Mowhanau Cliff Line Retreat Review

Prepared for

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1. Introduction

Coastal hazard zones (CHZs) describe the present and potential future coastal hazard for a particular area of the coast. In 1999 coastal hazard zones were defined for a 2300 m stretch of coast line centred on the settlement of Mowhanau (Gibb, 1999) (Figure 1.1 and Figure 1.2). The major coastal hazard at Mowhanau is erosion and landslip. Gibb (1999) split the CHZ in to three zones: Extreme Risk Zone (ERZ), High-Moderate Risk zone (H-MRZ) and a Safety Buffer Zone (SBZ).

The ERZ is or is likely to be subject to adverse effects from catastrophic landslip at any point in time in any one year. Landward of the ERZ, the H-MRZ is or is likely to be subject to long term retreat based on a 100 year projection. The SBZ is or is likely to be subject to the adverse effects from natural hazards, should the rates of erosion accelerate and/or cliff slope angle reduces.

When cliff slope reduces toward an equilibrium state the rate of erosion will decrease. An equilibrium state is reached by the deposition of talus material at the cliff base. This material acts as a protection to the base of the cliff to prevent undermining by wave action and the potential for further instability. The cliff top will retreat under the process of weathering and other discontinuity characteristics (Selby, 1993; de Lange and Moon, 2005).

In line with the recommendation of Gibb (1999), that the coastal hazard zones be reassessed between 2009 and 2014, this report provides an up to date, quantitative and qualitative, assessment of cliff line erosion rates. The results of this report will aid in the decision making process to determine whether adjustments to the current hazard and buffer zones are required.

Figure 1.1. Ortho-rectifed 2011 image of Mowhanau Village with prominent features and cliff line sections annotated; Inset showing study site national location.

Figure 1.2. Ortho-rectifed 2011 image of the study site with the current Coastal Hazard Zones, as established by Gibb (1999).

2. Study Site

Mowhanau is located on the North Island of New Zealand in the district of Wanganui (Figure 1.1). To the north west of Mowhanau Village is the Kai Iwi Stream, to the south east is Mowhanau Stream. Both water courses terminate on the beach adjacent to Mowhanau Village. The streams effectively delineate the wide Mowhanau Beach area, where north west and south east of the Kai Iwi and Mowhanau Streams the cliff line runs, broken only by small streams, to the district boundary and Castlecliff, respectively. Figure 1.2 is a 2011 ortho-rectified image showing Mowhanau Village and an overlay of the current CHZ established by Gibb in 1999. There are several dwellings located within the H-MRZ, particularly in the Peat Avenue area.

At Mowhanau, the base of the cliff is composed of massive grey mudstone, overlain by unconsolidated coastal-marine sediments (see Flemming, 1953). This composition does not make for a high structural resilience and combined with an offshore mean significant wave height (H_s) of 1.5 m, and a predominant direction of 240°N (Figure 2.1), severe cliff line erosion is inevitable. Gibb (1999) estimates the stable cliff slope of the overlying unconsolidated layer and the base mudstone to be 36° and 42°-46°, respectively, and suggests an equilibrium slope of 40°. In 1999 Gibb observed slopes of up to 63° and 58°-90°, respectively.

