954a). Individuals who could not be identified were transferred to the National Memorial of the Pacific in Honolulu, Hawaii.

2.1.4 Vietnam War

Concurrent return, developed during the Korean War, was implemented from the outset of the conflict in Southeast Asia. However, unlike previous conflicts, at first the U.S. Air Force was responsible for processing and returning remains. This arrangement lasted from January 1961 to July 1965. As the conflict escalated it became clear that there was a need for the GRA and they began to be incorporated. On 1 July 1966 the Air Force officially handed mortuary responsibilities over to the Army. Eventually, a maximum of thirty-two primary collection points would be maintained throughout South Vietnam. The deceased were most frequently transported to these location from the battlefield by helicopter (Center 2000). They would then be forwarded to one of two main mortuaries, Tan Son Nhut Airbase in Saigon or Da Nang (Holland, et al. 2008, 49). There the remains would be processed and for the first time in Graves Registration history, embalmed in the country of conflict. Mortuary affairs personnel became so efficient that a body could be returned to the United States within 72 to 96 hours of death (Wolfe and Bryant 2003, 164). The two mortuaries were eventually closed in 1972 (Da Nang) and 1973 (Tan Son Nhut) as the conflict came to a close (Hoshower-Leppo 2002, 80).

The recovery of bodies during the Vietnam War was more difficult than in previous wars. This was partly the result of the small scale mobility that came with the first wide-spread use of helicopters. The military was able to move small groups of soldiers and marines to remote locations behind enemy lines to conduct operations. Missions often involved guerrilla tactics in rugged jungle covered mountains where it was relatively easy for a slain service member to be lost. This, combined with North Vietnam's extensive penetration into the South on the Ho Chi Minh trail, resulted in clear cut battle lines largely vanishing and individuals became missing throughout Vietnam and it neighboring countries. Additionally, the extensive use of jet aircraft throughout Southeast Asia resulted in airmen being lost in extremely destructive circumstances in very isolated regions.

While the Army effectively processed fallen service members that could be extracted during or immediately after a hostile engagement, the handling of those person's whose fate was uncertain was an entirely different matter altogether. The first step for any individual to be placed into this category of abiguity was for them to become separated from their assigned unit. As mentioned above, this separation could be the result of an aircraft crash due to either hostile activity or non-combat related issues. A person could also become disconnected as part of a ground battle by being lost during an engagement, captured by the enemy, or killed. Service members who deserted or went absent without leave (AWOL) are not included in the discussion below. When service members became separated from their units military regulations required that they be placed into one of three categories: prisoners of war (POW), killed in action/body not recovered (KIA/BNR), or missing in action (MIA) (Hawley 2005, 43).

The definition of a POW was a person who had been confirmed to be in the custody of the enemy. The confirmation portion of the definition was considered to be paramount and an individual would not be included in the category unless demonstrable evidence had been received confirming that a service member was both alive and in captivity (Hawley 2005, 44). Typically, in accordance with the Geneva Convention of 1949, a government who is holding POWs must provide a list of all individuals to their home country. Throughout the Vietnam War the North Vietnamese government refused to do this, instead classifying American troops as war criminals which were not covered by the convention (Veith 1998, 90). This led to the American government having to merely speculate at the total number of POWs.

Like POWs, the evidence surrounding KIA/BNR had to conclusively demonstrate that there was no way that the individual could have survived the loss incident in question. Army regulations maintained that “conclusive evidence of death must be more than an indication of death. The facts must be such that death is the only plausible alternative under the circumstances” (Clarke 1979, 14). Similarly, the Air Force required that “available information indicates beyond any reasonable doubt that a missing person could not have survived” (Clarke 1979, 14). An example of this category would be an aircraft crash witnessed by friendly forces where the pilot was not seen to eject.

The final category, missing in action (MIA), encompasses those service members whose fate could not be determined. They were typically separated from their units under circumstances where there was insufficient information to arrive at any decisive conclusion. An example of this would be if a flight of two aircraft flew through a large cloud bank with only one emerging on the other side. It should be noted that the category of MIA did not make any determination as to whether the individual may be alive or deceased (Hawley 2005, 47).

The task of finding the missing, regardless of category, fell to two organizations. For the first 72 hours after an individual went missing, the Joint Search and Recovery Center (JSARC) was responsible (Veith 1998, 112). After that initial three day period the Joint Personnel Recovery Center (JPRC) took over the effort, whose operation was codenamed Bright Light (Veith 1998, 102). The JPRC was created on January 24, 1964 as part of the Studies and Observation Group (SOG) within the Military Assistance Command, Vietnam (MACV), which was considered to be a special operation and thus top secret (Veith 1998, 3). The JPRC’s establishment had taken eight months due to interservice and interagency rivalries and conflicts. The Army wanted complete control of the organization, but the Air Force resisted because the majority of the missing were their aircrew. Eventually, the organization with a staff of fewer than 10 people was placed under an Army command, but it was agreed that the JPRC commander would always be from the Air Force (Veith 1998, 102, 105).

Operationally, the JPRC faced numerous challenges. Despite having a mandate to find and recover missing personnel, they had no authority to carry out the mission (Veith 1998, 352). Additionally, the organization did not have any dedicated forces or equipment (Veith 1998, 104). Because of this, the JPRC had to first receive permission from higher authorities to launch a rescue attempt to retrieve a downed pilot or raid a prison camp, and second, they had to find a unit that would provide the assets with which to undertake the mission. This often resulted in slow response times which allowed for rescue plans to occasionally be compromised and prisoners to be moved before teams arrived on the ground. Furthermore, various ambassadors and the Central Intelligence Agency (CIA) did not allow the JPRC to conduct any operations inside Laos until August 1972 out of fear that the hidden war would be discovered (Veith 1998, 57-78).

Over the nine years of its existence the personnel of the JPRC made valiant efforts to recover missing or captured Americans. One hundred and twenty-five rescue operations were conducted in attempts to free individuals from prisoner camps. While 110 bodies were recovered, no living Americans were freed (Veith 1998, 352). Through the development of evasion and survival training programs for aircrews the JCRC did have limited success in recovering downed pilots. As the war slowed down in the latter half of 1971 and through 1972 the JPRC began to focus more on aircraft crash sites and managed to recover six sets of remains (Veith 1998, 343).

The JPRC also attempted to obtain the release of prisoners already held in Hanoi starting in 1966, but had very little success until late in the war. This was despite trying to negotiate through intermediaries such as the International Committee for the Red Cross, the East German government, and the North Vietnamese Embassy in Laos. Eventually private citizens in the United States who were known to be sympathizers of the North were used to broker deals for the release of a few service members (Veith 1998, 79-89). With the signing of the Paris Peace Accords on 27 January 1973, 591 remaining American prisoners were released by the North Vietnamese over the course of February and March 1973 (Mather 1994, xx, 12). However, over 1,600 still remained unaccounted for.

2.2 History of the Joint POW/MIA Accounting Command

The complicated and convoluted circumstances surrounding the United States’ exit from the Vietnam War and the government’s handling of the missing led to a powerful grassroots movement spearheaded by the National League of Families of Prisoners of War and Missing in Action in Southeast Asia (Allen 2009; Families 2011; Franklin 1993; Hawley 2005). The League demanded that the U.S. do everything in its power to account for all of the individuals who had not come home. This ground-swell ensured that the search continued for the missing from Southeast Asia and, over time, has extended across multiple generations of organizations and expanded to include conflicts as early as WWI.

A complete history of the various organizations that have been tasked with accounting for America's missing service personnel since the Vietnam War has never been written and published. Numerous texts including books (e.g. Constein 2005; Sheehan 1988; Swift 2003, 2005), magazine articles (e.g. Franz 2008; Hylton 2008; Karcher 2008; Poole 2006; Snyder 2005), and newspaper columns (e.g. Bender and Baron 2008; Bloom 2008; Bumiller 2009; English 2009; Jansen 2008; Meo 2007) have been written by journalists and independent authors. All of these are written from the outsiders perspective and have only provided brief snapshots of one of the various accounting organizations at a specific moment in time. Two books (Bell and Veith 2004; Mather 1994) have been written by former Joint Casualty Resolution Center (JCRC) personnel. Mather's book documents the JCRC's casualty resolution efforts from approximately 1975 to 1991, while Bell's is an autobiographical narrative of his military service during the Vietnam War along with his active duty and civilian roles in the JCRC. None of these provide a detailed, insider's perspective or explanation of how the JPAC and the CIL currently operate. Another category of publications related to the CIL are those that have resulted from the actual forensic casework conducted by the scientific staff over the decades (e.g. Adams 2003a, b; Holland 1995; Holland, et al. 2008; Hoshower 1998; Moore, et al. 2002; Stephan, et al. 2011; Warren 1978, 1979, 1984; Webster 1998). However, again, none of these works fully explain the recovery or identifications process.

This section provides a brief overview of the entities that have been tasked with finding America's missing service members. They are presented in chronological order based upon the date of their creation. Contemporaneous organizations continuously interacted with each other and in numerous instances individuals moved directly from a disbanding unit to the one that was replacing it. Incredibly, JPAC currently has employees who were morgue technicians during the Vietnam conflict and at the Central Identification Laboratory – Thailand (CIL-THAI).

2.2.1 Joint Casualty Resolution Center

The JCRC was created on January 23, 1973 (Hawley 2005, 56; Swift 2003, 28), the same day that the JPRC was closed down. All of the paper and electronic case files were transferred from Saigon, Vietnam to Nakhon Phanom Air Base in northeast Thailand. What had been a small 10 man undertaking throughout the Vietnam War suddenly became an effort involving 160 personnel. While the JCRC was principally comprised of special forces search and rescue teams, because it was a joint command there were individuals from every branch of service (Mather 1994, 11).

Initials efforts were aimed at training personnel to investigate air and ground losses, building a relationship with the newly created Central Identification Laboratory-Thailand (CIL-THAI), and establishing liaison offices in Vientiane, Laos and Saigon, Vietnam. Liaison offices were also intended for Phnom Penh, Cambodia and Hanoi, but the host governments would not allow them. Furthermore the JCRC could only work in South Vietnam, so, as with the Korean War, one again U.S. forces did not have access to portions of the battlefield.

Recovery missions commenced as part of the Four Party Joint Military Team (FPJMT) which was comprised of representatives from the United States, the Republic of Vietnam, the Democratic Republic of Vietnam (North Vietnam), and the Provisional Revolutionary Government (Viet Cong) (Mather 1994, 5-6). In addition to extensive advertising, 12 missions to land sites in the first ten months of 1973 resulted in the recovery of 11 Americans. Extensive underwater surveys were also undertaken of the coast of Vietnam between Da Nang and Hue during the summer of 1973, but the remains of only one individual were found. Direct American involvement with on-the-ground operations came to an end in December 1973 when a recovery team was attacked in the Mekong Delta and an individual was killed (Mather 1994, 22-23). From that point onward, the JCRC personnel remained in Saigon while the South Vietnamese conducted the actual searches. The areas available for missions, and the size of the JCRC, continued to shrink throughout 1974 as the North Vietnamese pushed south until all of Vietnam became unavailable on April 30, 1975 with the fall of Saigon (Mather 1994, 22-23).

The JCRC moved from Thailand to Barbers Point, Oahu, Hawaii in May 1976 and reduced in staffing from approximately 80 to 20 personnel (Mather 1994, 49). Without physical access to Vietnam the JCRC turned to other lines of information while they were forced to wait for political developments. During the second half of the 1970s and into the 1980s an extensive campaign was undertaken throughout Southeast Asia including Thailand, Malaysia, Singapore, and Indonesia to interview refugees who were fleeing Laos and Vietnam. Thousands of reports were collected and useful information was obtained regarding what happened to some individuals as well as how war-time rumors about missing personnel were started and spun out of control. However, a large number of false leads were also generated (Mather 1994, 71-79) and numerous con artist attempted to convince the JCRC that there were still American service members being held prisoner (Mather 1994, 112-118).

Despite initially not allowing American personnel into the country, the JCRC engaged the Vietnamese in a dialogue which resulted in the repatriation of sets of remains (Table 5). JCRC personnel made steadily increasing progress towards being able to search in Vietnam for missing service members. In October 1980 the two sides met for the first time to discuss the implementation of physical searches in Vietnam. Over the next three and a half years talks focusing solely on technical issues occurred two or three times per year. In August 1984 JCRC personnel were allowed to visit crash sites, but not conduct any work. In July 1985 a crash site was surveyed and finally, in November 1985, a B-52 crash site north of Hanoi was the location for the first joint excavation (Mather 1994, 137). A watershed year occurred in 1988, which saw the JCRC conduct three missions: a six site investigation in September; two recovery teams in October; and three in December (Mather 1994, 165). A landmark event occurred in April-May 1991 when a coordination office was opened in Hanoi and staffed by two American personnel (Mather 1994, 173).

Table 5. Sets of remains repatriated by the Vietnamese government from 1977 to 1988. (Mather 1994, 55, 59-60, 62, 127-128, 155, 160, 166)

Date	Sets of Remains
March 1977	12
October 1977	22
August 1978	11
July 1981	3
October 1982	4
June 1983	8
September 1986	1
November 1986	3
September 1987	3
November 1987	5
March 1988	17
April 1988	27
July 1988	25
November 1988	23
December 1988	38

Parallel progress occurred between the U.S. and the Lao People's Democratic Republic. After years of hard work by the American embassy representatives from the JCRC first met with Lao officials in 1983 to discuss technical issues. The first joint U.S./Lao investigation occurred in December 1983 and an initial joint excavation in February 1985. By August 1988, the Lao government agreed to a year round program of activities. This established practice was carried forward when the JCRC was absorbed into the Joint Task Force – Full Accounting (JTF_FA).

2.2.2 Central Identification Laboratory Thailand

The CILTHAI was established in March, 1973 at Camp Samae San, Thailand (Hoshower-Leppo 2002, 80). In collaboration with the JCRC, the CILTHAI was tasked to continue the search for, and identification of, missing Americans from the Vietnam War. The small office was staffed by the "chief of the laboratory, a physical anthropologist, a supervisory identification specialist, four identification specialists, and a supporting clerical and administrative staff" (Warren 1981, 176). The remains recovered by JCRC and CILTHAI during their searches in South Vietnam from 1973 to 1975 were transported to the laboratory for identification. The staff of the CILTHAI also continued to work to identify the few unidentified remains that had been brought from the mortuary in Saigon.

Charles Warren worked as a physical/forensic anthropologist at the laboratory from 1973 to 1975 and was succeeded by Robert Pickering. Pickering served as the anthropologist in charge of CILTHAI until the laboratory was relocated to Hawaii in 1976 due to the loss of access to Vietnam (Pickering and Bachman 2009, 4-5).

2.2.3 U.S. Army Central Identification Laboratory Hawaii

The United States Army Central Identification Laboratory Hawaii (CILHI) was created in 1976 when the CILTHAI facility was relocated to Honolulu, Hawaii (Swift 2003, 28). To date, it has been the longest running of the American organizations that have been involved in casualty resolution (1976 to 2003). As such, it has undergone the greatest expansion, change, and adaptation as its mission was broadened and new technologies were developed.

With the Central Identification Laboratory's change in location from Thailand to Hawaii came an added dimension to its mission. CILHI became responsible for recovering and identifying the missing from the Korean War and WWII in addition to Vietnam (Bell and Veith 2004, 132). The small scientific staff continued to process the sets of remains as they were unilaterally turned over by the Vietnamese and in January 1978 identified the first three soldiers lost in a C-47 crash during WWII in India. In June 1978 a WWII soldier was identified from Papua New Guinea and in May of the following year seven crewmen from a B-24J were also identified. The first identification from the Korean War occurred in January 1982.

However, in the mid-1980s, findings were disputed by families of the missing and CILHI was heavily criticized for making identifications using unacceptable scientific techniques, employing unqualified personnel, relying on inadequate facilities and equipment, and not having a sufficiently rigorous review process for findings. A thorough review of the organization was conducted in 1985 and the recommendations for more stringent quality assurance were implemented. This included the CILHI moving into a new building with purposely designed laboratory space in July 1991 (Office 1992).

A second assessment of the CILHI was undertaken as part of the Select Committee on POW/MIA Affairs, U.S. Senate whose efforts stretched from 1991 to 1993. The general accounting office's report (Office 1992, 2-3) found that the CILHI was no longer deficient in the previously indicated areas and that the earlier misidentifications were isolated incidents and the potential for future errors was very unlikely. The committee also noted that with the opening of Vietnam and Laos to American investigation and recovery teams and the inclusion of earlier conflicts in the CILHI's case load that a substantial increase in laboratory staff was warranted.

CILHI grew rapidly through the mid to late 1990s and by the early 2000s approximately 170 military and civilian personnel comprised four major sections: Operations and Support, Casualty Data Analysis, Search and Recovery Operations, and the Laboratory. (Hoshower-Leppo 2002, 81). Operations and Support was responsible for planning all aspects of missions including coordination with other CILHI sections, the JTF-FA, and foreign governments. For any given country the section would determine the number of missions for the year and the calendar dates for each. Within each mission, the number and size of the recovery and investigation teams were set and their primary and alternate cases selected (Hoshower-Leppo 2002, 81).

The Casualty Data Analysis section was assigned the task of researching, collecting, compiling, and analyzing the background information about each loss incident. This could include witness statements, reports of search and recovery efforts that may have taken place shortly after an aircraft crash, witness statements collected by investigation teams, and archival research from the country the loss took place in. They also maintained the personnel records including medical and dental files of each individual who remained unaccounted for. The Search and Recovery Operations section was primarily comprised of the military personnel who conducted the missions excavating aircraft crash and burial sites. Each Military search and recovery team was accompanied by a CILHI anthropologist. The Laboratory section was made up of approximately 20 anthropologists and three forensic odontologists, all of whom had obtained advanced degrees with specialized training in human skeletal analysis and archaeological field methods. Anthropologists had two primarily responsibilities. The first was to direct the recovery efforts in the field to ensure that proper archaeological methods were followed. The second was to examine, analyze, and document the evidentiary materials that were accessioned into the CILHI.

An important division of responsibility existed between the CILHI and its two contemporaneous counterparts: the JCRC and the JTF-FA. The JCRC and the JTF-FA were principally responsible for determining the loss locations of unaccounted for individuals from only the Vietnam War. They did not work towards the casualty resolution of service members from other conflicts. The CILHI located the loss locations for individuals from WWII, the Korean War, and the Cold War and conducted recovery missions for all four conflicts. The CILHI was also responsible for conducting the laboratory analysis of all accessioned remains and material evidence.

Deoxyribonucleic acid (DNA), a powerful tool for the identification of missing persons, proved itself to be a legally acceptable means of individuating someone in the 1990s. For the CILHI, mitochondrial DNA (mtDNA) was, and remains, especially effective. It is inherited maternally, very robust, and can be extracted from small fragments of skeletal remains that have been buried for decades (Irwin, et al. 2007; Stone, et al. 2001). In conjunction with the Armed Forces DNA Identification Laboratory (AFDIL), mtDNA reference samples from appropriate family members of missing individuals started being collected, analyzed, and checked against sequences that have been extracted from small samples taken remains in the laboratory (Holland, et al. 1993). All genetic sequences from both sources are permanently stored in a database and are cross-checked twice a year in case a family reference sample has been collected that matches a set of remains that are already in the CIL.

2.2.4 Joint Task Force – Full Accounting

The JTF-FA was created in January 1992 and enfolded the JCRC (Mather 1994, 183). The new Army organization was stationed at Camp Smith, Oahu, Hawaii and had the express purpose of continuing the effort to determine the loss locations of missing individuals from only the Vietnam War. As a Joint Task Force it was only expected to exist for five years, which resulted a very high operational tempo. Six to seven missions per year were conducted to both Laos and Vietnam with as many as five investigations teams on each deployment. Investigation teams typically consisted of small groups of specialized personnel including a team leader, a team sergeant, analysts, and a linguist. This investment of resources often meant that as many as fifty cases would be investigated in approximately four to five weeks (Maves 2011).

To aid in this massive undertaking three detachments were created: Detachment 1 in Bangkok, Thailand; Detachment 2 in Hanoi, Vietnam; and Detachment 3 in Vientiane, Laos. When teams worked in Cambodia, the Detachment 1 staff would travel to Phnom Penh and set up operations (Teel 2011). These offices had small staffs that were responsible for acting as the liaison to the host government for day to day affairs and for coordinating all in-country and logistics. In addition to facilitating the investigation teams from JTF-FA, the detachments also supported recovery teams from the CILHI.

A problem with the rapid pace in the early years of the JTF-FA was that many cases were prematurely placed into the category of no further pursuit; a status when every possible lead has been exhausted. This usually resulted when an investigation team interviewed a small number of witnesses regarding a particular loss incident and did not gain any credible information. Instead of spending additional effort, leaders frequently determined that the case could not be resolved. Many of these cases have been revisited since the JPAC's founding, and additional efforts have resulted in identifications (Maves 2011).

2.2.5 Joint POW/MIA Accounting Command

The JPAC was formed on October 1, 2003 through the merger of the JTF-FA and the CILHI (Wolfowitz 2003). By bringing the two agencies together policy makers aimed to eliminate redundancies and increase efficiency in the accounting process. Today, the JPAC mission is:

> "During fiscal year 2015 – 2019 the Joint Prisoner of War/Missing in Action (POW/MIA) Accounting Command's (JPAC) secures access to applicable countries conduct global search, recovery, and laboratory operations in order to identify individuals missing as a result of past conflicts in accordance with the Department of Defense's (DoD) fullest possible accounting policy."

Joint means that the command includes members from each of the branches of service with military billets proportioned according to their respective percentage of the missing. Thus, the JPAC predominantly consists of Army soldiers because the Army has the greatest number of missing. As is typical with most components of the United States Military, the JPAC is organized into multiple directorates. Of the 13 sections, all are currently located on Joint Base Pearl Harbor – Hickam with the exception of Detachments 1 through 3 which are permanent offices in Southeast Asia (Table 6).

Table 6. JPAC departments and their current areas of responsibility and functions.

Directorate	**Responsibilities**
Headquarters Detachment	Manages daily functions including developmental training, physical training, fitness evaluations, safety programs, and creating and maintaining the JPAC's duty roster. Responsible for military discipline, recommendation, initiation, and follow-through of Uniform Code of Military Justice. Oversees facilities management in regards to work orders and new construction in order to facilitate improvements and maintenance of JPAC facilities.
J1	Coordinates all human resource support requirements of the command to include military and civilian personnel, administration, awards, travel, training, and evaluations.
Research & Analysis	Formerly the J2, this directorate conducts historical research and analysis in support of investigations to determine the loss locations of missing individuals. Provides case background information for recovery operations. Requisitions, archives, and maintains individual deceased personnel files (IDPF), map collections, completed case files, and a reference library. Responsible for the data contained in electronic databases including Bright Light, the Centralized Accounting Repository and Information System (CARIS), and Enterprise Geographic Information System. Fields investigation teams. The directorate is divided into World War II, Korean War, and Southeast Asian Conflict sections.
J3	Establishes and executes procedures to ensure common operational understanding across and external to the JPAC, to include: 1) The coordination, integration, and synchronization of all operations. 2) Discharge of assigned responsibility for direction and control of operations throughout all phases of missions. 3) Directs and controls all JPAC operations by planning, coordinating, information sharing, and integrating all aspects of MIA Operations. 4) Responsible for formulating, coordinating, and distributing planning and situational awareness products to include the 5-Year Plan, the yearly operational plan, joint field activity orders, situational reporting and tracking.

Directorate	**Responsibilities**
J4	Establish policies and procedures, plans, supports and executes logistical requirements. Responsible for developing, managing and overseeing procurement operations through, micro-purchases, contracts and blanket purchase agreements. Operates and manages four logistical warehouses located in three separate locations in the functions of receipt, storage and issue of equipment and supplies. Provides vehicle maintenance and procurement oversight, management and direction to four separate locations. Oversees and manages property accountability for the command.
J5	Developing policy guidance for command interaction with U.S. governmental agencies and with foreign governments. Specifically, the directorate develops and coordinates talking points, memorandums for record, memorandums for financial arrangement and other POW/MIA-related policy guidance for use during technical negotiations and meetings with foreign governments. Additionally, the J5 coordinates visits by foreign officials to the JPAC and the U.S. Pacific Command for bilateral discussions and orientation.
J6	Provide information technology support and knowledgebase within JPAC which includes the help desk, computer system administration, system integration, data management, communications, information assurance, and network security.
Central Identification Laboratory	The primary functions of the CIL are to: 1) Direct scientifically sound recoveries for missing U.S. service members and other mission-related U.S. personnel. 2) Provide scientifically sound tests of human remains and non-biological material evidence. 3) Establish identifications of individuals under the CIL's jurisdiction. Conduct research in forensic science methods and techniques. 4) Support humanitarian missions in support of homeland defense, current-day mishaps, and national and international mass disasters. 5) Provide forensic support to foreign governments and international organizations as directed. 6) Provide forensic support to law enforcement and investigative agencies. 7) Collaborate with national and international scientific and forensic organizations to advance the field (Laboratory 2011, 1).
Investigation & Recovery	Comprised of approximately 24 teams that make up the core of the recovery teams and are responsible for executing the missions at the loss locations identified by the Research and Analysis section under the direction of a CIL anthropologist or archaeologist. Technical sections within I&R include the Forensic Imaging Center, explosive ordnance disposal team, and medical shop.
External Relations	JPAC External Relations undertakes public affairs operations in support of the joint commander while communicating accurate, unclassified information about DoD activities to DoD, U.S., national, international, and internal audiences, and media. Public Affairs utilizes timely and accurate information to keep the American people and the DoD informed, and establishes the conditions that lead to confidence in America's military and its readiness to conduct operations in peacetime, conflict and war. It is the policy of the DoD to make available timely and accurate information so that the public, Congress, and news media may assess and understand the facts about national security and defense strategy.

Directorate	Responsibilities
Detachment 1	Located in Bangkok, Thailand this detachment is responsible for coordination and tactical command of all missions conducted in Burma, Cambodia, India, Malaysia, and Thailand.
Detachment 2	Located in Hanoi, Vietnam this detachment is responsible for coordination and tactical command of all missions conducted in Vietnam.
Detachment 3	Located in Vientiane, Laos this detachment is responsible for coordination and tactical command of all missions conducted in Laos.

During fiscal year 2013, from October 1, 2012 to September 30, 2013, the JPAC conducted field operations in 19 countries. These mission where comprised of 50 recovery teams and 27 investigation teams. For fiscal year 2014, ending September 30, 2013, the JPAC intends to visit 17 countries with a total of 37 recovery teams and 19 investigation teams. The decrease in the number of recovery and investigation teams is due to the previously mentioned budgetary shortfalls and the extended hiring freeze across the U.S. federal government. Between fiscal year 2013 and 2014 the countries include Austria, Belgium, Burma, Cambodia, Canada, China, Common Wealth of the Northern Mariana Islands, France, Germany, Greenland, Hungary, India, Italy, Kiribati, Laos, Netherlands, Palau, Papua New Guinea, Philippines, Solomon Islands, South Korea, United States, Vanuatu, and Vietnam.

The JPAC is currently undergoing a major expansion in both facilities and total number of personnel to include both civilian and military positions. An additional CIL facility has been established at Offutt Air Force Base in Omaha, Nebraska that will eventually employ approximately two dozen scientific staff along with additional administrative and support positions. This should greatly increase the pace at which the CIL will be able to analyze skeletal remains and establish identifications. It will also allow the CIL to hopefully begin work on several larger projects such as the USS Oklahoma. In addition, the JPAC will be moving into a new building on JBPH-H in 2015 that has been custom designed for the organization.

In addition to actively pursuing casualty resolution of America’s missing servicemen, the CIL also serves as a forensic resource for other government agencies at all levels. Personnel are can be designated to temporarily assist local police departments within the state of Hawaii on search and recovery operations, examine skeletal and dental remains, or provide expert witness testimony at trial. The CIL also has a fully functional autopsy suite that can be utilized in case of a mass fatality event.

3 Background – Theaters and Aircraft

In addition to understanding the history of America's efforts to account for its missing service members the context in which the majority of the cases included in this thesis were lost must also be examined. The Pacific and China Burma India theatres in which they flew, can, and have, been the subject of numerous lengthy volumes (e.g. Bergerud 2000; Nalty 1997; Nalty, et al. 1994; Spencer 1994; Tillman 2010; Tunner 1964). As such, only a brief synopsis of each theater is presented to provide the reader with a context within which to place the losses described in Chapters 5 through 7.

One of the critical components to understanding where individuals eventually come to rest in a crash scene is, or course, the aircraft itself. The overall shape of the vehicle, its internal structures, and the positions of each of the crew within the aircraft all play a role. The aircraft included in this thesis underwent innumerable design changes as they were modified and improved over the course of their different variants. A detailed and accurate accounting of all of the modifications for any one of these aircraft could comprise an entire thesis. As such, the major design features of each aircraft will be addressed and only those specific variants that are included in Chapters 5 through 7 and 9 will be discussed in detail. This will include analysis of the ability to egress from the various aircraft. The Consolidated B-24 Liberator is addressed in the greatest detail because it comprises the majority of the cases. Correspondingly, those aircraft that are not as common in the data-set receive a more general overview.

A constant amongst all of the aircraft included in this thesis concerns the numbering of the engines. From the pilot's point of view, engines are numbered from the left to the right. In a two engine plane, such as the B-25 or C-47, the left engine is the number one engine and the right engine would be the number two engine. For a B-24, the left-most, outboard (farthest from the fuselage) engine is the number one engine and the inboard engine would be the number two engine. Correspondingly, the inboard engine on the right wing would be the number 3 and the outboard the number 4.

3.1 The Pacific and China-Burma-India Theater Air Wars

The United States was forced into World War II as a direct result of the air war in the Pacific with the bombing of Pearl Harbor, Oahu, Hawaii on December 7, 1941. The same day, west of the International Date Line, the Japanese also attacked Clark Airfield, Iba

Airfield, and Manila in the Philippines. WWII was the first modern war spanning the Pacific and fighting it would not have been possible without long range cargo and bombardment aircraft. Men and equipment had to be transported vast distances to remote locations and offensive weaponry needed to be set upon the enemy without the large pitched land battles that were common in Europe. To make it possible, the United States increased production of aircraft to previously unimagined levels. Corresponding aircraft-related infrastructure improvements were also undertaken. For example, more than 100 air strips were built by Army aviation engineers and Navy Seabees in the Pacific Theater alone (Tillman 2010, 68). Ultimately, it would be the air war that brought an end to WWII.

3.1.1 The Pacific Theater

There were two distinct areas of control within the Pacific Theater that were divided by an imaginary north-south line that passed through the middle of the Solomon Islands at approximately 160° longitude. The Navy, under the command of Admiral Chester W. Nimitz, controlled the Central Pacific Ocean Area (CPOA) to the east of the line, and the Southwest Pacific Area (SWPA) to the west was the purview of the Army and General Douglas MacArthur (Nalty, et al. 1994, 262). The two commanders, and their respective branches of service, were often in disagreement, but in some instances they worked together and achieved remarkable results.

The American air response to the bombing of Pearl Harbor was the infamous Doolittle Raid. With America desperately needing a morale boost from the attack on Hawaii and the continued onslaught of Japanese forces in the Southwest Pacific, Lieutenant Colonel James H. Doolittle led sixteen specially configured B-25 Mitchells off the deck of the USS *Hornet* on April 18, 1942. Launching early due to having been spotted by a Japanese patrol vessel, their target was Tokyo. Flying at a low altitude to avoid radar detection the attackers surprised the Japanese defences and bombed a variety of military and industrial targets. Passing over Japan relatively unscathed, 15 of the aircraft continued on to China, but the crews were forced to bail out or crash land before reaching their intended airfields having run out of fuel because of the early launch. One plane landed in Russia. The raid had the desired effect of providing a substantial increase in morale to the American public. Militarily, it resulted in Japan recalling large portions of its fleet from the Indian Ocean to defend home waters but probably also provided additional incentive for Admiral Isoroku

Yamamoto to capture Midway Island (Doolittle and Glines 2001; Glines 2000; Lawson 2004; Nelson 2002).

Japanese efforts over the course of the spring of 1942 resulted in the capture and control of the Philippines, French Indo China (Vietnam, Laos, and Cambodia), Burma, Dutch East Indies (Indonesia), the Mariana Islands, the Caroline Islands, the Marshall Islands, the Solomon Islands, and the northern half of New Guinea. The seemingly unstoppable Japanese expansion was finally halted at the Battle of the Coral Sea on 5-8 May, 1942 when the invasion force was prevented from reaching Port Moresby (Alcorn 1981, 9; Bergerud 2000, 40-41). It was the first time that Japanese forces failed to reach their objective. The naval engagement was also the first time vessels from two belligerents never came within sight of, or directly fired a shot at one another. Instead it was the first occurrence of aircraft carriers pitted against each other where aircraft were used as the mechanism of destruction (Willmott 2002, 37-38). Despite losing one carrier, American forces sank one Japanese carrier and damaged another so badly that it was not able to participate in the subsequent Battle of Midway from June 4^{th} to the 6^{th}. As with the Battle of the Coral Sea, Midway saw aircraft carriers pitted against each other, but American forces held the distinct advantage of knowing the location of the Japanese fleet and, as a result, won a decisive victory by sinking four enemy aircraft carriers (Parshall and Tully 2005, 416-417). The Americans lost a second carrier and with depleted carrier forces neither side was willing to risk their remaining 'mobile airports' to major confrontation and so the air war in the Pacific was fought by land-based aircraft for the next twelve months (Bergerud 2000, 90).

In this regard, the land-based Fifth Air Force, commanded by General George C. Kenney, convinced MacArthur of a strategy of aerial attrition to the point that the Americans would control the skies over New Guinea. Only then, under the cover of an 'air shield', would advances be made by land and sea (Nalty, et al. 1994, 267). To this end, Kenney's aircraft served four major roles: reconnaissance, supporting ground troops, sinking ships, and destroying enemy air bases (Bergerud 2000, 554). Reconnaissance missions were regularly launched with the express purpose of scouting enemy harbors, shipping lanes, airfields, garrisons, and troop movements. They were typically conducted at high altitudes to ensure safety from both anti-aircraft fire and any aircraft that might be launched against them. The photography component allowed officers in the rear to plan future bombing missions. Weather information over the treacherous peaks of New Guinea was another valuable piece of intelligence provided by reconnaissance aircraft.

Support for ground troops came through both combat and non-combat actions. For example, strafing of enemy positions by fighter aircraft such as P-40s and P-39s during the early days of the battle for Guadalcanal was common (Nalty 1997, 329). Later, with developments in radar technology, fighters such as the Northrop P-61 Black Widow would be able to attack Japanese infantry strong points at night (Nalty, et al. 1994, 270). Perhaps the greatest support for ground troops came by way of the C-47 (see below). It demonstrated itself to be one of the most efficient and, in many cases, the only way to access the mountainous jungle terrain. Equipment and reinforcements were brought north from Australia and the wounded were evacuated. Indeed, as the war progressed, cargo aircraft such as the C-47 were also the quickest and safest way to transport men and supplies over the Owen Stanley Mountains to the northern shore of New Guinea.

Initially, the USAAF had difficulty attacking ships on the open ocean with larger, land-based bombardment aircraft. The conventional tactic of high altitude precision attacks from 18,000 ft (5,486 m) or above proved to be almost completely useless because ships could simply avoid the bombs by evasively maneuvering after the bombs had been released (Bergerud 2000, 587-588). General Kenney and his staff eventually developed new, more effective, tactics. One of these became known as skip-bombing. This technique involved flying at a very low altitude and releasing bombs only a few hundred feet before passing over an enemy ship. Ordnance was set with a time delay fuse so that it would detonate after penetrating the vessel (Murphy 1993). With practice crews managed to raise the percentage of all bombs that found their targets from 1% to over 70% (Murphy 1993, xii). Another adaptation was increasing the strafing abilities of medium sized aircraft (Bergerud 2000, 589). A-20s and B-25s were equipped with numerous forward-firing machine guns and even 75 mm cannons (see below). The high point of Allied success at sinking enemy ships came during the Battle of the Bismark Sea on March 1-2, 1943. The Japanese launched a convoy of eight supply transports protected by eight destroyers from Rabaul, New Britain to reinforce and resupply Lae on the north coast of New Guinea. The Fifth Air Force was waiting and sunk all of the transports and half of the destroyers. Between 3000 and 5000 Japanese troops were killed (Bergerud 2000, 590-592; Nalty, et al. 1994, 272; Staff 1950, 110-111).

The new tactics proved so effective against enemy ships that General Kenney added them to the repertoire of medium-altitude bombing against enemy air bases. Air operations were constant throughout 1942 and 1943 as Allied aircraft continuously bombed and strafed numerous enemy airfields throughout the Solomon Islands, the Admiralty Islands and the north coast of New Guinea. The steady influx of additional aircraft from the United States combined with the ever-increasing stranglehold on Japan’s ability to resupply its forces with materiel and men slowly, yet inevitably, led to a complete mastery of the skies over the Southwest Pacific Area. Controlling the skies provided several advantages. It reduced the likelihood of attack on Allied air bases and aircraft being destroyed on the ground. Movement of men and supplies by both cargo aircraft and sea transport could be undertaken with a higher degree of safety. Correspondingly, the opposite became true for the enemy.

Using airpower as the tip of his sword, General MacArthur’s overall strategy was to selectively capture key locations and airfields that were lightly defended, allowing him to continuously expand his control of the skies while bypassing large garrisons of Japanese troops, leaving them isolated from resupply (Staff 1950, 100-101). This worked effectively in the Solomon Islands when the Woodlark and Kiriwina Islands were taken and air fields were constructed which provided cover for the capture of selective areas of New Georgia (Staff 1950, 117-118). This same pattern was repeated along the north coast of New Guinea from July to November 1943 and resulted in Wewak being cut off (Nalty, et al. 1994). This campaign also culminated in a devastating November 2, 1943 attack on Rabaul which was eventually cut off. By the time MacArthur had finished his campaign in the southern portion of the SWPA, he had isolated approximately 350,000 Japanese troops (Bergerud 2000, 656).

Two notable events in the Pacific Theater air war are worth mentioning. The first occurred on April 18, 1943 when Allied forces launched Operation Vengeance, which consisted of 18 P-38 Lightnings sent to intercept two Mitsubishi G4Ms, one of which was carrying Admiral Yamamoto. The operation was a gamble because it risked exposing to the Japanese that Allied forces had broken the Japanese naval code. The attack was successful and both bombers were shot down (Davis 1969; Davis 2005; Glines 1990). The second is the Battle of the Philippine Sea, the aerial portion of which is commonly referred to as ‘The Great Marianas Turkey Shoot’ (Morison 2011; Y'Blood 1981). On June 19 to 20, 1944 the largest carrier battle in history occurred to the west of the Mariana Islands between the U.S. Task Force 58 – comprising 15 aircraft carriers and over 900 aircraft – and the assembled Japanese fleet with its 9 flattops and approximately 480 planes (Tillman 2006, 3). The overwhelming numbers, combined with new, more advanced aircraft and better trained pilots resulted in the sinking of three Japanese carriers and the downing of

476 aircraft (Tillman 2006, 286). The decisive victory eliminated Japanese naval air power from the war and ensured eventual Allied control of the Mariana Islands.

Continued aerial and marine bombardment of Guam, Tinian, and Saipan was followed by Marine Corps landings and the resultant capture of all three islands by August 10, 1944. Allied forces were now approximately 1500 miles south of Tokyo, i.e., they were within range of the new Boeing B-29 Superfortress (Tillman 2010, 68). Consequently, dozens of Army engineering and Navy Seabee battalions went to work, constructing 6 bases with 11 runways by almost literally moving mountains with hundreds of vehicles and building asphalt plants to provide thousands of tons of paving material for runways and ancillary roads (Tillman 2010, 70-75). On November 24, 1944, two years and seven months after Jimmy Doolittle’s Raiders surprised the Japanese, American air power returned to the skies above Tokyo. Initial attacks followed USAAF doctrine by implementing high-altitude precision bombing. However, this proved to be largely inaccurate and ineffective. In February 1945, General Curtis LeMay and his staff began to question this tactic and shifted to lower altitude incendiary bombing instead. Initial trials were promising and the eventual results were catastrophic for the Japanese. On the night of March 9-10 alone, over 16 square miles of Tokyo was burned to the ground. The capture of Iwo Jima in February and March and Okinawa from April to June provided a safe landing spot for ailing B-29 and allowed for North American P-51 Mustangs escorts. The previously mentioned Navy Task Force 58 also contributed with precision attacks on airfields and other smaller targets. The aerial mining of critical waterways around Japan and the concentrated efforts to sink coal barges that ran from Hokkaido to Honshu further crippled the already stricken war effort. Clearly defeated, yet still defiant, Japan did not finally surrender until after atomic bombs were dropped on Hiroshima and Nagasaki on August 6th and 9th, respectively (Bergerud 2000; Nalty 1997; Nalty, et al. 1994; Tillman 2010).

3.1.2 The China-Burma-India Theater

By the time the United States was finally drawn into WWII on December 7, 1941 conflict had been raging for two years in Europe since the German invasion of Poland on September 1, 1939. The Second Sino-Japanese War had been ongoing for more than four years in Asia since the Marco Polo Bridge Incident and the Japanese capture of Beijing in July 1937.

Shortly after Pearl Harbor, leaders in Washington D.C., as well as Allied commanders, decided that China had to be supported and kept in the war (Koenig 1972, 18; Spencer 1994, 32). The simple reason for this was that as long as the Chinese were still capable of fighting, the Japanese would be forced to keep as many as two million men on the Asian continent and not fighting American forces throughout the Pacific Theater.

American and British forces had been unofficially supporting the Chinese with war material via the Burma Road, which began in Lashio, Burma and wound for 770 miles through jungle and mountains to Kunming, China (Constein 2005, 32). Throughout the early years of the Second Sino-Japanese War and the beginning of WWII, this was the only route by which Allied forces were supplying the Chinese, because the Japanese controlled the South China Sea and had blockaded the Chinese coastline (Tunner 1964, 58). The United States also supported the Chinese with the American Volunteer Group, better known as the *Flying Tigers*, which were commanded by General Claire Chennault. The small group of aircraft and pilots fought valiantly from December 1941 to March 1942 in the defense of the port city of Rangoon, Burma (Spencer 1994, 31). The loss of Rangoon and subsequent additional ground in as far north as Myitkyina resulted in the closure of the Burma Road, the only supply line to China at the time (Spencer 1994, 26). The only other feasible solution was an airlift. However, not only had there never been an airlift on the scale that was about to be attempted, it was going to be undertaken over some of the highest mountains in the world. To the men who conquered it, it became known as, simply, The Hump.

Personal accounts of flying The Hump are provided by Carl Constein (2005), Jeff Ethell and Don Downie (2004), Otha Spencer (1994), and Lieutenant General William H. Tunner (1964). Hump flights commenced from any one of six bases in the Assam Valley, India. Standard procedure following takeoff was to circle the airfield climbing at a rate of 91 m/min until an altitude of 3050 m was reached. Aircraft then headed southeast while continuing to ascend in order to pass over the 3800 m Naga Hills that were, incidentally, well known for being inhabited by head hunters (Tunner 1964, 83). Aircraft flew over broad expanses of northern Burmese jungle in the Chindwin Valley and then adjusted to a more easterly course as they climbed even higher. Air crews then faced a series of high, N/S-running mountain ranges divided by the major rivers of Southeast Asia. First came the Kumon Mountains which were followed by the Irrawaddy and Salween Rivers. As planes traveled east, the mountains grew ever higher in the Santsung Range until they reached altitudes of 5490 m to pass over the Mekong and Red River before descending to

Kunming, China at approximately 1830 m on the northern shore of Lake Dian. The 885 km journey usually took about three-and-a-half hours. The return trip followed largely the same path except slightly to the north, which required aircraft to fly even higher due to taller mountains.

While, at first glance, the flight route appears relatively straightforward, it was anything but. Air crews constantly faced extremely challenging conditions, of which weather was the foremost. The high, uncharted peaks caused warm tropical air to be uplifted and turn into towering dense clouds. Ground fog and heavy rain often reduced the ceiling to only a few hundred feet above the runway and reduced visibility to the length of a runway (Spencer 1994, 71-72). These combined circumstances forced many flights to be completed entirely on instruments (Constein 2005, 71). The lofty altitudes necessary for the journeys also resulted in the build-up of ice on the aircraft, which could become deadly if de-icing systems failed (Spencer 1994, 7). Completing each round trip was made even more difficult by violent storms. Pilots regularly recounted incidents of updrafts and downdrafts forcing changes of altitudes in thousands of meters in very short periods of time (Spencer 1994, 146), turbulence so violent that airframes were permanently bent, and hail large enough to cause dents in the fuselage. Another result of the powerful storms were planes that were blown so far off course that they had to over-correct by as much as 45 degrees (Constein 2005, 106; Ethell and Downie 2004, 112). Additional difficulties included overloaded aircraft, minimal navigational aids, a lack of weather reporting, and poor maintenance (Spencer 1994, 27). If the dangers in the skies were not enough, bailing out or crash landing often meant a risk of being captured by tribes known for head hunting (Constein 2005, 77; Tunner 1964, 83). Overall, the accident rate for Hump cargo flights was higher than that of combat operations (Spencer 1994, 166).

The initial steps undertaken by the U.S. towards overcoming this challenging air route occurred in a somewhat disorganized and halting fashion throughout 1942. First was the activation of three squadrons of C-47s (totaling 25 aircraft) in February, 1942. Second, the 1st Ferrying Group, 10th Air Force, flew the first reconnaissance flights in April 1942 after Burma had been lost (Spencer 1994, 40). The 10th Air Force only managed to transport 700 tons of cargo eastwards over The Hump from April 8 to June 14 (Weaver and Rapp 1944). Third, in June, 1942, the Army Air Forces created the Air Transport Command (ATC) which was assigned the task of transporting men and material for the entire war effort, which included the CBI airlift (Spencer 1994, 51). It would take until the end of the year for the ATC to fully assume command. In the interim, multiple units and organizations operated independently from different bases with little coordination or effectiveness. By December approximately 1,200 tons were flown to China (Love 2003, 28).

The Hump matured in 1943 with the addition of modified Consolidated B-24s in the form of the C-87 variant in January and the C-109 variant in February. These were used, respectively, for cargo/personnel and fuel transport (Spencer 1994, 66-67). Airlift capacity increased again in April with the first delivery of Curtiss-Wright C-46s. The C-46 was larger than the C-47 and thus could carry vehicles, earth-moving equipment and fully-assembled 105 mm howitzers (Love 2003, 29). Additionally, the C-46 had a higher service ceiling and performed better at altitude than the C-47 (Love 2003, 28). Despite the addition of the new aircraft tonnage, totals only reached approximately 2300 in June, 1943 (Forces 1945, 311), which resulted in investigations as to why the airlift was falling short of expectations (Spencer 1994, 90). The effort was found to be performing insufficiently, leading to Colonel Thomas O. Hardin assuming command of the ATC CBI Hump airlift in September, 1943 with the express purpose of raising the tonnage totals. Hardin instituted policies directing pilots to fly in all weather, no matter how severe, as well as initiating flights at night in October of the same year (Constein 2005, 105). Hardin’s policies, and the addition of more aircraft, increased the tonnage from approximately 5,100 in September to 12,500 by December, 1943 and to nearly 19,000 by July, 1944 (Forces 1945, 311; Spencer 1994, 100). Unfortunately, the accident rate correspondingly increased to the point that the commanders in Washington D.C. became concerned.

Brigadier General William H. Tunner was assigned the task of improving the safety record while continuing to increase the tonnage being flown to China. He assumed command of The Hump airlift in August 1944 and held the position until the end of the war. Tunner brought a hand-picked command staff with him to India to oversee and direct the many improvements that would be necessary to meet the mandates placed upon him. His first actions were to improve the deplorable living conditions and re-establish the proper military discipline that had become completely absent (Tunner 1964, 55-57). The pilot rotation schedule was restructured, aircrew were sent to jungle survival school, and personnel were allowed to take small amounts of leave and visit other parts of India (Tunner 1964, 97-100). Furthermore, well-organized search-and-rescue operations were established and the first dedicated weather squadrons patrolled The Hump from early 1945 (Spencer 1994, 154). Local Indian and Chinese citizens were also hired to complete many tasks which freed up Americans for other jobs. Elephants were even used to load planes (Spencer 1994, 144).

The approach to the aircraft was also overhauled. Prior to Tunner, each aircraft was maintained and all of its problems were fixed by a team of flight engineers and mechanics. Under Tunner's direction Production Line Maintenance (PLM) was established in which aircraft went through a series of seven stations, each one attending to specific duties (Tunner 1964, 65, 94). PLM decreased the amount of time it took to service each aircraft, which increased operation time. All of the attention to both people and planes did indeed result in an increase in Hump cargo totals and a decrease in the accident rate.

Increases in Hump tonnage totals were also aided by two significant events. First, the arrival of the Douglas C-54 Skymaster, a massive four-engine transport arrived to the CBI in October, 1944. It could carry more cargo than both the C-47 and C-46 and the four engines gave it greater reliability. Second, victory in Europe on May 8, 1945 allowed the Allies to focus all of their efforts on the Pacific and CBI theatres. To conclude, Tunner's leadership in the CBI Theater was so successful that it is still studied today by Air Force officers (Hoppe 1995).

3.2 Bombardment Aircraft

As mentioned above, the wide-scale use of aircraft during WWII fundamentally changed that way that wars were fought. Bombardment aircraft extend belligerents' abilities to attack the enemy by hundreds, and in some cases thousands, of miles behind the front lines of ground forces. This resulted in the destruction of vital infrastructure such as manufacturing, communications, and transportation. For the first time an enemy could be severely hampered and civilian populations stunned well behind the front lines of the troops on the ground.

The two bombardment aircraft included in this thesis share a similar pattern in their design. The most relevant feature for this study is that there are multiple duty stations running from the nose to the tip of the tail. Those duty stations are also consistent between the aircraft types. For example, the navigator/gunner and the bombardier were situated in the nose with the flight deck immediately above and to the aft. Due to these similarities the aircraft are consolidated and treated as a single sample.

3.2.1 Consolidated B-24 Liberator

The Consolidated B-24 Liberator is a four-engine heavy bomber developed specifically for the long range requirements of WWII (Figure 2). More B-24s have been produced than any other military aircraft. According to Donald (1995, 40), "…some 15 major variants totalled 18,188, or 19,203 including spares," were produced with the first aircraft rolling off of the assembly lines after the beginning WWII and the last before it ended. At one point, a new B-24 Liberator was being completed every 100 minutes (Davis 1987, 28). In September 1944, a peak operation strength of 6,043 B-24 Liberators was reached by allied forces (Johnsen 2001, 104).

Image removed due to copyright restrictions.

Figure 2. Consolidated B-24 Liberator in flight.
(Seaman 2014a)

The development of the B-24 Liberator began when the Army Air Corps issued Type Specification C-212 in 1935. The document detailed the requirements for a new four-engine heavy bomber that had to be capable of traveling 4828 km at 483 km/h with a service ceiling of 10,670 m with a capacity for 3636 kg of bombs. The Consolidated Aircraft Company submitted their Model 32 design (Davis 1987, 4; Kinzey 2000, 4).

This design incorporated numerous innovative design features. These included the ‘Davis airfoil’, Fowler flaps, twin tail rudders, tricycle landing gear, the shape of the hull in cross-section, bomb bay size and door design, and fuel tank design (Figure 3). The Davis airfoil was unique, at the time, in that it had a very high aspect ratio, or a wide span with a low chord (front to back measurement). It also had a sharp camber and reflex curve on the underside. These characteristics, along with the retractable Fowler flaps allowed for greater lift and increased range through reduced drag. The wide spacing between the front and the rear spars within the wing provided additional space for fuel, which also increased the range of the bomber (Hess, et al. 1998, 153-155). The twin tail configuration could sustain a large amount of damage and the aircraft would remain flyable.

Tricycle landing gear provided two primary advantages. A steerable front wheel allowed for easier steering on the ground. The combination of the landing gear design and the retractable Fowler area-increasing flaps meant that the B-24 Liberator had a much shorter takeoff roll than the B-17 Flying Fortress (Davis 1987, 4; Donald 1995, 40; Johnsen 2001, 8; Kinzey 2000, 4). Over the course of the war, this feature proved to be valuable as B-24s were heavily utilized in remote locations (where airstrips were occasionally extremely short) throughout the Pacific and CBI theaters of operation.

In contrast to many of the other large aircraft of the period such as the B-17 Flying Fortress, the Boeing B-29 Superfortress, the C-46 Commando, and the C-47 Skytrain that had round fuselages, the B-24 was narrow and deep. At its greatest dimensions, the fuselage was 2.26 m wide and 3.17 m tall (Johnsen 2001, 51). This depth provided the space for the required bomb payload. Each one of the B-24’s two bomb bays was equal to the single bomb bay of a B-17 (Blue 1975, 11-12). Then fuel tanks were specially fitted into the forward bomb bay the B-24 could carry the same payload as a B-17, but 965 km further.

The B-24 was not without its faults. The same Davis airfoil that added so many benefits also made the aircraft more difficult to fly. Pilots found it difficult to hold in tight formations above 6,096 m (Bowman 2002, 34), and the narrow chord made it far less durable. Damage to any of its major structures frequently resulted in the wing collapsing alongside the fuselage (Kinzey 2000, 6). Additionally, the lightly built bomb bay doors were found to easily collapse on impact when ditching the aircraft in water. This characteristic allowed the fuselage to fill with water very quickly making it difficult for the crew to escape (Davis 1987, 16).

Image removed due to copyright restrictions.

Figure 3. Consolidated B-24 Liberator.
(Davis 1987, 17)

The Liberator Production Pool (LPP) was established in 1941. Over the course of 1942, the LPP eventually grew to incorporate five different manufacturing facilities owned by four different companies. Manufacturing began with Consolidated's San Diego plant (January 1942) and sub-assemblies were soon on their way to Consolidated's new facility in Fort Worth, Texas (May 1942) and Douglas Aircraft Company's plant in Tulsa, Oklahoma (August 1942) for final assembly. Ford Motor Company was also recruited by the Army Air Forces to produce B-24s in Willow Run, Michigan (September 1943). The final member of the pool was North American Aviation in Dallas, Texas (April 1943).

The first production B-24s that rolled off of Consolidated's San Diego assembly line, designated B-24A, were originally intended for the French military, but due to the German occupation they were delivered to the Royal Air Force in December 1940 (Davis 1987, 9). The initial defensive armament configuration included two .30-caliber machine guns in the tail and a .50-caliber machine gun in each waist position and another in the glazed nose (Kinzey 2000, 11). Placing a gun in the tail of the aircraft was a unique feature for an American bomber at the time. Some of the early versions were field modified to incorporate a tunnel gun, which was located in the floor of the aft of the aircraft between the waist guns and the tail.

The B-24 underwent substantial changes between the first production models and the B-24D. The most noticeable was the extension of the nose by 0.8 m, extending the length of the aircraft from 19.4 m to 20.2 m (Hess, et al. 1998, 158; Kinzey 2000, 12). The 1,200 hp Pratt & Whitney Twin Wasp radial engines were upgraded and the air intake cowlings were redesigned. The defensive armaments were also substantially upgraded. Two additional .50-caliber machine guns were added to the cheeks on each side of the nose and a Martin power-operated turret was added to the upper fuselage behind the cockpit. Furthermore, a Consolidated A-6A power turret with two .50-caliber machine guns was installed in the tail, and a fully retractable Sperry manned ball-turret, identical to late model B-17Es, was placed in the belly to protect the aircraft from below (Davis 1987, 15-18; Kinzey 2000, 14-31). Eventually, a total of 2,696 B-24Ds would be delivered to the military (Kinzey 2000, 14).

More B-24Js were produced than any other variant, 6,678 (Kinzey 2000, 54). Like the developments that occurred from the B-24A to the B-24D, additional changes and modifications were made as the aircraft was developed into the B-24J. The most obvious was the nose of the aircraft. Even with the three .50-caliber machine guns, Army Air

Force field commanders still found that the B-24 was vulnerable to frontal attacks because of insufficient firepower. In the Pacific Theater the 90th Bombardment Group, *The Jolly Rogers*, overcame this difficulty by installing a Consolidated A-6A power turret from the tail of a wrecked aircraft into the nose of one of their B-24Ds (Davis 1987, 27; Hess, et al. 1998, 149, 158, 214). This modification proved to be so successful that it was quickly adopted by various maintenance depots and eventually the manufacturing plants. The gunner's visibility was improved in both the dorsal and tail guns with the inclusion of larger plexiglas panels. The waist gun positions were staggered down the length of the fuselage so that their operators wouldn't interfere with each other. Improvements also included updated fuel systems, bomb sights, automatic pilot controls, deicing systems, and electronic supercharger regulators

Despite countless iterations and numerous variants of the B-24, the fuselage compartments and the basic crew positions remained the same (Figure 4). Early versions, such as the B-24A, were typically manned by eight personnel. The forward-most compartment was occupied by the navigator and the bombardier and their associated equipment including navigational tools, bomb site, and bomb release controls (Figure 5 and Figure 6). The navigator was also typically responsible for operating the nose guns. Aft, and above the nose compartment, was the flight deck (Figure 7). The pilot sat on the port side and the co-pilot to the starboard. The radio operator's station was positioned immediately aft of the co-pilot, facing the starboard side of the plane. The other major, unoccupied, compartment in the B-24 is the nose wheel section that was situated aft of the nose compartment and beneath the flight deck. In addition to housing the landing gear during flight, there is a small crawl-way allowing the crew to move between the bombardier's compartment and the rest of the aircraft (Figure 8) (Bowman 2009).

The B-24's double bomb bays divided the forward sections of the aircraft from the large aft compartment. The bomb bays were equipped with slanted racks that angle outward at the top (Figure 9). This feature allowed for the crew to move from the fore to the aft of the aircraft relatively easily without a parachute on (Kinzey 2000, 43), but it was far more difficult when wearing one (Bowman 2009, 89). This often resulted in crew members not wearing parachutes during the mission and only donning them out of necessity (Bowman 2009, 90-91). This choice could mean the difference in whether or not a crew member would be able to successfully escape a stricken aircraft. The rear fuselage compartment was the longest of the five and held the duty stations for the waist gunners (Figure 10). The tail turret comprised the rear of the B-24 (Figure 11).

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Figure 4. Consolidated B-24 crew duty positions.

The addition of new defensive armaments as the different variants were produced increased the number of crew members aboard the aircraft. The dorsal turret incorporated with the B-24D added another individual to the flight deck, immediately aft of the radio operator (Figure 12). The aircraft's engineer manned this position. The standardization of the Sperry ball-turret to the belly of the aft compartment added another person. These two additions brought the total number of personnel up to ten. It was not uncommon, however, for additional service members such as an observer or a photographer to be aboard an aircraft depending on its mission.

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Figure 5. Nose turret and navigator duty stations.
Clockwise from top left: View of nose turret; navigator’s radio compass, looking up towards the nose turret, navigators compartment (Bowman 2009, 45).

Image removed due to copyright restrictions.

Figure 6. Bombardier duty station
Clockwise from top left: bombardiers station below the nose turret; bombardier duty station; bomb selector panel; Norden bomb sight (Bowman 2009, 73).

Image removed due to copyright restrictions.

Figure 7. Flight deck.
(Johnsen 2001, 62)

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Figure 8. Crawlspace (left) extending from the nose compartment, under the flight deck, towards the bomb bays.
(Bowman 2009, 64)

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Figure 9. Clockwise from top left: ball turret in relation to waist gunner positions; looking aft down the bomb bay catwalk, detail of ball turret; view from ball turret. (Bowman 2002, 115)

Image removed due to copyright restrictions.

Figure 10. Waist gunner duty position.
Clockwise from top left: Ammunition box; staggered waist guns; window hatches; exterior view of waist gun (Bowman 2009, 101)

Image removed due to copyright restrictions.

Figure 11. Tail turret duty position.
Clockwise from top left: Tail turret; view from tail turret; looking aft from waist gunner position to tail turret; external view of vertical tail plane and tail turret (Bowman 2009, 129).

Image removed due to copyright restrictions.

Figure 12. Clockwise from top: view to aft from dorsal turret; two external views of dorsal turret; looking up into the dorsal turret.
(Bowman 2009, 87)

The gunners' positions were isolated, cramped and difficult to exit from. This was especially the case if one of the individuals had been hit. Often, a surviving crew member would have to try and get the body out of the turret to determine if the gun was still operational and then man it (Bowman 2002, 48-49). The Sperry ball turret was so small that there was insufficient space for the gunner to wear his parachute (Bowman 2002, 47). This meant that the operator had to climb out of the turret into the rear portion of the fuselage, don his parachute and then make his way to an egress point (Bowman 2009, 114). These tasks could be exceptionally difficult if the B-24 was heavily damaged or had lost a wing as described above. Specific procedures were in place regarding the order in which each crew member was to bail out from each exit point (Figure 13). It is important to note that the forward-most exit point was only usable after the pilot had to lower the front landing gear. Likewise, the bomb bay doors had to be opened to escape. Damage to either mechanism that opened either set of doors could have prevented their use.

Image removed due to copyright restrictions.

Figure 13. Egress location and order for the B-24.

In sum, the Consolidated B-24 Liberator proved to be a major step forward in aircraft engineering. Due to technological advancements, it had an increased range and armament capacity in both ordnance load and defensive capability over previous bombardment aircraft. Crewed by eight to twelve men, the B-24 played a pivotal role in the Allied war effort, particularly during the early and middle portions of the Pacific Theater.

3.2.2 North American B-25 Mitchell

Despite having principally built small observation aircraft, the North American Aircraft Company made a major leap when they began work on a medium bomber in 1937. Initially tested by the military in 1938, it received wide praise and North American was poised the following year to take advantage of the Army Air Forces' call for designs of a new twin engine bomber (Donald 1995, 188; Kohn 1978, ii). Upon selection the aircraft was designated B-25 and over, 11,000 would be built between 1940 and 1945, with 9,816 going to the USAAF (Donald 1995, 193).

In appearance, the B-25 is reminiscent of the (larger) B-24. It has an oblong cross section that is narrow and deep, tricycle landing gear, twin tail rudders, and a stepped cockpit (Figure 14 and Figure 15) (Forces 1942). It lacked, however, some of the most innovative features of the B-24, such as the Davis Airfoil and the retractable Fowler flaps. The airframe was relatively simple, which allowed numerous modifications to be made to the aircraft. Like the B-24, these alterations most frequently first came about in the field and then later on they were added to the production lines. This allowed the B-25 to be adapted to a wide variety of roles (McDowell 1978, 8; Sharpe, et al. 1999, 498).

Image removed due to copyright restrictions.

Figure 14. North American B-25B Mitchell in flight. (Seaman 2014a)

Image removed due to copyright restrictions.

Figure 15. North American B-25C/D Mitchell.
(Forces 1942, xxv)

The general trend across the multiple versions of the B-25 was the increase in firepower and engine horse power. The initial B-25A, the model in production at the outbreak of the war, was powered by two Wright Cyclone engines with 1,350 horse power and lightly armed with a single .30 caliber machine gun in the nose, two in the rear, and a .50 caliber in the tail (Kohn 1978, iii; McDowell 1978, 6). Subsequently, the B-25 was found to be in need of more defensive protection and so .50 caliber dorsal and ventral power turrets were added to the rear portion of the fuselage of the B version and the tail gun was removed (McDowell 1978, 10). The B25C/D received an engine upgrade, enlarged fuel tanks and modifications to the nose guns. The .30 caliber was replaced with a Browning .50 caliber and an additional, fixed .50 caliber, to be fired by the pilot, was installed.

A major shift in the way the B-25 was utilized came with the G model; this was a result of the unique characteristics faced in the Pacific, discussed above. With targets widely dispersed and well camouflaged, high altitude, precision bombing was not as effective. Field commanders improvised and found that hit and run strafing tactics produced much better results and set their mechanics to modifying their existing aircraft. They started by removing the bombardier and adding two more .50 cal machine guns in the nose as well a twin pack of .50 cal guns on each side of the fuselage, resulting in a total of eight forward firing guns controlled by the pilot. All of this was primarily designed to protect the aircraft while it was firing the 75 mm cannon that had also been added to the nose (McDowell 1978, 23). This was the first successful application of airborne artillery and it proved to be highly effective against Japanese ships (Kohn 1978, ix-xi). These changes were then incorporated into the manufacturing process.

The B-25H saw the dorsal turret relocated between the pilots and the navigator and the installation of blistered .50 caliber gun stations on each side of the rear portion of the fuselage. Firepower returned to the tail with twin .50 caliber guns. This brought the total number of Brownings up to fourteen (Donald 1995, 192; McDowell 1978, 29). Over 1000 were eventually produced. The final model of the B-25 was the J, with 4,390 having been manufactured. A variety of nose configurations were common, but the most intimidating had four more .50 calibers added to bring the total fixed forward facing guns to twelve and the total for aircraft to eighteen (Donald 1995, 190; Sharpe, et al. 1999, 499). As Allied forces pushed north across the western Pacific the need for strafing Japanese ships decreased, and the bombardier nose was brought back (McDowell 1978, 33).

A B-25 was typically operated by a five- or six-man crew. Forward-most in the aircraft was the bombardier who, in early versions, was responsible for the nose gun. Above and to the rear, the pilot and co-pilot were seated abreast with the pilot on the port side. Between the pilot and the bomb bay were the navigator’s station and, in later models, the top turret gunner. Immediately to the rear of the bomb bay was the radio operator. Duty stations aft of this position varied considerably over the life of the B-25 to include a top turret, a bottom turret, aerial photography, two waist guns, and (in early and later models) a tail gun(s).

Unlike the larger B-24, the B-25 was a much more difficult aircraft for a person to maneuver through, which becomes critical when an airman was trying to bail out. The small spaces could be made even more challenging if sharp flaps of metal were bent inward due to battle damage. For those in the front half of the plane, the egress point was a square hatch in the floor of the navigator's station that was hinged on the edge closest to the nose. This meant that the door had to be pushed open against a 320+ km/h wind. The navigator could most easily escape followed by the pilot and co-pilot. The bombardier, however, had to squeeze through a small rectangular crawl-way underneath the pilots' compartment. This passageway is barely large enough for a person, much less one wearing bulky clothing and a parachute. The crew members in the rear of the aircraft exited through a hatch in the floor similar to the one in the front. The radio operators and gunners could reach the opening relatively easily, but the tail gunner had to work his way through the narrow aft passageway.

The North American B-25 Mitchell proved to be a highly versatile aircraft that was easily modifiable to meet the ever changing needs of Allied forces as they advanced across the Southwest Pacific.

3.3 Cargo Aircraft

With personnel spread around the globe Allied forces had to ensure that troops could reach the front line and that equipment and supplies would follow on. Two of the most prominent aircraft to haul cargo around the world were the Douglas C-47 Skytrain, or Dakota, and its replacement the Curtiss-Wright C-46 Commando.

3.3.1 Curtiss-Wright C-46 Commando

The Curtiss-Wright C-46 Commando's is a twin engine medium cargo aircraft (Figure 16 and Figure 17). Its origins were based in the passenger airline industry. Across all variants, approximately 3,000 aircraft were eventually manufactured (Donald 1995, 60-36). Initial models were designed by George A. Page in 1936 and referred to by the company as the CW-20. Initially designed to be a passenger airliner, the C-46 was pressed into service by the U.S. military and go through several different models and numerous iterations to include the Navy version, the R5C-1 (Love 2003, 19).

Image removed due to copyright restrictions.

Figure 16. Curtiss-Wright C-46 Commando in flight. (Seaman 2014b)

The basic fuselage of the CW-20, when viewed from the front, is of two circles that intersected at a common chord line, with lower circle having a smaller diameter than the upper (Figure 18) (Love 2003, 9). This resulted in a ‘double-decker’ appearance of two cylinders attached together. The top edge of the wings extended from the chord line, so they were set relatively low on the fuselage and did not have to bisect the main compartment (Donald 1995, 60). At 23.2 m in length, a wingspan of 32.9 m, and a height of 6.7 m, the Commando was substantially larger than the C-47. In addition to size, there were other innovations that set the C-46 apart from the C-47. The windscreen and the rivets were flush with the contour of the fuselage, which was constructed from abutting, not overlapping, panels. The engine nacelles were fitted with low drag cowls on their underside. In addition, the nacelles were set slightly below the top of the wing to ensure that airflow was uninterrupted as it passed over the lifting surfaces. Page’s design also eliminated protruding carburetor and oil cooler scoops. All three landing gear were fully retractable behind doors that were also flush with the outer skin of the plane (Donald 1995, 60; Love 2003, 5).

Image removed due to copyright restrictions.

Figure 17. Curtiss-Wright C-46 Commando.
(Love 2003, 10)

Image removed due to copyright restrictions.

Figure 18. Cross section of the C-46 fuselage.
(Love 2003, 11)

Twenty-five of the first 46 aircraft ordered by the USAAF were built to the CW-20 specifications, with the first one rolling out of a plant in Buffalo, New York on June 20, 1941. However, several modifications were necessary to transform the planned commercial airliner into the C-46A military cargo hauler. More powerful 200 horse-power Pratt &Whitney R2800-43 Double Wasp 18-cylinder, air-cooled, radial engines were selected. The intended pressurization of the aircraft was abandoned. The floor of the main compartment was reinforced to support heavier loads. The port, aft passenger door was replaced by a larger cargo door with two inner doors, one for boarding and another for paratroopers to exit through during jumps. The number of windows was reduced from ten to four on each side of the fuselage, and fold-up seating along the walls was installed that could accommodate 40 men (Figure 19) (Donald 1995, 60-61; Love 2003, 8-9).

Image removed due to copyright restrictions.

Figure 19. C-46 cargo compartment.
(Love 2003, 11)

The remaining 21 C-46As from the original purchase, plus an additional 1226 were ordered across five batches between September 1940 and December 1942. Due to the high war-time demand, two more manufacturing facilities were opened, one in Louis, Missouri and another in Louisville, Kentucky (Love 2003, 9). The basic configuration of the C-46 required a minimum crew of 3. The pilot and co-pilot, seated port and starboard, respectively, were situated in their own compartment in the very front of the aircraft. Immediately to the aft was a separate space for the navigator/radio operator whose duty station faced the starboard side of the fuselage. The majority of the remainder of the aircraft was comprised of the cargo compartment that was 14.6 m long, 2.4 m wide on the floor, and had a maximum height of 2 m (Love 2003, 8). Larger pieces of military equipment, such as a fully assembled 105 mm howitzer, could be accommodated.

The C-46 was a larger, more powerful aircraft than the C-47. Its engines, cargo compartment, and wing fuel tanks allowed for 5300 kg of cargo to be transported 3150 km. Sacrificing cargo capacity for range with the installation of additional auxiliary fuel tanks within the cargo compartment allowed the C-46 to travel 5000 km. The C-46 had a cruising speed of 378 km/h, a maximum speed of 435 km/h, and a service ceiling of

28,200 m. These characteristics made the aircraft ideal for the CBI Theater and Hump operations (Love 2003, 9).

The C-46B and C-46C were experimental aircraft that eventually led to the C-46D. The notable change with this model was the addition of another cargo/personnel door. It was located on the starboard side of the aft portion of the fuselage directly opposite the port door. This allowed the 50 paratroopers seated in the redesigned cargo compartment to exit the aircraft twice as fast during airborne assaults (Donald 1995, 61; Love 2003, 21). Approximately 1400 C-46Ds were constructed between September 1944 and July 1945, and would be the last model to be mass produced for the military. The Curtiss-Wright aircraft company continued manufacturing the C-46 with the E, F, G, and H models. The only substantial variation in them was the stepped windshield on the 17 E-type aircraft (Love 2003, 23-27).

3.3.2 Douglas C-47 Skytrain/Dakota

The Douglas C-47 Skytrain/Dakota was the most widely produced twin-engine cargo aircraft of the WWII era (Figure 20 and Figure 21). According to Donald (1995, 102), approximately 11,000 were manufactured before production ended in 1945. In addition to being referred to as the Skytrain, the C-47 is also often referred to as the Dakota, Dizzy Three, Gooney Bird, Skytrooper, and Spooky. The basic airframe is also occasionally referenced as a C-48, C-49, C-50, C-53, C-117, or the Navy's version, the R4D (L. Davis 1995, 31).

The roots of the C-47 can be traced Donald W. Douglas and his innovative designs that evolved from the DC-1 through to the DC-3. The DC-1 was designed to meet specifications for Transcontinental and Western Airlines and included revolutionary characteristics such as a nearly circular fuselage tall enough for a person to stand upright. The fuselage was joined to, and above, a center wing engine nacelle section, with the remainder of the wings attached laterally to each side allowing for easier maintenance. It rolled off the assembly line in Santa Monica, California on June 23, 1933 at 18.3 m in length, a wingspan of 25.9 m, and a height of 4.9 m. It was large enough for a galley and a lavatory, both firsts in the air industry (L. Davis 1995, 6-7). The DC-2 was 0.6 m longer than the DC-1, and had several additional modifications including new flaps, a re-engineered rudder assembly, and wheel brakes. This model was also equipped with a variety of different engines from both Wright and Pratt and Whitney (L. Davis 1995, 9).

Image removed due to copyright restrictions.

Figure 20. Douglas C-47 Skytrain in flight.
(Seaman 2014b)

Additional demands from the commercial airline industry for sleeper berths saw the DC-2 increased in size once again to the DC-3. Rounding of the fuselage sides added 0.7 m to the width and another 0.8 m was added to the length. The wings were widened by 3.0 m and were modified to more tapered tips. This allowed for a larger fuel capacity and greater range. The tail and rudder assemblies were also enlarged and the engines were upgraded (L. Davis 1995, 25).

The military life of the DC-3 began in 1940 when the Army issued specifications for a new transport aircraft. The Douglas aircraft company found itself in an excellent position to meet the new requirements with the DC-3, which had been in production since 1936. To make it suitable for military use Douglass upgraded the engines again to supercharged 1,200 horsepower Pratt and Whitney Twin Wasps (Sharpe, et al. 1999, 456). The fuselage was strengthened so that two large cargo bay doors could be added to the port side with a cargo hoist above it. The floor of the cargo area was reinforced so that heavier loads could be carried and tie-down loops and hooks were installed (L. Davis 1995, 25-26; Donald 1995, 102). Post conversion, the cargo area was capable of holding 6000 kg of cargo and was large enough to hold a jeep with a trailer or a jeep with a 37 mm anti-tank gun. The cargo area could be reconfigured to hold 28 fully armed paratroopers or 18 litter patients (Figure 22). The C-47 could also be equipped with extra carrying capacity under the fuselage for up to six parachute pack containers or two spare propellers (Donald 1995, 103; Sharpe, et al. 1999, 458).

Image removed due to
copyright restrictions.

Figure 21. Douglas C-47 Skytrain.
(Greeen 2014)

Image removed due to copyright restrictions.

Figure 22. Forward view a C-47 cargo compartment carrying paratroopers. (Wired 2014)

The C-47B model was outfitted with yet another type of Pratt and Whitney engine. This was the R-1830-90 with specially designed blowers which raised the service ceiling of the aircraft to 7,600 m making it suitable for operating in the CBI theater and flying The Hump (L. Davis 1995, 28; Sharpe, et al. 1999, 456). With this engine, the C-47 had a cruising speed of 185 mph (298 km/h) and a maximum speed of 229 mph (369 km/h).

The first C-47 was delivered to the Army Air Forces from Douglas' Long Beach, California plant on December 23, 1941, just sixteen days after the attack on Pearl Harbor. The demand for the aircraft was so great that there was not enough space in the Long Beach, California plant to build them fast enough, so another facility was opened in Tulsa, Oklahoma (Donald 1995, 103-104). The C-47 served as the backbone of the Air Transport Command which was formed on July 1, 1942. It fulfilled duties as varied as officer transport, paratrooper drops, cargo hauling, casualty evacuation, navigational trainer, and to tow gliders, the latter obviously being especially important during D-day on June 6, 1944 (Sharpe, et al. 1999, 456-457).

A C-47 was typically manned by three personnel; the pilot and co-pilot/navigator, seated port and starboard, respectively, were in the forward most compartment with the radio operator in a separate section immediately to the rear (Donald 1995, 103). It was also common for a crew chief/flight engineer or load master to be on a flight as well. The preferred egress point when bailing out was the cargo door at the rear of the fuselage due to the proximity of the port propeller to the crew door. The C-47 did possess another escape hatch in the ceiling of the cockpit, but it could not be used during flight (Spencer 1994, 85).

The C-47 continued to serve the US Military through the Korean War with its final role coming during the Vietnam War. Approximately two-dozen were modified into AC-47D Spooky Gunships. These variants had three 7.62 mm belt fed miniguns fixed to the floor of the cargo compartment that were aimed out the port side of the fuselage. This allowed the pilot to perform a left pylon turn and control the firing of the miniguns from his control yoke. This allowed the aircraft to maintain fire on a single point for an extended period of time without having to make several passes. The cargo compartment allowed each Spooky Gunship to carry tens of thousands of rounds of ammunition. They proved to very highly effective at providing suppressive fire, halting enemy advances, and devastating hilltop fortifications.

4 Methods

While this thesis is archaeological, and to a lesser degree anthropological in nature, it is focused on a facet of the subject that is relatively unfamiliar to most practitioners of the discipline. Few archaeologists have ever excavated an aircraft crash in a remote location with the goal of recovering human remains which will eventually be analyzed, identified, and returned to their families. Due to the unique characteristics of the JPAC mission, both in the field and laboratory, specialized guidelines have been developed by the organization to provide structure to the entire process. As a result, two major areas will be discussed within this chapter. The first will detail the CIL's standard operating procedures for current work and the second will address the methods that were utilized for the data collection, analysis and interpretation within this thesis.

4.1 The Central Identification Laboratory's Standard Operating Procedures

Fundamentally, the JPAC's mission is the recovery and identification of missing personnel. Like all field methodologies utilized in the highly varied discipline of archaeology, the survey and recovery strategies undertaken by the CIL are designed to meet their own specific goal. However the archaeological sites that are dealt with by the JPAC are often very different from traditional archaeological sites. They are commonly aircraft crashes which results in several unique characteristics. First, the sites are not intentionally created by the individuals whom the JPAC is seeking. Second, this accidental nature of their creation frequently situates them in very remote and challenging locations, which may include anything from swamps in Papua New Guinea to mountain sides in the Himalayas in northeast India. Third, the site is the result of an inherently violent and destructive event, meaning that it began in taphonomically adverse conditions.

