COASTAL SYSTEMS LIMITED

Kapiti Coast Erosion Hazard Assessment

2012 Update

A report prepared for the Kapiti Coast District Council

Following the October 2013 local body election, the Kapiti Coast resident's group CRU dominated the council and had the words "This report cannot be relied upon" printed on CSL hazard assessments. This was essentially motivated by self interest (fear of property value loss). CSL reports use current best practice, are peer reviewed and are fit for purpose.
The hazard lines depicted in Appendix I identify areas potentially exposed to erosion hazard based on a conservative (high-level) assessment procedure. A site-specific assessment should be carried out to refine the hazard likelihood and risk if development is considered within any such area. This approach is consistent with the original council brief and also with current (2017) Ministry for the Environment coastal hazard guidance.
CSL 2020

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EXECUTIVE SUMMARY

This report updates the 2008 Erosion Hazard Assessment which was a comprehensive erosion analysis covering the entire 38 kms of sandy coast and (12) inlets administered by the Kapiti Coast District Council (KCDC). The 2008 Assessment considered three 50 yr open coast scenarios (seawalls hold, seawalls fail and are repaired, and seawalls are removed) and two 50 yr inlet scenarios (inlets managed and unmanaged (natural). The 2008 Erosion Hazard Assessment used a best practice empirically-based approach which quantifies the predicted cross-shore erosion hazard distance by summing several components whose values were statistically derived. The hazard components consist of:

- longer-term shoreline change;
- shorter-term shoreline fluctuations;
- shoreline retreat associated with anticipated acceleration in sea-level rise from global warming;
- shoreline retreat to achieve a stable slope following dune erosion, and
- combined uncertainty which provides a safety margin.

The 2008 report’s findings, however, were not implemented into the KCDC District Plan, as the guiding statue for management of the New Zealand coast (the New Zealand Coastal Policy Statement 1994 [NZCPS 1994]) was, at that time, in the advanced stages of a comprehensive review (begun in 2003) and the possibility existed that the revised Policy Statement could include materials that would affect the hazard assessment and and/or its District Plan application.

In December 2010 the New Zealand Coastal Policy Statement (NZCPS 2010) became operative. In March, 2011, CSL were instructed to update the 2008 Erosion Hazard Assessment in keeping with directives in the NZCPS 2010 and also taking into account other guidelines, e.g. the MfE guidelines on climate change, and information which had become available during the interim, e.g. Marine Parade Revetment investigation, and wave modelling and longshore sediment transport (littoral drift) values for the Kapiti Coast. In addition, the consultants assisting the council with planning implementation requested further materials be included in the Updated Assessment.

The 10 point Terms of Reference for this Update Assessment are set out in Section 1 with the primary directives being:

(i) To define open coastal erosion prediction lines (CEPLs) for periods of 50 yrs and (at least) 100 yrs, with the 50 yr option to include lines for both managed[1] and unmanaged[2] scenarios (1 and 2), while the 100 yr option only addressing the unmanaged scenario (3), and

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[1] *Managed* refers to the maintenance and repair (if damaged) of *community* seawalls. Note *private* protection structures are not included within this assessment.

[2] *Unmanaged* refers to removal of seawalls where they do exist.

(ii) To define inlet erosion prediction lines (IEPLs) for periods of 50 yrs and (at least) 100 yrs with both options including both managed and unmanaged scenarios.

The same erosion prediction models for the open coast and the inlets used for the 2008 Erosion Assessment were used in this Update Assessment.

Open coast erosion output presented within this Update report consists of erosion component values derived for the 75 measurement sites (Figure 2.1, Appendix B) along the Kapiti Coast (values in Appendix D1-3), with the resulting CEPLs being provided to the council as electronic line files. The results are briefly described as follows:

The open coast **50 yr managed** predicted erosion distances from the reference shoreline (approximately the present shoreline) range between 25.6 and 120 m (mean = 44.2 m) with the highest erosion values being along the northern QEII coast and lowest values corresponding to the seawalled sections of Paekakariki and Raumati coast and along the northern coast between Te Horo Beach and the Otaki Rivermouth. The only values which differ from the 2008 Assessment are along the north Raumati-south Paraparaumu coastline (2008 = 20.4 to 53.4 m c.f. 2012 = 19.9 to 47.7 m).

The open coast **50 yr unmanaged** predicted erosion distances from the reference shoreline range between 25.6 and 72.2 m (mean= 45.6 m) with the highest erosion values being along the South Raumati coast and around the foreland, and the lowest values being along the north coast and in particular between Te Horo Beach and the Otaki Rivermouth. Once again the only values which differ from the 2008 Assessment are along the north Raumati-south Paraparaumu coastline (2008 = 32.9 to 73.9 m c.f. 2012 = 31.9 to 47.2 m).

The open coast **100 yr unmanaged** predicted erosion distances from the reference shoreline range between 39.4 and 129.7 m (mean= 85.8 m) with the highest values being along the South Raumati coast and foreland, and the lowest values between Te Horo and the Otaki Rivermouth.

Inlet erosion output presented within this report consist of sections (4.4.2 to 4.4.14) describing and summarizing the physical characteristics and depicting erosion prediction line derivation for each inlet, plus a *summary figure* (Figures 4.3 to 4.15). In each inlet's summary figure the IEPLs are depicted merging with the open coast CEPLs with these lines also being provided as electronic files.

The inlets vary dramatically in their dimensions, behaviour, management regime and predicted erosion. Overall, inlets north of the foreland were larger than south coast inlets (5.4 to 71 ha c.f. 0.6 to 5.5 ha). Predicted erosion lines are similarly further landward for northern inlets than southern, for example for managed inlets under the 50 yr scenarios, the northern inlet prediction lines ranged between 33 to 120 m landward of the adjacent open coast compared with 10 to 88 m for south coast inlets with the numbers of affected properties following the same pattern (up to 26 per inlet in the north compared with 12 in the south.

The erosion hazard assessment process used is a generic approach due to the extensive spatial coverage coupled with available time and funding. However, using a generic method where there is such a range of types of open coast, types of inlets and variation in management regime, inevitably leads to some apparently inconsistent results. For example, at the managed southern Otaki Inlet, the predicted erosion line is landward of the natural inlet erosion line due to stopbank alignment influencing the more recent inlet configuration. Alternatively, some results may be over-estimated due the application of representative component values between measurement points. For example, along parts of the south coast large spatial variation in dune height between measurement points occur so an upper value was selected and applied throughout the sector in the interests of precautionarity (required by statute). Such issues can be resolved, and prediction lines thus further refined, when and where necessary, using more localized site-specific assessments as these are carried out with greater detail (and at greater cost).

An erosion hazard assessment such as this is a detailed scientific study which predicts potential hazard (magnitude and probability) over different prediction periods. By contrast, erosion management is a process whereby the science-based erosion predictions are transformed into hazard management zones for inclusion within the District Plan. This conversion process is presently being undertaken by the KCDC planning staff who also factor in a range of other matters including the requirements of statues, regulations and planning provisions, recognizing that different types of development carry different risk levels and the need to provide for reasonable use of existing property, and recognizing the future needs of the community and including adequate public consultation.

Finally, it is noted that the CSL erosion hazard assessments have been peer reviewed, either in part or in full, by several experts (see Acknowledgements), and reviewer Dr Mike Shepherd's overview comments on the present Update Assessment are included as the final appendix (H).

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1.0 INTRODUCTION

The Kapiti Coast Erosion Hazard Assessment was completed by Coastal Systems Ltd (CSL) in April 2008 for the Kapiti Coast District Council (KCDC). The report comprised Part 1: Open Coast, Part 2: Inlets, and Part 3: Data-Base, each being contained within a separate volume. However, the report's findings were not incorporated into the District Plan as the guiding statue for management of the New Zealand coast (the New Zealand Coastal Policy Statement 1994 [NZCPS 1994]) was in the advanced stages of a comprehensive review (begun in 2003) and the possibility existed that the final document could include changes that would affect the assessment itself and its application. In December 2010 the New Zealand Coastal Policy Statement became operative. In March, 2011, CSL were instructed to update the 2008 Erosion Hazard Assessment, for both the open coast and the 12 inlets, in keeping with changes in the NZCPS and also taking into account other guidelines and information which had become available in the interim.

Terms of Reference: March 2011

The Updated Erosion Hazard Assessment (hereafter referred to as the 2012 Update Assessment) should incorporate the following:

1. Relevant requirements of the *New Zealand Coastal Policy Statement NZCPS 2010* (hereafter referred to as the NZCPS 2010);
2. Relevant requirements contained the Ministry for the Environment's 2008 publication: *Local Government Guidance Manual on Coastal Hazards and Climate Change* (hereafter referred to as the Guidance Manual 2008);
3. Any other relevant research or management reports carried out since completion of the 2008 Erosion Hazard Assessments.
4. Hazard lines are to be identified for the following two scenarios:
    - **(a)** A prediction period of 50 years. For open coast areas with "community[1]" protection structures (seawalls), these structures will be repaired if storm damaged. For inlets, channel management will continue, and
    - **(b)** A prediction period of 100 years. For the open coast, protection structures will not be included within the assessment. For inlets, channel management will continue.
5. The derived hazard lines should be scientifically robust and defendable.

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[1] Community structures are defined as those designed and constructed by government agencies. In most cases these were constructed following the 1976 erosion event and have been maintained by government agencies thereafter. Other structures are defined as private and their effects have not been incorporated within this assessment.

In June 2011, the draft Erosion Hazard Update report comprising revised hazard lines, updated hazard component values and hazard lines was forwarded to council. These materials were then used by the Waikato-based consultancy the *Focus Resource Management Group* to provide a framework (rather than specific wording) for planning provisions with which KCDC staff could incorporate the CSL hazard assessment outputs into the District Plan, which is being reviewed. The Focus Group required additional hazard information to be included within the final Updated Erosion Hazard Assessment (2012 Update Assessment).

Terms of Reference: April 2012

6) *Profile extrapolation to check present estimates of "catch-up" erosion;*
7) *Mapping of the 100 yr natural inlet erosion line;*
8) *Inclusion of the 50 yr unmanaged (seawalls removed) open coast erosion hazard line, and the corresponding 50 yr unmanaged (natural) inlet erosion hazard line, and*
9) *Include geomorphological evidence in the vicinity of inlets which indicates the potential for greater erosion than presently assessed.*

In addition, KCDC staff subsequently required:

10) *Change the terminology for the modelled 50 and 100 yr erosion lines from Coastal Erosion Hazard Distances (CEHDs) to Coastal Erosion Prediction Distances (CEPDs),* and *Coastal Erosion Hazard Lines (CEHLs) to Coastal Erosion Prediction Lines (CEPLs).*

> Note that the *distances* here refer to the cross-shore distance erosion is predicted to reach (from a pre-defined reference point) while the *lines* occur in the alongshore direction and join the erosion points which the distances define.
>
> This terminology change was to help distinguish between the CSL modelled erosion lines and the hazard management lines that will be incorporated within the District Plan as the latter may incorporate other factors such as reserve strips.

The 2012 Update Assessment will include a range of base material from the 2008 Assessment so the reader will more easily be able to follow the assessment process. However, the 2008 Assessment is a comprehensive report and technical readers should refer to it for more detailed explanation/justification of the hazard assessment procedures used by Coastal Systems Ltd.

The 2012 Update Assessment begins (Section 2) by summarizing relevant recent official guidance and statutory changes. In addition, relevant material contained in the recent CSL

2010 report “Marine Parade Revetment Erosion Update Assessment and Management Programme” are described. The open coast erosion analysis is described in Section 3 and the inlet erosion analysis is described in Section 4. Section 5 describes the Data Base which is being fully revised. A range of practitioners have provided comment or review on the assessments, either in part or in full, and these experts are listed in the Acknowledgements. In addition, Dr Mike Shepherd, one of New Zealand’s most experienced coastal scientists, reviewed the final report and his overview comments have been included as the final appendix (H).

2.0 NEW INFORMATION

2.1 Guidance Manual 2008

2.1.1 Introduction

In 2004, the Resource Management Act 1991 was amended to require the effects of climate change to be taken into account in managing the use, development and protection of natural and physical resources. In that same year the Ministry of the Environment released version 1 of its *Coastal Hazards and Climate Change* (MfE, 2004) to support local government decision-making regarding resource management. The second version was released in July 2008 (here referred to as the *Guidance Manual 2008*) and incorporates the findings of the Intergovernmental Panel on Climate Change released in 2007 (IPCC, 2007). The Guidance Manual 2008 provides additional information on the key effects of climate change on coastal hazards as well as making several recommendations (p5) on how to incorporate these effects within longer-term decision-making.

The Guidance Manual 2008 stresses that climate change will not introduce any new types of coastal hazard but will affect some existing hazards by modifying hazard drivers such as sea-level rise (SLR), tides, storm surge, waves, and sediment supply, with these drivers combining to affect erosion and inundation (p22, 28). While potential sea-level rise and direct impacts are relatively well understood, implications for the other hazard drivers are less so and the manual provides pragmatic guidance (p ix), or indicative guidance (p 28), in these situations. The climate change-induced effects relevant to coastal erosion are summarized below. How they impact upon, or are dealt with in, the present (2012) Update Assessment have been underlined.

2.1.2 Sea-level rise

The IPCC (2007) predicted sea-level rise for the periods 1980-2000 to 2090-2100 would be 18 to 59 cm. The IPCC (2007) authors also added an additional 10 to 20 cm to the upper limit of 59 cm to allow for uncertainties in ice-sheet stability. MfE's 2008 Guidance Manual (Table 2.3, p20) recommends the 2060 - 2069 (50 yrs) base value for sea-level rise (SLR) at 0.31 m, with consequences of an additional 0.22 m being considered. For a prediction period 2100 - 2109 (100 yrs), the base value should be 0.7 m with consequences of an additional 0.3 m being considered. However, SLR datum is the 1980-1999 average, whereas the present (2012) Update Assessment uses 2008 so 0.05 m is subtracted. The actual values used for the present Update Assessment are described below in Section 3.1.3.

2.1.3 Coastal Erosion

The Guidance Manual 2008 specifically describes the erosion drivers and how they can be qualitatively affected by climate change within different coastal environments (p32-38). In general, expected increases in water level, along with increases in wave height and storminess will have, in some areas, the potential to increase the spatial extent and temporal frequency of shoreline wave attack, and thus an increase in erosion potential.

However, the manual also notes that on western coasts (thus including the Kapiti Coast), an increase in sediment supply may also occur as climate change is expected to increase both the episodic and mean annual supply of sediment via rivers and streams (p26). In addition, on western coasts an increase in coastal cliff erosion may further increase the littoral sediment input, the inference being that these changes in sediment supply may retard erosion. Until more quantitative guidance is available as to the effects of climate change on erosional processes, the present (2012) Update Assessment incorporates such uncertainty within the margins of error.

The Guidance Manual 2008 (p38) considered the following methods appropriate for use in an erosion assessment:

- Identification of erosion rates using an empirical approach based on analysis of multi-decadal shoreline data-sets;
- Determination of future acceleration in erosion using a profile-based shoreline translation model, and
- Inclusion of a robust incorporation of uncertainties within the assessment.

Such methods were used CSL's earlier (2008) erosion hazard assessment and the same methods used in the present Update Assessment.

2.2 New Zealand Coastal Policy Statement 2010

The 1994 New Zealand Coastal Policy Statement (NZCPS, 1994) is a mandatory guide on interpreting the Resource Management Act 1991 as it relates to management of the New Zealand coastal environment. The first revision of the Statement began in 2003 with a proposed version being released in May, 2008 and the final revised version becoming operative in December 2010. Relevant polices relating to erosion hazard assessments are now described, along with how they impact upon, or are dealt with in, the present (2012) Update Assessment.

Policy 24 relates to the *identification of coastal hazards*. Of specific relevance to the present (2012) Update Assessment are the following matters (which are not necessarily mutually exclusive).

1) *Hazard risk shall be assessed over at least a 100 yr timeframe*.
This is being accommodated in the Update Assessment by using both 50 and 100 year prediction period scenarios.

a) *Have regard for the physical drivers and processes which cause coastal change including SLR*.
The 2008 Erosion Assessment describes the region's geomorphology (landforms and their formative processes), with emphasis on inlets as these are particularly dynamic coastal landforms and a magnet for residential settlement/development. The 2008 Assessment (and

the 2012 Update) uses methods appropriate to the differing geomorphologies. The 2012 Update Assessment provides a range of additional process information.

b) *Regard for short and long-term natural shoreline fluctuations*
The 2008 Assessment (and the 2012 Update) defines these behavioural modes using shoreline data abstracted from survey plans and vertical aerial photographs by modern analytical photogrammetric methods and analysed using rigorous statistical methods.

c) *Geomorphological character*
See (a) above.

f) *Influences that humans have had, or are having, on the coast.*
The Kapiti Coast has been, and is being, subject to process modification by a variety of shoreline and inlet structures and other management practices. The 2008 Erosion Assessment and the present (2012) Update Assessment consider scenarios involving the open coast's seawalls, inlet control structures and other management practices. The open coast structures to be considered in the present (2012) Update Assessment are described in Appendix A and their environmental effects from a hazard assessment perspective are quantified therein and in Section 3. Inlet structures and their past and future environmental effects are described for each inlet in Section 4.4 below.

h) *The effect of climate change on the above and on sediment dynamics*
In addition to assessment of the effect of rising sea level on erosion along the Kapiti Coast, this policy also requires the wider effects of climate change must now also be considered, e.g. a changes in storm behaviour and hence in erosion rates. The Guidance Manual 2008 provides indicative guidance only as these effects are generally not well understood. As noted above, this uncertainty has been addressed in terms of increasing the safety margin - this being consistent with the Precautionary Approach contained in Policy 3 of the NZCPS 2010.

And taking into account national guidance and the best available information on the likely effects of climate change on the region or district.
The 2012 Update Assessment has taken such information into account.

2.3 Marine Parade Revetment environmental impact investigation

2.3.1 Expanded shoreline data-base

The Marine Parade Revetment (MPR) environmental-impact investigation was reported in CSL (2010). That study incorporated a detailed shoreline analysis of the north Raumati - south Paraparaumu coast using samples from 1942, 1952, 1956, 1965, 1973, 1980, 1985, 1992, 1998, 2001, 2005, 2007 and 2010 derived from vertical aerial photographs. By comparison, for some sites as few as five shorelines were used in the 2008 Assessment, so a higher level of behavioural accuracy was provided by reanalyzing using the additional data from the MPR study. This new information was particularly significant as the 2008 Erosion Hazard Assessment found the north Raumati-south Paraparaumu coast, i.e. Wharemauku Stream (10.0 km from Fisherman’s Table Restaurant) and the Tikotu Stream (12.6 km) to be the stretch of Kapiti Coast with the most “tenuous stability”. The expanded data-set and its analysis to locate the 50 and 100 yr erosion prediction lines are detailed in the Data-Base spreadsheets (see Section 5). In addition, while the 2008 assessment used 8 measurement sites (C10.29, C10.40, C10.64, C11.17, C11.42, C11.64, C12.12 and C12.50), an additional two critically located sites were used in the present Update Assessment (C10.91 and C11.88), with a further 6 intermediate sites (X10.53, X11.07, X11.76, X11.88, X12.01 and X12.31) used to more accurately define between-site variation. Note that the full set of measurement sites are illustrated in Figure 2.1, and the measurement reference points and survey co-ordinates are set out in Appendix B.

Shore-parallel protection structure (SPPS) end-effects

The primary objective of the MPR environmental impact assessment was to define the extent of possible revetment-associated erosion alongshore from the structure ends (end-effect erosion). Such erosion is common and results from the structure affecting wave processes; this typically results in the formation of an embayment extending alongshore from the terminus of the structure (see Figure 2.2).

The MPR study used a variety of methods to assess end-effects including measurements from other SPPS/embayments on the south Kapiti Coast, and used these as well as data reported from other coastal sites to define several empirical relationships for predicting embayment dimensions. The MPR study results were used in the present (2012) Update Assessment to define standardized end-embayment dimensions. A summary of the equations and their application to each community SPPS are given in Appendix A. Note that existing structures not included in Appendix A are defined as private structures rather than community structures.

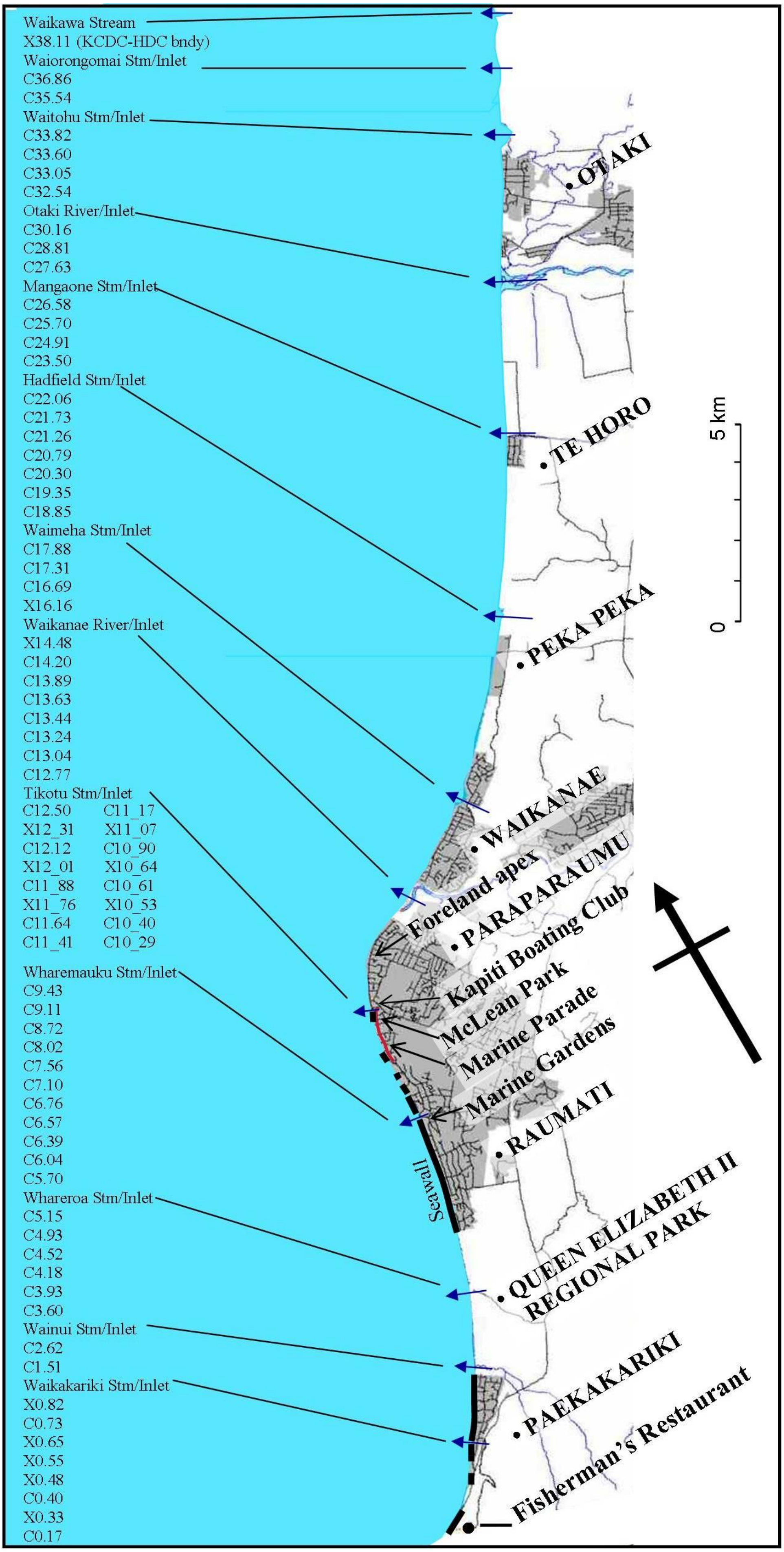

Figure 2.1 Map of the coastal area administered by the Kapiti Coast District Council which is referred to as the 'Kapiti Coast' in this report. Urban areas, water courses and stream mouths, seawalls and other locations referred to in the text have been marked. References across the top of map locate *coastal measurement sites* with the prefix **C** referring to sites used to provide data for determining erosion hazard **C**omponent values, references beginning with the prefix **X** referring to sites used to provide e**X**tra data for more detailed hazard intermediate assessment, and the subsequent numbers refer to each site's longshore distance (km) from the datum at the southern end of Paekakariki Beach.

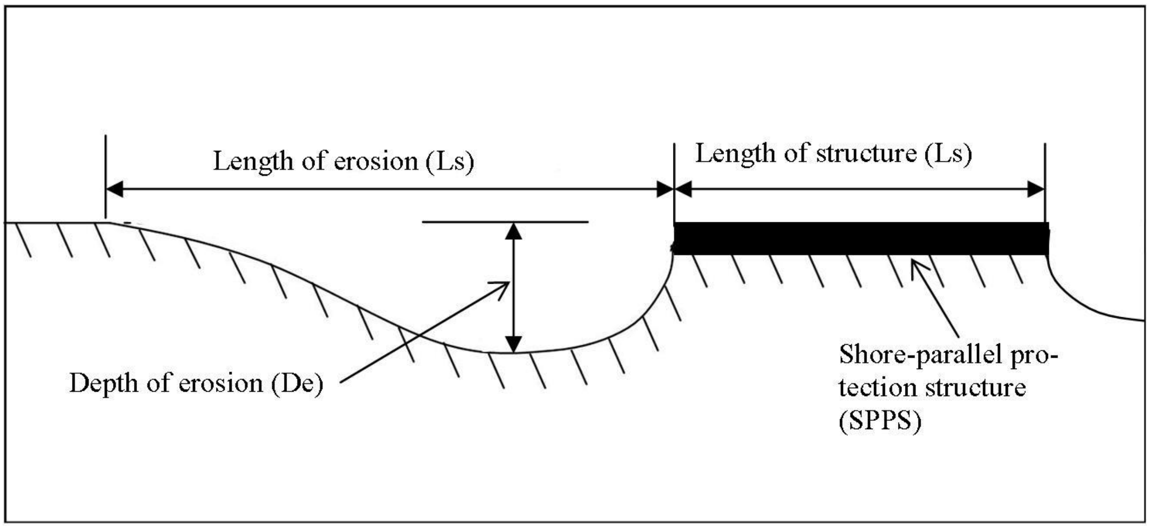

Figure 2.2 Typical embayment form adjacent to SPPS. Dimensional terms are used to define empirical relationships in text. Not to scale.

2.4 Wave modelling for the Kapiti Coast

Numerical nearshore wave modelling for the Kapiti Coast was carried out by MetOceans Solutions Ltd in 2010 a 12 yr hindcast deepwater wave data set provided by the National Oceanic and Atmospheric Administration (NOAA). CSL used the resulting wave output to model longshore sediment transport for the Kapiti Coast (Appendix G), and this was used in Section 3.1.3.

It is noted that in 2011, wave measuring instruments were deployed along the Kapiti Coast and in early 2012 higher resolution wind field data became available. MetOceans are now in the process of calibrating their numerical wave model; however, the revised data had not been received in time for using in this 2012 updated erosion assessment.

3.0 OPEN COAST EROSION HAZARD ANALYSIS

3.1 Methods

The underlying approach used for the 2008 Open Coast Erosion Assessment (and for the present (2012) Update Assessment) is defined by equation 1. The equation components and derivation procedures are briefly described below; however, the reader is referred to the 2008 Erosion Hazard Assessment (Part 1) for a more detailed description.

$$CEPD = LT + ST + RSLR + DS + CU \qquad (1)$$

Where CEPD = coastal erosion prediction distance, LT = longer-term shoreline change, ST = shorter-term shoreline fluctuation, RSLR = shoreline retreat associated with sea-level rise (SLR), DS= dune stability, and CU = combined uncertainty.

3.1.1 Longer-term shoreline change (LT)

Longer-term shoreline change refers to any overall trend apparent in historical data, with such behaviour being caused by factors such as larger-scale climate and geological processes. In the CSL assessments, the LT component is derived by linear regression analysis of historical shorelines taken primarily from vertical aerial photos where the vegetation-front is used as the shoreline indicator. Along those sections of the Raumati and Paekakariki Coasts characterized by seawalls, which were first established in the mid 1950s, the limited aerial-based shoreline data set was supplemented with shorelines derived from cadastral survey maps. The shoreline indicator on the survey maps was usually the high water mark at the time of the survey and this is usually several metres seaward of the vegetation-front. The matter of shoreline indicators and implications for the analysis and assessment is described and discussed in greater detail in the 2008 Erosion Assessment Part 1, Section 2.2.

The modelling includes procedures for dealing with nonlinear shoreline behaviour. The basic model is represented by equation (2).

$$\mathrm{Y} = a + b\mathrm{X} + e \qquad (2)$$

Where Y is the dependent variable (shoreline location), X is the independent variable (time), a is the intercept on the Y-axis, b is the slope coefficient (rate of shoreline change) and e is the fitting error.

The rate of change *(b)* is multiplied by the prediction period (50 or 100 yrs) to provide a shoreline retreat or advance value for use in equation 1. Note that alongshore smoothing was carried out to derive the 95% confidence band over adjacent transects where similar cross-shore shoreline behaviour was apparent, thus preserving alongshore trends. Note that this alongshore processing procedure was also used when deriving the other component values. Where positive rates occur, LT is set at zero, this being a precautionary measure used by the industry in recognition of the uncertainly inherent in predicting sustained seaward shoreline migration over prolonged periods of time where the underlying process is not well understood.

The method for calculating the *seawalls repair* and *seawalls remove* LT values is described in detail in the 2008 Assessment, Part 3 (Data-Base) Briefly, linear modelling was carried out on data from each transect to produce rates of change for an *earlier period* (1870s to early 1950s) and also for a *later period* (1940s to 2007) with the earlier period selected to precede the coastal structures while the later set contained the full aerial-based record, thus maximizing potential accuracy. It was from the later set that rates for non-seawalled sections of coast were derived, while the earlier set provided underlying rates of change for the seawalled sections of coast (all occur along the south coast). In addition, when extrapolating 50 or 100 yrs into the future at seawalled sites under the seawalls removed-scenario, an allowance had to be made for ~50 yrs of erosion which the seawalls had prevented. This allowance was estimated using the earlier period rate and this additional erosion was referred to as *catch-up erosion*.

The low number of shoreline samples in the earlier period data-sets increased the uncertainty in the regression results. Further problems with the earlier period data resulted from incompatibility between the initial sample(s) consisting of shorelines taken from the survey plans which, as noted earlier, used the high water line as shoreline indicator, and the aerial photo-based shorelines from the end of the earlier period data-set using the more landward located vegetation-front. The resulting systematic error between the two types of indicator caused an over-estimate of erosion rates and an underestimate of accretion rates. While this is qualitatively acceptable in coastal hazard assessment given the requirement to adopt a precautionary approach (NZCPS 2012, Policy 3), the quantitative uncertainty caused the Focus Group's reviewer (of the 2011 draft Update Assessment) to request a profile extrapolation analysis (see Terms of Reference 6) on the grounds that this may provide some independent justification for the values being used from the early period regression analysis. The profile analysis is set out in Appendix C and the results support the earlier period regression-based methodology.

3.1.2 Shorter-term shoreline fluctuation (ST)

Shorter-term shoreline change refers to cross-shore fluctuations (up to 30 yrs) which can be caused by the superposition of significant storms, medium-term climate cycles or sediment variation (associated with littoral change, river input and rivermouth dynamics). Quantifying ST is also based on regression analysis. In particular, the fitting error (e in equation 2) is used to derive the cross-shore fluctuation distance = 3* SEE (standard error of estimate) which encompasses 99% of the population value.

3.1.3 RSLR = Shoreline retreat associated with sea-level rise (SLR)

The 2008 Erosion Hazard Assessment defined the shoreline effect of sea-level rise (SLR) associated with global warming using the best available predictions of SRL (NIWA, 2000), and a shoreline response model (equation 3) adapted from Komar et al., 1999.

$$R = S/\tan \beta \qquad (3)$$

Where R is the profile shift (retreat) in the landward direction, S is the predicted rise in sea level and tan β is the average inter-tidal slope.

As indicated earlier, since completing the 2008 Assessment, there has been additional official guidance pertaining to coastal effects of climate change. The 2008 Erosion Hazard Assessment used a SLR value of 0.3 m for the 50 yr prediction period based on the NIWA (2000) recommendation. The 2008 Guidance Manual recommends a base value of 0.26 for a 50 yr prediction period (see Section 2.1.2). The 2008 Guidance Manual also recommends that the consequences of an additional 0.22 m be considered. As the SPPSs will be operating under the 50 yr scenario, and as relatively minor SLR occurs within the next 50 yrs (compared with the predicted subsequent increments), a value of 0.3 will be used for this scenario, i.e. the same value as used in the 2008 Erosion Hazard Assessment.

For the 100+ yr scenario, the 2008 Guidance Manual recommends a base value of 0.65 with consequences of an additional 0.3 m needs to be considered. A value of 0.9 m per 100 yrs is considered appropriate.

Regarding which model to use to ascertain shoreline response to climate change, the 2008 Guidance Manual simply states that a profile-based shoreline translation model should be used. As described in the 2008 Assessment, there are a range of models available and in that assessment a model adapted from Komar et al., 1999, was used. This model translates the profile landward along the line of the average beach slope a distance proportional to the rise in sea-level.

The most commonly used model in erosion hazard assessment is the Brunn Rule (Bruun, 1983) which translates the profile between the offshore limit of sediment transport (closure depth) to the crest of the foredune by that amount required to fit the predicted SLR. However, as described in the 2008 Erosion Hazard Assessment (Part 1, Appendix C), the Brunn Rule has several limitations including the range in methods available to estimate closure depth and their output varying by a factor of 3, no offshore or onshore sediment loss, no alongshore flux in sediment transport, no variations in sediment properties across the profile and no profile control by hard structures such as substrate geology, adjacent headlands or engineered structures. However, longshore sediment transport modelling for the Kapiti Coast (Appendix G) shows substantial alongshore variation both in terms of magnitude and direction, so this Bruun Rule assumption is not met. Bruun Rule predictions for specific sites have varied from measured rates by factors of 2 to 5 (both over- and under-prediction) with greatest variation occurring where the assumptions are least fulfilled (Everts, 1985; Zhang et al., 2004). As in the 2008 Assessment, the 2012 Update uses the Komar-based model as it offers greater certainty for assessing the shoreline response to SLR along the Kapiti Coast.

