Surviving the Tarawera eruption: the experience of Māori settlements in the Red Zone

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The relations of large objects to one another, can be observed better at a distance than close at hand, when we see nothing clearly except what is immediately next to us.

James Froude, *Oceana* 1886.

1. Introduction

The 1886 Tarawera eruption was the first major volcanic eruption seen in colonial New Zealand. It was unique in its 4·5-hour eruption from multiple vents along a mountain and sub-lake fissure of 15–18 km. Much investigation has been made of the geology and volcanology (Nairn 1979, Rowe et al). Less has been made of the casualties and even less of the casualties' locations, outside the major village of Te Wairoa. Differing estimates of mortality are 90–150, with ~ 120 being the recent estimate (Lowe 2001). Virtually no investigation has been made of lake residents who may have survived one, two or all phases of the Tarawera-Rotomahana eruptions that June night.

The timeline of the eruptions varies by observer and location. This is due to several factors. It began late at night and observers awoke at different times with the ground shaking. There was no town clock, nor likely a chronometer at Te Wairoa. Uncalibrated watches recorded different times. The shaking intensity varied according to the observers' distance: those closer awakened earlier. No official report author witnessed the eruption— hence the government investigators relied on reports from folk they interviewed on brief visits to the region. The interviewer and interviewees were not always bilingual. There was no inquest.

There was a racial bias with colonists providing nearly all the interviewees. Few Māori reports were published in English, other than those of Alfred Warbrick (1860–1940), Sophia Hinerangi (c.1834–1911), Kimihia (*fl.* 1886) and Willy Bennett (1874–1959). Māori reports were often untimed. This is a pity, for those nearest the eruptions, and those who survived from close quarters, were Māori. Alfred Warbrick was probably the closest observer (10 km) and gave one of the best-timed eyewitness descriptions yet was largely ignored by later researchers. Huta Tangihia (*fl.* 1886) was even closer (5–6 km) but wisely did not stay to witness the eruptions. Based upon eyewitnesses and with a modern understanding of the eruption, I assemble a fresh timeline drawing on Māori and colonial sources with a priority for eyewitnesses who were close to at least one stage of the eruptions, with a watch.

Establishing the headcount of those around the eruption *Red Zone* (6–10 km from the Rotomahana vents) on the night is difficult, owing to poor records and census data for Māori. There were ~84 Māori settlements and gardens around the Tarawera lake and massif. Oddly, they are not catalogued. Some are undocumented, and locations are confused. There was uncertainty over which settlements were occupied. It was winter on the plateau and the author attests to cold winters that see snow on Mount Tarawera. Outdoor activities, such as gardening, would be at a low ebb, although the season was late that year.

The region had not been surveyed by the colonial government before the eruption. Fortunately, the settlements had been mapped by Ferdinand Hochstetter (1831–1884) when

he surveyed the central North Island in 1859. This was part of the German contribution to New Zealand science— small in number but profound in impact. Ernest Dieffenbach (1811–1855), Hochstetter (aka the Father of New Zealand geology), and Julius Haast (1822–1887) essentially wrote the early geological and natural history of New Zealand.

2. Methods

2.1. Location fixing

The first step in seeking survivors is to fix their likely locations at 11.30 pm on Wednesday, 9 June 1886. The first pre-eruption, large-scale mapping of the lake settlements around Lakes Tarawera, Rotomahana, Rotomakariri and Rerewhakaaitu was made by Ferdinand Hochstetter as part of his geographic and geological maps and survey (see Figure 1). These were digitally repatriated to New Zealand by Sascha Nolden between 2010 and 2015. Hochstetter's central North Island survey was reconstructed and published by Nolden and the author (Bunn and Nolden 2016, 2018, 2023).

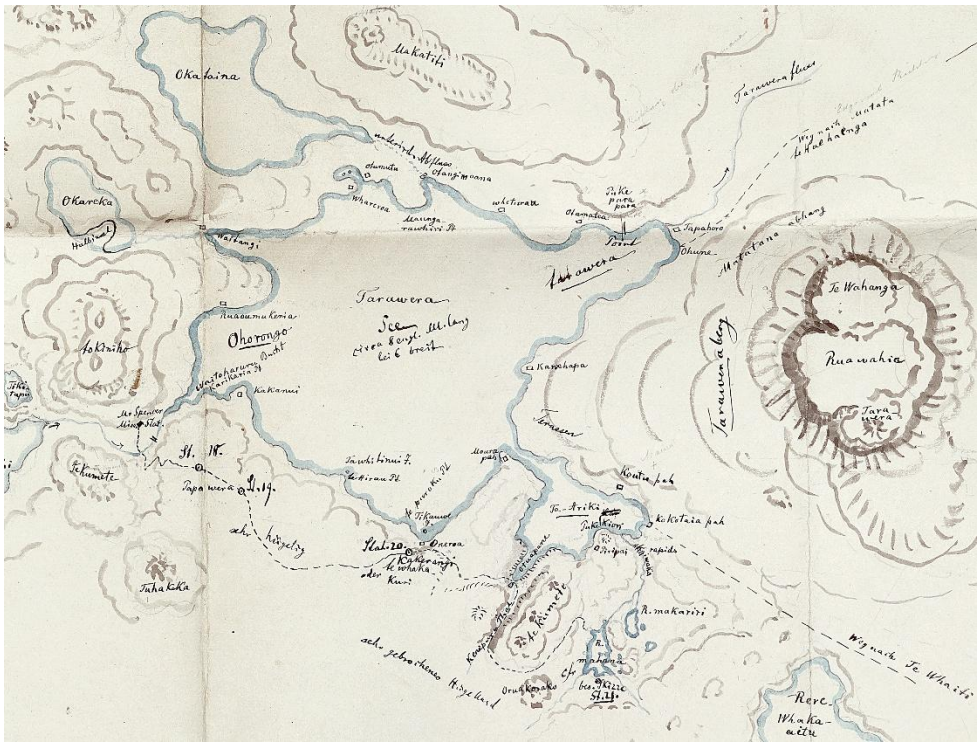

Fig. 1. Hochstetter's survey map of Lakes Tarawera, Rotomahana, Rotomakariri and Rerewhakaaitu (From: S. Nolden & S. B. Nolden, *Hochstetter Collection Basel: Part 3 – New Zealand maps and sketches*, Auckland: Mente Corde Manu, HCB 3.5.6 (detail)).

The settlements were elaborated by searches of the New Zealand Archaeological Association (NZAA) ArchSite, news media and reports from the Rotorua District Council, the Tuhourangi Tribal Authority, Ngati Rangitihi Hapu, Heritage New Zealand and Te Arawa Lakes Trust. The latter report draws on NZAA records. In turn, these rely on 1960s research by Cecil Watt *(fl.* 1961) and Ken Moore *(fl.* 1971), with recent additions by Ken Phillips. Ron Keam (1932–2019) assembled an unmatched eruption archive, but confined himself to description, rather than a forensic analysis (Keam 1961–1978, 1988).

To begin, Hochstetter's 1859 Observation Station 20 on Kakerangi was located on the high contour above Oneroa. His large-scale map shows the Tuhourangi track linking Te Wairoa with Lake Rotomahana. In Figure 2, bearings from Station 20 to seven landmarks around Lake Tarawera were transcribed, translated and declination-adjusted using the National Oceanic and Atmospheric Administration (NOAA) Historical Declination Viewer https://www.ncei.noaa.gov/maps/historical-declination/.

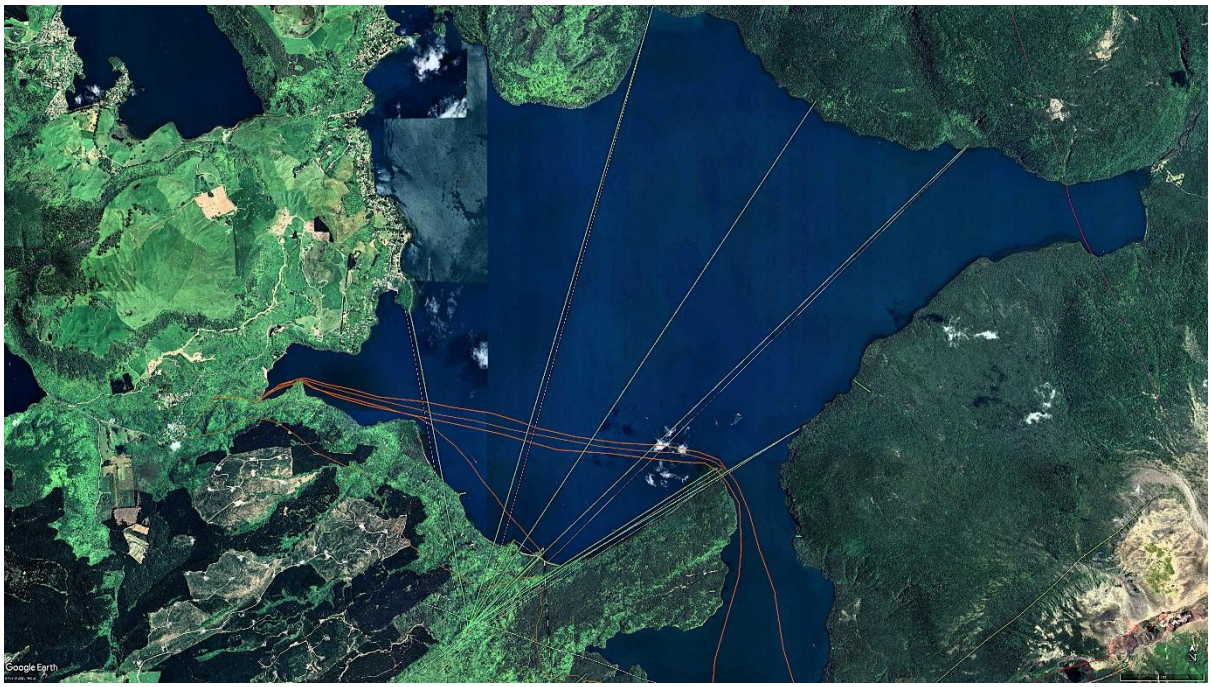

Fig. 2. Hochstetter's bearings from his Observation Station 20 on Kakerangi (green rays). The umber rays are canoe escape courses from the Ngutuahi Arm to Wairoa (Bunn/Google Earth™).

The Station 20 location was validated by a seven-bearing resection using reciprocal bearings from Rua-O-Mukeria (aka Kariri), Otangimoana, Otamatea, Oneroa, Moura Point, Pukekiore Point and Ohume Landing. The Kakerangi bearings enabled further sites to be triangulated from adjacent bearings, e.g. Otamatea and Oneroa lay on the same bearing. The Tikauwe (aka Te Kauae) island pa was located on the shoal off Oneroa. Wheturau was located after correcting the NZAA Otamatea location with a survey bearing. Oneroa was connected with the lost Totarariki and Matakana sites using combined Hochstetter and NZAA data. This assisted the review of eruption survivors and fatalities. An 1841 Dieffenbach bearing on Lakes Rerewhakaaitu and Rotomakariri assisted with the location of Te Ariki and Otuapane.

2.2. Tarawera settlements and gardens

Using the combined resources, a database of 46 settlements around the Tarawera-Rotomahana Basin is presented in Table 1. Many were unoccupied on June 9.

Table 1. The 46 sites around Lakes Tarawera and Rotomahana (clockwise from six o'clock.)

	Settlements around Lakes Tarawera and Rotomahana, as at June 1886.					
Names	Location	Type	NZAA Code	Affiliation	Latitude S	Longitude E
Waingnongogno	Lake Rotomakariri	Kainga	n/a	Ngati Rangitihi	~38.2560	176.4471
Puai Island	Lake Rotomahana	Kainga	n/a	Tuhourangi	~38.2632	176.4302
Pukura Island	Lake Rotomahana	Kainga	n/a	Tuhourangi	~38.2633	176.4323
Patiti Island	Lake Rotomahana	Pa	V16/2		~38.2680	176.4453
Te Ariki-Piripai1	Rapatu Bay	Kainga	n/a	Tuhourangi	~38.2466	176.4519
Kokotaia	Lake Tarawera	Pa	V16/70	Tuhourangi	~38.2466	176.4523
Ngawhiro	Lake Tarawera	Kainga	V16/264		~38.2460	176.4531
Pukekiore	Lake Tarawera	Pa	V16/72	Tuhourangi	~38.2458	176.4425
Piripai2	Te Rata Bay	Kainga	n/a		~38.2455	176.4408
Oneroa	Oneroa Bay	Kainga	U16/28	Ngati Apiti & Ngati Taoi	~38.2266	176.4144
Te Kauae	Lake Tarawera	Pa	U16/30	Tuhourangi	~38.2256	176.4148
Otuapane	Lake Tarawera	Kainga/Garden	U16/26		~38.2425	176.4165
Hakaipari	Lake Tarawera	Pa	U16/27	Ngati Putu, Taoi &/or Apiti	~38.2394	176.4209
Totoariki	Oneroa Bay	Garden	n/a	Tuhourangi	38.2269	176.4129
Mataru Makino	Lake Tarawera	Pa	V16/17	Ngati Taoi	~38.2303	176.4389
Moura	Lake Tarawera	Pa	V16/18	Ngati Rangitihi	~38.2177	176.4397
Tawhitinui	Lake Tarawera	Pa	U16/29		~38.2196	176.434
Hawaiki	Lake Tarawera	Kainga	U16/146		~38.2133	176.3974
Kakanui	Lake Tarawera	Pa	U16/31		~38.2129	176.3954
Karikaria	Lake Tarawera	Pa	U16/4	Ngati Hinemihi	~38.2077	176.3805
Te Wairoa	Lake Tarawera	Town	U16/23.	Tuhourangi	~38.2125	176.3631
Punaromia	Lake Tarawera	Rock Art	U16/11		~38.2040	176.3785
Te Kawau	Lake Tarawera	Kainga	U16/32	Ngati Hinemihi	~38.2040	176.3785
Ruaomukeria	Lake Tarawera	Kainga	n/a	Ngati Hinemihi	~38.2028	176.3813
Kariri	Lake Tarawera	Pa	U16/15		~38.1994	176.3956
Waitangi	Lake Tarawera	Kainga	U16/60		~38.1792	176.3886
Waitangi	Lake Tarawera	Stream	U16/187		~38.1781	176.379
Tokoniho	Lake Tarawera	Kainga	n/a	Tuhourangi	~38.1976	176.3719
Te Karamea Bay	Lake Tarawera	n/a	U16/61		~38.1734	176.3922
Otumutu	Lake Tarawera	Pa	U16/8		~38.1684	176.4003
Whareroa	Lake Tarawera	Pa	V16/258	Tuhourangi	~38.1692	176.3973
Otamatea	Lake Tarawera	Pa	V16/73		~38.1809	176.4719
Wheturau	Lake Tarawera	Kainga	n/a		~38.1767	176.4527
Tapahoro	Lake Tarawera	Pa	V16/58	Ngati Rangitihi	~38.1842	176.5015
Kanaehapa	Lake Tarawera	Pa	V16/288		~38.2071	176.4584
Te Puna	Lake Tarawera	Kainga	V16/287		~38.2243	176.4502
Te Koutu	Lake Tarawera	Pa	V16/69	Tuhourangi	~38.2366	176.4553
Otangimoana	Lake Tarawera	Kainga	n/a		~38.1658	176.4299
Ohune	Lake Tarawera	Landing	n/a		~38.2124	176.4508
Makatiti	Lake Tarawera	Hut	n/a		~38.1409	176.4663
Ruawahia	Tarawera massif	Garden	n/a		~38.2575	176.5577
Pakaraka	Tuminui	Kainga	U16/93	Tuhourangi	~38.2491	176.3191
Manganui	Lake Tarawera	Kainga	N86/6	?		
Onepoto	Lake Tarawera	Kainga	N86/6	?		
Matakana	Oneroa Bay	Garden	n/a	Tuhourangi	-38.2273	176.4147
Pahipoto	Rangitaiki River	Kainga	n/a	Ngati Rangitihi	-38.0103	176.8137