Due to these challenges the CIL has developed standard operating procedures (SOP) for all phases of the accounting process to ensure predictable, consistent, and scientifically sound results. Areas covered by the SOP include, for example, General Casework Procedures, Measurement & Observation Traceability, Lab Case File Management, Surety, Analytical Notes & Documentation, and Peer Review. For the purposes of this thesis, the most relevant sections of the SOP are Recovery Scene Processing, Determining Biological Profiles, and Forensic Odontology

4.1.1 Remote Operations

Remote operations are defined to include all CIL-directed field activities regardless of the stage in the accounting process in which they may take place. This can encompass interviewing witnesses and informants, site evaluation and assessment, surface and subsurface surveys, and excavation. While the CIL follows standard archaeological methodologies and techniques, the guidelines for these activities are laid out in SOP 2.0 Recovery Scene Processing (CIL 2014). It has been specifically authored to provide a sufficient level of specificity to ensure that field activities meet necessary requirements, but general enough to allow for individual archaeologists to adapt their recovery strategies to meet the unique needs of each site they encounter while still satisfying the underlying spirit, principle, and intent of the document.

4.1.1.1 Investigation and Survey

When the work by the JPAC's Research and Analysis (R&A) section has accumulated sufficient information to indicate a region of a country where several loss incidents are likely to be located, an investigation team (IT) is launched (Table 7).

Table 7. The personnel that comprise a JPAC investigation team.

Position	Directorate	Duties
Survey Leader (SL)	CIL	Civilian archaeologist who is the scientific expert and directs all efforts on the site during the survey.
Team Leader (TL)	I&R	Military officer responsible for the safety of the team, logistics, transportation, and interactions with host country officials and landowners.
Investigation Leader (IL)	R&A	Senior civilian Historian/Analyst and is responsible for selecting the cases for field investigation on a mission. This individual also handles several of the cases.
Historian/Analyst	R&A	Civilian individual is responsible for compiling the background information and historical documentation for their assigned cases as well as conduct the off-site background interviews.
Linguist	R&A	Civilian or military who serves as a translator between the American team and host country nationals. Also provides cultural guidance to the team about the host country.
Explosive Ordnance Disposal Technician	I&R	Military enlisted who is responsible for matters relating to any unexploded ordnance that may be encountered during a mission.
Medic	I&R	Military enlisted who ensures the health of the team and treats any illnesses or injuries.

Position	Directorate	Duties
Life Support Investigator	CIL	Civilian or military who specializes in the clothing and equipment worn and used by aircrews. They are also highly knowledgeable in regards to the different types of aircraft and their components.
Forensic Photographer	I&R	Civilian or military who is responsible for photo-documenting the site during all phases of the survey.

While an IT's goal is to both locate aircraft crash and burial sites and attempt to associate or correlate them to a loss incident this thesis will focus on crash sites only. A site is a spot on the ground some place in the world where there is an aircraft crash, while a loss incident is the case of a missing individual or group of individuals. It is not simply a process of finding an aircraft crash in the jungle. The site and the case are separate things which have to be connected through lines of evidence. Historical information may indicate the loss of an aircraft in a specific location and the IT may find that type of aircraft within several kilometres of that spot, but that does not always mean that the correct aircraft has been found.

The difficulty is that there are operational losses. These are instances in which an aircraft was lost, but all of the individuals aboard survived the incident. In some cases an abandoned aircraft can continue on for tens of kilometers. These types of sites are common from the Vietnam War era, but they are also occasionally encountered in relation to WWII. The challenge they pose is that they result in an aircraft crash, but one where there are no remains. Not only do ITs face the daunting task of finding a crash site, but they also have to determine what type of aircraft it is, if anyone was aboard the plane at the time of impact, and, if possible, the specific aircraft serial number.

To go about accomplishing these tasks in the Pacific Theater, the process frequently begins by canvassing the closest villages that surround a suspected loss location. Extensive and detailed interviews are conducted with any individuals who may have useful information. Local residents are very familiar with the rural areas around their communities and will frequently know about any crash sites within the vicinity. If they do, the IT will then request that they lead the team to the site.

Upon arrival at a site a preliminary, loosely organized scatter survey is typically conducted to allow the survey leader to make an initial assessment. A second interview is then commonly conducted with the witness or informant in which the SL can ask specifically-tailored questions related to the site itself to help clarify any uncertainties and to flesh out the history of the site since the crash. This may include asking about any metal scavenging activities that may have occurred or if any human remains have been observed. Next, an organized transversal pedestrian search is undertaken across the primary wreckage concentrations to locate and identify the various sections and components of the aircraft as well as terrain features such as impact craters. Detailed examinations are then made of those sections of the aircraft that are most likely to result in the IT finding items that can confirm if people were aboard at the time of the crash and to determine the serial number of the aircraft.

One method that is somewhat unique to the JPAC is the use of metal detectors, which play a major role in the pedestrian survey process. In areas of heavy, dense vegetation 1-2 m wide pathways are cut through the undergrowth to radiate out from what is thought to be the center of the debris field. A trained crew member walks down one of the paths, beginning at the central hub, passing the metal detector over the surface of the ground to determine where the metal signatures terminate. Repeating this process down each one of the radiating paths allows the archaeologist to determine the size and shape of the incident related debris field as well as concentrations of wreckage. Metal detectors can also be useful in finding out how far wreckage has been transported down a dry wash or stream bed.

In the remote mountains of southwest Pacific islands, little scavenging has usually occurred and large fragments of wreckage are still present, whereas in Southeast Asia and Europe crash sites can be so heavily scavenged that almost no metal is visible on the surface. In these situations it becomes necessary to execute a systematic subsurface sampling program. Transect lines are established and metal detected with each signature investigated and recorded. Test pits are also excavated at regular intervals along the transects. These techniques allow the SL to determine the size and shape of the debris field, the different densities of wreckage within the site, and where a recovery team is most likely to recover evidentiary materials. Documenting the site includes extensive notes, detailed tape and compass maps, and extensive photographs.

In addition, the IT collects all of the necessary information to potentially plan and execute a recovery mission. This includes locations of the site, any necessary helicopter landing zones, potential base camp locales, and nearest water sources, roads and towns. It also identifies the landowner and the pertinent government officials and agencies through which coordination will have to occur.

4.1.1.2 Recovery Operation

Recovery operations are undertaken when investigation and survey efforts have yielded sufficient evidence for the JPAC to believe that there is a strong likelihood of recovering remains and a specific crash site or burial location. A recovery team is made up of a specialized set of core personnel, and additional individuals such as mountaineers are added when necessary (Table 8). In addition, in many countries the team will hire local villagers to help with vegetation clearing, passing buckets, and screening. The inclusion of local villagers in fieldwork is an area that warrants future research because in some countries, such as Laos, the people who end up assisting in the process may have been living in the area during the war and suffered as a result.

Table 8. The personnel that comprise a JPAC recovery team.

Position	Directorate	Duties
Recovery Leader (RL)	CIL	Civilian archaeologist or anthropologist who is the scientific expert and directs all efforts on the site during the excavation.
Team Leader (TL)	I&R	Military officer responsible for the safety of the team, logistics, transportation, and interactions with host country officials and landowners.
Team Sergeant (TS)	I&R	Enlisted military who functions as the site foreman and executes the recovery at the direction of the RL.
Linguist	R&A	Civilian or military who serves as a translator between the American team and host country nationals. Also provides cultural guidance to the team about the host country.
Explosive Ordnance Disposal Technician (EOD)	I&R	Military enlisted who is responsible for matters relating to any unexploded ordnance that may be encountered during a mission.
Medic	I&R	Military enlisted who ensures the health of the team and treats any illnesses or injuries.
Communications Technician	J6	Military enlisted who ensures that the team is able to communicate with other in-country teams, forward detachments, and the JPAC headquarters.
Life Support Investigator (LSI)	CIL	Civilian or military who specializes in the clothing and equipment worn and used by aircrews. They are also highly knowledgeable in regards to the different types of aircraft and their components.
Forensic Photographer	I&R	Civilian or military who is responsible for photo-documenting the site during all phases of the excavation.
Supply Sergeant	I&R	Military enlisted who maintains accountability of the teams equipment and ensures it remains in good working order.

Recovery non-commissioned officers	I&R	Military enlisted who participate in the excavation and screening of sediment.

The most common first step undertaken by a recovery teams is an initial visual inspection of the site. The objectives are to relocate the terrain features, major aircraft wreckage components, any evidence that was observed by the IT, and to note any changes that may have occurred in the interim. The RL and TS select of the locations for the site infrastructure such as a, break area, supply storage, screening stations, latrines, and an unexploded ordnance (UXO) pit. The next step is the removal of vegetation from the site and at the locations where the structures are to be built. The amount cleared is determined by the archaeologist and is typically centered on the areas where there is the highest likelihood to find human remains, typically at the cockpit wreckage or in the fuselage impact crater. Clearance is usually undertaken in stages as finds from the excavation dictate its expansion.

Like most archaeological excavations, CIL recovery operations utilize a grid system to control the recovery effort. However, the size of most aircraft crash sites and the need to make efficient progress has led to the standard unit being 4-x-4 m. The excavation grid is emplaced and oriented based upon the terrain of the site with one axis oriented directly upslope-downslope. The grid can be established using a total station, digital theodolite, or the ever faithful tape measure and compass. Grid north is set as the axis that is closest to magnetic north without exceeding 45°. An arbitrary stake is designated the datum and labeled N500/E500 to ensure that the unit coordinates remain in positive numbers. The wooden stakes are then numbered with each unit being designated by the stake in its southwest corner.

Rakes are used to gather all loose leaf litter on the ground surface. Excavation is undertaken one unit at a time using rakes, shovels, picks, hoes, and brooms as well as smaller hand tools such as trowels (Figure 23). Soil removal is undertaken in a careful and controlled manner starting at one edge of a unit and working evenly to the opposite side. Floors are kept flat and side walls vertical allowing the RL to observe any changes in the sediment and identify possible features.

All forest detritus and sediment is transported to the screening station via a bucket line wheelbarrows, or occasionally mechanical equipment. The CIL uses 6.4 mm (1/4 inch) mesh in all three of its different types of screening operations: dry, low-flow wet, and high-flow wet (Figure 24, Figure 25, and Figure 26). Dry screening is simply hanging a series of screens from a cross beam. Low-flow wet screening places the dry screens on fixed rails with a catchment tarp underneath. A PVC piping system is suspended over the screens and garden hose level water pressure is pumped through the system and over the sediment. High-flow wet screening utilizes large, extra-deep custom built screen boxes and 5.1 cm (2 in) fire hose nozzles to process large amounts of sediment very quickly.

Figure 23. Excavation of a unit.
(Esh 2011a, 17)

Figure 24. Example of dry screening.
(O'Leary 2009, 6)

Figure 25. Example of low-flow wet screening.
(Silverstein 2007b, 11)

Figure 26. Example of high-flow wet screening.
(Megyesi and O'Leary 2011, 6)

Local workers assist the JPAC team with the screening process. Each screen is checked by an American team member before anything is discarded. All items that are not naturally from the environment where the recovery effort is taking place are collected. The RL and LSI carefully examine the collected items and determine which ones have evidentiary value. The CIL has three categories of evidence, or evidentiary materials. The first is human remains. The second is termed material evidence and includes items such as identification tags, keys, rings, coins, watches, pocket knives, glasses, etc. Third is life support equipment, which is military issued equipment that sustains an aircrew while they are on a mission. This encompasses items such as helmets, flak armor, cold weather clothing, head sets, throat microphones, and parachute equipment, etc. Provenience is always maintained throughout the excavation, screening and sorting processes and evidentiary materials are bagged based upon the unit and depth from which they were recovered.

An excavation unit is deemed to be finished after a visual inspection by RL has determined that there are no features or soil anomalies and a metal detector has confirmed that there are no additional incident related materials (IRM). The excavation of a site continues until the RL determines that the likelihood of recovery additional human remains can be considered to be minimal. The guidelines for this conclusion are typically defined by the recovery effort having reached both the geographic and stratigraphic extent of evidentiary materials. The geographic limit means that a 2 m buffer containing no evidentiary materials, has been excavated past the last unit that contained evidence. The stratigraphic limit is satisfied by insuring that the depth of excavation exceeds the deepest fragment of incident related material. A metal detector is used for this because the majority of aircraft fragments are much harder and denser than human remains which results in them being driven farther into the ground than pieces of a person during a crash. These are general guidelines that can be adjusted depending upon the topography of a site, patterns within a wreckage debris field, and the methods of excavation.

4.1.1.3 Documentation

As is appropriate for archaeological field work, the CIL extensively documents all activities. Central Identification Laboratory RLs use unique, custom-designed field notebooks for both survey and excavation. The fields include, but are not limited to: site location, site description, evidence of disturbances, vegetation, excavation strategies and screening methods, sediment descriptions, unit logs, and evidence catalogs. In addition to categories that apply to the site itself, detailed notes are taken describing what was completed each day, challenges encountered, solutions to problems, interactions with landowners or host country officials, and interpretations about any patterns that may be observed. The RL also draws a to-scale site map that record all relevant terrain features, transects surveyed, units excavated, and evidence recovered. At least one soil profile is always completed for every excavation to document the sediment matrix from which the incident related material is being recovered. In many cases more than one profile is recorded to document different aspects of a single recovery scene. A good example of this would be when an excavation takes place both within a rice paddy and on its adjoining bank. Aircraft impact craters often require additional documentation due to the complex disturbance and distribution of sediments involved.

A search and recovery report (SAR) is authored for each excavation. The archaeologist who completes the excavation of a site that has required multiple missions is responsible for writing a final SAR, which incorporates all of the previous SARs as well as their own work. These reports include the background of the case, location of the site, a detailed description of the recovery scene, methods used during the excavation, and findings. These field findings are considered preliminary, and reporting of remains in the SAR is handled in a conservative manner. Generic terms such as possible osseous remains, osseous remains, and possible human remains are used and specific skeletal elements are generally not mentioned. This policy is followed to ensure that there are no contradictions between reports after laboratory analysis is completed in Hawaii. Thus, while SARs list which grid unit an identification tag may have been found in and display it on a site map, they do not show where the remains of each crew member was recovered from.

4.1.2 Laboratory Operations

For most part, laboratory analysis does not begin until after a site has been closed, which, as has been previously mentioned, can take as long as several years. The first step is for the case file manager to examine all of the field work that has taken place as well as the different categories of evidentiary materials that were recovered. He or she then notifies the functional area manager for each appropriate type of evidence. This includes the people who are in charge of the forensic anthropology, forensic odontology, and material evidence. Each functional area manager assigns their portion of the case to an analyst.

4.1.2.1 Forensic Anthropology Reports

The skeletal remains, excluding the teeth, are included in the Forensic Anthropology Reports (FAR). The principle goal of this component of the case work is to develop a biological profile (i.e. sex, ancestry, age-at-death, stature, and traits of individuation). Anthropologists developing a biological profile from the remains of an unknown individual work in the “blind.” This means that the analyst does not know any of the physical characteristics of the individuals who may be involved in the loss incident.

The first step in the process, especially for those cases involving multiple individuals, is to resolve any commingling. Proper fieldwork can potentially play a major role in this. When an archaeologist conducting the recovery recognizes articulated remains *in-situ,* he or she is supposed to excavate them carefully, document the relationships between the elements, and maintain their provenience. While this step commonly occurs, there is no formal guidance on how this information is transfered from the recovery leader in the field to the skeletal analyst in the laboratory in a fashion that does not introduce bias into the process. When possible, skeletal elements that were found articulated are laid out on tables along with all of the other osseous material that is associated with the case. An initial evaluation of any re-articulations among elements, pair matching of bones, and major refits is also undertaken at this time.

A DNA sampling strategy is developed by the analyst in concert with the DNA Coordinator (DNAC). The overall goal is to cut the smallest number of samples that is likely to result in obtaining sequences for each of the individuals aboard the aircraft and allow as many of the major skeletal elements as possible to be associated with an individual. This is accomplished by calculating the minimum number of individuals (MNI) for the total skeletal assemblage. Attention is also paid to which elements are selected because different parts of the skeleton have varying levels of success producing usable DNA based upon their cortical bone yield (Meehan 2007). Fragments that have been subjected to substantial thermal alteration are also avoided when possible. Small samples (1.0 to 5.0 g) are cut from each of the selected bones and sent to the Armed Forces DNA Identification Laboratory (AFDIL) for processing. If the initial round of sampling does not result in a sequence for each of the missing individuals, another round of cuts will often occur. It is not uncommon for large bombardment aircraft cases to require more than 100 samples to be cut. The specifics of the resulting AFDIL sequence data that are provided back to the DNAC at the CIL are discussed in the DNA Reports section below.

The DNAC takes the data and separates and groups them by sequence. Thus, for example, samples 01A, 02A, 06A, and 15A all might share sequence 1, while samples 03A, 04A, 08A, and 12A might share sequence 2. This allows the skeletal analyst to sort the remains by individual. At this point, the task of refitting as many fragments as possible back together is undertaken. Those pieces that cannot be associated with a specific individual are included in the group identification. Once the commingling has been resolved to the greatest extent possible the anthropologist begins to determine as much of the biological profile as possible for each individual.

Both metric and non-metric methods are used in determining four of the major components of a biological profile for an individual: sex, ancestry, age-at-death, and stature (Table 9). The methods listed in Table 9 are merely examples of the techniques used in the CIL – the table is not meant to be an exhaustive listing. Characteristics of individuation such as trauma and other general observations are generally made with only non-metric attributes. One of the major tools used by the CIL in determining a biological profile is FORDISC 3.0, a computer program used for a variety of metric tests to help determine ancestry, sex, and stature based upon standard measurements of the skeleton (Jantz and Ousley 2005).

Table 9. Examples of metric and non-metric methods of determining biological profiles utilized at the CIL.

Biological characteristic	Metric	Non-metric
Sex	(Jantz and Ousley 2005; Stewart 1979)	(Bass 2005; Buikstra and Ubelaker 1994; Phenice 1969; Rogers 1999; Rogers, et al. 2000; Walker 2005, 2008)
Ancestry	(Holliday and Falsetti 1999; Jantz and Ousley 2005; Moore-Jansen, et al. 1994; Wescott 2005)	(Bass 2005; Edgar 2005; Hefner 2009; Rhine 1990; Scott and Turner 1997)
Age-at-death	None	(Bass 2005; Brooks and Suchey 1990; Buckberry and Chamberlain 2002; Harris 2007; İşcan, et al. 1984, 1985; Katz and Suchey 1986; Lovejoy, et al. 1985; Mann, et al. 1991; McKern and Stewart 1957; Mincer, et al. 1993)
Stature	(Galloway 1988; Giles 1991; Jantz and Ousley 2005; Trotter and Gleser 1958)	None

The first step in determining a biological profile is determining the sex of the individual, which can be reached through both metric and non-metric methods. Sex is the first step because all of the remaining components of the biological profile are based upon it. Second, the ancestry is assessed. Like sex, metric and non-metric means are available. Third, the age-at-death of the individual is estimated through the use of non-metric traits. Finally, stature is calculated primarily using FORDISC with adjustments for the age of the individual based upon other, independent research. The staff of the CIL are actively engaged with the academic literature. Adjustments are regularly made to the SOP and the procedures that are used in the identification process. In addition, internal assessments are undertaken to evaluate the effectiveness of the methods that are currently in use. The best example of this is a recent study looking at the different methods of aging used at the CIL (Brown 2009).

Each set of remains is also closely examined for characteristics of individuation. This includes any indications of trauma (DiMaio 1999; Galloway 1999), pathological conditions (Aufderheide and Rodríguez-Martín 1998; Lovell 2000), handedness (Krogman and İşcan 1986), occupational markers, and any other anomalies (Hauser and DeStefano 1989). Other general observations such as weathering (Behrensmeyer 1978) and taphonomic processes (Lyman 1994) are also included in the analysis and reporting.

The description, analysis, and findings of the skeletal remains are written up in a forensic anthropology report (FAR). A report is authored for each set of remains that can be attributed to a single individual, plus a group report for those bone fragments that cannot be determined to be exclusively from one of the personnel aboard the aircraft.

4.1.2.2 Forensic Odontology Reports

Forensic odontology analysis and reports address the dental remains and prostheses associated with a case. The method of identification involves comparing ante- and postmortem dental information. There are two techniques of odontological analysis utilized at the CIL: radiographic based and records based. Radiographic comparisons are made when antemortem radiographs are available in a service member's Individual Deceased Personnel File (IDPF). First, the radiograph is scanned. Next, the teeth recovered from an excavation are digitally x-rayed. The two images are then examined for patterns and similar features. These can include, but are not limited to: general morphology of the teeth, the size and shape of any restorative material, pathologies, and other anomalies. Unfortunately, antemortem radiographs are typically only available for Vietnam War losses. However, the U.S. military has been looking after the teeth of their personnel and maintaining documentation for much longer.

Records based analysis is undertaken when antemortem radiographs are not available. The first step in records based analysis is to examine the recovered teeth and complete a dental chart for each individual associated with a loss incident. Then, each person's antemortem dental records are reviewed and a modern dental chart is created. All of the antemortem charts are entered into a large table. The postmortem charts are also transferred onto this table and the two data sets are assessed for similarities and discrepancies. When sufficient similarities are encountered that the analyst concludes that there is match, the Odonto Search Program may be used (Adams 2003a, b). Per the CIL SOP 3.5:

> "OdontoSearch assists in determining the relative frequency of a postmortem dental restorative pattern in comparison to appropriate databases, thereby estimating the frequency of this pattern in various populations. The statistical analysis, with appropriate confidence interval estimation, may add further support that the recovered remains are indeed the person in question and not, through chance, the remains of another individual" (CIL 2012, 3).

While the CIL odontologists do not make identifications, they may make a professional opinion based upon their assessment of the various characteristics of the comparison. There are five categories of opinion. Positive identification is described as when "the antemortem and postmortem dental information are from the same individual, i.e., the dental remains are those of the individual in question" (CIL 2012, 4). Probable identification is defined as when "there are enough concordant features to determine that the remains are probably (i.e., more likely than not) those of the individual depicted in the antemortem records, although not enough to be completely certain" (CIL 2012, 4). Possible identification is characterized by when the comparison of antemortem records and post mortem data "exhibits similar restorative and/or anatomic features, but due to the quality of either the postmortem remains or the antemortem evidence, or lack of unique characteristics, it is not possible to definitively establish dental identification" (CIL 2012, 4). Exclusion is when the comparison determines that there are inexplicable differences between antemortem records and post mortem data and that "the remains are not those of the individual in question" (CIL 2012, 4). Finally, insufficient evidence can be concluded when there is not enough information for the odontologist to make an opinion.

The description, analysis, and findings of the odontological remains are written up in forensic odontology report. A report is authored for each set of dental remains that can be attributed to a single individual, as well as a group report for those teeth that cannot be determined to be exclusively from one of the personnel aboard the aircraft.

4.1.2.3 DNA Reports

The Armed Forces DNA Identification Laboratory (AFDIL) based in Dover, Delaware is a department within with Armed Forces Medical Examiner System (AFMES). Their mission is to

> "provide worldwide scientific consultation, research and education services in the field of forensic DNA analysis to the Department of Defense and other agencies. To provide DNA reference specimen collection, accession, and storage of United States military and other authorized personnel" (AFMES 2013).

The AFDIL's primary role within the accounting community is to determine matches between the osseous samples from unknown individuals and family reference samples. To this end, the AFDIL collects DNA from three primary sources. The first are the bone and tooth samples selected from the cases at the JPAC-CIL as discussed above. The second are family reference samples that are procured from appropriate, matrilineally related relatives for one of the missing service personnel. These family members are located through genealogical research primarily conducted by the casualty offices of the various branches of the U.S. military and occasionally the CIL's DNAC. In addition, to control for any potential contamination, DNA swabs are collected from every person who has entered the evidence handling areas within the CIL.

All four sources provide the material for DNA to be extracted, replicated, and sequenced. Mitochondrial DNA (mtDNA) is common and robust within cells and can be more easily extracted from skeletal samples than nuclear DNA. Specific sections of the mtDNA are sequenced that differentiate the samples from one another. Other sections of the mtDNA are also sequenced, allowing the AFDIL to determine the species that the sample came from, and, if it is human, its probable ancestry. The mtDNA sequence data is always used to de-commingulate the remains. In the unlikely occasion that two or more individuals within a case share too similar a mtDNA sequence, nuclear DNA testing will be utilized. This includes Y chromosome and autosomal sequencing. The results of these tests are returned to the CIL's DNAC.

The CIL's DNAC also sends to the AFDIL the list of family members who need to be compared to the sequence data extracted from the skeletal remains. Then, through the matching of the short sections of mtDNA mentioned above, the AFDIL determines which samples from a particular case are associated with a particular family reference sample. A report is produced for each sequence within unknown individuals and it is sent to the CIL.

The research and development section at the AFDIL is continuously working to develop new techniques to extract usable DNA from fragments of bone that are very small, have been subjected to severe thermal alteration, or chemical preservation. They are also making strides in the use of Y-chromosome and other forms of nuclear DNA matching.

4.1.2.4 Material Evidence Reports

Concurrent with the analysis of the biological remains recovered from a crash site, the personal effects of the individuals who were aboard the aircraft undergo study. Per the CIL SOP 3.6:

> "Material evidence testing provides support for identifications in the area of time, space, and context, as well as associating specific items of evidentiary value (e.g., identification media, personal effects, military equipment) to specific individuals or groups of individuals. Material evidence may also provide evidence that can help to interpret the circumstances of a loss" (CIL 2013b, 1).

Artifacts are thoroughly cleaned and examined, with provenience being maintained at all times. The text on any identification media, which is defined as any item that contains the name or any other personal information of one of the individuals associated with the loss incident, is compared against that person's IDPF. Make and model is determined for as many items as possible, which often times can provide a *terminus post quem* for the assemblage. When possible, each artifact is associated with one of the crew members through field provenience, text on the item, or by its natural exclusivity such as a bombardier wing badge. Items that provide the most support for the identifications are placed at the front of the material evidence report (MER). This would include identification media. Next, private purchase personal effects are included, and finally any relevant military issued equipment.

4.2 Thesis Methodology

The methods used in this thesis are broken down into two sections. The first, Case Study Selection, explains how the cases that are included in Chapters 5, 6, and 7 were selected from the numerous loss incidents that the JPAC has successfully completed. The second, Case Study Analysis, details how each duty station aboard the two categories of aircraft was analyzed to determine the relationships between the remains themselves and the appropriate corresponding wreckage.

4.2.1 Case Study Selection

The primary database used by the JPAC to keep track of the thousands of cases and evidence accessions, as well as the tens of thousands of missing service members, is the Centralized Accounting Repository Information System (CARIS). The CARIS was founded using the loss information accumulated by the Bright Light program during the Vietnam War. The data, which was originally stored as paper files, was transferred to a digital format in the form of a crude database that shared the name of the SOG group. The computer program was renamed, updated, and expanded to include losses from the Korean War and World War II. The database is cross-referenced such that it is possible to start with a single piece of information and use it to find out all of the other details about a case. For example, if only the loss incident number it known, a JPAC employee could use it to find out the names of the associated individuals and all of the accession numbers of the evidence that has been brought into the CIL. However, the CARIS was not designed for searches in bulk categories with restricting subfields such as every loss of a particular type of aircraft within a specified geographic region. In order to complete searches of this nature a second program must be used.

A program called SAP BusinessObjects was already in use at the JPAC. The software can be designed to search an organization's databases in accordance with the various categories that are contained within that database. For the JPAC it has been custom-tailored to search through the CARIS based upon its numerous fields. For the purposes of this thesis, the CARIS was queried to produce a list of all Boeing B-17s for which there had been an accession of evidence in to the CIL. There was no restriction based upon geography. This query was repeated for Consolidated B-24s, North American B-25s, Curtiss C-46s, and Douglas C-47s. Unfortunately, there is no searchable "case closed" or "case completed" field within the CARIS. This resulted in having to check each of the cases found by BusinessObjects within both the CARIS and the case file section of the CIL's partition of the JPAC computer network to determine which of them had been completed. Additionally, the lists obtained through BusinessObjects were cross referenced against the CIL's master tables of identifications to ensure that cases were not accidentally overlooked. No discrepancies were encountered.

Counts of the completed cases for the above aircraft types are presented in Table 4. These counts include U.S. Navy versions of the B-24 and B-25 bombardment aircraft as well as the C-47 cargo planes that were modified during the Vietnam War to be the first spooky gunships, discussed above in Chapter 3. They do not include cases where the JPAC identified additional portions of individuals who were originally identified either during or shortly after WWII or the Vietnam War. Cases from both WWII and Vietnam were included for C-47s because this thesis is focused on type of aircraft as opposed to a specific conflict. While the C-47s used during the Vietnam War were modified for the guns on the port side of the aircraft, the basic airframe and cockpit crew requirements remained unchanged.

Table 10. The number of cases the JPAC has completed for the specified aircraft types.

Aircraft	Number of completed cases
B-17	7
B-24	22
B-25	6
C-46	1
C-47	7
Total	43

Within each aircraft type, the cases were sorted by the date of identification, which is effectively the same as when the case is completed. Then, each case was preliminarily reviewed starting with the most recent and working backward in time. The first step was to review the SARs. This was necessary because during the excavation the archaeologist had to, at a minimum, record in their notes where the diagnostic crew duty station wreckage components were located within the debris field. Without this important piece of data it would not matter if it was possible to establish where in the recovery scene the skeletal remains were found because there would not be any context within which to place the remains. The second step was to examine the FAR bench notes and DNA sampling log to determine if the provenience of the bone samples cut for DNA testing in a particular case had been retained and carried forward. This critical step in the laboratory analysis had to have been completed for the identification process to be run backward. Without the provenience being maintained it would not be possible to determine where each skeletal element from an individual came from within the crash scene.

A total of 12 cases were found to at least partially meet both criteria (Table 11). The remaining 31 cases were found to be unusable due to a variety of factors. The lack of one, or both, of the criteria discussed above were the most common reason that a loss incident was not included in the case studies. While the field and laboratory work conducted in earlier iterations of the JPAC were scientifically sound, recording requirements and methodological minimums have been raised to a more rigorous standard over the course of the effort to account of America’s missing service members. A total of twelve usable cases were included in the excellent, good, and possible categories. It is also not possible to increase the sample size through any other sources. The JPAC is the only organization in the world that is conducting forensic excavations and analysis of remains from large WWII era bombardment and cargo aircraft.

Table 11. The number of cases by specified aircraft type that proved usable for the thesis.

Aircraft	**Number of usable cases**
B-17	0
B-24	7
B-25	1
C-46	1
C-47	3
Total	12

During the process of case study selection in autumn 2010 the two test cases presented in Chapter 9 (MACR 4505 and REFNO 0271) were not included because they were still in the early stages of excavation. Instead they were chosen to be the test cases against which the hypotheses developed from the case studies could be tested. This course of action was advantageous because it meant that the sites associated with the two test cases were excavated with the most up-to-date and rigorous methods employed by the CIL. The archaeologists were aware that the cases were going to be included in this thesis and so extra attention was given to collecting the appropriate and necessary information. It also ensured that provenience information was maintained through the DNA sampling process.

Next, the case studies were placed into two groups: bombardment and cargo aircraft. As discussed in Chapter 3, despite being smaller than a B-24, the B-25 shares many overall design similarities including a vertically elongated fuselage, shoulder mounted wings, tail configuration, and, most importantly, crew position locations within the aircraft. For these reasons the B-25 and B-24 have been combined into a single grouping for this analysis. The C-46 and C-47 are more similar than the bombardment aircraft. Each of them have wings that are set low on the fuselage, a forward flight deck, a small compartment for the navigator/radio operator and then a large cargo compartment.

All of the reports and other documentary materials that accumulated for each case were studied in detail. This included the SARs, FARs, FORs, MERs, and their respective field and bench notes. The CIL's DNA sample log and the results from the AFDIL were also examined. Identification media and human remains were selected as the two categories that would be used to document where each individual was located within the crash scene. Other personal effects were excluded because for them to be associated with a specific crew member they typically need to be found *in situ* with identifiable remains. Thus, to have included them would have been redundant. Tables listing the DNA samples for each case were created that display the original sample number, skeletal element, provenience, and associated individual. The results of this table along with the provenience of the identification media from the MER were then plotted onto the to-scale site maps for each case along with the locations of the pertinent fragments of aircraft wreckage. The digital maps have been redrafted based upon the original field notes and SARs. They have also been standardized to the greatest extent possible. However, the level of consistency is limited. No two wreckage debris fields are the same and the site maps were originally drawn by different archaeologists with varying levels of illustrative skill. This new information, along with the relevant sections of the various reports, was summarized for each case and are presented below in Chapters 5, 6, and 7.

Another new facet to the analysis of each case is the degree of perpendicularity of its crash. Degree of perpendicularity is defined as the angle between the ground and the direction of travel of the aircraft at the time of impact. For example, an aircraft skidding in on its belly with substantial forward momentum on a flat open field would have a very low degree of perpendicularity. If that same aircraft were to collide with the same field while in a vertical dive it would have a very high degree of perpendicularity. A high degree can also be achieved if an aircraft is flying along forward and strikes a vertical cliff. A low degree of perpendicularity can be described as shallow, while a high degree would be regarded as steep. Determining intermediate angles necessitates an understanding of the aircraft's direction of travel during the crash. Even if the site is on a very steep hillside, if the plane crashed in a cross-slope direction the angle of impact is going to be lower. The cases discussed in Chapters 5 through 7 are placed into five categories of degree of perpendicularity: very low, low, moderate, high and very high. This tool will allow for an assessment of whether or not remains are distributed differently within a crash scene based upon the angle at which an aircraft impacted the ground.

While direction of travel and degree of perpendicularity can be inferred from impact craters and the distribution of wreckage within the crash site, WWII aircraft were not equipped with the modern "black boxes" of today's passenger liners that record every aspect of a plane's telemetry. This severely limits an archaeologist's ability to provide a highly detailed reconstruction of a crash. Given this, a conservative approach toward, and a minimal level of interpretation of, crash dynamics is taken in this thesis.

4.2.2 Case Study Analysis and Hypothesis Development

To begin to answer this thesis' fundamental question – "Where are an individual's remains found within a crash scene in relation to their assigned duty station aboard the aircraft?" – a change in the way the material is being explored is necessary. Through Chapter 7, cases are examined as single entities; however, beginning with Chapter 8 each individual crew position becomes the focus. Keeping bombardment and cargo aircraft cases separate, patterns and trends in regard to the disposition of the individuals associated with each duty station are analyzed.

Each case's to-scale site map containing the plotted locations of the skeletal remains and identification media were printed out in large-scale format. A ruler was then used to measure the distance from the appropriate duty station wreckage to the most distant fragment associated with that individual regardless whether it was an osseous fragment or a piece of identification media. Because the CIL typically excavates in 4-x-4 m units with shovels and screens the sediment on such a large and fast-paced scale, it is often not possible to assign a more detailed provenience to a piece of evidence. When more precise provenience was not available it was assumed that the evidence was found in the middle of the 4-x-4 m unit. This strategy was also adopted for units of any other size and shape. If evidence was found to be mixed with the appropriate wreckage, a distance of zero was recorded. In addition to the maximum distance between crew position and evidence, the distance between the two most separated fragments of each individual was also measured. These two variables make it possible to determine both how far a person is likely to be from their duty station and their total distribution within the site. For example, it might be possible for a crew member to be ejected a large distance from the aircraft during a crash, yet remain almost entirely intact. This would result in a large number being recorded for distance from wreckage and have a score of zero for overall distribution. On the other hand, the multiple fragments of another person aboard the plane may be found scattered in multiple directions, yet in close proximity to certain wreckage.

In addition to the previously discussed constraints surrounding how the aircraft impacted the ground, two assumptions are necessary in order to proceed with the analysis of the cases. The first assumption is that each individual was actually in their assigned duty station at the time of the crash. At first glance, this appears to be a substantial inference relating to a key tenet of this thesis. However, throughout the various stages of a mission, the aircraft's crew are most likely to be in their proper position. Outbound aircraft that were heading to their targets, those lining up for and executing their bombing runs, as well as those engaged in aerial combat, are likely to have had all of their personnel where they were supposed to be to ensure that the mission had the highest likelihood of being successfully completed. Each individual was specially trained for their role and the entire crew was more likely to survive if each member was doing what they knew best. If an aircraft became damaged, the crew would most likely remain with the plane as opposed to attempting to parachute from it. This was particularly the case in New Guinea, the Southwest Pacific theater, and the CBI theater due to the vast expanses of water and extremely rugged, mountainous terrain (Claringbold 1995, 8; Spencer 1994). Crossing tall mountain ranges combined with challenging weather conditions also likely contributed to aircraft impacting the ground without the crew ever knowing they were about to crash. Personnel may have been more likely to swap positions when aircraft were returning from missions and the threat of attack was lower. However, while the B-24 was a large aircraft, it was cramped inside when fully manned and moving about within it was not particularly easy. First-hand accounts indicate that it was not possible to traverse the narrow catwalk that extended down the middle of the bomb bay while wearing a parachute (Bowman 2009, 89). The B-25 was even smaller, with only the crawl space above the bomb bay to move between the fore and aft sections of the plane. Instances in which the archaeological record suggests that an individual was most possibly not in their duty station are noted throughout Chapters 5, 6, 7 and 9. Despite the above, the issue of crew behaviour during a crash will be discussed in depth in Chapter 10.

Second is the assumption that a minimal level of erosion has occurred on each site over the 60+ years between the loss incident and the various recovery efforts. If erosion proves to be a substantial taphonomic factor on the sites, then the recovery location of the remains and identification media will be, at least partially, the result natural processes as opposed to predominantly from the crash itself. However, any erosional effects that may be occurring on crash sites do not inhibit the analysis undertaken in this thesis. It simply means that they have to be taken into account when determining the distance that remains are found from the corresponding wreckage. This is because the JPAC is primarily interested in the recovery of said remains regardless of the mechanism that led to their location at the time of the excavation. Erosion is taken into account for each of the case studies, the two test cases, and the hypothesis testing. It is also addressed in the results and discussion section.

These measurements are presented in a table for each duty station aboard the two types of aircraft. The analysis for each duty station does not include every case because in some circumstances a particular individual was not individually identified or that crew member survived the crash. The cases within the tables are listed from smallest debris field to largest. Both distances measurements are listed as well as the estimated degree of perpendicularity of the crash. This allows the different cases to be easily compared and also makes it determine if there is any pattern based upon the angle of impact of the crash. The use of maximum distances presented in these tables helps to ensure that any findings or recommendations for future courses of action by the JPAC and the CIL will be excavating a greater than necessary area as opposed to a smaller one which could potentially result in failing to recover pertinent evidence.

Based upon the results shown in each table, hypotheses are developed as to how far each crew member can expected to be found from their corresponding duty station wreckage and how spread out their remains are likely to be within the debris field. Whether or not the distribution of evidentiary materials is related to the degree of perpendicularity of the crash is also discussed. Additionally, an overall hypothesis is presented for both bombardment and cargo aircraft.

4.2.3 Hypothesis Testing

The third component of this thesis is the testing of the hypotheses developed in Chapter 8 against two additional cases, the details of which were unknown at the time the hypotheses were created. The bombardment aircraft hypotheses are tested against data gathered from a very large B-24D crash site in Papua New Guinea. The cargo aircraft hypotheses are examined in relation to a large Vietnam War era AC-47D crash site in the Lao People's Democratic Republic. These two loss incidents were reviewed and are present in Chapter 9 in the same format as the case studies to ensure comparability. Skeletal remains and identification media with provenience for each individual were plotted onto the site maps and the pertinent distances measured and recorded. The hypotheses were then compared against these results for each of the duty stations aboard both aircraft. Factors such as the size of the site and degree of perpendicularity are taken into account and addressed. The results of the hypothesis testing are discussed in Chapter 10.

5 Bombardment Aircraft Cases – Part 1

This chapter is the first of three that present the eight bombardment and four cargo aircraft case studies (Figure 27). A detailed view of New Guinea is provided in Figure 28. A total of eight WWII bombardment aircraft cases had both the location of duty station aircraft wreckage recorded during the excavation and sufficient provenience information carried forward through the laboratory analysis to be included. The four smaller crash sites, in terms of the overall size of the debris field, are presented in this chapter. Three of the cases are Consolidated B-24 Liberators and one is a North American B-25 Mitchell. Table 12 lists these cases from smallest to largest, and their locations can be found in Table 13 and Figure 29. The four cases with larger debris fields are detailed in Chapter 6.

5.1 MACR 10020

MACR 10020 involves the October 9, 1944 loss of nine individuals aboard B-24D *Mr. Five By Five*, tail number 42-40505, from the 360th Air Services Group (ASG) during a training flight (McDermott 2005b, 1). The 360th ASG was part of the Far East Air Forces Combat Replacement Training Center at Nadzab, PNG which was responsible for providing new bomber crews with training in Southwest Pacific aerial warfare (Craven and Cate 1983, 329). Aircraft #42-40505 was last seen departing the Nadzab airfield and there were no additional radio communications. The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Engineer, Radio Operator, Assistant Radio Operator/Gunner, and two additional Gunners.

There was no specifically designated flight plan so an extensive search was undertaken by 1st Far East Bomb Squadron, also based in Nadzab. Three flights on October 9th and 10th searched the Markham Valley to the northwest and southeast of Nadzab as well as south along the coast from Lae to Nasau Bay, but there was no sign of the aircraft. Officers in charge of the search attributed their inability to find the crash on the large area of the search zone and the density of the jungle vegetation. The AGRS reviewed the status of MACR 10020 in June 1946 and determined that every effort had been made to find the aircraft at the time of the incident and after concluding that none of the unknown remains in the area matched the crew members who were aboard #42-40505 on October 9, 1944 (McDermott 2005b).

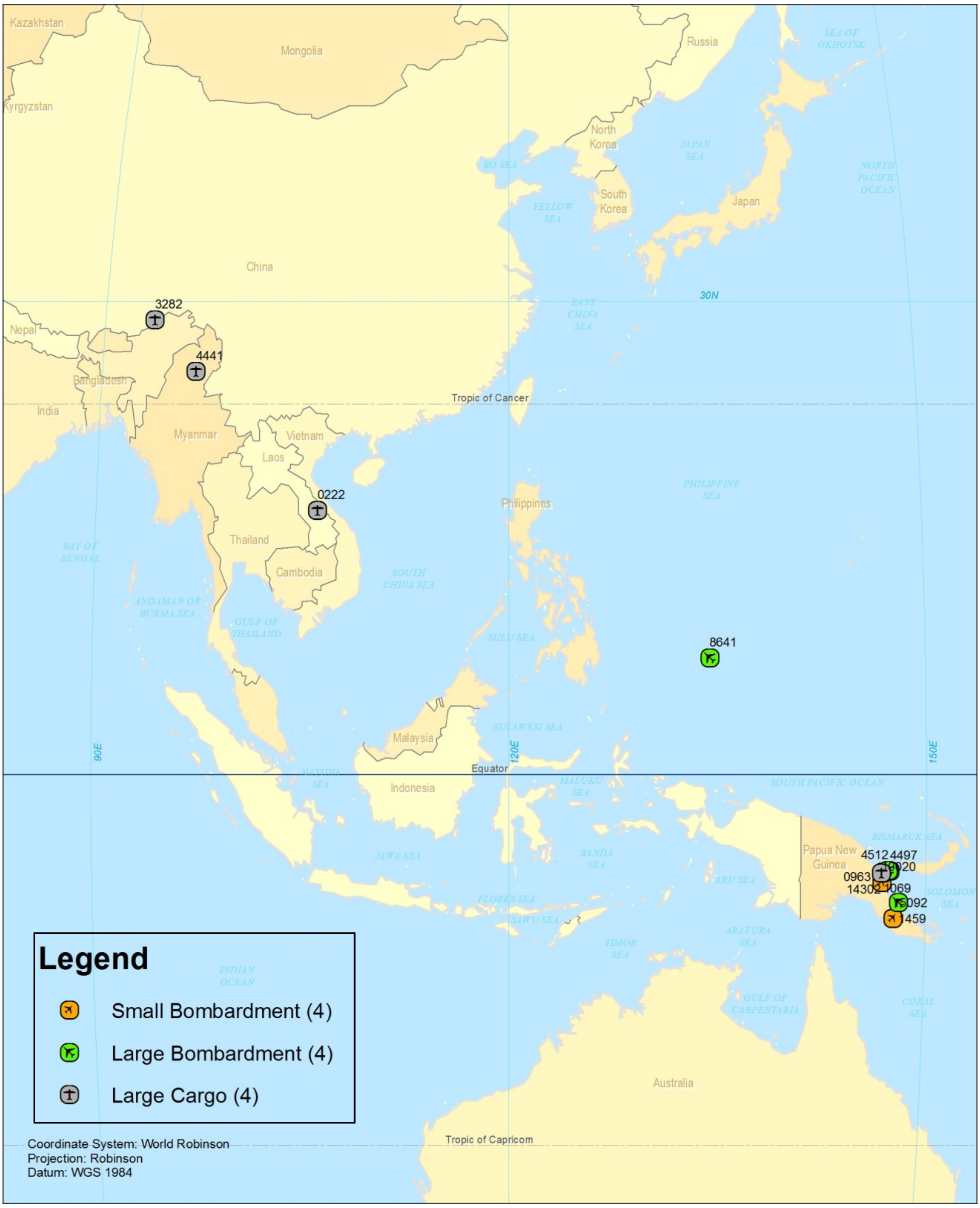

Figure 27. The eight bombardment and four cargo aircraft case studies presented in Chapters 5 through 7.

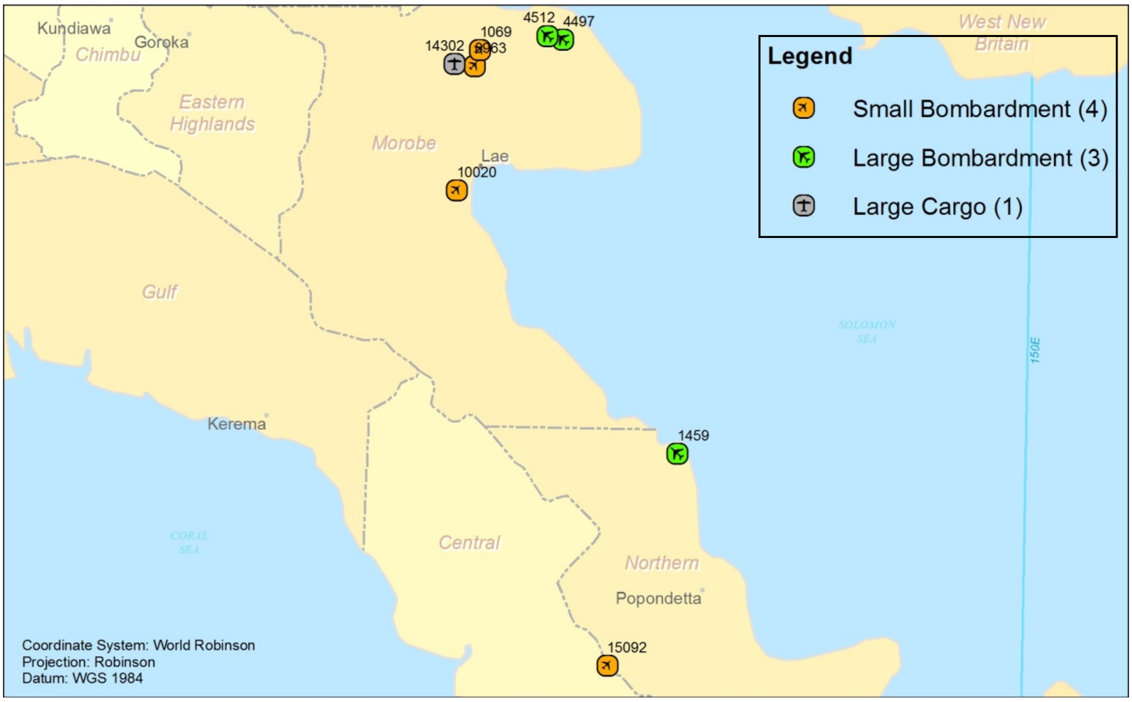

Figure 28. Detail view of the case studies located in New Guinea.

Table 12. Smaller bombardment aircraft cases – Part 1.

Incident (MACR)	Loss Date	Aircraft Type	Tail Number	Number of Missing
10020	October 9, 1944	B-24D	42-40505	9
0963	October 27, 1943	B-24D	42-40918	12
15092	December 5, 1942	B-25C	41-12907	7
1069	November 5, 1943	B-24D	42-40972	9

Table 13. Loss locations of bombardment aircraft cases discussed in this chapter.

Incident (MACR)	Country	Province	District
10020	PNG	Morobe	Lae
0963	PNG	Morobe	Boana
15092	PNG	Central	Efogi
1069	PNG	Morobe	Deyamos

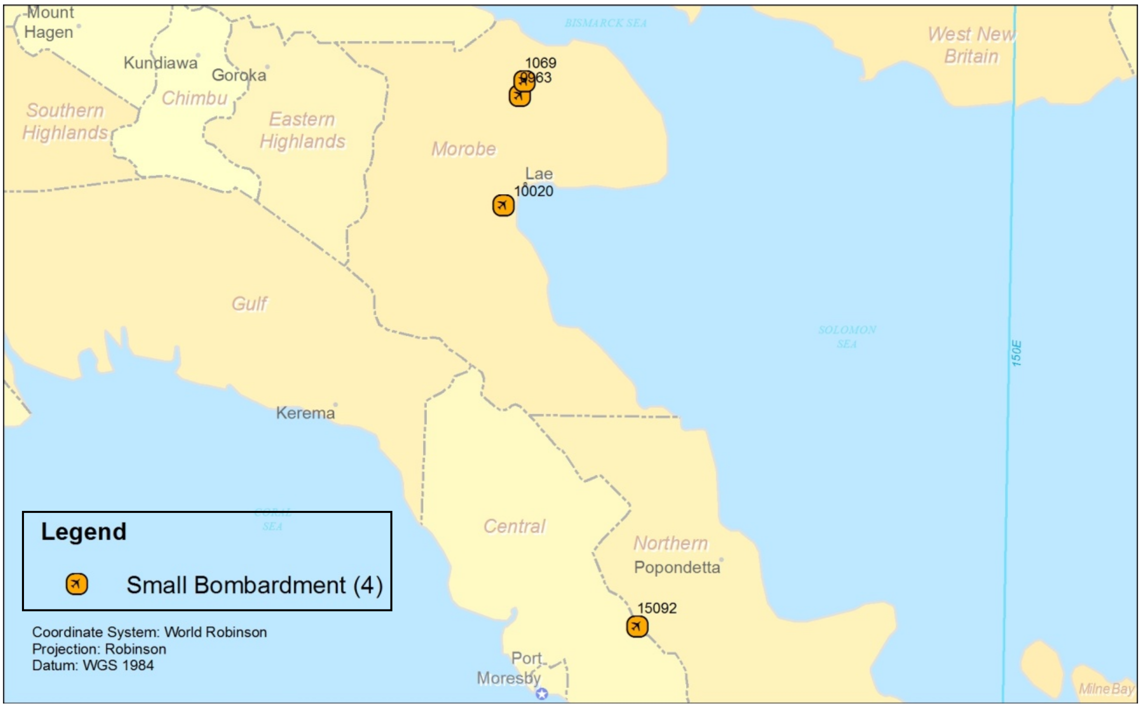

Figure 29. Map of New Guinea showing the locations of the bombardment aircraft crashes discussed in this chapter.

This crash came to light through its discovery by local villagers who live in the area and use the mountainous terrain for hunting. One of the residents mailed a letter to the U.S. Embassy in Port Moresby in February, 2002. In it, he claimed to know about an aircraft crash and provided information from identification tags that he allegedly found at the site. When the correspondence was forwarded to CILHI that same month the information taken from the identification tags was found to be from the Pilot and the Engineer associated with MACR 10020 (McDermott 2005b, 3).

From November 4th through the 7th, 2002 an IT that was deployed to Papua New Guinea investigated MACR 10020 (Danielson 2003b, 2). They traveled to Bugaiu Village and interviewed the two individuals who had found the crash site (PP-00254), collected the identification tags, and wrote the letter to the American Embassy. During the conversation they handed over three identification tags and a key on a chain. The three tags were for the two previously mentioned members of the MACR 10020 crew. Subsequently, the IT surveyed the crash site and recovered human remains and an identification tag for Gunner 1.

The Site (PP-00254), correlated to MACR 10020, is located at approximately 1300 m (4,300 ft) above sea level in the Herzog Mountains approximately 18 km southwest of Lae. The closest village to the site is Bugaiu Village, Lae District, Morobe Province (Figure

30). The recovery scene can be located on the following topographic map: Title: Nadzab; Edition: 1; Series: T 601; Sheet: 8284; Scale: 1:100,000; Horizontal Datum: Australian Geodetic 1966.

Figure 30. Topographic map showing the location of Site PP-00254 (red star).

Site PP-00254 is situated on a gradual to moderate slope covered in thick rain forest vegetation. The southeast facing hillside has an aspect of 123° and an inclination that varies between 12° across the upper portion of the site and 40° in the lower sections. A relatively narrow, shallow wash that forms the base of an intermittent stream starts in the upper portion of the site and extends downslope to the east through the remainder of the debris field. Site PP-00254 is contained within and surrounded by a triple-canopy tropical rainforest comprised of both hard and softwood varieties. The most prevalent vegetation is the old-growth trees up to 30 m tall. Smaller deciduous trees comprised the intermediate canopy, with lower levels being dominated by a variety of ferns, vines, bushes, and other broad leafed plants. The ground surface is characterized by humps of topsoil as well as thick layers of organic leaf litter and carpets of moss that obscure many of the smaller fragments of the aircraft. The archaeologists who led the recovery at the crash noted a unique characteristic of the site. Due to its proximity to the ocean and orographic lifting the site is constantly wet due to misting from cloud formation and/or heavy rain showers (Danielson 2003a, 3, 11; 2003b, 5-6).

The aircraft debris field at site PP-00254 is the smallest of the B-24 cases, extending approximately 30 m upslope-down slope (roughly west to east) and 20 m cross slope (north-south) (Figure 32). The largest fragments of wreckage on the site were the tail and the wings. The mostly intact tail section was still attached to a small portion of fuselage. The tail turret was not connected to the horizontal and vertical stabilizers, on which the plane's serial numbers were still clearly visible (Danielson 2003b, 12). Instead, the turret was found leaning up against a section of the tail, providing further indication that the site had been disturbed by local villagers. Both wings from roughly the inboard engines outward were also present. The edges of the wing that would have been closest to the fuselage exhibited melted edges. The port wing and engines one and two are in the south east portion of the debris field and are in a northwest-southeast orientation. The starboard wing and engines 3 and 4 are located upslope of the intermittent drainage and oriented in a roughly east-west direction. Surprisingly, large sections of the fuselage were almost completely absent (Danielson 2003a, 10-15).

Figure 31. An overview of the site after vegetation clearing.
The yellow arrow indicates the head of the intermittent stream with two radio boxes located in area, red arrows indicate mounds of debris, and blue arrow is the tail section. View to East (Danielson 2003b, 6).

Closer visual inspection of the area between the wings and the tail revealed a dense concentration of wreckage approximately 12 m long (upslope-downslope) and 10 m wide (cross slope). This area was dominated by several large mounds of wreckage which were comprised of large conglomerates of melted aluminum containing various components of the aircraft. Readily identifiable amongst the piles were the top turret rotating ring, armor plating from multiple gun positions, the nose wheel strut, two radio boxes, a fragment of the cockpit instrument panel, and the frame for the pilot's seat. Additionally, all of the .50 caliber defensive guns, aside of those in the tail turret, were found in this small area.

The recovery of the site commenced with the N500/E500 unit and initially proceeded from west to east (upslope to downslope) staying north of the N500 line. Next, the southwest corner was completed, followed by another west to east pass across the concentration south of the N500 line. Finally, the southeast corner was addressed. At the conclusion of the recovery effort twelve 2-x-2 m units, eighteen 2-x-4 m units, and twelve 4-x-4 m units were excavated for an approximate total surface area of 384 m^2 with depths ranging from 10 to 50 cmbs (Figure 33 and Figure 34). Over the course of the mission several patterns were observed by the archaeologist in the field. First, fragments of the aircraft extending from the nose to slightly aft of the waist gunner positions were found within the dense central concentration between the wings and the tail. Second, very few fuselage fragments were encountered outside of this area. Third, all of the human remains and almost all material evidence, including identification media (Table 14), were recovered from within the concentration (Danielson 2003a).

The archaeologist on site slowed the pace of excavation in the units with the highest likelihood of recovering remains by reducing the unit size and switching from the use of shovels to trowels (Danielson 2003b, 8). A more careful strategy allowed for associations to be made between the identification media and the remains that were recovered (Christensen 2005e, 54-59). This would eventually allow anthropologists in the laboratory in Hawaii to reduce the number of samples that needed to be submitted for mtDNA sampling.

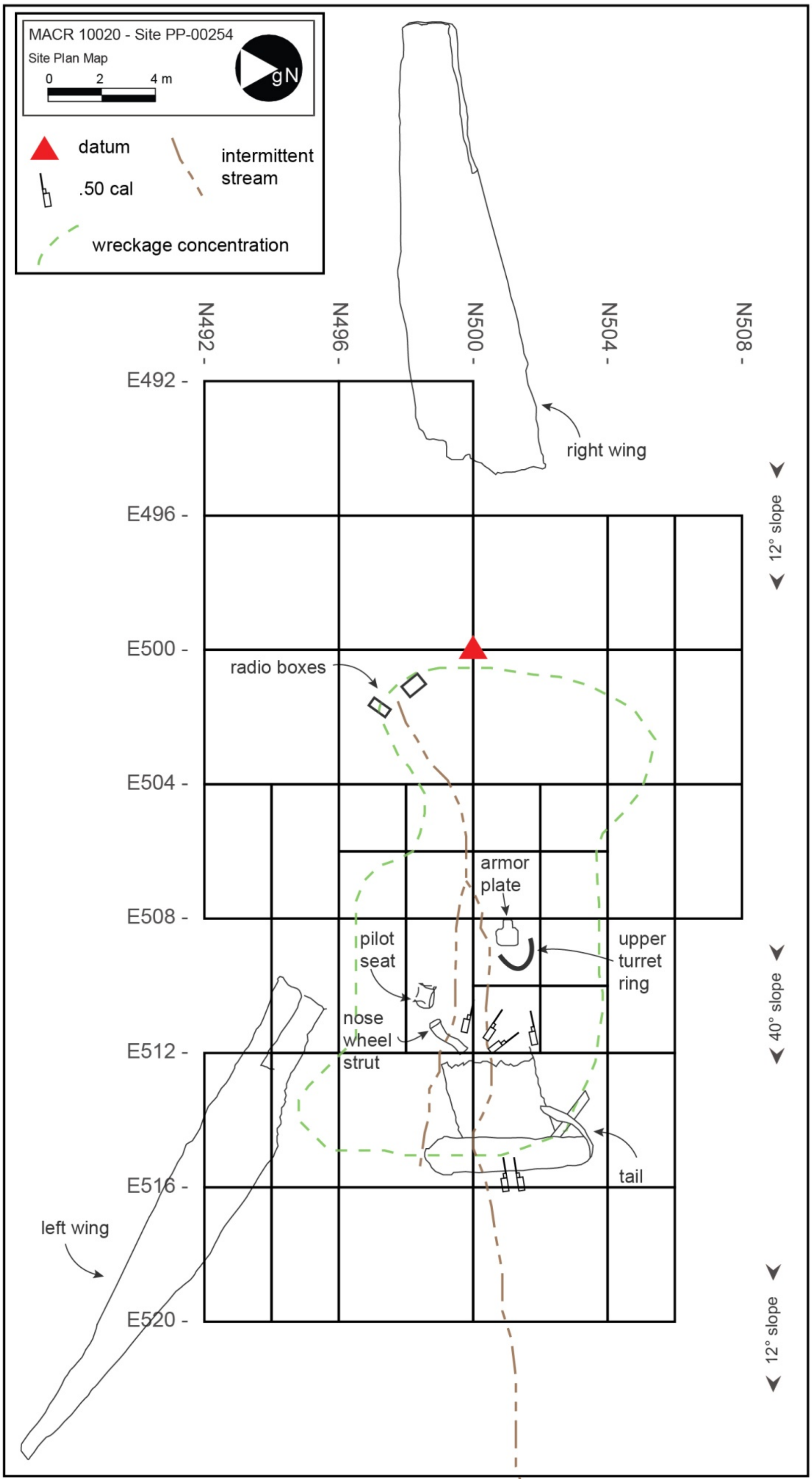

Figure 32. Map of Site PP-00254 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Danielson 2003b)

Figure 33. Final photo of upper section of the recovery scene.
Yellow arrow indicates site datum (500N/500E). View to east (Danielson 2003b, 14).

Figure 34. Lower portion of recovery scene.
Yellow arrow indicates the datum. View to southwest (Danielson 2003b, 14).

Table 14. Provenience of identification media found at Site PP-00254.

Provenience	Identification Media
N494/E512	2 identification tags (Bombardier)
N496/E496	Identification bracelet (Radio Operator)
N496/E500	Class ring (Radio Operator)
N496/E506	Identification tag (Radio Operator) and an identification bracelet (Co-pilot)
N496/E512	2 identification tags and an identification bracelet (Gunner 1) and an identification bracelet (Bombardier)
N498/E506	2 identification tags (Engineer)
N498/E508	2 identification tags (Pilot)
N500/E500	3 identification tag (2 Assistant Radio Operator and 1 Radio Operator)
N500/E512	Identification tags and a USAAF ring (Navigator)
N502/E506	2 identification tags and an identification bracelet (Gunner 2)

However, before turning to the laboratory work, several conclusions that were not specifically noted by the archaeologist in the field can be drawn from the excavation of Site PP-00254. First, general shape and small size of the debris field suggests that the aircraft likely impacted the ground at very high degree of perpendicularity. Second, the presence of numerous parts and components from different sections of the fuselage in relative close proximity to one another indicates that the body of the aircraft underwent a massive compression in a fore to aft direction. The implications of this, for example, are that the remains from one of the waist gunners could potentially come to rest in proximity of the radio operator's equipment or that the navigator could be adjacent to the bombardier station components. Third, the large clusters of melted metal indicate that the aircraft burned after impact. This highly destructive taphonomic environment had a severe effect on the bodies, which resulted in the recovery of relatively few, highly deteriorated fragments of human remains 58 years later.

The analyses of the skeletal (Pokines 2005a, b, c, d, e, f, g, h, i) and dental remains (Dunn 2005a, b, c, d, e, f) recovered from the site supported some of the observations and conclusions drawn from the field work. The report addressing the remains (Pokines 2005a, 1-2) that could not be associated with a specific individual noted evidence for several taphonomic processes. Sharp fracture margins amongst the highly fragmentary collection indicate that the remains underwent perimortem trauma consistent with the type of massive blunt force trauma that would occur in an aircraft crash. The majority of the remains exhibited extensive thermal alteration that ranged in color from black (carbonized) to white (calcined). Bone only becomes calcined with prolonged exposure to temperatures of over 800° centigrade (Shipman, et al. 1984). Extensive surface erosion was common on those remains that were not thermally altered to the point where only delicate, lattice like structures remained. This could have been the result of contact with plant roots and/or damage from insects. These numerous deleterious changes to the remains prevented the forensic anthropologist assigned to complete the FARs from completing any rearticulations or pair matches of skeletal elements. This meant that the only those osseous fragments that yielded usable mtDNA sequences or teeth that could be matched through dental records would be associated with a specific individual.

In addition to preventing any rearticulations or pair matches, the taphonomic affects to the remains resulted in few good choices for mtDNA testing. The skeletal and dental fragments with the least amount of thermal alteration that were also found in relative close proximity to identification media were selected to be sampled. In addition, some fragments that were not recovered in close association, but were still likely to yield usable DNA sequences were also chosen. In all, a total of 27 samples were sent to the AFDIL for mtDNA testing. Twenty-five produced successful results, yielding eight distinct mtDNA sequences, while two proved to be inconclusive. Table 15 lists each of the samples, the element from which it was taken, its recovery provenience, and the individual it was found to associate with.

Table 15. Results of mtDNA sampling for MACR 10020.

Sample	Element	Provenience	Individual
A	Tooth #9	N496/E512	Co-pilot
B	Tooth #18	N502/E506	Gunner 2
C	Tooth #20	N500/E508	Engineer
D	Tooth #19	N502/E510	Engineer
E	Tooth #30	N496/E506	Co-pilot
F	Tooth #23	N500/E512	Engineer
G	Cranial	N496/E512	Engineer
H	Right femur	N496/E512	Bombardier
I	Right ulna	N496/E512	Bombardier
J	Left femur	N496/E512	Bombardier
K	Humerus	N496/E512	Bombardier
L	Right humerus	N496/E512	Inconclusive
L.1	Right humerus	N496/E512	Bombardier
M	Femur	N502/E506	Gunner 2
N	Left tibia	N496/E508	Gunner 1
O	Radius	N498/E508	Pilot
P	Long bone	N500/E512	Navigator
Q	Tibia	N502/E510	Engineer
R	Femur	N496/E512	Co-pilot

Sample	Element	Provenience	Individual
S	Right femur	N496/E500	Radio Operator
T	Right radius	N496/E512	Bombardier
U	Humerus	N496/E512	Gunner 1
V	Tibia	N496/E512	Bombardier
W	Femur	N496/E508	Gunner 1
X	Fibula	N496/E508	Inconclusive
X.1	Fibula	N496/E508	Gunner 1
Y	Long bone	N496/E508	Gunner 1

In addition to the skeletal remains sorted through mtDNA analysis, some of the dental remains and all of the dental prostheses were also determined to belong to specific individuals based upon comparisons to antemortem odontological treatment records. A maxillary left second molar (#15) was associated to Gunner 1 (Dunn 2005e). A maxillary left central incisor (#9) was associated to the Engineer (Dunn 2005f). A complete maxillary denture and partial mandibular denture replacing teeth #17-#21, #25, and #29-#32 was the property of the Bombardier (Dunn 2005b) and a cast-gold denture replacing teeth #23, #24, and #25 was determined to have belonged to the Assistant Radio Operator (Dunn 2005a). No actual remains were identified as being those of the Assistant Radio Operator.

The recovery location of identified remains and material evidence that could be associated with a particular individual are displayed below (Figure 35). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty.

- The Pilot’s osseous elements (Pokines 2005c) and both of his identification tags were recovered from the unit that contained the pilot’s seat (Figure 35).

- The Co-pilot, was represented by a single femur shaft fragment and two teeth (Dunn 2005d; Pokines 2005e). The bone fragment and one tooth were recovered from the same excavation unit as his identification bracelet and within 2 meters of the Pilot’s remains, while the remaining tooth was approximately 6 m to the east (Figure 35).

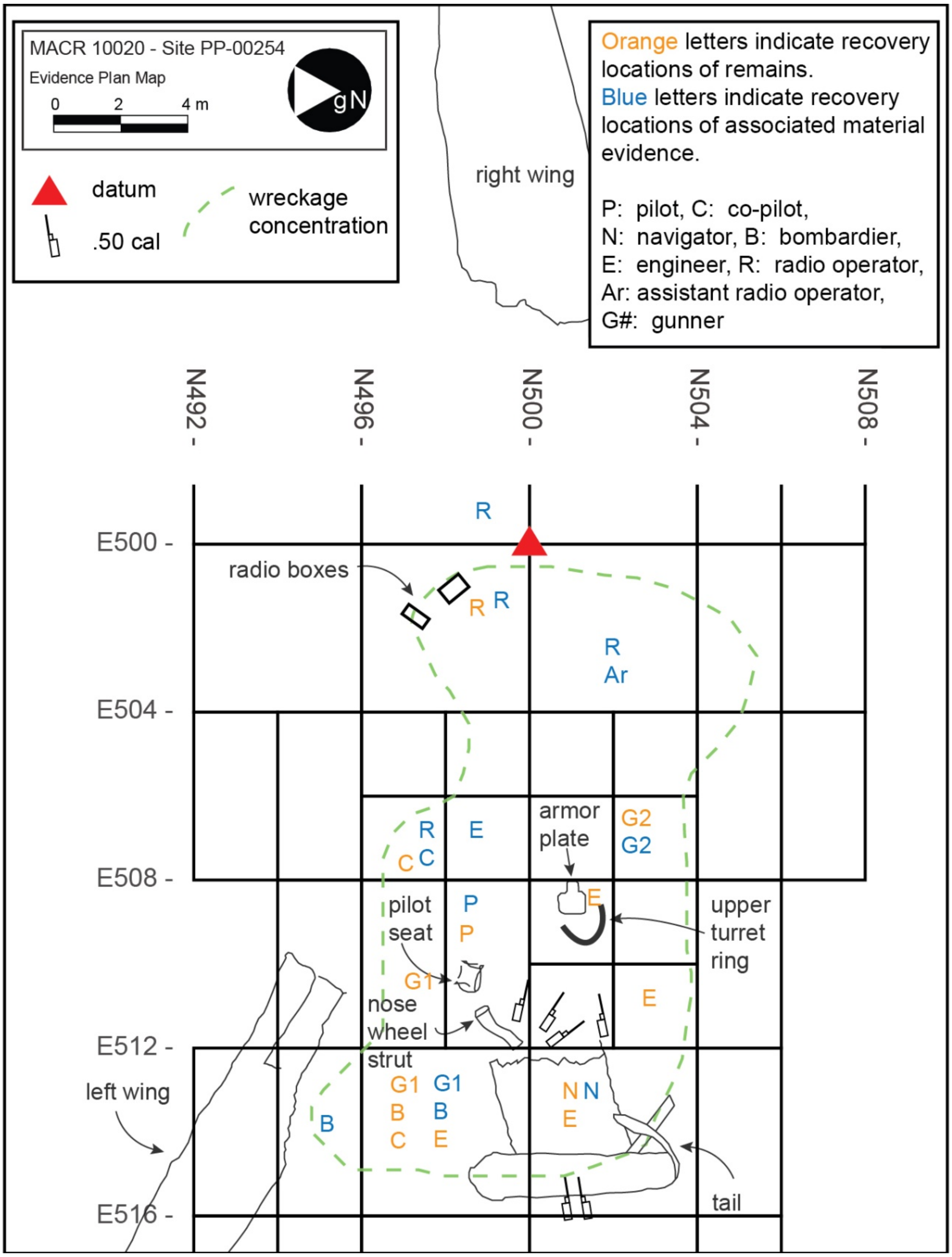

Figure 35. Map of Site PP-00254 showing the locations of identification media, identified remains, and recognizable aircraft components.
(Adapted from Danielson 2003b)

- An unsided femur midshaft was the only osseous fragment that could be determined to be the Navigator (Pokines 2005b). It was found in the same excavation unit as his two identification tags and USAAF ring. The unit was located underneath the small amount of fuselage that was still attached to the tail (Figure 35).

- The identified remains of the Bombardier consisted of multiple incomplete skeletal elements: a right proximal humerus with most of the shaft present; a distal left humerus shaft portion; a right radius diaphysis; a right ulna diaphysis; a distal left femur shaft portion; an unsided femur midshaft portion; and a tibia midshaft fragment (Pokines 2005d). All of his remains were found within the same unit as his identification bracelet and his two dental prostheses. His ID tags were approximately 2 m to the west in an adjacent unit. While these items were located in N496/E512, which is adjacent to the main strut for the nose landing gear (Figure 35). This piece of the aircraft is located immediately aft of the bombardier’s duty station. None of the Navigator’s instruments were found amongst the melted conglomerates of wreckage.

- The identifiable remains of the Engineer, are the most widely distributed within the recovery scene. They are comprised of an unsided tibia midshaft fragment, a cranial vault fragment, and four human teeth (#9, #19, #20, and #23) (Pokines 2005h). The elements were recovered from at least four separate units and the cranial fragment and Tooth #20 are approximately 9 m (Figure 35). While one fragment was recovered from the same unit as the upper turret ring, the position the Engineer most likely would have occupied during the flight, there is not a clear pattern between his remains and his duty station.

- A single femur shaft fragment was identified as being the Radio Operator (Pokines 2005i). Despite the his possessions being spread across four units, his class ring was found in the one that contained the piece of osseous material and two radio boxes (Figure 35).

- As previously mentioned, no actual skeletal or dental material was identified as being the Assistant Radio Operator. However, his gold denture and two identification tags were all recovered from the same unit: N500/E500 (Figure 35).

- Gunner 1 was represented by five skeletal fragments (Pokines 2005f). A single unit resulted in the recovery of four of them: a distal left tibia, two unsided femur shaft portions; and an unsided fibula shaft. A humerus shaft portion along with two identification tags and an identification bracelet were recovered one unit to the east and slightly south of the tail wreckage.

- Finally, Gunner 2 was identified based upon two teeth (#15 and #18) and a femur shaft fragment (Pokines 2005g). The femur portion, teeth #15 and #18, Cpl Mohr's identification tags and identification bracelet were all found in the same unit (N502/E506).

Eight of the nine servicemen who died aboard B-24D #42-40505 on October 9, 1944 were individually identified by the JPAC-CIL nearly 61 years to the day of the loss on October 5, 2005 (Holland 2005c). Cpl De Carlo was included in the group identification on the same date.

The distribution of remains and personnel effects at Site PP-00254 reflects the very high degree of perpendicularity with which the aircraft impacted the ground. The debris field is small, with an even smaller central concentration of wreckage. This case also demonstrates that remains can still be obtained recovered that yield usable mtDNA from challenging taphonomic environments.

5.2 MACR 0963

MACR 0962 involves the October 27, 1943 loss of 12 individuals aboard a B-24D, tail number 42-40918, from the 5th Air Force, 90th Bombardment Group; 320th Bombardment Squadron (Johnson and Phillips 2009). The aircraft took off from an airfield near Port Moresby on a reconnaissance mission to observe enemy shipping lanes in the Bismarck Sea. During the flight, they were directed to land at Dobodura on the north coast of New Guinea Island due to bad weather. The aircraft acknowledged the instruction and reported their position as being over the middle of the Bismarck Sea. However, other reports placed the aircraft over the Huon Gulf. The heavy bomber never arrived in Dobodura or its home station and there was no further radio contact. The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Observer, Engineer, Radio Operator, Photographer, and four Gunners.

All 12 men were declared missing in action on October 27, 1943. Extensive aerial searches were undertaken along the coast of Huon Gulf beginning on October 29th and extending for eight days. Eventually, on October 28, 1944, the twelve airmen were declared dead after the military determined that the aircraft most likely crashed into the water. The AGRS searched the New Guinea area from 1946 through 1948. The identification data for the ten men were compared against the information retrieved from the unidentified remains from the area but there were no matches. On June 28, 1949 the twelve man crew of B-24D #42-40918 were declared non-recoverable (Johnson and Phillips 2009, 4-6).

Fifty-four years later, on August 9, 2003 a JPAC IT operating in the Lae area received information from a local informant who claimed to have found an aircraft crash site in the mountains of the Huon Peninsula. He turned over an aircrew identification card that belonged to the Pilot and informed the team that the crash site contained human remains. JPAC IT teams attempted to reach the site on March 22 and November 16 2004, but were unable to do so on each occasion due to inclement weather. During the first visit, however, the IT met with another informant who gave them the Co-pilot’s identification tags. The site was finally successfully surveyed on January 21, 2005. The IT observed a large quantity of aircraft wreckage as well as human remains, life support equipment, and personal effects including identification tags for the Photographer (Johnson and Phillips 2009, 8-9).

The site (PP-00081) correlated to MACR 0963 is located at roughly 3,271 m (10,700 ft) in the upper reaches of the Cromwell Mountains in the Sarawaget Range which comprise the center of the Huon Peninsula along the northeast coast of New Guinea (Figure 36). The largest nearby population center is Lae, approximately 50 km to the south. The closest village to the site is Qamben Village, Boana Sub-District, Morobe Province. The site is located on topographic map: Name: Sarawaget; Sheet: 8285; Series: T601; Edition: 1; Scale: 1:100,000; Datum: Australian Geodetic 1966 (Figure 37).

Figure 36. Landing zone at 3505 m (red arrow) and crash site at 3271 m AMSL (yellow arrow) photographed from the air.
View to southeast (Tyrrell 2007, 4).

Site PP-00081 lies in a stepped, east-west running gully that slopes downhill to the west at angles ranging from 15° to 80°. The north and south sides of the gully vary between 30° and 90° in slope. Vegetation within the site is a mix between tropical subalpine forest and kunai grass. The dense patches of grass, combined with mosses, cover the entire ground surface with the exception of parts of the stream that runs through the bottom of the gully and the larger boulders and fragments of wreckage (Tyrrell 2007, 13).

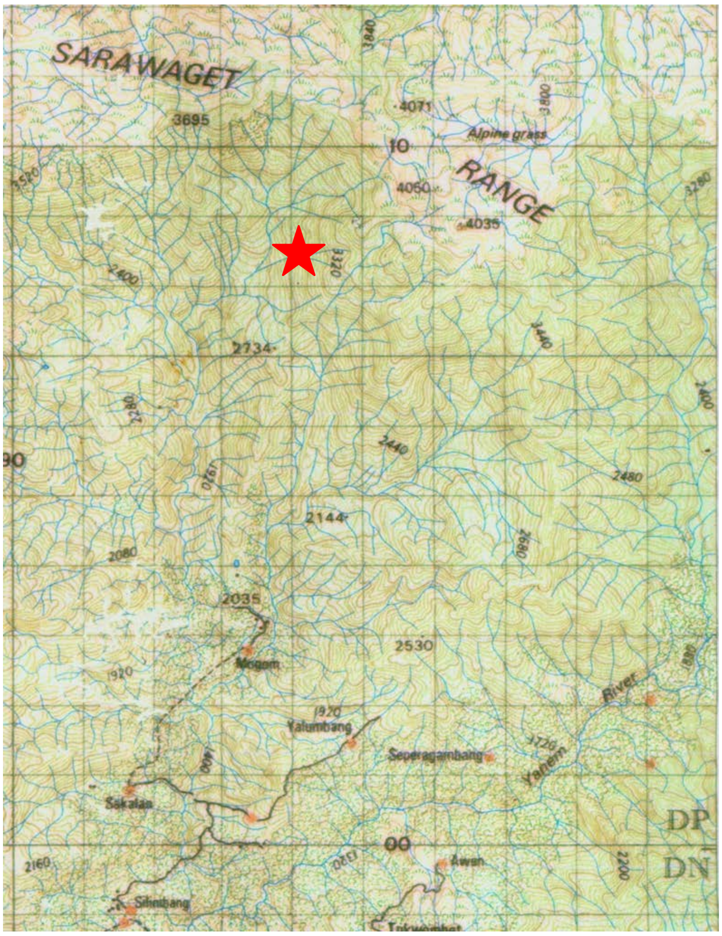

Figure 37. Topographic map showing the location of Site PP-00081 (red star).