3.1.4 Dune stability (DS)

This component accounts for scarp retreat to achieve a stable slope following storm erosion of the foredune. The model used to determine retreat of the scarp top (equation 4) is based on the *slope replacement theory* for non-cohesive materials (Clark and Small, 1982).

$$STR = h/2(\tan \propto) \qquad (4)$$

Where STR is the landward distance the scarp-top must retreat to achieve dune stability (DS in equation 1), h is the height of the escarpment and $\propto$ is stable slope angle (34 degrees).

3.1.5 Combined uncertainty (CU)

This component relates to the safety margin derived by combining *measurement errors* associated with the other four components. The method of determining the combined measurement error value is defined by equation 5 which is referred to as the root mean square or root sum of squares method and used when the individual terms are independent. When error terms are dependent they are simply added together. These procedures are based on variance addition which is described in statistical texts such as Larsen and Marx (1986). It is also noted that when determining the error term for individual components, and the components themselves comprise several error terms, the same rules of combination apply.

$$CE = \sqrt{(E_1^{\,2} + \ldots\ldots\ldots + En^2)} \qquad (5)$$

where CE = combined error (shoreward directed), E_1 = first error term, and En = n^th error term.

In addition, a range of *other factors* (precautionary measures used in data processing) serve to increase the overall safety margin and some of these *other factors* were quantifiable and incorporated when determining the error terms (*E_1 to En*). These *other factor*s were described in detail in the 2008 Erosion Hazard Assessment and include:

- weighting in the LT shoreline analysis to emphasize more recent erosion,
- setting positive LT values to zero,
- selecting the 95% LT and ST values over several adjacent sampling sites (where similar geomorphology/shoreline behaviour occurs),
- not subtracting the New Zealand average regional historical SLR of 1.7 mm/yr, or the relative vertical movement resulting from local tectonic adjustment, which is estimated to be average 0.4 to 0.5 mm/yr of uplift in the Kapiti area, from the global value given in the Guidance Manual,
- selection of the maximum dune height per sector, together with the minimum stability angle when determining DS, and

- basing each component's representative measurement error value on the 95% confidence interval of values from all alongshore measurement sites.

These *other factors* are particularly important in compensating for the uncertainty surrounding climate change. The reader will recall from Section 2 above, that the Guidance Manual 2008 and NZCPS 2010 also required consideration of other aspects of climate change including wind and wave regime changes yet minimal guidance was provided on how to quantify such effects.

3.2 Component values

The erosion assessment
model for the open coast (equation 1) was used to process data obtained for 61 Coastal measurement sites and 14 eXtra sites along the 38 km long Kapiti Coast (see Figure 2.1, and Appendix B). The extra sites were to provide more detail for locations where shoreline behaviour was unclear or tenuous. This section derives component values for LT, ST, RSLR, DS and CU at each site.

3.2.1 Longer-term shoreline change (LT)

With the exception of the north Raumati-south Paraparaumu coast (see below), no additional shorelines were incorporated into the 2012 Update Assessment,.

The 2008 Erosion Hazard Assessment identified the following three sections of open coast in which shoreline longer-term erosion was unclear:

1) **South Paekakariki** was investigated in greater detail and this study was included in the 2008 Assessment, Part 1, Appendix A and the result for long-term erosion of 0.075 to 0.25 m/yr was incorporated into the assessment. It is noteworthy that this 1 km section of coast presented particular problems for the Ministry of Works and Development in the late 1970s and early 1980s. During that time an episode of extensive erosion resulted in 13 houses being removed along what is now the Ames Street Reserve as they were "in immanent danger of collapsing onto the beach" (Gibb and Depledge, 1980). However, that episode of erosion ended and she shoreline has been relatively stable thereafter. The concrete foundations of the 13 homes are still visible in the reserve and serve as a reminder for the need of ongoing monitoring and improved understanding of processes operating along the Kapiti Coast.

2) **North Paraparaumu** has undergone slow erosion (0.3 m/yr) since the 1960s with accretion occurring prior to this; such behavour appear to be linked with Waikanae Inlet dynamics. As explained in the 2008 Asssessment (Part 1), where such non-linear behavour is demonstrated and not fully understood, the precautionary approach is to use the more recent (erosional) trend. However, it is noted that a detailed study of sediment dynamics around the Kapiti foreland is presently

underway and an increased understanding of shoreline behaviour along the north Paraparaumu coast could result in a different long-term rate of change applying to the erosion hazard assessment.

3) **South Paraparaumu-North Raumati** is the section of coast where the overall accretional behaviour to the north changes to the typically erosional behaviour to the south. As such, the shoreline behaviour defined in the 2008 Assessment was somewhat erratic and contrasts between early and later periods which indicated a more detailed assessment could be helpful. The 2010 MRP study provided up to 9 additional shoreline samples (n = 13) and 8 additional measurement sites (n = 16). The effect on hazard parameters is now assessed

Several of the resulting time-series are plotted in the 2010 MPR report (Figure 7B) and all plotted in the 2012 Updated Data-Base. The aerial photo-based linear regression results for slope (rate) and dispersion (SEE) about the mean, together with the derived LT and ST values are shown in Table 3.1. Of note are the positive rates generally decreasing from north to south and SEE reducing to the south and to a lesser extent to the north. These results are consistent with this reach of coast being the transition between accretion and erosion. In Table 3.1, LT was thus set to zero for all sites, and the 3*SEE values smoothed in the longshore direction to give ST values. The final sets of LT and ST values (plus all other component values) are listed in Appendix D for the various prediction and management scenarios.

The 50 yr managed LT results listed in Appendix D (Scenario 1) range between 0 and 75 m, with the zero values occurring either where seawalls exist or where positive (accretionary) rates occur (NB these were set to zero, see Section 3.1.1). The higher

Table 3.1 Shoreline linear regression analysis and hazard parameter derivation along the south Paraparaumu and north Raumati open coast including eXtra sites and additional shoreline samples.

Site	Period	Rate	LT	SEE	SEE 3*	ST
C10.29	1942-2010	0.01	0	2.5	7.5	7.1
X10.53	1942-2010	0.03	0	1.4	4.2	11.0
C10.61	1942-2010	0.11	0	1.5	4.5	12.0
X10.91	1942-2010	0.25	0	4.5	13.5	17.0
X11.07	1942-2005	0.28	0	7.0	21.0	20.0
C11.17	1942-2005	0.21	0	5.3	15.9	21.0
C11.41	1942-2005	0.23	0	6.7	20.1	22.0
C11.64	1942-2005	0.30	0	7.2	21.6	22.0
X11.76	1942-2010	0.16	0	7.8	23.4	22.2
X11.88	1942-2010	0.15	0	6.8	20.4	22.0
X12.01	1942-2010	0.25	0	4.3	12.9	21.0
C12.12	1942-2010	0.30	0	2.1	6.3	20.0
X12.31	1942-2010	0.52	0	5.8	17.4	19.5
C12.5	1942-2010	0.57	0	6.0	18.0	18.0

Note data for central sites truncated in 2005 as MPR influence effective thereafter.
SEE refers to *standard error of estimate* - a measure of dispersion (NB Section 3.1.2).

retr end to 75 m at the South Raumati end. As discussed in Appendix C, this systematic increase may be associated with medium-term sediment variation or the effect of the substantial seawalls fronting the South Raumati coast and to a lesser extent the north Paekakariki coast. Moderate values (10-12.5 m) occur at south Paekakariki and a spike (15 m) at north Paraparaumu. Compared with the 2008 Assessment's values (Part 1, Appendix B2), there are two areas where different LT values occurred: at south Paekakariki some increases associated with not accounting for the private seawalls, and along the north Raumati coast some decreases following analysis of the improved data-set.

The 50 yr unmanaged LT results listed in Appendix D (Scenario 2) range between 0 and 25 m. Zeros occur where progradation is expected and, with the exception of north Paraparaumu, this regions stretches north from the Wharemauku inlet. The largest erosion values occur along the South Raumati coast where the catch-up values are greatest. Moderate values (5 to 12.5 m) occur along QEII and mid-north Paekakariki, and a spike (15 m) occurs at north Paraparaumu. Compared with the 2008 Assessment's values (Part 1, Appendix B3), the values are the same with the exception of the Marine Parade Revetment area in north Raumati-south Paraparaumu where analysis of the improved data-set enabled the previous long-term erosion values to be removed.

The 100 yr unmanaged LT results listed in Appendix D (Scenario 3) range between 0 and 50 m and have the same alongshore pattern as the 50 yr scenario with zeros occurring where progradation is expected and the largest erosion values occur along the South Raumati coast. NB this scenario was not included I the 2008 Assessment.

3.2.2 Shorter-term shoreline change (ST)

With the exception of the reassessed north Raumati-south Paraparaumu-north Raumati coast (Table 3.1), the ST values listed in Appendix D remained unchanged from the 2008 Assessment. These values range between 7.1 and 36.0 m (mean = 15 m) with the highest values occurring around the foreland where substantial change occurs. These values apply to both the 50 and 100 yr scenarios.

3.2.3 Shoreline retreat associated with sea-level rise (RSLR)

The shoreline retreat associated with SLR remains unchanged (from the 2008 Assessment) for the 50 yr scenarios and the values are listed in Appendix D. Values range between 0 and 21.4 m (mean = 11.6 m), with zeros corresponding to sites with protection structures and higher values occurring where beach slopes are lowest (around the foreland). For the 100 yr scenario, RSLR values range between 14.5 and 64.3 m (mean = 44.3 m), with lower values where beaches are steeper, i.e. south Paekakariki and south of the Otaki Rivermouth.

3.2.4 Dunes scarps adjustment (DS)

The same DS values from the 2008 erosion assessment apply in the 2012 Updated Assessment and apply for both the 50 and 100 yr scenarios. While dune topography may vary with differing prediction periods, the values used in the 2008 assessments are spatially robust, with extensive areas of dune being incorporated when deriving representative values. Values range between 5.2 and 18.8 m (mean 4.9 m) with higher values corresponding to areas of higher dune relief along the south Kapiti Coast.

3.2.5 Combined uncertainty (CU)

The 2008 Erosion Assessment's 50 yr measurement errors apply to the 2012 Update's 50 yr managed scenario, i.e. LT = 3.7, ST = 2.6, RSLR = 1.6 and DS = 2.3. However, LT and RSLR uncertainty values increase for the 100 yr scenario such that LT = 7.4 m and RSLR = 4.8 m.

Combining the 50 yr independent terms using equation 5 gives a combined value of 5.3. For natural open coasts, a representative value of 6 m was used to compute the CEHD values in equation 1. However, where shore-parallel protection structures (SPPSs) exist, LT = RSLR = 0 so CU = 3.5. But an additional 5 m was added to allow for extra scour potential associated with bed lowering in front of the structure due to long-term erosion. For SPPS areas a representative value of 9 m was used in equation 1.

Applying equation 5 to the 100 yr scenario measurement error data gives a combined value of 9.5 m. A representative value of 10 m was adopted for the entire coast as this scenario assumes no protection structures exist.

3.3 Erosion predictions

3.3.1 Coastal Erosion Prediction Distances (CEPDs)

The location of open coast erosion hazard lines are determined by first combining the hazard component values to give *coastal erosion prediction distances* (CEPDs) and then relating these distances to ground positions via a measurement origin referred to as a *reference shoreline*. The most robust approach to locating a reference shoreline, when hazard components have been derived using regression modelling, is to set the time variable to the year of interest and run the model. For the 2008 Assessment, the year of interest was 2008. For the 2012 Update this was not changed as at most the difference in not re-running the model using 2012 as the year of interest would be 1 m. With the exception of some sites along the revised (expanded data-set) north Raumati-south Paraparaumu coast, the 2012 Update Assessment reference shoreline values are the same as those used in the 2008. The 2012 Update values are listed in Appendix B, and the derivation of the reference shoreline from the *measurement reference point* at each transect is given in the Data Base.

The CEPDs for the 50 yr managed and unmanaged hazard assessment scenarios, and the 100 yr unmanaged hazard assessment scenarios are listed in the data summary sheets (Appendix D, Scenarios 1 to 3 respectively). The CEPDs for the 50 yr managed scenario (1), which includes the influence of the existing community SPPSs, ranges between 25.6 and 120 m (mean = 44.2 m) with the highest values being along the northern QEII coast and lowest values corresponding to the seawalled sections of Paekakariki and Raumati coast and also between Te Horo and the Otaki Rivermouth. The only values which differ from the 2008 Assessment are generally reduced values along the north Raumati-south Paraparaumu coastline (2008: 20.4 to 53.4 m c.f. 2012: 19.9 to 47.7 m).

The CEPDs for the 50 yr unmanaged scenario (2), for which all existing structures are removed, ranges between 25.6 and 72.2 m (mean= 45.6 m) with the highest values being along the South Raumati coast and around the foreland, and the lowest values being along the north coast and in particular between the Mangaone and Otaki Inlets. Once again the only values which differ from the 2008 Assessment are generally reduced values along the north Raumati-south Paraparaumu coastline (2008: 32.9 to 73.9 m c.f. 2012: 31.9 to 47.2 m).

The CEPDs for the 100 yr unmanaged scenario (3), for which all structures are removed, ranges between 39.4 and 129.7 m (mean= 85.8 m) with the highest values being along the South Raumati coast and foreland, and the lowest values between Te Horo and the Otaki Rivermouth.

3.3.2 Coastal Erosion Prediction Lines (CEPLs)

Once the CEPDs have been spatially located landward of the reference shoreline, these points are joined to define the *coastal erosion prediction line* (CEPL) with additional effort to preserve alongshore curvatures not discernable in the measurement set. While a plot of the CEPLs has not been included in the 2012 Update report, the lines have been provided to the KCDC as vector files for use in aerial photo overlays as required.

4.0 INLET EROSION HAZARD ANALYSIS

4.1 Methods

Inlets, arguably, are the most dynamic of coastal geomorphological systems, driven by the interactions between marine and fluvial processes. Sand-dominated inlets are typically characterized by frequent channel migration and changes in bar and spit morphology which often result in considerable shoreline change both within and between inlets. Inlets often offer shelter, food resources and picturesque settings, making them favoured sites for indigenous and colonial settlement and more lately holiday and retirement developments. This pattern has been accompanied by ever increasing hazard risk from increasing property density coupled with anthropogenically-induced coastal process change. A schematic diagram and associated terminology of a typical Kapiti Coast inlet is shown in Figure 4.1

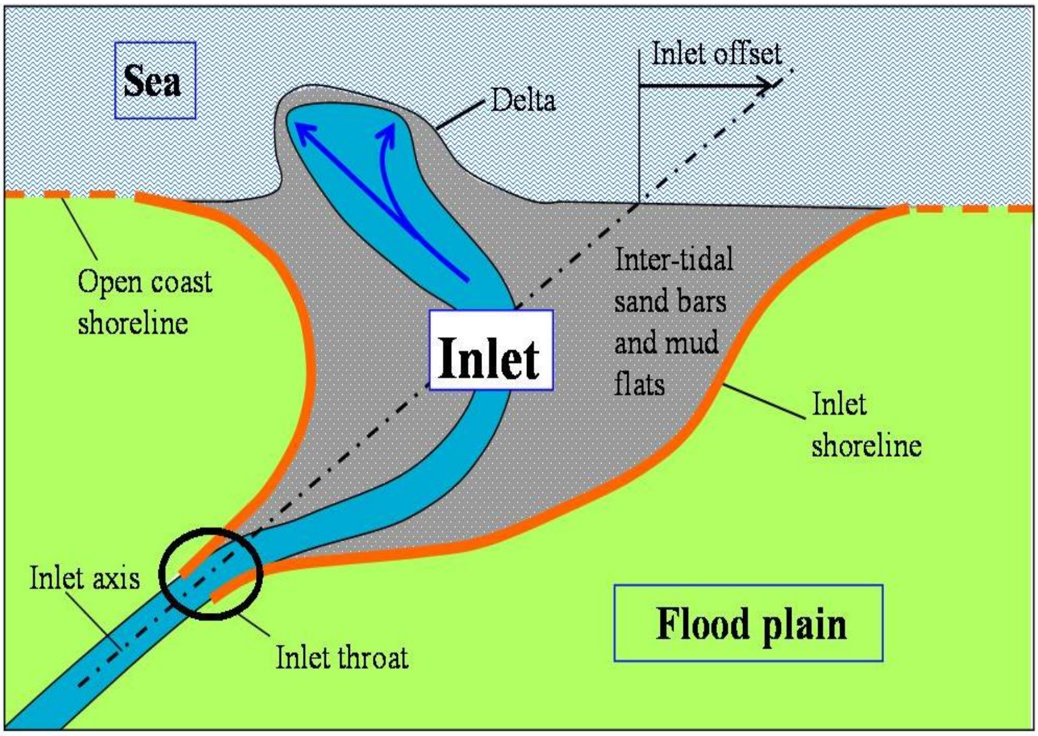

Figure 4.1 Morphology and terminology of a typical inlet on the Kapiti Coast

The open coast erosion assessment model (equation 1) required modification to account for inlet morphological behaviour and the 2008 Assessment (Part 2) used a variation (equation 6) to predict inlet (cross-shore) erosion hazard distances (IEPD).

$$IEPD = IMC - (LT + RSLR + DS + CU) \qquad (6)$$

Where IMC = inlet migration curve, LT = longer-term shoreline change, RSLR = retreat of the shoreline associated with sea-level rise (SLR), DS= dune stability, and CU = combined uncertainty.

The bracketed terms in equation 6 are the same as defined for the open coast (Section 3.1), while the *inlet migration curve* (IMC) replaces the open coast ST component. In particular, this is the curve fitted to the landwardmost locations of the inlet (aerial photo-based) shoreline migration envelop (see Figure 4.2). The IMC differs for managed and natural inlets with the managed IMC being derived from that subset of shorelines corresponding to time inlet management practices had occurred and the natural IMC being derived from the subset of shorelines for the time prior to management.

Inlet management consists of structures such as guide walls and earth bunds and *mouth cuts* (channel excavations) to constrain longshore channel migration. In some cases, partitioning of the inlet shoreline data-set resulted in one sub-set being too short to confidently define the inlet's associated shoreline characteristics so all the shorelines were used and a single IMC thus defined which likely contained a bias toward the larger sub-set.

While such partitioned data sets were usually "broadly suitable" to represent 50 yrs of inlet behaviour, they are usually too short to confidently represent 100+yr shoreline behaviour, and such extrapolation must be done with caution. The complexity of coastal processes and morphological behaviour must be understood and this requirement is now clearly stated in general terms in the NZCPS 2010, Policy 24 (a) and (c).

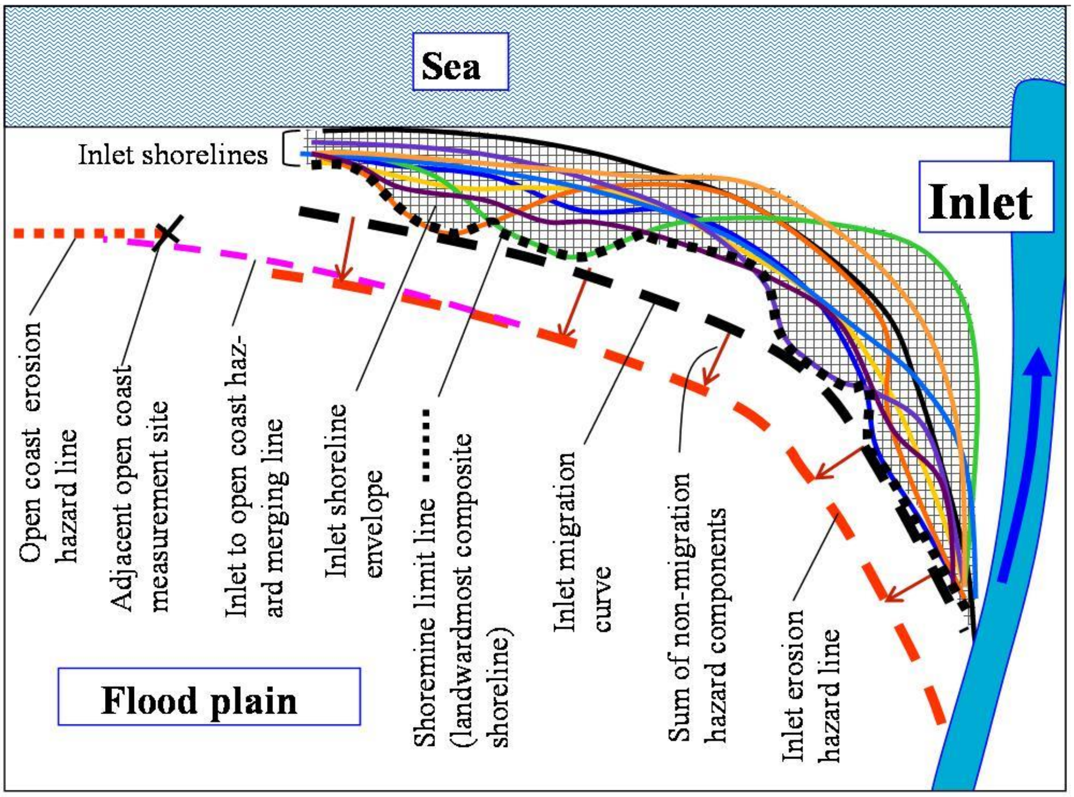

Figure 4.2 Conceptual illustration of derivation of inlet migration curve (IMC), inlet erosion prediction (hazard) line and relationship to the open coast erosion hazard line.

The 2008 Assessment provided a geomorphological description of each of the 12 inlets. The present 2012 Update Assessment provides additional information including catchment characteristics (area, discharge) and inlet dimensions. In addition, earlier shorelines based on geomorphic signatures (see Appendix E) have been identified to indicate the potential for greater erosion than expected using the inlet erosion prediction model (equation 6). This is important as the aerial photo-based shoreline data-set used to derive parameter values in equation 6 was usually inadequate for extrapolating out to 100+yrs. The various characteristics for each of the 12 inlets are described below in sub-sections (4.4.2 to 4.4.13) and marked on an aerial photos (Appendix F, Figures F4.3 to F4.14) contained therein.

4.2 Component values

Values for the component terms LT, RSLR, DS and their respective CU error terms are taken directly from the open coast measurement site closest to the inlet and are listed for each inlet in Sections 4.4.2 to 4.4.13.

No additional inlet shorelines have been included in the 2012 Update Assessment. The shoreline envelopes for each inlet are depicted in Figures 4.3 to 4.14. Note that for quick reference, the superimposed shorelines for each inlet have been included as Appendix F.

The IMC measurement error is 3.6 m, compared with the ST error which is 2.6 m. However, weighting the IMC to the location of maximum shoreward incursions of the envelope (see Figure 4.2) provides an unquantified margin of safety.

Combining the 50 yr independent inlet error terms using equation 5 results in a combined value of 5.9 m, and the 100 yr combination gives a value of 9.8 m, so representative values of 6 m and 10 m respectively were used for all inlets.

4.3 Erosion prediction

The location of the inlet erosion prediction lines (IEPLs) were determined graphically by offsetting the distance LT + RSLR + DS + DS landward of, and perpendicular to, the IMC. This procedure is conceptually illustrated in Figure 4.2. Note that while the IMCs for the various inlets are unchanged from the 2008 Assessment, the location of the 50 yr inlet erosion hazard lines required some adjustment to account for occasional change to the other terms in equation 6, i.e. LT, RSLR, DS and CU.

When determining the final location of the IEPLs, particular attention was also paid to the inlet throat geometry during the retreat process as this controls the channel orientation and inlet configuration offset. So an inlet with, for example, a northerly offset could have a southerly offset after 100 yrs of erosion and the IEPLs had to account for this situation.

The IEPLs were merged with the relevant open coast CEPLs. For example, if the adjacent coast was managed (had seawalls), then the managed IEPL was merged with this line. In the vicinity of the inlet throat, where existing infrastructure exists, managed inlet erosion curves were merged with this control. In the 50 yr natural inlet and 100 yr managed inlet scenarios, similar landward merging with infrastructure applied. However, where no artificial controls exist, these IEPLs were merged with the existing channel by reproducing naturally occurring inlet throats. In the 100 yr natural inlet scenario, it was assumed no structures exist for all inlets.

It is also noted that if only a single IMC was defined, then this was merged with both both managed and unmanaged IEPLs thereby defining managed and natural IEPLs, albeit not as pronounced as had managed and natural IMCs been used.

The resulting IEPLs for each inlet are illustrated in Figures 4.4.2 to 4.4.13.

4.4 Individual inlet summaries

4.4.1 Introduction

This section addresses each inlet in turn, describing the various updated materials alluded to in previous sections and also reproducing some of the 2008 Assessment material to provide continuity for the reader. Each inlet will be described in terms of its size and geometry (based on the aerial-based shorelines and envelope), catchment size and mean annual flood flow at the mouth (these two characteristics being provided by SKM, hydrological modelling consultants to the KCDC). Summary figures (Figures 4.3 to 4.14) depict the aerial photo-derived shoreline envelope and inlet management control structures. The management regimes are summarized within the inlet texts; however, more comprehensive descriptions are contained in the 2008 Assessment, Part 2, Section 3. The updated component values (LT, RSLR, DS and CU) for adjacent open coast measurement sites are listed in the text. The resulting inlet IEPLs are plotted on the summary figure and shown merging with the relevant open coast CEPLs. Findings from the earlier shoreline investigation (Appendix E) are also described and plotted in the summary figures and any other influences in determining IEPLs such as change in inlet offset are noted in the text.

4.4.2 Waiorongomai Inlet

The Waiorongomai Inlet has a maximum area of ~6.8 ha and alongshore length up to ~600 m based on the aerial photograph record. The channel typically has a northerly offset, the catchment area is 400 ha (4 km^2) and the mean annual flood flow is 1.9 m^3/s**.** The open coast shoreline beyond the inlet is undergoing long-term progradation at 0.6 m/yr.

As described in the 2008 Inlet Assessment, the much larger Waikawa Stream, which presently has its outlet some 1.6 km to the north, has in the past flowed south to merge with the Waiorongomai inlet and this influence has been incorporated within the erosion hazard assessment as the KCDC territorial boundary is ~600 m north of the present Waiorongomai outlet.

Past shorelines and derived hazard characteristics are summarized in Figure 4.3. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F1, and the shoreline dynamics are described in the 2008 Hazard Assessment.

The Waiorongomai Inlet itself is not subject to channel management. However, to limit southward channel migration the Waikawa channel is controlled by rock groynes and occasional channel realignment by mouth cutting. It is thus relevant to consider both the managed and natural Waikawa inlet when assessing the erosion hazard north of the Waiorongomai Stream. In particular, the 1942 to 1965 shorelines comprise the natural inlet set, while the 1972 to 2007 shorelines make up the managed inlet set. By contrast, no management affects the south Waiorongomai Inlet.

The 50 yr and 100 yr erosion projection lines on both sides of the inlet were derived by adjusting the inlet migration curve (IMC) landward by 27.3 m (LT = 0, RSLR = 18 m, DS = 3.3 m, CU = 6 m) and 63.3 m (LT = 0, RSLR = 50 m, DS = 3.3 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site (C36-86, see Appendix D). The updated inlet erosion prediction lines (IEPLs) are illustrated in the summary figure.

As evident in Figure 4.3, the channel orientation as it enters the inlet will not change under both the 50 and 100 yr erosion prediction scenarios, so it is likely the present channel offset and inlet configuration will be maintained.

The earlier shorelines depicted in Figure 4.3 lie within the 100 yr natural IEPL. While this provides some confidence in the 100 yr erosion estimates it is noted that severe dune instability and parabolic development in the recent past have obscured much of the earlier shoreline record.

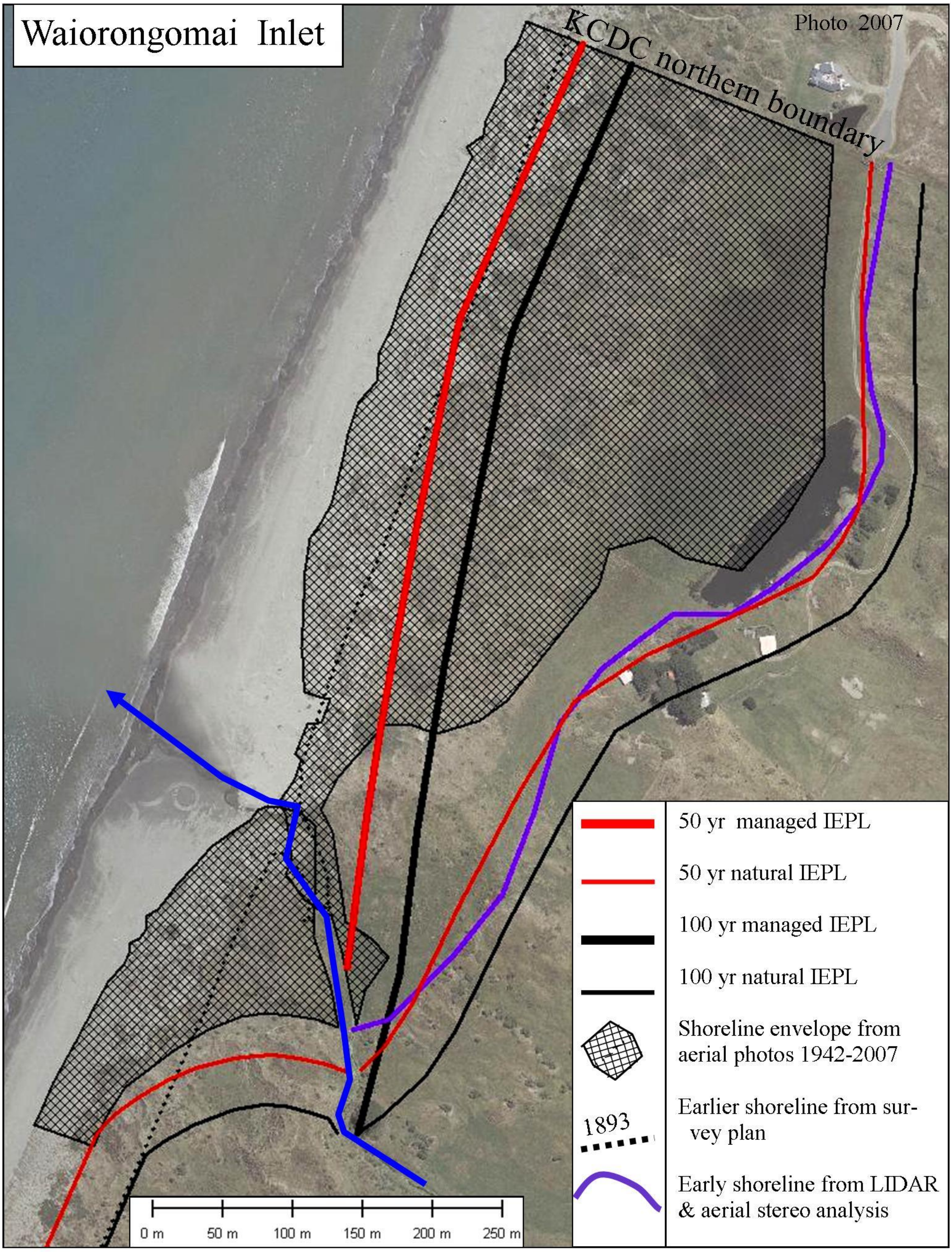

Figure 4.3 Summary of Waiorongomai Inlet's past shorelines and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. The bulbous nature of shoreline and hazard prediction lines to the north are influenced by the Waikawa Inlet some 1.6 km to the north.

4.4.3 Waitohu Inlet

The Waitohu Inlet has a maximum area of ~34 ha and alongshore length up to 1400 m, based upon the aerial photograph record. The channel typically has a northerly offset. The Waitohu Stream's catchment area is 4600 ha (46 km^2), and the mean annual flood flow is 31 m^3/s. The adjacent coast is prograding at 0.72 m/yr to the north and 0.55 m/yr to the south.

Past shorelines and derived hazard characteristics are summarized in Figure 4.4. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F, and the shoreline dynamics are described in the 2008 Hazard Assessment.

Inlet management consists of several guide walls (marked in Figure 4.4) controlling the channel alignment as the stream enters the inlet, together with occasional "mouth cutting", i.e. channelisation by excavation/bund formation using heavy earthmoving equipment as detailed in the 2008 assessment.

The natural inlet shorelines comprise the 1942 to 1966 samples, together with all other shorelines on the northern side of the inlet, as these were not affected by management practices. The managed inlet shorelines comprise the 1973 to 2007 samples.

On the southern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 25.3 m (LT = 0, RSLR = 16.8 m, DS = 2.6 m, CU = 6 m) and 62.6 m (LT = 0, RSLR = 50 m, DS = 32.6 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site (C33-8, see Appendix D). On the northern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 26.0 m (LT = 0, RSLR = 16.7 m, DS = 3.3 m, CU = 6 m) and 63.3 m (LT = 0, RSLR = 50 m, DS = 3.3 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site (C35-54, see Appendix D). The updated inlet erosion prediction lines (IEPLs) are illustrated in Figure 4.4.

As evident in Figure 4.4, the channel orientation as it enters the inlet will not change under both the 50 and 100 yr erosion prediction scenarios, so it is likely the present channel offset and inlet configuration will be maintained.

The earlier shorelines depicted in Figure 4.4 indicate erosion has occurred in the vicinity and landward of the 100 yr natural IEPL, in particular closer to the throat, thus suggesting the predictions may be conservative.

