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A synthesis of historical environmental changes to Brooklands Lagoon/Te Riu o Te Aika Kawa, Canterbury

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Summary

Brooklands Lagoon / Te Riu o Te Aika Kawa ('Brooklands') is an important wetland and estuarine ecosystem in Canterbury. It is a site of cultural significance to Ngāi Tūāhuriri, and is also valued by the wider community. Home to an array of life, it is connected to the Pūharakekenui/Styx and Waimakariri rivers, and is part of a wetland landscape complex that includes the Avon-Heathcote / Ihutai estuary to the south and the Ashley / Rakahuri estuary to the north. Notionally situated within the territorial boundary of Christchurch City Council and jurisdictionally encompassed by the regional council Environment Canterbury, it has been legally determined to be part of the coastal marine area. The complicated administrative arrangements for the lagoon mirror the biophysical and human challenges to this surprisingly young ecosystem since its formation in 1940.

Here we present a synthesis of the historical events and environmental influences that have shaped Brooklands Lagoon. Before existing as an intertidal ecosystem, the Waimakariri river mouth was situated in what is now the southern end of the lagoon. A summary timeline of key events is set out in the table below. These included the diversion of the Waimakariri River mouth via the construction of Wrights Cut in the 1930s, which influenced the way that the lower reaches of the river interacted with the land and sea. A large flood in 1940 shifted the river mouth ~2 to 3 kilometres north, that created the landscape that we see today. However, this has not remained stable, as the earthquake sequence in 2010 and 2011 subsided the bed of the estuary.

The changes are ongoing, as sea level rise and coastal inundation will place ongoing pressure on the aquatic ecosystem and surrounding land. How to provide accommodation space for Brooklands as an estuary will be a key planning and community challenge, as Environment Canterbury begins the engagement for the review of its Regional Coastal Plan. There is also a requirement to safeguard its ecological health under the 2020 National Policy Statement on Freshwater Management. This will necessitate an integrated mountains to sea (ki uta ki tai) management approach as the lagoon is affected by wider catchment activities. We hope that this report will contribute to, and inform these processes by providing a comprehensive historical synthesis, and by identifying considerations for the future collaborative management of Brooklands Lagoon, and protection of its values. In essence, we suggest that Te Riu o Te Aika Kawa deserves some sustained aroha.

Table 1: Influential events prior to, and post the formation of Brooklands Lagoon/Te Riu o Te Aika Kawa.

Date	Event	Consequence
1868	Ngāi Tahu makes claims to the Māori Land Court that Kemp's 1848 land 'purchase' did not leave enough land or all of their mahinga kai sites	A relatively tiny 'Māori reserve' on the western banks of the lagoon is given back to tangata whenua
1930s	Employment schemes in Great Depression	Wrights Cut and cut in sand spit
1940	Sustained heavy rainfall on 28 February burst stop banks along Waimakariri River caused flooding	Shift in Waimakariri mouth ~2-3km north leading to formation of Brooklands lagoon
1993	Court decision is made on 'where to draw the line' of the coastal marine area for Canterbury estuaries	The lagoon is legally deemed to be a part of the coastal marine area
1994	The first New Zealand Coastal Policy Statement (NZCPS) is promulgated under section 57 of the Resource Management Act (RMA) 1991.	Policies for the coastal environment nationally are introduced to give effect to the Purpose and Principles of the RMA
2010	The inception of the Canterbury Earthquake Sequence on 4 September 2010	Subsidence of the lagoon begins resulting in changes to benthic and edge habitats. Brooklands suburb designated 'Red Zone'.
2020	Environment Canterbury begins early engagement for the review of the 2005 Regional Coastal Plan	The second version of the NZCPS gazetted in 2010 will need to be given effect.

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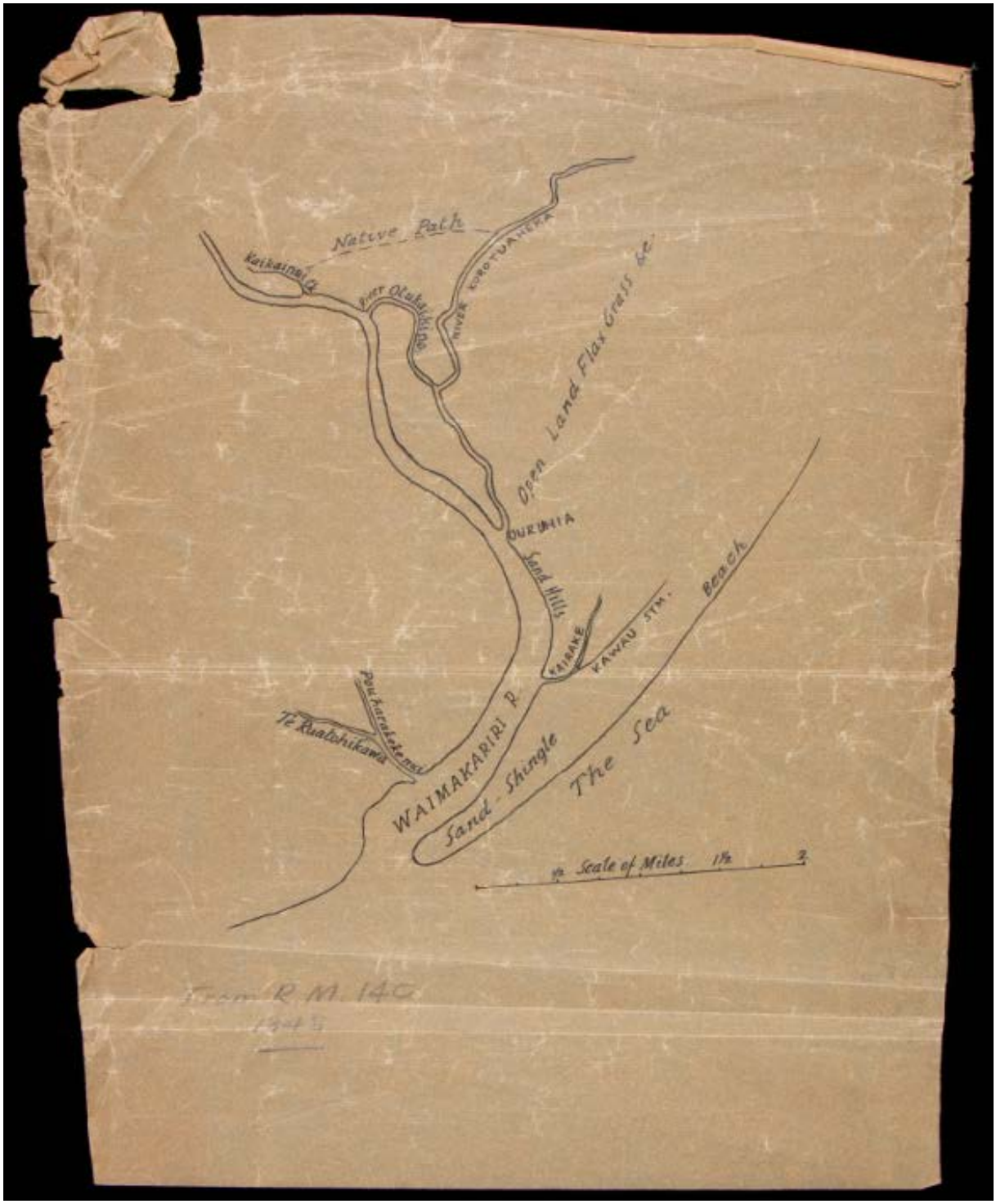

Plate 2: Scale: half mile to an inch, shows Waimakariri River Mouth (Red Map 140 Returned to Land Information New Zealand), 1848. Canterbury Museum CMU4316.

Chapter 1. Introduction

Brooklands Lagoon / Te Riu o Te Aika Kawa[1] is an area that has gone through many changes since being formed 81 years ago. Before existing as the estuary that we see today, the Waimakariri River mouth exited through a sandbar of what is now the southern part of the lagoon. The diversion of the Waimakariri River mouth via the construction of Wrights Cut in the 1930s, influenced the way that the lower reaches of the river interacted with the land and sea. An intertidal estuary formed after the river mouth shifted ~2 – 3 kilometres during the large floods of 1940. Ocean currents increased in force and influence locally, thus raising the salinity and sand content in the lagoon (Schlam & Reid, 2015). Over time, the water entering Brooklands Lagoon from the Waimakariri River added fine sediment to bed of the lagoon as the often sediment laden river water could no longer flow through the lagoon and exit into Pegasus Bay (Knox & Bolton, 1978). Figure 1 depicts this geomorphological history.

Brooklands Lagoon is a site of cultural significance to Ngāi Tūāhuriri. The lagoon is affected by the water from the Waimakariri River and tributaries; the Pūharakekenui / Styx River; the tides of Kairaki and Spencerville beaches, which are a part of Pegasus Bay; and land-use activities within these waterways and surrounds (AECOM New Zealand Limited, 2017; Christchurch City Council, 2010a).

It is home to a diversity of bird, fish and plant species, and has been exposed to an array of challenging natural and human caused events in the past, such as earthquakes, flooding, algal blooms, motorcycling, and jet skiing, which have cumulatively altered the biodiversity and mauri of the area (AECOM New Zealand Limited, 2017; Christchurch City Council, 2010a). Some of these activities pose ongoing threats to Brooklands Lagoon, and the adverse effects range from destruction of saltmarsh areas, disturbance to wildlife, and periodic deoxygenation of the sediment resulting in impacts on the food web (Bolton-Ritchie, personal communication, January 28, 2021).

With ongoing concerns regarding sea level rise and coastal inundation on New Zealand's coastline, it is important that the current state, uses and pressures on Brooklands Lagoon are articulated so that proactive planning and management for the future of the estuary ecosystem can occur. This information can contribute to the Environment Canterbury Regional Coastal Plan review, which is its initial stages. The plan review will need to give full effect to the New Zealand Coastal Policy Statement (NZCPS) which was comprehensively updated in 2010 after a commission of inquiry. The NZCPS is mandatory under the Resource Management Act (RMA) 1991.

The NZCPS has strong biodiversity and ecosystem health objectives and policies, which have been recently been reinforced by the concept of Te Mana o te Taiao (the mana of the environment) in the 2020 Aotearoa New Zealand Biodiversity Strategy. This aims to achieve thriving ecosystems and the indigenous species they sustain, by maintaining and/or restoring ecological health and connectivity.

The opportunity for an integrated resource management approach has also arisen with the recent release of the National Policy Statement for Freshwater Management (NPS-FM) 2020. This statement is also promulgated under the RMA, and requires local authorities to recognise the interconnectedness of the whole environment from the mountains of the Waimakariri catchment to Brooklands Lagoon and the coast. An integrated and sustainable management approach (ki uta ki

[1] Note: English and Te Reo names for places will be used interchangeably throughout this report.

tai) is to be collaboratively developed in partnership with mana whenua, and involve the wider community, with the objective to manage activities more effectively on land and within freshwater.

This report contributes to these processes by providing a comprehensive synthesis of the history of the lagoon. Current management challenges that occur are outlined, along with an overview of the implications of current policy and legislative developments. We hope that the historical events described also serve to reinforce the enriching connection with nature that helps to nourish people's lives. This is also a key aim of the Aotearoa New Zealand Biodiversity Strategy, which also expressly includes the ability for tangata whenua as Treaty partners to exercise tino rangatiratanga and kaitiakitanga over ecosystems such as Brooklands Lagoon/Te Riu o Te Aika Kawa.

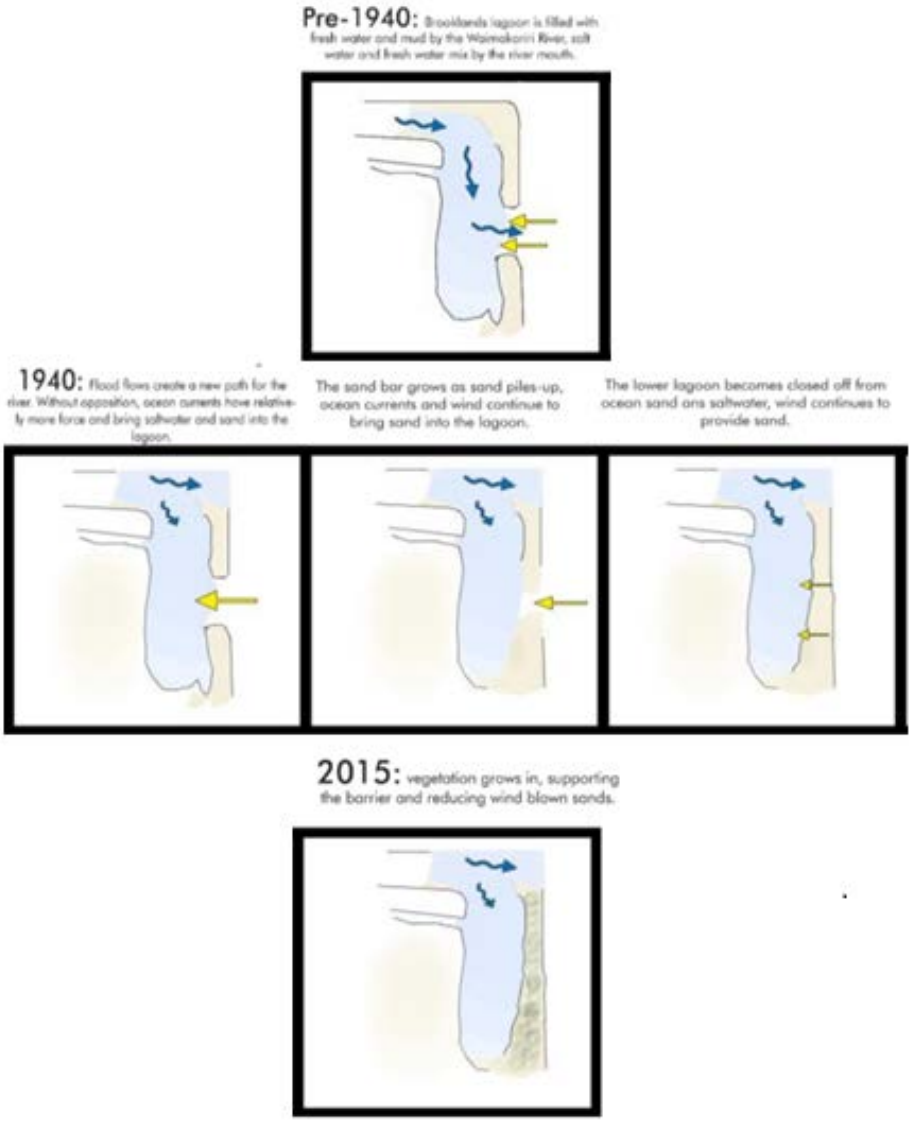

Figure 1: An annotated diagram of the summarised history of Brooklands Lagoon (Used with permission and adapted from Schlam & Reid, 2015).