The site was divided into three zones (Figure 39). The primary concentration of wreckage measuring roughly 16 m east to west and 12 m north to south was labeled Zone 1. This small area, not dissimilar in size to Site PP-00254 (MACR 10020), contained the vast majority of the aircraft wreckage including the entire fuselage which was very densely compacted against the north wall of the gully (Figure 38) (Tyrrell 2007, 6, 15). All of the .50 caliber machine guns were found in Zone 1, except for one, which was discovered in Zone 2. This second zone is a broad, steep alluvial fan expanding out below Zone 1. It is comprised of colluvial and alluvial outwash of various sized clasts from the gully and, aside from the one, 50 cal, contains a low density scatter of small fragments of aircraft wreckage. Zone 3 is located 25 m above and 7 m east (up the ravine) from Zone 1. It is 13 m east to west and 6 m north to south. Only light, small pieces of aircraft wreckage were found in the third zone.

Figure 38. View of the site looking east across Zone 1 prior to excavation. Note the large area of accumulated wreckage and slumped material on north and south slopes of gully (red arrows). View to east (Tyrrell 2007, 6).

Excavation began along the western (downslope) edge of Zone 1 and proceeded in the clockwise direction along the north wall of the gully. Due to the highly compacted wreckage intermixed with boulders, most sediment was removed with trowels and other small hand tools. This careful excavation strategy allowed the team to document the recovery of remains and other evidentiary materials *in situ*. Screening was conducted and removed wreckage was placed in previously excavated units as work proceeded. When Zone 1 was completed, the team moved up to Zone 3 and excavated a single 6-x-6 m unit around a parachute canopy fragment. Finally, two 1-x-1 m test pits and one 1-x-2 m test pit were excavated at strategic location in the stream bed between Zones 1 and 2. Three 1-x-1 m test pits were also excavated on the alluvial fan itself. A small, hidden cache of human remains that had been created by a local villager was also collected. Over the course of the recovery effort a total surface area of approximately 270 m^2 was excavated to an average depth of 1.5 m, although some areas were as deep as three meters below the original ground surface (Tyrrell 2007).

Over the course of the recovery effort several patterns were observed by the archaeologist in the field. First, fragments of the aircraft extending from the nose to slightly aft of the waist gunner positions were found within Zone 1. Second, very few fuselage fragments were encountered outside of this area. Third, no engines or wing fragments were encountered during the excavation. Fourth, all of the human remains and almost all material evidence, including identification media (Table 16), were recovered from within eight excavation units of Zone 1 (O'Leary 2010b).

Table 16. Provenience of identification media found at Site PP-00081.

Provenience	**Identification Media**
N492/E496	St Christopher medallion (Bombardier)
N500/E492	Identification tag (Radio Operator)
N500/E496	2 identification tags and class ring (Gunner 3), wedding ring and watch (Gunner 1)
N500/E507.6	Identification bracelet (Bombardier)

There are important similarities and differences between Site PP-00081 (MACR 0963) and Site PP-00254 (MACR 10020). The similarities include, first, general shape and small size of the debris field suggests that the aircraft likely impacted the ground at very high degree of perpendicularity. Second, the presence of numerous parts and components from different sections of the fuselage in relative close proximity to one another indicates that the body of the aircraft underwent a massive compression in a fore to aft direction. The implications of this, for example, are that the remains from one of the waist gunners could potentially come to rest in proximity of the radio operator’s equipment or that the navigator could be adjacent to the bombardier station components. The most notable difference between the two crash sites is that there is a distinct lack of evidence of burning and melting of the aircraft wreckage. This resulted in a less destructive taphonomic environment which led to the recovery of a greater quantity and larger fragments of human remains.

The patterns observed as a result of the analysis of the skeletal (Burke 2009a, b, c, d, e; Tuller 2009a, b, c; Winburn 2009a, b; Winburn and Pokines 2009a, b, c) and dental (Franklin 2009a, b, c, d) remains reflects the conclusions reached from the field work in that there are similarities and differences between MACR 0963 and MACR 10020. As with the previously discussed case, the most commonly observed trait was evidence of perimortem fracture which is consistent with the massive blunt force trauma that occurs in aircraft crashes. Skeletal elements ranged in color from dark brown to white, with the majority being tan. Staining and discoloration also occurred in high frequency to include green, rust, and blue colors (Holland, et al. 1997).

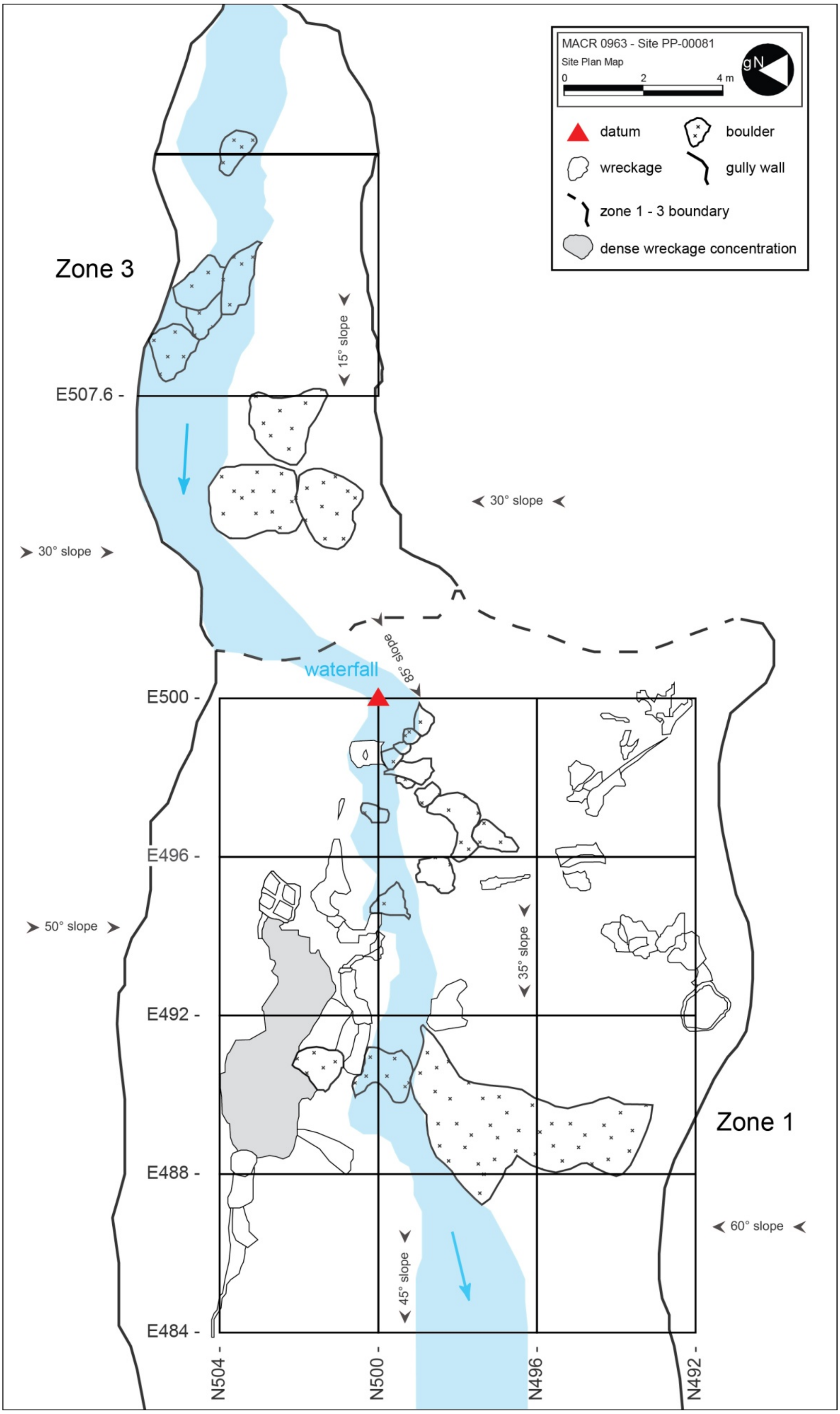

Figure 39. Map of Site PP-00081 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Tyrrell 2007)

Commingling in this case was severe due to the large quantity of remains being found in such a small area. As a result, a greater number of samples than usual, 115, were submitted to the AFDIL for mtDNA sequencing. Unfortunately, provenience was poorly maintained during the skeletal analysis and DNA sampling process, so reconstructing the exact location of the remains within the crash scene is only possible for three of 12 individuals aboard the aircraft. However, precise provenience information for each individual is not especially important in this particular case due to the reasons discussed above, including the compaction of the aircraft and the small area within which the remains were recovered. Table 17 lists each of the samples for which provenience was maintained, the element from which it was taken, its recovery provenience, and the individual it was found to associate with. Fragment refitting was also instrumental in resolving the comingling.

Table 17. Results of mtDNA sampling for MACR 0963 where provenience was maintained through the skeletal analysis.

Sample	Element	Provenience	Individual
02A	Left fibula	N500/E496	Gunner 3
04A	Fibula	Unilateral	Gunner 1
05A	Fibula	Unilateral	Gunner 1
06A	Fibula	Unilateral	Gunner 1
18A	Left humerus	N500/E496	Gunner 1
22A	Left humerus	N500/E496	Gunner 3
23A	Left humerus	N500/E496	Gunner 2
25A	Right humerus	N500/E496	Gunner 3
29A	Right humerus	Unilateral	Gunner 3
30A	Right humerus	Unilateral	Gunner 1
31A	Right humerus	Unilateral	Gunner 2
36A	Right temporal	N500/E496	Gunner 3
37A	Ulna	N500/E496	Gunner 3
38A	Right ulna	N500/E492	Gunner 1
39A	Right ulna	N500/E496	Gunner 3
40A	Right ulna	N500/E496	Gunner 3
43A	Left ulna	N500/E496	Gunner 1
44A	Left ulna	Unilateral	Gunner 2
45A	Left ulna	N500/E496	Gunner 3
47A	Left radius	N500/E496	Gunner 1

Sample	Element	Provenience	Individual
50A	Right radius	N500/E496	Gunner 2
51A	Right radius	N500/E496	Gunner 1
52A	Right radius	Unilateral	Gunner 1
54A	Right radius	Unilateral	Gunner 3
56A	Left radius	Unilateral	Gunner 3
57A	Left radius	Unilateral	Gunner 2
58A	Right scapula	N500/E492	Gunner 3
59A	Right scapula	N500/E492	Gunner 2
61A	Right os coxa	N500/E492	Gunner 1
62A	Right os coxa	N500/E492	Gunner 2
64A	Left os coxa	N496/E496	Gunner 2
65A	Tibia	N500/E496	Gunner 3
68A	Tibia	Unilateral	Gunner 2
69A	Tibia	N500/E496	Gunner 3
83A	Femur	N500/E496	Gunner 2
86A	Femur	N500/E496	Gunner 3
92A	Left femur	Unilateral	Gunner 3
95A	Right femur	Unilateral	Gunner 1
97A	Right femur	Unilateral	Gunner 3
105A	Mandible	Unilateral	Gunner 3
106A	Mandible	Unilateral	Gunner 3

Table 18. Dental remains correlated to a specific crew member associated with MACR 0963.

Name	Associated dental remains
Co-pilot	#5 - #9
Radio Operator	#7, #10 - #15, #17 - #21, and #26 - #28
Gunner 2	#1 - #3, #7 - #12, #14 - #16, #29 and #31
Gunner 3	#18, #19, #30, and #31

The recovery location of identified remains and material evidence that could be associated with a particular individual where the provenience is known are displayed below (Figure 40). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty.

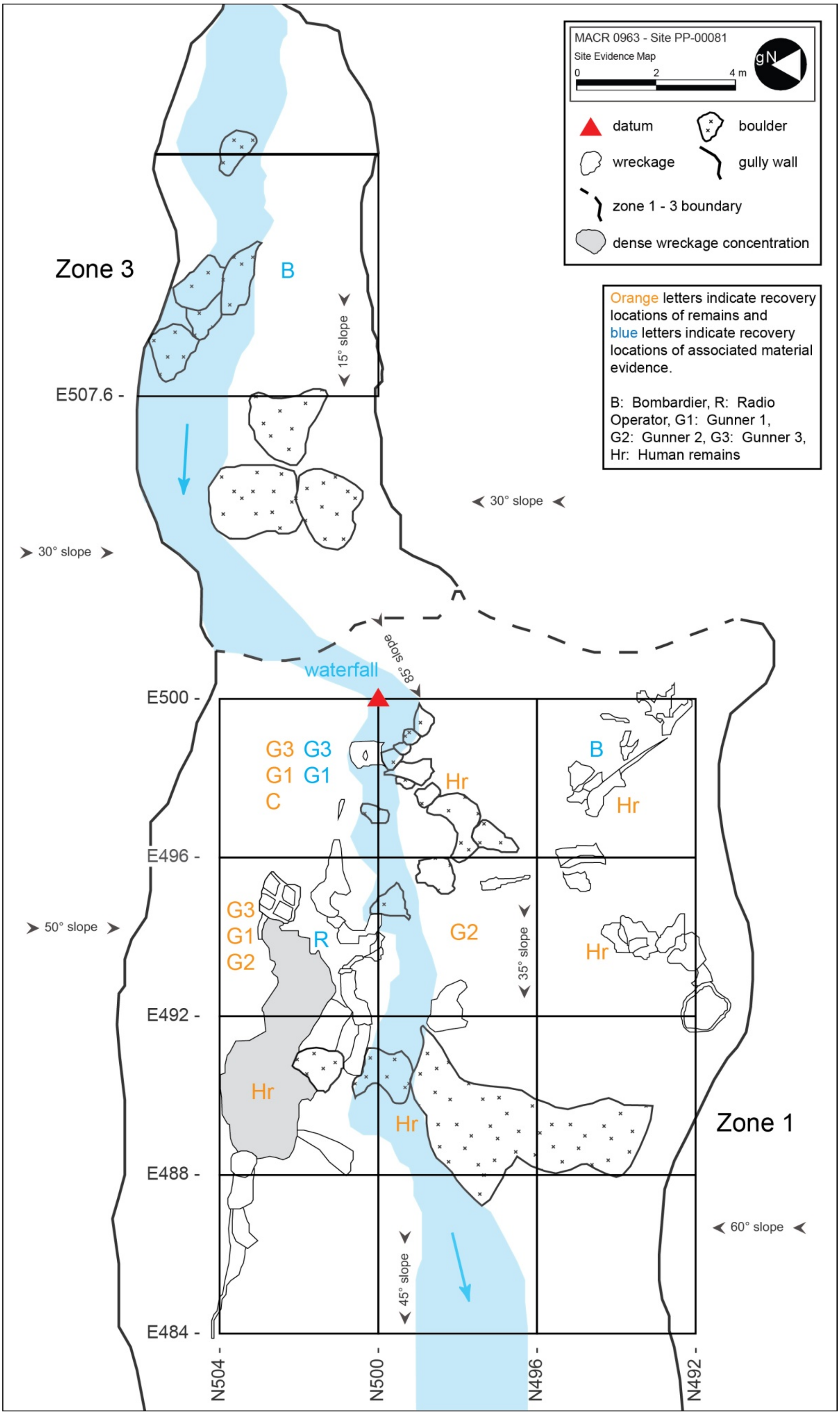

Figure 40. Map of Site PP-00125 showing the locations of identification media and those identified remains that could be associated with a specific provenience. (Adapted from Tyrrell 2007)

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- The Pilot is represented by a right temporal portion, and fragments of both humeri, a right radius, a right femur, a right tibia, an unsided femur shaft portion, and an unsided fibula shaft portion. No provenience information is available for any of these remains.

- The Co-pilot was associated to several teeth and fragments of each of his humeri, femora, tibias, and fibulas. Provenience information is unavailable for any of these remains.

- Fragments of both humeri, femora, tibias, and a right fibula were associated to the Navigator. No provenience information is available for these remains.

- Five fragments of skeletal elements were found to be associated with the Bombardier, including humeri, a left femur, and both tibias. Provenience information is unavailable for any of these elements. A St. Christopher medallion with his initials on the back was found in N492/E496 and his identification bracelet was recovered from N500/E507.6 (Figure 40).

- The Observer, is represented by a left femoral shaft fragment, which was associated through mtDNA testing. Provenience is not available.

- The Engineer is represented by fragments of a right humerus, right femur, and left tibia which were all associated through mtDNA testing. There is no provenience information for these remains.

- Fragments of maxilla, mandible, left scapula, both humeri, both radii, right ulna, right os coxa, both femora, and left fibula were associated to the Radio Operator/gunner through dental comparison and mtDNA testing. Provenience is unavailable for these skeletal elements. One of his identification tags was recovered from N500/E492 (Figure 40).

- Gunner 1 is represented by several skeletal elements. A left humerus and fragments of both radii were recovered from N500/E496, fragments of his ulnas and right os coxa were found in N500/E492, and additional remains were included from the unilateral turnover. His wedding ring and watch were recovered in N500/E496 (Figure 40).

- Gunner 2 was distributed across three different units and the unilateral turnovers. His left humerus, right radius, and an unsided femur fragment were recovered in N500/E496. The right scapula and right os coxa were found in N500/E492 while his left os coxa was in N496/E496. The left ulna, left radius, right humerus, and an unsided tibia fragment were from unilateral turnovers.

- Gunner 3 is the most complete skeleton of the crew. N500/E496 contained fragments of his right temporal, both humeri, both ulnas, femur, tibia, and right fibula. His right scapula was located in N500/E492. Finally, fragments of his mandible, right humerus, both radii, and right femur were part of the unilateral turnover. Gunner 3's two identification tags and his class ring were also found in N500/E496 (Figure 40).

- Through mtDNA analysis and fragment refitting Gunner 4 is associated with fragments of both humeri, radii, femora, and tibias. Provenience information is unavailable for these remains.

- Fragments of a left humerus, right femur, and right tibia are associated with the Photographer, based upon mtDNA testing. Provenience information is unavailable for these remains.

The twelve Army Air Forces personnel who died aboard B-24D tail number 42-40918, on October 27, 1943 were individually identified by JPAC on March 3, 2010, more than 66 years after the incident.

MACR 0963 best demonstrates how the working backwards through the identification process is hindered by the failure of the CIL DNAC and skeletal analysts to maintain provenience through the DNA sampling process. Even though all 12 of the crew members were individually identified, it was only possible to plot 5 of them onto the site map; three using skeletal remains and two based on personal effects.

5.3 MACR 15092

MACR 15092 involves the December 5, 1942 loss of seven individuals aboard a B-25C, tail number 41-12907, nicknamed “The Happy Legend” from the 5th Air Force, 38th Bombardment Group, 405th Bombardment Squadron (Unknown 1942). The Happy Legend was a replacement aircraft that joined a ten plane formation for an attack on Buna, Papua New Guinea when one of the primary B-25s had engine trouble immediately after takeoff in Port Moresby. 1st Lt Maggart’s aircraft was observed by other pilots in the formation prior to entering the clouds that hung over the Owen Stanley Mountain Range en route to Buna, but that it did not reappear on the other side (Young 2008). The personnel aboard B-25C 41-12907 were listed as MIA that day. The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Radio Operator, Engineer, Photographer, and a Gunner.

In February 1943 members of the 1st Australian Corps salvage team located a crash site in dense, high-elevation rainforest that contained aircraft wreckage including a section of the fuselage painted with the numbers “907” in yellow, human remains, and identification media for the Radio Operator. The Australian unit’s report does not specifically tie the remains to the identification media, but it did result in AGRS changing the status of the crew from missing in action to killed in action on February 13, 1943. Despite the crash site having been located two years later in April, 1945, and again in June, 1949, AGRS documentation notes that the individuals aboard “The Happy Legend” were non-recoverable (Young 2008, 3-5).

Unlike the other cases discussed in this chapter, joint American and Royal Australian Air Force personnel visited the water-filled crash site twice in 1961 and again in 1964. On each occasion the crash crater was filled with water, which prevented the teams from conducting recovery operations (Young 2008, 5-6). Disturbance of the bottom of the crater resulted in the release of petrol fumes and an oil slick forming on the surface of the water.

The site (PNG-23) correlated to MACR 15092 is situated at approximately 1,900 m (6,200 ft) above sea level on the southern slope at the southern end of the Kokoda Gap in the Owen Stanley Mountain Range. It is approximately 1.4 km north of Little Myola Lake. Port Moresby, the closest city to the site, is approximately 80 km to the southwest. The site is located on topographic map: Name: Efogi; Sheet: 8479; Series: T683; Edition: 1-

AAS; Scale: 1:250,000; Horizontal Datum: Australian Geodetic Datum 1966 (Figure 41) (Goodman 2005a; Tyrrell 2001).

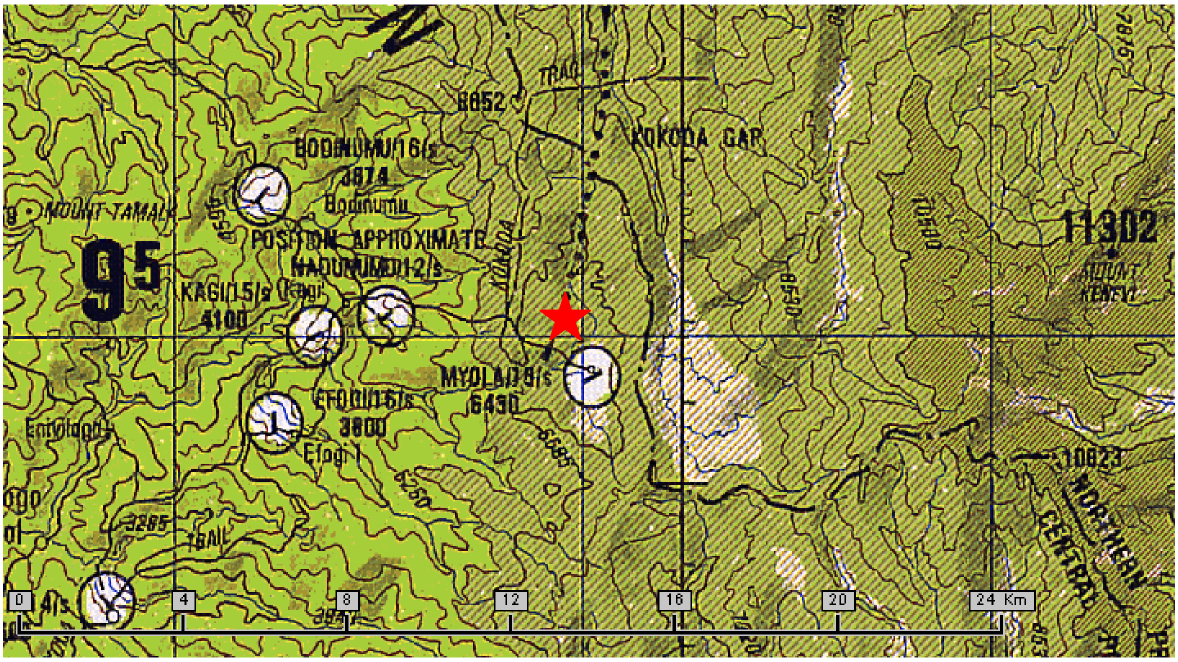

Figure 41. Topographic map showing the location of Site PNG-23 (red star).

Site PNG-23 is located on a relatively flat expanse of land that contains both Myola Lake and Little Myola Lake. Both are mostly dry, but fed by weakly flowing perennial streams. The vegetation is dense, high-altitude triple-canopy tropical rainforest. The upper most layer is dominated by tall deciduous trees while smaller trees comprise the intermediate canopy, with lower levels being made up of a variety of ferns, vines, bushes, and other broad leafed plants. The site is within a roughly heart-shaped clearing that measures approximately 78 m north to south and 70 m east to west.

The northern end of the clearing contains a crater ringed by a large blast berm which is consistent with those described and depicted by Hupy and Schaetzl (2006, 828). Measured from the peak of the berm, the crater is 18 m east to west and 15 m north to south and approximately 4.5 m deep. The water level within the crater fluctuated based upon recent rainfall and ranged in depth from 75 cm to 3.5 m across the multiple recovery efforts (Figure 42).

Figure 42. Impact crater at the outset of the final recovery effort. View to southeast (Goodman 2005a, 7).

Removing the water from the crater with pumps took considerable effort during each mission (Figure 43). Draining the water revealed large fragments of aircraft wreckage including a wheel attached to a landing strut in the center, a propeller blade in the northern portion, and a 500 lb bomb in the southeast wall of the berm. Additional fragments of aircraft wreckage can be found up to 100 meters from the crater with the majority being concentrated to the northeast (Goodman 2005a, 4; Lloyd-Jones 2001, 4; Tyrrell 2001, 4-5).

Nine recovery missions were launched to Site PNG-23 over a 19 year period beginning in 1986 and extending until the winter of 2005 when the excavation of the site was finally completed (Table 19). Recovery strategies utilized by the archaeologists varied based upon the water level in the crater, which was determined by the amount of rainfall occurring at each time of the year. During the May to June 2001 mission the water level was very low and 4-x-4 m units were excavated. The final two missions to the site were undertaken when the water level was much higher and so the crater was simply divided into quadrants. Block excavation extended out from the crater to the peak of the blast berm. Test pits were completed past the blast berm, but no evidentiary materials were recovered.

**Figure 43. View of the crater after the removal the water.
View to southeast (Goodman 2005a, 8).**

Table 19. Missions to Site PNG-23, general results, and pertinent references.

Mission Dates	Results	Reference
Jul 1986	Pump failure, unable to excavate.	No report written
Aug – Sep 1995	95 m^2 excavated: N-S and E-W trenches through the crater, the SE quadrant and part of the SW quadrant.	(B. Davis 1995)*
Jan 1999	Unable to excavate due to height of water table.	No report written
Apr 2001	Unable to excavate due to adverse weather.	(Lloyd-Jones 2001)
May – Jun 2001	128 m^2 excavated in the northwest and center/bottom of the crater.	(Tyrrell 2001)
March 2002	Unable to excavate due to UXO.	No report written
March 2004	EOD assessment of UXO hazard.	No report written
Oct – Nov 2004	95 m^2 excavated in the NW quadrant.	(Goodman 2005a)
Jan – Mar 2005	272 m^2 excavated from across all quadrants.	(Goodman 2005a)

* Provenience information for evidentiary materials are not available from this report.

The teams excavated a total approximate surface area of 590 m^2 at Site PNG-23 to a maximum depth of 4.5 m below datum (mbd) (Figure 44 and Figure 45). Due to the high water table, sediment slumping, and the length of time between some of the mission, many areas had to be excavated more than once. The missions recovered human remains, including soft tissue, primarily from the deepest portion of the crater which was heavily laden with fuel. An extensive assemblage of material evidence was recovered from the crater, but only a relatively small portion of it was identification media (Table 20) (Fox 2005; Goodman 2005a).

Table 20. Provenience of identification media found at Site PN-23

Provenience	Identification Media
Unknown	Identification tag (Radio Operator), wallet with mess card and driver's license (Navigator)
SE quad 3.6 -4.0 mbd	Identification bracelet (Radio Operator)

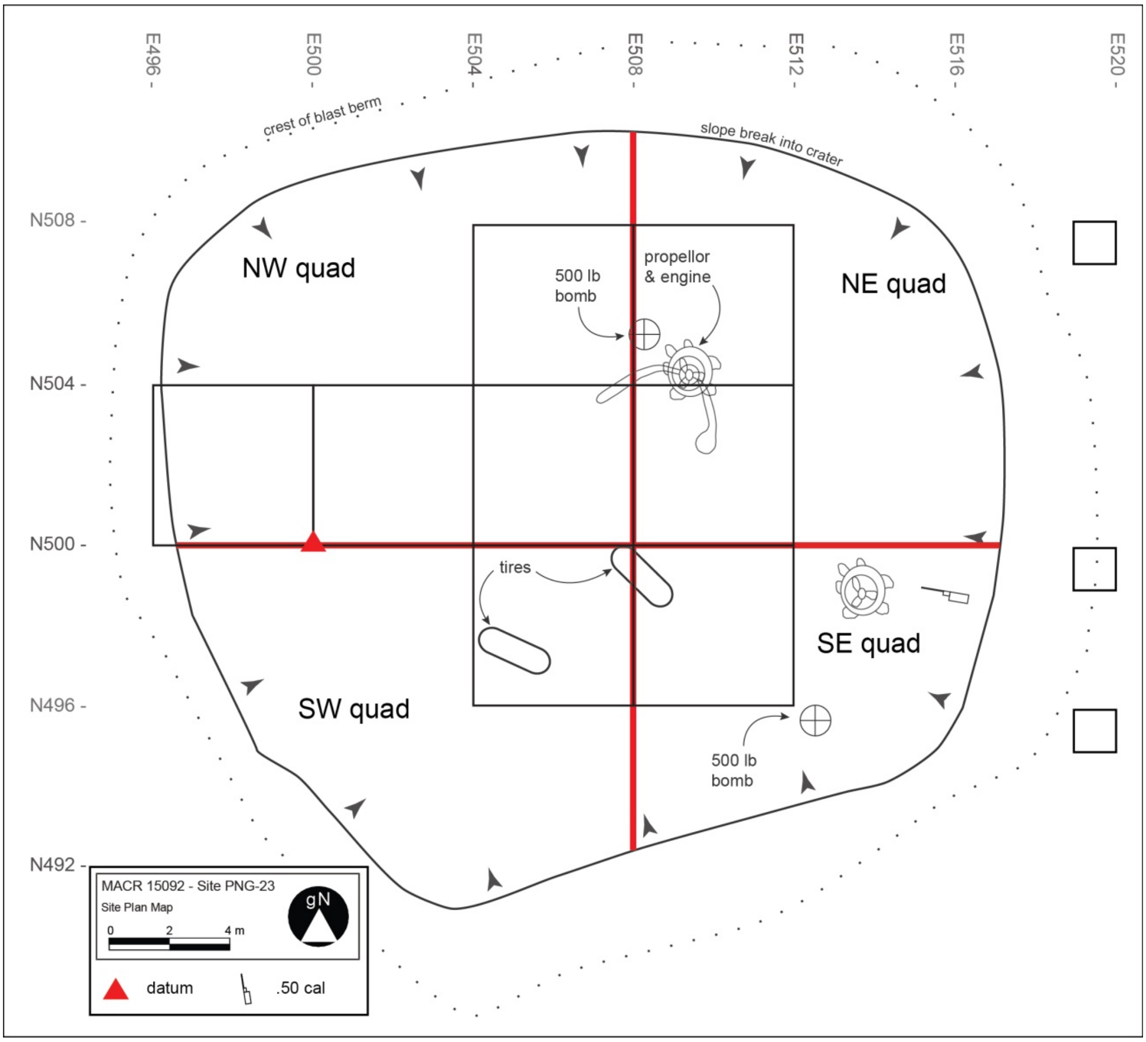

Figure 44. Map of Site PNG-23 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Goodman 2005a)

Figure 45. Aerial view of crater upon completion of excavation.
View to northeast (Goodman 2005a, 16).

Upon initial inspection, the crater at Site PNG-23 appeared unusually large for a B-25 aircraft crash and was more similar to some of the crash sites of the B-24s that are detailed in Chapters 5 and 6. Several factors aided in discerning the site formation processes: a detailed examination of the stratigraphy of the crater, the presence of a 500 lb bomb, and the realization that the aircraft had crashed prior to reaching its target destination. Based upon these factors it was determined that the crater is not the direct result the aircraft hitting the ground, but rather was created when some of the munitions that were aboard B-25C #41-12907 exploded after impact.

The detonation of the ordnance would have almost instantaneously fragmented the majority of the aircraft into small pieces and ejected them out into the surrounding clearing and forest. This results in the final location of the majority of the aircraft wreckage being the result of the bombs and not the crash itself. These aspects of the site formation process prevented the archaeologist from making any inferences about the crash dynamics of the loss or determining what degree of perpendicularity at which the B-25 may have struck the ground.

Analysis of the skeletal (Rhode 2008a, b, c, d, e) and dental remains (Torske 2008a, b) was somewhat unique when compared to the other cases detailed in Chapters 5 through 7. First, over 6.0 kg of soft tissue was recovered from the site and adipocere was common on the skeletal elements. This is the only such case detailed in this thesis. Second, like the majority of the other cases, perimortem trauma was readily apparent on skeletal elements from all parts of the body. However, unlike many of the other cases, there was very little post-mortem damage to the remains. This is likely the result of the dense clay sediments, fuel, and the majority of the crater being below the water table. Thermal alteration of the remains was only observed on a very low percentage of the osseous material (Rhode 2008a, 2, 5).

The taphonomic processes associated with MACR 15092 are highly unique. The explosion of the bombs upon the aircraft's impact resulted in the remains being extremely fragmented. However, the large amount of fuel trapped in the crater resulted in those remains being preserved in excellent condition for the ensuing 60 years. Due to the highly fragmentary nature of the remains, mtDNA testing was the primary method for resolving the comingling. Sixty samples, including both hard and soft tissues, were submitted for analysis and they yielded four unique sequences (Table 21). Articulations between elements were found for two of the individuals aboard the aircraft.

Table 21. Results of mtDNA sampling for MACR 15092.

Sample	Element	Provenience	Individual
01A	Right humerus	N496/E504	Engineer
02A	Humerus	N496/E504	Radio Operator
03A	Left femur	N496/E504	Radio Operator
04A	Soft tissue	*	Engineer
05A	Soft tissue	NW Quad	Inconclusive
06A	Long bone	SE Quad	Radio Operator
07A	Left 5th metatarsal	SW Quad	Gunner
08A	Long bone	SW Quad	Radio Operator
09A	Long bone	SE Quad	Engineer
10A	Long bone	SE Quad	Inconclusive
11A	Rib	SE Quad	Engineer
12A	Cranial fragment	SE Quad	Radio Operator
13A	Cranial fragment	SE Quad	Gunner
14A	Rib	SE Quad	Engineer
15A	Cranial fragment	SE Quad	Radio Operator
16A	Left humerus	SE Quad	Gunner
16B	Left humerus marrow	SE Quad	Gunner
17A	Femur muscle tissue	NW Quad	Radio Operator
18A	Long bone	SE Quad	Radio Operator
19A	Long bone	SE Quad	Engineer

Sample	Element	Provenience	Individual
20A	Long bone	SE Quad	Engineer
21A	Long bone	SE Quad	Radio Operator
22A	Left mandible incisor root	SE Quad	Radio Operator
23A	Knee tissue	NW Quad	Radio Operator
24A	Skin flap	NW Quad	Radio Operator
25A	Soft tissue - foot	SW Quad	Gunner
26A	Soft tissue - foot	SW Quad	Gunner
27A	Skin	SW Quad	Gunner
28A	Long bone	SE Quad	Engineer
29A	Long bone	SE Quad	Engineer
30A	Skin	NE Quad	Engineer
31A	Clavicle	N496/E508	Engineer
32A	Rib	N504/E508	Radio Operator
33A	Femur	N504/E508	Radio Operator
34A	Os coxa	N504/E508	Engineer
35A	Mandible	N496/E504	Radio Operator
36A	Radius	N496/E504	Radio Operator
37A	Talus	N496/E504	Gunner
38A	Long bone	N496/E504	Radio Operator
39A	Cervical Vertebra	N496/E504	Radio Operator
40A	Sacrum	N496/E504	Navigator
41A	Scapula	N496/E504	Navigator
42A	Long bone	N500/E508	Radio Operator
43A	Temporal	N500/E508	Gunner
44A	Tibia	N500/E508	Gunner
45A	Tibia	N500/E508	Engineer
46A	Scapula	N500/E508	Radio Operator
47A	Scapula	N500/E508	Radio Operator
48A	Scapula	N500/E508	Radio Operator
49A	Phalange	N500/E504	Radio Operator
50A	Phalange	N500/E504	Radio Operator
51A	Right femur	*	Engineer
52A	Right femur	*	Inconclusive
53A	Rib	*	Gunner
54A	Rib	*	Engineer
55A	Os coxa	*	Navigator
56A	Lumbar vertebra	*	Engineer
57A	Scapula	*	Radio Operator
58A	Os coxa	*	Radio Operator
59A	Long bone	*	Radio Operator
60A	Long bone	*	Navigator

*Provenience data for these samples is unavailable.

Dental remains recovered at Site PNG-23 included a partial left mandible and 10 loose teeth or fragments of teeth. The left mandible, containing tooth roots for teeth #18, #20, and #21 and an isolated incisor were found to belong to the Radio Operator on the basis of mtDNA testing (Torske 2008b). The remaining teeth and teeth fragments lacked sufficient potential to yield usable DNA sequences and bore no individuating features and were this included in the group remains (Torske 2008a).

The recovery location of identified remains and material evidence that could be associated with a particular individual are displayed below (Figure 46). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty.

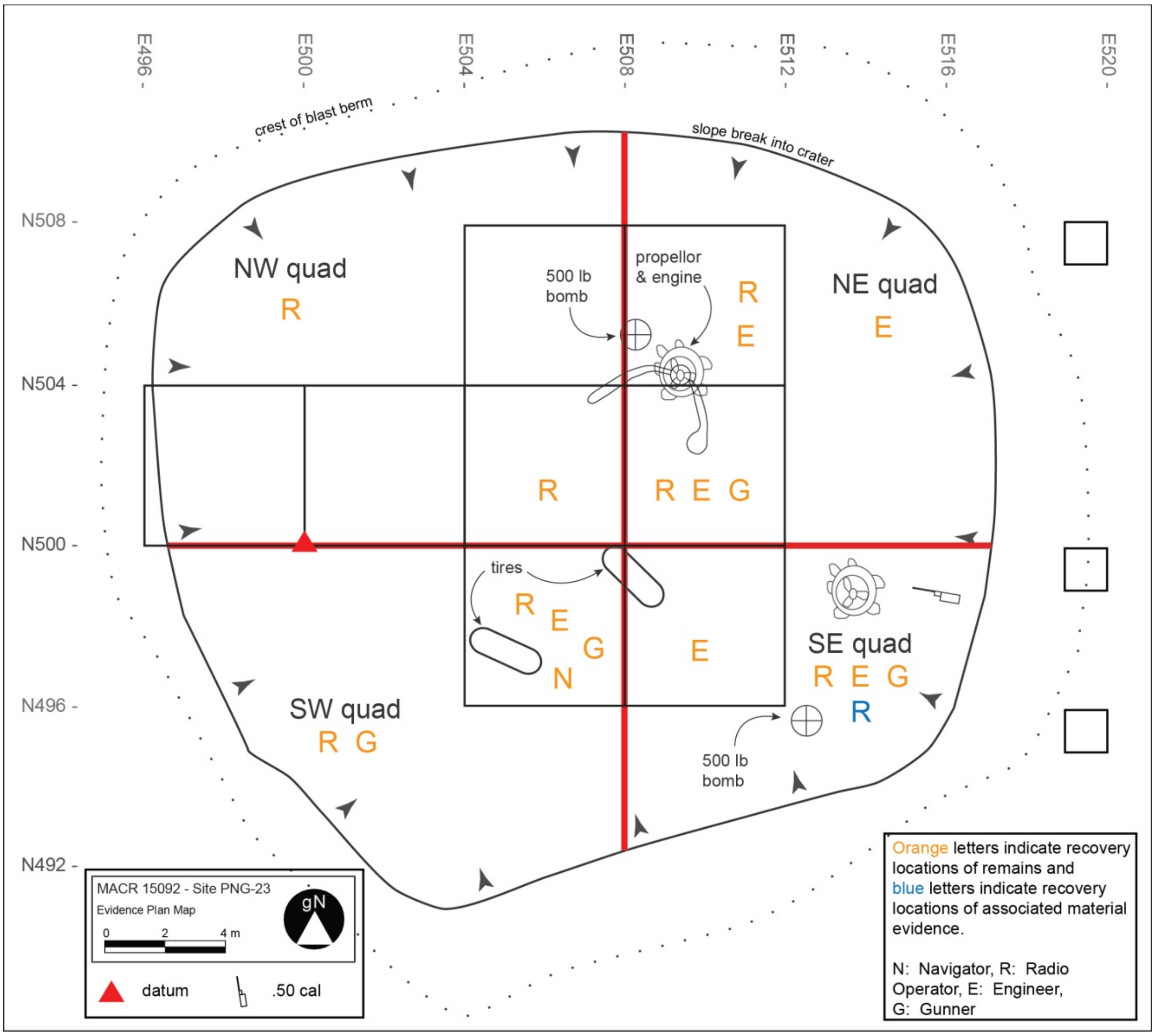

Figure 46. Map of Site PNG-23 showing the locations of identification media, identified remains, and recognizable aircraft components.
The placement of the quadrant heading and the Individuals listed under them is representative of the quadrant, not the exact location where the evidentiary materials were recovered. (Adapted from Goodman 2005a)

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific crew member yields the following conclusions for each individual:

- No personal items or remains were recovered that could be associated to the Pilot.

- No personal items or remains were recovered that could be associated to the Co-pilot.

- Those remains identified as the Navigator include a scapular fragment, left os coxa fragment, three long bone fragments, and a left femoral head (Rhode 2008b, 1). All of these remains were recovered from the lower levels of the impact crater in N496/E504 (Figure 46).

- No personal items or remains were recovered that could be associated to the Bombardier.

- The Radio Operator is represented by fragments of crania, left mandible , cervical vertebra, rib, scapula, humerus, radius, os coxa, femur, and a portion of soft tissue. These remains were found in all four quadrants of the crater as well as N496/E504, N500/E504, N500/E508, and N504/E508 (Figure 46).

- Fragments of rib, clavicle, vertebrae, upper and lower limbs, and portions of soft tissue were identified as being the Engineer. These remains were spread across the eastern two quadrants and the following units: N496/E504, N496/E508, N500/E508, and N504/E508 (Figure 46).

- Those remains identified as the gunner include fragments of crania, left humerus, tibia, and right foot. These remains were recovered from the southern two quadrants as well as N496/E504 and N500/E508 (Figure 46).

Four of the seven Army Air Forces personnel who died aboard B-25CD tail number 41-12907, on December 5, 1942 were individually identified by JPAC on September 16, 2008, just shy of 66 years after the incident. The remaining three individuals were identified as a group on the same day (Holland 2008a).

MACR 15092 is an example of the use of atypical provenience areas that do not follow a standard archaeological site grid. In this case, the crater was subdivided into quadrants. While they were appropriate in this situation due to the extremely loose, muddy sediments, overall it reduced the level of resolution as to where evidentiary materials were recovered from within the crash site. This type of excavation strategy should be reserved for when it is truly necessary.

5.4 MACR 1069

MACR 1069 involves the November 5, 1943 loss of nine individuals aboard B-24D, tail number 42-40972 from the 5th Air Force, 43rd Bombardment Group, 63rd Bombardment Squadron (Coleman 1943, 1). The aircraft was equipped with a radar unit in the place of its belly turret and regularly flew low-level night missions to disrupt Japanese shipping (LLoyd 1993, 41, 117). The aircraft departed Dobodura, Papua New Guinea at 1800 hours on November 4 with enough fuel for a 12 hour flight. They were on an armed reconnaissance around Kavieng at the northern tip of New Ireland, Bismarck Archipelago. At 0040 hours on November 5 the Radio Operator reported three direct hits on a Japanese cruiser in the waters to the south of the western end of New Ireland and that the target was destroyed. The last message received from the aircraft was at 0120 hours stating “Turn on radio range.” No position was provided at that time. No additional radio transmissions were received through 0600 hours (Trigt 1943). The bomber never returned to Dobodura. The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Radar Operator, Radio Operator, Engineer, and two Gunners.

An aircraft was launched on the afternoon of November 5 to search for the missing B-24, but no evidence of the plane could be found. The nine crew members were declared missing in action on November 5, 1943. Negative search results led the AGRS to believe that the aircraft had crashed into the ocean. The Adjutant General’s Office of the War Department declared the individuals aboard B-24D #42-40972 presumptively dead as of January 15, 1946. The AGRS eventually deemed them unrecoverable on June 3, 1948 after comparing the known details of the crew against all of the unknown sets of remains from the area (Christensen 2003b, 1; Lehl 2005d, 2-3).

In March 2002, 54 years after the loss incident, the United Stated Embassy in Port Moresby received notification from a Morobe Province official about the discovery of an airplane crash in the Sarawaget Mountains. The official was put in touch with a CILHI team on March 18 that was already working out of Lae as part of 02-3PP. When interviewed, he presented the team with aircraft data plates and two identification tags and explained that they had come into his possession from a man who lived in Yalumet Village. The identification tags belonged to the Co-pilot and the Navigator who were manifested as being aboard B-24D #42-40972, MACR 1069 (Christensen 2003b, 2; Lehl 2005d, 3).

The information prompted an itinerary change allowing the IT to investigate the new lead towards the end of their mission. On April 20, 2002 the CILHI team traveled to Yalumet Village and met with the individual who found the crash site and the identification tags. He claimed to have found the crash sometime in early 2002. In addition to having taken the identification tags from the site, he was also in the possession of a large quantity of human remains, which he relinquished to the team. The informant also led the team to the crash site via helicopter, but multiple difficulties prevented them from reaching the crash site (Christensen 2003b, 2; Lehl 2005d, 3-4).

The site (PP-00088) correlated to MACR 1069 is located at approximately 3200 m in elevation (10,500 ft) on the northern side of the Sarawaget Mountians. The nearest village to the site is Imom, Yalumet Station, Deyamos District, Morobe Province, 6.6 km from the site. The site can be located on the map: Name: Sarawaget; Sheet: 8285 IV; Series: T601; Edition: 1-AAAS, 1979; Scale: 1:100,000; Datum: Australian Geodetic Datum 1966 (Figure 47) (Christensen 2003a).

Site PP-00088, is spread across three roughly parallel drainages that are located on a steep northwest facing slope that varies in inclination between 45° and 70° (Figure 48). The west drainage is approximately 8 m wide and has an active water seep trickling through it. The steep sides funnel down to an exposed bedrock face in the lower portion of the debris field. The central drainage is the broadest at approximately 14 meters across, shallowest, and also has the gentlest slope of the three. The characteristics of the east drainage are between those of the previous two. It is nine meters wide and has an intermediate depth and incline. At the bottom of the hill all three drainages meet an actively flowing stream face that runs to the north. The vegetation at site PP-00088 is markedly different from the cases discussed above. This is primarily due to its being located at a much higher elevation which results in colder temperatures that inhibit the growth of large broadleaf palms and ferns as well as extensive bushes, vines, and thick carpets of moss. Instead the site is dominated by a mixed forest of *Podocarpus* conifers and *Nothofagus* beeches (Christensen 2003a, 16, 20; 2003b, 6).

The primary distribution of aircraft wreckage at site PP-00088 is oriented along a 10°/190° azimuth that diagonally spans all three drainages (Figure 48 and Figure 49). Despite having broken into numerous fragments, the wreckage fragments are generally arranged across the hillside in the appropriate relative position to one another. Farthest up slope and to the south were the portions of the aircraft that make up the tail. The horizontal and vertical portions of the starboard half of the tail are on the western side of the west drainage, while the port sections rest slightly downslope on the eastern side of the drainage. This half of the tail is still connected to the rear portion of the fuselage by control cables (Christensen 2003b, 10). The tail turret is wedged into a tree adjacent to the starboard tail (Christensen 2003a, 7). The aircraft's serial number (42-40972) was clearly visible on each vertical section of the tail.

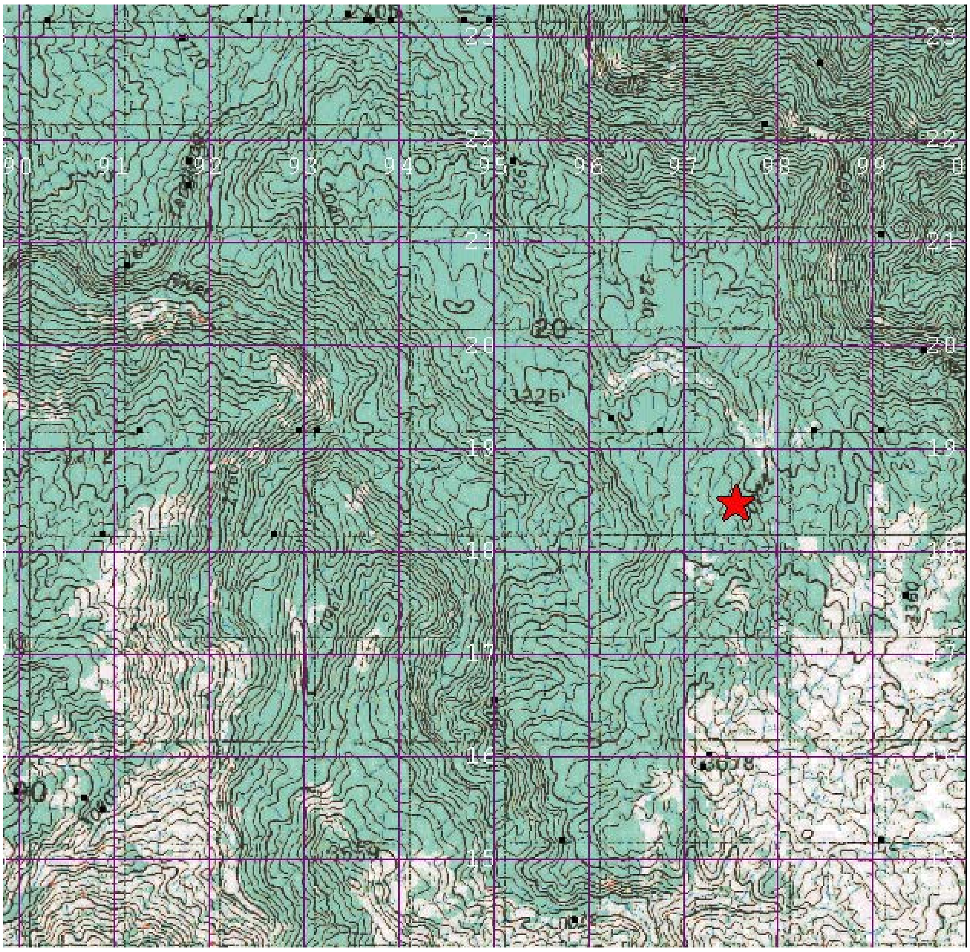

Figure 47. Topographic map showing the location of Site PP-00088 (red star).

Figure 48. View to the south of the central (left) and west (right) gullies before excavation. The east gully, containing the nose of the aircraft, is behind the trees along the left margin. View to south (Christensen 2003b, 18).

The control cables mentioned above extended northwards from the aft fuselage to a section of the belly of the aircraft that rested on the ridge between the west and central drainages. The first four meters extending down from the ridge towards the bottom of the central drainages was free from wreckage. The left wing, with its tip pointing downslope, dominates the middle portion of the central drainage. The forward half of the wing was burned away leaving engine numbers one and two as well as the landing gear exposed in their approximate original positions. The inboard portion of the right wing, number three engine, and right landing gear were eventually determined to be farther upslope in the central drainage in the same relative position and condition as the left wing. The dorsal gun turret ring was located between engines two and three. The cockpit wreckage rested on the eastern face of the central drainage near the crest leading to the eastern drainage. The copilot’s seat was largely intact, but the pilots position was more damaged (Figure 49) (Christensen 2003b, 9-10, 12, 15, 18, 26).

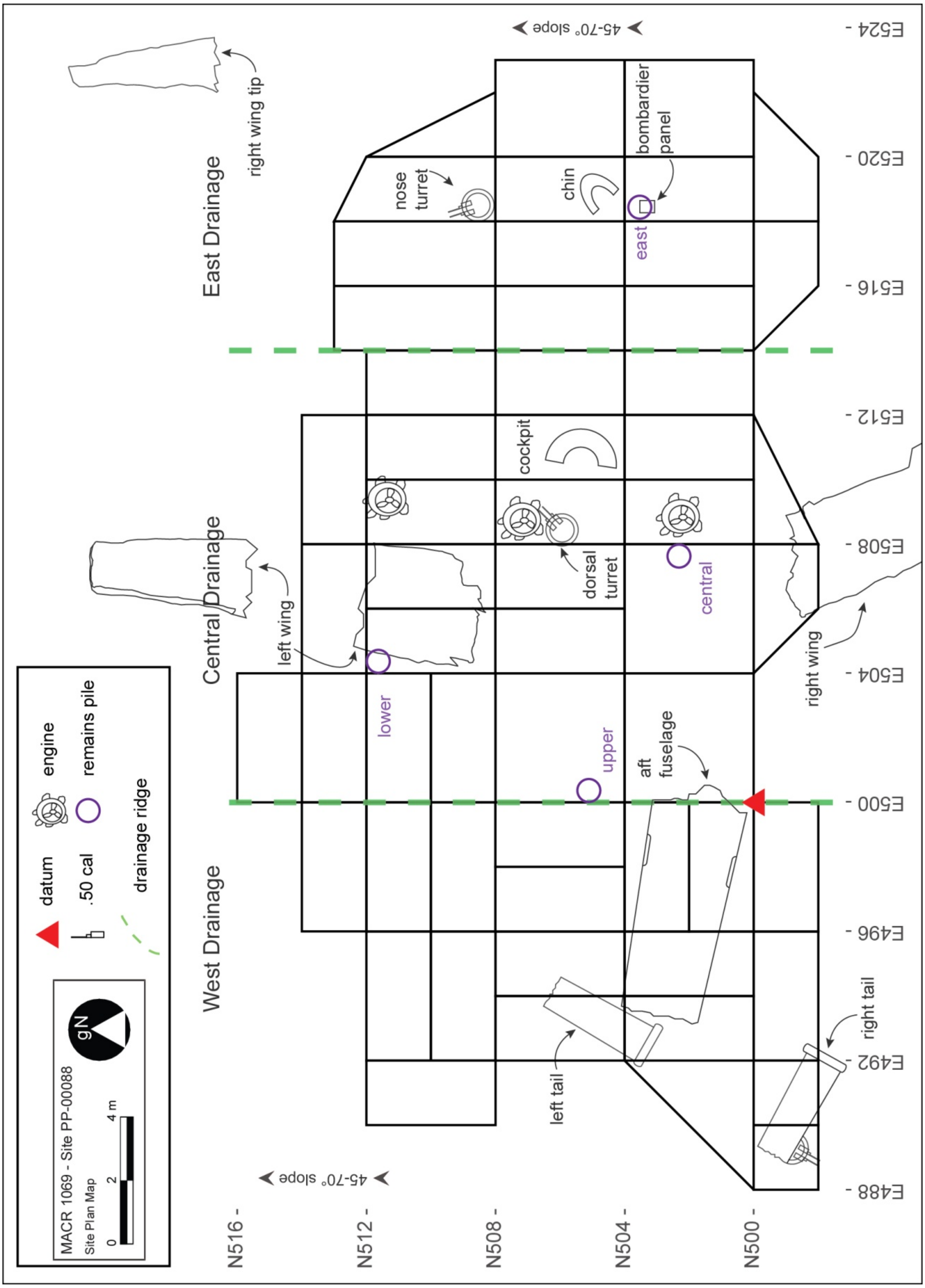

Figure 49. Map of Site PP-00088 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Christensen 2003b)

The forward most compartment of the B-24, including the bombardier’s station and the nose gun turret, rested on the surface of the east drainage in close alignment with the other sections of fuselage (Figure 49). Both were heavily damaged. Engine number four was located approximately 15 m upslope of the nose wreckage in the bottom of the gully and the outboard portion of the right wing was 10 m downslope (Christensen 2003b, 10, 20). A low density scatter of small fragments of metal extended approximately 8 m to the east of the east drainage.

Aside from the large sections of aircraft wreckage, the most noticeable aspect of the recovery scene was the four small concentrations of human skeletal remains. Clearly no longer *in-situ*, the concentrations were labeled Upper, Lower, Central, and East by the archaeologist. Conversations with the individuals who discovered the site revealed that they had created the piles from the remains that were within a roughly 1 m radius. The recovery of the site began with the collection and cataloging of the four piles. Special attention was paid to the location of each concentration within the recovery scene, by recording its location both within the excavation grid and in relation to the adjacent aircraft components. The East Concentration was located just upslope of the chin/nose of the aircraft in N500/E518 and appeared to represent a single individual. The Lower Concentration, immediately west of the port wing in N508/E504, had been collected from the downslope area of the cockpit. It also contained one individual except for an extra cranium. The Central Concentration was located just upslope of the cockpit on the boundary between N500/E504 and N500/E508. It contained remains from the immediate cockpit area and a rough field evaluation resulted in a MNI of four. The Upper Concentrations rested on the ridge between the west and central drainages just below the aft portion of the fuselage along the west wall of N504/E500 (Christensen 2003a, 36; 2003b, 10) (Figure 49).

Excavation commenced with split operations with one unit in the southeast corner of the recovery scene in the east drainage and another in the northwest corner in the west drainage (Christensen 2003a, 31). The excavation in the west drainages proceeded in a downslope to upslope direction towards the tail wreckage. Conversely, in the east drainage, work progressed from upslope to downslope. The central drainage was completed subsequently. Each of the three drainages were excavated individually and units were adjusted to match the natural boundaries of the topography (e.g., N500/E520, N504/E520, and N508/514) (Christensen 2003a). Throughout the recovery process, to ensure greater spatial control, the archaeologist primarily worked with 2-x-4 m units.

Sediment was removed with trowels in areas where the likelihood of finding remains was high or whenever evidentiary materials were unexpectedly encountered. Clusters of remains were mapped and photographed prior to their removal and their location within the site grid and relative position in relation to the aircraft wreckage recorded. Two substantial partial articulated sets of remains were encountered: A and B. Set A, located in the central portion of the east drainage spanning N500/E518 and N504/E520, included elements of both legs and one boot containing a foot (Christensen 2003b, 20-22). Set B was uncovered along the eastern side of the central drainage in N504/E512. It also contained lower leg portions and boots as well as additional semi-articulated remains from the cranium and arms.

At the conclusion of the mission, an approximate surface area of 461 m^2 was excavated to depths as much as 1 m (Figure 50). However, the majority of the site did not require more than 50 cm of sediment to be removed (Christensen 2003b, 16). Extensive burning was observed within the central drainage in those areas where the fuselage would have joined the wings (Christensen 2003b, 26). Additionally, few identification media found within the recovery scene (Table 22) (Connell and Silverstein 2005). This is likely due to the local villagers who collected remains and created the bone piles.

Figure 50. Final photo of the central (left) and west (right) gullies.
Portions of the aircraft wreckage were removed during excavations. View to south (Christensen 2003b, 18).

Table 22. Provenience of identification media found at Site PP-00088.

Provenience	Identification Media
N504/E508	Identification tag and bracelet (Pilot), identification tag (Radio Operator), and identification bracelet (Co-pilot)
N504/E510	Identification tag (Pilot), identification tag (Co-pilot), and identification tag (Radio Operator)

Several observations can be made in regards to the crash based upon the excavation. The large, mostly intact sections of wreckage that were found resting in proper relative alignment across a distance only slightly longer than a complete B-24 suggests that the aircraft was moving at a relatively low velocity when it impacted the mountain. The orientation of the wreckage with the cockpit lying downhill of the tail indicates a very low degree of perpendicularity.

Analysis of the recovered skeletal (Berg 2005; Crowder 2005; Goodman 2005b, c, d, e; Tuller 2005a, b, c, d) and dental (Gleisner 2005d, e, f, g, h, i, j, k, l; Gleisner and Torske 2005) remains determined that they were largely intact and generally well preserved. Massive perimortem blunt force trauma, typical of aircraft crashes, was common and some elements exhibited evidence of subsequent thermal alteration ranging between Shipman et al's (1984) Stages II and V. Weathering is consistent with Behrensmeyer (1978) Stage II (Berg 2005, 9).

The four piles created by the local villagers, MACR 1069 possessed a higher degree of commingling that most of the other cases studies presented. To address this problem, 24 samples were submitted for mtDNA sequencing from the four piles as well as three teeth. They yielded nine distinct sequences, representing all of the individuals that were known to be aboard aircraft 42-40972 on November 5, 1943. Table 23 lists each of the samples, the element from which it was taken, its recovery provenience, and the individual it was found to associate with.

Table 23. Results of mtDNA sampling for MACR 1069.

Sample	Element	Provenience	Individual
01A	Right femur	N500/E504 N500/E508	Co-pilot
02A	Right femur	N500/E504 N500/E508	Navigator
03A	Right femur	N500/E504 N500/E508	Engineer
04A	Right femur	N500/E504 N500/E508	Radio Operator
05A	Right femur	N500/E504 N500/E508	Gunner 2
06A	Left femur	N504/E508	Pilot

Sample	Element	Provenience	Individual
07A	Right femur	N508/E504	Radar Operator
08A	Right femur	N504/E512	Bombardier
09A	Right femur	N500/E518	Gunner 1
10A	Right humerus	N500/E518	Gunner 1
11A	Mandible	N504/E512	Bombardier
12A	Right humerus	N508/E504	Radar Operator
13A	Right clavicle	N504/E508	Pilot
14A	Right tibia	N504/E500	Gunner 2
15A	Right humerus	N504/E500	Gunner 2
16A	Left humerus	N504/E500	Engineer
17A	Left humerus	N504/E500	Gunner 2
18A	Left os coxae	N500/E504 N500/E508	Co-pilot
19A	Left humerus	N500/E504 N500/E508	Navigator
20A	Left humerus	N500/E504 N500/E508	Co-pilot
21A	Left humerus	N500/E504 N500/E508	Radio Operator
22A	Tooth #11	N504/E512	Bombardier
23A	Tooth #32	N508/E504	Radar Operator
24A	Tooth #16	N508/E504	Radar Operator

In addition, the good condition of the remains, combined with provenience information, allowed CIL physical anthropologists to successfully determine numerous pair matches and articulations resulting in more elements being associated with specific individuals. Furthermore, numerous dental remains, both loose and contained within mandibular and maxillary fragments, were positively associated with the nine crew members through post-mortem – antemortem matching (Table 24).

Table 24. Dental remains correlated to a specific crew member associated with MACR 1069.

Name	Associated dental remains
Pilot	#1, #3, #4, #6, #13, #15 - #17, #19 - #24, and #31
Co-pilot	#1 - #8 and #11 - #16
Navigator	#1 - #7, #9 - #22, and #25 - #32
Bombardier	#2 - #7, #9, #11, #12, #14 - #23, #25, and #27 - #32
Radar Operator	#1-#17, #20, #27, #28, #31, and #32
Radio Operator	#4 - #7 and #9 - #13
Engineer	#2, #9, #10, #12, #13, #17, #18, #21, and #22
Gunner 1	#2 - #7 and #10 - #16
Gunner 2	#2, #3, #5, #14, #18, #19, #21, #22, #28, #30, and #31

The recovery location of identified remains and material evidence that could be associated with a particular individual are displayed below (Figure 51). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty.

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- The remains of the Pilot were largely complete, only missing in their entirety the right os coxae and right lower leg. The skeletal elements were recovered immediately downslope of the pilot's station (Figure 51). His identification media were recovered with the remains and within the cockpit wreckage (Christensen 2003b, 26).

- The Co-pilot, was primarily recovered from the co-pilot's station of the aircraft (Figure 51). This included the lower limbs as well as tooth #6 which was found embedded in the cockpit instrument panel (Christensen 2003a). Some elements were individuated from the Central Remains Concentration through mtDNA analysis.

- While the majority of his remains were recovered from the Central Remains Concentration, the Navigator was widely distributed across the site (Figure 51). His lumbar vertebrae and left femur were in the Central Remains Concentration and part of the right radius was located in N500/E518.

- The Bombardier was determined to be the articulated set of remains B (Figure 51). The fairly complete skeleton recovered just below the ridge between the Central and East Drainages in N504/E512 had been separated from the wreckage of the forward compartment of the aircraft which rested in the eastern gully.

- The remains of the Radar Operator comprised the majority of the Lower Remains Concentration in N508/E504 (Figure 51). The mostly complete skeleton had been gathered up to form the concentration from a small area in the downslope portion of the central drainage below the melted remnants of the rear fuselage, which would have the held the radar in the belly of the aircraft (Christensen 2003b, 32).

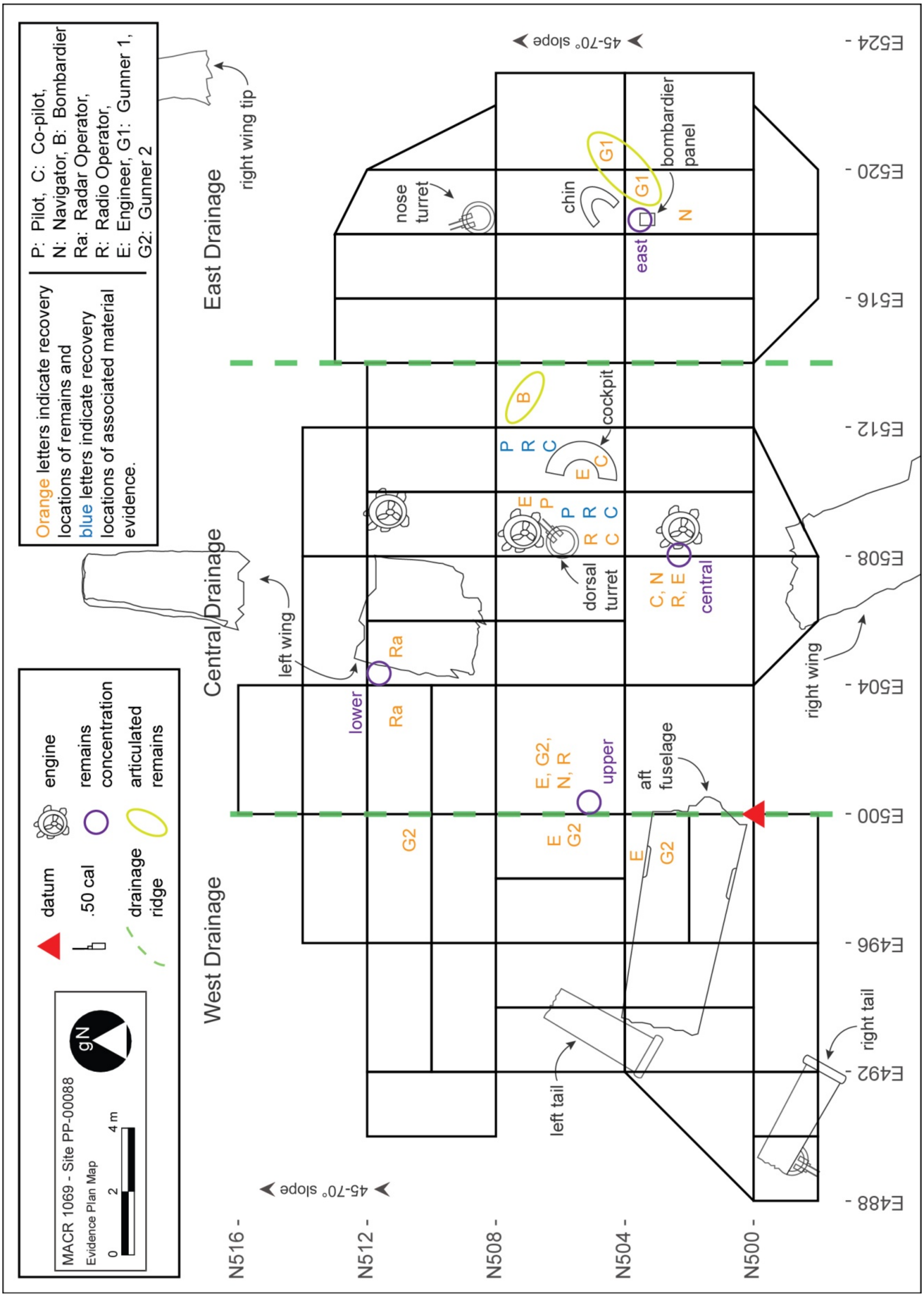

Figure 51. Map of Site PP-00088 showing the locations of identification media, identified remains, and recognizable aircraft components.
(Adapted from Christensen 2003b)

- The majority of the remains identified as the Radio Operator were recovered from the Central Remains Concentration, including the left os coxa and femur as well as portions of the right tibia and fibula. The remaining sections of the right lower leg were found in the Upper Remains Concentration, while several of the vertebrae were located in N504/E508, the unit immediately to the west and what would have been aft of where the cockpit came to rest. His identification media were recovered from the same unit as well as N504/E510 (Figure 51).

- The most widely distributed set of remains belonged to the Rngineer. The skeletal elements were primarily recovered from the Upper Remains Concentration and also N502/E496 (Figure 51). The aft portion of the fuselage containing the wait guns rests in unit N502/E496 and the Upper Remains Concentration is approximately 2 m away, slightly downhill. Fragments of the right femur were found in the dorsal turret and the cockpit.

- Gunner 1 was found to be the articulated set of remains A spread diagonally between N500/E518 and N504/E520. These remains were approximately 4 m upslope of the nose gun turret and in close proximity to bombardier’s control panel which is in the same compartment as the nose gunner (Figure 51).

- Gunner 2 was recovered from the Upper Remains Concentration and N502/E496, N504/E498, and N510/E496 (Figure 51).

Each of the nine servicemen who died aboard B-24D #42-40505 on November 4, 1943 were individually identified by the JPAC-CIL approximately 62 years after the loss on February 10, 2006 (Holland 2006b).

MACR 1069 is a complicated case because it involves the four remains concentrations that were created by the locals who discovered the site. Upon first inspection it appears that these concentrations prevent the ability to determine where remains were found within the site. However, the Central Remains Concentration, located upslope of the starboard side of the aircraft, proved to contain the remains of those individuals who manned the duty stations which are immediately aft of the pilot compartment as well as the co-pilot. This included the co-pilot, radio operator, and engineer (Connell and Silverstein 2005, 83).

6 Bombardment Aircraft Cases – Part 2

The four larger bombardment aircraft crash cases, based upon size of debris field, are presented in this chapter. All of them are Consolidated B-24 Liberators lost during WWII. Each of them had both the locations of duty station aircraft wreckage recorded during the excavation and sufficient provenience information carried forward through laboratory analysis to be included here. Table 25 lists these cases from smallest to largest, and their locations can be found in Table 26.

Table 25. Bombardment aircraft cases – Part 2.

Incident (MACR)	Loss Date	Aircraft Type	Tail Number	Number Missing
1459	December 3, 1943	B-24D	42-40475	11
4497	April 16, 1944	B-24D	42-72946	10
8641	September 1, 1944	B-24J	42-73453	8
4512	April 16, 1944	B-24J	42-100225	11

Table 26. Loss locations of bombardment aircraft cases discussed in this chapter.

Incident (MACR)	Country	Province	District
1459	PNG	Northern	Ioma
4497	PNG	Morobe	Tewae Siassi
8641	Palau	Babelthaup	Aimeliik
4512	PNG	Morobe	Tewae Siassi

6.1 MACR 1459

MACR 1459 involves the December 3, 1943 loss of a B-24D, tail number 42-40475, with 11 servicemen aboard (McIntosh 1943, 1). The aircraft was assigned to the 5th Air Force, 43rd Bombardment Group, 63rd Bombardment Squadron. The Pilot and his crew departed Dobodura, Papua New Guinea on a solo armed reconnaissance mission in search of a Japanese convoy that had previously been spotted near New Hanover Island in the Bismark Sea. At 2200 hours the aircrew reported having dropped their bomb load, but missing a Japanese vessel and shortly thereafter at 2220 radioed the confirmed sighting of six enemy vessels located approximately 70 miles southeast of New Hanover Island. At 2330 Aircraft 42-40475 informed the airstrip at Dobodura that they expected an arrival time of 0025 on December 4, 1943. At 0030 a message was received from the aircraft requesting

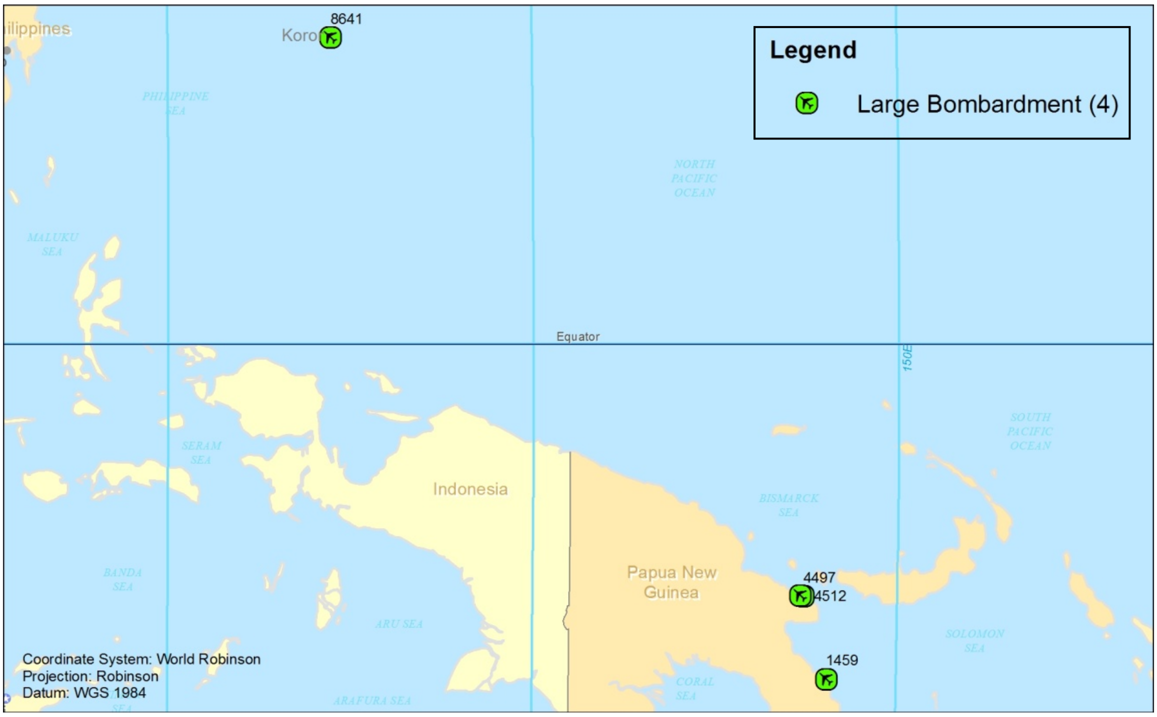

Figure 52. Map of the Southwest Pacific showing the locations of the bombardment aircraft crashes discussed in this chapter.

that the runway landing lights be turned on. At 0035 the airfield received an inquiry as to why the lights were not on. Despite the runway lights having been turned on at 0001 hours, no additional radio transmissions were received and the bomber never returned to Dobodura (McIntosh 1943; Young 2007, 2). The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Observer, Radio Operator, Engineer, Radar Operator, Assistant Engineer/Gunner, and two additional Gunners.

Four aircraft from the bombardment squadron searched from Finschhafen to Milne Bay, coastal and inland mountain regions on December 4 and 5, 1943 for a combined total of 18.75 hours, but there was no sign of the missing liberator. The 11 crew members were declared missing in action on December 5, 1943 and on January 20, 1946, the AGRS changed their status from missing to presumed dead. A subsequent review in 1948 determined that the aircraft was most likely lost over water in the Bismarck Sea and so the AGRS declared the individuals to be non-recoverable (Young 2007, 3-4).

In March of 2000, 57 years after the crash, JPAC was notified that three local nationals had found an aircraft crash in the mountains while hunting. They purportedly discovered four engines, ordnance, guns, parachutes, various apparel fragments, and an identification tag for one of the Gunners that was manifested on B-24D #42-40475, MACR 1459, on December 3, 1943. An investigation team traveled to Deboin Village in November of

2002, but was unable to survey the site because the individuals who originally found the site could not relocate it (Young 2007, 4). A second attempt was made in 2004 which proved to be successful. During the investigation, the team discovered a radio data plate and a portion of a vertical stabilizer from the tail with the number 240475, correlating the crash site to MACR 1459 (Tyrrell 2004, 7-8).

The site (PP-00125) correlated to MACR 1459 is located at approximately 300 m in elevation (1000 ft) in the foothills on the northern side of the Owen Stanley Mountains. The largest nearby population center is Popondetta, approximately 75 km to the south. The closest village to the site is Iwaia and Deboin Villages, Ioma District, Northern Province. The site can be located on the map: Name: Koena; Sheet: 8581; Series: T683; Edition: 1-AAS, 1979; Scale: 1:100,000; Datum: Australian Geodetic Datum 1966 (Figure 53) (Silverstein 2007b, 2-4)

Figure 53. Topographic map showing the location of Site PP-00125 (red star).

Site PP-00125 is situated on a north facing slope that varies in inclination between 13° and 30°. A small 2-5 meter deep gully with a gently flowing stream forms the eastern boundary of the site. A smaller, intermittent stream curves around the site from the west to the north where it eventually joins with the deeper stream to the northeast of the debris field. Vegetation within the site can be characterized as double canopy tropical forest. It primarily consisted of large deciduous hardwoods with a mixed understory of smaller trees, vines, shrubs, forbs, grasses and various bushes. Due to its lower elevation and rainfall levels, the site is not dominated by palms and the ground surface is not covered by thick carpets of moss (Danielson 2004a; Silverstein 2007a; b, 4-8, 16) (Figure 55).

The maximum distribution of aircraft wreckage at Site PP-00125 extends approximately 55 m cross slope (east-west) and 25 m upslope-down slope (north-south). The crash site is very similar to Site PP-00254, MACR 10020, in that there is a small central concentration of wreckage that exhibited extreme thermal alteration surrounded by large fragments of wing and tail. The irregularly-shaped central concentration at Site PP-00125 is 16 m wide (cross slope) and 12 m long (upslope-downslope). Like Site PP-00254 there are large conglomerates of melted aluminium containing aircraft components, but there are also large sections of aircraft that remain relatively intact including a section of the fuselage where it connects to the wing as well as the port section of the aft fuselage including the waist gunner's portal. A section of wing and the number three and four engines are also within the central concentration. The cockpit and forward compartments of the B-24 make up the western-most end of the central concentration and are heavily overgrown with tree roots. The outboard portion of the port wing and the number one and two engines rest to the south (upslope) of the concentration (Figure 54). The right vertical tail stabilizer and three bomb bay doors are located approximately 24 m to the east. The aircraft's serial number (240475) was clearly visible on the vertical section of the tail (Figure 55). The wreckage distribution clearly indicates that the aircraft was flying in a westerly direction at the time of the crash.

