Location of Te Wahitapu Stream and other possible streams in 1877

30 April 2009

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Dr Willem de Lange
Department of Earth & Ocean Sciences

Introduction

I am a Senior Lecturer in the Department of Earth and Ocean Sciences, and my research interests deal mostly with coastal processes and natural hazards; in particular tsunami hazard.

I was asked to establish, with as much confidence as is possible, the path of Te Wahitapu Stream in 1877. I was also asked to consider the possibility that:

- Other streams may have been present on or in the vicinity of Te Wahitapu Stream in 1877;
- The 1877 or later Tsunami may have altered the course of the boundary stream.

This report will consist of the following sections:

- A review of the findings of previous studies.
- A brief summary of prehistoric and historic tsunami events affecting the coast around Matapouri and the possibility of other streams discharging the northern end of Matapouri Beach.
- An assessment of the location of Te Wahitapu Stream since 1877
- Conclusions and recommendations.

Previous studies

Four previous studies were provided for review:

- Brook (1999) – Summary of geology and geomorphology of Matapouri Beach, with short discussion of paths followed by Te Wahitapu Stream.
- Coffey Consultants (2008) – A revised report discussing geophysical surveys involving resistivity and seismic reflection data obtained for a portion of Matapouri Beach.
- Riley Consultants (2008a) – A review of the Coffey Consultants (2008) report, which also presents some results of auger data collected within the area surveyed by Coffey Consultants.
- Riley Consultants (2008b) – A further report summarising more field data collection at Matapouri by Riley Consultants and Dr Brook.

All reports appear to be in agreement about the basic geology of Matapouri Beach, which consists of steeplands on Torlesse Greywacke, and lowlands consisting of a variety of Holocene sedimentary deposits. The main features of the lowlands are a sequence of shore parallel dune ridges at the coast that merge into a belt of hummocky predominantly sandy terrain, and eventually into swampy estuarine deposits closer to the steepland. On visiting the site in April 2008, it was found that there are also colluvial fans at the base of the steeplands.

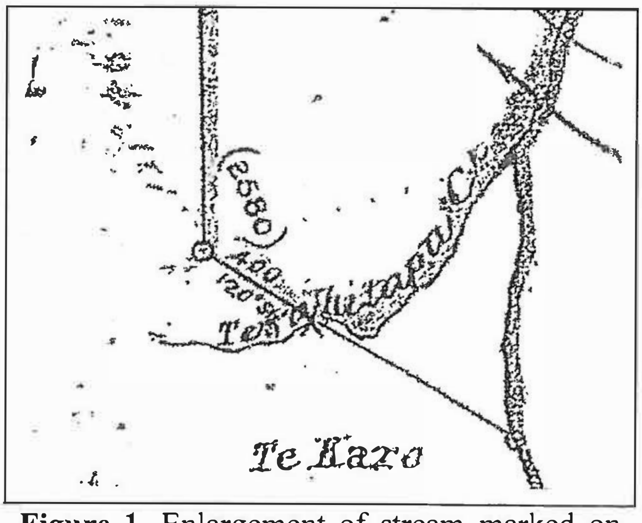

Figure 1. Enlargement of stream marked on ML3903, which I read as Te Wahitapu C^k.

The lowlands are largely developed, and as part of the development of the area the stream channels have been straightened and deepened in the lowest swampy areas.

The Coffey Consultants (2008) report concentrates on geophysical data collected from a small area of Matapouri Beach immediately south of a greywacke stack (Whiritoa) and thought to have previously been occupied by a channel referred to as Terahitapu Creek (as depicted on ML3903). The document referred to is unclear (Figure 1): however, I read the stream name as "Te Wahitapu C^{k}". The other reports only refer to Te Wahitapu Stream, and I assume all three names refer to the same feature, as I cannot find any evidence of two separate streams with different names in close proximity.

Both geophysical techniques used do not work well in undifferentiated materials. Resistivity measurements require variations in conductivity, which in relatively free draining material is normally associated with the position of the water table. It is possible that a former stream channel may be infilled by silt-sized and/or organic sediment that can affect both the location of the local water table and the conductivity of the groundwater. During a site visit in April 2009, there was no convincing evidence in the present Te Wahitapu Stream channel to indicate that such sediment is likely to have been deposited in the vicinity of dunes in the past. The auger data referred to in all reports also indicate that there is unlikely to be suitable material to show the presence of channel infill in the resistivity data.

Zone A of the resistivity data was inferred to represent "poorly consolidated, relatively permeable, saturated sediments, containing freshwater". However, the augur data showed no saturation in the upper 5 m of the profile, which had a maximum depth of around 6 m. Zone B was inferred to represent "highly mobile, conductive salt-water saturated beach sediments", yet Figure 6 of Coffey Consultants (2008) places this zone within the seaward margin of the dunes. It is probable that the resistivity data represent the depth to the water table, and do not indicate stratigraphic relationships.