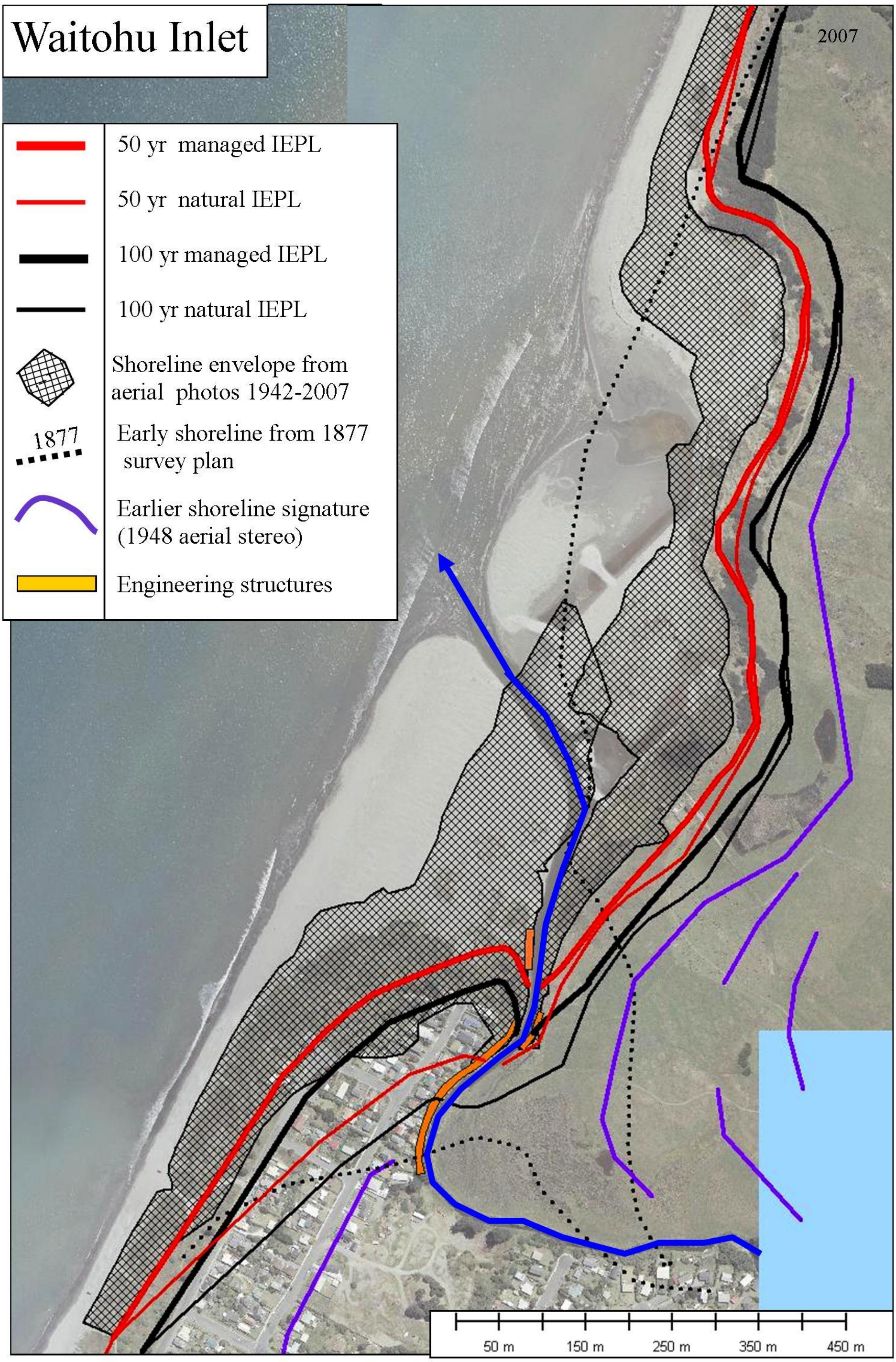

Figure 4.4 Waitohu Inlet's past historical shorelines and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. The erosive effects from the marked engineering structures have been accounted for in the managed inlet scenarios.

4.4.4 Otaki Inlet

The natural (pre-1950s) Otaki Inlet has a maximum area of 41 ha and alongshore length up to 1500 m, although the very early shorelines suggest the inlet could have an area up to 48 ha and length up to 2200 m. By contrast the managed inlet (discussed below) is adjusting toward an area of some 24 ha and alongshore length of 800 m. The Otaki River's catchment area is 34,900 ha (349 km^2), and the mean annual flood flow is 1115 m^3/s, making it the largest fluvial system on the Kapiti Coast. It also contrasts with the other rivers and streams by being a gravel-dominated braided system right to the mouth. In its natural state the channels migrated laterally between river banks which were up to 900 m apart and the river affected up to 2400 m of coast. The Otaki Inlet dynamics interact with the Rangiuru Stream which joins the Otaki River slightly upstream of the mouth. Long-term open coast shoreline progradation is 0.55 m/yr to the north and 0.4 m/yr to the south.

Past shorelines and derived hazard characteristics are summarized in Figure 4.5. For reference the full set of aerial photo-based shorelines have been overlayed in Appendix F, Figure F, and the shoreline dynamics are described in the 2008 Hazard Assessment.

The inlet dynamics have been constrained by stopbanks constructed, in the main, in the late 1940s (details in the 2008 Hazard Assessment, volume 2) and the realignment gave the channel a slight southward offset. By contrast the pre-managed inlet had no offset although the very early shorelines (see Figure 4.5) suggest both north and south offsets may have occurred. Contemporary river management techniques for minimizing erosion of the inlet shorelines comprise river training works which maintain the channel within its preferred alignment, and mouth cuts. Stopbank and inlet management has resulted in much of the pre 1950s northern inlet infilling and a tendency for erosion along the southern inlet shoreline.

The natural shorelines used for analysis are those obtained from the 1939 and 1946 aerial photos. The managed shorelines were obtained from the 1957 to 2007 aerial photos.

On the southern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 11.7 m (LT = 0, RSLR = 4.8 m, DS = 0.9 m, CU = 6 m) and 24.4 m (LT = 0, RSLR = 14.5 m, DS = 0.9 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C30.16 (see Appendix D). These updated inlet erosion prediction lines (IEPLs) are illustrated in Figure 4.5. Note that the natural erosion prediction line lies seaward of the managed prediction line due to the stopbank induced channel offset affecting the managed shoreline data-set.

On the northern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 18.5 m (LT = 0, RSLR = 11.1 m, DS = 1.4 m, CU = 6 m) and 44.7 m (LT = 0, RSLR = 33.3 m, DS = 1.4 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C32-54 (see Appendix D). These updated inlet erosion prediction lines (IEPLs) are illustrated in Figure 4.5.

As evident in Figure 4.5, channel orientation as it enters the inlet may take on a more shore-normal orientation under the 100 yr natural scenario and the 100 yr IEPL configuration accounts for this possibility.

Earlier shorelines (Figure 4.5) depicted in the vicinity of the IEPLs indicate that the 100 yr predictions may be underestimated. In addition, very early shorelines south of the river infer a systematically prograding coastal plain, while on the northern side of river flood plain processes (in conjunction with the Rangiuru Stream) predominate landward of the 300 to 500 m wide coastal dune system characterized by parabolic development.

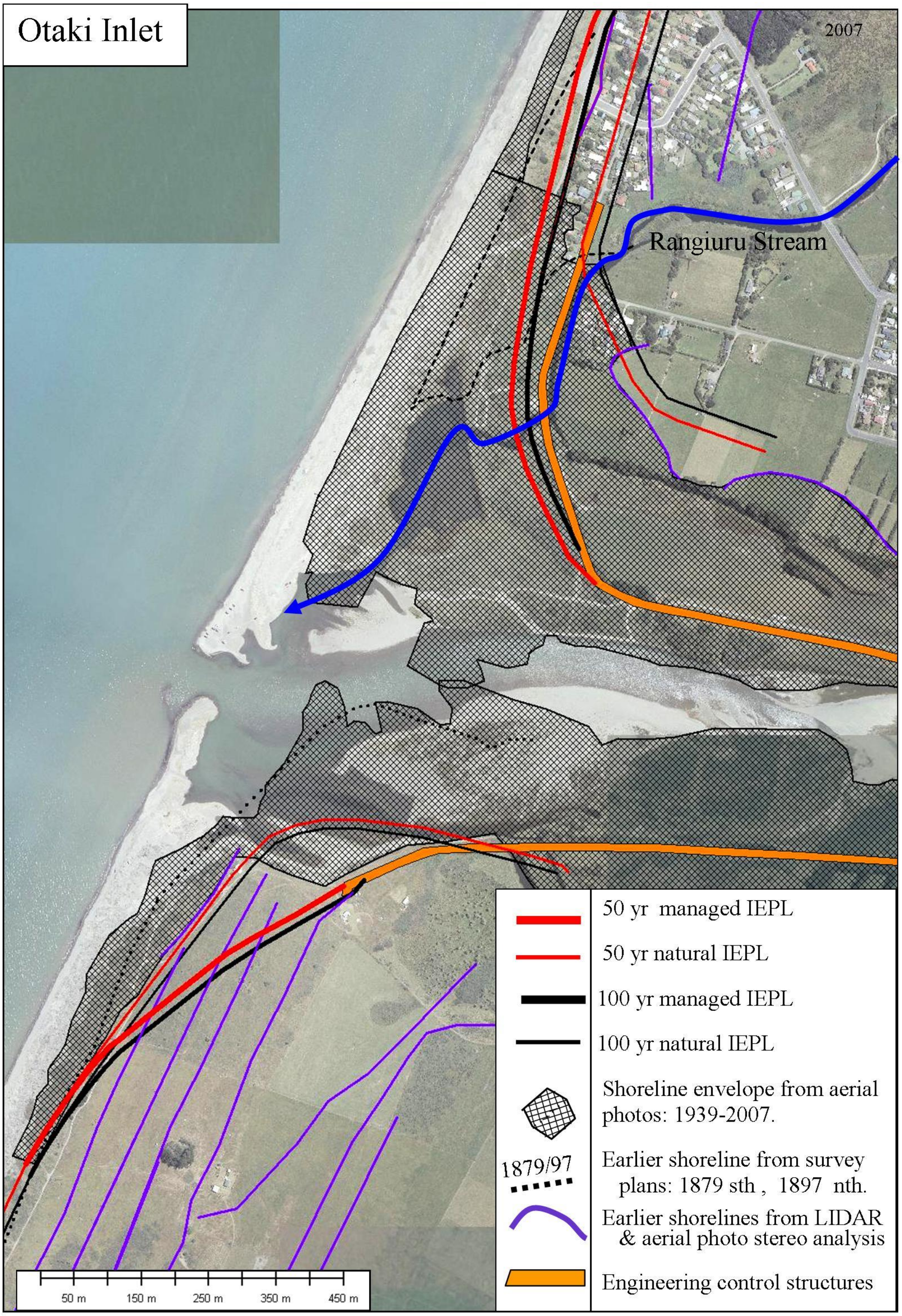

Figure 4.5 Otaki Inlet's previous shoreline locations and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. The erosive effects from marked engineering structures have been incorporated within the managed inlet assessment scenarios.

4.4.5 Mangaone Inlet

The Mangaone Inlet has a maximum area of 5.4 ha and alongshore length up to 750 m. The catchment area is 5,000 ha (50 km^2), and the mean annual flood flow is 29 m^3/s. The Mangaone stream carries fine sediment while the inlet and adjacent beaches are gravel dominated (supplied by the Otaki River). This inlet has a small southerly offset, although earlier shoreline evidence shows it may have previously had a northerly offset. The long-term open coast shoreline progradation is about 0.4 m/yr on each side of the inlet.

Past shorelines and derived hazard characteristics are summarized in Figure 4.6. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F4 and the shoreline dynamics are described in the 2008 Hazard Assessment.

The aerial photo record for the Mangaone Inlet shows no evidence of inlet management in terms of channel diversion, bank protection or guide walls. However, more recently, stream mouth cutting has been carried out to prevent lateral migration of the channel. Given the apparent lack of significant management practices in the past and a more recent trend toward shoreline stability, it was considered not to be necessary to carry out a managed inlet assessment.

On the southern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 19.0 m (LT = 0, SLR = 12.5 m, DS = 0.5 m and CU = 6 m) and 48.0 m (LT = 0, RSLR = 37.5 m, DS = 0.5 m, CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C26.58 (see Appendix D). These updated inlet erosion prediction lines (IEPLs) are illustrated in Figure 4.6.

On the northern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 15.6 m (LT = 0, RSLR = 8.8 m, DS = 0.8 m, CU = 6 m) and 37.3 m (LT = 0, RSLR = 26.5 m, DS = 0.8 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C27.63 (see Appendix D). These updated inlet erosion prediction lines (IEPLs) are illustrated in Figure 4.6.

As evident in Figure 4.6, channel orientation as it enters the inlet may take on a more shore-normal or even northerly offset under the 100 yr scenario, so the 100 yr IEPL configuration on the northern side of the inlet was adjusted to incorporate this possibility.

The earlier shorelines depicted in Figure 4.6 indicate erosion has occurred in the vicinity and landward of the 100 yr natural IEPL, thus suggesting the predictions may be under-estimated.

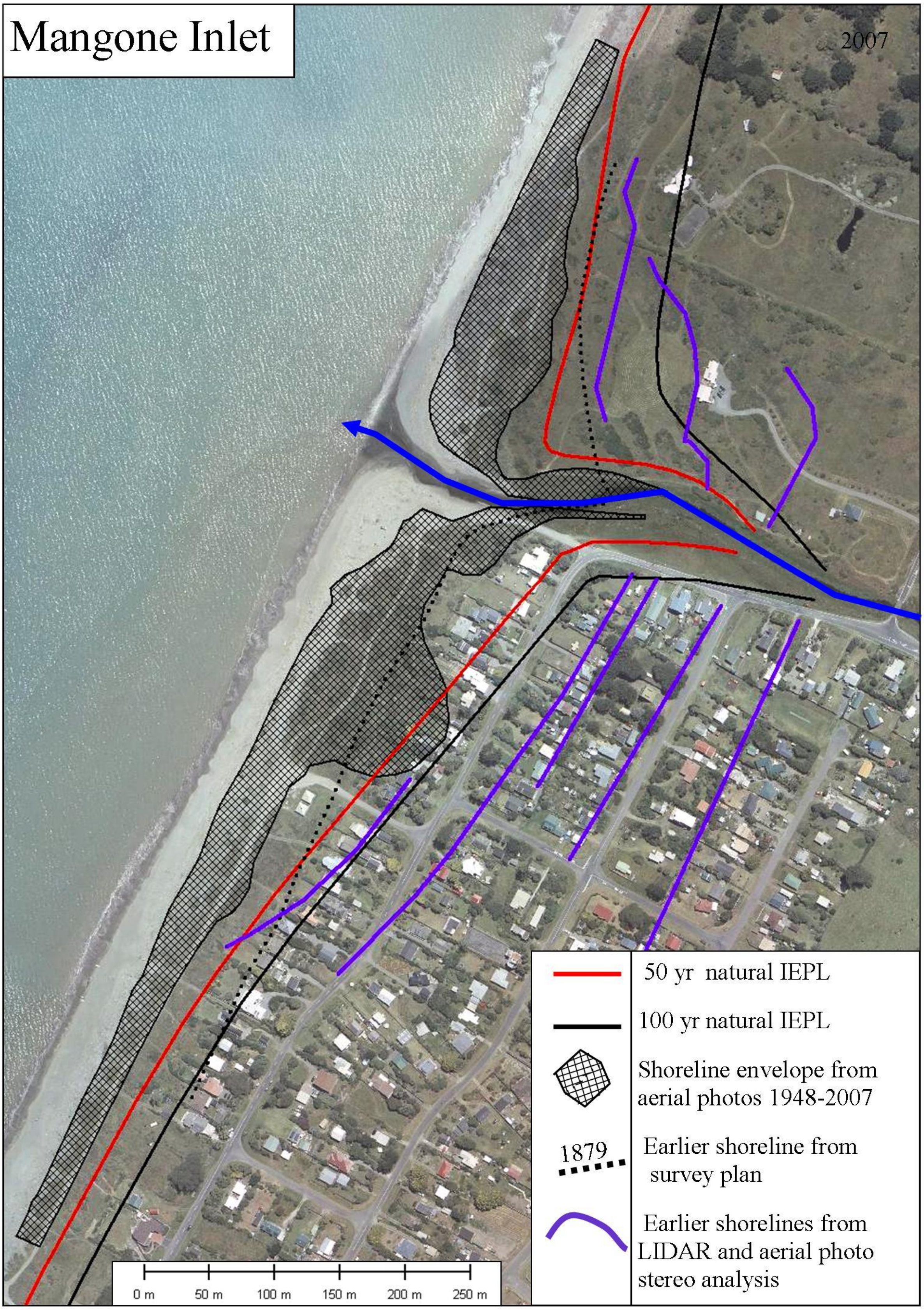

Figure 4.6 Mangaone Inlet previous shoreline locations and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods.

4.4.5 Hadfield Inlet

The Hadfield Inlet has a maximum area of 7.3 ha and alongshore length up to 800 m. The catchment area is 1,100 ha (11 km^2), and the mean annual flood discharge is 8 m^3/s. The inlet has a southerly offset, although earlier shoreline evidence shows that it may previously have had a northerly offset. Long-term open coast shoreline progradation is 0.44 m/yr on the south coast and 0.51 on the north coast.

Past shorelines and derived hazard characteristics are summarized in Figure 4.7. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F5 and the shoreline dynamics are described in the 2008 Hazard Assessment.

The aerial photo record for the Hadfield Inlet shows no evidence of inlet management in terms of channel diversion, bank protection or guide walls. However, more recently, stream mouth cutting has been carried out to control lateral migration of the channel. Given the apparent lack of management practices in the past and a more recent trend toward shoreline stability, it was not necessary to carry out a managed inlet assessment.

On the southern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 28.1 m (LT = 0, SLR = 18.8 m and DS = 3.3 m and CU = 6 m) and 69.6 m (LT = 0, RSLR = 56.3 m, DS = 3.3 m, CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C22.06 (see Appendix D). These updated inlet erosion prediction lines (IEPLs) are illustrated in Figure 4.7.

On the northern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 25.6 m (LT = 0, RSLR = 17.7 m, DS = 1.9 m, CU = 6 m) and 64.8 m (LT = 0, RSLR = 52.9 m, DS = 1.9 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C23.5 (see Appendix D). These updated inlet erosion prediction lines (IEPLs) are illustrated in Figure 4.7.

As evident in Figure 4.7, channel orientation as it enters the inlet may take on a more shore-normal or even northerly offset under the 100 yr scenario, so the 100 yr IEPL configuration on the northern side of the inlet was adjusted to incorporate this possibility.

The earlier shorelines depicted in Figure 4.7 lie within the 100 yr natural IEPL. While this provides some confidence in the 100 yr natural erosion estimates it is noted that severe dune instability and parabolic development in the recent past have obscured much of the earlier shoreline record.

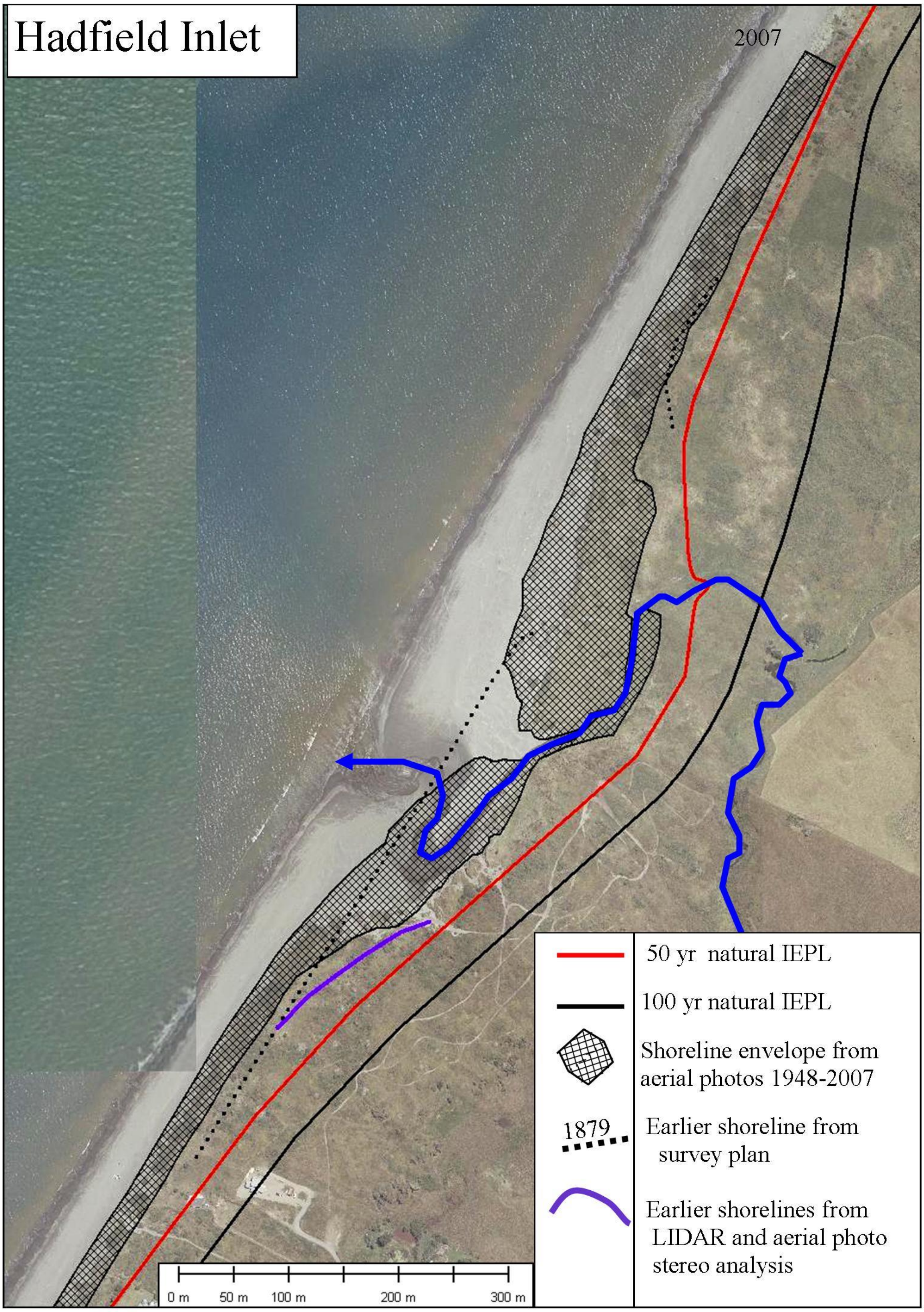

Figure 4.7 Hadfield Inlet's previous shoreline locations and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods.

4.4.7 Waimeha Inlet

The Waimeha Inlet has a maximum area of 8.8 ha and alongshore length up to 600 m, based upon the aerial photograph record. The channel typically has a northerly offset, the catchment area is 1900 ha (19 km^2), and the mean annual flood flow of 13 m^3/s. The adjacent coast is prograding at 0.4 m/yr to the north and 0.34 m/yr to the south.

Past shorelines and derived hazard characteristics are summarized in Figure 4.8. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F6, and the shoreline dynamics are described in the 2008 Hazard Assessment.

In early colonial times the Waimeha Stream flowed into the Waikanae River but its flow had greatly reduced by the late 19th century. In 1921 the present stream outlet was artificially opened, although very early shorelines indicate the Waimeha had previously had its outlet in this area (see Figure 4.8). For further detail on the early Waimeha see Section 3.7 – Waikanae Inlet, and also the 2008 Inlet Assessment, Volume 2).

Manawatu Catchment Board reports note that temporary structures exited in the vicinity of the Waimeha Inlet prior to the mid-1980s; however, these are not evident in the earlier aerial photo record with the first observed groyne appearing in the 1988 photo. There is now a mouth cutting regime to limit the extent of lateral migration. The increased management over the last few decades justifies the division of shorelines into an natural and managed sets with the natural set comprising the 1942 to 1966 shorelines, and the managed set containing the 1973 to 2007 shorelines.

On the southern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 23.6 m (LT = 0, RSLR = 15 m, DS = 2.6 m, CU = 6 m) and 57.6 m (LT = 0, RSLR = 45 m, DS = 2.6 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site (C17.88, see Appendix D).

On the northern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 23.0 m (LT = 0, RSLR = 15 m, DS = 2 m, CU = 6 m) and 57.0 m (LT = 0, RSLR = 45 m, DS = 2 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site (C18.85, see Appendix D). The updated inlet erosion prediction lines (IEPLs) are illustrated in the summary figure.

As evident in Figure 4.8, the channel orientation as it enters the inlet will remain offset to the north under both the 50 and 100 yr erosion prediction scenarios, so it is likely the present channel offset and inlet configuration will be maintained.

The lack of relevant earlier shorelines in Figure 4.8 gives some confidence to the IEPLs. However, as this inlet was subjected to natural processes for only 50 yrs before management constraints occurred, it may not have achieved its potential configuration dimensions. To test this hypothesis, the set of 11 inlet lengths were linearly regressed (equation 7) and nonlinearly regressed (equation 8) regressed against the corresponding catchment areas (equation 7). Note Otaki was excluded as it was classed as an outlier, possibly reflecting its braided gravel bed and gradient contrasts with the other inlets. The associations were statistically significant ($r = 0.855$ and 0.888 respectively) and the residuals for the Waimeha were -18 m and -6.5 m respectively, indicating that it was nearing its equilibrium configuration prior to the onset of management practices.

$$Li = 9.748Ac + 432.9 \qquad (7)$$

$$Li = 1.33Ac^{0.5} + 118 \qquad (8)$$

Where Li = inlet length and Ac = catchment area

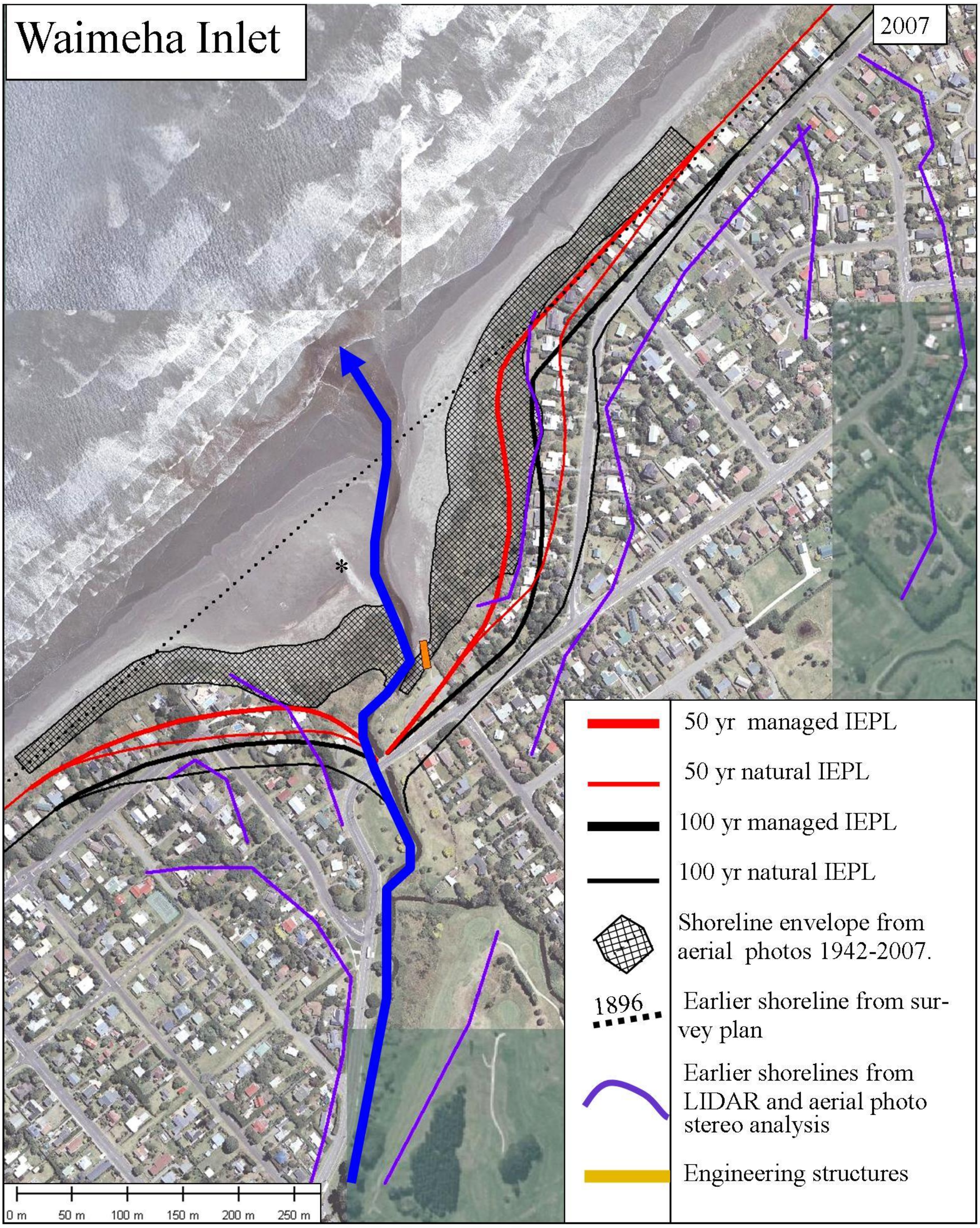

Figure 4.8 Waimeha Inlet's previous shoreline locations and inlet erosion prediction lines (IEHPs) for 50 and 100 yr assessment periods. Inlet control from the marked engineering structure and less permanent channelization works (e.g. earth bund marked *) have been incorporated within the managed inlet assessment scenarios. Note that only the "earlier shoreline" closest to the stream mouth is associated with the Waimeha Inlet which was artificially cut in 1921. The other marked "earlier shorelines" appear to relate to an earlier time when the Waimeha Stream entered the sea at this location.

4.4.8 Waikanae Inlet

The natural Waikanae Inlet (pre-1960s) has a maximum area of 71 ha and alongshore length up to 1800 m. By contrast the present managed inlet (discussed below) has an area of 35 ha and alongshore length of 1000 m. The catchment area of the Waikanae River is 15,300 ha (153 km^2), and the mean annual flood flow is 148 m^3/s. The channel (both natural and managed) has a southerly offset. The Waikanae Inlet (both natural and managed) is the largest on the Kapiti Coast, and this relates to the size of the fluvial system coupled with fine sediment in its lower reach which facilitates channel migration. The adjacent northern (Waikanae Beach) open coast has a long-term shoreline progradation rate of 0.27 m/yr while the adjacent southern (Paraparaumu) coast has a long-term erosion rate of 0.28 m/yr. By contrast the rear shoreline of the inlet (Otaihanga side) is remarkably stable.

Past shorelines and derived hazard characteristics are summarized in Figure 4.9. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F7, and the shoreline dynamics are described in the 2008 Hazard Assessment.

In early colonial times the Waikanae River bifurcated near Waikanae Township and followed two main courses - the northern Waimeha and the southern Waikanae. These branches reunited at the position of the present Waimanu Lagoon and their resultant southerly orientation may have contributed to the inlet’s southerly offset. About 1890 the Waimeha bifurcate was cut-off, with the southern branch (present Waikanae River course) receiving the full flow. In the early 1920s, the present Waimeha channel was excavated and the remnant Waimeha further seaward forming the present Waimanu and Waimeha Lagoons.

Over the past 60 yrs in particular, the lower Waikanae River and Inlet have undergone substantial change due to gravel extraction, channelisation, bank protection works and rivermouth control for the purposes of flood mitigation and erosion prevention associated with the Waikanae River Catchment Control Scheme. In addition, groynes were constructed at the Waikanae side of the inlet in the late 1960s to early 1970s as part of a residential development project and substantial reclamation carried out on the Paraparaumu side of the inlet in the late 1960s, also for residential development. Present management consists of mouth cutting. The various management works and practices have halved the inlet area and constrained the lateral extent of channel migration by almost a half. Further details on this inlet’s history are described in the 2008 Hazard Assessment, Part 2, Section 3.7.

The increase in management since the late 1960s provides the basis upon which to divide the shoreline data into earlier (natural) and later (managed) subsets. However, because the jetties at the northern end of the inlet and the subdivision earthworks at the southern end resulted in systematic shoreline adjustment, the 1966 to 1980 shorelines were classed as ‘transitional’ and not included in the analysis.

As with the rest of the north Kapiti coast, the open coast shorelines on both sides of the inlet are unmanaged, so both natural and managed inlet erosion offsets (from the IMCs) are calculated using unmanaged open coast component values.

On the southern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 44.1 m (LT = 15, RSLR = 20 m, DS = 3.1 m, CU = 6 m) and 103.1 m (LT =30, RSLR = 60 m, DS = 3.1 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site (C14.20, see Appendix D).

On the northern side of the inlet the 50 and 100 yr erosion projection lines were derived by adjusting the inlet migration curve (IMC) landward by 24.3 m (LT = 0, RSLR = 15 m, DS = 3.3 m, CU = 6 m) and 58.3 m (LT = 0, RSLR = 45 m, DS = 3.3 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site (C16.16, see Appendix D). The updated inlet erosion prediction lines (IEPLs) are illustrated in the Figure 4.9.

While the central (eastern) Otaihanga side of the inlet is in fact part of the southern inlet shoreline, it is unreasonable to use the offsets from the southern coastal site (C14.2) because the long-term trend in this central location is relatively stable compared with the negative LT value for the southern open coast (NB the adjacent north coast has a positive LT rate of 0.27 m/yr). An offset value of 29.1 m and 73.1 m (setting LT = 0) was thus used to derive the hazard line for the central inlet.

As evident in Figure 4.9, the channel orientation as it enters the inlet under the 50 yr and 100 yr natural inlet scenarios has a slight southward orientation so the present inlet configuration will likely still apply.

The early survey shoreline (1872), and the aerial-stereo shorelines in the vicinity of the inlet, lie close to and in places landward of, the natural 50 and 100 yr erosion prediction lines indicating the erosion assessment modelling may be underestimated in the central-southern sectors. The yet earlier (LIDAR-based) shorelines demonstrate the consistent shape of the inlet through time.