Site PP-00125 was excavated on two occasions. The first recovery mission was conducted from March 18 through April 10, 2004. Excavation began at the western end of the central wreckage concentration in unit N504/E500 and progressed from west to east staying south (upslope) of the N508 line. Next a second pass from west to east was undertaken north (down slope) of the N508 line. Four units were then excavated surrounding the tail and bomb bay door wreckage (Danielson 2004a). The second team followed on from January

Figure 54. Primary wreckage concentration. View to south.
Cockpit wreckage (1); the left section of fuselage with port waist gunner door (2); a section of fuselage where it joins the wing 3); the starboard wing (4) (Silverstein 2007b, 5).

24 to February 9, 2007 and excavated to the west, south (upslope), and between the units that had already been completed at the central concentration and the tail wreckage. At the conclusion of the recovery effort one 1-x-4 m unit, twelve 2-x-4 m units, and forty-six 4-x-4 m units were excavated for an approximate total surface area of 386 m^2 with depths ranging from 10 to 80 cmbs (Figure 56). Patterns of wreckage distribution within the excavation mirrored those from Site PP-00254. First, the fuselage components were found within the dense central concentration. Second, very few fuselage fragments were encountered outside of this area. Third, all of the human remains and almost all material evidence, including identification media (Figure 55), were recovered from within the concentration (Table 27) (Christensen 2007; Silverstein 2007b, 16).

Even though Site PP-00125 is similar to Site PP-00254, MACR 10020, and the two sites being excavated by the same archaeologist (Danielson 2003a, 2004a), the recovery strategies that were utilized were somewhat different. Where Site PP-00254 was excavated slowly in small units, Site PP-00125 was processed at a faster pace and in large unit sizes. Despite this, the archaeologists were able to record detailed provenience for where critical evidentiary materials were found within the central concentration.

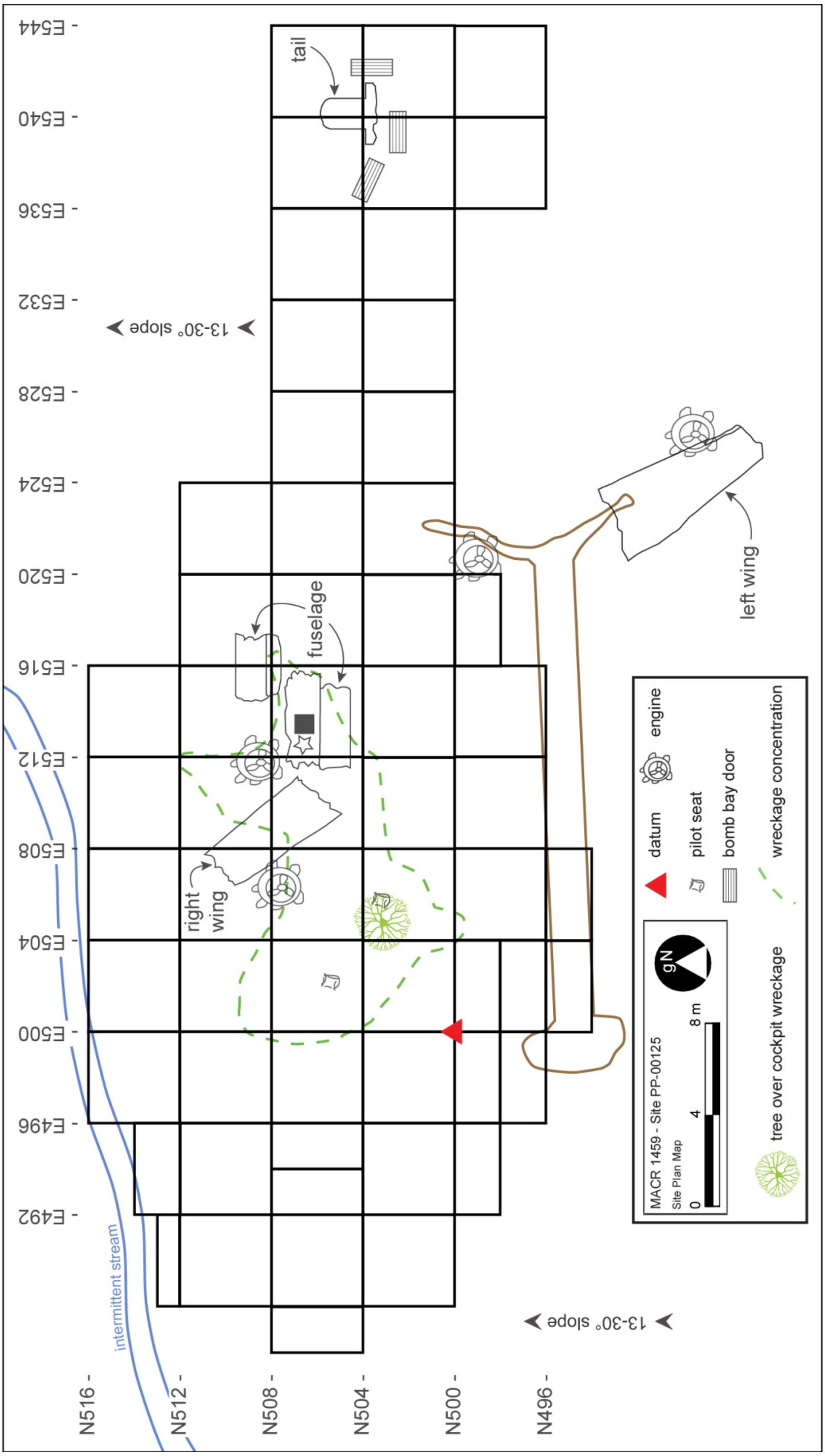

Figure 55. Map of Site PP-00125 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Silverstein 2007b)

Figure 56. Final photograph of the site upon completion of the excavation. Tree in center of photograph was the location of the cockpit. View to east.

Table 27. Provenience of identification media found at Site PP-00125.

Provenience	Identification Media
N498/E504	Navigator wing badge (Navigator)
N500/E500	2 identification tags (Engineer), identification bracelet (Co-pilot)
N500/E504	Identification tag (Co-pilot)
N504.5/E490	Identification tag (Navigator)
N504/E496	2 identification tags (Pilot), 2 identification tags (Bombardier), USAAF bombardier ring (Bombardier)
N504/E500	Captain's rank insignia (Pilot), USAAF bombardier ring (Observer), class ring (Observer)
N504/E512	Identification bracelet (Gunner 1)
N505/E493	Identification tag (Navigator)
N508/E500	Wedding ring (Co-pilot)
N508/E508	2 identification tags and identification bracelet (Radar Operator)
N509/E494	Identification tag (Co-pilot)

The conclusions that can be reached about the MACR 1459 crash reflect a general similarity between Site PP-00125 and Site PP-00254. First, the overall shape, small size of the debris field, and distribution of aircraft wreckage suggests that the aircraft likely had its tail ripped off before it impacted the ground at a high degree of perpendicularity. However, the 8 m spread between the cockpit wreckage and the waist gunner position indicate that the angle of impact was not as steep as MACR 10020. Second, many of the most recognizable components of the aircraft, such as the .50 cal machine guns and propeller blades, had been moved by local villagers and piled up against one of the engines. This included some of the diagnostic parts that can be associated with specific duty station aboard the aircraft. Third, the large clusters of melted metal indicate that the aircraft burned after impact like the MACR 10020 aircraft. This highly destructive taphonomic environment resulted in the recovery of the least amount of skeletal material of any case included in this study (Figure 55).

Analysis of the skeletal (Berg 2007a, b, c, d, e, f) remains as well as the teeth (Silver 2006c) confirm the conclusions reached from the field work. Extensive thermal alteration was present that ranged in color from dark brown to black (carbonized) to white (calcined) (Ranging from stages II to V; Shipman, et al. 1984). Many of the calcined remains have a black interior, indicating the some organic material remained (Berg 2007a, 1). Extensive surface erosion was common on those remains that were not thermally altered to the point where only delicate, lattice like structures remained. The overall degradation of the remains obscured fracture patterns and prevented any rearticulations or pair matches.

As a result, only those remains from which a mtDNA sequence could be obtained would be associated with a specific individual. Due to the paucity of remains, mtDNA sampling was conducted on each skeletal fragment that was large enough to have a good probability of producing an usable DNA sequence. Eleven samples were submitted, 10 of which yielded sequences representing five crew members (Table 28).

Table 28. Results of mtDNA sampling for MACR 1459.

Sample	Element	Provenience	Individual
1A	Femur	N508/E508	Gunner 1
2A	Femur	N500/E508	Radio Operator
3A	Right humerus	N504/E512	Gunner 2
4A	Right tibia	N512/E508	Gunner 1
5A	Left femur	N504/E500	Co-pilot
6A	Left humerus	N500/E500	Radio Operator
7A	Long bone	*	Radio Operator
8A	Right metatarsal 1	*	Inconclusive
9A	Long bone	*	Radio Operator
10A	Long bone	*	Radar Operator
11A	Long bone	*	Co-pilot

*Provenience data for these samples is unavailable.

Four dental prostheses were recovered during the excavations (Silverstein 2007b, 14). A maxillary removable partial denture, replacing teeth #3-5, #7, #10, and #12-14, and two separate mandibular removable partial dentures, replacing teeth #28-30 on the right and teeth #17-20 on the left, were found to belong to Gunner 1 (Silver 2006a). Another maxillary removable partial denture replacing teeth #13-15 and possibly tooth #4 or #5 was determined to belong to Gunner 2 (Silver 2006b).

The recovery location of identified remains and material evidence that could be associated with a particular individual are displayed below (Figure 57). Identified remains in this case are defined as skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty.

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each member of the crew:

- No remains could be exclusively determined to be those of the Pilot. However, one of his captain's rank insignia was recovered from the western end of the central concentration in unit N504/E500 and his two identification tags were found slightly further to the west in N504/E496 (Figure 57). These items were approximately 4 to 5 m away from the pilot's seat and cockpit wreckage that was wedged under the roots of a large tree in N500/E504.

- The Co-pilot, was represented by a left femur fragment and a long bone shaft fragment (Berg 2007b). The piece of the femur was found in N504/E500 near the co-pilot's seat. His personal effects were spread across four units: N500/E500 (identification bracelet), N500/E504 (identification tag), N508/E500 (wedding ring), and N509/E494 (identification tag). The first three items were found within the central concentration, with the second identification tag being unearthed approximately 4 m to the west.

- The Navigator was not represented by any remains after DNA testing was completed. His two identification tags were discovered three meters apart approximately 6 m past the western edge of the central concentration. A navigator wing badge was recovered from N498/E504, 4 m upslope from the tree with the cockpit wreckage.

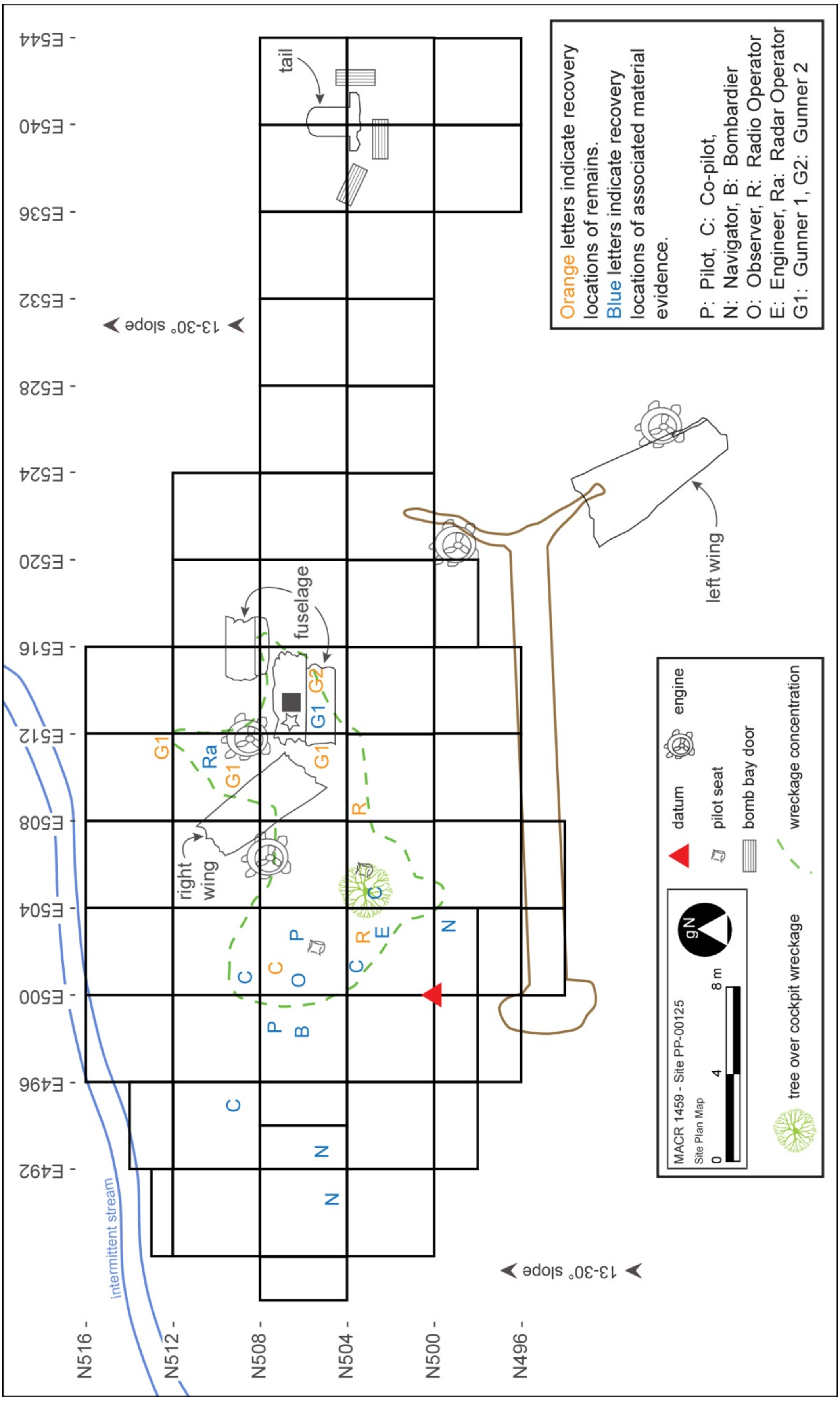

Figure 57. Map of Site PP-00125 showing the locations of identification media, identified remains, and recognizable aircraft components. (Adapted from Silverstein 2007b)

- No remains could be exclusively determined to be those of the Bombardier. His two identification tags and ring were recovered from N504/E496 (Figure 57). This location is consistent with where the nose compartment of the aircraft came to rest in the debris field.

- The onboard Observer's rings were recovered from the western end of the central concentration N504/E500 (Figure 57). No remains were identified as being exclusively his.

- The largest number of skeletal fragments correlated to an individual was from the Radio Operator. These included a femoral shaft fragment recovered in N500/E508 between the fuselage and cockpit clusters of wreckage. A left humeral shaft fragment found approximately 6 m away in N500/E500, which is forward of the cockpit wreckage (Figure 57). No provenience information is available for the remaining two skeletal fragments.

- Two identification tags belonging to the aircraft's Engineer were recovered from N500/E500 just west of the large tree that had grown over the cockpit wreckage (Figure 57). No remains could be exclusively correlated.

- The Radar Operator, is represented by a single long bone shaft fragment, but provenience was not recorded when the element was sampled for mtDNA. However, his two identification tags and identification bracelet were found in N508/E508 approximately 4 m from the two large sections of the aft fuselage (Figure 57).

- No personal items or remains that could be associated to the Assistant Engineer/Gunner were recovered.

- Two long bone shaft fragments that yielded mtDNA sequences that matched family reference samples for Gunner 1 were recovered in N508/E508 and N512/E508. His removable partial dentures were found in N504/E508. The remains and dental prostheses were all within approximately 4 m of the waist gunner position wreckage. Gunner 1's identification bracelet was found in N504/E512 underneath the waist gunner position wreckage (Figure 57).

- Gunner 2 was identified by a humerus shaft fragment and a dental prosthesis recovered from underneath the waist gunner position wreckage in N504/E512 (Figure 57).

Five of the eleven servicemen who died aboard B-24D #42-40475 on December 3, 1943 were individually identified by the JPAC-CIL only three months shy of 64 years after the loss on September 6, 2007 (Holland 2007). The remaining 6 were identified as a group on March 5, 2008 (Holland 2008b).

The MACR 1459 site shares characteristics with two cases presented in Chapter 5. It is similar to MACR 10020 in that the site burned after the crash. It is also akin to MACR 1069 as it crashed in a cross slope direction, which reduced the degree of perpendicularity. A new pattern observed with MACR 1459 is the ejection of items forward from the aircraft's primary direction of travel (Figure 57). This case also exemplifies the use personal effects to determine where individuals were located within the crash scene despite not recovering any of their remains due to the harsh taphonomic environment.

6.2 MACR 4497

MACR involves the loss of ten individuals aboard B-24D *Here 'Tis*, tail number 42-72946, from the 5th Air Force, 43rd Bomber Group; 403rd Bombardment Squadron (Lehl 2006, 1-2; Monahan 2002b). The aircraft departed Nadzab, PNG as part of the bombing strike on Hollandia and delivered its payload. On the return flight he joined up with three other B-24s and was flying the right wing position from the flight leader Captain Erwin C. Zastrow in the four plane formation. Approximately 50 miles north of Faita, flying at 2000 ft (610 m) the group encountered a solid cloud front from their altitude up to 9000 ft (2,743 m). Capt Zastrow instructed the MACR 4497 aircraft to break off and set a course for Saidor. The last contact with aircraft 42-72946 was when Capt Zastrow observed *Here 'Tis* gaining altitude and taking an approximate heading of 90 degrees (Wilson 1944, 2). The heavy bomber never arrived in Saidor. The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Engineer, Radio Operator, Assistant Radio Operator, Assistant Engineer, and two additional Gunners.

The aircraft associated with MACR 4497 was part of the infamous "Black Sunday" event on April 16, 1944. Almost the entire Fifth Air Force was mobilized to attack Hollandia, Dutch New Guinea, which today is known as Jayapura, the capital city of Irian Jaya

Province, Indonesia. The attacking contingent included: 68 B-24 Liberators, 51 B-25 Mitchells, 97 A-20 Havocs, and 76 P-38 Lightnings (Claringbold 1995, 22). The attack proved to be the death blow for the Japanese base (Staff 1950, 145), but a massive storm composed of towering cumulus and cumulonimbus clouds extending from as low as 100 ft up to 18,000 ft developed while the aircraft were attacking the target. The storm completely blocked the return path to Nadzab, a major U.S. airfield, through the Markham Valley. Low on fuel, facing violent weather, and forced to fly by instruments, 35 aircraft were lost to a variety of causes trying to return to their bases (Claringbold 1995, 33; Lehl 2005b, 3).

All ten men were declared missing in action on April 16, 1944. Per protocol, aerial searches were conducted for the aircraft over the next few days, but nothing was found. Bad weather and fuel exhaustion were given as likely reasons for the disappearance (Wilson 1944). MACR 4497 was next given attention in 1946 by the AGRS. The identification data for the ten men were compared against the information retrieved from the unidentified remains from the area and there were no matches. The men aboard the last flight of *Here 'Tis* were declared presumptively dead on February 25, 1946 and eventually deemed unrecoverable by the AGRS on June 8, 1949 (Lehl 2006, 4).

Surprisingly, the same initial correspondence that led to recovery of the crew of B-24J #42-100225 also provided the starting point for B-24D #42-72946. As with the previous case, the letter received by the U.S. Embassy in Port Moresby in March 2001 contained information taken from identification tags that came from individuals who were known to be aboard B-24D #42-72946, MACR 4497. In this instance CILHI confirmed that the ID tags contained the information for the bombardier and one of the gunners (Lehl 2006, 4-5).

From January to February 2002 an investigation team (IT) was deployed to Papua New Guinea. The IT successfully located and interviewed the informant who had written the letter. He recalled having found the crash site several years earlier while hunting in the mountains and admitted to having removed remains from the crash site. Subsequent to collecting the remains from the informant the IT visited the site on multiple occasions during January and February. On their first visit the IT assessed the site's potential for recovery and located the tail wreckage painted with the aircraft's identification number, which positively correlated Site PP-00046 to MACR 4497 (Berg 2002d). During a second visit the IT noted that the site had been disturbed so they established a datum and mapped the major aircraft wreckage components. In addition, they collected five separate clusters of human remains and material evidence that had been removed from their *in-situ* contexts by the local villagers. The anthropologist noted that “the piles appeared to be placed near the spots from which they were gathered and excavated out from” (Berg 2002b, 12). This careful recording allows the remains collected by the IT to be reunited in the laboratory with those recovered by the recovery teams.

The site (PP-00046) correlated to MACR 4497 is situated at approximately 1,500 m (4,900 ft) on the northern side of the Cromwell Mountains in the Sarawaget Range which comprise the center of the Huon Peninsula along the northeast coast of New Guinea. The largest population centers in any proximity to the site are Madang, approximately 128 km to the northwest, Finschhafen, approximately 72 km to the southeast, and Lae, approximately 80 km to the southwest (Emery and Tyrrell 2002, 5). The closest village to the site is Kunukio, near Sialum Station, Tewae Siassi District, Morobe Province. As previously mentioned above, Site PP-00046 is only 700 m from the crash location of B-24J #42-100225, MACR 4512 (discussed below). The site is located on topographic map: Name: Kabwum; Sheet: 8385; Series: T683; Edition: 1-AAS; Horizontal Datum: Australian Geodetic Datum 1966 (Figure 58).

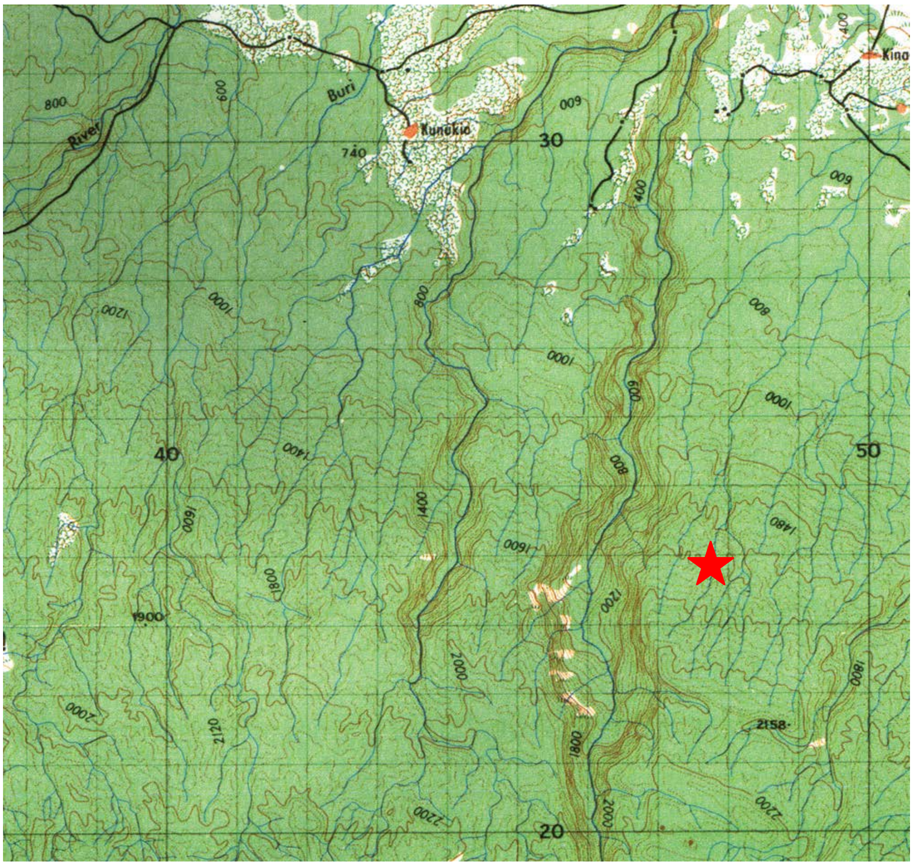

Figure 58. Topographic map showing the location of Site PP-00046 (red star).

Site PP-00046 is located on a steep, heavily forested east-facing slope bounded to the north and south by two small ravines that feed eastwards into a 15 m deep gorge that runs along an azimuth of 310°/130° and eventually drains onto the coastal grassland plains (Figure 59). The slope of the hillside within the recovery scene between the two ravines varies between 40° and 55° (Figure 60). Given that site PP-00046 is only 700 m away from Site PP-00200, the vegetation is very similar. Within, and surrounding, the site is typical triple-canopy tropical forest dominated by old-growth trees up to 30 m tall. Smaller deciduous trees comprised the intermediate canopy, with lower levels being dominated by a variety of ferns, vines, bushes, and other broad leafed plants. The ground surface is characterized by large limestone boulders, humps of topsoil, organic leaf litter and thick carpets of moss that obscure many of the smaller fragments of the aircraft (Berg 2002d, 9-10; Emery and Tyrrell 2002, 7-10; Monahan 2002b, 6-8).

Figure 59. Site PP-00046 prior to vegetation clearing. Tire and landing gear strut are visible in the foreground (red arrows) (Monahan 2002b, 7). View to south.

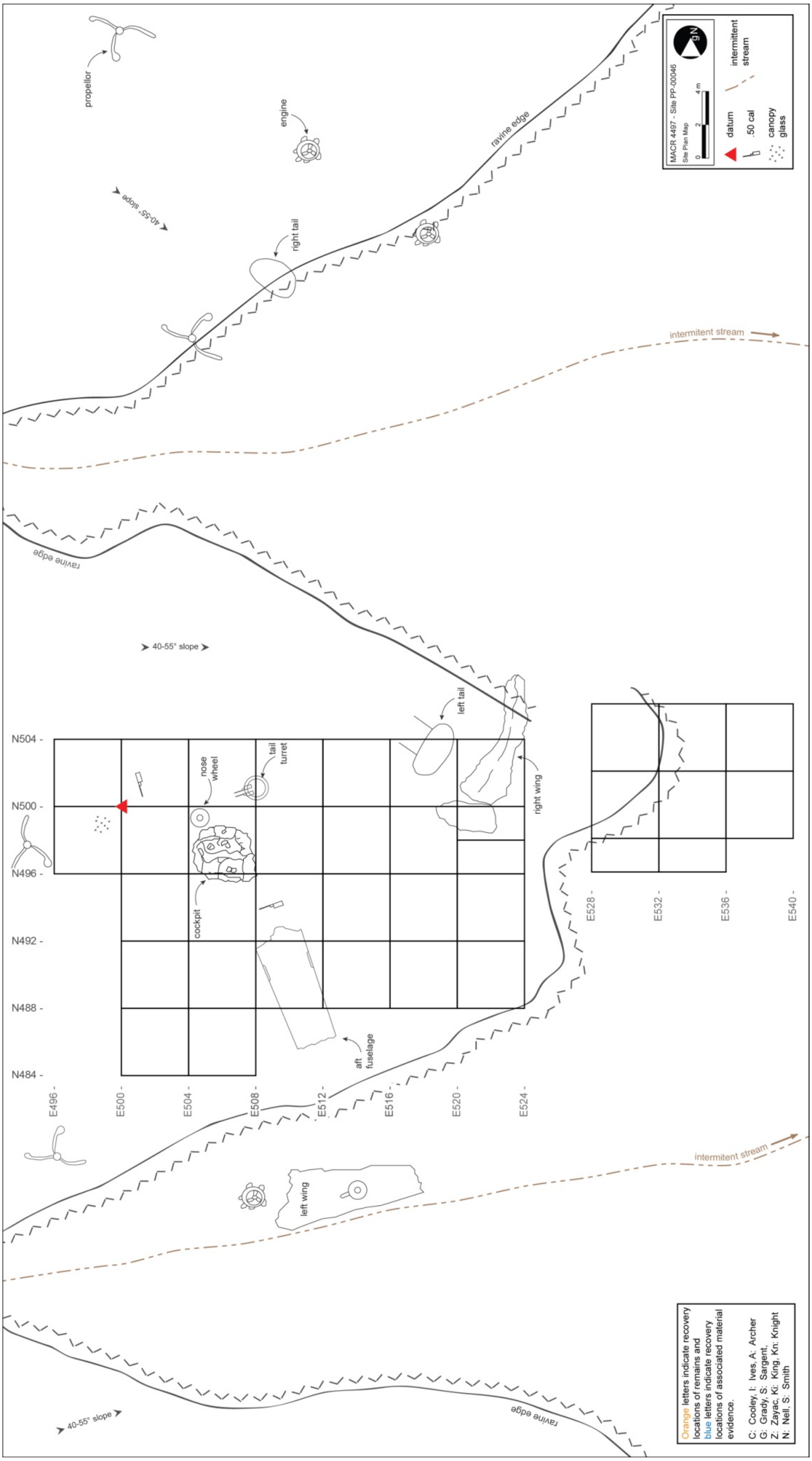

Figure 60. Map of Site PP-00046 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Monahan 2002b)

The approximately 75 m diameter debris field is centered on the relatively flat, but steeply sloped face that lies between the two ravines. Most major pieces of the aircraft rest within this area, including: the cockpit, aft fuselage, forward landing gear, as well as the .30 and .50 caliber defensive machine guns. Both wings with the landing gear retracted, radial engines, propellers, and tail sections are found within the two ravines. Evidence of human scavenging was evident in the form of the tires having been slashed open to remove the rubber from the inner tubing as well as panels of wreckage with moss covered sides facing downwards and clean surfaces exposed. However, the majority of the wreckage appeared undisturbed (Berg 2002d, 9-10; Emery and Tyrrell 2002, 7-10; Monahan 2002b, 6-8).

Full scale recovery efforts commenced on March 27, 2002 (Emery and Tyrrell 2002, 1) and would continue for three missions over the course of the spring. Excavation began along the western (upslope) edge of the debris field in units that encompassed aircraft wreckage which appeared to be consistent with the forward compartment, flight deck, and the navigator and radio operator positions. The second team continued the excavation in a two unit wide strip eastward (downslope) following the evidentiary materials. These units included two parts of the aft fuselage: the waist gunner positions and the belly turret wreckage (Emery and Tyrrell 2002, 16-17). During the third mission, two additional lanes of units, one to the north and one to the south of the initial east-west oriented swath were excavated. The remaining portion of the aft fuselage and the tail turret were included in this work. Finally, a block of units were excavated to the east of the primary excavation area in the ravine bottom to ensure that evidentiary materials had not eroded downslope (Figure 60).

A very careful excavation strategy was undertaken at Site PP-00046. All vegetation was removed prior to the disturbance of the topsoil. Only trowels were used to remove sediment and, relatively unique to this case, many of the fragments of human remains had to be extracted from the mangled wreckage itself using small hand tools and electric cutting equipment (Emery and Tyrrell 2002, 17). These two practices, despite slowing the pace of the recovery effort, enabled the archaeologist in the field to recognize and record the spatial relationships between the skeletal remains, material evidence, and aircraft wreckage as each was discovered *in situ*. Dense concentrations of human remains were recovered from the wreckage associated with the forward compartments of the aircraft the aft fuselage, the belly turret, and the tail turret. Numerous articulations within the skeletal elements were identified by the archaeologists (Emery 2002; Monahan 2002a) and several artifacts could be correlated to specific individuals (Damann 2003) (Table 29).

Figure 61. Final photograph of the main excavation are at Site PP-00046 (Monahan 2002b, 13). View to northwest.

Table 29. Provenience of identification media found at Site PP-00046.

Provenience	Identification Media
N495/E508	Identification tag (Gunner 2)
N488/E504	Identification tag (Gunner 1)
N488/E508	2 identification tags (Engineer)
N492/E508	High school ring (Assistant Engineer)
N492/E516	2 identification tags (Assistant Radio Operator)
N496/E500	Identification Card (Co-pilot)
N500/E508	Wedding ring (Pilot)

Several conclusions can be drawn from the fieldwork. The clearly retracted aft landing gear indicates that the pilots did not know that they were about to crash into the mountain. The relatively broad debris field, yet compact distribution of fuselage wreckage, indicates that the aircraft impacted with a relatively moderate degree of perpendicularity. The wings and tail sections were likely separated from the fuselage by the large trees in the area and scattered across the hillside and ravines. Additional evidence for this is the tail turret having come to rest near the cockpit wreckage instead of being located to the southeast of the aft fuselage. The orientation of the fuselage wreckage indicates that the B-24D was flying in a north westerly direction. Finally, the archaeologists who conducted the recovery of the site did not note any evidence of extensive burning within the debris field.

Analysis of the skeletal (Pokines 2006a, b, c, d, e, f, g, h, i, j, k) and dental (Torske 2006a, b, c, d, e, f, g, h, i, j) remains revealed taphonomic patterns similar to those found in MACR 10020. Sharp fracture margins consistent with massive, peri-mortem blunt force trauma that is typical for aircraft crashes were found on all elements within the skeleton. Consistent with the absence of indications for burning within the debris field during the recovery, only approximately 5% of the recovered remains exhibited any thermal alteration (Pokines 2006a, 12). The discoloration was primarily black and dark grey, not light grey or white, which suggests that the remains were not exposed to lower temperatures for relatively short periods of time. Surface erosion was common on much of the remains. Cupreous staining was also occasionally observed on the osseous material.

Overall, the remains were in relatively good condition. This allowed for more than 20 successful pair matches across the assemblage, including at least one for every individual associated with the loss. The exception to the generally good state of preservation was the epiphyses of the long bones, many of which had eroded away. This limited the number of rearticulations that could be determined to four, all of which were between a radius and ulna. To reassociate unilateral turnovers and the remains found in the five aforementioned piles with specific individuals and to aid in resolving commingling 57 samples were selected for mtDNA testing (Table 30). Furthermore, numerous dental remains, both loose and contained within mandibular and maxillary fragments, were positively associated with the nine crew members through post-mortem – antemortem matching (Table 31).

Table 30. Results of mtDNA sampling for MACR 4497.

Sample	Element	Provenience	Individual
01A	Right humerus	N495/E505	Engineer
02A	Right humerus	N493/E504	Navigator
03A	Right humerus	N495/E505	Co-pilot
04A	Right humerus	N488/E504	Radio Operator
05A	Right humerus	N492/E500	Navigator
06A	Right humerus	N492/E516	Assistant Radio Operator
07A	Right parietal	N493/E509	Assistant Engineer
08A	Right parietal	N495/E505	Engineer
09A	Right parietal	N495/E505	Co-pilot
10A	Right humerus	N492/E508	Gunner 1
11A	Right femur	N492/E516	Assistant Radio Operator
12A	Right os coxa	N495/E505	Co-pilot
13A	Right os coxa	N493/E509	Assistant Engineer
14A	Right os coxa	Unilateral	Bombardier

Sample	Element	Provenience	Individual
15A	Occipital	Unilateral	Pilot
16A	Frontal	Unilateral	Bombardier
17A	Right tibia	N495/E505	Co-pilot
18A	Left tibia	Unilateral	Pilot
19A	Right femur	N495/E505	Co-pilot
20A	Right femur	N492/E516	Gunner 1
21A	Right femur	N495/E505	Engineer
22A	Right femur	Unilateral	Assistant Engineer
23A	Right femur	N493/E504	Navigator
24A	Right femur	Unilateral	Pilot
25A	Right femur	N488/E504	Radio Operator
26A	Right femur	Unilateral	Bombardier
27A	Right femur	N501/E507	Gunner 2
28A	Tooth #11	N496/E504	Engineer
29A	Tooth #17	N493/E504	Navigator
30A	Tooth #30	N493/E504	Navigator
31A	Tooth #32	N495/E505	Co-pilot
32A	Tooth #29	N492/E508	Assistant Engineer
A	Tooth #1	Unilateral	Assistant Engineer
B	Tooth Rt Max molar	Unilateral	Bombardier
C	Tooth #4	Unilateral	Bombardier
D	Tooth #5	Unilateral	Bombardier
E	Tooth #7	Unilateral	Bombardier
F	Tooth Max canine	Unilateral	Bombardier
G	Canine	Unilateral	Bombardier
H	Tooth #13	Unilateral	Bombardier
I	Tooth #14	Unilateral	Bombardier
J	Tooth #15	Unilateral	Unilateral
K	Tooth #29	Unilateral	Pilot
L	Tooth #20	Unilateral	Pilot
M	Tooth #21	Unilateral	Bombardier
N	Man Left molar	Unilateral	Bombardier
O	Man Left molar	Unilateral	Pilot
P	Tooth #27	Unilateral	Bombardier
Q	Tooth #28	Unilateral	Bombardier
R	Tooth #29	Unilateral	Inconclusive
S	Tooth #29	Unilateral	Bombardier
T	Mand Rt molar	Unilateral	Bombardier
U	Mand Rt molar	Unilateral	Bombardier
V	Right humerus	Unilateral	Pilot
W	Right humerus	Unilateral	Gunner 2
X	Right humerus	Unilateral	Bombardier
Y	Right humerus	Unilateral	Assistant Engineer

Table 31. Dental remains correlated to a specific crew member associated with MACR 4497.

Name	Associated dental remains
Pilot	#6, #8, #10, #18, #20, #28, #30, and #31
Co-pilot	#17 - #19, #22, - #24, #27, #28, and #30 - #32
Navigator	#11, #17, #18, #22, #28, #30, and #32
Bombardier	#2, #5 - #7, #11, #13, #14, #18, #21, #27 - #31
Engineer	#1 - #7, #9 - #11, #17, #18, #20, #21, #24, #27 - #29, #31, and #32
Assistant Radio Operator	#4 - #6, #8, #9, #11 - #16, #18, #21 - #25, #27 - #29, and #31
Assistant Engineer	#1, #3 - #5, #8, #9, #11, #12 - #16, #28, #29, #31, and #32
Gunner 1	#18 and #19
Gunner 2	#2, #3, #5 - #8, and #9-#14 #17, #18, #21 - #29, #31, and #32

The recovery location of identified remains and material evidence that could be associated with a particular individual are displayed below (Figure 62). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty.

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- The identified remains of the Pilot primarily consisted of those that were unilaterally turned over to JPAC investigation and recovery teams (Figure 62). This included cranial fragments, both humeri, both tibia, and left femur. The only skeletal element recovered during excavation that could be conclusively identified to the Pilot was his right femur, which was found approximately 4 m in front of the cockpit wreckage in N500/E496 (Figure 62). His wedding ring was also found approximately 4 m from the cockpit wreckage in N500/E508.

- The Co-pilot's remains were recovered from almost entirely *in situ* contexts immediately adjacent to the cockpit wreckage (Figure 62). Only a few elements from the lower appendicular portion of the mostly complete skeleton had to be associated through pair patching. His identification card was unearthed in N495/E500, just upslope of the cockpit wreckage.

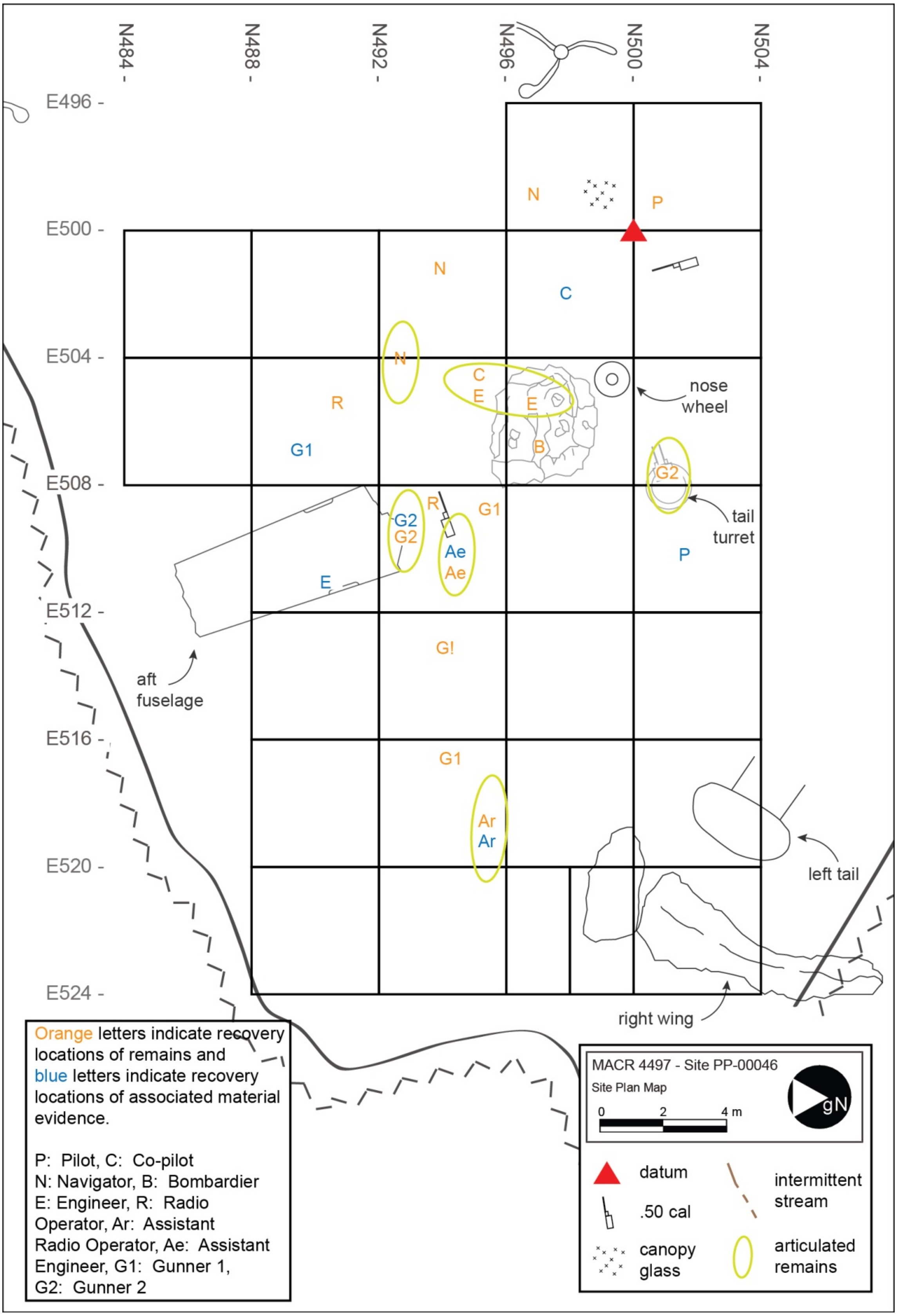

Figure 62. Map of Site PP-00046 showing the locations of identification media, identified remains, and recognizable aircraft components.
(Adapted from Monahan 2002b)

- The pelvis and legs comprised the majority of the remains identified as the Navigator. They were recovered from articulated, *in situ* contexts at N493/E504 with the feet still contained within boots (Pokines 2006d, 8). This concentration was approximately 3-4 m cross slope and behind the cockpit wreckage (Figure 62). His right humerus and half of his mandible was recovered in N492/E500 and several teeth were found in N496/E496.

- The Bombardier was almost exclusively recovered through unilateral turnover. Of the scant remains that were identified as the bombardier, only his left humerus was recovered during excavation. It was found underneath the cockpit wreckage in N496/E504 (Figure 62).

- The Engineer, was primarily recovered *in situ* in N492/E504 and from within and underneath the cockpit wreckage in N496/E504. This included all major long bones, left os coxa, and cranial fragments (Pokines 2006f, 2). His two identification tags were found amongst the aft fuselage wreckage in N488/E508 (Figure 62).

- Four elements were identified as the Radio Operator, (Pokines 2006g, 2). His right humerus and both femora were recovered from N488/E504, just upslope of the aft fuselage wreckage. The distal portion of the left humerus was found N492/E508 (Figure 62). The Radio Operator was the only individual for whom no teeth recovered.

- The most downslope set of remains recovered were those of the Assistant Radio Operator. Primarily consisting of appendicular elements, the osseous materials were found articulated *in situ* along with both of his identification tags straddling in the northeast corner of N492/E516 (Pokines 2006i, 2) (Figure 62). This is approximately 8 m east of the main orientation of the fuselage wreckage. The Assistant Radio Operator would have most likely been manning a .50 cal machine gun during the mission.

- The Assistant Engineer, was found between the aft fuselage and the cockpit wreckage in N492/E508 (Figure 62). The mostly articulared *in situ* remains included both clavicles, both humeri, both femora, right tibia, as well as cranial, pelvic, and rib fragments (Pokines 2006j, 2). The assistant engineer would have most likely been manning a .50 cal machine gun during the mission.

- Gunner 1 was the most widely distributed individual across the site. His remains extended downslope from the anterior end of the aft fuselage wreckage as follows: humeri in N492/E508, left femur at N495/E509, two teeth in N492/E512, and right femur in N492/E516 (Figure 62).

- The remains from the upper half of the tail gunner were recovered from between the aft fuselage and the cockpit wreckage in N492/E508. This included the mandible, both humerai, and right radius and ulna. However, his femora and left tibia were found under the tail turret wreckage in N500/E504 (Figure 62).

The ten Army Air Forces soldiers who died aboard B-24D *Here 'Tis*, tail number 42-72946, on April 16, 1944, or "Black Sunday" were individually identified by JPAC on July 28, 2006, a little more than 62 years after the incident (Holland 2006a).

The MACR 4497 site is a very good example of how erosion is not a particularly significant factor is site formation processes. Even on 40° to 50° slopes, nearly complete sets of articulated remains were encountered (Figure 62). The reasons for this include the large amount of wreckage, the crew members wearing numerous layers of clothing, and the very fast rate of vegetation growth in the tropics. This case is also one of the few examples where a site was over-excavated. There were no evidentiary materials along the downslope edge of the main block of units to indicate that eastern cluster (downslope) of units warranted excavation.

6.3 MACR 8641

MACR 8641 documents the September 1, 1944 loss of eight individuals of an eleven man crew aboard B-24J number 42-73453 from the 13th Air Force, 307th Bombardment Group, 424th Bombardment Squadron (Marshall 1944). On that date, as part of the overall strategy in the Southwest and Western Pacific Theaters, eighteen aircraft took off in the early morning from Wakde Airstrip, which today is known as Insoemoar Island, Indonesia along the northern coast of New Guinea Island. Their destination, approximately 1,150 km (720 mi) to the northeast, was Koror Town, Palau. The small atoll was considered a critical staging point for General MacArthur's forthcoming invasion of the Philippines. As the aircraft reached the target it was struck twice in the left wing by anti-aircraft artillery fire and the number two engine caught on fire. Two witnesses both observed aircraft #42-73453 enter a dive-to-right in an attempt to put the fire out. During this time they observed two individuals exit the aircraft and their parachutes open. Shortly after, the left wing folded back along the fuselage and broke off causing the plane to spiral out of control, break in half, and land in the water between Koror and Babelthuap Islands (Kusunoki 2008, 2). Other B-24s from the 424th circled down to approximately 4000 ft but did not observe any individuals in the water. The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Engineer, Assistant Engineer, Radio Operator, Assistant Radio Operator, Photographer and two additional Gunners.

All eleven men were listed as missing in action on 1 September, 1944 and remained in that status through the end of the war. After cessation of hostilities the Japanese government notified American forces that the Bombardier, Assistant Radio Operator, and Photographer had been captured on September 1, 1944 and sent by boat to the Philippines as POWs. After an extensive review of all eleven personnel by the Adjutant General's Office of the Department of War, a finding of death was issued on March 15, 1946. On April 21, 1949 AGRS declared the remains unrecoverable after comparing the biological information for each crew member were compared against the unidentified remains from the region (Kusunoki 2008, 3; Marshall 1944).

The resolution of the casualties listed in MACR 8641 began again in May 2000 when a professor from the University of Guam contact the CILHI with information that possibly pertained to the three individuals who were thought to have survived the crash and been sent to the Philippines. Extensive archival research into Japanese military police testimony given at war crimes trials after the war by CILHI and JPAC investigators has lead to the conclusion that Bombardier, Assistant Radio Operator, and Photographer were most likely executed on either September 4th or 5th, 1944 and buried on Babelthuap. An excavation at Gasupan Hill in January, 2004 during mission 04-1PS failed to find any evidence of the three missing airmen (Kusunoki 2008, 4-6). During the excavation the recovery team was approached by a third party researcher who claimed to have found a submerged B-24 Liberator off the southwest coast of Babelthuap Island (Emery 2009, 2-3; Kusunoki 2008, 6). On January 30 and 31 JPAC-CIL personnel conducted a scuba diver reconnaissance survey that included a wreckage inventory and an assessment of areas that possessed a high likely hood of contained evidentiary materials. Three weeks later, in February 2004 additional investigatory work was undertaken to map the wreckage distribution. Human remains and other incident related materials were collected at this time and returned to Hawaii (Belcher 2004, 9).

The recovery scene correlated to MACR 8641 is comprised of three separate concentrations of aircraft wreckage, Loci A, B, and C, which are located in Aimeliik State, Babelthuap Island, Republic of Palau. Loci A and B, initially identified by the investigation teams in January and February, are on opposite sides of a large coral head. Locus C, discovered during the excavation of the site, is 220 m on a bearing of 160° from Locus A, and 240 m on a bearing of 150° from Locus B. The site can be located on map: Name: USGS Topographic Map of Oreor, Republic of Palau, Caroline Islands; Series: N707-E13441; Scale: 1:25,000; Datum: Guam 1963; Date: 1983 (Figure 63 and Figure 64).

Loci A and B are divided by a large, 80 m diameter coral head (Figure 65). Locus A, on the east side, is comprised of the steep basal portion of the coral head that meets the sandy sea bottom at angles between 60° and 80°. From the base of the coral the seafloor slopes gently downward in a northwest to southeast direction until leveling off at a depth of approximately 22 m. Locus B, like A, is similarly located near the bottom of the coral formation. However, the west side of the coral head is not as steeply sloped (45°) as it meets the seabed, which then descends away towards the southwest to the same depth as Loci A. Locus C, southwest of the coral head containing the majority of the wreckage, is situated on an open, relatively sandy stretch of sea bottom near a separate reef arm. It slopes at 35° to the northwest where is reached a maximum depth of 20 m in a navigation channel (Emery 2009, 8-9).

In addition to their specific localized environments, there are conditions that were consistent at all three loci due to the crash site being located in 8 to 23 m sea water. Palau's low latitude results in annual water temperatures between approximately 25° to 27°C (78° to 82°F) and the wreckage being subjected to high levels of ultraviolet radiation. Semi-diurnal tidal fluctuations of up to 2 meters, combined with relatively constant currents, has resulted in a hydrodynamic environment in which sediments have been deposited along the northeast side of the large fragments of wreckage. The aircraft wreckage at all three loci supports a Indo-Pacific Biota ecosystem of organisms that is typically found in the tropical reef life zones of Micronesia. This includes a wide variety of corals, cnidaria, sponges, annelids, mollusks, arthropods, echinoderms, and bony and cartilaginous fishes. All of these environmental factors caused both physical and chemical disturbances to the incident related material including staining, oxidation, and corrosion of metal, glass, leather, textiles, and in some instances, human remains (Emery 2009, 18).

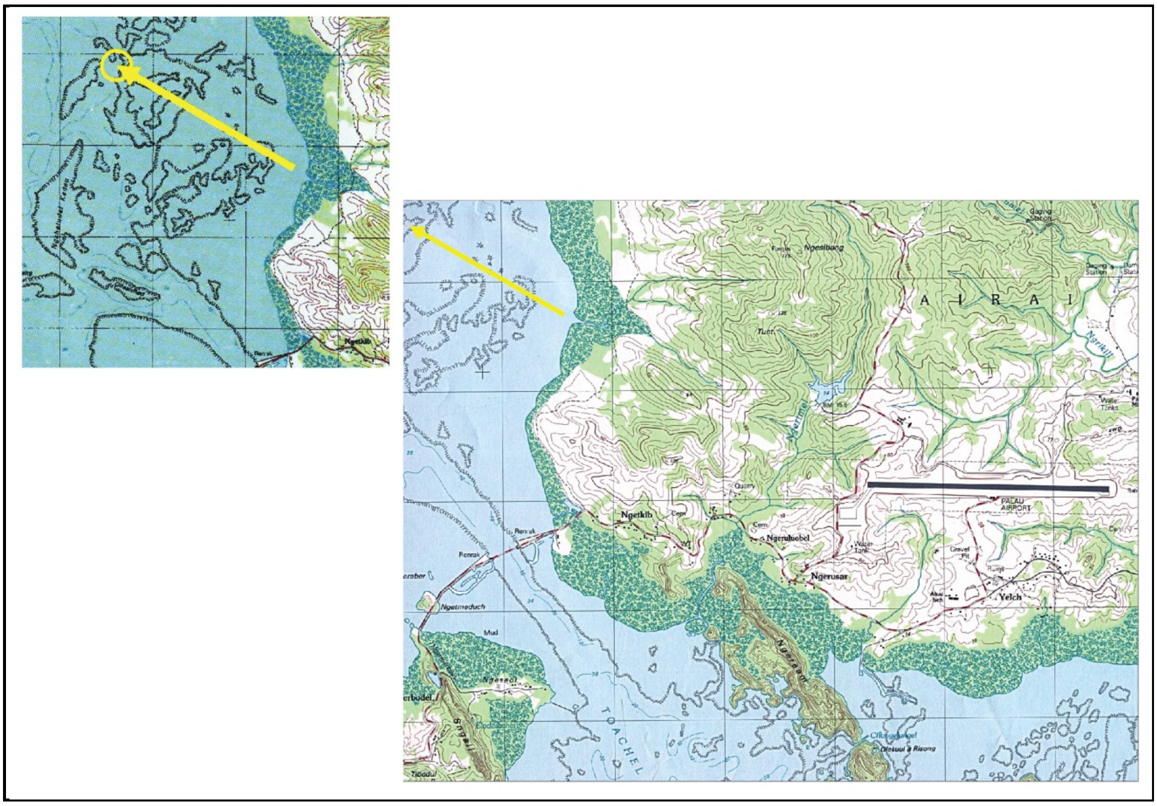

Figure 63. Topographic map showing the location of Site PP-00023 (Emery 2009, 6)

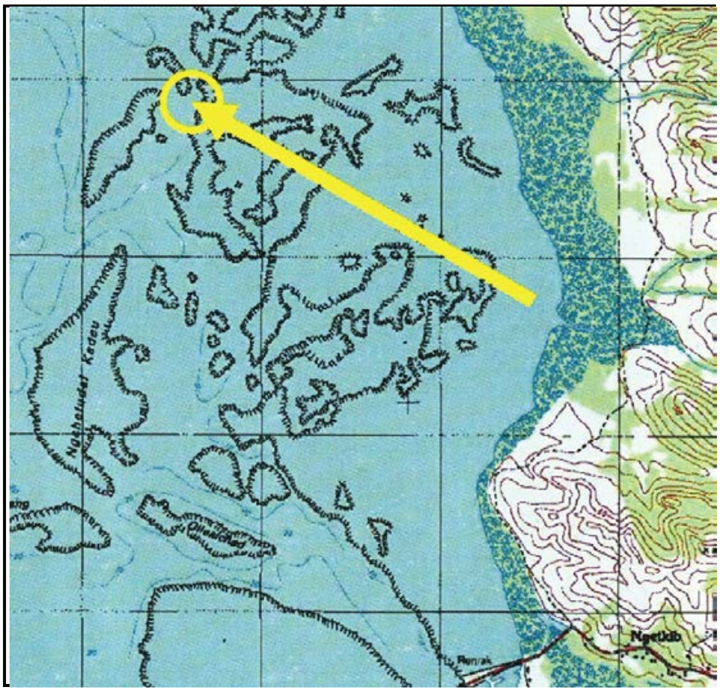

Figure 64. Detail view of the same map showing the coral head and the crash location (yellow arrow and circle). (Emery 2009, 6)

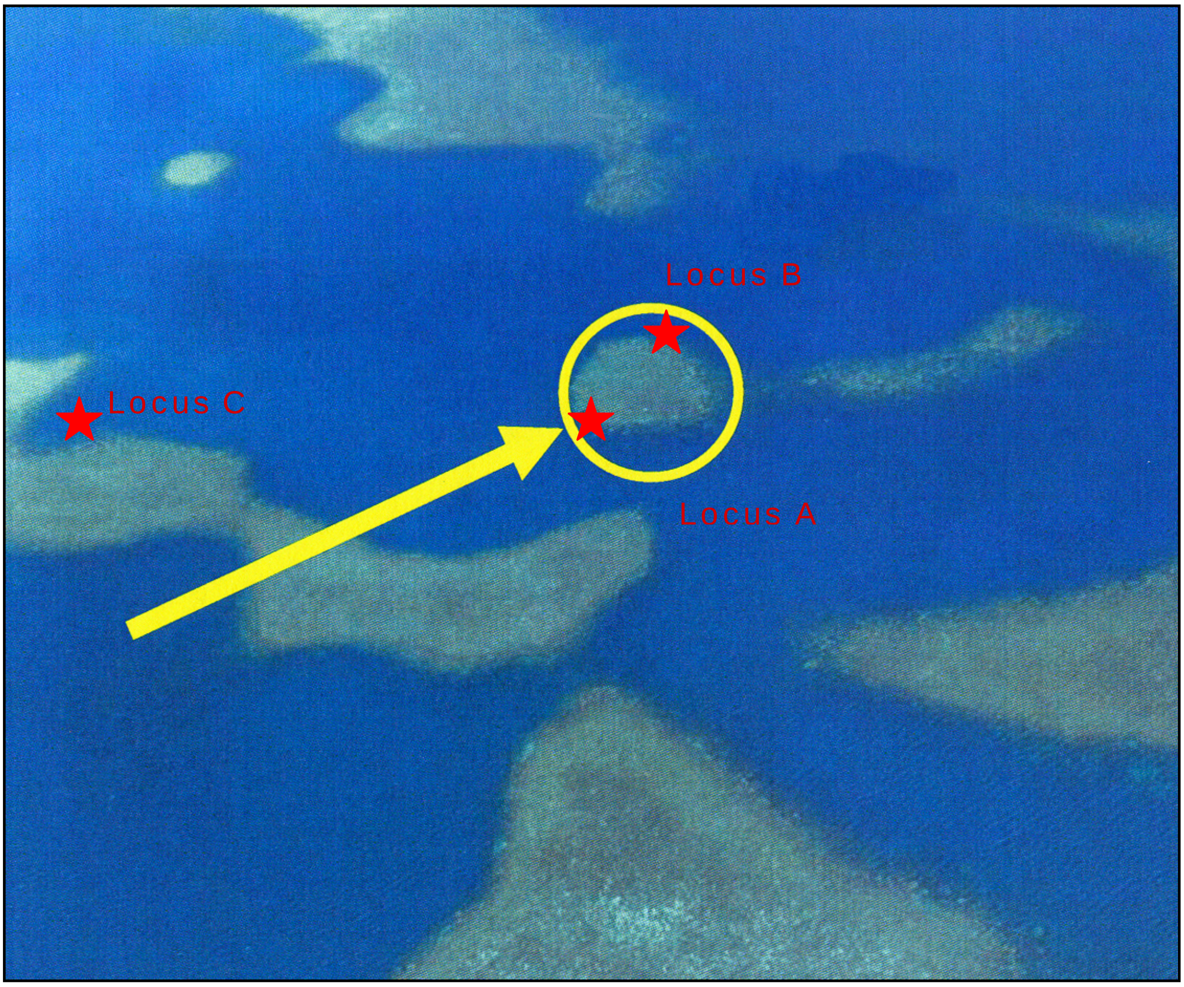

Figure 65. Aerial photograph of the coral head dividing the crash site and the three site loci (red stars).
Yellow arrow denoting coral head location is also oriented to magnetic north (Emery 2009, 7).

Feature 1, which makes up the major portion of Locus A, consists of a large section of fuselage from just aft of the rear bomb bay, just forward of the belly ball turret, to the rear window frame adjacent to the horizontal stabilizer of the tail (Figure 66, Figure 67, and Figure 68). The wreckage is approximately 10 m long in a 140°/320° orientation and 6 m wide at its maximum. The fuselage rests on its port side with the starboard waist gunner's window facing up off of the sea floor and the forward portion angled downwards. The starboard horizontal and vertical stabilizers are still attached to the fuselage, but the tail gun turret itself is not present (Emery 2009, 8).

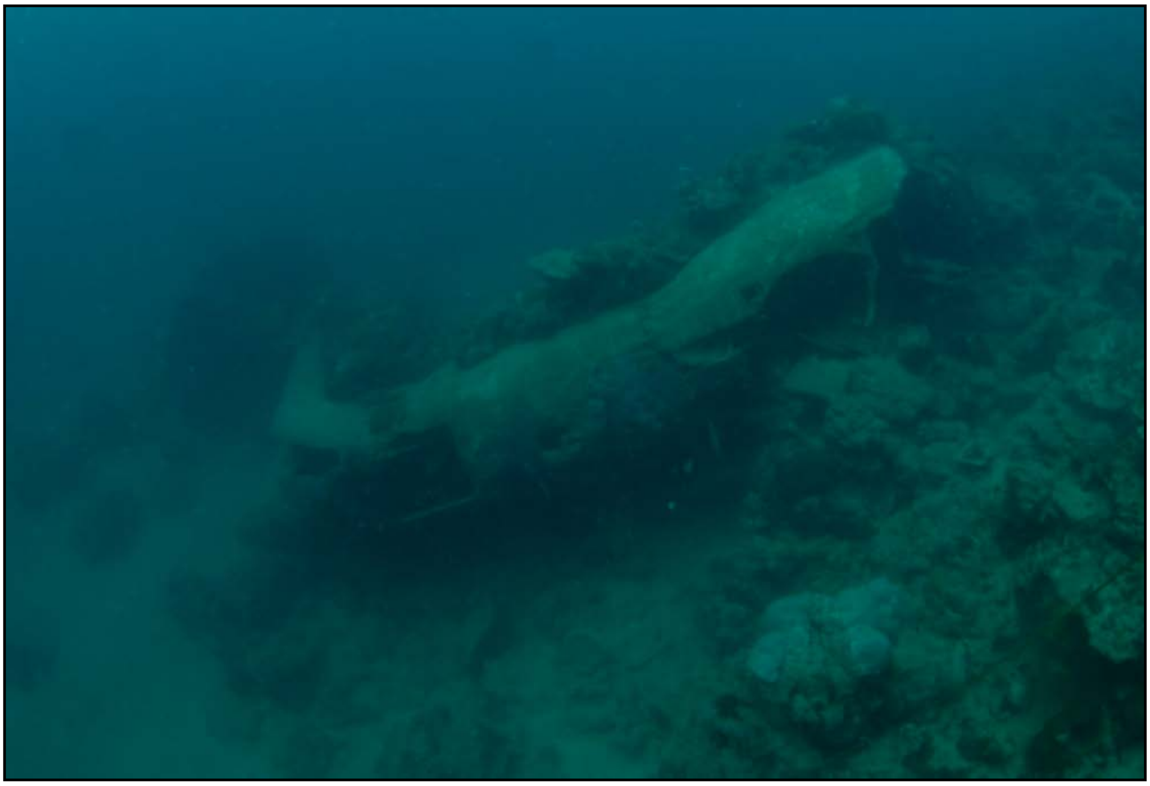

Figure 66. Locus A Feature 1, the aft portion of the aircraft fuselage from approximately the of the bomb bay doors and belly gun to the starboard tail components.
(Emery 2009, 9)

Figure 67. Locus A Feature 1, view to northwest.
(Emery 2009, 10)

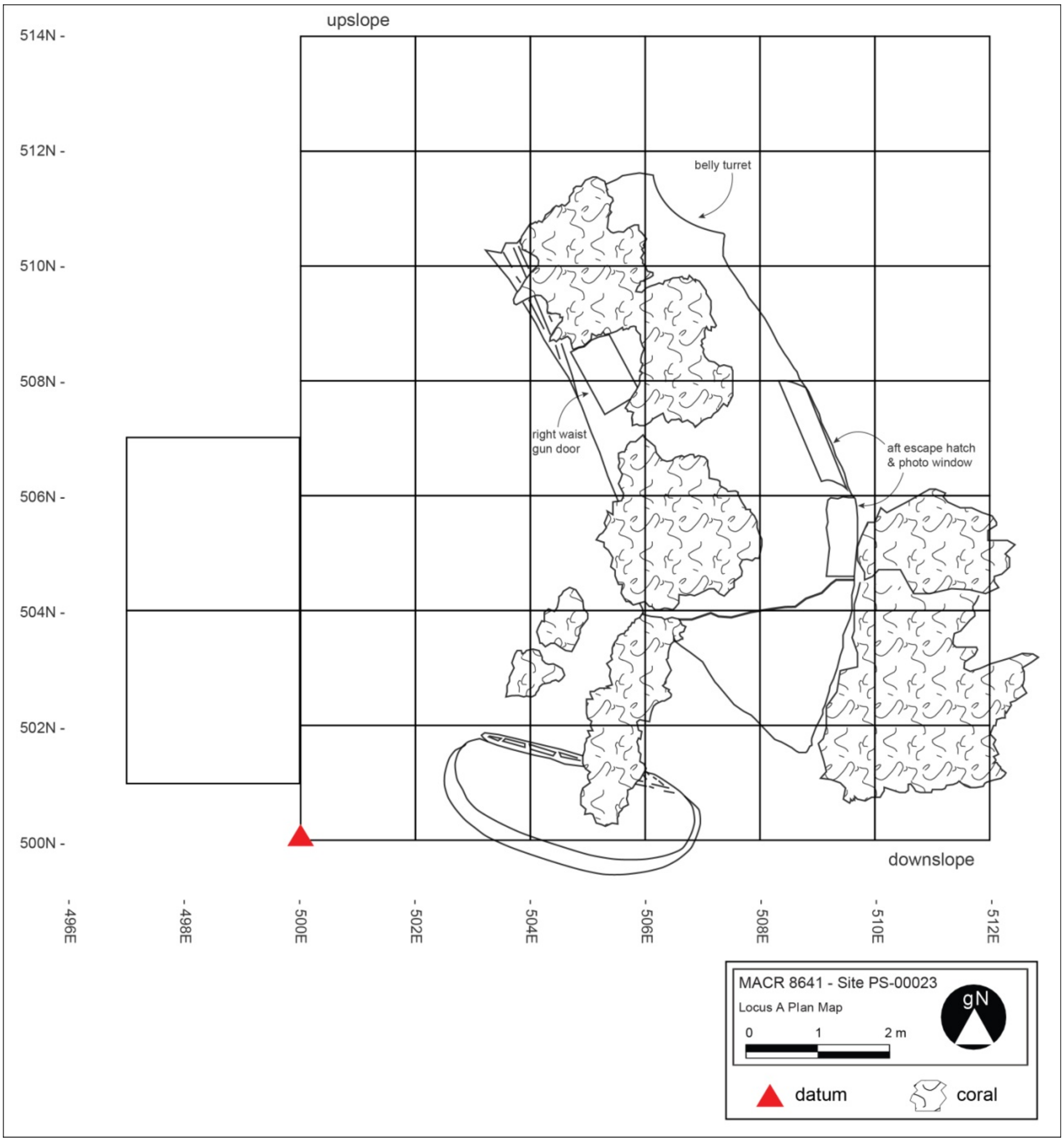

Figure 68. Map of Site PS-00023, Locus A, depicting the major aircraft fragments and prominent terrain features.
(Adapted from Emery 2009)

Feature 2 is the forward section of the fuselage that is located at Locus B. Wreckage from the top gun turret, radio operator and navigator positions, cockpit, and the forward nose compartment are all present and arranged in a northeast-southwest orientation in an approximately 12-x-12-m area (Figure 69 and Figure 70). The two nose turret .50 cal machine guns are located at the southwest corner of the 144 m^2 and are closest the transition between the coral head and the sea floor. The flight deck including the pilot seats, center console, and nose landing gear assembly compartment were situated farther up the gradually clopping coral oriented along the azimuth 100°/280°. Farthest to the northeast was the base rotational ring from the nose gun turret. Additional wreckage at Locus B that was resting on the sea floor a short distance away from the coral head included two engines, a propeller, and the outboard section of the right wing (Emery 2009, 8-9).

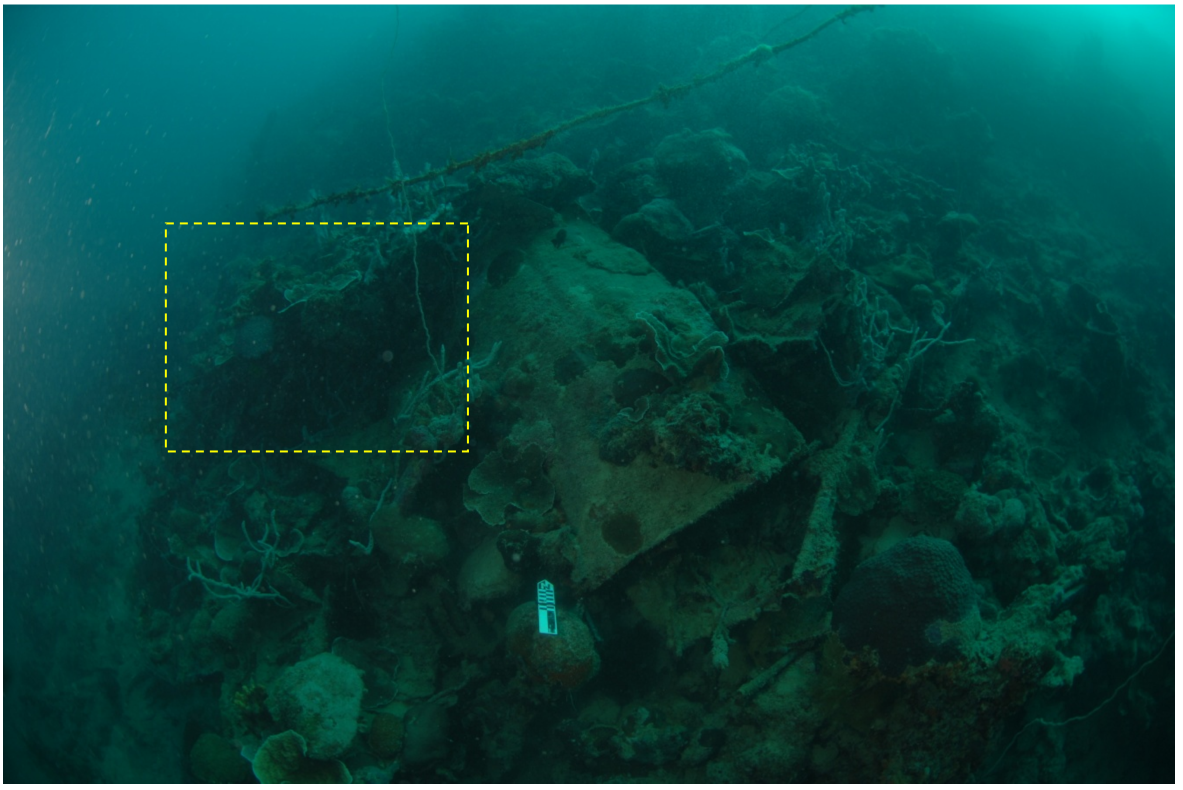

Figure 69. The cockpit wreckage area and flight deck pedestal (yellow box) within Locus B Feature 2.
(Emery 2009, 13)

Feature 3 at Locus C was an isolated fragment of wreckage comprised of the port tail assembly. The vertical portion of the stabilizer was still attached to the horizontal section and they were oriented in the cardinal directions. The piece of the vertical stabilizer that is normally positioned below the horizontal segment was completely detached and was resting inverted on the sea bottom about 2 m away.

As expected, the left wing, which had been hit by the anti aircraft fire, was never located. Surprisingly, despite finding the aft portion of the fuselage and both the port and starboard tail sections, the tail gun turret was never discovered either.

Three missions were necessary to complete the recovery at Site PS-00023: April 8 – May 20 2005, January 29 – March 29 2007, and 18 January – 29 February 2008. Underwater excavation follows the same basic archaeological methods and techniques as terrestrial work including establishing a datum and excavating in grid units. The major difference is that the primary means of sediment removal is a 10 cm diameter suction dredge system

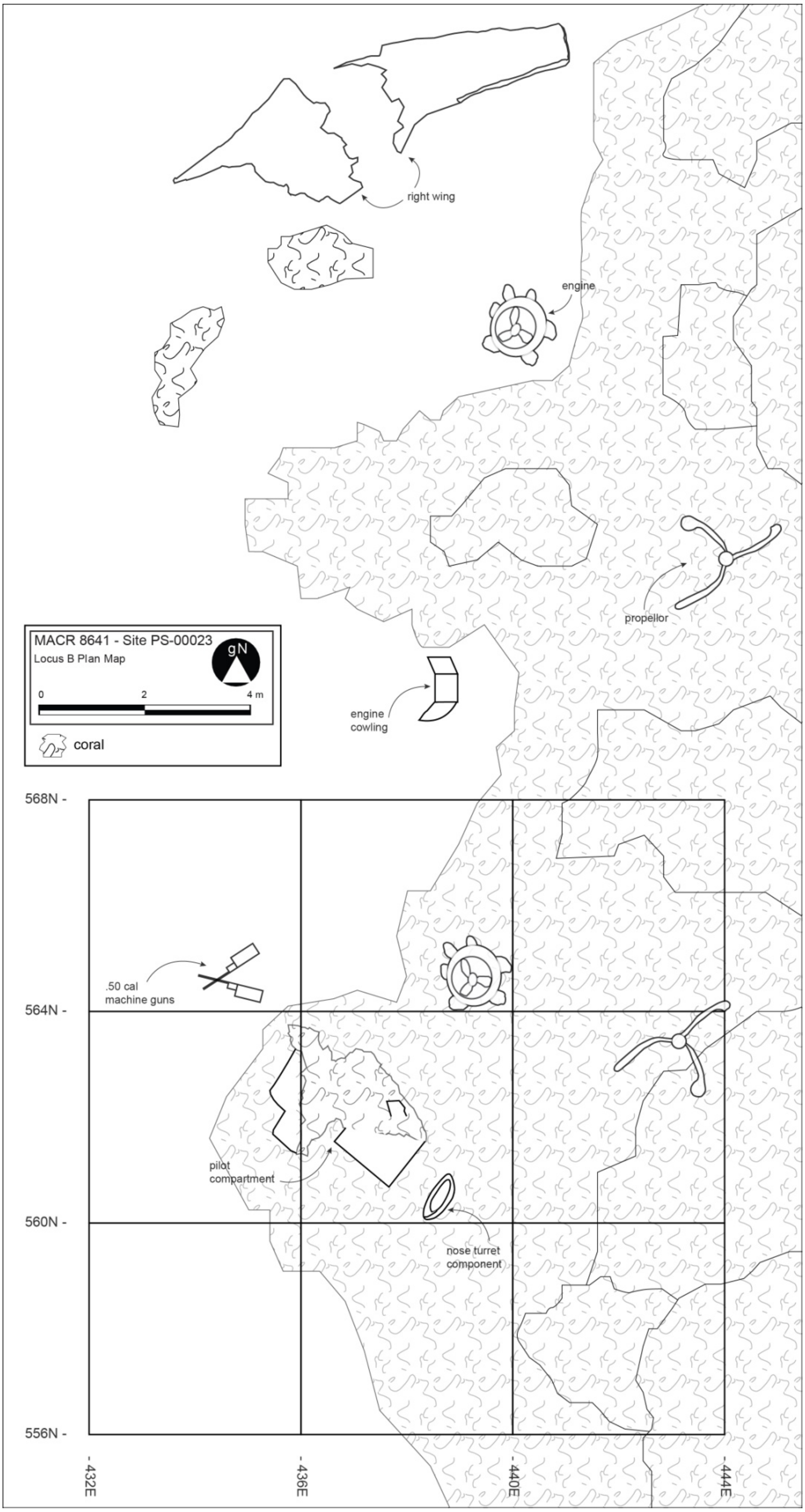

Figure 70. Map of Site PS-00023, Locus B, depicting the major aircraft fragments and prominent terrain features.
(Adapted from Emery 2009)

that transports material to a large, 1/4" mesh lined metal basket, which is then raised to a barge on the surface where it is wet screened. Trowels and other small hand tools are used to remove incident related materials from coral concretions and smaller spaces. The narrow opening of the dredge and the use of small hand tools allowed excavators to spot evidentiary materials *in situ* and record detailed field provenience including articulations between skeletal elements (Emery 2009, 22).

Excavation began in Locus A along the outside of the fuselage (Feature 1). This area was not completed due to safety concerns about the stability of the fuselage on the steep coral slope. In 2007 a specially fabricated cradle was used to support and stabilize the fuselage, allowing the completion of excavation at Locus A. The barge was then repositioned over Locus B, and Feature 2. Work at the forward fuselage section occupied the remainder of the 2007 mission as well as the first half of the 2008 mission. Finally, Locus C, Feature 3, was completed (Emery 2009, 26-28). Combined, a total approximate surface area of 468 m^2 was excavated to an average depth of 66 cm below the sea floor. The depth of excavation varied substantially due to incident related material and evidentiary materials have settled and filled many deep inter-coral spaces. Clusters of articulated osseous remains with associated personal effects including items such as identification tags, coins, apparel fragments, military equipment were found during all three missions (Silverstein 2008) (Table 32). These groupings were associated with the waist gun door, pilot seat, and nose gunner duty stations.

Table 32. Provenience of identification media found at Site PS-00023.

Provenience	Identification Media
N560/E436	Identification tag (Pilot)
N508/E504	Identification tag (Gunner 2)
N506/E504	Identification tag (Gunner 2)
N560/E440	2 identification tags (Assistant Engineer)

Surface examination and excavation revealed that each of the two major sections of the B-24, the forward fuselage with the right wing and the aft fuselage settled in relatively small areas. This indicates that there was little to no forward momentum of the aircraft debris when it impacted the water and that there was a degree of perpendicularity close to 90. It also appeared that the forward fuselage section sustained substantially more damage from impacting the water the aft. This was evidenced by the front landing gear having been found pushed between the pilot and co-pilot seats, while the aft section was largely intact and uncrushed.

Analysis of skeletal (To 2009a, b, c, d, e) and dental (Franklin 2008a, b, c, d) remains reflects a dynamic tropical marine taphonomic environment. The constant movement of sand has abraded many of the surfaces causing physical changes to the remains. To notes that “the borders of the skeletal fragments are similar in appearance with the intact cortical surface of the surrounding bone“ (2009a, 2). Additionally, many edges have been worn and abraded. These effects made it difficult to differentiate between perimortem and post-mortem trauma in some instances. However, angular fractures were frequent enough to sufficiently conclude that the individuals underwent massive blunt force trauma consistent with an aircraft crash. Many of the skeletal elements have calcareous concretions adhering to them containing a variety of small fragments of aircraft wreckage and marine life such as shells. Staining and discoloration from contact with various types of metal is also common.