Seismic reflection measurements rely on density changes, and work best if there are sharp discontinuities in the density profiles. This is most likely to detect coarser material, or layers that are more consolidated. Auger data reported by Riley Consultants (2008a & b) indicate that there are paleosols present, as well as layers of shell or gravel, that may act as reflectors of seismic energy. The auger data reported by Coffey Consultants do not indicate the presence of any stratigraphic units. It is probable that the seismic data represents relatively continuous paleosols and intermittent thin coarse lenses. The vertical exaggerations in the diagrams distort the stratigraphic layers, suggesting a broad U shape. Such a channel shape is not consistent with the current Te Wahitapu Stream, which has a narrow incised channel.

Coffey Consultants (2008) conclude that the geophysical data are consistent with the presence of a buried channel associated with Terahitapu Creek. However, this interpretation is not supported by ground-truth data included in the report.

The other three reports are consistent in arguing that there is no evidence of a former stream channel. The earliest report (Brook 1999) summarises the geology and argues that Te Wahitapu stream has not flowed south of Whitiroa based on two main lines of evidence:

- There is no evidence of a meandering stream channel across the lowlands leading to the proposed discharge region south of Whitiroa.
- The inner, oldest dunes form a continuous deposit containing prehistoric Maori midden material. The lack of any obvious break indicates that no breaches have occurred during the last 130 years.

Figure 1 of the Brook (1999) report was missing from the copy I viewed. However, the descriptions in the report tallied with features viewed during the site visit in April 2009. I also undertook a stereoscopic examination of a pair of aerial photographs of Matapouri taken in 1942. Figure 2 is an enlargement of photo 404/18 for the area occupied by the Te Wahitapu Stream at the northern end of Matapouri Beach in 1942. The stream has obviously been straightened inland to improve drainage. However, between the confluence of the two main tributaries and the coast, the channel appears to be little modified.

The aerial photos show extensive dune blowouts south of Whitiroa, including the area surveyed by Coffey Consultants (2008). The dunes close to the stream mouth are severely eroded compared to the present (Plate 1). There is also no evidence of a stream channel approaching the dunes between the channel marked in Figure 2 and the Te Wairoa estuary to the south, consistent with Dr Brook's (1999) report.

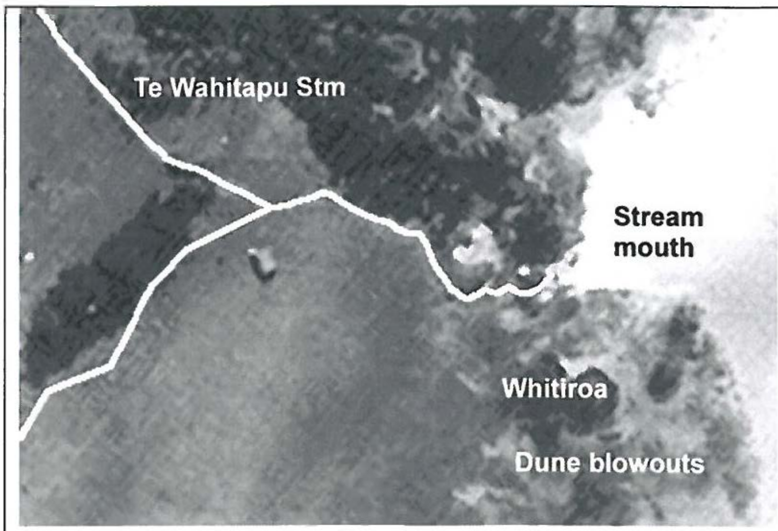

Figure 2. Location of Te Wahitapu Stream on aerial photo 404/18 taken in 1942. The channel position is almost the same as the present day channel (Plate 2A).

Riley Consultants (2008a) reviewed the Coffey Consultants (2008) report and were critical of their interpretation of geophysical data, finding that the data are inconclusive and do not support the presence of a former channel. The report also presents the results of auger boreholes with SCALA penetrometer bulk density measurements. The data indicates the presence of paleosols within dune sands, overlying a more competent stratum inferred to be either weathered greywacke or consolidated sand. The report also mentions the presence of trace gravels within the deposit. Riley Consultants (2008a) did not find saturated sediments, consistent with the Coffey Consultants (2008) boreholes. This suggests that the interpretation of a saturated freshwater zone within a channel made by Coffey Consultants (2008) is not valid.

The final Riley Consultants (2008b) report includes the results of further sub-surface surveys undertaken by Dr Brook. The auger holes in this report are about half the depth of those in the earlier reports. However, material suitable for radiocarbon dating was retrieved from the holes, and found to have calibrated age of AD 1430-1670 (99% confidence of being older than AD 1800). Therefore, all the holes are likely to have penetrated deeper than any deposit relating to tsunami impacts in the late 19th Century. The stratigraphic sequence determined by this report is consistent with the general coastal stratigraphy found on the New Zealand coast, and consists of several paleosols with evidence of human habitation.

Plate 1. Northern end of Matapouri Beach looking towards the mouth of Te Wahitapu Stream

All of the evidence presented in the supplied reports is predominantly from a small area immediately south of Whitiroa, with some data from the current stream. No comparative data were available for areas of Matapouri Beach that are not affected by a stream channel.

