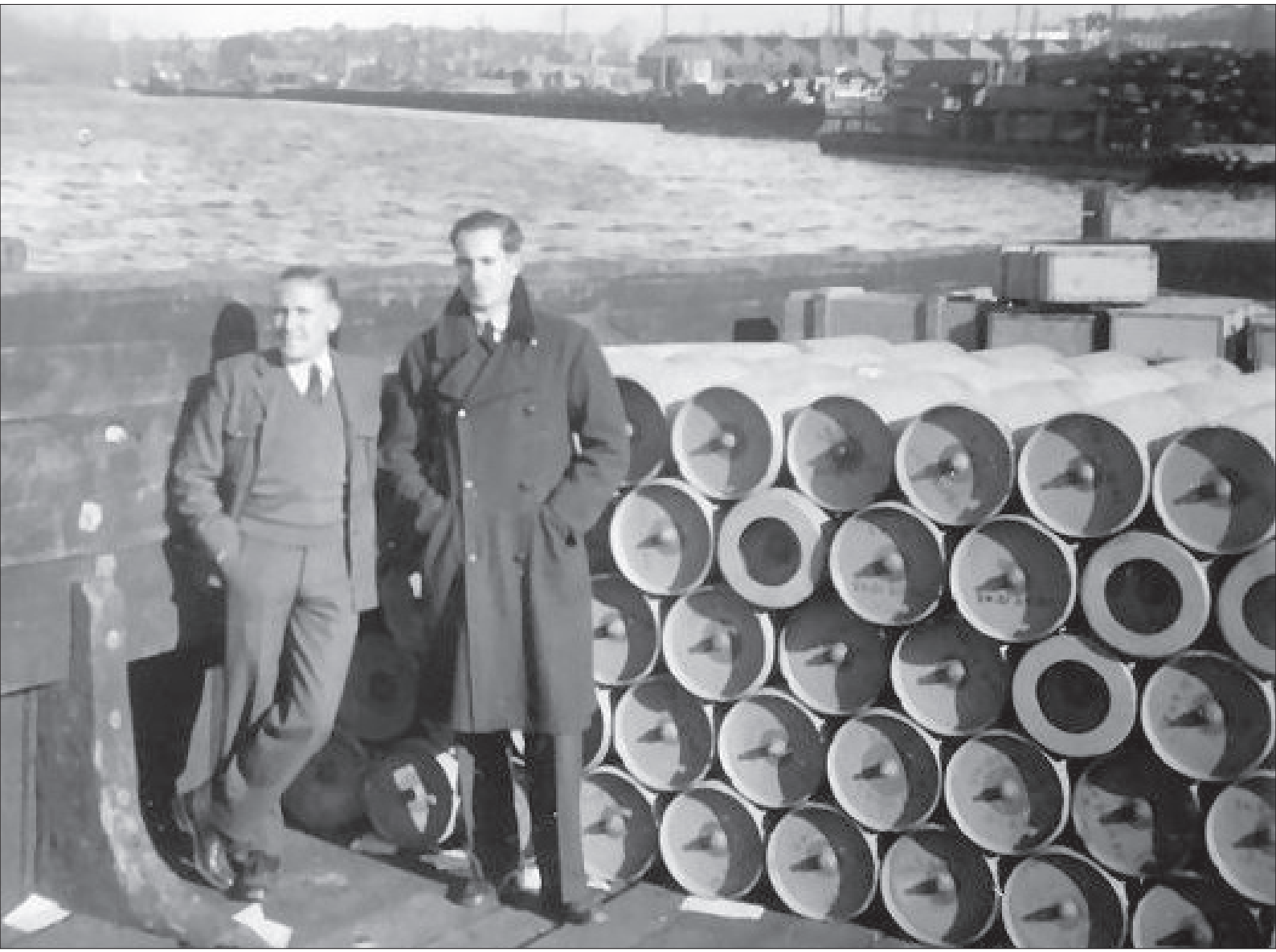
Australian Government
Department of Defence

Chemical Munitions Sea Dumping off Australia



Geoff Plunkett

Chemical warfare agent sea dumping off Australia

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Summary

Although the dumping of toxic material in the sea is now prohibited, historically, the disposal of unwanted waste in the ocean has been common practice. Due to its immense size, the ocean was thought to have an unlimited absorptive capacity, ensuring that any dumped waste would have only a very localised effect. Moreover, the material was generally dumped beyond the continental shelf, well away from any human activity. Even for fishing trawlers operating in the early 1970s (when dumping was still permitted), a depth over 120 metres was considered 'very deep water'. Today, however, trawlers work at depths up to 1500 metres and material dumped decades before is more likely to be accidentally recovered. For reasons such as this, it is important to know the precise location of dumped hazardous material, both to prevent human contact and to assess the possible ecological consequences.

Sea dumping of unwanted chemical munitions has occurred at many sites around the world. Most of the dumping episodes occurred following the end of World War II when unused war stocks required disposal. An estimated 300,000 tonnes[1] of chemical munitions were dumped in West European and North Atlantic waters. At least 21,030 tons of chemical weapons were dumped in Australian seas at the end of World War II by the United States (US) Army and the defence forces of Australia.[2] This figure probably includes the weight of the munition bodies (e.g. artillery shell, bomb or storage drum) and hence the quantity of actual chemical warfare agents could be lower.[3] In Australia the sea dumping of all significant amounts of chemical warfare materials had largely ceased by 1948. Records indicate that there have been three ad hoc dumping episodes since then, in 1956/1957, 1965 and 1970.

Confirmed cases of dumping occurred in the seas off three states: Queensland (east of Cape Morton and Townsville), New South Wales (south-east of Sydney) and Victoria (west of King Island). Some of the chemical weapons were loaded onto decommissioned ships which were scuttled under supervision. The remainder were dumped in containers or as loose shells or bombs. Mustard gas (sulphur mustard) was the most common type of chemical warfare agent dumped at sea.

During the disposal operation there were several contact incidents involving workers handling the chemical weapons and the possibility of members of the public encountering munitions that had floated to the shore. Since World War II there have been at least five accidental recoveries of chemical warfare materials from the marine environment: two 1-ton cylinders of mustard gas trawled by fishermen, two shells dredged while sand mining and a 1-ton cylinder which washed ashore. The bulk of the chemical weapons dumped off Cape Moreton lie outside current trawling areas, but could pose a threat to other activities, including mining of the sea bed. The material off the coast of Sydney appears to be located in an old dumping area that is not used by trawlers. Mustard gas is only slightly soluble in water, but once it dissolves, it hydrolyses (reacts with water) rapidly. Mustard gas leaking at a slow rate through corroded containers will hydrolyse and should break down close to the dump positions. At worst, leaking mustard gas should pose a threat only to biota living on or near the discarded drums and artillery shells. The hydrolysis products are believed not to have a significant effect on fish and the dump sites do not correlate with protected marine environments.

Overseas experience has shown that public awareness of the location of chemical weapons dumping sites can reduce accident rates. Similarly, identification of the chemical

munition dumping sites in Australia could prevent possible exposure. As the dump sites in Australian waters are located in areas rarely fished or known to be foul, the risk of accidental recovery by a trawler is low. The likelihood of the general public contacting a chemical weapon is also minimal but cannot be excluded. This was highlighted in 1999 and 2000 when, on two separate occasions, a mustard gas-filled shell was located at the same quarry as sand dredged from Moreton Bay. If recovered, *any* ordnance (chemical or non-chemical) must not be touched or tampered with as mishandled ordnance can be lethal. Chemical warfare materials recovered from dump sites have caused serious injury despite the fact that the material is over 70 years old. In 1964, an Australian resident was killed after making contact with a land-based chemical munition. Medical professionals should be aware of the possibility that patients will present having been exposed to chemical warfare agents. In such cases, the local police will contact the relevant authority for the appropriate disposal of these chemical agents.

The mustard gas bomb which killed an Australian resident in 1964

Introduction

While the dumping of material in the sea is now restricted, historically, the disposal of unwanted waste in the ocean has been a common international practice. The ocean was long considered to have an unlimited absorptive capacity, ensuring that any dumped waste would have only a very localised effect. Moreover, the material was deliberately dumped well away from human activity. Many items, including boats, chemicals, ammunition, inorganic waste and other hazardous material were dumped in the world's seas often with little understanding of the possible danger to human safety and the ecology of the sea.[4] There was no expectation that the dumping areas would be exploited for their resources at some point in the future. In the early 1970s, fishing trawlers operating at a depth over 120 metres were considered to be working in 'very deep water'. Today, however, trawlers in Australian waters work in depths to 1500 metres and material dumped in previous decades has been accidentally recovered. Such recoveries attracted public attention in 1972–1973 when several drums of industrial waste were recovered by trawlers off Sydney. There were immediate moves to limit sea dumping, culminating in the introduction of the *Environment Protection (Sea Dumping) Act 1981*. Currently, most permits are issued solely for dredge spoil disposal and for the creation of artificial reefs.[5]

During World War II chemical munition stocks were held at many sites around Australia. Japanese expansion had reached as far as Papua New Guinea and Japanese forces had been known to use chemical weapons during the fighting in mainland China. For its part, Australia had reserved the right to use chemical weapons in order to retaliate. The stocks of chemical munitions in Australia were held under General MacArthur's Chemical Warfare Plan for the South West Pacific Area (SWPA). Although their use was dependent on the joint agreement of General MacArthur and the Australian Prime Minister, the stocks were stored in Australia under US Army, Royal Australian Air Force (RAAF), Australian Army or Navy supervision. None of the chemical warfare materials stockpiled in Australia were used during combat and at the end of the war the material required disposal.[6]

This report, based on Australian and US government records and other published material, surveys where chemical munitions have been dumped in Australian seas and precisely what quantities have been dumped.[7] The report also examines what may have happened to the containers after they were dumped, including the corrosion rate of the cylinders/munitions and the breakdown of mustard gas.[8] It is vital to know precisely where chemical weapons may lie, both to prevent human contact and to assess the possible ecological consequences.

International Resolution on Chemical Munitions Dumped at Sea

In 2013 the United Nations General Assembly unanimously passed a resolution on chemical weapons dumped at sea. The resolution urged member states to 'discuss and promote the issues relating to waste originating from chemical munitions dumped at sea, including international cooperation and the exchange of experiences and practical knowledge.'[9] This report aims to fulfil the requirements of that resolution.

Chemical munitions sea dumping episodes

International dumping of chemical munitions

The dumping of chemical weapons at various sites around the world at the end of World War II is well-documented. Large amounts of chemical munitions were dumped in Western European and North Atlantic waters, with an estimated 300,000 tonnes of chemical warfare materials dumped close to Europe in the aftermath of World War II. The 300,000 tonnes of dumped materials consisted of more than 600,000 objects.[10] Some 40,000 tonnes of chemical munitions were dumped into the Baltic Sea alone.[11] Upwards of 4900 tons of chemical weapons (118,000 shells and 574,000 canisters) were dumped off Japan by Japanese workers under orders from the US occupation forces.[12] Dumping was regarded as the best method of disposal, as the quantities were too great to store or burn. The chemical munitions were loaded into decommissioned ships which were scuttled; in other cases, loose bombs or containers were simply dumped over the side.

Chemical munitions dumping in Australian waters

Because of the requirement for a substantial manpower commitment and the dangers of maintaining large stocks of chemical warfare agents over a long period as they became unserviceable, it was soon apparent that these agents would have to be destroyed. On 8 September 1945, the Department of Air proposed that, given a decision to destroy all or part of the RAAF stocks, the only feasible method would be drowning at sea at 500 fathoms (914 metres).[13] The weapons to be disposed by this method were described as: aircraft bombs of various weights charged with phosgene and mustard gas; aircraft spray installations charged with mustard gas;[14] and steel drums of various capacities ($3^1/_3$ gallons[15] to 90-gallon drums) charged with mustard gas. The areas in which a depth of 500 fathoms could be easily accessed and thus could be designated as suitable for disposal, comprised: 250 miles from Darwin; 100 miles from Townsville; 120 miles from Bowen; and 25 miles from Sydney. During this time preparations were being made at RAAF No. 1 Central Reserve[16] for the chemical warfare materials to be drowned. The September 1945 report from the Commanding Officer (CO) notes that 'chemical warfare agent items are receiving regular attention pending arrangements being completed for disposal by drowning.'[17]

Following a request from the High Commissioner's office in the United Kingdom (UK) (with a view to saving on transport and shipping costs), trials were initiated to investigate the practicability of disposing of large stocks of mustard gas by burning.[18] A RAAF Headquarters letter of 3 October 1945 advised that, while mustard gas ammunition was still most likely to be dumped at sea, burning trials were nonetheless being conducted. Two experimental burns were subsequently completed to test the efficiency of destruction of a range of munition types. One was conducted at the Australian Field Experimental Station (Proserpine) where RAAF stores were incinerated, while the second occurred near 1 Base Ammunition Depot (Albury) where Army mines were destroyed. The results of the tests saw chemical weapons stocks disposed of not only by sea dumping, but also by burning and venting (only phosgene weapons were vented).

Before chemical munitions were dumped at sea, tests were often conducted on the individual types to assess their buoyancy in the marine environment.[19] It was later recognised that not all the dumped chemical weapons settled to the seabed as some material was recovered from the shore (see below). Sea dumping of chemical warfare materials in the waters off each state will be discussed in the next section.

Northern Territory

Unknown Location — 1944

On 16 December 1944 three men from 51 Field Ammunition Depot, an army store based near Adelaide River township, were sent to Darwin to help load a ship with army chemical ammunition and unserviceable ammunition for sea dumping. If, what and where the warfare agent was dumped is unknown.[20]

East Timor — 1945

An area east of East Timor was designated as a disposal site for chemical munition stocks held by the RAAF in the Northern Territory.[21] The area was bounded by the following coordinates:[22]

8° 51' S, 129° 12' E
8° 56' S, 129° 12' E
8° 51' S, 129° 16' E
8° 56' S, 129° 16' E

It is unlikely any chemical munitions were dumped here as 2000 tons of chemical weapons held at 88 Mile (the only known storage site for RAAF chemical warfare agents in the Northern Territory) were destroyed by burning at Long Airfield at the end of World War II.[23]

Queensland

Townsville — 1943

On 8 April 1943, approximately 11,000 M47A2 100 lb bombs destined for the US chemical storage depots at Charters Towers and Kangaroo,[24] were unloaded from a ship at Townsville Wharf.[25] A distinct mustard gas odour permeated the vessel with leaking bombs found in three holds — two in number 2 hold, one in number 4 hold and two in number 5. The five leaking bombs were wrapped in protective bags, taken '10 miles out to sea' and dumped.

Mourilyan Harbour — 1944

The 1985 Gillis Report, an oral history of chemical warfare in Australia, cites an eyewitness involved in chemical weapon operations during the war who recalls dumping an unspecified number of 4.2-inch mortars in Mourilyan Harbour:

> At Innisfail a very stupid thing happened. Our armament expert, the British guy, James I think it was, decided to fire mortars with primary propellant only, so we got something like 50 percent of UXB's [unexploded bombs] and these were left lying around for 3 or 4 weeks, and then he had them picked up and I didn't know about this. I was sort of general rouseabout in this thing anyway and it should have been my job to dispose of them. He wanted to use the firing area again but he didn't want to contaminate it with mustard by blowing things up so he picked them all up and I met the truck on the way to dump them in the Mourilyan Harbour. They had active fuses in them because they hadn't been activated by sufficient charge in the tail and anyone of them could have gone off. The 152 fuses needed a reasonable setback to function. I was in the staff car. I met the truck on the way down to Mourilyan Harbour with two of my boys sitting on the UXB's and James the armament guy in the front seat. I made them get the hell out of the truck and I went and took the truck down on my own to Mourilyan Harbour to dump them in there. He was firing primary only because the range was so short and that's alright because he had plenty of ammunition but they should not have been moved. They should have been exploded on the spot.[26]

Although no specific site where the unexploded bombs had been dumped in the harbour was identified, an examination of aerial photos from 1944 reveals that most parts of the harbour could not be accessed. As the operator was in a hurry to offload a dangerous (live) cargo, the site chosen would have required vehicle access, deep water and minimal handling. There was no mention of using small craft (noting that in any case further transportation could have resulted in a deadly explosion).[27]

There was only one location that met these criteria — off the eastern end of the Mourilyan wharf as it existed during World War II. This site allowed vehicle access directly to the edge of the wharf and immediate deep water disposal. This wharf was removed in the 1960s with the construction of a new concrete wharf, extending eight metres further into the harbour, designed to handle the bulk loading of sugar. Significant dredging is believed to have taken place alongside the wharf with a study in 1996 showing significant reclamation at the mouth of an adjoining creek. The change to this creek redirected sediment flow under the wharf which increased the level of silting up to three metres.[28] This would indicate that

any chemical munitions located under the centre of the current wharf could be immersed in 10 metres of water and buried up to three metres in sediment. This would make any investigation extremely difficult and limit the opportunity for chemical ordnance to be inadvertently located during wharf activities. There are no confirmed reported ordnance finds from the harbour area.

