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Cadastral shoreline digitization project: Waikato Region

1.0 INTRODUCTION

When large-scale European settlement began in the 1840s, Crown and New Zealand Company surveyors began mapping harbours, towns, roads, arable land, geology, and occupation and ownership boundaries. Plans containing legal boundaries were referred to as cadastral plans; however, the term is now loosely used to cover all types of surveyed historical maps. Within these cadastral plans can be found quantitative information of coastal landforms that predate by some 60 to 100 years the vertical aerial photographic record of such features which began, for most of the New Zealand, in the 1940s. One of the earliest (1842) settlement plan for is shown in Figure 1 with modern shoreline overlain to illustrate dramatic coastal change through historical time at this location However, as yet we have been unable to locate information as to how this map was surveyed. While this limits its know accuracy and quantitative usefulness for comparative analysis, it does, nonetheless provides invaluable qualitative geomorphological information.

In 1874, the government reviewed the country's surveying and mapping and found only about 30% of the land had been adequately triangulated and only around 7% had accurate cadastral boundaries. In 1876, with the abolition of the provincial government system, the Department of the Surveyor-General was created. This department merged with the Crown Lands Department in 1891 to become the Department of Lands and Survey which persisted until the government reforms of the 1980. The Department of Lands and Survey then became the Department of Survey and Land Information (DOSLI) and in 1996 DOSLI was split into Land Information New Zealand (LINZ) and Terralink NZ Ltd.

Surveyors often recorded or sketched topographic features in their field books and their cartographers sometimes reproduced these on their plans. The coast itself was defined using a range of indicators such as the land-sea boundary, the high water mark (HWM) at the time of survey, the dune line, the cliff line, or a river, stream or estuary bank. Inclusion of early cadastral-based coastline information in temporal landform analysis can potentially provide greater insight into the nature and rates of past change and hence lead to more reliable prediction of future change.

However, abstracting usable data from these plans is not straightforward due to inaccuracies incurred during the original survey and plan production, storage conditions and the mediums aging characteristics, digital transformation procedures by LINZ in the 1980s and 1990s, and shoreline digitization processes used in the present project. In addition, there are issues relating

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to the nature and measurement of the landform indicators themselves. Accuracy and error assessment are thus major considerations when using cadastral-based data and this will be discussed in the following section (2) on Plan Characteristics and Accuracy.

The present project's objective is to provide digitized shorelines from all[1] historical survey plans from the Waikato Regional Council's jurisdiction. Plan and shoreline detail and output accuracy are summarised in the Metadata section (3). This procedure covers the following areas:

-Buffalo Beach

-Cooks Beach

-Kaiaua

-Marakopa

-Miranda

-Pauanui

-Port Waikato

-Raglan

-Tairua

Project outputs are provided in a folder for each site that contains the following:

-A spreadsheet (named "metadata") with an introductory section (sheet), a survey plan characteristics and accuracy section (sheet) and, a sheet with details for each location;

-The set of digitized shorelines for each site

-The corresponding set of survey plans that the shorelines were abstracted from - these plans are included to assist a user with shoreline interpretation.

1. Included are survey plans available in the LINZ data-base and any additional plans that are easily accessible. However, only plans containing shorelines actually surveyed for the production of that plan were processed, i.e. plans reproducing shorelines from earlier plans (a common practice) are not included. If uncertainty surround the dating authenticity of a shoreline, this is noted in the Metadata.