In Table 2, Watt and Moore documented 41 sites as gardens, linked to the settlements.

Table 2. 41 Tarawera Garden Locations from NZAA records. These contain the first locations for Totarariki and Matakana at Oneroa Bay.

Garden Locations which may have been occupied on June 9, 1886.		
Settlement	**Affiliation**	**Satellite Gardens**
Oneroa	Ngati Apiti & Ngati Tao	**Totarariki**, Te Ture O Uenuku, **Matakana**, Te Waitoitoi.
Karikaria	Ngati Hinemihi	Te Puaroa, Kikotawa, Te Petipeti.
Ruaomukeria	Ngati Hinemihi	Te Wharekari, Te Rerengaokio, Te Anga, Hopekaarangi, Pupuhinga.
		Also, Paraharaha, Otamaurekura, Ranhgiuru, Matairama, Tarapatiki.
Hakaipari	Ngati Apiti	Te Taumoi, Wairua Waikarapa, Paraheru, Otuapane, with Mangakara.
Tawhitinui		Tuoniroa, Hawaiki, Te Kawau, Arikirau.
Mataru Makino	Ngati Taoi	Otuapane
Te Kawau	Ngati Hinemihi	Te Puaroa, Kikotawa, Te Petipeti.
Te Kauae	Tuhourangi	**Totarariki**, Te Ture O Uenuku, **Matakana**, Te Waitoitoi.
Waingongogno	Ngati Rangitihi	Pareokio, Te Mimiohinemati,Te Anaiwairua, Whangaapuka.
Moura	Ngati Rangitihi	Three Pa: Titika, Rangiti (Orangiaiti), Otoriha (Kotoriha).
Kakanui		Kokohai, Tapuwaiharuru, Te Upuaka, Te Awaawaroa.

The above 87-site database compares with the 29 NZAA site records and the ≤ 100 Tarawera sites recalled by tribal historians.[1]

2.3. Māori mortality clusters

Next, the locations of major casualty events were ranked. This disclosed errors in the historical record, which reports that the major Māori eruption casualties occurred at Te Ariki (27–52 deaths), with the second cluster at Moura (25–39 deaths). A third, unrecorded mortality cluster of 23 deaths is herein reported at Oneroa Bay. A fourth of 18 deaths is now likely at Waitangi. The Te Ariki mortality presented a problem. It is the most frequently mentioned site in the historiography, but this research shows there were multiple locations termed Te Ariki.

2.4. Māori demographics

The Māori demographics are poorly documented, as New Zealand censuses at the time did not gather Māori demographic data. The numbers included *half-castes living as Maori* [sic]. In the Rotorua Riding, there were 1,377 Māori recorded in the May 1886 report (Brabant 1886). The 1881–1886 decline was estimated at ~ 1·25%. The census noted respiratory diseases as the leading cause of death for the young and old.

2.5. The Red Zone

Given that most eruption mortality was assumed due to base surges from the Rotomahana-Okaro vents, a Red Zone was established around the Rotomahana vents, using surge evidence from Ian Nairn in 1979 (Nairn 1979). Nairn sketched a circular 6 km surge range and published their direction arrows in Figure 3. In 2001, Lowe and Keam reviewed the eruption mortality and extended the Red Zone to 10 km from the Great Crater at Rotomahana in Figure 3 (Lowe 2001). This encloses the area experiencing the impact from surges, ballistic

[1] For sites with Hochstetter's bearings and a map location on/near the shore, the coordinates should be precise to four decimal places at this latitude, i.e. the latitude precision is ~ ± 5·6 m and for longitude ~ ± 4·4 m. For those sites with a map location, I suggest a precision of three decimal places ± 55·7 m latitude and ± 43·9 m longitude. This is adequate for imaging search-boxes.

rocks and stones, mud sky-fall, winds and ash, affecting respiration and movement. Outside this, the impact was presumed to lessen.

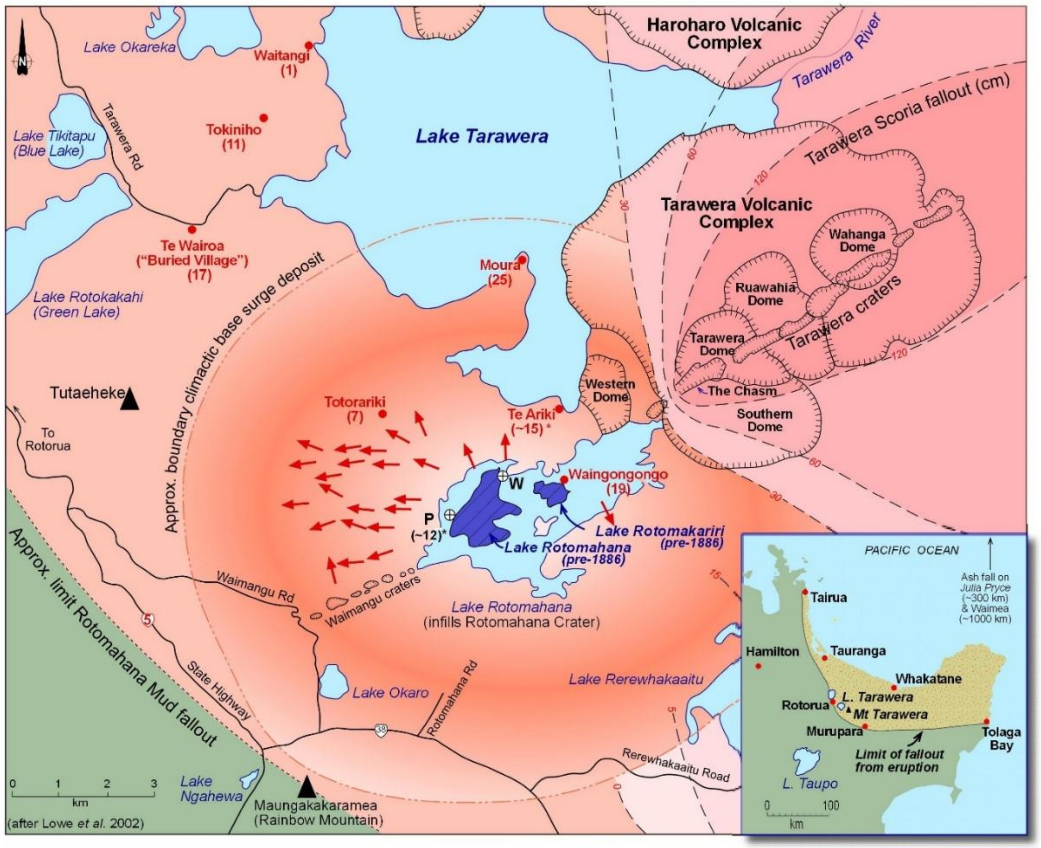

Fig. 3. Map of the Rotomahana Basin c. 2001 showing base surge directions and ranges. (Courtesy David Lowe). The blue images for Lakes Rotomakariri and Rotomahana predate this author's 2014–2025 research, setting their more northerly location.

In Figure 3, the 10 km radius includes Moura and Oneroa Bay.

2.6. Tamihana Te Keu, Matakana and Totarariki at Oneroa Bay

After plotting the 46 Tarawera settlements, there is a suspicious lack of sites along Oneroa and Te Rata Bays. These have prime, north-facing land for homes, fishing and gardens. From photography, we know that, for example Piripai had attached gardens. Watt, Hochstetter and Percy Smith (1840–1922), plus photography of Te Ariki, suggest the answer may lie with Tamihana Te Keu, the *Chief of Rotomahana.* The published prints of Te Ariki (aka Piripai, aka Philippi) are of the same settlement and garden. Te Keu and family members are prominent in prints. Watt had access to Māori sources. Some of his records are held in Whakatane.

Te Heu, his wife and seven children died in the eruption at Totarariki (*Star* June 14, Keam 1988). The locations of Totarariki and Matakana were undocumented (Keam 1988). There were no inquests establishing the death toll from the 1886 eruption (Brabant 1887). In his first compilation of Māori casualties, the 14 Matakana deaths were assumed to be double-counted (Keam 1988). Yet, in 1961 Watt had identified Totarariki and Matakana as gardens

vicinal with Oneroa and its island pa Te Kauae. This is important, for these deaths form the third largest mortality cluster (*Herald*, June 16).

2.7. Logistic regression analysis

This is a statistical method, measuring the factors affecting an outcome. In this case, we wish to find the factors helping or hindering the Māori residents in surviving the Tarawera eruption. In a regression model, we plug in risk factors to assess their importance, while holding others aside. The method is now used in many disciplines. In the 1970s, the author pioneered such path regression with beta coefficients in health economics research (Bunn 1978, 1979a, 1979b, 1980). This is the first application to the Tarawera eruption.

For this research, 13 occupied settlements (kainga) were selected, i.e. Wairoa, Puai and Pukura Islands, Rapatu Bay, Te Rata Bay, Oneroa Bay, Moura, Makatiti, Ruawahia (2), Tokiniho (aka Tokoniho), Waingongongo, Waitangi and Pahipoto. In some, the residents died, and in others, they escaped. The dependent variable is Survival, i.e., whether the *Flight or Freeze* decisions made by residents were correct for their survival. The independent variables included the distance from Tarawera and Rotomahana vents, mobility, health, reaction-time, visibility, leadership, objective, motivation, path access, path quality, group size, flight or freeze, travel choice and eruption phase.

Model iterations were made with small groups of factors to identify the important variables. This first application was constrained by the small number of occupied settlements and the demographic data. The historical records emphasise European mortality and survival. Lake settlements with known occupancy and outcome are a subset of the total, so we cannot generalise. The subset is formed by three factors. First, most pa were unoccupied as the region was free of conflict. Second, there had been a disease outbreak in Wairoa in April-May, with the funerals attracting mourners from around the lake. Thirdly, it was winter, and outside activities were at a seasonal low. Also, many settlements have not been surveyed or excavated. For Te Ariki, confusion persists over its site. The computation of logistic regression is now commonplace with online calculators. Further statistical details are available from the author.

2.8. Time and Distance modelling of eruption escape paths

Humans facing a threat trigger the fight-or-flight mechanism, the evolutionary sympathetic nervous system response to a stressor. After recognising a stressor like the Tarawera eruption, the Māori and Pakeha reaction would be Flight or Freeze, the latter in the hope that the eruption would pass by. Those electing a flight strategy take a direction away from the threat. Rotorua residents fleeing on foot in pyjamas took the west road. Given the topography with few paths, those Māori fleeing the lake settlements could choose between trails or a canoe. Employing Hochstetter's survey and maps, together with historical trail maps and the NZAA archive, we can, for the first time, fix coordinates for the settlements known to be occupied, i.e. Puai Island, Waingongongo, Moura and Oneroa Bay. We can also trace the paths residents would take. Given the regression constraints, the key variables of distance from the vents and access to an escape path were modelled using a Time and Distance model. The settlements included Puai Is. (fleeing to the North West, South and Southeast), Waingongongo (North, West and South), Rapatu Bay (North, West, South and canoe), Te Rata Bay, Otuapane, Moura (by canoe) and Oneroa.

2.9 Causes of death and the gas cloud

No published forensic analysis could be found of the causes of death for Māori around Lake Tarawera. Given that most bodies were not recovered, there is a lack of post-mortem data. Roof collapses, asphyxiation (from ash particles), and burial in falling mud and stones are mentioned. There are reports of distressing sulphurous smells in Te Wairoa and Rotorua, but these were not interpreted as a hazard. Rotorua residents and tourists quickly undergo olfactory desensitisation (nasal fatigue). That night, this was a hazard as at concentrations >100 ppm, H_2S desensitises the olfactory nerves, if the level rises to a lethal concentration (Bunn 2023c). H_2S > 300 ppm causes respiratory distress and collapse, while at 700–1000+ ppm, immediate unconsciousness and death in minutes (NIOSH 2007).