North Brook Island — 1944

In 1944 a series of chemical weapon trials was held on North Brook Island. One of these involved Liberator aircraft dropping M47 bombs filled with mustard gas. In one sortie 'four bombs overshot the island and dropped into the sea'. Since the aircraft were flying in from the east and south, the bombs may have sunk to the west or north of the island. One bomber was unable to release its load (possible maximum of 15 bombs) and jettisoned them at sea at an undisclosed location.[29]

A mustard gas trial on North Brook Island

Townsville — 1945

65 lb bombs and M47A2 100 lb bombs

World War II records (war diaries) from the Bowen RAAF Chemical Research Unit[30] state that 65 lb bombs were loaded onto trucks and transported to the marine section Flying Boat Maintenance Unit at Bowen for disposal in the seas north-east of Townsville on 15 February 1945. The number disposed is unknown.

An unspecified number of leaking M47A2 bombs[31] stored at the Chemical Research Unit were dumped at sea on 21 September 1945.[32] Although the location for both the 65 lb and M47A2 100 lb bomb dumps was not specified, it is likely that they were within either of two dump zones chosen near Bowen to dump chemical munitions from both the RAAF chemical depot at Talmoi (No. 19 Replenishing Centre) and the Chemical Research Unit at Bowen (Figure 1). For the most westerly site, the bounding coordinates were: [33]

18° 00' S, 147° 55' E
18° 15' S, 147° 55' E
18° 00' S, 148° 10' E
18° 15' S, 148° 10' E

The more easterly site had an area described by the following coordinates:

18° 05' S, 148° 30' E
18° 20' S, 148° 30' E
18° 05' S, 148° 45' E
18° 20' S, 148° 45' E

320 M47A2 100 lb bombs

On 12 October 1945 two experimental sea dumpings were effected using Chemical Research Unit stocks of chemical weapons.[34] The army tug *Keera* was loaded with 320 mustard-charged M47A2 100 lb bombs which were dumped at 18° 30' S, 148° 5' E at 1098 metres (600 fathoms). The crated bombs had been loaded as deck cargo. A single bomb, attached to a 10-fathom line (18 metres), was dropped over the side to test buoyancy. Although it disappeared below the surface, the test was deemed inconclusive as a '500 fathom line was not available'. Despite this the dumping proceeded with the bombs unpacked from their crates and dropped singly over the side as the vessel cruised at three knots. Since the tug zigzagged to ensure a 'fair' distribution of the weapons over the designated dump point, it is likely that the bombs will be scattered around this coordinate, increased by a drift to the south (see Eastern Australian Current description below).

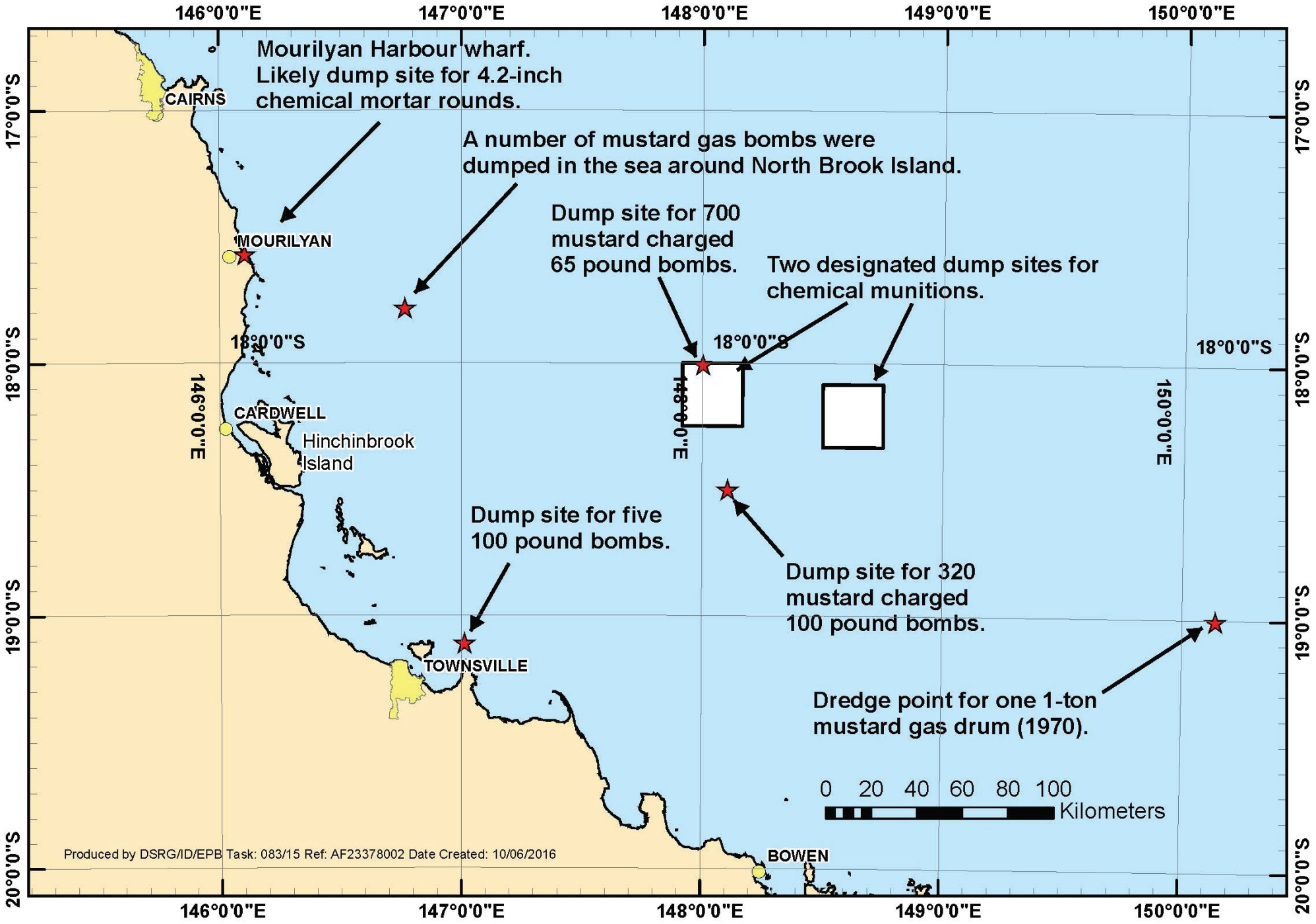
700 65 lb bombs

On 14 October 1945 the same boat dumped 700 mustard-charged 65 lb bombs at 18° S, 148° E. They were dropped at a depth of 1098 metres (600 fathoms).[35] Just as for the M47A2 bombs, a buoyancy test was completed with three 65 lb bombs attached in turn to a 10-fathom line and dropped overboard. In this case the bombs floated and were retrieved.

A decision was made to pierce each bomb. Personnel wearing protective clothing removed the bombs from the crates and, holding the bombs over the side, pierced them three times with a pickaxe. Mustard flowed into the sea and the bombs sank immediately. Initially, the rough seas saw contaminated spray fly over those men operating astern; however once these men were moved no personnel remained astern of those puncturing the remaining bombs. During the disposal operation the *Keera* steamed slowly into the wind, again ensuring a spread around the target point. The chemical weapons from this latter dumping fall within the coordinates of the more westerly RAAF dump square (see Figure 1).

Tug Keera

Figure 1 - *Chemical munitions dump areas and recoveries off Townsville*



Cape Moreton — 1945

In late 1945, sea dumping occurred off Cape Moreton near Brisbane. Records state a total of 8000 tons of chemical munitions, believed to represent all remaining US chemical weapon stocks, were dumped in this area. This figure probably includes the weight of the containers which housed the agent (artillery shell, storage container or bomb) and hence the amount of actual chemical agent could be less than 8000 tons.

Brankowitz indicates that the following chemical weapons from the US Darra depot were dumped at sea 25 miles from Cape Moreton between 2 October and 20 December 1945:[36]

- Ton Containers (H), 876 each or 8000 tons
- Ton Containers (L), 93 each or 8000 tons
- Drums, 55 gallon (CNS), 314 each
- Drums, 55 gallon (CNB), 432 each
- Projectiles, 75-105-155mm, gas unspecified, 3500 tons or 8000 tons
- Candles (DM), 8000 tons

The data are contradictory, e.g. the number of 1-ton bulk storage drums either totalled 876 or 8000 (8000 tons), the difference a factor of 10. There were never more than a thousand 1-ton drums of US-manufactured mustard gas in Australia and the 876 tally is consistent with the inventories in the Chemical Warfare Plan (see Appendix A).[37]

The US dump total of 8000 tons (of all US types of chemical weapons combined) is confirmed in two sources, an October 1945 memorandum signed by the Acting Deputy Director of Navigation and Lighthouses, Queensland[38] and a cable from the US to Australian authorities in 1983.[39]

In 1944 the US forces moved a large quantity of chemical warfare materials from Australia to Oro Bay in Papua New Guinea. All the Australian-based stocks of US 100 lb bombs (from Kangaroo and Columboola) and the entire chemical inventory from Charters Towers were loaded onto two ships at Townsville for shipment in November 1944.[40] The 100 lb bombs from Columboola had previously been loaded on one or both of these ships at Pinkenba wharf in Brisbane.[41]

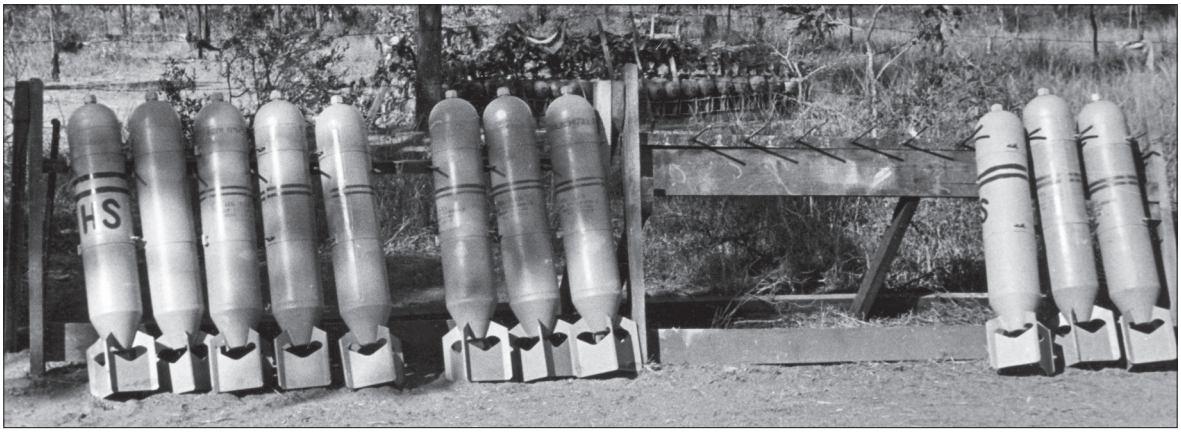
Prior to the sea dumping off Moreton Island, remaining US chemical weapon stocks ('toxics') were stockpiled at a single location — the Darra depot. This was initiated in May 1944 when the Kane toxic yard at Geelong was transferred.[42] In April 1945 personnel arrived at Kingwood and Columboola[43] to escort the mustard stocks to Darra and, in May, the gas shells at Kangaroo moved south to the same depot.[44]

The US Army proposed to dump the 8000 tons of chemical munitions just beyond the 183 metre line (100 fathoms), 18 kilometres off Cape Moreton (see Figure 2). At 12.5 nautical miles east of the northern tip of Cape Moreton there was a designated dumping site as proclaimed by the *Beaches, Fishing Grounds, and Sea Routes Protection Act 1932*, with a centre point of 27° S, 153° 42' E at 256 metres (140 fathoms) and a diameter of five nautical miles (the most westerly circle in Figure 2). This was one of 14 dumping sites designated around Australia by a Federal Government Act of Parliament. Although originally chosen as places to dump derelict vessels, these sites were used as general waste dumping grounds where chemicals and other material were deposited.[45] This site became an official Australian Army dumping position for unserviceable ammunition, although the date of its first use is unknown. As the 183-metre line (100 fathom line)[46] was targeted as a minimum dumping

depth, it is certain that a proportion, if not most of the 8000 tons were dumped within the designated dump site.[47] This is because the most westerly point of the dump circle borders the 100 fathom line. Several Australian and US government records also indicate that some of the chemical weapons were dumped further out to sea at 25 miles east of Cape Moreton at 27° S, 154° E at a depth of 1098 metres (600 fathoms).[48] These coordinates represented the centre point for another official Australian Army dumping site, again with a diameter of five nautical miles. This second army dump circle replaced the army dump circle closer to Cape Moreton, although the date on which this occurred is not recorded.[49]

The gas was brought from the Darra depot in contractors' trucks, over the Story Bridge and to Pinkenba. The 1-ton bulk drums were loaded on the ship *City of Fort Worth*. They were stored below deck and there was no possibility they could have fallen off the deck prior to their arrival at their dumping location. They could not have been dumped at the 25-mile mark as the ship had an absolute maximum speed of 10 knots and could not have undertaken the daily return journey to this point.[50]

Thus, in summary, chemical munitions could theoretically be scattered from the 183 metre line (100 fathom line) to 2.5 nautical miles beyond the 1097 metre line (600 fathom line) within the rectangle shown in Figure 2. However, noting that the vessels would have adhered to the minimum dumping depth (due to least effort and limited speed), the material is likely to be concentrated towards the western boundary just beyond the 100 fathom line and in the legislated dump circle. This target depth was stated in both the 1946 and 1956 operations (discussed below). It should also be noted that vessels during this period did not have sophisticated navigational equipment and may not have been exactly at the predetermined position.[51]



United States chemical munitions in storage prior to sea dumping

Cape Moreton — 1956/1957

The US chemical storage depot at Darra came to public attention after two teenagers discovered a mortar bomb in June 1954 and were killed in the subsequent explosion.[52] Inspections by the Australian military in 1956 and 1957 revealed a range of chemical munitions and chemical warfare agent laboratory samples that had been left after the US relinquished the site at the end of World War II.[53]

On 18 September 1956, six fused 105 mm[54] shells filled with mustard gas, which had been bundled in units of three, were located at the base of a tree.[55] A bushfire had burnt the cardboard housings allowing the rounds to roll out, with four lying on the surface of the ground. The build-up of debris around the shells indicated they had remained undisturbed since the depot had been abandoned. A small section of body painting was discernable on one shell showing the characteristic two green bands denoting a mustard gas filling. The shells were deeply pitted and the fuses (M57) in two instances had corroded to the extent that the ogive (the upper section of the shell) was disintegrating. In view of their close proximity to habitation and their dangerous condition, the rounds were removed and dumped off Cape Moreton beyond the 100-fathom line at the same location as the post-war dump.

In 1957 a variety of chemical warfare agent samples was recovered. A plan to burn the bottles *in situ* was abandoned due to variable winds. Instead the containers were placed in steel boxes in a mixture of soil and bleach powder and prepared for sea dumping. An explosive charge was specially designed to detonate once the boxes hit the ocean bed. In addition to the samples, eight tons of contaminated soil, sourced from three pits, and containing a mixture of chemical warfare agents and other chemicals were loaded into locally produced 'sisalkraft 30/30 bags' which weighed 40 to 45 lb when filled.[56]

Both the samples and contaminated soil were dumped beyond 100 fathoms off Cape Moreton.[57] As a minimum the following sample items were sea dumped:

- 1 stoppered jar (labelled) containing 3 oz mustard
- seven 5 oz sealed bottles which contained chloropicrin or chloropicrin mixture (probably CNS)
- one 2 oz jar (labelled) CG (phosgene)
- 1 jar labelled HS (no appreciable content)
- 52 closed glass bottles, jars or ampoules. Chemical warfare agents identified included Y3 (mustard), Lewisite and '-cyano–' (possibly cyanogen), Chloropicrin (PS), Chloroacetophenone (CN) and US-manufactured Levinstein mustard (HS). One small ampoule analysed by the government analyst contained mustard mixed with an unidentified chemical.