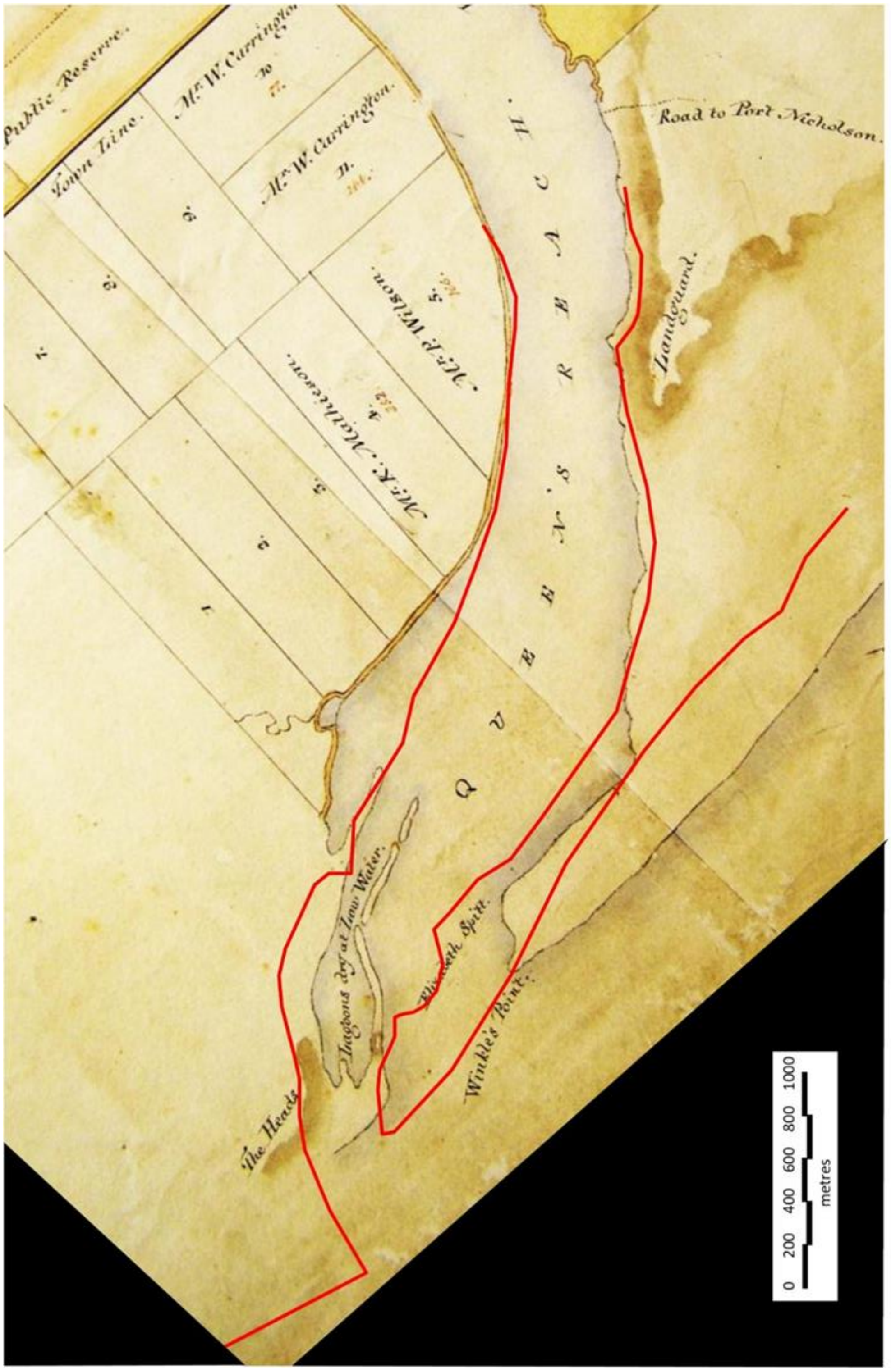

Figure 1 The seaward part of the New Zealand Company's 1842 settlement map of Petre (Wanganui). The red line depicts the modern shoreline.

2. PLAN CHARACTERISTICS and ACCURACY

2.1 Types of survey plan

There are three main types of cadastral survey plan:

- Survey Office Plans (SO)
- Māori Land Plans (ML)
- Deposited Plans (DP)

As well as the identification prefix, each plan has a number which is broadly chronological within each type.

Cadastral title plans can date back to the 1840s and the older plans may include names of European settlers, Māori and early English place names, as well as the 'appellation' (legal description).

2.2 Searching for cadastral plans

About 95% of historical plans were scanned during the 1990s and are held by LINZ. The remainder are roll plans or very fragile plans and Archives NZ will copy these upon request. However, identifying historical plans containing shoreline information for an area of interest is not straightforward as the LINZ index simply gives plan names but no date, no actual area of coverage nor any reference to a shoreline. Locating relevant plans can thus be particularly time consuming and expensive as LINZ charge per plan or for a search licence.

2.3 Shoreline indicator

As noted in the Introductory section, the surveyed shoreline may be indicated by several different features and these are given in the relevant metadata. For open coast beaches the high water mark (HWM) at the time of survey was typically used (e.g. see Figure 2). This indicator would later be replaced by the mean high water mark (MHWM), apparently this being defined by observation over time (for example 2 months in the case of 1913, DP 9251), although it appears surveyors may have used the terms interchangeably (e.g. see Figure 2 caption). Actual elevation-based MHWM were eventually adopted from the 70s using various MSL datum. In some cases the foredune toe or vegetation-front were used as open coast shoreline indicators. If no indicator was marked on beach plans, then the HWM is assumed. Cliff indicators (clifftop of cliff base, HWM and even a fronting-platform edge) were invariably not marked on plans; the field book may assist interpretation as may comparing the georeferenced plan with aerial photography. A range of Inlet indicators may also have been used including HWM, edge of bank or channel margin at the time of surveying.

It is important to know the nature of the indicator as some can vary daily in response to marine or fluvial conditions, while others such as a foredune toe or vegetation line respond only to extreme storm events (erode) and then recover (prograde) over months to years. Inlets are the most dynamic of coastal landforms with their margins able to migrate alongshore 10s or even 100s of metres per year making the indicator uncertainty less significant in determining historical behaviour (variation/extremes). Cliff lines are the most stable indicators with erosion (cliffs don't prograde) being dependent on the rate of marine undercut and terrestrial weathering and can range from virtually nothing for hard rock to over metres per year for weakly lithified material.

The relationship between a cadastral plan shoreline and the shoreline derived from the later vertical aerial photography, satellite imagery or LIDAR is also critical as the associated data sets may not be compatible and some allowance must made if such data sets are to be combined for analysis. For example, the vegetation front is typically used as the shoreline indicator with aerial photographs and satellite images and this indicator is located landward of the HWM and MHWM hence introducing a systematic error. Some reconciliation can me made if the typical variation between indicators (e.g. vegetation front and MHWM) can be determined from modern monitoring data - and it is reasonable to assume temporal consistency. Alternatively, if numerous aerial samples are available and the HMW is definable on them, then a uniform data set can be generated that includes the cadastral data. However, in this case, short-term variability (as noted above) can obscure a longer-term signal making the identification of statistically significant relationships less likely. By contrast, the cliff-top can be detected in aerial and satellite images thereby enabling a consistent data-set free of short-term noise to be generated and thus provide for significant trend definition. LIDAR provides three-dimensional data so can merge with the elevation-based indicators used in the later cadastral plans.