Study Area

Jurisdiction

Brooklands Lagoon is a river dominated intertidal estuary situated on the east coast of the South Island in New Zealand (Bolton-Ritchie, 2007). It is located in the Canterbury / Waitaha region, which is under the jurisdiction of Canterbury Regional Council, also known as Environment Canterbury. The adjoining but now largely-abandoned Brooklands suburb ('Red-Zoned' after the 2010-11 earthquake sequence) is situated within the territorial boundaries of the Christchurch City Council.

Location and Size

The 'lagoon' is approximately 4.5 kilometres long and its width varies from approximately 250 metres to 750 metres (Boyle, 2011). The sand spit on the eastern side of the lagoon varies in width from ~80 to 450 m wide (Figure 2).

Brooklands Lagoon is a receiving environment for several waterways from within the Waimakariri Catchment: the Waimakariri River, the Styx River/Pūharakekenui, and the Kaiapoi River (Figures 3 and 4). Due to overland runoff, the lagoon also receives impacts upstream activities. These include farming, forestry, urban areas and industrial uses; all of which can influence the health and quality of the water and ecosystem within Brooklands Lagoon. There is also a tidal and coastal influence through its connection to the Waimakariri river mouth and Pegasus Bay. Salinity levels vary throughout the lagoon (Christchurch City Council, 2015).

Figure 2: Map showing the surrounds of Brooklands Lagoon (Adapted from Google, n.d.).

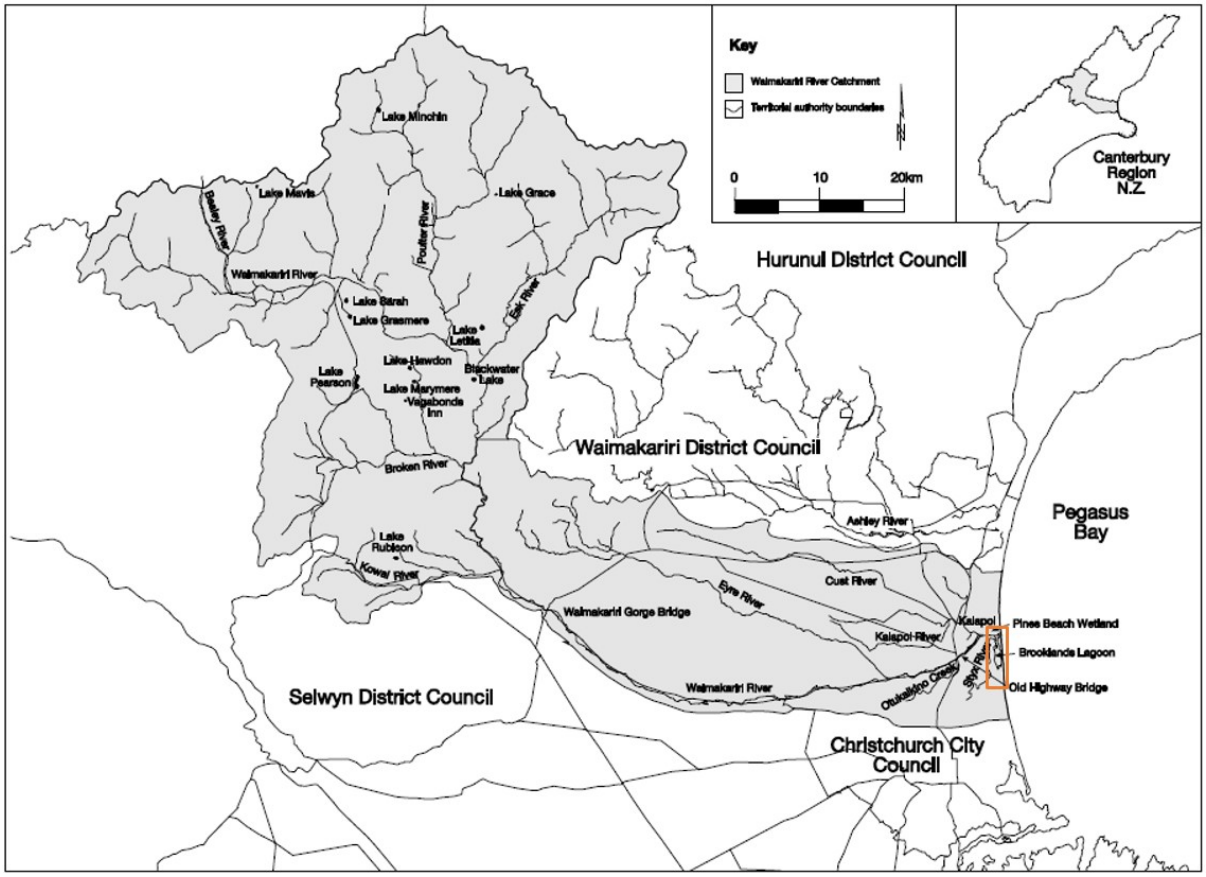

Figure 3: Map showing the extent of the Waimakariri River and catchment, with Brooklands Lagoon outlined by an orange rectangle (Adapted from Environment Canterbury, 2017).

Ecology and Geomorphology

Brooklands is classified as: 6B 'Spit enclosed (sand/mud)' in the New Zealand Coastal Hydrosystem classification. This reflects that the lagoon is included as a part of the Waimakariri River classification: 6 'Tidal River mouth' (Hume et al., 2016; Ministry for the Environment, 2017). This is characterised as being permanently open, and having a "narrow inlet restricted by sandy spit with lagoon or wide tidal channel upstream" (Hume et al., 2016, p. 18). Further, it is an estuarine environment with a dominant substrate of fine sand granules or mud (Hume et al., 2016).

Soils on the localised surrounds of the lagoon are characterised as being raw, well-drained soil with low moisture retention (Manaaki Whenua, n.d.-b). The surface geology in these surrounds is loose sedimentary material (sands, silts and clays) that is largely alluvial in origin, along with organic soils (Manaaki Whenua, n.d.-a; National Institute of Water and Atmospheric Research, n.d.-a). There is herbaceous saline vegetation (saltmarsh, rushlands and herbfields) in and around the lagoon, and exotic grassland and forest exists on these fringes also (Manaaki Whenua, n.d.-a; Canterbury Maps, n.d-a). The exotic grassland and forest pertains to pine (*Pinus radiata*) and marram grass (*Ammophila arenaria*) which were planted on the eastern sand spit when dune stabilisation works that were carried out after grazing animals ate the oioi (*Apodasmia similis*) rushes (Biggs, 1947).

Protected Areas

There are protected areas surrounding Brooklands Lagoon including Seafield Park Scenic Reserve and Conservation Area Brooklands Waterski Club which are covered under the Reserves Act 1977 and Conservation Act 1987 respectively (Land Information New Zealand, 2020). Different reserves are administered by different organisations (Figure 4).

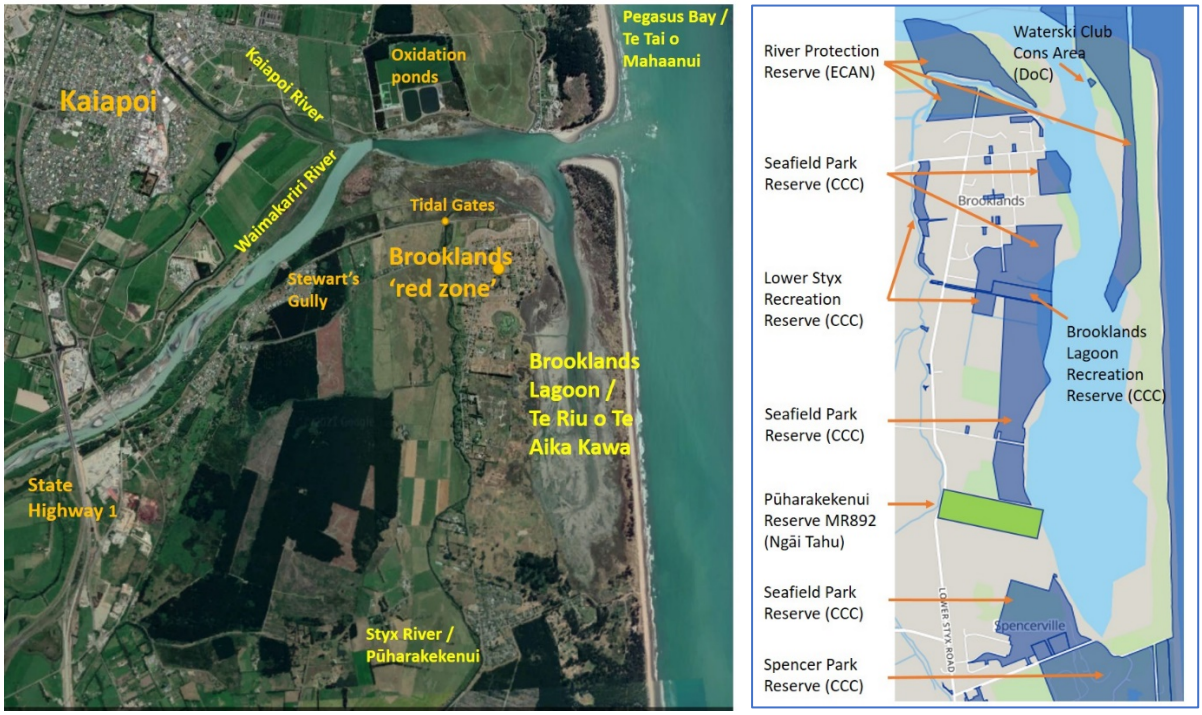

Figure 4: Key sites mentioned throughout this report (Adapted from Google, n.d. and Land Information New Zealand, n.d). Note that the shape of boundaries of the Pūharakekenui Reserve are indicative only.

Chapter 2. Methods

This report focuses on the history of Brooklands Lagoon, using publicly available resources, including institutional records.

The work was carried out under a ten-week summer research scholarship co-funded by Environment Canterbury and Lincoln University. The relatively short time for the project precluded the following:

- Primary data collection from kōrero with iwi and/or surveys with members of the public.
- Physical data collection and in-depth analysis of biophysical elements found within and around Brooklands Lagoon.
- A comprehensive investigation into the present-day catchment(s) land-use.
- An evaluation of the resource allocation of monitoring and management by local authorities.

Publicly available documents from the Waitangi Tribunal, Te Rūnanga o Ngāi Tahu, and Mahaanui Kurataiao Limited were examined, although the information presented in this report does not purport to be a history of the tangata whenua relationship with the area.

To conduct this historical synthesis of Brooklands Lagoon, we used the following range of methods:

Literature Review

Comprehensive searches were undertaken from the following sources:

- Library Searches:

  - **Lincoln University Library**: The online [digital] catalogue and physical collections of work were explored for information pertaining to Brooklands Lagoon. This included the thesis collection. Abstracts were read to ensure relevance to this project and references were also read, creating a snowballing effect to identify other relevant literature. Items that were identified covered topics such as (but not limited to): Brooklands Lagoon, Brooklands, estuaries in Christchurch, and historical shoreline change.

  - **Christchurch City Library - Tūranga**: Past local authority plans, books, and other information was collated from a catalogue search. The Christchurch City Library's online database was also used to look up archived newspaper articles. Search terms: Brooklands Lagoon, Brooklands.

  - **University of Canterbury Research Repository**: The University of Canterbury Research Repository was used to review past data collation in and around the Lagoon. Abstracts were read to ensure relevance to this project and references were also read, creating a snowballing effect. Search term: Brooklands Lagoon.

  - **National Library of New Zealand's Papers Past online database**: This was used to gather information on flooding and creation of the Brooklands Lagoon. Search term: Brooklands.

- **Canterbury Museum**: A search for history on the area was conducted in the Canterbury Museum's archives. Search terms: Brooklands Lagoon, Waimakariri River mouth.

- **Christchurch Art Gallery**: The location tool on the online database for the Christchurch Art Gallery was used to view any related images from their collections. Assistance was then sought.

Other information sources

- **Google search**: Search terms: Brooklands Lagoon, Waimakariri River mouth, Pūharakekenui, Pūharakeketapu, Styx River, Ngāi Tahu map, Ngāi Tūāhuriri, Canterbury Earthquake Sequence, Te Riu o Te Aika Kawa, Canterbury Drainage Board, mr892 Māori reserve, Wrights Cut, Waimakariri District Council Oxidation Ponds, Waimakariri River Catchment, Kemp's Deed, rāhui, flood protection Waimakariri River, Sand Hills Run, Christchurch Drainage Board, 28 August 1992 coastal marine area Brooklands, iwi management plan Canterbury. Results included webpages from (but were not limited to): Stuff News, The Styx, Te Ara – The Encyclopedia of New Zealand, Christchurch City Council, Environment Canterbury, Canterbury Museum and the Ministry for the Environment.

- **Stuff News**: A separate search was conducted on the Stuff New Zealand website, which includes the major metropolitan daily The Press, using the search term "Brooklands Lagoon". A total of 39 results were read for relevance.

Institutional sources

- **Kōrero with public servants** at Christchurch City Council and Environment Canterbury were held to understand more about the past, present and future management, and their understanding of the management priorities for the area. Several unpublished research papers were obtained as a result.

- **Site visit**: A familiarisation site visit to Brooklands Lagoon was carried out on 28 February 2020 with coastal scientist Dr Lesley Bolton-Ritchie of Environment Canterbury, to look at the current nuisance macro-algal blooms and other disturbances in the lagoon.

Chapter 3. Pre-1930s Context

Prior to 1940, Brooklands Lagoon was a part of the Waimakariri River channel, with the mouth approximately 2 to 3 kilometres south of where it currently exits. However, in 1930, 'shovel ready' projects were carried out in the lower reaches of the Waimakariri River. To give prior context to the state and uses of the environment before the inception of these works and the lagoon, this chapter will outline naturally occurring events prior to human settlement, cultural connections to the area and the impacts of early European settlement on the receiving environment.

There is a history of natural occurrences that shaped the current landforms of New Zealand, such as flooding, earthquakes, storms and tsunamis but this is beyond the scope of this report. A natural change that has been occurring prior to settlement in the wider Christchurch area is that the shoreline has fluctuated in movement over the last 10,000 years, as shown in Figure 6.

