

1 Introduction

The Department of Veterans' Affairs (DVA) is reporting on four studies relating to the mortality and cancer incidence of Australian military and civilian participants in the British nuclear weapons tests in Australia, conducted between 1952 and 1963. These studies were initiated because of the health concerns expressed by Australians involved in the nuclear tests.

The study reported here (Volume 1) estimates Australian participants' exposure to **ionising radiation**.¹ This report provides radiation **dose** estimates for use in the other three studies.

The other three studies examine the mortality — particularly mortality from cancer— and cancer incidence in Australian participants, compared to the general Australian population and in relation to estimated ionising radiation exposure levels of the participants. One of them is a **case-control** study nested within the cancer incidence study, which examines the association between **leukaemia** and ionising radiation doses. These three studies are reported in Volume 2.

1.1 Objective

The objective of this dosimetry study is to broadly categorise the exposure to ionising radiation incurred by various groups of Australian participants in the British nuclear weapons tests and associated '**minor trials**'² conducted in Australia between 1952 and 1963. This study is concerned only with exposures to ionising radiation. In line with the main study protocol, no attempt has been made to investigate possible exposures to other toxic materials that may have been used in, or in conjunction with, the **atomic weapons** trials.

There is currently limited information regarding each participant's tasks and activities, time of service at a test site, and specific ionising radiation doses. This lack of information has made it difficult to accurately categorise ionising radiation exposure levels for each individual involved in the tests. Therefore, the categorisation of individuals into different exposure levels is based upon the activities of their work group, and the ionising radiation doses that may have been recorded for other individuals within that group.

1.2 Study organisation and administration

The conduct of this study was the responsibility of DVA on behalf of the Repatriation Commission. The study's Scientific Advisory Committee (SAC) proposed that an expert subcommittee and panel be established to produce the dosimetry report. The study was planned in consultation with a Consultative Forum, obtained appropriate ethics approvals, and was given scientific and technical guidance by the SAC.

1 Scientific and technical terms **in bold** are explained in the glossary.

2 The British program included both the detonation of 12 nuclear fission devices and a wide range of 'minor trials'; that is, tests of weapons components, safety tests of weapons and tests of neutron initiators. In this report 'major' or 'weapons tests' refers to the explosion of nuclear weapons, 'minor trials' to the other experimental programs.

1.2.1 Australian Government Department of Veterans' Affairs

The conduct of this study was a responsibility of DVA on behalf of the Repatriation Commission. The DVA project staff are listed in Appendix 1.

1.2.2 Consultative Forum

A Consultative Forum, with representatives from Australian ex-Service organisations; DVA; Department of Defence; Department of Education, Science and Training; and Comcare was established to provide advice on the conduct of the study. The forum provided a means for discussion on issues relating to the study methodology and for feedback from test participants. Representatives from the Consultative Forum also provided invaluable information concerning the conduct of the nuclear tests and the surrounding contextual issues. The membership of the forum is shown in Appendix 2.

1.2.3 Scientific Advisory Committee

The SAC consisted of respected academics and practitioners with expertise relevant to the study. Its role was to review and advise on the methodology of the study. The SAC proposed that an expert subcommittee and panel be established to undertake the dosimetry study. The members of the SAC are listed in Appendix 3.

1.2.4 Dosimetry Subcommittee

The Dosimetry Subcommittee was established to undertake the research for, and the writing of, this report. The members of this subcommittee were invited to take part in the study based on their expertise in **health physics**. The members of the subcommittee are shown in Appendix 4.

1.2.5 Exposure Panel

The Exposure Panel was established to review the ionising radiation doses assessed by the Dosimetry Subcommittee and to assign exposure categories to those Australian participants included in the mortality and cancer incidence studies. These dose assignments are reported within this study and will be used in the mortality and cancer incidence studies. The Exposure Panel members were selected from the Dosimetry Subcommittee by virtue of their specific expertise and experience in ionising radiation dose reconstructions.

1.3 Study protocol

A protocol for the study was developed and agreed upon by the SAC and the Dosimetry Subcommittee. The study protocol is included as Appendix 5.