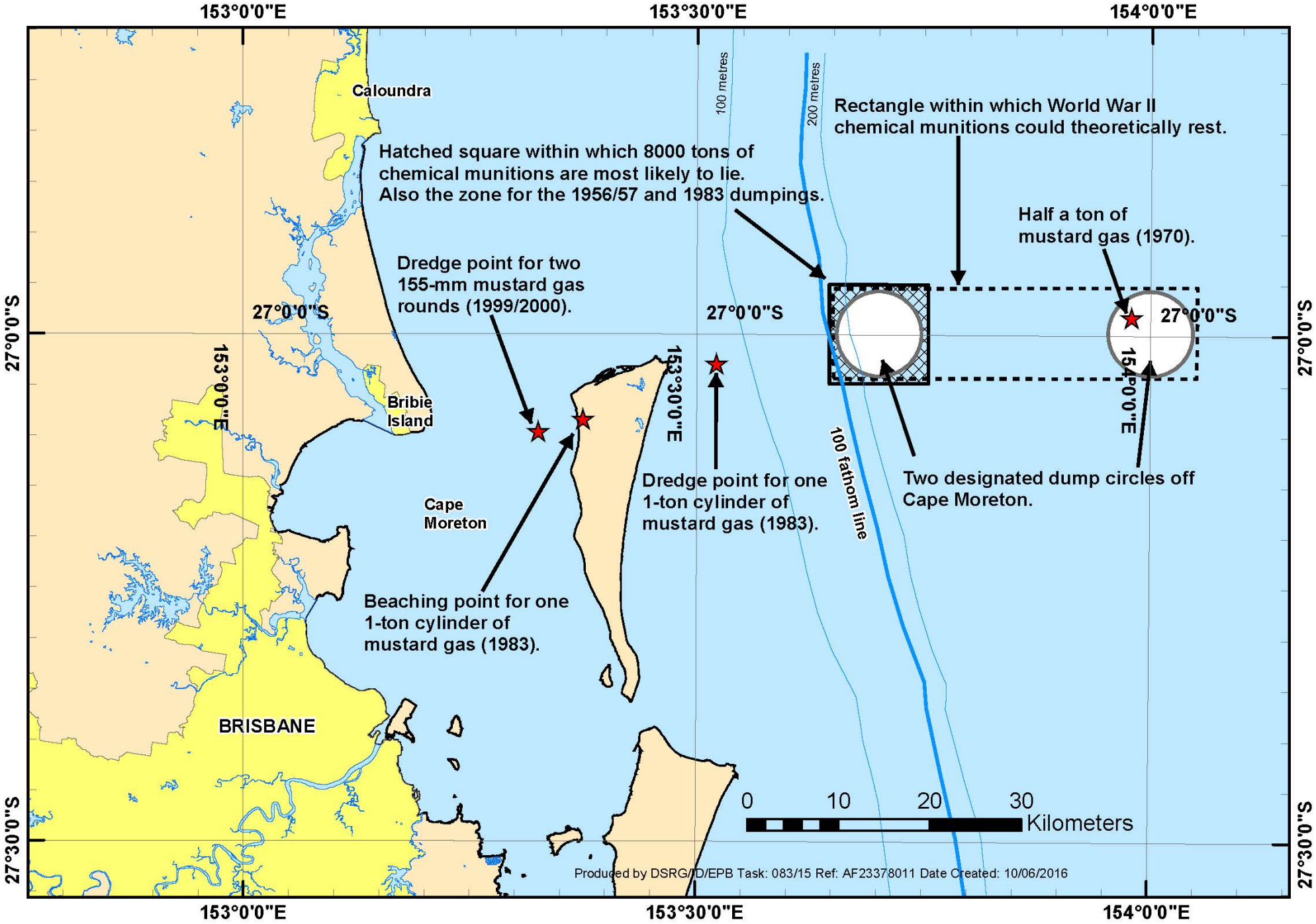
Cape Moreton — 1970

A document headed 'Army Dumping Activities' recorded the dumping of half of a ton of mustard gas within the second dumping circle 25 nautical miles east of Cape Moreton at 26° 59' 30" S, 153° 57' E on 23 January 1970 at 450 fathoms (823 metres).[58] The origin of the material is unknown.

Preparations for the 1956/1957 Cape Moreton sea dump

Preparations for the 1956/1957 Cape Moreton sea dump

Figure 2 - *Recoveries and likely dump area for 8000 tons of Chemical Munitions dumped off Brisbane*



John Brewer Reef

Munitions were first discovered on John Brewer Reef when a member of the public located an anti-tank mine (Mine AKT) while scuba diving in 1986. A survey in 1988 revealed World War II munitions, primarily M4 anti-tank (MK4 – AT) mines, but also 105 mm shells and small arms ammunition. As the munitions were of US origin it was speculated that they came from the nearby Kangaroo depot near Townsville, noting that 105 mm chemical shells had been stored there.[59] This view was reinforced by a cable from the US to Australian authorities in February 1989 which stated, '6396 tons of toxic material and 1600 tons of small arms ammunition were dumped quote, off the coast of Australia – site unknown, unquote … this could possibly be at JBR site because of the reference to small arms.' It is now known that the chemical shells were transferred from Kangaroo to Darra prior to their dumping off Cape Moreton.[60] As the DM (Adamsite) candles were not specifically mentioned in the transfer from Kangaroo to Darra, it has been speculated that they were dumped on John Brewer Reef. Although it is theoretically possible a marine-encrusted DM candle could be misidentified as a M4 Anti-Tank mine,[61] there is no evidence that chemical weapons were dumped here.[62] US sources state that it observed a minimum dumping depth of 100 fathoms (183 metres) for chemical weapons dumped in the sea off Australia. However, the John Brewer Reef finds are in the 20 to 30 metres range.

New South Wales

Sydney — 1946

According to an eyewitness report from the person responsible for overseeing the sea dumping of Australian Army supplies of chemical munitions, most were dumped 18 miles south-east of Sydney's South Head. This seems to correlate with the dump circle designated off Sydney by the *Beaches, Fishing Grounds, and Sea Routes Protection Act 1932* where the defence forces are recorded to have dumped ordinary ammunition and other material after World War II (Figure 3). This dump circle had a centre point at 34° S, 151° 36' E with a diameter of five nautical miles. The depth at the centre point is approximately 275 metres (150 fathoms).

Some 5000 tons of chemical weapons are believed to have been dumped off Sydney.[63] The initial dumping operations consisted of loading chemical agents into the hulks of ships damaged by enemy action or ships that were being decommissioned.[64] These ships were towed to the dumping site and sunk using explosive charges placed in the ship's keel (at both bow and stern) or by naval gunfire using solid, armour-piercing rounds. Records exist for two of the scuttled vessels which were sunk away from the main dump site 18 miles from Sydney Heads. The first ship used was the SS *Bantam* which had been bombed and badly damaged at Oro Bay, New Guinea, in 1943.[65] It was towed to Sydney and, following the end of the war, was loaded with 27,500 chemical rockets, 8000 4.2-inch chemical mortars from 1 Base Administration Depot (Albury) and RAAF chemical stores including bombs from Marrangaroo and Smoke Curtain Installation (SCI)[66] tanks from Picton.[67] There were also high explosive shells from an unknown source. The ship was scuttled 136° Macquarie Light at 32 miles on 24 September 1946 at 34° 18.8' S, 151° 43.6' E at 1829 metres (see Figure 3).[68]

The ammunition disposed of in the *Bantam* was stored inside the ship's hold. The ships used for scuttling became progressively smaller until eventually old Manly ferries and dredges were used. In these craft the ammunition was not always stored in the hold. Another ship, the ex-Manly ferry *Binngarra*, was scuttled on 11 December 1946 with an unknown quantity of chemical munitions. The disposal position was 122° Macquarie Light, 35.5 miles at 1100 fathoms[69] (2012 metres) at 34° 10.2' S, 151° 53.1' E which is within a proposed RAAF chemical weapons dumping area (see Figure 3 and below). Eventually the supply of old ships was exhausted and dumping operations continued with the ammunition loaded as deck cargo and being pushed overboard. The army chemical weapons were shipped by train from Albury to the timber wharf at Rozelle. They were then loaded on ships for dumping. From 1 July 1946 to 1 September 1946 records show a number of trainloads of chemical weapon stores consisting of 3-inch mortar, 4.2-inch mortar and 25-pounder ammunition shipped to Sydney for sea dumping.[70] Also on 2 December 1946 a shipment of 334 tons of 5-inch rockets and 25-pounders was moved to the coast for sea dumping.[71] An inventory from 1943 shows the range of chemical munitions that may have been dumped (Appendix B), excluding the mines which were burnt at Table Top, New South Wales.[72] Note also that 1634 tons of this inventory were sea dumped off Victoria (King Island).

Several other short records are available concerning the sea dumping of chemical warfare materials off New South Wales. From March to May 1946 the CO of No. 1 Central Reserve noted the following in March 1946: 'All charged SCI from Picton and charged bombs at Marangaroo have been convoyed by motor transport to the State Explosive Wharf in Sydney for destruction by drowning at sea'; in April 1946: 'This tunnel [Picton] has recently been cleared of chemical warfare stocks' and also 'chemical warfare stocks are now being loaded at Sydney for destruction by drowning at sea'. Finally, in May 1946, the CO's report again states that 'Chemical warfare stocks are also being loaded at Sydney for destruction by drowning at sea.'

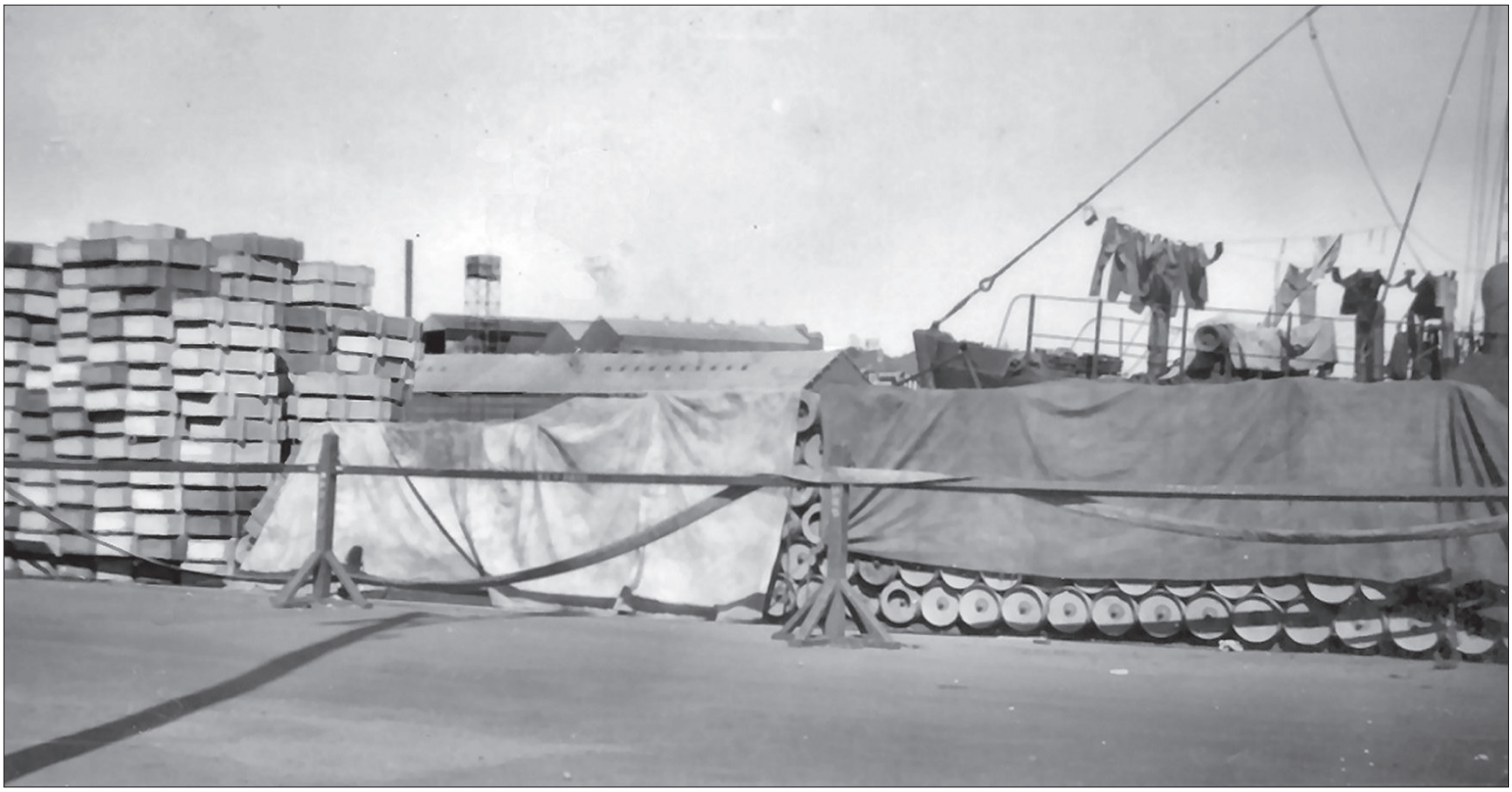
An old map shows a proposed warfare agent disposal area for RAAF supplies of chemical munitions at:

34° 02' S, 151° 42.5' E
34° 12' S, 151° 42.5' E
34° 02' S, 151° 55' E
34° 12' S, 151° 55' E

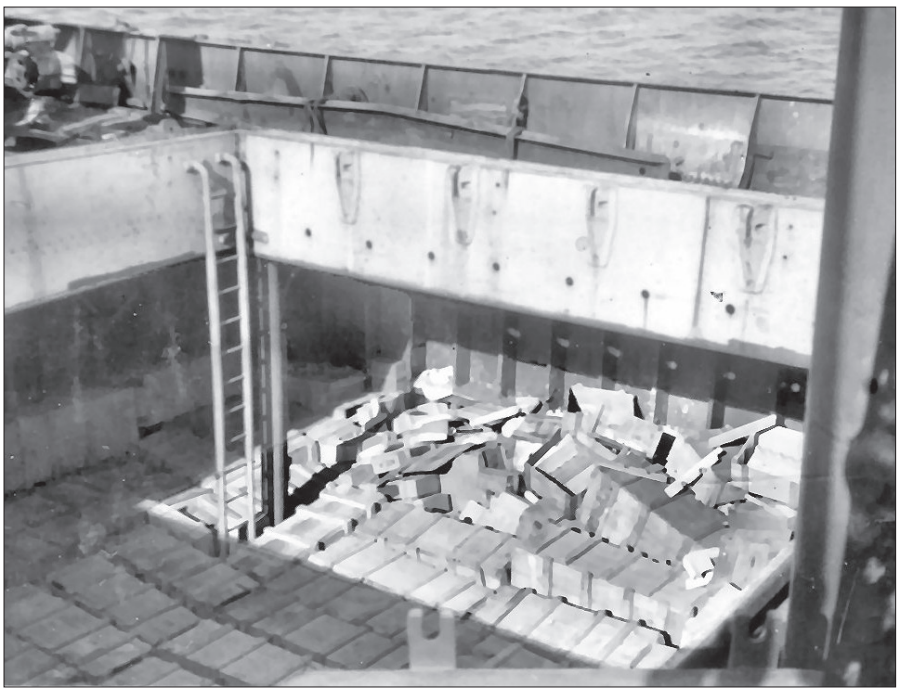
(Figure 3). This was close to the designated dump circle apparently used by the army (Figure 3). An inventory (Appendix C) shows the range of chemical munitions held at No. 1 Central Reserve. It is important to note that 2000 tons of RAAF chemical weapons from No. 1 Central Reserve were burnt at Newnes State Forest.[73] There is no evidence that significant sea dumping occurred off New South Wales beyond the December 1946 date for the *Binngarra*.