3.0. Findings

The first survey mapping of Māori settlements around Lakes Tarawera, Rotomahana and Rotomakariri was by Hochstetter in 1859. Māori chiefs gave him the names of landscape features while spurning local surveyors. They learnt that disclosure led local surveyors to sequestrate their land. Hochstetter had their confidence as he took their confidential information overseas.

3.1. Lake Tarawera

Hochstetter described the lake from Te Mu: "… Its general form, excluding of its deep side coves, is that of a rhombus, with its main diagonal running from West to East." (Hochstetter 1867, 405). This remains true, and from the Landing, the eye is drawn to the eastern end at Tapahoro and the southern shore along Oneroa Bay. By boat, the southern Ngutuahi arm is invisible until one closes with Moura Point and its shoals. From the Landing, the pre-eruption lake could have its head at Oneroa Bay, with the Ngutuahi Arm a river discharging into it at Moura Point. Hochstetter saw the Ngutuahi Arm as an extension of the Kaiwaka Channel to Moura.

3.2. Finding Te Ariki

After Te Wairoa, the most frequently mentioned place around Lake Tarawera in the nineteenth century tourist literature and photography is one called Te Ariki or Piripai. It was a waypoint for tourists en route to the Pink and White Terraces. Before that, Te Ariki was a term for the Ngutuahi Arm, hence any settlement in the arm could be labelled Te Ariki. There are many locations for Te Ariki in the literature. As the place with the greatest eruption mortality, it's vital we locate it. The research to establish the location is included in the appendix. This led to undocumented Māori centres and mortality in Te Rata and Oneroa Bays. It seems likely that the term Te Ariki (for the Ngutuahi Arm) became a collective term for Kokotaia pa, Piripai and Ngawhiro in Rapatu Bay, and probably the Piripai in Te Rata Bay. It is possible that Oneroa and Te Kauae were included.

3.3. Totarariki, Matakana and Tamihana Te Keu at Oneroa Bay

This analysis is the first to triangulate Oneroa and Te Kauae, using Hochstetter's survey and Watt's notes. These establish the satellite gardens of Totarariki, Te Ture O Uenuku,

Matakana, and Te Waitoitoi along Oneroa Bay. This helps locate where Chief Tamihana (Thompson) Te Keu and his family died at Totarariki. Watt reports Totarariki was a cultivation near Oneroa. This north-facing ridge offered prime gardening with stream 1050543 for watering. Oneroa Bay offers easy landing, and the bathymetry shows it was in pre-eruption days. Te Keu's home lay at Oneroa Bay. On June 13 1886, Joseph Warbrick (1862–1903) passed Te Keu's buried house en route to Te Ariki, five miles from Wairoa and four miles from Te Ariki (5/9 = 55.6 %), (*Star* June 14, *Press* June 15). Te Keu's wife and seven children were being excavated by relatives. Keam reports Te Keu dying there with his wife and family, hence the Oneroa death toll is nine. The Tuhourangi Trail to Rotomahana was mapped by Hochstetter and passes Oneroa. As the crow flies, Oneroa is 55% of the way. Following the trail, it is 56%. These figures show Te Keu did not live at Te Ariki in Rapatu Bay or Te Rata Bay. This finding suggests the photograph of Te Keu and children in Figure A5 was exposed at Oneroa, and the adjacent cultivation is Totarariki.

Tamihana (Thompson) Te Keu was known by colonists as *The Thundercloud of Rotomahana* and levied tolls on tourists (Williams). He represents a bridge to the tourism economy of Wairoa, which replaced the agrarian economy. In the Te Ariki arm, although tourism supplied fees and food income, gardening remained active at Moura, Oneroa Bay, and probably at Te Rata Bay. The four garden sites along Oneroa Bay help answer a question that puzzled researchers. Photography showed too few homes for a large population. It was spread across Rapatu, Te Rata and Oneroa Bays. A larger population (with tourists) in the Ngutuahi Arm required more gardens to balance the koura and inanga from this best Tarawera fishery.

The 23 residents who died in Oneroa Bay comprise the third largest group of fatalities after Rotomahana and Moura. Keam assumed the Matakana deaths were double-counted (Keam 1988). They must now be added to the toll and their identities sought. Keam seemed unaware of Watt, Moore and their NZAA records, which date from 1961.

3.4. Māori demographics, health trends and morbidity

As a health economist-diagnostic radiographer, the author reviewed the risk factors predisposing the Māori residents to a greater health impact. During the previous century, the indigenous population halved from introduced diseases, conflict, poor housing and health care. Respiratory diseases were the common cause of death amongst Māori children and the elderly. This decline helps explain the unoccupied settlements and frequent funerals at Te Wairoa in 1886. It is likely that Te Wairoa mortality was above the national average, due to tourism. The tourists imported infectious viral and bacterial diseases from Europe and ports along the sea route to New Zealand. STIs would be imported by the young, affluent, male tourists to Te Wairoa. Māori lake settlements, having less intimate contact with tourists, would suffer less.

Tuberculosis, pertussis, flu, bronchitis and pneumonitis predisposed Māori residents to acute respiratory distress when inhaling irritant volcanic ash. The 1886 Māori census reported a month before that

> ... the deaths being generally those of children and old people. The adults who die early ... suffer from lung complaints. Low fever has been known to exist from time

> to time ... and has been fatal to ... children. Whooping cough has also been prevalent ...“ (Brabant 1886).

There are no national indigenous health statistics for New Zealand or Australia in the nineteenth century. The indigenous population of New Zealand halved during the nineteenth century, from ~ 90–100,000 and with a life expectancy of ~ 25–30 years. In Australia, the decline was ~ 70–90% with a life expectancy of ~ 30–35 years. In New Zealand, this was due to diseases for which the Māori had no immunity, the loss of agricultural land and conflict. The same factors held in Australia, with *terra nullius* permitting greater settler conflict with the Aborigines.

At the eruption, Māori life expectancy continued to be lower than that of Aborigines (or the UK at 44–48 years). https://teara.govt.nz/en/taupori-maori-maori-population-change While fecundity and fertility rates were similar for both populations, infant mortality rates of 20–25% persisted in New Zealand versus 30–50% in Australia. The Māori were spared the smallpox epidemics, which caused ~ 50–70% mortality rates in parts of Australia. Both populations endured STIs with syphilis and gonorrhoea, causing chronic pelvic inflammatory disease, infertility, miscarriages and maternal mortality. Climate, lifestyle and housing differences led to more respiratory diseases in New Zealand, with measles and typhoid fever.

By 1886, Māori society was crumbling, and those living around Mount Tarawera with pulmonary disease had reduced exercise tolerance. Being indoors added smoke inhalation to the risk factors. This reduced pulmonary reserve affected their capacity to cope with ash inhalation, and hypoxia affected the ability of children and the elderly to outrun the eruption.

3.5. Māori eruption mortality statistics

To zero-base the Māori fatalities, I reviewed Keam’s list and another 17 published reports. In Table 3 are 19 estimates of Māori fatalities at Tarawera. The numbers in black are original data. Many estimates are partial, and the blue data are infilled from credible sources for comparison. Gilbert Mair’s leadership in search and rescue and his status in Māori and colonial society make him a primary source of headcounts for survivors, versus the visiting media. Members of his Arawa Column were among the dead (Keam 1988). As a militia commander, he would know the families. Walking between both worlds, he launched the national appeal to Māori and Pakeha communities (*Herald* June 16). His casualty reports ought to have more currency.

Table 3.19 estimates of Māori mortality from the Tarawera eruption

				Estimates of Maori Mortality at Tarawera								
Source	Place	Moura	Te Ariki	Waingongogno	Puai	Te Wairoa	Tokoniho	Totarariki	Matakana	Waitangi	Others	Total
Brabant	c. 1886											90-100
Mair	1886	40	50	19		15	11	7	14	1	2	159
Herald	1886 min	45	30	19		15	11	7	14	1	2	144
Herald	1886 max	45	95	19		15	13	9	14	1	2	213
Mehaka	1886	23	59									n/a
Star	1886	30	35	18	8	15	11	8	14	1	2	142
Warbrick	1886	39	51		11							n/a
Leys	1950	39	52				19			11		147
Smith	1950											147
Keam	1961	39										n/a
Keam	1978	39										n/a
Nairn	1979	39	52		11	14						n/a
Keam	**1988**	**25**	**16**	**18**	**11**	**10**	**11**	**7**	**14**	**1**	**2**	**115**
Andrews	1986											>150
Andrews	2005											>150
Lowe	2001		27									~120
NRH*	2025	23	49	19		15	11	7	14	1	2	141
NRH*	Revised	40	95	19		15	11	7	14	1	2	204
Bunn	**2025**	39	33	18	11	15	13	9	14	18	2	172
	* Ngati Rangitihi Hapu											

The new death toll takes Gilbert Mair's (1843–1923) and his brother William Mair's (1832–1912) and Warbrick's numbers for Moura and Te Ariki, as they knew each family and most of the dead (except visitors). Rotorua was a small town where everybody knew everybody. It retains that flavour. Mehaka, a Te Ariki resident is the last eyewitness from the centres: "having left Te Ariki on Tuesday [one day before the eruption], has enumerated 59 persons known to be there and 23 at Moura ..." (*Star* June 15). Mehaka's 59 persons includes Waingongongo, as Brown was included in his preliminary body count of 42 (*Star* June 12). Waingongongo was a kilometre from Rapatu Bay with Moura 3 km away. Keam's cases are added for other clusters unless there were errors, as for Totarariki (a miscount), Matakana (an omission), Tokiniho (a revision) and Waitangi (most likely an omission). Outliers were discarded. The death toll grew in the early days as more information arrived. The generally accepted twentieth century figure of 153 total deaths is associated with Joseph McRae (1849–1938) in the media.

Keam's ten Wairoa fatalities (plus Tuhoto Ariki, who died in hospital) disagree with Mair and the *Star*, and I adopted their figure of 15 Māori persons. Both Mair and Warbrick reported greater casualties at Moura and Te Ariki, as did the Ngati Rangitihi Hapu, the *Star*, Leys and the *New Zealand Herald*. It appears omissions exist. These could be due to stringency in requiring the dead to be correctly named. The new composite mortality equals ~ 172 persons, more than Lowe and Keam in 2001 or the previous total of 150–153 persons (Lowe 2001). The catalogue published by Keam in 1988 and revised in 2001 with Lowe is the most complete individual identification. However, Lowe and Keam recognised there could be omissions (Lowe 2001).

3.6. Settlement populations and experiences

There is uncertainty on the night as to the whereabouts of Māori residents. Given the population decline and the season, few settlements were occupied. It was mid-winter, and the temperature likely dropped from ~ 12°C to ~ 6°C with a chill factor. After a late autumn harvest, gardening activities involved storing the crop in pits. Life up on the plateau was

otherwise indoors. The tourism season was over. We know the eastern settlements were unoccupied. For this analysis, we consider the key sites from c. 84 kainga, pa and gardens around Lakes Rotomahana, Rotomakariri and Tarawera. Survivors of the ground shaking and the first eruption phase (the Tarawera eruption) could come from any of four regions. To survive the second and third eruption phases (see Table 4) called for luck and prompt evasive action.

3.6.1. Northern sites

Te Wairoa, Kariri, Te Kawau/Ruaomukeria, Tokiniho, Waitangi, Otumutu/Whareroa.

Of these sites, accessible on foot from Te Wairoa, fatalities were reported only from Tokiniho and Waitangi. The remaining sites are considered unoccupied. The reasons include the sites being pa or gardens, or that the residents were in Te Wairoa for the funeral. These sites were outside the 10 km Red Zone.

There were ~ 70 Māori homes at Te Wairoa (Simmons 1991). Some 15 Māori whares are mapped in Te Wairoa, as well as Chief Wi Te Kepa Rangipūawhe's house and Hinemihi. One whare is excavated and can hold one or two adults. This is reasonable for a Māori population of ~ 120 with some sole occupants, such as Tuhoto Ariki and Rawiri. Mourners could stay in Hinemihi meeting house, where 45 survived. https://www.britishcouncil.org.au/crossing-points/anthony-hoete-hinemihi-how-grass-hut-transforming-global-heritage

Survival rates at Te Wairoa were for Māori ~ 93% and Pakeha 60%. This reflected differences in housing construction.

3.6.2. Eastern sites

Otangimoana, Wheturau, Otamatea, Tapahoro, Kanehapa, Ohume, Ruawahia and Makatiti.

Most of these were unoccupied, though there was doubt about Tapahoro. Makatiti and Ruawahia were occupied. At least two families on Ruawahia escaped the first and second eruption phases from the Red Zone. The Tangihia family were ~ 5–6 km from the rift. On Makatiti, Alfred Warbrick was 9–10 km away.

3.6.3. Southern sites

Te Puna, Te Koutu, Piripai, Waingongongo, Otuapane, Pukehou, Moura, Puai.

Every casualty report focuses on Moura and Te Ariki (Piripai, often including Waingongongo). Until now, Waingongongo has not been located on Lake Rotomakariri, and the position of that lake was uncertain (Bunn 2023a). Hochstetter's survey and Dieffenbach's report helped locate both in Figure 4.

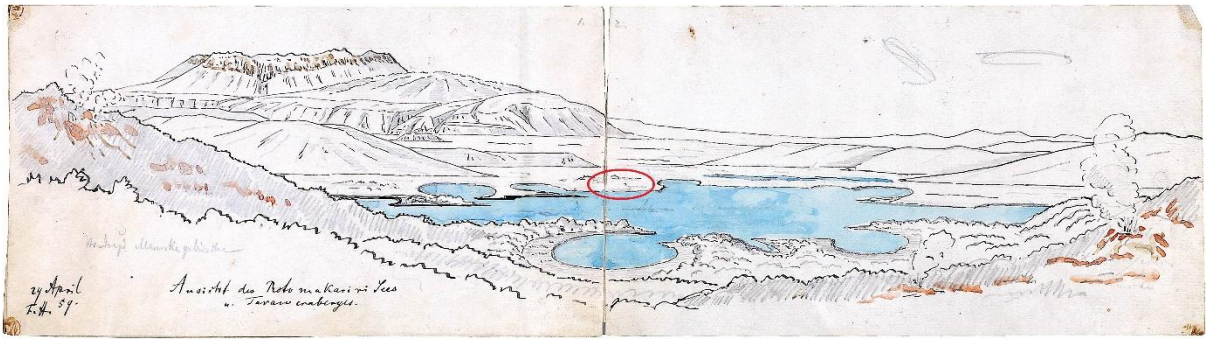

Fig. 4. Probable location of Waingongongo settlement (circled) sketched by Hochstetter on Lake Makariri. (From: S Nolden & SB Nolden, *Hochstetter Collection Basel: Part 3 – New Zealand maps and sketches*, Auckland: Mente Corde Manu, HCB 3.5.14).