2.4 Shoreline measurement

Surveys were typically carried out using a "traverse" which consists of a series of adjoining straight lines forming a closed outline with each segment being defined by a bearing and length. The traverse could thus be accurately plotted and was also tied in to a standard co-ordinate system via observable Trig Stations. Natural features such as the shoreline were then located by making "offset" measurements at right angles to the traverse line which was ideally located close to, and parallel with, the shoreline of interest (examples marked in Figure 2). Later the elevation-based MHWMs were defined by locating the relevant elevation on the beach face then "fixing" this position using distance and bearing measurements. Alongshore spacing of adjacent shoreline measurements varies between about 20 m and 500 m depending on shoreline variation and the purpose (hence accuracy requirements) of the survey.

Plans depicting a shoreline but no traverse line, and/or offsets or fixings, are problematic in that the shoreline may have been copied from another (earlier) plan, or the shoreline location may have simply been estimated/sketched. Every effort was made to locate plans of an original survey. Such information, or lack of, is noted in the metadata.

Surveyors recorded their observations in a uniquely numbered “Field Book” and most books from the 20th century and also some from the 19th century are available from the LINZ archive. The Field Book may include sketches and additional interpretive information not shown on the plan.

2.5 Accuracy

The various limitations described above relate to the detection/measurement accuracy and stability of reference shorelines and the compatibility of shorelines derived from different sources. These limitations can be assessed based on the information summarised in the metadata coupled with the requirements of a contemporary use.

By contrast, the accuracy of the digitized cadastral shoreline in relation to the original ground survey can be numerically defined by combining the following three components:

2.5.1 Graphical errors

These include original survey and plotting errors, sheet dimensional distortions, general sheet deterioration and scanning, co-ordinate conversions and other errors incurred when LINZ compiled their (digital) data base. However, the major factor affecting graphical errors is the scale at which the original plan was drawn. The accuracy of the LINZ spatial data-base has been calculated (95% confidence level by LINZ) in relation to scale and relevant values are given in the metadata. Note that the scale was missing on some early plans so for the present exercise it was estimated based on the overall surveyed distance depicted in a plan. If the grid-based georeferencing approach is used (see below) then this error will reduce somewhat; however for the present exercise no adjustment has been made.

2.5.2 Georeferencing errors

These occur when transforming a plan to a predetermined scale, orientation and co-ordinate system to enable the overlaying of images for comparative analysis. Such a transformation involves the use of corresponding ground control points (typically boundary pegs or intersections) evident in both the LINZ spatial data base (the source information) and on the plan being georeferenced. Note, while the LINZ data-base depicts boundaries and other features/attributes, the actual plan LINZ adopted them from is not referenced and has to be "discovered".

It should be noted that plans made using the geodetic co-ordinate system (includes earth curvature) which were produced from 1950s, can be georeferenced using the map's northing and easting grid (grid-based approach) which is converted to NZTM (or whatever system is used for the georeferencing project) using the LINZ online LINZ co-ordinate conversion program.

Georeferencing can distort the original image to best fit the set of ground control points. An upper value (95%) is determined from the fitting errors to represent the georeferencing error and this is recorded in the metadata. The drafting and distortional accuracy of the plan to be transformed tends to determine the number of ground control points used in the transformation, with a greater number being required the more inaccurate the plan. The number of control points is also listed in the metadata. Where the plan is of particularly poor quality it is georeferenced in parts which are then merged to achieve acceptable accuracy.

Earlier plans may not show boundaries corresponding to those in the LINZ data base and in such cases more recent survey plans (which include earlier boundaries) are georeferenced and then used as the source image/data to georeferenced an earlier plan - a process referred to as "georeferencing step-back". Alternatively, processing more modern plans may help identify discrete pieces of LINZ data that are included but not obviously identifiable on an early plan - a process referred to as "georeferencing interpretation". Any plans used for step back or interpretation in additional to those used for shoreline digitizing, are also listed in the Metadata. The georeferencing error term was increased using the RSS approach (see equation 1 below) where step backing is used.

It is also noted that where a cadastral shoreline is only available on a plan "compiled" from other plans, an additional georeferencing component (using the RSS approach) was also included in the error analysis.

In some situations LINZ-based georeferencing points were simply not available and such a plan could not be utilized. However, in some cases stable geomorphological features could be identified based on aerial photo comparison. For example, where the edge of a well-defined rock outcrop showed minimal change between the first and last available aerial images (1940s to the present), it is reasonable to assume there was similarly minimal change back to when the feature was located during the cadastral survey – thus enabling it to be used as a ground control point.

Finally, where only 2 control points were available, the plan of interest was physically scaled and rotated (using a drawing programme) to fit the source plan. This analogue approach was that used exclusively before analytical transformation was available.

