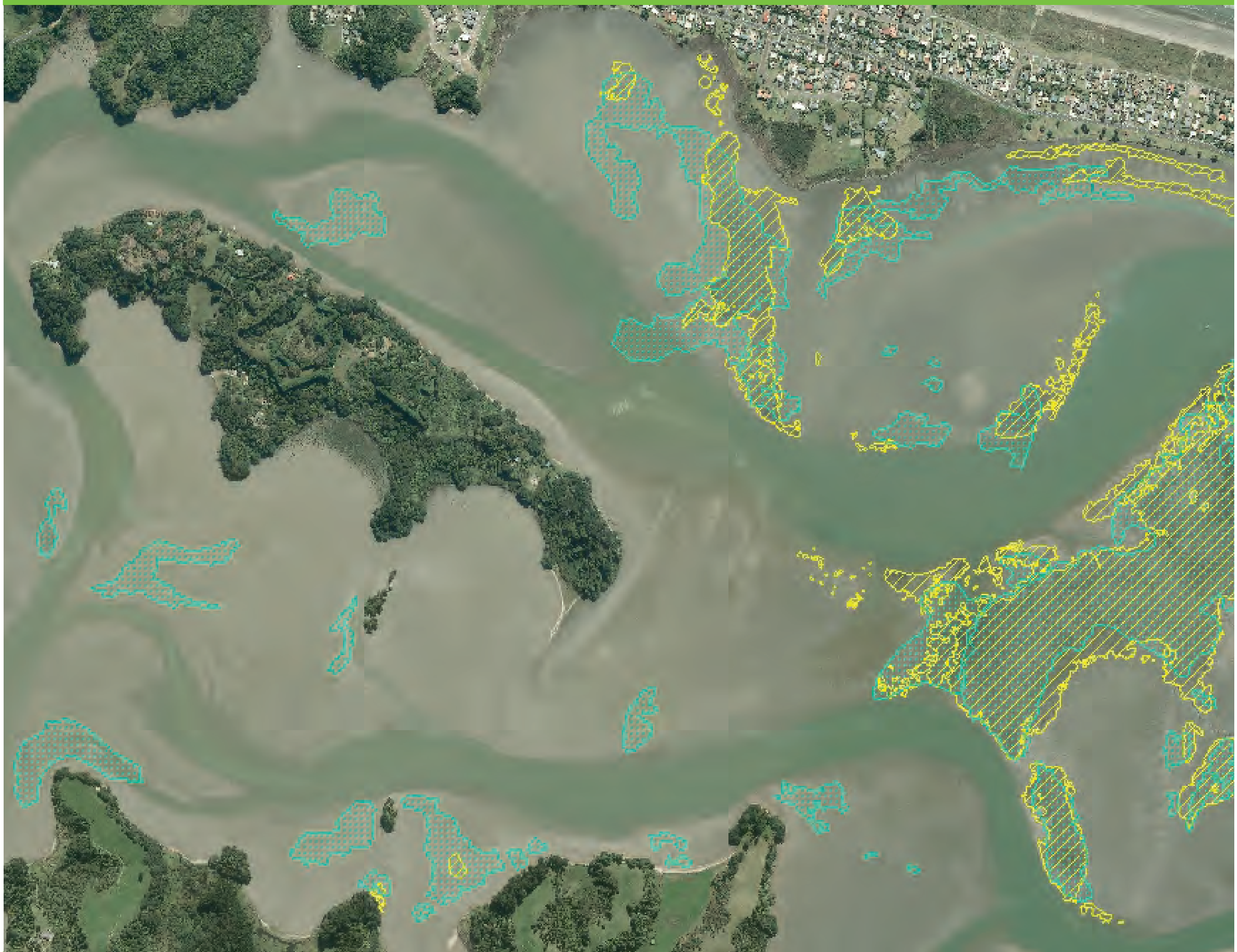
Extent of seagrass in the Bay of Plenty in 2011



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Prepared by Stephen Park

Cover: Seagrass in Ōhiwa Harbour showing the changes in distribution of the 1945 (aqua) and 2011 (yellow) mapped extents.

Acknowledgements

Kayla Manson and Connor Abbot are acknowledged for the hours of work they did on mapping most of the seagrass (31,000 tedious polygons) in Tauranga Harbour. The Geospatial Team are also acknowledged for their support in various stages of the mapping work.

Executive summary

Seagrass *(Zostera muelleri)* beds were mapped from 2011 aerial photography for the entire Bay of Plenty. Most of the region wide total of seagrass is in Tauranga Harbour (96.4%, 2,744.9 ha), while 3.5% (100.5 ha) is in Ōhiwa Harbour and the remaining 0.1% is found in Maketū, Waihī, Waiōtahe and Waioeka estuaries.

Comparison of seagrass in Tauranga Harbour between 1996 and 2011 shows a loss of 192 ha with a small increase in the southern harbour. A small increase was also found for Ōhiwa Harbour between 1996 and 2007 - however between 2007 and 2011 a loss of seagrass occurred. It is likely that the small increases in Ōhiwa Harbour between 1996 and 2007, and in the southern Tauranga Harbour between 1996 and 2011, are due in part to method differences.

In the Tauranga and Ōhiwa harbours, historic losses of seagrass tended to be in the upper harbour or sub-estuary areas, those with larger catchment influence. This spatial pattern of loss indicates that water quality issues related to sediment and nutrient inflows are an important factor. The 2011 spatial extent of seagrass compared to 1996 shows that distribution in relation to catchment inflows has not changed significantly as it has in the past. This indicates that catchment water quality factors associated with historic seagrass losses may be stabilising. This is further supported by the fact that the more recent seagrass losses in both Tauranga and Ōhiwa harbours appear to be at a much lower rate. The 2007 to 2011 rate of loss in Ōhiwa Harbour (0.25 ha/year) is lower than the 1945 to 1996 rate of loss (1.34 ha/year). Future mapping using identical methods will be important in verifying current trends.

Contents

Part 1: Introduction

1.1 Purpose

The purpose of this study is to provide mapping of seagrass extents throughout the Bay of Plenty and assessment of trends and changes over time. In particular the mapping provides:

- Monitoring data to meet Bay of Plenty Regional Council's legislative obligations to monitor the state of the environment under the Resource Management Act.
- Information to assist management of the Bay of Plenty harbour ecosystems and to help understand how land catchment activities influence changes in distribution or abundance of seagrass.

1.2 Scope

This report focuses on mapping of seagrass extents based on aerial photography delivered as part of the Regional Digital Aerial Mosaic (RDAM) programme for the Bay of Plenty. Specifically it will provide:

- Accurate estimates of seagrass extents in 2011 for the entire Bay of Plenty.
- An accurate estimate of rates of change over time in estuaries or sub-estuaries throughout the Bay of Plenty where historic extent information is available.

1.3 Background

1.3.1 Seagrass

Seagrass beds are known to be one of the most productive habitats in temperate coastal ecosystems. They also help to stabilise sandflats and increase structural complexity which increases overall species diversity. In New Zealand, subtidal seagrass beds are also known to be important habitats for juvenile fish including commercially important species such as snapper.

New Zealand has a single temperate species of seagrass which is generally referred to as *Zostera muelleri*. A phylogenetic analysis of genetic and morphological characteristics of the Australian and New Zealand species of *Zostera* by Les et al. (2002) determined that *Zostera capricorni, muelleri, mucronata* and *novaezelandica* were the same species and recommended that *Z. capricorni* be used. However, since *Z. muelleri* has priority, it should have been the accepted name and is commonly used to refer to this seagrass.

Seagrass is a euryhaline species (able to live in a wide range of salinities) that is capable of living near stream mouths or other areas where the water is fresh at low tide but requires periodic immersion in water of higher salinity. The ideal salinity range for optimum growth is around 10 to 30 practical salinity units (psu). Sea water has a salinity of 35 psu. Seagrass (*Zostera spp*.) is known to flower more frequently, increase seed production and have higher germination rates in lower salinity (Philips et al. 1983, Conacher et al. 1994, Tanner & Parham 2010, Ramage & Schiel 1998). *Z. muelleri* also has wide salinity tolerance and has been shown to produce the highest shoot density at 12 psu after ten weeks (Collier et al. 2014) compared to higher or lower salinities. In addition, estuarine seagrass has been shown to have lower vitality at higher salinities in the presence of high nutrient loads (Katwijk et al., 1999). These traits along with other important factors such as light limitation influence the distribution of seagrass.

1.3.2 Bay of Plenty coastline

The Bay of Plenty is located on the northeast coast of the North Island, New Zealand and has 258 km of exposed coastline stretching from Waihī in the northwest of the region to Lottin Point in the east. There are a number of coastal inlets and nearly all can be classed as estuaries. Larger inlets tend to be barrier enclosed estuaries while there are a number of smaller river mouth estuaries.

Tauranga Harbour

Tauranga Harbour is the largest estuarine inlet in the region being impounded by a barrier island (Matakana Island) and two barrier tombolos, Mount Maunganui at the southern entrance and Bowentown to the north (Healy and Kirk 1981). The harbour is shallow and covers an area of 201 km^2 with 66% of its total area being intertidal. It has three main basins with the largest being the northern and southern basins (separated at low tide) and the smaller Town Reach basin in the far south. At mean high water the northern basin has a volume of approximately 178 million m^3 and the southern basin a volume of 278 million m^3. There are more than 20 small sub-estuaries around the harbour.

The total harbour catchment covers an area of approximately 1,300 km^2 and is well developed with extensive horticultural and agricultural use. The northern harbour basin has a catchment area of 270 km^2 and a mean freshwater inflow of 4.1 m^3/s or 0.1% of the harbour volume per tidal cycle. The southern catchment has a total area of 1,030 km^2 and a mean freshwater inflow of 30.5 m^3/s which is 0.48% of the harbour volume per tidal cycle.

Ōhiwa Harbour

Ōhiwa Harbour is a 26.4 km^2 estuarine lagoon enclosed by the Ōhope and Ōhiwa barrier spits. It is shallow with 83% of its area being exposed sand and mudflats at low tide. The harbour has a very low volume compared to the spring tidal compartment and is dominated by tidal currents. Residence time of water in the harbour is low and estimated to be 1-2 tidal cycles. The Nukuhou River with a median flow of 0.98 m^3/s is the main freshwater inflow to the harbour.

Other estuaries

The larger of the remaining Bay of Plenty estuaries are all barrier enclosed and include Waihī Estuary covering 2.4 km^2, most of which dries at low tide. The main freshwater inflow is the Pongakawa Stream with a median flow of 4.6 m^3/s. Maketū Estuary covers 2.3 km^2 and is very shallow with extensive tidal flats. It is the former outlet for the Kaituna River and currently receives only 100,000 m^3 per tidal cycle of the river flow. Whakatāne and Waiotahe Estuaries cover around 1.3 km^2 and 1.0 km^2 with small areas of intertidal flats influenced by river flow. The remaining estuaries are smaller again and tend to be river mouth estuaries with a very high river influence.

Part 2: Location and methods

Seagrass mapping for the whole of the Bay of Plenty region was carried out using 2011 aerial photography. This includes all estuaries extending from the northern end of Tauranga Harbour along the coast to Whangaparaoa River near Cape Runaway in the east. The 2011 aerial photography comprised a digital tiled mosaic of the whole region. Resolution of photography (flown at 13,000 ft) was 25 cm pixels over the areas covering the estuaries. Some estuary areas near the open coast have additional photography at 12.5 cm pixel resolution. Spatial registration accuracy of 2011 aerial photography is +/- 0.50 m for >90% of coverage.

Mapping of seagrass beds was done using GIS software (ArcMap 10.2) to create data sets (polygons) classified according to the average coverage (20%, 50%, 75%, 95% and 100%) in any areas they occur. To ensure consistent accuracy of mapping at a scale of 1:500, a protocol was used to guide the mapping process (see Appendix 1). Mapping was essentially a desktop exercise with minimal ground truth surveys for Tauranga Harbour due to the large extents. Ōhiwa Harbour and the smaller estuaries all had ground truth surveys to verify the existence of seagrass beds.

Assessment of total seagrass coverage in any harbour or other defined area is based on summing up the total area mapped in each class, then using the midpoint (i.e. 60-90% class midpoint = 75%) to calculate out an estimate (average) of the actual area covered for each class and then adding up all the classes of coverage mapped. For Ōhiwa Harbour and the smaller estuaries, all assessments of change are based on a whole harbour/estuary basis. Tauranga Harbour has been divided up into a series of smaller areas (see Figure 2) to allow for analysis of sub-estuary areas or more open regions of the harbour.

Data presented for earlier surveys (1945, 1959, 1992 and 1996) is based on lower resolution photography (generally 1 m pixels) and is mapped at a higher scale (1:2,000). Methodology was changed for the current and future surveys to allow more accurate comparison of spatial abundance and distribution within smaller areas such as the sub-estuaries around Tauranga Harbour. This will also allow more detailed analysis of water quality and other factors as suitable datasets are established.

Part 3: Results

3.1 Entire Bay of Plenty

Occurrence of seagrass in the Bay of Plenty is predominantly within Tauranga and Ōhiwa harbours. Small areas of seagrass occur in Maketū, Waihī, Waiotahe and Waioeka estuaries. There is no seagrass found in the very small riverine estuaries between Ōpōtiki and Whangaparaoa River near Cape Runaway in the Eastern Bay of Plenty.

Tauranga Harbour has a total area of 2,744.9 ha or 96.4% of all seagrass in the Bay of Plenty. Ōhiwa Harbour has a total area of 100.5 ha or 3.5% of the Bay of Plenty total. The remaining 0.1% occurs in Maketū, Waihī, Waiotahe and Waioeka estuaries.

Mapping of the seagrass extents is held by Bay of Plenty Regional Council on its GIS database. Time series data is provided below for Tauranga and Ōhiwa harbours. Maketū Estuary also has time series data which has been previously published (Park 2014) and identifies a marked loss of seagrass linked to the loss of freshwater inflow from the Kaituna River.

