Geomorphological Assessment and Shoreline Analysis of Waikawa, Ohau and Hokio Inlets

A report prepared for Horizons Regional Council as part of coastal hazard investigations

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1.0 INTRODUCTION

Coastal Systems Ltd have been engaged to prepare a background report assessing the geomorphology and defining inlet migration curves for the Hokio, Ohau and Waikawa Inlets on the Horowhenua Coast (Figure 1) as part of the coastal hazards assessment being undertaken by Tonkin and Taylor Ltd (primary consultants) for the Horizons Regional Council.

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 increasing hazard risk due to increasing property density coupled with changes in coastal processes which are to some extent anthropogenically-induced. A schematic diagram and associated terminology of a typical inlet on the North Island’s southwest coast is shown in Figure 2. Note that the offset can be substantial as it is for the three inlets under consideration in this report.

Open coast erosion hazard distances (CEHD) are assessed using equation 1, and this requires modification to account for inlet morphological behaviour. Equation 2 was then used to predict inlet (cross-shore) erosion hazard distances (IEPD).

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

$$IEPD = IMC - (LT + RSLR + DS + CU) \qquad (2)$$

Where, LT = longer-term shoreline change, ST = shorter-term shoreline fluctuations, RSLR = shoreline retreat associated with sea-level rise, DS= dune stability, CU = combined uncertainty and IMC = inlet migration curve.

Values for the bracketed terms in equation 2 are as derived for the adjacent open coast. The *inlet migration curve* (IMC) replaces the open coast’s SE (shorter-term fluctuation) component. The IMC is derived by fitting a curve to the landwardmost locations of the inlet (aerial photo-based) shoreline migration envelop (see Figure 3). The IMC differs for managed and unmanaged inlets with the managed curve being derived from that subset of shorelines corresponding to the time inlet management practices have occurred, while the unmanaged IMC is derived from the subset of shorelines for the time prior to management. Note, inlet management consists of structures such as guide walls, groynes and mouth cuts (channel excavations) to constrain channel shape and alongshore migration.