2.5.3 Digitization errors

Manually digitizing a georeferenced shoreline introduces a third source of error which can become significant if the original plan was in poor condition (distorted or disintegrating). The variation is sampled and an upper value selected for inclusion in the metadata and combined error computation.

The combined error is calculated using the root sum of squares (RSS) procedure (equation 1) derived from variance addition as these error terms are considered to be independent of each other.

$$CE = \sqrt{(E_1^2 + \dots\dots\dots + En^2)} \qquad (1)$$

Where CE = combined error, E_1 = first error term, and En = n^{th} error term.

In addition, where multiple georeferencing error terms are involved, e.g. where "step backs" have been used, then these are first combined using the RSS method. The combined error for each plan is listed in the metadata.

As noted earlier, an upper value is used for each error term (as defined by ~95% Confidence Interval) and equation 1 produces a corresponding upper value. This approach is used as coastal hazard assessments require the derivation of very likely impact. By contrast, the likely error range would be less than half this value.

Comments are also included in the metadata which note abnormalities associated with a particular plan and/or its georeferencing transformation. Of particular note is where a plan has plotted an earlier shoreline. These are often found to be in error when the early plan itself is georeferenced. Errors were typically 5 to 30 m; however, in the most extreme case, miss-plotting can exceed 150 m (see Figure 2 and comments made in the Port Waikato metadata). We emphasise the need to locate and process original survey plans rather than use earlier shorelines drawn on later plans.

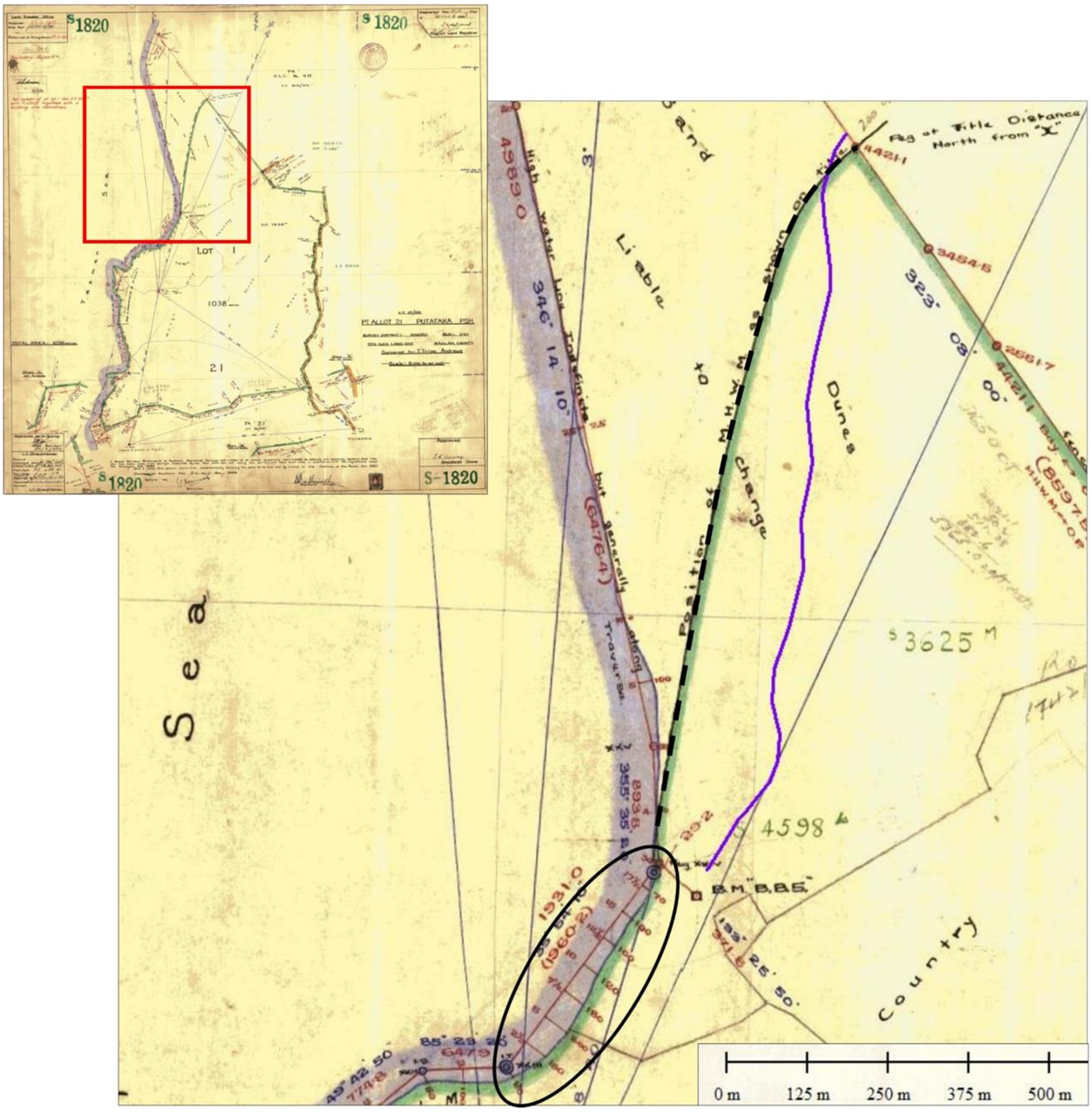

Figure 2 Cadastral plan features relevant to shoreline determinations as shown on the 1953 plan DPS 1820 of Port Waikato. The shoreline approximates the High Water Line at the time of surveying as well as showing the mean high water mark (MHWM) as depicted by the dashed black line as defined on the title which dates form 1878. However, this line is incorrect as the actual shoreline, defined by survey plan (SO 1420) has been overlaid in purple. The shoreline indicator in plans of this era was in fact the high water mark (HWM). This example clearly demonstrates the inadvisability of accepting early shorelines shown on later plans. The black ellipse defines a 380 m long "traverse" segment between two clearly marked "pegs". The shoreline is defined by offset measurements made every 50 m along the traverse line.