1.4 Methodology

The approach adopted in this study has been to use the list of participants prepared by DVA, known as the '**Study Roll**', coupled with an extensive review of the available

documentation to assess possible radiation exposures. The Study Roll is drawn from a preliminary nominal roll of Australian participants in the British atomic tests in Australia. Wherever possible, records of film badge results have been used. In other cases, radiation exposures have been derived by computation. Chapter 6 sets out in detail the methods used to derive possible exposure categories. The Dosimetry Subcommittee was unaware of participants' names, other than those mentioned in primary historical sources and major secondary sources.

1.5 List of major tests

The United Kingdom conducted 12 major nuclear weapons tests in Australia between 1952 and 1957. These explosions were carried out in five separate operations (see Table 1.1). The tests occurred at the Monte Bello Islands, off the northwest coast of Western Australia, and at Emu Field and Maralinga, in the western desert region of South Australia (see Figures 1.1 and 1.2).

Table 1.1 Nuclear weapons tests in Australia

Local date and time ^a	Site	Explosion type	Height (m)	Measured yield (kT) ^b
<i>Hurricane Test at Monte Bello Islands, WA</i>				
3 Oct 1952 (0800)	Off Main Beach, Trimouille Island	Underwater	-2.7 m	25 ^c
<i>Totem Series at Emu Field, SA</i>				
15 Oct 1953 (0700)	T1	Near surface: Tower	31	9.1 ^c
27 Oct 1953 (0700)	T2	Near surface: Tower	31	7.1 ^c
<i>Mosaic Series at Monte Bello Islands, WA</i>				
16 May 1956 (1150)	G1: Trimouille Island	Near surface: Tower	31	13.5 ^c or 16 ^d
19 Jun 1956 (1014)	G2: Alpha Island	Near surface: Tower	31	56 ^c or 98 ^d
<i>Buffalo Series at Maralinga, SA</i>				
27 Sept 1956 (1700)	One Tree	Near surface: Tower	31	12.9 ^c
4 Oct 1956 (1630)	Marcoo	Surface	0.2	1.4 ^c
11 Oct 1956 (1427)	Kite	Air drop	150	2.9 ^c
22 Oct 1956 (0005)	Breakaway	Near surface: Tower	31	10.8 ^c
<i>Antler Series at Maralinga, SA</i>				
14 Sept 1957 (1435)	Tadje	Near surface: Tower	31	0.93 ^c
25 Sept 1957 (1000)	Biak	Near surface: Tower	31	5.7 ^c
9 Oct 1957 (1615)	Taranaki	Airburst: balloon support	300	26.6 ^c

^aOther reports may provide the UK date and time of tests.

^bMeasured yield (kT) as reported by the UK (see notes c and d for sources)

^cUK Ministry of Defence Tabulation SFS/A/26 (W.N. Saxby, 14.3.84) referencing Atomic Weapons Research Establishment (AWRE) Classified Reports T1/77 and T2/80

^dUK Atomic Weapons Research Establishment (AWRE) Report T23/57 'Operation Mosaic', p. 11 (1957); the higher yields were considered in the dose assignments reported here.