Tsunami events

Table 1 summarises the dates of historic tsunami events that are likely to have affected Matapouri since AD 1800, with maximum wave heights larger than 0.25 m. Since the establishment of the Pacific Tsunami Warning System in the 1960s, and the development of open coast sea level stations around New Zealand in the 1990s, more small tsunami are being detected. However, these do not cause significant coastal impacts, so Table 1 concentrates on events that could cause the diversion of a small stream discharging through dunes onto a sandy beach.

Table 1. Summary of historic tsunami events larger than 0.25 m for the coast between Auckland and Bay of Islands (de Lange and Healy, 1986; Fraser, 1998). The maximum height refers to the maximum for the entire stretch of coast, unless measurements were available close to Matapouri as indicated.

Date	Source	Maximum height (m)
13 August 1868	South America	3.1
10 May 1877	South America	3.7
27 August 1883	Indonesia	1.8
4 November 1952	Kamchatka	0.9 (Matapouri)
22 May 1960	South America	2.8 (Tutukaka)
28 March 1964	Alaska	0.6
14 January 1976	Kermadec Is.	0.7 (Tutukaka)

It is evident that the tsunami of 10 May 1877 was the largest historic event to strike the coastline between Auckland and the Bay of Islands. The 3.7 m maximum recorded was at Paihia, and includes local amplification, as the corresponding height at Russell was 1.8 m. Therefore, the height at Matapouri is likely to have been lower.

Considering the historic events in Table 1, the maximum possible tsunami height at Matapouri is around 3 m, which is three times the value predicted for Ngunguru Spit using numerical modelling of a South America source tsunami by NIWA (Walters et al., 2007). Therefore, 3 m is not likely to under-estimate the tsunami height at Matapouri in 1877.

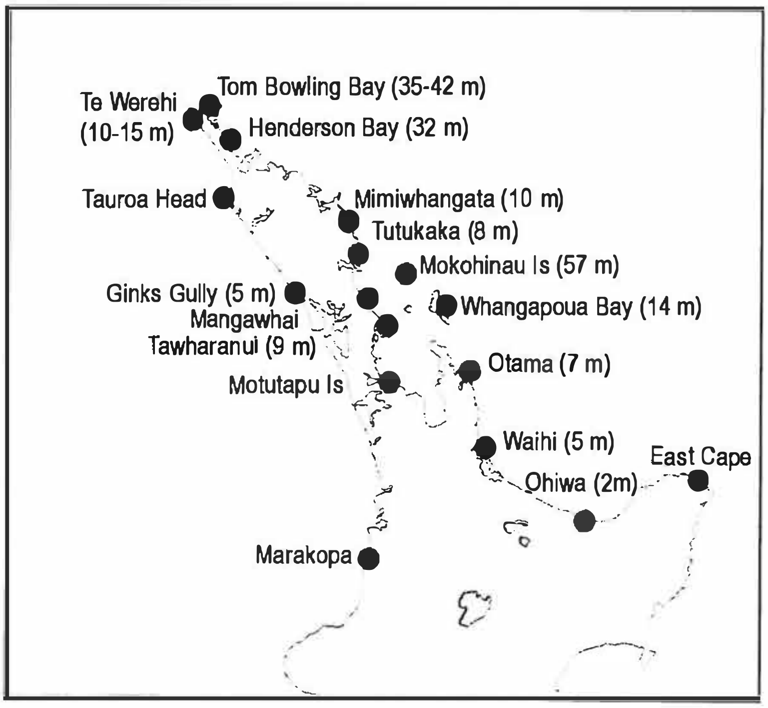

Figure 3. Locations with 14-16th Century palaeotsunami deposits and their estimated maximum runup (de Lange et al., 2008).

Palaeotsunami events for New Zealand are not well documented. However, Chagué-Goff *et al* (2006) summarise the available data for Northland. Due to difficulties with preservation, palaeotsunami records are biased towards larger events; usually with heights exceeding 5 m for New Zealand (Lowe and de Lange, 2000). Therefore, it is almost certain that more tsunami events have occurred than reported by Chagué-Goff *et al* (2006).

Figure 3 summarises data intended for palaeotsunami deposits that have all been dated between the 14th and 16th Centuries for the upper North Island. Palaeotsunami deposits have also been located at Whananaki and Woolleys Bay (Chagué-Goff, 2006). It is likely that most of these deposits represent one event generated close to New Zealand around the start of the 15th Century (AD 1380-1420), although the exact age and source is uncertain (de Lange et al., 2008). The deposits at Tutukaka and Mimiwhangata suggest that the maximum height at Matapouri would have been around 9 m. This is consistent with numerical simulations of this event by both NIWA and the University of Waikato.