Sydney — 1965

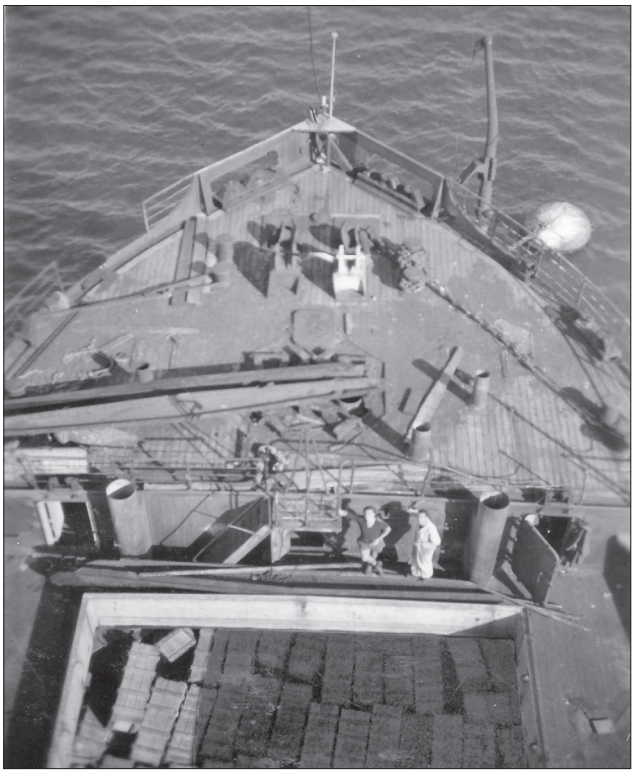
One dumping is known to have occurred off New South Wales since World War II. Nine filled and two empty mustard gas bottles weighing over 4 pounds were dumped in position 34° 23' S, 151° 26' E on 12 October 1965 in 310 fathoms (567 metres). These had come from the Nuclear Biological Chemical Defence School and were probably used in its defensive courses.[74]



Chemical munitions await loading onto the Bantam



The Bantam on its way to scuttling



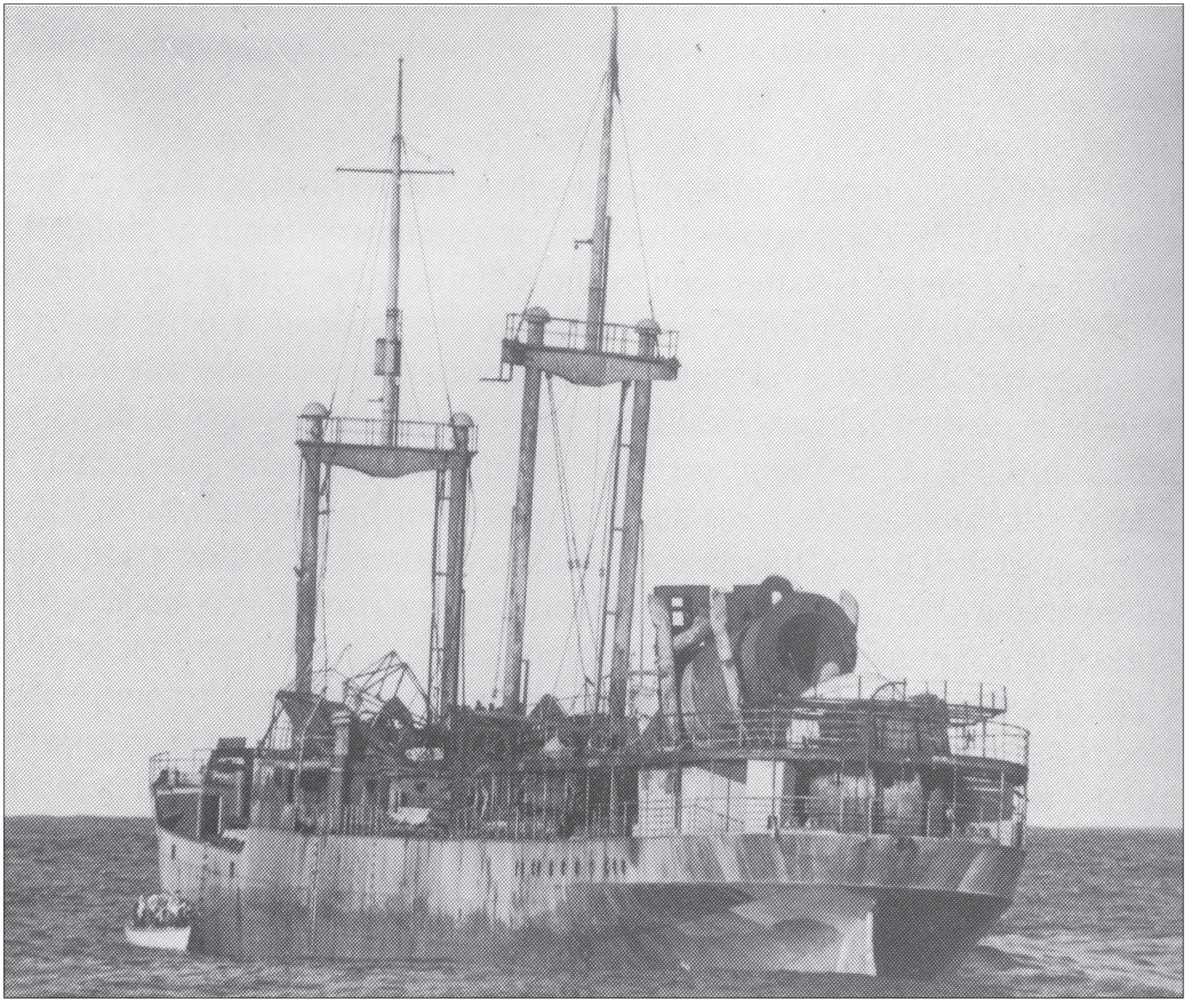
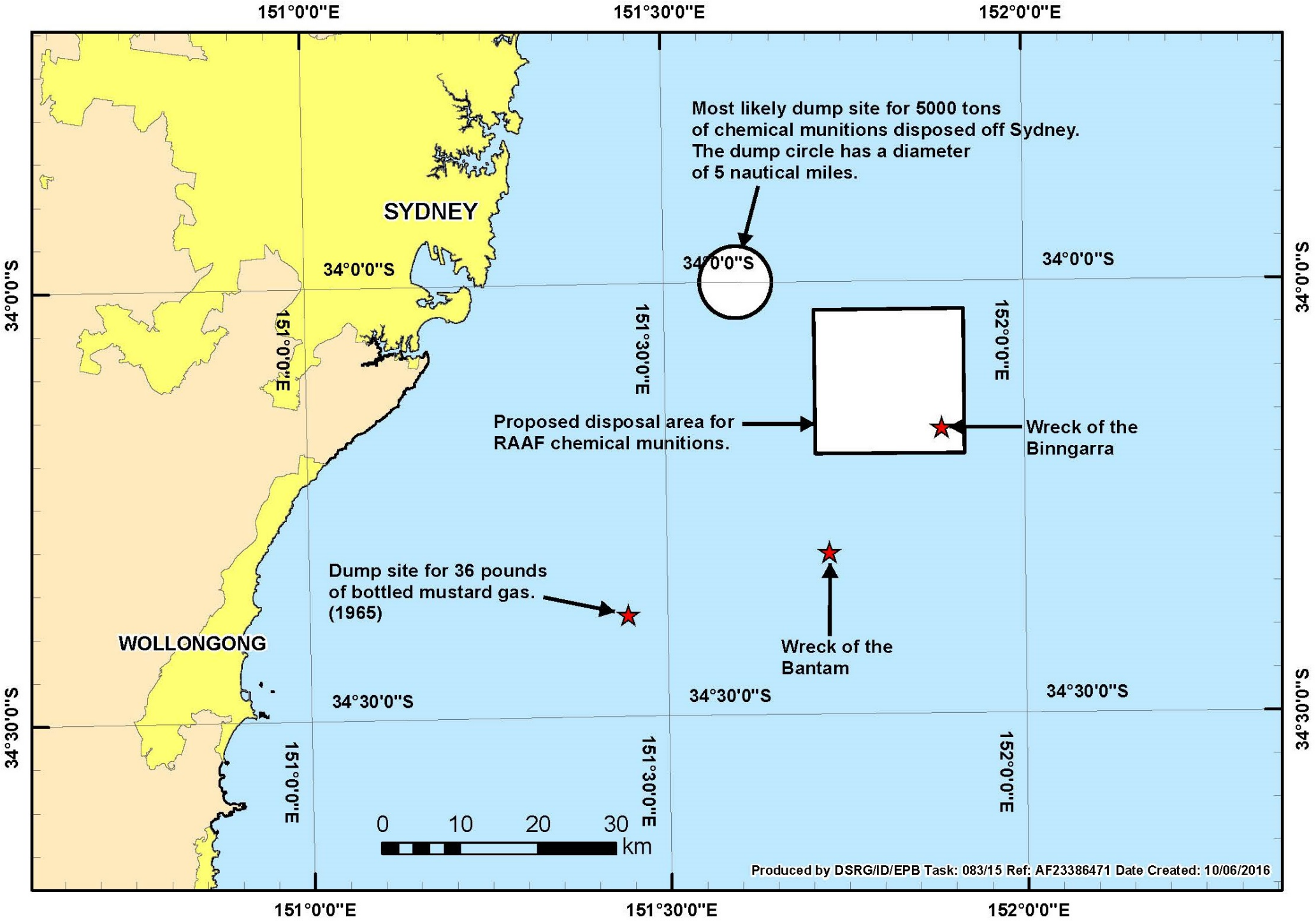


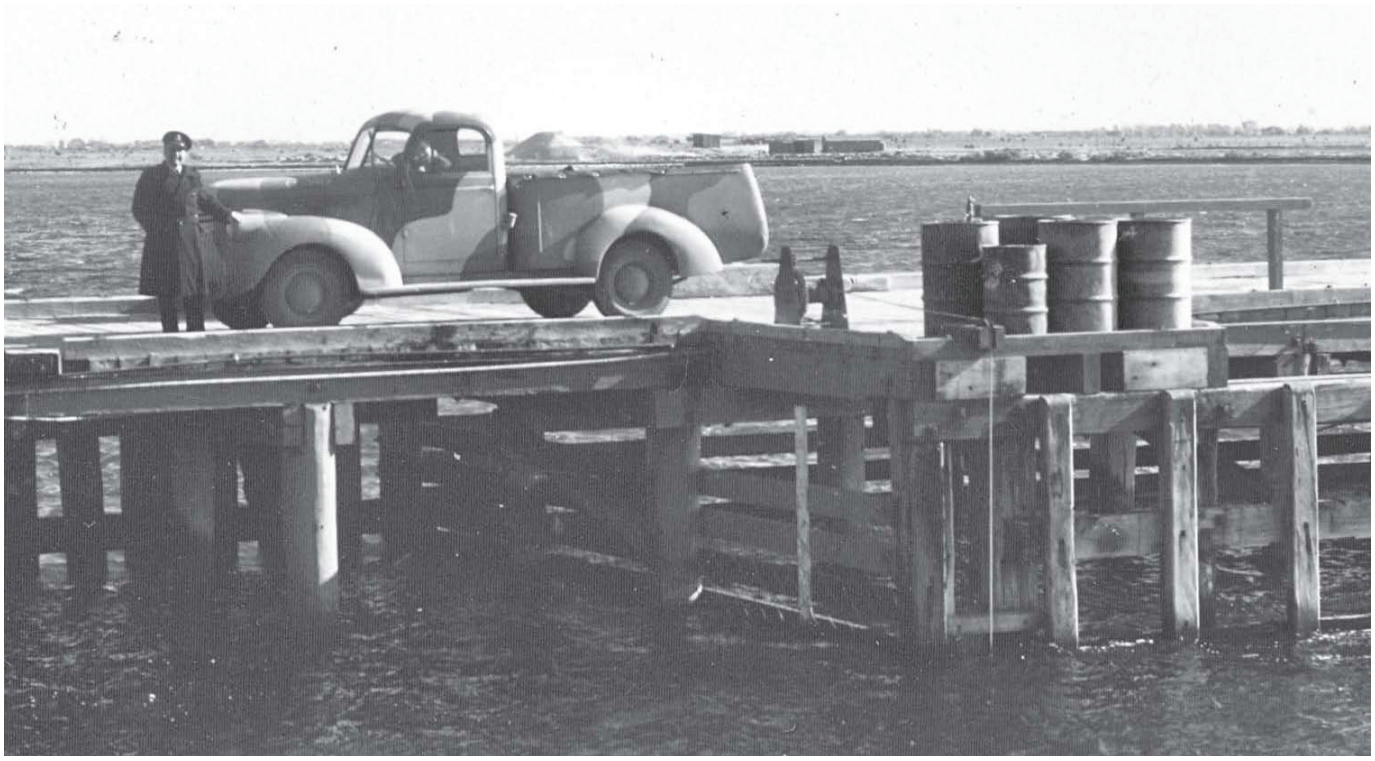
Figure 3 - *Chemical munitions dump areas off Sydney*



Victoria[75]

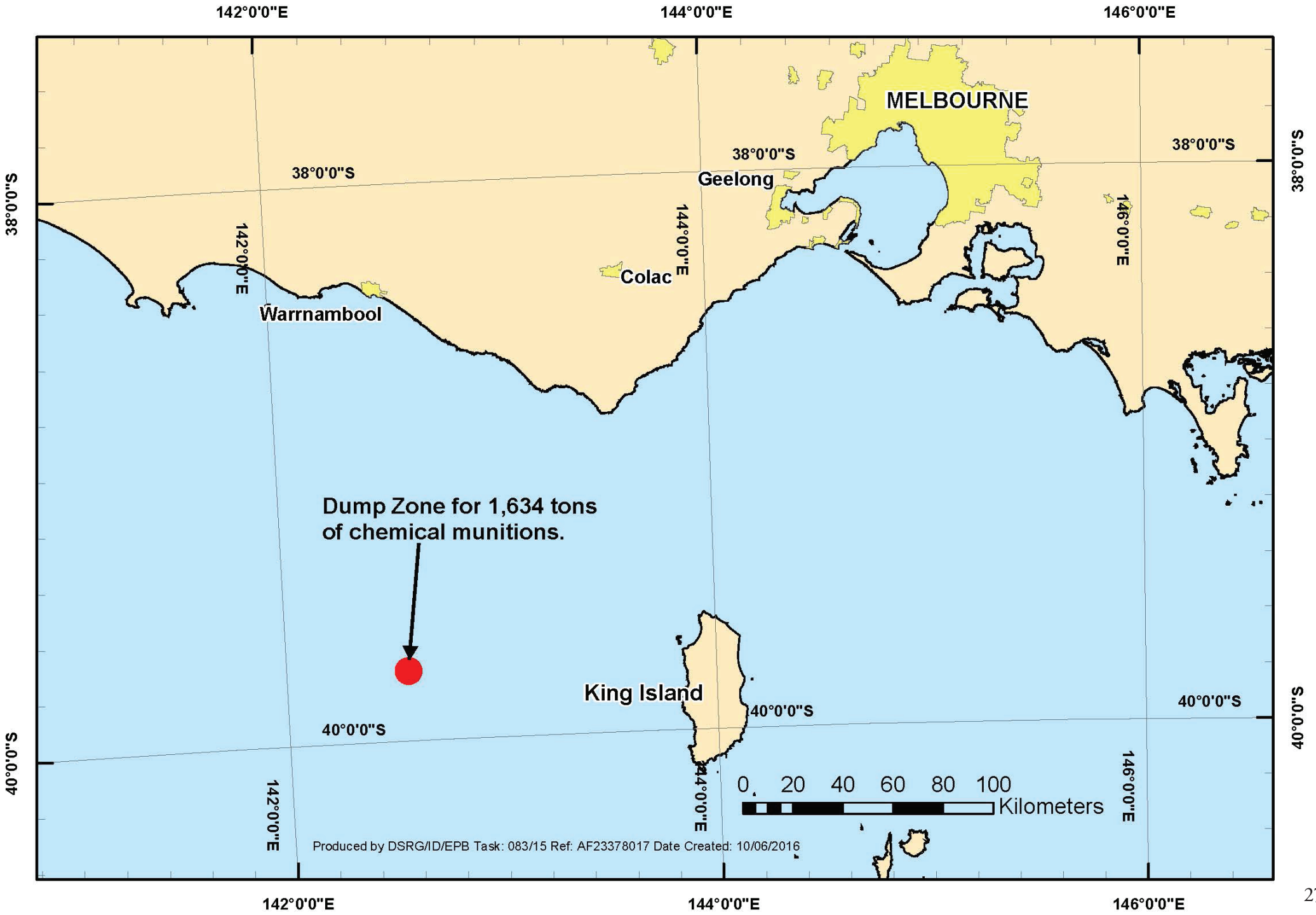
King Island — 1948

In preparation for a sea dump of chemical munitions ammunition from the Australian Army depot at Albury (1 Base Administration Depot) on 5 August 1948, approximately one-third of the crew of LST (Landing Ship Tank) 3017 were sent to Albert Park Barracks to watch instructional films on chemical warfare shell and ammunition, the films having been supplied by the army.[76] On 9 August the ship's company was supplied with anti-gas respirators and the loading of chemical munition shell commenced at Williamstown on the morning of 10 August 1948.[77] Having loaded the ship with 400 tons of chemical munition shell, dumping was completed on the afternoon of 17 August within a 3 mile radius of 39° 45' S, 142° 34' E (see Figure 4).[78] On 24 August 1948, 402 tons of chemical warfare shell were loaded and then dumped the following day (25 August 1948). Loading of a further 400 tons of chemical ammunition was completed on 2 September and the ship proceeded to the dump area west of King Island. Dumping was completed on the morning of 3 September. On 5 September, loading of chemical shell was recommenced; by 8 September a total of 432 tons of chemical ammunition had been loaded. Owing to inclement weather, the ship did not proceed to sea until the next day, with dumping completed in the dump zone on 10 September. It can be reasonably concluded that all 1634 tons of chemical ammunition were dumped within the circle as described above.