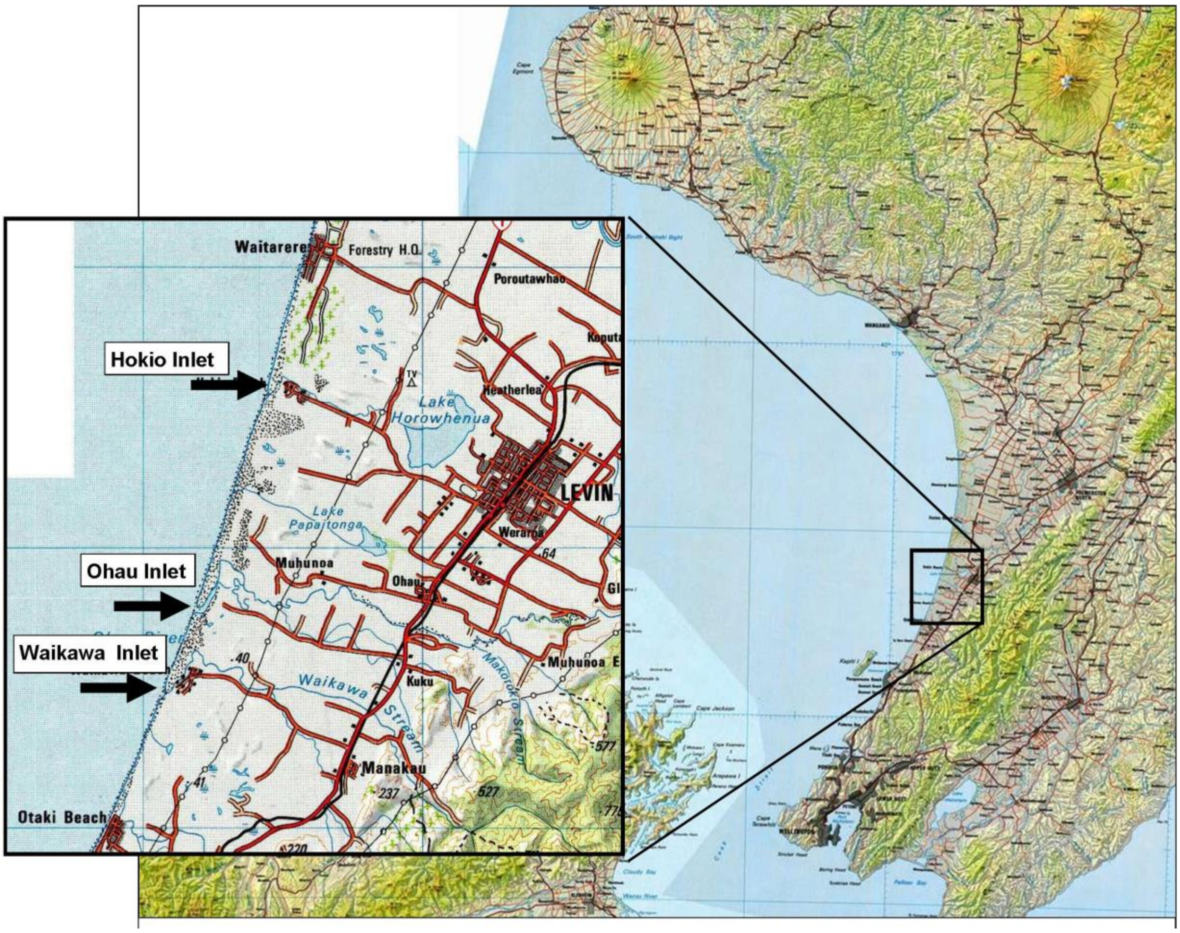

Figure 1 Location map of Hokio, Ohau and Waikawa Inlets on the Horowhenua Coast

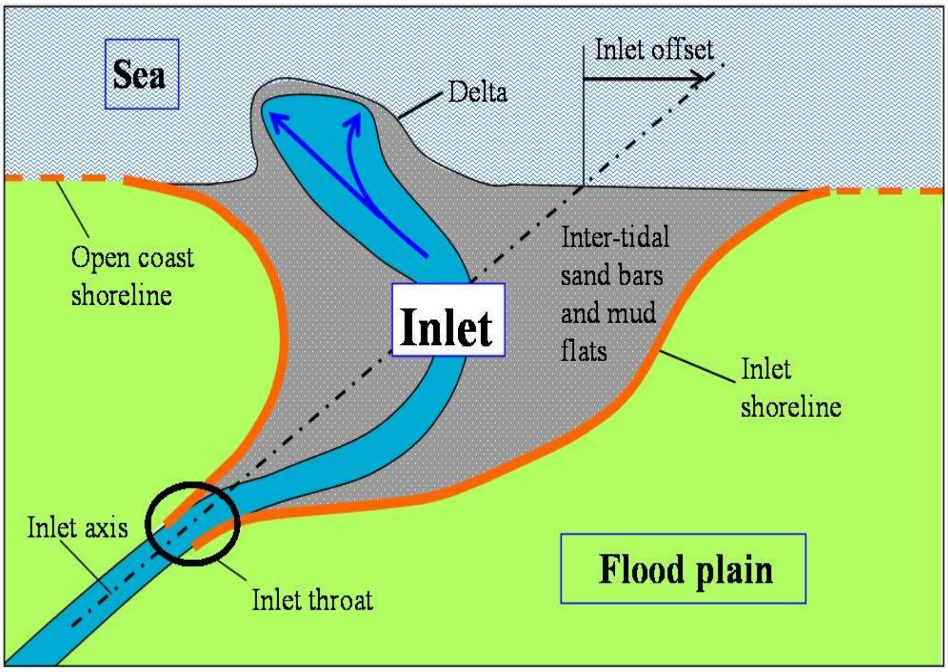

Figure 2 Morphology and terminology of a typical inlet on the Manawatu Coast

While such partitioned data sets are "broadly suitable" to represent 50 yrs of inlet behaviour, they are often too short to confidently represent 100+yrs of shoreline change, so extrapolation must be done with caution. In particular, the underlying geomorphology of the inlet must be well understood in term of its past behaviour and its predicted future behaviour. Such an approach is also now required by the NZCPS 2010, Policy 24 (a) and (c).

Geomorphological assessments utilize information from the following sources: early survey plans, which in the present investigation date back to 1872 to 1894; vertical aerial photographs; LIDAR, and any other readily available, reliable materials. Field inspection also provides useful evidence. The shoreline indicator on early survey plans was typically the mean high water (MHW) line; however, other indicators could have been used including the dune line, spring high water line, channel margin or inlet vegetation line. The usual shoreline indicators abstracted from aerial photos are the seaward edge of vegetation (approximates the dune toe). In addition, aerial photos contains a wealth of morphological signatures, especially under stereo analysis (3D vision). More recedntly, LIDAR provides high resolution 3D data for generation of a digital terrain model (DTM) which allows for detailed inspection and analysis. Many features on early aerial photos find expression (and explanation) within the more recent DTM.

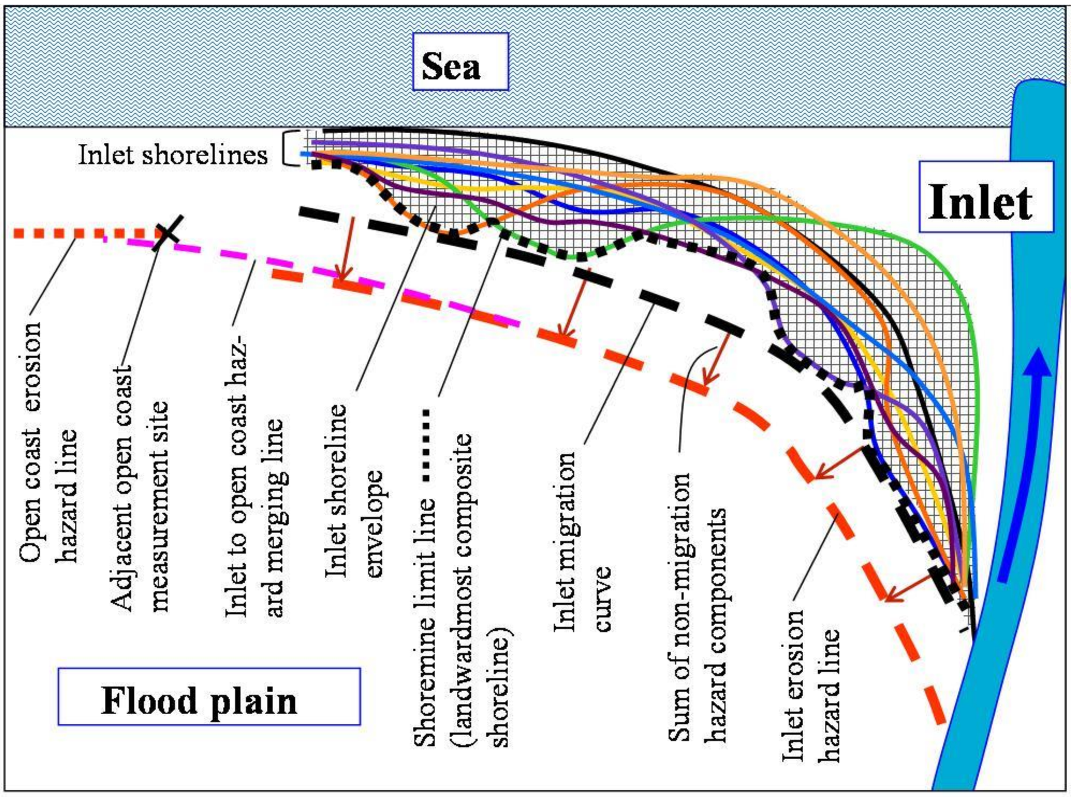

Figure 3 Conceptual illustration of derivation of inlet migration curve (IMC), inlet erosion prediction (hazard) line and relationship to the open coast erosion hazard line.

If inlets are subject to systematic influences such as open coast progradation and/or net alongshore migration, then particular care is required when selecting shoreline subsets to be used for deriving natural and managed IMCs as some shorelines may represent morphology that will not be replicated in the assessment period, and some potential future moprphologies may not be evident within the existing shorelines/morphology. These situations occur at all three subject inlets (Waikawa, Ohau and Hokio).

Further complication in determining IMCs occurs when upstream fluvial (meander) processes cut new entrances into the inlet which results new inlet throat locations. This behaviour is a characteristic of the Ohau inlet.

Erosion hazard is usually assessed over both 50 yr and 100+ yr prediction periods. The former applies to existing development so owners can make interim use of property which may be subject to potential coastal hazard. In such cases special resource consent conditions apply to address the hazard risk such as removal of a building when erosion reaches a predetermined trigger point. Councils' may also need to have policies to maintain/strengthen protection works as required. As it is feasible to predict erosion with a period of 50 yrs, the managed IMC is an appropriate base curve for deriving a 50 yr erosion hazard line.