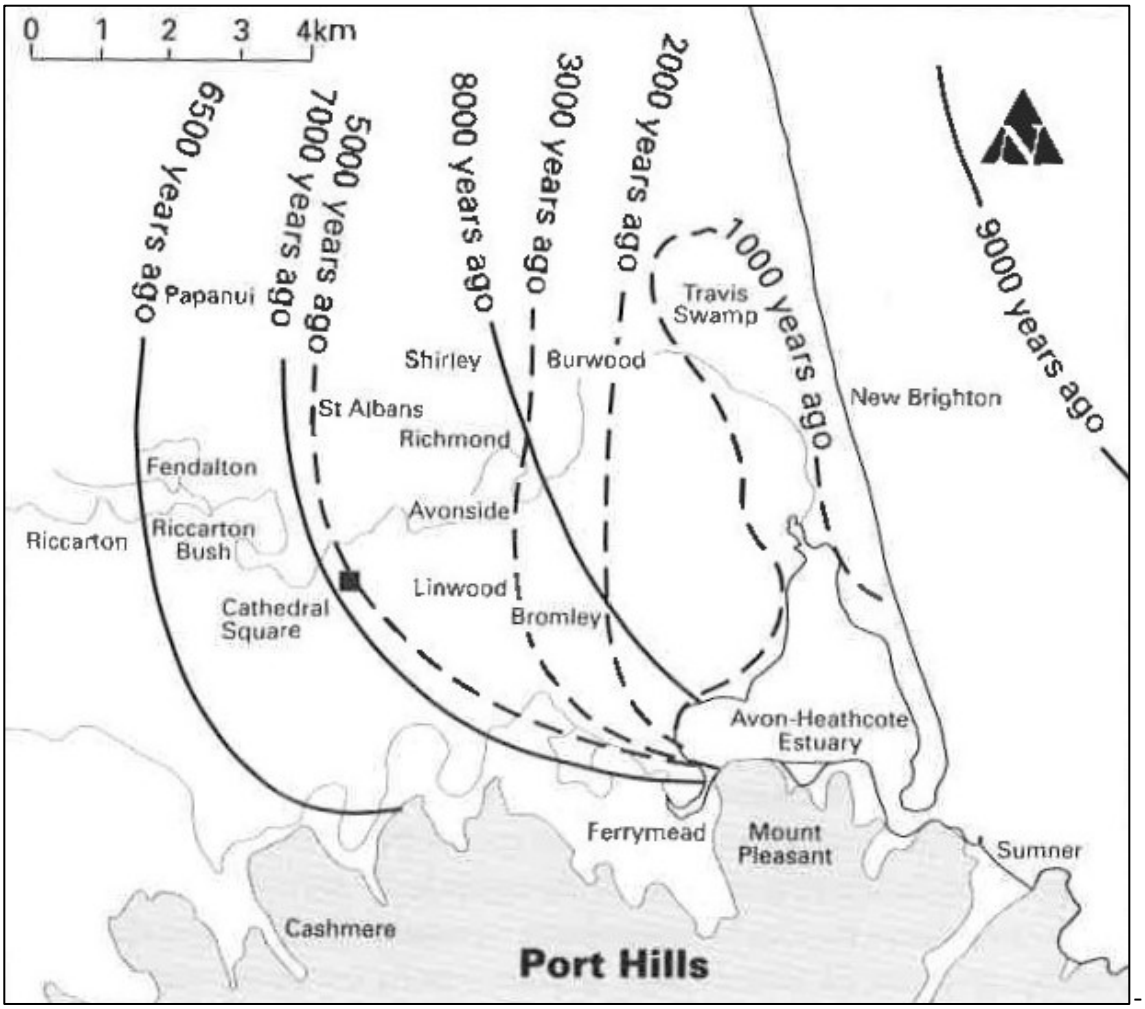

Figure 6: Image showing how dynamic the coastline just south of Brooklands Lagoon has been in the last 10,000 years (From Brown and Weeber,1992, as cited in Owen, S. J. (Ed). The Estuary: Where Our Rivers Meet the Sea: Christchurch's Avon-Heathcote Estuary and Brooklands Lagoon, 1992, p. 4).

3.1. Cultural connections to the area

The te reo name for the lagoon is Te Riu o Te Aika Kawa, which was originally the name of the Māori reserve that is on the southwest border of the lagoon (Te Rūnanga o Ngāi Tahu, n.d.). In Beattie's 1945 'Māori Place-names of Canterbury', it states that Te Riu o Te Aika Kawa translates in English to "the canoe-shaped hollow of Aikakawa" (Beattie, 1945, p. 101). However, Te Rūnanga o Te Ngāi Tahu, the kaitiaki of the area have since said the te reo name means "the area of Te Aika protocols (authorities)" (Te Aika, 2008, as cited in Orchard et al., 2012, p. 14). This name refers to the wider catchment of Brooklands Lagoon, and was given its name as "Te Aika, a descendant of Urihia, developed a strong association with the Brooklands Lagoon area" (Orchard et al., 2012, p. 14) which is retained by the Te Aika whanau today (Orchard et al., 2012).

Historically, the area around the river mouth was an important site for mahinga kai for Ngāi Tahu, with an array of fish, shellfish and plants being gathered seasonally and according to tikanga Māori (Mahaanui Kurataiao Ltd, 2013). As well as being a mahinga kai source of its own, it was an access point to the Pūharakekenui / Styx River catchment "and the fishing grounds of Te Tai o Mahaanui (Eldon & Kelly, 1985; Tau et al., 1990, as cited in Orchard et al. 2012, p. 1). The area was once part of an extensive wetland ecosystem prior to intensive colonial settlement (Figure 7).

The area around the Waimakariri river mouth was part of an interconnected system of mahinga kai sites which were used by Ngāi Tahu as seasonal food sources, points of trade and navigation routes throughout Waitaha (Orchard et al., 2012). Te Riu o Te Aika Kawa has been identified as a tapatapa, which refers to the naming of natural features in a landscape after ancestors, a wāhi tapu urupā, which are burial grounds, and a place of tūrangawaewae, which means "the enduring presence of the people within an area" (Orchard et al., 2012, p. 13).

Kati Urihia are noted as being the hapū that had authority over the area of Te Riu o Te Aika Kawa, as this was a place of which mana whenua was exercised by "the descendants of Urihia" (Orchard et al., 2012, p. 13). One such descendant of Urihia was Te Aika, for whom the area was named given his strong association (Orchard et al., 2012).

By the arrival of the first European settlers, Māori settlements along the coastal swamp areas were well established (Boyle, 2011). These were areas in which an abundance of food could be gathered, and at Te Riu o Te Aika Kawa this included a seasonal fishing camp (Boyle, 2011). The Waimakariri River mouth was an important food source "up until the 1880's when game fishing legislation banned the taking of game fish from the river making it difficult to fish for non-game species" (Boyle, 2011, p. 6).

The Te Aika whanau maintain connections and whakapapa to Te Riu o Te Aika Kawa, such as at their turangawaewae of Pūharakekenui Māori Reserve (MR892) where "Te Hapū O Kāti Urihia Ahu Whenua Trust represents the hapū and whanau of Kāti Urihia, that have manawhenua within this area" (Christchurch City Council, 2009, p. 22). Furthermore, Te Ngāi Tūāhuriri Rūnanga also whakapapa to this area, and have mana whenua over Te Riu O Te Aika Kawa (Christchurch City Council, 2009).

Figure 7: Overlay of land cover on 19th Century Black Maps, approx. c.1856 (Taken from Canterbury Maps).

3.2. Effects of early European Settlement

Whilst the colonial system of planning and environmental management has created fragmented ownership of the estuary and surrounds, Māori view "the landscape and the people within it" (Parliamentary Commissioner for the Environment, 2020, p. 9) as inseparable. Any story of Brooklands Lagoon therefore needs to explore how the Waimakariri River catchment was used, altered and controlled, as this ultimately influenced the formation of the lagoon and some of the important biophysical changes that resulted in the habitats and species that now occur there.

The early European settlers arrived in Canterbury in the 1840s, and they relied on tangata whenua for transportation along the coastline, and the rivers and lagoons that intersected with it (Boyle, 2011; Christchurch City Council Libraries, n.d.).

In 1848, the land commissioner Henry Kemp was sent to the South Island of New Zealand by Governor Grey to purchase land for settlement (Waitangi Tribunal, 1997) . Kemp, whom was acting on behalf of the Crown was instructed by Lieutenant Governor Eyre to reserve Ngāi Tahu mahinga kai sites as well as an abundance of land for their current and future requirements and to mark the boundaries of these reserves before purchasing land (Commissioner Mackay, 1888). However, Kemp purchased the land off the Ngāi Tahu chiefs before determining the boundaries of the reserves, thus leaving Ngāi Tahu "entirely in the hands of the Government as to the quantity of land to be set apart" (Commissioner Mackay, 1888, p. 3). This resulted in the Crown failing to set aside sufficient reserves for Ngāi Tahu, and "the Crown also determined that mahinga kai sites were restricted to those areas currently under cultivation as gardens, or the places where there were fixed structures such as eel weirs" (Te Rūnanga o Ngāi Tahu, 2017). Kemp's land purchase damaged the mauri of all mahinga kai sites in Canterbury as it fragmented their ownership and failed to acknowledge their interrelatedness, and also meant that some of the resources used by mana whenua were no longer accessible to them, including in the Waimakariri River mouth area (Waitangi Tribunal, 1997).

In 1849 the Waimakariri River mouth and its north branch (now known as the Kaiapoi River) began to be used as a trading port by Alfred Rhodes (Boyle, 2011). In "the early 1850's up to one hundred small trading vessels regularly called in" (Boyle, 2011, p. 6). The early 1850s also brought the division of land by European settlers (Boyle, 2011). A Scottish man named George Leach had ownership of "the large block that gave its name to Brooklands Lagoon" (Boyle, 2011, p. 6). At this time, the sandy soils were becoming exposed as stock and rabbits were overgrazing on the land which resulted in sand blowing inland (Boyle, 2011). Maps from this time, such as the one shown in Figure 8 which is adapted from the 19th Century Black Maps (Figure 7), show the extent of sand, swamp and vegetation in the area, as well as the dual sand spits of Brooklands Lagoon at this time.

In 1852, the area west of what is now Brooklands Lagoon was part of a pastoral farm known as 'Sandhills Run'. It continued its life as a sheep run until the early 1900s, with reports of up to 2,000 sheep inhabiting the area between Waimairi [south of what is now Spencer Park] and the Waimakariri River (Biggs, 1947). This resulted in sand drifting inland due to a reduction in vegetative cover making the dunes unstable (Biggs, 1947). The farm impacted the protective sand dunes along the coastline, "and it is recorded that even by the 1870s, the native shrubland, pingao and spinifex grass had been stripped by rabbits, sheep and cattle, and invaded by weeds" (Worner, 2009, p. 7).

In 1857, Charles Torlesse carried out a coastal survey, and found the Waimakariri River mouth was "one hundred yards wide" (Cooper, n.d., as cited in Boyle, 2011, p. 6). Torlesse also noted that the river mouth had a tendency to move up to a quarter mile north or south of its usual course (Boyle, 2011). In higher reaches of the Waimakariri River catchment at this time tussocklands and forests were being removed, burned down and overgrazed (Boyle, 2011). As well as this, swamp lands were being drained as their potential to provide excellent agricultural land was recognised and took the priority of colonialist settlers (Boyle, 2011). This process typically affected the flow of New Zealand rivers, increasing them "by 20 to 50 percent" (Cooper, n.d., as cited in Boyle, 2011, p. 7).

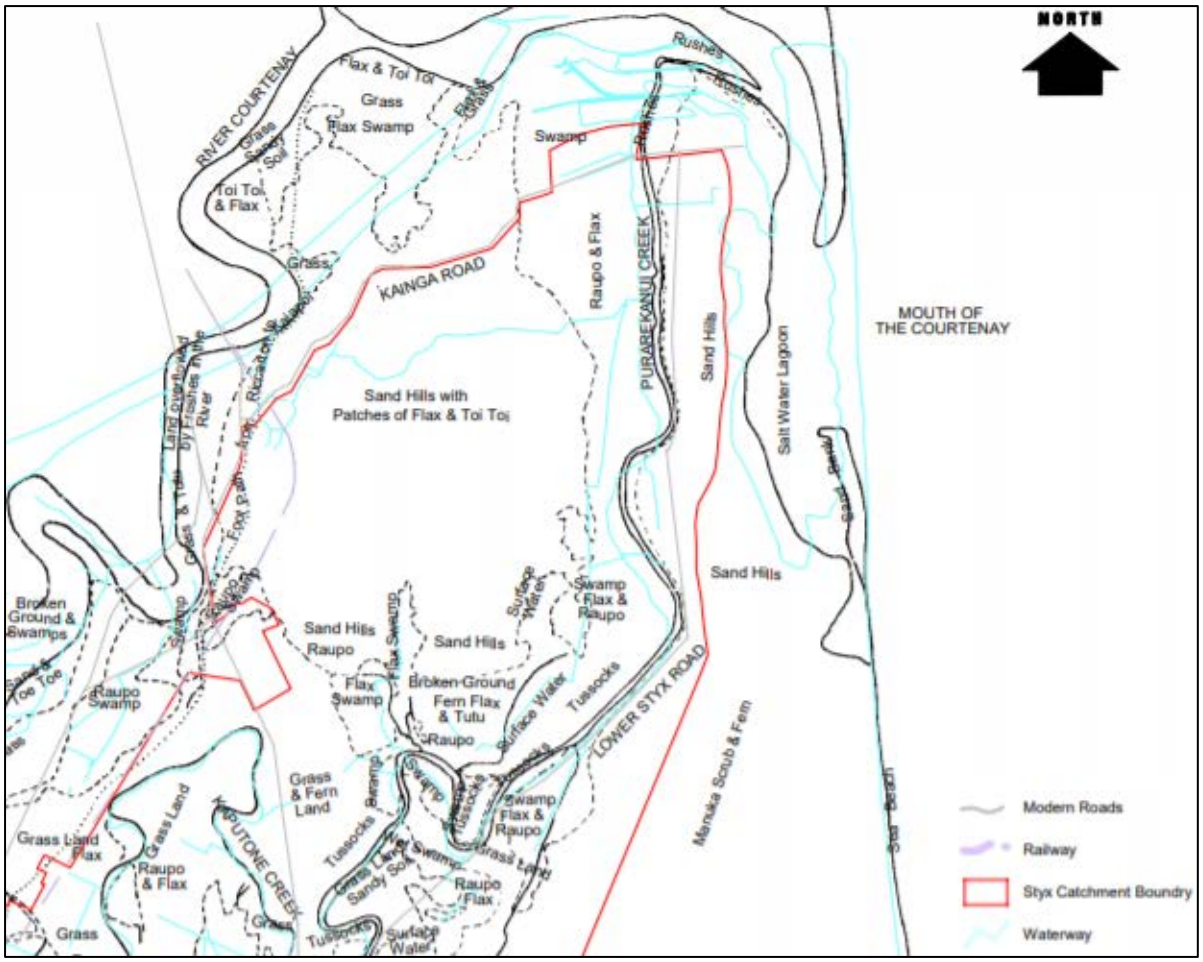

Figure 5: Catchment of the Styx, "showing Waterways, Swamp and Vegetation in 1856" (Adapted from The Styx Living Laboratory Trust, 2004).