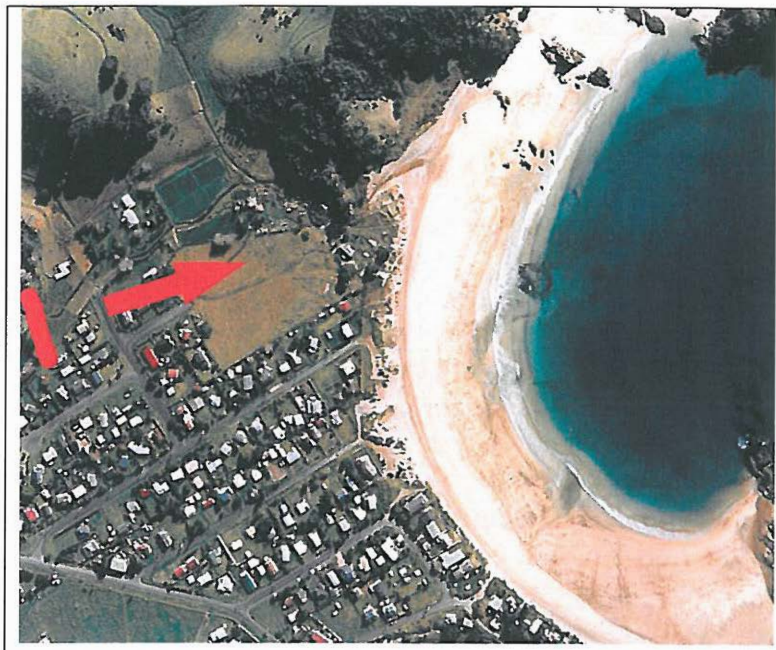

Plate 2. Upper (A) image is an enlargement of a portion of the aerial photograph of Matapouri provided by Mr Ringer. Lower (B) image is a view looking WNW across the eastern end of the grassy area marked with a red arrow in the upper image. Hummocky topography indicating tsunami inundation is evident in both images.

The dunes at Matapouri in April 2009 (Plate 1) are more than 3 m above MHWS, so a 3 m tsunami is not likely to breach the dunes at present. However, a 9 m tsunami is capable of doing so. The dunes at present have been modified by human activities over the last 800 years as demonstrated by the Riley Consultants September 2008 report on carbon dating of dune deposits. It is likely that these modifications have resulted in a steepening and increased elevation of the frontal dunes as reported at other beaches. Therefore, the dunes may have been lower in 1877 and ~600 years ago. It is recognised that tsunami inundation can modify coastal dunes, resulting in characteristic geomorphologic features such as washover lobes and hummocky topography (de Lange and Moon, 2007; Goff et al., 2008). Although other processes can produce similar features, they are generally smaller and less extensive than those produced by tsunamis.

Matapouri has been extensively modified by development, which obscures the original geomorphology. However, the 1942 and more recent aerial photographs indicate the presence of hummocky topography at the northern end of Matapouri Beach (Fig. 2 and Plate 2A). This was evident during the site visit (Plate 2B). This area is unaffected by the dune blowouts evident in a photo of Matapouri dating back to AD 1900 (Plate 5).

Geomorphology alone is not sufficient evidence to prove that tsunami inundation has occurred (Dawson and Stewart, 2007). The auger records provided by Riley Consultants include additional evidence: the lowest stratigraphic unit in boreholes M2 to M5 is consistent with tsunami deposits found elsewhere in Northland, including South Whananaki. The 15th Century tsunami deposit is normally found in association with distinctive pumice clasts, Loisels Pumice, which was located by Dr Brooks (1999 report) around the mouth of Te Wahitapu Stream and within the dunes nearby. During the site visit, Loisels Pumice was found in the banks of Te Wahitapu Stream, confirming Dr Brooks work.

Plate 3. Earthworks through the hummocky topography shown in Plates 2A & B. Scattered gravels are evident throughout the deposit. The red outline was on the image provided and highlights coarse material.

The Loisels Pumice occurs as part of a lag deposit near the base of the tsunami deposit. It can be found in associated with fragmented marine shells and rounded gravels derived from offshore. Such a deposit has been found at Woolleys Bay (Chagué-Goff et al., 2006), and the stratigraphic columns of Dr Brook and the provided image of earthworks (Plate 3) suggest it also occurs at Matapouri.

It is probable that the large tsunami at the start of the 15th Century overtopped the sand dunes at Matapouri and inundated the lowland behind. This event is significantly larger than any event recorded since AD 1800. The auger data, and present geomorphology indicate that, while there has been remobilisation of sand dunes by wind, there has not been a comparable tsunami inundation event since the 15th Century. The much smaller 1877 tsunami event is very unlikely to have overtopped the dunes, as was the case for the 1960 tsunami event. Tsunami have caused movement of river mouths and tidal channels, as occurred at several locations around New Zealand in 1868 and 1960 (de Lange and Healy, 1986). This has mostly involved the redistribution of intertidal and sub-tidal sandbanks. It is possible to shift the position of a river channel, but it is not common. For example, the 11 m