Waingongongo likely appears on Hochstetter's 1859 watercolour of Lake Rotomakariri in Figure 4. From the perceived structure (circled), Waingongongo was a good defensive position with water on three sides.

3.6.4. Western sites

Oneroa, Te Kauae, Totarariki, Matakana, Tawhitinui, Hawaiki, Kakanui, Karikaria.

These sites are underreported in eruption accounts. This is odd for three reasons. First, the tourist canoes paddled along this coast. Second, there were good landings (rare around this lake). Third, the north-facing land along Oneroa, Te Hinau and Hawaiki Bays provided good gardening with streams and a solar aspect. Oneroa was occupied when Hochstetter walked past it to Rotomahana. He noted the Tawhitinui island pa off Te Hinau Point and Te Kauae pa off Oneroa Point.

Watt records a Tuhourangi chapel and four gardens along Oneroa Bay, i.e. Totarariki, Matakana, Te Waitoitoi and Te Ture O Uenuku. Oneroa Bay was a vital part of the Tuhourangi agrarian economy. It suffered nine casualties at Totarariki and 14 at Matakana, making Oneroa Bay the third-worst cluster. Previous investigators failed to examine Oneroa Bay and the death toll was understated.

3.7. First responders' searches

Insight into the occupied settlements (and potential survivors) is gained from the first responders. Their priority was Te Wairoa, and nearly all Māori and Pakeha resources over 10–12 June were directed here. From June 13, the priority shifted to the Ngutuahi Arm with Ngati Rangitihi from Matata trying to reach Te Ariki and Waingongongo via Tapahoro over 13–14 June. Joe Warbrick was the first to follow the trail to Rotomahana across Kumete Ridge on June 13. By June 14, Pakeha efforts, which had been limited to Pareheru, were geared up by Mair and Alfred and Arthur Warbrick for a private rescue boat to Moura and Rapatu Bay. Smith's official group, after an abortive effort on June 13, reached Hapeotoroa Hill that day as Morgan and Wairehene reached the Kaiwaka Channel area.

The northern, eastern and western coasts were largely ignored, apart from Smith's recovery of the sole Waitangi survivor and Tokiniho, reached on July 14.

3.8. Role of Te Wairoa in survival

There had been four funerals in Te Wairoa that April, with many visitors. On May 23, Chief Aporo Te Wharekaniwha died, and his funeral attracted mourners from around the lake. It probably commenced by May 30 and ended about June 4. Some mourners lingered until June 9. The resident Māori population of Te Wairoa was reportedly 120 persons with 45 visitors. Some 62 fled to Guide Sophia's home, and another 45 made for Hinemihi. More joined the Tuhourangi chief Wi Kepa Te Rangipūawhe at his house, and other hotel workers were uncounted. These sites contained ~ 120 of the estimated ~ 165. Adding the 15 known Wairoa fatalities that night sums to ~ 135 people, leaving ~ 30 people unaccounted. Most of the Māori population gathered in three buildings, with the remainder, such as Tuhoto Ariki and Rawiri et al, staying at home. The funeral saved the lives of mourners from lake settlements (*Waikato Times* 1932). Hinemihi and Sophia's homes were at opposite ends of the settlement. Those in the western end would head for Hinemihi, while those in the east made for Sophia's house. It took days to establish the missing, the dead and the survivors. Kaiteriria became a casualty clearing station.

3.9. Whence for survivors?

The lake settlements cited by those on hand, such as Warbrick, Bennett et al, as destroyed, were Te Ariki, Moura, Tokiniho and Waitangi. For potentially undocumented survivors, Oneroa, Totarariki, Matakana, Tapahoro, Waingongongo and Puai/Pukura Islands must be added. No other settlements were subject to search and rescue efforts by Māori or Pakeha. Māori visitors were visiting some sites, and mourners vacated others (*Waikato Times* 1932).

Here, we focus on the known sites and the possibilities for escape on the night. Given that the coastline sites were accessed by canoe (except for Puai and Tokiniho), we examine seaborne evacuation as well as escape via trails. Those west of the massif would run west, away from the volcano, to the nearest centre— Te Wairoa.

3.10. Causes of death

In forensic pathology, there are (simply) two causes of death: the Proximate and the Immediate causes. When a Moura resident died that night, the proximate cause was probably hydrogen sulphide (H_2S) and/or carbon dioxide (CO_2) poisoning. The immediate cause was respiratory failure leading to cardiac arrest. A contributing cause for children and the elderly was existing pulmonary disease.

Geologists claim that: "Pyroclastic density currents from the Rotomahana segment caused all of the casualties from the eruption" (Rowe et al). This may be true of the Immediate cause (for we all die of cardiac failure). It is likely untrue for the Proximate cause, which, the evidence suggests, was exposure to toxic gases. Given the respiratory disease among the Māori population, CO_2 and H_2S (with ash inhalation) was a Proximate cause, with the Immediate cause, pulmonary failure from bronchospasm or airways obstruction leading to cardiac failure. Another cause was trauma from projectiles, although ballistic analysis suggests a minor role. Toxic gas poisoning is unmentioned in the period reports; it probably being ascribed to asphyxiation without any Proximate cause.

The forensic analysis and the settlements ”Time and Distance” analysis suggests that many Red Zone fatalities occurred before the base surges arrived, with gas interrupting escape attempts.

3.11. Base Surges and survival

The first cause of mortality in the Ngutuahi Arm was said to be a base surge from the Great Crater under Lake Rotomahana, and secondary surges (Nairn 1979; Rowe et al). Next was the skyfall of mud and stones from Tarawera, Rotomahana and Okaro. Impact trauma to humans and animals was recorded from ballistic projectiles. Nairn recorded surges 6 km from Great Crater. His Red Zone included Rapatu and Te Rata Bays, Waingongongo and Otuapane. In 2001, Lowe reviewed the eruption mortality statistics and extended Nairn’s 6 km base surge Red Zone to 10 km. This now includes Moura, Oneroa Bay, Te Puna, Tawhitinui and possibly Kakanui and Hawaiki.

In 2021, Rowe et al advanced Nairn’s 1979 analysis, reporting:

> At 3.30 am a particularly violent earthquake was felt and witnesses reported that massive dark plumes rose from the Rotomahana/Rotomakariri basin region . . . producing a raining mud from Rotomahana, mixed in with the pyroclasts from the Mt. Tarawera portion of the fissure and a 10–13 km eruption column. . . .
>
> At Rotomahana, a low magma flux... produced large amounts of ejecta. Distribution of that ejecta was primarily by density currents (surges...), with the result that the low-flux end of the eruption produced the greatest human impact. ... Pyroclastic density currents from the Rotomahana segment caused all of the casualties from the eruption...

Rowe et al estimated: “about 20% of the Rotomahana Mud deposit consists of juvenile basalt pyroclasts from Rotomahana, a large proportion of which are dense and blocky ...”

They also provided the first Rotomahana Mud isopachs (ash depth maps), reporting the peak, elliptical zone of ≤ 4 m depth includes Rapatu and Te Rata Bays. Moura and Oneroa Bay lie within their 0.8–1 m isopach. These are average depths as around the crater rim, ejecta ≤ 60m was deposited (Keam 1988). The Rowe et al claim that surges caused all the casualties does not explain fatalities outside the Red Zone. Most Europeans in Wairoa died when buildings collapsed.

3.12. Volcanic degassing produced a lethal, low-lying CO_2–H_2S cloud

There is evidence in the historical record of another unrecorded cause of death— a toxic gas cloud. This includes the eruption timetable, the negative evidence for waterborne escapes, the meteorological conditions, eyewitness accounts of toxic gas, the incidence of group fatalities indoors, dead vermin and the exposures of Moura bodies (*Star* June 17).

The first empirical research into diffuse volcanic gas clouds was published only in 2024 (Viveiros and Silva). In eruptions, CO_2 is often associated with H_2S, cited as the most hazardous eruption gas (Viveiros and Silva, Carfora et al). Volcanic gas inundation is a common proximate cause of death (Auker et al). The absence of evidence for waterborne escape may be explained by the cloud of CO_2 and H_2S gases emitted around Tarawera. There is evidence of toxic levels of these gases in the Rotorua region (Viveiros and Silva). The day

before the eruption, Whatapoho fumarole near Puai had auto-ignited after reaching combustible concentrations of H_2S and/or hydrogen (Massy 21, Bunn 2023c).

A gas cloud including CO_2 and H_2S was emitted before and during the eruption. In Te Wairoa, there were reports of pungent gas— the trademark Rotorua H_2S (rotten egg gas). The geography explains what happened at Moura. The gas cloud was emitted by the shaking and volcanic action south of the Ngutuahi Arm. It blew into it, settled over the water and wafted north into the Moura Narrows. Here, the arm narrowed by 79%, forming a venturi. With friction, a boundary layer formed on the shores, slowing the gas cloud and creating a pocket of toxic gas. This killed the residents. It also intercepted any evacuees from Rapatu and Te Rata Bays and Otuapane. The cloud blew towards the north shore, Tokiniho, Waitangi and Te Wairoa, where it was detected but no longer lethal, three days later when the first boat team had such respiratory distress, that they fashioned masks from their clothes (Warbrick 1934 68). This cloud explains why the survivors were elevated, i.e. at Makatiti and Ruawahia, while the fatalities were nearly all in the south, at lower kainga, i.e. Moura, Piripai, Oneroa and Puai. While taller animals survived, dead rats were everywhere on the surface, a "canary in the coal mine" (*Star* June 14).

3.13. The case of Moura village

The Moura evidence differs from other sites, i.e. Wairoa, Tokiniho, Oneroa and probably Waitangi, where residents sheltered. At Moura, the forensic evidence suggests they assembled outside.

No pre-eruption photographs at Moura are known. Figure 5 shows Moura Point, looking north with Moura village buried. Froude describes Moura as "a Māori farm on the water's edge. There were boats and nets hung up to dry, a maizefield, an orchard and a cabin." (Froude 1886). The < 45 residents needed 10–20 homes.

Fig. 5. The site of the destroyed village of Moura, Tarawera, circa 1887, Dunedin, by Burton Brothers, Frank Coxhead. Te Papa Tongarewa (LS.004507). Taken shortly after the eruption, as the lake rose.

From 1903, bodies were exposed, consistent with escapees being overtaken by toxic gas in the open (*NZ Times*, Keam 1988). Multiple exposures occurred over 1904–1905, when the lake level fell as the eruption dam on the Tarawera River breached (*Herald*, 14 November 1904). The Irish travel writer Beatrice Grimshaw (1870–1953) noted in 1905: "On the shores of the lake ... at one spot, the whitened bones of some of the natives who perished ... The name and titles of one who was a great chief are painted on a rock that overhangs the shore." This would be on the south hillock, with the insignia of Chief Hakaraia Peraniko. The lake fell ~ 4 m after November 1, 1904 from its peak of ~ 303 m a.s.l. (Bell, Hodgson and Nairn). The skeletons were exposed as the lake fell to 298–299 m. This is 7–8 m above its pre-eruption level and indicates the fatalities occurred close to the shoreline (given house sites allowed for lake rise and fall). Gilbert Mair reported the houses were washed into the lake by a mudslide, with three feet of mud cover (*Star* June 17). Warbrick says they were simply buried in mud to 75 feet. Figure 5 has no evidence of a mudslide and the landform indicates a shallow mud cover. Fitzgerald, who scuba-dived at Moura, found tree trunks embedded in the lake floor (cf. the sunken totara forest in Lake Rotomahana), but no houses (Fitzgerald, Bunn 2020). On balance, the residents did not die in their homes or in the lake. I suggest they assembled outside and were deciding whether to *flee or freeze* when overcome by gas, before the Rotomahana eruption (*Star* June 17).

In 1903 and 1904, the bodies were reinterred, hence in 1905, a new group emerged, apparently in the open, i.e. not indoors. At Waitangi, 23 years later, bodies were recovered in a whare with an intact roof (*Herald*, 26 July 1909). In 1932, the frames of seven houses and a meeting house at Tarawera stood through seven feet of ash (*Waikato Times*). Māori homes were robust. If/when further bodies are exposed, they may be found in prone or prone-oblique

positions. The residents would lose consciousness in seconds from gas and collapse. The patient does not suffer, unlike death in a volcanic surge with fractures, burns and scattering.

Interestingly, the eruption also changed the relative surface and bottom elevations of Lakes Tarawera and Rotomahana, enabling backflow through the porous isthmus between the two lakes, with the Kaiwaka Channel forming one rubble drain. This drainage into the crater occurred for a time during 1887–1893, until the Rotomahana level exceeded that of Tarawera and normal waterflow into Tarawera resumed (Bell, Hodgson and Nairn, Bunn 2022).