The 100+ yr assessment period applies to new development including subdivision (NZCSP 2010, Policy 25). Predicting landform, shoreline, protection structure performance and environmental effects in such dynamic environments necessarily involves much higher uncertainty than for the 50 yr period. The present assessment focuses on future geomorphological change to provide both managed and unmanaged IMC options (for use in the subsequent derivation of managed and unmanaged erosion hazard lines) for the client's consideration. It is noted that the neighbouring Territorial Authority, (the Kapiti Coast District Council) is presently proposing erosion hazard policy based on open coast and inlet assessments in which no protection structures were taken into account over the 100+ yr period, i.e. the 100+ yr erosion hazard line is based on the unmanaged IMC.

Of particular relevance to (windward) west coast inlets is the susceptibility of eroded inlet shorelines (by the range of fluvial/coastal drivers) to subsequent wind erosion. These inlets are typically boardered by dune sand and the steep, bare scarps which facilitate blowout and parabolic dune development with frontal wind drifts able to travel inland at rates of several metres per month particularly during aggressive El Nino conditions (CSL data from the Rangitikei Inlet in September to November 2007). Episodes of wind erosion may last months to years and it is thus desirable to incorporate an adequate buffer within a coastal erosion zone in the vicinity of inlets.

The following three sections provide a geomorphological description for each of the Waikawa, Oha and Hokio Inlets, including size and geometry (based on the aerial-based shorelines and envelope), catchment size and mean annual flood flow at the mouth (from http://wrenz.niwa.co.nz). Historical inlet behaviour and historical shorelines are described.

Inlet management regimes are described. The derived inlet migration curves (IMCs) are identified as are areas considered susceptible to future dune erosion processes. Tonkin and Taylor Ltd will subsequently adjust the IMCs landward to incorporate other erosive effects such as shoreline retreat associated with predicted climate change, erosion scarp adjustment and sand dune instability to derive the erosion hazard lines (EHLs).

2 WAIKAWA INLET

2.1 General

The Waikawa Inlet has a maximum area of ~68 ha and alongshore length up to ~2400 m based on the aerial photo analysis. The channel typically has a southerly offset, the catchment area is 7700 ha (77 km^2) and the mean annual flood flow at the mouth is 50 m^3/s. The inlet's adjacent seaward shorelines are undergoing long-term progradation of about 1.5 m/yr.

2.2 Past and present morphological behaviour

Past shorelines are overlayed in Figure 4. The earliest shoreline (1872) had its mouth 2.2 km north of the present mouth (defined here as the seaward end of the rock groyne), and at that time it flowed into the Ohau River. Other morphological evidence on the survey plans indicate the Waikawa may have flowed even further north prior to this. By the late 1879s the Waikawa was had its own oceanic mouth some 700 m to the south. The 1894 survey plan shows a very large "sandbank" fronting the coast and the Waikawa being constrained and deflected alongshore with the mouth having moved some 500m to the south (but still 1 km north of the present mouth).

Morphological evidence on the 1942 aerial photo indicates this large sediment body was able to force the entrance yet further alongshore and at the time of photography it was some 1600 m south of the present mouth and close to the Waiorongomai Stream which lies some 600 m south of the territorial boundary. Dune vegetation had established on this "welded sandbank" as far south as the present footbridge and the southward extending spit beyond had relatively low elevation and appears subject to breaching.

The 1965 mouth had returned northward with the inlets southern bank some 200 m north of the present entrance groyne and the north bank being a further 600 m. The 1965 aerial photo shows a major episode of dune instability was underway (Figure 5), possibly linked to a previous influx of sand along the coast. Since that time, the northern side of the inlet has migrated some 600 to 700 m to the south where it is constrained by the channel which has been fixed since the 130 m long stone groyne was established along the left bank during the 1983 to 1993 period. The foredune on the northern side of the inlet have steadily increased in height and extent and now enclose an 80 ha area of 1960s riverbed (see area marked #### in Figure 6) which now becomes a backwater during floods.

The southern side of the inlet migrated south following its 1960s northward excursion at a rate of ~50 m/yr! with the 1978 and 1983 photos showing the mouth extending southward with bracketing shorelines some 500 and 750 m from the groyne end.

The rivermouth groyne constructed after 1983 has fixed the orientation (southern offset) of the channel as it enters the inlet and limited the alongshore migration with the northern side stabilizing and the southern side systematically migrating northward some 200 m (~7