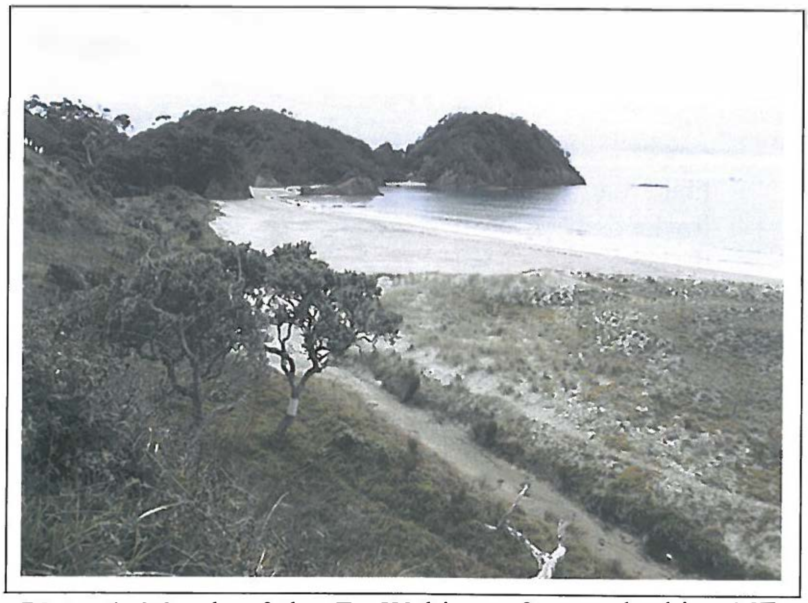

Plate 4. Mouth of the Te Wahitapu Stream looking NE. Migration northwards is limited by rock headland. Migration southwards has occurred as evidenced by the lowered dunes.

high 1998 Sandaun Tsunami struck a number of rivers and streams. None that we surveyed had moved along the coast by more than a few 10s of metres.

When a stream or tidal channel migrates along the coast, the dunes between the original location and the final location are reduced in volume. Typically they are lower in elevation, as occurred in the 1980s at Mangawhai (McCabe, 1985).

Lowered dunes do occur at the mouth of the present Te Wahitapu Stream. This indicates that the mouth does migrate north and south along the beach. Movement towards the north is limited by the rock headland. The current position is probably the maximum northern extent. The southward movement doesn't appear to have extended beyond Whitiroa (Plate 1 & 2A). Movement of the stream mouth is most likely to occur episodically during intense rainfall events. During the site visit the streambed was dry and the catchments associated with the stream are small. Overall the stream can be classified as underfit, as the overall stream channel, particularly through the gap between the headland and Whitiroa, is larger than the mean flows would predict. Therefore, it is likely that the intense rainfall associated with weather bomb events would be required to generate enough discharge to allow the stream to cut through the dunes near the southern end of the lowered zone.

It is possible that a tsunami could provide the additional volume of water to achieve this, but a breach like this typically occurs when the existing channel is blocked (Plate 4) and the water backs up enough to break out. A tsunami is more likely to clear the existing channel.

There is no geomorphic evidence to support the Te Wahitapu Stream, or any other stream, discharging to the south of the lowered dunes as far as the area affected by the Te Wairoa Stream.

Inland it is possible that there has been diversion of small tributary streams into the present Te Wahitapu Stream. The Brook (1999) report mentions that the swampy lowlands have been drained, and visual inspection suggests that present channels are partially dug out as drains. Before development, some of the small steepland catchments may have drained into the Te Wairoa Stream estuary, rather than into the sea via Te Wahitapu Stream.

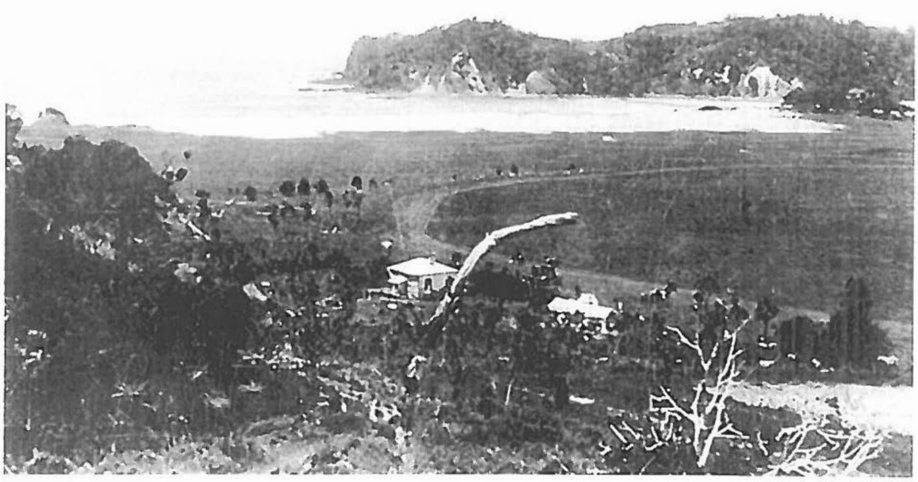

Plate 5. Racetrack 1900 photo supplied. This photo shows a region of dune blowouts affecting most of Matapouri Beach, but no evidence of dune lowering associated with stream migration. Te Wahitapu Stream discharges thorough the gap at left-hand edge of beach.