3.14. Tokiniho and Waitangi Settlements

The 1909 report of 18 Waitangi casualties was checked for confusion with Tokiniho but is likely substantive (*NZ Herald* 1909), (pers. comm. Rangitihi Pene, July 2025). The Tokiniho toll was first 10, then 13 and by Keam 11 (Keam 1988). The Waitangi survivor Kimihia first reported she and husband Te Hoe were in a large house at Waitangi. The roof fell in, her husband died and she fled to Kariri, being rescued on June 15, en route (*Star* June 15). Her claim that she took a left turn along the road meant she was heading for Kariri, not Wairoa. All left turns off Spencer Road go to the lake. Later, she changed her account to her aiming for Wairoa and Te Hoe dying en route (Keam 1988, Smith 2011). She reported that at Waitangi ”nobody was left but herself” (*Star* June 15). In 1909, 18 bodies were found in a whare on a hill near Lake Okareka (*NZ Herald* 1909). The roof was intact, versus the Tokiniho whare’s collapsed roof in 1887. The body count was 18 versus 10–11. The skulls were counted in 1909 giving a more accurate count for multiple skeletons. Waitangi is closer to Lake Okareka than the estimated position of Tokiniho (800 m vs 2,100 m). It was a large settlement that spread over Spencer Road and up the hill towards Lake Okareka. In 1853, the HMS Pandora crew had embarked from Waitangi.

3.15. Ballistic projectiles

The Wairoa eyewitnesses report flaming rocks penetrating homes, igniting fires and injuring residents. This puzzled the author as Te Wairoa is 11–14 km from the Tarawera massif, and the Rotomahana and Okaro vents are 8–10 km away. From Thomas (who also found it remarkable) forward, it has generally been accepted that no molten lava surfaced at Rotomahana, and there were no fresh lava bombs ejected. Finally, Rowe et al confirm that juvenile basalt was ejected from Rotomahana and Okaro as suggested by Nairn in 1979. This helps explain the red-hot rocks falling on Te Wairoa. However, while Te Wairoa is closer to Rotomahana, the distances from Tarawera and Rotomahana are maximal. Taddeucci et al reviewed 28 volcanoes from 17,000 BP– 2014 . Eruptions like Rotomahana-Okaro ejected bombs for < 1 km. Eruptions like Tarawera ejected bombs for 7–10 km, with Vesuvius the only volcano in recorded history to reach 9 km.

Fig. 6. A (wet) lava bomb with gypsum and zeolite inclusions, found in the shallows beside Tarata Peninsula in 2015 (Bunn).

In Figure 6, is a lava bomb the author recovered from the Tarata Peninsula. It would likely be ejected from a nearby vent. To test the likely origin of red-hot bombs falling at Wairoa, I applied the EJECT v. 1.4 ballistic trajectory model developed by Larry Mastin of the United States Geological Service (USGS). In Figure 7, the EJECT model is applied to the Rotomahana-Okaro vents and Te Wairoa elevations with 0·5 m All-Shaped bombs and a velocity of 400 m/s, as advised by Mastin. The maximum range is barely 6·5 km and less with asymmetric or smaller ejecta. For Rotomahana or Okaro projectiles to reach 8–10 km to Wairoa appears unlikely. A tailwind is a possible reason, but the wind rose and blew from the south before strengthening to the southwest, driving the ashfall away from Wairoa (Thomas 61).

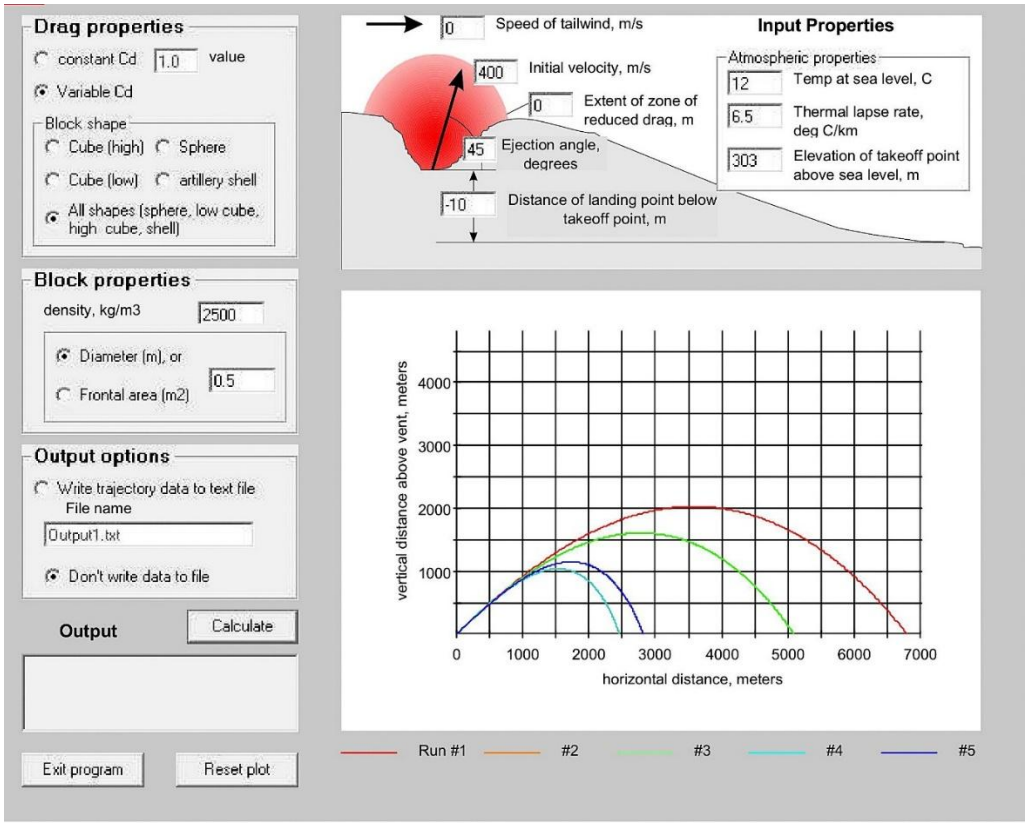

Fig. 7. Mastin's EJECT model for Rotomahana-Okaro vents with All-Shaped ejecta and a maximum velocity of 400 m/s. The maximum range is barely 6·5 km.

In Figure 8, the elevations are for Ruawahia vents to Te Wairoa. Here, the plunging bombs reach ~ 8·5 km, still short of the 11–14 km range from Tarawera. The only vent within range of Te Wairoa is the Black Crater at 8·2 km (Nairn 1979). Perhaps there are undiscovered vents nearer Te Wairoa? Ron Keam advised me he thought the Tarawera Rift extended kilometres southwest of Southern Crater at Waimangu. However, this increases the distance to Te Wairoa (pers. comm. Ron Keam, 15 November 2015).

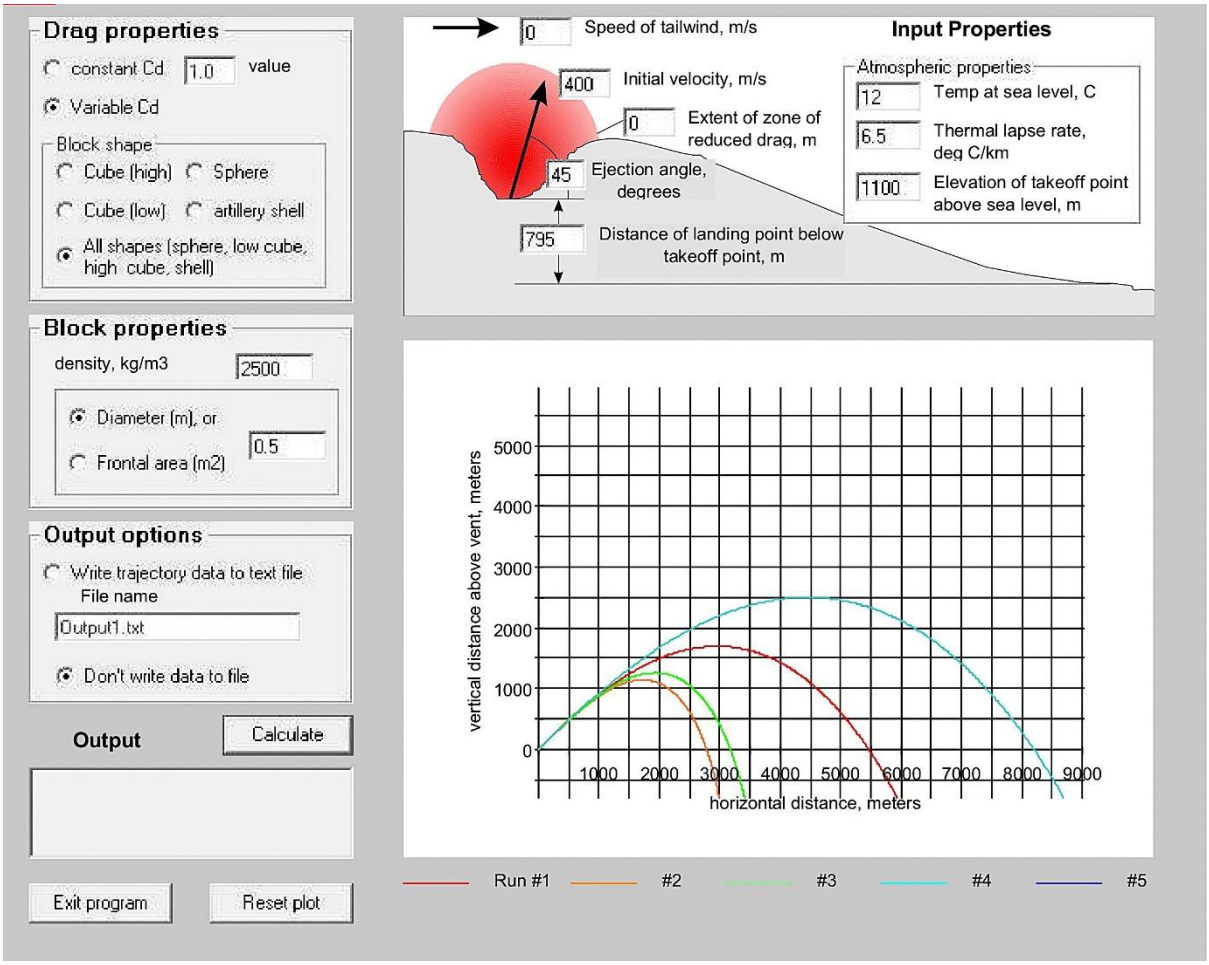

Fig. 8. Mastin's EJECT model for Tarawera Massif vents with All-Shaped ejecta and a maximum velocity of 400 m/s. Maximum range is 8·5 km.

3.16. Logistic analysis

Given that some populations survived while others did not, an investigation of the factors affecting survival was made by logistic regression. The first model runs suggested important variables, i.e. Age, Health, Night Vision, Leadership, Flight or Freeze, Path access, Motivation and Distance to vents. Variables with a negative impact were Reaction time, Group size, and Eruption phase. The beta coefficients pointed to Freeze or Flight, Leadership and Night vision being the most important decisions for survival. Reaction-phase timing and Group size were negative, i.e. delaying a decision and increasing group size militated against survival.

To improve model performance, the variables were reduced to four: distance from Rotomahana vent, Leadership, Path access, and Decision speed. This model suggested that the four factors explained ~ 40% of the survival of successful groups. However, the result was not statistically significant. To increase significance, the variables were reduced to two, i.e. Distance to the Rotomahana vent and Path Access. This model explained 72% of the survivors' success and was statistically significant at p = 0·001.

The beta coefficients together were significant in predicting the survival choice, but neither variable was significant alone. While useful, the analysis is limited by the small dataset. In

this case, it seems intuitively correct that the two most important things in an eruption are to have a path away from it and to obtain as much distance as possible.

3.17. Time and Distance modelling of eruption escape paths

The logistic analysis suggested a focus on paths around the three lakes and the window of opportunity for the settlements. For this analysis, the eruption phase start-times are shown in Table 4. The author places greater weight on eyewitnesses whose employment made them timely, such as the tourism guides and Thomas, who surveyed opinions.

Table 4. The Eruption Phases

Eruption Phase Timelines		
Event	**Start ***	**Notes**
Shaking	**2330 – 0030**	Timings vary by
Wahanga	**0130 – 0140**	observer location.
Ruawahia	**0200 – 0210**	
Tarawera	**0210 – 0230**	
Chasm	**~ 0230**	
Okaro	**~ 0230**	
Rotomahana	**0320 – 0345**	
* Times are expressed in 24-hour notation.		
The major eruptions ended by 0700 – 0800.		

From Table 4, observers close to the eruptions cited earlier quake times, for example, Guide Sophia from ~ 11.35 PM. The gap between shaking and the first eruption gave two Golden Hours for escape decisions. Most disregarded the early shaking and lost precious time. As the shaking intensified, those, for example, on Ruawahia exited before the eruption and survived. The first eruption was Wahanga. There was a second Golden Hour for those at Puai and Waingongongo, until the Chasm and Okaro erupted at the other end of the rift. A third Golden Hour occurred until Rotomahana erupted. Based upon survivor and casualty reports, attempts were made by land and water, such as at Moura. After ~ 3.30 AM, there was no escape from the Red Zone.

Using time and distance estimates along known paths, we can model the elapsed times from those locations. These can be compared with the windows of opportunity, when flight was feasible. While daytime family walking along familiar paths might average 3·5–4·5 km/h, that winter night with poor visibility, shakes and roaring volcanoes, families might average 1·5–2·0 km/h and less during the shaking. Children would panic, adults freeze, and dogs howl. For this analysis, we use an average speed of 1·0 km/h. An example of the run North from Puai, on foot to Te Wairoa, is in Table 5. Kumete Ridge could be reached, only to be overtaken by the Rotomahana base surges.

Table 5. Time and Distance study for those on Puai and Pukura islets.