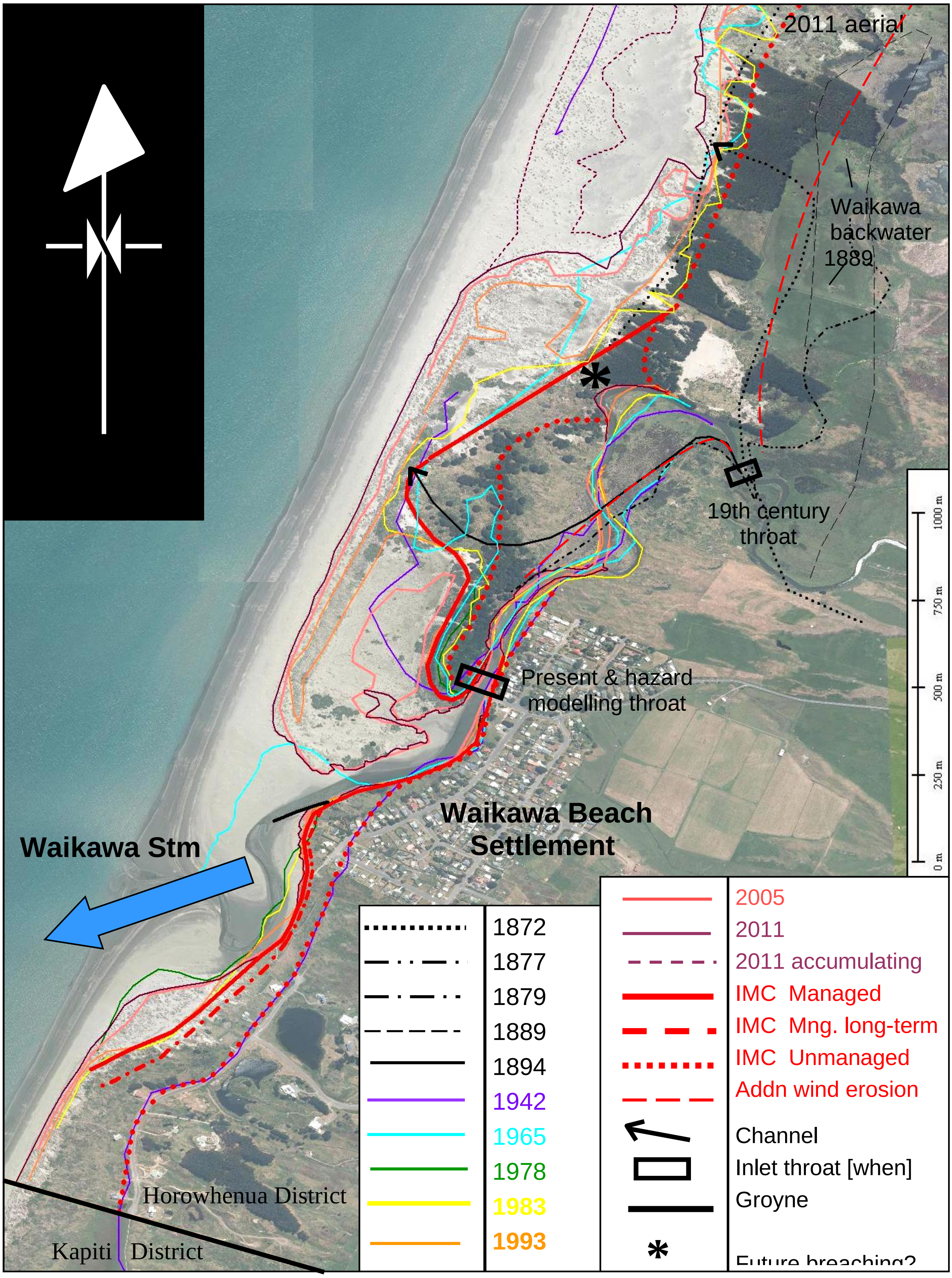

Figure 4 Waikawa Inlet showing historical shorelines and inlet migration curves (IMCs) for managed and unmanaged scenarios. Where no *managed long-term IMC is* shown then the *managed IMC* applies. Note the final erosion hazard lines will be offset landward to account for other influences such as effects from predicted climate change and possible additional offset for wind erosion hazard (marked).

m/yr). The back of the inlet (immediately south of the groyne) has prograded some 20 m along the first 100 m then eroded some 35 to 55 m over the following 400 m with more recent behaviour limited to ~10 m fluctuations.

2.3 Future morphological behaviours

If the groyne is maintained, over time it is reasonable to expect the northern dunes and shoreline will encroach on the channel which in turn will be forced against the structure and thus result in bed scour, the need for ongoing maintenance and strengthening, and flow restriction possibly contribute to upstream flooding. Yet further into the future, should open coast progradation continue, ongoing accumulation on the northern side of the inlet may well outflank the groyne thus causing a new southward dogleg in the channel and thus increasing the likelihood of erosion along the back and southern sides of the inlet along with and a more southward mouth location. Of course climate change predictions could markedly change shoreline behaviour on the open coast in which case the groyne could be under more frequent wave attack under storm conditions and the adjacent inlet more susceptible to erosion. If the groyne were allowed to fall into disrepair, the channel migration range will likely increase with the systematic southward trend evident in the pre-groyne data once again occurring. Depending on the balance between the underlying long-term progradation vs climate change-induced recession will depend the extent of inlet erosion in the vicinity of the present groyne and residential area.

There is also an area of interest regarding future morphological behaviour to the north of the present inlet where a dogleg in the channel (marked on Figure 4) that approximates the location where the 19th century sand influx diverted the channel southward. This area is of interest as the meander is migrating seaward at a rate of 1.5 to 2 m/yr and the Ohau channel in the late 1979s/early 1980s was only about 100 m from the present Waikawa dogleg meander (see Figure 3). The intervening topography is low lying at about 2 m above MSL. The Waikawa thus has the potential to once more flow into the Ohau, especially with the possibility of increased high flows associated with climate change. This could lead on to the Waikawa once more migrating south, this time by eroding existing dunes which are lacking substance in many areas where previous channels occurred (Figure 6), and even eventually joining the present channel - a process that has partially occurred at the Turakina Rivermouth, some 65 km north of the study area, over the past decade. This scenario demonstrates how significant morphological change can be in the longer term.

2.4 Inlet migration curves

The present inlet throat is approximately located at the footbridge, and while some evidence of meander development exists upstream, the long established channel approach to the inlet should persist into the future. The inlet's southern offset is long established both before and after the groyne construction so can be assumed to occur into the future.

Figure 5 Wind erosion and associated sand drifts (arrows indicate direction) about the Waikawa area in 1965. Note that while the stream presents a barrier to landward progression of mobile dunes, wind-blown sand can cross water courses and affect person and property further inland. Stabilized parabolic dunes on the inland side of the channel (marked *) would have formed when the stream has a more northern outlet such as in the 19th century (see Figure 4).

Managed IMCs

The post 1983 (managed) shorelines were used to define the managed inlet migration curve (IMC) using the method illustrated in Figure 2. The only variation is on the northern side of the inlet where the curve stays on the inland side of the infilled 1960s riverbed (Figure 6) as this low lying area will not be particularly resistant should the seaward foredune circum to erosion. Management would include groyne maintenance and strengthening, and also river control works to ensure the orientation as the channel approaches the inlet and also to ensure the Waikawa does not merge with the Ohau in the vicinity of the channel dogleg (Figure 4) some 900 m upstream of the Waikawa footbridge.

Because the post 1983 (managed) shorelines are too limited to confidently define the full IMC for the “longer-term” (100+ yrs) given the possible morphological responses already discussed, the following IMC modifications have been applied. No change is required for the northern side of the inlet as this shoreline has become very stable since groyne construction and the underlying tendency for morphological change will be for this shoreline to migrate south (by outflanking the groyne). Some additional shoreline response may occur along the rear and southern sides of the inlet, so a 100+ yr managed IMC is set