Location of Te Wahitapu Stream since 1877

In 1877, the available evidence shows that it is unlikely that Te Wahitapu Stream discharged south of Whitiroa. The main evidence as originally summarised by the Brook (1999) report: there is no compelling evidence that the dune sequence from Whitiroa southwards has been disrupted by a stream breach. Further, the 1877 tsunami is very unlikely to have breached the dunes. In order to affect the shift implied by the Coffey Consultants (2008) report, the tsunami would have needed to simultaneously breach the dunes north of Whitiroa, and infill a stream channel south of Whitiroa to a sufficiently high elevation to form a continuous dune ridge. Observations of recent large tsunami indicate that, while they can breach dunes, the inflow and return flows are concentrated in existing low points in dune system, making them predominantly zones of erosion. Accretion can occur late in the tsunami outflow, but this is not sufficient to block the channel (late in the outflow, the tsunami elevation is low).

After 1877, it is clear that there has been disturbance of the dunes with many blowouts that have moved inland (Plate 5). These have affected the area surveyed by Coffey Consultants (2008), but seem to have missed the area immediately west of Whitiroa (Plate 5).

Alternate locations have been suggested for Te Wahitapu Stream north of Whitiroa, particularly Shaw's SO 718 location (Figure 4). Other locations require that the stream channel pass through the greywacke stack Whitiroa, and are not considered further.

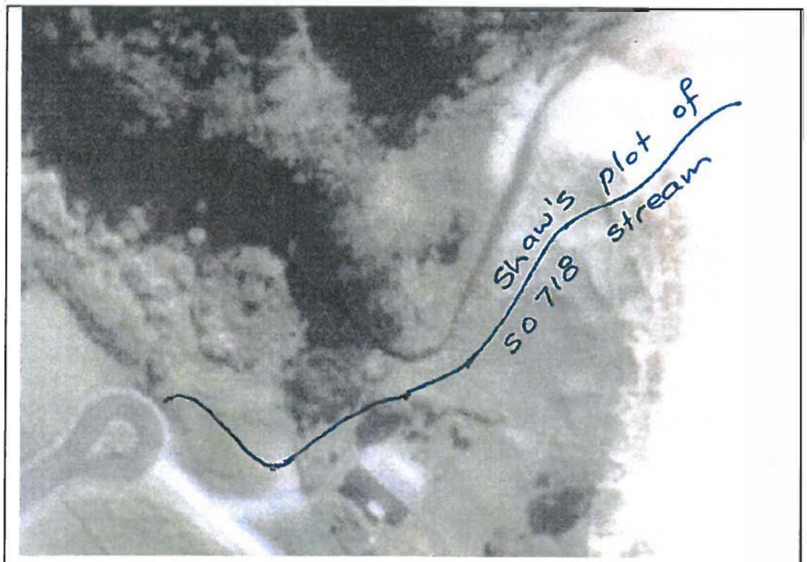

Figure 4. Suggested alternative location of Te Wahitapu Stream based on SO 718.

The SO718 is not a credible location for a stream channel. The channel to the right of the sharp bend evident in the present channel (right-hand half of Fig. 4) is possible. This area is part of the zone of erosion at the mouth of the stream evident in the 1942 aerial photograph (Fig. 2), and the stream probably occupied this area at some time. Since then dunes appear to have filled the gap, restricting the channel to the northern (upper) end of Figure 4.

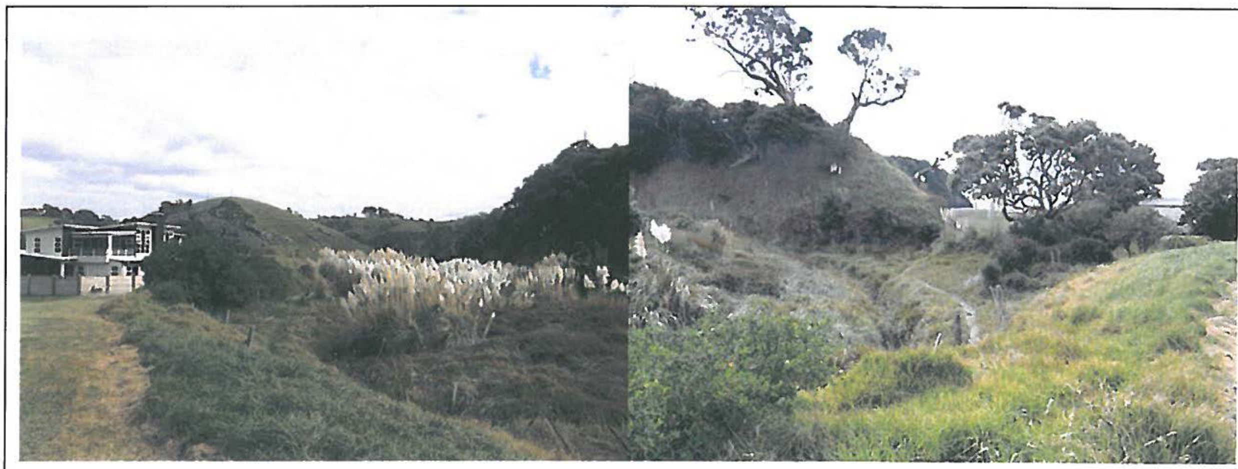

Plate 6. Present day Te Wahitapu Stream as viewed from left-hand end of SO 718 stream marked on Figure 4: (A - left) looking WNW; and (B - right) looking ENE. The steep vegetated north facing back marks the most southerly position potentially occupied by the stream since 1877.