Field provenience was the primary means of resolving comingling within the skeletal assemblage. To confirm the field observances, 53 samples were selected for mtDNA sequencing, all of which returned usable samples representing five different individuals (Table 33). Direct articulations between fragments of the same skeletal element and pair matches were also utilized on two of the personnel who were individually identified. Postmortem – antemortem dental matching was possible for four crew members (Table 34).

Table 33. Results of mtDNA sampling for MACR 8641.

Sample	Element	Provenience	Individual
01A	Left tibia	N560/E436	Pilot
02A	Right femur	N560/E436	Pilot
03A	Mandible	N506/E504	Gunner 2
04A	Left temporal	N510/E506	Gunner 2
05A	Left tibia	N560/E440	Assistant Engineer
06A	Right ulna	N560/E440	Assistant Engineer
07A	Right temporal	N560/E440	Assistant Engineer
08A	Mandible	N560/E440	Assistant Engineer
09A	Left clavicle	N560/E440	Assistant Engineer
10A	Left clavicle	N560/E436	Pilot
11A	Left clavicle	N564/E436	Pilot
12A	Right clavicle	N564/E436	Pilot
13A	Ulna	N560/E436	Pilot
14A	Left scapula	N560/E436	Pilot
15A	Right scapula	N560/E436	Assistant Engineer
16A	Left os coxa	N560/E436	Assistant Engineer
17A	Right os coxa	N560/E436	Assistant Engineer

Sample	Element	Provenience	Individual
18A	Right radius	N564/E436	Pilot
19A	Left radius	N560/E440	Assistant Engineer
20A	Left radius	N560/E436	Pilot
21A	Right humerus	N560/E436	Pilot
22A	Left humerus	N560/E436	Pilot
23A	Left humerus	N560/E440	Assistant Engineer
24A	Left fibula	N564/E436	Pilot
25A	Right temporal	N560/E436	Pilot
26A	Left ulna	N560/E436	Pilot
27A	Right fibula	N560/E436	Assistant Engineer
28A	Right tibia	N560/E436	Assistant Engineer
29A	Tooth #6	*	Navigator
30A	Tooth #11	*	Navigator
31A	Left femur	N560/E436	Pilot
32A	Right tibia	N564/E436	Pilot
33A	Right os coxa	N560/E436	Pilot
34A	Right scapula	N560/E436	Pilot
35A	Lumbar vertebra	N560/E436	Pilot
36A	Femur	N560/E440	Engineer
37A	Tibia	N564/E436	Pilot
38A	Ulna	N560/E436	Engineer
39A	Long bone	N560/E436	Pilot
40A	Long bone	N560/E436	Engineer
41A	Long bone	N560/E436	Pilot
42A	Long bone	N560/E436	Pilot
43A	Rib	N564/E436	Pilot
44A	Parietal	N560/E436	Pilot
45A	Right metatarsal 1	N560/E436	Assistant Engineer
46A	Left metacarpal 2	N560/E436	Pilot
47A	Right femur	N560/E436	Assistant Engineer
48A	Left femur	N560/E440	Assistant Engineer
49A	Left fibula	N556/E440	Assistant Engineer
50A	Right radius	N560/E440	Assistant Engineer
51A	Right clavicle	N560/E440	Assistant Engineer
52A	Left scapula	N560/E440	Assistant Engineer
53A	Rib	*	Assistant Engineer

*Provenience data for these samples is unavailable.

Table 34. Dental remains correlated to a specific crew member associated with MACR 8641 who did not bail out of the aircraft.

Name	Associated dental remains
Pilot	#2, #12 - 16, and #20 - 21
Navigator	#6 and #11
Assistant Engineer	#22, #29, #30, and #32
Gunner 2	#2, #11, #17 - 19, #30, and #32

The recovery location of identified remains and material evidence that could be associated with a particular individual are displayed below (Figure 71 and Figure 72). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty. Remains that could be attributed to a specific individual through provenience, articulation, and pair matching are also displayed.

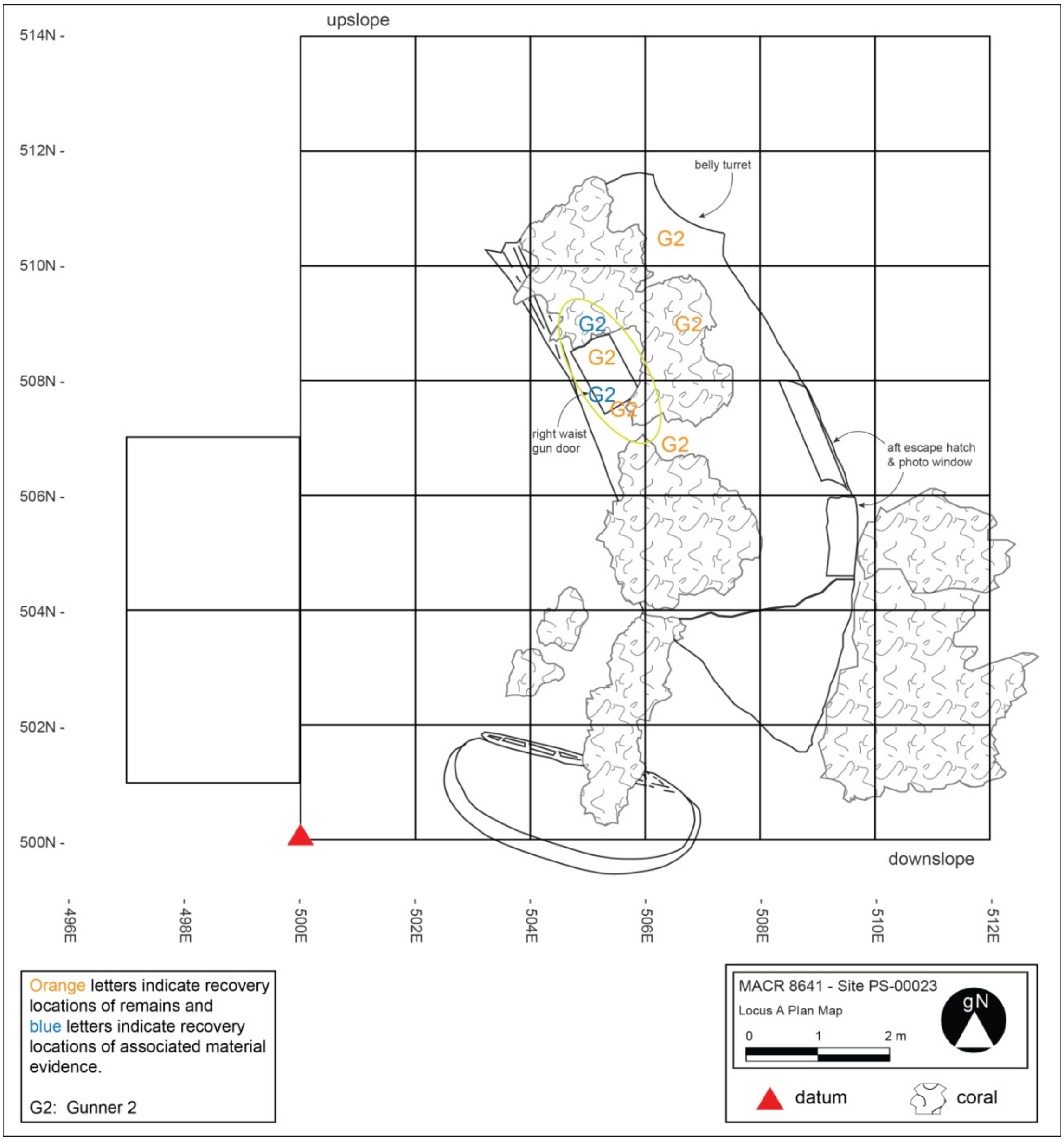

Figure 71. Map of Locus A, Site PS-00023 showing the locations of identification media, identified remains, and recognizable aircraft components.
(Adapted from Emery 2009)

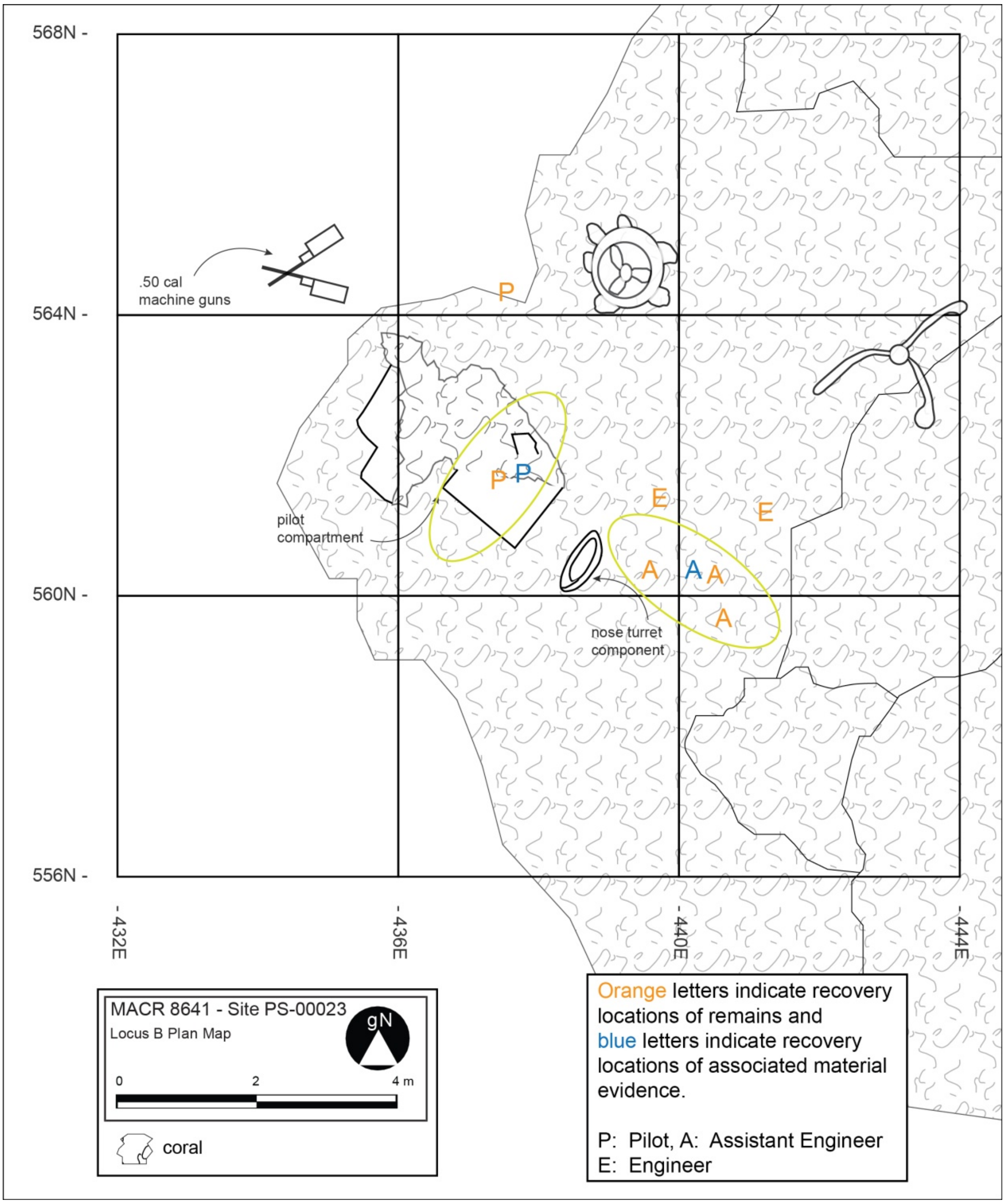

Figure 72. Map of Locus B, Site PS-00023 showing the locations of identification media, identified remains, and recognizable aircraft components.
(Adapted from Emery 2009)

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual who did not parachute from the aircraft:

- The largely complete skeleton of the Pilot was recovered *in situ* from the pilot seat in N560/E436 (Figure 72). One of his identification tags was also found in this location. Some elements were also recovered downlope of the cockpit wreckage in N564/E436.

- Remains were recovered *in situ* from the Co-pilot seat, but the CIL was unable to locate an appropriate matrilineal descendant of to provide a family reference sample for mtDNA comparison. Without being able to confirm any remains as belonging to the Co-pilot, those skeletal elements were included in the group identification.

- Two teeth were identified as belonging to the aircraft's Navigator. Provenience was not maintained by the analyst, so it is not possible to determine exactly where they were recovered.

- The Engineer was represented by three skeletal elements: a sliver of a femur recovered from N560/E440 and two ulna midshaft fragments found in N560/E436 (Figure 72). All three were within the immediate vicinity of the navigator and nose compartment wreckage.

- The Assistant Engineer was recovered almost entirely *in situ* from within the nose compartment wreckage. The remains surrounded the N560/E440 corner in the excavation grid (Figure 72).

- No personal items or remains were recovered that could be associated to the Radio Operator.

- No personal items or remains were recovered that could be associated to Gunner 1.

- Gunner 2 was found within the aft fuselage of the aircraft at Locus A. His remains and two identification tags were found primarily *in situ* underneath the starboard waist gunner's opening in units N506/E504 and N508/E504 (Figure 71). Additional elements were recovered from the surrounding units.

Of the 11 individuals aboard B-24J #42-73453 on September 1, 1944, eight were unable to escape the aircraft after it had been struck by anti-aircraft fire. All of them were identified on February 12, 2009, more than 64 years after the crash. Five as individuals and the remainder as a group (Holland 2009b).

In addition to being the only underwater case, MACR 8641 is unique to the case studies in two other aspects. First, it is the only aircraft that was flying at a high altitude when struck by enemy fire and broke in half resulting in an extended vertical fall. Additionally, this is the only case study, to include the cargo aircraft, in which crew members parachuted from the aircraft prior to the crash. The significance of this will be discussed in Chapter 10.

6.4 MACR 4512

MACR 4512 involves the April 16, 1944 loss of eleven individuals aboard B-24J, tail number 42-100225 from the 5th Air Force, 22nd Bomber Group, 408th Bomber Squadron (Lehl 2005b, 1). Like the MACR 4497 aircraft, MACR 4512 was part of the infamous “Black Sunday” event. The aircraft departed Nadzab, PNG to participate in the strike mission at Hollandia. There are no records of the crew’s actions over Hollandia, but they joined up with four other B-24s for the return flight to Nadzab. The group of five aircraft proceeded southeast along the coast and turned inland (south) just past Wewak and proceeded on to Annanberg where they encountered the storm. In an attempt to avoid the storm they turned east toward Madang and headed out to sea. The final sighting of aircraft #42-100225 was by 1st Lt Dwain E. Harry, another pilot in the returning B-24 formation. During the investigation into the loss of the aircraft he noted that the aircraft passed through a particularly large and dark cloud formation just off the coast of Saidor, and was not seen again (Lehl 2005b, 2-3). The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Observer, Engineer, Assistant Engineer, Radio Operator, Assistant Radio Operator, and two additional Gunners.

The following day, 15 B-25s from the 5th Bomber Command searched an extensive area encompassing Saidor, Nadzab, and Morobe Provinces for the missing aircraft, but nothing was found. The 11 crew members were declared missing in action as of April 16, 1944. MACR 4512 was examined again on multiple occasions over the next several years in an attempt to locate the missing individuals in any known, or unknown, graves, but no correlations could be determined. The U.S. Army declared the men presumptively dead as of February 25, 1946 and on December 15, 1947 the AGRS declared the remains of all 11 crewmen non-recoverable. In 1948, an analyst working on the case concluded that the aircraft most likely crashed into the ocean based upon the last observed location, which placed it over the sea, and the failure of the subsequent search to locate the aircraft over land (Lehl 2005b, 3-5).

Fifty-two years later, in March 2001, the U.S. Embassy in Port Moresby received a letter reporting the finding of human remains and identification tags from two WWII aircraft crashes. The text from each of the tags was included in the letter. The embassy faxed the letter to CILHI which confirmed that information from two of the identification tags belonged to the Assistant Engineer and one of the Gunner 2 who were aboard B-24J #42-100225, MACR 4512 on Black Sunday (Berg 2002c; Lehl 2005b, 5).

An IT was sent to Papua New Guinea from January to February 2002 to investigate the case. They successfully located and interviewed the author of the letter in regards to the site. He recalled having found the crash site several years earlier while hunting in the mountains and admitted to having removed remains from the crash site. Subsequent to collecting the remains from the informant, the IT traveled to the crash site. During the initial reconnaissance of the site the IT located a tail rudder with the number “2100225”, which correlated the crash site with the aircraft listed on MACR 4512 (Berg 2002c, 12-13).

The site (PP-00200) correlated to MACR 4512 is situated at approximately 1,500 m (4,900 ft) on the northern side of the Cromwell Mountains in the Sarawaget Range which comprise the center of the Huon Peninsula along the northeast coast of New Guinea. The largest population centers in any proximity to the site are Madang, approximately 128 km to the northwest, Finschhafen, approximately 72 km to the southeast, and Lae, approximately 80 km to the southwest (Emery and Tyrrell 2002, 5). The closest village to the site is Kunukio, near Sialum Station, Tewae Siassi District, Morobe Province (Figure 73). Interestingly, the site is only 700 m from the crash location of B-24D #42-72946, MACR 4497. The site is located on topographic map: Name: Kabwum; Sheet: 8385; Series: T683; Edition: 1-AAS; Horizontal Datum: Australian Geodetic Datum 1966 (Berg 2002c).

Site PP-00200 is located in the extremely rugged terrain. The complicated site is spread across eight east or west facing hillsides associated with five north-south oriented ridges (Figure 74). A 10 m wide 5 m deep, limestone bedrock and boulder strewn ravine runs along an azimuth of 35°/215° cutting between the two eastern most ridges (Figure 75). Hill slopes within the site range from small flat spots along the ridge-tops to nearly vertical in the case of the cockpit wash feature on the eastern face of the east-most ridge. On average, however, the hillsides vary between 50° and 70° (Figure 76). Within and surrounding the site is typical triple-canopy tropical forest dominated by old-growth trees up to 30 m tall. Smaller deciduous trees comprised the intermediate canopy, with lower levels being dominated by a variety of ferns, vines, bushes, and other broad leafed plants. The ground surface is characterized by large limestone boulders, humps of topsoil, ground roots from the large trees, organic leaf litter and thick carpets of moss that obscure many of the smaller fragments of the aircraft (Berg 2002c, 4-6; Haugen 2002b, 3-11; Sturm 2005, 4-8).

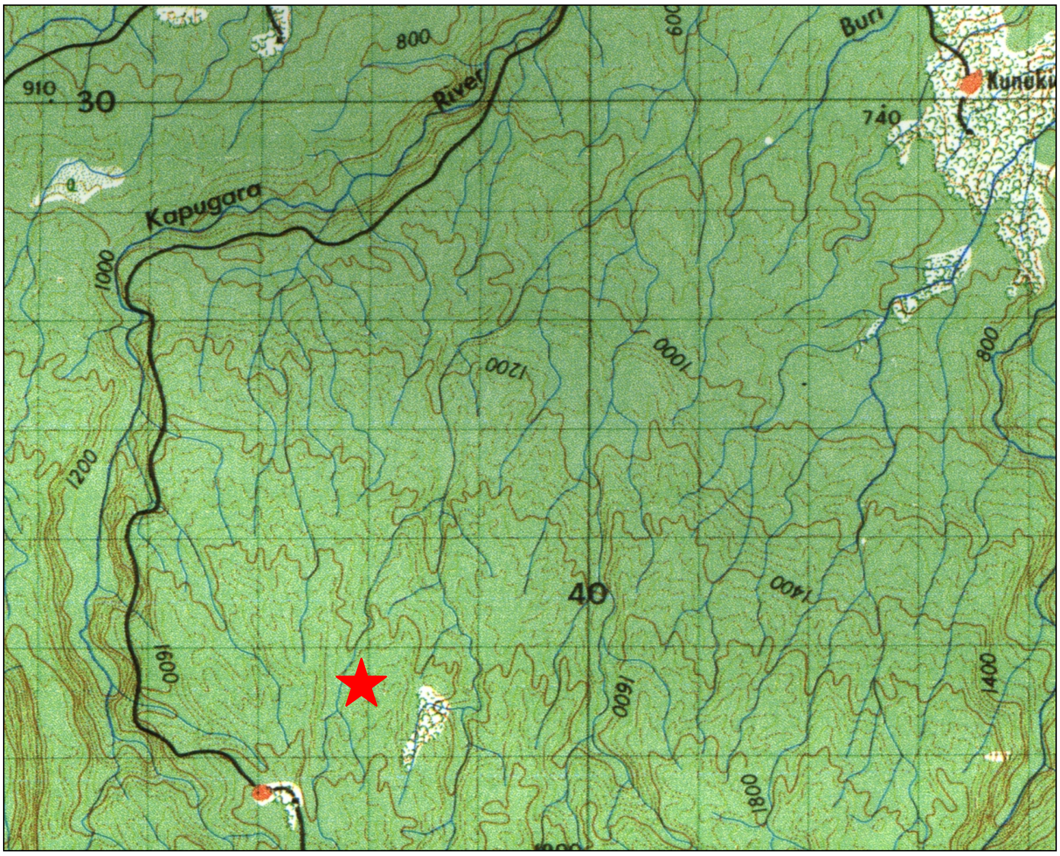

Figure 73. Topographic map showing the location of Site PP-00200 (red star).

Due to the site's complex topography the wreckage is described in an east to west direction with the east-most ridge being referred to as the first ridge. The western side of this first ridge has an approximately 30 m by 30 m parabola-shaped scatter of wreckage arcing away from the ravine. Diagnostic components within the outer reaches of this area included two .50 cal machine guns. The majority of the wreckage, including a complete bomb rack and a fragment of nose art, on this slope is situated in the center along the ravine and extends 20 m in a north-south direction and 15 m in an east-west orientation. An 80° wash slopes down to the top edge of the ravine that contains cockpit components and nose turret fragments. The ravine between the first and second ridges is the ravine, which contains the majority of the left wing including two engines, propellers, and landing gear. Two more .50 cal machine guns are present as well as several canteens and parachute components (Berg 2002a, 14-15; 2002c; Haugen 2002a; b, 3-11; Sturm 2005, 4-8).

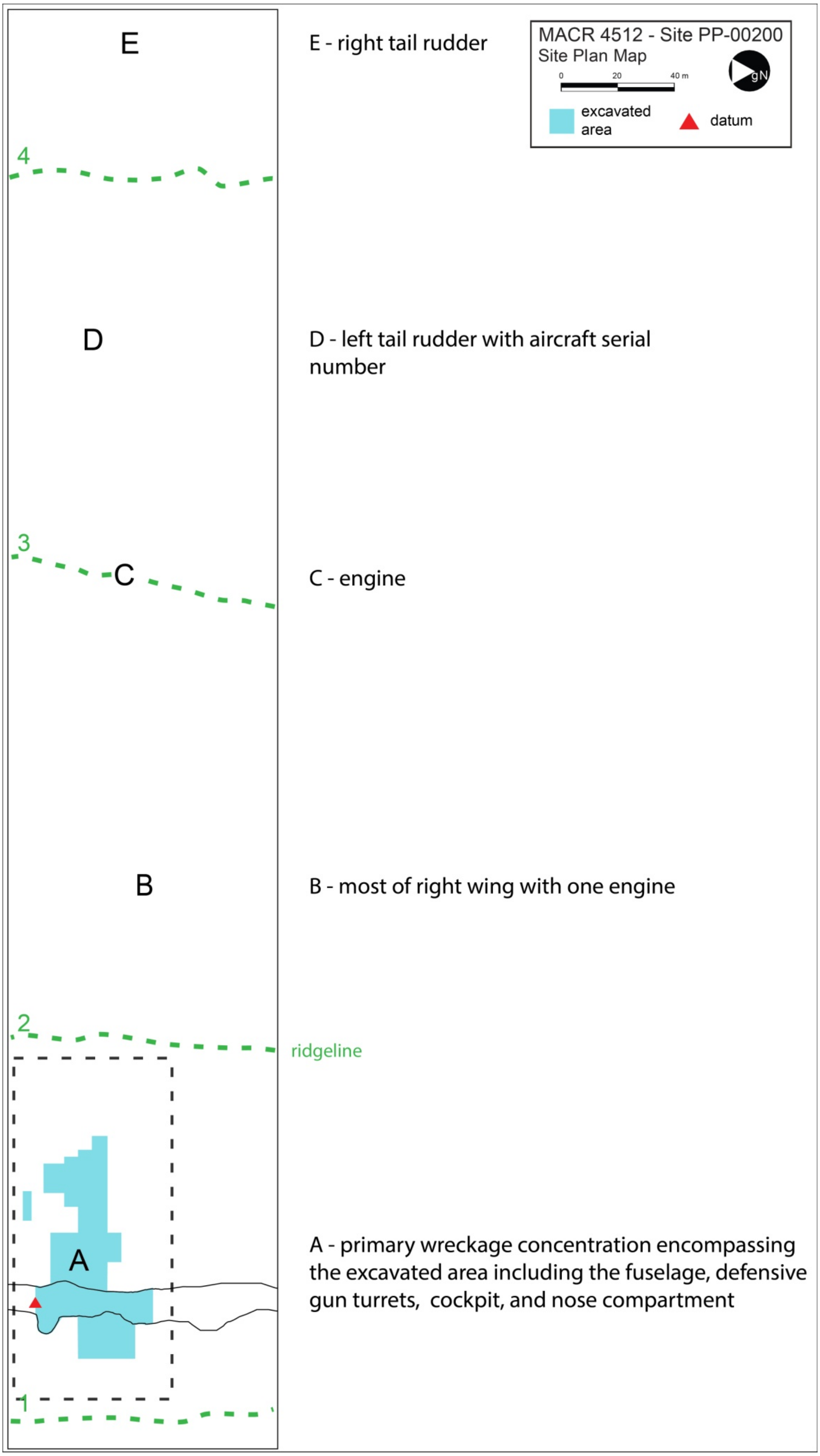

Figure 74. Map of Site PP-00200 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Sturm 2005)

Figure 75. The ravine prior to vegetation clearing. View to south. (Sturm 2005, 5)

Figure 76. The western slope above the ravine. View to northwest. (Sturm 2005, 7)

The majority of the aircraft wreckage of interest to JPAC's recovery efforts was located on the eastern face of the 2nd ridge. The wreckage extends for the entire 60 m between the western edge of the ravine and ridge line and is spread for approximately 30 m north-south.

In a roughly east-west orientation are large portions of the fuselage including two turrets, both waist gun positions, and two pieces of aircraft skin with the AAF's "stars and bars" insignia. Five more .50 cal machine guns, numerous oxygen canisters, a large wing fragment and a propeller are also present.

To the west of the second ridge there were no additional sections of the aircraft that would have been likely to contain human remains. Approximately 50 to 75 meters to the west of the second ridge, between the second and third ridges, sat a very large fragment of the right wing with one complete engine. Another engine rested on the third ridge approximately 200 m meters from the main wreckage concentration. Three hundred meters away in the gully between the third and fourth ridges was the previously mentioned tail rudder with the plane's serial number that allowed for the correlation of the crash site to the loss incident. Large fragments of fuel bladder and a propeller were also present. The final piece of wreckage, the right tail stabilizer, was uncovered between the fourth and fifth ridges about 500 m from the main wreckage concentration. No additional portions of the aircraft were discovered to the west of the fifth ridge. Numerous smaller, unidentifiable fragments of aircraft wreckage were scattered between all of the ridges (Berg 2002a, 14-15; 2002c; Haugen 2002a; b, 3-11; Sturm 2005, 4-8).

The IT commenced the recovery efforts at Site PP-00200 with a small excavation on the eastern slope of the second ridge. A 3-x-5 m unit was placed around a set of partially articulated remains that were eroding out of the steep hillside adjacent to the aft portion of the fuselage containing the waist gummer positions. An additional 1.25-x-1.5 unit was added because of elements that were trailing away to the north from the primary concentration (Berg 2002c, 11).

Two full recovery missions were necessary to complete the excavation of the crash site (Haugen 2002b; Sturm 2005). The first team, working from March 24 to May 4, 2002, began in the ravine between the two eastern most ridges and divided the area into three large units spanning its width (Figure 77). A grid of 5-x-5 m units was then established over the western slope of the first ridge. The cockpit wash feature was excavated next as a single provenience followed by the surrounding units. Upon completion of that slope the team turned their attention to the facing hillside. The grid was expanded and a narrow strip of units were partially excavated extending up away from the ravine. Only one of the units (N515/E475) was excavated to incident sterile sediments due to mission time constraints. The second recovery mission from May 22 to June 19, 2002 continued where the previous team left off. The grid on the eastern slope of the 2nd ridge was expanded and additional units were excavated in all directions until the limits of the evidentiary materials were reached.

Figure 77. The ravine and streambed after clearing and excavation. View to North. (Sturm 2005, 12)

The extremely steep terrain resulted in teams primarily excavating with trowels. This slower method resulted in the discovery and removal of multiple sets of *in situ*, articulated human remains. Forty-eight 5-x-5 m and two 2.5-x-5 m units as well as four larger provenience sections within the ravine bottom were completed during the recovery efforts. A total surface area of approximately 1,583 m^2 was excavated to an average depth of 30 cmbs (Figure 78). All three excavations recovered human remains and material evidence, including numerous pieces of identification media (Danielson 2005) (Table 35).

The exceptionally large, linear debris field of wreckage at Site PP-0020 is unique within the case studies. The overall size, shape, and distribution of wreckage within the debris field are indicative of the nature of the crash. The presence of tail wreckage and engines scattered for approximately 0.5 km to the west of the main wreckage concentration indicates that the aircraft was travelling in an easterly direction. It also shows that the B-24 was breaking apart while it was in the air. The fact that the majority of the aircraft rests between the first and second ridges shows that the fuselage likely remained intact until it

Figure 78. Photograph of the upper portion of the western slope at the completion of excavation. View is to the south.
(Sturm 2005, 29)

Table 35. Provenience of identification media found at Site PP-00200.

Provenience	**Identification Media**
Cockpit wash	Identification tag (Engineer)
N510/E450	Identification tag (Gunner 1)
N510/E460	Identification tag (Gunner 2)
N515/E455	Wristwatch back cover (Gunner 2)
N515/E475	Captain rank insignia (Pilot)
N515/E480	Identification tag (Pilot)
N520/E480	Identification tag (Aisstant Engineer)
N520/E500	Class ring (Observer)
N525/E475	Identification tag, identification bracelet, and class ring (Assistant Radio Operator)
N525/E510	Identification tag (Bombardier)

made contact with the ground. All of these observations suggest that the aircraft impacted the ground at a very low degree of perpendicularity.

The most notable pattern found during the analysis of the skeletal (Byrd 2005a, b, c, d, e, f, g, h, i, j, k; Emanovsky 2005a) and dental (Torske 2005a, b, c, d, e, f, g, h, i) remains was the extensive prevalence of postmortem damage. The authors noted that postmortem damage was found on all individuals and that its presence made the interpretation of perimortem trauma difficult. Where perimortem fractures were observed they clearly indicated massive blunt force trauma (Byrd 2005b, 2). Discoloration and staining was also noted amongst the group remains as well as relatively light levels of burning (Emanovsky 2005a, 6-7).

Field provenience, mtDNA sampling, and dental comparison were the primary means of separating individuals from the commingled remains. Sixty-five of the 70 samples submitted to the AFDIL yielded useable DNA sequence data. These 65 samples represented 11 distinct mtDNA sequences (Table 36). While pair matching was also utilized to a limited degree, it was only used in conjunction with the primary means of associating a skeletal element with an individual. Eleven pair matches were made spread over five different individuals. Additionally, numerous dental remains, both loose and contained within mandibular and maxillary fragments, were positively associated with the nine crew members through post-mortem – antemortem matching (Table 37).

Table 36. Results of mtDNA sampling for MACR 4512.

Sample	Element	Provenience	Individual
A	Tooth #21	N520/E500	Observer
B	Tooth #5	N510/E455	Gunner 2
C	Tooth #6	N510/E455	Inconclusive
D	Tooth #7	N510/E455	Gunner 2
E	Tooth #12	N510/E455	Gunner 2
F	Tooth #9	N518/E453	Gunner 1
G	Tooth #28	N518/E453	Gunner 1
H	Tooth #11	Cockpit wash	Engineer
I	Tooth #17	N505/E455	Assistant Radio Operator
J	Tooth #18	N505/E455	Assistant Radio Operator
K	Tooth #6	N520/E465	Assistant Radio Operator
L	Tooth #32	N520/E475	Assistant Radio Operator
M	Tooth #2	N515/E480	Pilot
N	Tooth #9	N515/E480	Pilot
O	Tooth #14	N515/E480	Pilot
P	Tooth #20	N515/E480	Pilot
Q	Tooth #22	N515/E480	Pilot
R	Tooth #32	N515/E480	Pilot
S	Tooth #1	N510/E460	Assistant Engineer
T	Tooth #2	N510/E460	Assistant Engineer
U	Tooth #3	N510/E460	Assistant Engineer
V	Tooth #6	N510/E460	Assistant Engineer
W	Tooth #24	N510/E460	Gunner 2
X	Tooth #26	N510/E460	Inconclusive
Y	Tooth #32	N510/E460	Assistant Engineer
Z	Tooth #6A	N525/E510	Engineer
AA	Tooth #6B	N525/E510	Bombardier

Sample	Element	Provenience	Individual
BB	Tooth #8	N525/E510	Bombardier
CC	Tooth #10	N525/E510	Bombardier
DD	Tooth #20	N525/E510	Inconclusive
DD.1	Tooth #20	N525/E510	Bombardier
EE	Tooth #25	N525/E510	Inconclusive
FF	Tooth #27	N525/E510	Bombardier
GG	Tooth #29	N525/E510	Bombardier
HH	Left tibia	N519.8/E448.2	Assistant Engineer
II	Left tibia	N518/E453	Gunner 1
JJ	Right humerus	*	Co-pilot
KK	Right ulna	N518/E453	Gunner 1
LL	Left femur	N510/E450	Assistant Engineer
MM	Right femur	N510/E455	Assistant Engineer
NN	Left femur	*	Radio Operator
OO	Left tibia	N520/E500	Assistant Radio Operator
PP	Left tibia	N520/E455	Observer
QQ	Left femur	N517.5/E450	Gunner 1
RR	Right parietal	N518/E453	Gunner 1
SS	Left femur	N518/E453	Gunner 1
TT	Left femur	N515/E480	Pilot
UU	Left femur	N510/E455	Gunner 2
VV	Left femur	Cockpit wash	Engineer
WW	Left femur	N525/E510	Bombardier
XX	Left femur	*	Assistant Radio Operator
51A	Right humerus	Unilateral	Gunner 2
52A	Right humerus	Unilateral	Gunner 1
53A	Right humerus	Unilateral	Assistant Engineer
54A	Right clavical	Unilateral	Assistant Engineer
55A	Right humerus	Cockpit wash	Engineer
56A	Femur	Cockpit wash	Engineer
57A	Left humerus	N515/E480	Pilot
58A	Left humerus	N510/E455	Gunner 2
59A	Left tibia	N510/E455	Gunner 2
60A	Cranial	*	Inconclusive
61A	Tooth #22	N510/E455	Gunner 2
62A	Left humerus	*	Radio Operator
63A	Right ulna	N520/E500	Observer
64A	Tibia		Navigator
65A	Right femur		Radio Operator
66A	Tooth #19	N525/E510	Engineer
A	Tooth #18	Unilateral	Assistant Engineer
B	Tooth #28	Unilateral	Assistant Engineer
C	Tooth #27	Unilateral	Gunner 2

*Provenience data for these samples is unavailable.

Table 37. Dental remains correlated to a specific crew member associated with MACR 4512.

Name	Associated dental remains
Pilot	#1 - #4, #6 - #10, #12, #14 - #24, #26 - #28, and #30 - #32
Co-pilot	None
Navigator	None
Bombardier	6, #8 - #10, #12, #14, #15, #18 - #22, #25 - #27, and #29 - #32
Observer	#5 and #8 connected by a fixed partial denture and #21 - #22
Engineer	#3 - #7, #11, #17, #19, #21, #26, #27, and #31
Assistant Engineer	#1 - #6, #14, #17 - #19, #21 - #23, #26 - #28, and #30 - #32
Radio Operator	None
Assistant Radio Operator	#5, #6, #17 - #20, #27 - #29, #30 - #32
Gunner 1	#1 - #13, #15, #16, #17 - #23, and #26 - #32
Gunner 2	#3, #5 - #7, #9 - #13, #15, #17, #18, #20 - #22, #24, #27 - #29, and #31

The recovery location of identified remains and material evidence that could be associated with a particular individual are displayed below (Figure 62). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty.

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- The remains of the Pilot were uncovered *in situ* and articulated in close proximity to the dorsal gun turret in N515/E480 (Figure 79). This is approximately 20 meters from the cockpit wash feature on the eastern side of the ravine. Skeletal elements, which were in fair to poor condition, included portions of both scapulae, clavicles, humeri, ulnas, femora, tibias, fibulas, as well as fragments of the cranium, ribs, and os coxa (Byrd 2005a, 4). One of the Pilot's identification tags was recovered amongst the remains and a captain's rank insignia was found just upslope in N515/E475 (Figure 79).

- The Co-pilot was identified through mtDNA testing of a single right humerus shaft fragment. Unfortunately, the element was sampled for DNA testing after the remains had been laid out on an analytical table, which resulted in the loss of provenience data. This prevents the ability to determine where the remains of the Co-pilot were found in the recovery scene.

- The Navigator was identified through mtDNA testing of a single right tibia shaft fragment. Unfortunately, the element was sampled for DNA testing after the remains had been laid out on an analytical table, which resulted in the loss of provenience data. This prevents the ability to determine where the remains of the Navigator were found in the recovery scene.

- The identified remains of the Bombardier included portions of both clavicles, scapulae, humeri, femora and tibias. Also present were the left ulna, manubrium, sternum, assorted carpals, metacarpals, tarsals, vertebrae, and fragments of the cranium and ribs (Byrd 2005b, 6). All of these were recovered *in situ* and articulated in N525/E510 within about three meters of the nose turret and eight meters from the cockpit wash (Figure 79). An identification tag for the Bombardier was found amongst the remains (Table 35).

- The Observer was represented by the scant fragmented remains of the mandible, left humerus, right radius, right ulna, and left tibia (Byrd 2005d, 4). The one piece from the lower body was found near the top of the main debris field on the east slope of the second ridge in N520/E445. The remaining portions were all recovered approximately 52 m downslope in one of the large excavation units the ravine (N520/E500) (Figure 79). The Observer's class ring was also found in the in the same unit (Table 35).

- The engineer were recovered *in situ* and articulated in the northwest corner of the cockpit wash feature on the western slope of the first ridge (Figure 79). They consisted of both huneri, femora, tibias, three left carpals, and a cranial fragment (Byrd 2005h, 4). One of the Engineer's identification tags was found amongst the remains (Table 35).

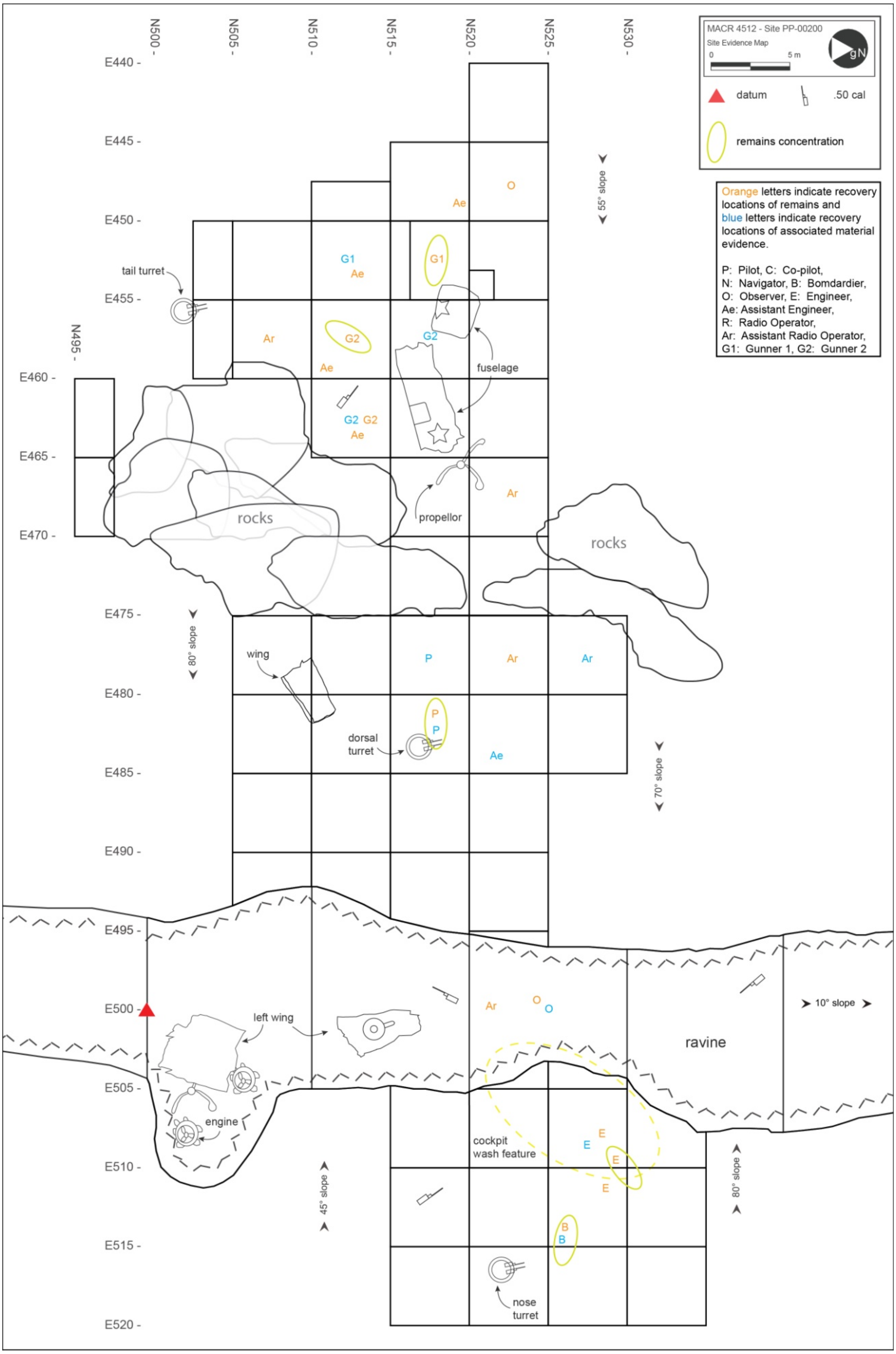

Figure 79. Map of Site PP-00200 showing the locations of identification media, identified remains, and recognizable aircraft components.
(Adapted from Sturm 2005)

- The Assistant Engineer was widely dispersed across the upper section of the east facing slope of the second ridge (Figure 79). North and westmost, at approximately N519.8/E448.2, was the left tibia and tarsals. Slightly downslope, the left and right femora were found in adjacent units, N510/E450 and N510/E455, respectively. The cranial fragments and dental remains were recovered below the lower limbs in N510/E460. One of the Assistant Engineer's identification tags was recovered in the screens while sediment from N520/E480 was being sieved.

- The Radio Operator included portions of both femora and the left humerus, all of which were segregated from the greater assemblage through mtDNA testing (Byrd 2005f, 3). Unfortunately, the elements were sampled for DNA testing after the remains had been laid out on multiple analytical tables, which resulted in the loss of provenience data. This prevents the ability to determine where the remains of the Radio Operator were found in the recovery scene.

- The Assistant Radio Operator was the most widely distributed individual within the recovery scene. The teeth and mandible fragments were spread above and around the large bedrock outcropping on the eastern facing slope of the second ridge in units N505/E455, N520/E465, and N520/E475 (Figure 79). The right scapula and humerus fragments were also found in these upper units. The Assistant Radio Operator's identification tag, identification bracelet, and class ring were all recovered in N525/E475 (Danielson 2005, 3). Both femora and fragments of each halves of the os coxae were uncovered in one of the large excavation units the ravine (N520/E500) (Figure 79).

- Gunner 1was found *in situ* and articulated at N518/E453 (Figure 79). The only portions of the skeleton that were missing included distal portions of various long bones, assorted hand and foot bones, the clavicles, and the mandible (Byrd 2005g, 6). One of Gunner 1's identification tags was found nearby in unit N510/E450.

- Gunner 2 is represented by both humeri, radii, ulnas, femora, tibias, os coxae fragments, as well as mandible fragments, left fibula, and various left foot bones were all recovered *in-situ* and articulated in unit N510/E455 (Byrd 2005k, 6). A tooth and one of Gunner 2's identification tags were found approximately 3 m downslope in N510/E460. A watch back with Gunner 2's initials incised into it was discovered in N515/E455 (Danielson 2005, 4, 32-33) (Figure 79).

Uniquely, of all of the sets of remains that were recovered in articulated, *in situ* contexts only the engineer and pilot from MACR 4512 are greatly separated from their corresponding duty station wreckage. The pilot was found in close association with the dorsal turret wreckage, which is the engineer's duty station during combat and the engineer was amongst the cockpit wreckage. It is quite possible that they may have been sitting in each others' seats at the time of the crash. This is a very puzzling scenario because the aircraft was flying through a gigantic storm at the time of the crash and it would stand to reason that the pilot would be at the controls. However, it was not unheard of during WWII as the engineer was qualified for co-pilot duties and could fly the aircraft in combat emergencies (Bowman 2009, 85). It is also possible that the engineer could have been trying to trouble shoot a mechanical problem or making some sort of emergency repairs.

Approximately 61 years after the eleven Army Air Forces soldiers died aboard B-24J tail number 42-100225, on April 16, 1944, or "Black Sunday," individual identifications were made for each of the crew members by JPAC on July 19, 2005 (Holland 2005a).

MACR 4512 is a unique case amongst the 8 bombardment loss incidents. The crash involved an aircraft that broke apart in mid air while traveling at a low degree of perpendicularity to the ground. This resulted in the largest debris field (Figure 74) of the case studies as well as crew members being spread over very large distances within the primary concentration of wreckage.

7 Cargo Aircraft Cases

Four cargo aircraft cases are detailed in this chapter, three Douglas C-47s and one Curtiss C-46 (Table 38 and Table 39). These cargo aircraft cases had both the locations of duty station aircraft wreckage recorded during the excavation and sufficient provenience information carried forward through laboratory analysis to be included here. Three were lost during WWII and the fourth went missing in the early portion the Vietnam War (Figure 80). As discussed in Chapter 4, because the C-47 airframe remained unchanged, both conflicts are represented. The cases are listed below, and presented, from smallest to largest based on the size of the debris field.

Table 38. Cargo aircraft cases.

Incident	Loss Date	Aircraft Type	Tail Number	Number Missing
3282	March 27, 1944	C-46	41-24688	4
4441	May 23, 1944	C-47A	42-23510	7
0222	December 24, 1965	AC-47D	45-1220	6
14302	December 10, 1944	C-47A	42-24215	5

Table 39. Loss locations of cargo aircraft cases discussed in this Chapter.

Incident	Country	Province	District
3282	China	Tibet	Milin
4441	Burma	Katchin	Myitkyina
0222	Laos	Savannakhet	Xepon
14302	Papua New Guinea	Morobe	Boana

Figure 80. Map showing the locations of the cargo aircraft cases discussed in this chapter.

7.1 MACR 3282

MACR 3282 involves the March 27, 1944 loss of four crew members aboard a C-46 aircraft, tail number 41-24688, from the Air Transport Command, Station #7. The aircraft departed Kunming, China to cross "The Hump" over the Himalayan Mountains in route to its home base at Sookerating, India. Despite optimal flying conditions for The Hump, an unknown individual aboard the aircraft radioed for a bearing partway through the flight. No other transmissions were heard from the C-46 and the plane never arrived at Sookerating, or any other airfield in India (Lehl 2005a, 2-3). The occupied crew positions were the Pilot, Co-pilot, Crew Chief, and Radio Operator.

The four men were declared missing on March 27, 1944. Search aircraft were dispatched along the aircraft's intended flight path for several days following the loss. Additionally, other cargo aircraft were instructed to look for the wreck as they made their regular transits, but the plane was not found. At the end of the war the AGRS compared the personal data of each of the four individuals against the unknown remains from the CBI region, but there were no matches. They were declared presumptively dead on March 26, 1946 and eventually deemed non-recoverable in 1948 (Lehl 2005a, 5).

Almost sixty years after the aircraft went missing, in January 2001, the CILHI received word through the Defense Prisoner of War/Missing Personnel Office that the Chinese Government had discovered and investigated an aircraft crash in a remote region of Tibet. The Chinese provided a tail number which matched the aircraft associated with MACR 3282. Due to the dynamic political relationship with the People's Republic of China, the JPAC decided to forgo the usual investigation and instead move directly to recovery (Lehl 2005a, 5; Pokines 2003, 2).

Site CH-00627 is located approximately 130 km southwest of Bayi City, Mikin District, in southeastern Tibet, People's Republic of China. High in the eastern Himalayan Mountains, the site is at an elevation of 4,770 m (15,650 ft). The site can be found on the topographic map Name: Melkho; Sheet: H-46-116; Series: 08-46-116; Edition: 1984; Scale: 1:100,000 (Figure 81).

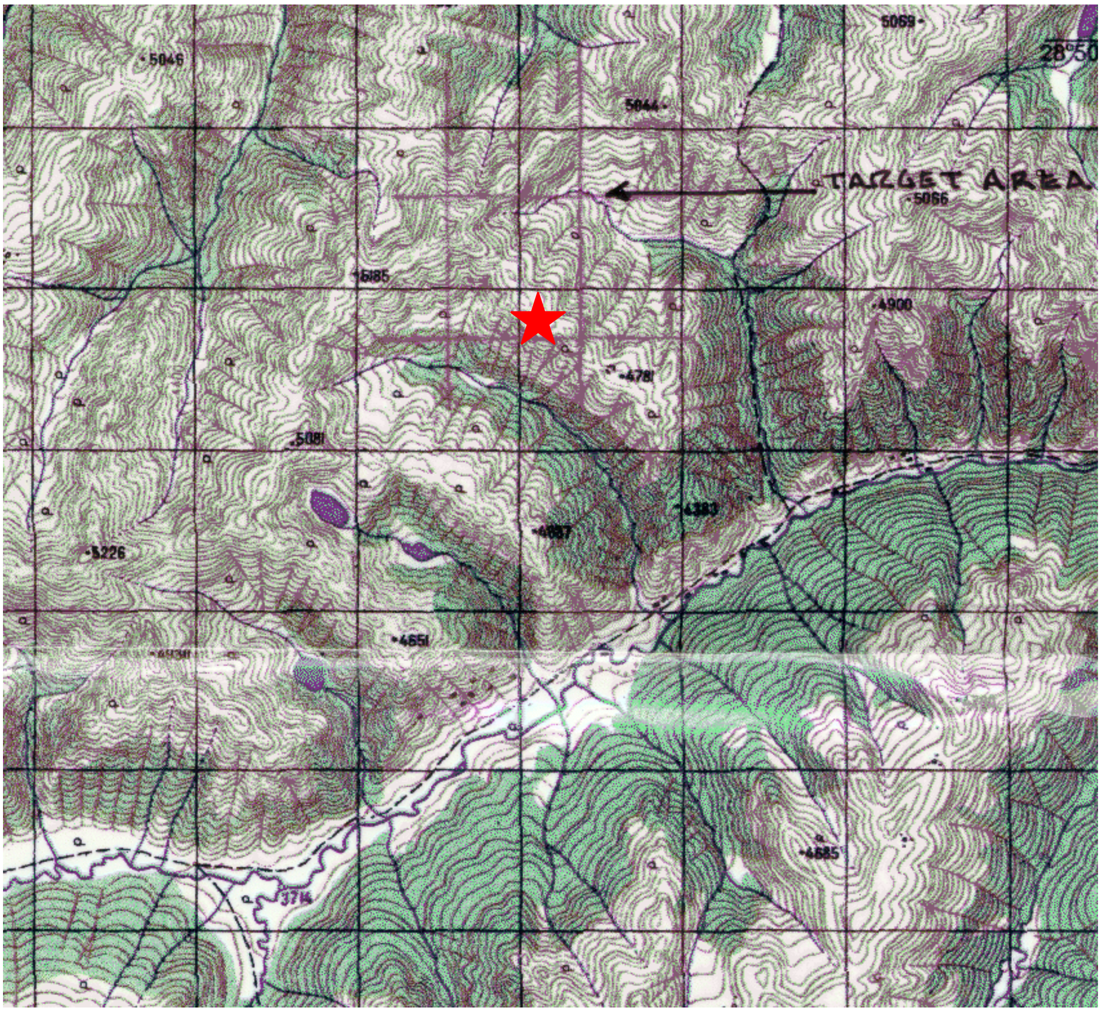

Figure 81. Topographic map showing the location of Site CH-00627 (red star).

Site CH-00627 rests in a shallow draw at the base of a cliff on a 25° south-facing slope above a large valley (Figure 82). The hillside, and especially the draw, is dominated by loose boulders. Soil development is minimal due to the high elevation and the only vegetation consists of small scrub grasses and bushes. The site consists of an entire C-46 cargo aircraft that has partially compressed and piled up at the bottom of the cliff. The fuselage faces uphill and the cockpit has been completely destroyed. The majority of both wings are detached, with their outboard tips pointing down slope. However, stubs of the wings are still attached to the fuselage and it was observed that the landing gear were retracted. The tail has bent to the port side of the fuselage with the tail fin having also been folded over to port (Figure 83). Evidence of scavenging was prevalent. All copper wiring was missing from the cockpit components and no boots, clothing or parachute components were recovered. Rectangular holes were cut into the wings and tail so that the control cables could be removed. Recent disturbance to the site was also noted as green grass was present underneath the right tail stabilizer, which had been dragged approximately 40 m downhill from the main wreckage concentration.

Figure 82. Site CH-00627.
Visible are: (A) the main fuselage, (B) bent tail, (C) right wing, (D) left stabilizer, and (E) left wing, (Pokines 2003, 11). View to east.

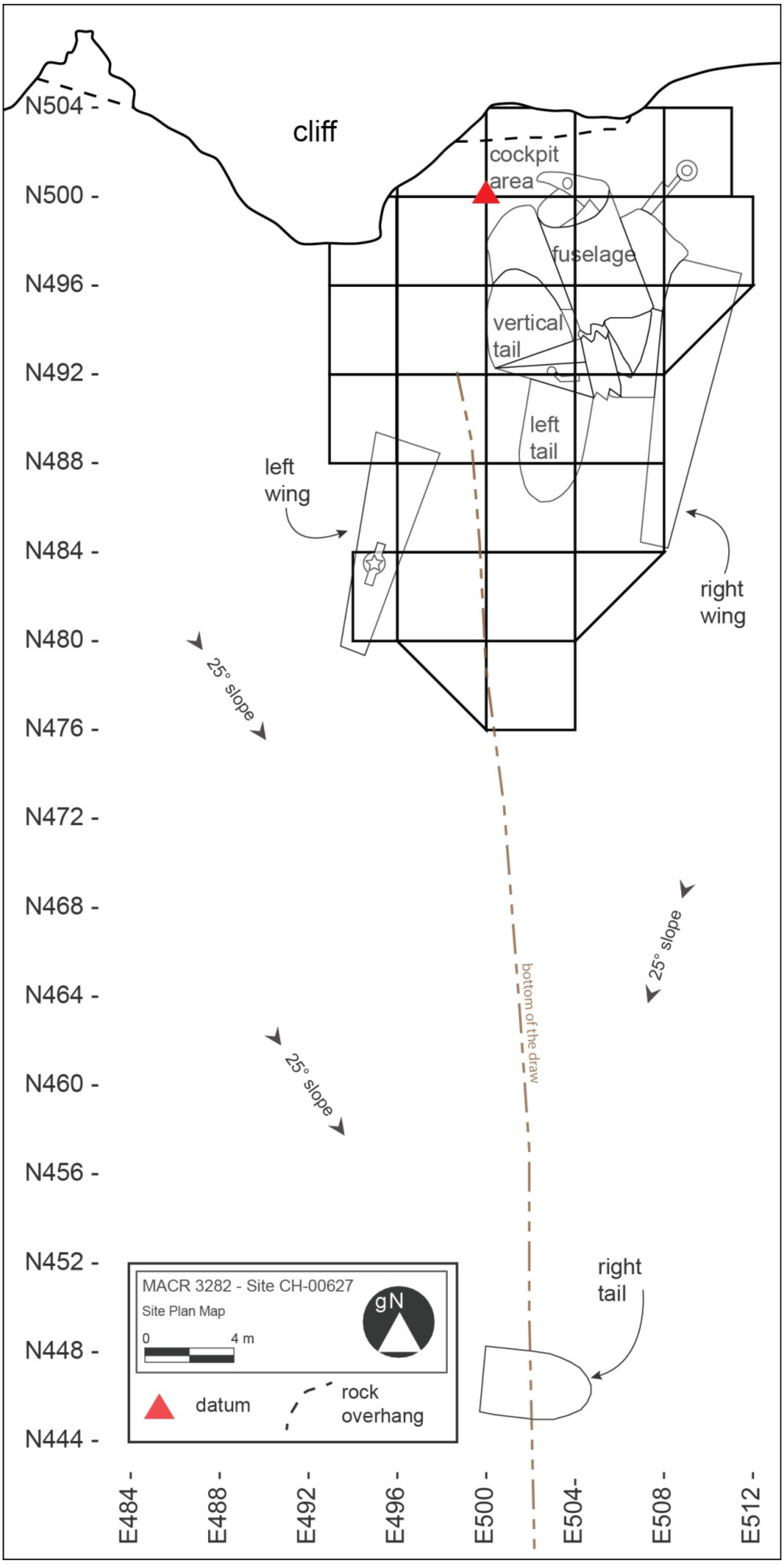

Figure 83. Map of Site CH-00627 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Pokines 2003)

Recovery efforts commenced on August 28, and extended until September 14, 2002. While standard archaeological procedures were utilized throughout the recovery effort, some departures were necessary such as demarcating the excavation grid with spray paint due to the lack of soil and the inability to excavate under the large fragments of wreckage due to their size and weight. When possible, hoes were used to reach under the wreckage. Excavation began with N500/E500, the unit encompassing the majority of the cockpit wreckage. It then proceeded down slope, and narrowed to follow the bottom of the natural draw to ensure that no evidentiary materials had eroded down slope (Pokines 2003). A total surface area of approximately 290 m^2 was excavated to an average depth of 35 cm. The only piece of identification media, found in N496/E500, was a knife sheath incised with the pilot's initials (Belcher 2005, 15-16).

Examination and assessment of the field notes and search and recovery report clearly indicate that based upon the orientation of the wreckage the aircraft was traveling in a northeasterly direction, suggesting that the aircrew was indeed disoriented during the flight. The aircraft likely flew into the cliff, and came to rest in a pile at its base. This impact would have been at a very high degree of perpendicularity. No evidence of fire was found at the crash scene. The extensive post-incident disturbance of the site has likely had a substantial impact. The absence of boots, clothing, parachutes, and other personnel effects suggests that scavenging activities most likely disturbed the human remains on the site. Resultantly, the location where those remains were recovered from my not reflect the actual crash itself.

Analysis of the skeletal (Emanovsky 2005b, c, d) and dental (Gleisner 2005a, b, c) remains are largely consistent with the findings discussed in Chapters 5 and 6. Perimortem trauma was common on all regions of the skeleton as evidenced by both the pattern of the breaks (Galloway 1999) and the similar coloring of fracture surfaces and surrounding external cortical bone (Ubelaker and Adams 1995). Two contrasting taphonomic patterns were observed amongst the remains. Skeletal elements that were hidden underneath rocks and aircraft wreckage show little to no weathering. Those fragments that were exposed exhibit alteration to the extent of stage four out of Behrensmeyer's five weathering stages (1978). Evidence of thermal alteration to the remains was not observed.

Mitochondrial DNA sampling was the primary method of resolving the commingling within the assemblage. A total of 28 samples were submitted to the AFDIL, all of which yielded useable sequences. Despite having family reference samples for all four servicemen associated with MACR 3282, only two individuals were represented: the Co-pilot and Radio Operator. Visual pair matching and articulations also associated some skeletal elements with each of two individuals indicated through mtDNA. Additionally, both loose teeth and those contained within mandibular and maxillary fragments were positively associated with the Co-pilot through antemortem – postmortem matching. They include: #2- #4, #6, #11, #14, #20 - #23, and #28 - #32.

Provenience was not maintained through the mtDNA sampling process, so it is not possible to determine the exact location within the crash scene that the remains associated with the Co-pilot and Radio Operator were recovered. However, the majority of the remains were recovered from N496/E500 and N500/E500 with smaller amounts being found in N500/E504 and slightly downslope in N492/E496, N488/E496, and N488/E500 due to erosion (Figure 84). The numbers of skeletal fragments decreased as the excavation proceeded downslope. Overall, the wreckage debris field is quite small for an aircraft the size of a C-46. Combined with the condensed distribution of remains, which was probably expanded due to scavenging activities, it can be interpreted that the remains of all of the crew members originally came to rest near the cockpit wreckage during the crash.

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- No remains could be associated with the Pilot of the C-46. A knife sheath incised with his initials was found in N496/E500, where the cockpit wreckage was located.

- The Co-pilot was represented by multiple cranial fragments and several teeth as well as portions of both clavicles, scapulae, humeri, ulna, and os coxae. Also included were the left radius, right femur, left tibia, left talus, and left calcaneus.

- No remains or material evidence associated with the Crew Chief were found during the recovery effort.

- Fragments of the cranium, mandible, both clavicles, humeri, ulna, os coxae were recovered. Portions of the left radius, right femur, and left tibia were also present. All of these were associated with the Radio Operator.

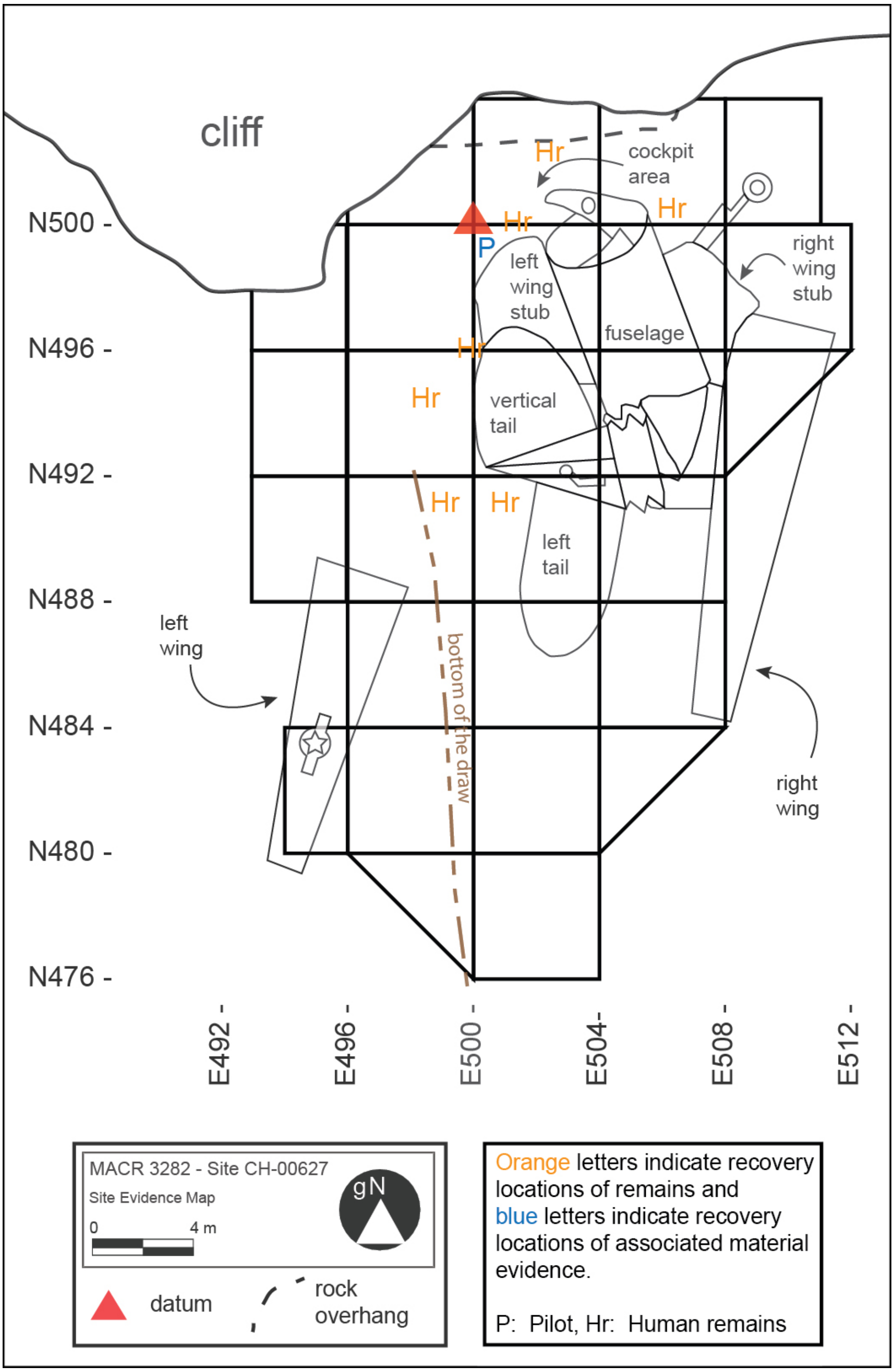

Figure 84. Map of Site PP-00627 showing the locations of identification media, identified remains, and recognizable aircraft components.
(Adapted from Pokines 2003)

A little more than 61 years after the four man crew of C-46, tail number 41-24688, died on March 27, 1944, individual identifications were made for two of the servicemen and a group identification was established for all four on July 18, 2005 (Holland 2005b).

Missing Aircrew Report 3282 serves as a good example for several facets of this thesis. First, it is an archetypal example of crash with a high degree of perpendicularity where the plane was traveling in a horizontal direction and impacted a vertical surface. Second, the ability to fully reconstruct the crash site is impeded by the failure to carry the provenience information through the DNA sampling process. Third, it also demonstrates the affect that scavenging can have on a crash site. All of these will be discussed in greater detail in Chapter 10.

7.2 MACR 4441

MACR 4441 involves the May 23, 1944 loss of a C-47A (tail number 42-23510) with seven crew members aboard from the 4th Troop Carrier Squadron which was part of the 10th Air Force. The aircraft departed Dinjan, India on a parachute cargo drop mission in the vicinity of Myitkyina, Burma. The crew made regular radio calls, the last of which at 0819 hours, as the mission progressed through continually deteriorating weather, but ultimately failed to reach the target (Speelhoffer 2009, 1-4). The occupied crew positions were the Pilot, Co-pilot, Navigator, Radio Operator, and three Drop Crew.

Army Air Forces reported the plane as missing and subsequently conducted 12 search missions totaling roughly 66 hours, but were unable to locate the aircraft. The MACR investigation concluded that the loss of the aircraft was probably weather-related. At the end of the war the AGRS compared the personal data of each of the five individuals against the unknown remains from the Burma region, but there were no matches. A finding of death for the crew was issued by the War Department on April 3, 1946 and they were eventually deemed non-recoverable in October of 1947 (Speelhoffer 2009, 4).

Almost 60 years later, in March 2001, the U.S. Army CILHI received information from U.S. embassy staff in Rangoon, Burma that a local priest had found an aircraft crash and possessed two identification tags. The information listed on the ID media matched two of the individuals who were listed in MACR 4441 as being aboard C-47A #42-23510 on May 23, 1944. An investigation team travelled to Burma in January 2003. Due to political issues they were unable to visit the site but did receive human remains, an identification tag, and two identification bracelets from a local resident who had been scavenging the crash site. A JPAC investigation team returned to Burma in November 2003 and were able visit the site where they observed extensive aircraft wreckage including a section that was painted with the 4th Troop Carrier Squadron insignia, which only lost one plane in the CBI theater (Speelhoffer 2009, 9-12).

Site BM-00180 is located in the rugged foothills of the Katchin Mountains approximately 50 km northwest of the city of Myitkyina and 20 km north of Nanmti. It is at an elevation of roughly 896 m (2900 ft). The site can be found on the topographic map (Tactical Pilotage Chart); Sheet: H-10C; Series: TPC; Edition: 2; Datum: (Lat/Long) (Figure 85) (Pokines 2004, 2).

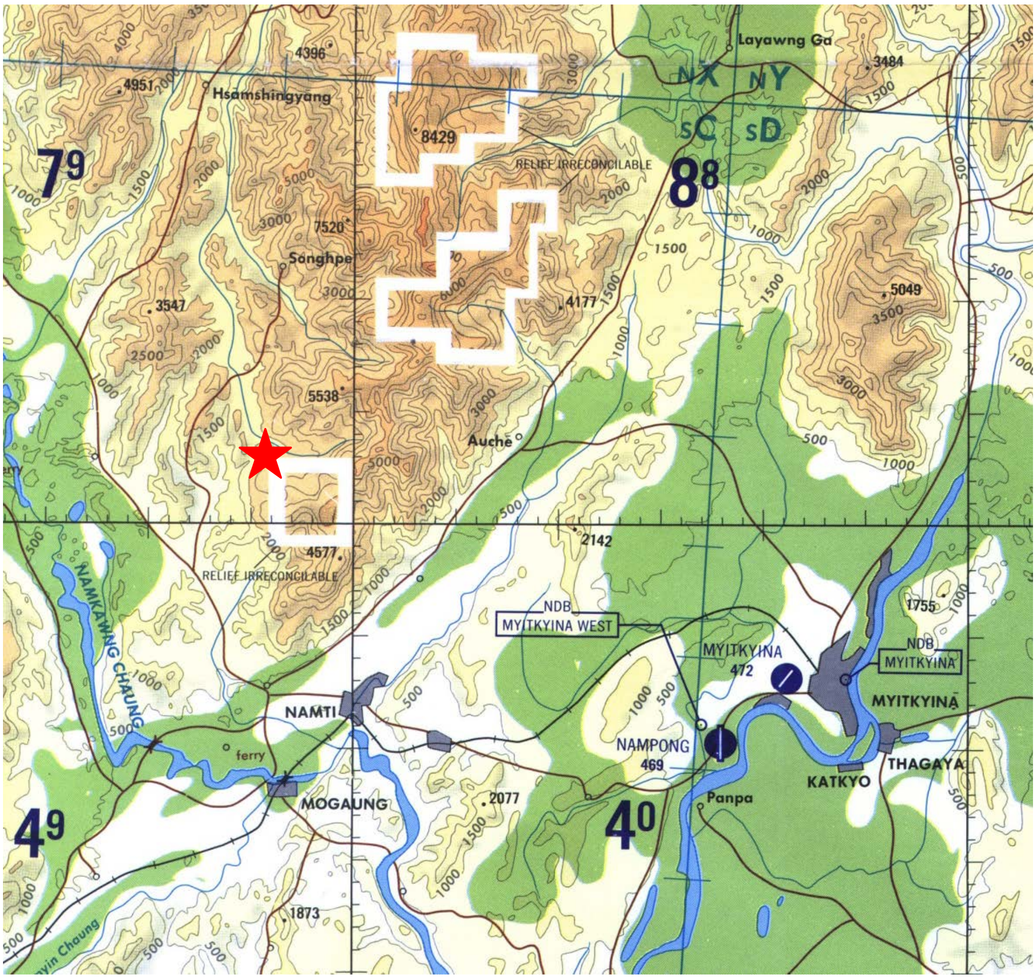

Figure 85. Topographic map showing the location of Site BM-00180 (red star).

Site BM-00180 is primarily located in a narrow perennial stream that flows to the east/northeast at a bearing of approximately 55°. Hillsides slope up at 10-15° on each side of the stream. They are covered with typical dry tropical forest consisting of an upper canopy of deciduous trees and a variety of dense bushes, vines, and other palms. Thick clusters of bamboo are also interspersed. Several bedrock outcrops and areas of exposed boulders are located to the southwest and southeast of the debris field (Pokines 2004, 2-6).

Prior to the start of excavation numerous large fragments of aircraft wreckage were visible on the surface of the site (Figure 86). Overall, the debris field was approximately 32 m southwest-northeast by 20 m southeast-northwest. The debris was primarily oriented in line with the stream and despite scavenging of the site they were still in approximate relative position to one another. The tail section rests on its port side farthest downstream at the northeast edge of the debris field. The majority of both wings, with badly damaged leading edges, large fragments of fuselage, and an engine are centrally located within the debris field in the streambed. An additional engine and propeller are scattered on the southern slope and make up the southwest edge of the site. The cockpit is completely destroyed and its fragments are spread across a 10 m by 4 m area along the stream bed in the middle of the wreckage scatter (Figure 87). Parachute and harness hardware was also observed on the surface within the cockpit debris. Eighty-one millimeter mortars, part of the aircraft's cargo, were also present (Pokines 2004, 2, 6, 7).

Figure 86. The central area of Site BM-00180 prior to excavation.
A ditch and bamboo aqueduct were constructed to drain the site. View is northwest (Pokines 2004, 5).

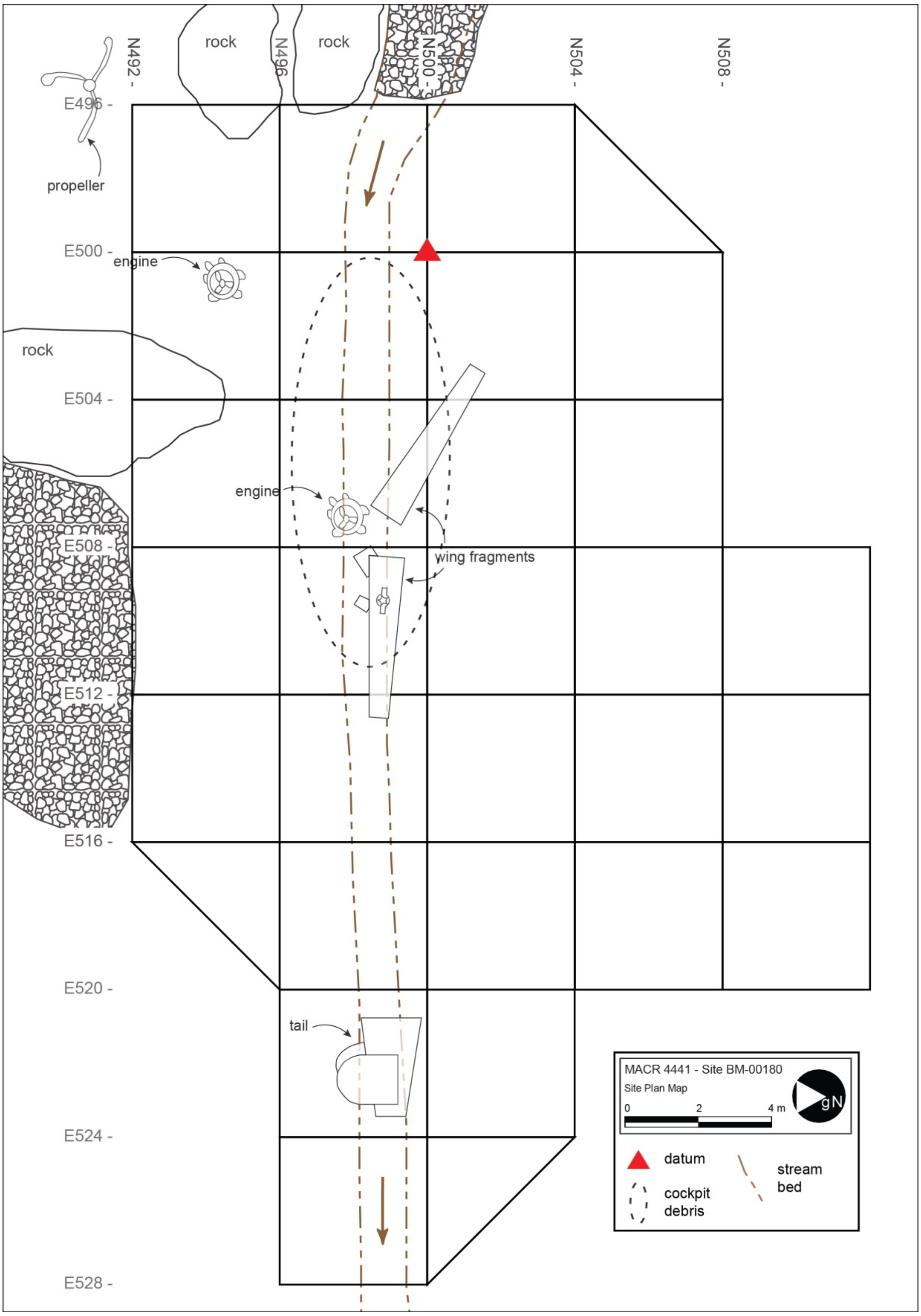

Figure 87. Map of Site BM-00180 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Pokines 2004)

The recovery of Site BM-00180 was undertaken from February 27 through March 18, 2004. Working with a grid of standard 4-x-4 m units excavation of the site began in the waterlogged streambed. Sediment from the stream itself was laid out to dry so that it could be screened several days later. Upon completion of the units that encompassed the stream work moved to the adjacent hillsides. A total surface area of approximately 470 m^2 was excavated to average depth of 50 cm within the stream itself and 25 cm on the slopes (Figure 88). A small amount of human remains, material evidence, and personal effects were recovered (Pokines 2004). While several items of identification media were included in the material evidence report associated with this loss incident only one of them was found during the excavation. An identification tag for Pvt Richard M. Dawson was recovered from stream sediments in N496/E508 (Danielson 2004b, 2; Pokines 2004, 6).

Figure 88. Site BM-00180 at the close of excavation.
The engines and tail section are not in their original locations. View is northeast (Pokines 2004, 10).

Several observations were made during the recovery effort. First, based upon the distribution of the larger fragments of wreckage it is clear that the C-47 was traveling in a west/southwest direction. The lack of impact crater and overall size of the wreckage fragments suggests that it struck the ground at a slow speed and a low degree of perpendicularity. Second, evidentiary materials were found exclusively within 2 m of the stream channel and erosion appeared to be minimal. Third, large amounts of melted metal (mostly from the fuselage), charcoal layers within the sediment, and casing fragments from detonated 81 mm mortars indicated that the crash site burned extensively after the crash (Pokines 2004, 10-20).