3.2 Tauranga Harbour

Mapping of Tauranga Harbour has been previously carried out for 1959 and 1996 with results presented in Park (1999a, 1999b). Although there are numerous other dates on which aerial photography has been carried out, those were two surveys in which the quality of imagery or degree of cloud cover were acceptable for the whole harbour.

3.2.1 Tauranga Harbour total seagrass extents

The historical extents are compared to the 2011 extents in Table 1 below and shown graphically in Figure 1.

Table 1 Extents of seagrass cover (ha) in Tauranga Harbour for 1959, 1996 and 2011.

Year	Total (ha)	Northern (ha)	Southern (ha)
1959	4,423.917	1,978.093	2,445.824
1996	2,936.998	1,802.075	1,134.923
2011	2,744.894	1,566.457	1,178.436

As shown in Table 1, Tauranga Harbour had lost over 1,000 ha (34%) of seagrass beds between 1959 and 1996 with most of that loss occurring in the southern harbour where around 50% disappeared. Between 1996 and 2011 the overall loss is 192 ha (6.5%) with all of the loss having occurred in the northern harbour. Of note is that between 1959 and 1996 the loss for the whole harbour was around 27 ha/year and then between 1996 and 2011 it has reduced down to 12.8 ha/year which is significantly lower. In the same period the southern harbour total showed a very small increase (3.8%).

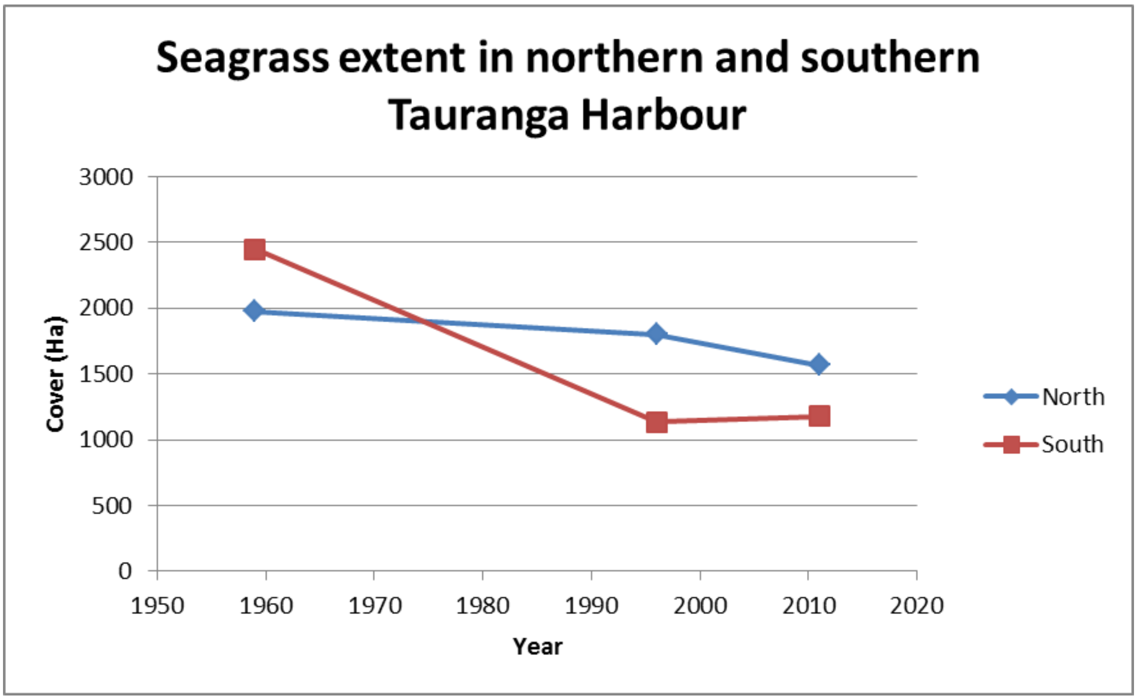

Figure 1 *Extents of seagrass cover (ha) in northern and southern Tauranga Harbour for 1959, 1996 and 2011.*

3.2.2 Tauranga Harbour sub-estuaries/areas seagrass extents

To provide a consistent basis for historical comparison of seagrass extents, regions of the harbour have been defined using a mapping layer which can be used in GIS to classify all the seagrass beds mapped in each of the surveys. The location map is provided in Figure 2 while the total extent of cover in each area for each of the surveys is set out in Table 2 below along with the percentage change that has occurred since the previous survey.

Table 2 *Extents of seagrass cover (ha) in defined areas of Tauranga Harbour for 1959, 1996 and 2011 and percent change between each survey.*

	1959	1996	% change	2011	% change
Northern harbour locations					
Blue Gum Bay	381.201	359.537	-6	372.273	4
Bowen Blackney	98.530	79.414	-19	65.564	-17
Egg Island	63.729	81.927	29	31.805	-61
Katikati	28.454	38.210	34	45.355	19
Kauri Point	84.539	124.361	47	59.019	-53
Matahui east	311.744	286.741	-8	213.074	-26
Matahui west	123.388	44.680	-64	63.655	42
Matakana north	109.911	98.573	-10	48.416	-51
Mid-harbour north	421.928	364.895	-14	372.696	2
Ongare	8.609	4.764	-45	9.054	90
Rereatukahia	31.074	0.000	-100	0.118	-
Tuapiro Athenree	266.701	271.008	2	253.789	-6

	1959	1996	% change	2011	% change
Northern harbour locations					
Tuapiro Estuary	9.077	16.926	86	12.244	-28
Uretara Estuary	13.521	6.274	-54	5.014	-20
Waiau Estuary	25.685	24.765	-4	14.382	-42
Southern harbour locations					
Aongatete	77.615	47.497	-39	50.270	6
Duck Bay	50.788	19.584	-61	29.081	48
Hunters Creek	106.587	86.630	-19	80.819	-7
Mangawhai Estuary	28.961	12.479	-57	19.138	53
Mid Harbour south	765.417	370.161	-52	450.884	22
Motuhoa Island	150.106	13.281	-91	33.848	155
Ōmokoroa	24.748	14.161	-43	26.905	90
Opureora	231.716	141.125	-39	109.337	-23
Otumoetai	51.501	32.405	-37	17.999	-44
Pahoia	5.493	4.070	-26	8.598	111
Rangataua Bay	184.726	39.965	-78	25.228	-37
South Entrance	0.360	0.000	-	0.005	-
Te Puna Beach	86.569	8.734	-90	7.710	-12
Te Puna Estuary	22.306	10.078	-55	17.537	74
Town Reach	89.183	42.929	-52	26.472	-38
Waikaraka Estuary	3.059	1.516	-50	2.593	71
Waikareao Estuary	6.024	0.742	-88	1.276	72
Waimapu Estuary	54.651	45.739	-16	44.793	-2
Wainui Estuary	18.857	6.108	-68	17.528	187
Waipapa Estuary	107.685	45.125	-58	50.438	12
Waipu Bay	66.266	56.329	-15	48.449	-14
Wairoa Estuary	299.092	132.954	-56	107.218	-19
Welcome Bay	14.113	3.312	-77	2.311	-30

In the northern end of Tauranga Harbour, the Blue Gum Bay, mid-harbour north and Tuapiro/Athenree areas contain 64% of the seagrass beds and between 1996 and 2011 there is very little change in coverage. Between 1959 and 1996 this area also showed only a minor decrease in seagrass coverage. The Bowentown/Blackney Channel mapping area has shown a steady decline (17-19%) which is mainly confined to the beds located on the flood tide delta. Other areas in the more open area of the northern harbour showing a significant decline between 1996 and 2011 include Matahui east (-26%), Egg Island (-61%), Kauri Point (-53%) and Matakana north (-51%) areas. The Matahui west area showed a large decline from 1959 to 1996 but has shown an increase in coverage (42%) between 1996 and 2011. The adjacent Katikati area has shown increases between all surveys.

Figure 2 *Areas of Tauranga Harbour defining the mapping areas used for naming location of seagrass beds and subsequent analysis of long-term changes in coverage of seagrass (ha) in northern and southern Tauranga Harbour for the 1959, 1996 and 2011 surveys.*

The small enclosed sub-estuaries of the northern harbour (Waiau, Tuapiro, Rereatukahia and Uretara) have shown losses since 1996 although the amount lost in terms of hectares is minor (7%) in terms of overall change in the northern harbour. Figure 3 below shows graphically the changes that have occurred in the extent of total seagrass cover for those four estuaries.

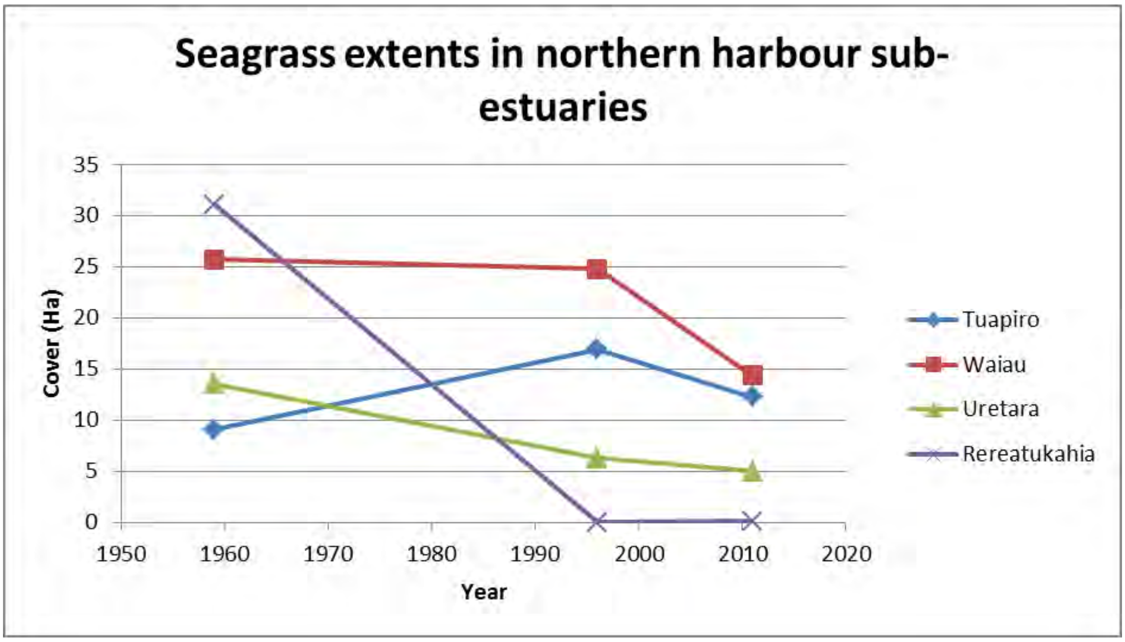

Figure 3 *Seagrass abundance (ha) in four northern Tauranga Harbour sub-estuaries for the 1959, 1996 and 2011 surveys.*

As in the northern half of the Tauranga Harbour, the largest extents of seagrass occur on the more open flats of the southern harbour with 38% occurring in the upper mid harbour mapping area. This area shows an increase since the 1996 survey but is still below the 1959 coverage. This area accounts for over 50% of the total increase seen in the southern harbour between 1996 and 2011.

Areas showing the most significant losses in the southern harbour since the 1996 survey include the Otumoetai, Town Reach and Rangataua Bay areas. These areas also showed significant declines in the 1959 to 1996 period. Nearly all areas in the southern harbour show a long-term loss in seagrass cover since 1959 with the exception of the Ōmokoroa, Wainui and small Pahoia and Waikaraka areas. The Motuhoa Island, Ōmokoroa, Pahoia, Te Puna and Wainui areas all show significant increase of seagrass cover since 1996.

Figure 4 below shows the trends in six of the sub-estuary areas in southern Tauranga, all of which have a decline in seagrass cover since 1959. The Mangawhai, Te Puna and Wainui Estuaries show an increase since 1996.

Comparison of all data between 1996 and 2011 needs to be undertaken with care due to the differences in photography resolution (1 m pixels) and mapping scale (1:2,000) and any bias those differences may have produced for total extents.

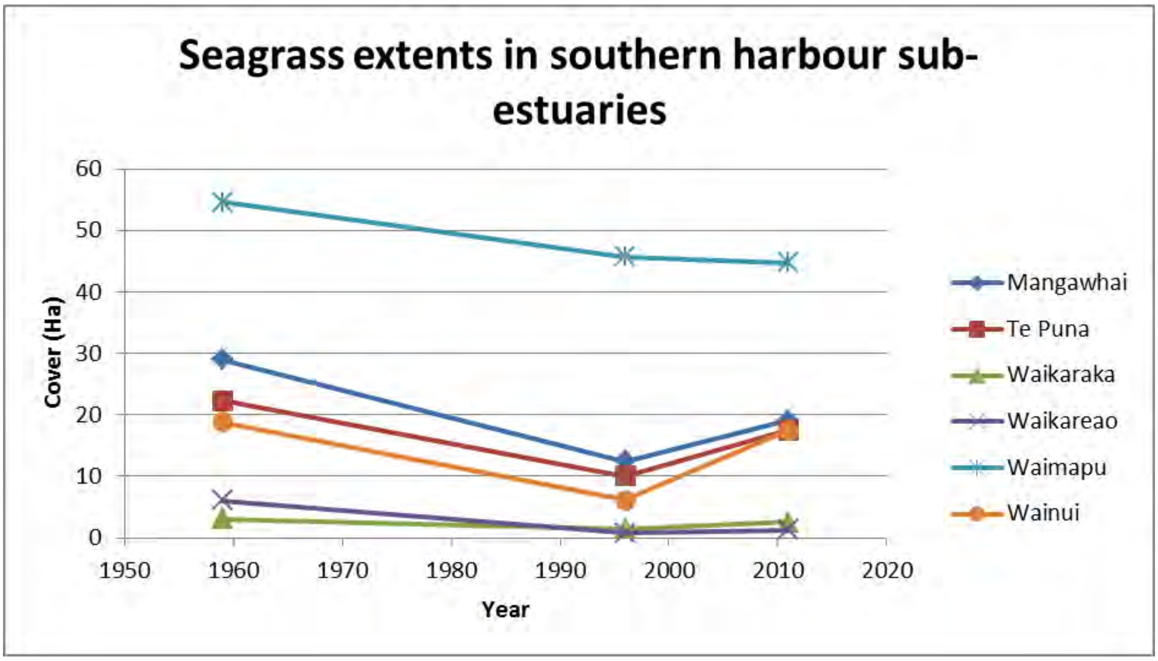

Figure 4 *Seagrass abundance (ha) in six southern Tauranga Harbour sub-estuaries for the 1959, 1996 and 2011 surveys.*

3.3 Ōhiwa Harbour

Ōhiwa Harbour has been mapped for seagrass extents for the years set out below (Table 3). The 1945, 1992 and 1996 mapping estimates are based on lower resolution photography and higher mapping scale. In the period 1945 to 1996, there was a decline in total seagrass coverage with 33 ha lost. Between 1996 and 2007 there is an increase and then between 2007 and 2011 a very small decline has been recorded. As mentioned above for the Tauranga Harbour data, care needs to be taken when comparing seagrass extents based on the different resolutions and scale which may have some bias in the total coverage values generated.