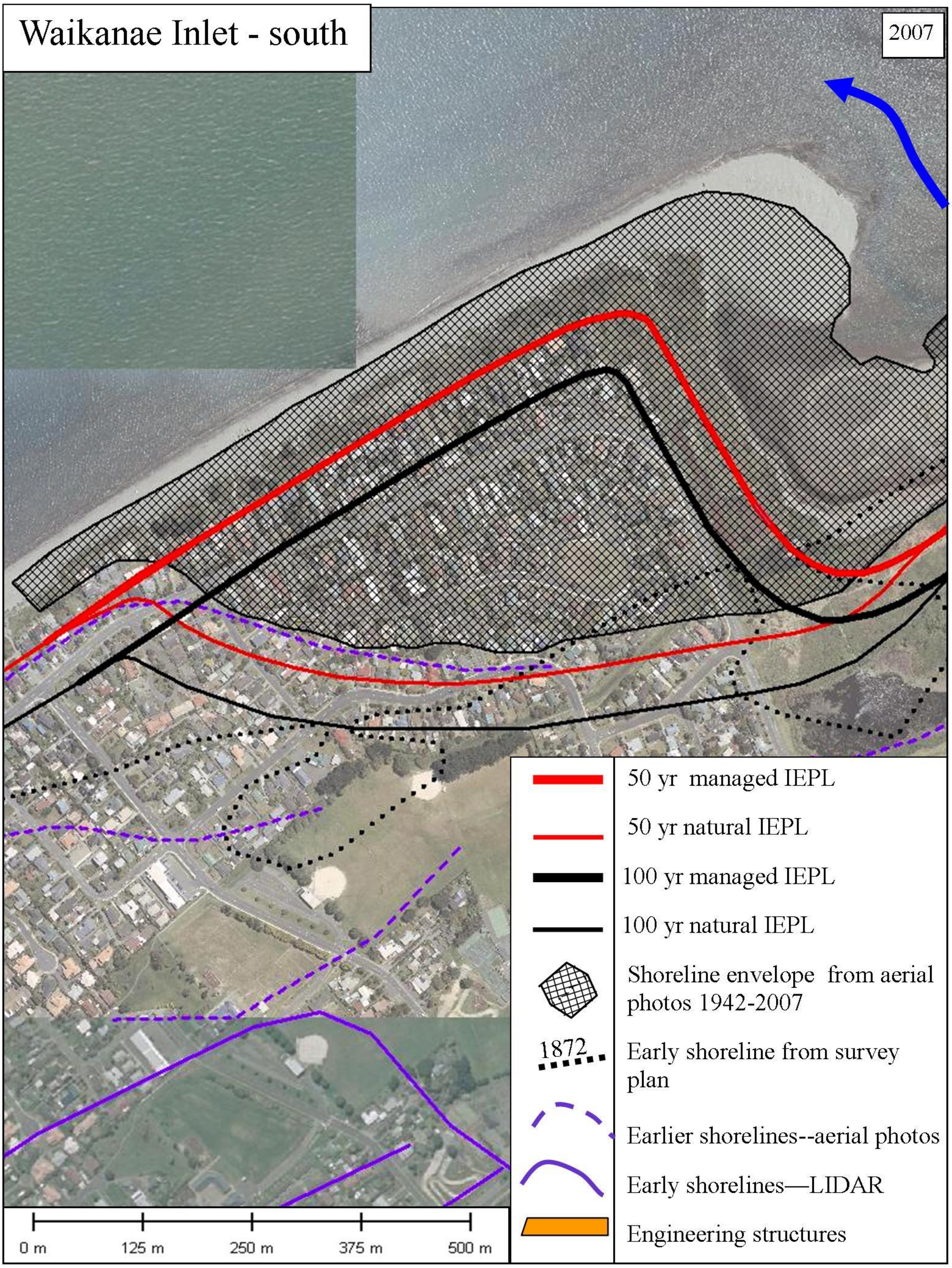

Figure 4.9A Southern Waikanae Inlet's previous shoreline locations and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. The erosive effects from marked engineering structures have been incorporated within the managed inlet assessment scenarios.

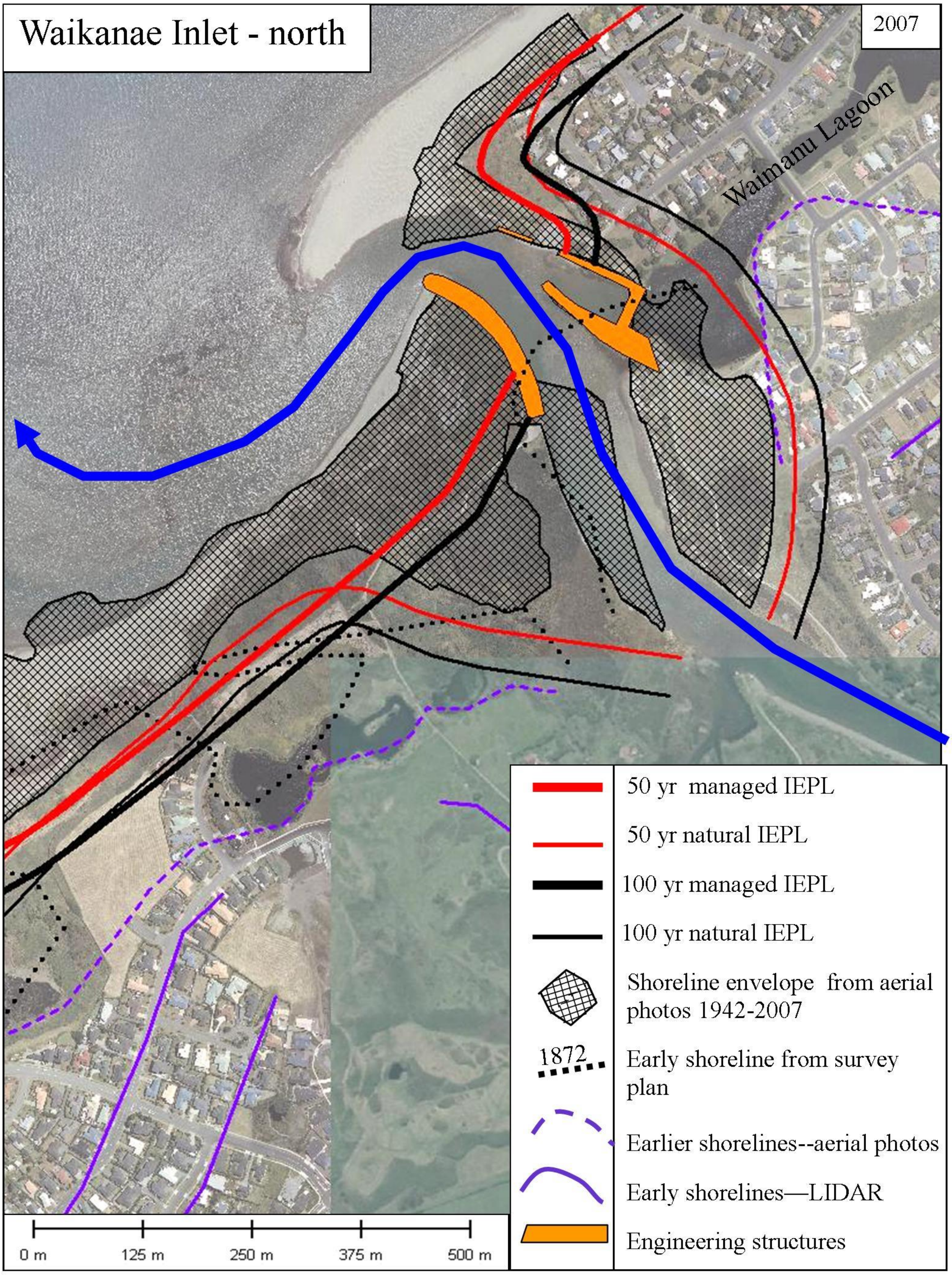

Figure 4.9B Northern Waikanae Inlet's previous shoreline locations and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. The erosive effects from marked engineering structures have been incorporated within the managed inlet assessment scenarios

4.4.9 Tikotu Inlet

The Tikotu Inlet has a maximum area of 1.3 ha, and alongshore length up to 220 m based the aerial photograph record. The channel has a southerly offset and the catchment area is 100 ha (1 km^2) and the means annual flood is 0.6 m^3/s . The adjacent coast is prograding at 0.51 m/yr to the south and 1.47 m/yr to the north.

Past shorelines and derived hazard characteristics are summarized in Figure 4.10. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F8 and the shoreline dynamics are described in the 2008 Hazard Assessment.

The adjacent southern coast has been intensely developed for recreation and amenity since the 1960s with culvert and guide wall constraining channel's approach into the inlet and a 290 m seawall affecting the southern inlet and adjacent open coast shorelines. However, by the late 1990s the prograding open coast shoreline was beyond the seawall and the fronting foredune is now over 20 m wide. Lateral migration of the channel is further limited by a mouth cutting regime. In the erosion assessment, the managed inlet shorelines are from 1973 and the natural inlet shorelines are prior to 1965.

The open coast shoreline on the southern side of the inlet has both seawall remove (unmanaged) and seawall repair (managed) options to calculate IEPLs. Under the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 26.1 m (LT = 0, RSLR = 17.7 m, DS = 2.4 m, CU = 6 m) and 66.4 m (LT = 0, RSLR = 54 m, DS = 2.4 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C12.50 and these values are the same for both the seawalls repaired and seawalls removed scenarios (see Appendix D). For the 50 yr managed inlet scenario the IEPL offset from the IMC (set at the seawall) = 29.4 m (LT = 0, ST = 18, RSLR = 0 m, DS = 2.4 m, CU = 9 m). Note that as the IMC is set at the seawall which extends right along the inlet's south side there is no allowance made for recession should the wall fail (before repaired), so the open coast ST value was included. The actual IEPL was fixed at the seawall as the present shoreline is over 20 m seaward and should this be eroded then it is assumed that structure will be able to withstand the remaining erosion potential (9.4 m). The managed 100 yr IEPL extends from the unmanaged 100 yr CEHL to join the road culvert.

The open coast shoreline on the northern side of the inlet (and all inlets northward) has only unmanaged CEHLs as no seawalls control the open coast adjacent to inlets from this inlet northward. Under the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 26.0 m (LT = 0, RSLR = 18.8 m, DS = 1.2 m, CU = 6 m) and 67.5 m (LT = 0, RSLR = 54.3, DS = 1.2 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C12.77 (see Appendix D). For the 50 yr managed inlet scenarios, the offset from the managed inlet migration curve (IMC) is again 26.0 m (LT = 0, RSLR = 18.8 m, DS = 1.2 m, CU = 6 m). For the 100 yr managed inlet scenario, the IEPL extends from the unmanaged 100 yr CEPL to the inlet throat infrastructure while maintaining the shape of the 50 yr managed IEPL.

As is evident in Figure 4.10, the channel orientation as it enters the inlet will remain offset to the north under both the 50 and 100 yr erosion prediction scenarios, so it is likely the present channel offset and inlet configuration will be maintained.

Earlier shorelines in Figure 4.10 both straddle and lie landward of the natural 100 yr IEPL indicating the modelled predictions may be underestimated.

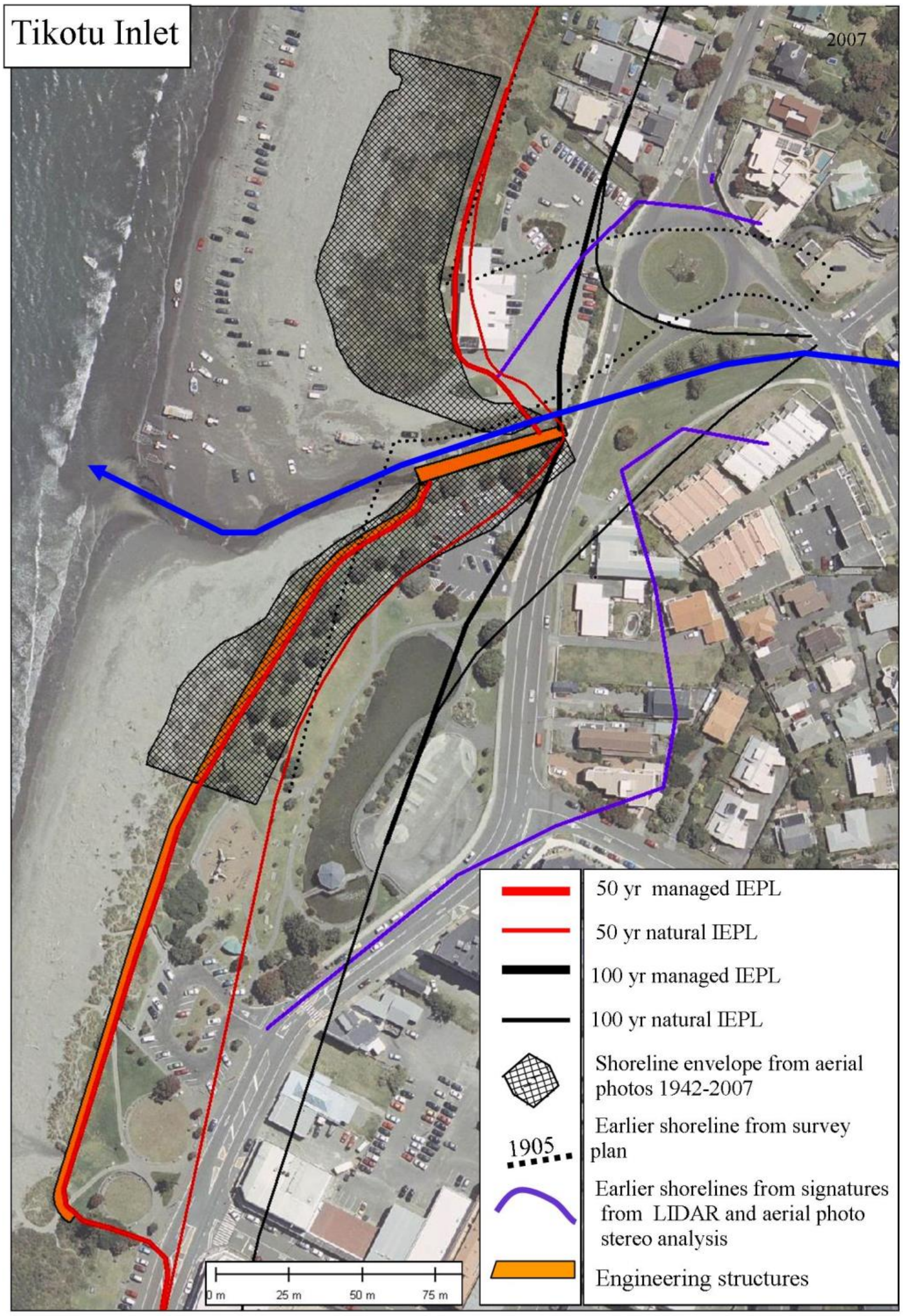

Figure 4.10 Tikotu Inlet's previous shoreline locations and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. The erosive effects from marked engineering structures have been incorporated within the managed inlet assessment scenarios.

4.4.10 Wharemauku Inlet

The Wharemauku Inlet is the most modified on the South Kapiti Coast and has had three distinct configurations since colonization. The early inlet had an extreme northerly offset (inlet area = 5.5 ha and length = 650 m). A major diversion cutting out the Marine Gardens loop resulted in the inlet taking a southerly offset (inlet area = 1.8 ha and length = 360 m). During the 1950s the coast was fixed by seawalls, then during the 1970s channel guidewalls were constructed to join the southern coastal seawall and these modifications reduced the inlet to a mere 0.06 ha with a length of 110 m. Note that the south coast and guidewall are community structures so their effects are taken into account within this hazard assessment. However, the north coast seawall is not defined as a community seawall as it was designed and maintained by residents and is thus not taken into account within the assessment. A mouth cutting regime completes the inlet’s management regime.

The Wharemauku catchment area is 1,400 ha (14 km^2) and the mean annual flood flow 11 m^3/s. In the longer-term the adjacent open coast shorelines appear to be near equilibrium.

Past shorelines and derived hazard characteristics are summarized in Figure 4.11. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F9, and the shoreline dynamics are described in the 2008 Hazard Assessment. .

On the southern coast the seawall and guide wall became effective during the 1970s, so shorelines from 1942 to 1966 will represent the natural (southern) inlet, with the 1973 shoreline being classed as transitional and excluded from the analysis.

On the northern coast the private open coast seawall was in place by 1952, thus providing only 10 yrs data (3 samples) to distinguish natural from managed inlet shoreline behavioural characteristrics; this is insufficient so a single inlet migration curve (IMC) was defined on the basis of the full set of shorelines.

The open coast shoreline on the southern side of the inlet has both seawall remove (unmanaged) and seawall repair (managed) options to calculate IEPLs. Under the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 35.6 m (LT = 10, RSLR = 15 m, DS = 4.6 m, CU = 6 m) and 79.6 m (LT = 20, RSLR = 45 m, DS = 4.6 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C9.43 (see Appendix D). For the 50 yr managed inlet scenario the offset = 13.6 (LT = 0, RSLR =0, DS = 4.6, CU = 9) and this is offset from the seawall. For the 100 yr managed scenario the IEPL extends from the unmanaged 100 yr CEPL to the inlet throat infrastructure while maintaining the shape of the 50 yr managed IEPL.

The open coast shoreline on the northern side of the inlet has only the unmanaged option for use in calculating the IEPL offset (from the single IMC, see above) as the existing private seawalls were not to be included in the assessment. Under the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 23.0 m (LT = 0, RSLR

= 15 m, DS = 2 m, CU = 6 m) and 57 m (LT = 0, RSLR = 45 m, DS = 2 m , CU = 10 m) respectively, these being the sum of relevant components from the closest coastal measurement site C10.29 (see Appendix D). While the offset to locate the IEPL was based on unmanaged CEPL values, the use of a single IMC resulted in the natural IEPL being underestimated.

As is evident in Figure 4.11, a southerly offset will occur as the channel enters the inlet under both the 50 and 100 yr erosion prediction scenarios, so the natural inlet configurations will be maintained.

Earlier shorelines in Figure 4.11 are in places landward of the 100 yr natural IEPLs, indicating the predictions are underestimated. However, these earlier shorelines were associated with the channel approaching the inlet from the south and a large meander loop (see 2008 Erosion Assessment) would need to be restored (unlikely) for these early shorelines to be relevant.

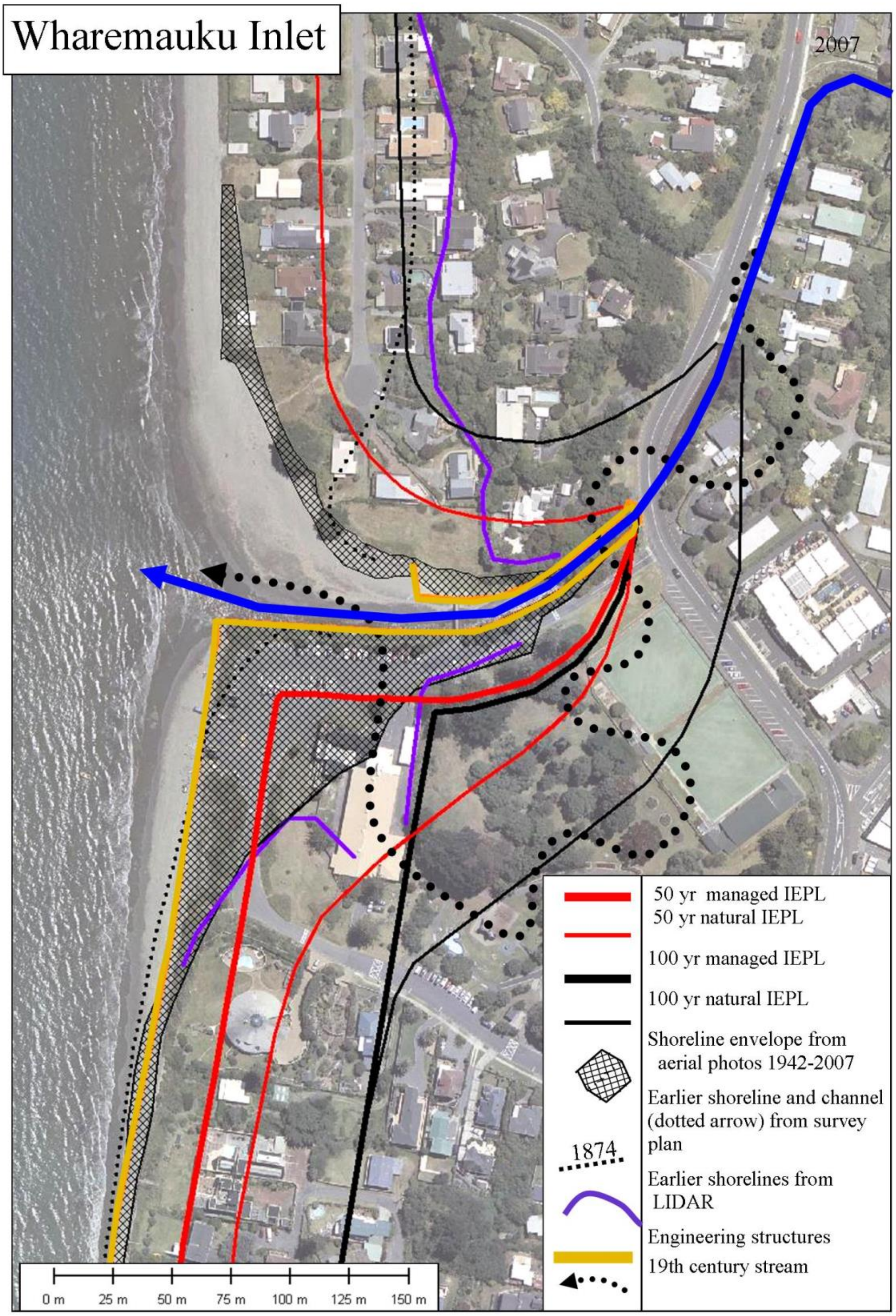

Figure 4.11 Wharemauku Inlet's previous shorelines and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. The erosive effects from marked engineering structures have been incorporated within the managed inlet assessment scenarios.

4.4.11 Whareroa Inlet

The Whareroa Inlet has a maximum area of 2.2 ha and alongshore length up to 360 m. The Whareroa Stream’s catchment area is 1,600 ha (16 km^2) and the mean annual flood discharge is 17 m^3/s. While the present inlet configuration is relatively symmetrical, a southerly offset occurred earlier in the 20th century when the channel had a more northerly approach into the inlet. More recently inlet structures and management practices (detailed below) have kept the channel alignment shore-normal. Open coast shoreline erosion rates average 0.55 m/yr to the south and 0.67 m/yr to the north. However, a distinct increase in erosion occurred in the latter part of the 20th century (See Undated Data Base) and if these values are excluded, then the average long-term rates reduce to 0.15 m/yr for the adjacent southern open coast and 0.24 m/yr for the north coast. This change in shoreline behaviour broadly coincides with the establishment of extensive seawalls along the Raumati and Paekakariki coasts so it is incorporated within the hazard assessment. However, the change could also be due to medium-term variation in sediment supply.

Past shorelines and derived hazard characteristics are summarized in Figure 4.12. For reference the full set of aerial-based shorelines have been overlaid in Appendix F, Figure F10, and the shoreline dynamics are described in the 2008 Hazard Assessment.

While there is evidence of a mid 1960s groyne on the beach to control channel alignment, the present 100 m long guidewall-groyne on the left side of the inlet dates from the late 1980s and remains effective in both controlling the lower channel position and in stabilizing the southern inlet shoreline. An official mouth cutting regime is also available to keep the channel away from the inlet shorelines.

The Whareroa Inlet has unmanaged open coast shorelines to either side; however, as noted above, shoreline effects from the substantial seawalls along the Paekakariki and Raumati coasts cannot be ruled out so both managed and unmanaged CEPLs were derived for the entire QEII open coast. Due to the unlikelihood of residential development in this area, only a single IMC was derived. By merging with the managed and unmanaged CEPLs both managed and natural IEPLs could be defined for the 50 yr prediction period and natural IEPL for the 100 yr period (given the unlikelihood of future development it was not considered necessary to define the 100 yr managed IEPL).

On the southern side of the inlet for the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 40.9 m (LT = 10 m, RSLR = 13.6, DS = 11.3 and CU = 6) and 82.2 m (LT = 20, RSLR = 40.9, DS = 11.3 and CU = 10) respectively, these being the sum of relevant components from the closest coastal measurement site C4.93 (see Appendix D). For the 50 yr managed inlet scenario the offset = 57.4 (LT = 26.5, RSLR = 13.6, DS = 11.3, CU = 6).

On the northern side of the inlet for the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 45.8 m (LT = 12.5, RSLR = 14.3, DS = 13.0 and CU =6) and 91.0 m (LT = 25, RSLR = 43.0, DS = 13.0 and CU = 10) respectively, these being the sum of relevant components from the closest coastal measurement site C5.7 (see Appendix D). For the 50 yr managed inlet scenario the offset =66.8 m (LT = 33.5 m, RSLR = 14.3, DS = 13.0 and CU = 6).

As is evident in Figure 4.12, the channel will approach the inlet at a range of angles, as the shoreline retreats to the 50 and 100 yr erosion prediction lines, so appropriate variation in inlet configuration was incorporated when locating the IEPLs.

Earlier shorelines in Figure 4.12 are seaward of the 100 yr IEPL giving some confidence to the modelled shorelines.

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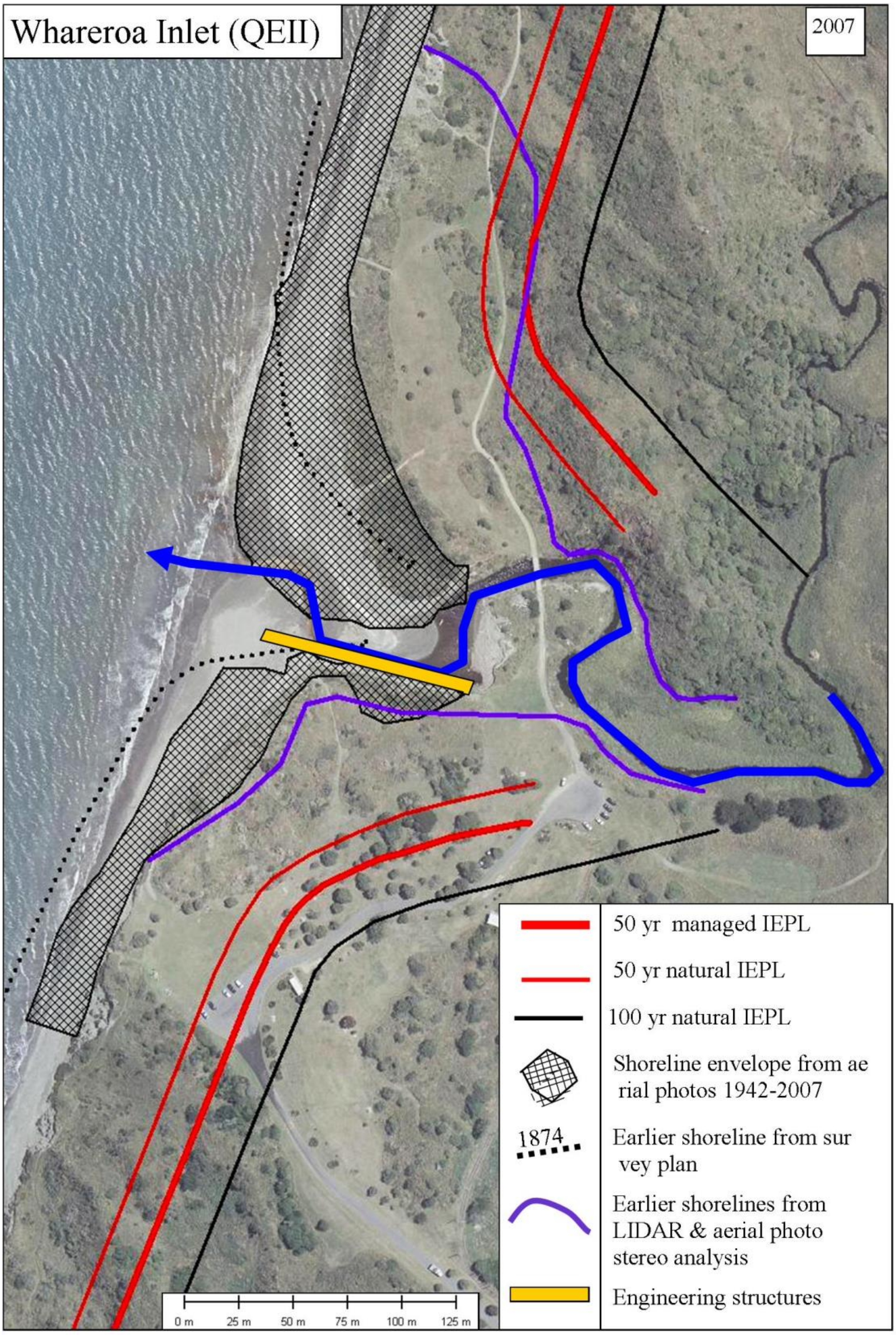


Figure 4.12 Whareroa Inlet's previous shorelines and derived inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods.

4.4.12 Wainui (Wharerata) Inlet

The Whareroa Inlet has a maximum area of 1.5 ha and alongshore length up to about 400 m. The Whareroa Stream catchment area is 800 ha (8 km^2), and the mean annual flood discharge is 11 m^3/s. This inlet has had a northerly offset throughout the historical record. Background erosion rates on the adjacent open coast
average about 0.1 m/yr; however, more recently the erosion rate has increased to about 0.3 m/yr.

Past shorelines and derived hazard characteristics are summarized in Figure 4.13. For reference the full set of aerial-based shorelines have been overlaid in Appendix F, Figure F11, and the shoreline dynamics are described in the 2008 Hazard Assessment.

A channel guide wall and groyne were built to contain south bank erosion during the 1980s and an official mouth cutting regime is in place to further constrain lateral channel migration.

No attempt was made to separate the inlet shorelines into managed and natural as inlet management has had a minimal effect on shoreline location, and residential development is not expected to occur in the general vicinity. The inlet migration curve was thus identified on the basis of the landwardmost composite shoreline from the full set of aerial-based shorelines. Managed and natural IEPLs were then derived by calculating offsets (from the IMC) based on open coast hazard component values for the seawalls repair (managed) and seawalls removed (unmanaged) options.

On the southern side of the inlet for the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 31.2 m (LT = 10 m, RSLR = 10.7, DS = 4.5 and CU = 6) and 66.6 m (LT = 20, RSLR = 32.1, DS = 4.5 and CU = 10) respectively, these being the sum of relevant components from the closest coastal measurement site C2.62 (see Appendix D). For the 50 yr managed inlet scenario the offset = 21.2 m (LT = 0, SLR = 10.7 m, DS = 4.5 m and CU = 6). For the 100 yr managed scenario the IEPL extends from the unmanaged 100 yr CEPL to the inlet throat infrastructure while maintaining the shape of the 50 yr managed IEPL.

On the northern side of the inlet for the 50 and 100 yr natural inlet scenarios, the offsets from the inlet migration curve (IMC) are 31.3 m (LT = 5, RSLR = 13.6, DS = 6.7 and CU =6) and 67.6 m (LT = 10, RSLR = 40.9, DS = 6.7 and CU = 10) respectively, these being the sum of relevant components from the closest coastal measurement site C3.60 (see Appendix D). For the 50 yr managed inlet scenario the offset = 40.8 m (LT = 14.5 m, SLR = 13.6 m, DS = 6.7, CU = 6 m). For the 100 yr managed scenario the IEPL extends from the unmanaged 100 yr CEPL to the inlet throat infrastructure while maintaining the shape of the 50 yr managed IEPL.

As is evident in Figure 4.13, the channel will approach the inlet from the north as the shoreline retreats to the 50 and 100 yr erosion prediction lines, so the IEPLs incorporated configurations with channel offset to the south.

Earlier shorelines in Figure 4.13 are seaward of the 100 yr IEPLs giving confidence to the predicted shoreline erosion.

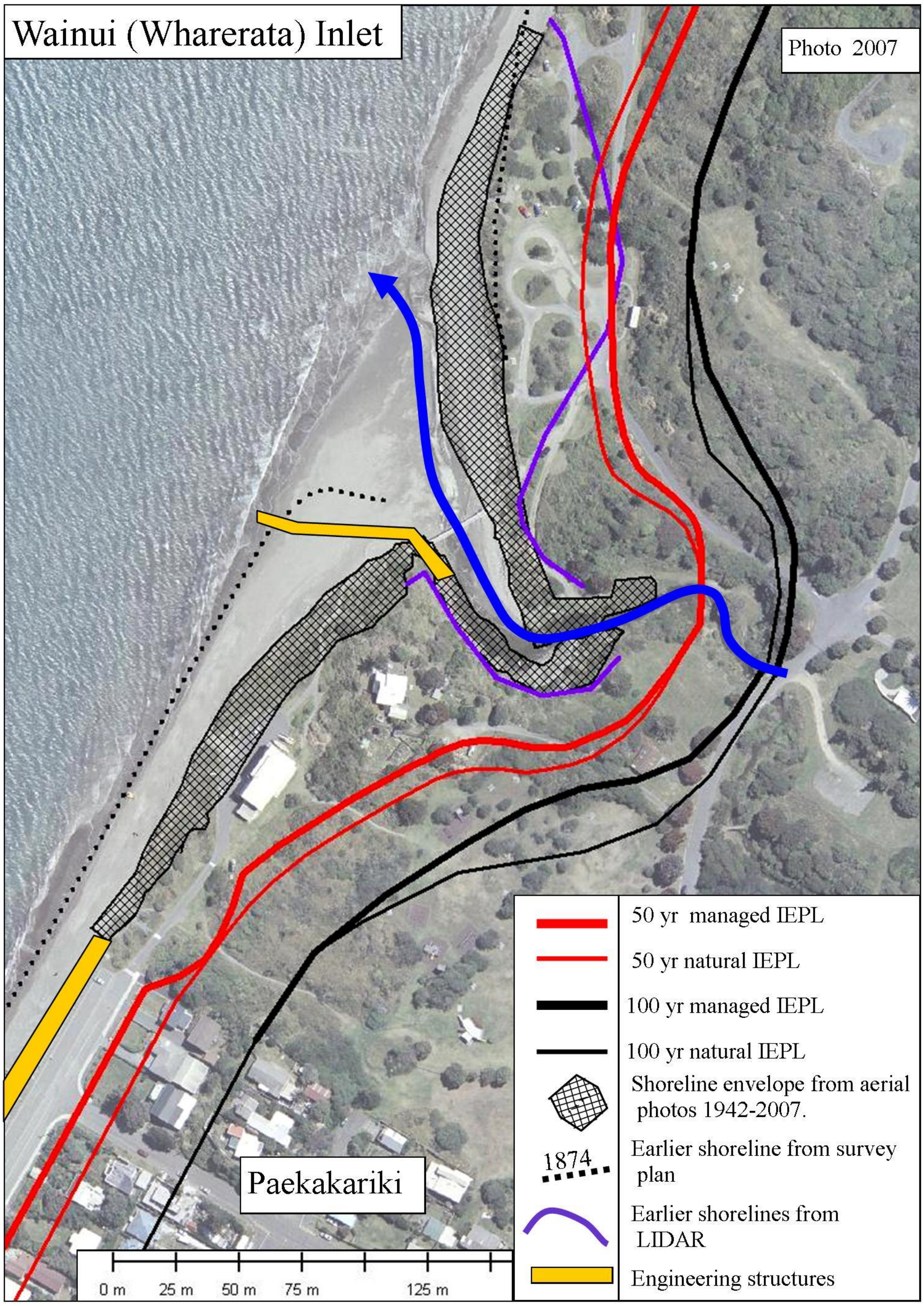


Figure 4.13 Wainui Inlet's previous shoreline locations and derived inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods.