3. META DATA

3.1 Buffalo Beach

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
BUFFALO BEACH											
Plans for shoreline digitzation											
1870	ML 1973	Yes	HWM assumed	No	7 <>	1: 7920 (10)	9.2	8.9	3.6	13.3	<> 6 LINZ, 1 geomorph, inaccurately drawn. Georeferenced the area of interest only
1876	ML 4047	Yes	HWM assumed	No	3 <>	1:792 (1)	0.9	3	1.5	3.5	<> scaled and rotated to morphologically shape-fit DP 3430
1879	DP 3430	Yes	Various ^	No	3 <>	1: 3960 (5)	5.5	3.7	1	6.7	^ HWM assumed on coast. Both reclaimed shoreline plus assumed bank within inlet
											<> Georefn as 2 parts. 3 points each. One stepback control point off 1885 SO 3919
1882	DP 95	Yes	Bank assumed	No#	3	1:1188 (1.5) ##	1.3	0.7	0.3	1.5	# transect along/close to bank. ## estimated
1883	DP 357	Partial	HWM assumed	Few (200-400m)	8	1: 6336 (8) ##	7.9	4.1	1.5	9.0	## estimated
1885	DP 379	Yes	Bank and wall ^	Yes (15 to 20 m)	3	1:1188 (1.5)	1.3	0.3	0.3	1.4	^ Two shorelines named: edge of bank and breakwater (of Kaui slabs)
1890	DP 921	Yes	Bank assumed	No #	4	1:3168 (4) ##	4.4	1.2	0.7	4.6	# transect along bank. ## estimated
1896	ML 3550	Yes	HWM assumed	No	5<>	1: 7920 (10)	9.2	2.4	2	9.7	<> stepback georeference of 1913 ML 9050
1906	DP 5145	Yes	HWM assumed	No	4	1: 7920 (10)	9.2	5	2	10.7	
1911	SO 16673	No	HWM assumed	No	7	1: 7920 (10)	9.2	6.9	2	11.7	**HIGH UNCERTAINTY** - a roading plan with compiled shorelines - possible sketching
1913	ML 9050	Yes *	HWM assumed	No	6	1: 3168 (4)	4.1	1.8	0.7	4.5	* seaward road traverse along shoreline
1927	DP 21167	Yes	MHWM	Yes (50 to 80 m)	8<>	1: 6336 (8) ##	7.9	3.3	1.5	8.7	<> one control point scaled
1929	DP 22686	Yes	MHWM	Yes (20 to 60 m)#	5	1: 1584 (2)	1.8	1.4	0.5	2.3	Incorporated offsets within harbour from plan 1926 SO 24196
1954	DPS 3542	Yes	MHWM	Yes (40 to 100 m)	6	1: 1584 (2)	1.8	0.7	0.5	2.0	
1955	DPS 4704	Yes	MHWM	Yes (20 m)	7<>	1: 3168 (4)	4.1	2.8	0.7	5.0	<> stepback georeference of 1953 DPS 2792
1956	DPS 4410	Yes	MHWM	Yes (45 m)	3	1: 1584 (2)	1.8	0.8	0.5	2.0	
1969	SO 45056	Yes	MHWM	Yes (20 m)	4	1:792 (1)	0.9	0.6	0.2	1.1	
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1885	SO 3919				3						
1926	SO 24196				4						
1930	DP 23068				5						
1953	DPS 4725				5						
1953	DPS 2792				4						
1954	DPS 3542				6						
1955	DPS 4704				5						
1957	DPS 4410				4						

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3.2 Cooks Beach

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
COOKS BEACH											
Plans for shoreline digitzation											
1862	ML 15834	No*	HWM assumed	No	2<>	1: 7920 (10)	9.2	20	7	23.1	**HIGH UNCERTAINTY** as may incorporte sketching. See box for further details
1890	SO 5500	Yes	HWM assumed	No	5<>	1: 7920 (10)	9.2	6	2	11.2	
1920	SO 21048	Yes	HWM	No	3	1: 3960 (5)	5.5	4.2	1	7.0	
1950	DPS 899	Yes	MHWM	Yes (20 to 40 m)	9	1:1188 (1.5)	1.3	0.8	0.3	1.6	
1950	DPS 900	Yes	MHWM	Yes (30 to 40 m)	3	1:1188 (1.5)	1.3	0.8	0.3	1.6	
1954	DPS 2788	Yes	MHWM	Yes (30 to 60 m)	4 <>	1: 4752 (6)	6.3	1.6	1.2	6.6	<> no LINZ features available so easting/northing intersetion points used (see note in Section2) Note the southern embayment shoreline was digitized form the detailed inset diagram
1962	DPS 8284	Yes	MHWM	Yes (40 to 55 m)	7	1:792 (1)	0.9	0.5	0.2	1.0	
1962	DPS 8285	Yes	MHWM	Yes (60 m)	7	1:792 (1)	0.9	0.8	0.2	1.2	
1971	DPS 15943	Yes	MHWM	Yes (25 m)	6	1:792 (1)	0.9	0.5	0.2	1.0	
1975	DPS 22459	Yes	MHWM	Yes (200 m) #	6	1:600 (NA)	0.8	0.4	0.2	0.9	# Offset density concerning as shoreline non-linear. Consult Fieldbook 241 p36-69 for possible clarification.
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1975	DPS 22460				4						