The earliest recorded efforts for flood protection on the Waimakariri River were documented in 1860 by Samuel Butler (Sweeney, 2016). He described the river as leaving its channels and changing course on 'a whim', and the long-term control of the river was seen as difficult to obtain (Sweeney, 2016). In addition, he expressed concern for the fact that the river appeared to be changing course again, looking as if it were to head to an old course of the river approximately one-hundred yards away (91.44 metres) which led directly into the city centre of Christchurch (Sweeney, 2016). Butler described the flood protection efforts at the time as:

"Government had put up a wooden defence, at a cost of something like two thousand pounds, but there was no getting any firm standing ground, and a few freshes carried embankment, piles and all, away, and ate a large slice off the bank into the bargain; there is nothing for it but to let the river have its own way" (Butler, 1860, as cited in Sweeney, 2016, p. 3).

Floods during the 1850s and 1860s led to a new channel being formed within the Waimakariri River. A new channel across Kaiapoi in 1868, which at the time was an island, led to the north branch of the Waimakariri 'choking' as it filled with sediment (Boyle, 2011). The Waimakariri Harbour Board was constituted in c. 1866 and dredging began on the north branch to remove the silt that was hindering shipping" (Cooper, n.d., as cited in Boyle, 2011, p. 7)

In 1868, the Native Land Court granted Pūharakekenui Māori Reserve (MR892) "to the original owners of Kaikanui Reserve on the edges of the lagoon" (Christchurch City Council, 2015, p. 94; Plate 4) This was carried out as compensation by the Crown for the effects that Kemp's land purchase had on Māori land and mahinga kai sites (Commissioner Mackay, 1888).

The Christchurch Drainage Board was established in October of 1875 due to ongoing issues with groundwater levels, increasing population, diseases carried in waterways, and periodic flooding. The drainage board was tasked with managing wastewater and the drainage of wetlands. This board existed for over 100 years, and during this time it "progressively deepened, widened and straightened the Avon, Heathcote and Styx Rivers" (Watts, 2011, p. 8), thus influencing the amount and type of water that flowed through the Styx River and into Brooklands Lagoon (Watts, 2011). The Waimakariri Harbour Board was also established around this time, and began dredging the northern branch of the river to remove silt to improve access for vessels (Boyle, 2011).

In 1879, Ngāi Tahu land claims were investigated by the Smith-Nairn Royal Commission of Inquiry. During this time, "Taare Wi Teihoka and others from Ngāi Tūāhuriri recorded Te Riu-o-Te-Aika-Kawa as a kāinga mahinga kai (food-gathering place) where tuaki (cockles), rōrōa (shellfish sp.), pātiki (flounder), and whētiko (mudflat top shell) were gathered" (Te Rūnanga o Ngāi Tahu, n.d.). In 1887, the title of Pūharakekenui Māori Reserve (MR892) was investigated by the Native Land Court under the Native Equitable Owners Act 1886 to ensure that all whom held a right to ownership of the reserve were determined (Te Rūnanga o Ngāi Tahu, n.d.).

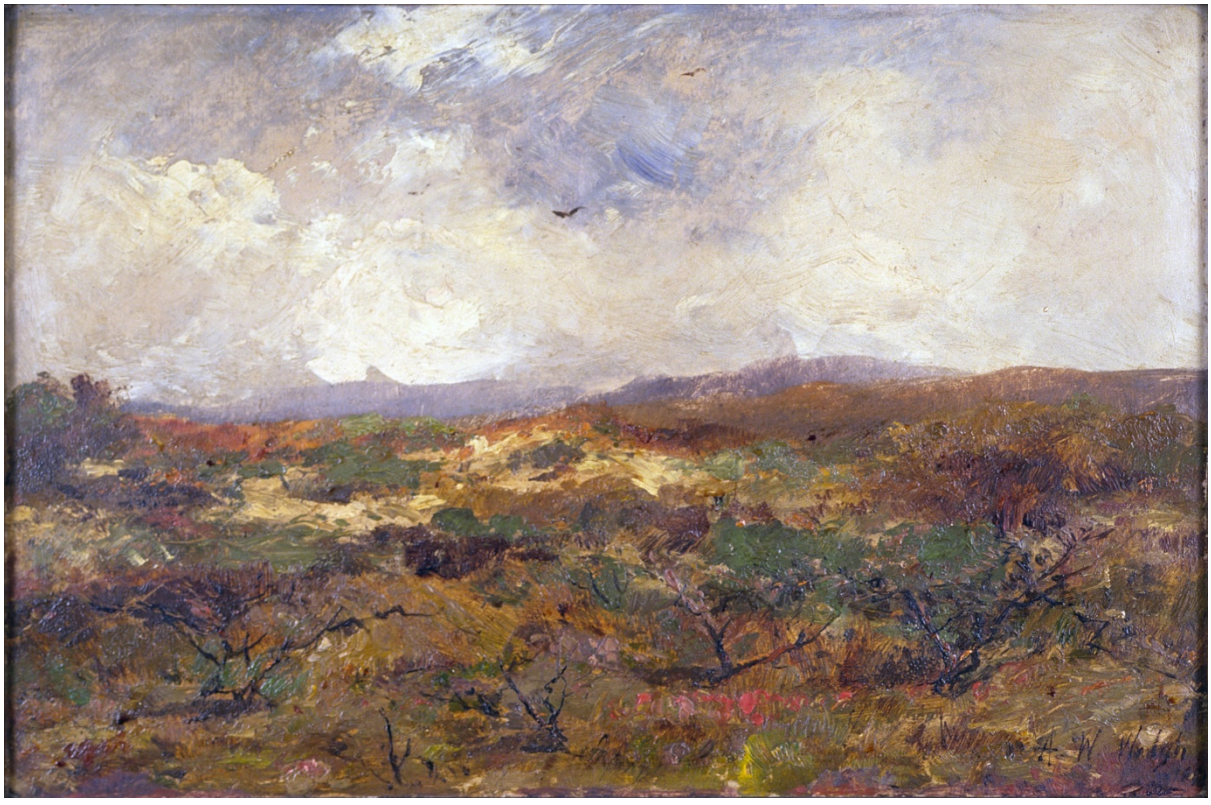

Plate 3: Alfred Wilson Walsh
Margin of the Sandhills
Collection of Christchurch Art Gallery Te Puna o Waiwhetū; purchased, 1975

In 1921, planning for the Brooklands township commenced, including a proposed road layout (Boyle, 2011) (Note: the origin of the name "Brooklands" was not able to be identified). The proposed main road was drawn into what is now the centre of Brooklands Lagoon (Boyle, 2011). When the river mouth shifted in 1940, this changed the plan for the Brooklands township (Boyle, 2011).

Concerns about shingle aggradation and the associated flood risks posed in the lower reaches of the Waimakariri River had been raised for years, and the Waimakariri River Trust was formed under 'The Waimakariri Improvement Act 1922' (Boyle, 2011). The Waimakariri River Trust were tasked with finding a "solution to the flooding problem on both the north and south banks of the river" (Nagy, 2016, p. 28). In 1925, an engineer, Mr. F. C. Hay proposed options to resolve the aggradation, and ultimately one of these was chosen, which was to control a channel that would guide the river "into the north end of the lagoon (but still south of today's river)" (Cooper, n.d., as cited in Boyle, 2011, p. 7). Other experts from Europe and North America advised on this option, adding that "the river needed to be channelled and straightened as it flowed out to sea in order to carry shingle and sand more efficiently" (Cooper, n.d., as cited in Boyle, 2011, p. 7).

Plate 4: Town of Seafield Park Estate, Town of Brook Map, showing Mouth of Waimakariri River and Brooklands Lagoon with proposed landing place for sea planes. Diagrammatic by Smith and Anthony, A Wells Civil Engineer, Christchurch. Canterbury Museum CMU1791.[2]*.*

[2] *Map created circa 1922.*

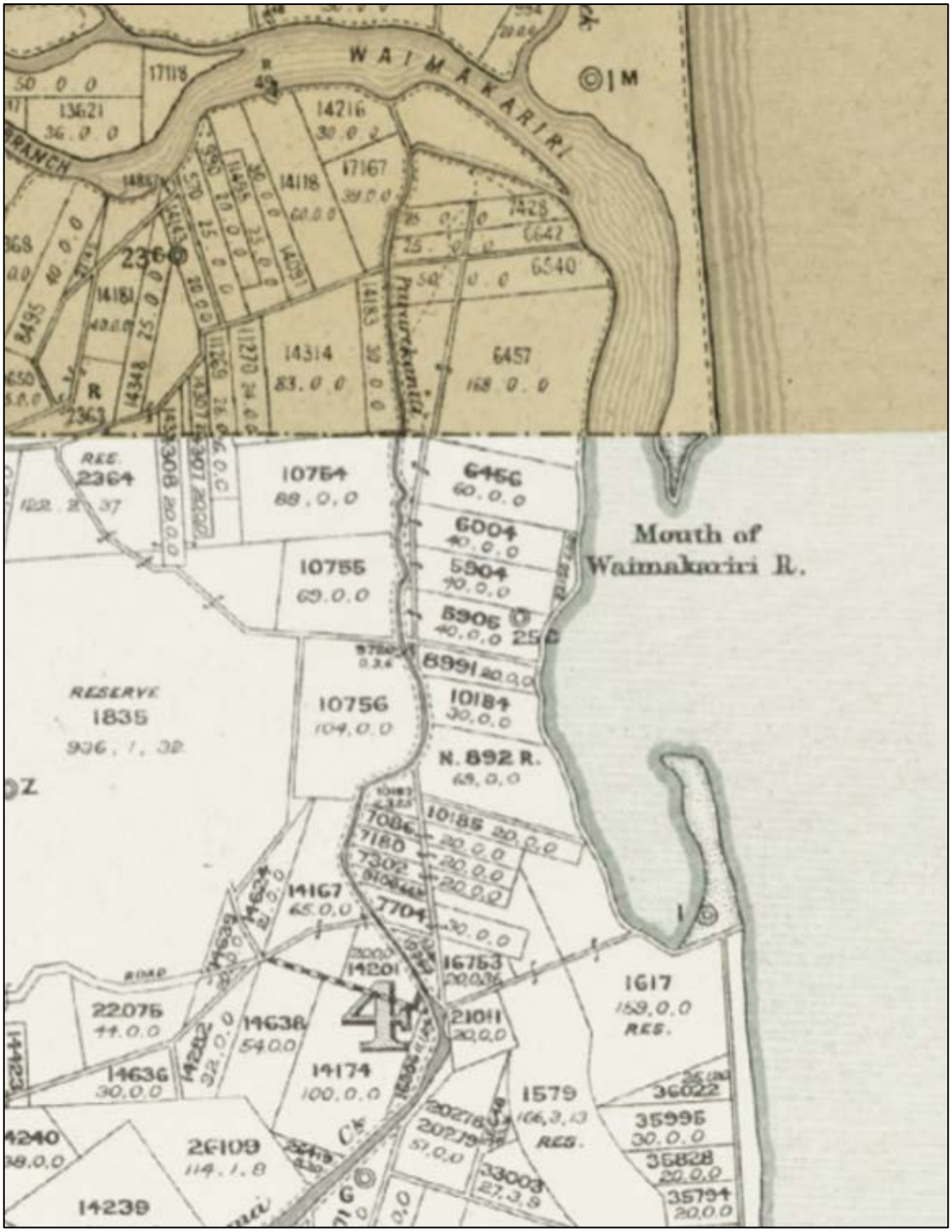

Plate 5: The Waimakariri River mouth is reproduced on every NZMS13 map from 1899-1929 in the same way as shown above, which shows the wide river mouth and no lagoon (From New Zealand Lands and Survey & Land Information New Zealand, 1899).

Chapter 4. 1930-1940: Attempts to reduce flooding and nature takes its course

Employment schemes were launched during the Great Depression of the 1930s. Pine plantations were established along the Waimakariri River banks as a part of this, and willow (*Salix* spp.) and poplar (*Populu*s spp.) were also introduced along the riparian edges of the river (Christchurch City Council, 2015). Hay's Scheme, named after its proposer Mr F. C. Hay, was another program that was carried out during this time, and realignment works occurred in the lower reaches of the Waimakariri River (Environment Canterbury Regional Council, n.d.-c; Nagy, 2016).

These works are known as Wrights Cut and are shown in Figure 9. Wrights Cut which was made "through Coutts Island in the lower reaches of the river and to create a new system of stopbanks and groynes along the river" (Christchurch City Council, 2015, p. 116). The cut aimed to reduce the risk of the Waimakariri River flooding into Christchurch city, and allowed the river to move shingle, sediment and floodwaters at a rate that was faster than could be achieved before the cut was made (Christchurch City Council, 2015).

Wrights Cut also allowed the Waimakariri River to "bypass a tight loop in the river channel, closing the old South Branch at Crossbank [now McLeans Island], stabilising the river mouth, and creating a lower diversion channel between Stewarts Gully and Brooklands Lagoon" (Boyle, 2017, as cited in Todd et al., 2017, p. 75). The end result of Wrights Cut was that the Waimakariri River was pushed into a single channel in its lower reaches and no longer had to pass its way around islands (Environment Canterbury Regional Council, n.d.-c).

Excavation works were also carried out by engineers in the sand hills during this time to support the river straightening works that had occurred at Wrights Cut. This was to allow the Waimakariri River to exit straight into the ocean and not to the south (Worner, 2009). As part of this, more than 1000 ten-tonne concrete blocks were placed along the northern spit "to stabilise what they expected to be the new mouth" (Worner, 2009, p. 7). However, the river continued to flow south before exiting to the ocean.

In 1931, work was also undertaken by relief workers to create a road that went from the end of Beach Road in New Brighton to Waimairi Beach, then allowing motorists to continue down the beach to Brooklands ("A New Road: North Beach to Waimakariri," 1931).

The earliest aerial imagery of Brooklands Lagoon was found to be from 1932 and it is clear that the Waimakariri River mouth exited through a long northern and southern spit, as shown in Figure 10. In 1934, the first tidal gates were installed by the North Canterbury Catchment Board to ensure that the Waimakariri River flood waters would not enter the Styx River (Hicks & Duncan, 1993).