Mustard gas drums in transit for sea dumping near King Island

Figure 4 - *Chemical munitions dump area off Victoria*



Exposure to dumped chemical munitions

International incidents

Periodic accidental recoveries of drums filled with chemical warfare agent continue to occur, the last reported as recently as 2015.[79] During the spring of 1984, 11 Danish fishermen were exposed to mustard gas and were burned while fishing in the Baltic Sea.[80] From 1994 to 2012 there have been 106 fishery chemical munition contacts recorded in the Baltic Sea.[81] The 2013 HELCOM report identified the following groups as the most vulnerable to a chemical weapons exposure: fishing operators, offshore construction and maintenance workers, sub-surface workers (commercial, navy and emergency response), harbour/wharf staff and workers, rescue and emergency services, recreational divers, beach visitors and seafood consumers.

Many accidental recoveries have resulted from trawling in fishing areas around Japan.[82] By 2010 there had been 820 incidents with 400 people injured and more than 10 killed.[83] Eight areas off the Japanese coast were designated for sea dumping, although dumping outside these areas is known to have occurred. Fifty-two people were wounded in 11 accidents at one dumping site alone. Kurata identified several key factors in the occurrence of accidents:

1. The sites where the chemical weapons were dumped often violated the guidelines developed for dumping in Japanese waters (1000m depth and 18.5 km from shoreline), as they were much closer to the shore.

2. In Japan little attention was paid to the correlation of sites with fishing areas and ecologically protected areas.

3. There was insufficient public knowledge of dumping site locations.

Australian incidents

All the recorded contacts with dumped chemical agents have occurred in the state of Queensland. The Australian public became aware of chemical weapons dumping in Australia in November 1945 when the disposal operation off Brisbane was under way. A US soldier was killed and one injured while attempting to salvage brass cartridge cases at the Darra depot. As a consequence, the chemical munitions were dumped without the brass recovery.[84]

Maroochydore — 1945

Jettisoned tear gas grenades in wooden boxes washed ashore at Maroochydore, 60 to 70 miles north of Brisbane in 1945.[85]

Cape Moreton — 1945

Newspaper reports in 1945 revealed that a 1-ton cylinder dumped by the ship the *City of Fort Worth* and only partially filled, had floated, with most of the cylinder under water.[86] Given the prevailing currents it was expected to wash up on the northern coast of New South Wales.[87] It clearly posed a problem for the public if opened deliberately or if accidentally smashed against rocks. However, it appears the cylinder was never recovered and most likely sank south of the dump site.

Townsville — 1945

As mentioned earlier, crew members of the tug *Keera* were severely burnt while disposing of mustard gas bombs.[88] These bombs had been hung over the side of the tug and axes used to smash holes in them to prevent flotation.[89]

Coral Sea — 1970

On 19 January 1970 a US 1-ton mustard gas cylinder was reportedly recovered by a fishing trawler in 69 fathoms of water (east of MacKay) at 20° 42.8'S 153° 35.7' E.[90] Records indicate that $556.90 was paid to a Mr Triplett for medical treatment, damage to netting and loss of catch.[91] Later in the 1970s, a 1-ton container 'washed ashore in this area', although the coordinate provided is 359 km from the shoreline, a sizable distance.[92] It is unclear how the cylinder reached this location, given that it could not have floated against the prevailing current from the Cape Moreton dump.

Moreton Island — 1983

On the evening of 24 August 1983 the prawn trawler *Harvest Moon* netted a large drum 5.3 kilometres due east of Cape Moreton at a depth of 61 fathoms (110 metres).[93] The drum may have been dragged there by previous trawling operations from up to a depth of 100 fathoms, the maximum depth for trawlers operating in this location at the time.[94] The trawler moved to the western side of Moreton Island, one mile north of the wrecks at Bulwer, where the cylinder remained in the net, 18 inches above the water. The next morning it was examined by divers. With the bottom end of the cylinder hidden by trapped prawns and fish a decision was made to land it to allow further inspection. The trawler was beached three to four kilometres south of the settlement of Bulwer, and the drum moved 10 metres up from the high tide mark by a tractor.

Visual inspection suggested that the 10-millimetre wall was still sound, with no obvious signs of corrosion penetrating it, although once opened there were signs of light corrosion on the inner wall. A small shaped charge was attached close to the top of the cylinder to vent the contents. This produced a one-inch hole from which a vertical jet of flame emerged to a height of 10 feet for three seconds. The inside of the cylinder burnt, giving off a pungent odour. Two more shaped charges were used to extinguish the fire by concussion. Further examination revealed a plate, encrusted with barnacles and rust, and secured by four brass screws and inscribed 'Chemical Warfare Service – USA Serial No D-7223 Test 6-42'.

A 15-centimetre hole was cut to take samples during which time approximately 80 litres of mustard, along with a fine black substance was spilt onto the beach.

Three distinct phases were discovered in the drum;

1. clear blue/green coloured aqueous liquid smelling strongly of decomposition products — on standing or on disturbing the surface, the liquid threw out a yellow solid which floated as a film on the surface before falling to the bottom

2. black crystalline solid (sulphur coloured with complex decomposition products and probably containing metallic salts)

3. black oily liquid denser than water[95]

The initial samples revealed a mixture of sea water and 10% mustard with metallic salts (sulphides and chlorides of iron resulting from the corrosion of the container wall together with sulphur in colloidal suspension). At the bottom of the drum there proved to be another layer below the 'crystals', a dark viscous liquid judged at least 50% pure.

Using drinking cups the contents were placed in a bucket and then transferred to a number of 200 litre drums, half-filled with water and five kilograms of Calcium Hypochlorite (HTH, 65% available chlorine). Contaminated sand around the drum was also placed in the drum. Large volumes of chlorine gas evolved in an exothermic reaction. Two more holes were cut in the drum to access all the contents. The reaction of the purer liquid at the bottom of the drum with the neutralising solution was 'violent' (strongly exothermic) and took two hours to cool down.

With as much of the contents removed as possible, a large hole was dug in the sand next to the drum. The hole was lined with a plastic tarpaulin and the drum rolled in. The hole was filled with a water/chlorine mixture and the drum allowed to decontaminate for one hour. The container was then hooked under a helicopter and dropped in the sea-dumping circle 12.5 nautical miles east of Cape Moreton.

The decontaminant solution was removed from the hole, placed in 200 litre drums, along with the liner and draining containers. The drums were removed. The sand surrounding the drum was then covered in 25 kilograms of Calcium Hypochlorite and 25 kilograms of super tropical bleach and dug in.

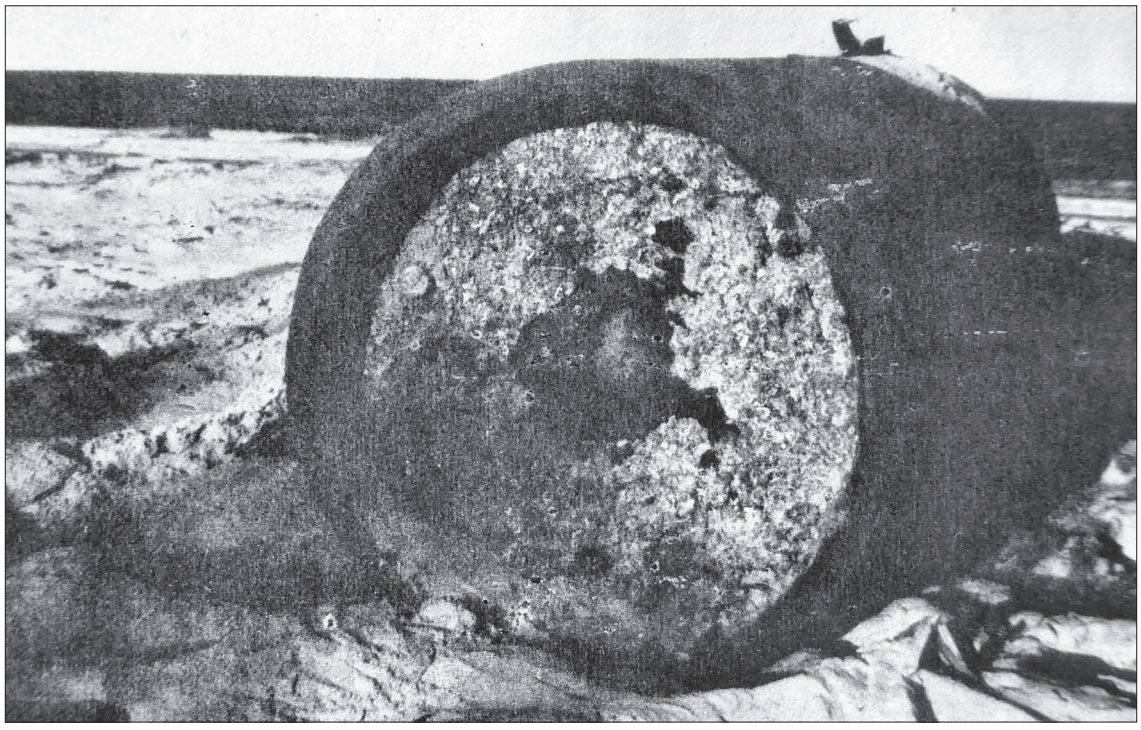
An analysis of the drum by the Defence Science and Technology Organisation (DSTO) concluded:

> Mustard gas produced by the Levinstein process is contaminated with elemental sulphur from the time of manufacture, and also with acid chlorides and hydrochloric acid. The decomposition of mustard by water is limited by the rate of solution of mustard in water rather than by the actual hydrolysis rate. Therefore water entering the cylinder would sit above the mustard as a separate layer and the hydrolytic degradation to thiodiglycol would occur slowly at the interface. It is therefore possible that the sea water was present from the start, and that the degradation of the mustard has proceeded slowly since then. If the container was lying inert on the sea bed with no mixing motions, solution of the mustard would be very slow. It is not clear how the water got into the container.

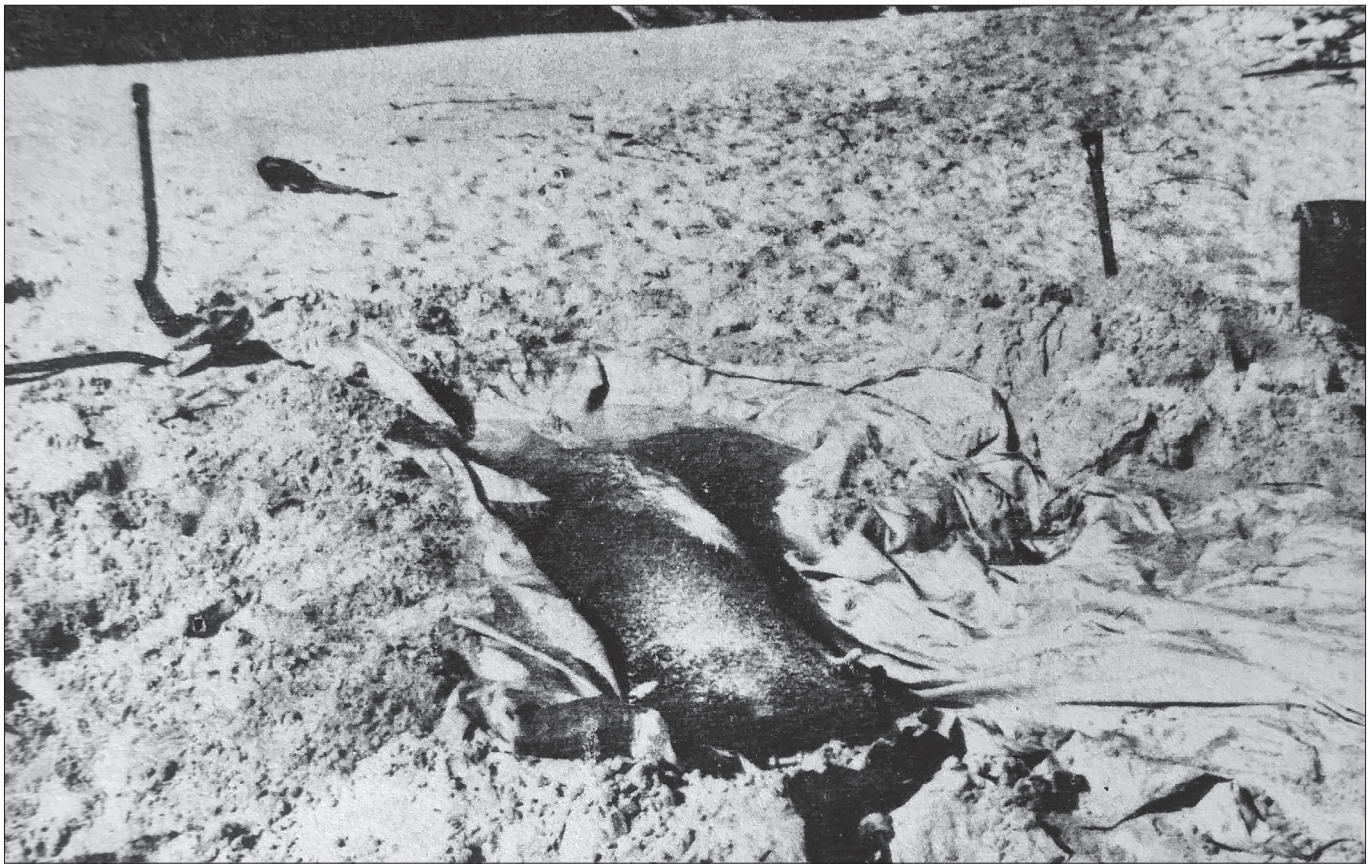
> Visual examination suggested that the wall was still sound, and there were no signs of corrosion right through the wall. The valves were shut and the blanking plugs fitted.
>
> One explanation is that the container was partially empty when thrown into the sea, and that the hydrostatic pressure at the sea bed gradually forced in water through any available route (e.g. the threads of the valve stems). It is surprising that the container was not more corroded. Corrosion from outside to inside could well occur in 38 years, a process which would be aided by the well known corrosive properties of Levinstein mustard working from inside to out. It is unfortunate that the decontaminated container was dropped back at sea before being examined by metallurgists and corrosion scientists. This action has also prevented us from making predictions as to the likely life of other mustard containers in Moreton Bay. Clearly if this container was near the point of gross perforation, then it is likely that other containers have also filled with water and become partly hydrolysed, so that in a few years the risk may be negligible. Conversely, if this container was sound apart from a few pinholes due to metallurgical faults, then other containers could be completely sound and full of mustard for another twenty years or more.[96]

As indicated, personnel *in situ* stated that the cylinder was sound, suggesting that 40 years' submersion had little impact on its integrity.

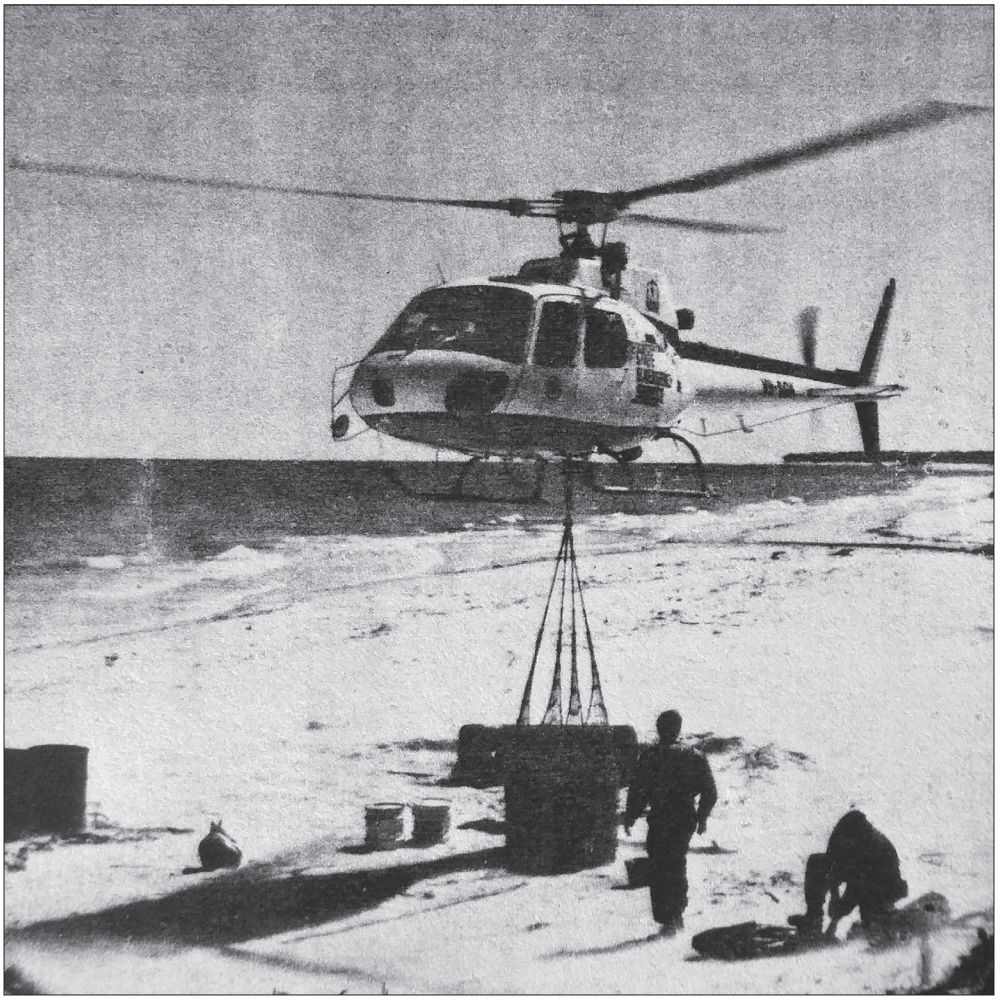
Based on the description of the barrels and their construction, it is quite likely they were able to maintain their integrity during the 200 metres descent. The use of thick walled welded steel construction with reinforcing bands (military grade), combined with partially filled liquid contents would likely withstand the increased pressure. Over time, corrosion and pitting on both the exterior and interior of the drums may weaken them resulting in future leakage or implosion. Slow leaks through the valve and cap over time is also possible.