4.4.13 Waikakariki Inlet

The Waikakariki Inlet has a maximum area of 0.6 ha and an alongshore length up to about 200 m. The Waikakariki Stream catchment area is 200 ha (2 km^2) and the mean annual flood discharge is 3 m^3/s. This inlet has had a northerly offset throughout the aerial photo record, but earlier shoreline indications are that it may have once had a more shore-normal alignment. Background average erosion rates on the adjacent open coast are estimated to be between 0.12 and 0.2 m/yr.

Past shorelines and derived hazard characteristics are summarized in Figure 4.14. For reference the full set of aerial-based shorelines have been overlaid in Appendix F, Figure F12, and the shoreline dynamics are described in the 2008 Hazard Assessment.

Inlet management consists of a guidewall where the channel meets the inlet, seawalls (some dating from the mid 1950s) along much of the inlet sides and extending along the adjacent coast, and a mouth cutting regime. As directed by the terms of reference, the effects of these structures were not included within the erosion prediction line computations. Only a single inlet migration curve (IMC) was defined due to the small inlet size and the small sample of natural shorelines. This IMC may thus have a bias toward a managed inlet rather than a natural inlet.

On the both sides of the inlet, unmanaged 50 and 100 yr CEPL parameter values (for coastal measurement site 1.51) gave IMC offsets of 37.6 m for 50 yrs (LT = 12 m, SLR = 7.9 m, DS = 11.7 m and the inlet CD = 6 m), and 60.4 m for 100 yrs (LT = 24 m, RSLR = 23.7 m, DS = 11.7 m, CU = 10 m), see Appendix D. As there is a single IMC and the CEPL is for an unmanaged scenario, the IEPL is for a natural inlet with seaward bias (as the IMC has a managed inlet bias - see above).

As the shoreline retreats to the 50 and 100 yr erosion prediction lines (Figure 4.14), the channel will approach the inlet from the north (c.f. the south as at present), so the IEPL configurations provide for channel offset to the south.

Earlier shorelines in Figure 4.14 are all seaward of the 100 yr IEPLs giving some confidence to the predicted shoreline erosion.

Finally it is noted that the 50 yr IEPL on the north side of the inlet merges with both managed and unmanaged 50 yr CEPLs. The occurrence of a managed 50 yr CEPL is due to the community seawall along, and in the vicinity of, the Parade. It is further noted that the managed 50 yr CEPL's embayment shape results from the effect the seawall has on coastal processes (NB Section 2.3 and Appendix A).

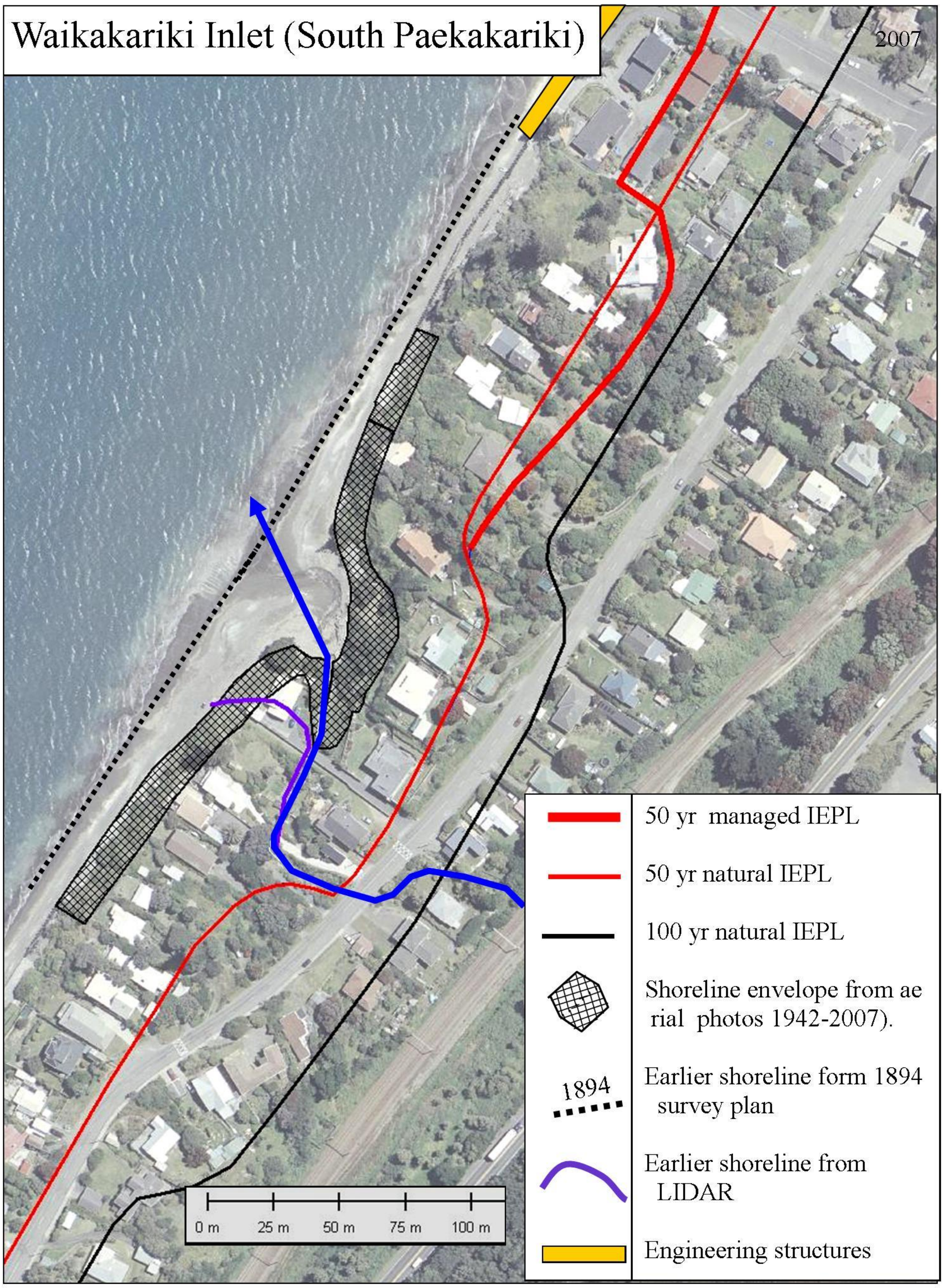


Figure 4.14 Waikakariki Inlet's previous shoreline locations and inlet erosion prediction lines (IEPLs) for 50 and 100 yr assessment periods. Only effects from marked structures have been incorporated within the 50 yr managed assessment scenario.

5.0 UPDATED DATA BASE

5.1 Introduction

The Erosion Hazard Data Base comprised Part 3 of the 2008 Hazard Assessment and has been updated as part of the present Assessment. The *Data-Base* has the following three objectives:

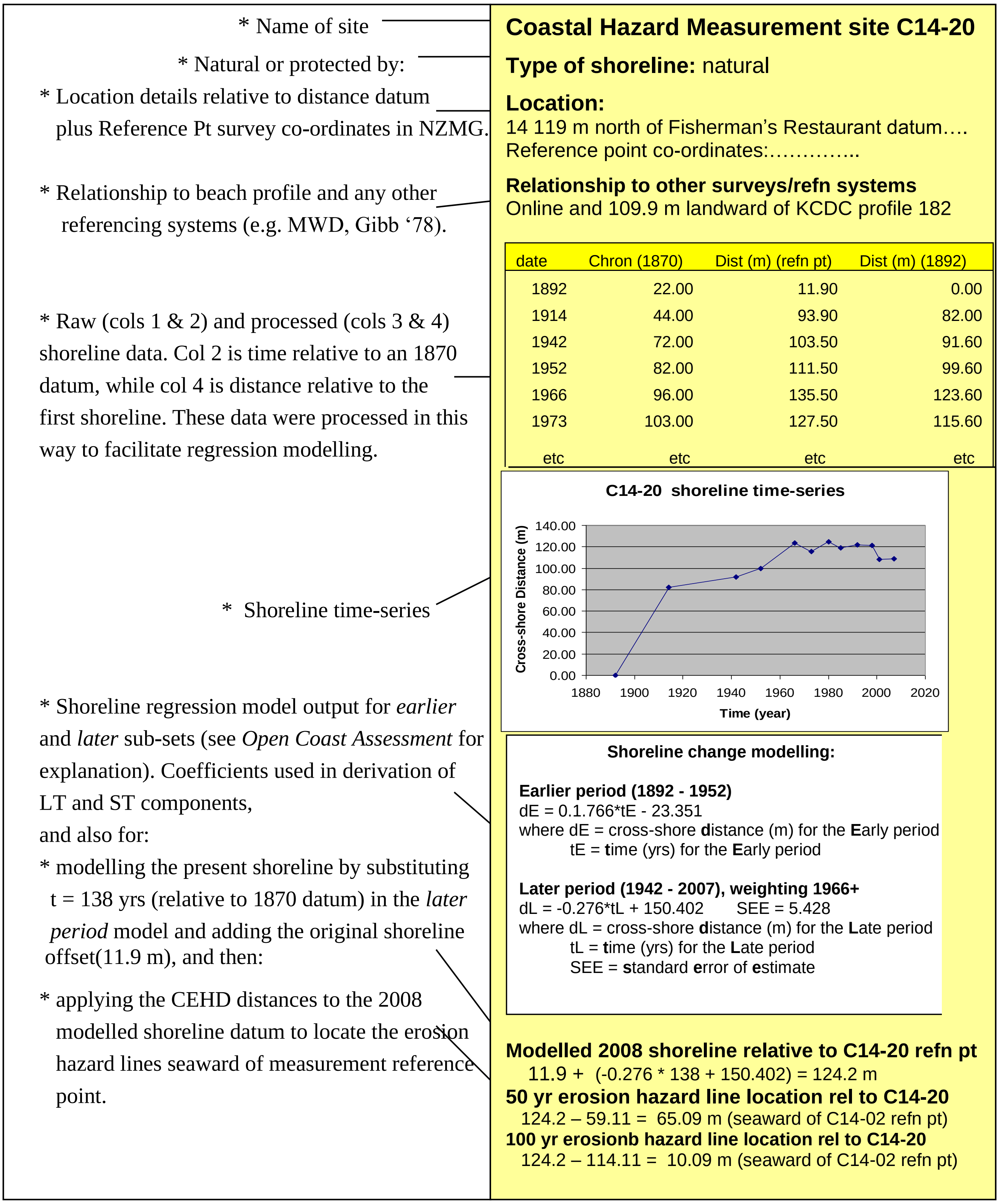
- To provide information for each measurement site including shoreline data and its analysis, and location of the final erosion prediction lines;
- To detail how components (terms in equation 1) are derived for each measurement site, and
- To facilitate future assessment updates.

The Data-Base is presented as two spreadsheets, one for *measurement-site information* and the other for *component derivations*. These spreadsheets contain all previous materials (from the 2008 Data Base) plus the 2012 updated data. The main modification/additions in the 2012 Updated Data-Base relate to inclusion of a 100 yr scenario and additional measurement sites and shoreline samples for the north Raumati-south Paraparaumu section of coast.

5.2 Measurement-site information

A separate sheet is assigned for each measurement site within the spreadsheet. An example (measurement site C14-20) is depicted in Figure 5.1. Each sheet details the measurement (or reference) point name and co-ordinates (NZMG), as well as spatial relationships to previously used survey/reference systems. Note when selecting measurement sites for the CSL erosion hazard assessment, previously used reference marks/transect locations (some dating back to Ministry of Works and Development sites from the 1970s) were used where possible, or locations at least in the vicinity of such earlier sites. However, care was also required to ensure adequate spatial density of sites to capture shoreline characteristics and behavioral variation. Consequently, many additional measurement sites had to be included.

Shoreline data, i.e. distances from the measurement point to each shoreline (alongshore averaged over say 50 m to remove temporary morphological noise), are presented in the table which also lists the chronology of the samples (for all sites, temporal datum was set to 1870 thereby predating all historical samples) and distance from the earliest shoreline (to facilitate subsequent analysis). A time-series plot appears below the table. Regression modelling to determine the rate of change and variation is then set out. The regression model is given that locates the *reference shoreline*. The open coast erosion prediction distances (CEPDs), as derived in the component derivation spreadsheet (see Section 5.3 below), can then be scaled from the reference shoreline. Alternatively, a calculation is included (bottom right in Figure 5.1) which provides a distance to the erosion prediction point directly from the measurement site itself.



* Name of site

* Natural or protected by:

* Location details relative to distance datum plus Reference Pt survey co-ordinates in NZMG.

* Relationship to beach profile and any other referencing systems (e.g. MWD, Gibb '78).

* Raw (cols 1 & 2) and processed (cols 3 & 4) shoreline data. Col 2 is time relative to an 1870 datum, while col 4 is distance relative to the first shoreline. These data were processed in this way to facilitate regression modelling.

* Shoreline time-series

* Shoreline regression model output for *earlier* and *later* sub-sets (see *Open Coast Assessment* for explanation). Coefficients used in derivation of LT and ST components,

and also for:

* modelling the present shoreline by substituting t = 138 yrs (relative to 1870 datum) in the *later period* model and adding the original shoreline offset(11.9 m), and then:

* applying the CEHD distances to the 2008 modelled shoreline datum to locate the erosion hazard lines seaward of measurement reference point.

Coastal Hazard Measurement site C14-20

Type of shoreline: natural

Location:
14 119 m north of Fisherman's Restaurant datum….
Reference point co-ordinates:…………..

Relationship to other surveys/refn systems
Online and 109.9 m landward of KCDC profile 182

date	Chron (1870)	Dist (m) (refn pt)	Dist (m) (1892)
1892	22.00	11.90	0.00
1914	44.00	93.90	82.00
1942	72.00	103.50	91.60
1952	82.00	111.50	99.60
1966	96.00	135.50	123.60
1973	103.00	127.50	115.60
etc	etc	etc	etc

Shoreline change modelling:

Earlier period (1892 - 1952)
dE = 0.1.766*tE - 23.351
where dE = cross-shore **d**istance (m) for the **E**arly period
tE = **t**ime (yrs) for the **E**arly period

Later period (1942 - 2007), weighting 1966+
dL = -0.276*tL + 150.402 SEE = 5.428
where dL = cross-shore **d**istance (m) for the **L**ate period
tL = **t**ime (yrs) for the **L**ate period
SEE = **s**tandard **e**rror of **e**stimate

Modelled 2008 shoreline relative to C14-20 refn pt
11.9 + (-0.276 * 138 + 150.402) = 124.2 m
50 yr erosion hazard line location rel to C14-20
124.2 – 59.11 = 65.09 m (seaward of C14-02 refn pt)
100 yr erosionb hazard line location rel to C14-20
124.2 – 114.11 = 10.09 m (seaward of C14-02 refn pt)

Figure 5.1 Example sheet from Measurement-Site Information spreadsheet

5.3 Component derivation

A separate sheet is assigned for the derivation of each component. In addition, summary sheets are included for each scenario and these summary sheets are reproduced as Appendix D (1 to 3) in this report. For the 2008 assessment, three scenarios were assessed: *seawalls hold*, *seawalls are repaired and seawalls are removed* with each assessed over a 50 yr period. For the 2012 assessment, the *seawalls hold* option was not included, but a 100 yr assessment was included for the *seawall remove* option (i.e. a natural coast). Each separate sheet contains notes explaining the process by which the component values were derived.

The LT sheet lists rates of change (as derived in the measurement-site information spreadsheet using equation 2) for both *earlier* and *later* periods, then after appropriate longshore smoothing (Section 3.3.1), these values were converted into LT distances based on each management option and assessment period. Note that for seawalled sections of coast, under the *2008 seawalls hold* and *seawalls repaired* options, and also for all prograding coasts, LT = 0. Note also that for seawalled sections of coast under the *seawalls remove* option, an *erosion catch-up* value was included (NB Section 3.1.1).

The ST sheet lists SEE values and then, following appropriate longshore smoothing (Section 3.3.1), ST values (3*SEE_smoothed). ST values are the same for both 50 and 100 yr assessment periods and *seawalls repair* and *seawalls remove* options, but for seawalled sections of coast they were set to zero under the *2008 seawalls hold* option.

The RSLR sheet provides detail on the beach profile surveys used for each measurement site. Note not all beach profile sites corresponded with the measurement sites used in the CSL assessments, so linear interpolation was applied in conjunction with appropriate longshore smoothing (Section 3.3.1). Derivation of RSLR values were then achieved by applying equation 3. Note that for seawalled sections of coast, under *2008 seawalls hold* and the *seawalls are repaired* options, RSLR = 0.

The DS sheet provides detail on the LIDAR-based dune (scarp) height used to represent each measurement site and then the derivation of DS values by applying equation 4 Note that for seawalled sections of coast, under the *2008 seawalls hold* option, DS = 0.

The CU sheet lists the combined uncertainty values (determined using equation 5) as given in Section 3.2.5, namely 6 m (50 yrs) and 10 m (100 yrs) for both the open coast (*where no seawalls exist or they are removed*) and for inlets. Under the *2008 seawalls hold* option, CU = 0 and where *seawalls are repaired* CU = 9 m (for 50 yrs only as there is no 100 yr seawall repair option).

Note that inlet component values LT, RSLR and DS in equation 6 are the same as the open coast values given in the component derivation spreadsheet, with the actual values used for each inlet given in Sections 4.4.2 to 4.4.14. The remaining component, the inlet migration curves (IMC) were graphically determined for each individual inlet as described in Section 4.1.

5.4 Future updating

To facilitate future erosion assessment updates, and to provide forward warning of possible process-morphological change, it is recommended that spreadsheet data tables be updated as new monitoring results become available. This should not be confused with full processing to determine new CEHDs. For example, when a new aerial photo survey is carried out, the shoreline can be defined and distance (from the transect reference point) measured and this value added to the appropriate table in the *measurement-site information spreadsheet*. This new point is automatically graphed and a new regression line modelled. Changes can thus easily be visually detected and steps taken such as additional monitoring .

6.0 OTHER CONSIDERATIONS and RECOMMENDATIONS

6.1 Site-specific assessments

Erosion hazard assessments can be categorized as *regional, local and site-specific* with the spatial coverage decreasing and analysis detail increasing accordingly. Regional assessments therefore tend to be undertaken for rural areas and local assessments for urban areas. The present Kapiti Coast erosion assessments were undertaken at the local level within, and on the margins of, settled areas, while somewhat less detail was applied in the rural areas.

A generic assessment model was applied along the entire coast with some modification for coastal structures and for inlets. However, applying a generic model where widespread coastal variation occurs can lead to some seemingly inconsistent results such as the southern Otaki Inlet where the managed predicted erosion line is landward of the natural inlet erosion prediction line due to stopbank alignment. Furthermore, even with data points spaced at only a few hundred metres (local assessment level) significant variation between the points (as defined by adjacent coastal measurement sites) could still occur. For example, large spatial variation in dune height, and thus in dune stability values, occurred within some sectors and the largest observed value was applied throughout that sector. In addition, the approach used in the present assessment of applying the upper 95% value for longer-term rates and shorter-term variation derived from several adjacent sectors to all those sectors, may have resulted in an overly large component value being applied to some locations. While general precautionary approaches such as these help to minimize uncertainty and increase the safety margin, they may also result in some hazard distances derived in this report being overly cautious.

A site-specific assessment focuses on a small area (a single property or subdivision), maximizes the use of exiting data, acquires more data if necessary, and if appropriate the (generic) assessment model can be modified to better fit the site. *Site-specific* erosion hazard assessments can result in District Plan hazard zones and conditions being modified.

Recommendation: that the KCDC emphasis to the public, at appropriate times, the difference between (the present assessment's) local/regional hazard assessment and a site-specific assessment.

6.2 Other coastal hazards

Sand-dune instability

Wave and current-driven shoreline erosion, the basis of the present erosion hazard assessment, *may* subsequently lead to dune instability by wind flowing across devegetated dune-scarps. This is particularly likely in the vicinity of inlets where dunes often occur and channel migration coupled with storm-wave surge make shorelines particularly vulnerable. Dune *blowouts* can follow and if left unchecked these may evolve into *parabolic* dunes and accompanying sand drifts which are hazardous in terms of property burial and wind-blown sand nuisance. Much of the Kapiti, Manawatu and Wanganui coasts are characterized by such dune forms and in places these *transgressive dune* have migrated several kilometers inland.

Recommendation: That dune scarping be identified and monitored until either natural revegetation is observed or blowouts (the harbinger of more extensive instability) develop, in which case remedial soil conservation measures be undertaken.

6.2.2 Storm inundation

Coastal inundation (or flooding) associated with storm waves coupled with storm tide (tide plus storm surge) is a well recognized coastal hazard referred to as *storm inundation*. This process can enhance shoreline erosion, particularly in the vicinity of inlets, and as such, defining the characteristics and spatial extent may be helpful when carrying out future erosion hazard assessments (especially site-specific assessments - NB Section 6.1). The NZCPS 2010 requires areas potentially affected by such a hazard to be identified, with resulting areas of high risk being assessed over at least 100 yrs. While an appropriate assessment return period is still being considered by the Department of Conservation, it is likely to be 100 and possibly 200 yrs. In addition, it is noted that the KCDC flood plain modelling incorporates a coastal boundary condition based on storm inundation level, so assigning a robust value to this parameter has further benefit.

Recommendation: That a coastal inundation sensitivity analysis be obtained, with high risk areas then being assessed at the recommended return period. Furthermore, that joint probability analyses be carried out for those inlets where river/steam data is available, to identify probabilities of combined occurrence.

6.3 Monitoring and future re-assessment

The KCDC has in place an excellent long-term coastal monitoring programme developed over several years, indeed decades, which recognises their range of coastal environments, hazard potential and a desire to better understand coastal processes. These data have thus not only been collected to enable comprehensive erosion hazard assessment, but also to fascilitate general environmental impact assessment for coastal management and proposed developments, and to assist with coastal process investigations.

The present monitoring programme broadly consists of:

- Vertical aerial photography (~5yrly)
- LIDAR (5 yrly)
- Beach profiling (~2 yrly)
- Bathymetric surveys (5-10 yrly)

Additional monitoring is also carried out for specific investigations projects such as six monthly low tide aerial photography of the Waikanae Rivermouth and Kapiti as part of a long-term sediment dynamics study to help predict periods of accretion and erosion along the south Paraparaumu-north Raumati coast.

The KCDC has also undertaken wave climate and sea-level investigations.

This present Erosion Hazard Assessment is comprehensive, based on the most up-to-date methods and has been thoroughly peer reviewed. Unless significant new materials/guidelines arise, this assessment should apply for the next 10 yrs, after which it should be revised to incorporate monitoring data, climate change information, hazard assessment technique refinement and relevant output from any site-specific erosion hazard assessments. However, some interim update of the Data-Base is recommended (NB, Section 5.3)

Recommendation: That as new data becomes available as part of the monitoring programme, that these be processed and added to the Data-Base spreadsheets. This will not only facilitate the hazard revision process, but will enable significant atypical coastal behaviours to be identified and more closely monitored/tracked.

6.4 Erosion hazard zones

An erosion hazard assessment, such as this document, is a science-driven assessment providing (statistically-based) hazard impact magnitudes over different prediction periods, hence the output term *erosion prediction lines*. By contrast, erosion management is a process by which the science-based hazard magnitudes are converted into hazard management zones for inclusion within the District Plan, hence the term *erosion hazard lines or zones*. The conversion process is presently being undertaken by the KCDC planning staff with assistance from consultants such as the Focus Resource Management Group. In addition to working with the results of the present Erosion Hazard Assessment, there are a range of other factors which need to be addressed, including implementing the requirements of statutes, regulations and planning provisions, recognizing that different types of development carry different risk levels and the need to enable reasonable use of exiting property, recognizing the changing future needs of the community and allowing for adequate public consultation.

Recommendation: That the KCDC emphasise to the public, at appropriate times, the difference between science-based erosion hazard assessments and planning/management based hazard zones

ACKNOWLEDGEMENTS

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R D Shand

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Dr Roger Shand

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APPENDIX A Shore-parallel protection structures and end-embayment dimensions

Empirical relationships to define end-embayment dimensions associated with a shore-parallel protection structure (SPPS) as derived in the Marine Parade Revetment investigation (CSL, 2010), were noted in Section 2.3.2. The equations are reproduced below along with a description of the various SPPSs along the Kapiti Coast and application of the following dimension equations. Note that several types of SPPS are used to control wave-induced shoreline erosion, including bulkheads (vertical structure face), seawalls (moderately steep face) and revetments (low-slope structure face), with the term *seawalls* often being used generically.

Field and laboratory results found embayment length (Le) to be a function of structure length (Ls) as defined by equation A1.

$$Le = 6.089Ls^{0.5357} \tag{A1}$$

Laboratory results have found that cross-shore depth of the erosion embayment (De) to length of the embayment (Le) can be expressed by equation A2.

$$De = 0.15\,Le \tag{A2}$$

On the south Kapiti coast, these formulae were found to apply to southern end embayments, with the embayment length of the northern end of structures being less than 50 % of the structure length. Equation A3 was considered suitably conservative for use in the present erosion hazard Update Assessment.

$$Le(nth) = 0.66Le(south) \tag{A3}$$

Where Le(north) = northern embayment length, and Le(south) = southern embayment length

Furthermore, equation A1 applies to structures where Ls is between 100 and 500 m. When Ls < 100 m equation A4 should be used (based on McDougal et al., 1987).

$$Le = 0.7^{*}\,Ls \tag{A4}$$

When Ls > 500 m equation A5 applies, based on the QEII embayment dimensions associated with the 3 km long South Raumati seawall.

$$Le = 170 \text{ m for all } Ls \tag{A5}$$

A brief historical description of open coast shoreline protection works along the southern Kapiti Coast is as follows. Present shoreline protection structures are broadly located in

Figure 2.1. Isolated shoreline protections works are evident in the early aerial photos from the 1940s. These include several road end structures. Following extensive erosion associated with storms in July 1954 and October 1957, a seawall was established along the Raumati-Paekakariki coast, in particular between 0.62 km north of Fisherman's Table Restaurant and 0.07 m north of Tainui Street in North Raumati, a distance of approximately 10.0 km (Donnelley 1959). The wall consisted of driven railway iron with backfill of boulders or interlinkage with heavy brushwood . These works received central government funding and proved effective until maintenance ceased in the late 1960s (McHugh, 1981).

A wooden seawall was constructed immediately south of the Tikotu Stream in the early 1960s in association with the reserve being constructed at that time. This wall has been buried since the 1990s because of natural beach progradation.

During the early 1970s the the Kapiti Borough Council began experimenting with wooden seawall design (McHugh, 1981); however, at the time of the erosive storm in September 1976 (Gibb and Wiltshire, 1976) there was little effective protection. Subsequent community and local and central government initiatives resulted in a subsidised scheme for a continuous uniformly designed timber seawall covering the Parade at Paekakariki (~1.5 km), and along the highly eroded South Raumati coast to the Wharemauku Stream (~3 km). These walls, now referred to as *community seawalls*, have subsequently been strengthened with rock.

Private protection structures exist along the South Paekakariki and north Raumati shorelines, often integrated with surviving iron rails from the early 1950s protection works. Some of these more recent structures have been professionally designed and constructed and have planning consent. However, some residents prefer to let the shoreline behave naturally within the constraints of the early railway irons and end effects from adjacent structures. The KCDC is at present reviewing the use of private seawalls and developing policy and guidelines relating to the future of such structures.

End-embayment dimensions for the SPPSs to be incorporated within the 2012 Update Assessment's 50 year scenario are given below. These dimensions have been derived from the empirical relationships defined above.

The Parade seawall, Paekakariki

This structure was built in the late 1970s following damage to the earlier protection works. The structure is repaired periodically and is programmed for replacement over the next 10 yrs. At the northern end the structure terminates just south of the Wainui Stream. At the southern end the structure extends south of the Parade/Beach Road intersection for some 70 m and protects two private properties. At the present time, the full length of 1660 m (Ls) is classified as a *community seawall* and its alongshore effects are calculated as follows.

Southern embayment dimensions:
Le = 170 m (equation A5), De = 25.5 (equation A2)

Northern embayment dimensions:
Ls = 113 m (equation A3), De = 17 m (equation A2)

South Raumati Seawall

This 3000 m (Ls) long structure was built in the late 1970s following extensive failure of the 1950s protection structure and property damage during the September 1976 storm. For much of its length the structure consists of a lower structure, aligned with the rail irons from the 1950 protection structure, and an upper wall set back a several metres. The Esplanade section of wall was rebuilt in 2010. The South Raumati SPPS is classified as a *community seawall* and its alongshore effects are calculate as follows.

Southern embayment dimensions:
Le = 170 m (equation A5), De = 25.5 (equation A2)

Northern embayment:
There is no northern embayment as the structure's northern terminus joins onto the inlet guidewall which extends along the left bank of the Wharemauku Stream.

Tanui Street seawall

It is not known when this SPPS was first established. It is 20 m long and to the north it joins a private wooden wall that is in disrepair and to the south it joins a maintained wooden seawall. Only the 20 m (Ls) long structure fronting Tanui Street is classified as a *community seawall*.

Southern embayment dimensions:
Le = 14 m (equation A4), De = 2 m (equation A2).

Northern embayment dimensions:
Le = 9 m (equation A3), De = 1.5 m (equation A3)

Arawa Street seawall

It is unknown when the 20 m (Ls) long road-end structure was first established. To the north it joins a private wooden structure (advanced disrepair) and to the south a private concrete structure (maintained) with the latter being evident in the 1942 aerial photo.

Southern embayment dimensions:
Le = 14 m (equation A1), De = 2 m (equation A2).

Northern embayment dimensions:
Le = 9 m (equation A3), De = 1.5 m (equation A3)

Marine Parade revetment

This 420 m (Ls) long rock revetment was established in 2006-7 to provide toe protection for a reconstructed dune fronting Marine Parade. This structure adjoins unprotected coast to both the north and south.

Southern embayment dimensions:
Le = 155 m (equation A1), De = 23 m (equation A2).

Northern embayment dimensions:
Le = 99 m (equation A3), De = 15 m (equation A3)

McLean Park Seawall (Paraparaumu Beach).

This 200 m long wooden seawall was constructed on the south side of the Tikotu Stream in the early 1960s and 100 m (Ls) of its length extends along the open coast. The structure has been buried by dune sand since the 1990s.

Southern embayment dimensions:
Le = 89 (equation A1), and De = 13 m (equations A2)

APPENDIX B Transect (or measurement) reference points and reference shoreline locations

Transect measurement point (TRP)	Easting (NZMG)	Northing (NZMG)	Refn shoreline's dist (m) from TRP
Distance datum[1]	2673201.67	6021248.27	
C0-17	2673323.27	6021367.22	42.9
C0-40	2673461.90	6021550.86	37.1
C0-73	2673645.16	6021829.45	39.2
Waikakariki Inlet			
C1-51	2674034.61	6022499.72	23.5
C2-62	2674595.35	6023461.42	32.8
Wainui Inlet			
C3-60	2675023.50	6024346.00	6.7
C3-93	2675177.50	6024633.00	27.5
C4.18	2675286.53	6024855.81	36.9
C4-52	2675428.40	6025173.79	44.5
C4-93	2675574.26	6025559.46	35.7
C5-15	2675723.65	6025734.17	110.5
Wairoa Inlet			
C5-70	2675883.65	6026274.81	82.0
C6-04	2675979.55	6026599.57	71.7
C6-39	2676056.77	6026943.78	43.6
C6-57	2676099.88	6027116.54	17.8
C6-76	2676146.16	6027301.78	76.5
C7-10	2676204.43	6027638.97	54.5
C7-56	2676357.98	6028071.02	112.0
C8-02	2676348.88	6028552.75	10.4
C8-72	2676493.00	6029241.58	42.6
C9-11	2676516.87	6029627.45	9.5
C9-43	2676585.16	6029939.78	40.9
Wharemauku Inlet			
C10-29	2676725.16	6030815.53	129.8
C10-40	2676674.84	6030926.05	93.5
C10-61	2676639.97	6031134.19	63.7
C10-91	2676608.82	6031435.03	50.1
C11-17	2676624.81	6031690.19	68.8
C11-41	2676569.69	6031927.05	8.6
C11-64	2676595.26	6032154.81	14.7
C11_88	2676637.34	6032393.96	27.6
C12-12	2676702.94	6032628.68	54.1
C12-50	2676948.83	6032963.49	207.0
Tikotu Inlet			
C12-77	2676939.99	6033234.06	112.7
C13-04	2677036.11	6033479.70	121.3
C13-24	2677118.46	6033657.09	125.8
C 13-44	2677216.82	6033837.19	144.6
C13-63	2677303.52	6033992.51	161.2
C13-89	2677437.19	6034185.27	141.5
C14-20	2677685.63	6034385.45	124.2

Waikanae Inlet			
C16-69	2679777.67	6035711.99	103.9
C17-31	2680290.46	6036087.68	111.0
C17-88	2680718.33	6036446.88	103.7
Waimeha Inlet			
C18-85	2681408.54	6037143.78	79.7
C19-35	2681813.42	6037470.78	151.6
C20-30	2682478.05	6038164.26	205.4
C20-79	2682768.27	6038564.23	189.9
C21-26	2683076.91	6038936.11	224.6
C21-73	2683413.79	6039277.65	311.8
C22-06	2683602.93	6039555.41	322.7
Hadfield Inlet			
C23-50	2684178.08	6040885.10	133.0
C24-91	2684896.57	6042111.85	152.7
C25-70	2685255.01	6042820.85	124.6
C26-58	2685751.45	6043553.76	232.5
Mangaone Inlet			
C27-63	2686354.72	6044437.66	391.8
C28-81	2686707.07	6045578.12	201.8
C30-16	2687604.97	6046660.28	551.5
Otaki Inlet			
C32-54	2688231.09	6048988.07	86.8
C33-05	2688487.72	6049423.75	118.5
C33-60	2688756.30	6049907.40	135.1
C33-82	2688800.11	6050123.49	88.0
Waitohu Inlet			
C 35-54	2689524.96	6051674.97	72.5
C36-89	2690143.43	6052866.93	157.6
Waiorongomai	Inlet		

1. Location datum on the south side of Fisherman’s Table Restaurant

APPENDIX C Profile extrapolation analysis

This analysis was required under the Terms of Reference No 6:

> *Profile extrapolation to check present estimates of "catch-up" erosion.*

Catch-up refers to an erosion allowance where SPPSs have protected the shoreline from long-term erosion for ~50 yrs and they are then removed.