The highly destructive post-crash environment combined with the length of time the material was exposed to acidic Southeast Asian soils resulted in the recovery of only a very small amount of skeletal (Baker 2008; Burke and Pokines 2008) and dental (Shiroma 2009a, b, c) remains: a cranial fragment, three hand bones found in the same glove, and five teeth. This prevented any pair matching or rearticulations, which resulted in the skeletal analysts having to rely on the six samples that were sent to the AFDIL for mtDNA. Antemortem – post-mortem dental comparisons were undertaken to identify each individual. Dental remains correlated to a specific individual are displayed in (Table 40).

Table 40. Dental remains correlated to a specific crew member associated with MACR 4441.

Name	Associated dental remains
Co-pilot	#18, #28, and a malformed maxillary tooth
Navigator	#4

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- No remains or material evidence associated with the Pilot were found during the recovery effort.

- The Co-pilot, is represented by the two teeth with amalgam restorations and a malformed maxillary tooth. The remains were recovered from within the cockpit debris (Figure 89).

- Based upon mtDNA testing, the three hand bones and tooth #4 were identified as being from the Navigator. The hand bones were found in N496/E504 and the tooth was recovered from within the cockpit debris area of the site (Figure 89).

- No remains or material evidence associated with the Radio Operator were found during the recovery effort.

- No remains or material evidence associated with Drop Crew 1 were found during the recovery effort.

- Drop Crew 2 is represented by an identification tag bearing his name that was recovered from N496/E508 (Figure 89). No remains could be associated with Drop Crew 2.

- No remains or material evidence associated with Drop Crew 3 were found during the recovery effort.

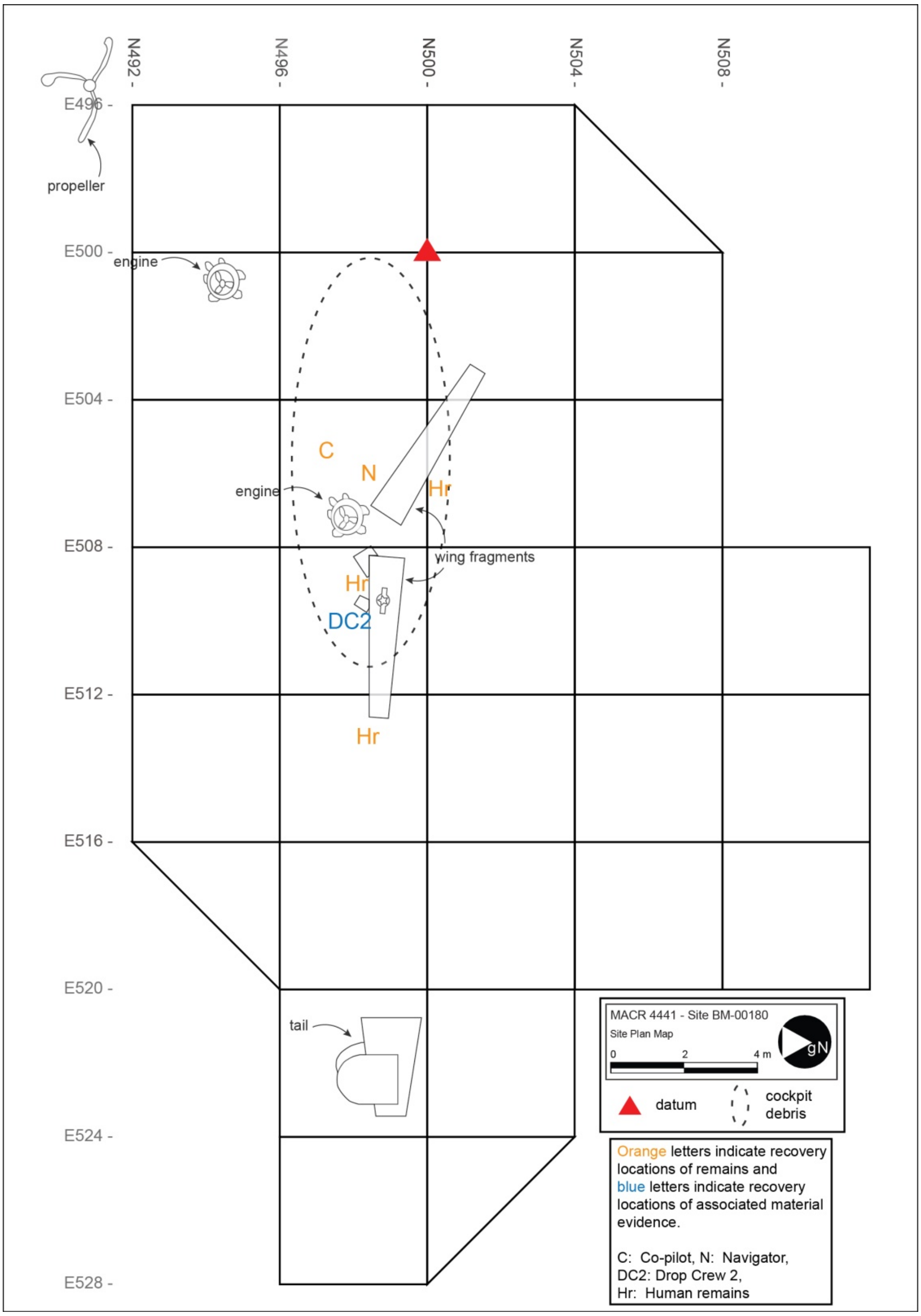

Figure 89. Map of Site BM-00180 showing the locations of each individual and pertinent recognizable aircraft components.
(Adapted from Pokines 2004)

Close to 65 years after seven Army Air Forces soldiers died aboard C-47A Tail number 42-23510 on May 23, 1944 individual identifications were made by the JPAC for 1st Lt Robert M. Anderson and 1st Lt Joseph J. Auld on April 13, 2009. A group identification was made for the crew on the same day (Holland 2009a).

7.3 REFNO 0222

REFNO 0222 involves the December 24, 1965 loss of an AC-47D (tail number 45-1120; call sign: Spooky 21) with six crew members aboard. The aircraft departed Da Nang Air Base, Vietnam at 0728 hours for an armed reconnaissance mission under the direction of an airborne command and control aircraft. The command and control aircraft directed Spooky 21 to attack a specific location. Shortly thereafter at 1056 hours a “Mayday” message from Spooky 21 was heard by two separate aircraft over an ultra high frequency emergency channel. No further contact was made with Spooky 21 (Phisayavong 2012a, 1). The occupied crew positions were the Pilot, Co-pilot, Navigator, Flight Engineer, and two Gunners.

Extensive searches were made surrounding the strike location and in a 50 mile wide corridor between Da Nang and the intended target over the following two days, but there were no signs of the missing aircraft. The six individuals aboard AC-47D #45-1120 were placed into MIA status. After the war, they were administratively declared to be KIA/BNR. The first investigations into REFNO 0222 were undertake in January 1993 by JTF-FA and additional investigation teams conducted field work in November 1993, January 1995, March 1995, November 1999, July 2001, and August 2001. Numerous witnesses were interviewed and the information gathered eventually led analysts to a crash site. Informants also indicated that there were three locations near the crash site where Americans that were related to the aircraft crash may be buried (Phisayavong 2012a, 2-4).

Site LA-00370 is located approximately 7 km west of Xepon Town near Na Bo Village, Xepon District, Savannakhet Province, Lao People’s Democratic Republic. The crash site rests on the floor of a broad valley created by the Xepon River. It can be found on map: Name: Muang Phin; Sheet: 6242 III; Series: L7015; Edition: 4-TPC; Scale: 1:50,000; Datum: Indian 1960 (O'Leary 2010a, 3) (Figure 90).

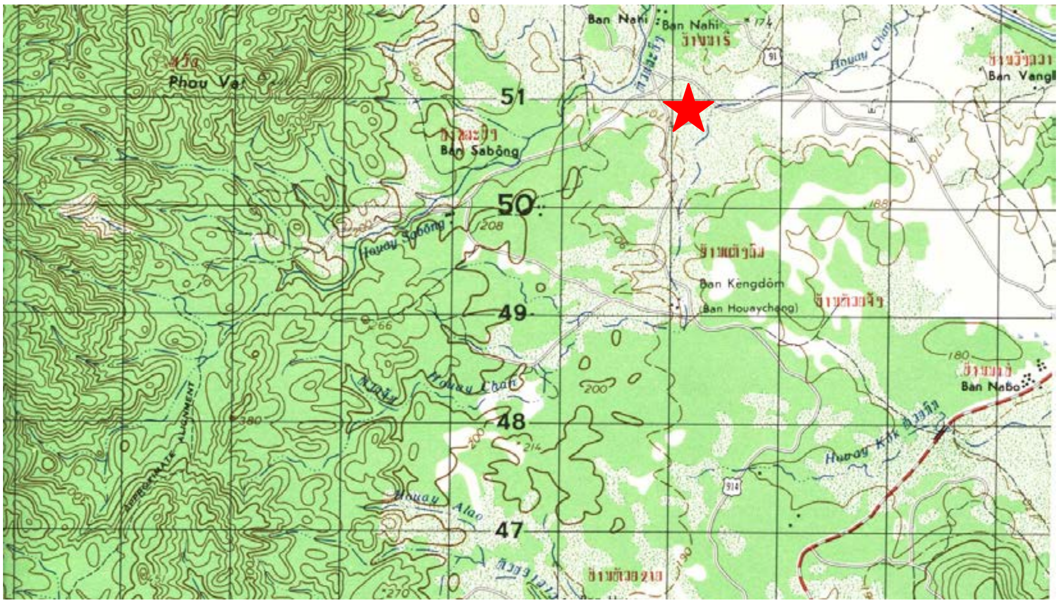

Figure 90. Topographic Map showing the location of Site LA-00370 (red star)

Site LA-00370 is comprised of four areas: A through D. Areas A, B, and C are witness-indicated, alleged burial locations in lightly wooded areas surrounding rice paddies. Area D, where the aircraft impacted the ground, is primarily located in a single rice paddy that is contained within a northwest – southeast oriented rice paddy system (Figure 91 and Figure 92). The debris field extends into the two adjacent paddies and also out into a lightly vegetated are to the northeast. The flat paddies are separated by packed earthen walls ranging in height from 20 to 50 cm. Water flows through the system from southeast to northwest. The banks to either side of the paddies have a gentle slope of 5° and are covered in tall deciduous trees, thick clusters of bamboo and other small bushes and shrubs. Large bomb craters are very common throughout the area both within the paddies and in the surrounding forest (O'Leary 2010a, 3).

The primary feature of the site at the outset of recovery operations was the oblong shaped vegetation anomaly within the paddy (Figure 93). This feature was differentiated from the rest of the paddy by the type of vegetation that grew within it as well as having a darker soil color. This pattern was noted during both the dry and wet seasons over the course of the multiple recovery efforts (Christensen 2011, 2; Justus 2011, 3). It could be clearly distinguished from a bomb crater due to its irregular shape and the absence of any depression (O'Leary 2010a, 3). Due to extensive scavenging by local inhabitants both during and after the war, no aircraft wreckage was visible on the ground surface. Witness statements indicated that at the time of the incident the tail wreckage was located in the portion of Area D that is outside of the rice paddy.

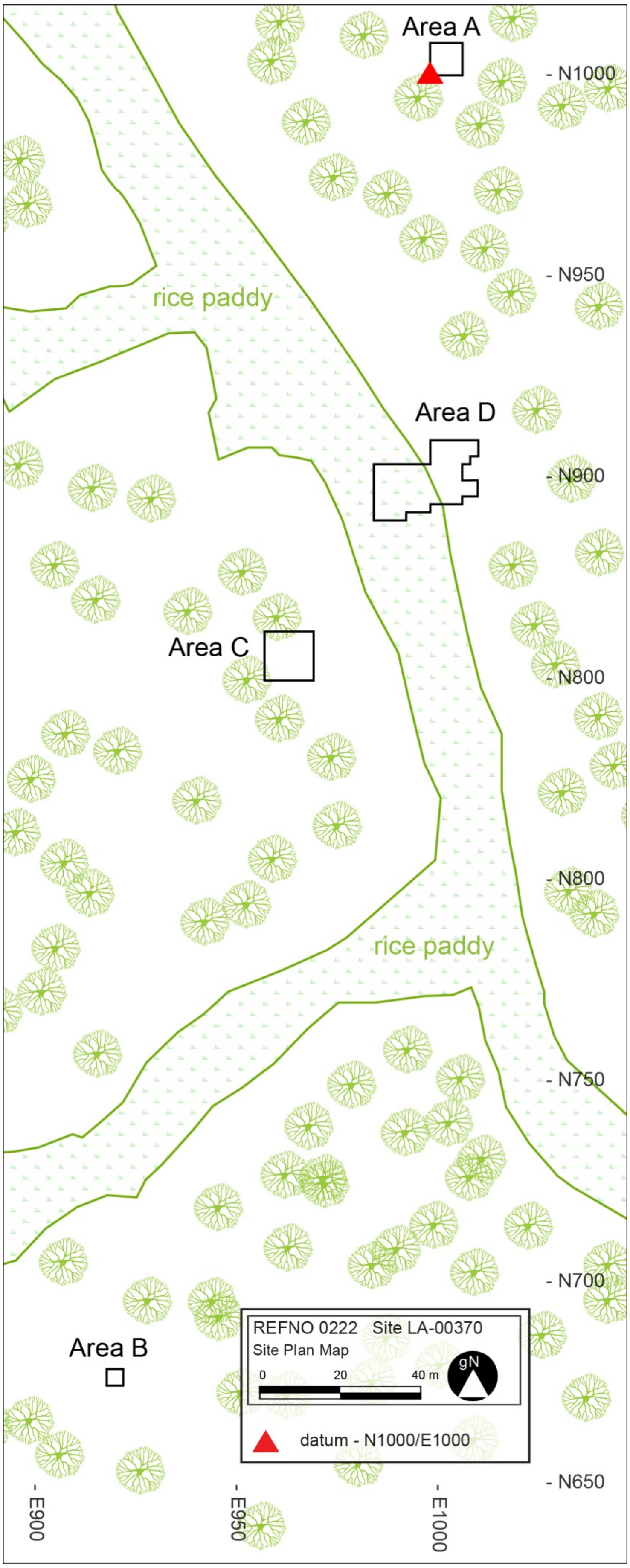

Figure 91. Map of Site LA-00370 depicting the four excavated areas. (Adapted from Justus 2011)

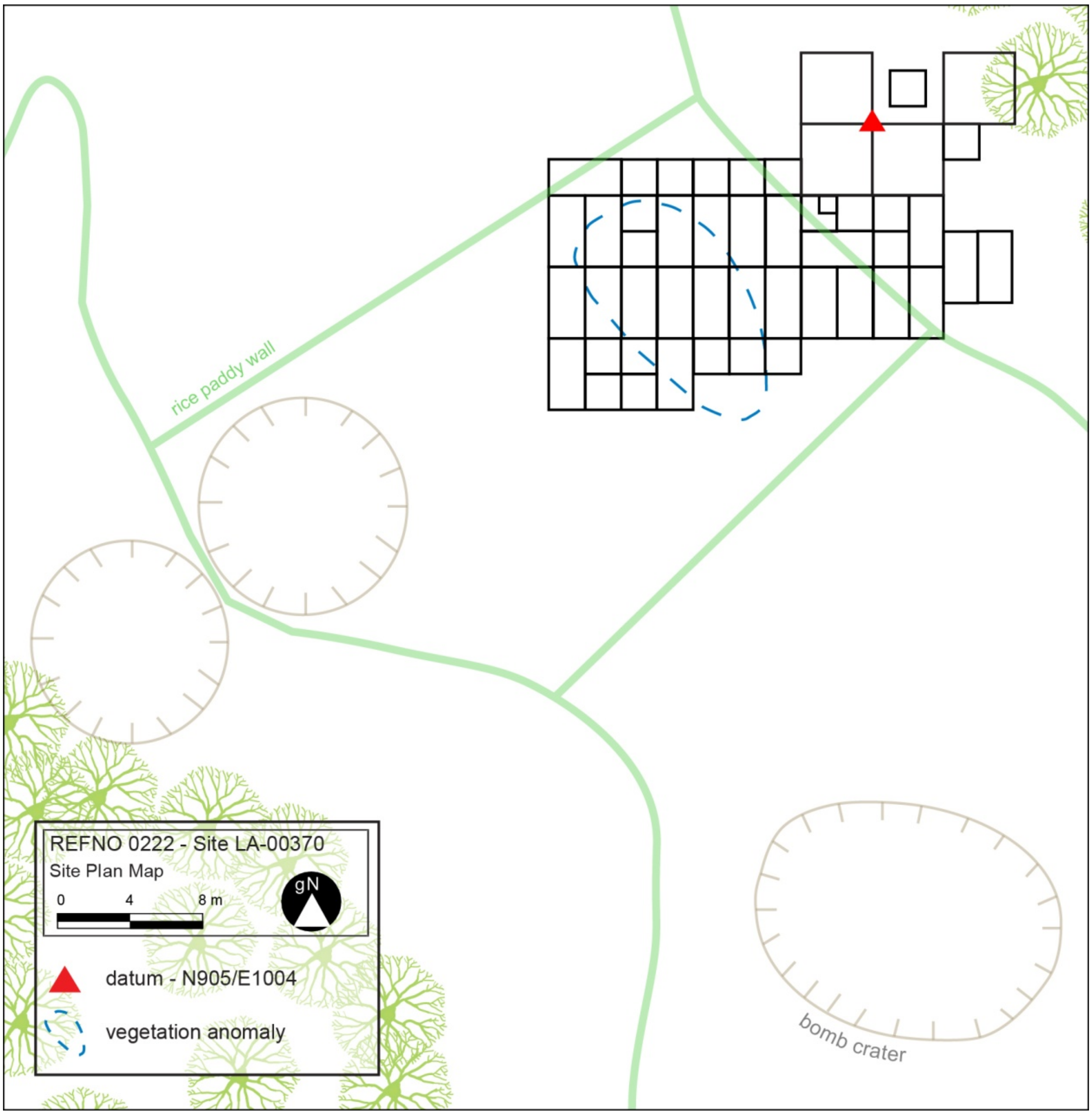

Figure 92. Detail map of Area D at Site LA-00370. (Adapted from Justus 2011)

Recovery of Site LA-00370 began on November 6, 2001 with the excavation of the three witness indicated locations of possible burials, Areas A through C (Benedix and Monahan 2001). No indications of a burials or any incident related material was found at these three areas at which time the recovery effort shifted to the portion of Area D that was outside of the rice paddy where the team recovered a belt buckle (Benedix and Monahan 2001, 17). A nine-year lapse of work at the site was finally ended during the dry season in January 2010 when a recovery team began excavation of the vegetation anomaly in the rice paddy at Area D (Figure 93). The feature was bisected with a row of 2-x-4 m units. The impact crater associated with the fuselage was encountered, the excavation of which resulted in the recovery of osseous remains and additional material evidence including a ring, coins, and a key (O'Leary 2010a, 11). The partially melted ring had the text “14k” stamped on the inside of the band. Fourteen karat gold has a melting point of 880 degrees celcius.

Figure 93. Aerial photograph of Site LA-00370, Area D showing the vegetation anomaly (blue ovoid).
View is to the northwest (O'Leary 2010a, 7).

Subsequent missions expanded the excavation both within and outside of the rice paddy at Area D where a single tooth was recovered (Megyesi and O'Leary 2011, 11). Overall, a total surface area of approximately 610 m^2 was excavated at Site LA-00370 to depths ranging between 5 and 160 cmbs with an average of 138 cmbs. Human remains, osseous remains, material evidence, and life support equipment was recovered from throughout the excavations undertaken at Area D. However, no identification media was recovered for any of the individuals associated with REFNO 0222 (Pietruzska and Fox 2011).

Excavation of Area D revealed three impact craters arranged in a roughly triangular formation (Figure 94). These three depressions correspond to the fuselage and engines of the AC-47D. Their orientation, distribution, and depth explain the vegetation anomaly observed on the surface of the rice paddy as well as indicate that the aircraft struck the ground at a high degree of perpendicularity. Numerous cockpit components were found in the bottom of the fuselage crater. The left engine hole is much larger than the other two due to scavenging activities. Tree trunks with axe chop marks at each end were recovered from both the fuselage crater and the starboard engine crater indicating that they had been filled after the incident. Forty years of farming in the rice paddy has removed the majority of the incident related materials from the plough zone, or top 25 cm of the rice paddy. Underneath the plough zone the amount of aircraft wreckage increased substantially. The preponderance of the remains recovered at Site LA-00370 were found within the fuselage impact crater. Additional skeletal fragments were recovered from N897-901/E998-1000 and a single tooth from N897-899/E1000-1004.

Figure 94. Site LA-00370, Area D at the conclusion of excavation.
Note the fuselage (A) and port (B) and starboard (C) engine craters in a triangular formation. View to east (Justus 2011, 29).

The skeletal remains recovered at Site LA-00370 consist of numerous small unidentifiable long bone fragments, the largest being approximately 2 cm by 3 cm. The remains are friable and range in color from black to white, which is an indicator of exposure to high temperatures over an extended period of time (Hefner 2011). The color and condition of the remains classify as Stages 3 and 4 according to Shipman et al. (1984) which indicates that the osseous material was exposed to temperatures as high as 940ºC. This taphonomic effect prevented the determination of a biological profile, pair matching or articulations, as well as resulted in no usable DNA being recovered from the three samples that were sent to AFDIL for testing (Hefner 2011). The one tooth recovered on the site is an unrestored #14 (left maxillary first molar). The tooth is from SSgt Arden K. Hassenger because he was the only member of the crew who did not have a restoration at tooth #14 (Jones 2011).

The recovery location that could be determined for each individual is displayed below (Figure 95). Identified remains for REFNO 0222 are defined as the dental remain that was an odontological match to the records of a casualty associated with the loss.

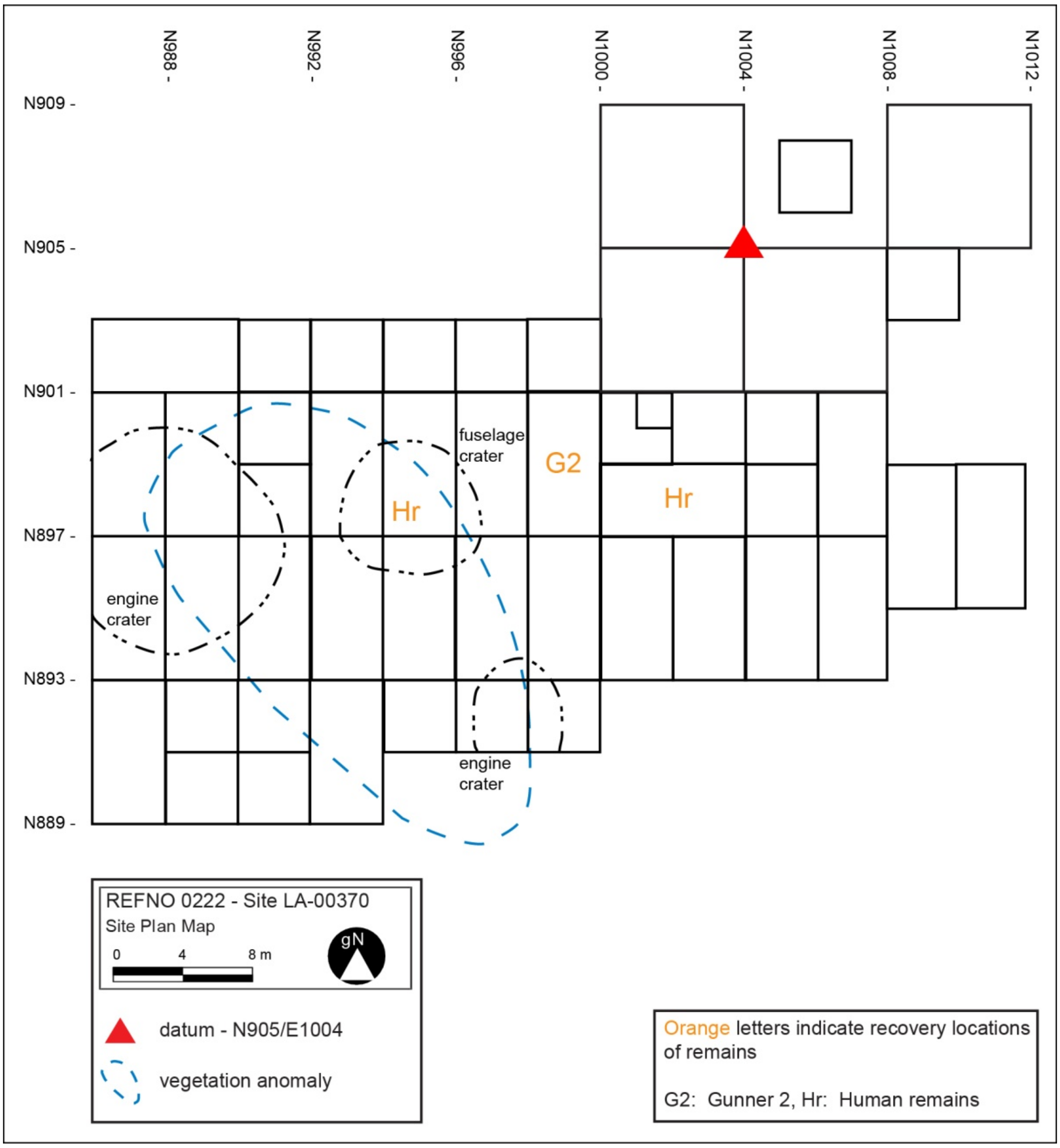

Figure 95. Map of Site LA-00370 showing the locations of each individual and pertinent recognizable aircraft components.
(Adapted from Justus 2011)

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- No remains or material evidence associated with the Pilot were found during the recovery effort.
- No remains or material evidence associated with the Co-pilot were found during the recovery effort.
- No remains or material evidence associated with the Navigator were found during the recovery effort.

- No remains or material evidence associated with the Flight Engineer were found during the recovery effort.

- No remains or material evidence associated with Gunner 1 were found during the recovery effort.

- Gunner 2 is represented by a single tooth recovered from N897-899/E1000-1004. No material evidence was recovered that could be associated with Gunner 2.

One of the six Army Air Forces personnel who died aboard AC-47D, tail number 45-1120, on December, 24 1965 was individually identified by the JPAC on March 5, 2012, a little more than 42 years after the incident. The remaining five individuals were identified as a group on the same day (Holland 2012).

7.4 MACR 14302

MACR 14302 involves the December 10, 1944 loss of four crew members and one passenger, who was not manifested, aboard a C-47A aircraft, tail number 42-24215, from the 317th Troop Carrier Group, 41st Troop Carrier Squadron, 5th Air Force. The aircraft departed Dobodura, Papua New Guinea on a supply mission to Hollandia at 1222 hours (Watson 1944). The last contact with the aircraft was made by radio at approximately 1300 when the Pilot requested weather information on their intended flight path. 1st Lt Richard Korthals, another C-47 pilot from the same squadron who was also flying in the Saidor area, advised the MACR 14302 Pilot that the weather was bad over the Huon Peninsula and that an alternate route over the sea was advisable. The occupied crew positions were the Pilot, Co-pilot, Radio Operator, Engineer, and a Passenger.

When the aircraft failed to arrive in Hollandia at its scheduled time a search was undertaken, but ultimately yielded negative results. The MACR investigation concluded that the loss of the aircraft was probably weather-related and that the wreckage was in extremely difficult terrain and unrecoverable. In addition, the MACR investigation determined that the passenger had boarded the aircraft just prior to its departure from Dobodura (Watson 1944). At the end of the war the AGRS compared the personal data of each of the five individuals against the unknown remains from the PNG region, but there were no matches. They were declared presumptively dead on December 11, 1945 and eventually deemed them non-recoverable on June 10, 1949 (Lehl 2005c, 2-3).

Twenty-nine years later, in October 1978 the U.S. Embassy in Australia forwarded information for multiple aircraft crash sites found by two Australian informants to the Memorial Affairs Division of the U.S. Department of the Army, who in turn, passed it to the U.S. Army CILHI. Included in the documentation were materials that contained the tail number of the aircraft associated with MACR 14302 (Lehl 2005c, 3-5). On April 23, 1979 a CILHI team, accompanied by one of the informants, conducted a survey of the crash site (PP-00031) and collected a fragment of maxilla containing three teeth. From October 21 through 28, 1980 a CILHI recovery team excavated the crash site and recovered a relatively complete skeleton. After laboratory analysis, the Co-pilot and the Engineer were identified on October 15, 1980 and October 15, 1981, respectively. Because only two of the five individuals aboard the aircraft on December 10, 1944 had been identified, JPAC sent an investigative team back to the site in March 2004 (Lehl 2005c, 3-5; Silverstein 2005, 2).

Site PP-00031 is located approximately 18 km northwest of Baindoung Town, Boana District, Morobe Province, Papua New Guinea. The site is comprised of two areas near the top of a ridge in the Sarawaget Mountains of the Huon Peninsula. The first area is located 3,800 m in elevation and the second is approximately 300 m lower at 3,500 m. The site can be found on the topographic map Name: Sarawaget; Sheet: 8285; Series: T601; Edition: 1; Scale: 1:100,000; Datum: Australian Geodetic Datum 1966 (Figure 96) (Silverstein 2005, 2).

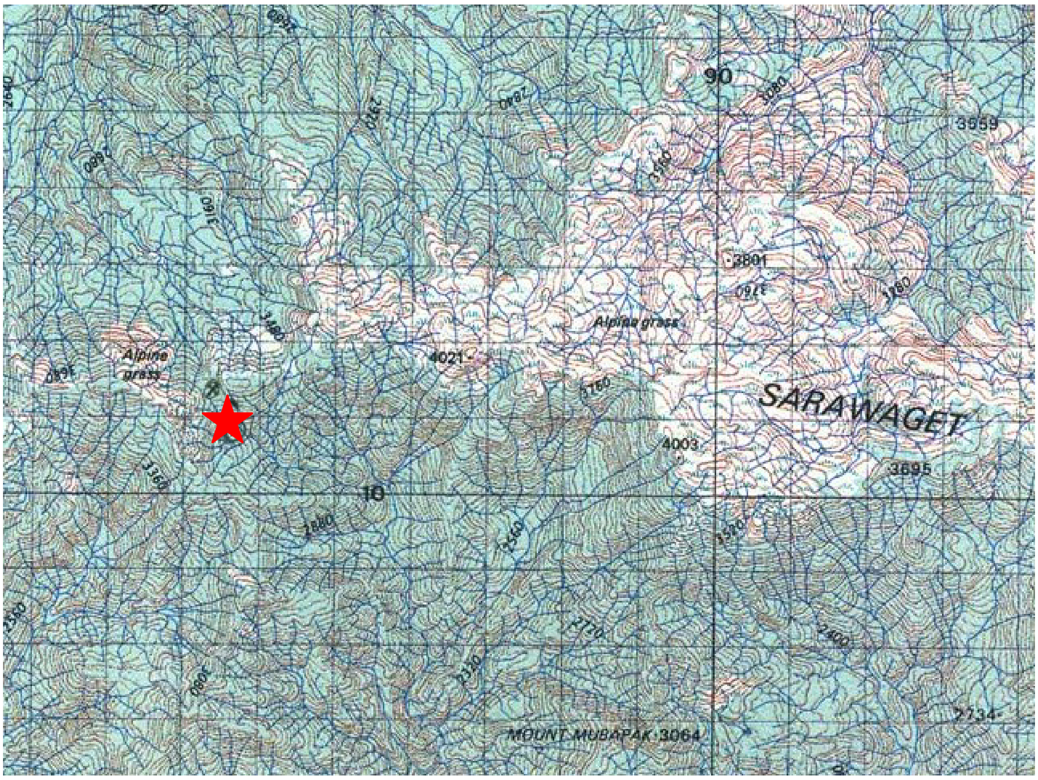

Figure 96. Topographic map showing the location of Site PP-00031 (red star).

The upper area of Site PP-00031 is located approximately 30 m below the crest of a ridge on a steep slope. The location is dominated by large boulders that are covered in vegetation typical for a location which is at the transition between tropical montane forest and alpine tundra. The lower area of the site is located on a south facing shelf with a slope that varies between 10° and 30° (Figure 97, Figure 99, and Figure 99). Firmly within the tropical montane rainforest zone, the lower area is covered in moss covered trees and dense thick mats of tough monkey grass which cover everything but the largest pieces of wreckage. Trees are only present outside the area of wreckage concentration. A stream is located on the southeast edge of the site and flows from northeast to southwest.

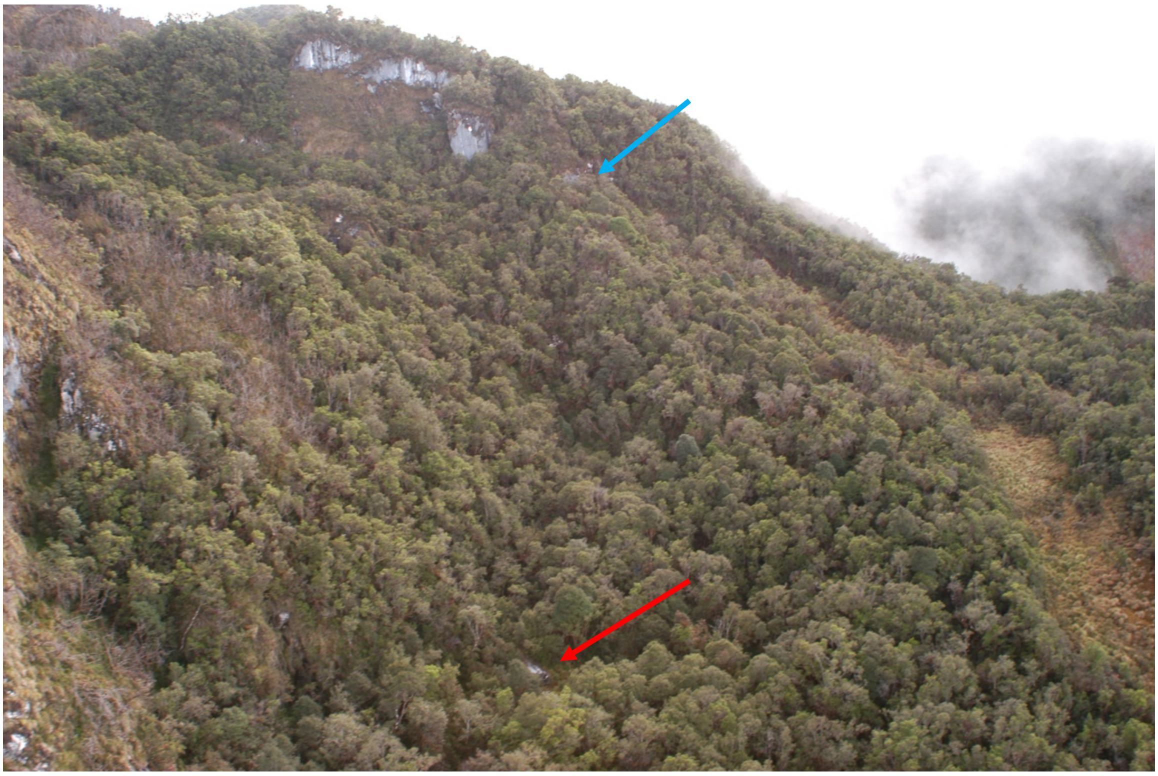

Figure 97. Aerial photograph showing the upper (blue arrow) and lower (red arrow) areas of Site PP-00031.
View to south east (Silverstein 2005, 5).

Figure 98. The fuselage of the MACR 14302 aircraft.
View to east (Silverstein 2005, 6).

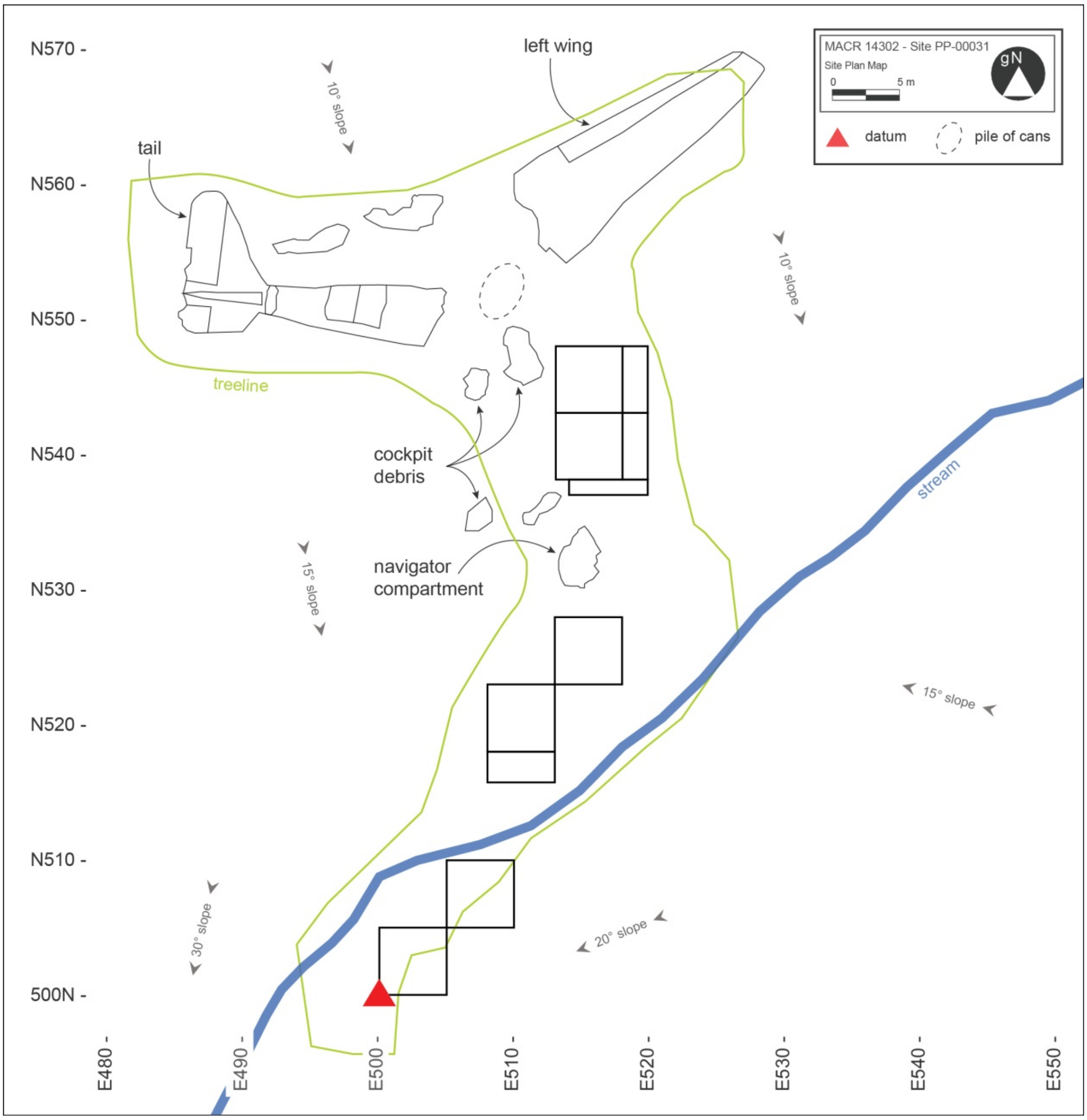

Figure 99. Map of Site PP-00031 depicting the major aircraft fragments and prominent terrain features.
(Adapted from Silverstein 2005)

The upper area of Site PP-00031 is comprised of the right wing of the aircraft. The remainder of the aircraft including the left wing, fuselage, and cockpit wreckage is all located in the lower area. The aft portion of the fuselage including the cargo compartment doors and tail is largely intact and oriented in a roughly east-west direction across the site. The left wing is also almost entirely complete and extends uphill to the northeast. Between the fuselage and wing, the aircraft's cargo load of tin cans forms a large pile. Also beginning at this point, fragments of the pilot and navigator compartments extend cross slope to the southeast towards the stream for approximately 15 m (Silverstein 2005, 4-6, 10) (Figure 99).

The recovery effort at Site PP-00031 required a single mission last from October 20 to November 16, 2004. An arbitrary reference datum was established to the southwest of the cockpit and navigator compartment wreckage and a grid of 5-x-5 m units was laid out across the debris field. Excavation began around two seats, but the presence of open buckles and a lack of personal effects or remains led the archaeologist to determine that the individuals must have been thrown clear of the aircraft during the crash. The focus shifted to the northeast corner of the grid upon the discovery of human remains during metal detector survey. Excavation of the articulated *in situ* remains was conducted with small hand tools such as trowels, brushes, wooden knives, and dental picks. Each of the five features, or distinct articulated sets of remains, was documented, removed, and bagged separately to maintain provenience. A total surface area of approximately 160 m^2 was excavated to an average depth of 25 cmbs. The excavation recovered human remains and material evidence, including identification media (Silverstein 2005; Tyrrell 2005).

Table 41. Provenience of identification media found at Site PP-00031.

Provenience	Identification Media
Feature 1	2 identification tags and a class ring (Co-pilot)
Feature 2	2 identification tags and a ring (Radio Operator)
Feature 4	Identification bracelet, wallet, identification cards (Pilot)
N508/E524	Fabric fragments with name on it (Passenger)

The distribution of wreckage clearly suggests that the aircraft lost its right wing, possibly by striking the ridgeline or simply breaking apart in the air. In either instance, while traveling in an easterly direction the C-47 impacted the ground at a relatively slow speed and a low degree of perpendicularity. This is primarily evidenced by the largely intact tail section and aft fuselage as well as the left wing which exhibits a relatively small amount of damage. Evidence of fire was encountered during the excavation in the form of burnt wood and melted aluminum along the inboard, broken edge of the left wing.

The pattern of substantial perimortem fracture within the osseous material continued when the skeletal (Christensen 2005a, b, c, d) and dental (Torske 2005j, k, l) remains were analyzed in the CIL. Patterns within the perimortem trauma were consistent with those described by Brownson et al. (1998)and Fulginiti et al. (1999). Root etching and general weathering is present in varying degrees. Evidence of mold growth was also observed. Despite evidence for burning at the site, no evidence of thermal alteration was observed on the remains.

Due to the small number of individuals involved in this incident and the very low level of commingling as a result of the crash dynamics and the excellent field work, mtDNA analysis was deemed unnecessary. Because it was recovered *in situ*, all of the osseous material could be assigned to a specific crew member and no remains were placed into a group category. Antemortem – post-mortem dental comparisons were undertaken to identify each individual. Dental remains correlated to a specific individual are displayed in Table 42.

Table 42. Dental remains correlated to a specific crew member associated with MACR 14302.

Name	Associated dental remains
Pilot	#1 - #16, #18 - #24, and #27 - #32
Co-pilot	#5 - 9, #11, and #18-31
Radio Operator	#2, #4 - #15, #18, and #20 - #28

The recovery location of each individual and their associated material evidence is displayed below (Figure 100). Identified remains are defined as dental remains that were an odontological match to the records of a casualty or skeletal remains that successfully yielded a mtDNA sequence that matched a family reference sample for a particular casualty.

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- The Pilot is represented by a mostly complete skeleton including crania and post-crania. The only major element not represented was the left os coxa. His remains were recovered in units N538/E517 and N538/E518 amongst the cockpit wreckage and a flight control wheel. His personal effects were found amongst the remains.

- The osseous materials associated with the Co-pilot consist of a mostly complete set of remains, which is not missing any major elements. The articulated skeleton was recovered from N542/E515 and N543/E515 intermingled with cockpit controls including a rudder pedal and instrument panel fragments. His personal effects were found amongst his bones.

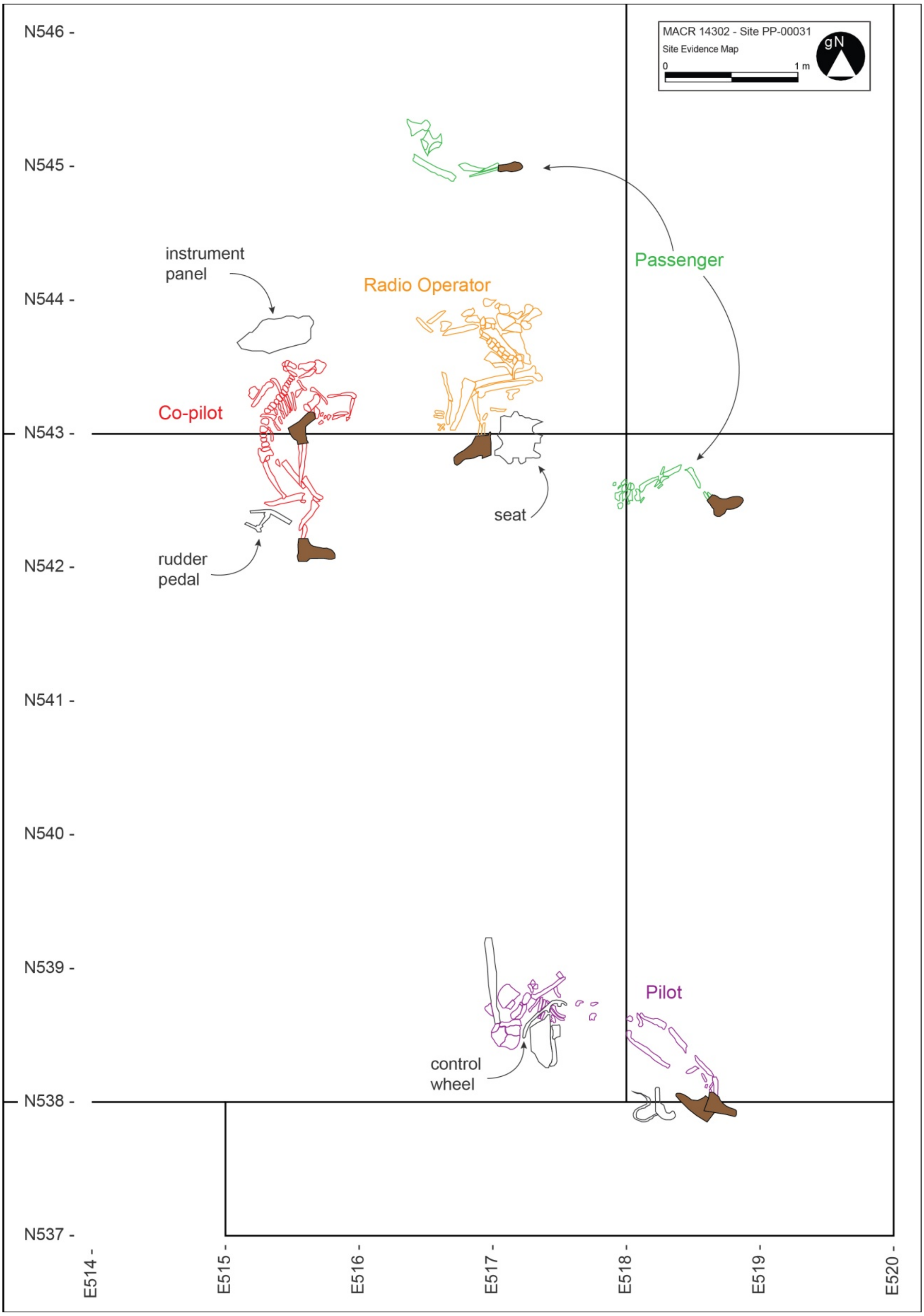

Figure 100. Map of Site PP-00031 showing the locations of each individual and pertinent recognizable aircraft components.
(Adapted from Silverstein 2005)

- The Radio Operator is represented by a mostly complete skeleton that was recovered immediately adjacent to the burnt remains of a seat in N543/E516 and N543/E517. His identification tags were found amongst the skeleton.

- The relatively complete skeleton of the Engineer was identified on October 15, 1981. No additional portions of the Engineer were recovered during the 2004 mission.

- Because the three complete articulated skeletons contained teeth that were positive dental matches to the Pilot, Co-pilot, and Radio Operator and the Engineer's previously identified remains included elements from both legs, the two remaining legs were associated to the aircraft's one Passenger. One leg was recovered from N542/E518 and the other from N545/E516.

Over 60 years after the five Army Air Forces soldiers died aboard C-47A tail number 42-24215 on December 10, 1944 individual identifications were made by the JPAC on July 21, 2005 for the Pilot, Radio Operator, and Passenger as well as the additional portions of the Co-pilot. No additional remains were recovered for the Engineer (Holland 2005d).

The outcome of the recovery effort conducted at MACR 14302 demonstrates a highly desirable, if not ideal, outcome. A minimal amount of surface area was excavated that resulted in the recovery of four sets of articulated remains with identification media. The absence of comingling meant that DNA testing was not necessary and that the laboratory portion of the identification process was completed quickly and efficiently.

8 Case Analysis

The proceeding three chapters presented completed JPAC cases of WWII bombardment and cargo aircraft. Each case was primarily treated as a individual unit. Comparisons drawn between them were intentionally restricted to characteristics of the crash sites themselves, such as size, shape, degree of perpendicularity, amount of burning, etc. As each case was discussed it was shown, when possible, where each individual aboard the vehicle and various items of identification media were recovered from within the crash site and their relation to the major components of wreckage. Making reference to similarities or differences concerning the spatial patterning and relationships between remains and wreckage was deliberately avoided.

In this chapter the focus moves from looking at single, separate loss incidents to specific duty stations aboard the two different categories of aircraft. Each position, beginning with the pilot, proceeding through the officers, and then from fore to aft through the plane is addressed individually looking across the cases presented in Chapters 5, 6, and 7. As before, bombardment aircraft are separated from the cargo aircraft.

Principally, the location of each set of a crew member's remains will be examined in relation to the wreckage from their assigned duty station. Additionally, the maximum distribution of each crew member within the site for the respective duty stations will also be considered. These distances are presented in tables throughout the chapter and are organized, top to bottom, from smallest to largest debris field. Patterns, trends, consistencies, and anomalies will be highlighted and discussed. Finally, for each duty station, a hypothesis will be presented for where an individual is most likely to be found in relation to the corresponding wreckage aboard the aircraft. As mentioned in Chapter 4, the distances included in the hypotheses are liberal estimates, meaning that they have been slightly overestimated. This is to ensure that any findings or conclusions will trend towards excavating a slightly larger area to help ensure that future JPAC missions have a higher likelihood of recovering human remains.

8.1 Bombardment Aircraft

8.1.1 Pilot

The flight deck, which contains the pilot on the port side and the co-pilot on the starboard side is the second compartment from the front of the aircraft. It is raised and aft of the nose compartment. It is directly above the forward landing gear when it is retracted and a small crawl space that is used to access the nose compartment.

Six of the eight bombardment aircraft crash case studies discussed in Chapters 5 and 6 resulted in the recovery of *in-situ* remains of the pilot that can be compared to the location of the cockpit wreckage. They are: MACRs 10020, 1069, 1459, 4497, 4512, and 8641. The lack of exact provenience for the pilot's remains from MACR 0963 prevents the case from being included in the analysis. MACR 15092 is not included because no remains or identification media were recovered for the pilot.

Table 43 lists the maximum distance that a pilot's remains were found from the cockpit wreckage in their respective crash scene and the maximum distance that each individual's remains were distributed within the overall debris field. In half of the cases, MACRs 10020, 1069, and 8641, remains were found within the same 4-x-4 m excavation unit as identifiable cockpit wreckage. In the case of MACRs 1069 and 8641 remains were found in the pilot seat itself. The one fragment of bone of the pilot associated with MACR 4497 and his ring were each approximately 4 m from the cockpit wreckage, but there was 10 m between the two (Figure 62). Finally, the greatest distance between pilot and cockpit was MACR 4512, with 20 m and a large ravine separating them (Figure 79).

Table 43. Maximum distances between pilots' remains and the corresponding wreckage and spread of the individual within the crash scene.

MACR	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
10020	0	0	Very high
1069	0	0	Very low
1459	4	4	High
4497	4	8	Moderate
8641	0	4	Very high
4512	30	0	Very low
Average	6.3	2.7	-

It appears that a moderate to high degree of perpendicularity results in an increased likelihood that the remains of the pilot will be recovered very close to, if not from within, the cockpit wreckage. However, amongst the loss incidents included in this assessment, the higher degree of perpendicularity, the more likely the aircraft is to have suffered a severe fire upon impacting the ground. So, while the pilot's remains may come to rest very close to the cockpit wreckage, they are going to be exposed to a very damaging taphonomic environment which may result in fewer remains being present to eventually be recovered during an excavation. Amongst the sample, low degree of perpendicularity crashes do not demonstrate a particular trend. In one case, MACR 1069, the pilot's remains were found partially within the cockpit wreckage and immediately downslope. Recovery efforts at the other case, MACR 4512, resulted in the recovery of a nearly complete set of articulated remains approximately 30 m away from the concentration of cockpit wreckage. Eliminating MACR 4512 from the calculation reduces average distance between remains and wreckage from 6.3 m to 1.6 m, which is more consistent with the trends presented below for co-pilots. The remains of the pilots are minimally distributed across their respective sites. There is no trend amongst high degree of perpendicularity cases, but low angle crashes do not spread out the pilot's remains. Size of debris field does not appear to be a factor in the dispersal of pilot remains.

Hypothesis: The remains of the pilot in a WWII bombardment aircraft crash scene are most likely to be found within approximately 8 m of the primary concentration of cockpit wreckage.

8.1.2 Co-pilot

It can be expected that the distribution pattern of remains for the co-pilot, whose duty station is immediately adjacent to the pilot, would be very similar to that of the aircraft commander. Remains for the co-pilot were recovered in seven of the eight bombardment aircraft cases presented in Chapters 5 and 6. The lack of exact provenience for the co-pilot's remains from MACR 0963 prevents the case from being included in the analysis. Due to provenience information not being sufficiently maintained through the skeletal analysis and DNA sampling process it is not possible to determine where the co-pilot remains from MACR 4512 were recovered from within the crash scene. As a result MACR 4512 is excluded from the co-pilot analysis. MACR 15092 is not included because no remains of identification media were recovered for the co-pilot.

Table 44 lists the average distance that co-pilot remains were found from the cockpit wreckage in their respective crash scene and the maximum distance that each individual's remains were distributed within the debris field. The remains of the co-pilot were found *in situ* in his respective seat in MACRs 1069 and 8641. In the crash site correlated with MACR 1459 the scant remains of the co-pilot were recovered in the same excavation unit as the co-pilot's seat. Additional identification media for the co-pilot of MACR 1459 was recovered from as much as 6 m away. The nearly complete *in situ* remains identified as the co-pilot recovered from the MACR 4497 crash site were found immediately adjacent to the duty station. One fragment of bone, a tooth, and an identification bracelet of the co-pilot associated with MACR 10020 were found in the same excavation unit approximately 4 m from the cockpit wreckage. An additional tooth was also recovered 4 m from the cockpit wreckage. However, 8 m separated the two groupings of evidentiary items (Figure 35).

Table 44. Maximum distances between co-pilots' remains and the corresponding wreckage and spread of the individual within the crash scene.

MACR	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
10020	4	8	Very high
1069	0	2	Very low
1459	0	12	High
4497	0	4	Moderate
8641	0	0	Very high
Average	0.8	5.2	-

Surprisingly, the interpretation for the distribution of the remains of co-pilots differs slightly from pilots. The distance that the remains are found from corresponding duty station wreckage does not appear to vary based upon degree of perpendicularity. Co-pilot remains were found within the seat itself in cases where the angle of impact is very low and very high as well as the various categories in between. Interestingly, the instances where remains and identification media were located farthest from the cockpit wreckage were cases with a very high and high degree of perpendicularity. The amount of remains representing the co-pilot recovered at high degree of perpendicularity sites is similar to that of the pilots due to the severely deleterious taphonomic environment associated with fire.

The distribution of co-pilots within sites is greater than for pilots. Unlike the aircraft commanders, however, there is no pattern within the co-pilots as to how far they will be dispersed within the crash scene degree of perpendicularity. Like the pilots, size of debris field does not appear to be a factor in the dispersal of co-pilot remains.

Hypothesis: The remains of the co-pilot in a WWII bombardment aircraft crash scene are most likely to be found within the same excavation unit containing the majority of the cockpit wreckage and generally no more than approximately 8 m from the primary concentration of cockpit wreckage.

8.1.3 Navigator/nose gunner

The forward-most position in the aircraft is crewed by the navigator/nose gunner. This individual shares the compartment with the bombardier, who sits immediately to his aft. To the rear of this compartment is the access crawl way and nose landing gear and the flight deck.

In situ remains of the navigator were recovered from five of the eight cases detailed in Chapters 5 and 6. They include: MACRs 10020, 15092, 1069, 1459, and 4497. The lack of exact provenience for the navigator's remains from MACR 0963 prevents the case from being included in the analysis. Unfortunately, due to provenience information not being sufficiently maintained through the skeletal analysis and DNA sampling process it is not possible to determine where the navigator remains were recovered from within the MACR 8641 and 4512 crash scenes. As a result, they are not incorporated in the development of the hypothesis for the navigator duty position.

The distance that navigator remains were found from the nose gun wreckage and the maximum distance that each individual's remains were distributed within the debris field are presented below in Table 45. The only osseous fragment for the navigator from MACR 10020 was found underneath the tail wreckage within the crash scene, but within 2 m of the front landing gear strut. This reflects the previously discussed compression of this aircraft during the impact. Multiple skeletal elements from the MACR 15092 navigator were from a single 4-x-4 m unit in the bottom of the crater, but it is not possible to determine their distance from the corresponding duty station wreckage because the location of those plane parts within the crash scene were not recorded during the various excavations. The one *in situ* skeletal element found at the site correlated to MACR 1069 was found within 2 meters of the chin of the aircraft and 6 m from the nose turret. No remains were recovered for the navigator associated with MACR 1459, but his identification tags were found approximately 6 m past the edge of the fuselage wreckage concentration in the direction that the aircraft is thought to have been travelling. Additionally, the navigator's wing badge was found immediately upslope of the edge of the wreckage concentration. Finally, like MACR 1459, the navigator for MACR 4497 was slightly spread out within the crash scene in an arc that ran from cross slope (behind) to upslope of the cockpit wreckage (Figure 62).

Table 45. Maximum distances between navigators' remains and the corresponding wreckage and spread of the individual within the crash scene.

MACR	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
10020	2	0	Very high
15092	0	0	Unknown
1069	4	0	Very low
1459	6	14	High
4497	5	7	Moderate
Average	3.4	4.2	-

The first trend within the navigator position, is that the individual filling that duty station is less likely to be recovered within or immediately adjacent to the nose turret as was the case with pilot and co-pilot. While there does seem to be this apparent difference from the flight deck crew, the navigator is similar to the pilot and co-pilot in that there is no variation in distribution of remains based upon degree of perpendicularity of the impact. Remains are found both close to and farther from identifiable wreckage in crashes with higher degrees of perpendicularity. Similarly, both low degree and high degree crashes have spread remains approximately the same distance.

The distribution of navigator remains within crash sites is not determined by degree of perpendicularity. Skeletal elements were found in close proximity to one another in both high and low angle cases. However, the distance between remains does appear to be associated with the overall size of the debris field. In small crash sites the remains were not spread out, while in larger sites remains were separated from each other.

Hypothesis: While the navigator is unlikely to be found within, or immediately adjacent to the nose turret, his remains are most likely going to be recovered within 8 meters of the forward compartment wreckage in a WWII bombardment aircraft crash scene.

8.1.4 Bombardier

Six out of the eight cases discussed in Chapters 5 and 6 proved to be usable in determining the distribution of bombardiers within crash scenes. They include MACRs 10020, 0963, 1069, 1459, 4497, and 4512. MACR 15092 is not included because no remains of identification media was recovered for the pilot. MACR 8641 is not included because the bombardier survived the loss incident.

Table 46, below, details the distances between the aircraft wreckage associated with the bombardier duty station and the most distant fragment of individuating evidence found for each bombardier as well as the maximum distance that each individual's remains were distributed within the debris field. All of the osseous remains for the bombardier from MACR 10020 were found in a unit adjacent to the front landing gear strut, which is located immediately aft of the bombardier's position within the bombers. His identification tags were in the next unit, approximately 6 m away from the strut. Bombardier remains from MACR 0963 were recovered within the 12-x-12 m concentration of wreckage, but his identification bracelet was found approximately 20 m upslope. The articulated remains of the MACR 1069 bombardier were recovered between the cockpit (2 m away) and nose compartment wreckage (6 m away). Two identification tags and a ring were found at the edge of the melted forward compartment wreckage at the site correlated to MACR 1459. The scant remains uncovered at MACR 4497 were underneath the flight deck wreckage, which is above and aft of the bombardier's station. Lastly, a nearly complete set of remains was recovered *in situ* approximately 3 m from the nose turret and 4 m from the cockpit feature.

Table 46. Maximum distances between bombardiers' remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
10020	6	0	Very high
0963	20	20	Very high
1069	6	0	Very low
1459	0	0	High
4497	0	0	Moderate
4512	5	0	Very low
Average	6.1	3.3	-

Patterns for bombardiers are very similar to navigators in that they are less likely to be recovered amongst their duty station wreckage than pilots and co-pilots. One trend is that both high and low degree of perpendicularity impacts resulted in remains being dispersed similar distances. Second, both of the low degree of perpendicularity cases resulted in separation of the individual from the duty station wreckage. Third, however, there is inconsistency in high degree cases. In MACR 1069 the maximum distance was 20 m, but in MACR 1459 the osseous materials were found amongst the wreckage. Fourth, material evidence tended to be projected further during the crash than human remains.

The 20 m distance from wreckage value for MACR 0963 is the result of the St. Christopher medallion that was found upstream from the main wreckage concentration at the site from which all of the bombardier's remains were recovered. As with previously discussed crew positions, degree of perpendicularity is not a factor in the distribution of the remains of bombardiers. Neither is size of debris field. In fact, the only case in which there is separation is at MACR 0963 where an identification bracelet was the only piece of evidentiary material found outside the primary concentration of wreckage.

Hypothesis: While the bombardier is unlikely to be found within, or immediately adjacent to the nose turret, his remains are most likely going to be recovered from within 8 meters of the forward compartment wreckage in a WWII bombardment aircraft crash scene.

8.1.5 Radio Operator

In a B-24 the radio operator sits directly behind, and on the same level as the pilot and co-pilot, whereas radio operators often served as the waist gunner in B-25s. Five out of seven Liberator cases detailed in Chapters 5 and 6 are included in the analysis for the position. They are: MACRs 10020, 0963, 1069, 1459, and 4497. MACR 8641 is not included because neither remains nor identification media were recovered that could individually identified as the radio operator. MACR 4512 is not included in the analysis due to provenience information not being sufficiently maintained through the skeletal analysis and DNA sampling process. This has resulted in the inability to determine where the remains of the radio operator were recovered within the crash scene.

The details of the distribution of radio operator remains within their respective crash scenes are detailed below in Table 47. Despite some of his personal belongings being somewhat spread out across the recovery scene, the MACR 10020 radio operator remains were recovered from the same unit as the radio equipment. No provenience data is available for the remains of the radio operator associated with MACR 0963, but one of his identification tags was found in one of the units containing the densest concentration of wreckage. The remains of the MACR 1069 radio operator were found in a unit immediately behind the cockpit wreckage based upon an eastward direction of travel for the aircraft at the time of the crash. The MACR 1459 radio operator's bones were recovered from both the western and eastern sides off the majority of the cockpit wreckage. At MACR 4497, remains identified as the radio operator were recovered amongst the wreckage between the aft portion of the fuselage and the cockpit, which is what would be expected. Additional portions of his skeleton were found approximately 4 m away from the port side of the aft fuselage.

Table 47. Maximum distances between radio operators' remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
10020	0	8	Very high
0963	0	0	Very high
15092	8	8	Unknown
1069	0	0	Very low
1459	4	0	High
4497	4	4	Moderate
Average	2.6	3.3	-

As noted with the previously analyzed crew positions, there does not seem to be any pattern to the distribution of the radio operator's remains within the crash scene based upon the degree of perpendicularity of the aircraft crash. Skeletal elements were found alongside radio equipment (e.g. MACR 10020) or in locations amongst the wreckage that correspond to that crew position within the aircraft (e.g. MACR 1069) in both high degree and low degree cases. The radio operator position is comparable to the co-pilot position in that the remains are found very close to the duty station wreckage within the crash scene.

As with the separation of remains from the corresponding duty station, there does not appear to be any correlation between degree of perpendicularity of the crash and the spread of each individual within the crash scene. Very high degree of perpendicularity cases resulted in both an 8 m distribution of identification media in MACR 10020 and a spread of 0 m in MACR 0963. Additionally, both very high and very low degree of perpendicularity impacts resulted in a lack of scatter amongst the radio operators' remains.

Hypothesis: The remains of the radio operator in a WWII bomber aircraft are likely to be recovered in close association (4 m) with the duty station's equipment or located within the crash scene between the fuselage and cockpit wreckage.

8.1.6 Engineer/Dorsal Gunner

In addition to being responsible for keeping the aircraft in operational condition, the aircraft engineer was also assigned to the dorsal gun turret during missions. This station is immediately aft of the radio operator's position and also raised up so that the seat where the gunner sits is about level with the radio operator's head. This is the highest position in the aircraft.

All of the cases presented in Chapters 5 and 6 are included in the analysis of the engineer position. Table 48 presents the details of the distribution of engineer/dorsal gunner remains within their respective crash scenes. The engineer was the most widely distributed individual aboard the MACR 10020 aircraft with all of his remains and personal effects being found within 6 m of the dorsal turret ring. The engineer was found in the deepest portions of the crater in four of the 4-x-4 m units and the two eastern quadrants at the crash site correlated with MACR 15092. The engineer's remains from MACR 1069 were found in the unit containing the dorsal turret, but also underneath and adjacent to the aft fuselage wreckage. Only identification tags were found for the engineer of MACR 1459 and they were located forward (west) of the pilot compartment wreckage. MACR 4497's engineer was found *in situ* between the fuselage wreckage and partially under the cockpit wreckage. His identification tags were found amongst the aft fuselage wreckage. The three skeletal fragments that were individuated to the engineer of MACR 8641 were recovered from an area adjacent to the nose compartment wreckage. *In situ* remains of the engineer were found within the cockpit wreckage of the MACR 4512 crash site. This was approximately 30 m away from the dorsal turret. The lack of exact provenience for the engineer's remains from MACR 0963 prevents the case from being included in the analysis.

Table 48. Maximum distances between engineer remains and dorsal gun wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
10020	6	8	Very high
15092	8	8	Unknown
1069	10	12	Very low
1459	4	-	High
4497	4	8	Moderate
8641	4	2	Very high
4512	30	2	Very low
Average	9.4	6.7	-

The remains of the engineer/dorsal gunner exhibit some of the greatest separation from their duty station wreckage of the crew positions discussed in this chapter. This pattern holds true across the entire spectrum of degree of perpendicularity. However, it should be noted that this is the one crew position where the very low degree of perpendicularity crashes have highest separation values. Furthermore, the separation of remains from duty station does not appear to be based on the overall size of the crash site. The engineer's remains are farthest from the corresponding wreckage in both MACR 10020, the smallest, and MACR 4512, the largest site. The higher separation in low angle crashes may be due to this crew position within the aircraft being highly exposed and even partially outside of the fuselage. The frequency of the engineers/gunners being distributed within a crash scene is greater than the previously discussed duty positions. However, the degree of perpendicularity is not indicative of the extent to which they will be spread across a crash scene. Remains were close together and farther apart in both low and high degree of perpendicularity crashes.

The effects observed for the pilot of MACR 4512 as a result of the apparent swapping of seats by the pilot and the engineer in that loss incident are correspondingly present for the engineer. The average maximum distance between remains and duty station wreckage is 9.1 m when all of the cases are included. However, the figure drops to 5.7 m when MACR 4512 is excluded from the calculation. The unique distribution pattern of remains within MACR 4512 is an anomalous case when compared to the others and will be discussed in greater detail in Chapter 10.

Hypothesis: Remains of the engineer/dorsal gunner are likely to be found in relatively close association (8 m) with the corresponding wreckage in a WWII bombardment aircraft crash scene, but additional remains may be recovered as much as 10 m away.

8.1.7 Ball Turret Gunner, Radar Operator, Photographer

Moving towards the rear of the aircraft, behind the dorsal gunner is the bomb bay, which occupies the central third of the fuselage and is in line with the wings in WWII bombardment aircraft. Aft of these was a section of the aircraft that could be modified to accommodate a variety of different pieces of equipment depending on the specific function that an aircraft was being built for. Standard, combat mission B-24s were equipped with a ball turret, but this was also where a photographer, or radar operator would be stationed.

Table 49 lists the maximum distance that ball turret gunners remains were found from the aft fuselage wreckage in their respective crash scene and the maximum distance that the remains from a single individual were dispersed across the site. The B-25 included in

Chapter 5 is a C model and did not have this crew duty position. As a result, six of the seven Liberator cases discussed in Chapters 5 and 6 are included in the analysis of the location or remains for the belly position located in the forward portion of the aft fuselage. A gold denture and an identification media for the MACR 10020 ball turret gunner were recovered within the wreckage concentration in a unit adjacent to the radio equipment. Remains for MACR 0963 were found within the dense wreckage concentration and an adjacent unit. The *in-situ* bones of the radar operator aboard MACR 1069 were found approximately 8 m downslope of the aft fuselage wreckage. Identification media for the radar operator listed on MACR 1459 was found 4 m from the aft fuselage wreckage. Remains from MACR 4497 were found at a location within the wreckage that corresponds to the belly turret as well as approximately 8 meters downslope. The belly gunner's remains from MACR 4512 were broadly spread across one slope of the site with the most distant fragment being found 20 m upslope and behind the duty station wreckage. MACR 8641 is not included because the photographer parachuted out of the aircraft after it was struck by anti aircraft artillery fire.

Table 49. Maximum distances between belly position crew members remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
10020	4	0	Very high
0963	4	4	Very high
15092	4	4	Unknown
1069	8	0	Very low
1459	4	0	High
4497	8	8	Moderate
4512	20	47	Very low
Average	6.3	9.0	-

In MACRs 0963 and 4497 some of the skeletal elements of the crew member who was assigned to the belly turret position were recovered amongst the corresponding aircraft wreckage. The remains of the individual assigned to the belly turret position in the remainder of the MACRs listed in Table 49 were not found amongst the duty station wreckage. In all of MACRs, however, remains had been separated from the duty station by an average of 6 m, or 8 m if MACR 4512 is included. Separation of remains from the duty station does not appear to be tied to degree of perpendicularity or overall size of the debris field. In MACRs 10020, 1069, and 1459 the belly turret position individual was not scattered across the recovery scene, while MACRs 0963, 15092, and 4497 exhibited some distribution. As with the pilot, engineer, and waist gunner, the portions of the belly turret crew member were found very widely spread across the site with the farthest elements 20 m from the corresponding wreckage.

The distribution of this crew duty position is similar to the engineer/dorsal gunner. In all of the cases other than MACR 4512 the remains were found close to the corresponding wreckage and the average distance is increased by the anomalous case. The average maximum distance between remains and duty station is 8.0 m when all of the cases are included. However, the figure drops to 5.6 m when MACR 4512 is excluded from the calculation. The unique distribution pattern of remains within MACR 4512 is an anomalous case when compared to the others and will be discussed in greater detail in Chapter 10.

Hypothesis: Some remains of the individual manning the belly turret position can be expected to be found at the forward end of the aft fuselage wreckage in a WWII bombardment aircraft crash scene. Additional remains will most likely be found within 8 m of the duty station wreckage.

8.1.8 Waist Gunners

Occupying the majority of the aft fuselage, the two waist gunners stood back to back and faced out away from the midline of the aircraft. They were positioned between the belly turret position and the tail gunner and had one of the easiest escape routes available to them.

Of the eight bombardment aircraft crash case studies discussed in Chapters 5 and 6, seven of them resulted in the recovery of *in-situ* remains of the pilot that can be compared to the location of the aft fuselage wreckage. They are: MACRs 10020, 0963, 1069, 1459, 4497, 8641, and 4512. MACR 15092 is not incorporated because neither remains nor identification media were found for the waist gunners.

Table 50 lists the maximum distance that waist gunner remains were found from the aft fuselage wreckage in their respective crash scene and the maximum distance that the remains from a single individual were dispersed across the site. At MACR 10020 each waist gunner was found in a single unit, 8 m apart. The two gunners for MACR 0963 were both spread across the same two units. Skeletal remains from the MACR 15092 navigator were from four of the 4-x-4 m units in the bottom of the crater and all four quadrants, but it is not possible to determine their distance from the corresponding duty station wreckage because the location of those plane parts within the crash scene were not recorded during the various excavations. The articulated remains of one of the MACR 1069 waist gunners was recovered 21 m from the aft fuselage wreckage. It is likely that the radar operator from this same MACR was also responsible for manning the other waist gun. One waist gunner bailed out of the MACR 1459 aircraft, but the other was found in the same unit as the appropriate wreckage and up to two units away. Both waist gunners associated with MACR 4497 were found articulated and *in situ*, but one of them was found amongst the corresponding duty station wreckage while the other was 9 m downslope. Like MACR 1459, one of the waist gunners managed to bail out of the MACR 8641 aircraft. The remains of the other were found within the aft fuselage wreckage. Articulated, *in situ* partial remains were recovered for one of the MACR 4512 waist gunners in a unit adjacent to the wreckage. However the other waist gunner was found as far away as 30 m from the same wreckage.

Table 50. Maximum distances between the waist gun crew members' remains and the corresponding wreckage, the spread of each waist gunner within the crash scene, and the distance between the two waist gunners.

Case	Distance from wreckage (m)	Intra-individual distance between remains (m)	Distance between the waist gunners	Degree of Perpendicularity
10020	4	2 and 0	8	Very high
0963	4	4	-	Very high
15092	-	8	-	Unknown
1069	8 and 21	8 and 0	23	Very low
1459	6	7	-	High
4497	0 and 9	0 and 0	9	Moderate
8641	0	-	-	Very high
4512	5 and 37	5 and 48	43	Very low
Average	9.4	6.4	20.7	-

All of the skeletal elements of two crew members, except one from MACR 4497 and one from 8641, who were assigned to the waist gun position were recovered amongst the corresponding aircraft wreckage. Portions of an individual's skeleton were found at the duty station wreckage for MACRs 10020, 0963, 1069 1459, 4497, and 4512. No osseous materials were found near the waist gun components for a crew member at MACR 1069, 4497, and 4512. MACRs 10069, 4497, and 4512 are listed twice because in each case one crew member fit each pattern.

In moderate to very high degree of perpendicularity crashes the remains are found close to the wreckage. Amongst the very low angle crashes, MACRS 1069 and 4512, three out of four individuals were recovered 8 m, 21 m and 45 m away, respectively. However, the two cases differ in that at 1069 one set of remains were found fully articulated and at 4512 the individual was spread over 43 m.

The maximum distance between any two fragments of the two waist gunners is 43 m in the case of MACR 4512. This is a result of one of the individuals being spread over such a large portion of the site. The second greatest separation is MACR 1069 at 23 m where one individual is partially located at the fuselage remnants and another was two ridges away near the nose wreckage. In the MACR 10020 crash site both gunners were separated from the wreckage by 4 m, but in opposite directions. MACR 4497 has one crew member at the wreckage and another that had come to rest approximately 9 m downslope.

The unique pattern observed amongst the previous two duty stations at Site PP-00200 (MACR 4512) continues with one of the waist gunners. However, in addition, one of the waist gunners associated with MACR 1069 was also found widely separated from the corresponding wreckage. In both instances the inclusion of these cases results in an average maximum distance between remains and duty station of 9.4 m. This is the highest average of any duty station in either category of aircraft. The figure drops to 6.5 m when MACR 4512 is excluded from the calculation. The distance drops even further to 3.8 m if both MACR 4512 and MACR 1069 are excluded. The unique distribution pattern of remains within MACR 4512 is an anomalous case when compared to the others and will be discussed in greater detail in Chapter 10.

Hypothesis: Regardless of degree of perpendicularity or size of debris field, the remains of waist gunners are most likely to be found within 10 m of the corresponding aircraft wreckage in a WWII bombardment aircraft crash scene.

8.1.9 Tail Gunner

The tail turret is the most aft-ward crew position in the aircraft and is reached by passing through waist gummer compartment. Of the eight bombardment aircraft crash case studies discussed in Chapters 5 and 6, five of them resulted in the recovery of *in-situ* remains of the tail gunner that can be compared to the location of the corresponding wreckage. They are: MACRs 0963, 1459, 4497, and 4512. MACRs 10020 and 1069 were only flying with

9 crew members due to the nature of their missions and did not have tail gunners. No remains of personal items of the MACR 8641 tail gunner were recovered.

Table 51 lists the maximum distance that tail gunner remains were found from the aft tail turret in their respective crash scene and the maximum distance that the remains from a single individual were dispersed across the site. The tail gunner aboard MACR 0963 was found amongst the main 12-x-12 m wreckage concentration, but the exact provenience is unknown. The deepest portions of the southern side of crater and two of the 4-x-4 m units at MACR 15092 contained skeletal elements from the tail gunner. However, it is not possible to determine their distance from the corresponding duty station wreckage because the locations of those plane parts within the crash scene were not recorded during the various excavations. Partial remains of the MACR 1459 tail turret were recovered from underneath the aft fuselage wreckage. The lower half of the MACR 4497 tail gunner was recovered from underneath the tail turret while the upper half was found amongst the forward end of the aft fuselage wreckage.

Table 51. Maximum distances between tail turret crew members remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
0963	8	-	Very high
1459	0	0	High
4497	8	8	Moderate
4512	0	4	Very low
Average	4.0	5.3	-

The tail gun position has the smallest sample size of the bombardment aircraft duty stations. There is no apparent pattern in the distribution of tail gunner remains based upon the degree of perpendicularity. In high angle cases skeletal materials were found both within the tail turret wreckage and up 8 m away. Remains were also recovered from within the duty station wreckage in crashes with both high and very low degrees of perpendicularity. Overall size of the debris field also does not appear to be a determining factor. Likewise, the distance a turret gunner's remains are going to be distributed across the crash scene are not determined by perpendicularity or size of debris field.

Hypothesis: Regardless of degree of perpendicularity or size of debris field, the remains of tail gunners are most likely to be found within 8 m of the tail turret wreckage in a WWII bombardment aircraft crash scene.