Notes 1862 plan ML 15834 was the only Cooks Beach survey plan available until the subdivisions of the 1950s. Its year of 1862 was based on Gazetting dates written onto the plan. It appears this plan was used to define regional surveyed blocks including Dacre's Grant in the early 1860s: Dacre's Grant extended from the Whitianga entrance to the Purangi Rivermouth - thus including all of Cooks Beach. ML 15834 locates the inland boundaries and coastal extent of this 3390 acre (1372 ha) survey block reasonably accurately with some evidence of transects including at the Purangi rivermouth*. However, the intervening coastline is less clearly defined - implying some sketching may have been used along Cooks Beach.
ML 15834 was georeferenced using a scaled and rotation to morphologically shape-fit the 1944 aerial photo, which had been georeferenced from LINZ data. Two georeferenced versions are provided based on fitting variation.
Surveys in 1895 (SO 5) and 1917 (SO 19723) for road routes, excluded a surveyed coastline.
A short history of Dacre's Grant by Toby Morcom can be found in the 2006 "Cooks Beach, Ferry Landing, Flaxmill Bay Community Plan" (Thames Coromandel District Council). This local history notes the ownership changed about the turn of the century; however I doubt if this would have requried a new survey plan. The local history also refers to a proposed major subdivision involving the entire coastal reach by licenced surveyor John Dawson in the 1920s and this may have been accompanied by a shoreline survey. Unfortunately the TCDC have been unable to locate this plan.

3.3 Kaiaua

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
KAIAUA											
Plans for shoreline digitzation											
1885	ML 1072	Yes	HWM assumed	No	9 <>	1: 7920 (10)	9.2	5	3.6	11.1	<> Georeferenced in 3 parts (to maximise fit)
1909	SO 17612	Yes	HWM	Yes (100 to 200 m)	12	1: 7920 (10)	9.2	5	2	10.7	
1913	SO 17430	Yes*	HWM ^	No	11 <>	1: 7920 (10)	9.2	5.6	2.8	11.1	<> Georefn as 2 parts * North has traverse, South no traverse but shoreline along marked road
											^ Back of lagoon marked Spring HWM
1924	DP 17526	Yes	HWM assumed	Yes (20 m)	8	1: 3960 (5)	5.5	2.7	1.5	6.3	Resurveyed 1885 shoreline fronting lagoon.
1925	DP 18331	Yes	HWM assumed	Yes (20 m)	3	1: 1584 (2)	1.8	1.6	0.8	2.5	
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1912	ML 9200				6						
1917	ML 10738				8						
1920	SO 20723				5						
1930	ML 12721				7						
1948	DP 33564				3						
1949	DP 37341				8						
1965	DP 182367				4						
1965	ML 14481				7						
1986	SO 58223				4						
1996	DP 181190				5						
1997	DP 185334				4						

3.4 Marakopa

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
MARAKOPA											
Plans for shoreline digitzation											
1900	ML 6641	Yes	HWM assumed	No	11<>	1: 7920 (10)	9.2	8.9	2.3	13.0	ML 6641 had poor ledgability. <> Used 1922 ML 12940 compilation plan which plotted the original ML 6641 traverse and shoreline.
1911	ML 7823	Yes	HWM assumed	No	11	1: 7920 (10)	9.2	8	2	12.4	Stepback off ML 8384 Stepback off DP 8725
1911	ML 8384	Yes	HWM assumed	No				2.4			Stepback off DP 8725
1911	ML 8531	Yes	HWM	No	6	1: 7920 (10)	9.2	3.8	2	10.2	
1913	DP 8725	Yes	HWM	No	11	1: 1584 (2)	1.8	1.7	0.5	2.5	
1929	SO 25220	Yes	Edge vegetation	Yes (12 to 40 m)	7	1: 1584 (2)	1.8	1.1	0.5	2.2	
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1911	ML 8045				8						
1911	ML 8331				7						
1911	ML 8384				6						
1911	SO 16552				6						
1912	ML 8608				6						
1916	SO 18795				4						
1923	SO 22900				6						
1965	DPS 9815				3						