		Escape Routes from Puai Islet 10 June 1886									
Start Location	Route	Waypoint	Meters	Method	Speed km/h	Transit Time mins.	Cumulative Distance m.	Cumulative Time mins.	Destination	Possible Success	Km to Locus
Puai	Shore	Tekapo	257	Canoe	3	5	257	5	Shore	Possible	0·8
Tekapo	Path	Ngawhana	173	Foot	2	7	430	12	Huts	Possible	0·6
Ngawhana	Path	Cave	175	Foot	2	7	605	19	Shelter	Possible	0·4
Ngawhana cave	Path	Hilltop	135	Foot	2	4	740	23	Eruption view	Possible	0·3
Return to Cave	Path	Cave	135	Foot	2	4	875	27	Cave	Possible	n/a
Discussion		Cave	0			10	875	37	Cave	Possible	n/a
Cave-Tekapo	Path	Tekapo	438	Foot	2	18	1,313	55	Path to North	Possible	0·6
Tekapo-Kaiwaka	Path	Terrace	1,025	Foot	2	41	2,338	96	Poroporo crossing	Possible	1·2
Kaiwaka-Saddle	Path		2,280	Foot	2	96	4,618	191	Kumete Saddle	Unlikely	3·1

For those taking to canoes, there were also hazards. The quakes would create seiches, which swamped the dugout canoes designed for calm waters. Lake Tarawera is 11 km long, and wind-waves reach hazardous heights along the fetch. On the night, the canoes were overloaded with terrified families who would lie down to cut the risk of capsize. It was usual for passengers to bail in rough weather. A canoe might reach ~ 5 km/h, but if shipping water and overloaded, we use a realised speed of 3 km/h. This is still three times that of foot-travel and would encourage the use of canoes despite the seiches and ballistic projectile risk. At Wairoa, bodies were exhumed along the roads after fleeing folk were felled by projectiles. However, there are no reports of empty canoes drifting in mid-lake after the eruption, nor of canoes reaching Te Wairoa on June 10.

After 15 time and distance simulations from key locations, providing families fled during one of the Golden Hours, they could make several kilometres before the Rotomahana surges. By canoe from Oneroa to Punaromia was promising, but no one returned on this route. They elected to stay. No one from Moura survived. The best strategy was to quickly exit Waingongongo and run southeast for Te Whaiti via Ash Pit Rd on Lake Rerewhakaaitu. We know at least one undocumented Māori person survived, and I suggest he or she took this route (Moore 130).

4.0. Discussion

Calculating the Māori survivors and death toll is complicated by the ambiguity over locations. Te Ariki was the colloquial Māori name for the Ngutuahi Arm of Lake Tarawera. The maps of Smith and Hochstetter support this. Photographs are often labelled Te Ariki. For example, Figure A5 is labelled “Te Ariki, Head of the Lake”. From this research, there was no single kainga called Te Ariki. The literature records that the major Māori eruption casualties occurred at Te Ariki (27–52 deaths). Te Ariki became the collective term for Kokotaia pa, Piripai and Ngawhiro in Rapatu Bay, Waingongongo and probably the kainga in Te Rata Bay. This research suggests that the cluster at Oneroa was separate. The uncertainty led to understatement of the death toll.

Two settlements around the Ngutuahi Arm were renamed Piripai, in Rapatu Bay and Te Rata Bay. In Rapatu Bay, there are different locations. In Te Rata Bay, there is Hochstetter’s location, but no NZAA record. In Oneroa Bay, there is corroborating NZAA garden data and a matching coastline, but poor topography. On balance, and with the inclusion of Ken Phillips' records and Taylor’s sketch, the placename Piripai1 lies in Rapatu Bay. If so, that leaves an undocumented Piripai2 in Te Rata Bay, and Totarariki and Matakana

undocumented along Oneroa Bay. No survivors are reported from these bays. From this research, Oneroa Bay had the third largest loss of life.

It is possible that some Te Ariki photographs are of gardens along Oneroa Bay. The paucity of homes may reflect seasonal occupation. Given Māori proclivity for naming landforms and features, multiple gardens would be named. Watt states the four Oneroa Bay gardens lie near Oneroa. Figures A4 and A5 may show Totarariki and a Piripai. Future archaeological investigation should be made here and at Te Rata Bay.

For groups who froze in their homes, it proved successful only in Te Wairoa and Makatiti. At Wairoa, two Māori buildings with steep-pitched roofs, some smaller residences and a hen-house shed the ash. One damaged hotel survived. Barnard notes that

> Te Wairoa received ~ 80 cm of ash and mud ... with drifts of over 2 Metres ... [and] If 30 cm of ash falls on Rotorua or Kawerau, many buildings will collapse under the load of ash. The 4 kPa standard that most roofs are built to, will be equal to about 250 mm of dry tephra, or 200 mm of saturated tephra...

The only possible survival in the Red Zone during the surges would have been in caves. Chief Rangiheuea's party had that option at Ngawhana.

5.0. Conclusion

While most lake settlements are unexcavated, it appears many Māori residents froze at home and died. Flight offered a better chance in the Red Zone and beyond it from vulnerable homes, as Chief Wi Te Kepa Rangipūawhe decided. The two Māori buildings at Wairoa prevented greater fatalities.

The investigation into survivors of the 1886 Tarawera eruption is best undertaken now. The lack of online data hindered past investigators. Before the advent of Hochstetter's survey, there were no reliable spatial data or survey bearings for the Tarawera, Rotomahana or Rotomakariri settlements. Despite generations of geology research, knowledge of the eruption process at Rotomahana was incomplete until 2021 (Rowe et al). The impact of gas emissions was largely overlooked. With these innovations and the NZAA reports of Watt, Moore and Phillips, the Tarawera demographic challenge becomes soluble. The improved understanding of Te Ariki is central. The focus on Te Rata Bay and Oneroa Bay solves demographic questions over Totarariki and Matakana casualties. A similar focus from the author's Okareka home addresses Tokiniho and Waitangi casualties. The logistic regression was handicapped by the small dataset, but indicated key survival variables. This enabled the Time and Distance modelling that helped explain why (apart from Ruawahia), no survivors from within the Red Zone are reported. At least one did survive, possibly from Waingongongo. It is likely that in pursuing a casualty list, Type II statistical errors occurred— casualties were omitted if a name was in doubt. The Oneroa Bay-Totarariki-Matakana and Tokiniho-Waitangi findings and this review increase the casualty list to 172 Māori persons with an upside. Those who froze, if given their time over, would likely choose flight.

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Appendix A The Location of Te Ariki

A1.0. Te Ariki

Te Ariki requires accurate placement as the location with the greatest fatalities. The name is confused in the historical record. Hochstetter was given Te Ariki as the name of the Ngutuahi Arm. On his return to Te Mu by canoe, he commented that the Kaiwaka [Channel] “... empties into the South-East cove of the lake, called Te Ariki, which is very picturesquely surrounded by steep, rocky shores. Near the Pah Moura, on a peninsula stretching far into the lake, the river turns into the great lake… ” (Hochstetter 420). Hochstetter saw Te Ariki as a river— another term for the Ngutuahi Arm. Navigating the Ngutuahi Arm today, it is easy to share this impression. Hochstetter also commented on changes to the settlement names: “At the shore of the lake there are various Māori settlements, the original names of which... were changed into biblical appellations, such as Ruakeria into Kariri (Galilee), Te Ariki into Piripai (Philippi).” (406). He placed Piripai in the Te Ariki arm on Te Rata Bay.

A1.1. Te Ariki, a lake arm

In 1858, Smith mapped the Te Ariki river or arm as the Ngutuahi Arm. Akutina Rangiheuea described it as Te Ariki for Hochstetter in 1859. From his Observation Station 21 at Lake Rotomahana, Hochstetter took a bearing on the westernmost point on Lake Tarawera below the Tarawera Massif. His diary entry for this is “*Nördliche Ecke am schmalen Eingang der Te Arikibucht des Tarawerasees 3° 10’*.” Sascha Nolden transcribes and translates this as [Northern corner at the narrow entrance of the Te Ariki Bay of Lake Tarawera]. This unnamed point is opposite Moura Point, and explains how Hochstetter was shown the Moura Narrows as the mouth of Te Ariki Bay (aka the Ngutuahi Arm).

He also took bearings from Station 20 on other landmarks, as well as lake settlements. Among these were Ruaoumukeria, Otangimoana Bucht, Otamatea Settl., Oneroa Settl., Moura Pt., Pukekiore Pt., and Ohume Landungsplatz. These are plotted to provide coordinates for the settlements in Table 1.

Tourists, photographers and historians cemented the misconception, as tourists disembarked their canoes at several sites, depending on the weather, the Rotomahana level, their pedestrian fitness, the Kaiwaka Channel (when shallow, it was unnavigable), food availability from settlements en route, or for the guide’s convenience (Bunn 2023b). Any of these places could be termed as being on Te Ariki Bay. Ron Keam (1932–2019) commented on “ … the rather indiscriminate use of the term ‘Te Ariki' to cover Waingongongo as well as Te Ariki proper.” (Keam 1988, 243). The finest late description of the Terraces is by James Froude (1818–

1894) in 1885, with the best description of the Kaiwaka Stream descent and Moura, but his Guide Kate unfortunately did not advise him of the names in Rapatu Bay.

Warbrick describes Te Ariki: "pushing along for another two miles [it is two miles from Moura Point to Rapatu Bay] we reach the Ngutuahi or Te Ariki Arm, a long bay of the lake … Te Ariki village, a kainga and notable fortified pa in old times, once stood here on the water-edge." (Warbrick 109). To Warbrick, Te Ariki was the name of the arm, the kainga and the pa. This matches Hochstetter's map showing the pa was called Kokotaia and it stood on the water's edge.

A1.1.1. Te Ariki as Piripai in Rapatu Bay

From the earliest tourist accounts, they disembarked in the Te Ariki arm at a village, one that by 1849 was renamed Piripai. The Rev. Seymour Spencer (1812–1898) arrived at Te Wairoa in 1848. The Philippi name was current by 1849, when Rev. Richard Taylor (1805–1873) sketched Figure A1, from Rapatu Bay, entitled *Piripai, Tarawera, Lake, Mar, 15, 1849*.

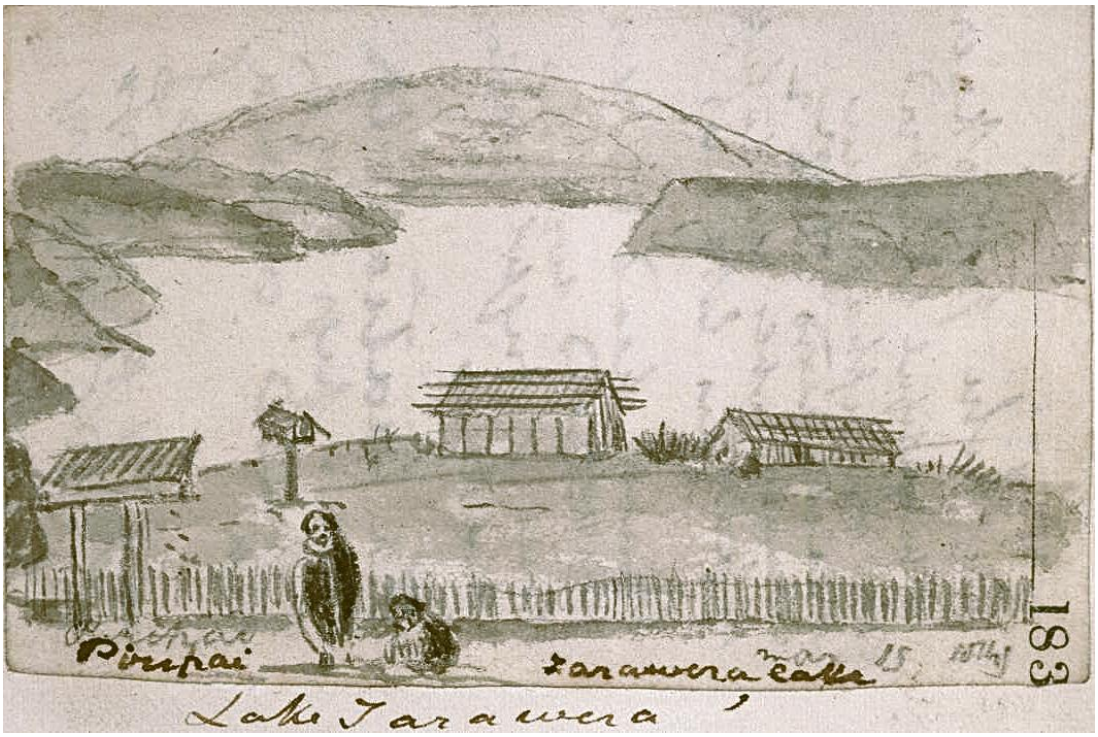

Fig. A1. Piripai, Tarawera Lake in 1849 by Richard Taylor (Alexander Turnbull Library, E-296-q-015-1).

Taylor's background shows the Whakapoungakau Range and the midground from Rapatu Bay, with the entry into the Te Ariki Arm at Moura Point on the left. The village is on a point with two dwellings showing, a *whata* (drying rack for inanga) and a pātaka-pou (storehouse). These place the site today above the centre of Rapatu Bay, with Kokotaia and Ngawhiro lying to the east.

Sir George Grey (1812–1898) visited in 1849 and recorded the names:

> … a settlement called Te Ariki or Piripai (Philippi), situated at the extremity of a long creek or arm of the lake called Ngutuahi … The creek of Ngutuahi widens out into a sort of small lake after a short distance, at the extremity of which is the

> settlement of Te Ariki … The ascent to it is very steep, and on the side of the hill … the Governor, Mr. Chapman and I walked over to Roto Mahana, which is situated at a distance of about a mile …" (216–18).

This implies Rapatu Bay as they walked up the Kaiwaka Channel. Like Hochstetter, Grey referred to the Ngutuahi Arm as a creek.

The tourist canoes might put ashore in Rapatu Bay, and according to Watt et al, two kainga: Ngawhiro and Te Ariki (aka Piripai and/or Philippi). Figure A1 suggests Piripai lies above the centre of today's Rapatu Bay, allowing for eruption and lake level changes. Kokotaia and Ngawhiro would then lie in the eastern bay in Figure A2. Hochstetter mapped Kokotaia Pah in this bay.

In Figure A2, the pre-eruption Rapatu Bay shoreline contains two points, forming a pair of inlets.