Table 3 *Extents of seagrass cover (ha) in Ohiwa Harbour for 1945, 1992, 1996, 2007 and 2011 and percent change between each survey.*

Year	Pixel size (m)	Mapping scale	Total cover (ha)
1945	1	1:2,000	121.000
1992	1	1:2,000	88.000
1996	1	1:2,000	83.345
2007	0.25	1:500	101.822
2011	0.25	1:500	100.505

Total seagrass coverage for the whole of Ōhiwa Harbour over the period 1945 to 2011 is also shown in Figure 5.

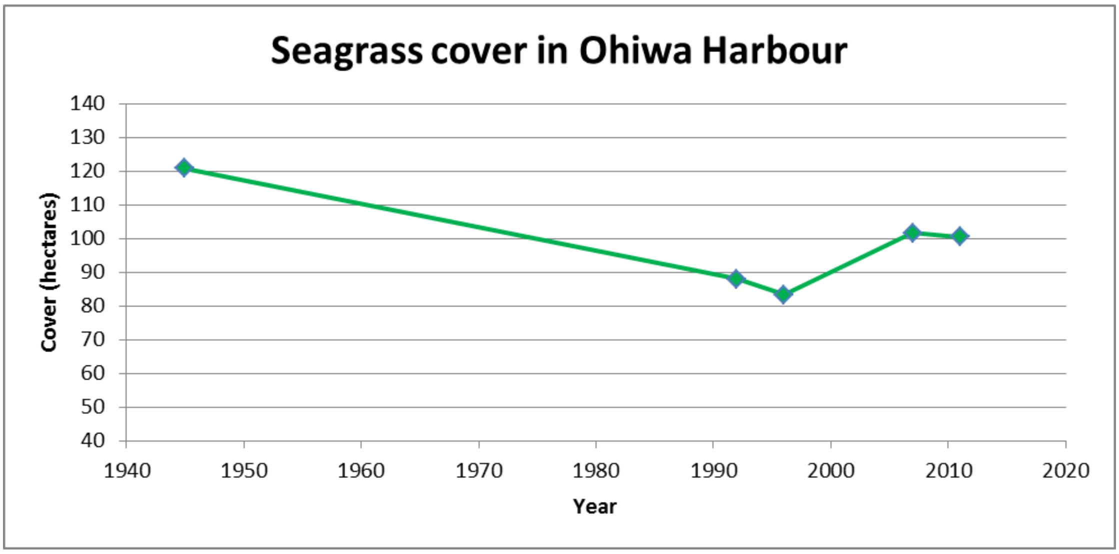

Figure 5 *Seagrass abundance (ha) in Ohiwa Harbour for the period 1945 to 2011.*

A map showing the 1945 and 2011 seagrass spatial extents is provided in Appendix 3. This shows that the loss of seagrass between 1945 and 2011 is mainly from the upper harbour areas. It also shows several areas of seagrass that were mapped in 2011 but not in 1945. These areas were difficult to pick up despite the higher resolution of the 2011 photography; hence it is possible that they were also present in 1945.

In Figure 5, the increased cover of seagrass shown between 1996 and 2007 may not be real and is more likely an artefact of differences in the mapping resolution and scale used. Hence it is possible that the long-term loss of seagrass shown between 1945 and 1996 has continued to occur. Between 1945 and 1996 the annual rate of seagrass loss was 1.34 ha/yr. Between 2007 and 2011 the rate of loss is however much lower at 0.25 ha/yr.

Part 4: Discussion

For Tauranga Harbour the 2011 seagrass mapping provides the first harbour-wide assessment of extents and abundance since 1996. Earlier mapping (1959 and 1996) had shown that extensive seagrass loss was occurring in the harbour (Park 1999a, 1999b) and that much of the loss was from upper harbour areas (sub-estuaries) and subtidal beds. This pattern of loss shows strong links to catchment effects (i.e. sediment) although a study by Dos Santos (2011) shows that other stressors on seagrass abundance are also occurring such as that from grazing impact of black swans.

Differences found in this assessment between 1996 and 2011 are not as easy to interpret as the earlier surveys which span a longer time period and show the clear spatial pattern linked to catchments. Comparison is also complicated by the difference in photography resolution which is likely to have resulted in some additional areas of seagrass being picked up compared to the older lower resolution photography. This is apparent for the Ōhiwa Harbour data where several areas were picked up and verified by ground truth survey. Hence increases observed in Tauranga Harbour between 1996 and 2011 may be solely the result of this difference and some of the losses at various locations may be even larger.

Despite the difficulty in comparing the seagrass abundance between the surveys, the patterns seen in the data are still informative. The overall result for the southern Tauranga Harbour suggests that there is a lower rate of loss, as was observed in Ōhiwa Harbour between 2007 and 2011. This could imply that the water quality factors (especially sediment) linked to previous loss of seagrass have not worsened between 1996 and 2011 and that a new equilibrium is being reached. This is in line with Tauranga catchment water quality results since 1989 to 2008 for stream inflows with none of 12 sites showing any increase in total suspended solids, while three showed some increase and two a decline in total oxidised nitrogen (Scholes & McIntosh 2009). Within the harbour, only three out of 10 sites show a long-term increase in total suspended solids and only two show an increase in readily available nitrogen (Scholes 2015). Future surveys using the same methods will be important in confirming what the current loss rates are.

The spatial extent (location) of the beds shows there is not as much loss in the sub-estuaries or upper harbour areas with large associated catchments compared to the 1959/1996 change. In southern Tauranga Harbour one of the areas of highest loss was the Otumoetai area. Between 1996 and 2011 this area was heavily grazed on numerous occasions by black swans which may have contributed, although the pattern of loss is predominantly from deeper areas which suggest water quality factors. In future, spatial GIS analysis using high resolution bathymetric models could help to quantify depth related water quality factors.

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Appendices

Appendix 1 – Seagrass mapping protocol

Seagrass mapping protocol – NERMN

Spatial mapping of seagrass for the purpose of regional monitoring (NERMN) throughout the Bay of Plenty should be done every five years using the five-yearly supply of digital ortho-rectified aerial photography as a mosaicked RDAM with 25 cm pixel resolution.

Mapping using GIS software shall have a defined attribute table using the classification parameters from previous extent mapping as held in our corporate SDE database. Parameters cover the appropriate hydrological and vegetative classes to ensure that the mapping can be included in any general biodiversity database or assessments.

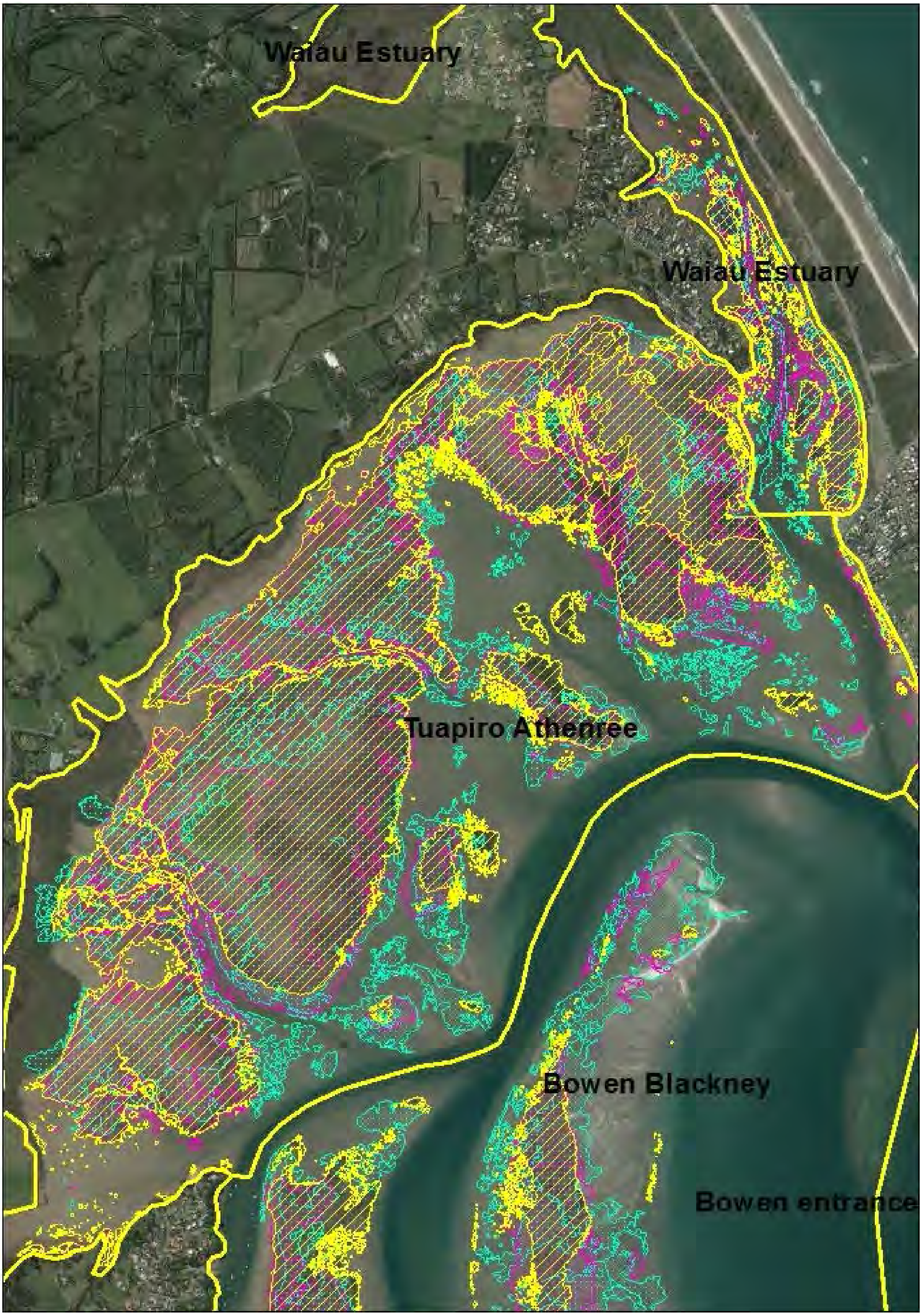
To enable accurate comparison of seagrass extent change over time, polygons are mapped according to the cover or patchiness of the seagrass beds in an area. These cover classes are 0-40% (20%), 40-60% (50%), 60-90% (75%), 90-99% (95%) and 100%. The figures in brackets are the code used in attribute tables for the cover class entry.

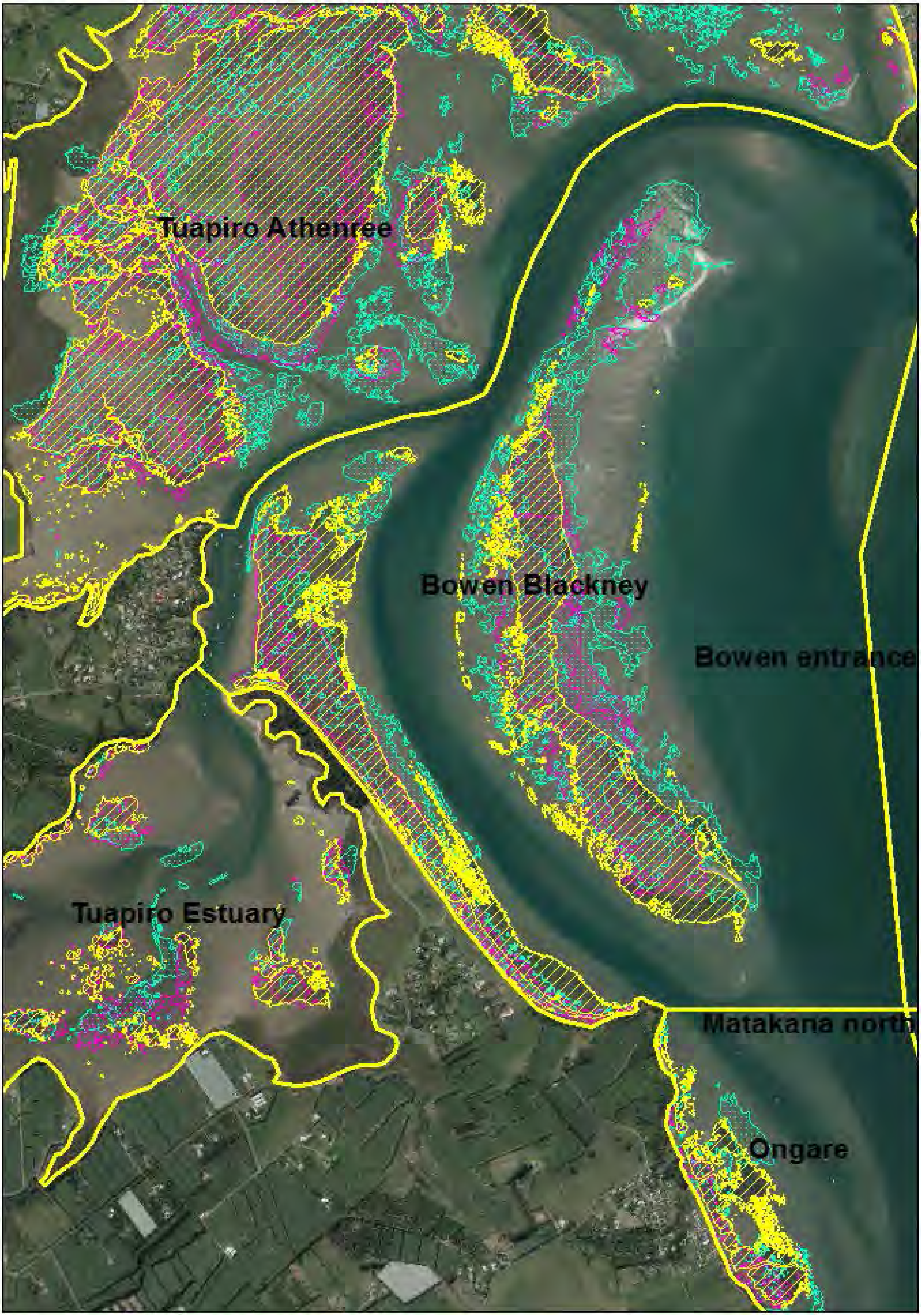
Mapping is to be done at a minimum working scale of 1:500 but not more than 1:700 (i.e. usually 1:600) and the accuracy of the finished work will be suitable for publication at scales of 1:5,000 or greater. To provide guidance on the expected accuracy of the work the following should be followed:

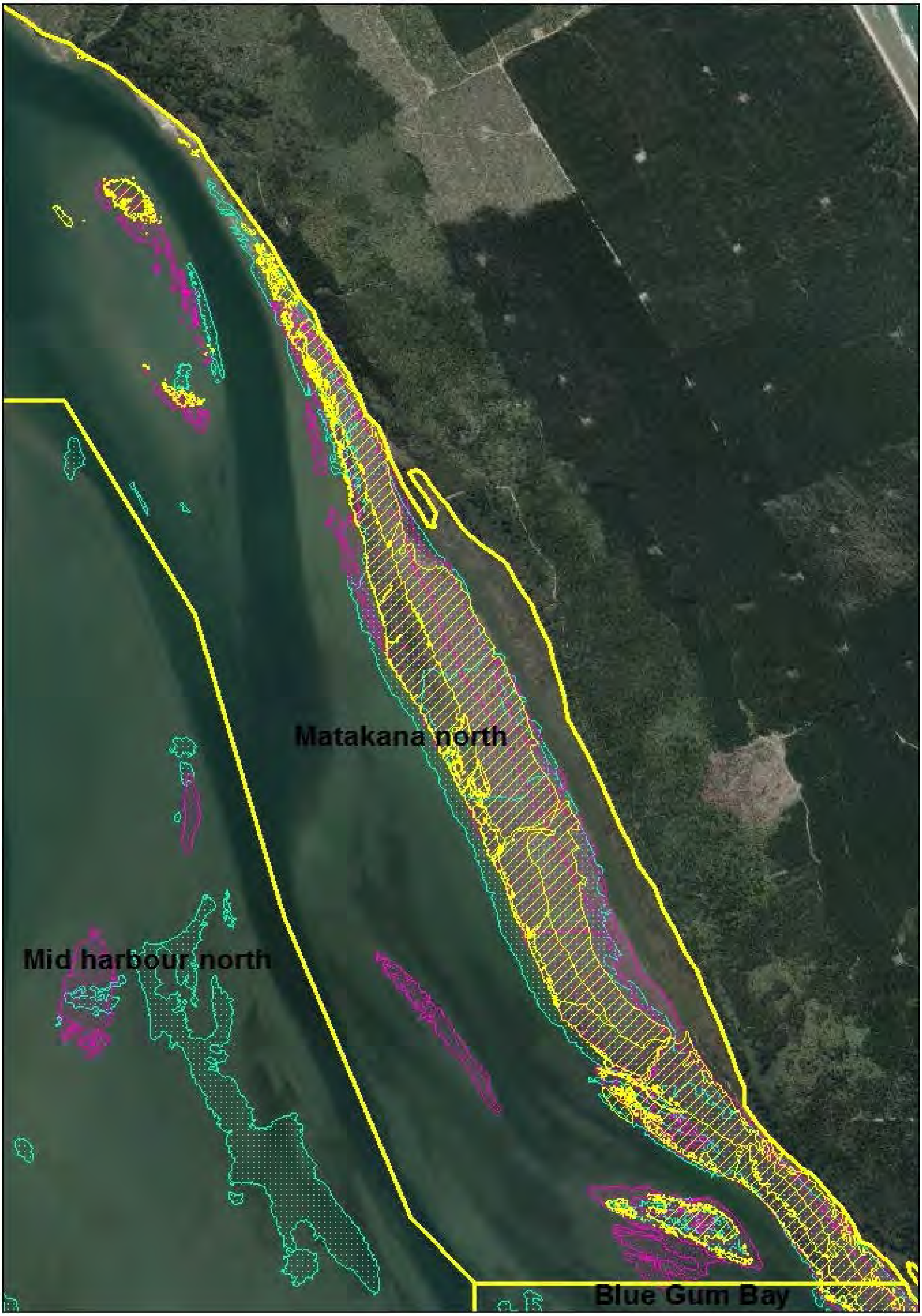
- Where larger seagrass patches (1.5 m x 1.5 m or bigger) occur as isolated beds around 5 m or more from other seagrass patches they should be mapped as a polygon showing their extent and classified at 100% cover. If part of a loose aggregation/area of seagrass patches then map polygon tightly around perimeter of greatest extent excluding as much empty area as can be reasonably done and classify overall coverage accordingly.
- In large contiguous areas of seagrass patches at varying density the seagrass beds should be mapped to define areas of similar coverage as per the coverage classes. The minimum area of seagrass patches mapped by a polygon into a defined density class should be at least 25 m^2 (i.e 5 m x 5 m) if within 5 m of larger patches or aggregations of small seagrass patches. Areas smaller than this will just be included into larger polygon areas with an appropriate overall density classification as above.
- Small seagrass patches down to 1 m x 1 m (1 m^2) are to be included in mapping where they occur as aggregations. However, if individual patches around 1 m^2 or less occur at distances of around 10 m or more from other seagrass, then they are not mapped at all.
- In areas of small seagrass patches or larger patches that have low leaf density (and usually poor colour/contrast) which are hard to positively identify, ground truth verification should be made. Some coastal areas have 12.5 cm pixel resolution photography available and this can be used as a reference to help confirm whether seagrass is present.

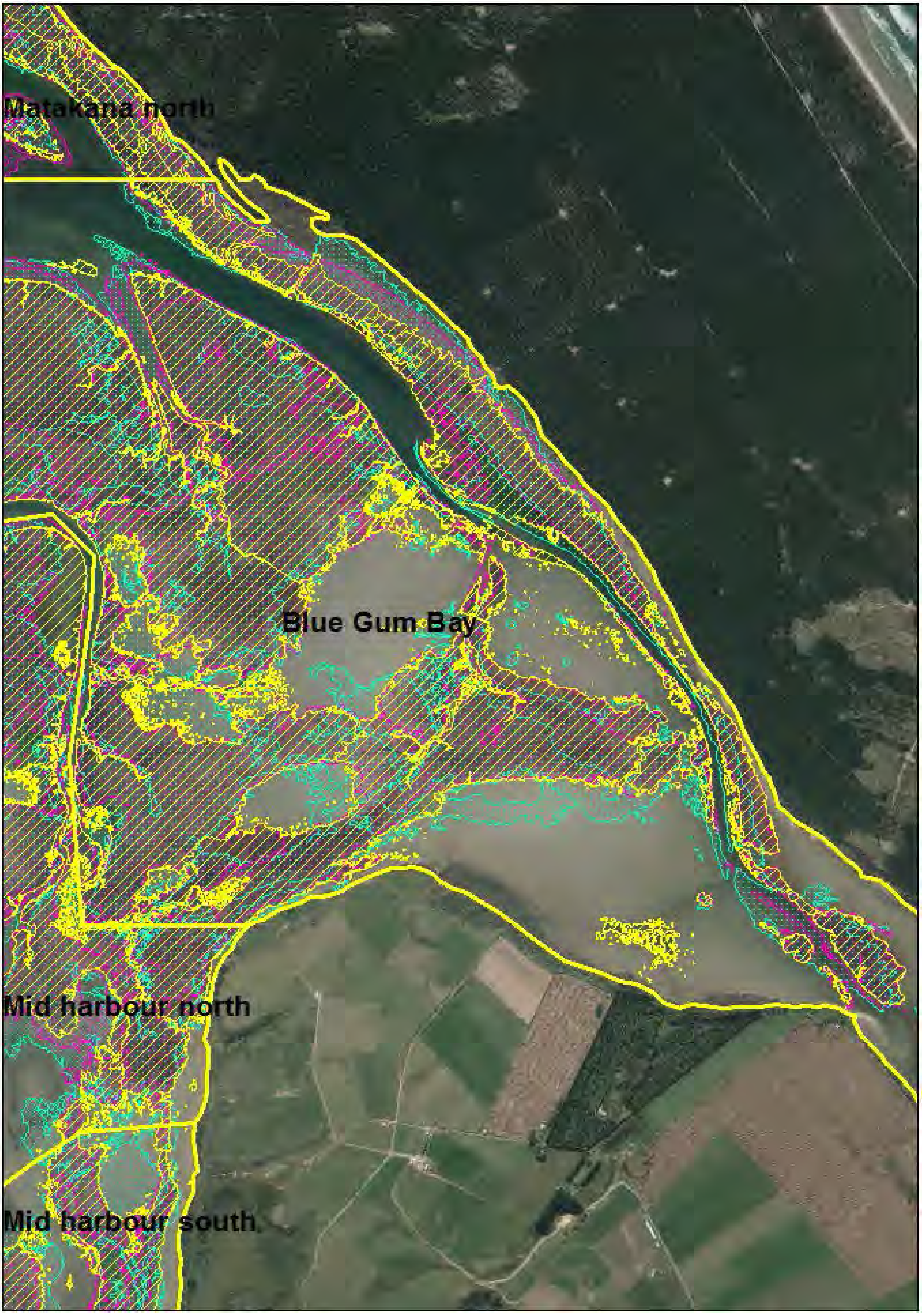
Seagrass coverage (classes/codes) is not based on the leaf density but rather the perimeter of the beds. Some beds may have numerous small patches inside the beds extent which has no seagrass present. In these cases classify as per the overall average coverage. If the bare patches inside the seagrass beds are large (>5 m x 5 m) then they can be cut out of the polygon. However, if there are very numerous bare patches in a bed then it would be better just to classify as per the average overall coverage.

Appendix 2 – Tauranga Harbour seagrass extents in 1959 (aqua), 1996 (purple) and 2011 (yellow) by mapping area