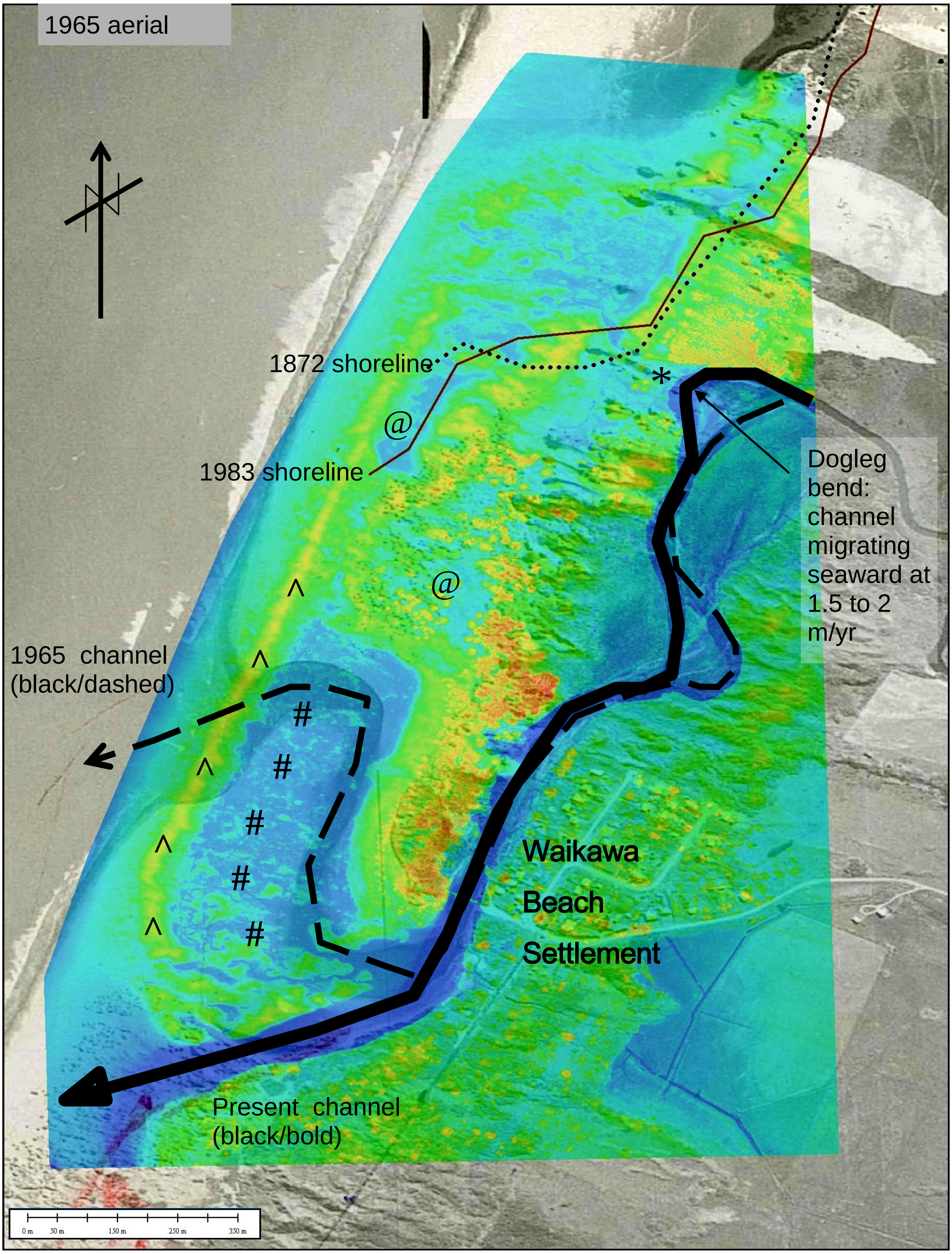

Figure 6 Digital terrain model (based on 2005 LIDAR) depicting elevation (lower=blue, moderate =green, high=yellow/brown) superimposed upon the 1965 aerial photo (same as in Figure 5) to illustrate (i) low relief area between dogleg bend and earlier Ohau Inlet shorelines (marked *), (ii) area with low relief in dunes associated with 1960s inlet channel (marked (###), (iii) other low elevation areas in the northern dune complex associated with earlier channels (marked @), and (iv) narrow present foredune (marked ^ ^ ^).

landward by some 10 m, this being the average fluctuation observed within the post groyne shoreline envelope. The combination of the northern shoreline outflanking the groyne and the effects of climate change mean that the observed northward migration of the southern shoreline since groyne construction cannot be assured in the longer-term and it is beyond the scope of this assessment to model any such behaviour. As a precautionary measure, the longer-term managed southern IMC has been offset southward by some 100 m, this being 50% of the observed post groyne shoreline change.

Unmanaged IMC

The pre-managed shoreline samples (1942 to 1983) are used as a basis to define the 100+ yr unmanaged IMC (method illustrated in Figure 2). In most places the initial (1942) shoreline is the most landward so is used to define the IMC. Given the tendency for the inlet to migrate southward and the open coast to prograde, the landwardmost shoreline is likely to over predict the landward extent of the northern side of the inlet. However, this side of the inlet is undeveloped and likely to be so for the foreseeable future so over-estimation of inlet margin retreat in this area is acceptable. Given the dynamic nature of the Waikawa Inlet, und the uncertainties in morphological response to future changes in forcing and sediment supply, the landwardmost and southernmost location of the initial shoreline is considered appropriate to define the long-term unmanaged IMC.

The unmanaged IMC also incorporates possible erosive effects associated with any future merging of the Waikawa Stream and Ohau river. The IMC in this area is topographically constrained so defined using the DTM.

2.5 Erosion Hazard Lines

The 50 yr EHL can confidently be based upon the managed IMC, subject to the stipulated management conditions noted in Section 2.4, plus additional conservation measures required to contain wind erosion.

There are two options for the 100+ yr EHL.

1) The EHL is based upon the "longer-term" managed IMC, and subject to the stipulated management conditions noted in Section 2.4 plus additional conservation measures as required to contain wind erosion.

2) The EHL is based upon the unmanaged IMC. This option requires no management assurances from council and makes some allowance for wind effects which occasionally affect this area. However, the Waikawa Beach Settlement is particularly vulnerable to wind-blown sand given its location downwind of (i) the seaward reach of the Ohau River, (ii) the confluence of a future Waikawa-Ohau merger, (iii) subsequent southward migration of rerouted Waikawa, and (iv) an unstable northern open coast should climate change effects lead to significant foredune erosion. Additional buffer against wind hazard is thus advised and **consideration should be given to adjusting the EHL landward on the northern**

side of the inlet as depicted in Figure 4 by the dashed red line. This additional precautionary measure should be acceptable given that this area is presently undeveloped.

Option 2 better meets the purpose of the RMA 1991 in that it more comprehensively promotes the sustainable management of natural and physical resources

3 OHAU INLET

3.1 General

The Ohau Inlet has a maximum area of ~160 ha and alongshore length up to ~3900 m based on the aerial photograph record. The channel typically has a southerly offset, the catchment area is 18,800 ha (188 km^2) and the mean annual flood flow at the mouth is 265 m^3/s. The inlet's adjacent seaward shorelines are undergoing long-term progradation of about 1.1 m/yr.

3.2 Past and present morphological behaviour

Past shorelines are overlayed in Figure 7. The 2012 aerial photo shows the Ohau Inlet throat at the northernmost extent of the inlet. However, the early survey plans (1872, 1879 and 1889) show the throat some 450 m south with the aerial photo shoreline record showing the river systematically migrated northward to its present locations at ~4 m/yr, although the rate has slowed to ~2 m/yr over the past 20 yrs. Of further relevance in the earlier aerial photo record is a relict throat some 1000 m south of the present throat. This configuration appears to have resulted from a large meander evident in the early survey plans breaching the inlet side some time between the 1889 survey and the 1942 photo (location marked in Figure 7 as *Early 20th century throat*). River control works have cut off the culprit meanders with the channel now maintained further landward (see Figure 7).