Catch-up values used in the 2008 Erosion Hazard Assessment were based on the rate of shoreline change prior to the seawalls construction (Earlier Rates), rather than transferring rates from adjacent non-walled shoreline for which there were longer data-sets available for analysis. The rationale for using the pre-seawall rates of shoreline change being that the extensive nature of the Raumati and Paekakareki seawalls could be affecting processes along adjacent natural sections of coast so transferring rates from such locations could over-estimate catch-up values. Pre-seawall (Earlier) rates and post-seawall (Later) rates of change are depicted in Figure C1. Also shown are the seawall remove rates and seawall repair rates (for natural shorelines adjacent to seawalls) which were derived by conservative smoothing (Section 3.3.1) of pre and post-seawall rates respectively.

Five profile transect locations are also depicted in Figure C1 and these are shown in more detail in Figure C2A. Two profile transects occur along the Paekakareki seawall (220 and 230), one at a central location in the non-seawalled QEII (240) , and two along the South Raumati seawall (250 and 260).

The average (characteristic) profile for each transect was derived by firstly applying a 1 m cross-shore interpolation routine to each of the 6 profile samples common to each transect (2000, 2001, 2005, 2007, 2008, 2011), these having been surveyed and reduced to distance (from a landward benchmark) and elevation (to MLS using WVD 1953) by Cuttriss Consultants Ltd. Each interpolated set of profiles were then elevation-averaged (mean) at 1 m cross-shore intervals. These average profiles are superimposed in Figure C2B, with the top of the seawalls being marked (large dots) so relative profile offsets can be appreciated. If these average profiles were translated so the top of the structures (dots) aligned in the cross-shore direction, then it is clear that the beach fronting the seawalls has, as expected, been lowered. It is assumed that profile response has been occurring since the first Kapiti Borough Council seawalls were constructed following the particularly erosive storms of the mid 1950s.

Terms of Reference #6 requires a landward extrapolation of the seawalled profiles. This is to provide an estimate of where a "natural" shoreline would be based on fitting an "equilibrium" profile shape. Various functions (quadratic and power) were fitted to the QEII natural profile (240). However, a satisfactory fit could not be achieved, possibly because the lower part of the profile was not included in the interpolation (this section of the profile had not been included in all surveys), and because the backshore/dune was

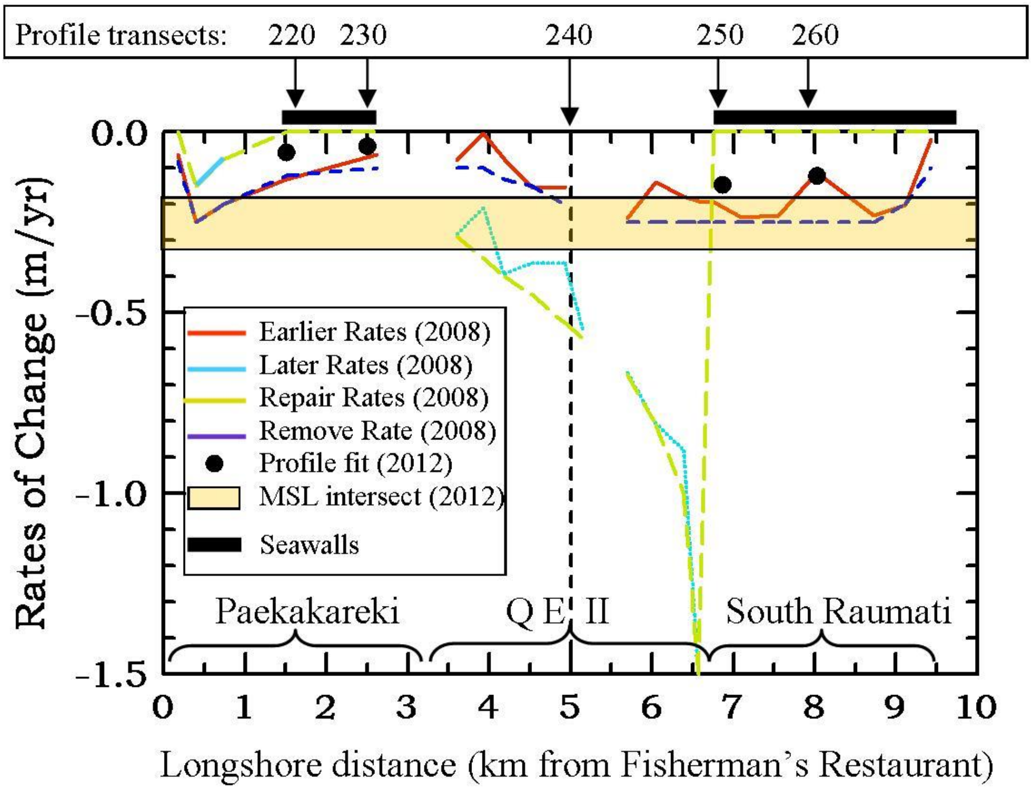

Figure C1 *Rates of shoreline change between Paekakareki and Raumati taken from the 2008 Erosion Hazard Assessment, and profile analysis results from the present study.*

typically in a truncated (scarped) state. But the averaged curve (for site 240) is relatively smooth so could be directly fitted to the seawall profiles (see Figure C3). The typical shoreline indicator used in the 2008 Hazard Erosion Assessment was the vegetation front, and at the QEII site this occurs at ~3 m above MSL (based on averaging 15 spot levels taken along the shoreline during a 2005 survey by Cuttriss Consultants). The distance differences between the actual seawall and fitted profile at the 3 m elevation were 3 m at transect 220, 2 m at transect 230, 7.5 m at transect 250 and 6.5 m at transect 260. Applied over 50 yrs this results in rates of 0.06 m/yr, 0.04 m/yr, 0.16 m/yr and 0.14 m/yr for sites 220, 230, 250 and 260 respectively. These *profile fitting* values are marked by black dots in Figure C1 and are qualitatively similar to the 2008 Early Rates used to estimate the catch-up erosion values, but magnitudes are up to 50% less.

An alternative profile analysis approach was also carried out, this being to translate each average profile such that all profiles coincided at their MSL intersections with the cross-shore distance between vegetation level intersections providing catch-up estimates. The resulting MSL-profile intersection overlay is depicted in Figure C4. The dashed black curves are the QEII average profile which is assumed to characterise the natural coastal profile in this vicinity. The dashed 240 characteristic curves have been fitted so as to

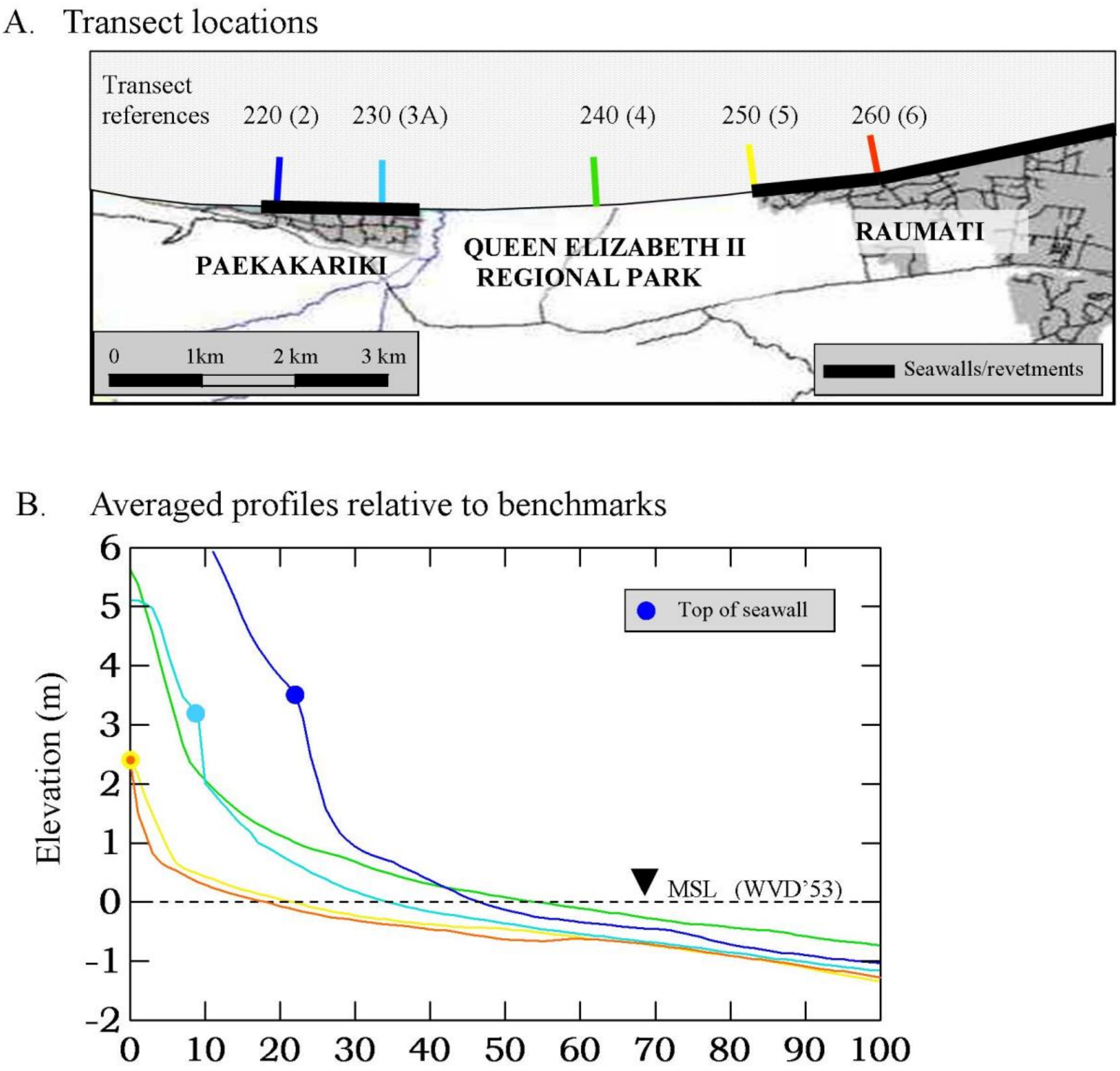

Figure C2 *Profiles transect locations (A) and superimposed average profiles (B) relative to landward benchmarks. Top of seawalls also depicted*

bracket the seawall profiles (220, 230, 250 and 260) seaward of the structures. The distance between the bracketing profiles and the assumed present day natural profile is 14 to 21 m. However, it is noted that the present seawall fronts coincide with the location of the initial structures constructed in the mid 1950s and these walls were established 10 to 20 feet (say 5 m) seaward of the shoreline (Donnelley (1959), p52). Subtracting this value gives catch-up values of 9 m (0.18 m/yr) to 16 m (0.32 m/yr) and these values are depicted by the band in Figure C1. Unfortunately the fitting routine did not enable separation of Paekakareki and Raumati values. It can be seen (Figure C1), that the MSL-Profile Intersection results bracket the 2008 Early Rates-based catch-up values, but over-estimate the Paekakariki 2008 values by about 50%. When considering how much significance to place on this difference, the following factors are relevant:

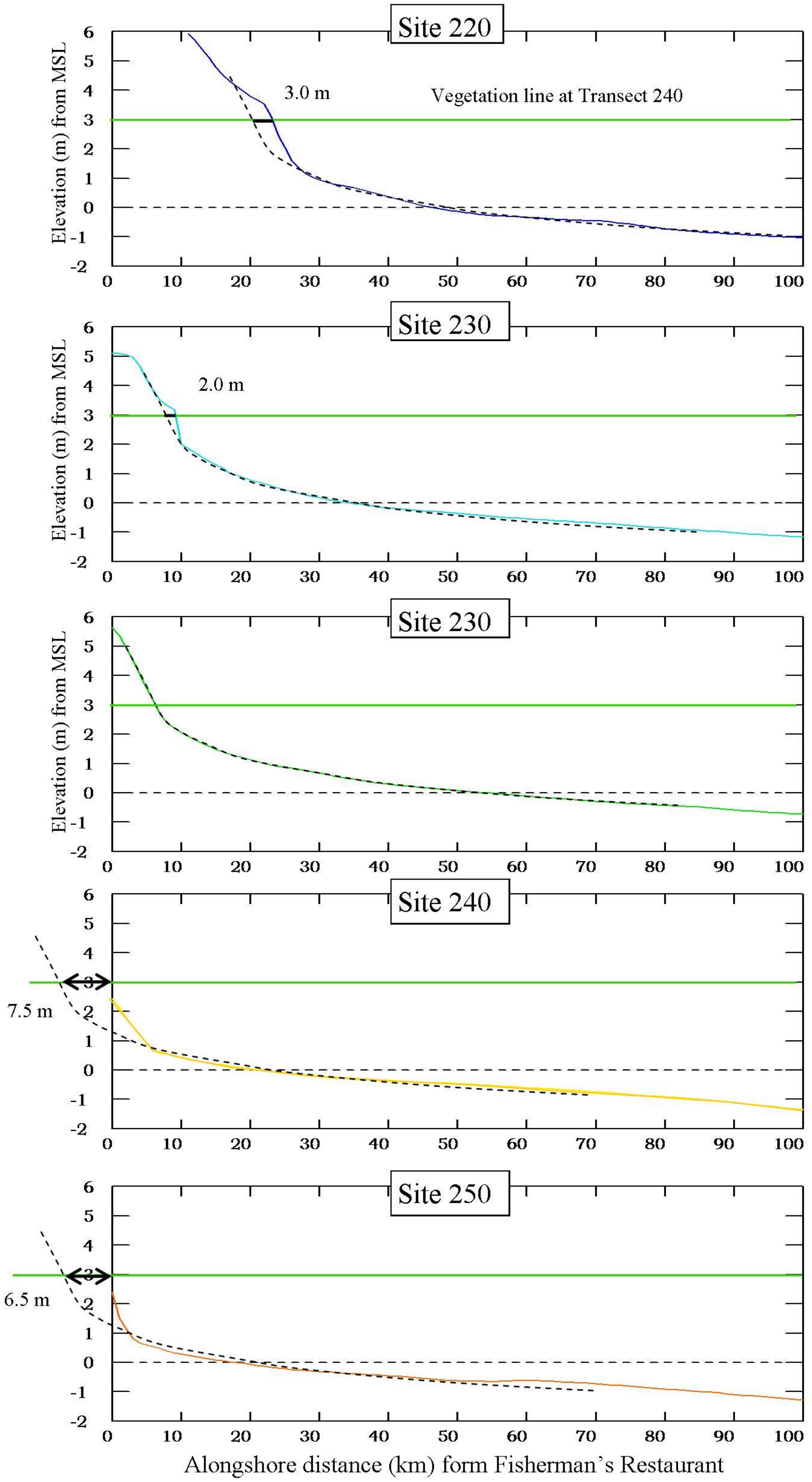

Figure C3 *QEII (230) profile (dashed curve) fitted to average profiles from the other (seawalled) sites. The QEII curve is assumed to represent the characteristic profile shape for an unmanaged coast. Arrows define catch-up erosion.*

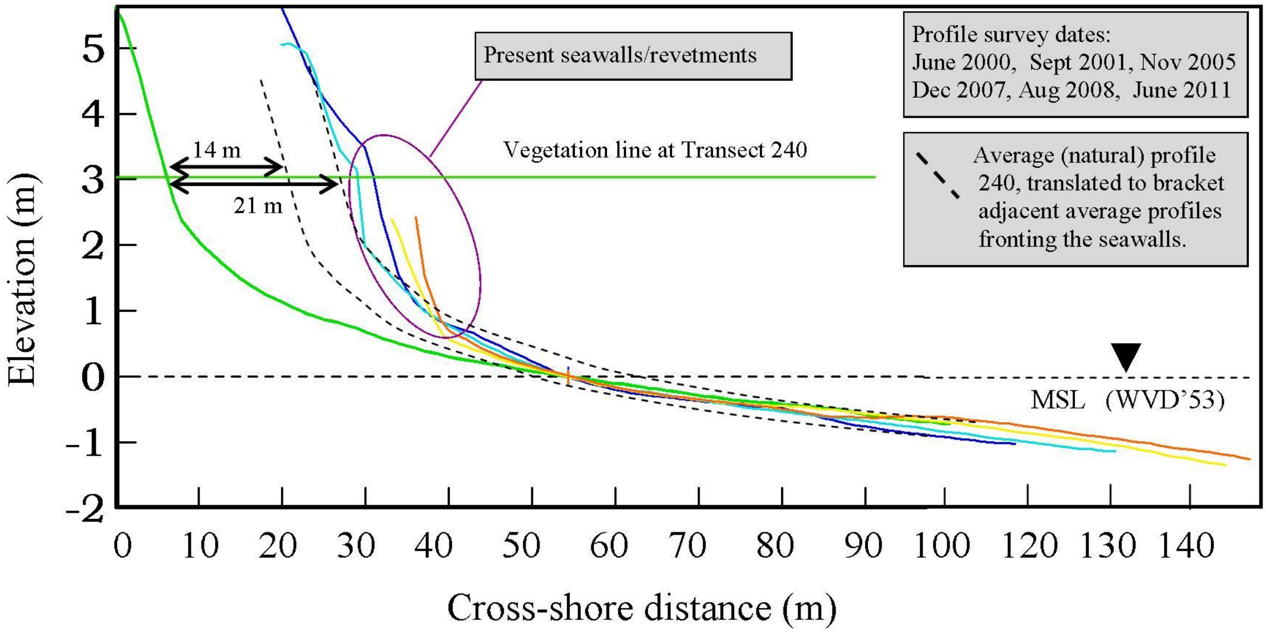

Figure C4 *Overlay of average profiles translated to common MSL intersection with bracketing natural profile (240) marked by dashed lines. Transect locations and colour code as shown in Figure 2A. Arrows define catch-up erosion.*

Firstly, when interpreting the results in this assessment we should be mindful that each method has limitations. There are only 6 profile samples for each transect and this is marginal regarding the sample size required to achieve statistical stability. The number of shorelines used to determine catchup in the 2008 (and 2012) Assessment was also low; but in this case the earliest samples were based on MHWM (c.f. the vegetation front) which results in an over-estimate of shoreline erosion.

Secondly, the 2012 *profile-fit* analysis provided results qualitatively consistent with the 2008 Early Rates-approach, with confidence in the latter methods' alongshore variation coming from several independent sampling sites.

Thirdly, the 2012 *MSL-profile intersection* approach was unable to separate Paekakareki results from Raumati results.

Fourthly, neither of the profile-based methods have been verified.

Conclusions:

(1) The Raumati catch-up values derived in the CSL 2008 Erosion Hazard Assessment are supported by the average profile analyses, and

(2) The 2008 Paekakareki catch-up values appear reasonable in light of the average profile analyses and the various limiting factors.

APPENDIX D Open coast erosion component and predicted distance summary sheets

Scenario 1

50 yr managed, i.e. seawalls remain (maintained and repaired)

Distance	LT_50	ST_50	RSLR_50	DS_50	CU_50	CEPD_50
0.2	0.0	-15.0	-5.40	-6.70	-6.0	-33.10
0.4	-12.5	-15.0	-6.12	-14.83	-6.0	-54.45
0.7	-10.0	-15.0	-6.52	-18.75	-6.0	-56.28
1.2 km	Waikakariki Inlet					
1.51	0.0	-15.0	0.00	-11.71	-9.0	-35.71
2.62	0.0	-15.0	0.00	-4.45	-9.0	-28.45
3.3 km	Wainui Inlet		.			
3.60	-14.5	-10.0	-13.64	-6.67	-6.0	-50.81
3.93	-17.5	-10.0	-13.64	-10.23	-6.0	-57.37
4.18	-20.0	-10.0	-13.64	-10.75	-6.0	-60.39
4.52	-22.5	-10.0	-13.64	-10.01	-6.0	-62.14
4.93	-26.5	-10.0	-13.64	-11.27	-6.0	-67.40
5.15	-28.5	-10.0	-13.64	-11.27	-6.0	-69.40
5.4 km	Whareroa Inlet		.			
5.70	-33.5	-10.0	-14.29	-12.97	-6.0	-76.76
6.04	-40.5	-10.0	-14.29	-10.82	-6.0	-81.61
6.39	-50.0	-13.0	-14.29	-14.90	-6.0	-98.19
6.57	-75.0	-15.0	-14.29	-9.64	-6.0	-119.92
6.76	0.0	-15.0	0.00	-4.08	-9.0	-28.08
7.10	0.0	-15.0	0.00	-9.64	-9.0	-33.64
7.56	0.0	-15.0	0.00	-11.86	-9.0	-35.86
8.02	0.0	-15.0	0.00	-8.01	-9.0	-32.01
8.72	0.0	-15.0	0.00	-6.67	-9.0	-30.67
9.11	0.0	-15.0	0.00	-5.56	-9.0	-29.56
9.43	0.0	-15.0	0.00	-4.60	-9.0	-28.60
10.0 km	Wharemauku	Inlet	.			
10.29	0.0	-7.1	-15.00	-5.34	-6.0	-33.44
10.40	0.0	-9.0	0.00	-1.85	-9.0	-19.85
10.61	0.0	-12.0	-15.79	-5.19	-6.0	-38.98
10.91	0.0	-17.0	-15.79	-4	-6.0	-42.79
11.17	0.0	-21.0	-15.79	-2.59	-6.0	-45.38
11.41	0.0	-22.0	0.00	-2.08	-9.0	-33.08
11.64	0.0	-22.0	0.00	-2.00	-9.0	-33.00
11.88	0.0	-22.0	-17.65	-2	-6.0	-47.65
12.12	0.0	-20.0	-17.65	-2.00	-6.0	-45.65
12.50	0.0	-18.0	0.00	-2.37	-9.0	-29.37
12.6 km	Tikotu Inlet		.			
12.77	0.0	-18.0	-18.75	-1.19	-6.0	-43.94
13.04	0.0	-26.0	-18.75	-0.89	-6.0	-51.64
13.24	0.0	-30.0	-20.00	-0.59	-6.0	-56.59
13.44	0.0	-34.5	-20.00	-0.96	-6.0	-61.46
13.63	0.0	-36.0	-21.43	-0.59	-6.0	-64.02
13.89	0.0	-15.0	-21.43	-1.11	-6.0	-43.54
14.20	-15.0	-15.0	-20.00	-3.11	-6.0	-59.11
14.6 km	Waikanae Inlet		.			

16.69	0.0	-15.0	-15.00	-3.34	-6.0	-39.34
17.31	0.0	-15.0	-15.00	-2.59	-6.0	-38.59
17.88	0.0	-12.0	-15.00	-2.59	-6.0	-35.59
18.3 km	Waimeha Inlet		.			
18.85	0.0	-12.0	-15.00	-2.00	-6.0	-35.00
19.35	0.0	-12.0	-15.79	-2.00	-6.0	-35.79
20.30	0.0	-12.0	-16.67	-1.78	-6.0	-36.45
20.79	0.0	-12.0	-17.65	-1.33	-6.0	-36.98
21.26	0.0	-12.0	-17.65	-2.00	-6.0	-37.65
21.73	0.0	-12.0	-18.75	-1.85	-6.0	-38.60
22.06	0.0	-12.0	-18.75	-3.34	-6.0	-40.09
22.6 km	Hadfield Inlet		.			
23.50	0.0	-12.0	-17.65	-1.85	-6.0	-37.50
24.91	0.0	-12.0	-16.67	-1.56	-6.0	-36.22
25.70	0.0	-12.0	-14.29	-1.56	-6.0	-33.84
26.58	0.0	-12.0	-12.50	-0.52	-6.0	-31.02
27.3 km	Mangaone Inlet		.			
27.63	0.0	-12.0	-8.82	-0.82	-6.0	-27.64
28.81	0.0	-12.0	-6.52	-1.11	-6.0	-25.63
30.16	0.0	-14.0	-4.84	-0.89	-6.0	-25.73
31.0 km	Otaki Inlet		.			
32.54	0.0	-14.0	-11.11	-1.41	-6.0	-32.52
33.05	0.0	-14.0	-13.04	-1.26	-6.0	-34.30
33.60	0.0	-14.0	-15.79	-2.22	-6.0	-38.01
33.82	0.0	-14.0	-16.67	-2.59	-6.0	-39.26
34.5 km	Waitohu Inlet		.			
35.54	0.0	-14.0	-16.67	-3.34	-6.0	-40.00
36.89	0.0	-18.0	-16.67	-3.34	-6.0	-44.00
37.2 km	Waiorongomai	Inlet				

Appendix D, Scenario 2

50 yr unmanaged, i.e. seawalls removed and coast line adjusts

Distance	LT_50	ST_50	RSLR_50	DS_50	CU_50	CEPD_50
0.17	-8.0	-15.0	-5.40	-6.70	-6.0	-41.10
0.40	-12.5	-15.0	-6.12	-14.83	-6.0	-54.45
0.73	-10.0	-15.0	-6.52	-18.75	-6.0	-56.28
1.2 km	Waikakariki Inlet					
1.51	-12.0	-15.0	-7.89	-11.71	-6.0	-52.61
2.62	-10.0	-15.0	-10.71	-4.45	-6.0	-46.16
3.3 km	Wainui Inlet		.		.	
3.60	-5.0	-10.0	-13.64	-6.67	-6.0	-41.31
3.93	-5.0	-10.0	-13.64	-10.23	-6.0	-44.87
4.18	-6.3	-10.0	-13.64	-10.75	-6.0	-46.64
4.52	-7.5	-10.0	-13.64	-10.01	-6.0	-47.14
4.93	-10.0	-10.0	-13.64	-11.27	-6.0	-50.90
5.15	.	-10.0	-13.64	-11.27	-6.0	-40.90
5.4 km	Whareroa	Inlet	.		.	
5.70	-12.5	-10.0	-14.29	-12.97	-6.0	-55.76
6.04	-12.5	-10.0	-14.29	-10.82	-6.0	-53.61
6.39	-12.5	-13.0	-14.29	-14.90	-6.0	-60.69
6.57	-12.5	-15.0	-14.29	-9.64	-6.0	-57.42
6.76	-25.0	-15.0	-14.29	-4.08	-6.0	-64.36
7.10	-25.0	-15.0	-14.29	-9.64	-6.0	-69.92
7.56	-25.0	-15.0	-14.29	-11.86	-6.0	-72.15
8.02	-25.0	-15.0	-15.00	-8.01	-6.0	-69.01
8.72	-25.0	-15.0	-15.00	-6.67	-6.0	-67.67
9.11	-20.0	-15.0	-15.00	-5.56	-6.0	-61.56
9.43	-10.0	-15.0	-15.00	-4.60	-6.0	-50.60
10.0 km	Wharemauku	Inlet	.		.	.
10.29	0.0	-7.1	-15.00	-5.34	-6.0	-33.44
10.40	0.0	-9.0	-15.00	-1.85	-6.0	-31.85
10.61	0.0	-12.0	-15.79	-5.19	-6.0	-38.98
10.91	0.0	-17.0	-15.79	-4.00	-6.0	-42.79
11.17	0.0	-21.0	-15.79	-2.59	-6.0	-45.38
11.41	0.0	-22.0	-15.79	-2.08	-6.0	-45.87
11.64	0.0	-22.0	-16.67	-2.00	-6.0	-46.67
11.88	0.0	-22.0	-17.15	-2.00	-6.0	-47.15
12.12	0.0	-19.5	-17.65	-2.00	-6.0	-45.15
12.50	0.0	-18.0	-17.65	-2.37	-6.0	-44.02
12.6 km	Tikotu Inlet		.		.	.
12.77	0.0	-18.0	-18.75	-1.19	-6.0	-43.94
13.04	0.0	-26.0	-18.75	-0.89	-6.0	-51.64
13.24	0.0	-30.0	-20.00	-0.59	-6.0	-56.59
13.44	0.0	-34.5	-20.00	-0.96	-6.0	-61.46
13.63	0.0	-36.0	-21.43	-0.59	-6.0	-64.02
13.89	0.0	-15.0	-21.43	-1.11	-6.0	-43.54
14.20	-15.0	-15.0	-20.00	-3.11	-6.0	-59.11
14.6 km	Waimeha	Inlet	.		.	.
16.69	0.0	-15.0	-15.00	-3.34	-6.0	-39.34
17.31	0.0	-15.0	-15.00	-2.59	-6.0	-38.59
17.88	.	-12.0	-15.00	-2.59	-6.0	-35.59

18.3 km	Hadfield Inlet		.		.	.
18.85	0.0	-12.0	-15.00	-2.00	-6.0	-35.00
19.35	0.0	-12.0	-15.79	-2.00	-6.0	-35.79
20.30	0.0	-12.0	-16.67	-1.78	-6.0	-36.45
20.79	0.0	-12.0	-17.65	-1.33	-6.0	-36.98
21.26	0.0	-12.0	-17.65	-2.00	-6.0	-37.65
21.73	0.0	-12.0	-18.75	-1.85	-6.0	-38.60
22.06	0.0	-12.0	-18.75	-3.34	-6.0	-40.09
22.6 km	Mangaone Inlet		.		.	.
23.50	0.0	-12.0	-17.65	-1.85	-6.0	-37.50
24.91	0.0	-12.0	-16.67	-1.56	-6.0	-36.22
25.70	0.0	-12.0	-14.29	-1.56	-6.0	-33.84
26.58	0.0	-12.0	-12.50	-0.52	-6.0	-31.02
27.30	.		.		.	.
27.63	0.0	-12.0	-8.82	-0.82	-6.0	-27.64
28.81	0.0	-12.0	-6.52	-1.11	-6.0	-25.63
30.16	0.0	-14.0	-4.84	-0.89	-6.0	-25.73
31.0 km	Otaki Inlet		.		.	.
32.54	0.0	-14.0	-11.11	-1.41	-6.0	-32.52
33.05	0.0	-14.0	-13.04	-1.26	-6.0	-34.30
33.60	0.0	-14.0	-15.79	-2.22	-6.0	-38.01
33.82	0.0	-14.0	-16.67	-2.59	-6.0	-39.26
34.5 km	Waitohu Inlet		.		.	.
35.54	0.0	-14.0	-16.67	-3.34	-6.0	-40.00
36.89	0.0	-18.0	-16.67	-3.34	-6.0	-44.00
38.2 km	Waiorongomai Inlet					

Appendix D, Scenario 3

100 yr unmanaged, i.e. seawalls removed and coastline adjusts

Distance	LT_100	ST_100	RSLR_100	DS_100	CU_100	CEPD_100
0.17	-16.0	-15.0	-16.20	-6.70	-10.0	-63.90
0.40	-25.0	-15.0	-18.37	-14.83	-10.0	-83.19
0.73	-20.0	-15.0	-19.57	-18.75	-10.0	-83.32
1.2 km	Waikakariki Inlet					
1.51	-24.0	-15.0	-23.68	-11.71	-10.0	-84.40
2.62	-20.0	-15.0	-32.14	-4.45	-10.0	-81.59
3.3 km	Wainui Inlet					
3.60	-10.0	-10.0	-40.91	-6.67	-10.0	-77.58
3.93	-10.0	-10.0	-40.91	-10.23	-10.0	-81.14
4.18	-12.5	-10.0	-40.91	-10.75	-10.0	-84.16
4.52	-15.0	-10.0	-40.91	-10.01	-10.0	-85.92
4.93	-20.0	-10.0	-40.91	-11.27	-10.0	-92.18
5.15		-10.0	-40.91	-11.27	-10.0	
5.4 km	Whareroa Inlet					
5.70	-25.0	-10.0	-42.86	-12.97	-10.0	-100.83
6.04	-25.0	-10.0	-42.86	-10.82	-10.0	-98.68
6.39	-25.0	-13.0	-42.86	-14.90	-10.0	-105.76
6.57	-25.0	-15.0	-42.86	-9.64	-10.0	-102.49
6.76	-50.0	-15.0	-42.86	-4.08	-10.0	-121.93
7.10	-50.0	-15.0	-42.86	-9.64	-10.0	-127.49
7.56	-50.0	-15.0	-42.86	-11.86	-10.0	-129.72
8.02	-50.0	-15.0	-45.00	-8.01	-10.0	-128.01
8.72	-50.0	-15.0	-45.00	-6.67	-10.0	-126.67
9.11	-40.0	-15.0	-45.00	-5.56	-10.0	-115.56
9.43	-20.0	-15.0	-45.00	-4.60	-10.0	-94.60
10.0 km	Wharemauku	Inlet				
10.29	0.0	-7.1	-45.00	-5.34	-10.0	-67.44
10.40	0.0	-9.0	-46.50	-1.85	-10.0	-67.35
10.61	0.0	-12.0	-47.37	-5.19	-10.0	-74.56
10.91	0.0	-17.0	-47.37	-4	-10.0	-78.37
11.17	0.0	-21.0	-47.37	-2.59	-10.0	-80.96
11.41	0.0	-22.0	-48.90	-2.08	-10.0	-82.98
11.64	0.0	-22.0	-51.00	-2.00	-10.0	-85.00
11.88	0.0	-22.0	-52.94	-2	-10.0	-86.94
12.12	0.0	-19.5	-52.94	-2.00	-10.0	-84.44
12.50	0.0	-18.0	-54.00	-2.37	-10.0	-84.37
12.6 km	Tikotu Inlet					
12.77	0.0	-18.0	-56.25	-1.19	-10.0	-85.44
13.04	0.0	-26.0	-56.25	-0.89	-10.0	-93.14
13.24	0.0	-30.0	-60.00	-0.59	-10.0	-100.59
13.44	0.0	-34.5	-60.00	-0.96	-10.0	-105.46
13.63	0.0	-36.0	-64.29	-0.59	-10.0	-110.88
13.89	0.0	-15.0	-64.29	-1.11	-10.0	-90.40
14.20	-30.0	-15.0	-60.00	-3.11	-10.0	-118.11
14.6 km	Waikanae Inlet					
16.69	0.0	-15.0	-45.00	-3.34	-10.0	-73.34
17.31	0.0	-15.0	-45.00	-2.59	-10.0	-72.59
17.88	0.0	-12.0	-45.00	-2.59	-10.0	-69.59
18.3 km	Waimeha Inlet					

18.85	0.0	-12.0	-45.00	-2.00	-10.0	-69.00
19.35	0.0	-12.0	-47.37	-2.00	-10.0	-71.37
20.30	0.0	-12.0	-50.00	-1.78	-10.0	-73.78
20.79	0.0	-12.0	-52.94	-1.33	-10.0	-76.28
21.26	0.0	-12.0	-52.94	-2.00	-10.0	-76.94
21.73	0.0	-12.0	-56.25	-1.85	-10.0	-80.10
22.06	0.0	-12.0	-56.25	-3.34	-10.0	-81.59
22.6 km	Hadfield Inlet					
23.50	0.0	-12.0	-52.94	-1.85	-10.0	-76.79
24.91	0.0	-12.0	-50.00	-1.56	-10.0	-73.56
25.70	0.0	-12.0	-42.86	-1.56	-10.0	-66.41
26.58	0.0	-12.0	-37.50	-0.52	-10.0	-60.02
27.3 km	Mangaone Inlet					
27.63	0.0	-12.0	-26.47	-0.82	-10.0	-49.29
28.81	0.0	-12.0	-19.57	-1.11	-10.0	-42.68
30.16	0.0	-14.0	-14.52	-0.89	-10.0	-39.41
31.0 km	Otaki Inlet					
32.54	0.0	-14.0	-33.33	-1.41	-10.0	-58.74
33.05	0.0	-14.0	-39.13	-1.26	-10.0	-64.39
33.60	0.0	-14.0	-47.37	-2.22	-10.0	-73.59
33.82	0.0	-14.0	-50.00	-2.59	-10.0	-76.59
34.5 km	Waitohu Inlet					
35.54	0.0	-14.0	-50.00	-3.34	-10.0	-77.34
36.89	0.0	-18.0	-50.00	-3.34	-10.0	-81.34
38.2 km	Waiorongomai	Inlet				

APPENDIX E Early shoreline signatures

Terms of Reference No 9 requires collection of:

> *Geomorphological evidence in the vicinity of inlets which indicates the potential for worse erosion than presently assessed.*

The shorelines used in this hazard analysis were as depicted on historical aerial photos and as such span the period back to when these records began in the 1930s and 1940s. Earlier shorelines, or in some cases shorelines which occurred in the period between aerial photography, can be defined using signatures on (a) survey plans, (b) by stereo analysis of early aerial photographs, and (c) using a LIDAR-based digital terrain model, and these data sources and signatures are now discussed.