In October 1936, a storm led to the Waimakariri River reaching its highest recorded flood level which resulted in part of the northern sandspit of the Waimakariri River mouth being partially washed away (National Institute of Water and Atmospheric Research, n.d.-c). This is shown in Figure 11.

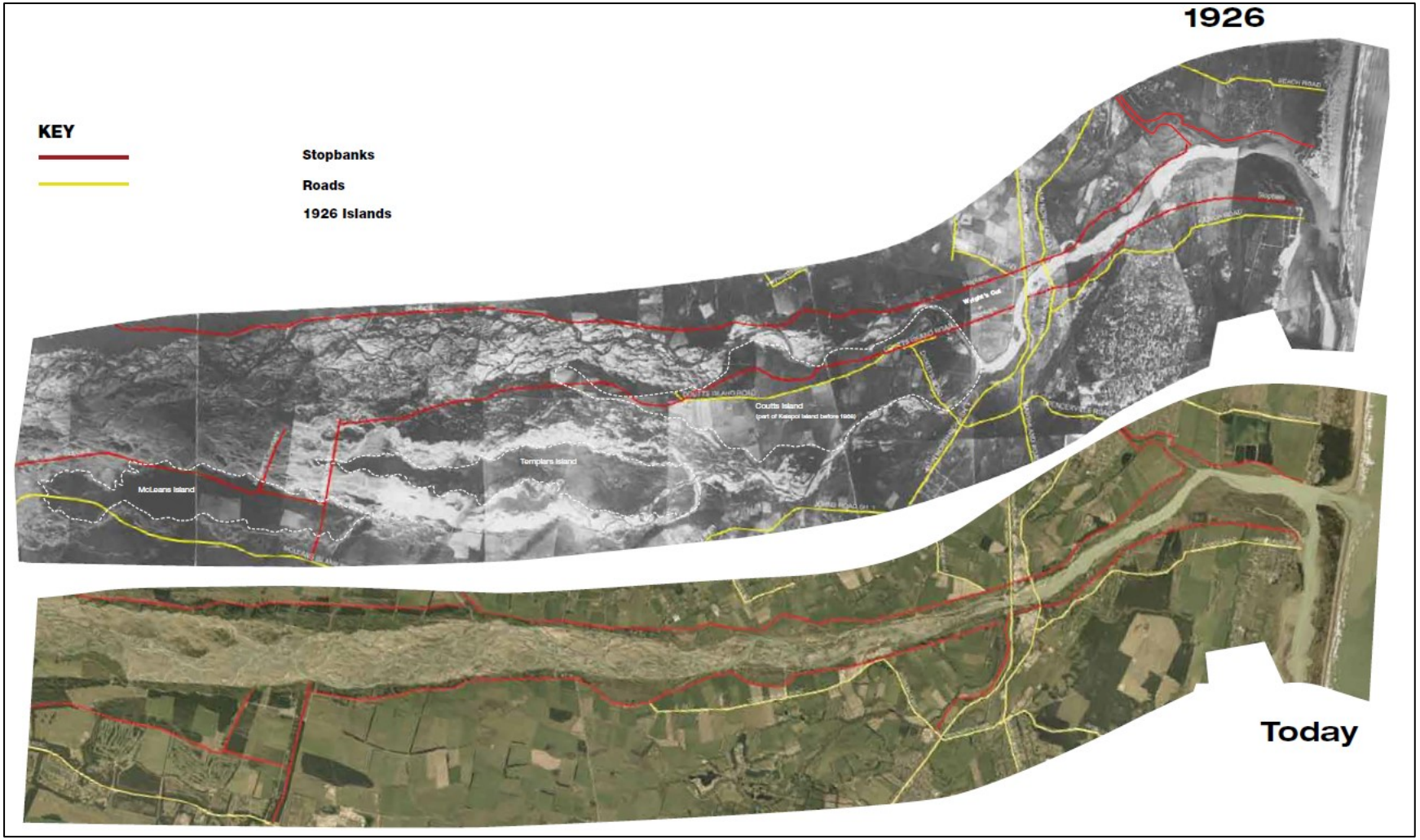

Figure 6: A map of the lower reaches of the Waimakariri River in 1926 before Hays Scheme occurred from 1928. Pictured are the islands that existed in the lower reaches of the Waimakariri River, as well as the original river mouth. (From Environment Canterbury, n.d.-c).

Figure 7: Cropped from: Aerial survey of Waimakariri River from mouth to Courtenay taken from altitude 8000ft, September 1932. Canterbury Museum Vernon ID 653029

Figure 8: Storms occurring in 1936 as well as the works carried out in the early 1930s led to the Waimakariri River mouth having two exits to sea (From Environment Canterbury Regional Council, n.d.-a).

Following heavy rain in the Southern Alps on the 28th and 29th of February 1940, a significant flood occurred in the Waimakariri River (National Institute of Water and Atmospheric Research, n.d.-b). The river was bank to bank and burst through stopbanks at some points, damaging bridges and washing away houses (National Institute of Water and Atmospheric Research, n.d.-b). It was recorded as having "a peak discharge of 176,000 cusecs (4984 cumecs) at the traffic bridge" and reaching "a velocity of 15 ft per second (16.5km/hr)" (National Institute of Water and Atmospheric Research, n.d.-b). The effects of this large flood on Brooklands Lagoon can be seen in Figure 12.

This flood ultimately ended up shifting the Waimakariri River mouth approximately 3 kilometres north to where it flows to the sea today, and was helped along this path by the excavation work that had been carried out in the early 1930s (Boyle, 2011; Worner, 2009). Prior to this flood, "the current Brooklands Spit area was a broad expansion of water and shifting sand bars with little vegetation" (Boyle, 2016, as cited in Todd et al., 2017). However, this was not the channel that had been created via stabilisation works in the early 1930s (Worner, 2009). The moving of the river mouth to its current position changed Brooklands Lagoon "from an active part of the lower river course to a tidal backwater" (Cooper, n.d., as cited in Boyle, 2011, p. 6).

Figure 9: The spit was entirely flooded during this 1940 flood (From Environment Canterbury Regional Council, 1940).

Chapter 5. 1941-1980s: Plans, schemes and the stabilisation of the sandspit

5.1. Floods and erosion

In 1941, the Soil Conservation and Rivers Control Act was enacted which created catchment districts (Gregg, 2008). The Soil Conservation and Rivers Control Council was also established at this time and had four aims: "promote soil conservation, prevent and reduce erosion, prevent flood damage, use land in a way that would achieve these aims" (Gregg, 2008). The council created the catchment boards, of which the main responsibility was to prevent and reduce the amount of damage that could be caused by flooding and erosion within their catchment(s) (Gregg, 2008). In 1946, the North Canterbury Catchment Board was formed and took over the role that the Waimakariri River Trust had held (Boyle, 2011).

From 1940 to 1959, the elongation and stabilisation of Brooklands Lagoon spit occurred due to natural geomorphological processes as shown in Figure 13. In the 1940 – 1944 image, the Pūharakekenui/Styx River exited directly into the ocean, and had a shifting sandbar. However, in the 1955 – 1959 image, the mouth of Pūharakekenui exited into Brooklands Lagoon, which had a long southern spit and the northern spit had eroded.

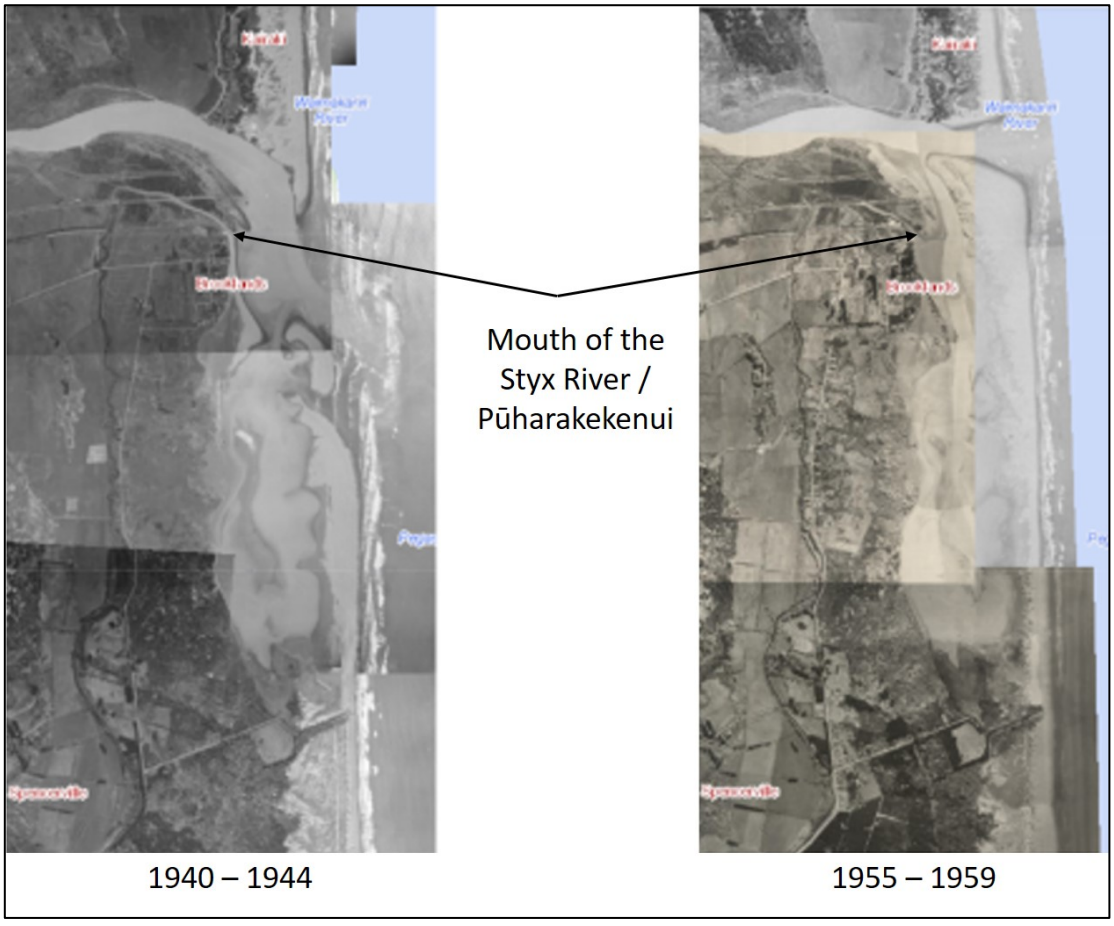

Figure 10: Showing the difference in the Northern and Southern sandbars from 1940 to 1959 (Adapted from Land Information New Zealand, Statistics New Zealand & Environment Canterbury Regional Council, n.d.; Land Information New Zealand, Statistics New Zealand, New Zealand Aerial Mapping et al., n.d.)

Two large floods occurred in the 1950s, which led to a review of the plans for the Waimakariri River. The outcome was a flood protection management scheme, which commenced in the 1960s (Sweeney, 2016). Prior to this in 1952, the Christchurch Drainage Board had taken over the responsibility for the management of the Styx River catchment and commenced works to improve the drainage, including dredging of the area (The Styx Living Laboratory Trust, 1990).

In 1968, a group of residents from Brooklands and the lower reaches of Pūharakekenui notified the Drainage and Catchment Boards that sediment in the bed of Brooklands Lagoon had been building up (Boyle, 2011). It was noted that this may have been contributing to the ongoing flooding problems upstream of the lagoon in the Waimakariri River (Boyle, 2011). Another survey was carried out in the Waimakariri River and Brooklands Lagoon, with results showing "that considerable aggradation had occurred since 1931, particularly in the main channels" (Cooper, n.d., as cited in Boyle, 2011, p. 6). The outcome of the residents' complaint has not been discovered.

In the early 1970s, the sandspit on the eastern side of Brooklands Lagoon was comprised "of three rows of tall sand dunes" (Cooper, n.d., as cited in Boyle, 2011, p. 8). This changed during the period of 1973 to 1977 when a series of high sea levels and storms occurred. These resulted in a ~15 – 18 metre strip of the dune system being washed away (Boyle, 2011). Pine trees and marram grass were planted along the Brooklands Lagoon spit in an attempt to provide stability of the shifting sands (Boyle, 2011). Local opinion is that a major windstorm in the 1970s resulted in the self-seeding of the spit (Boyle, 2011).

Storms in 1978 resulted in the old Waimakariri River mouth in the Brooklands Lagoon spit being reopened. This ended up being 250 metres wide and resulted in an excess of sand flooding into the lagoon due to high tides and strong winds, thus altering the sediment and salinity in the lagoon (Boyle, 2011). The fore dune was rebuilt with the assistance of Spencer Park rangers, whom "built wind netting fences which quickly stabilised the sand and marram grass was planted" (Cooper, n.d., as cited in Boyle, 2011, p. 8). To ensure the sand dunes in this area of the spit are protected, a further two kilometres of fencing were incorporated into them (Boyle, 2011).

In the 1980s, the flood protection management scheme on the Waimakariri River that began in the 1960s was completed. The outcome of this scheme was "a continuous line of primary stopbanks between the mouth of the Waimakariri River and upstream of Mcleans Island" (Sweeney, 2016, p. 3). In addition, the Styx River tidal gates were replaced in 1981 (Todd et al., 2017).

5.2. Ecological issues

A report titled 'The Ecology of the Benthic Macro Flora and Fauna of Brooklands Lagoon Waimakariri River Estuary' was published in September 1978 for the Christchurch Drainage Board in regard to the proposed Northern Sewerage Drainage Plant (Knox & Bolton, 1978). This identified the presence of a diversity of birds, estuarine invertebrates, fresh and salt water fish as well as estuarine vegetation species.

The purpose of the proposed plant was to process the effluent being discharged into the lower reaches of the Waimakariri River (Knox & Bolton, 1978). The key issues identified are in Table 2, and reflect activities within the catchment as well as directly in the lagoon.

The key recommendation for resolving these issues was for the development and implementation of a management plan for Brooklands Lagoon[3]. Due to time limitations we were not able to obtain the drainage board records to ascertain the outcome of this recommendation.

Table 2: Key issues identified in Brooklands Lagoon by Knox and Bolton 1978.

Issue	Effect
Effluent Discharges	Heavy metal and biological contamination Nutrient over enrichment
Lagoon infilling and sedimentation	Shallowing from 4ft deep in 1938 to approximately 1ft deep in 1978 Change in sediment composition Increase in mudflats Changes in vegetation distribution and species richness
Recreational/Human activities	Dumping of waste (e.g., Figure 15), Disturbance to species. Deterioration of water quality

Figure 11: Plate 8 from Knox & Bolton (1978, p. 108) shows car bodies on the western bank of the Lagoon.