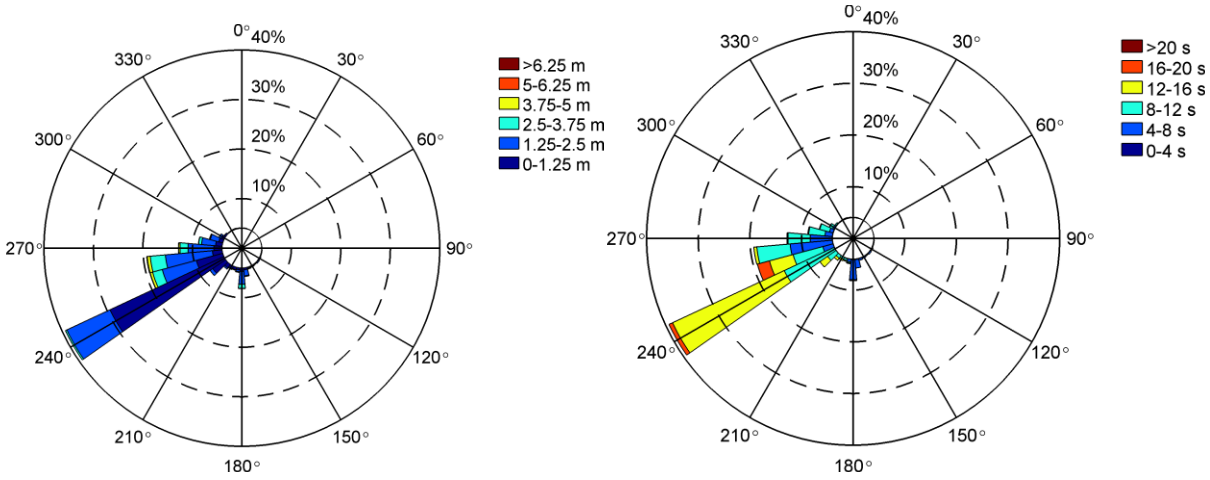

Figure 2.1. Directional wave roses of wave height (left) and period (right) from 174.5°E/40°S constructed from Wave watch III hindcast data for the years 2005 to 2013.

3. Method

Historical georeferenced aerial photos, recently acquired land-based LIDAR survey data, historical survey data and survey data reproduce form historical documentation was compiled in a GIS database, along with existing hazard and buffer zones. The datasets used in this study are described in Table 3.1. The cliff top and toe are annotated from georeferenced photographs and historical documentation to construct arrays of easting and northing values (XY data) to allow a comparison with survey data.

Table 3.1. Data sets available for use in the current study

Year	Description
21/7/1942[1]	Georeferenced Photo
5/4/1962	Reproduction from Aerial Survey
4/2/1982	Reproduction from Aerial Survey
1/9/1999[2]	RTK Survey
2011	Georeferenced Photo
30/5/2013	RTK Survey

The XY data for the available years was sub-sectioned in to 5 areas: Northwest Cliff; Kai Iwi; Beach; Mowhanau; and Southeast Cliff, as shown in Figure 1.1. The cross shore differences between data sets were calculated at 50 m intervals (30 m for the Mowhanau Section) by interpolating along the XY arrays, creating 39 potential nodes for comparisons of the cliff top (Figure 3.1) and 31 nodes for the cliff toe (Figure 3.2). This is achieved by converting the XY arrays to polar coordinates and rotating by 29°, the exception to this is the Mowhanau section which is rotated 137.5°, extracting the XY value and calculating the difference at the interpolated nodes. The steps are then reversed to revert the node XY arrays back to the Cartesian coordinate system (NZMG). Subsequently erosion rates are calculated from the cross shore differences by dividing by the number of years elapsed between XY array data. From these data, geospatial vector format files are constructed to be incorporated into the GIS database.

Method Considerations:

- In some comparison cases polylines would over lap and illogically indicate progradation of the feature. Where this occurred for cliff top comparisons the nodes were simply omitted. In cliff toe comparisons the nodes were permitted as deposition of material as talus can extend the apparent position of the cliff toe.
- Because the alongshore extents of the datasets differ no value was calculable for a number of nodes. In this scenario these nodal points are omitted.
- Due to the potential errors associated with georectification the 2011 aerial image did not provide a satisfactory comparison with survey data (1999 and 2013 RTK) and has there for been omitted from the distance and erosion rate calculations.
- As the most recent representation, the 2011 image is used as the background to present all other data.

[1] Average from 10/6/1942 and 31/8/1942
[2] Estimate – only month and year provided in Gibb (1999)

Figure 3.1. Locations of interpolated nodes for the cliff top.