(a) Early survey plans extend back to about 1870 and usually define the shoreline by the high water mark, i.e. a mark controlled by marine of fluvial conditions and thus seaward of the more stable vegetation-front indicator that is typically used for aerial photo-based analysis. However, at times surveyors mapped the dune toe, e.g. the 1897 Waitohu survey plan. Survey plans thus provide a seawardmost dated indicator of early shorelines and are particularly useful for identifying an inlet's early behavioural history.

(b) Aerial photography began in the 1930 and most areas in New Zealand were covered by the late 1940s. Successive photographs were typically taken with an overlap for the purpose of enabling three-dimensional viewing (and data abstraction) by using special *stereo-based* equipment. Anthropogenic development can obscure the 3D effect so the earliest photos were used for analysis. Geomorphic indicators of earlier inlet shorelines are typically curved (plan view) sand dunes (which mark the location of previous inlet margins), or seaward-truncated parabolic (landward orientated) dunes which indicate past scarping by wave and or fluvial processes. Open coast shorelines are also indicated by such dune signals and, in particular, distinct longshore-parallel crest and trough topography with greater relief typically associated with periods of shoreline relative stability possibly interspaced with episodes of shoreline erosion. Without further detailed analysis these indicators could not be dated, so only those in proximity to survey and aerial shorelines are considered relevant to this hazard assessment and these are commented upon when considering each inlet (Section 4.4.2-4.4.13). However, the very early shoreline signals evident further landward have also been mapped (Figure 4.2.3-4.2.14) to indicate yet longer-term morphological behaviour which characterizes the area under consideration.

(c) LIDAR (flown in 2003) provides a detailed "cloud" of closely sampled three dimensional data points which enables a 3D computer display *(digital terrain model)* which accurately defines topography. While landscape modification has destroyed some features evident in early aerial photos, features tend to be more clearly defined and the use of 2.5 m and 5 m contours helped identify previous dune-based shorelines in the vicinity of inlets.

APPENDIX F Inlet shorelines obtained from aerial photographs and superimposed upon the earliest photo

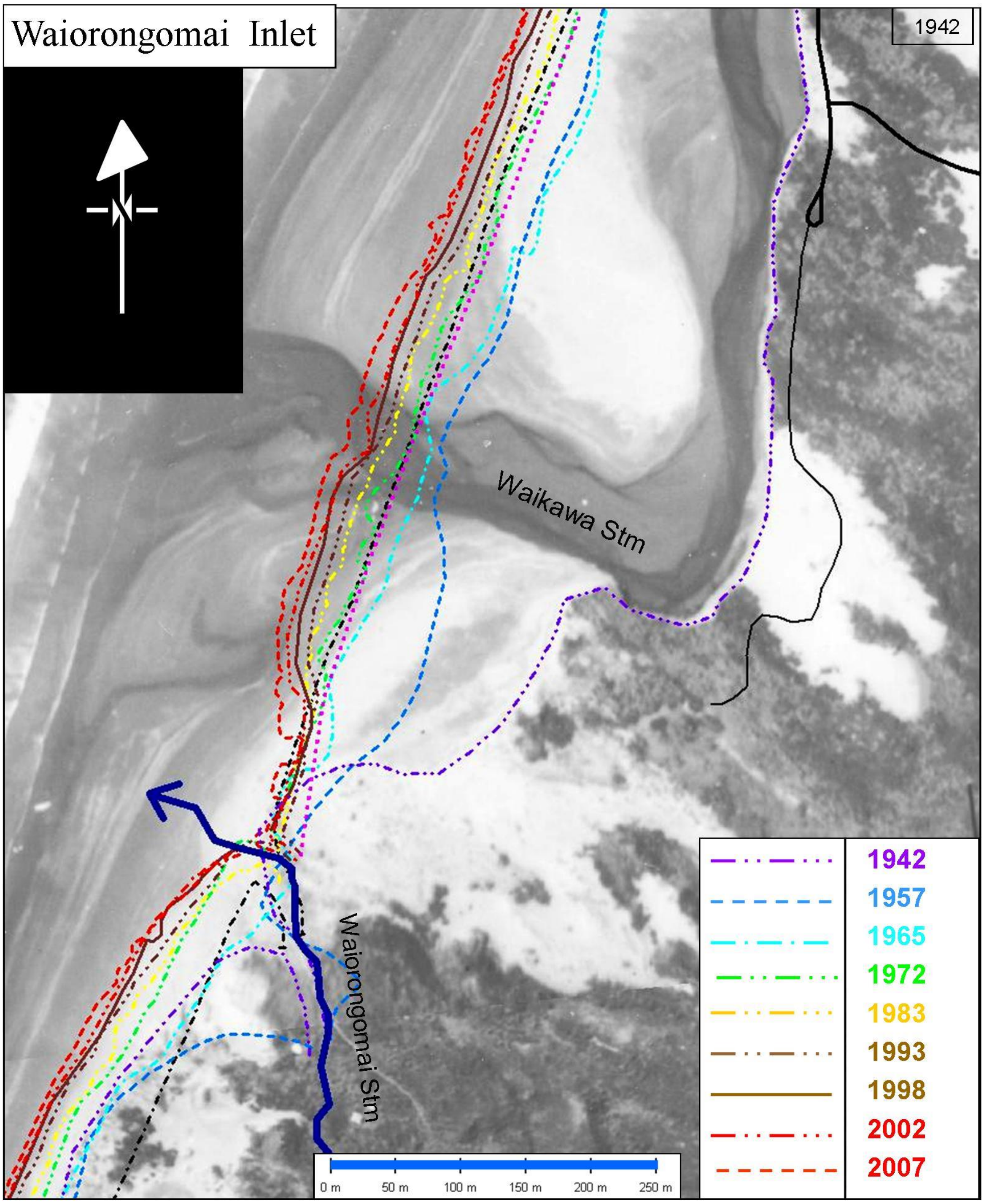

Figure F1 Historical shorelines from vertical aerial photos for the Waiorongomai and Waikawa Inlets superimposed upon the earliest photo (1942). Contemporary roading and accessways (black lines) are marked to assist with interpretation.

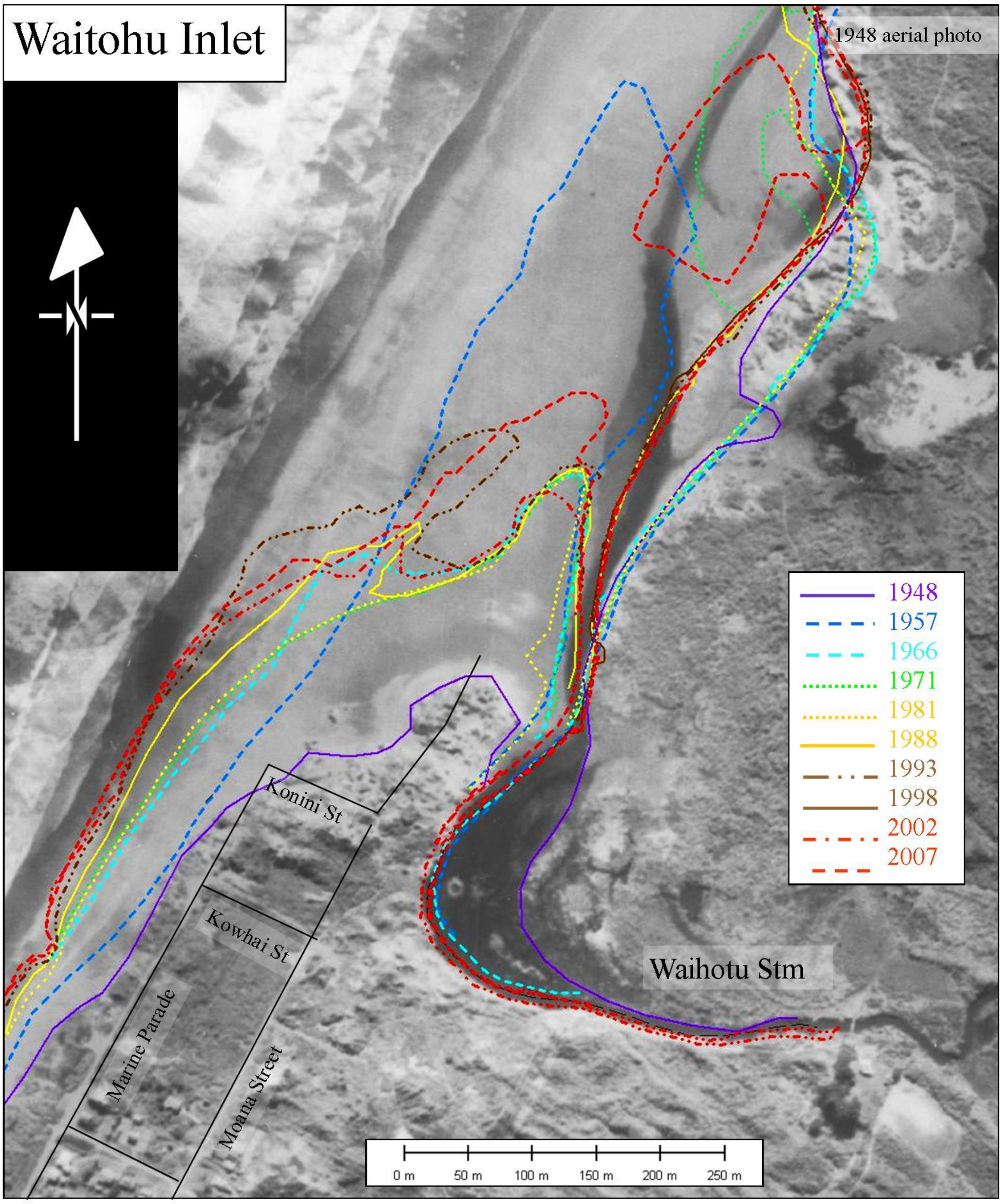

Figure F2 Historical shorelines taken from vertical aerial photographs for Waitohu Inlet superimposed upon the initial photo (1948). The contemporary roading has been overlaid to assist with interpretation.

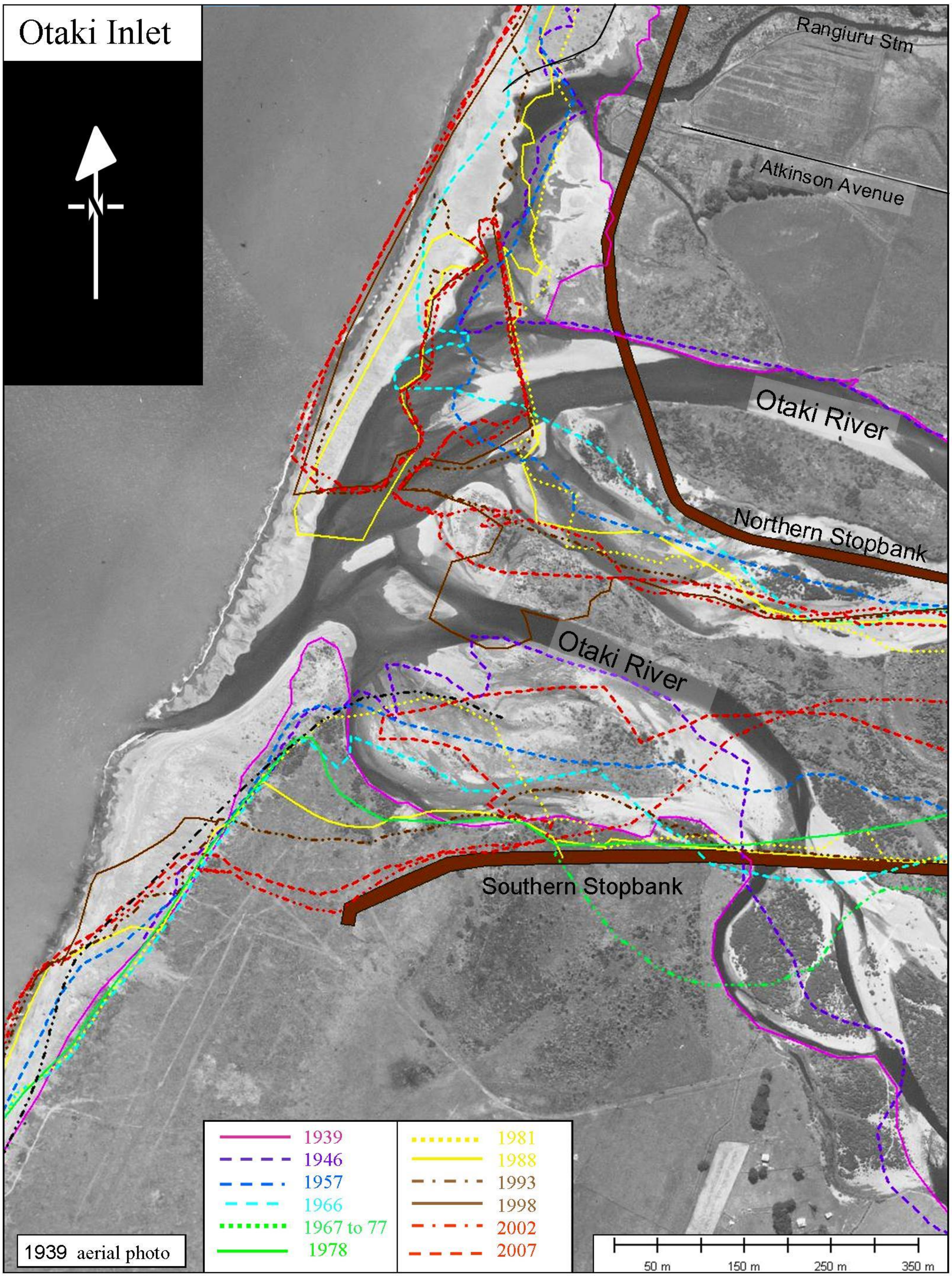

Figure F3 Otaki Inlet historical shorelines taken from vertical aerial photographs superimposed upon the earliest photo (1939). The contemporary roading and stopbanks have been marked to assist interpretation.

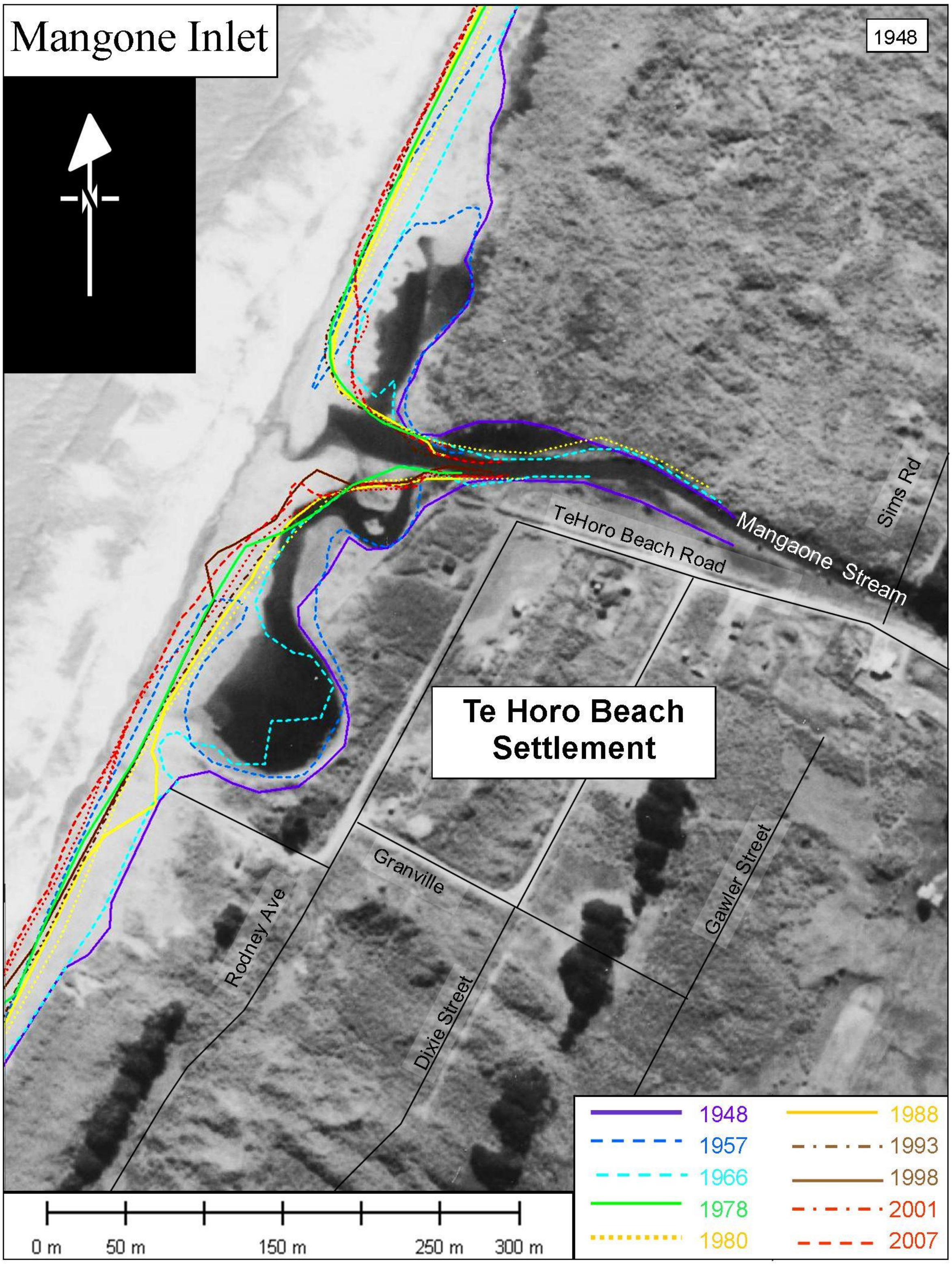

Figure F4 Historical shorelines from vertical aerial photos superimposed upon the first sample (1948). Contemporary roading marked.

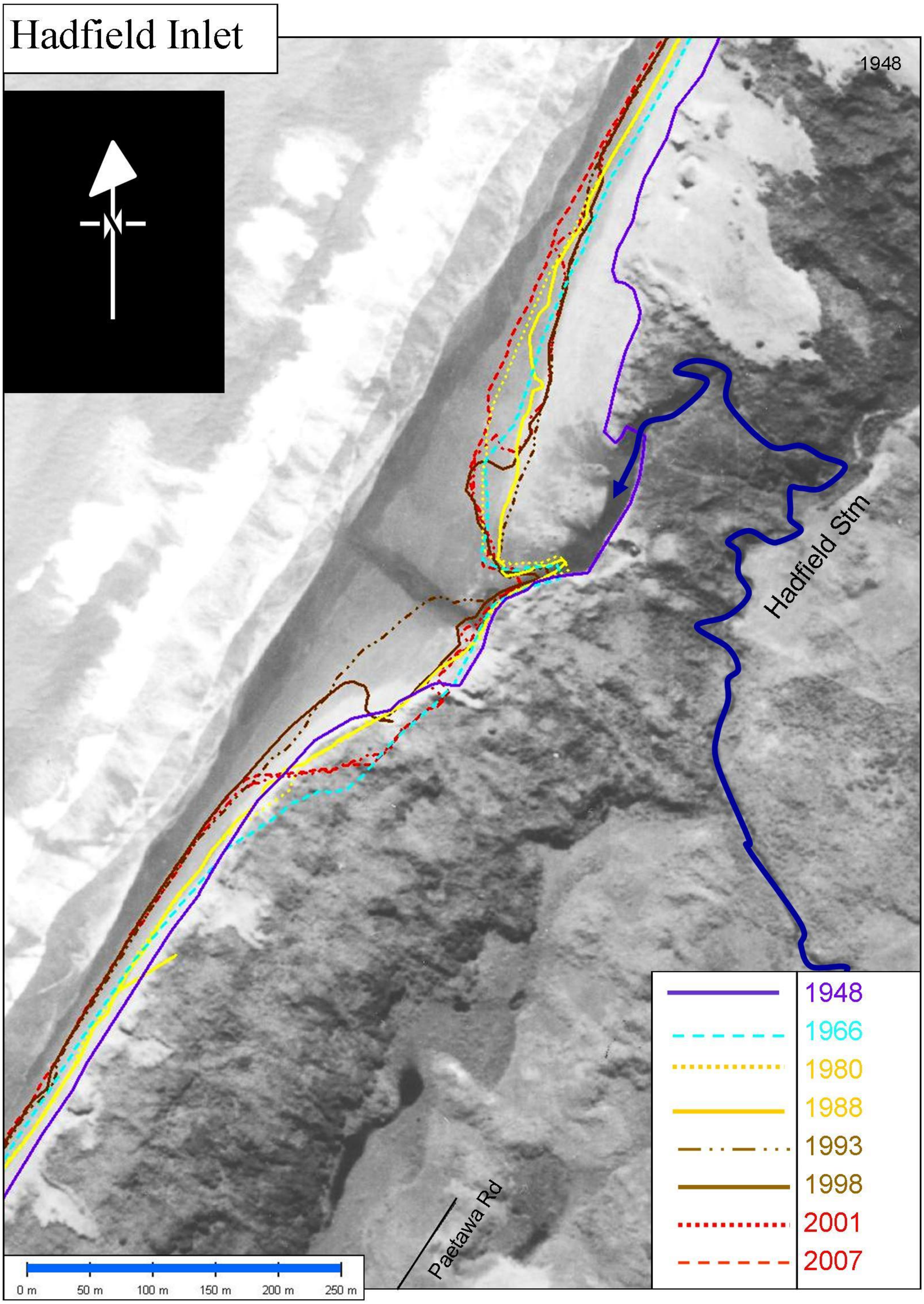

Figure F5 Historical shorelines from vertical aerial photos superimposed upon the earliest photo (1948).

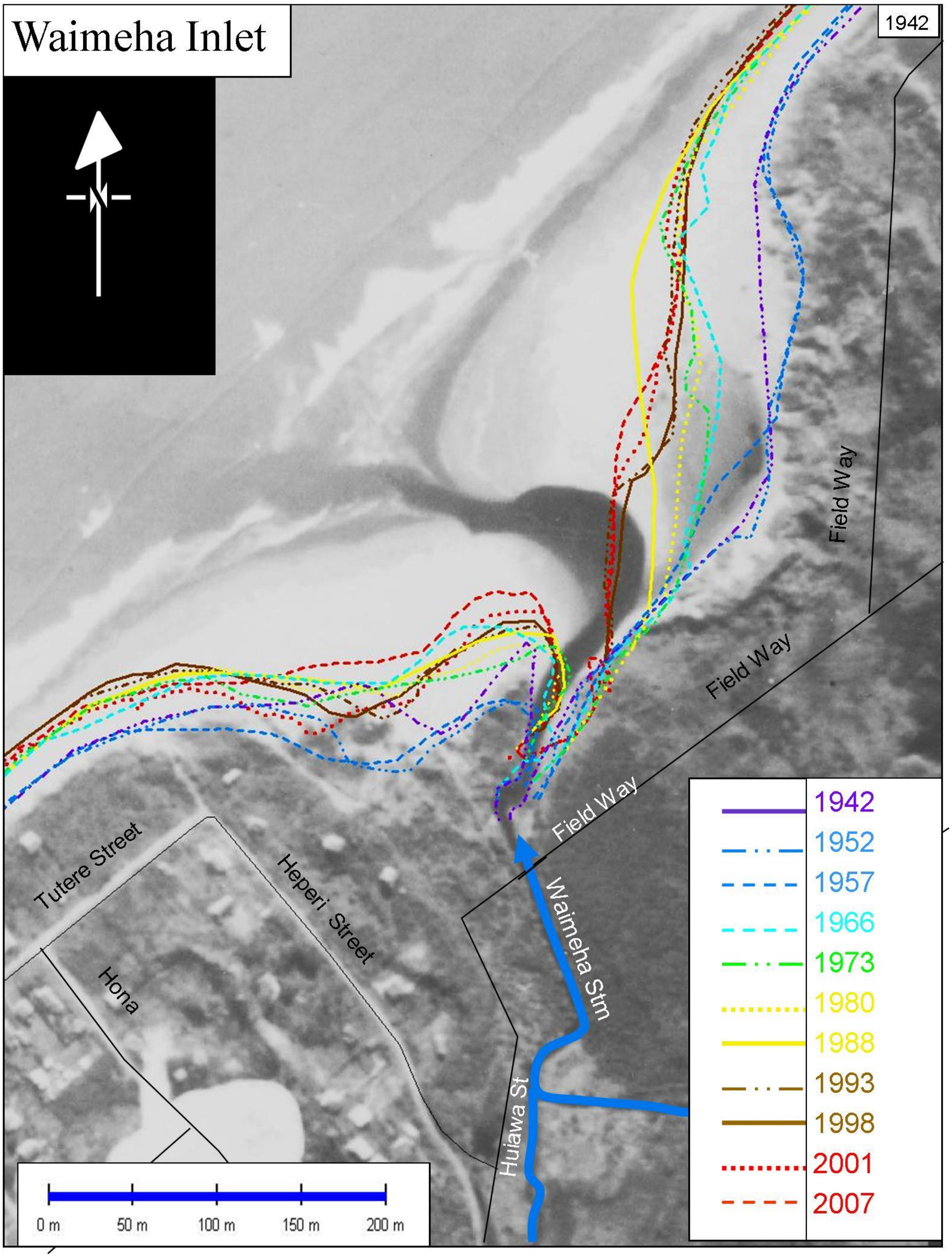

Figure F6 Historical shorelines from vertical aerial photos superimposed upon the initial photo (1942). Present roading is included to assist with interpretation.

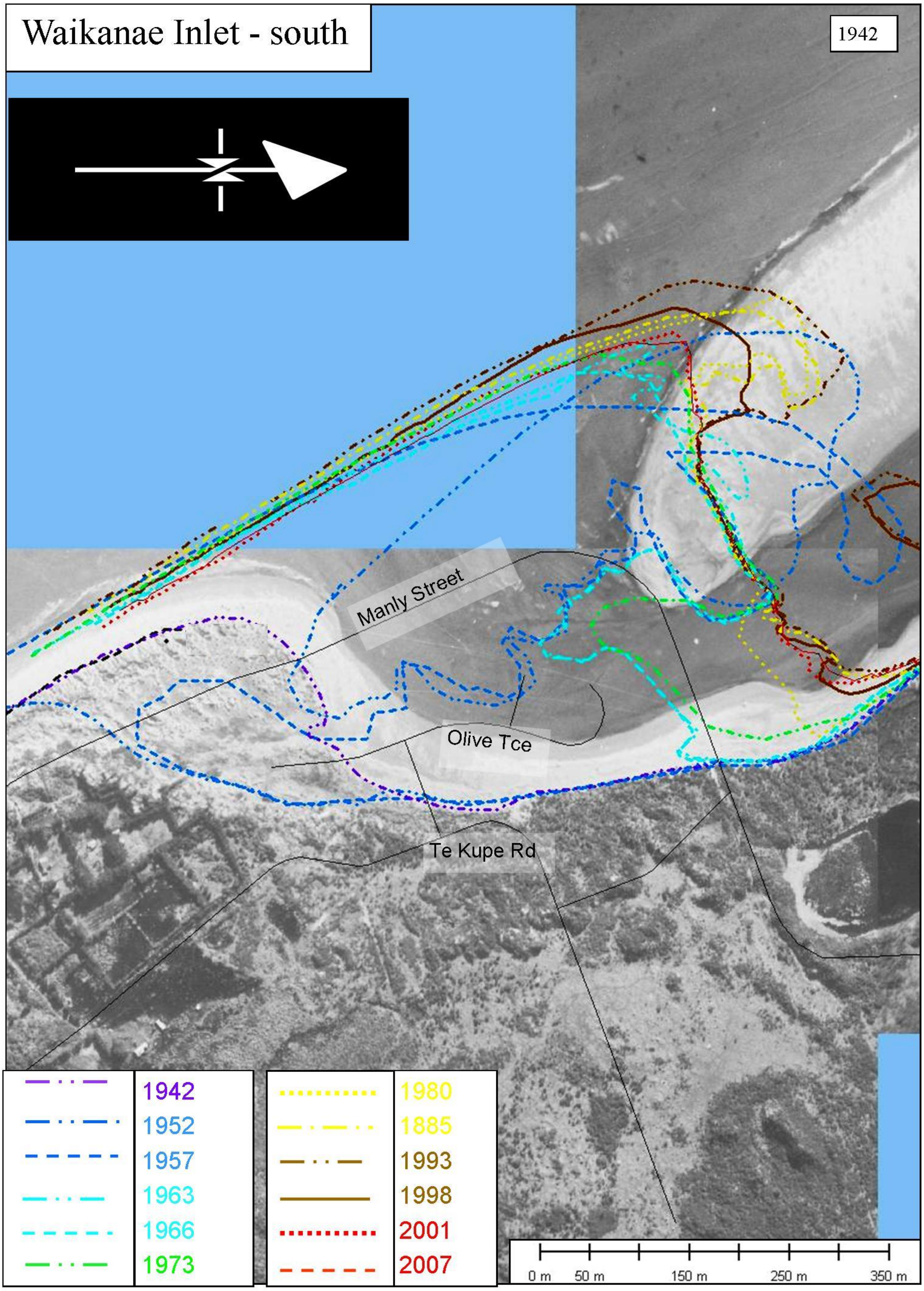

Figure F7A Waikanae southern inlet historical shorelines from vertical aerial photographs superimposed upon the earliest photo (1942). The contemporary roading marked to assist with interpretation.