[3] The findings and recommendations are set out in Appendix 2

Chapter 6. 1990-2009: Defining a landward boundary, managing stressors and cumulative effects

6.1. Jurisdictional Changes and Institutional Framework

Following on from the creation of regional councils in 1989, the Resource Management Act (RMA) was introduced in 1991 (Scarsbrook & Rutherford, 2016; Wilson, 2015). Its purpose is to "promote the sustainable management of natural and physical resources" (Resource Management Act 1991, s 5). Part of achieving sustainable management includes the management of water resources (Scarsbrook & Rutherford, 2016). The RMA also set out provisions for Māori involvement, the need to take into account the principles of the Treaty of Waitangi, and the mandatory requirement that a New Zealand Coastal Policy Statement was "in place at all times" (Rosiers, 2004, p. 18).

On August 28 1992, a Planning Tribunal gave an interim decision on the landward boundary of the Coastal Marine Area at the Waimakariri River mouth and Brooklands Lagoon (*Minister of Conservation v Christchurch City Council,* [1993] 2 NZRMA 593). The Tribunal was the decision-making authority as the Minister of Conservation, Christchurch City Council and Canterbury Regional Council (also now known as Environment Canterbury) could not decide where to define this boundary. The interim boundary was defined as "the mouth of the Waimakariri River, at or about a point represented by the end of its channelised form westward of Brooklands Lagoon" (*Minister of Conservation v Christchurch City Council,* [1993] 2 NZRMA 593, p. 3).

In 1993, an appeal was heard before judges Williamson and Fraser of the Christchurch High Court to define the landward boundary of the Coastal Marine Area between the lower reaches of the Waimakariri River mouth and Pegasus Bay. The Minister of Conservation appealed the prior decision as he believed the coastal marine area should "include the lower reaches of the river to the limit of saline-tolerant flora and fauna" (*Minister of Conservation v Christchurch City Council,* [1993] 2 NZRMA 593, p. 4). The Minister also argued that the Planning Tribunal's interim decision was mistaken in selecting the boundaries by a defining landform "in preference to evidence of relevant natural and physical resources and ecosystems" (*Minister of Conservation v Christchurch City Council,* [1993] 2 NZRMA 593, p. 16). However, the High Court was not convinced, leaving the landward boundaries of the coastal marine area defined by the Planning Tribunal in 1992.

In 1994, the first New Zealand Coastal Policy Statement (NZCPS) under the RMA was enacted. The purpose of the NZCPS was "to state policies in order to achieve the purpose of this Act in relation to the coastal environment of New Zealand" (RMA 1991 s. 56). The NZCPS set out policies for coastal issues and had provisions for Māori interests in the coastal marine area, and consultation according to the principles of the Treaty of Waitangi (Rosier, 2004). The Minister of Conservation is the responsible Minister for promoting sustainable management in the coastal marine area out to 12 nautical miles, and must agree to regional coastal plans. Environment Canterbury had to give effect to the NZCPS in the Canterbury Regional Policy Statement and Regional Coastal Plan.

Plate 6: An extension was added to the Blue Lagoon restaurant in 1990, with the building extending into Brooklands Lagoon (From Christchurch Star, 1990).

The RMA also requires the Treaty of Waitangi/Te Tiriti o Waitangi to be taken into account in achieving the Act's purpose (s8). It also states that the relationship of Māori with their culture and traditions with their ancestral lands, water, sites, waahi tapu and other taonga is a matter of national importance (s6). Particular regard is to be had to kaitiakitanga.

In 1998, the Ngāi Tahu Claims Settlement Act (NTCSA) was passed into law, which recorded an apology by the Crown to the Iwi for breaches of Te Tiriti. The Crown acknowledged the statements made by Te Rūnanga o Ngāi Tahu of the cultural, spiritual, historic and traditional association with the coastal marine area under s313 NTCSA. The statutory acknowledgment for Te Tai o Mahaanui (Selwyn-Banks Peninsula) in Schedule 101 NTCSA has its northernmost extent at the mouth of the Waimakariri River (as depicted on the Environment Canterbury Maps GIS Viewer). Although this does not include Brooklands Lagoon, it may be an oversight given the determination by the Planning Tribunal, as it does show Avon-Heathcote Estuary / Ihutai as included in the statutory acknowledgment area. Brooklands Lagoon is, however, depicted as a Rūnanga Sensitive Area/wāhi taonga.

The estuary was also identified as an area of 'Significant Natural Value' under the RMA in Environment Canterbury's 2005 operative Regional Coastal Environment Plan. This classification meant that meaning that some activities were restricted to prioritise environmental protection, as it the area is significant for Māori cultural values, as well as for biophysical attributes (Environment Canterbury Regional Council, 2020).

6.2. Erosion and sedimentation

In 1993, a report titled 'Sedimentation in the Styx River Catchment and Brooklands Lagoon' was prepared for Christchurch City Council (Hicks & Duncan, 1993). A number of similar issues to those set out in Knox and Bolton's 1978 report were identified, such as increasing sedimentation particularly in the southern part of the lagoon. Other observations included:

- The lagoon was increasing in width and elevation since its stabilisation in the 1940s. An increase in vegetation helped this stabilisation to occur.
- The mouth of the Styx River / Pūharakekenui had moved over the last few decades, which was thought to be partially due to natural causes and partially due to the lagoon shallowing.
- Whenever the Waimakariri River flooded, the lagoon bed was covered in a few mm of mud. Some of this sediment was uplifted by wave action, and could be removed by outgoing tides.
- The likelihood of coastal sand injections, migration of the Waimakariri river mouth and sedimentation from the Styx River inputting into the lagoon were low.
- Scouring was occurring at the northern end of the lagoon.
- Gradual infilling was occurring at the southern end of the lagoon.
- Sedimentation rates were predicted to increase, most noticeably in the southern part of the lagoon which has more quiescent water flow.
- A shallow delta was naturally created where the Pūharakekenui enters Te Riu o Te Aika Kawa, "which appears to have forced the tidal channel in this narrow part of the lagoon eastwards against the spit" (Hicks & Duncan, 1992, p. 9).
- The sandspit of the lagoon was eroding. This was attributed to *Pinus radiata* filtering windblown sand, meaning that sand that had eroded away could not be replaced.

6.3. Ecological issues

The ecological effects of sedimentation were revisited in 2007. Environment Canterbury carried out a study which looked at the sediments and macrobiota (visible plants and animals) across five sites in Brooklands Lagoon (Bolton-Ritchie, 2007). The purpose of this study was to use estuary sediment as an indicator of the overall estuary condition to ensure that the area of significant natural value (as defined in the Regional Coastal Environment Plan (2005) was being protected and enhanced (Bolton-Ritchie, 2007). The findings were similar to the study by Knox and Bolton in 1978:

- Compared to 1978 sites, the relative proportion of sand in the surface sediment decreased and mud in the surface sediment increased.
- There were low organic content, low nutrient concentrations, low copper, lead and zinc concentrations in the intertidal sediment.
- The presence and abundance of macrobiota was different compared to the 1978 report, presumably due to the difference in sediment.

In 2007, a report on the salt marsh of the Avon-Heathcote Estuary / Ihutai identified that the native musk (*Mimulus repens*) was found in Brooklands Lagoon, "but here too it may disappear due to the spread of rushlands as seen in the Avon-Heathcote Estuary" (Jupp et al., 2007, p. 59). The current status of the musk in the lagoon, which usually inhabits in damp or soggy soils, was not able to be ascertained (de Lange, n.d.).

6.4. Sea level rise

In 1999, Tonkin and Taylor Ltd produced a report that studied the potential impacts of sea level rise in Christchurch (Tonkin & Taylor Ltd, 1999). Their key findings for Brooklands Lagoon were:

- Water levels in Brooklands Lagoon would rise 0.2 metres by 2050 and 0.5 metres by 2100.
- Due to the predicted water level rise in the lagoon, "sand dunes around the margins of the lagoon will retreat in the order of 2.5 m by 2050 and 6.5 m by 2100" (p. viii).
- Saltmarsh and tidal flats found in Te Riu o Te Aika Kawa would retreat, significantly more so if the protection of pastoral lands was prioritised as there would be less room for them to migrate. This would mean that habitat would be lost for intertidal and migratory species.
- An estimated "20% of the flood tide volume entering the Waimakariri mouth goes into Brooklands Lagoon" (Boyle, 1999, as cited in Tonkin and Taylor, 1999, p. 42).

Plate 7: Pine and marram grass on eastern side of the estuary. Photo: J. Hodder-Swain.

Chapter 7. 2010-2021: A plan, an earthquake sequence, and climate change

7.1. An aspirational plan prior to the earthquakes

In August 2010, just prior to the Canterbury earthquake sequence, the Christchurch City Council (CCC) approved and released its parks master plan for Brooklands Lagoon. This plan was not a statutory document as CCC do not have jurisdiction over the estuary as part of the coastal marine area. However, it was created to "provide opportunities to highlight the many open space, natural and tangata whenua values of the area, touch on the issues affecting the area and propose actions to resolve some of these issues and enhance the values" (Christchurch City Council, 2010a, p. 7).

The purpose was: "to guide, influence and advocate for the ongoing integrated management of the open space in the Brooklands Lagoon/Te Riu o Te Aika Kawa area, providing direction with long term objectives developed from a visionary, conceptual and consultative planning approach" (Christchurch City Council, 2010a, p. 7). Accompanying plans for the nearby Seafield and Spencer Parks were included (Christchurch City Council, 2010a, 2010b, 2010c). Whilst these aspirations remain valid, much has changed over the past decade socially, culturally and ecologically.

The earthquake sequence in 2010 and 2011 had a devastating effect on the Brooklands community. A significant area of residential land was zoned as being unsuitable for continued occupation ('red-zoned'). Most of the houses have been removed, with a few residents still remaining. The earthquake sequence also subsided parts of the estuary, with consequential biophysical effects.

The following sections outline the planning implications for the future of the lagoon, which are important to address given the unfolding of climate change effects and associated rise in sea-level. We begin by looking at the planning landscape since that time. Next, we provide a synopsis of the Ngāi Tahu assessment of the state of the local environment after the earthquakes. An overview of ecological changes from published and unpublished research is then set out. Lastly, we look at the combination of earthquake subsidence and sea-level rise on the estuary and surrounding land.

7.2. Changes to the planning landscape

In 2010, the New Zealand Coastal Policy Statement (NZCPS) was reviewed (Belford, 2010). Some of the key differences to the 1994 version were a stronger focus on coastal hazards mapping, a greater emphasis placed on integrated management, and the adoption of a management approach based around risks (Environment Guide, 2018; Orchard, 2011). In 2015, the coastal hazard provisions of the Canterbury Regional Coastal Plan (2005) were updated pursuant to s24 of the Canterbury Earthquake Recovery Act (2011). This involved the identification of areas assessed as being vulnerable to coastal erosion and sea water inundation, and included the cumulative effects of sea level rise over the next 100 years. Figure 16 shows the updated planning map for the lagoon.

In 2019, a report was produced for Environment Canterbury reviewing tsunami evacuation zones (Jack, 2019). In this report, Brooklands Lagoon was identified as a 'red zone', which it also was in the previous report on the matter (Jack, 2019). Being labelled a 'red zone' means that Brooklands Lagoon "can be designated off limits [no public access] in the event of any expected tsunami that is above the minimum MCDEM [Ministry of Civil Defence and Emergency Management] warning threshold of 0.3 metres" (Jack, 2019, p. 8).

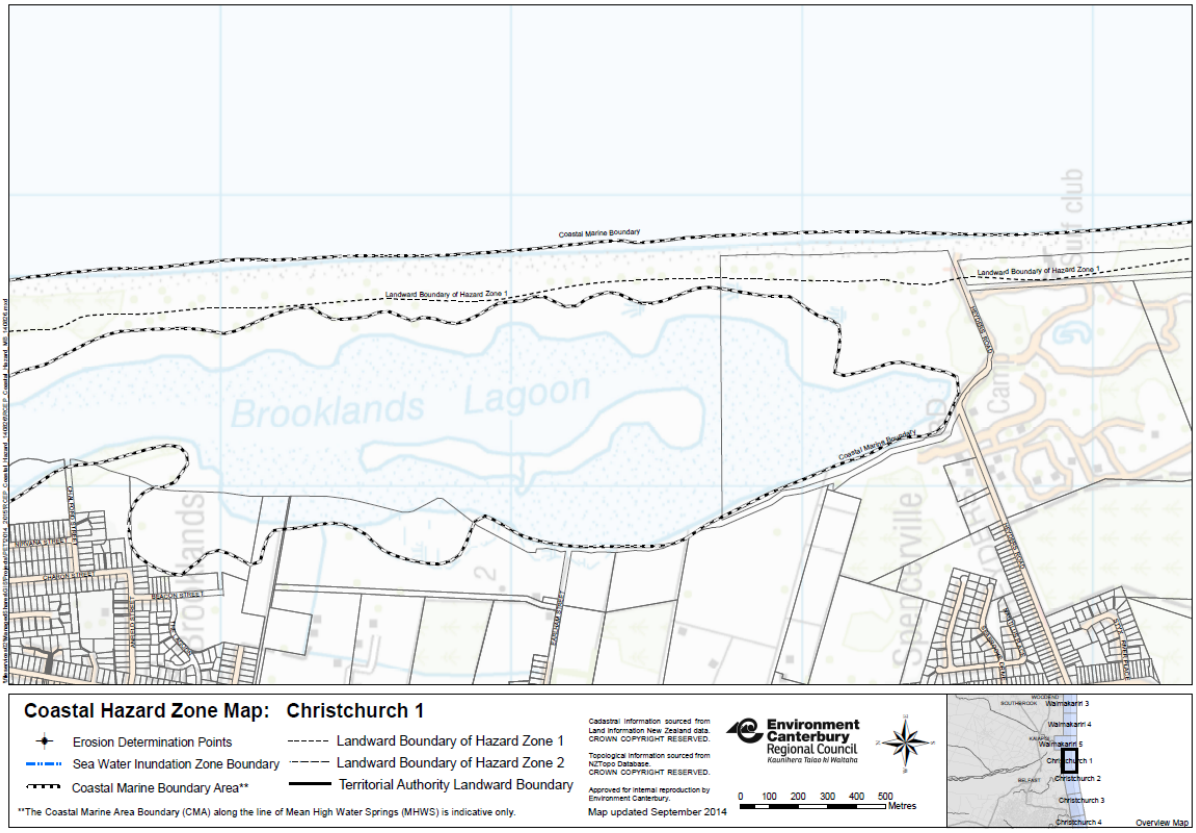

Figure 12: Canterbury Regional Coastal Plan hazard zone map for Brooklands Lagoon, revised in 2015. Note the definition of the coastal marine area which includes the wetted area of the lagoon and the estuarine margin encompassing saltmarsh (Environment Canterbury n.d-c)..