3.5 Miranda

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
MIRANDA											
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1865	SO 1315	Yes*	HWM assumed	Yes# (200 to 500 m)	5	1: 7920 (10)	9.2	6.7	3.9	12.0	* Traverse 100 to 200 m landward of shoreline. # offsets widely spaced @ 200 to 500 m
											Note 1871 ML 2423 (south), 1877 ML3012 (south) and 1873 ML 2925 (north) lacked control for georeferencing
1891	ML 6269_2	Yes	HWM assumed	No	7	1: 15840 (20)	22	10.1	3.5	24.5	**Note** ML 6269 shoreline is marked on 1913 DP 9251, but ± 10-20 m plotting error. Demonstrates importance of georeferencing original source for defineing a shoreline
1913	DP 9251	Yes	MHWM^	Yes (100 m)	7	1: 7920 (10)	9.2	7	2	11.7	^ averaged over 2 mths
1913	DP 12260	Yes	HWM assumed^	Yes (40 m)	5	1: 3960 (5)	5.5	5.8	1.7	8.2	^ annotated "Shell Bank"
1963	DP 53345	Yes	MHWM	Yes (20 to 100 m)	5	1: 3960 (5)	5.5	3.6	1.5	6.7	
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1893	ML 6269 (sheet 1)				4						
1917	DP 11846				3						

3.6 Pauanui

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
PAUANUI BEACH											
Plans for shoreline digitzation											
1895	SO 6910 D2	Yes	HWM assumed	No	7	1: 7920 (10)	9.2	3.1	2	9.9	
1967	DPS 11962	Yes	MHWM	Yes (20 to 300 m)	5	1: 3960 (5)	5.5	2.5	1	6.1	**Note** 1871 ML 2423 (south), 1877 ML3012 (south) and 1873 ML 2925 (north) lacked control for georeferencing
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1895	SO 6910 D2				8						**Note** ML 6269 shoreline is marked on 1913 DP 9251, but ± 10-20 m plotting error. Demonstrates importance of georeferencing original source for defineing a shoreline

3.7 Port Waikato

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
PORT WAIKATO											
Plans for shoreline digitzation											
1858	SO 1216	Yes	HWM assumed	No	19 <>	1: 6336 (8)	7.9	6.5	5	11.4	<> Stepback 6 off SO 1179, 13 LINZ
1864	SO 362				20	1:1584 (2)	1.8	2.1	0.5	2.8	
1877	SO 1420	Yes	HWM^ Platform	No	3 <>	1: 7920 (10)	9.2	10	3.8	14.1	2012-15 using geomorphic control (platform corner evident in the 1877 plan and the 1944
1951		Yes	MHWM	Yes (5 to 35 m)		1:1188 (1.5)	1.3	1.5	0.3	2.0	
1953	DPS 1820	Yes	MHWM	Yes (50 to 100 m)	12 <>	1: 6336 (8)	7.9	9.9	2	12.8	<> This plan was a poor quality drawing so georeferencing was off the 'accurately' drawn reference plans 1955 DPS_3625 and 1957 DPS_4761 which included replotting of the DPS_1820 shoreline transect. See further comment in the box below
1978	DPS 265557	*	^	#	6	1: 5940 (7.5)	7.5	2.8	1.5	8.1	
1981	SO 51882	*	^	#	4	1: 5940 (7.5)	7.5	2.8	1.5	8.1	
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1877	SO 1179				9						
1883	SO 3240				4						
1921	So 22078				6						
1955	DPS 3625				9						
1877	SO 1434A				4						
1877	SO 1447				5						
1957	DPS 4761				14						
1957	DPS 4598				13						

Note 1871 ML 2423 (south), 1877 ML3012 (south) and 1873 ML 2925 (north) lacked control for georeferencing

Note ML 6269 shoreline is marked on 1913 DP 9251, but ± 10-20 m plotting error. Demonstrates importance of georeferencing original source for defineing a shoreline

* ^ # Plans 1979 DPS_27544 and 1981 SO_61882 include a MHWM shoreline "adopted from the 1979 aerial photo SN 5164". The MHWS adoption method is neither known nor assessed.

The 1953 plan (DPS 1820) incorrectly plots a 1877 shoreline (from plan SO 1179) some 165 m seaward of the correct 1877 shoreline location as determined from plan SO 1420 (and shown on plans SO 1434A and SO 1447). SO 1420 is traverse-based while SO 1179 shoreline was not traverse-based and appears to have been sketched/estimated.

3.8 Raglan

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
RAGLAN											
Plans for shoreline digitzation											
1861	SO 903-3	No	HWM ^	No	14 <>	1: 1180 (15)	15	11	3.3	18.9	See box
1885	SO 3809	Yes	HWM assummed	No	7 <>	1: 7920 (10)	9.2	2.9	2	9.9	
1914	ML 9408	Yes	HWM assummed	No	17 <>	1: 7920 (10)	9.2	8.7	2.9	13.0	
1924	ML 13518	Yes	HWM assummed	No	8 <>	1: 7920 (10)	9.2	2.1	2	9.6	<> stepback 6 off SO 31512
1933	DP 24725	Yes	MHWM	Yes (40 to 80 m)	7	1: 3168 (4)	4.1	1.3	0.7	4.4	
1941	SO 31512	Yes	MHWM	Yes #	16<>	1: 7920 (10)	9.2	2.1	2	9.6	
1987	DPS 44506	Yes	MHWM	Yes (fixings)	6	1:4000 (NA)	5.5	1.6	1	5.8	
1987	DPS 45471	Yes	MHWM	Yes (fixings)	13	1:2000 (NA)	2.4	1.5	0.5	2.9	
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1922	SO 22322				5						
1949	ML 16770				7						
1964	DPS 9326				6						
1964	LTS 9609				11						
1966	DPS 10769				5						
1969	SO 44836				11						
1970	DPS 14566				9						
1987	DPS 45471				13						