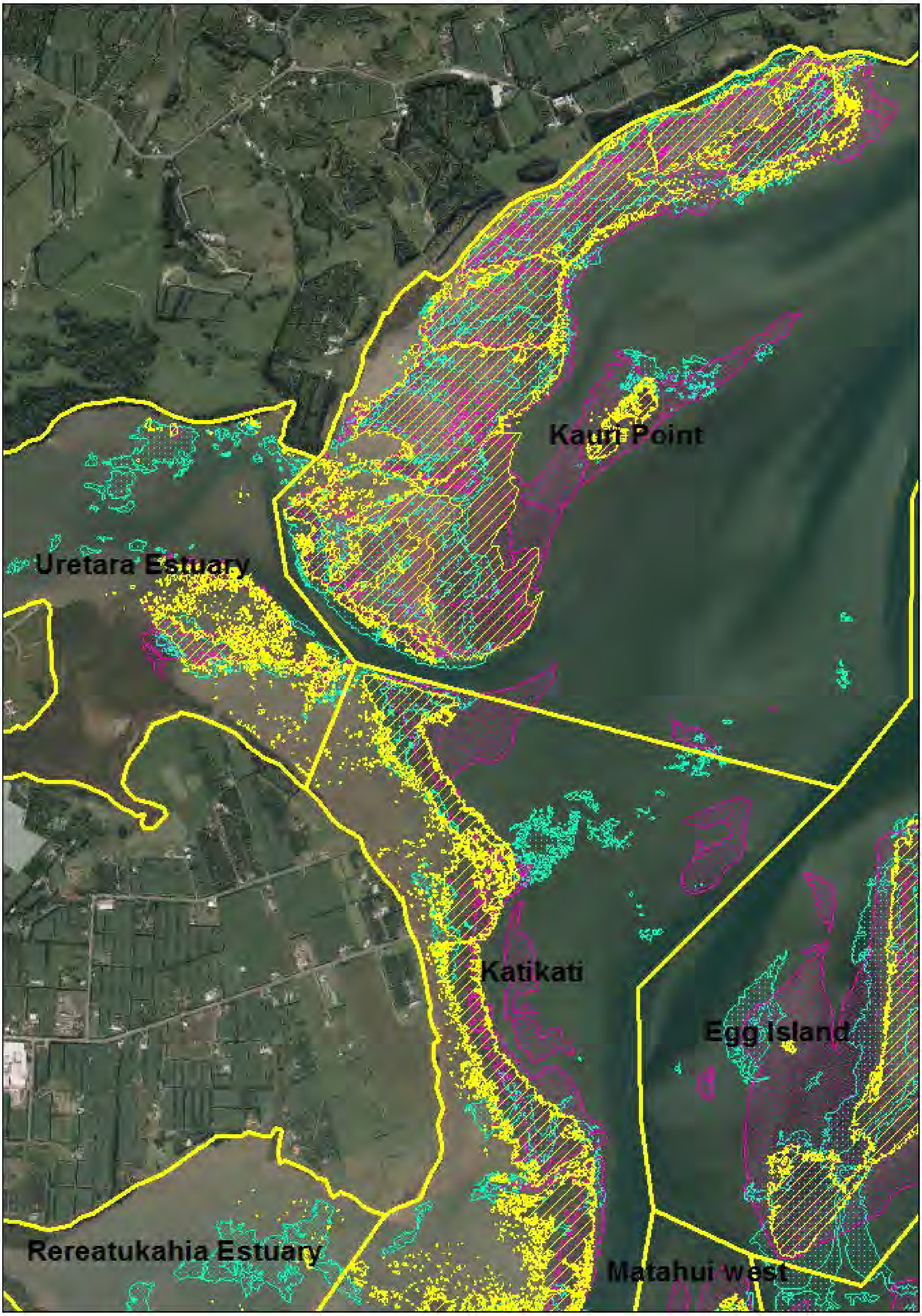


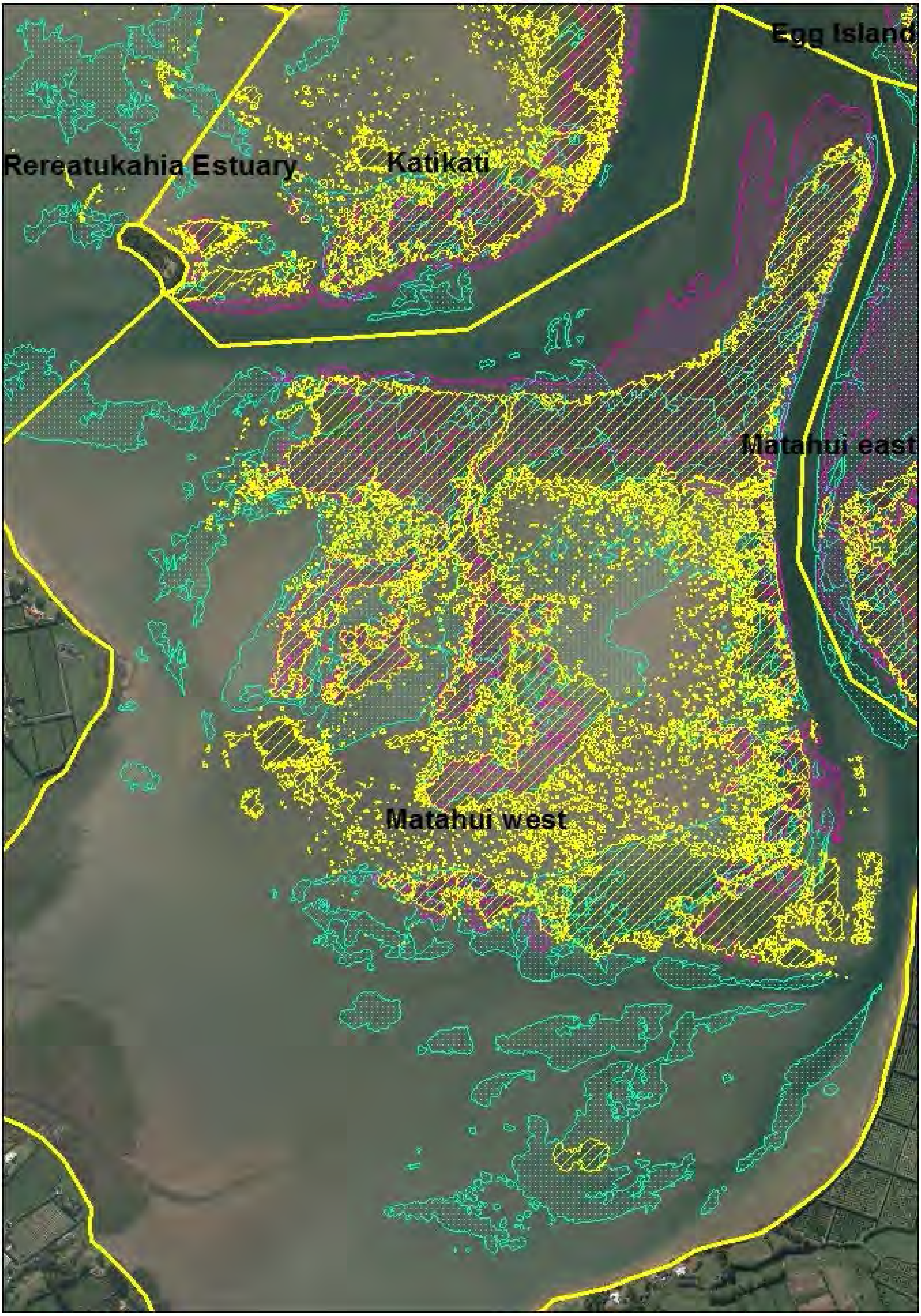

Tuapiro Athenree
Bowen Blackney
Bowen entrance
Tuapiro Estuary
Matakana north
Ongare

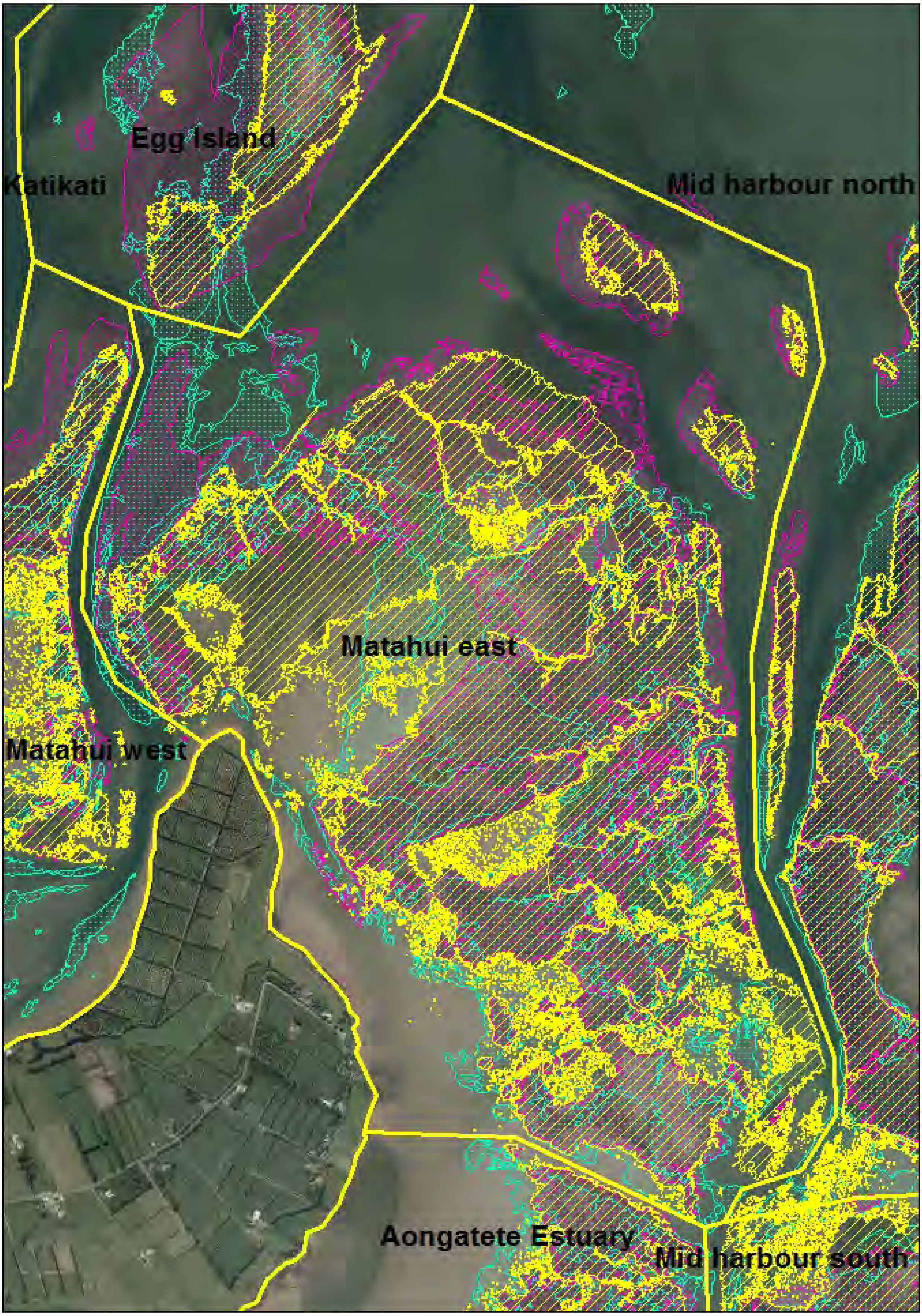

Matakana north
Mid harbour north
Blue Gum Bay

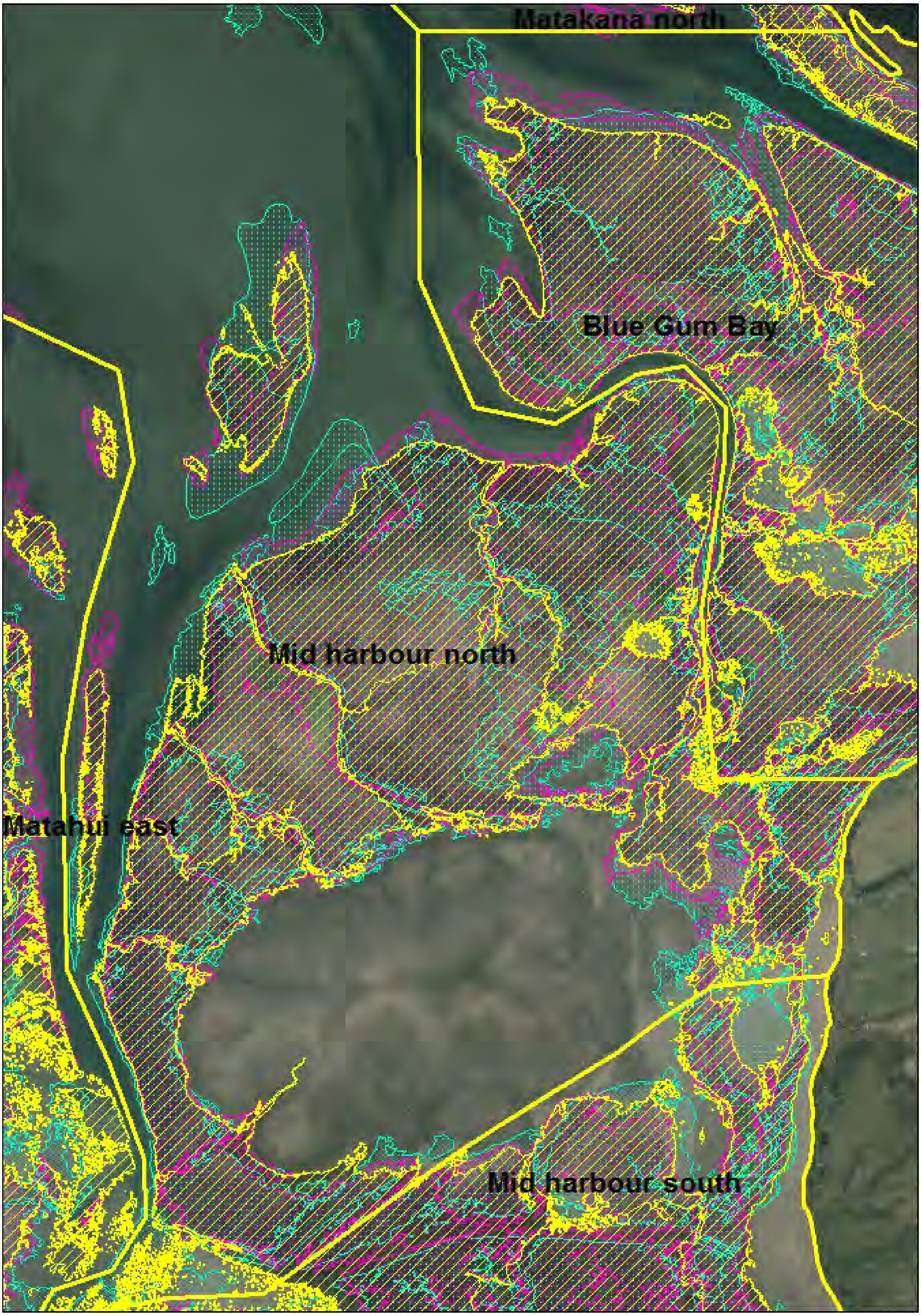


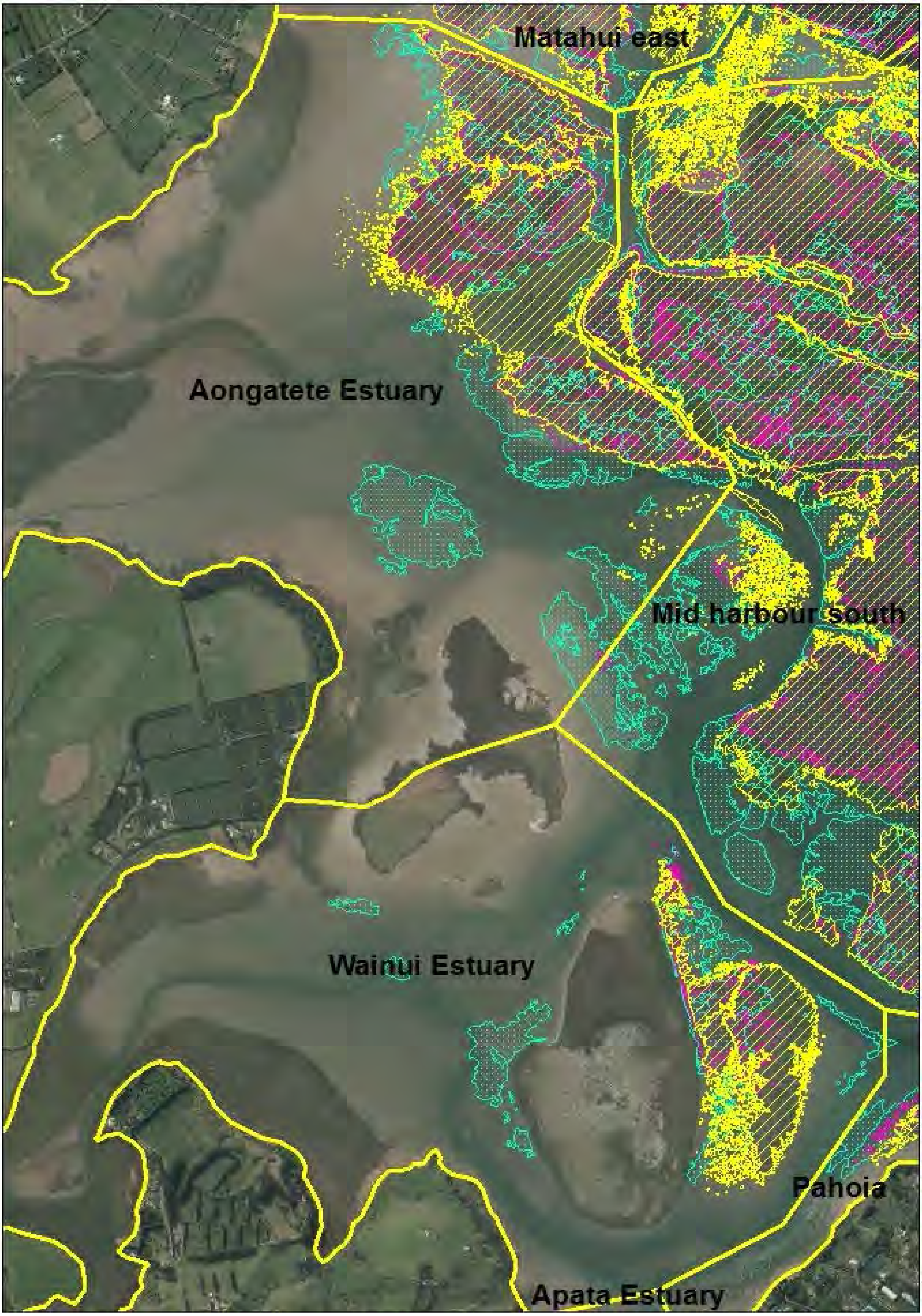
Matakana north
Blue Gum Bay
Mid harbour north
Mid harbour south