The earthquakes resulted in the district plan being reviewed under the provisions of the Canterbury Earthquake (Christchurch District Plan) Order 2014. In a summary of information on the red zone in 2016, Brooklands Lagoon was listed as a site of ecological significance in the proposed Christchurch Replacement District Plan, which stated the following:

"The Brooklands Lagoon SES is an originally rare ecosystem that contains indigenous vegetation communities that have been greatly reduced within the Low Plains Ecological District, and is also of local, national and international importance in terms of it supporting a representative assemblage of indigenous and migratory birdlife, including 20 threatened, At-Risk or uncommon species" (Christchurch Replacement District Plan, n.d., as cited in Regenerate Christchurch, 2016, p. 2).

Brooklands spit, located on the north east side of the lagoon, was listed as reserve land (Regenerate Christchurch, 2016). Sites of archaeology and heritage on the eastern boundary of the lagoon relate to Māori occupation of the area (Regenerate Christchurch, 2016).

Chapter 19 of the Proposed Christchurch District Plan outlines the objectives and policies for the coastal environment. Adverse effects are to generally avoided, except in urban areas; and activities can occur if they preserve and enhance the natural character, natural features, and natural landscapes of the coastal environment.[4]

[4] Policy 19.1.3. In terms of: a) biophysical and geological aspects and natural landforms; b) natural elements, processes and patterns; c) ecological significance; d) protection of indigenous biodiversity; e) potential for restoration or rehabilitation; f)

The NZCPS policies include biodiversity provisions which seek to avoid adverse effects on estuarine ecosystems, and to manage sedimentation from catchment activities more effectively. Environment Canterbury has yet to fully implement the NZCPS 2010 through a complete review of the 2005 Regional Coastal Plan. In 2020, Environment Canterbury took the decision through its Annual Plan process to begin engagement on a review of the Regional Coastal Plan.

The NZCPS objectives and policies on biodiversity and ecosystem health have recently been reinforced by the concept of Te Mana o te Taiao (mana of the environment) in the 2020 Aotearoa New Zealand Biodiversity Strategy. This strategy aims to achieve thriving ecosystems and the indigenous species they sustain by maintaining and/or restoring ecological health and connectivity.

The opportunity for an integrated resource management approach has arisen with the recent release of the National Policy Statement for Freshwater Management (NPS-FM) 2020. This statement promulgated under the RMA requires local authorities to recognise the interconnectedness of the whole environment from the mountains of the Waimakariri catchment to Brooklands Lagoon. The NPS-FM calls for an integrated and sustainable management approach, *ki uta ki tai*, to be collaboratively developed in partnership with mana whenua, and involve the wider community, with the objective to more effectively manage activities on land and within freshwater.

7.3. Ngāi Tahu - state of the takiwā and management plan

In 2012, a report was produced on the State of the Takiwā in the Styx River catchment and Brooklands Lagoon as a part of a reporting series by Te Rūnanga o Ngāi Tahu and Mahaanui Kurataiao Ltd (Orchard et al., 2012). This was the first report of its kind for Pūharakekenui and Te Riu o Te Aika Kawa.

Cultural health indicators and Ngāi Tahu's takiwā monitoring system were used across sites to determine their overall cultural health. Whilst individual sites were monitored, Ngāi Tahu believe that all sites are related, and the iwi takes a ki uta ki tai (mountains to sea) approach to environmental management, which acknowledges the interconnectedness of waterways. The key findings of this report in relation to Brooklands Lagoon were:

- There was a lack of "naturally occurring ecosystem types which supported cultural values" (p. 41), and those remnants that were still present needed to be protected.
- All monitored sites had an alarming amount of E. coli present, well above drinking water standard. The site monitored at Seafield Park salt marsh was also significantly above the contact recreation alert level.
- Much of the catchment is highly modified, including the presence of stopbanks and tidal floodgates which degrade cultural values associated with the area. However, these values did improve at some sites closer to the coast.
- Indigenous vegetation, bird and fish species varied in their presence throughout the catchment. Riparian planting of indigenous vegetation was supporting the restoration of traditionally found plant species. This was seen by Orchard et al. as "a practical and essential management response for improving cultural values" (p. 33), though it was noted that this could not address all of the cultural concerns raised in the report.

visual qualities and amenity values; g) heritage values attached to items, places and features; h) the relationship of Ngāi Tahu – manawhenua and their culture and traditions with their ancestral lands, water, sites, wāhi tapu and wāhi taonga; i) recognised cultural heritage and customary rights; j) open space and recreation, and; k) natural hazards.

- Concerns were raised at the inanga (whitebait) spawning site, which is close to the tidal flood gates under the Harbour Road bridge. These included how the flood gates may be negatively impacting the spawning site, the highly modified land close to this location, bank slumping, and in what way the Canterbury earthquakes changed the water levels in the area.
- Values pertaining to mahinga kai were mostly poor to moderate, with no sites having very good mahinga kai values. However, most sites were labelled by the working group as sites that they would be willing to harvest from.
- Cultural values could be recognised and/or improved in earthquake recovery activities.

In 2013, Mahaanui Kurataio Limited[5] published the Mahaanui Iwi Management Plan (Mahaanui Kurataiao Ltd, 2013). Provisions in the iwi management plan for Brooklands Lagoon are found in the 'Waimakariri' section of the plan, and the subsection 'Te Riu o Te Aika Kawa / Pūharakeketapu / Brooklands Lagoon'. Policy WAI 10.6 aims to work with Christchurch City Council to implement the Ngāi Tahu Objectives and Planning Proposals for use and management, as set out in the *Brooklands Lagoon/Te Riu o Te Aika Kawa Area Parks Master Plan (2010)* (Mahaanui Kurataiao Ltd, 2013).

The importance of Brooklands Lagoon was set out in the Iwi management plan as follows (p225):

"*Brooklands Lagoon, known both as Te Riu o Te Aika Kawa and Pūharakeketapu, is a coastal hāpua highly valued for mahinga kai resources such as tuna, kanakana, kōura and harakeke. There are also urupā and places of spiritual practice associated the area. Pūharakekenui flows into Te Riu o Te Aika Kawa, and there are strong cultural associations between the waterway and the hāpua, and other waterways and wetlands as far south as Te Waihora. Maintaining water quality standards in the hāpua that enable quality mahinga kai habitat is an issue of significance for tāngata whenua. Local observation suggests that low flows in the Waimakariri are limiting the ability of the river to periodically flush the lagoon, and maintain mahinga kai habitat*."

The recovery of Brooklands/Te Riu o Te Aika and Styx River/Pūharakekenui post-earthquake received attention in the Natural Environment Recovery Programme for Greater Christchurch - *Whakaara Taiao*[6] (Environment Canterbury Regional Council, 2013). The relevant strategic aims of the recovery programme were: Investigate and monitor coasts and estuaries; Reduce flood risks and restore drainage capacity of waterways; Manage sediment from liquefaction; and Rehabilitate, restore and enhance wetlands changed by the earthquakes. It is beyond the scope of this report to assess the implementation of this strategy.

7.4. Ecosystem responses to the earthquakes

In the 2010 Parks master plan, the Christchurch City Council drew from a report from Worner & Partridge (2008), which noted three types of saltmarsh habitats occurred in Brooklands Lagoon (Table 3). Ongoing sedimentation occurred in Brooklands Lagoon when the Waimakariri River was in flood, however, it was thought that much of this was removed with estuary tides (Christchurch City Council, 2010a)Hicks & Duncan 1993). The Council also mentioned that the potential for sand to wash or blow over the sandbar should decrease as it grows in width and height over time, and stabilises with the support of the existing vegetation such as pine and marram grass.

[5] Mahaanui Kurataiao Ltd is the resource management organisation for the six Mahaanui Rūnanga: Ngāi Tūāhuriri Rūnanga; Te Hapū o Ngāti Wheke Rūnanga; Te Rūnanga o Koukourārata; Ōnuku Rūnanga; Wairewa Rūnanga; Te Taumutu Rūnanga.
[6] The strategy was co-developed by Te Rūnanga o Ngāi Tahu, Christchurch City Council, Environment Canterbury, Canterbury Earthquake Recovery Authority, and the Waimakariri and Selwyn District Councils.

In 2011, a report titled 'An Investigation into the Southward Migration of the Waimakariri River mouth' was produced for Environment Canterbury (Boyle, 2011). The findings indicated that if a breakout in the sandbar of the lagoon were to occur, Te Riu o Te Aika Kawa would be left as a deep backwater which would quickly infill with sediment spilled from the river, blown over the sand spit by the prevailing north easterly wind, or washed over by storm waves. Boyle also concluded that even with the present lagoon configuration, the Styx River likely exerts only a small influence on lagoon sedimentation processes, mainly in reworking the lagoon sediments towards the mouth and then generally only when the tide is low. The supply of sediment to the lagoon from the Styx catchment is small compared the volume circulating from the Waimakariri River (Boyle, 2011).

Table 3: The three saltmarsh habitat types in Te Riu o Te Aika Kawa / Brooklands Lagoon (Adapted from Christchurch City Council, 2010a).

Name	Southern habitat	Central/Northern habitat	Styx/Waimakariri habitat
Sediment	Very fine and water-logged	Coarse, sandy and free-draining	Lack signs of sediment deposit
Vegetation	Mostly three-square (*Schoenoplectus pungens)* and oioi (*Apodasmia similis*). Other species in this ecosystem denote its brackish water influence.	Mostly sea rush and other herbaceous species which denote the dominance of salt water in this ecosystem.	Mostly oioi, some marsh ribbonwood (*Plangianthus divaricatus*) present.
Salinity	Reduced	Ranges seasonally	Reduced

In 2015, a Christchurch City landscape study was published by the Christchurch City Council (Christchurch City Council, 2015). The findings of this study in relation to Brooklands Lagoon were:

- The mudflats in Brooklands Lagoon were submerged at high tide.
- "Extensive mudflats can be found around the central section of the lagoon that are home to a range of shellfish species, including tuaki/cockles, while the southern end contains more vegetation, such as reed-beds/jointed wire rush and some raupo" (p. 94).

An unpublished University of Canterbury study in 2015 compared plant and sediment distributions taken pre-earthquake by Worner and Partridge in 2008 to publicly available satellite imagery, and field data that the authors collected (Ratigan & Reid, 2015). Key findings of this unpublished study were:

- The subsidence that the Canterbury Earthquake Sequence caused in Brooklands Lagoon affected the ecosystem of the lagoon.
- Some parts of the ecosystem increased in exposure to water due to the decrease in elevation in the lagoon causing the water level to rise.
- The southern end of Brooklands Lagoon was sandier than pre-quake.

The increase in sand may be related to sand 'volcanoes' caused by liquefaction, as identified in the top 15cm of core taken from the estuary bed (Schlam & Reid, 2015). The core was extracted from the southern end, near the old Waimakariri River mouth, and the change from a marine to an estuarine environment was evident in shifts in foraminifera and sediment composition. It is unlikely that the southern end of the lagoon will become sandier due to the inputs from the Waimakariri river and the low volume of sand transported into the lagoon from Pegasus Bay (Hicks et al., 2018).

7.5. Water Quality

There are no permanent water quality monitoring sites within the lagoon. However, there is a freshwater monitoring site along the Styx River at the Harbour Road bridge. Monitoring data posted on the LAWA website[7], shows E. coli has a 5 year median of 170 n/100 ml which is in the worst 50% of sites nationally. Ammoniacal Nitrogen (5 year median of 0.0375 g/m^3) and dissolved reactive phosphorus (0.0315 g/m^3) are in the worst 25% of sites nationally. Turbidity readings are relatively low at 2.4 NTU reflecting that inputs into the lagoon are not significant cf. the Waimakariri River.

Within the lagoon itself, in 2016, stormwater mains were "discharging to the Brooklands Lagoon at the end of Blue Lagoon Drive and from Seafield Park subdivision to Seafield Park Wetland" (Regenerate Christchurch, 2016, p. 5). However, the contribution of stormwater to water quality in the lagoon is unknown. In 2018, the Christchurch City Council applied to Environment Canterbury for a global stormwater consent (Reuther, 2018). In a hearing, Nick Reuther, an Environment Canterbury Senior Consent Planner, said that "There is little information available in general on the stormwater contribution to water quality in Brooklands Lagoon" (Reuther, 2018, p. 34).

7.6. Earthquake Subsidence and Sea Level Rise – a double whammy

In 2013, Tonkin and Taylor Ltd produced another report that studied the potential impacts of sea level rise in Christchurch (Tonkin & Taylor Ltd, 2013). Their key findings for Brooklands Lagoon were:

- Sea level rise could change the tidal interactions and sediment loads in Brooklands Lagoon.
- Water levels will increase in the lagoon with sea level rise as the Brooklands Lagoon mouth and Waimakariri River mouth are wide enough for this to occur.
- "Sea level rise is likely to result in an enlarged lagoon footprint at high tide" (p. 49) as the terrain surrounding Brooklands Lagoon is flat.
- The Lower Styx ponding area could spill into Brooklands Lagoon with sea level rise. If this were to occur, lagoon waters could increase the salinity levels found in the ponding area.
- An increase in storm events, combined with sea level rise are likely to lead to coastal inundation increasing in frequency.
- By the year 2115, "approximately 700 ha of land is expected to be lost as the shoreline retreats inland" (p. 49).
- The vegetation in Brooklands Lagoon may not survive due to an array of factors. First of all, the rate in which the climate and sea level change may be too rapid for some vegetation. Another reason is that geographic and topographic conditions may not be suitable for the vegetation. A final reason is that physical structures and pre-existing plant communities may limit the amount of landward migration that can occur by this vegetation.
- A mean 1 metre increase in sea level rise is predicted to permanently drown the tidal mudflats found in Brooklands Lagoon.
- Salt marsh environments are predicted to "re-establish in higher elevations in areas where pasture and salt meadow currently exist" (p. 50).
- Species of fish and birds that are found in Brooklands Lagoon are predicted to migrate to new locations if sea level has a mean 1 metre increase.