Figure 3.2. Locations of interpolated nodes for the cliff toe

4. Erosion Overview

Figure 4.1 and Figure 4.2 show that between 1999 and 2013, the exposed cliff line at Mowhanau continued to erode landward, and the Mowhanau Cliff section continued to erode to the south east. Erosion distances of the cliff top at the west end of the Northwest Cliff Section are less than at the eastern end where the cliff top has eroded an average of 8.7 m from nodes 10 to 14. In the Mowhanau Cliff section (nodes 21 to 24), the average erosion distance is 2.6 m toward the southeast. The average erosion distance in the Southeast Cliff Section is 5.1 m. The west end of this section, from nodes 25 to 30 averages a retreat of 6 m. This average value is reduced by nodes 28 and 29 where the cliff retreated by on 0.5 m and 2.8 m, respectively. This area is in the lee of the remaining stack, and the nodes directly adjacent have much higher retreat distances (2.8-10 m). The dwelling closest to the cliff line on Peat Avenue is <25 m from the 2013 cliff top position

Figure 4.3 and Figure 4.4 shows the cliff toe position in 1982 and 2013, the 2013 toe line includes the toe of the riprap armour adjacent to Mowhanau Village. The position of the toe has moved a maximum of 3.1 m at node 12. In places (e.g. node 13) the tow of the riprap is equal to or in advance of the 1982 position, suggesting that the erosion control system is effective. However, a comparison of the 2013 riprap toe line and with the original toe line after installation is not possible, but would provide an insight in to the durability of the system and if there is potential for a failure in the future.

Figure 4.1. Cliff top erosion rates for the 1999 to 2013 period.

Figure 4.2. The 1999 and 2013 cliff top location lines.

Figure 4.3. Cliff toe erosion rates for the 1982 to 2013 period.

Figure 4.4. The 1982 and 2013 cliff toe location lines.

5. Historic Erosion Rates

As reported in Gibb (1999) there have been a number of erosion rate estimations made for the study site. In the vicinity of the Mowhanau Stream, Flemming (1953: cited in Burgess, 1971) reported erosion rates of 1.5 m/yr for the period 1876-1893; and 0.44 (Burgess, 1971) to 0.89 (Gibb, 1999) m/yr the period 1876-1916. Burgess (1971) estimates rates of 0.68, 0.46 and 0.68 m/yr for the periods 1942-1953, 1953-1962 and 1962-1969 derived from aerial photos and a field survey, respectively. Gibb (1978) reported net erosion rates of 0.56 m/yr for the period 1876 to 1969. Johnston (1988) estimated erosion rates of 0.2-0.6 m/yr. Using the same dataset, Smith and Ovenden (1998) estimated 0.04-0.68 m/yr with an average of 0.35 m/yr at Mowhanau Stream, and 0.23-1 m/yr adjacent to Peat Avenue.

Using accurate surveying techniques and historical photographs, Gibb (1999) estimated erosion rates for: the cliff line northwest of the Kai Iwi stream of 0.1-0.38 m/yr, with and average of 0.2 m/yr; proximal to the Kai Iwi Stream of 0.1 m/yr; between the Kai Iwi and Mowhanau Streams of 0.3-0.5 m/yr between 1902 and 1999; southeast of the Mowhanau Stream of 0.39-1.26 m/yr from 1942 to 1999, averaging 0.8 m/yr. Gibb also notes the removal of 2 stacks adjacent to Peat Avenue between 1962 and 1982, and a 40 m retreat of another stack from 1942 to 1999. Adjacent to Peat Avenue net rates average 0.5 m/yr from 1942-1999. Heading south east average rate is 0.32 m/yr for the same period.

Figure 5.1 presents the historic estimations of erosion rates detailed above and cliff top erosion rates calculated in this study for the exposed cliff just southeast of where the Mowhanau Stream terminates. No clear trend can be discerned from the plot, this in part may be due to the large ranges by which erosion rates are cited to by previous investigators. In addition there is some ambiguity regarding the alongshore location each investigator is referring to. The plot does however show that the latest estimations of erosion rates are not in excess of previously estimated rates.