Mustard gas drum on Moreton Island, 1983



Mustard gas drum in plastic tarpaulin on Moreton Island



Mustard gas disposal operation on Moreton Island

Moreton Island — 1999/2000

Two 155-mm (6-inch) howitzer rounds have been dredged from the vicinity of Moreton Island on two separate occasions and discovered in dredged sand stored at the Boral site in Hemmant.[97] The first was reported on 17 April 1999. The unfused round, giving off a 'strange odour', blistered the wrist of a defence operative when cleaned.[98] It was filled with mustard gas and had been dredged from Yule Bank, west of Moreton Island. The second was located on 11 May 2000 and is presumed to have come from the same location.[99] If the shells (included in the 8000 ton Darra depot sea dump) were stored on deck on their way to the 100 fathom line it is possible they were lost overboard in transit. A more likely scenario is they were translocated; picked up by a trawling operator (most likely east of Cape Moreton), discovered in the net, dropped overboard and subsequently recovered in sand-mining operations.

155 mm mustard gas shell

The fate of chemical munitions and chemical warfare agents after dumping

While, given the influence of sea currents there would have been some drift of lighter material, most chemical munitions are likely to have sunk close to their dump positions. As described, at least one cylinder has been reported to have floated from the original dump position.

Once on the seabed the cylinders would become embedded in sediment or encrusted with sea life. The rate of release of chemical warfare agents depends on the corrosion rate of the cylinders and the properties of the agent. It is important to understand how the chemical warfare agents, once released, will break down in water and to assess the possible environmental effects and risks to the public. These issues will be considered in turn.

Corrosion of cylinders

The corrosion of ammunition shells and cylinders is a complex phenomenon, the rate depending on the location of the dumped munitions. HELCOM notes that the presence of oxygen, high salinity and current will increase corrosion, while burial in sediment and low oxygen will preserve the item for a longer period. The 1-ton cylinder retrieved off Cape Moreton had remarkably little corrosion and no obvious penetration points (based on a visual inspection only). Unfortunately metallurgists and corrosion specialists did not examine the drum before it was re-dumped and were unable to confirm whether there were any pinhole corrosion points. It was also reported that some of the cylinders were already partially rusted when dumped.[100] Bulk cylinders were typically made from relatively thin steel compared with artillery ammunition, filled with thickened or unthickened mustard gas. Heavy walled artillery projectiles are likely to remain intact longer than other cylinders, although the 1-ton cylinder was reported to have had a thickness of 10 millimetres. The rate of corrosion of steel imbedded in anoxic (low oxygen levels) sediments without bacterial activity can be as low as 0.01 millimetres per year.[101]

The breakdown of chemical warfare agents in sea water

While a variety of chemical warfare agents were dumped at sea, mustard gas was the primary agent involved. Mustard gas, also known as sulfphur mustard [di(2-chloroethyl) sulfide], is actually an oily liquid at standard temperature. As mustard gas was the primary chemical warfare agent dumped, this section will concentrate on its behaviour in sea water.

Factors affecting the breakdown of mustard gas in sea water

Although mustard gas has a low solubility in water, once it dissolves it quickly hydrolyses (reacts with water) to primarily form thiodiglycol, together with other compounds including sulphonium and chloride salts.[102] The final products of the hydrolysis are considered to be non-toxic.[103] The dissolution (dissolving) rate and hydrolysis rate are dependent on water quality and other environmental conditions. Some of these important variables include an increased rate with increased temperature, current/ turbulence and with decreased

salinity.[104] The effect of sea current and sea temperature at the two main dump sites will be assessed in the next section.

Effect of sea currents and temperature on breakdown rate

Sea currents on the east coast of Australia (from about 18° S to 32° S) are dominated by the East Australian Current (EAC) which flows strongly southwards.[105] Current velocity generally decreases with depth. As the mustard gas leaks at both of the main dump sites (Cape Moreton and Sydney) it should mix in the bottom boundary layer, be diluted and hydrolyse close to the dump site. Under the influence of the EAC it will most likely travel south at approximately the same depth. The dissolution and hydrolysis rate will be assisted by the temperature found at the dump positions. The mean temperature at a depth of 275 metres off Sydney is 12.73° Celsius.[106] At 200 metres in the western dump circle off Cape Moreton a temperature of 16.54° Celsius was recorded.[107] Towards the outer limit of the Cape Moreton dumping rectangle (around 1098 metres/600 fathoms) temperatures in the range 4° to 6° Celsius have been recorded.[108] While the melting point of pure mustard gas is 14.4° Celsius, in order for it to be maintained in a solid state, the material would need to reside in an environment many degrees below the melting point, for example at least at the freezing point of water, since any impurity would substantially lower the melting point. Although the pressures at these depths would counteract the reduction in the melting point to some extent it is not likely to affect the overall conclusion that as the surrounding temperature would be at least 10° Celsius at the shallower dump sites, it is almost certain that the material would be present in a liquid state. Even at 5° Celsius at the theoretical deepest site off Cape Moreton, it will most likely remain liquid.[109] This contrasts with the cooler Baltic waters where the mustard gas is said to be in a solid state.[110] This higher temperature has a favourable implication for the hydrolysis rate. Conditions in Australia more closely approximate those found in Kuwait waters where Khordagui and Al-Ajmi have modelled the hydrolysis rate of mustard gas at 15° Celsius, the average minimum sea temperature in winter.[111] They predicted a half-life (where half of the mustard gas is hydrolysed) of three hours. This is a considerably faster rate than for mustard gas present in a solid state; indeed Epstein et al. have estimated that a 1-ton *solid* cylinder of mustard gas in sea water (presumably without a casing and in still water) would take five years to hydrolyse.[112]

Current measurements are available close to the shallower dump circle off Cape Moreton, a couple of degrees to the south and north. A current meter placed to the south in 1983 at 29° 00.4' S, 153° 50.3' E at 190 metres revealed a current velocity up to a maximum of approximately 50 centimetres/second.[113] At another site north of the dumped mustard gas at 25.85° S, 153.90° E at 300 metres, Merrifield and Middleton found flows to a maximum of approximately 25 centimetres/seconds.[114] Current flows off Sydney at 120 metres can reach speeds of 60 to 80 centimetres/second.[115]

Water will enter a chemical munition casing through any egress points (corrosion holes or valve threads etc) and hydrolyse some of the mustard gas within its housing. This was seen in the 1-ton bulk cylinder dredged off Cape Moreton which contained a substantial amount of water and hydrolysis products in the upper layer. Any remaining mustard will leach slowly through these egress points and, with the large volumes of water washing past the container, will remain at low concentrations and hydrolyse quickly.[116] Complicating matters a solid surface can develop at the water/mustard gas interface, the mechanism of which is

poorly understood. The crust, which can thicken over time, limits further dissolution and hydrolysis.[117]

Thus, it is reasonable to surmise that mustard gas will slowly leak as its housing corrodes and small egress points develop.[118] As long as the location remains undisturbed, the combination of slow leakage rate, warm sea temperature and currents will quickly dissolve and hydrolyse the mustard gas, both within its housing and as it diffuses through the exit points. At Cape Moreton and Sydney, the hydrolysis products will be rapidly dispersed to the south by the EAC.

This is consistent with the recent studies of the chemical munitions dumped near Hawaii. Mustard gas and it degradation products have been detected in sediment at the dump sites with a distribution consistent with ocean currents. In addition, 'The continued release of HD from the munitions casing over time could also account for the detection of CWA in this investigation.'[119]

25 pounder shells prior to sea dumping off Sydney. B4 = tear gas, Y4 = mustard gas

Risks to the public in Australia

Due to the locations of the dumped chemical weapons, the risk of trawlers encountering them is low. Only two cylinders and two shells have been snared since the war which indicates that the majority of the material is away from current trawling and dredging operations. The chemical munitions retrieved would appear to have been stray cylinders (or the others are now buried); for example, the area up to 100 fathoms off Cape Moreton has been extensively trawled by prawn fishermen. The site off Sydney is a well-known foul ground and is generally avoided by trawlers. Only one cylinder has washed ashore since World War II, so the risk to the general public appears very low. This contrasts with overseas experience where there have been many encounters and accidents with trawled or washed-up cylinders.[120] Although the areas are not currently trawled, the chemical munitions may still pose a threat to future trawling or other activities including sea mining. As the containers deteriorate, they may become more likely to break open when they hit the deck of fishing vessels. However, if they are heavily corroded their contents will be mainly sea water and hydrolysis products.

Potential environmental effects

Literature that addresses the effects of chemical warfare agents' exposure on marine biota remains limited.[121] A 2016 study concluded, 'Despite the potential impact of CWA, there is no knowledge about their long-term toxiocolgical effects on benthic faunal communities. Some substances have possible carcinogenic, teratogenic or genetic effects.'[122] The 2013 CHEMSEA Baltic Sea study showed no significant generic health effects in cod fish from chemical weapon dump sites compared to control sites.[123] However, at lower organisational levels, such as organ, tissue, cellular and sub-cellular levels, 'some stress responses could be recorded in the cod from chemical munition dumpsites using the applied suite of biomarkers.' Supporting this, higher stress responses were also observed in mussels deployed closer to the dumped chemical weapons (65 metres) compared to the controls and to mussels caged closer to the water surface (35 metres). It is believed that fish do not bioaccumulate the agent due to its solubility in water.[124] There are two sites off Australia where many thousands of tons of mustard gas have been dumped. The site off Cape Moreton covers a large area and, as described, includes a designated dumping site as proclaimed by the *Beaches, Fishing Grounds, and Sea Routes Protection Act 1932* near Cape Moreton itself. Originally chosen as a site to abandon derelict boats away from shipping routes and trawling operations, it became a general dumping ground for a large variety of unwanted material. To my knowledge, no biological surveys have been undertaken at the site.[125] The sea bed at the centre point is described as sand and shell.[126] Although there are limited records of non-chemical weapon dumping episodes over the half-century this area was available as a waste dumping ground, the data that exists (for the 1960s) gives an indication of the amount of waste that may have accumulated.[127] There have been many disposal operations close to the dump circle 25 miles east of Cape Moreton.[128] Other material would lie on the sea bed within this rectangle.[129] If the cylinders, bombs or shells began to leak they would pose a danger only to biota surviving in this accumulated debris. The hazard, if any, would

depend on the rate of leakage of mustard from the container and, as argued, this is likely to be slow and gradual. Based on the data provided above, fish using the dump areas as artificial reefs should be minimally affected by the leakage of mustard gas. The nearest identified environmentally protected area to the dump site is the Moreton Bay Marine Park, declared in 1993. Surrounding Cape Moreton, its boundary extends three nautical miles from the coast. It is a significant distance from the 100 fathom line and thus the closest of the dumped chemical warfare materials. As discussed, current flows around the mustard gas will be to the south. As the Marine Park is to the west of the dumping circle, the mustard gas should pose no threat. A similar situation exists at the major dumping site off Sydney where at least 68 boats have been dumped. There are also submarine cables running through the area. This dump site was certainly known and used by the defence forces immediately after World War II.[130] The nearest protected areas are well away from this site.

The future of dumped chemical munitions in Australian waters

As the two main dump areas do not coincide with any protected marine environments there are unlikely to be any major environmental impacts from material remaining at the site although, as noted earlier, material could have floated away from the site during dumping operations, possibly to marine protected areas.[131] Retrieval of the dumped chemical weapons would seem to pose an unnecessary risk, both in handling the material and associated with the dangerous waste dumped with the chemical munitions (known to include ammunition and most likely to also include industrial chemicals). Further, it would seem impractical to individually locate thousands of scattered bombs and artillery shells, many now presumably buried by sediment and other waste. Although technological solutions for the recovery of munitions have improved, there is no clear imperative to touch these dump sites.

International experience has shown that, wherever possible, public awareness of the location of chemical munition dumps has assisted in preventing contact incidents. Kurata writes that, since a national public inquiry in 1972, when information was released concerning the Japanese dumping sites, there had been no casualties by the time of publication. This compares with several deaths and dozens of wounded from dumped chemical munition contact in the period from World War II to 1972. He urges the release of such information in other countries to prevent future accidents. As the locations of chemical weapons dumping sites in Australia are not publicly known, this paper has revealed their coordinates to prevent possible exposure. Given that the locations of chemical warfare material dump sites in Australian waters are in rarely fished areas, the risk of accidental recovery by a trawler is low. Only four items have been trawled or dredged and one washed ashore over the last 70 years. The risk of the general public contacting a sea-based chemical weapon is extremely small. However, if recovered, *any* ordnance (chemical or non-chemical) must not be touched or tampered with under any circumstances. Chemical weapons recovered overseas have caused serious injury despite the fact that the material is over 70 years old.[132] In 1964, an Australian resident found a land-based chemical munition and smeared himself with the contents (mustard gas) in the mistaken belief that it could relieve his arthritis. He

later died.[133] Medical professionals should be alert to the possibility of a patient presenting with symptoms caused by exposure to a chemical weapon. Any incidents should be reported to the local police who will in turn contact the authority responsible for its appropriate disposal.

This paper aims to prevent accidents occurring at the chemical munitions dump sites where coordinates have been revealed. Hopefully, it will also encourage other governments to reveal the locations of their chemical munition sea dump sites to ensure the protection of both members of the public and the natural marine environment.

Crated mustard gas spray tanks being prepared for sea dumping off Sydney by the chemical warfare armourers

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Acronymns

AC	Hydrogen Cyanide/Prussic Acid
ACT	Australian Capital Territory
AWM	Australian War Memorial
BAD	Base Ammunition Depot (Army)
BBC/B4	Bromobenyzlcyanide
CG	Phosgene
CNS	A Type of Tear gas
CO	Commanding Officer
CR	Central Reserve
CRU	Chemical Research Unit (RAAF)
CW	Chemical Weapon/Munition
DM	Adamsite
EAC	East Australian Current
EPA	Environment Protection Agency
FBMU	Flying Boat Maintenance Group
H/HD	Sulphur Mustard gas
HMAS	Her Majesty's Australian Ship
HQ	Headquarters
L	Lewisite
LC	Light Case (bomb)
LST	Landing Ship Tank
NBCD	Nuclear Biological Chemical Defence (School)
RAAF	Royal Australian Air Force
SCI	Smoke Curtain/Cloud Installation
SWPA	South West Pacific Area
UK	United Kingdom

US	United States
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
Y3/Y5/Y13	Mustard Gas

Appendix A

Stockage of Chemical Munitions, United States[134]

Advance Chemical Depot, Aviation, Charters Towers, Queensland

81 tons mustard (H), in bulk
94 tons lewisite (L), in bulk
15 tons CNS, in bulk
23,500 bombs, M47A2, 100-lb (H)
100 bombs, M47, 100-lb (L)
600 bombs, M47, 100-lb (empty)
496 M10 spray tanks, empty
204 M20 spray tanks, empty
55 – 1000-lb (CG) (Navy) (1 May 1944)
60 – 1000-lb (AC) (Navy) (1 May 1944)

Kangaroo (SOS Dump) (26 miles north of Townsville)

15,540 bombs M47A2, (H) 100-lb
18,168 - 75 mm gun (H)
14,370 - 75 mm howitzer (H)
198 - 105 mm howitzer (H)
1401 - 155 mm howitzer (H)
1171 - 155 gun (H)
300 DM Candles (toxic smoke)

Darra (near Brisbane Queensland)

373 tons mustard (H), in bulk
101 tons lewisite (L), in bulk
82 tons tear gas solution (CNS) in bulk
4945 bombs, empty, 100-lb
5595 DM candles (toxic smoke)
5489 - 105 mm howitzer (H)

Columboola (200 miles west of Brisbane)

26,023 bombs, (H) 100-lb
4815 - 75 mm gun (H)
36,036 - 75 mm howitzer (H)
93,453 - 105 mm howitzer (H) (1 June 1944)
14,241 - 155 mm howitzer (H) (1 June 1944)
585 - 155 gun (H)

Brisbane

9121 chemical land mines (US) empty (June 1944)
134 M10 tanks, airplane smoke, empty
240 M20 spray tanks, empty
6 M33 spray tanks, empty

Geelong (40 miles south-west of Melbourne)

431 tons mustard (H), in bulk
3160 DM candles (1 June 1944)

Kingswood (25 miles west of Sydney)

56,909 - 105 mm howitzer (H)
10,825 - 155 mm howitzer (H)

Appendix B

Stockage of Chemical Munitions, Australian Army[135]

Albury NSW

260,268 – 25 pounder (Y4)
2000 – 25 pounder (Y4 with perspex)
86,758 – 25 pounder (B4)
500 – 25 pounder (B4 with perspex)
27,100 – 6-inch how BE (Y4)
39,600 – 4.2-inch mortar bomb (Y13 and Y4)
8076 – 4.2-inch mortar bomb (CG)
4483 - DM generators (No. 20)
323 - DM generators (No. 21)
19,450 – lachrymatory generators No. 2 Mk IV
3-inch Mortar Bomb – 272 tons CG (by July 1945)
460 lbs – CG in 3.5, 9 & 10 lb cylinders
5004 – ground bombs (training)
20,160 – ground 6-lb bombs (Y3 & Y5)
5000 – Chemical mines
500 – Chemical mines (training)
22,500 – 5-inch rockets (CG)

The Australian Army held 742,910 capsules lachrymatory (MK I, II and III) for training and a total of 42,499 DM Ampoules in September 1944.