Figure 1.1 Map of Australia showing nuclear test sites

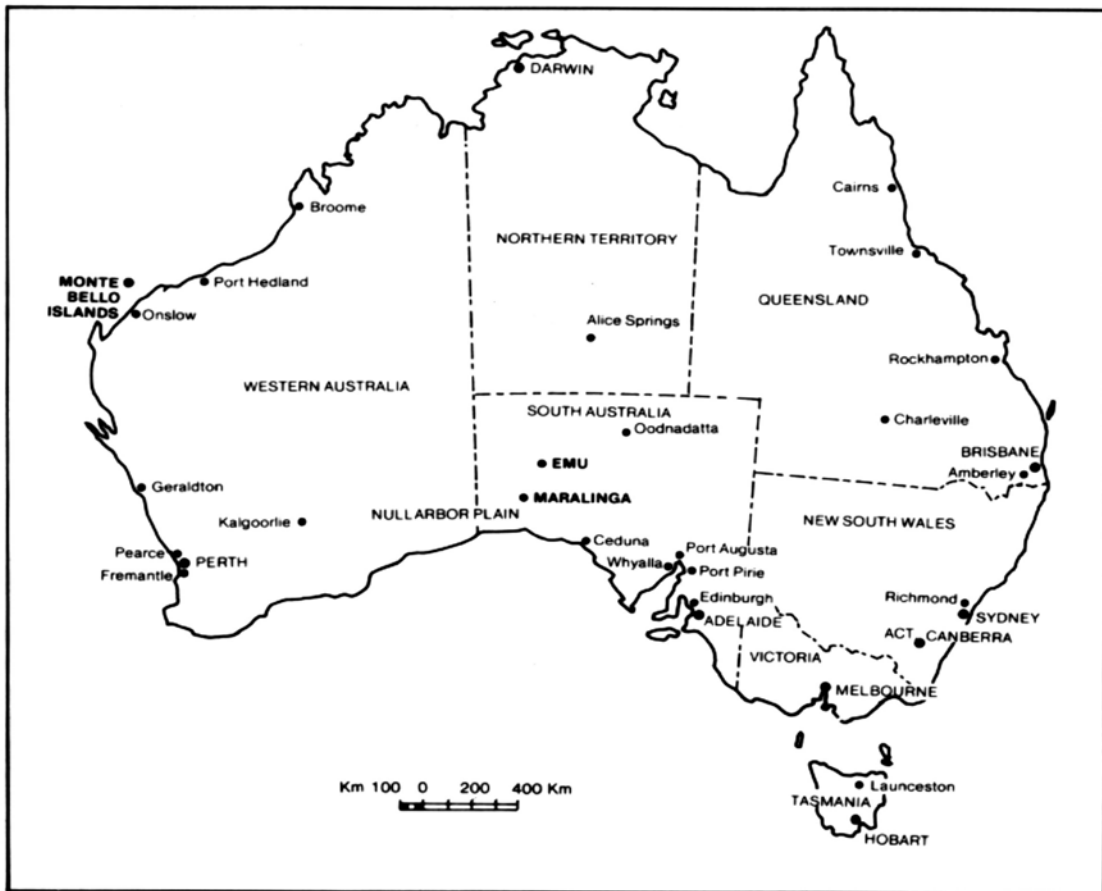
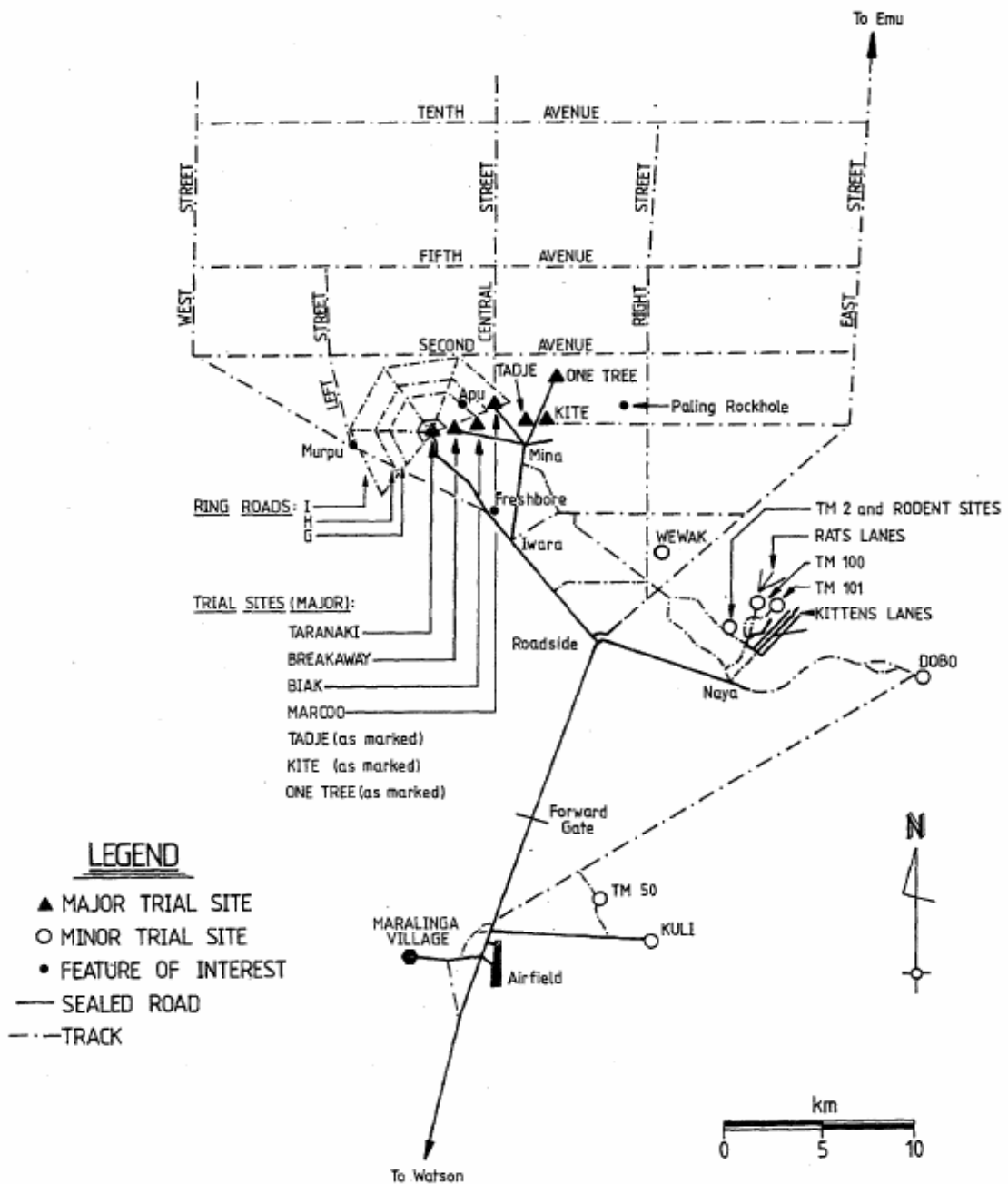