A north (attached) spit characterizes the inlet and at times has extended over 3 km to the south of the present throat. The 1872 survey plan shows the spit at full extension and intercepting the Waikawa Stream (Figure 4). The early spit was 200 to 500 m wide and the 1879 plan notes that it was covered by extreme tides. This is a very large sediment body appears to be the same sand bar responsible for diverting the Waikawa southward in the late 19th century.

The 1879 survey plan shows the spit breached and the river entering the sea some 1200 m from the present throat. This pattern of spit extension and breaching appears throughout the aerial photo record with the latest extreme configuration being in the late 1970s/early 1980s. More recently the mouth has been confined to the northern half of the inlet with substantial sand accumulation and vegetation establishing on the southern half as depicted in Figure 7. The shoreline envelope at the rear of the inlet varies in width between 50 and 380 m (mean = 140 m).

3.3 Future morphological behaviours

Continued systematic northward migration of the inlet must be considered viable if natural processes and/or river control works maintain the orientation of the inlet's approach channel.

That area between the southern meander breach (Early 20th century) and the present throat some 1000 m to the north is low lying, has many relict channels (oxbow lakes) and lacks dune development along its inlet margin, all characteristics which make it vulnerable to fluvial erosion and inlet throat change.

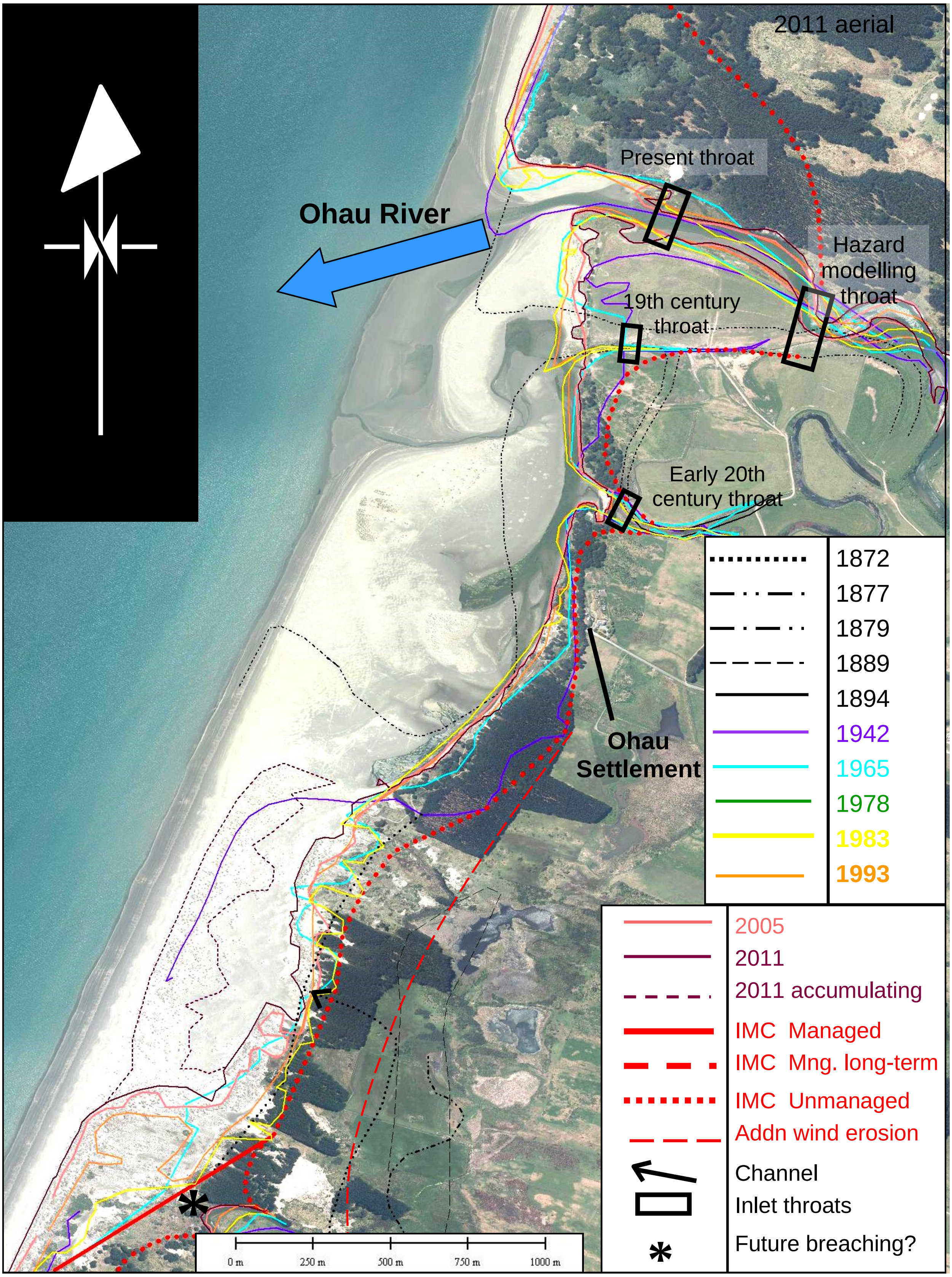

Figure 7 Ohau Inlet showing historical shorelines and inlet migration curves (IMCs) for managed and unmanaged scenarios. If no *Managed long-term IMC* is shown, then the *Managed IMC* applies. Note the final erosion hazard lines will be offset landward to acount for other influences such as effects from predicted climate change and possible additional offset for wind erosion hazard (marked).

The southern part of the historical inlet must also be considered potentially active in the future for the following reasons. While river control works may constrain the throat to the north of the inlet, the fact that the mouth occupied its southernmost location as recently as the 1980s suggests that the full range of potential (historical) locations should be considered viable, especially under an extended timeframe (100+ yrs).

3.4 Inlet migration curves

The IMCs are constructed using both the early survey plans and aerial photo-derived shorelines and approach channels as this envelope is considered potentially active. Consequently, the IMCs originate from a throat common to this extended data set, such that this throat lies several hundred metres landward of the present throat (Figure 8). With the exception of upstream river control works, **which are assumed to be maintained into the future such that the river approaches the coast within the historical envelope**, the Ohau inlet is unmanaged so a single IMC is derived.

The northern inlet IMC extends at a low angle from the throat to reflect the orientation of the approach channel, before curving seaward in keeping with the present inlet shape then bending northward to merge with the landwardmost shoreline some 1000 m beyond the present inlet. This *cubic spline* shape is characteristic these west coast inlets.