Appendix C

Select Site Stockage of Chemical Munitions, Royal Australian Air Force[136]

No. 1 Central Reserve

Marrangaroo Tunnel

7991† – 30-lb LC (Y probably all Y3)[137]
4705† - 250-lb LC (Y probably all Y3)[138]
3596† – 250-lb LC (CG) 1 November 1943 (1096, 1 June 1944)
200 – 250-lb LC (empty)
3090 – 65-lb LC (empty) 550 (6500, 1 June 1944)

†subsequently dispersed to two northern depots

Picton Tunnel

570 SCI[139]
500 lb charged mustard
15 SCI 500 lb (empty) (1 June 1944)
75 SCI 250 lb (empty) (18 August 1944)

Endnotes

1 The use of either 'tonne' or 'ton' in this report reflects the measure used in the primary documentation.

2 The terms 'chemical munition', 'chemical weapon' and 'chemical warfare material' are used interchangeably in this report. The definition includes bulk storage drums. Chemical munitions were filled with chemical warfare agents including mustard gas.

3 The terms 'chemical warfare agent', 'chemical weapon' and 'war gas' were used interchangeably by the British and Australians while toxic (gas) was the term principally used by the Americans. The term 'chemical warfare agent' applies strictly to the contents of a chemical munition, e.g. mustard gas or phosgene.

4 This assertion is based on conversations with some of those involved in the chemical weapons dumping operations off Australia. See G. Plunkett, *Sea Dumping off Australia: Historical and Contemporary Aspects*, Department of Defence/ Department of the Environment and Heritage, 2003.

5 This remains the case in 2018. See Plunkett, ibid.

6 See G. Plunkett, *Chemical Warfare in Australia: Australia's Involvement in Chemical Warfare 1914 – Today* (2nd edn.), Leech Cup Books, 2013.

7 Dumping of chemical warfare agents was often referred to as 'sea drowning' at the time.

8 Mustard gas is the historical name given to sulphur mustard blister agent (2,2' - dichloroethyl sulphide).

9 United Nations General Assembly Resolution A/RES/68/258, 20 December 2013, 'Cooperative measures to assess and increase awareness of environmental effects related to waste originating from chemical munitions dumped at sea.' See also A/RES/65/149, 20 December 2010.

10 See A. Kaffka (ed.), *Sea-dumped chemical warfare agent: aspects, problems and solutions*, NATO ASI Series No. 1, Disarmament technologies, Vol. 7, Kluwer Academic Publishers, The Netherlands, 1996 and R. Leewis, 'Environmental impact of shipwrecks in the North Sea II. Negative aspects: Hazardous substances in shipwrecks', *Water Science and Technology*, 1991.

11 HELCOM, *Chemical Munitions Dumped in the Baltic Sea*, Report of the ad hoc Expert Group to Update and Review the Existing Information on Dumped Chemical Munitions in the Baltic Sea (HELCOM MUNI), Baltic Sea Environment Proceeding, No. 142, 2013.

12 H. Kurata, 'Lessons learned from the destruction of chemical warfare agent of the Japanese Imperial Forces' in *Chemical Warfare Agent Destruction and Conversion*, Stockholm International Peace Research Institute, Taylor & Francis, London, 1980.

13 The Navigation Directorate of the Department of Supply and Shipping was asked to advise on suitable locations and instructed the RAAF to dump in at least 500 fathoms of water off the continental shelf.

14 It was eventually concluded that the use of a hulk would present a more suitable option than chartering a vessel. Hulks were cheaper and 'there would be no subsequent flotation of items and the plugs would not need to be removed. All the chemical warfare material could be sunk at any depth, at any desired distance from

shore, all in one sealed hold.' National Archives of Australia (NAA), Canberra, A705 15/31/19 Part 1 (digitised).

15 Chemical, Special No. 6 drum.

16 RAAF No. 1 Central Reserve Headquarters was at Marrangaroo. The reserve also encompassed three chemical weapon sub-depots in New South Wales at Glenbrook, Picton and Clarence, all of which used tunnels for storage. See Plunkett, *Chemical Warfare in Australia* for more detail.

17 A little later, in a monthly report (either October or November 1945), the CO wrote: 'Chemical warfare agent stocks are being inspected with a view to disposal by sinking at sea.'

18 On 21 September 1945 the success of a burning trial of 65 lb bombs in the UK was noted, although it was still unclear whether Australia would burn or sea dump stocks; 'present opinion is that Australia may consider burning rather than sea dumping'.

19 For an example, see the table in Appendix A, chemical warfare agent stocks at No. 1 Central Reserve, data to show behaviour on immersion in sea water, NAA, Canberra, A705 15/31/19 Part 1 (digitised). The assessment involved determining weight (crated and uncrated); establishing the limits of minimum and maximum weights when variations were found to exist; measuring the overall volume of all stores and calculating the weight of sea water displaced by each item. If the weight of the munition/container was greater than the weight of sea water it displaced then it would sink.

20 One ton of chemical munitions was issued to 51 Field Ammunition Depot on 7 January 1944. J.E. Harker notes, presumably sourced from Australian War Memorial (AWM) file AWM52 15/15/5.

21 NAA Canberra, A705 15/31/19 Part 1 (digitised). The coordinates were determined from a map found on this file.

22 Symbology for coordinates: °=degrees, '=minutes, "=seconds, S=south, N=north, E=east and W=west.

23 See Plunkett, *Chemical Warfare in Australia*.

24 Ibid.

25 US Department of Defense, Second Detachment 62nd Chemical Depot, AP, 922 Company Report on Unloading Shipment of 100 pound M47 A2 HS Bombs, 1943.

26 A total of 248 rounds were fired in the trial of which 96 were charged mustard. Department of Defence, Chemical Defence Report No. 19, 1944. The number dumped is unknown. See the Gillis Report at: http://mustardgas.org/The-Gillis-Report-(1985)-Australian-Field-Trials-With-Mustard-Gas-1942-1945.pdf

27 This account is based on Major Keith Parker, *UXO Site Assessment on Mourilyan Harbour*, June 1996.

28 The current flow under the wharf could have shifted the mortars an unknown distance prior to their burial by sediment. They had a gross weight of 20 lb of forged steel with a 3.75 lb charge of mustard.

29 Department of Defence, Chemical Defence Report No. 30, 1944.

30 Described in Plunkett, *Chemical Warfare in Australia*.

31 This type of bomb was imported by the US forces in Australia. Some were held by the Chemical Research Unit for aerial tests in conjunction with the Australian Field Experimental Station research facility, initially located at Innisfail and then Proserpine

(see Plunkett, *Chemical Warfare in Australia*). There is a reference in the 760th Chemical Depot Company Historical Record to a movement of 50 M47A2 bombs to the Australian Field Experimental Station at Bowen (sic) in 1944.

32 Chemical Research Unit war diary.

33 NAA Canberra, A705 15/31/19 Part 1 (digitised). These dumping episodes are also mentioned in the Chemical Research Unit war diary.

34 Ibid.

35 Ibid.

36 See W. Brankowitz, Meeting Notes – Summary of Chemical Warfare agent Sea Dumps by the United States, 30 January 1989. According to a memorandum, tear gas grenades that washed ashore at Maroochydore, 60 to 70 miles north of Brisbane, had been jettisoned by US personnel on or before 4 September 1945. See memorandum dated 4 September 1945, signed by the Acting Deputy Director of Navigation and Lighthouses, State of Queensland, Ref NQ 45/5 W/S, M45/195/1/3846 (former Department of Transport file). Mustard gas shells were also dumped before 3 October 1945 according to information in a letter dated 3 October 1945 signed by the Assistant Secretary Marine, Department of Supply and Shipping, M45/195/1/3849 (former Department of Transport file EPA 94/6789). Thus it can reasonably be concluded that chemical munition dumping operations were underway by early September 1945. These and other sea dumping records are included in the Federal Department of the Environment 11-part record series EPA 94/6789: EPA - Waste Management Bch - Sea Dumping Records - Database.

37 See Plunkett, *Chemical Warfare in Australia.*

38 Ref NQ 45/5, former Department of Transport file EPA 94/6789.

39 The cable was dated 11 November 1983 and signed by the Acting Chief of Joint Operations.

40 One was the Liberty ship *Munroe*. The 100 lb bomb movement is mentioned in the 760th Chemical Depot Company Historical Record.

41 Historical Summary, HQ Base 3, for month of October 1944.

42 Headquarters 62nd Chemical Depot Company, Base 2, APO 922, 1 June 1944.

43 105th Chemical Processing Company, Monthly Historical Summary, 1 April 1943.

44 Military History of Base Two, APO 922, for the month of May 1945, 290 tons in total.

45 See Plunkett, *Sea Dumping off Australia*.

46 Information based on a letter dated 3 October 1945, signed by Assistant Secretary (Marine), Department of Supply and Shipping, M45/195/1/3849 (former Department of Transport file). Various newspaper articles, including the Melbourne *Sun*, 19 November 1945; *Daily Telegraph* and *Courier Mail* (Brisbane), both dated 17 November 1945, also contain references to this activity. See EPA 94/6789.

47 The dump circle was an official 'old' Australian Army dumping ground that was being deliberately targeted by the forces before and after World War II for the dumping of unserviceable ammunition and *dangerous materials* (my emphasis - based on a warning notice to fisherman issued by the Australian Army); an equivalent dump ground off Sydney was also being used by the defence forces during 1945/1946 (see Figure 3 and footnote 130).

The 'Old' Army dump circle was replaced by a 'New' Army dumping ground (date unknown) located further to the east and in deeper water at 27° S, 154° E (figure 2 shows the 'Old' dump circle being the most westerly and the 'New' dump circle further to the east; see also footnotes 127 & 128). One record states the chemical munitions was most likely dumped in the two gazetted areas off Cape Moreton as stated in the Notice to Mariners. The Notice to Mariners lists the dump areas as proclaimed by the *Beaches, Fishing Grounds, and Sea Routes Protection Act 1932* and as there is only *one* gazetted area off Cape Moreton, this reference must be referring both to the gazetted area and the 'new' Army dump ground in deeper water.

48 Letter dated 23 November 1945, signed by Acting Deputy Director, Navigation and Lighthouses, State of Queensland, M45/195/1/3949, former Department of Transport file EPA 94/6789. This letter was written in response to a query as to where the ship, the *City of Fort Worth*, was dumping chemical warfare agents. See Brankowitz, Meeting Notes – Summary of Chemical Warfare agent Sea Dumps by the United States.

49 This second site was the centre point of a second official army dump site which replaced the one closer to Cape Moreton. It had coordinates of 27° S, 154° E with a diameter of five nautical miles. Data does not indicate when it was first used as a dump circle by the Australian Army. Within the second dump circle the following is known to have been dumped: October 1968, 600 lbs of boxed rifle barrels and sulphur bottles; January 1969, 2649 lbs of electric plating vats; 1 ton of ordnance stores on 6 November 1965; 0.5 tons medical stores and sulphur drugs, 2 February 1966; 20 December 1966, medical stores from water pouce, 0.25 tons; 0.5 tons of metal, 22 January 1969 and 1 ton of scrap metal, 17 August 1971. Data from Plunkett, *Sea Dumping off Australia*.

50 Crew member Ron Parsons, re-interviewed 8 May 2015.

51 HELCOM, *Chemical Munitions Dumped in the Baltic Sea*, 2013.

52 *The Courier Mail*, 11 September 1956.

53 Headquarters Northern Command, *Second Report of the Finding of Live Ammunition in the Inala Area*, Department of Defence, 1957.

54 M60, fuse PD M57.

55 This is referred to as a clover leaf. There is evidence some of the rounds had been unpacked from their clover leaf formation into boxes prior to their transport to Darra from Kangaroo, Columboola and Kingswood. Dave Humphreys pers. comm.

56 The bags were used in the absence of vapour-tight metallic containers. Sisalkraft was selected in view of its waterproof qualities in case wet conditions were encountered during the disposal operation. The bags were transported to the disposal craft in tip trucks. The steel trays of these trucks were swabbed with sodium hyperchlorate and hosed out after unloading. To prevent any contamination to the ships, the bags were stowed on board in tarpaulin 'envelopes' to contain vapour or spillage during the 24 hours at sea prior to dumping. Tarpaulins were decontaminated with bleach powder and finally hosed clean.

57 At 600 feet, *The Courier Mail,* 16 May 1957.

58 By vessel 'Landing Craft Mechanised 1059'. This data was obtained from a listing headed 'Army Dumping Activities' which covered the date range, 7 March 1962 to 9 December 1971.

59 Marine Baseline Assessment, John Brewer Reef, 16 December 2013, Golder Associates.

60 Military History of Base Two, APO 922 for the month of May 1945, 290 tons in total.

61 Suggested by Dave Humphreys in AECOM, *A Preliminary Risk Assessment – Munitions Disposal Area at John Brewer Reef*, 2012.

62 Reinforced by the fact there are over 100,000 mines on the reef and Kangaroo stored just 300 chemical mines. The only possibility is dump site 'J' which has 200 mines.

63 Based on an interview conducted on 26 May 1992 with the overseer of the dumping operation. Some of the information in this paragraph was collected by Major Chris Hely. This dump circle is more strictly *south-east* than south south-east of South Head. However, the point 18 nautical miles from South Head in a south south-east direction gives a depth of 144 metres, some two nautical miles short of the continental shelf. It was explicitly stated the chemical warfare material was dumped over the shelf.

64 It was concluded that the use of a hulk was a more suitable method than chartering a vessel. It was cheaper and 'there would be no subsequent flotation of items and the plugs would not need to be removed. All the chemical warfare material could be sunk at any depth, at any desired distance from shore, all in one sealed hold.' NAA Canberra, A705 15/31/19 Part 1 (digitised).

65 R. Parsons and G. Plunkett, *Scuttled and Abandoned Ships in Australian Waters* (2nd edn.), self-published by R. Parsons, 1998; see also Plunkett, *Sea Dumping off Australia*.

66 Originally designed to provide smoke screens for camouflage purposes, they were modified to spray mustard gas from aircraft. They are also referred to as Smoke Cloud Installation.

67 Based on an interview with RAAF chemical warfare armourers who were involved with the loading of the *Bantam*. According to a report by the CO No. 1 Central Reserve dated March 1946, all SCI stocks from Picton had been moved to the wharf for dumping. From March to July the RAAF gas warfare agents were loaded onto the *Bantam*. See Kevin Garr pers. comm., based on personal diary notes; Plunkett, *Chemical Warfare in Australia*.