8.1.10 Summary

The predominant trend amongst the eight bombardment aircraft crash cases is one of consistency. This is regardless of the size of the debris field, estimated degree of perpendicularity of the crash, or the scale at which the aircraft are examined. The mean separation of a crew member's remains and their corresponding duty station wreckage for the forward half (pilot, co-pilot, navigator, bombardier, radio operator, and engineer/dorsal gunner) of the aircraft is 5.1 m. The aft positions (ball turret gunner/photographer/radar operator, waist gunners, and tail gunner) are slightly higher at 7.7 m. The average a distance for all assessable individuals in the case studies is 6.1 m.

In general, an individual's remains within the crash scene can be expected to be recovered relatively close to their corresponding duty station wreckage (Table 52). Remains associated with eight of the nine crew positions are found within approximately 8 m of the corresponding duty station wreckage. Additionally, an individual's remains, when scattered, are also typically within relatively close proximity of one another. Again, in only one duty station are the remains scattered over a distance greater than 8 m.

Table 52. Maximum average distances between crew remains and duty station wreckage and distribution of a crew member's remains within a site.

Duty station	Average distance from wreckage (m)	Average spread of remains (m)
Pilot	6.3	2.7
Co-pilot	0.8	5.2
Navigator/ nose gunner	3.4	4.2
Bombardier	6.1	3.3
Radio operator	2.6	3.3
Engineer/top turret gunner	9.4	6.7
Ball turret gunner/ radar operator, photographer	6.3	9.0
Waist gunner	9.4	6.4
Tail gunner	4.0	5.3
Average	5.4	5.1

The exception to this pattern is the MACR 4512 loss incident (Site PP-00200), which has a much larger separation and distribution of the remains for the engineer/top turret gunner, ball turret gunner/ Radar operator, photographer, and waist gunner that the other cases. The potential causes for, and results of, this situation will be discussed extensively below in Chapter 10.

Summary Hypothesis: In general, the remains of crew members in a WWII bombardment aircraft crash scene can be expected to be recovered from within approximately 8 m of their corresponding duty station wreckage.

8.2 Cargo Aircraft

Typically, fewer service personnel were aboard cargo aircraft as compared to bombardment planes. The crew were also concentrated towards the front of the plane as opposed to being spread from nose to tail. These duty stations were the pilot, co-pilot, and radio operator/navigator. Individuals that did not have an assigned duty station in the cockpit were stationed in the large cargo compartments that comprised the majority of the fuselage. As a result, the cargo aircraft are broken down into four duty stations: pilot, co-pilot, radio operator/navigator, and cargo compartment.

8.2.1 Pilot

The flight deck is the forward-most compartment in both the Curtiss-Wright C-46 Commando and the Douglas C-47 Dakota, with the pilot sitting on the port side. Pilot remains were recovered in two of the four cargo aircraft cases presented in Chapter 7, MACRs 3282 and 14302. MACR 4441 and REFNO 0222 are not included because no remains, identification media, or personal effects were recovered for the pilot in either of the losses.

Table 53 lists the maximum distance that a pilot’s remains were found from the cockpit wreckage in their respective crash scene and the maximum distance that each individual’s remains were distributed within the debris field. At the site correlated with MACR 3282 no remains of the pilot were recovered, but a leather knife sheath incised with the pilot’s initials was found within the cockpit wreckage scatter. The articulated skeleton of the MACR 14302 pilot was recovered *in-situ* and intermixed with fragments of cockpit debris.

Table 53. Maximum distances between pilot remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
3282	0	0	Very high
14302	0	0	Low
Average	0	0	-

In the two cases where remains or personal effects could be attributed to the pilot, they were found amongst the corresponding the duty station wreckage. This pattern is present in both a very high and a low degree of perpendicularity crash. It is not possible to determine if the angle of impact is a factor in the distribution of a pilot within the crash scene because the knife sheath is the only item that can be directly attributed to the pilot in MACR 3282 due provenience information not being carried forward through the DNA sampling process.

Hypothesis: The remains of the pilot in a WWII cargo aircraft crash scene can be expected to be found within the primary concentration of cockpit wreckage.

8.2.2 Co-pilot

The co-pilot sits on the starboard side of the cockpit compartment in both the C-46 and C-47. Co-pilot remains were recovered in two of the four cargo aircraft cases presented in Chapter 7, MACRs 4441 and 14302. While remains were recovered for the co-pilot in MACR 3282 they are not included in this analysis because provenience information was not carried forward through the DNA sampling process. REFNO 0222 is not included because no remains, identification media, or personal effects were recovered for the co-pilots.

The maximum distance that a co-pilot's remains were found from the cockpit wreckage in their respective crash scene and the maximum distance that each individual's remains were distributed within the debris field are shown below in Table 54. Three of the co-pilot's teeth were found within the cockpit wreckage scatter at the site correlated with MACR 4441. Like the pilot at Case 14302, the co-pilot was also found recovered *in-situ* Between fragments of a rudder pedal and a large portion of the instrument panel. The co-pilot was located approximately 5 m away from the pilot (Figure 100).

Table 54. Maximum distances between co-pilot remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
4441	0	0	Low
14302	0	0	Low
Average	0	0	-

The two crashes that resulted in the recovery of co-pilot remains that could be traced back to a specific location within the crash scene were both characterized by a low degree of perpendicularity. In each instance the remains were immediately adjacent to the corresponding wreckage and were not spread out within the debris field. These results do not provide any information regarding cargo aircraft crashes with a degree of perpendicularity.

Hypothesis: The remains of the co-pilot in a WWII cargo aircraft crash scene can be expected to be found within the primary concentration of cockpit wreckage.

8.2.3 Radio Operator/Navigator

The C-46 and the C-47 are similar in that the radio operator or navigator sit in a compartment immediately to the aft of the flight deck. However, in the C-46, this crew station faces the starboard wall of the fuselage, while in the C-47 it faces the port side of the aircraft. Radio operator/navigator remains were recovered in two of the four cargo aircraft crashes discussed in Chapter 7. They are MACRs 4441 and 14302. Remains of the radio operator in MACR 3282 were recovered, but this case is not included in this analysis because provenience information was not carried forward through the DNA sampling process. REFNO 0222 is not included because no remains, identification media, or personal effects were recovered for the navigator.

Table 55 displays the maximum distances that radio operator/navigator remains were found of their respective duty station components and the distances that each individual is distributed across the site. Three hand bones and a tooth from the navigator aboard MACR 4441 were found within the cockpit debris. The radio operator for MACR 14302 was recovered *in-situ* immediately adjacent the seat he would have been sitting in aboard the flight (Figure 100).

Table 55. Maximum distances between radio operator/navigator remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
4441	0	0	Low
14302	0	0	Low
Average	0	0	-

The conclusions that can be reached for this duty position aboard the cargo aircraft are almost identical to that of the co-pilot. The two crashes that resulted in the recovery of co-pilot remains that could be traced back to a specific location within the crash scene were both characterized by a low degree of perpendicularity. In each instance the remains were immediately adjacent to the corresponding wreckage and were not spread out within the debris field. These results do not provide any information regarding cargo aircraft crashes with a degree of perpendicularity.

Hypothesis: The remains of the radio operator or navigator in a WWII cargo aircraft crash scene can be expected to be found within the primary concentration of cockpit wreckage.

8.2.4 Cargo Compartment Crew

The cargo compartments in the two aircraft are very similar. Each of them has bench seating along the sides and a cargo door on the port side towards the aft end. The only substantive difference is that the C-46 is larger than the C-47 and thus had the ability to carry a larger payload. Remains from individuals who would have been stationed in the cargo compartment were found in three of the four cargo aircraft cases presented in Chapter 7: MACRs 4441 and 14302 as well as REFNO 0222. MACR 3282 is not included because no remains, identification media, or personal effects were recovered for the crew chief in the loss.

The maximum distances that remains of the cargo compartment crew were found from their respective duty station components and the distances that each individual is distributed across the site are provided below in Table 56. MACR 4441 and REFNO 0222 each had three individuals who would have been located in the cargo compartment. In both cases items were only found for one of the individuals. An identification tag for one of the MACR 4441 drop crew was recovered at the eastern end of the cockpit wreckage scatter that also contained large sections of fuselage. A tooth from one of the REFNO 0222 gunners was recovered in the bank immediately adjacent to the rice paddy close to where witnesses had indicated the tail wreckage had been scavenged. The remains of the passenger aboard MACR 14302 were recovered near the individuals from the forward sections of the aircraft but approximately 10 m from the cargo compartment wreckage. However, the individual’s two legs were found 3 m apart.

Table 56. Maximum distances between cargo compartment crew remains and the corresponding wreckage and spread of the individual within the crash scene.

Case	Distance from wreckage (m)	Distance between remains (m)	Degree of Perpendicularity
4441	0	0	Low
0222	4	0	High
14302	10	3	Low
Average	4.7	1	-

The cargo compartment crew are the first amongst the cargo aircraft duty stations to be recovered with any separation from their corresponding wreckage. This pattern holds true for crashes with both high and low degrees of perpendicularity. However, there is a lack of consistency within those crashes with low angles of impact. In one loss incident, MACR 4441 the remains were found amongst the fuselage wreckage, while in MACR 14302, the skeletal elements were closer to the cockpit wreckage.

Hypothesis: The remains of the cargo compartment crew in a WWII cargo aircraft crash scene can be expected to be found within 8 m of the largest concentration of fuselage wreckage.

8.2.5 Summary

Despite the lack of evidence recovered at some of the cargo aircraft crash sites (REFNO 0222 and MACR 4441) and the provenience information not being carried through the mtDNA sampling process (MACR 3282), sufficient information was collected to allow for additional, more general conclusions to be reached. The most notable is a broader pattern amongst the forward crew positions including the pilot, co-pilot, and radio operator/ navigator. All of the remains and personal effects were recovered either within, or in very close proximity to, the cockpit wreckage or the fuselage impact crater (Figure 84, Figure 89, Figure 95, and Figure 100). This trend is consistent in both C-46 and C-47, size of debris field, and degree of perpendicularity of the crash. In no instance were any skeletal material found farther away than a few meters.

A notable observation regarding the MACR 14302 site is the positions of the pilot and co-pilots in relation to one another and the crash itself. The orientation of the wreckage indicates that the aircraft was traveling in an easterly direction at the time it impacted the ground. As such, it would expected that the pilot, who sits on the port side of the aircraft, would be found more north of the co-pilot, who sits on the starboard side, within the debris field. This, however, is not the case. The co-pilot was in fact recovered to the north of the pilot by almost 5 m.

Summary hypothesis: Amongst WWII cargo aircraft crash scenes, the remains and personal effects of the crew that are stationed within the forward two compartments will be found within very close proximity to the corresponding duty station wreckage or the crater produced by the fuselage. Individuals who would have been assigned to the cargo compartment can also be expected to be recovered from within the main concentration of cockpit wreckage.

9 Bombardment and Cargo Test Cases

Thus far, a collection of previously completed bombardment and cargo aircraft crash cases has been presented. Locations, terrain, local geographical and environmental factors, along with crash dynamics have been discussed. Within both aircraft categories each duty station has been critically assessed and examined to determine the distribution of the corresponding crew member. This analysis considered distance any fragment of a crew member was recovered from the associated duty station wreckage as well as the greatest distance between elements from a single individual. Patterns and trends were discussed and a hypothesis has been developed as to the most likely location within a crash scene an individual is likely to be found for each duty station.

Two additional cases are presented in this chapter, one bombardment aircraft and one cargo aircraft. These cases were intentionally excluded from Chapters 5 through 7 and remained unexamined so that the hypotheses in Chapter 8 could be developed without bias. This strategy also allows them to serve as test cases for the hypotheses.

The two cases included in this chapter are currently still active within the JPAC and the CIL. For the bombardment aircraft, the excavation of the site has been completed, all of the DNA results have been received from the AFDIL, and the skeletal and odontological material is currently undergoing laboratory analysis. For the cargo aircraft, the excavation is approximately 90% complete with numerous items of identification media having been recovered. These personal effects will serve as the proxy for the remains in this case so as to allow the testing of the hypotheses developed in Chapter 8.

Because the two cases are still being actively worked, some of the details that were included in the cases presented in Chapters 5 through 7 cannot be discussed. These include the case number, the aircraft serial number, the date of loss, and any location information more detailed than the country of loss. An additional departure from Chapter 5 through 7 is that the word possible will be used in front of any reference to human remains for the cargo aircraft test case. This is the result of the skeletal material from the case not yet having gone through laboratory analysis at the present time due to the unfinished excavation of the site.

9.1 Bombardment Aircraft Test Case

The bombardment aircraft crash test case involves the loss of twelve individuals aboard an B-24D assigned to the 5th Air Force, 90th Bombardment Group, 321st Bombardment Squadron approximately two thirds of the way through the Pacific Theater of WWII. The aircraft departed Nadzab Airfield as part of a large formation of heavy bombers that were targeting airfields and antiaircraft defensive fortifications around Hansa Bay on the northern coast of New Guinea. Several witnesses aboard other aircraft that survived the mission reported that when the test case aircraft broke formation to begin its bombing run the number two engine was struck by antiaircraft artillery. The B-24 then aborted the bomb run, jettisoned its ordnance, and began to turn away. At this time it was hit by another round of antiaircraft artillery, caught fire, and began to break apart as it went down. Observers indicated that they saw five parachutes descending from the crippled bomber. Escorting P-38 fighters remained over the burning crash site and reported that they saw two individuals who had parachuted from the aircraft moving around on the ground in the vicinity of the crash site (Speelhoffer 2013, 1-3). The occupied crew positions were the Pilot, Co-pilot, Navigator, Bombardier, Engineer, Radio Operator, Assistant Radio Operator, Photographer, and four Gunners.

All of the men were declared missing in action on the date of the crash. The 321st Bombardment Squadron flew over the crash site and dropped food and supplies for two days after the loss, but did not observe any additional signs of the missing crew members. Approximately six months later, information surfaced through Australian forces that four American airmen had been captured by Japanese forces near Hansa Bay around the time of the loss incident. Allegedly, as the four individuals were being moved towards larger contingents of Japanese forces they eventually died or were killed and buried in three separate locations. Extensive work by the AGRS from 1944 through 1949 resulted in the recovery and eventual identification of three of the individuals aboard the aircraft: the navigator, photographer, and one of the gunners. Over the course of this process the War Department declared the 12 men dead in February 1946. In July 1949 AGRS officials reviewed all of the available information regarding the loss and determined that the remaining nine crew members were non-recoverable (Speelhoffer 2013, 4-7). No additional work would be undertaken on the case for approximately 52 years.

In September 2001 an investigation team traveled to the Hansa Bay area to canvas villages in an attempt to locate anyone who may know of any airplane crashes in the region. In one of the villages informants told the team that during the war an aircraft had been shot down and that men had parachuted out of it. One of the villagers also alleged that two of the men had made their way to one of the villages from where the AGRS had recovered one of the individuals. With the aid of the local residents the team traveled to the site and found an extensive debris field with numerous large fragments of wreckage from a B-24. One of these pieces was one of the vertical stabilizers and the airframe serial number painted on the side was still legible. The number matched the plane that is included here as the bombardment aircraft test case. Another investigation of the site was undertaken in July 2004. The team interviewed the landowner of the site and discovered additional fragments of wreckage that had not previously observed. In April 2008 a third investigation team returned to the site to collect additional information for the upcoming recovery effort. At that time a local resident handed over some skeletal material that reportedly came from the site (Speelhoffer 2013, 7-8).

The bombardment aircraft crash test case site consists of five separate areas, A through E, which are spread out across an area approximately 640 m north-south and 440 m west-east (70 acres) (Figure 101). The entire site is situated in rolling hills separated by gullies and intermittent steams, which quickly become swollen during rain (Figure 102). The slopes are covered in dense triple-canopy tropical forest. The upper canopy consists of large (50 cm diameter) hardwood deciduous trees. Lower stories are dominated by smaller trees, larger palms, and bamboo. Closest to the ground are a wide variety of densely packed bushes, ferns, vines, smaller palms, shrubs, and grasses. A dense layer of leaf litter is common throughout the site (Figure 103). The closest village is several kilometres away and the local residents who own various portions of the site use the land for gathering wild foods and hunting. Footpaths, which typically followed the ridgelines, crisscrossed the site and connected the various wreckage concentrations (Esh 2009, 6; 2010, 7; 2011a, 7).

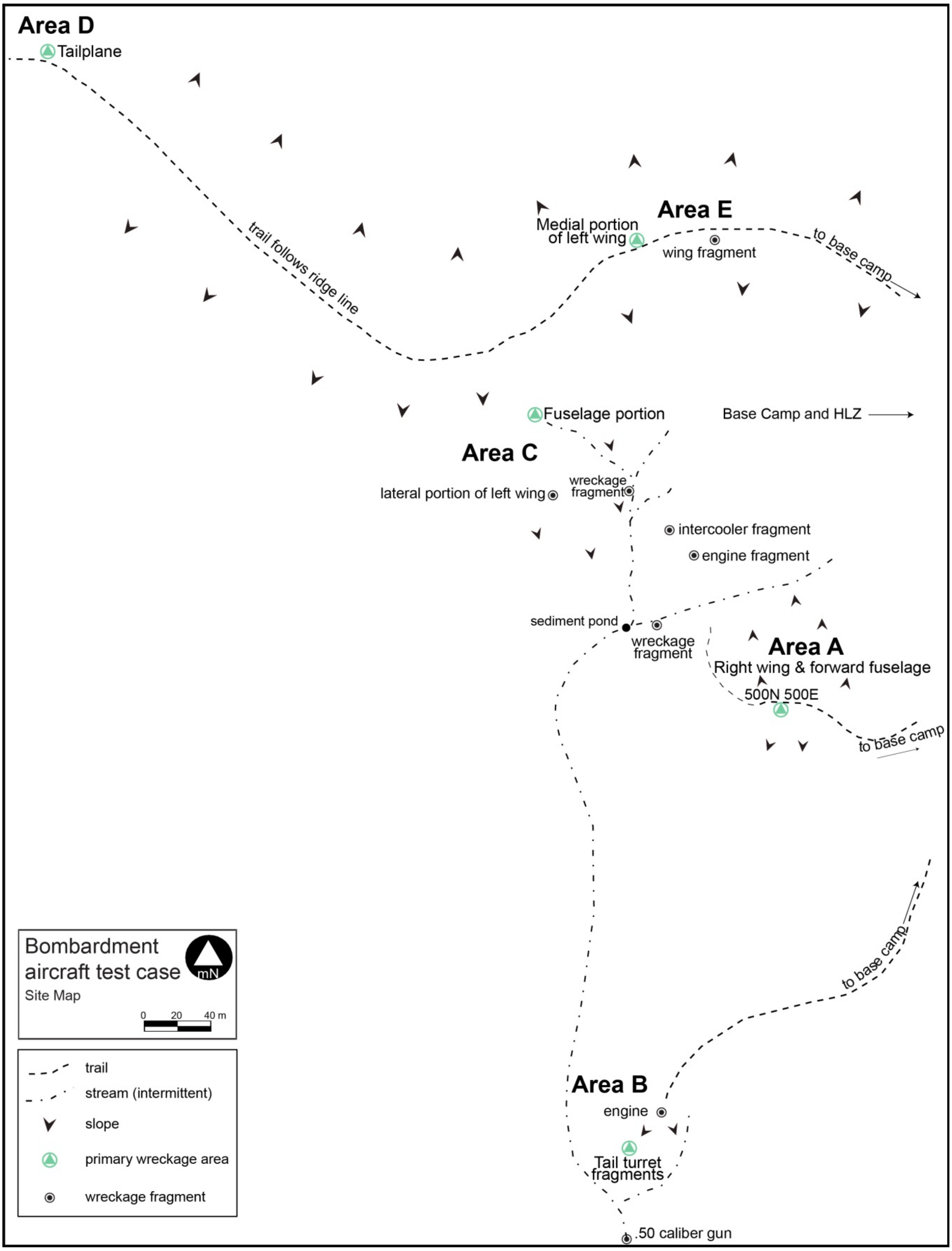

Figure 101. Overall map the bombardment aircraft test case site.
Note the wreckage concentrations and topographic features (Esh 2009, 8; 2011a, 8).

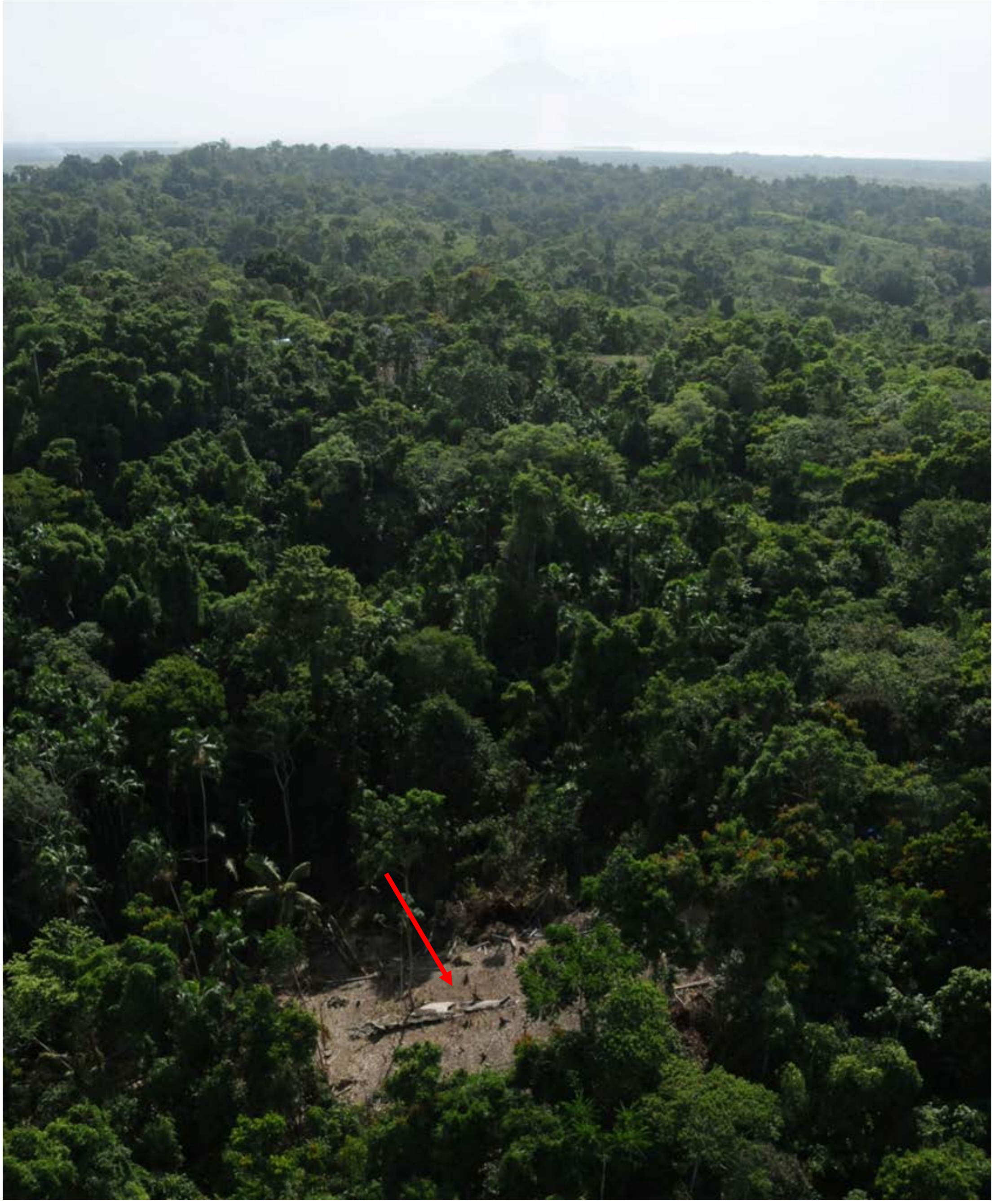

Figure 102. The bombardment aircraft test case crash site.
Area A is highlighted with a red arrow ; Hansa Bay and Manam Island are in the far background.. View to east (Esh 2009, 7).

Area A, which contains the majority of the aircraft wreckage, is approximately 15-x-30 m and rests on a north facing hillside that varies between 15° and 40° in slope (Figure 103 and Figure 104). The uppermost portion of the wreckage is roughly 15 m below the crest of the hill and it extends to the east-west running stream at the bottom. Area A contains the forward portion of the fuselage, which includes the nose compartment, the flight deck, the radio operator station, the top turret, and the forward bomb bay. The majority of the right wing is also within Area A, but only one of the engines is present. The wing is oriented in a north-south direction with the tip upslope to the south and the inboard portion more downslope. Major fuselage fragments including the flight deck and nose compartment are concentrated in the upslope portion of Area A near the wing. Fragments of a gunner's turret were found approximately 10 m downslope of the cockpit wreckage. Unprompted by JPAC, the local inhabitants had cleared the area of vegetation prior to the first recovery team's arrival (Esh 2009, 6-8).

Figure 103. Area A within the bombardment aircraft test case crash site prior to vegetation clearing.
View to north (Esh 2009, 9).

Area B is located approximately 280 m to the south southwest of Area A and is the southern-most portion of the debris field (Figure 101). It is also the largest of the five wreckage concentrations, is approximately 40-x-45 m and was not discovered until 2009 during the first excavation (Figure 105). A large portion of an engine with the propeller still attached rests at the top of a hill. Smaller fragments of wreckage are strewn farther down the hill to the southwest and southeast. Portions of the tail gunner's turret were found amongst this wreckage. Local residents informed the recovery team that the .50 caliber guns had been dug up and moved to a nearby stream bed. The team was able to locate and photograph one of the weapons (Esh 2009, 10).

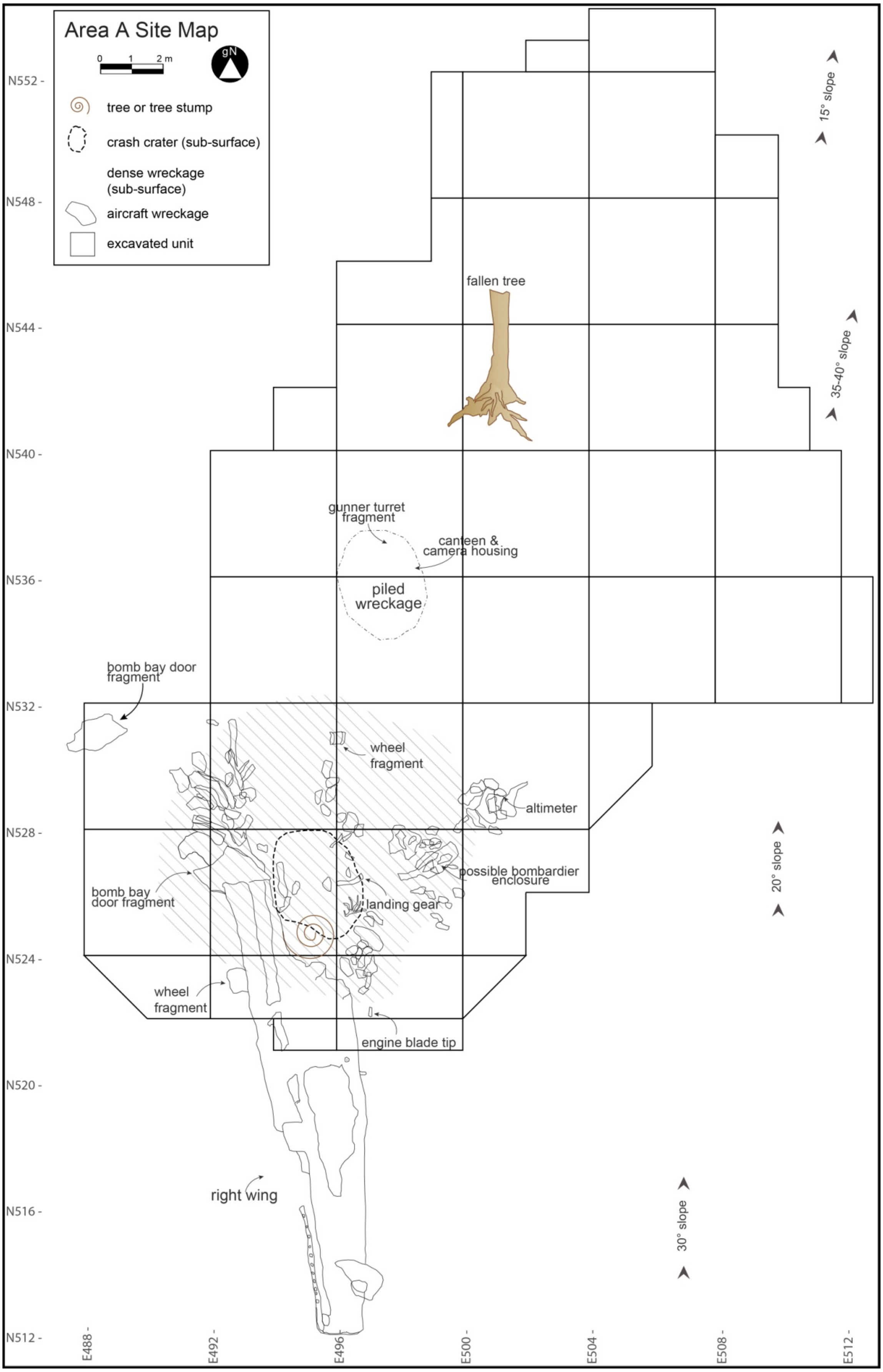

Figure 104. Plan map of Area A within the bombardment aircraft test case crash site Major aircraft fragments, prominent terrain features, and incident related archaeological features are displayed. (Drafted from Esh 2011a)

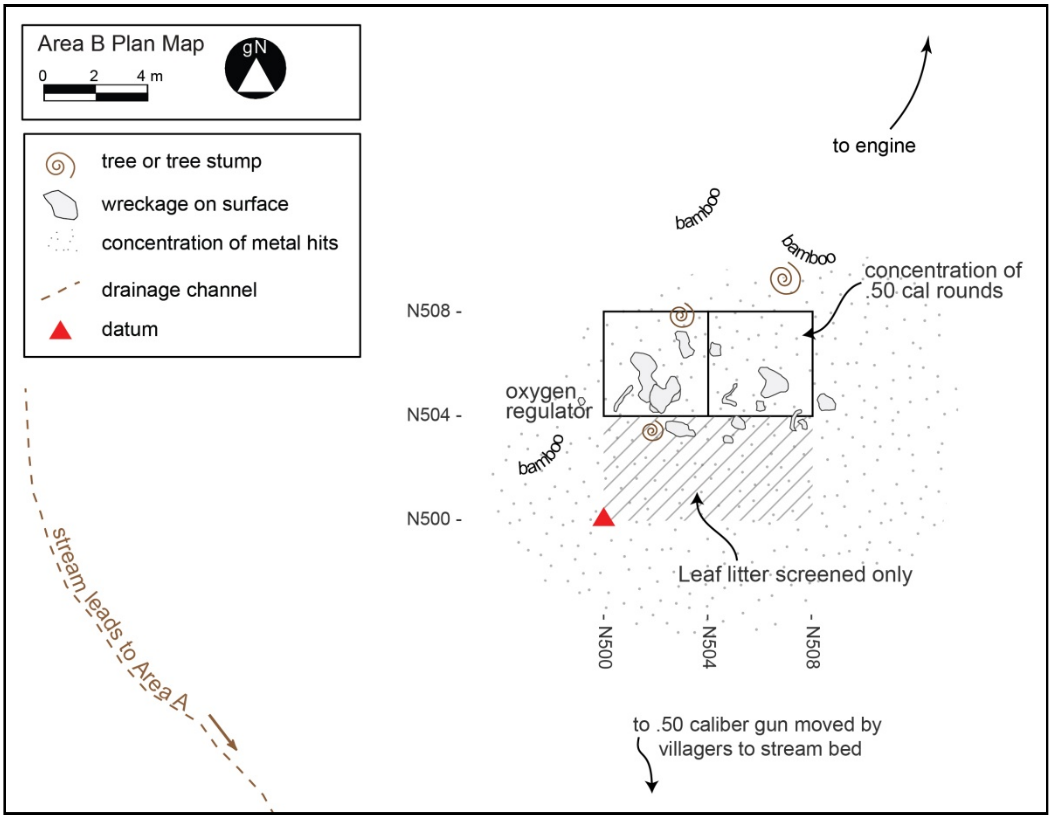

Figure 105. Plan map of Area B within the bombardment aircraft test case crash site. Major aircraft fragments and prominent terrain features are displayed. (Drafted from Esh 2011a)

Area C is 220 m northwest of Area A (Figure 101). The aft portion of the fuselage from the rear bomb bay to just past the waist gunner positions is located in a roughly 6-x-8 m area that straddles a shallow, dry stream bed that slopes gently to the southeast at 5° to 10° (Figure 106 and Figure 107). This drainage eventually connects with the stream at the bottom of the hill at Area A. Metal detection at Area C revealed that a subsurface wreckage scatter extended over a maximum area of approximately 15-x-30 m with the highest density of metal signatures coming immediately downslope of the visible fuselage sections. The outboard portion of the left wing is located 55 m to the south. Part way between Areas A and C are portions of an engine and intercooler (Esh 2009, 11; 2011a, 13).

Figure 106. Area B within the bombardment aircraft test case crash site after vegetation clearing.
View to northeast (Esh 2011a, 13)

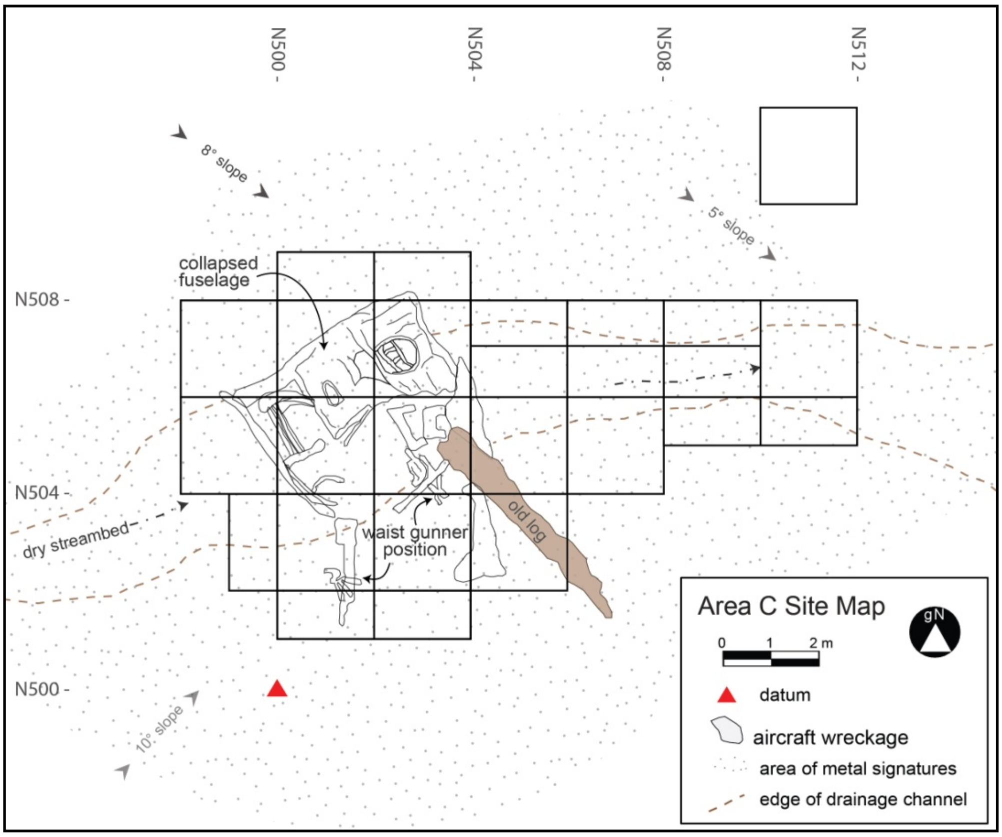

Figure 107. Map of Area C within the bombardment aircraft test case crash site.
Major aircraft fragments and prominent terrain features are displayed. (Drafted from Esh 2011a)

Area D, which comprises both the northern and western-most edges of the debris field is approximately 570 m northwest of Area A (Figure 101). The wreckage is concentrated in a 5-x-11 m area along a broad, relatively level ridgeline (Figure 108 and Figure 109). It consists of the B-24's fuselage aft of the waist gunner windows and tail plane including both horizontal and vertical stabilizers, which are still painted with the aircraft's serial number and the logo of the 90th Bombardment Group. Notably absent from the wreckage in Area D is the majority of the tail gunner's turret. Shockingly, the majority of this wreckage is in Area B, roughly 720 m to the southeast (Esh 2010, 12; 2011a, 14).

Figure 108. The tail section of the B-24 at Area D within the bombardment aircraft test case crash site.
View to southwest (Esh 2011a, 14).

Area E is on a ridge top approximately 240 m north-north-west of Area A (Figure 101). It is the smallest of the wreckage concentrations and only contains the medial section of the left wing. It is unusual that this portion of the wing, which is closest to the fuselage, is 175 m from the closest fuselage fragment in Area C. Furthermore, the lateral, or outboard-most, section of the same wing is located in Area C. Excavation was never undertaken at this location because it was determined that there was no likelihood of recovering evidentiary materials (Esh 2011a, 6).

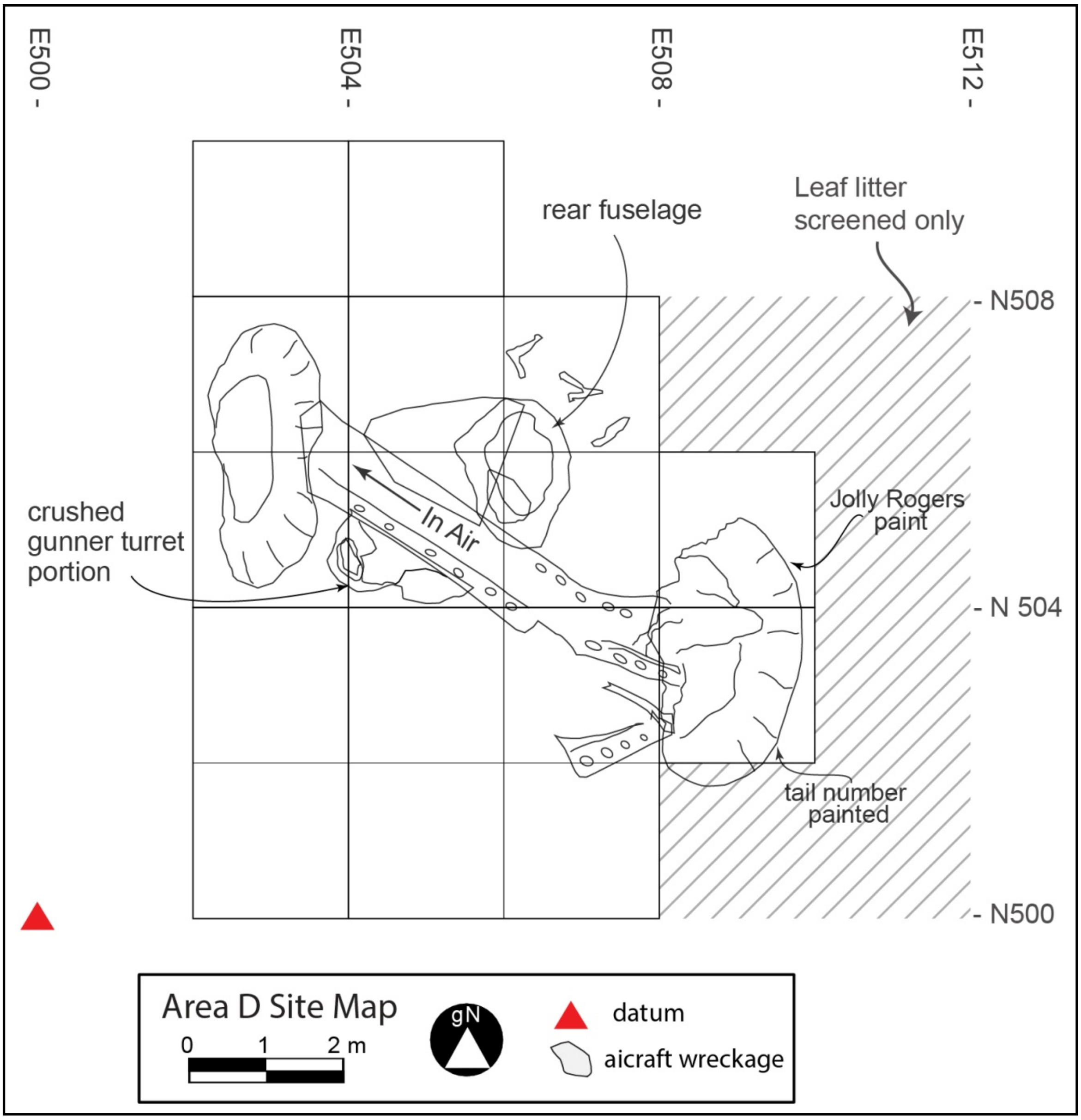

Figure 109. Map of Area D within the bombardment aircraft test case crash site Major aircraft fragments and prominent terrain features are displayed. (Drafted from Esh 2011a)

The first recovery team began work on the site on August 20, 2009. The archaeologist conducted extensive interviews with the residents of the local villages who had been hired to help with the recovery effort. The secondary witnesses related several pieces of the information that had been passed down to them through oral tradition which are relevant to the analysis of bombardment aircraft test case crash site. First, a minimal amount of scavenging had occurred over the years and all of the major sections of the plane were still in the locations where they had come to rest as a result of the crash. Second, when the first villagers arrived at the crash site a few days after the loss they allegedly found several dead bodies wrapped in parachutes downslope of the largest amount of wreckage. The locals also informed the archaeologist that the pilot was farthest down the hill, along the edge of the stream.

After a thorough survey of all five wreckage locations Area A was selected to be excavated first because of the presence of the forward portions of the fuselage. Due to the density of evidentiary materials being recovered each 4-x-4 m unit was broken down into 2-x-2 m quadrants (NW, NE, SW, and SE) in order to allow the archaeologists to maintain better spatial control of the items being recovered. In addition, four Features (1 through 4) were identified within Area A. These features were carefully excavated with small hand tools such as trowels, paint brushes, and bamboo skewers to ensure that skeletal materials were not damaged and could be recorded *in situ*. The pace of excavation was hampered because the top 10 cm of sediment could be easily dry screened, but the lower 15-20 cm of dense clay necessitated wet screening. This meant that each unit effectively had to be excavated twice (Esh 2009, 15-16). These methods and constraints allowed for detailed field provenience to be maintained, but resulted in the entirety of the 2009 mission being focused on Area A. The first 2010 excavation also solely concentrated on expanding the excavation at Area A and was also able to determine approximately 75% of the evidence sterile boundary as defined in Chapter 4 (Black 2010, 11). The second excavation in 2010, approximately a year after the first recovery effort, finally completed the work at Area A (Esh 2010).

There are two primary patterns to the deposition of evidence within Area A. The first is the uphill fuselage portion which includes the nose compartment and flight deck. In general, this area exhibits a high quantity of various sized fragments of aircraft wreckage, a thermal alteration in the shallower deposits, a low level of erosion, and osseous remains being found *in situ*. Features 2 and 3 are included in this portion (Figure 104). Feature 2, which is associated with fragments of what the archaeologist identified as the bombardier's enclosure, contained a concentration of personal effects, but no identification media or skeletal remains (Esh 2011a, 30). Feature 3 is defined by a small impact crater in the eastern half of N524/E492. Beginning at approximately 25 cm below surface, the feature contained three clusters of *in situ*, articulated skeletal remains. Skeletal Set 1a contained a pelvic girdle and lower limbs and was separated from Skeletal Set 1b, upper torso bones, by the main strut from the front landing gear. Skeletal Set 2, approximately 50 cm south of Skeletal Set 1b, was also comprised of pelvic girdle and lower limb fragments (Figure 110).

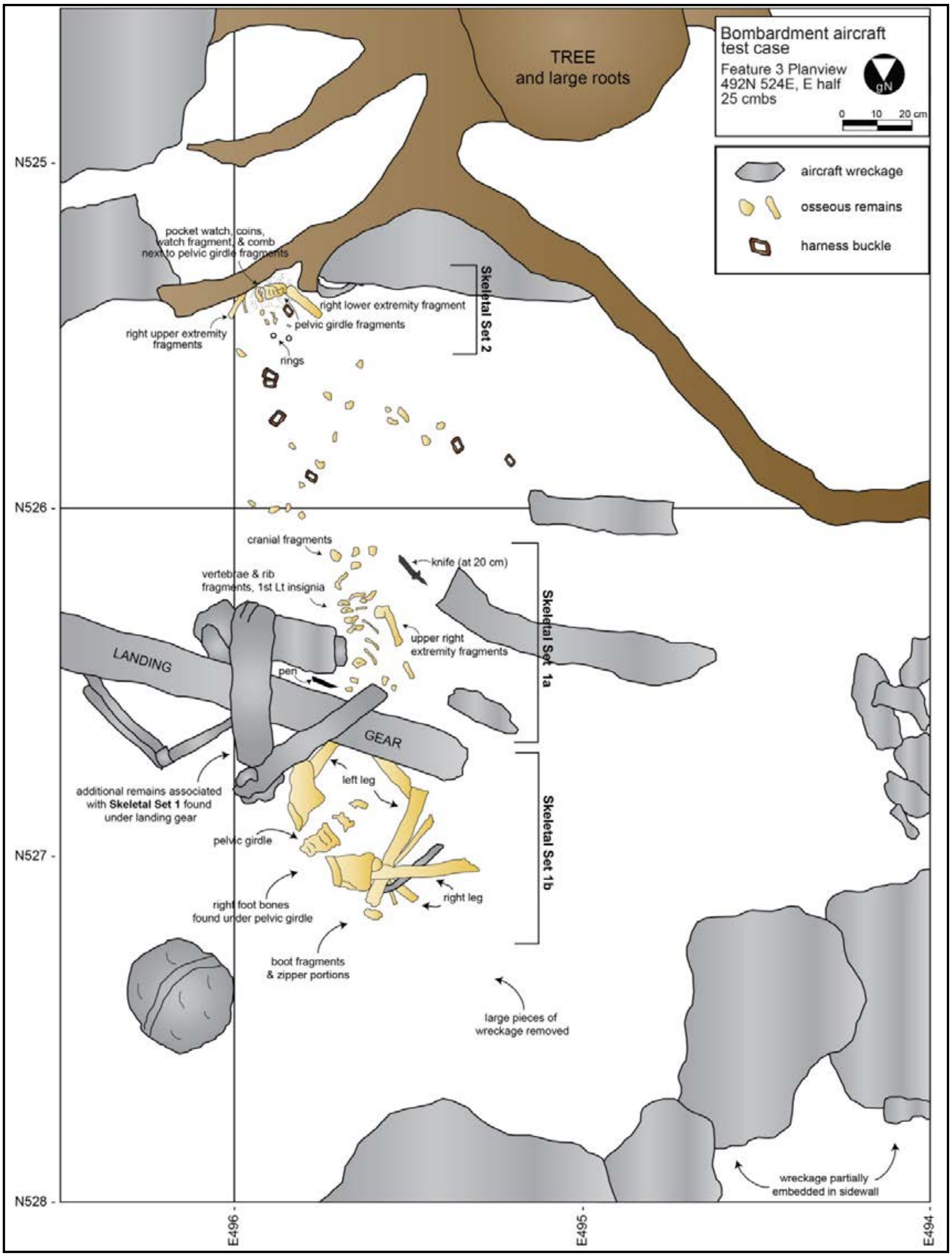

Figure 110. Plan view of Feature 3 at 25 cmbs, with possible evidence detailed. Note that grid north is toward the bottom of the map (Esh 2011a, 34).

The second pattern within Area A is found on the slope below and to the northeast of the fuselage concentration. In this portion, there is a lower density of aircraft wreckage that is scattered for approximately 20 m down the hillside, the majority of which was recovered from the top 10 cm below surface. Evidentiary materials, including bones, were found intermixed with the leaf litter, on the ground surface, and partially buried. The majority of the incident related material appeared to have been disturbed and subjected to erosional processes. Despite this, two concentrations (Features 1 and 4) of evidence were uncovered (Esh 2011a, 23-28).

Feature 1 is a 2-x-2 m concentration of material evidence primarily situated in N532/E500, SW Quad and N532/E496, SE Quad. Centered within this concentration is a 30-x-30 cm area that contained skeletal remains and a dental prosthesis. Feature 4 is comprised of two separate groupings of evidence: 4a and 4b. Feature 4a is a cluster of skeletal material and material evidence in N536/E500, NW and NE Quads. Feature 4b is the area in N540/E500, SW Quad that has been disturbed by the roots of a fallen tree. Osseous remains and material evidence were recovered from within it. Dense concentrations of parachute canopy fabric and numerous hardware components were found intermixed with the remains (Esh 2011a, 22-23, 27-28).

One anomaly was encountered during the recovery effort at Area A. At the beginning of the summer 2010 excavation the sediment settling pond in a dammed up section of the creek bottom had to be emptied of the first two excavations' wet screening outflow. This pond is located approximately 80 m downstream of Area A and 140 m from Area C (Figure 101). At the bottom of the pond a human long bone shaft fragment was discovered. First, all of the sediment from the previous excavations was rescreened. No additional evidentiary or incident related materials were recovered. Next, the sediments that were originally in the creek bottom were removed until the bedrock was exposed and were screened. Again, no additional evidentiary or incident related materials were recovered. This indicates that the screening conducted by the first two excavations was done correctly and that the human bone fragment was likely already in the stream bottom prior to the JPAC's arrival at the site. Additionally, pedestrian surveys and metal detector sweeps were conducted from both Area A and Area C down to the dam as well as below the dam. Wreckage extended for approximately 30 m downstream from Area C, but continued no further. No additional incident related materials, evidence, or other osseous remains were encountered (Esh 2011a, 48-49).

After completing the excavation of Area A, the summer 2010 team also conducted recovery operations at Area B. Due to the distance between wreckage areas within the site a new grid datum of N500/E500 was established in each area. The engine in Area B was determined to have a very low likelihood of yielding evidentiary materials and so the excavation concentrated on the tail turret wreckage. An 8-x-8 m area encompassing the tail turret wreckage was staked out and the leaf litter was collected and screened (Figure

105). Two 4-x-4 m units were excavated to incident sterile deposits. Wreckage pieces consistent with the tail turret of the aircraft were recovered as well as numerous .50 caliber rounds, casings, and projectiles. No evidentiary materials were encountered (Esh 2010, 49-53; 2011a, 50-54).

Area C was the final section of the bombardment aircraft test case crash site to be excavated. In 2011 an 8-x-16 m grid was established surrounding the wreckage of the aft fuselage and both waist gunner positions (Figure 107). Excavation commenced at the southwest (uphill) corner and proceeded to the east. Soil was excavated from within, under and around all of the large wreckage components, which were removed from the excavation area as work progressed. The bottom of the dry stream bed that ran through the area was excavated and screened separately from the sides. This allowed the archaeologists to determine the amount of erosion that had occurred since the crash. Evidentiary materials were recovered from a 50 cm deep impact depression that was discovered underneath the bulk of the fuselage wreckage labeled as Feature 5. The feature is approximately 4-x-4 m surrounding the N506/E502 stake within Area C and contained osseous remains that had been severely thermally altered, personal effects and miscellaneous life support equipment (Esh 2011a, 55-62).

Area D was also excavated during the summer 2010 recovery mission. An 8-x-10 m grid was laid out surrounding the tail plane (Figure 109). The leaf litter was collected and screened, resulting in the recovery of a few small fragments of metal and .50 caliber ammunition. Next, excavation was conducted inside, under, and around the wreckage. Osseous materials were recovered from directly underneath where the tail turret would have been located (Esh 2010, 54-57; 2011a, 63-66).

Four missions, totaling 96 days, spanning 3 years were necessary to complete the excavation of the bombardment aircraft test case crash site. The approximate surface areas excavated by wreckage concentration were: Area A: 486 m^2 (Figure 111); Area B: 32 m^2; Area C: 78 m^2 (Figure 112); and Area D: 64 m^2 (Esh 2011a, 1). The total surface area for the bombardment aircraft test case crash site was 660 m^2 with the depth of excavation ranging from 10 to 30 cm across the majority of the site to a maximum of 70 cm within Area A, Feature 3. Surprisingly, despite the large amount of osseous remains, no identification media were located during the recovery effort. This included amongst the articulated, *in situ* remains in Area A, Feature 3.

Figure 111. Aerial photograph of Area A within the bombardment aircraft test case at the conclusion of excavation.
View to northeast (Esh 2011a, 47).

Figure 112. Area C within the bombardment aircraft test case at the conclusion of excavation.
The Feature 5 evidence concentration is delineated by the white dashed line. View to west (Esh 2011a, 62).

Despite several first-hand witnesses who were aboard other aircraft, there are no accounts that provide any detail as to the direction the aircraft was traveling at the time of impact, although the statements do indicate that the B-24 was on fire and breaking up. This is corroborated by the thermal alteration observed on the wreckage and much of the recovered evidence and the extremely dispersed debris field (Figure 101). The broad scatter of wreckage combined with the relatively shallow impact craters such as Feature 3 in Area A and Feature 5 in Area C suggests that there was a low degree of perpendicularity to the crash. While the historical witness statements do not provide any clues as to the direction of travel at the time of impact, the distribution of wreckage does provide clues. The overall spread of aircraft components suggests that the B-24 was traveling on a south-easterly heading (Figure 101). The arrangement of the bomb bay doors, forward fuselage wreckage, and right wing fragments confirm that the forward portion of the aircraft was moving from west to east when it impacted the ground. The recovery of both osseous remains and personal effects from within the leaf litter indicates that erosion appears to have been a factor in the transport of evidentiary materials in the downslope portion of Area A. However, it cannot be determined if this occurred prior to the first JPAC mission or between the three separate excavations of the Area.

Detailed examination and analyses of the skeletal and dental remains are currently ongoing at the CIL. While no final conclusions can be made at this time, initial observations tend to reflect the trends observed throughout the cases presented in Chapters 5 and 6. Perimortem trauma is ubiquitous amongst the remains and thermal alteration is also common, particularly amongst those fragments which could not be associated with a specific individual. A total of 98 samples were extracted from the recovered osseous material and submitted to the AFDIL for sequencing. The results of this testing as of November 17, 2013 are displayed below in Table 57.

Table 57. Results of mtDNA sampling for the bombardment aircraft test case.

Sample	Element	Provenience	Individual
01A	Right femur	Unilateral	Co-pilot
02A	Right ulna	Unilateral	Co-pilot
03A	Tibia	Unilateral	Engineer
04A	Tooth #22	Unknown	Radio Operator
05A	Tooth #20	Unknown	Inconclusive
06A	Tooth #6	Unknown	Co-pilot
07A	Mand left molar	Unknown	Radio Operator
08A	Tooth #11	Unknown	Co-pilot
09A	Left tibia	Sediment pond	Sequence 7
10A	Mandible	Area A, Feature 3	Inconclusive
10B	Mandible	Area A, Feature 3	Inconclusive
11A	Right humerus	N547/E502	Sequence 6
12A	Femur	N547/E506	Sequence 6
12B	Femur	N547/E506	Sequence 6

Sample	Element	Provenience	Individual
13A	Right humerus	N543/E500	Engineer
14A	Fibula	Unilateral	Radio Operator
15A	Right radius	Unilateral	Radio Operator
16A	Left femur	N532/E496, SE Quad	Radio Operator
17A	Left femur	N536/E496, SE Quad	Co-pilot
18A	Right humerus	N532/E504	Co-pilot
19A	Right humerus	N524/E496	Gunner 3
20A	Right humerus	N524/E492	Gunner 3
21A	Left humerus	N540/E500	Engineer
22A	Right femur	N524/E492, SE Quad	Gunner 3
23A	Left femur	Area A, Feature 3	Bombardier
24A	Left os coxa	Area A, Feature 3	Bombardier
25A	Thoracic vertebra	Area A, Feature 3	Bombardier
26A	Right scapula	Area A, Feature 3	Bombardier
27A	Humerus	Unilateral	Co-pilot
28A	Fibula	Unilateral	Engineer
29A	Long bone	N540/E500	Co-pilot
30A	Long bone	N544/E504, SW Quad	Sequence 6
31A	Long bone	N544/E504, SW Quad	Engineer
32A	Long bone	N544/E504, SW Quad	Engineer
33A	Long bone	N544/E504, SW Quad	Engineer
34A	Long bone	N540/E504, SW Quad	Co-pilot
35A	Long bone	N532/E500, SW Quad - Feature 1	Radio Operator
36A	Long bone	N536/E500, NE Quad	Co-pilot
37A	Long bone	N536/E500, NE Quad	Co-pilot
38A	Left fibula	N532/E496, SE Quad	Radio Operator
39A	Fragment	Unilateral	Assistant Radio Operator
40A	Fragment	Area C, N504/E500 - NW Quad	Inconclusive
41A	Vertebra	Area C, Feature 5	Assistant Radio Operator
42A	Vertebra	Area C, Feature 5	Assistant Radio Operator
43A	Calcaneus	Area C, N504/E500 - SW Quad, Feature 5	Inconclusive
44A	Cranium	N540/E500, NE Quad	Engineer
45A	Cranium	N540/E500, NE Quad	Inconclusive
46A	1st rib	Area A, Feature 3	Bombardier
47A	Rib	Area A, Feature 3	Bombardier
48A	Left clavicle	Unilateral	Co-pilot
49A	fragment	N524/E492, SE Quad	Gunner 3
50A	Rib	N524/E492, Feature 3	Gunner 3
51A	Cranium	N536/E500, Feature 4	Co-pilot
52A	Long bone	N536/E500, Feature 4	Co-pilot
53A	Long bone	N536/E500, Feature 4	Co-pilot
54A	Temporal	N536/E500, Feature 4	Co-pilot

Sample	Element	Provenience	Individual
55A	Cranium	N536/E500, Feature 4	Co-pilot
56A	Rib	Area C, N504/E500, SE Quad	Inconclusive
57A	Temporal	Unilateral	Bombardier
58A	Cranium	Unilateral	Co-pilot
59A	Cranium	N532/E500, NW Quad	Inconclusive
60A	Os coxa	N544/E492, Feature 3	Bombardier
61A	Long bone	N536/E500, Feature 4	Co-pilot
62A	fragment	N524/E492, SE Quad	Gunner 3
63A	Femur	N544/E492, Feature 3	Inconclusive
64A	Femur	Unilateral	Engineer
65A	Cranium	N524/E496, Feature 3	Gunner 3
66A	Cranium	N524/E496, Feature 3	Non-human
67A	fragment	N524/E492, SE Quad	Gunner 3
68A	Long bone	N532/E500, SW Quad	Radio Operator
69A	Long bone	N544/E504, NW Quad	Non-human
70A	Long bone	Area A, Feature 3	Inconclusive
71A	Long bone	Area A, Feature 3	Bombardier
72A	Cranium	N540/E500, SE Quad	Inconclusive
73A	Cranium	N540/E500, SE Quad	Inconclusive
74A	Fibula	Unknown	Engineer
75A	Scapula	Unilateral	Co-pilot
76A	Cranium	Unilateral	Co-pilot
77A	Tibia	Unilateral	Co-pilot
78A	Long bone	Unilateral	Co-pilot
79A	Cranium	N524/E496, SW Quad	Gunner 3
80A	Radius	N544/E504	Sequence 6
81A	Long bone	N544/E504	Engineer
82A	Long bone	N544/E504	Engineer
83A	Right ulna	N524/E492, SE Quad	Inconclusive
84A	Vertebra	N524/E492, SE Quad	Inconclusive
85A	Femur	N524/E492, SE Quad	Gunner 3
86A	Cranium	N532/E508, NW Quad	Inconclusive
87A	Cranium	N536/E508, SE Quad - west half	Inconclusive
88A	Clavicle	N532/E596, SE Quad	Radio Operator
89A	Radius	N532/E496, SE Quad	Radio Operator
90A	Radius	N532/E496, NW Quad	Radio Operator
91A	Clavicle	N532/E496, SE Quad	Radio Operator
92A	Long bone	N532/E496, SE Quad	Radio Operator
93A	Left scapula	N524/E492, Feature 3 - east half	Inconclusive
94A	Right clavicle	N544/E492, Feature 3 - east half	Bombardier
95A	Right femur	N544/E492, Feature 3 - east half	Bombardier

Sample	Element	Provenience	Individual
96A	Mand right molar	Unknown	Sequence 6
97A	Tooth #30	Area C, N504/E500	Assistant Radio Operator
98A	Tooth #12	Unknown	Gunner 3

Eight unique mitochondrial sequences were obtained from the 98 samples sent for mtDNA analysis. Sequences 1 through 5 and 8 were all found to match a family reference sample that had been obtained from the descendent relatives of the missing crew members. However, sequences 6 and 7 did not match any of the family references currently on file at the AFDIL. Sequence 6 was found in six (11A, 12A, 12B, 30A, 80A, and 96A) of the 98 samples sent for mtDNA analysis (Table 57). These six skeletal fragments were found closest to the downslope edge of the Area A excavation, within approximately 4 m of each other (Figure 113). No duty station wreckage was recovered in association with the remains. The simplest explanation for why Sequence 6 did not match any of family reference samples is that the persons who submitted them are not actually appropriate matrilineal descendents of the missing serviceman. Another potential reason is that the historical record is inaccurate. Albeit much less likely, there is an extremely remote possibility that there was a mistake in the three identifications made by the AGRS after the war.

Sequence 7 was obtained from only one sample (09A) and it was found to have a Q1 haplogroup signature, which is a marker found only in individuals with an ancestral history to the region of present day Indonesia. This is the single bone that was recovered from the sediment settling pond downstream from Areas A and C when it was being cleaned out at the beginning of the third recovery mission to the site (Figure 101). Based upon the archaeological context and the haplogroup signature, which is not consistent with what is known about the ancestry of the crew members, this skeletal fragment is most likely from a person indigenous to the region.

The recovery location of remains that could be associated with an individual from a particular duty station are displayed below in Figure 113 and Figure 114. For this test case, remains are defined as skeletal elements that successfully yielded an mtDNA sequence that matched a family reference sample for a particular casualty. This was the case for sequences 1-5 and 8. These crew members are represented by an abbreviation for their duty station. Even though it has yet to be associated with a specific crew member, Sequence 6 is also shown in Figure 113. In addition, concentrations of parachute components within Area A are displayed.

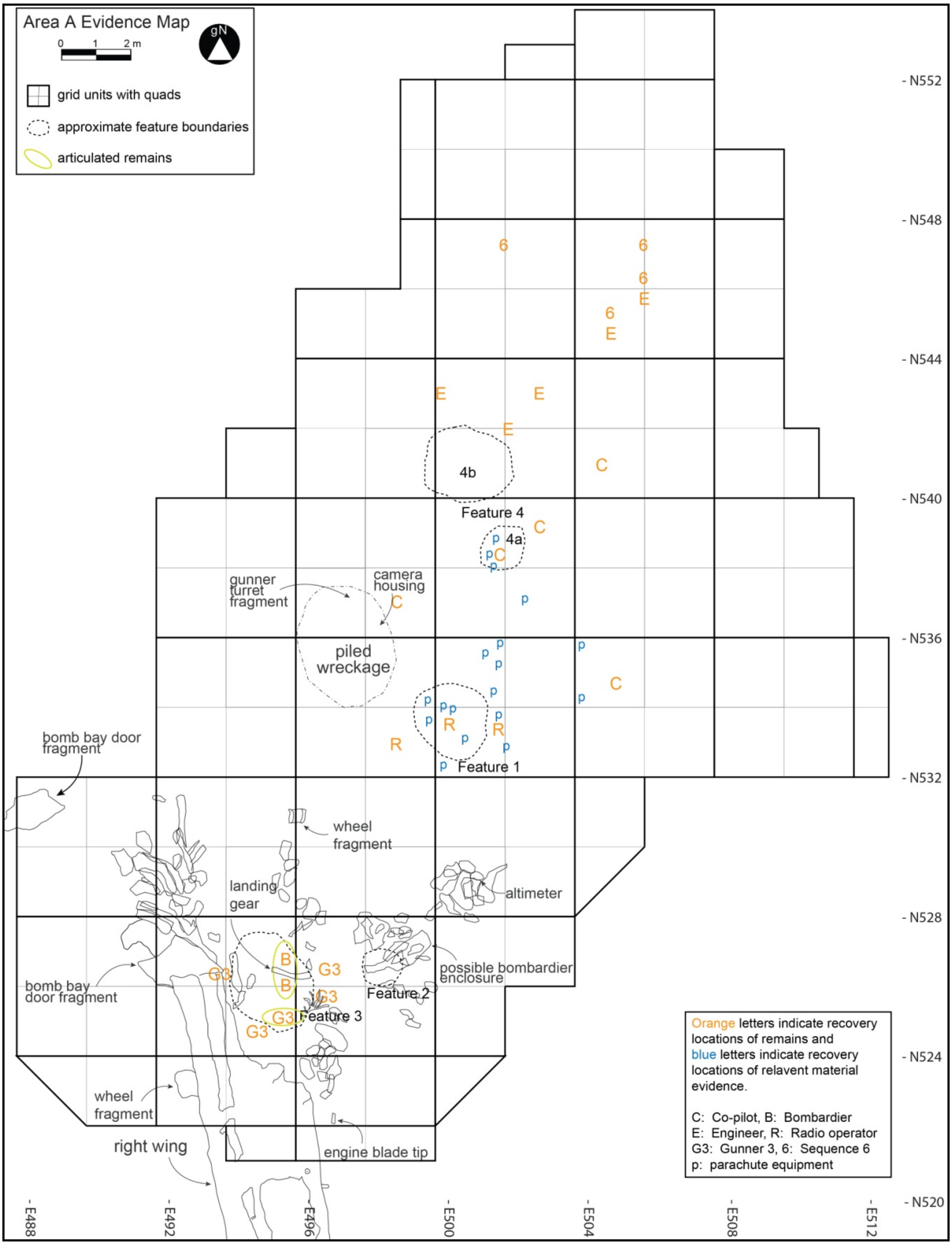

Figure 113. Map of Area A within the bombardment aircraft crash test case site.
The locations of identified remains and recognizable aircraft components are displayed. (Drafted from Esh 2011a)

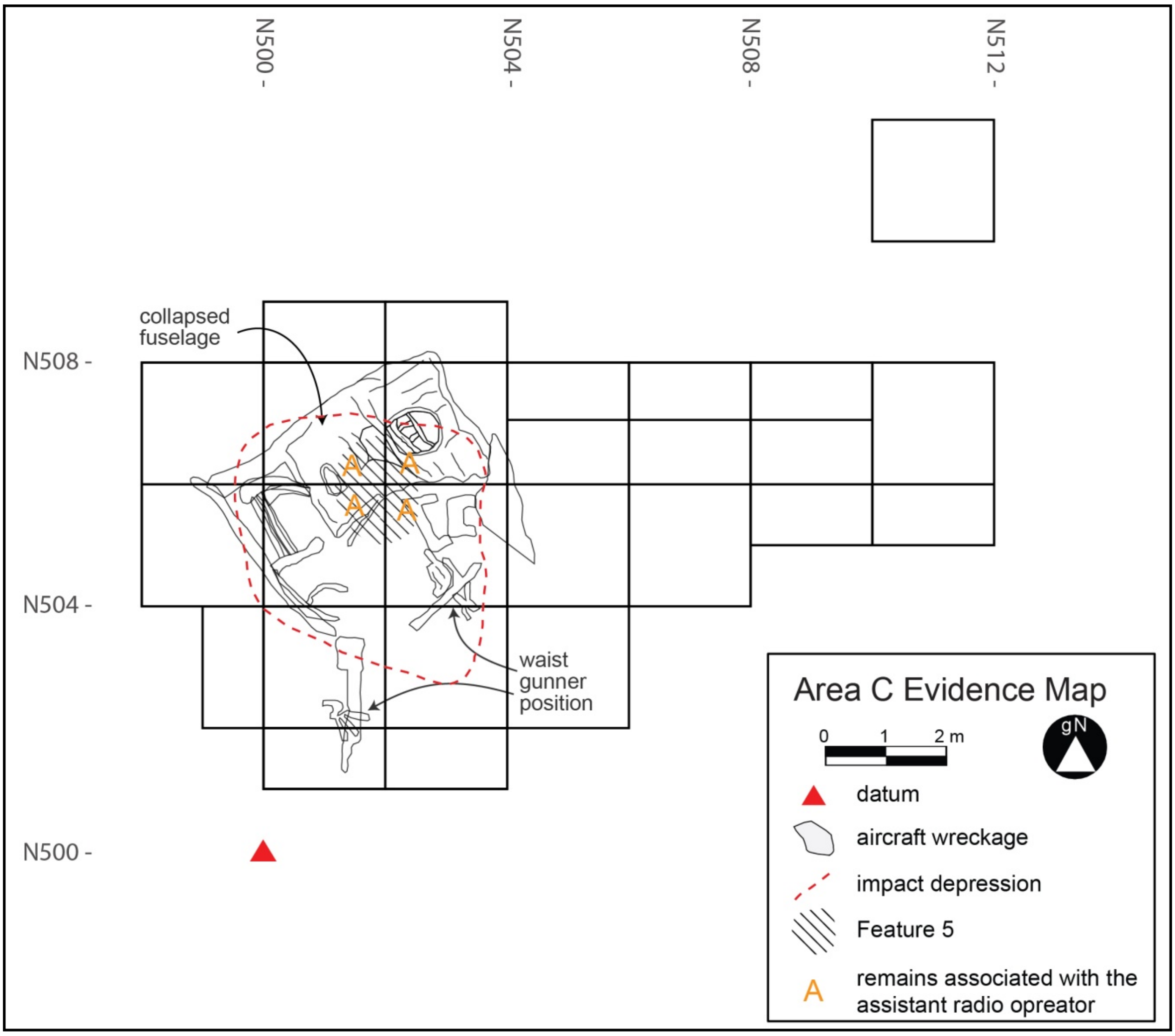

Figure 114. Map of Area C within the bombardment aircraft crash test case site. The locations of identified remains and recognizable aircraft components are displayed. (Drafted from Esh 2011a)

Examination of the distribution of remains and personal effects that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- The Pilot of the bombardment aircraft test case is possibly the individual who resulted in Sequence 6 during mtDNA testing. At the time of the submission of this thesis it was not determined if Sequence 6 is the Pilot or Gunner 1.

- More than half of the skeletal fragments that were found to belong to the Co-pilot were recovered from within Feature 4a in Area A (Figure 113). The remaining bones were found close by in N532/E504, N536/E496 SE Quad, N536/E500 NE Quad, N540/E500 NE Quad, and N540/E504 SW Quad. No duty station wreckage was recovered in association with the remains.

- Based upon historical information the Navigator safely parachuted from the aircraft and died while in Japanese custody. His remains were recovered from a burial in Giri Village, a few kilometers from the crash site and identified by the AGRS on June 19, 1948.

- The Bombardier's remains were comprised of the *in situ* and articulated remains from Feature 3 in Area A described as Skeletal Set 1a and 1b during the recovery effort. These remains were bisected by the front landing gear strut and were adjacent to nose compartment wreckage.

- The Engineer's remains were found downslope of Feature 4b in N543/E500, N540/E500, N540/E500 NE Quad, N544/E540, and N544/E504 SW Quad. No duty station wreckage was recovered in association with the remains.

- The Radio Operator was found within and immediately around Feature 1 in Area A. Aside from Feature 1 skeletal material was recovered from N532/E496 SE Quad, and N532/E500 SW Quad. No duty station wreckage was recovered in association with the remains.

- Gunner 1 of the bombardment aircraft test case is possibly the individual who resulted in Sequence 6 during mtDNA testing. At the time of the submission of this thesis it was not determined if Sequence 6 is Gunner 1 or the Pilot.

- Based upon historical information Gunner 2 safely parachuted from the aircraft and died while in Japanese custody. His remains have not been recovered.

- Gunner 3 was also found in Feature 3 in Area A, but was more dispersed than the Bombardier. Gunner 3's remains were also found in N524/E492 NE Quad, N524/E492 SE Quad, N524/E496 SW Quad, and N524/E496 NW Quad. These remains were adjacent to nose compartment wreckage.

- Based upon historical information Gunner 4 safely parachuted from the aircraft and died while in Japanese custody. His remains were recovered from a burial in Bogia Village, a few kilometers from the crash site and identified by the AGRS in May 1950.

- Based upon historical information the Photographer safely parachuted from the aircraft and died while in Japanese custody. His remains were recovered from a burial in Bogia Village, a few kilometers from the crash site and identified by the AGRS on June 19, 1948.

- The remains associated with the Assistant Radio Operator were recovered within and immediately around Feature 5 within Area C. Feature 5 was collocated with the waist gunner position wreckage.

There are two peculiarities concerning which individuals successfully parachuted from the aircraft and where certain individuals were found within the crash site. First, the navigator was able to bail out of the aircraft after it was struck by enemy fire. This is strange because the navigator's position in the aircraft is one of the hardest exit from. He must go through the bombardier's position and then squeeze through the small crawl space under the flight deck and next to the retracted forward landing gear to reach the bomb bay. Additionally, Gunner 3 was recovered adjacent to the Bombardier amongst the nose compartment wreckage in Feature 3. Due to the difficulty in transiting to and from the nose compartment it is likely that Gunner 3 was in the navigator's position at the time of the loss incident. This is particularly odd because the aircraft was lining up for its bombing run, a time when the navigator is of critical importance.

Second, the locations where the Co-pilot, Engineer, Radio Operator, and Sequence 6 were deposited within the site, and eventually recovered from, are most likely not the result of the crash itself. There are several lines of evidence that support this conclusion.

1. Witness statements from other pilots who flew over the crash site after it occurred and saw at least two of the survivors who parachuted from the aircraft on the ground amongst the wreckage.
2. Prior to excavation commencing, local residents informed the archaeologist that bodies wrapped in parachutes had been found downslope of the main wreckage concentration.
3. These accounts were at least partially confirmed by the discovery of two distinct clusters of remains with parachute components as well as two additional groupings of remains without parachute equipment.
4. Sequence 6 has a 50% chance of being the pilot.

All four were located below the wreckage in Area A. The majority of the evidentiary items were found on, or immediately under, the surface and none were deeper than 25 cm below the surface. A very low density of small fragments of aircraft wreckage were found at both surface and subsurface levels on the lower slope of Area A and no diagnostic duty station wreckage was found with any of the remains.

As of the submission of this thesis (early June 2014) the laboratory analyses, peer review process, case file coordination, and administrative tasks have not been finalized for the bombardment aircraft test case.

9.2 Cargo Aircraft Test Case

The cargo aircraft crash test case involves the loss of seven individuals aboard an AC-47D assigned to the 4th Air Commando Squadron during the early years of the Vietnam War. The aircraft departed Da Nang Air Base, Vietnam at approximately 0300 hours for a night armed reconnaissance mission with a scheduled duration of three hours. Last contact with the crew was at 0322 hours via radio. At 0900 flight line officials at Da Nang Air Base determined that the aircraft was overdue and initiated attempts to communicate with the missing aircraft and contacted alternate airfields to see if the C-47 had landed elsewhere, but they were unable to locate the plane through either means (Phisayavong 2012b, 1-2). The occupied crew positions were the Pilot, Co-pilot, Navigator, Flight Engineer, Loadmaster/Gunner, as well as two additional Gunners.

The crew was declared missing that day and extensive search and recovery operations were conducted over the following two days along the route laid out in the mission's flight plan with negative results. The personnel were eventually reclassified from a MIA status to a KIA status at varying times throughout the 1970s ranging from October 9, 1973 to as late as November 20, 1978.

The case received no further attention until the early 1990s when the JTF-FA began pursuing it. In May 1992, initial field investigations were conducted in Vietnam at the last known location of the aircraft based upon the radio communication at 0322 hours, but they were unable to find any local residents who knew of plane crashes in the area. Four years later, in August 1996, fieldwork was undertaken across the border in Laos where a C-47 crash was discovered, but the tail number found on the wreckage indicated that it was not the aircraft that the team was searching for. In February 1997 another C-47 crash site was located that was only 3 km off of the intended flight path of the subject aircraft, but no evidentiary materials could be located during the pedestrian survey. Lacking solid physical evidence that the location surveyed in February 1997 was that of the subject aircraft, additional field investigations were undertaken in the area in May 1997, January 2009, and August 2009 to exclude other crash locations in the vicinity. An investigation team returned to the February 1997 location in February 2010 and surveyed a larger area which resulted in the discovery of personal effects that indicated that at least one individual had been aboard the aircraft at the time of impact (Phisayavong 2012b, 2-5).

The recovery scene of the cargo aircraft test case is located in a mountainous region of Laos characterized by steep, forested hills cut through by twisting streams that merge to form small rivers. The site itself is situated in an east-west oriented, U-shaped valley. Steep slopes rise up from the north, east, and south sides of the valley floor, which gently tilts at approximately 5° towards the open west end (Figure 115). The northern hillside, at 20°, is less steep than the southern, which varies between 30° and 40°. A dry drainage originates from the southeast corner of the valley and extends to the south. This results in the southern hillside being sufficiently curved that it is not possible to see the southeast corner of the excavated area from the western edge. Further down the valley, to the west of the site, is a swampy area that serves as the origin for a small stream (Esh 2011b, 4-6; Ingvoldstad and O'Leary 2013, 3-5; Megyesi and To 2011, 3-5) (Figure 116).

Figure 115. The U-shaped valley bottom of the cargo aircraft test case crash site after vegetation clearing.
View to east (Megyesi and To 2011, 4)

During the two investigations and when the first recovery team arrived the site was dominated by double canopy forest typical for the region. This consists of an upper canopy of deciduous hardwood trees and a dense undergrowth of bushes, shrubs, vines, bamboo, palms, and grasses (Megyesi and To 2011, 3-5). The initial recovery team cleared the vegetation from the valley floor. The fast growth rate in the tropical climate necessitated some re-clearing in areas that had already been excavated by subsequent recovery teams. Additional vegetation was also removed as the excavation was expanded (Esh 2011b, 4-6; Ingvoldstad and O'Leary 2013, 3-5).

A medium sized impact crater was discovered approximately 6 m up the south slope from the valley floor while the second recovery team was vegetation clearing (Figure 117). The crater is oblong in shape and measures roughly 6 m north-south and 10 m east-west (Esh 2011b, 9). No large fragments of aircraft wreckage were visible on the surface of the site due to the heavy scavenging activities that are common in Southeast Asian countries. Through metal detector survey transects the debris field was determined to be roughly cone-shaped with long pointed end extending to the southeast. Overall, the debris field is approximately 150 m northwest-southeast and 80 m northeast-southwest (Ingvoldstad and O'Leary 2013, 8-9).