The southern IMC follows the early survey plan channel seaward before curving south to meet the landward aerial shoreline envelope in keeping with the method illustrated in Figure 3. The IMC deviates landward in keeping with the early 20th century inlet breach, and two alternatives are depicted at the inlet's southern extreme to merge with the Waikawa's IMCs which includes a entry at the site of its nineteenth century mouth.

3.5 Erosion Hazard Lines

The EHLs for both the 50 and 100+ yr assessment periods are derived by summing the open coast parameter values (equation 1) and offsetting the resulting distances from the IMC.

Should the Ohau Inlet again become active to the south as last occurred during the late 1970s/early 1980s, then significant wind erosion along the inlet margin could occur. **Consideration should thus be given to deepening the erosion hazard zone when defining the final EHLs in this area, and a suggested setback line is shown in Figure 7 (dashed red line).**

4 HOKIO INLET

4.1 General

The Hokio Inlet has a maximum area of ~23 ha and alongshore length up to ~1450 m based on the aerial photograph record. The channel has a southerly offset throughout the early survey plan and aerial photo records, although geomorphic evidence discussed below indicates an earlier (slight) northerly offset. The catchment area is 7,000 ha (70 km^2) and the mean annual flood flow at the mouth is 35 m^3/s**.** The inlet's adjacent seaward shorelines are undergoing long-term progradation of about 1.6 m/yr on the northern side and 1.0 m on the southern side.

4.2 Past and present morphological behaviour

Past shorelines are overlayed in Figure 8. A large indentations on the 1942 northern open coast shoreline coupled with the adjacent (to landward) curving channel meander (forming dogleg marked in Figure 8) indicate that the earlier inlet may have had a northerly offset, and other morphological indicators in the aerial photographs support this assertion including the depicted deflation area (RL = 3 m). The dogleg channel configuration has remained constant throughout aerial photo record possibly due to the adjacent sand dune (up to 15 m high and possibly formed of sand from the deflation basin) impeding meander development. The prograding northern open coast shoreline has enabled and a 200 m wide foredune complex to develop through the 69 yr aerial photo record.

The Hohio Inlet is characterized by systematic southward migration with the northern shoreline migrating over 100 m during the aerial record, and southern shorelines up to 300 m. This systematic migration is also inferred by the 1887 channel shape which bends (deflected?) southward and suggests that the large sediment influx which played such an important role in the historical evolution of both the Waikawa and Ohau inlets may also have been influential here.

The photogrametric DTM (not shown) defines a low lying area between the channel dogleg (marked in Figure 8) and foredune and this is also indicative of rapid coastal progradation.

A 130 m long groyne orientated ~20 degrees south of shore normal is first evident in the 1983 aerial photo. The groyne was constructed along the northern side of a seaward perturbation which existed throughout the earlier aerial photo record (a similar configuration exists at Waikawa). Note such features typically occur where an approach channel meets an inlet. It appears that the groyne structure was build to contain bank erosion considered a threat to southern end of the settlement. This erosion may be caused by the littoral sand influx during the 1960s (evident in the aerial photo) deflecting the channel landward.

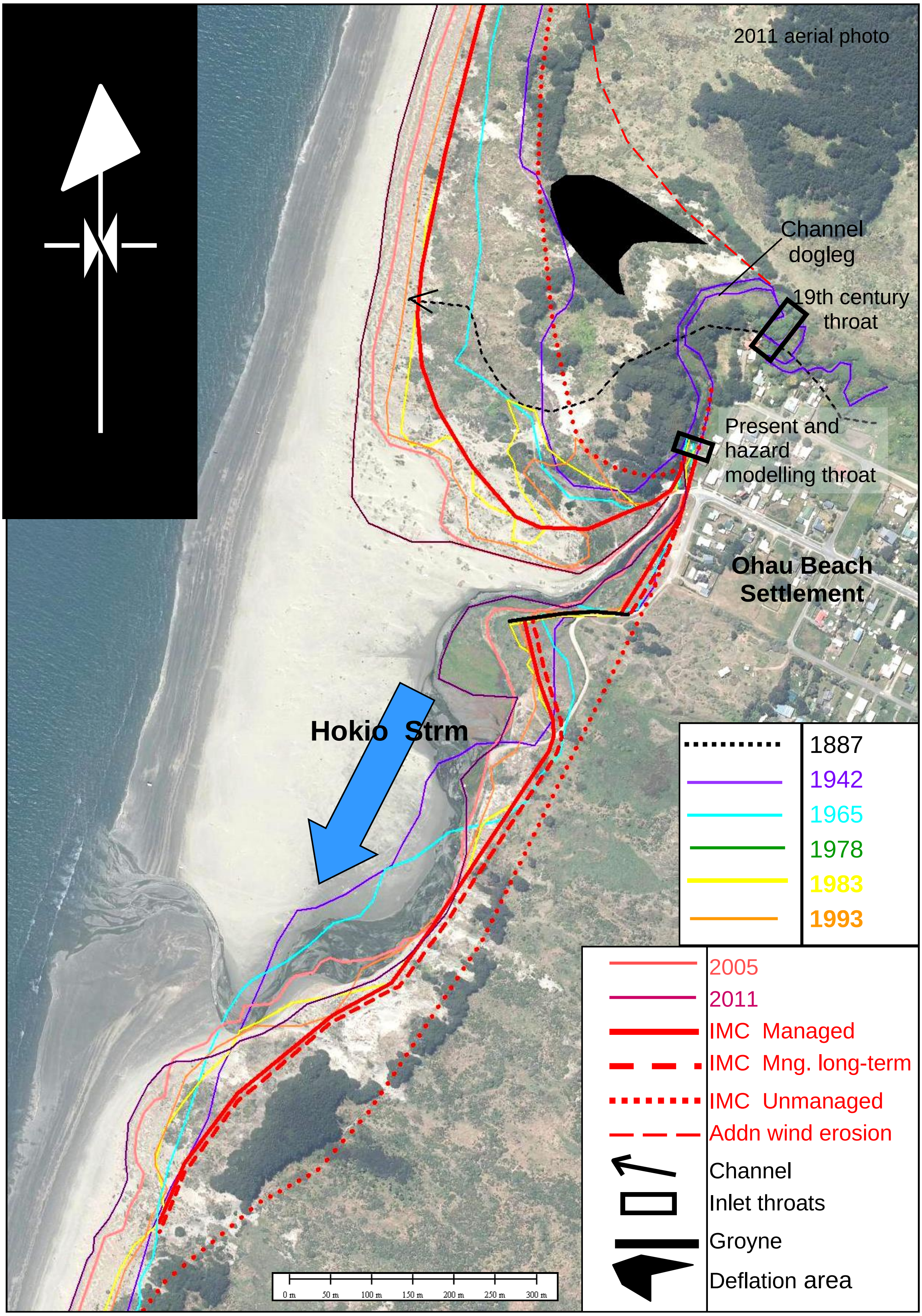

Figure 8 Ohau inlet showing historical shorelines and inlet migration curves (IMCs) for managed and unmanaged scenarios. Where no *Managed long-term IMC is* shown then the *Managed IMC* applies. The marked deflation area has been stable for the past 10 yrs. Note the final erosion hazard lines will be offset landward to account for other influences such as effects from predicted climate change and possibly additional offset for wind erosion hazard (marked).