68 Australian War Memorial file AWM78 228/1 'HMAS *Murchison*: Reports of Proceedings': 'During the dog watches an army scuttling party was transferred to the 9,000 ton hulk *Bantam*, which was loaded with lethal gas and ammunition, and had been towed to a position 136° Macquarie Light 32 miles by the tug *Tancred*. After scuttling charge fuzes had been ignited and the party re-embarked, HMAS *Condamine* and HMAS *Arunta* carried out FC firings [this term, in the context of the shoot, most probably means fire control rather than full charge; definition from Major Graeme Andrews and Major Keith Parker pers. comm.] at the hulk, which sank 10 minutes after the first charge detonated and disappointingly before HMAS *Murchison* could open fire. Direct hits by HMAS *Condamine* were observed'; Report of Proceedings month ending 30 September 1946. The following is reportedly included in 'HMAS *Condamine*: Reports of Proceedings': '… at 1705 when we engaged the Bantam, our first salvo was reported 100 yards over and *Murchison* observed 3 direct hits on Bantam. Due to the heavy swell firing conditions were most difficult' (From Major Chris Hely notes). See also the *Sydney Morning Herald*, 9 April 1992, front page. A different coordinate is given in a Fishing Grounds and Sea Routes Protection Regulations 'Report of Sinking of Ship at Sea' which gives 34°.07' S, 151°.151' E at 100 fathoms (record held by Royal Australian Navy Hydrographic Office).

69 AWM78 228/1; Report of Proceedings, month ending 31 December 1946.

70 War records for Albury (Australian War Memorial, War Diary Records for 1 Base Ammunition Depot, Albury — the Australian Army's storage depot for chemical warfare agents —, AWM52 13/14/2) list the following (all mustard gas unless otherwise stated): '1 July 1946, Issued 168 tons 4.2" [inch] mortar for destruction by sea dumping; 7 July 1946, Owing to leakers with first shipment of 4.2" mortar decided to change to 25 pounder [pdr] until all 4.2" inspected. Loaded 270 tons 25 pdr; 8 July 1946, loaded 90 tons 25 pdr completing train of 360 tons; 14 July 1946, Issued 360 tons 25 pdr to Sydney for destruction; 21 July 1946, Loaded 315 tons 25 pdr; 22 July 1946, Loaded 45 tons 25 pdr completing train of 360 tons to Sydney; 29 July 1946, Issued 285 tons 25 pdr to Sydney. Unable to complete train due to shortage of transport; 4 August 1946, 150 tons 4.2" mortar and 118 tons 25 pdr; 11 August 1946, Issued 6,907 boxes 4.2" mortar and 25 pdr for movement to Sydney; 18 August 1946 340 tons of 3" mortar, 4.2" mortar and 25 pdr for Sydney; 25 August 1946, 360 tons 25 pdr to Sydney; 1 September 1946, Issued 279.5 tons to Sydney.' This shipment included B - BBC (tear gas).

71 This shipment included B4, thickened BBC (tear gas).

72 See Plunkett, *Chemical Warfare in Australia*.

73 These weapons comprised some 20,000 bulk containers (110,000 gallons).

74 Letter stamped 29 October 1965, HMAS *ANZAC* at sea, ref. No. 169/13. Date of supply of the items was thought to be at least 10 years prior to the dump date. EPA 94/7012.

75 Sourced from AWM78 337/1.

76 Confirmation that the ammunition came from 1 Base Administration Depot is based on an interview with Jim Munroe who assisted the dumping operation and also from the Australian Archives, New South Wales file, Series Number SP459/1 Control Symbol 406/1/2575, which, in discussing the programs for ammunition dumping by LSTs, including the 3017, notes that 'included in the 7,152 tons of ammunition to be sea dumped at Albury is 2,156 tons of heavy cases chemical warfare ammunition' (20 May 1947). It is a reasonable assumption that the 522 ton difference was also dumped in this target area.

77 During the afternoon the chemical warfare films were brought on board and shown to the remaining two-thirds of the ship's company. Decontamination exercises were conducted each day the chemical shell was on board.

78 In excess of 1000 metres. Royal Australian Navy Hydrographic Office (pers. comm.).

79 See: http://www.digitaljournal.com/news/world/danish-fishing-boat-catches-ww2-mustard-gas-bomb/article/424736.

80 A. Aasted, 'Fisherman exposed to Mustard Gas. Clinical experience assessment of risk of developing cancer', *Ugeskr*, Laeg, 147(28), 1985.

81 HELCOM, *Chemical Munitions Dumped in the Baltic Sea*, 2013.

82 Kurata, 'Lessons learned from the destruction of chemical warfare agent of the Japanese Imperial Forces'.

83 See: http://www.japantimes.co.jp/news/2013/07/27/national/history/a-drop-in-the-ocean-the-sea-dumping-of-chemical-weapons-in-okinawa/

84 *Consolidated Military History of Australian Base Section*, AFWESPAC, APO 927, for the month of November 1945.

85 This occurred sometime before 4 September 1945. On 22 August 1945 the US Army authorities proposed to jettison 473 44-gallon drums of tear gas which tests had shown would implode at 60 feet. With the trial completed they 'were to proceed with the jettison'. The dates suggest these two entries may be related. The *Consolidated Military History of Australian Base Section*, AFWESPAC, APO 927, for the month of December 1945, states that 'Dumping operations have been completed on all CWS [Chemical Warfare Service] toxic gases in Australia, as directed by HQ AFWESPAC, including tear gas solutions plus containers'. Although not a chemical weapon incident, press reports also revealed that a member of the public had been severely burned by liquid chlorine gas after opening a 44-gallon drum near Evans Head in November 1945. The *Herald*, 27 November 1945, EPA 94/6789.

86 Newspaper articles, *Courier Mail*, 19 November 1945 (EPA 94/6789); *Melbourne Sun*, 19 November 1945.

87 South of Coolangatta.

88 The *Herald*, 26 November 1945.

89 Several marksmen were stationed at the stern to ensure all the bombs sank (according to an eyewitness account).

90 Brankowitz, Meeting Notes – Summary of Chemical Warfare agent Sea Dumps by the United States.

91 Dumping of Ammo - Defence files. Ammunition and Explosives. Discovery/Recovery. Chemical Disposal Op – Moreton Island – Aug 83. Q- 1300 – 6 -24; Dumping of Toxic Substances off Queensland, MPO – 83 – 10460, Part 1.

92 Brankowitz, Meeting Notes – Summary of Chemical Warfare agent Sea Dumps by the United States.

93 The trawler was owned by a Mr Bob Sanderson. Defence files, Ammunition and Explosives. Discovery/Recovery. Chemical Disposal Op – Moreton Island – Aug 83. Q- 1300 – 6 -24; Dumping of Toxic Substances off Queensland. MPO – 83 – 10460, Part 1.

94 Michael Wood, Trawling Representative, Moreton Bay Seafood Industry Association, pers. comm.

95 *Examination and Disposal of a Chemical Store Brought Ashore on Moreton Island in August 1983*, DSTO MRL Report OCD 83/15.

96 Ibid.

97 Located at 150 Anton Road. Considerable rust scaling had occurred reducing the outside diameter of the projectiles by up to 12 millimetres. The most likely leakage point for chemical warfare agents from these types of projectiles is at the fuze adapter in the nose of the projectile. This is the thinnest point on the projectile and therefore the most vulnerable point for the action of corrosion and erosion. The long period these projectiles have spent in the sea makes accurate identification extremely difficult if not impossible given the condition of identifying features (length, diameter, shape, stamped markings, driving band etc) and the addition of heavy marine growth. It was later found that the projectiles, initially believed to be safe to move (no initiating mechanism — fuze), were now likely to contain chemical warfare agents (Captain Peter Ritchey pers. comm.). Several of these projectiles were sea dumped during the 1957 disposal operation. An eyewitness also recalls seeing 44-gallon drums of chemical warfare agents being pushed into the Whitsunday Passage (near Bowen) off a barge

at the end of World War II, although there is no corroborating evidence. A suggestion that chemical warfare agents were discarded at Bougainville Reef (off Cooktown) at 15° 58' 5" S, 147° 21' E is also unconfirmed.

98 Explosive Ordnance Disposal Report, QLD-99-0048.

99 Explosive Ordnance Disposal Report, QLD-00-0062.

100 Sydney *Daily Telegraph*, 17 November 1945.

101 T. Hellström and M. Ödalen, *Long-time behaviour of mustard gas dumped in the Bornholm Basin,* BOX-WIN Technical Report No. 6, Report C100, Dept. of Earth Sciences, University of Gothenburg, 2013.

102 The production of these salts will have different consequences depending on location. With containment it is likely to concentrate to some extent and lower the pH. This may facilitate corrosion. Outside the container the salts will be diluted by sea water and have little effect (M. Mcleod and R. Mathews pers. comm.).

103 T. Stock, 'Sea-dumped chemical warfare agent and the chemical warfare agent convention' in Kaffka (ed.), *Sea-dumped chemical warfare agent: aspects, problems and solutions*, NATO ASI Series No. 1, Disarmament technologies, Kluwer Academic Publishers, The Netherlands, 1996; Hellström and Ödalen, *Long-time behaviour of mustard gas dumped in the Bornholm Basin*.

104 See H. Khordagui and Al-Ajmi, 'Potential fate of blistering Chemical Warfare Agents in the coastal waters of Kuwait', *Journal of Environmental Science and Health*, A29 (4), 1994 and R. Trapp, *The detoxification and natural degradation of Chemical Warfare Agents*, Stockholm International Peace Research Institute, Taylor & Francis, London, 1985 for the chemistry of mustard gas hydrolysis and the measured effect of these different environmental variables on the rate of hydrolysis.

105 J.H. Middleton, 'The Oceanography of Australian Seas' in *State of the Marine Environment Report for Australia*, Technical Annex 1, The Marine Environment, L. Zann and P. Kailola (eds.), Ocean 2000, Department of the Environment, Sport and Territories, 1995.

106 34.125° S, 151.625° E. World Ocean Atlas, 1995-2012. http://nodc.noaa.gov

107 1 September 2006. 27.042° S, 153.666° E. NODC, US Argo Project. The figures from the World Ocean Atlas (1995-2012) are similar, http://nodc.noaa.gov

108 South Pacific Cruise Data 1990–1993; New South Wales EPA pers. comm.

109 Prof. Damon Ridley pers. comm. A temperature of 5.27° was recorded on 2 July 1983 at 1000 metres (27° S, 153.9° E), http://nodc.noaa.gov

110 Trapp has noted that mustard gas containers dumped in the Baltic Sea are leaking and that the bulk of the mustard gas 'remains as dangerous as it was when dumped, being protected against sea water attack by its solid state, its very low tendency to dissolve, side products of hydrolysis and dimerization products forming a protective phase when turbulence is lacking, and by the container itself'. Trapp, *The detoxification and natural degradation of Chemical Warfare Agents*.

111 Khordagui and Al-Ajmi, 'Potential fate of blistering Chemical Warfare Agents in the coastal waters of Kuwait'.

112 Viewed in abstract form only. See Epstein et al., *Summary report on a data base for predicting*

consequences of chemical disposal operations, US Army, Edgewood Arsenal, 1973.

113 H. Freeland, J. Church, R. Smith and F. Boland, *Currents Meter Data from the Australian Coastal Experiment; a Data Report*, Report No. 169, CSIRO Marine Laboratories, 1985. The current meter was 12 metres above the sea bed.

114 The current meter was 50 metres above the sea bed. See M. Merrifield and J. Middleton, 'The Influence of strongly varying topography on coastal-trapped waves at the Southern Great Barrier Reef', *Journal of Geophysical Research*, Vol. 99, No. C5, 1994.

115 New South Wales EPA pers. comm., as measured during the summer of 1995. The rate of current flow during this summer would be slightly faster than 'normal' due to the EAC being particularly active.

116 It would never reach saturation level. Mustard which had been thickened with rubber or perspex would flow less freely.

117 T. Hellström & M. Ödalen, *Long-Time Behaviour of Mustard Gas Dumped in the Bornholm Basin*. Technical Report No. 6. Dept. of Earth Sciences, University of Gothenburg, 2013.

118 C. Briggs, S. Shjegstad, J. Silva and M. Edwards, 'Distribution of chemical warfare agent, energetics, and metals in sediments at a deep-water discarded military munitions site.' *Deep Sea Research Part II*, Topical Studies in Oceanography 128, 2016.

119 As already noted the corrosion rate will be faster for bulk cylinders than artillery shells.

120 The effects of chemical warfare agents on human health are numerous and include respiratory and skin problems. Mustard gas and Lewisite are blister agents, blistering the skin after contact. As an alkylating agent, sulphur mustard damages DNA. See C. Pechura and D. Rall (eds.), *Veterans at risk –The Health Effects of Mustard Gas and Lewisite*, National Academy Press, Washington, 1993.

121 HELCOM, *Chemical Munitions Dumped in the Baltic Sea*, 2013.

122 L. Koticki, K. Grzelakn and J. Bełdowski, 'Benthic communities in chemical munitions dumping site areas within the Baltic deeps with special focus on nematodes.' *Deep Sea Research Part II*, Topical Studies in Oceanography 128, 2016.

123 See: http://www.chemsea.eu/

124 See Stock, 'Sea-dumped chemical warfare agent and the chemical warfare agent convention'. S. Koide, J. Silva, A. Jeff A, V. Dupra and M. Edwards, 'Bioaccumulation of chemical warfare agents, energetic materials, and metals in deep-sea shrimp from discarded military munitions sites off Pearl Harbor'. *Deep Sea Research Part II*, Topical Studies in Oceanography 128, 2016.

125 Current to 2017.

126 Royal Australian Navy Hydrographic Office pers. comm.

127 Federal Government records indicate that 1022.5 tons of ammunition were deposited in the dumping circle between 7 March 1962 and 30 June 1964. A further 4000 lbs of ammunition was dumped in February 1968 and an old dredge on 3 June 1969. See Plunkett, *Sea Dumping off Australia*.

128 This second site was the centre point of a second official army dump site which replaced the one closer to Cape Moreton. It had coordinates of 27° S, 154° E with a diameter of five nautical miles. Data does not indicate when it was first used as a dump circle by the Australian Army. Within the second dump circle the following is known to have been dumped: October 1968, 600 lbs of boxed rifle barrels and sulphur

bottles; January 1969, 2649 lbs of electric plating vats; 1 ton of ordnance stores on 6 November 1965; 0.5 tons medical stores and sulphur drugs, 2 February 1966; 20 December 1966, medical stores from water pouce, 0.25 tons; 0.5 tons of metal, 22 January 1969 and 1 ton of scrap metal, 17 August 1971. Data from Plunkett, *Sea Dumping off Australia*.

129 Records show that, after the war, non-chemical ammunition was dumped beyond the 100 fathom line. US supplies including vehicles, old barges with ammunition and general stores were dumped after World War II. Peter Seib, pers comm.. Seib's father-in-law was involved in the dumping. Material trawled off Cape Moreton includes typewriters, clothing and medical supplies (Peter Seib pers. comm). Six hundred tons of grenades were also dumped in the rectangle after the war (T. Davis pers. comm). Conventional ammunition was dumped in unknown quantities by vessels such as the MV *Katoora*.

130 Limited data shows 300 tons of ammunition was dumped here in August/September 1945 including 18-pounder shells with fuzes removed and boxed, and 50 boxed SAA cartridges were dumped on 15 April 1945. In 1946 bombs, incendiary rolls, obsolete war planes and engines and more ammunition were dumped. Material dumped in 1976 includes the Bosun, a crane lighter, and sodium-filled exhaust valves. More valves were dumped between 1978 and 1982. In 1993, a human body was buried at sea here. Data from Plunkett, *Sea Dumping off Australia*.

131 There is anecdotal evidence to suggest that some trawler operators, off both Cape Moreton and Sydney, having snared conventional ammunition within fishing areas, re-dumped the material at sea at a site away from trawling operations. This transmigration of the dumped material means that the original coordinates of the dumping sites may no longer hold. It is possible that chemical warfare material has been trawled in the past and re-dumped in this fashion. I thank Major Keith Parker for this suggestion. The following is also offered by Major Chris Hely: 'There are a number of incidences where dumped Explosive Ordnance (not necessarily chemical munitions), although initially sinking appears to have become buoyant at lower levels; probably due to denser layers of water because of temperature etc differences. The items appear to have floated on top of these denser layers and consequently washed up considerable distances from where they were originally dumped. It was probably as a result of these incidences that buoyancy testing became common practice.'

132 In the case of fishermen, no attempt should be made to transfer the container or munition to the deck of the boat.

133 G. Plunkett, *Death By Mustard Gas: How Military Secrecy and Lost Weapons Can Kill*, Big Sky Publishing, Sydney, 2014.

134 From Annex No. 1 to Chemical Warfare Plan, SWPA, Stockage of Chemical Warfare Agent, 1 November 1943.

135 From Annex No. 1 to Chemical Warfare Plan, SWPA, Stockage of Chemical Warfare Agent, 1 November 1943.

136 From Annex No. 1 to Chemical Warfare Plan, SWPA, Stockage of Chemical Warfare Agent, 1 November 1943. Bulk storage drums were also held but were destroyed by burning. See Plunkett, *Chemical Warfare in Australia*.

137 1 November 1943 (2391, 1 June 1944). Some of these were burnt at Newnes State Forest.
138 1 November 1943 (1403, 1 June 1944).
139 The SCI are from an inventory dated 18 August 1944.