Note 1871 ML 2423 (south), 1877 ML3012 (south) and 1873 ML 2925 (north) lacked control for georeferencing

Note ML 6269 shoreline is marked on 1913 DP 9251, but ± 10-20 m plotting error. Demonstrates importance of georeferencing original source for defineing a shoreline

Notes

The 1861 plan SO 903 sheet 3 is the earliest shoreline for Ngaranui Beach and the Pilot Reserve South Head. The next plan for this reach being 1933.

the plan scale is not shown. Estimation using aerail extent of the plan is Line thickness indicates 10 ch to 1 inch (9 m error). Alternatively, for a "remote" plan LINZ recommend a scale-based error of at lease 15 m.

<> While suitable boundaries exit to allowed for recitifaction, there was no control gcps withing 500 m of the shorelines, so the extrapolation will have incorporated some error.

^ In addition, there is an additional non-annotated seaward line the entire length of the mapped coast, together with two further seaward lines (dashed) at the southern end whose annotations cannot be deciphered. These additional (3) lines may denote later additions. Field book was not available.

SO 44836 (1969) is a compiled plan which maps a smoothed shoreline along Ngaranui Beach corresponding to SO 903-3 providing false assurance as at the south end of Ngaranui Beach the marked (HWM) shoreline is landward of elevated topography thereby questioning the nature of the mapped feature and whether it was actually measured or estimated/sketched

The SO 903-3 shoreline fronting the Pilot Station Reserve at South Head corresponds with compiled plan SO 22322 (1922), thus confirming our georeferencing and the validity of at least the eastern end of the SO 903 shoreline.

3.9 Tairua Beach

Year	Plan Name	Shoreline Traverse *	Shoreline Type ^	Shoreline definition: Offsets (spacing) #	Georeferencing control <>	Scale ## (Chains to inch)	Plan errors (LINZ)	Georeferencing error	Shoreline digitiz error	Combined error (95%)	Comments
TAIRUA BEACH											
Plans for shoreline digitization											
											Note 1861 plan SO 167 lacked control for georeferencing
1895	DP 1477	Yes	HWM assumed	No	20<>	1: 11880 (15)##	15	4.8	2.1	15.9	**Note** 1871 ML 2423 (south), 1877 ML3012 (south) and 1873 ML 2925 (north) lacked control for georeferencing
											## estimated
1948	DP 35338	Yes	MHWM	Yes (20 m)	8	1: 4752 (6)	6.3	1.8	1.2	6.7	**Note** ML 6269 shoreline is marked on 1913 DP 9251, but ± 10-20 m plotting error. Demonstrates importance of georeferencing original source for defineing a shoreline
1950	DP 26	Yes	MHWM	Yes (20 m)	4	1:792 (1)	0.9	0.9	0.2	1.3	
1950	DP 27	Yes	MHWM	Yes (20 m)	3	1:792 (1)	0.9	0.8	0.2	1.2	
1953	DPS 2002	Yes	MHWM	No	4	1:792 (1)	0.9	0.7	0.2	1.2	
1953	DP 34418	Yes	MHWM	Yes (20 m)	7	1: 1584 (2)	1.8	1.1	0.5	2.2	
1955	DPS 4480	Yes	MHWM	No	5 <>	1: 3960 (5)	5.5	2.5	1.0	6.1	<> 1 stepback point of 1973 DPS 18839
1955	DPS 4481	Yes	MHWM	Yes (20 m)	3	1:792 (1)	0.9	1	0.2	1.4	
1962	DPS 8738	Yes	MHWM	No	4	1: 1584 (2)	1.8	0.9	0.5	2.1	
1963	DPS 8976	Yes	MHWM	Yes (10 to 120 m)	5	1:792 (1)	0.9	0.4	0.2	1.0	
1963	DPS 8977	Yes	MHWM	Yes (60 m)	4	1:792 (1)	0.9	0.7	0.2	1.2	
1963	DPS 8978	Yes	MHWM	Yes (10 to 20 m)	4	1:792 (1)	0.9	1	0.2	1.4	
1963	DPS 9481	Yes	MHWM	Yes (5 to 40 m)	5	1:792 (1)	0.9	0.5	0.2	1.0	
1965	DPS 10623	Yes	MHWM	Yes (5 to 20 m)	3	1:792 (1)	0.9	0.5	0.2	1.0	
1966	DPS 11323	Yes	MHWM	Yes (20 m)	4	1:2376 (3)	3.1	1.2	0.6	3.4	
1967	DPS 11723	Yes	MHWM	Yes (60 to 120 m)	3	1:792 (1)	0.9	0.5	0.2	1.0	
1979	DPS 28019	Yes	MHWM	Yes (20 m)	4	1:1500 (NA)	1.7	1.3	0.5	2.2	
Reference Plans (for "stepback" georeferencing and/or interpreting LINZ data)											
1969	DPS 13916				3						
1973	DPS 18839				3						

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