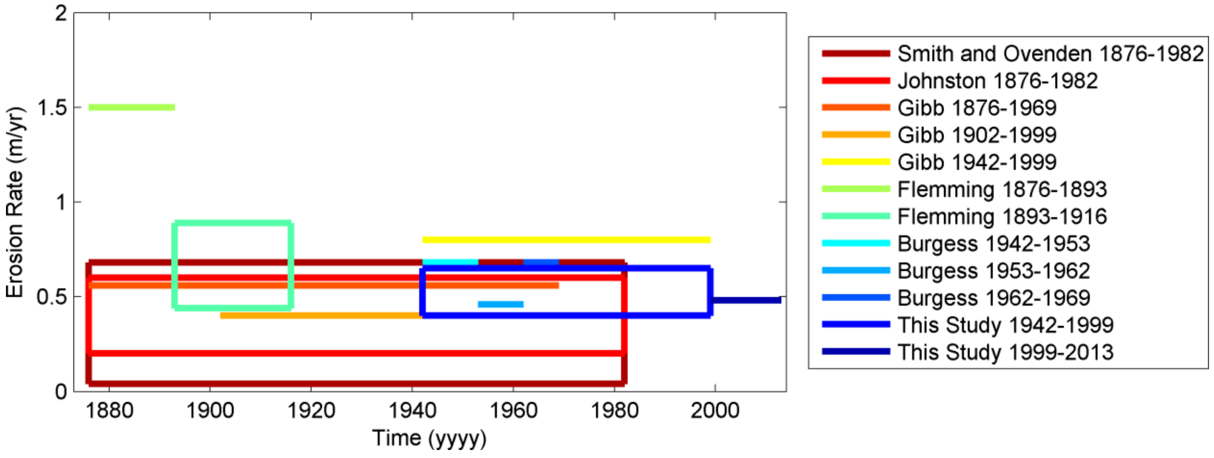

Figure 5.1. Compilation of historic and contemporary erosion rates.

Latest estimations in this report are directly comparable. Minimum and maximum values are extracted from nodes 25 and 26. The minimum value in the 1999-2013 period (node 25) is higher by 0.8 m/yr, indicating an increase in erosion rate. In light of this observation, Figure 5.2 has been constructed to compare the cliff top erosion rates for the 1942-1999 and 1999-

2013 periods at each transect location along the coast (Figure 3.1). At more than 66% of the comparable nodes the erosion rate has increased. The greatest increases occur at the southern end of the northwest cliff section and for much of the southeast cliff section, including the Mowhanau Stream section. A paired t-test shows that there is a significant difference between the erosion rates at the 95% confidence level $(p = 0.001)$. The average increase is 0.3 m/yr.

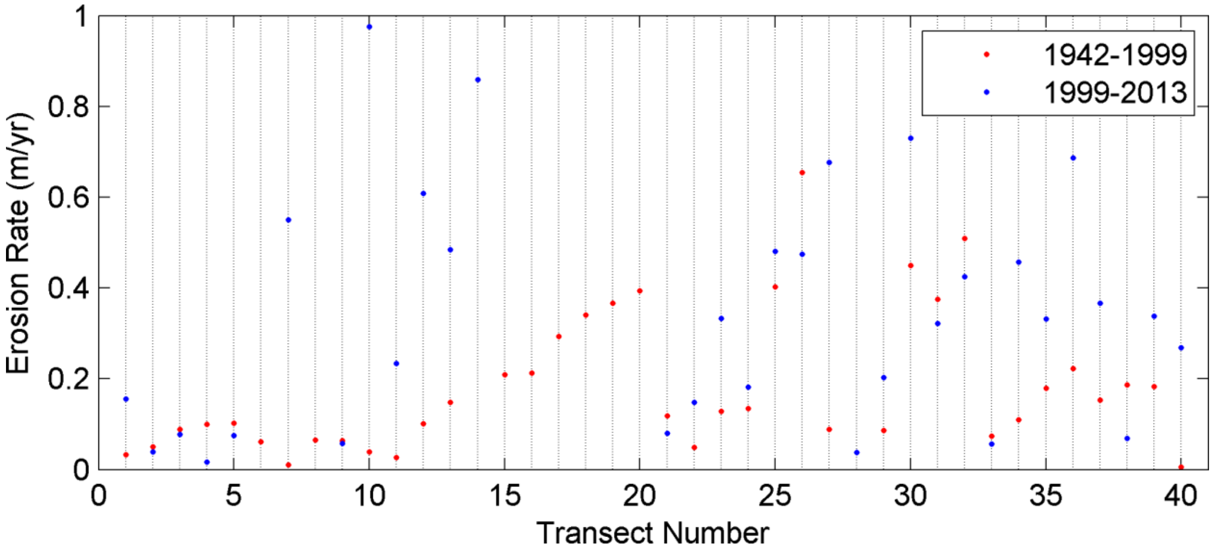

Figure 5.2. A comparison between the 1942 to 1999 and 1999 to 2013 erosion rates.