Figure 1.2 Maralinga



1.5.1 Operation Hurricane

The first major test, entitled Operation Hurricane, consisted of one device exploded on 3 October 1952 at 0800 Western Standard Time (WST) in the Monte Bello Archipelago off the northwest coast of Western Australia.

1.5.2 Operation Totem

Operation Totem was the second British nuclear test series in Australia, consisting of two explosions. The first occurred on 15 October 1953 and the second on 27 October 1953. Both detonations occurred at 0700 Central Standard Time (CST). Operation Totem was conducted at Emu Field, which is situated in the western desert region of South Australia.

1.5.3 Operation Mosaic

The third test series was Operation Mosaic. It involved two detonations, both carried out on the Monte Bello Islands. The first detonation occurred on 16 May 1956 at 1150 (WST) and the second on 19 June 1956 at 1014 (WST).

1.5.4 Operation Buffalo

Operation Buffalo was the fourth series of tests and it consisted of four detonations at Maralinga, the permanent testing site established 190 km south of Emu Field. The first detonation occurred on 27 September 1956 at 1700 (CST), the second on 4 October 1956 at 1630 (CST), the third on 11 October 1956 at 1427 (CST), and the fourth on 22 October 1956 at 1205 (CST).

1.5.5 Operation Antler

Operation Antler was the final series of tests, consisting of three detonations, all of which occurred at Maralinga. The first detonation occurred on 14 September 1957 at 1435 (CST), the second on 25 September 1957 at 1000 (CST), and the third on 9 October 1957 at 1615 (CST).

1.6 List of minor trials

In addition to the major tests, approximately 600 minor trials, in several series, were carried out between 1953 and 1963. Five different types of trials were conducted (see Table 1.2).

Primarily, these minor trials aimed to examine aspects of weapon design and safety, and generally did not involve significant levels of nuclear fission. However, some series, in particular some of the Kittens and especially the Vixen B experiments, did generate relatively large quantities of radioactive contamination. The early trials (Kittens, Tims and Rats) tested individual components of the nuclear weapon, while Vixen A investigated the dispersal of radioactive material and Vixen B assessed the effect of various types of potential accidents on the weapons.

Table 1.2 The minor trials conducted in Australia

Name	Location ^a	Period	No. trials	Purpose
Kittens	Emu Field and Naya	1953–1961	99	Tests of weapons components: neutron initiator development (polonium-210 [²¹⁰ Po], beryllium and uranium) ^{b,c,d}
Tims	Naya and Kuli	1955–1963	321	Tests of weapons components: tamper development (uranium and beryllium at Kuli) and studies of plutonium compression under explosive force (at TM100/101 at Naya)
Rats	Naya and Dobo	1956–1960	125	Tests of weapons components: developmental experiments involving internal radiography and explosive dispersal of uranium
Vixen A	Wewak	1959–1961	31	Dispersal of various radioactive materials by fire and explosion (including uranium and plutonium)
Vixen B	Taranaki	1960–1963	12	Effect of accidental detonation and ongoing weapons development (explosive dispersal of uranium and plutonium)

^aTrials were carried out at Maralinga, with the exception of some Kittens experiments conducted at Emu Field, 190 km north of Maralinga.