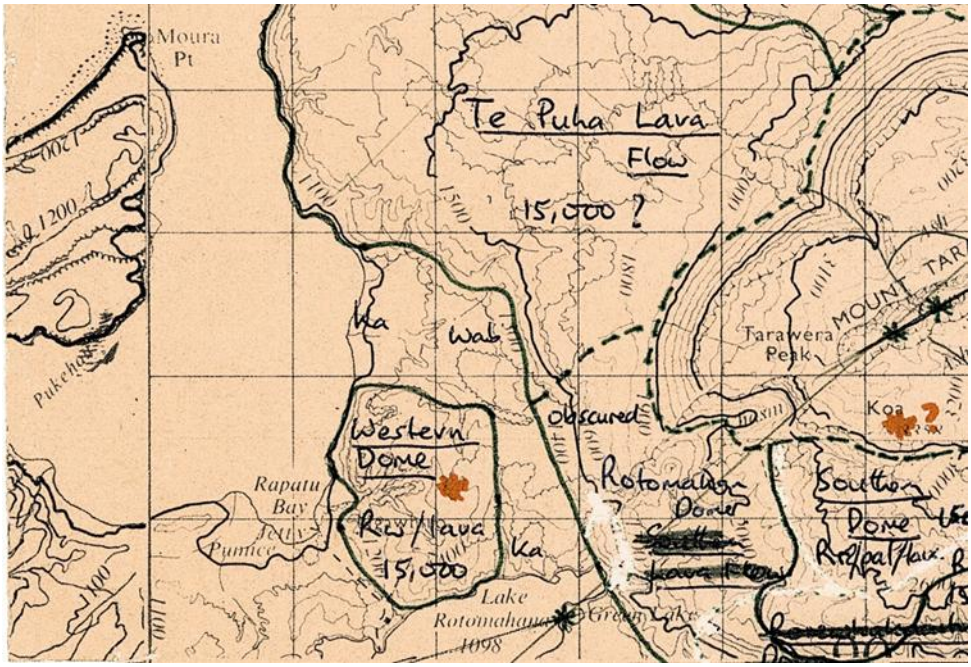

Fig. A2. Showing Rapatu Bay with the original shoreline sketched, and two points projecting into the bay. I.A. 1989. Geological map of New Zealand 1:50,000 Sheet V16 AC Mount Tarawera. 1st ed. Lower Hutt: New Zealand Geological Survey.

https://geodata.nz/geonetwork/srv/api/records/f13ebed4-8eae-4292-9d0b-742255866c98

In Figure A3, Hochstetter mapped two inlets in Rapatu Bay with Kokotaia in the eastern inlet. This contrasts with the NZAA record. The bay was reshaped by the eruption.

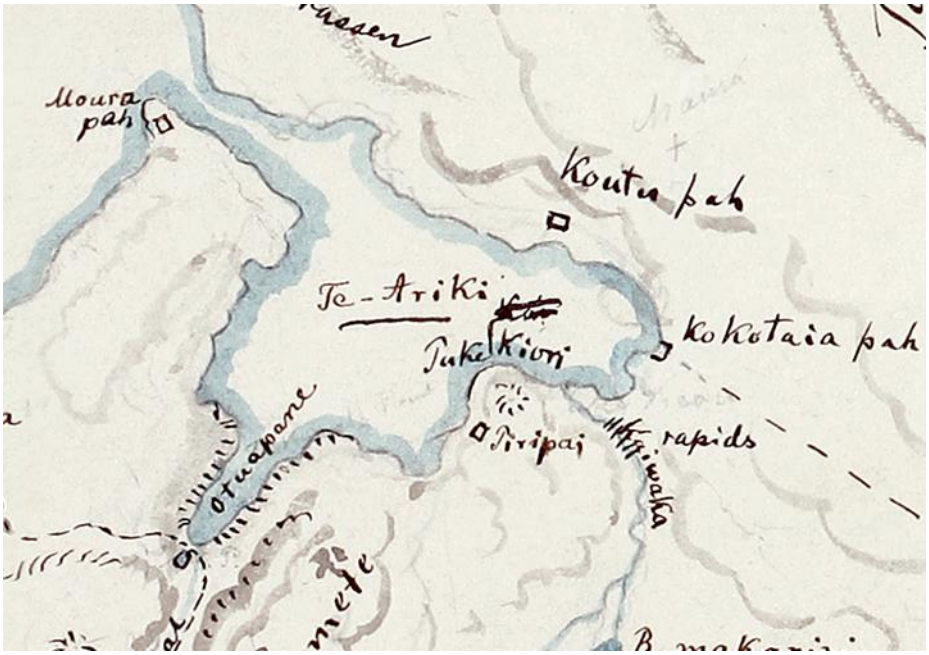

Fig. A3. Hochstetter's map of Rapatu Bay showing Kokotaia in the eastern inlet with Piripai in Te Rata Bay. Ngawhiro is unmarked but was east of Kokotaia according to NZAA (From: S. Nolden & S. B. Nolden, *Hochstetter Collection Basel: Part 3 – New Zealand maps and sketches*, Auckland: Mente Corde Manu, HCB 3.5.6 (detail)).

A1.1.2. Te Ariki in Te Rata Bay?

Dieffenbach, in 1841, was probably the first trained Western observer in the area. He reports staying in a small bay and bathing in a warm rock pool. He climbed the ridge and took a bearing on a small lake at "south 60°east" (120°) with the two lakes of Lake Rotomakariri. We add 14° declination for a 134° azimuth. From the Wairua Stream, this bearing bisects Lakes Rerewhakaaitu and Rotomakariri/Rangarua. Taking the reciprocal of 314°, his location lay above the Wairua exit and was Otuapane in Te Rata Bay (Dieffenbach 385).

In November 1853, the crew of HMS Pandora visited. Lt Jones reported they

> ... Left Waitangi at 9AM paddled across Lake Tarawera- our natives sang the whole way. Peripi [Piripai ARB] just before midnight. There are hot pools there, into which our natives plunged. Next day, walked across the portage to Lake Rotomahana, where the party stayed for two days.

This implies that Peripi lay in Te Rata Bay with the portage across the low ridge above the settlement (but it could imply Rapatu Bay).

Smith in 1858 also reported a kainga in Te Rata Bay. Smith labelled Hakaipari as the western Ngutuahi Arm and included two sites Hochstetter missed, Pukekiore Pah, above the Kaiwaka Channel exit and a kainga in western Te Rata Bay. The NZAA record identifies Hakaipari as an island pa at Otuapane. There is no sign in bathymetry. It lies under ash eroding down the Wairua Stream.

A year later, Hochstetter also reported a kainga in Te Rata Bay named Piripai. His 1859 mapping was assisted by Rev. Spencer over April 31–May 2 as "… heavy rain held him at Te Mu for two more days". According to Nolden, "…Taking advantage of Spencer's knowledge

of the district, Hochstetter spent the next two days completing his maps ...” Such a sojourn with a local expert must have contributed to Hochstetter’s mapping (Bunn 2020, 31). Rev. Spencer would know of the name change to Piripai, but we do not know whether he saw this map entry. If he did, and it was an error, he would correct it.

The author flyfished Te Rata Bay with Cliff Soanes of Rotorua Anglers Association, and he reported a kainga on the ridge. The NZAA log only Pukekiore Hill in Te Rata Bay. Smith mapped Pukekiore Pa in Rapatu Bay. The traditional landowners do not record a Te Rata Bay kainga (Te Arawa Lakes Trust). A kainga in Te Rata Bay was ~ 1 km from the White Terrace (as the crow flies). The Rapatu Bay settlements were ~ 2 km. Guides and tourists would prefer the shorter walk. The Te Rata Bay and Rapatu Bay kainga were probably referred to as Te Ariki. One or both were later termed Piripai.

Between 1859 and 1886, there were no large-scale maps of Rapatu and Te Rata Bays. In 1886, Smith showed Te Ariki west of Pukekiore Hill in one map and west of Rapatu Bay in another, with Ngawhiro in Rapatu Bay. That year, Edward Weller (1819 – 1884) showed Te Ariki beside Pukekiore Hill. In 1887, Algernon Thomas (1857–1937) placed it there. Alfred Warbrick showed it at the bottom of the Ngutuahi Arm. Later researchers followed the 1886 maps.

The traditional landowners relied on the NZAA for sites in Rapatu and Te Rata Bays (Te Arawa Lakes Trust 2016). These rely on Watt and often do not specify locations.

In 2001, Ken Phillips completed the report “Archaeological Survey Tarawera & Waimangu Scenic Reserves.” This includes Te Ariki, with the Māori history concurring that Te Ariki was near Kokotaia, which was abandoned in c. 1855. On balance, the evidence favours Ngawhiro being Te Ariki.

Phillips notes John Johnson (c. 1794–1848) in 1847, describing Te Ariki:

> A few poor huts lying on a narrow strip of land beneath an imposing basalt precipice and on the plateau above formed the settlement of Te Ariki. This latter spot had been selected from having the double advantage of a shelving pebbly shore, where canoes could be beached ... and a wai ariki or hot bath ...

This favours eastern Rapatu Bay.

Note: Every Te Ariki site has an eruption landform change. The ejecta depth is said to be ~ 9–12 m while the lake level is 6–8 m higher. To an extent, one cancels the other.

Given that the period mapping is inconclusive and tourist diaries equivocal, after 1859, we turn to photography. Alfred Burton (1859–1932), William Crawford (1844–1915) and Charles Spencer (c. 1856–1913) exposed Te Ariki views.

Watt (and Moore) relied on a Spencer photograph in Figure A4. The author, a diagnostic radiographer, also interpreted this print. The field of view is narrow, implying a long focal-length lens, rather than a cropped negative. The ridge looks stacked. The foreground and midground imply tilt. The people are on swampy ground, which was inundated when the lake rose. Across the water are a kainga and a large garden, where the layout matches Figure A6 and other photographs (Te Papa photographs 048755, 0.000969/02, 010293, 042284).

Fig. A4. Te Ariki destroyed 10th June 1886 by a volcanic eruption of Mount (Alexander Turnbull Library 1/2-139861-F).

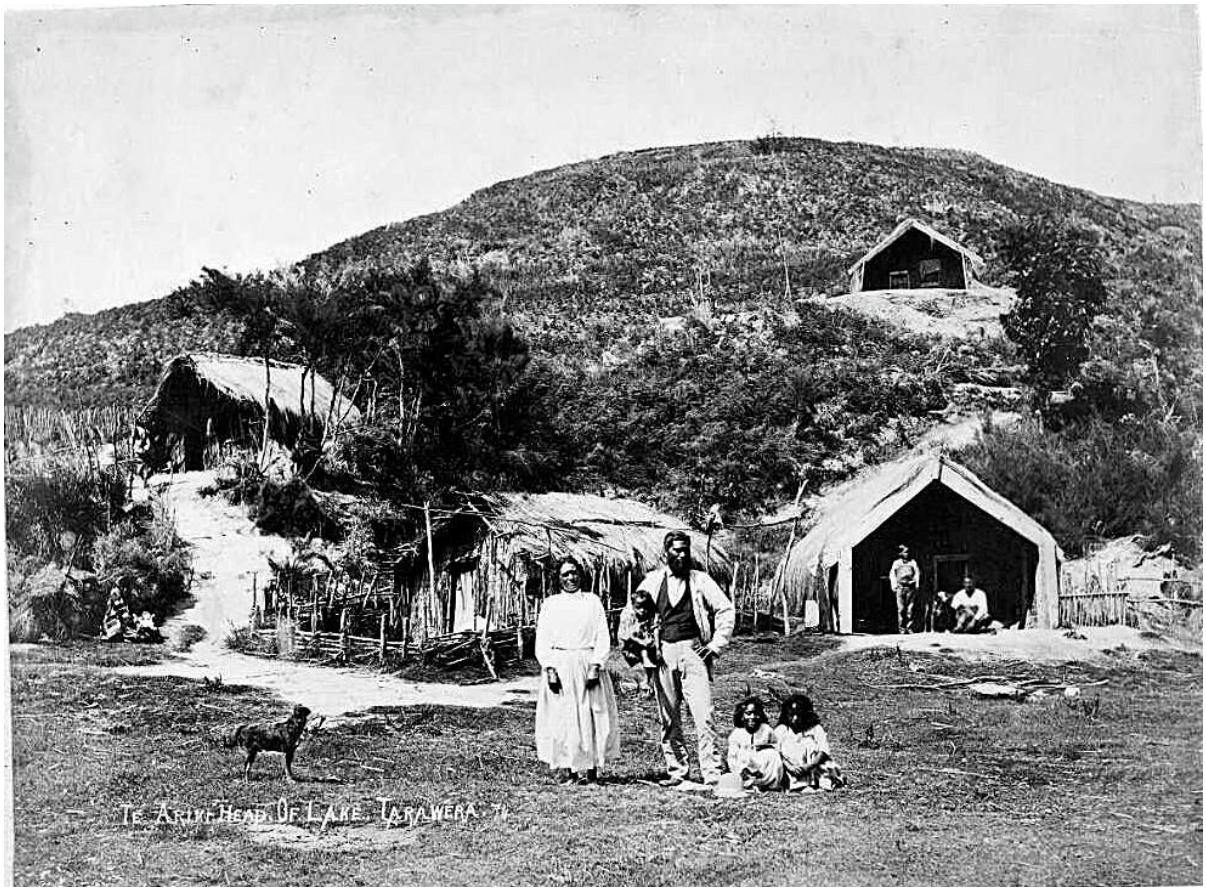

Fig. A5. Te Ariki, Head Of Lake. Tarawera. The Te Keu family (Alexander Turnbull Library 1/2-037815-F).

In Figures A4 and A5, the ridge above the homes can be compared with a geographic visualisation tool, i.e., Google Earth Pro. In Figure A6, the ridge above Hot Water Beach in Te Rata Bay gives a reasonable match to Figures A4 and A5.