Further inland, the location of the channel is constrained by the topography. Plates 6A and 6B show the southern margin of the flood plain occupied by the present day Te Wahitapu Stream. A steep vegetated bank, which grades in to the hummocky topography discussed earlier, marks this margin. This bank is evident in same location in the 1942 aerial photograph, indicating no change in 67 years. The only change noted for the area covered by Figures 2 & 4, and Plates 6A and 6B is a second channel closer to the headland that cuts off the bend in the stream closest to the steep bank in Plate 6A.

Between Whitiroa and the headland, the channel is confined by bedrock and a boulder layer (Plate 7), restricting the amount of channel movement on the northern side. To the south, no greywacke was evident in the channel margin. However, apart from a narrow zone occupied by a path, the bank rises steeply up to a platform occupied by a large tree and shed. This is the northern margin of greywacke stack Whitiroa, and it is likely that greywacke is present close to the southern channel bank.

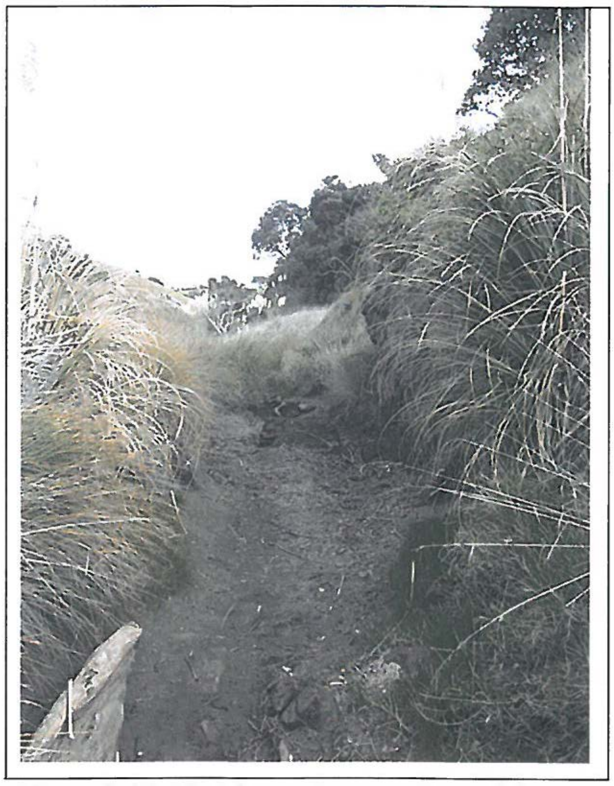

Plate 7. Te Wahitapu Stream channel in gap between Whitiroa and headland. Greywacke is exposed in right-hand bank, and greywacke boulders underlie the streambed.

Further inland, the channel has the capacity to migrate, and also appears to have been modified by human activities. However, there is a limited zone within which the channel could move as it is constrained by steeplands to the north, and higher hummocky topography towards the south.

The SO 718 channel marked in Figure 4 runs across high ground south of the bank delimiting the floodplain of the present day Te Wahitapu Stream. If the stream had been in this position in 1877, and migrated northwards, it would require infilling of the former channel to an elevation higher than the present day floodplain. The area is outside the zone affected by blowouts in either the 1900 photo (Plate 5) or the 1942 aerial photograph (Fig. 2). It is most likely that the higher ground represents landforms present before the 1877 survey.

Conclusions and recommendations

Based on the evidence provided, a site visit, and published material on similar beaches along the northeast coast of the North Island, the Holocene development of Matapouri Beach is likely to have been:

- Sea level reached approximately the present position about 7000 years ago, and has fluctuated about this level by <1 m since (de Lange and Moon, 2005; de Lange and Moon, 2007). At this stage Whitiroa was a stack on a rocky shore platform, as Te Wahitapu Stream is incapable of eroding the gap between Whitiroa and the main headland during the Holocene (underfit stream).
- There was a rapid onshore movement of sand producing a sand spit extending southwards to the present Te Wairoa Stream estuary, surrounding Whitiroa and enclosing a tidal lagoon. The sand was derived from material deposited on the seabed during the previous glacial, and only a small proportion was locally derived (Schofield, 1970). Without detailed coring it is not possible to assess the position of Te Wahitapu Stream at this time. However, it probably discharged into a lagoon behind the sand spit, eventually entering the sea at the southern end of the beach.

- The lagoon progressively infilled, and forest was established on the spit.
- At the start of the 15th Century a large tsunami overtopped the sand spit, depositing sediment over the lowlands/lagoon and affecting drainage. At this time it is likely that Te Wahitapu Stream was redirected through the gap north of Whitiroa. This event produced the hummocky topography between the sand dunes and the swampy flats, and is responsible for scattered gravels and shell fragments at depths of about 3 m in the dunes.