6. Coastal Hazard Zone

Figure 6.1 shows the current Coastal Landslip Hazard Zones, the 2013 cliff top and toe locations, and the 1999 cliff top location. Along much of the Northwest Cliff Section, as in 1999, the 2013 cliff top location remains within the ERZ. The exception occurs around node 5 where the 2013 cliff top encroaches in to the H-MRZ. The 2013 cliff to location remains within the ERZ, except between node 5, however, the overlap is small and likely to be a function of either survey or accuracy/resolution and or CHZ designation resolution.

In the Kai Iwi and Beach Sections, the ERZ is landward of the 2013 riprap toe location. At the Mowhanau Cliff Section the 2013 cliff top encroaches on the H-MRZ at the northern end, but for the most part stays within the bounds of the ERZ, as does the 2013 cliff toe line. Along the Southeast Cliff Section the cliff top location remains with the ERZ entirely. However, around node 30, proximal to the dwellings of Peat Avenue the 2013 cliff top location is as close as 5 m of the H-MRZ.

Table 6.1 compares the rate of long term retreat (R) specified by Gibb (1999) (1902-1999 and 1942-1999), used to determine the current Coastal Landslip Hazard Zone (CLHZ), and the latest rate of long term retreat estimate in this study (1942-2013). On the whole, Gibb's R values are conservative and the latest R values are lower. The exception to this is in the northwest cliff section, proximal to nodes 13 and 14 where the erosion rate has accelerated by 0.11 and 0.03 m/yr, respectively; and at node 25 where the erosion rate has increased by 0.02 m/yr.

Table 6.1. Erosion rates and locations used by Gibb (1999) for the designation of CHZ alongside the most recently available long term erosion rates.

Site	Gibb (1999)	1942-2013	Transect #	ΔRate
XS-1	-0.2	-0.08	4	-0.12
XS-2	-0.2	-0.04	8	-0.16
XS-3	-0.1	-0.21	13	0.11
*	-0.1	-0.13	14	0.03
Kai Iwi Stream				
XS-4	-0.3	NA	NA	NA
IB-1	-0.5	NA	NA	NA
*	-0.5	NA	NA	NA
Mowhanau Stream				
XS-5	-0.4	-0.42	25	0.02
*	-0.8	-0.62	26	-0.18
*	-0.5	0	28	-0.5
*	-0.5	NA	NA	NA
XS-6	-0.5	-0.5	29	0
XS-7	-0.5	-0.36	30	-0.14
XS-8	-0.32	-0.18	34	-0.14
XS-9	-0.32	-0.21	39	-0.11