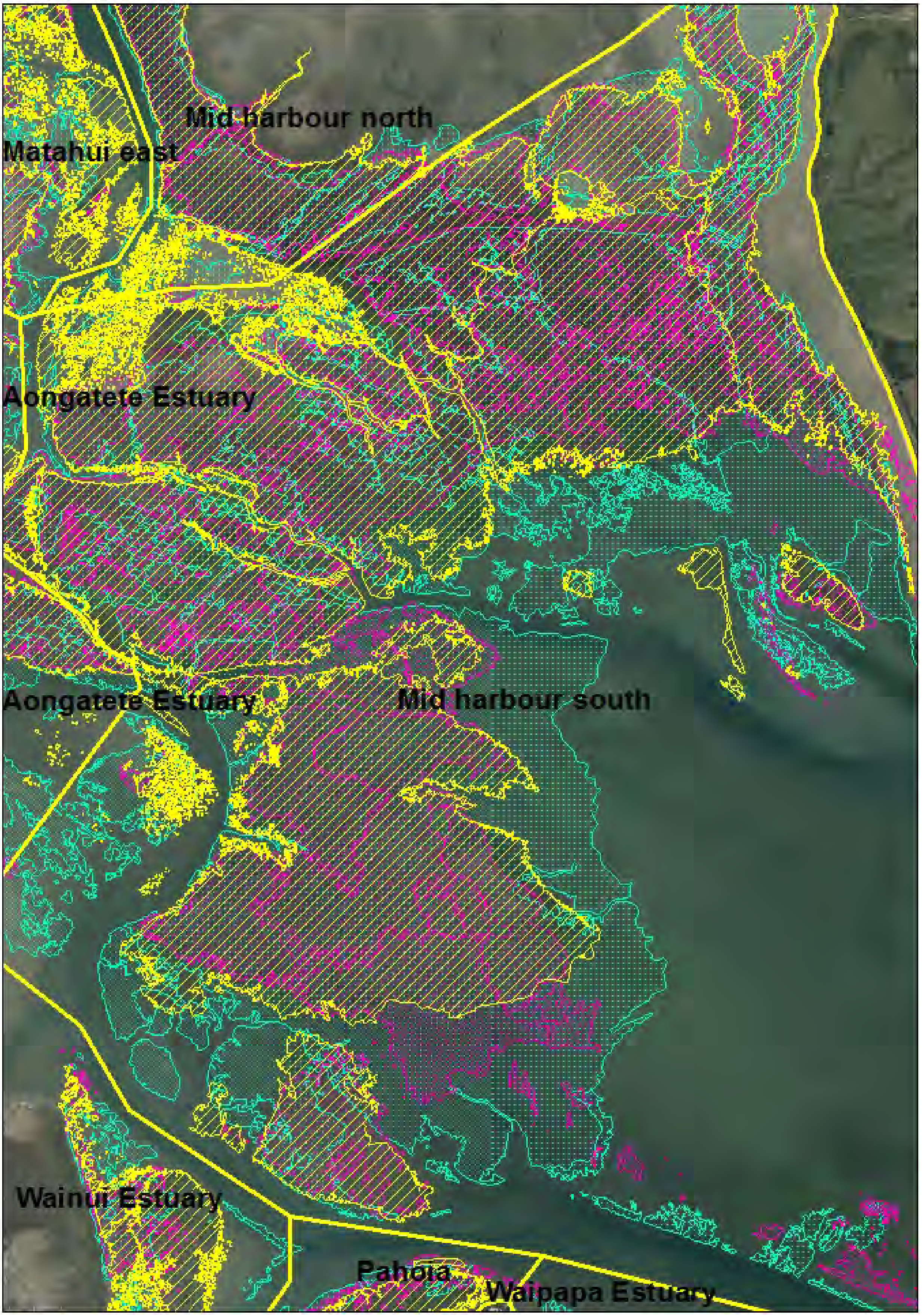

Kauri Point
Uretara Estuary
Katikati
Egg Island
Rereatukahia Estuary
Matahui west

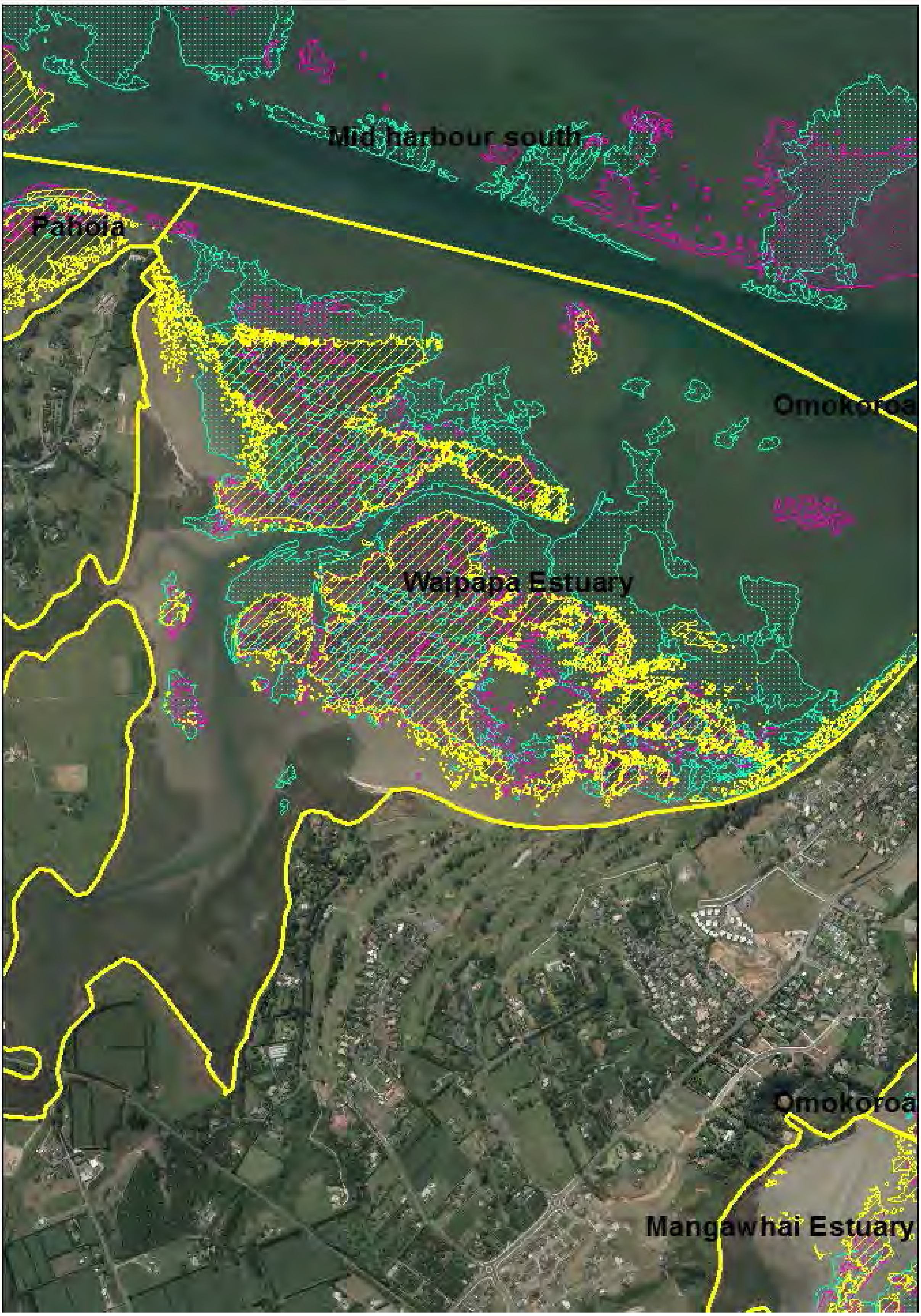

Egg Island
Rereatukahia Estuary
Katikati
Matahui east
Matahui west


Egg Island
Katikati
Mid harbour north
Matahui east
Matahui west
Aongatete Estuary
Mid harbour south