There is no evidence for the existence of another stream discharging immediately south of Whitiroa. Considering the available catchments, and the topography of the lowlands, water draining the steeplands would tend to drain southwards towards Te Wairoa Stream. I suspect that the southern tributary of Te Wahitapu Stream originally flowed into Te Wairoa, and was diverted northwards.

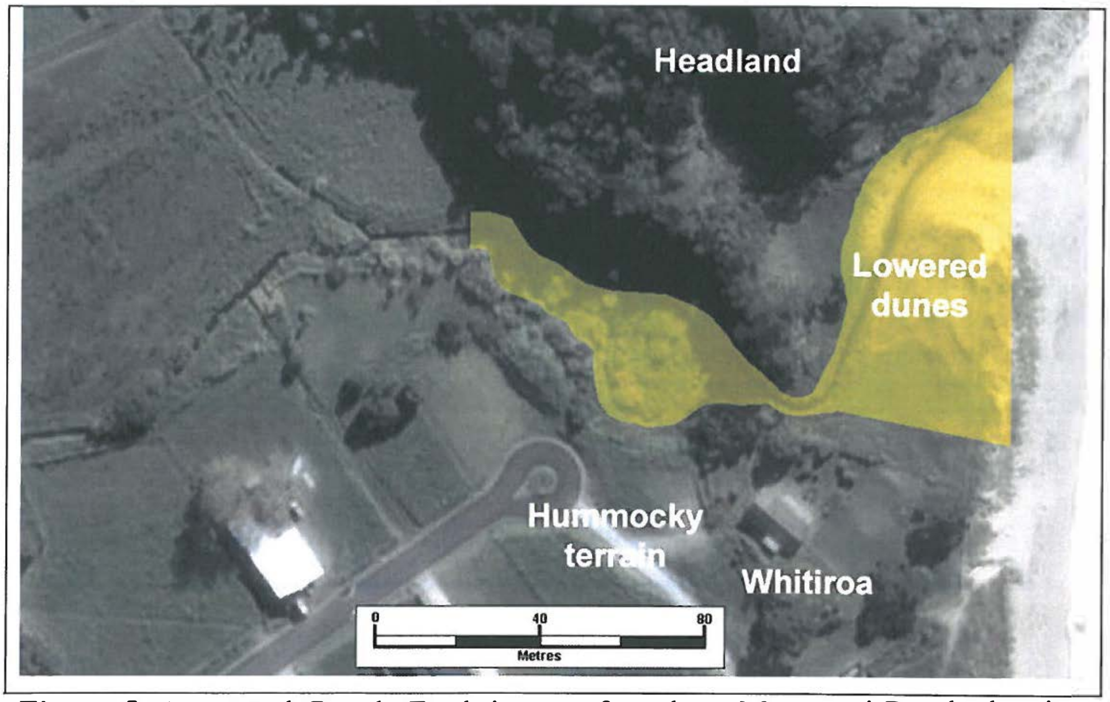

Figure 5. Annotated Google Earth image of northern Matapouri Beach showing features referred to in the report. The yellow shaded area indicates the maximum variation in the position of Te Wahitapu Stream since 1877.

The present location of Te Wahitapu Stream is likely to be similar to, but not the same as, the channel that existed around 1877 (Figure 5). This is because the channel through the lowlands is mostly is alluvium, which will allow it to migrate. There is clear evidence in terms of lowered dunes north of Whitiroa to indicate that the shoreline position has moved north and south over time. Whitiroa marks the southern extent of that migration. Although there are likely to have been minor changes in channel location for Te Wahitapu Stream, there is no evidence for a major shift in position since the 1877 survey. There is no evidence for another stream discharging south of Whitiroa that could have been confused with Te Wahitapu Stream at the time of the survey.

Additional evidence may be uncovered by further investigation. There are two geophysical techniques that could be employed: seismic refraction; and ground penetrating radar. Seismic refraction requires a higher energy source for seismic waves, and given the issues mentioned by Coffey Consultants (2008) in relation to their seismic reflection investigation, a seismic refraction study is likely to be considered unacceptable by the local community. Further, although it will have a greater penetration giving deeper profiles, it is likely to have insufficient resolution to provide useful on near surface stratigraphy.

Ground penetrating radar has been used in similar deposits. We used it to examine tsunami deposits at Tawharanui because it gave more useful results than seismic reflection and resistivity techniques (de Lange and Moon, 2007). However, it is affected by features such as fences and buried pipes. In the confined, developed area involved it is not likely to work very well.

Trenching is an option, and was discussed in the reports reviewed. Based on the auger data, trenching will result in disturbance of archaeological material. At Tawharanui, the 15th Century tsunami deposit was also associated with human remains. It is likely that trenching will upset the local community, and from the reviewed evidence, I do not expect that it will provide evidence for a buried channel south of Whitiroa.

The most useful technique to refine the shaded area in Figure 5 would be a series of auger holes as already undertaken at other locations by Coffey Consultants, Riley Consultants and Dr Brook. Assuming the shape of the stream surveyed in 1877 is correct, auguring perpendicular to of the southern margin of the present day stream channel should ascertain the position of greywacke that limits the southern extent of channel movement. I expect it to be within a couple of metres of the present stream channel at this point.

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