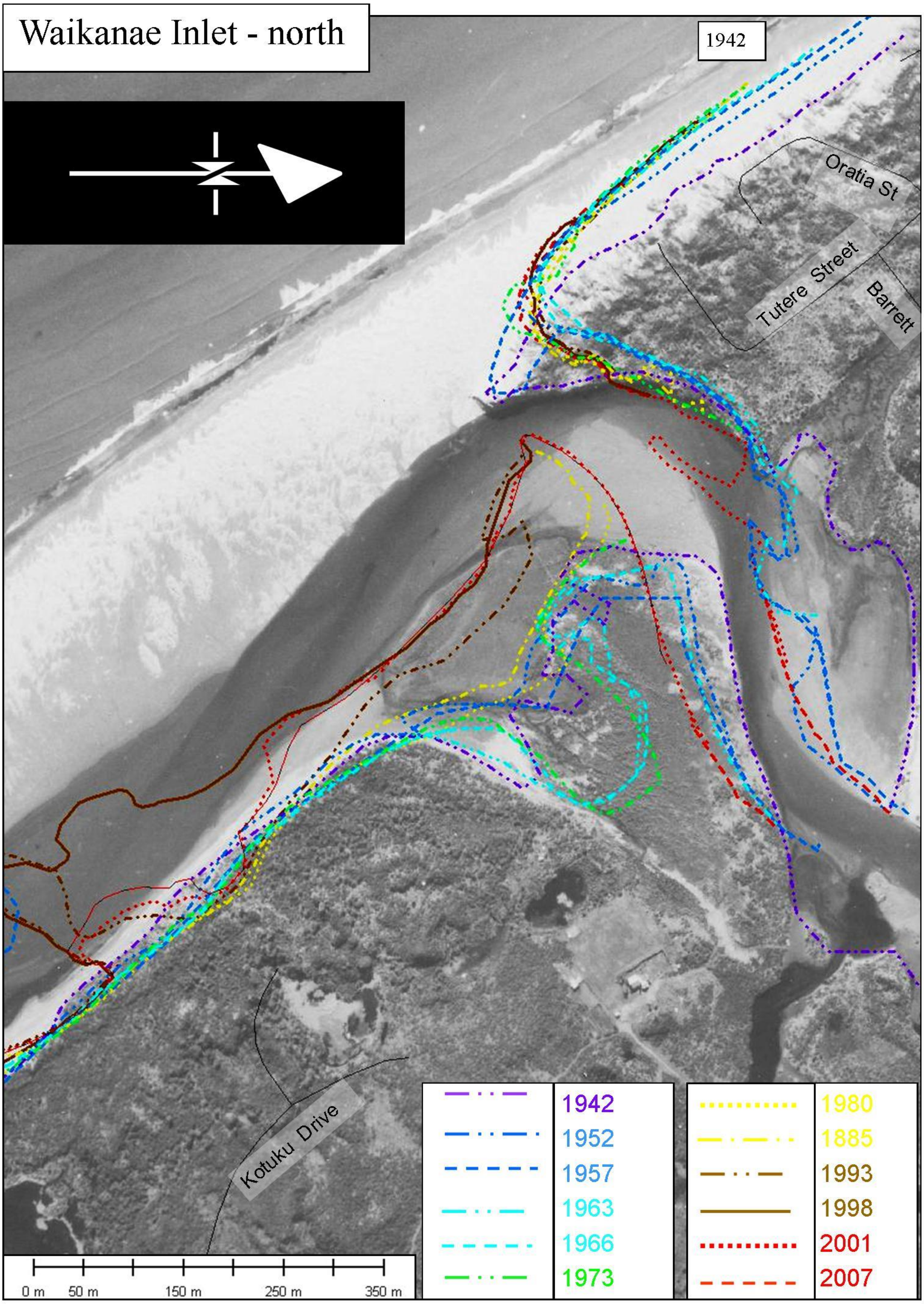

Figure F7B Waikanae northern inlet historical shorelines form vertical aerial photographs superimposed upon the earliest photo (1942). The contemporary roading marked

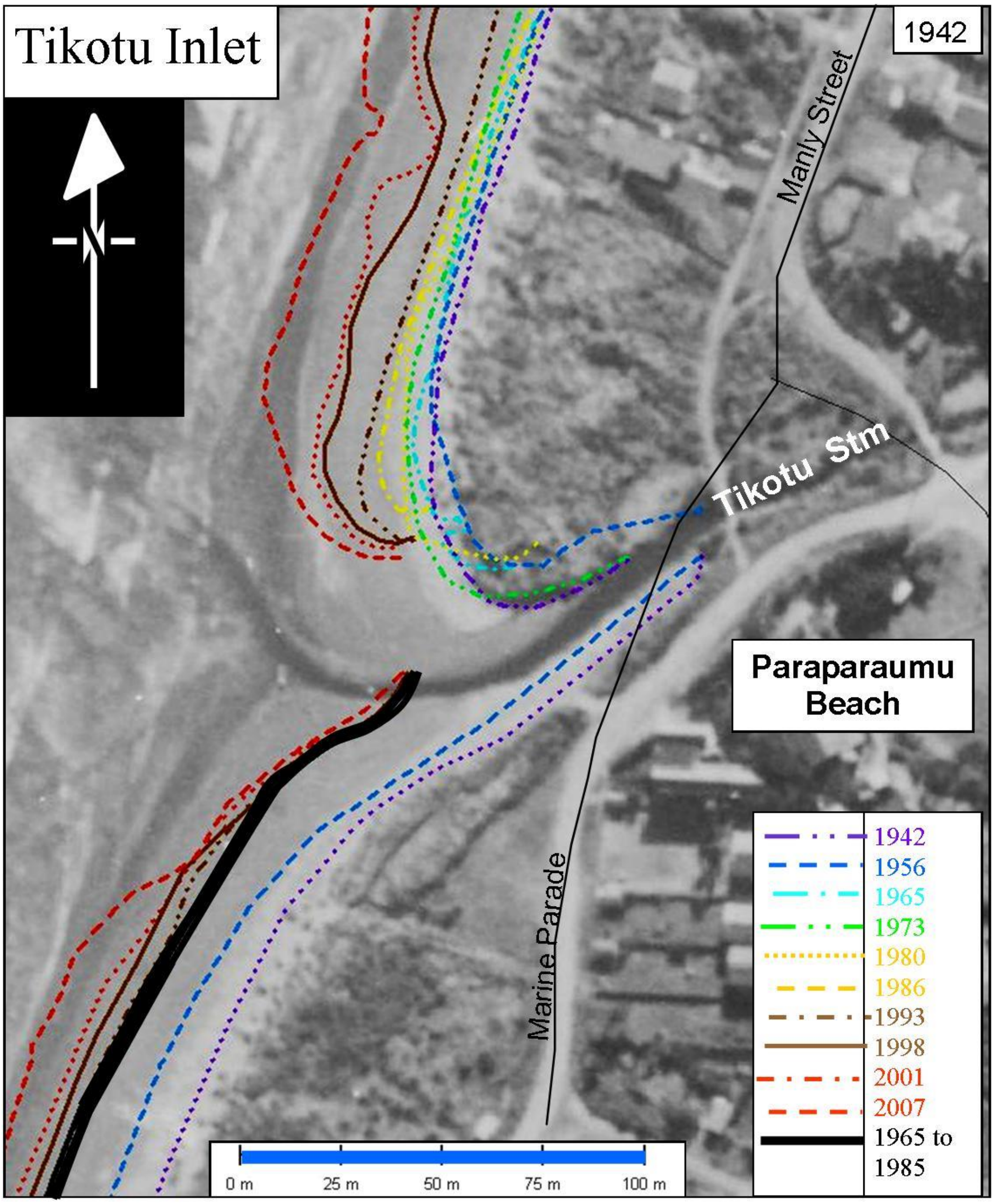

Figure F8 Historical shorelines from vertical aerial photographs superimposed upon the initial photo (1942). Note bold black line on the southern side of the inlet locates the 1965 to 85 shorelines which were then being controlled by the seawall. Present roading marked to assist interpretation.

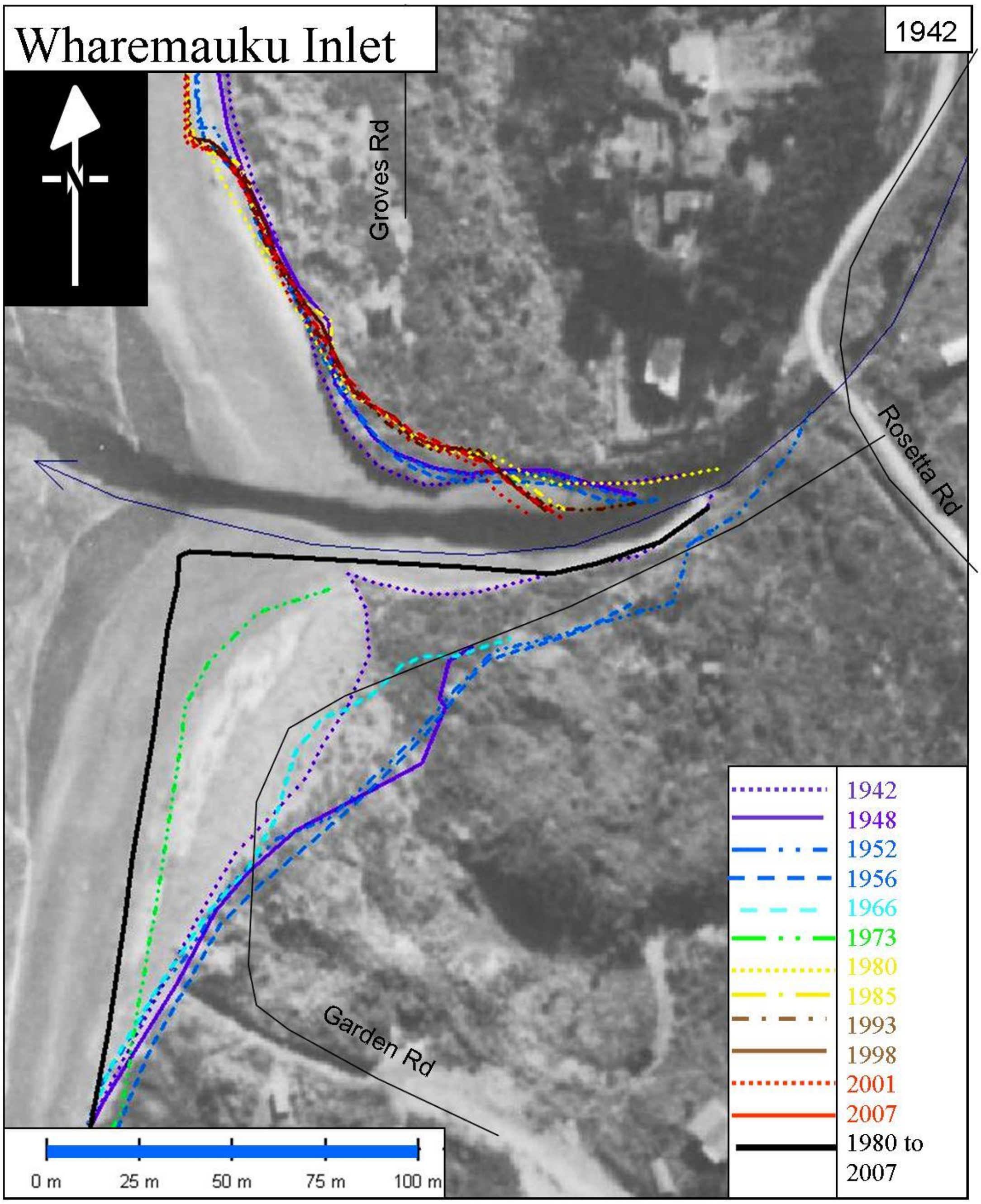

Figure F9 Historical shorelines from vertical aerial photographs superimposed upon the initial photo (1942). Note the bold black line on the southern side of the inlet locates the 1980 to 2007 shorelines which were constrained by the seawall. Present roading included to assist interpretation.

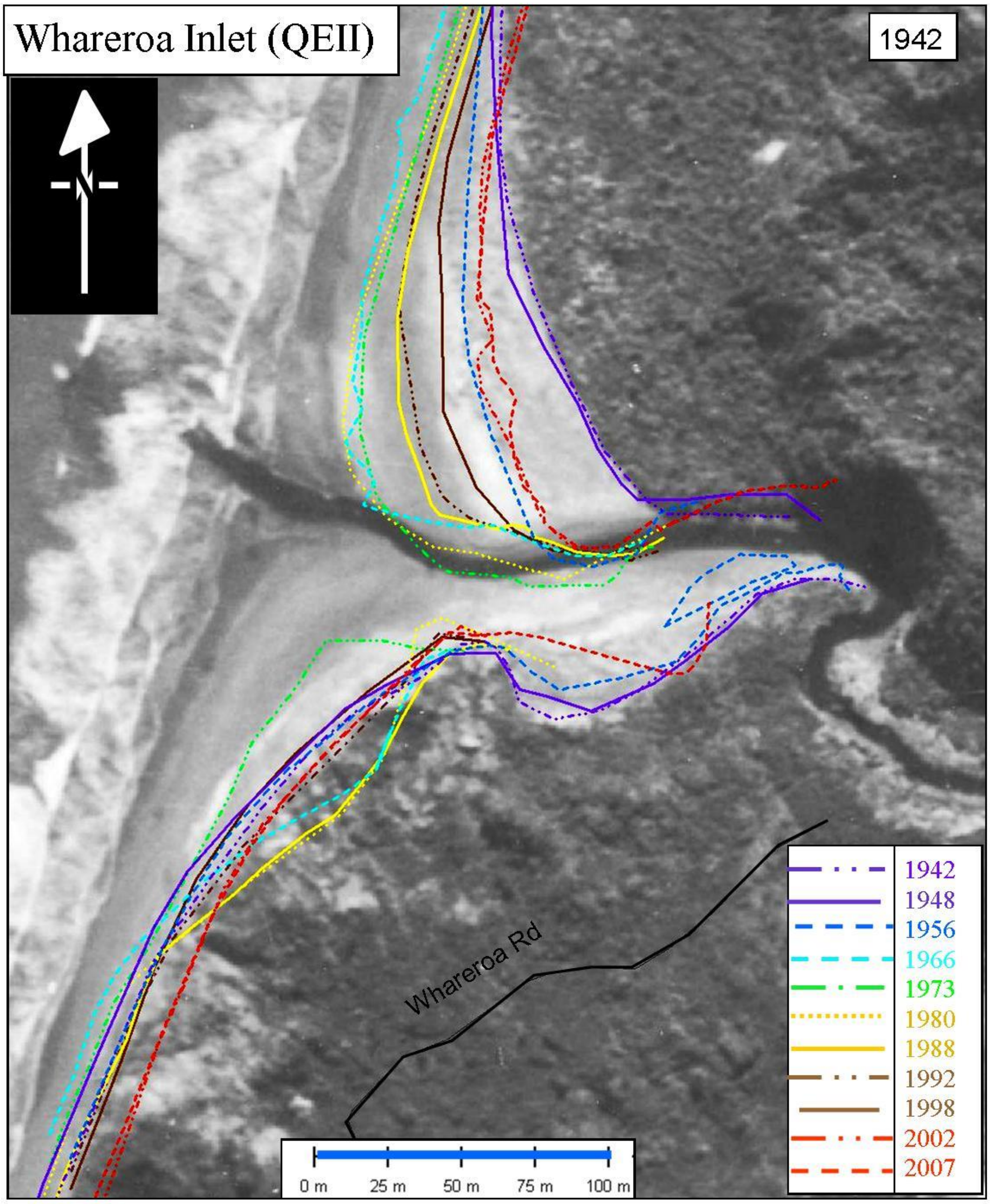

Figure F10 Historical shorelines from vertical aerial photographs superimposed upon the initial photo (1942). Present roading marked.

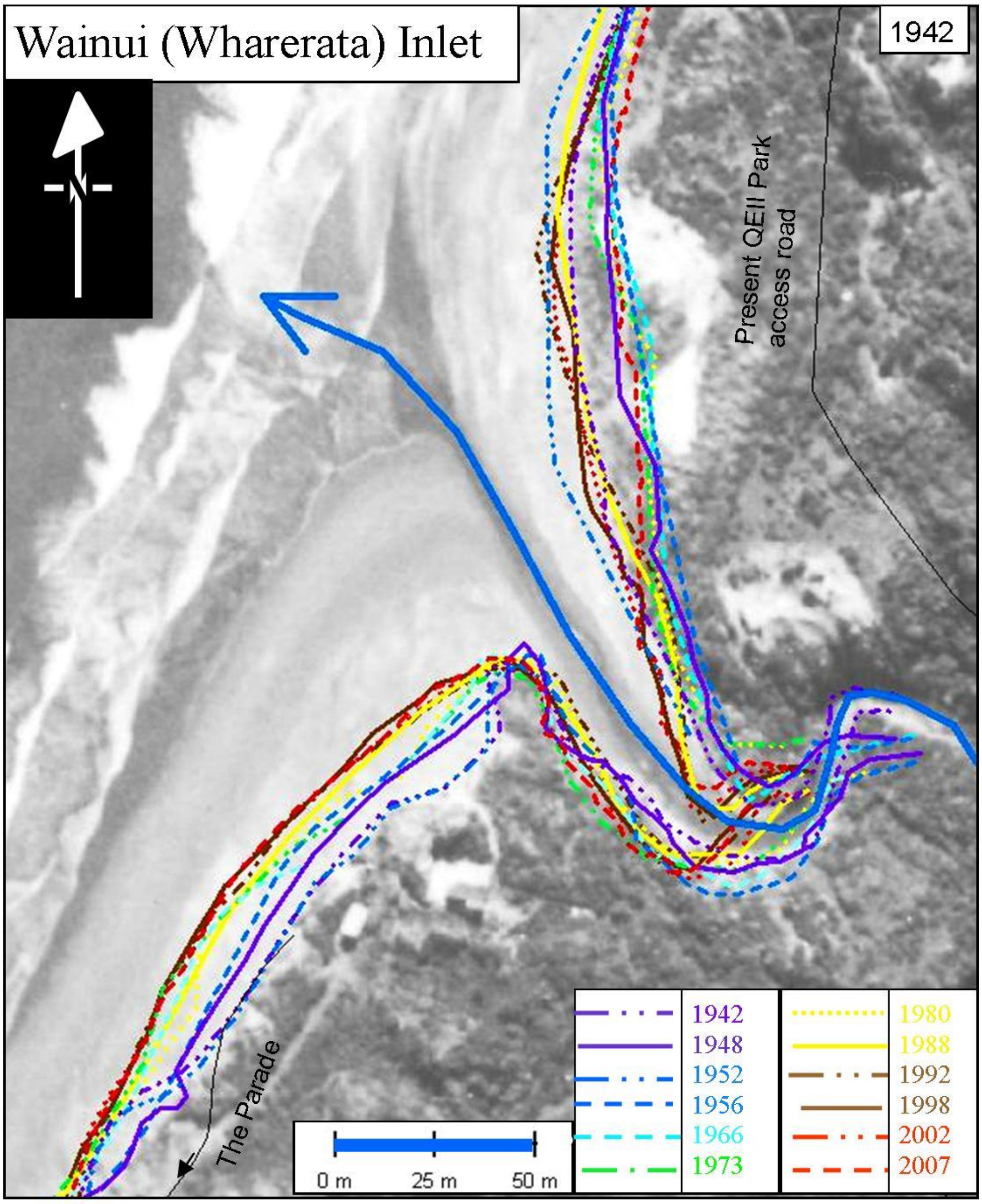

Figure F11 Historical shorelines from vertical aerial photographs superimposed upon the initial photo (1942). Present roading shown.

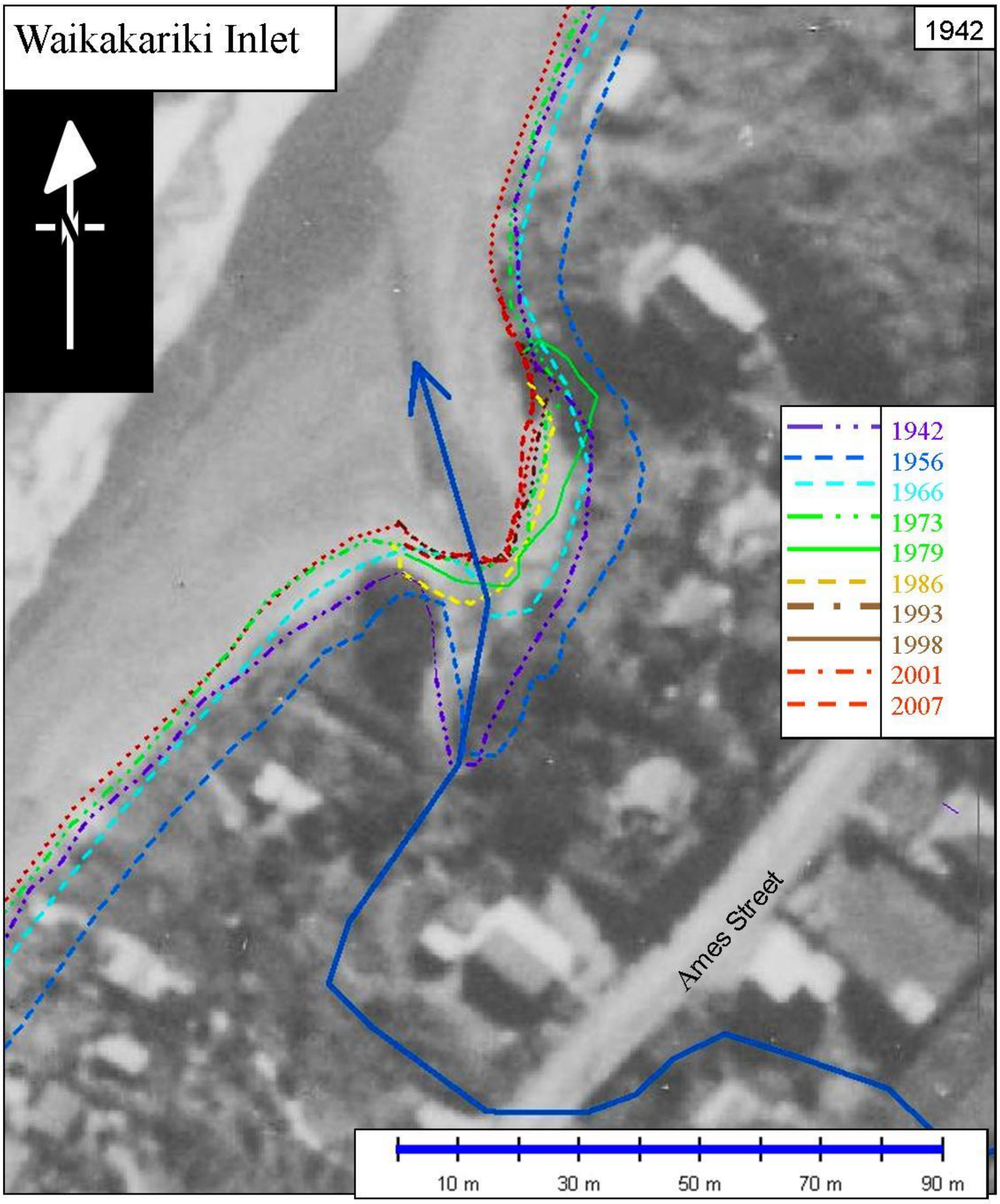

Figure F12 Historical shorelines from vertical aerial photographs superimposed upon the initial photo (1942).

APPENDIX G Longshore sediment transport modelling

Background

Longshore sediment transport is expressed in m^3/year and calculated using the following equation (G1) from Kamphius (2002).

$$Q_s = \frac{7.3}{3600} H_b^2 . T_p^{1.5} . m_b^{0.75} . D_{50}^{-0.25} . \sin^{0.6}(2\alpha_b) \qquad \text{(G1)}$$

Parameters are set out in Table G1.

This formula calculates the sediment transport rate across the entire surf zone based on several physical parameters including nearshore wave height, period and angle, sand grain size and cross-shore slopes. The Kamphuis Model has been found to be in good agreement with laboratory and field results without the need for extensive parameter calibration (Smith *et al*. 2003).

Table G1 Sediment transport parameters

Parameter	Physical Description	Unit
Q_s	Sediment transport	[m^3/year]
H_b	Significant wave height at break point	[m]
α_b	Wave angle at break point	[°]
T_p	Peak wave period	[s]
D_{50}	median grain size	[mm]
m_b	Nearshore slope	[-]

Method

1. Shore-normal transects were established between 16 offshore numerical wave modelling output sites (see Figure G1) and the Kapiti Coast shoreline.

2. For each transect, shoreline orientation, nearshore and offshore slopes were determined using the 2010 bathymetric survey data collected for the KCDC by Hunter Hydrographic Services. Nearshore slope was defined as the mean slope between the 0 m contour and the approximate outer surf zone limit during typical (mean) wave conditions. Offshore slope was defined as the mean slope between the offshore wave output location and approximate outer surf zone limit. Sediment size values are from Morris and Associates (1984). Various parameter values for each site are listed in Table G2

3. For each transect, the MetOceans 2010 hindcast wave characteristics (Hs, Tp, α_s) at 1 hour time steps over the period January 1998 to January 2010 were transformed

to break point using linear wave theory and the breakpoint located using the method of Goda (2007).

4. For each transect, sediment transport was then calculated using equation G1 for each of the hourly time steps, and then summed and averaged over the 12 years to produce an estimate of average annual sediment transport rate.

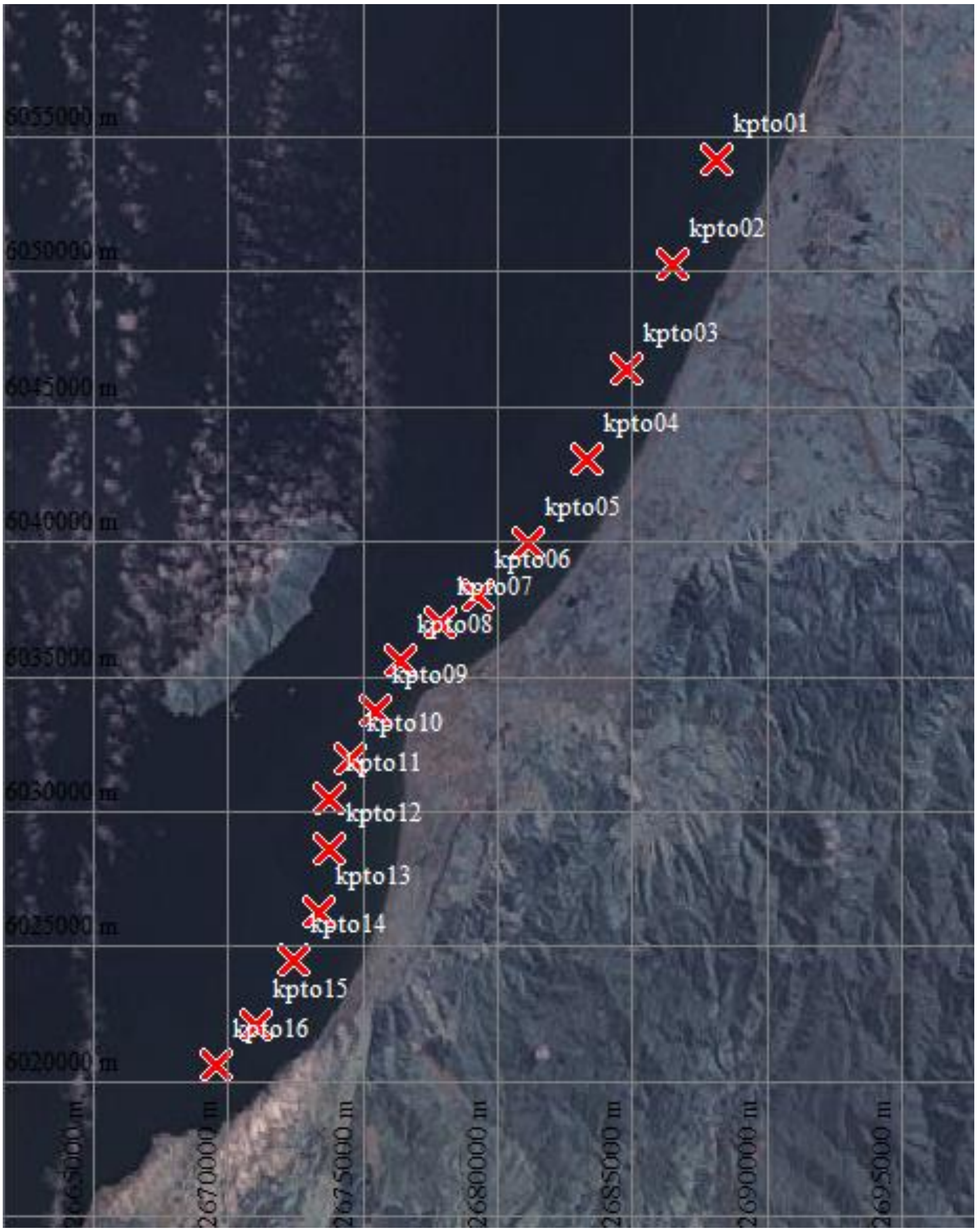

Figure G1 Wave output locations

Table G2 Parameter values

Profile	Metocean wave output locations		Wave output depth (m)	Coast Orientation (◦)	Offshore slope (-)	Nearshore slope (-)	D50 (mm)
	Lat	Long					
kpto01	-40.700	175.108	16	294	0.008	0.014	0.13
kpto02	-40.735	175.091	16	292	0.008	0.017	0.13
kpto03	-40.770	175.071	16	294	0.009	0.022	0.13
kpto04	-40.801	175.055	14	297	0.008	0.013	0.13
kpto05	-40.829	175.029	19	305	0.010	0.012	0.13
kpto06	-40.847	175.008	26	319	0.012	0.013	0.13
kpto07	-40.856	174.992	40	326	0.021	0.011	0.13
kpto08	-40.869	174.975	36	321	0.029	0.007	0.13
kpto09	-40.886	174.964	49	289	0.043	0.013	0.13
kpto10	-40.903	174.954	42	271	0.023	0.016	0.13
kpto11	-40.916	174.945	35	273	0.013	0.014	0.13
kpto12	-40.933	174.945	13	280	0.006	0.015	0.13
kpto13	-40.954	174.942	10	289	0.005	0.012	0.13
kpto14	-40.970	174.931	14	297	0.006	0.015	0.13
kpto15	-40.992	174.915	17	297	0.008	0.020	0.13
kpto16	-41.006	174.898	16	308	0.008	0.010	0.13

Results and discussion

Mean offshore wave characteristics, average yearly north to south, south to north, gross and net sediment transport are listed in Table G3 and net transport illustrated in Figure G2. Of particular note are the directional fluctuations in transport direction and these results are broadly consistent with computations and observations by the Ministry of Works and Development as summarized in Holland and Holland (1985). The strong north to south transport along the south coast is notable along with the reduced values in the lee of Kapiti Island and the south to north spike north of Otaki.

Table G3 Longshore sediment transport results

Profile	Sediment Transport (m^3/year)				
	South to North	North to South	Gross	Net	Net Direction
kpto01	24163	-11436	35598	12727	south to north
kpto02	20506	-21289	41795	-784	north to south
kpto03	20903	-26991	47894	-6087	north to south
kpto04	14256	-16141	30397	-1886	north to south
kpto05	12560	-10841	23401	1719	south to north
kpto06	9733	-6106	15839	3627	south to north
kpto07	4715	-4775	9490	-61	north to south
kpto08	2544	-3090	5634	-546	north to south
kpto09	7242	-4792	12033	2450	south to north
kpto10	7107	-6660	13768	447	south to north
kpto11	5387	-12048	17435	-6662	north to south
kpto12	5992	-19405	25396	-13413	north to south
kpto13	7145	-16432	23578	-9287	north to south
kpto14	11830	-13528	25358	-1698	north to south
kpto15	7571	-23656	31227	-16085	north to south
kpto16	8625	-7404	16029	1221	south to north

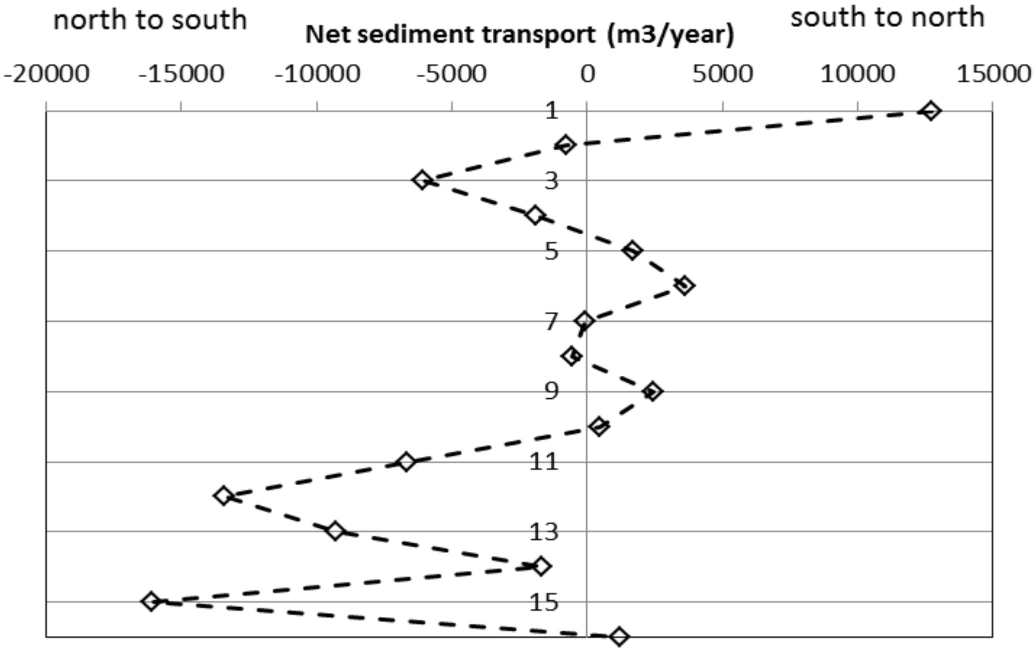

Figure G2 Mean net sediment transport characteristics

APPENDIX H Overview comments by reviewer Dr Mike Shepherd

I have been asked to comment on the report “Kapiti Coast Erosion Hazard Assessment - 2012 Update”, by Dr Roger Shand of Coastal Systems Ltd.

For the past 40 years I have researched, and lectured at Massey University on the geomorphology of the Manawatu-Kapiti coast and supervised many associated student research projects. By global standards, this coast is particularly dynamic, having undergone widespread change during the past few thousand years, at a rate that has not diminished since European settlement. To be successful, coastal management must be based upon a sound knowledge of both the geomorphological processes that generate shoreline change and the history of such change. Any coastal hazard assessment must incorporate such information; I note that this updated assessment, together with Dr Shand’s 2008 assessment, build upon and expanded existing knowledge. The additional input from some of New Zealand’s leading coastal scientists/consultants in the preparation of the reports add to their authority.

Dr Shand has updated his earlier 2008 erosion hazard assessment by incorporating the recommendations of the 2010 NZ Coastal Policy Statement and MfE 2008 Coastal Hazard Guidelines, as well as more recent wave and sediment transport modelling. In addition, new material has been added to the shoreline data set. The revised coastal hazard prediction lines have been calculated for both open coasts and inlets for a variety of scenarios.

The calculation of erosion prediction lines for the Kapiti Coast is a challenging task because of the wide range of coastal landforms and processes and the limitations of the historical data. It is also greatly complicated by the presence of shore protection structures of varying type, size and age. Dr Shand applied a rigorous scientific approach to quantify the erosion hazard so that prediction lines could be drawn. His results are necessarily conservative (precautionary) to comply with the recommendations of the 2008 MfE Guidance Manual. The scale of the coast and spacing of measurement locations necessitated a ‘generic’ approach, but he suggests that more detailed, site-specific assessments may allow some flexibility in the application of the hazard prediction lines.

This report can be commended for its transparency. The methods used (equations, components and derivation procedures) are clearly set out and the data used to calculate prediction lines are included in comprehensive spreadsheets. The inlet erosion prediction maps are clear and contain a wealth of support information so should be a valuable resource for Council and its planners.

While it is appreciated that assessment of coastal inundation hazards (tsunamis and storm flooding) is a separate exercise, their further definition should strengthen the erosion assessment.

I endorse the recommendations made in this report, and would stress the importance of future regular updating of the comprehensive data base. With greater pressure for settlement along the Kapiti Coast, it is essential that monitoring continues so that coastal behaviour can be better understood and Council’s future coastal planning decisions based upon an increasingly sound scientific foundation.

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APPENDIX I Erosion hazard lines overlying property boundaries

KEY

	Prediction Period	Likelihood	Management Regime	Relevant land-use control
🟨	50 years	Very unlikely	Unmanaged	Existing development: open coast including private seawalls
🟥	50 years	Very unlikely	Managed	Existing development: inlets* including public seawalls
🟫	100 years	Very unlikely	Unmanaged	New development: open coast including all seawalls
🟩	100 years	Very unlikely	Managed	New development: inlets*

* KCDC and GWRC have indicated they will to maintain/modify inlet control structures and management regimes into the foreseeable future