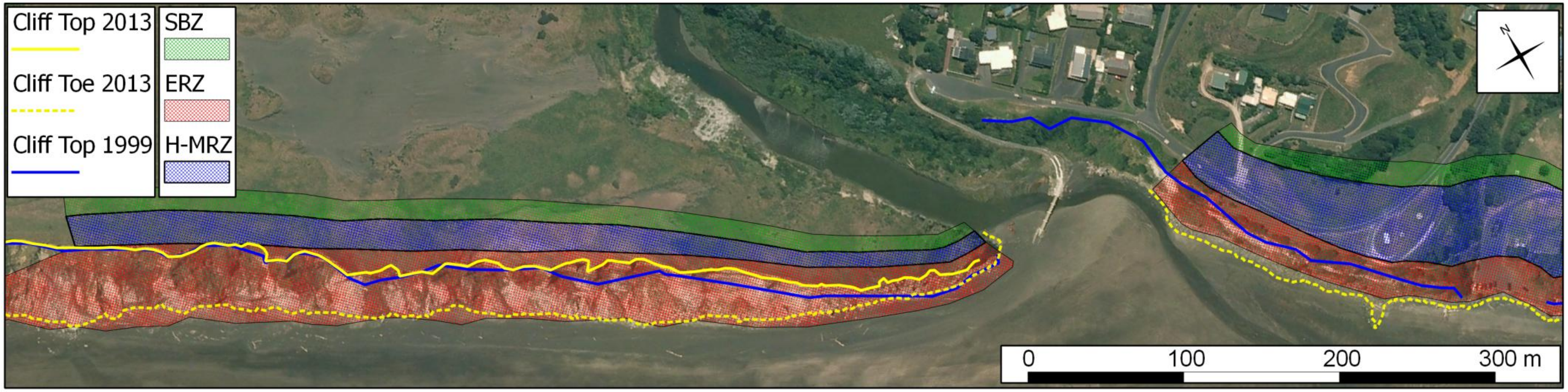

Figure 6.1. Ortho-rectified 2011 images of the study site with the current Coastal Hazard Zones, as established by Gibb (1999), 1999 cliff top line and the 2013 cliff top and toe lines for the east (top) and west (bottom) areas of the Mowhanau coastline.

7. Conclusions and Recommendations

The east end, closest to Mowhanau Village, of the Northwest Cliff Section appears to be eroding faster than the other parts of this section, where the 1999-2013 erosion rate is less than or approximately equal to the 1942-1999 rates (excl. nodes 1 and 7). In the Southeast Cliff Section erosion rates are on the whole accelerating, particularly at the far western end. In the 2013 survey the dwelling closest to the cliff line on Peat Avenue is <25 m from the 2013 cliff top position.

While a comparison of the 1942-1999 and 1999-2013 erosion rates indicates acceleration, when the data is considered in regard to erosion rates there is no clear trend and the latest estimations are not in excess of previously estimated rates. Consistent, accurate surveys along repeatable transects would be the best method in comprehensively establishing if erosions rates are accelerating. However this would be a long term project in order to capture a range of temporal cycles (inter-season to multi-decadal).

In addition, and as recommended by Gibb (1999), repeat surveys of the cliffs would establish whether the cliffs are tending toward an equilibrium state and becoming more stable. This recommendation is particularly important in regard to sea level rise, with the highest estimate for the years 2090-2099 of 0.59 m ±0.2 m (IPCC, 2007), as it could promote the removal of talus material which acts to reduce the cliffs tendency to equilibrium. However, coastal erosion rates in response to sea level rise are not currently well understood, e.g. initial increased erosion due to rising sea level could lead to an increased buffer zone of material resulting in a period of greatly reduced erosion, and so in the medium term rates may decrease. Thus, the need for comprehensive monitoring is doubly significant.

The toe of the riprap armour in 2013 is equal to or in advance of the 1982 position suggesting that the erosion control system is effective. Again, repeat surveys and/or inspections of defences would provide more details as to whether the system is being undermined and has the potential to fail.

The long term erosion rates used by Gibb (1999) to establish the current CHZs still exceed many of the contemporary rates. A few locations do exceed the rates used in 1999 and it may be prudent to revisit the CHZ calculations for these locations and compare CHZ widths with the current CHZs.

However, the long term rates of erosion are only one term of the equation used by Gibb (1999) to calculate the CHZ. The other parameter used in the CHZ calculations is the horizontal distance of retreat of the cliff top in relation to the cliff base to attain a stable slope. This parameter requires the height of the sea cliff above mean sea level (MSL). It is recommended that cliff height data is acquired and the simple equations be made for the entire cliff-line using the method of Gibb (1999). The coverage of the current and latest CHZs can then be compared, which would significantly aid the decision making process, and provide up-to-date CHZs.

8. Study Limitations

This study is focussed on erosion rates by dividing the distance eroded by the time elapsed between surveys/data capture. While this method is effectively the most practical, episodic mass failures can distort long term erosion rates (Hall, 2002; Runyan and Griggs, 2003). There are however methods to separate the long-term trend from episodic events (Glassey *et al*., 2003: cited in de Lange and Moon, 2005), but the requirements are long term observations that also capture the magnitude of episodic events.

While erosion distance and rate have been quoted in this report to sub-meter values, comparison polylines generated from the annotation of georectified images and documents can potentially have multi-meter errors. The documentation associated with the 1942 rectified images states a positional accuracy of 5-10 m. Incorporation of other georectified images was attempted during this study from Google Earth, LINZ and a 2011 image provided by Wanganui District Council. However, after a thorough assessment the accuracy of the data derived from these sources was deemed unsuitable for this study as a result of a poor georectification process and/or resolution.

9. References

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