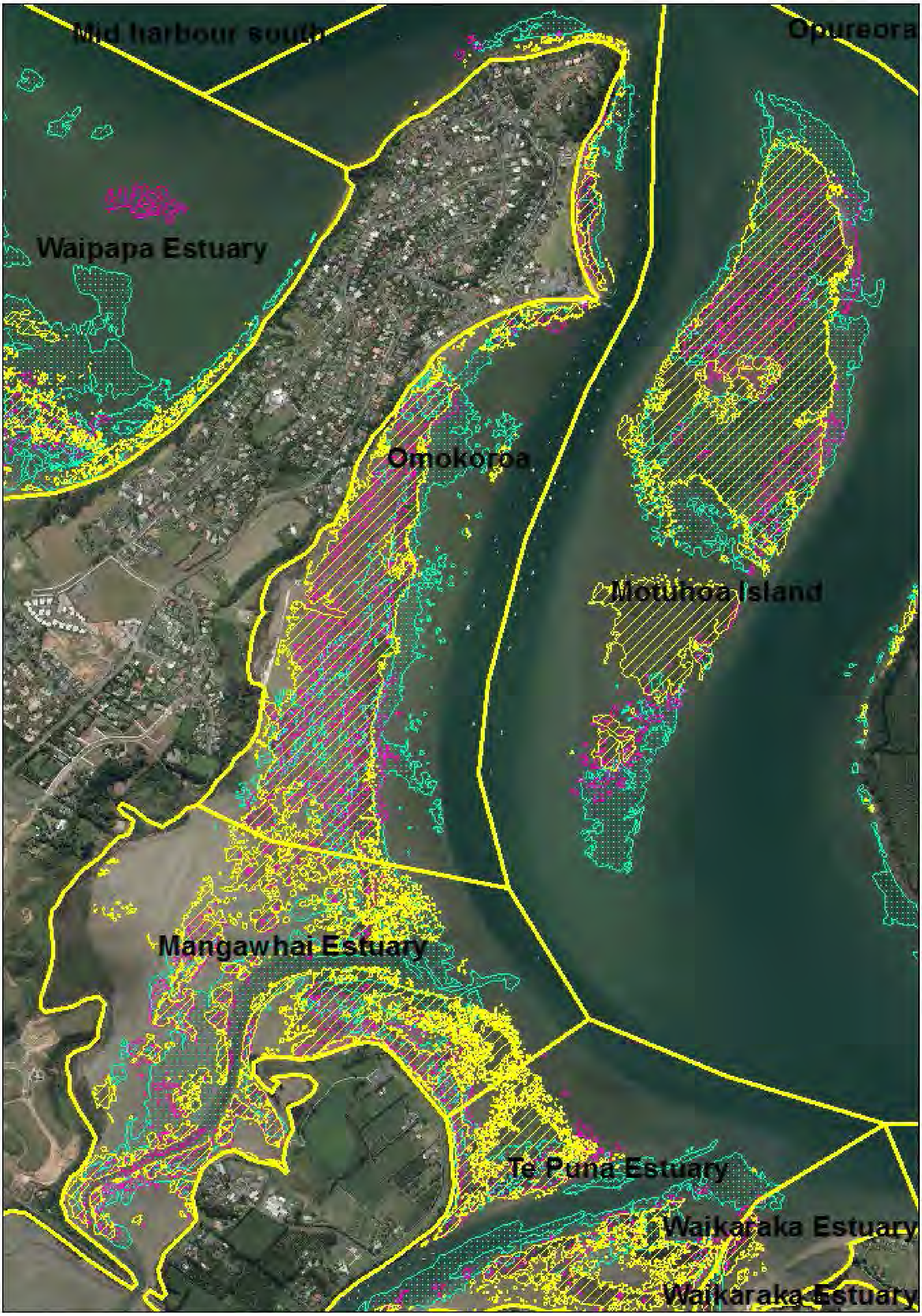

Matakana north
Blue Gum Bay
Mid harbour north
Matahui east
Mid harbour south

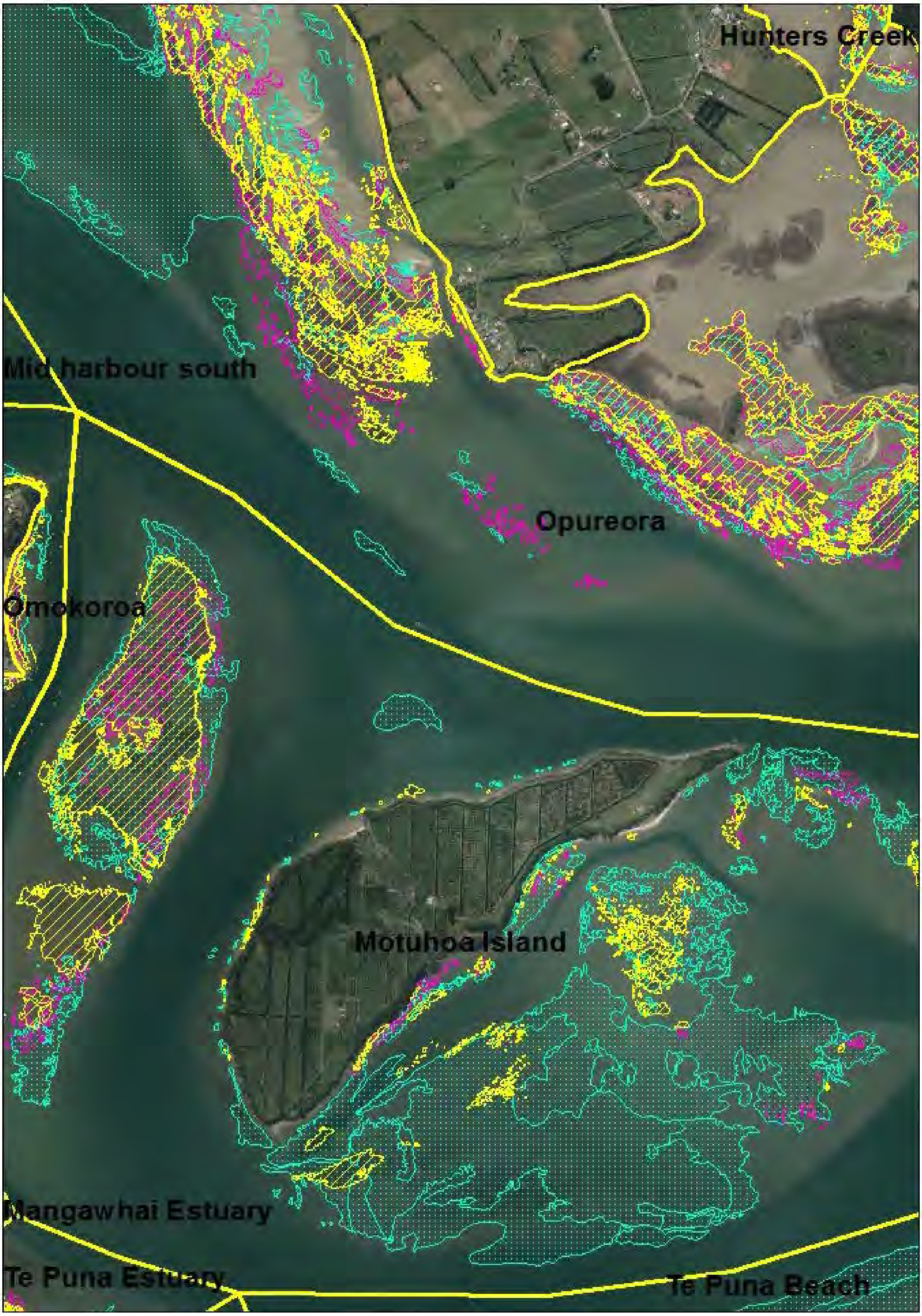

Matahui east
Aongatete Estuary
Mid harbour south
Wainui Estuary
Pahoia
Apata Estuary

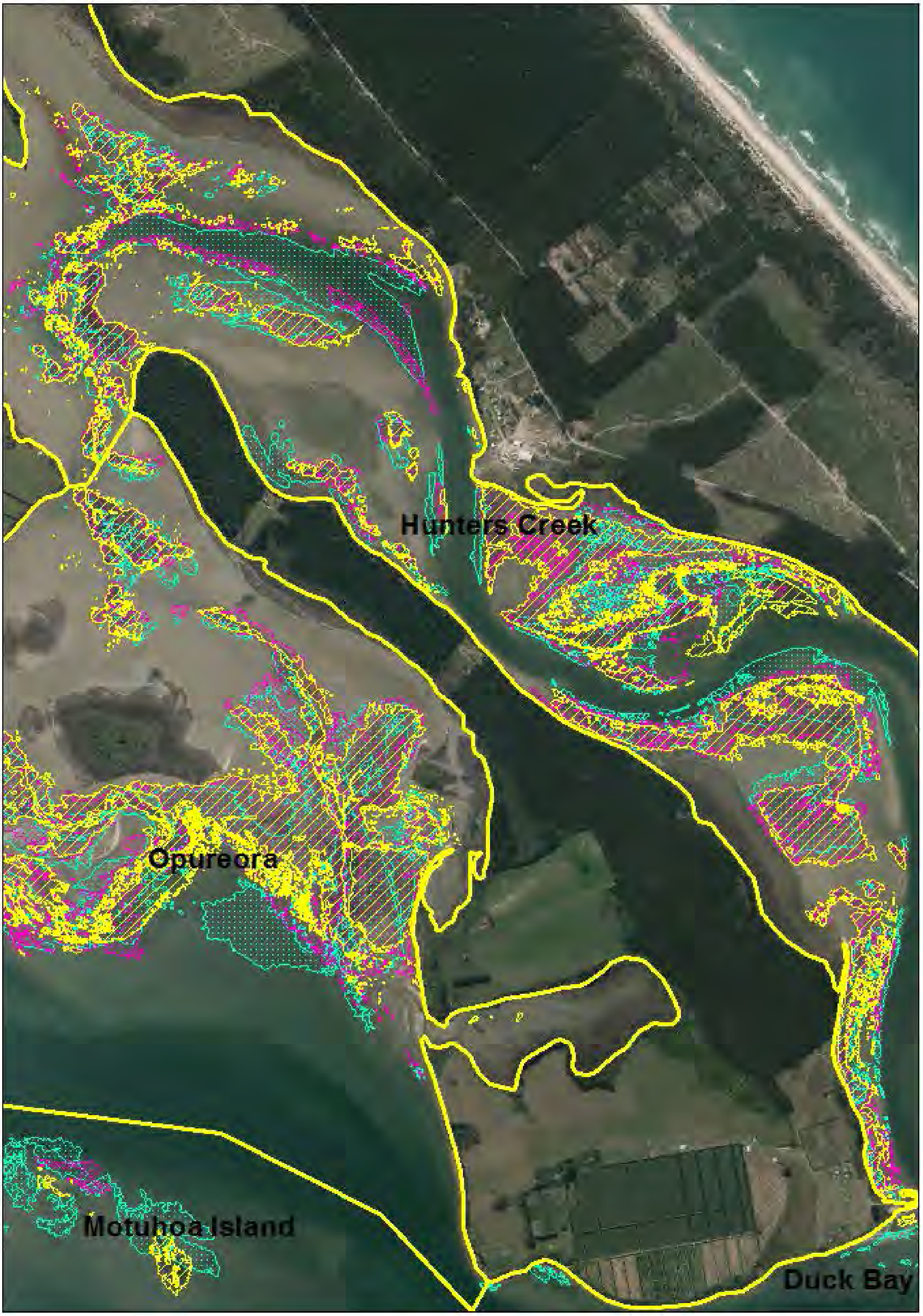

Mid harbour north
Matahui east
Aongatete Estuary
Aongatete Estuary
Mid harbour south
Wainui Estuary
Pahoia
Waipapa Estuary



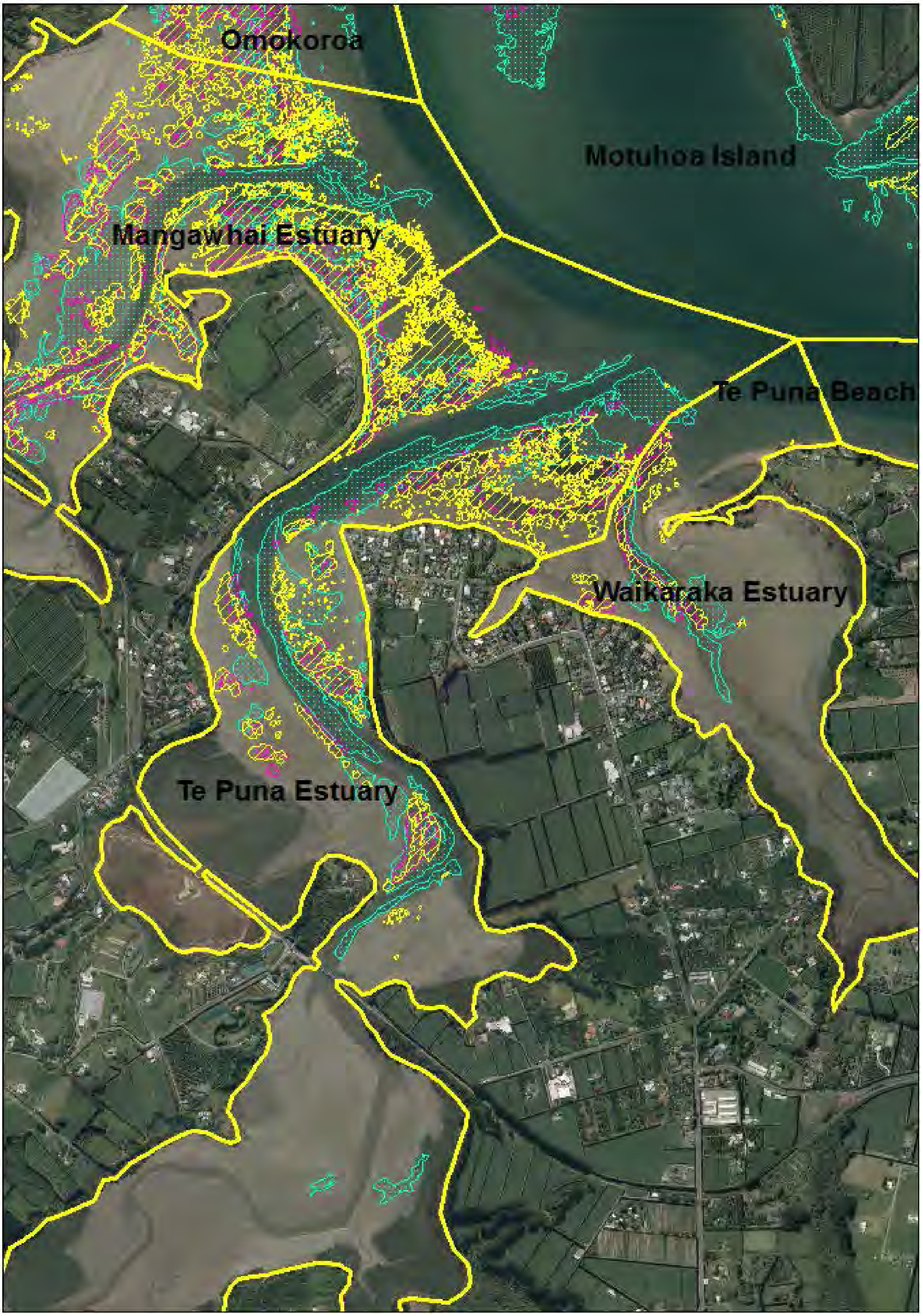
Mid harbour south
Pahoia
Omokoroa
Waipapa Estuary
Omokoroa
Mangawhai Estuary

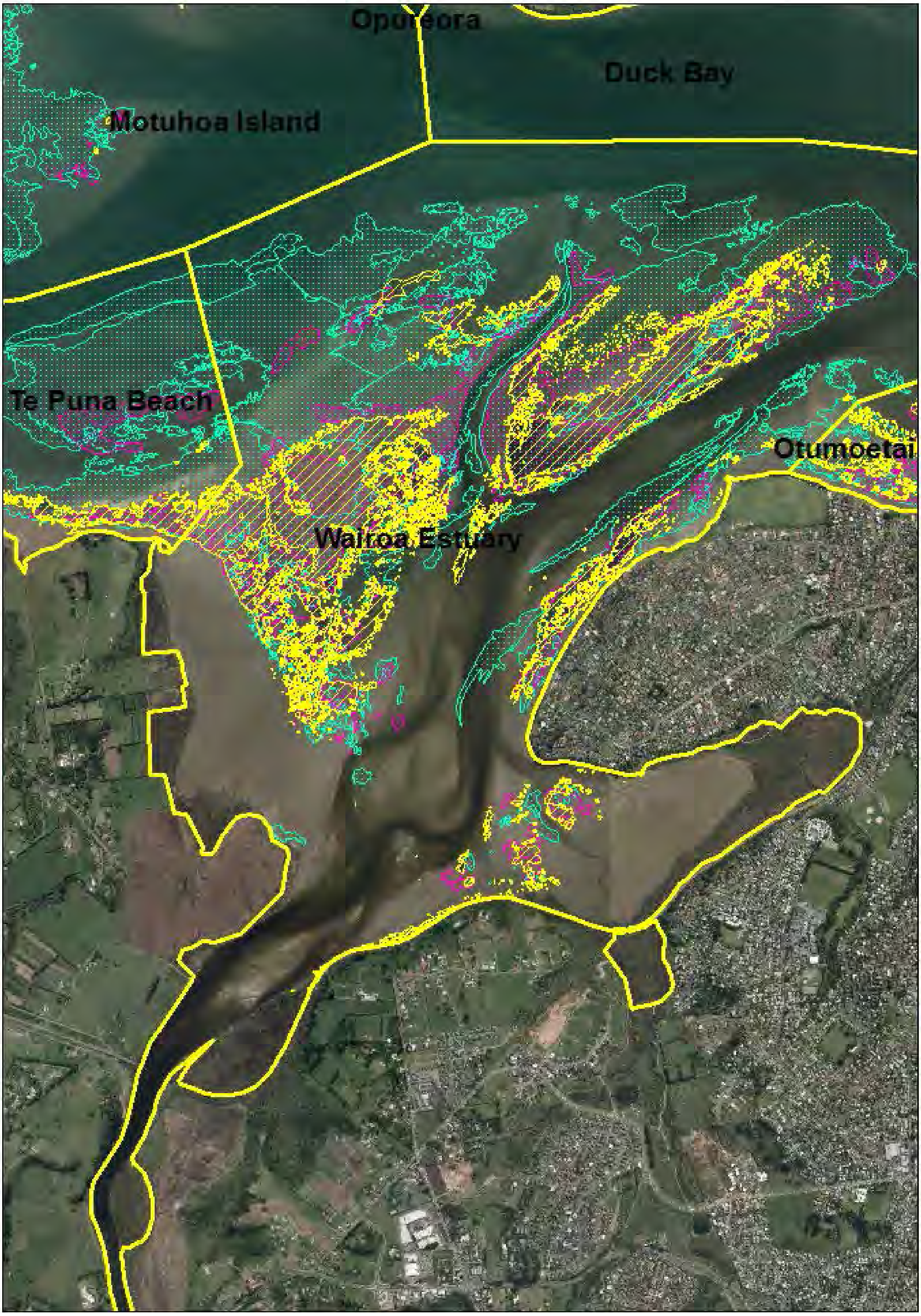

Mid harbour south
Opureora
Waipapa Estuary
Omokoroa
Motuhoa Island
Mangawhai Estuary
Te Puna Estuary
Waikaraka Estuary
Waikaraka Estuary