To date, three recovery operations, spanning three years, totaling 85 days have been undertaken at the cargo aircraft crash test case site. The first excavation was in the fall of 2010, the second in the fall of 2011 and the third during the winter of 2013. The first team cleared the vegetation within the valley floor and conducted pedestrian and metal detector surveys. The discovery of life support equipment during these surveys provided the location at which to commence excavation. An arbitrary datum was established as N500/E500 and a grid of 4-x-4 m units was laid out. Each unit within the grid is designated by the stake in its southwest corner. Each unit was excavated and screened separately to maintain provenience of the evidentiary materials contained within (Megyesi and To 2011, 5-6). During the 2012 mission, a total of 25 4-x-4 m units were eventually excavated encompassing a surface area of approximately 400 m^2 (Figure 116). The units encompassed the east end of the valley bottom and a small portion of the southern slope. The depth of the excavation ranged from 30 to 56 cm. The team recovered possible human remains attached to a fragments of dental prosthetic, material evidence, including additional dental prosthetic fragments, and large quantities of life support equipment (Megyesi and To 2011, 7-13).

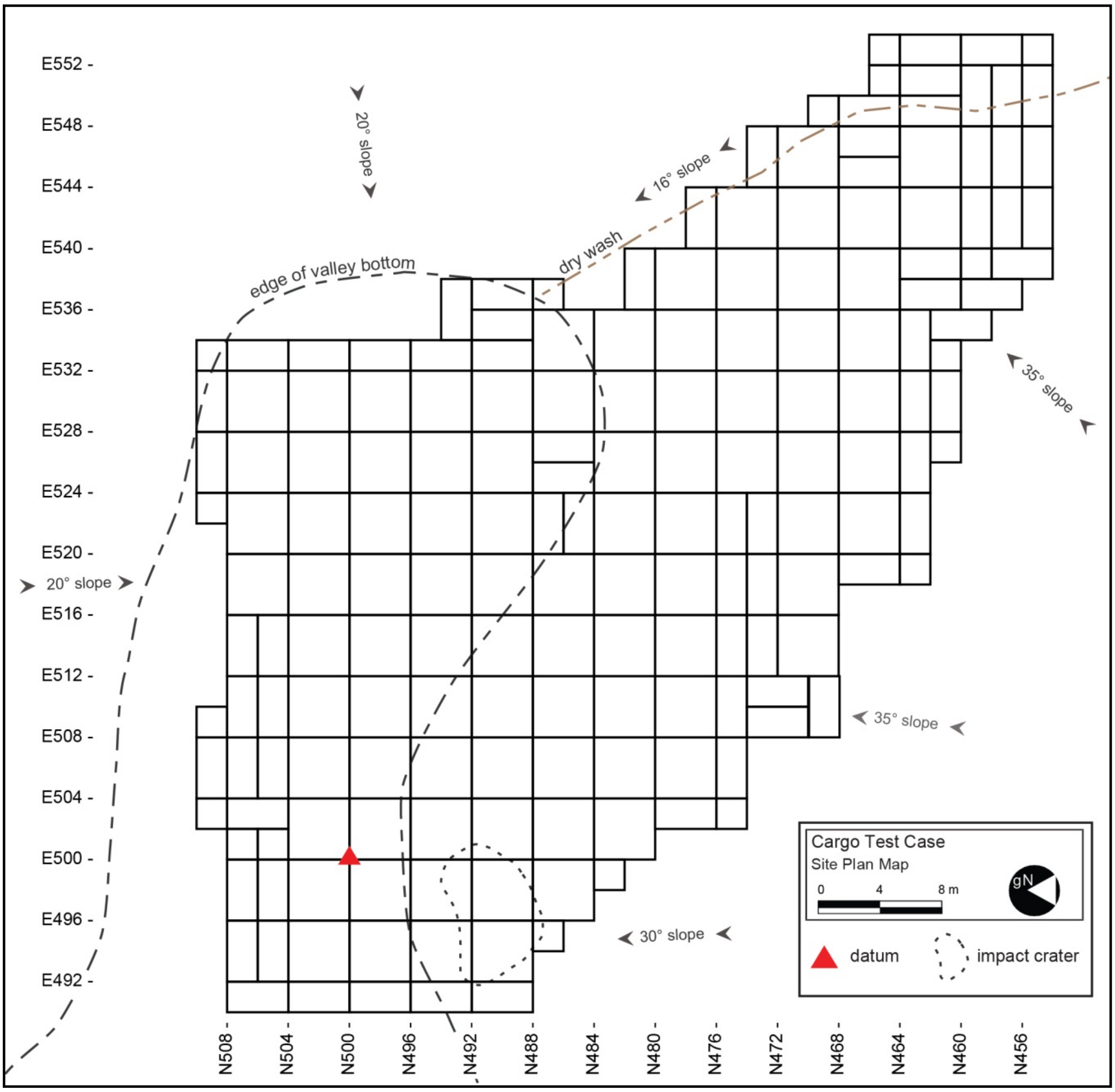

Figure 116. Map of the cargo aircraft test case site depicting the prominent terrain features. (Drafted from Ingvoldstad and O'Leary 2013)

Figure 117. The cargo aircraft test case crash site during the second recovery mission. The impact crater is highlighted (dashed white line). View to south (Esh 2011b, 6)

The following year another recovery team traveled to Laos to continue the excavation. Using the same datum, they extended the grid to the west and up onto the lower portion of the southern hillside. The team expanded the excavation to the east, north and west and an evidence sterile buffer was established on the east and north sides (Esh 2011b, 9). To the west the team focused on the impact crater and the area immediately downslope. A thick layer of unconsolidated mottled sediment extended down from the crater and capped the original surface from the time of the incident. This layer of sediment is the result of scavenging activities by local residents of the nearby villages. Within the crater, three smaller impact points were observed in a roughly triangular pattern. A propeller hub was found at the bottom of each of the two outer impact points and cockpit wreckage was recovered from the bottom of the central impact point. The arrangements of the three impact points correspond with the fuselage and the two engines (Esh 2011b, 10). While no skeletal material was recovered during this mission the team did find material evidence including additional dental prosthetic fragments and a large amount of life support equipment. It is notable that almost no evidentiary materials were only found on the western half of the impact crater and that the dental prosthetic fragments were located to the southeast of the crater (Esh 2011b, 15-17). In total, the 2011 recovery effort excavated a surface area of approximately 492 m^2 to depths ranging between 20 and 200 cm.

The most recent recovery effort at the cargo aircraft crash test case site was directed by Dr. Megan Ingvoldstad under the supervision of the author. Dr. Ingvoldstad was in a mentee status and while she directed the recovery effort and was supervised at all times by the author. Again, the same excavation grid was utilized to maintain continuity between the various recovery efforts. Based upon the indications determined by the 2011 recovery team, the 2013 efforts primarily focused on the southern side of the previously excavated area. Work proceeded up the southern hillside away from the valley floor and continued to the east and southeast expanding upon those units that resulted in the recovery of evidentiary materials. Like the previous mission, no skeletal material was recovered, but the team did find additional dental prosthetic fragments, several pieces of identification media (Table 58) and a large quantity of life support equipment. In total, the 2013 recovery effort excavated a surface area of approximately 1240 m^2 to depths ranging between 15 and 40 cm. The team was forced to suspend recovery efforts at the site due to the scheduled end of the mission (Ingvoldstad and O'Leary 2013, 8-14).

Table 58. Provenience of identification media found at the cargo aircraft crash test case site.

Provenience	Identification Media
N464/E540	Identification tag (Co-pilot)
N464-N468/E546-E548	Identification tag (Co-pilot)
N468/E532	Flight helmet fragment with name (Co-pilot)
N470-N474/E510-E512	Identification tag (Pilot)
N472/E524	Identification tag (Loadmaster) Geneva conventions card (Flight Engineer)
N472/E532	Identification tag (Loadmaster)
N480/E528	Identification card fragment (Co-pilot)
N484-N488/E524-E526	Identification tag (Gunner 2)
N484-N488/E526-E528	Identification tag (Gunner 2)

Over the course of the three excavations several patterns have emerged. First, 7.62 mm ammunition, which would have been located towards the aft of the cargo compartment and used in the AC-47D's miniguns, was primarily found along the western 10 m of the site, especially downslope of the impact crater. In contrast, very little 7.62 mm ammunition was recovered from the rest of the excavated area. This suggests that the majority of the aft fuselage likely came to rest in this area immediately after the crash. Second, fragments of cockpit wreckage were distributed in all corners of the excavated area but were primarily oriented in a northwest-southeast direction, originating at the crater. Third, evidentiary materials were also most heavily concentrated along this northwest-southeast line and decreased in frequency to the north east and southwest. Fourth, despite the fact that the amount of aircraft wreckage found in each unit decreased with distance from the impact crater, the likelihood of recovering evidentiary material did not (Esh 2011b, 8-22; Ingvoldstad and O'Leary 2013, 8-14; Megyesi and To 2011, 7-13).

Three missions worth of work has resulted in the excavation of a total surface area of approximately 2132 m^2 (Figure 118). The only piece of possible human remains recovered at the site is very small and attached to one dental appliance fragment that was recovered. The extreme paucity of skeletal and dental remains is most likely due to the highly acidic soils in the Southeast Asia and the prevalence of termites. As a result, the distribution of the crew within the cargo aircraft test case crash site is reliant upon the material evidence, particularly the numerous pieces of identification media that were recovered (Figure 119).

**Figure 118. Aerial photograph of the cargo aircraft test case crash site at the conclusion of the last excavation.
View to south (Ingvoldstad and O'Leary 2013, 14).**

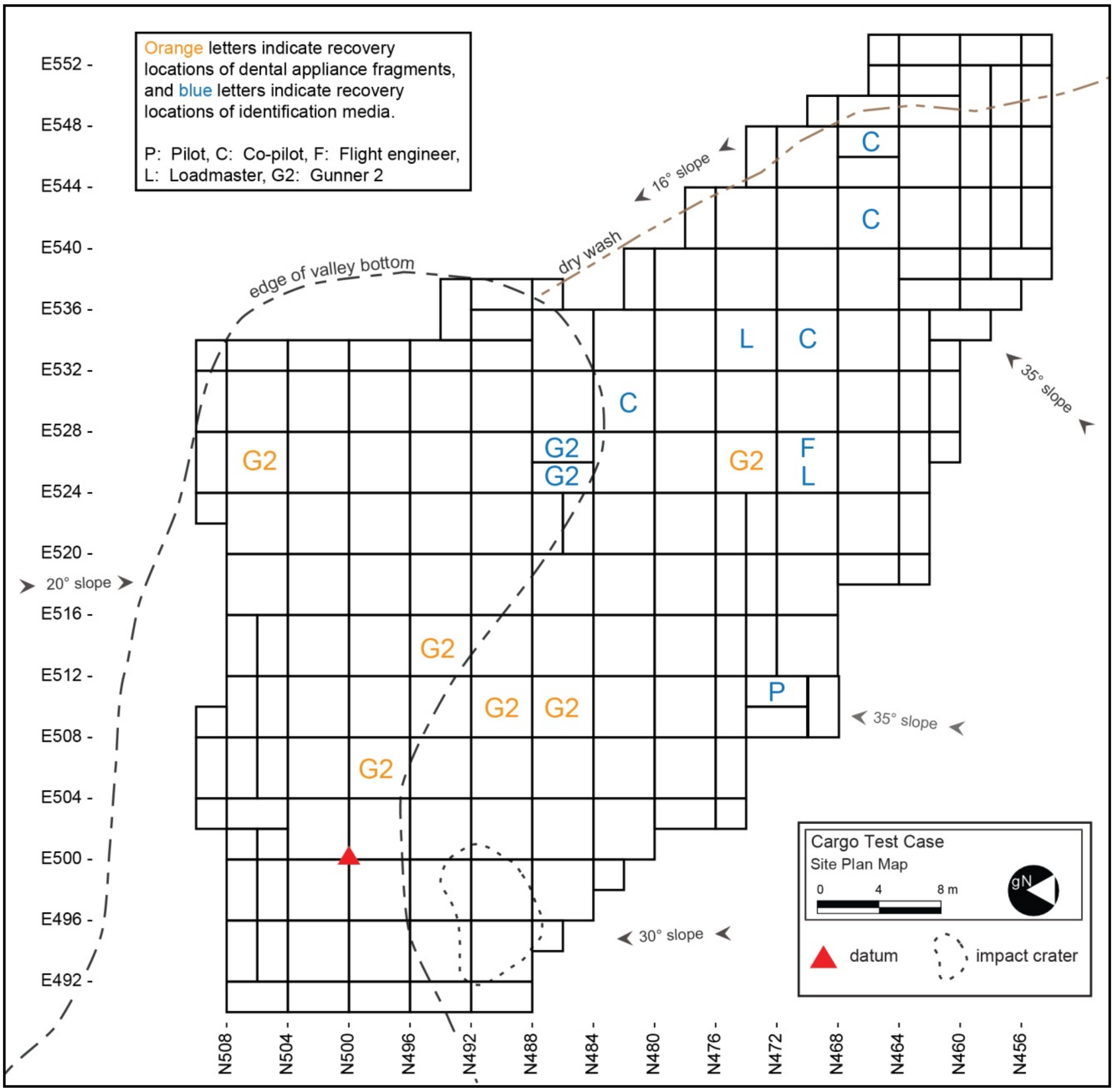

Figure 119. Map of the cargo aircraft crash test case site locations of identification media and dental appliance fragments.
(Drafted from Ingvoldstad and O'Leary 2013)

Examination of the distribution of dental prosthetic fragments and identification media that can be conclusively associated with a specific individual yields the following conclusions for each individual:

- The Pilot is represented by a single identification tag that was recovered from N470-N474/E510-E512. This location is approximately 23.0 m south, uphill, and slightly east of the impact crater (Figure 119).

- Evidence associated with the Co-pilot was distributed the farthest from the impact crater out all of the individuals aboard the aircraft. Beginning with the item that was closest to the impact crater, his identification card was found in N480/E528 and a fragment of a flight helmet with his name written on it was recovered from N468/E532 (Figure 119). Most distant from the crater were his identification tags in N464/E540 and N464-N468/E546-E548 (Figure 119).

- During the recovery effort no remains or material evidence were found that could be associated with the Navigator.

- The Flight Engineer's Geneva conventions card was recovered from N472/E524 (Figure 119).

- An identification tag with the name of the Loadmaster/Gunner was also found in N472/E524 (Figure 119).

- During the recovery effort no remains or material evidence were found that could be associated with Gunner 1.

- According to the dental records for the crew who were aboard the cargo aircraft test case plane, Gunner 2 was the only individual who had dental appliances. Fragments of the prosthetic were recovered in N496/E504, N492/E512, N488/E508, N484/E508, and N476/E524 (Figure 119). The fragment that contained the possible human remains was found in N504/E524. Gunner 2's identification tags were located in N484-N488/E524-E526 and N484-N488/E526-E528 (Figure 119).

Like REFNO 0222 (see Chapter 7), the cargo aircraft test case site was extremely heavily scavenged for metal by the local population after the Vietnam War. Over 99% of the C-47 had been removed from the site before the first excavation commenced. Despite this, the incident related material found at the site was recovered from *in-situ* contexts. The most notable observation from the recovery efforts has been the extremely wide distribution of both wreckage and evidentiary materials. This pattern is discussed in detail in Chapter 10. At present, based upon identification media, five of the seven crew members were aboard the aircraft at the time it crashed.

As of the submission of this thesis (early June 2014), the excavation of the crash site has not been completed. Additional work is scheduled for summer 2014. Upon completion of the field work, laboratory analysis will commence on the recovered materials.

10 Results and Discussion

As has been the case throughout this thesis, the results for bombardment and cargo aircraft will be presented separately and the discussions will proceed in a similar fashion. Several areas will be addressed in this chapter beginning with those results that have the finest level of resolution within a crash scene. The discussion will then proceed towards those conclusions which have decreasing amounts of specificity. First, is the presentation of the results from testing of the hypotheses developed in Chapter 8, based upon the case studies presented in Chapters 5 through 7, against the patterns observed in the two test cases discussed in Chapter 9. Second, for the bombardment aircraft, duty stations will be grouped together by compartment. This includes the nose compartment (navigator and bombardier), flight deck (pilot and co-pilot), aft flight deck (radio operator and engineer/dorsal gunner), and the waist gunner compartment (waist gunners). In the case of the cargo aircraft, the cargo compartment crew members will be analyzed as to their distribution throughout a crash scene. Third, the possible effects of the degree of perpendicularity of a crash will be assessed. Fourth, the relatively unique nature of MACR 4512 will be discussed and that compares to the rest of the case studies and bombardment test case. Fifth, general observations will be made regarding excavation strategy, the effects of erosion, and mtDNA sampling. Finally, the analysis will move beyond the crash dynamics and explore topics such as: why human remains come to rest where they do in the sites; JPAC's impact on the heritage of material culture; how this thesis fills a void in the literature; and how this research can lead to learning about people perceptions and interactions with conflict archaeology sites.

10.1 Bombardment Aircraft

The loss incident selected to be the bombardment aircraft test case, which was presented in Chapter 9, was chosen for several reasons. It involved a large B-24 Liberator crash in Papua New Guinea. It had been excavated once in 2009 and twice in 2010, all three of which were prior to the commencement of this thesis. As recent excavations they were conducted to the most up-to-date CIL methodologies and techniques. Because the field work at the site, and the subsequent analysis of the recovered materials, would not be complete for at least a two to three more years the case could not be included in the case studies. However, arrangements were made to ensure that I did not work on the case to avoid any potential bias. It was also possible to ensure that the provenience information of the recovered remains was carried forward through the DNA sampling process.

Unfortunately, in some ways, the bombardment test case proved to be less than ideal. Of the 12 man crew, four, or possibly 5 individuals parachuted from the aircraft after it was struck by enemy fire. Additionally, the historical, informant, and archaeological evidence strongly indicate that 4 sets of remains were removed from the crash by the survivors and placed just downslope.

As a result, only three crew members were recovered from contexts that were the result of the crash itself. Thus, hypotheses for only 3 crew positions can be directly tested. These are the bombardier, the assistant radio operator who was serving as one of the waist gunners, and an additional gunners.

10.1.1 Navigator

The Gunner recovered from *in-situ* contexts at the bombardment test case crash site was found partially articulated in the same feature that contained the bombardier. Additional fragments were also unearthed immediately surrounding the feature (Figure 113). As discussed in Chapter 9, this individual was most likely in the navigator's duty station serving as a gunner during the loss incident. As such, this individual is used to test the hypothesis developed for the navigator.

Based upon the analysis of the case studies, the navigator was recovered an average of 3.4 m from the corresponding duty station wreckage and was spread an average of 4.2 m across the site (Table 45). The navigator was predicted to be recovered within 8 m of the corresponding duty station wreckage. As mentioned above, in the test case the remains of the gunner were recovered within and around an impact feature that contained nose compartment wreckage. The greatest distance remains were recovered from the nose compartment wreckage was approximately 2.0 m and the maximum spread of remains across the site for the Gunner was also 2.0 m. All of the case studies that were included in determining the navigator hypothesis had at least some portions of the individual separated from the corresponding wreckage. However, in three of the five cases there was no spread of the remains across the site. Based upon this, the hypothesis developed for the navigator duty position is confirmed.

10.1.2 Bombardier

Based upon the analysis of the case studies, the bombardier was recovered an average of 6.1 m from the corresponding duty station wreckage and was spread an average of 3.3 m across the site (Table 46). The bombardier was predicted to be recovered within 8 m of the corresponding duty station wreckage. In the test case the remains of the bombardier were recovered *in-situ* from amongst the nose compartment wreckage within Feature 3 in Area A and were articulated and thus not spread across the site (Figure 113). Of the six case studies analyzed for this crew position two of the sites had remains that were recovered in immediate proximity of the bombardier station wreckage. In only one of the six case studies were the bombardier's remains spread out across the site. Based upon this, the hypothesis developed for the bombardier duty position is confirmed.

10.1.3 Assistant Radio Operator/Waist Gunner

All eight of the case studies factored into developing the hypothesis for the waist gunner position. On average, waist gunners were recovered 9.4 m from the corresponding duty station wreckage and were spread across 6.4 m (Table 50). However, this is one of the duty stations where the average has been raised by the findings of MACR 4512. Waist gunners were predicted to be recovered within 10 m of the corresponding duty station wreckage. In the test case, the remains of the assistant radio operator/waist gunner were recovered *in-situ* from amongst and under the aft fuselage compartment wreckage and were a maximum of 2 m apart (Figure 114). Two of the ten individuals used to calculate the average distance of individual from wreckage were found immediately adjacent to the wreckage from the waist gunner duty station. The distance the waist gunner was spread across the test case site is well below the 6.4 m average for the case studies. It is also smaller than the case studies when MACR 4512 is removed from the calculation (3.2 m). Based upon this, the hypothesis developed for the waist gunner duty position is confirmed.

10.1.4 Crew Compartments

Four crew compartments are discussed: flight deck (pilot & co-pilot), the nose compartment (navigator & bombardier), aft flight deck (radio operator & engineer/dorsal gunner), and aft compartment (waist gunners). The belly and tail turrets are not included in the aft compartment because a crew member is physically enclosed into them and separated from the aft compartment when they are manned. The greatest distance between an identified fragment of one individual to the other individual in each compartment was measured. This was completed for those cases where both individual were recovered from known locations within the crash scene.

10.1.4.1 Flight Deck

The average separation from wreckage and spread of remains for pilots is 6.3 m and 2.7 m, respectively, while the same figures are 0.8 m and 5.2 m for co-pilots (Table 52). The greater separation from wreckage found amongst the pilots is the result of the MACR 4512 pilot being found amongst the top turret wreckage. As previously mentioned, when this case is removed from the calculation, the average distance drops to 2.6 m, which is more consistent with co-pilots. However, for some reason co-pilots are more likely to be spread over a larger area than pilots. The average maximum distance between the pilot and co-pilot is 4.0 m (Table 59). This is greater than intra-individual distance for either crew member alone (Table 52).

Table 59. Maximum distances between the pilot and co-pilot.

MACR	Maximum distance (m)	Degree of perpendicularity
10020	6	Very high
0963	0	Very high
1069	2	Very low
1459	8	High
4497	8	Moderate
8641	0	Very high
Average	4	-

10.1.4.2 Nose Compartment

The average separation from wreckage and spread of remains for navigators is 5.0 m and 4.2 m, respectively, while the same figures are 4.0 m and 2.3 m for bombardiers (Table 52). While the distances are similar for both duty stations, the slightly larger numbers for the navigator may reflect the slightly more exposed nature of the position at the very front of the aircraft. The maximum distances between the navigator and the bombardier are consistent across the cases and the average maximum distance between the navigator and bombardier is 7.2 m (Table 60). Like the flight deck, this is greater than intra-individual distance for either crew member alone (Table 52).

Table 60. Maximum distances between the navigator and bombardier.

Case	Maximum distance (m)	Degree of perpendicularity
10020	6	Very high
0963	8	Very high
1069	8	Very low
1459	8	High
4497	8	Moderate
Average	7.2	-

10.1.4.3 Aft Flight Deck

The average separation from wreckage and spread of remains for radio operators is 1.6 m and 2.4 m, respectively, while the same figures are 8.1 m and 6.7 m for engineers/dorsal gunners (Table 52). The distance from wreckage and overall spread of remains is substantially higher for engineers/dorsal gunners when compared to radio operators. This is despite the fact that the two duty stations are within decameters of each other. A possible explanation is that the dorsal gunner sits so high in the aircraft that his head and shoulders are actually above the plain of the top of the fuselage when the turret is being manned. Unlike the navigator and bombardier, the maximum distance between the radio operators and engineers/dorsal gunners is inconsistent (Table 61). The average maximum separation between the due duty positions is 7.4 m, which is consistent with the distribution of engineers/dorsal gunners, but well above that of radio operators (Table 52).

Table 61. Maximum distances between the radio operator and engineer/dorsal gunner.

Case	Maximum distance (m)	Degree of perpendicularity
10020	15	Very high
0963	4	Very high
1069	12	Very low
1459	0	High
4497	6	Moderate
Average	7.4	-

10.1.4.4 Waist Gunners Compartment

As mentioned above, the average maximum separation from wreckage and spread of remains for waist gunners is 9.4 m and 6.4 m, respectively (Table 52). This distance of crew member to duty station is the highest for the bombardment aircraft, and the intra-individual distance is the third highest after the ball turret gunner/ radar operator, photographer (9.0 m) and the engineers/dorsal gunners (6.7 m) (Table 52). The average maximum separation between the two waist gunners is 20.7 m (Table 62). Those cases (MACR 1069 and 4512) with the greater distance between waist gunners are both crashes with a low degree of perpendicularity. However, MACR 4512 is much larger than MACR 1069 because it likely broke up in mid air shortly before hitting the ground.

Table 62. Maximum distances between the two waist gunners.

Case	Maximum distance (m)	Degree of perpendicularity
10020	8	Very high
1069	23	Very low
4497	9	Moderate
4512	43	Very low
Average	20.7	-

10.1.5 Degree of Perpendicularity

One of the factors discussed in Chapters 5 through 7 that may have an impact on distribution of remains within a bombardment aircraft crash site is the degree of perpendicularity of the crash. The average maximum distance between each individual and their corresponding duty station wreckage was calculated for each loss incident (Table 63). Missing Air Crew Reports 1069 (6.3 m), 0963 (7.2 m), and 4512 (18.1 m) have the highest averages. Of these cases, two have very low angles of impact (1069 and 4512), whereas one has a very high degree of perpendicularity (MACR 0963). An initial assessment suggests that there is no pattern in regards to the angle of an aircraft crash and the distribution of remains within the site. However, the 20 m maximum separation of the bombardier in MACR 0963 is the result of a St. Christopher medallion that was found in isolated contexts upslope of the main concentration of wreckage. All of the bombardier's remains and other personal effects were recovered from within the main wreckage concentration. If the medallion is removed from the analysis the average for MACR 0963 is reduced to 5.2 m, which is more similar to the other crashes with higher degrees of perpendicularity.

The greater scrutiny of MACR 0963 reveals a clearer picture regarding to how the angle of an aircraft crash impacts the spread of individuals and their personal items within the site. In general, crashes with a lower the degree of perpendicularity are more likely to have a greater level of separation between crew and wreckage. Missing Aircrew Report 4512, a case with a both a low degree of perpendicularity and a mid-air breakup of the aircraft, is the most scattered by a substantial margin (Table 63). This is followed by MACR 1069, which had a similarly low angle trajectory, but did not come apart before reaching the ground (Figure 49). It is notable that MACR 8641, which also broke apart in flight, but has a very low average separation distance for its crew, had a very high degree of perpendicularity.

10.1.6 MACR 4512

Missing Air Crew Report 4512 is perhaps the most unique case of the 14 that are included in this thesis. The site correlated to it, PP-00200, is the largest of the case studies and is only exceeded by the bombardment test case crash site. It is narrow and stretches for approximately 470 m across four ridgelines (Figure 74). The tail rudders, the right wing, and two engines broke off from the aircraft as it crashed along an easterly heading. The main fuselage also came apart as it finally came to rest on both sides of a deep ravine at one end of the debris field. The aft portion of the fuselage, bomb bays, and dorsal turret were allocated to the west side of the ravine with the flight deck, nose compartment, and nose turret on the east (Figure 79).

Initial examination of MACR 4512 reveals that it has the highest proportion of crew members scattered a large distance from their duty station wreckage with an average separation of 20.4 m (Table 63). This is the result of five of the seven crew members for which measurements could be taken having portions of their remains recovered from at least 16 m away (Table 63). However, it has already been speculated that the pilot and the engineer had possibly switched positions in the aircraft at the time of the crash. If it is assumed that those two individuals were in each other’s seats, then they would in fact be in contact with the “corresponding” components. This leaves the four duty stations that are located to the aft of the bomb bays: belly turret position, tail gunner, and one of the waist gunners.

The observer also has to be taken into account as his remains were spread across approximately 52 m of the site (Figure 79). Unfortunately, an observer does not have a set potion within an B-24. However, his left tibia was found upslope from the aft fuselage wreckage and the rest of the remains that could be identified as him were recovered in the ravine below, much like the assistant radio operator, it can be assumed

Table 63. Maximum distances between crew members' remains and their corresponding duty station wreckage within the crash scene.
The table is arranged from smallest to largest in terms of the size of the wreckage debris field.

Case	Pilot	Co-pilot	Navigator	Bombardier	Radio operator	Engineer, dorsal gunner	Photographer, ball turret gunner, radar operator	Waist gunners	Tail gunner	Average	Degree of perpendicularity
10020	0	4	2	6	0	6	4	4	-	3.3	Very high
0963	-	-	-	20	0	-	4	4	8	7.2	Very high
15092	-	-	0	-	8	8	4	-	-	5	Unknown
1069	0	0	4	6	0	10	8	8 and 21	-	6.3	Very low
1459	4	0	6	0	4	4	4	6	0	3.1	High
4497	4	0	5	0	4	4	8	0 and 9	8	4.2	Moderate
8641	0	0	-	-	-	4	-	0	-	1.0	Very high
4512	30	-	-	5	-	30	20	5 and 37	16	20.4	Very low
Average	6.3	0.8	3.4	6.1	2.6	9.4	6.3	9.4	8		

that he was located in the aft portion of the aircraft at the time of the crash. The distribution of remains for these two individuals is not likely due to erosion. This is evidenced by the presence of the pilot's remains which were recovered articulated and *in-situ* on the lower portion of the slope in between the two locations where the remains of the observer and radio operator were found.

In general, it appears the crash dynamic that resulted from the mountainous terrain and the aircraft's trajectory resulted in a very unique distribution of remains within the site. It is possible that the aft portion of the fuselage was ripped apart from the bomb bays and some of the crew members were torn apart and scattered across the debris field. The inexplicable aspect of the above interpretation is that one of the waist gunners was recovered 5 m from the corresponding duty station wreckage while the other was up to 37 m away. No evidence was noted by the archaeologists who excavated the site as to why this may have occurred. In addition, while not as extreme, this disparity was also observed at Site PP-00088 (MACR 1069).

10.1.7 Bombardment Aircraft Summary

While it was not possible to directly test the hypotheses for any of the other crew positions aside from the navigator, bombardier, and waist gunner, additional information can be extracted from the comparison of the bombardment test case to the case studies. It is a reasonable assumption that the four individuals (Co-pilot, Radio Operator, Engineer, and Sequence 6) who were found downslope of the main wreckage concentration in Area A were removed from the wreckage at that location and not carried the several hundred meters from any of the other wreckage areas at the site (Figure 101). Based upon this it can be concluded that all four individuals originally came to rest somewhere amongst the nose compartment, the flight deck, the radio operator station, the top turret, and the forward bomb bay portions of the aircraft. Additionally, because all five of these sections were located within a relatively compact 7-x-10 m area, it is likely that the four individuals were in relatively close proximity to their duty stations (Figure 103).

In general, the hypotheses presented in Chapter 8 were confirmed. The crew members of WWII bombardment aircraft can be expected to be found with approximately 8 m of their corresponding duty station wreckage. As demonstrated by MACR 4512, the exception to this is rule is when an aircraft breaks apart before hitting the ground as it is traveling on a trajectory with a low degree of perpendicularity.

10.2 Cargo Aircraft

The cargo aircraft test case, presented in Chapter 9, was chosen for several reasons. It involved the loss of a large C-47 Dakota crash in Laos. Fieldwork was in an even earlier stage that the bombardment test case. The same autumn that work on this thesis commenced excavation began on the site and would proceed intermittently throughout the course of the term of study. This provided the author the opportunity to complete the analysis of the selected case studies and develop hypotheses for the cargo aircraft duty stations prior to supervising a recovery effort at the site in January and February 2013 (Ingvoldstad and O'Leary 2013). Like the bombardment test case, the recovery effort was conducted to the most up-to-date CIL standards. However, as previously mentioned, the excavation of the site is not complete, but the information gathered from identification media thus far is sufficient to test the cargo aircraft hypotheses. Provenience information will also be able to be carried through the mtDNA sampling process during laboratory analysis.

Another aspect of the cargo aircraft test case that was similar to the bombardment test case was that it was not entirely ideal for testing the hypotheses developed from the sample cases. To date, only one small fragment of human remains has been found and it is adhered to the underside of a dental appliance fragment. This means that the hypothesis testing is being conducted based upon the recovery location of identification media for five of the seven individuals aboard the aircraft. The five duty stations being evaluated are: pilot, co-pilot, flight engineer, loadmaster, and one of the gunners.

10.2.1 Pilot

Based upon the analysis of the two case studies where the location of the pilot could be assessed, the individual was recovered from within the corresponding duty station wreckage concentration and was not spread out across the site (Table 53). The pilot was hypothesized to be found amongst the cockpit wreckage. In the test case, identification media for the pilot was unearthed approximately 23 m to the south-southeast of where the cockpit impacted the hillside. Only a single identification tag was recovered with the Pilot’s name preventing any determination as to how widely he may have distributed across the site (Figure 119). Based upon this, the hypothesis developed for the pilot duty position is not confirmed.

10.2.2 Co-pilot

Based upon the analysis of the two case studies where the location of the co-pilot could be assessed, the individual was recovered from within the corresponding duty station wreckage concentration and was not spread out across the site (Table 54). The co-pilot was hypothesized to be found amongst the cockpit wreckage. In the test case, an identification tag was recovered over 56 m to the southeast of the cockpit impact crater. Due to the curvature of the hillside at the site there is no line-of-sight between the impact crater and this location. His second identification tag, an identification card fragment, and a piece of flight helmet with his name written on it were also recovered to the southwest of the impact crater (Table 58 and Figure 119). The maximum spread of the Co-pilot's personal effects within the site is approximately 23 m. Based upon this, the hypothesis developed for the co-pilot duty position is not confirmed.

10.2.3 Cargo Compartment Crew

Identification media was recovered for three members of the crew who would have been positioned in the cargo compartment during the flight: the flight engineer, loadmaster, and one of the gunners. Based upon the analysis of the case studies, the cargo compartment crew were recovered an average of 4.7 m from the corresponding duty station wreckage and was spread an average of 1 m across the site (Table 56). The cargo compartment crew were hypothesized to be found within 8 m of the largest concentration of fuselage wreckage. In the test case, the flight engineer's Geneva Conventions card was recovered more than 41 m from the greatest concentration of fuselage wreckage. This was the only piece of identification media recovered for the flight engineer and so it is not possible to determine how widely he may have distributed across the site. Both of the loadmaster's identification tags were recovered to the southeast of the greatest concentration of fuselage wreckage during the third excavation. The most distant tag was approximately 46 m away and the two tags were found 9 m apart. Numerous fragments of the gunner's dental appliance as well as both of his identification tags were recovered. The most distant fragment of denture was found 38 m to the southeast. The piece containing the small amount of human remains was recovered 32 m to the east-northeast. However, the fragment closest to the greatest concentration of fuselage wreckage was only 10 m to the east. Overall, the fragments are scattered over approximately 372 m^2. His two identification tags were found approximately 31 m to the east-southeast (Figure 119). The total area across which all of the cargo compartment crew's identification media has been found is approximately 512 m^2. Based upon this, the hypothesis developed for the cargo compartment crew members is not confirmed.

10.2.4 Cargo Aircraft Summary

Initial assessment of the hypotheses developed for WWII cargo aircraft is that they were entirely inaccurate and thoroughly disproven. Analysis of the case studies indicated that the remains of the pilot, co-pilot, and radio operator/navigator would be found *in-situ* within the cockpit wreckage concentration or, at most, approximately 8 m from the point of impact. In some cases, such as MACR 14032, complete skeletons were found in physical contact with fragments of the instrument panel, control wheel, and seat components. In other cases, where fewer fragments of human remains were recovered due to the harsh taphonomic environment (REFNO 0222 and MACR 4441), they were still located within, or in close proximity to, the cockpit wreckage or point of impact. In contrast, the identification media at the test cargo test case crash site was found as far as 56 m from the point of impact

However, a deeper examination of the results of the test case reveals a more nuanced pattern. While the evidentiary materials were found very widely scattered across the site in relation to the point of impact, they were only separated from the point of impact, not the cockpit wreckage. Some portions of the flight deck were found at the bottom of the impact crater, but additional recognizable flight deck components such as gauge fragments, small pieces of the instrument panel, and control lever handles were spread to all corners of the excavated area. These parts originated at the crater and were primarily distributed in a southeast direction. This trend is also reflected in the evidentiary materials found at the site (Figure 119). Based upon this observation, the hypotheses developed for the pilot and co-pilot are partially confirmed and partially disproven. The portion of the hypotheses that are accurate is that the remains will be found amongst the cockpit wreckage. That these remains should be found in a small area close to where the aircraft impacted the ground is clearly not always the case.

The test case exhibits a different conclusion in relation to the hypotheses developed for the cargo compartment crew. Predicted to be recovered within approximately 8 m of the largest concentration of fuselage wreckage and largely intact, the identification media from the crew of the test case were found scattered throughout the central portion of the excavation with the closest fragment being found 10 m away. The distribution of the individuals themselves was also a departure from what was seen in the case studies. It is clear that hypotheses developed for the cargo compartment crew on WWII era cargo aircraft has been thoroughly disproven.

The unusual pattern at the cargo test case is that the identification media was found separated from the concentration of fuselage wreckage found downslope of the impact crater. The dense concentration of fired and unfired mini-gun ammunition indicates that while the individuals in the cargo compartment may have been ejected across the hillside, the smaller objects in the aft portion of the fuselage were not. The cause of this is unknown.

In total, the archaeological evidence from both the case studies and the test case indicates that the pilot and co-pilot's remains will be recovered from amongst the cockpit wreckage regardless of whether or not those portions of the aircraft are concentrated in a small area or have been spread across an entire hillside. The combined cases also indicate that it cannot be assumed that the cargo compartment crew are always going to be found in close association with largest concentration of fuselage wreckage.

10.3 Other results

Over the course of researching, writing-up, and analyzing the case studies as well as the test cases three topics were identified that pertained to both bombardment and cargo aircraft. The first is the methods utilized during the excavation of the sites. Second, are the effects of erosion on the sites and the role the process plays in interpreting where evidentiary materials are found within a debris field. Finally, the critical phase of DNA sampling is discussed including both the sampling strategy employed at the CIL and maintaining provenience throughout the process.

10.3.1 Excavation

The challenging, and occasionally contradictory, circumstances that JPAC archaeologists face when conducting recovery efforts forces them to adopt and utilize unique sets of methods in order to strike an appropriate balance between the need for productivity and scientific integrity. One set of factors are the large sites, goal of recovering as much of each individual as possible, and need for fiscally responsibility. These conditions provide an impetus for the archaeologist to work as quickly and efficiently, often excavating in large (4-x-4 m) grid units. These methods allow for large areas to be excavated at a rapid pace and for sites to be closed as soon as possible.

On the other hand, slower, more meticulous excavation in smaller units is more likely to result in the recovery of articulated, *in-situ* human remains as opposed to finding them during the screening process. The benefit of recovering remains from articulated, *in-situ* contexts is that it results in needing to cut fewer samples for mtDNA testing. This in turn can reduce both the overall time and cost of laboratory analysis and, more importantly, increase the amount of skeletal material that is included in individual identifications as opposed to the group identification. However, smaller units result in a slower pace of excavation which can increase the time and money needed to complete the recovery. This can be particularly challenging when a particular site can only be accessed for two to three months a year due to weather constraints.

Examination of the different strategies used throughout both the case studies and the test cases by the various archaeologists tends to lean towards the use of large 4-x-4 m units. A 5-x-5 m grid was used at Site PP-00200, which is correlated to MACR 4512. Only five of the fourteen cases discussed in this thesis primarily used smaller unit sizes such as 2-x-2s and 2-x-4s. They are MACRs 10020 (Figure 32), 1069 (Figure 49), 8641 (Figure 68), 0222 (Figure 92) and the bombardment aircraft test case (Figure 116) where the 4-x-4 m units were excavated in quadrants. Articulated remains were recovered in three of these five cases: 1069 (Figure 51), 8641 (Figure 71), and the bombardment aircraft test case (Figure 113) (Table 64). Ten of the fourteen cases were primarily excavated with larger units. The Palau case, MACR 8641, is counted in both groups because one portion of the excavation was undertaken in 2-x-2 m units, while another was completed in 4-x-4 m squares. Using a site grid with larger units did not prevent the recovery of articulated skeletal elements, but the proportion was lower. Only four of the ten cases resulted in the recovery of articulated remains. They are MACRs 4497 (Figure 62), 8641 (Figure 72), 4512 (Figure 79), and 14302 (Figure 100) (Table 64).

Table 64. Cases designated by small and large grid unit sizes and whether articulated, *in-situ* remains were recovered.

Case	Smaller units	Articulated remains	Larger units	Articulated remains
Bombardment				
10020	X			
0963			X	
15092			X	
1069	X	X		
1459			X	
4497			X	X
8641	X	X	X	X
4512			X	X
Cargo				
3282			X	
4441			X	
0222	X			
14302			X	X
Test cases				
BTC	X	X		
CTC			X	

The major departure from excavation by standard grid square was at Site PNG-23 associated with MACR 15092. During the final two excavations the impact/bomb crater was divided into quadrants (Goodman 2005a, 5). This strategy was primarily undertaken to account for the extremely soft sediment that was continuously slumping back into previously excavated areas. While this tactic should normally be avoided, it was an appropriate course of action in this specific circumstance. It was necessitated by the technical challenges of having a large crater in a swamp and the bomb explosion, or explosions, having already likely disturbed much of the crash contexts.

10.3.2 Erosion

Erosion has been shown to be a small factor in post depositional environments at the crash sites discussed in this thesis. Sites PP-00088 (MACR 1069), PP-00046 (MACR 4497), and PP-00200 (MACR 4512) are good examples. Despite the main wreckage concentrations being located on slopes ranging from 40° to 80° several sets of articulated, *in-situ* remains were recovered (e.g. Figure 51, Figure 62, and Figure 79). There are several reasons for the reduced impact of erosion. First, the aircraft is effectively a large metal container and crew members were frequently crushed within it. This prevented their remains from being removed through natural mechanisms. Second, due to flying at high altitude individuals were exposed to very cold temperatures and were forced to wearing large amounts of clothing and even electrically heated flying suits (Maguire 1995, 71). After the crash these layers would temporarily retain the body parts contained within them even if a person was disarticulated during the initial impact. Third, before the clothing could deteriorate, the extremely fast rate of plant growth in tropical environments would result in the establishment of flora that would hold the soil and remains in place and prevent erosion. At the bombardment test case crash site all of the vegetation was denuded from within Area A during the first recovery mission except for the largest trees (Esh 2009, 7). In the 132 day interim between the end of the first mission and the beginning of the second substantial re-growth occurred to include dense bushes, palms, ferns, and other plants as well as some trees that had already reached 2 m in height (Black 2010, 6-7). Relatively low levels of erosion were also observed at MACRs 10020, 1069, and Area C within the bombardment test case crash site despite all three of these sites having ephemeral stream drainages that passed directly through the wreckage concentration. Site PP-00081 (MACR 0963) exhibits the highest levels of erosion. Zone 1 of the site rested in a very steep gully that held a perennial stream. The water had carried sediment and smaller fragments of wreckage down onto an alluvial fan that was termed Zone 2.

10.3.3 DNA Sampling

Given the highly commingled nature of the skeletal materials that are recovered during JPAC missions, mtDNA sampling has become a critical step in the identification process. Table 65 shows the total number for samples cut for each of the cases included in this thesis as well as whether or not articulated, *in-situ* remains were recovered at the site. The number of samples that need to be cut are based on several factors that include, but are not limited to: the amount of skeletal material recovered, its taphonomic condition, the level of detailed field provenience recorded during the excavation, and the amount of fragmentation of the remains. For example, very few samples were needed for MACR 10020 because the severe fire after the crash likely destroyed most of the osseous material. On the other hand, MACR 0963 required a very large number of samples because of the severe commingling and fragmentation.

Table 65. The number of mtDNA samples for each case and whether or not articulated, *in-situ* remains were found during excavation.

Case	Number of DNA samples	Articulated remains
Bombardment		
10020	27	
0963	115	
15092	61	
1069	24	X
1459	11	
4497	57	X
8641	53	X
4512	70	X
Cargo		
3282	?	
4441	6	
0222	0	
14302	0	X
Test cases		
BTC	100	X
CTC	None to date	

10.3.3.1 DNA Sampling Strategy

There is a two-fold reason that efficient DNA sampling is a priority for the CIL. One is the amount of time that it takes for the AFDIL to complete their work with the samples they are sent by the CIL. The turnaround time can be several months. The other concern is one of fiscal responsibility as each sample is costly for the AFDIL to process. However, neither of these two factors outweighs the goal of individual identifications for as many service members as possible.

A high number of DNA samples can be expected to be needed for cases where a large amount of skeletal remains are recovered, but very few of the bones are found in articulated contexts. Missing Air Crew Report 0963 is an excellent example (Table 65). The opposite set of circumstances would likely result in fewer DNA samples being needed to resolve a case. This pattern can be seen in MACR 1069 (Table 65). One measure of efficiency that reflects the sampling strategies being utilized by the DNAC and the skeletal analyst assigned to the case is the number of samples that are cut for individuals who are recovered from primarily articulated, *in-situ* contexts. It provides information on whether provenience information is being utilized in addition to MNI when skeletal elements are being selected for sampling. Table 66 lists the number of DNA samples that were identified as being a crew member who was recovered from articulated, *in-situ* contexts. The total numbers of mtDNA samples for each respective case are also listed.

Table 66. The number of mtDNA samples matched to crew members whose remains were primarily recovered from articulated, *in-situ* contexts. The total number of mtDNA samples for the case are also listed.

Case	Number of DNA samples	Crew member	# of DNA samples
Bombardment			
1069	24	Bombardier	3
		Waist gunner	2
4497	57	Co-pilot	5
		Navigator	5
		Engineer	4
		Assistant radio operator	2
		Assistant engineer	3
		Tail gunner	2
8641	53	Pilot	26
		Assistant engineer	19
		Gunner	2
4512	70	Pilot	8
		Bombardier	7
		Engineer	6
		Gunner	10
		Gunner	8
Test cases			
BTC	100	Gunner	10
		Bombardier	10

The majority of the skeleton for each of the crew members listed in Table 66 were recovered from articulated, *in-situ* contexts as documented by the excavation field notes and SARs. These remains were bagged and labeled as such in the field to ensure that the provenience wasn’t compromised during their transport to the CIL. In general, the total number of DNA samples cut for each of these individuals is relatively low. This demonstrates that the skeletal analyst and the DNAC are taking provenience into account when selecting which elements to cut. For example, the 21 samples taken from the articulated individuals associated with MACR 4497 account for approximately 37% of the total samples for the case. However, this 37% is for 60% of the total crew in the MACR.

The efficiency is not as high in some of the other cases. In MACR 4512, 39 samples taken from the articulated individuals make up approximately 56% of the total samples, but this only accounts for 45% of the crew (Table 66). It is in these cases where additional scrutiny is warranted.

The set of remains that were eventually proven to be the pilot of MACR 4512 were found entirely articulated from his scapulas to his fibulas. In addition, the only other osseous remain found within 10 m of the skeleton was a single tooth (Figure 79). It is in situations such as these where there is room for improvement in the efficiency of sampling. The most notable individuals in Table 66 are the pilot and assistant engineer associated with MACR 8641 who were sampled 26 and 19 times, respectively. This makes up 85% of the total samples for the case, but the two crew members only account for 25% of the eight personnel who were in the aircraft when it crashed. The extremely high sampling rate for these individuals was an attempt by the skeletal analyst and the DNAC to find remains for the radio operator and one of the gunners. Overall, the DNA sampling strategy employed by the CIL is quite efficient, but in some cases additional attention to the field provenience could have resulted in fewer samples being cut.

10.3.3.2 Maintaining Provenience

A total of 106 Army Air Forces personnel were spread across all of the sites discussed in this thesis. This includes the bombardment test case because the mtDNA portion of the case has been completed and seven unique sequences have been obtained. Three categories of individuals are not included in this total. The first are the three crew members from the MACR 8641 incident and the four personnel from the bombardment test case who parachuted from their respective B-24s. Second, the engineer from MACR 14302 who was originally identified in 1981 is also not counted. The third is the cargo test case because excavation of the site has not been completed. Of the 106, individual identifications were made for 80 of the Army Air Forces personnel and 26 had to be included in the group identification for their respective loss incident (Table 67).

Table 67. The number of crew, individual identifications, and personnel where remains were recovered but provenience was not carried through the laboratory analyses by case.

Case	Crew	Individually identified	No provenience for remains
Bombardment			
10020	9	8	0
0963	12	12	8
15092	7	4	0
1069	9	9	0
1459	11	5	1
4497	10	10	0
8641	11 (8)	5	1
4512	11	11	3
Cargo			
3282	4	2	4
4441	7	2	0
0222	6	1	0
14302	5 (4)	4	0
Test cases			
BTC	12 (8)	7	0
CTC	7	?	

Across the 13 cases that could be assessed, 17 crew members were individually identified, but due to the provenience information not being maintained through the laboratory analyses it was not possible to determine where their remains had been located within their respective crash sites (Table 67). This comprises approximately 21% of the individual identifications and 16% of all of the personnel that could have been recovered from the crash sites. However, in some circumstances a crew member was not individually identified, but could still be placed within the site based upon the material evidence that was recovered. The assistant radio operator/gunner in MACR 10020 is one such example.

Perhaps the greatest reason why provenience might not have carried forward in some of the case studies is that the process is generally unidirectional going from commingled skeletal elements to identified individuals. There has never been the need to work through the entire laboratory portion of the identification process in reverse for a case and determine where each individual was located in the crash site. As such, there has never been the need to institute a provenience requirement for skeletal or dental analysis. The rigorous chain of custody procedures for items recovered from excavations and informant interview statements for unilateral turnovers document that an osseous assemblage is from a single site. As a result, there can be an attitude that since all of the remains are from the same site, mtDNA testing, re-articulation, and pair matching are sufficient to resolve the commingling.

Another factor is that the anthropologists are required to figuratively work “in the blind” meaning they are not supposed to have a priori knowledge of “the physical characteristics of the individual thought to be represented by the remains or other potentially biasing information” (CIL 2013a, 2). This typically prevents the skeletal analyst from reading the SAR or field notes from the excavation(s) that resulted in the recovery of the remains for which that are determining the biological profile. No method or mechanism currently exists to ensure that spatial and contextual information about articulated remains encountered in the field is transmitted to laboratory staff in a manner that does not bias the skeletal analyst.

10.4 Beyond Crash Dynamics

Thus far this thesis has primarily focused only on where remains are located within a crash site. There are, however, other questions that warrant investigation and discussion. First among these is attempting to determine an answer to the question of why the remains came to rest where they were eventually found. To what degree, if any, does human behavior and action during the crash impact where an individual is recovered in relation to the corresponding wreckage? Additionally, what can this tell us about the men who flew these aircraft? Another aspect that warrants a critical examination is the effect that the JPAC’s field activities are having on WWII material heritage and how that relates could potentially relate to tourism. This study also contributes to the broader literature of the history and archaeology of aviation during conflicts in that it sheds light onto the crash event itself, which has seen little examination to date.

10.4.1 Aircrew Behavior

World War II aircrews can be generally characterized as young and inexperienced. They were typically in their early to mid 20s with the pilot being the most experienced of the four officers aboard each aircraft. The distribution of pilot ranks among the 12 WWII cases discussed in this thesis is 4 second lieutenants, 5 first lieutenants, and 3 captains. They were ultimately responsible for the success of the mission and the safety of the crew while navigating over treacherous mountains through dangerous storms and surviving enemy aircraft and artillery fire. It was undoubtedly an intimidating task that necessitated strong leadership ability to have their entire crew working as a team within the aircraft.

In Chapter 4 several reasons were provided as to why crew members were likely to have been in their proper duty positions throughout a mission. However, after the presentation of the 14 cases included in this thesis, an examination of what actions personnel aboard the aircraft may have taken if they knew that a crash was imminent. Associated with this is attempting to determine if these actions may have affected where their remains came to rest in the crash site. The first step in this process is to assess if the service members aboard the aircraft were aware that they were about to crash. This is an inherently challenging task as several of the aircraft went missing without be observed by any other aircraft. Only two of the aircraft have a known cause of loss because they were seen to have been hit by enemy fire and then crash (Table 68). There is also a fair likelihood that these are the only two cases where individuals bailed out of the aircraft. Table 69 lists number of crew associated with each loss incident and the number of individuals that are known to have been aboard the aircraft at the time it impacted the ground based upon the recovery of either human remains of identification media. Case 15092 is the only case where several individuals were not recovered, but this case was also subject to bomb explosions after the crash. Among the cargo cases, three of them (MACR 4441, REFNOs 0222 and 0271) were subjected to highly acidic soils which can completely dissolve bone. All of this supports the statements made in Chapter 4 about crew members generally not bailing out in Papua New Guinea or The Hump.

Aside from MACR 8641 and the bombardment test case, it is not possible to determine why the other 12 aircraft did not return to an Allied airstrip. In at least 8 of the 12 it is known that the pilots were faced with the notoriously inclement weather of Papua New Guinea and The Hump (Table 68). Cases 4497 and 4512 were involved in the infamous Black Sunday storm on April 16, 1944, as described in Chapter 6. Air crews becoming disoriented and lost in these conditions is well documented (Claringbold 1995; Spencer 1994). Furthermore, all of the crash sites associated with adverse weather conditions were found on land. This suggests the possibility that the aircrafts' altitudes could have dropped too low and that the pilot may have only realized that the aircraft was doomed at the last possible second, if they had any idea at all. Flying through turbulence would have added further impetus for crew members to be strapped into their duty stations for safety and if they had no warning about an impending crash, they would not have had any time to move about the aircraft. Additionally, even if the crew knew that their aircraft was not going to return home safely, they were most likely not going to bail out into a storm.

Table 68. Circumstances surrounding the loss of each aircraft.
Observed by others is defined as whether or not friendly forces witnessed the plane impact the ground.

Case	Day/Night	Observed	Inclement weather
Bombardment			
10020	Unknown	No	Yes
0963	Day	No	Yes
15092	Day	No	Yes
1069	Night	No	Unknown
1459	Night	No	Unknown
4497	Day	No	Yes
8641	Day	Yes	No
4512	Day	No	Yes
Cargo			
3282	Unknown	No	Yes
4441	Day	No	Yes
0222	Day	No	Unknown
14302	Day	No	Yes
Test Cases			
BTC	Day	Yes	No
CTC	Night	No	Unknown

Table 69. The number of crew members associated with each loss incident and the number of them that are known to have been aboard the aircraft at the time of the crash.
The number in parentheses reflects the number of people who were thought to be on the plane at the time of impact and were still missing at the time of the recovery.

Case	Crew	Located in site
Bombardment		
10020	9	9
0963	12	12
15092	7	4
1069	9	9
1459	11	10
4497	10	10
8641	8	6
4512	11	11
Cargo		
3282	4	3
4441	7	3
0222	6	1
14302	3	4
Test cases		
BTC	8	7
CTC	7	5

Being faced with such a situation certainly had to have been frightening. Aircraft crews would have been fully aware of stories told by more seasoned pilots about planes that had already been lost to storms. While the pilot and co-pilot would have had direct control over the aircraft, the majority of the crew were simply along for the ride having to place their trust in the flight officers to get them home safely. Aside from the pilot and co-pilot, the bombardier and navigator would have been the only other crew members with a good view of what was ahead of the aircraft and riding at the very nose of the aircraft through a giant thunderstorm might have been the most unnerving seat of them all.

Practices in the European Theater were entirely different. Parachuting from a stricken aircraft was common place as a result of the more favorable terrain and overall general level of infrastructure development. Air crews knew that they were not going to land on a jungle covered mountainside and then have to make their way to the coast. The rumors of cannibals and head hunters that were a part of the Pacific Theater and the Hump were also absent. Many of the bombardment cases in Europe that are being developed by the JPAC for investigation and excavation in the future involve aircraft in which approximately half of the crew were able to parachute from the plane. Additional details about these cases and future avenues of research is provided in Chapter 11.

Overall, the generally low degree of distribution of remains from duty station wreckage (Table 63) for the majority of the crew positions suggests that personnel were in their assigned seat and not moving around the plane at the time of the crash. The obvious exception is MACR 4512, which is discussed above. When assessed in its entirety, the evidence indicates that crew behavior is not substantial factor in determining where remains come to rest within an aircraft crash site.

10.4.2 Impact to Material Heritage

The JPAC's fundamental goal is the recovery and identification of missing service members. It seeks to fulfil this obligation through any scientifically appropriate and legal means. This singular focus has, for the most part, meant that the organization has not thoughtfully considered the affect that its activities have on the material heritage of WWII. Sites, however, have typically undergone substantial changes between when they first formed and when a recovery effort commences. When a JPAC team arrives on a site the odds are that it has already been substantially altered since its original creation. The majority of sites throughout the world have undergone varying degrees of scavenging.

After the Vietnam War local residents in Southeast Asia removed so much metal from crash sites that it is rare to find any large fragments of the aircraft larger than 50-x-25-x-20 cm. A similar pattern is seen throughout Europe after WWII. To a lesser degree scavenging and site disturbance is still prevalent in remote locations such as high in the Himalaya Mountains (MACR 4441) and Sarawaget Range in Papua New Guinea (MACR 1069).

The initial survey component of JPAC's field work has a very minimal impact to a site. The small holes that are dug to investigate positive signatures during metal detector transects are easily refilled when the uncovered item is replaced after being recorded. In this fashion, the site remains largely undisturbed. A JPAC recovery effort is entirely another matter. The current processes of large-scale, bulk excavation has several results. First, is usually a large pile of aircraft wreckage that has been placed off to the side of the site. Second are the evidentiary materials that were collected and returned to the CIL. The only retained items are those that will contribute to the identification. While a JPAC excavation hardly ever encompasses an entire debris field, it almost always includes the central, and most information laden, portions of a site. In this way, the majority of the context of the crash has been completely destroyed. Third, as discussed in Chapter 4, the excavation is recorded with detailed notes, maps, and photographs, which become the only record of the site.

The original field documentation forms the basis of the SAR and is retained in perpetuity in the JPAC records room. However, it is not easily available to the public. Because they are sensitive forensic case-file material associated with missing persons, most JPAC documents are categorized as for official use only (FOUO) and can only be obtained through a freedom of information act request. In this respect, to a large extent, the detailed knowledge of the archaeological sites excavated by the JPAC and the information gathered from them is removed from the public domain.

In many places, such as Papua New Guinea, Southeast Asia, and The Hump, the crash sites excavated by JPAC are commonly very remote and often only reachable by helicopter. These types of locations are exceedingly unlikely to ever be visited by tourists. Sites in Europe, on the other hand, are typically much more accessible even if they are in rural areas.

10.4.3 Narratives of War

This detailed examination of aircraft crashes themselves has produced knowledge that helps to further the narrative regarding a portion of conflicts that has previously seen little attention. On the larger scale, many historical volumes have been written about air wars at the campaign level across Europe and the Pacific Theaters (e.g. Bergerud 2000; Bowman 2002; Tillman 2010). These texts focus on the strategies used by commanders over time across expansive geographic areas. They usually provide figures of the number of planes lost in taking a particular objective and occasionally for individual battles. The other end of the spectrum are the numerous books about the aircraft themselves (e.g. Avery 1994; Davis 1987) that document the minutia of topics such as the varying levels of horsepower produced by different combinations of engines and superchargers or the serial numbers of the specific aircraft built at a particular factory. Collection of the dead after WWII is also the subject of several large works (e.g. Steere 1951; Steere and Boardman 1957). These three groupings of books cover everything before and after the crash, but not the crash itself. This thesis fills that gap. It provides previously unavailable information derived from the archaeological record about the actual aircraft crash sites. It also details the factors that influence the formation processes of the site itself and the general characteristics of WWII aircraft crash sites.

While not directly addressed in this thesis, the research conducted at the JPAC to locate loss locations and excavate them brings personnel into contact with individuals who live near the crash sites. This potentially provides the opportunity to gather information in relation to how people perceive and interact with battlefields and conflict history and archaeology. It can examine how local residents interacted with crash sites at the time of their occurrence or shortly thereafter. Were the sites avoided or quickly visited and why? For older individuals in places such as Laos and Vietnam, have their opinions changed over time? If their thoughts and feelings have changed, how have they evolved? Additionally, as mentioned in Chapter 1, what are their thoughts on providing assistance to American military teams to help find the remains of people who may have bombed their villages? Given their willingness to come and help the JPAC in spite of this is particularly poignant. Younger generations, born after the end of the war, provide another line of inquiry as the conflict is merely history for them and not something that they had to survive. These types of interviews of the members of a community could also potentially document how a site has physically changed over time as well as people's perceptions of that same location.

Assessment of how this varies according to country or region of the world would also provide insight to different cultural viewpoints. For example, in Austria during WWII Written records and diaries kept by mayors, leaders of the local church, and even the local fire department. In Papua New Guinea and Oceania oral tradition has served as the vehicle to pass knowledge of the crash sites. How do these two systems of documentation compare? Even though nothing was written down, the residents who live in proximity to the MACR 4505 crash site alleged that the body moved farthest down the hill was the pilot. As discussed in Chapter 9, the archaeological evidence has narrowed that set of remains down to two people, one of which is the pilot. Furthermore, cultural viewpoints on death and the dead could be examined. The author has generally observed that Southeast Asian cultures do not bear a great superstition of the dead and will simply bury any remains and proceed with scavenging of a site. In contrast, people in the highlands of Papua New Guinea traditionally have a deep superstition of dead bodies which will often prevent them from visiting crash sites.

11 Conclusion

This thesis has examined Consolidated B-24 Liberator, North American B-25 Mitchell, Curtiss-Wright C-46 Commando, and Douglas C-47 Dakota cases where the missing service members have been recovered, identified, and returned to their families by the JPAC. Eight bombardment and four cargo aircraft cases were examined and the identification process run in reverse to determine where as many pieces of each crew member was found within the crash site in relation to their corresponding duty station wreckage. From this, hypotheses were developed for each duty station that encapsulated these observations as well as each category of aircraft as a whole. The predictions were then tested against two additional cases, one bombardment and one cargo aircraft, which had not been previously reviewed. Despite some unanticipated challenges with the two test cases it was possible to successfully evaluate the hypotheses.

11.1 Is Predictability Possible?

In a word, yes. It has been shown that it is possible to construct a model that predicts where human remains will be found within an aircraft crash scene based upon each individual's assigned duty station aboard an aircraft. While this conclusion can be reached for both bombardment and cargo aircraft, each category warrants a few final observations.

Unfortunately, due to the unique circumstances of the bombardment test case with some of the crew parachuting from the stricken B-24 and the bodies of others having been disturbed after the crash, only the navigator, bombardier, and assistant radio operator/waist gunner duty stations were directly tested against their respective hypotheses. In all three instances they were confirmed. While the predictions for the remaining crew positions could not be individually evaluated there is sufficient evidence to conclude that the unique components that can be found at each duty station serve as a strong indicator of where remains will be recovered. Skeletal remains were separated from the duty station wreckage from between 0.8 m (co-pilot) and 9.4 m (Engineer/top turret gunner and Waist gunner) with an overall average of 5.4 m. Given that the standard CIL excavation unit is 4-x-4 m, only two units are likely needed to be excavated to ensure that the remains will be recovered.

For the cargo aircraft, all four of the crew position hypotheses were evaluated against the test case. The initial assessment indicated that all of the hypotheses were going to be invalidated due to the more fragmented and broadly distributed pattern of wreckage and evidentiary materials in the test case when compared to the sample cases. However, a pattern did emerge. In all five cargo aircraft cases the distribution of the remains and/or personal effects mirrored that of the cockpit wreckage. When the cockpit components were largely intact and located within a tight cluster the remains were in a similar condition (e.g. MACR 14302 in Chapter 7). However, when the same wreckage was extremely fragmented and widely dispersed over a very large area (e.g. the cargo test case), the remains were as well.

Other factors involved with crash dynamics and site formation processes were also evaluated. The degree of perpendicularity with which an aircraft impacted the ground appears to have no affect on the distribution of remains within a crash site. For any single crew position skeletal elements and fragments were found both close to, and farther away from the associated wreckage in both crashes with low and high degrees of perpendicularity. For example, MACR 10020 had a very high degree of perpendicularity and MACR 1069 had a very low degree of perpendicularity, but in both cases the co-pilot was found immediately adjacent to the cockpit wreckage and the bombardier was found a maximum distance away of approximately 6 m. Size is also not a determining factor in the distribution of remains within a crash site. As can be seen in Table 63 there is no association between the size of the debris field and how far remains will be scattered as might be expected. Co-pilots had the greatest distance from corresponding wreckage in the smallest site (MACR 10020), while the photographer/ball turret gunner/radar operator position is relatively evenly distributed across the variously sized sites.

Additionally, based upon the analysis of the cases included in this thesis, air crew behavior and actions had little influence on where remains eventually came to rest within the crash site. It appears that the unwritten rule of ‘stay with the aircraft’ was closely followed. A scant total of only 7 individuals between two loss incidents parachuted from their aircraft. Almost all of the individuals in the other aircraft can be accounted for through some form of evidentiary materials recovered at the site. One likely reason that personnel aboard the aircraft did not bail out was that in at least eight cases the plane was lost when flying through treacherous weather. In some instances, it is likely that the young, nervous airmen never knew they were about to crash.

The one combination of factors that does appear to have a substantial impact on the distribution of remains within the crash site is whether or not the aircraft broke apart in the air as it was crashing at a low degree of perpendicularity. The aircraft associated with both

MACR 8641 and 4512 broke apart in mid-air, but because the MACR 8641 was at a high altitude it would have lost all of its forward momentum by the time it impacted the surface of the water off the coast of Palau. On the other hand, the extended wreckage distribution clearly indicates that the MACR 4512 Liberator was still traveling with a good deal of momentum in its final moments. With this combination of factors, which is also somewhat present in MACR 1069, the remains of the individuals manning certain crew positions can become very broadly scattered across the site. In sum, it is primarily the complex physical interaction between the crashing aircraft and the land surface that determines where remains are deposited within the crash site.

11.2 Potential Impacts

This thesis provides two methodological contributions to the discipline of archaeology. The first are the detailed description of the methods used by the JPAC during investigation and recovery operations. These techniques have been iteratively developed over the years to be able to account for almost any imaginable situation of set of characteristics. As such, other researchers and archaeologists will be able to incorporate some aspects of the large-scale, fast-paced methods used by the CIL into their own work. Second, the successful examination of the archaeological record to construct predictive models opens many possibly avenues of future applicability for the JPAC, traditional academic research archaeology and cultural resources management.

The results of this study fill a gap in the historical and archaeological literature surrounding 20th Century air warfare: the aircraft crash. At present, nearly every aspect of aerial combat including theater level campaign strategy, the intricate details of the planes, and recovery of the dead has been the subject of extensive writings. These sources, however, do not offer any information on the crash itself. The actual crash is merely treated as a starting or ending point, depending on the perspective of the author. This thesis bridges those two sides and provides a detailed, evidence-based examination of the process and outcomes of aircraft crashes. It assesses the factors that determine where crew members' remains will be located within the crash site.

The ultimate goal of the CIL's field work is to recover the remains of those individuals who were aboard the aircraft. Knowing where the osseous material is most likely going to be located at the start of an excavation is a very valuable piece of information. It can prevent an archaeologist from inadvertently beginning in the wrong place and having to find the correct area through additional excavation. This will help to ensure that recovery efforts are confined to as short a period of time as possible. It has also been documented within this study that all portions of wreckage associated with a crew member need to be excavated as a recovery effort proceeds. Across the 14 cases included in this thesis skeletal elements were recovered amongst wreckage from each duty station. Thus the CIL's typical level of thoroughness is reinforced by this study. Also in the vein of knowing how far to extend the excavation, there were no instances where skeletal remains were found to have been thrown completely clear of the aircraft debris field, even at MACR 4512.

The work by the JPAC has a substantial impact on the material heritage of aircraft crash sites resulting from the various 20th Century wars in which the U.S. was involved. Despite what can be very heavy scavenging by local population during and shortly after a conflict the remaining wreckage and artifacts reflect the depositional processes associated with the events that lead to the crash. Like all archaeological excavations, one conducted by the JPAC destroys these contextual relationships. However, the scale of the disturbance of a JPAC excavation is much greater because the majority of the most information laden areas are completely removed in an effort to recover as much of each individual as possible. Typically, only the outer portions of a debris field are left behind. Access to the detailed written and photographic documentation is restricted to its sensitive forensic nature. The end result is that there is little left to appreciate for those people who may follow on to a site and a freedom of information act request is necessary to obtain the files.

Even though they spanned two separate conflicts, all of the case studies for this thesis came from the Pacific region. Despite this, the conclusions generated by this research can have a very valuable contribution to the JPAC's future recovery efforts in Europe. In the Europe Theater when a bombardment aircraft was disabled by enemy fire it was common for approximately half of the crew to successfully parachute from the plane. The remaining personnel would thus still be in the aircraft when it impacted the ground. Then, the German Military and/or local residents would visit the crash site and collect the dead bodies that they could easily find and bury them in the local cemetery. However, in many cases one or two individuals would not be recovered from the crash site. After WWII the AGRS would disinter the Americans from the cemetery and visit the crash site, but typically would not find the members of the crew who were not previously collected from the crash site. The end result of these instances is numerous crash sites distributed throughout Western Europe where only one or two individuals may be scattered throughout a large debris field. Combining historical loss records on which individuals are still missing from a loss incident, the model developed in this thesis, and thorough on site metal detector survey will allow a recovery leader to identify those areas within the site that are most likely to contain human remains. This in turn can provide an archaeologist with the information they need to know to decide where to commence excavation.

11.3 Potential Improvements

It is not unexpected that an organization consisting of numerous highly educated, well trained professionals that has been pursuing the goal of identifying missing service members for more than three decades would have become very proficient at the task. The CIL's Standard Operating Procedures (SOP) for recovery scene processing and laboratory operations (CIL 2014) has been written with sufficient guidance to ensure that minimum best-practices are met, but are broad enough to allow a recovery leader to adapt the each unique situation they encounter in the field. The SOPs covering the analysis of recovered evidence are more stringent, but do allow for flexibility (CIL 2012, 2013a, b). However, despite a deep institutional knowledge, some portions of the CIL's operations have not been closely examined analytically due to the continuous workload of current cases that are moving towards identification. This thesis has shown that while the CIL is doing an excellent job overall in the identification of WWII aviators, there are a few areas where improvement can be made to increase efficiency.

11.3.1 Fieldwork

There are three areas in which the CIL can improve in the recovery operation phase of the identification process in relation to WWII bombardment and cargo aircraft losses. The first is the need to develop a means to more quickly bring staff members with lower levels of experience up to speed with those who have been with the CIL for longer periods of time. Specifically, a tool needs to be developed that will aid them in the recognition and accurate identification of the pertinent sections of the aircraft, especially when the wreckage has been highly fragmented or extensively scavenged. This could be accomplished through the creation of a searchable photographic database which is described in detail in the future research section below.

The second directly relates to the physical act of recovery effort and the recognition of site formation and modification processes. When recovery efforts are commenced on WWII bomber aircraft sites, the archaeologist needs to determine the overall size and shape of the debris field, and, more importantly, if the aircraft is likely to have broken up in the air. The recovery leader also needs to assess the degree of perpendicularity. The combination of these factors determine how large the crash site is likely to be as well as the how far across the site the remains are likely to be distributed. This can impact the size of the excavation units within the site grid and whether to primarily excavate the site with trowels or to use larger tools such as shovels. It has been demonstrated that articulated sets of remains can be recovered from either 2-x-2 m or 4-x-4 m units, but it remains imperative that archeologists be able to quickly recognize when an articulate skeleton has been encountered and to slow the recovery effort to the appropriate pace. Furthermore, larger areas of provenience such as the quadrants used at MACR 15092 and the ravine bottom sections at MACR 4512 should be avoided whenever possible and only be utilized in extreme circumstances.

Third, the CIL needs to develop formal instructions to ensure that the information regarding spatial relationships and contexts of articulated skeletal elements found on site are reliably and consistently transferred from the recovery leader in the field to the skeletal analyst in the laboratory. At present, there is only general guidance in the CIL SOP (CIL 2014) for maintaining provenience when collecting evidence. Search and recovery reports document articulated remains encountered during the excavation of the site, but the forensic anthropologist conducting the laboratory analysis is not allowed to read them to ensure that the determination of the biological profile is conducted in the “blind”. However, other methods that would not introduce bias and take advantage of the unique number given to each sealed bag of evidence could be implemented. Articulated remains are already documented with written notes, to-scale maps, and photographs. It would be a simple step to create a form that is filled out by the recovery leader that lists those evidence bags containing elements that were found in articulated contexts.

11.3.2 Laboratory work

Increasing the information flow from the field to the laboratory regarding the spatial relationships between osseous elements has an impact on the mtDNA sampling process. Failure to provide any contexts results in more samples needing to be cut which increases the overall cost and time of the analysis. At the other end of the spectrum, a completely articulated skeleton, from which full contextual information has been provided to the laboratory analyst, may still require several samples to be sent for analysis due to the need for certainty in the final conclusion. An incorrect identification, or mis-associating elements to the wrong individual, is the greatest mistake the CIL could make and so a certain level of mtDNA sampling will always be necessary. Additionally, second and third rounds of sampling are sometimes undertaken in hopes of finding an element from an individual who had not previously been located within the assemblage. However, it does behoove the CIL to engage in practices that reduce the number of DNA samples to the responsible minimum.

The shortcoming within the CIL's current practices that is most in need of improvement is the lack of a mandate that field provenience be maintained through the DNA sampling process. At present, the SOPs lack even a recommendation that the DNAC or skeletal analyst record the information in either the electronic DNA sampling log database or the bench notes. Including this step will impact the identification process by skeletal analysts paying closer attention to provenience as they sort a commingled assemblage into individuals. This will potentially result in more skeletal fragments being individually identified and not ending up in the group identification.

Furthermore, not collecting this type of information in the past prevented many of the previously completed cases from being included in this study. This could have potentially decreased the accuracy of the model when compared to what may have been possible with a larger sample size. Additionally, this type of data will be necessary for future projects described below that may follow in the mold established by this study.

11.4 Future Research

While it has proved possible to create predictive models of where individuals would be found within bombardment and cargo aircraft crash scenes based upon their assigned duty station aboard the aircraft, areas of uncertainty remain. This includes how one waist gunner aboard a bombardment aircraft can be distributed dozens of meters across a site and the other still be located immediately adjacent to the aft fuselage wreckage. Another example is the widely dispersed wreckage at the cargo aircraft test case which appears to be incongruous with the four case studies. In the future more cases need to be added to the case study sample size. The most effective way to do this would be to take the loss incidents that served as test cases in this thesis and include them with the case studies described in Chapters 5 through 7 and then repeat the analyses conducted in Chapter 8. The hypotheses could then be re-evaluated and adjusted appropriately. These new predictions could then be tested against the next WWII bombardment or cargo aircraft crash that the JPAC excavates. Multiple iterations of this process could potentially occur in the future to further refine the model. This line of inquiry is particularly appropriate given the unexpected challenges with the bombardment test case that only allowed the hypotheses for three duty positions within the bombardment aircraft to be directly tested.

It has been solidly established that duty station specific aircraft wreckage serves as a strong indicator of where human remains will be found within a crash site. In order to take full advantage of this conclusion another avenue of future research should be pursued. A product needs to be developed that will assist CIL recovery leaders of all experience levels in the accurate identification of pertinent aircraft wreckage. The CIL should spearhead a multi-faceted research trip to the National Museum of the United States Air Force (NMUSAF) on Wright-Patterson Air Force Base in Dayton, Ohio. This museum possesses a completely refurbished example of each of the aircraft types discussed in this thesis as well as other similar aircraft such as the Boeing B-17 Flying Fortress, Martin B-26 Marauder, and Douglas C-54 Skymaster. High-resolution photographs should be taken of the diagnostic and easily identifiable parts of the aircraft that are located at the various duty stations within each airplane. The level of detail needs to clearly capture the text on each gauge and control in the cockpit, for example. These photographs can then be used to create a searchable, virtual library that will fit on a DVD. By tagging each photo with the text on the various components it will be possible for the recovery leader to correctly identify the aircraft parts they encounter while in the field even if they are highly fragmented.

The methods used to develop the predictive model created in this thesis also have the potential to be applied to other types of aircraft across the 20th Century conflicts in which the U.S. has been involved. Examples could include single seat fighter aircraft from WWII such as the North American P-51 Mustang and Republic P-47 Thunderbolt. However, a possibly more advantageous place to apply the methods would be on higher speed Vietnam War-era, fighters such including the McDonnell Douglas F-4 Phantom II or the Republic F-105 Thunderchief. These types of aircraft travel at much faster speeds and frequently result in very large debris fields. Understanding where individuals come to rest within a crash scene such as this would be beneficial for the reasons described above in regards to WWII bombardment crashes in Europe. Furthermore, this type of predictive model building could possibly be expanded beyond intra-site dynamics. This could include a fairly common category of Vietnam War fighter aircraft loses where the body, or portions thereof, are removed from crash sites and buried nearby. An analysis of resolved cases could determine the average distance that remains are taken from the crash site which could assist in the evaluation of witness and informant statements as well as the previously discussed benefits to excavation strategy.

This thesis and the work the JPAC conducts offers opportunities for additional lines of research relevant to aspects of conflict and battlefield archaeology beyond the crash dynamics of aircraft. Particularly how people have interacted with and perceived the airplane crashes in the vicinity of where they live both today and in the past. Examination of this topic could explore how those relationships may have changed over time as well as how they differ around the world from one culture to another. Conclusions and determinations have been avoided because the author has only made general observations over the course of recovery missions and has not conducted any formal interviews or collected any data. Additionally, as was previously mentioned in Chapter 1, only future research has been discussed because this fascinating topic warrants its own dedicated thesis.

Finally, despite the numerous pages devoted how the aircrafts crashed, this thesis, and the work conducted by the JPAC, is fundamentally about people. First and foremost are the American servicemen who made the ultimate sacrifice for their country in times of need and whose remains were never returned. Many vanished without a trace, and became missing with no explanation as to why. No one was there to see their end and tell their story. Their families and loved ones were left behind with more questions than answers and have spent decades in a limbo of uncertainty. The JPAC seeks to locate, recover, and identify the missing so that the fallen can be returned home and honoured and so that their family members can have the closure they have so long desired. This research will hopefully contribute to that effort.

Until they are home.

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