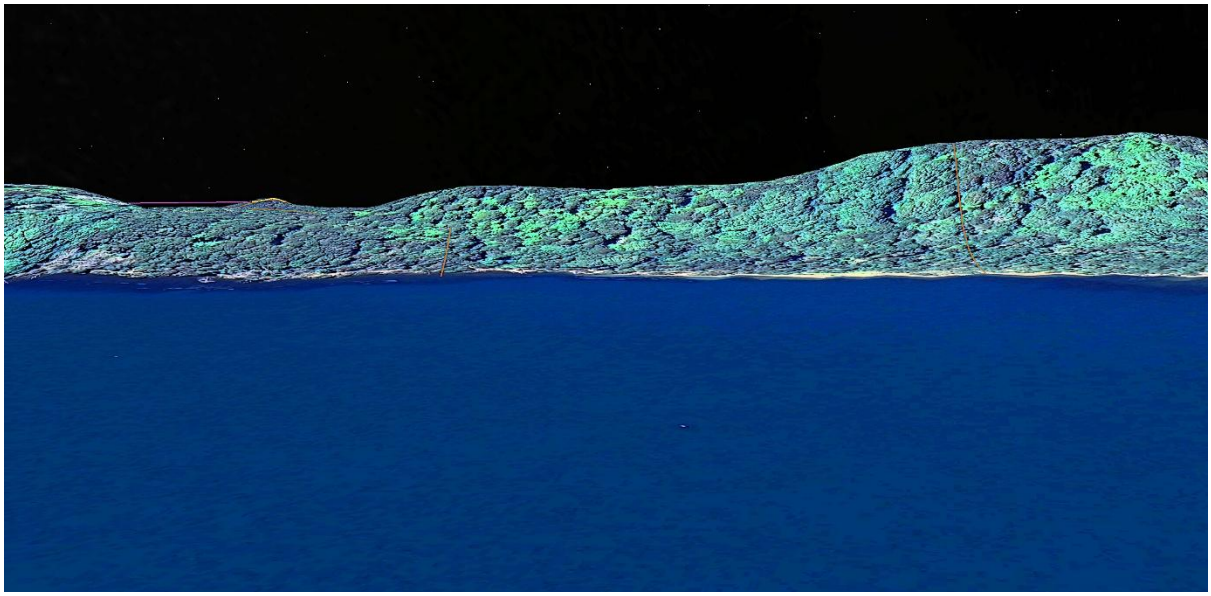

Fig. A6. Possible Kainga Location matching Ridge above Te Rata Bay (Google Earth/Bunn).

Figures A7 and A8 are a similar view across Rapatu Bay. Figure A8 has a similar background to Figure A4. If it is Te Rata Bay, the camera would be on an islet. If Figure A5 is Rapatu Bay, the camera is below Pukekiore Hill. Across the bay is a point. This is more consistent with Rapatu Bay. If Figures A4 and A5 are Kokotaia in Rapatu Bay, Ngawhiro should show to the east. It does not. Thus, the Rapatu Piripai site appears inconsistent with NZAA records, and this kainga may not be Piripai, at least not the Piripai in Rapatu Bay.

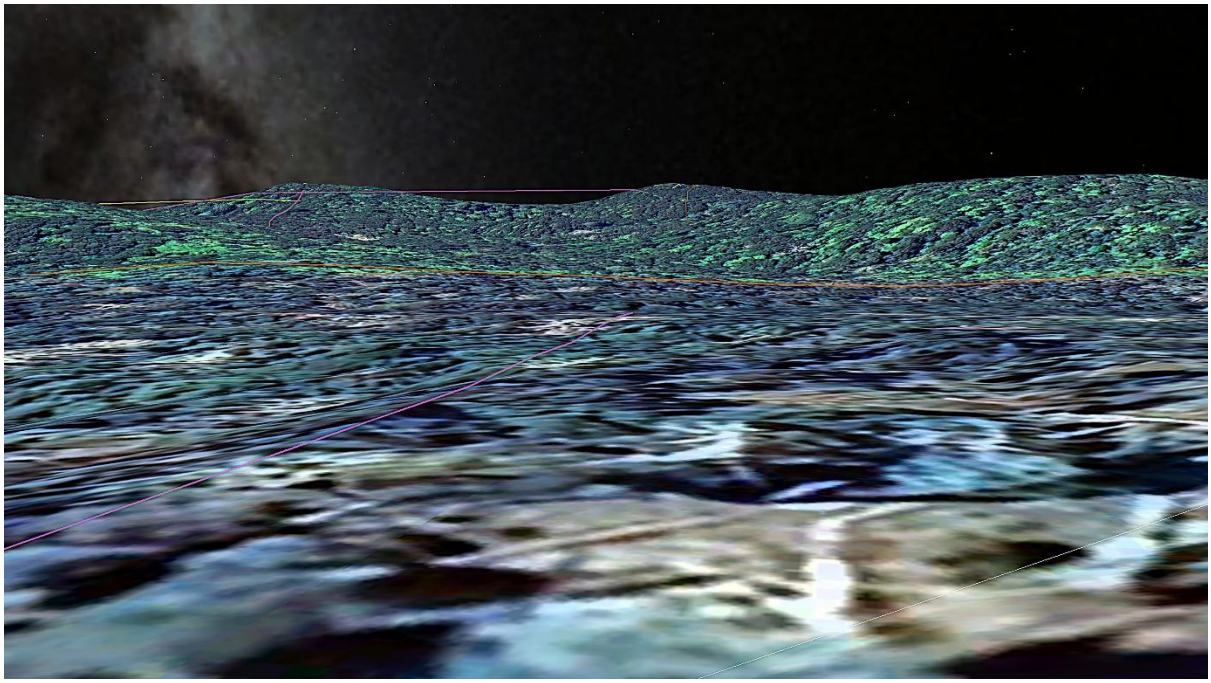

Fig. A7. Possible Kainga Location and perspective at western Rapatu Bay (Google Earth/Bunn).

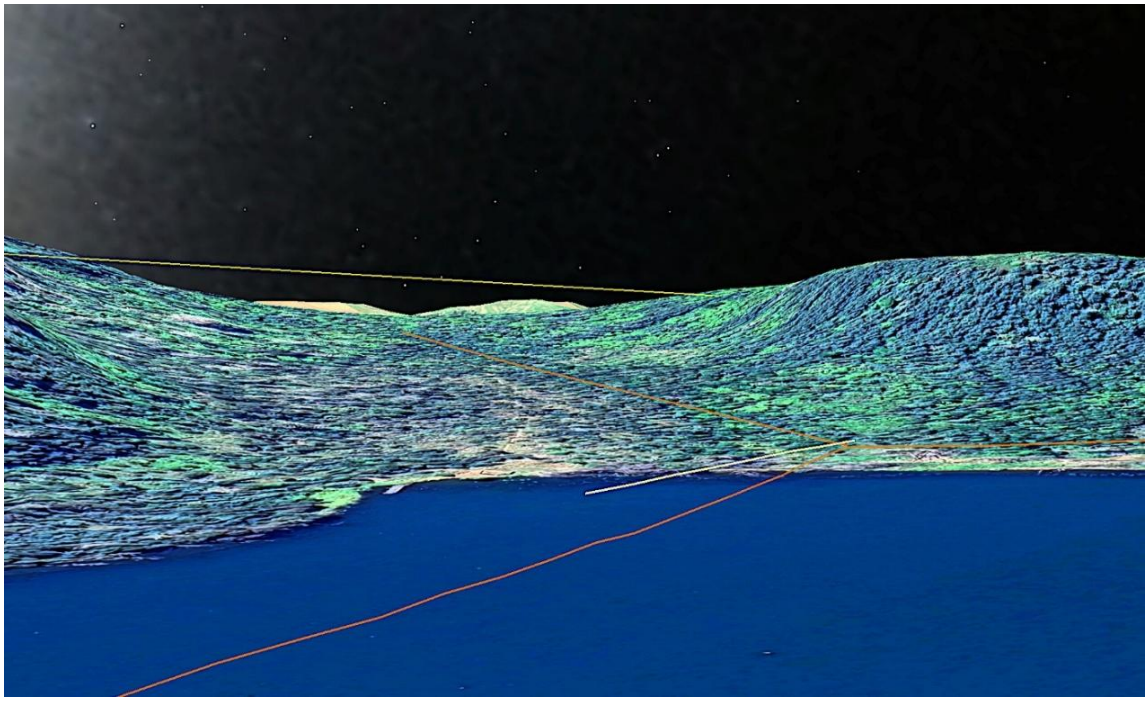

Fig. A8. Possible Kainga locations looking south into Rapatu Bay (Google Earth/Bunn).

A1.1.3. Te Ariki in Oneroa Bay?

Given that Oneroa Bay could represent the Head of the Lake, we consider Oneroa Bay as a site for Te Ariki. In Figure A9, four navigation points match the features in Figures A4 and A5.

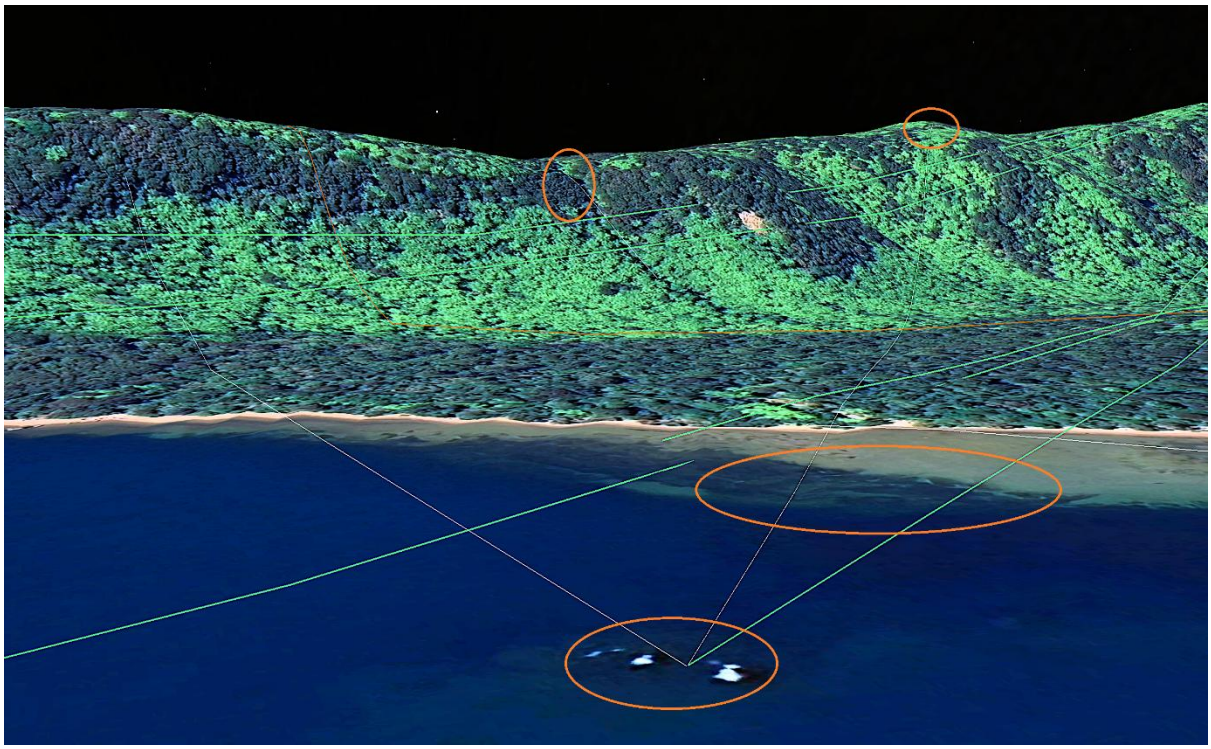

Fig. A9. The possible Piripai location in Oneroa Bay looking south from the Te Kauae pa shoal, showing features matching Figure A4. (Google Earth/Bunn).

These are outlined and include a submerged point, with Oneroa settlement to its south. The shoal is Te Kauae pa. The ridge watercourse exits near the village. The circled peak and skyline match Figure A4. However, the ridge elevation is too high, and Piripai is not here.

On a balance of probabilities a settlement in Rapatu Bay, one of several colloquially known as Te Ariki, and later known as Piripai; is the Māori centre with the greatest eruption mortality. For this reason, in the period eruption statistics, mortality at Piripai, Puai Is. and Waingongongo was sometimes aggregated.

Within Rapatu Bay, the accepted location during the 20th century came to be on the true right bank of the Kaiwaka at its exit. This was an invention by Keam, possibly based upon a misinterpretation of Figure A4 (Keam 1988). Such a location was improbable for reasons the author provided to the Tūhourangi Tribal Authority in 2017.

a) “Soft ground- The alleged location of a Te Ariki village location was on a low-sloping river delta. The ground would be soft and unstable.

b) Wet ground- The ground would often be wet or inundated as the lake level rose and fell.

c) Mosquitos- Tourist reports cite the Kaiwaka Channel as home to a vicious breed of mosquitos attacking tourists as they boated up and down the channel. These were probably sandflies and/or mosquitoes but these would also have afflicted any Tūhourangi village residents on the Kaiwaka Channel exit.

d) Solar angles- A village location under Pukekiore Hill would at some times of the year be late to get morning sun and/or lose it early. The Tūhourangi gardening committee would have argued for their food garden to be beside the village for security and ease of access, but also on a site with maximum solar exposure, to extend the growing season and maximize crop yields. Putting it under Pukekiore Hill makes no sense to a gardener.

e) Proximity to shore- The Tūhourangi villages for which we have photographic evidence i.e. Kokotaia and Piripai, show houses well back from the shoreline. I think this is for at least two reasons i.e. maximum solar exposure and dry feet when the lake rose and fell.

f) Poor road access- Kokotaia was conveniently positioned on the road from Rerewhakaaitu. This would deliver better communications and trade etc.” (pers. comm. Rex Bunn: Alan Skipwith and Rangitihi Pene, August 2017).
https://www.researchgate.net/publication/360560179_A_Note_on_Te_Ariki

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