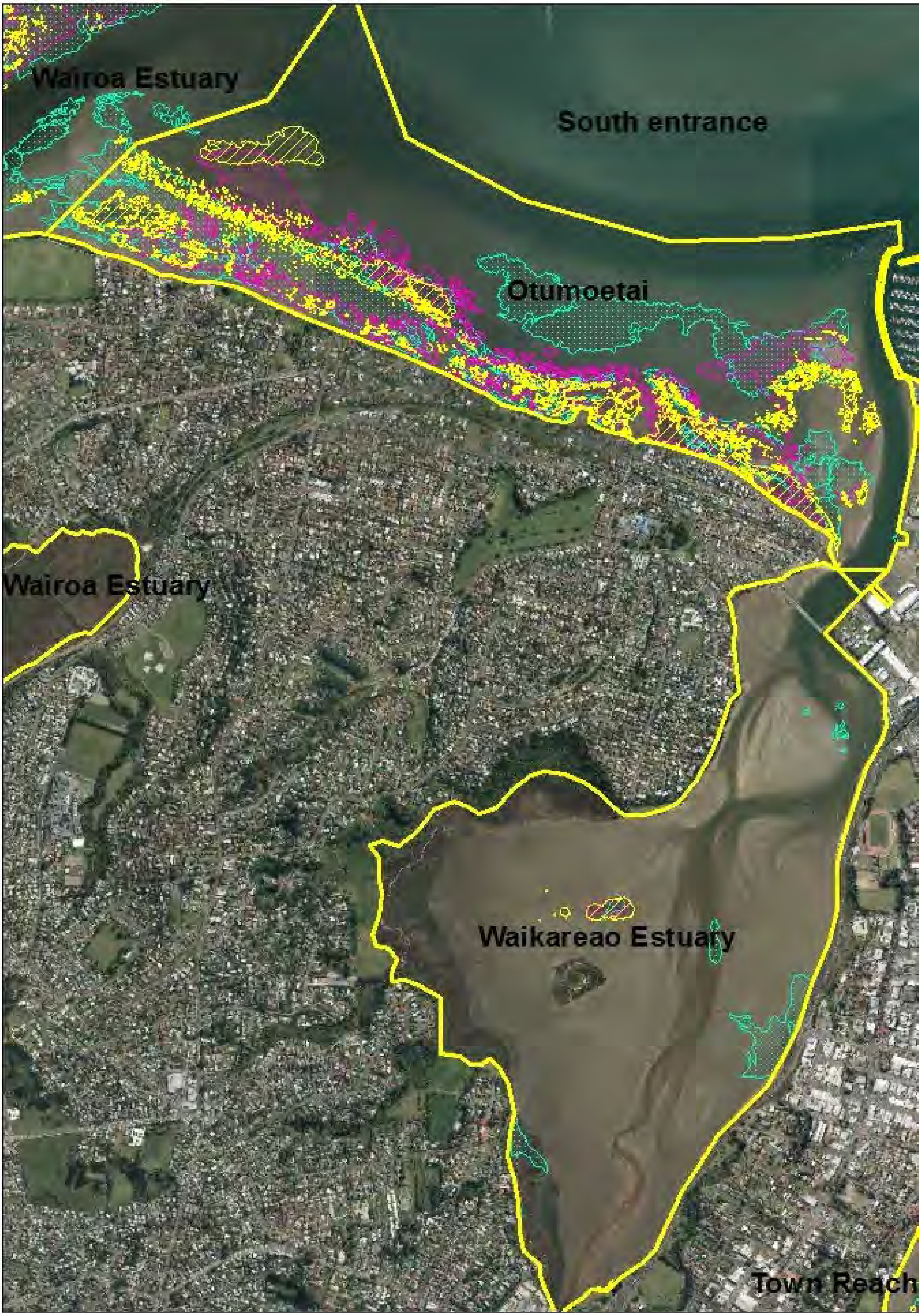

Hunters Creek
Mid harbour south
Opureora
Omokoroa
Motuhoa Island
Mangawhai Estuary
Te Puna Estuary
Te Puna Beach

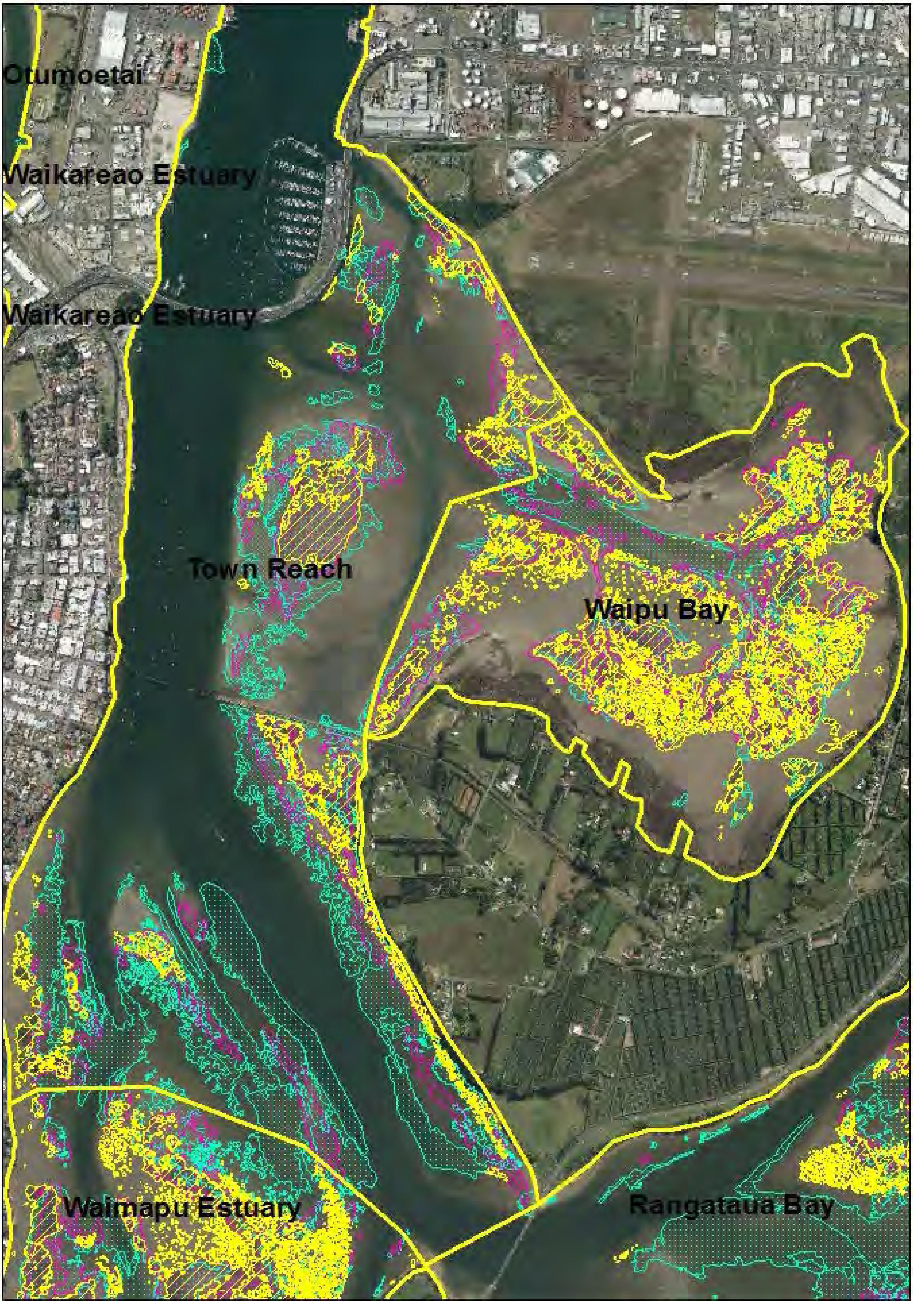


Hunters Creek
Opureora
Motuhoa Island
Duck Bay

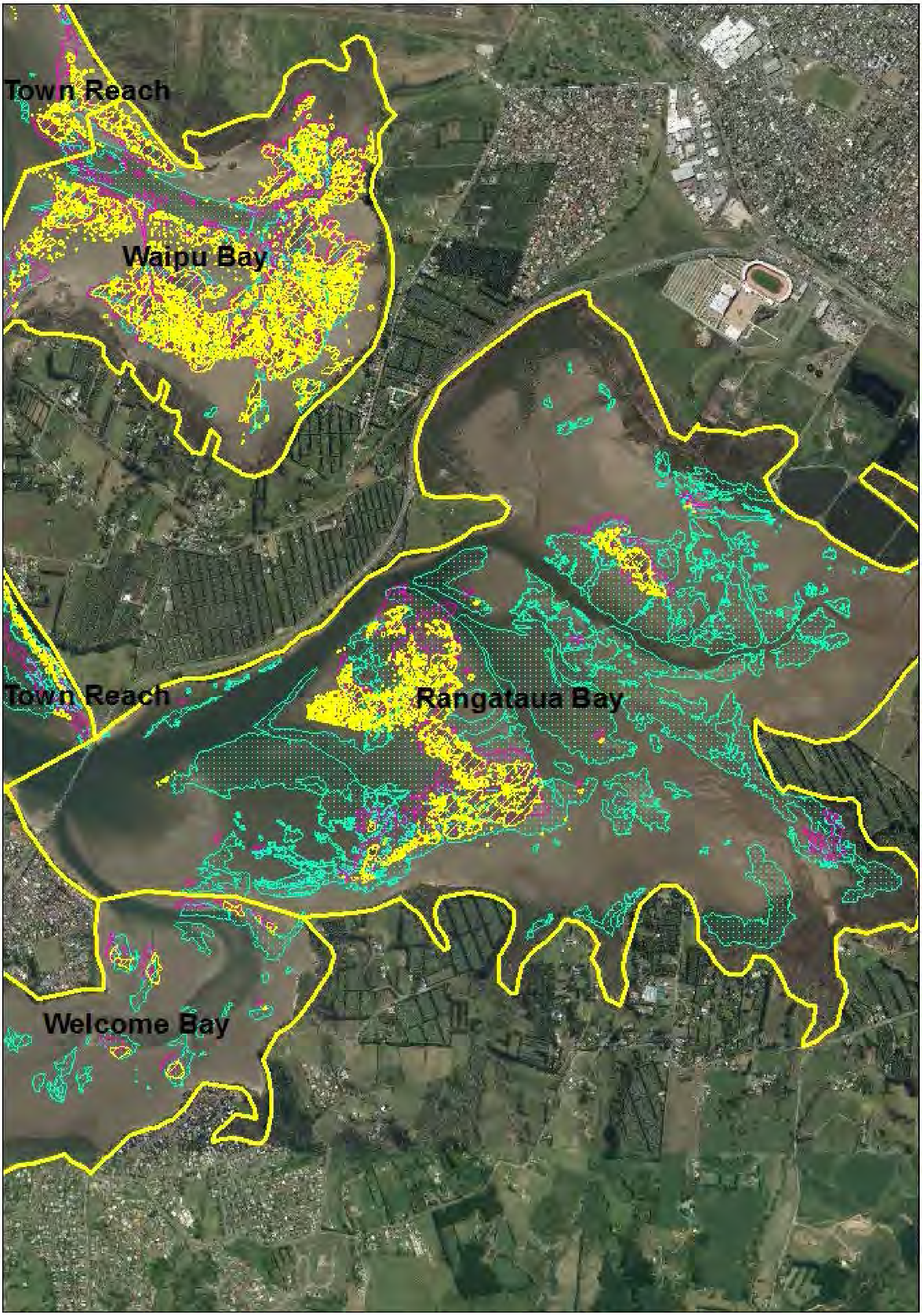

Omokoroa
Motuhoa Island
Mangawhai Estuary
Te Puna Beach
Waikaraka Estuary
Te Puna Estuary


Opureora
Duck Bay
Motuhoa Island
Te Puna Beach
Otumoetai
Wairoa Estuary


Wairoa Estuary
South entrance
Otumoetai
Wairoa Estuary
Waikareao Estuary
Town Reach


Otumoetai
Waikareao Estuary
Waikareao Estuary
Town Reach
Waipu Bay
Waimapu Estuary
Rangataua Bay

Waipu Bay
Waikareao Estuary
Town Reach
Rangataua Bay
Waimapu Estuary
Welcome Bay


Town Reach
Waipu Bay
Town Reach
Rangataua Bay
Welcome Bay

Appendix 3 – Ōhiwa Harbour seagrass extents in 1945 (aqua) and 2011 (yellow)