Under natural conditions, this perturbation may be expected to translate southward as the northern side of the inlet migrates south. However, since groyne construction the perturbation has grown in size especially on the southern side.

The northern shoreline has become relatively stable in the vicinity of the groyne, but further seaward sand accumulation, dune building and inlet shoreline migration (southward) are proceeding.

South of the groyne/perturbation, the channel’s point-of-contact (active erosion) with the inlet shoreline results in active erosion and this locus has migrated from 200 m beyond the structure at the time of construction to 400-600 m alongshore, behaviour that suggests a causal affect. Interestingly, the shorelines along the back of the inlet has not receded landward of the 1983 shoreline indicating the groyne is not having a significant effect. Eight to 10 m high active dune scarps occur in this area with associated sand drifts extending inland. However, such processes along the back/southern side of inlet are evident throughout the aerial photo record.

The southern inlet shoreline has migrated ~220 m southward during the aerial record at an average rate = 3.2 m/yr. The rate prior to groyne construction = 5 m/yr to the south, but after construction the shoreline adjusted northward some 23 m (linear regression rate = 0.8 m/yr. While this may reflect the structure influence, some slowing of the pre-groyne southward migration would be expected as the system moves toward equilibrium.

In summary, as at Waikawa, the groyne influence appears to be to constrain and confine inlet migration.

4.3 Future morphological behaviour

The northern side of the inlet will likely behave much as the Waikawa, with the groyne coming under increasing load as the shoreline and dunes encroach. Further into the future, and if open coast progradation continues, the northern inlet shoreline could outflank the groyne and a dogleg channel result with increased likelihood of erosion along the back of the inlet associated with channel meander processes. However, should climate change predictions eventuate, the underlying open coast progradation may be limited and the groyne itself, as well as adjacent rear inlet shorelines, will be more susceptible to erosive precesses.

The future behavour of the southern inlet shoreline is less certain. Given the uncertainty of the groyne effect in slowing the rate of southward inlet migration and the expected enhanced erosion associated with climate change, some ongoing seaward extension of the inlet must be assumed under the longer-term managed scenario and more significant southward migration under the natural scenario.

Finally it is noted that while the deflation area presents a potential weakness in the dune buffer should systematic erosion of the foredune and seaward channel meander at the dogleg occur, it is considered most unlikely in inlet reconfiguration would occur (with associated erosion affecting the settlement) as firstly the channel is historically stable at this location (see Section 4.2) and secondly, sand from an eroding foredune would fill the deflation zone. However, significant open coast erosion, from climate change or natural processes, could facilitate wind erosion and wind-blow sand upwind of the settlement, so incorporating additional capacity when making the EHL selection would be precautionary (Section 4.4).

4.4 Inlet migration curves

The present inlet throat is located ~50 m upstream of the beach access bridge, and given the stability of the upstream channel, the approach orientation into the inlet is likely to remain into the future. The inlet configuration (offset) to the south is long established both before and after the groyne construction, so can be assumed to persist into the future.

Managed IMCs

The post groyne shorelines (1983-2012) are used to define managed inlet behaviour (IMC) using the method illustrated in Figure 2. The managed scenario requires local government agents to maintain the groyne and ensure the approach channel alignment remains essentially unchanged.

Because the post groyne-affected (managed) shorelines are too few to confidently define the managed IMC in the “longer-term” (100+ yrs) given the possible morphological responses already discussed, the following modifications have been applied. No change is required for the northern side of the inlet as this shoreline has become very stable since groyne construction and the underlying tendency for morphological change will be for this shoreline to migrate south (by outflanking the groyne). Some additional shoreline response may occur along the rear and southern sides of the inlet so an additional 10 m offset is applied (as used in the Waikawa assessment). The combination of the northern shoreline outflanking the groyne and the effects of climate change mean that the observed (post groyne) northward migration of the southern shoreline cannot be assured in the longer-term and it is beyond the scope of this assessment to more definitively model any such behaviour. As a precautionary measure, the longer-term managed southern IMC has thus been offset southward by some 11 m, this being 50% of the observed post groyne net shoreline change, the same approach as used for the Waikawa assessment (Section 2)

Unmanaged IMCs

On the northern side of the inlet, the pre-groyne shorelines are used as the basis for defining the IMC. The perturbation immediately south of the groyne has been excluded from the IMC as this feature can be expected to migrate south as the inlet systematically extends in that direction. It is unclear how far south the inlet could migrate to reach equilibrium under an unmanaged regime; however, and there will be a limit thus making the average pre-groyne rate of 5 m/yr unlikely to persist throughout the assessment period. A rate of 50 % of the pre-groyne rate, i.e. 0.5 * 5, will be used, this also approximates the 1942 to 2011 rate of 2.7 m/yr.

4.5 Erosion Hazard Lines

The 50 yr EHL can confidently be based upon the managed IMC, but requires an assurance from local government that alignment upstream of the throat is maintained and the groyne also maintained.

There are two options for the 100+ yr EHL.

1) Based on the managed IMC this again requires local government agencies to ensure the alignment of the river channel at, and upstream of, the throat is maintained and inlet control structure maintained and modified to ensure the channel and inlet sides remain within the defined EHLs for at least 100 yrs.

2) Based on the natural IMC and requires no assurances from councils. The southward migration of the inlet has likely been overestimated by the IMC; however, this is acceptable given the undeveloped nature of the terrain. Furthermore, such an extension helps address the dune erosion and wind-blown issue which this area has been, and will continue to be, subjected toe, especially if climate change predictions eventuate.

   With this high potential for wind erosion and wind-blown sand in mind, **consideration should also be given to extending the landward margin of the EHZ on the northern side of the stream right to the present channel between the beach access bridge and the upstream dogleg, and thence seaward as a precautionary measure.**

Option 2 better meets the purpose of the RMA 1991 in that it more comprehensively promotes the sustainable management of natural and physical resources

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