^bUranium can refer to natural uranium (predominantly ²³⁸U at 99.3%) or enriched uranium (where the percentage of ²³⁵U has been increased above 0.7%).

^cIt should be noted that beryllium, although chemically toxic, is not radioactive and is not considered in this report.

^dNatural uranium was used as a tamper during the major explosions. It is of low specific activity (half-life 4.5x10⁹ years). The radioactive materials produced by neutron capture in uranium during fission (activation products) are of much greater radiological concern and are considered in Chapter 6, Section 6.4.1.

1.6.1 Kittens

The first series, Kittens, consisted of 99 trials conducted at both Emu Field and Maralinga (Naya) between 1953 and 1961.

1.6.2 Tims

Tims included 321 trials conducted at two Maralinga sites (Naya and Kuli) between 1955 and 1963.

1.6.3 Rats

The Rats series included 125 trials conducted at two Maralinga sites (Naya and Dobo) between 1956 and 1960.

1.6.4 Vixens (A and B)

All 31 Vixen A trials took place at Maralinga (Wewak) between 1959 and 1961. The Vixen B series involved 12 trials carried out at Maralinga (Taranaki) between 1960 and 1963.

1.7 Personnel involvement and tasks

Over 16 000 Australians, members of the Defence Forces and civilians, were involved directly and indirectly in various tests and trials. Included were 3300 members of the

Royal Australian Navy (RAN), 1650 members of the Australian Army, and 3200 Royal Australian Air Force (RAAF) personnel. The Australian military personnel were involved primarily in preparing test sites, monitoring and observing the tests, and cleaning up the sites.

In addition to working in the test areas, some Australian military personnel carried out tasks at sites remote from the tests that may have led to some ionising radiation exposures. This group was primarily aircraft maintenance personnel who were involved in the **decontamination** and servicing of aircraft that had flown through the mushroom clouds.

The 8600 Australian civilian participants were employees of firms contracted to construct, maintain and/or support the testing facilities, as well as Australian public servants and employees of semi-government organisations involved with the conduct of the testing program.

Most individual participants were present for only one major trial series, approximately 10% attended two series, and less than 3% attended three or more series.

1.8 Basis of the report

The work reported here is based on the study protocol (Appendix 5) approved by the SAC, and is concerned only with the reconstruction of possible ionising radiation exposures of Australian participants in the British nuclear test program conducted in Australia between 1952 and 1963.

1.9 Structure of the report

Each chapter in this report consists of two parts. The first is a summary of the contents of the chapter, written in nontechnical language. This is followed by the substance of the chapter, in more technical language.

Scientific, technical and mathematical terms used are highlighted in **bold** on their first occurrence in the text, and their meanings are explained in the Glossary.

The basic principles of ionising radiation are discussed in Chapter 2, with particular emphasis on those concepts that apply to exposure from nuclear weapons. Chapter 2 also includes information on radiation units. The variety of radiation units used are described in more detail in Appendix 6.

Chapter 3 discusses the various mechanisms and **pathways** by which participants in nuclear weapons testing can be exposed to ionising radiation.

Throughout the test series, there were various health physics procedures and requirements in place, which were intended to minimise the radiation exposure of participants. These are described in Chapter 4.

Information on which the participants' radiation exposures were estimated was gathered from a number of sources. These sources are described in Chapter 5.

Chapter 6 describes the ways in which radiation doses were calculated for the participants. It includes information on how radiation doses changed with time, and how internal and

external doses were calculated and combined. It also includes examples of how these results could be applied to particular situations.

Chapter 7 takes the results of Chapter 6 and applies them to the particular workgroups and activities at the test series. From this procedure, the dose assignments for those groups are derived. The chapter concludes with a discussion of the results.

1.10 Reference

Commonwealth of Australia (1985). *The report of the Royal Commission into British Nuclear Tests in Australia Vol 1 and 2*, Australian Government Publishing Service, Canberra.