[7] https://www.lawa.org.nz/explore-data/canterbury-region/river-quality/waimakariri-river-catchment/styx-river-at-harbour-rd-bridge/

A gap analysis report was produced for Christchurch City Council, who were "undertaking the Land Drainage Recovery Programme in order to assess the effects of the earthquakes on flood risk to Christchurch" (Todd et al., 2017, p. 1). The key findings in relation to Brooklands Lagoon were:

- As a consequence of the earthquakes, Brooklands spit increased in elevation, much of the lagoon slightly decreased in elevation, as shown in Figure 17.
- "The temporal relationship between the meteorological conditions which have the ability to cause fluvial flooding in the Waimakariri River catchment, pluvial flooding over Christchurch, and coastal storm surge is currently unestablished in the literature" (p. 17).
- That if a coastal storm and fluvial and pluvial flood were to occur at the same time, which is likely due to both events requiring similar meteorological conditions, it could result in coastal inundation at Brooklands Lagoon, as well as shoreline fringe erosion and restrict inland flood discharge, as "high seas can cause the rivers to back up inland" (p. 48). These events may also result in migration or instability and erosion of the Brooklands Spit.
- Climate change may impact the sediment supply to the Spit and increase storm events.
- If the morphology of the mouth of Brooklands Lagoon were to change, it "would result in large changes to the volume of water able to enter the estuary or lagoon in normal and storm tide conditions" (p. 56).
- If flooding were to occur within the primary stopbanks of the Waimakariri River, the potential effects for Brooklands Lagoon are inundation due to water level rise, instability and/or erosion of Brooklands Spit and the mouth of the lagoon, a breach in the sandbar where the old river mouth was, scouring of the main channel within the lagoon as well as of the tidal prism at the mouth due to increased water velocity, a change in sediment transport and tidal flows in the lagoon and the lower reaches of the Waimakariri River.
- There is a co-existence of medium to high hazards at Brooklands Lagoon.

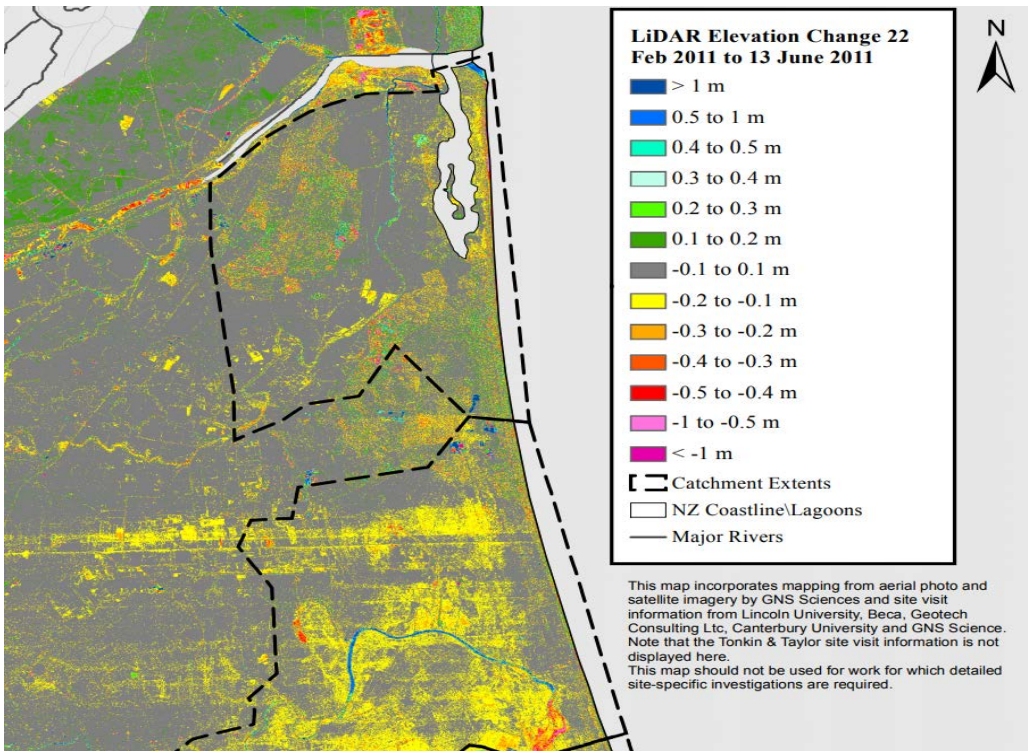

Figure 13: From Todd et al. (2017) for Christchurch City Council, showing the change in elevation change in the area after the February 22 2011 earthquake. The area surrounding Brooklands Lagoon generally subsided between 0.2 and 0.1 m.

Chapter 8. Discussion

The Parliamentary Commissioner for the Environment (PCE) recently reported on the way estuaries are being managed in Aotearoa New Zealand. This is because healthy estuaries deliver a range of ecosystem services to nature and also to humans for sustenance and enjoyment (Thrush et al., 2013).

These ecosystem services include the ability to capture carbon and cycle nutrients, as well as provide habitats for a range of shellfish, fish, invertebrates and birds. A healthy estuary provides humans with food, recreation, and aesthetic appreciation, as well as cultural and spiritual nourishment.

Estuaries are the receiving environment of a multitude of different pressures, and reflect the way we collectively treat our whenua and wai. Many of our rivers bring in contaminants from rural and urban environments in the form of sediment, nutrients, heavy metals, and bacteria (Parliamentary Commissioner for the Environment, 2020). . In addition to the upstream effects of different land uses, activities within estuaries can also cause stress to the system - such as overharvesting, disturbance to wildlife, rubbish, and clearance of vegetation along the estuary margin. Invasive species are also an increasing ecological issue. These pressures can combine, interact and build up to cause ongoing degradation to the biophysical, cultural and social values of estuaries The challenges don't end there though, as the effects of climate change on river flows, and the changing chemistry and height of the sea, pose risks to estuaries.

One of the key questions for estuaries is where can they migrate to when they are being squeezed by sea-level rise and hard landward boundaries (Woodruff, 2018). Even though we are focused on coastal hazards, our thinking has generally been around human infrastructure and social impacts. An increasingly important question is how can we accommodate estuaries to move to ensure their long term survival and provide for all the ecosystem services they provide, if we even can?

Brooklands Lagoon/Te Riu o Te Aika is a young estuary, formed only 81 years ago. Nevertheless, it has rapidly become an important estuarine and wetland ecosystem to nature and humans. It is part of an ecological network connected, as the wading bird flies, to the Ashley River/Rakahuri – Saltwater Creek estuary/Te Aka Aka in the north and Avon-Heathcote estuary/Ihutai to the south. However, over the course of its short existence, it has been subject to many of the aforementioned stressors (Figures 18 and 19), as well as the effects of the Canterbury earthquake sequence.

Estuaries are complex systems to manage (Figure 20). No one individual or organisation can address the myriad stressors facing Brooklands Lagoon by themselves. Iwi and the PCE have both called for an integrated management approach. The opportunity for such a collaborative approach from the mountains to the sea (ki uta ki tai) exists through the National Policy Statement of Freshwater Management (NPS-FM), and through the forthcoming review of the Regional Coastal Plan which is to give effect to the NZ Coastal Policy Statement.

In researching this report, and in the informal kōrero we had with different agency staff, we were surprised by the divergent views as to the future of the estuary, and even whom should manage it. We suggest this is unhelpful to the integrated approach required, and would urge public agencies to put their focus on building a relational and collaborative approach to ongoing management.

We also suggest Brooklands Lagoon/Te Riu o Te Aika needs some sustained aroha.

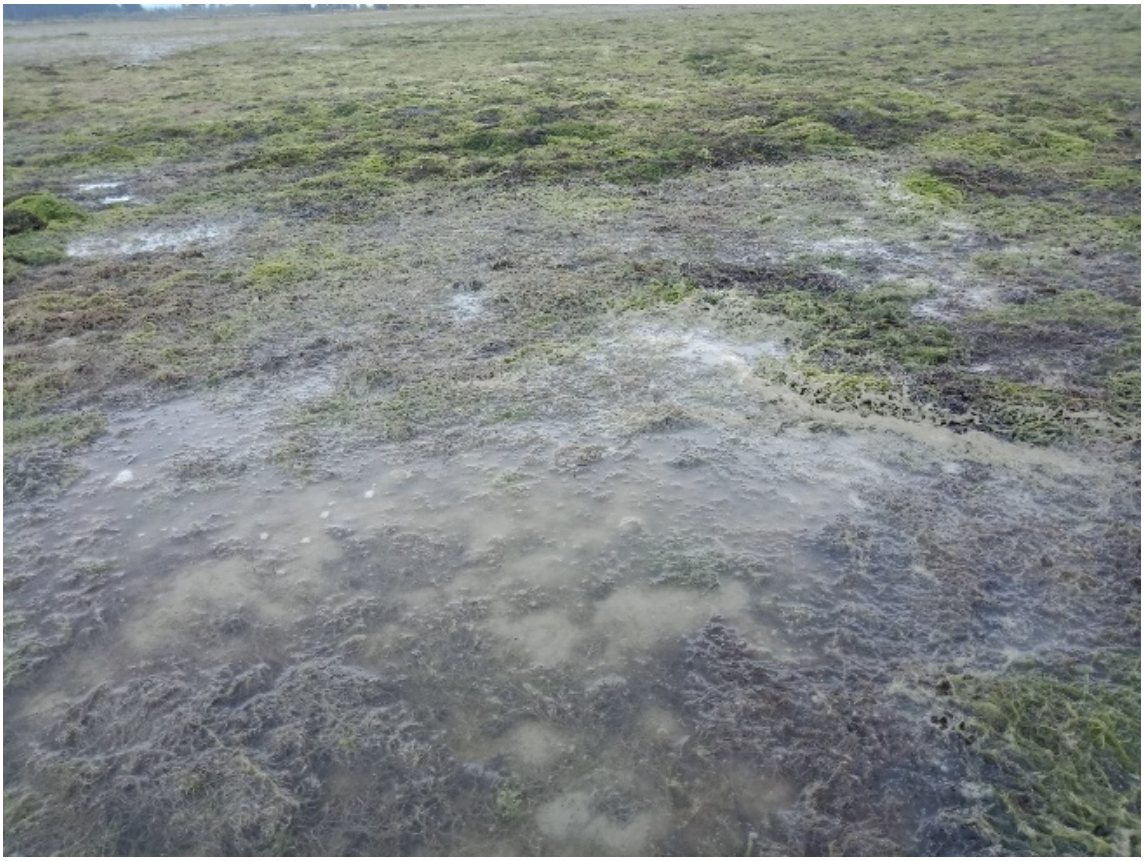

Figure 14: A mat of nuisance macroalgae present at low tide in Brooklands Lagoon, reflecting the effects of excessive nutrients combined with warm temperatures. Photo: J. Hodder-Swain.

Figure 15: Tyre marks present in Te Riu o Te Aika Kawa. January 2021. Photo: J. Hodder-Swain.

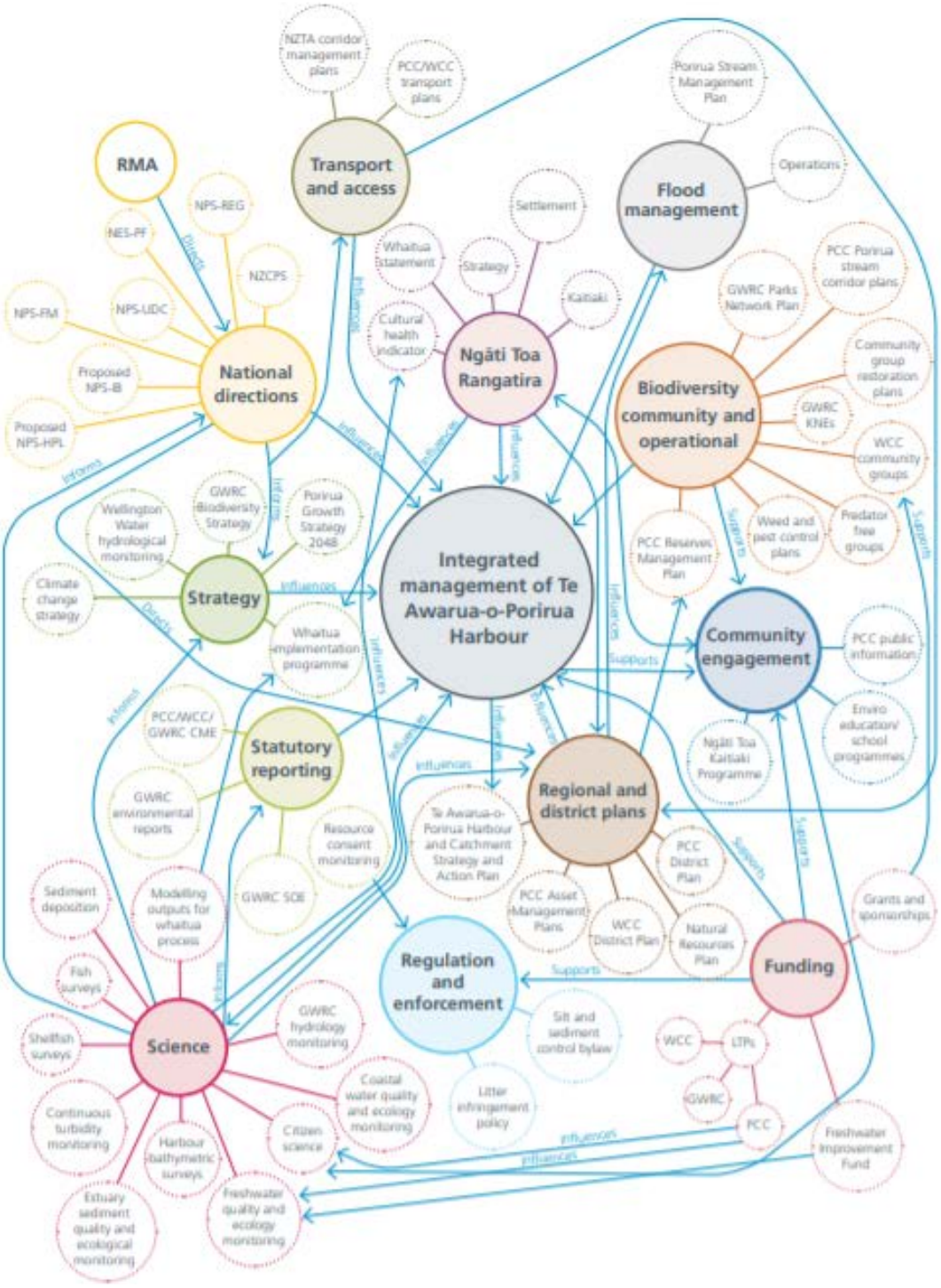

Figure 16: The web of integrated management at Te Awarua-o-Porirua Harbour. Note that some links of legislation are omitted (Parliamentary Commissioner for the Environment, 2020, p. 8)

Chapter 9. Current policy and legislative developments and implications

The decade of the 2020s is seeing a significant shift in the regulatory, political and socio-cultural landscape in Aotearoa New Zealand. The following have the potential to affect the long-term management of Brooklands Lagoon/Te Riu o Te Aika, and the success of its recovery.

- Te Rūnanga o Ngāi Tahu are seeking a declaratory judgment seeking recognition of its rangatiratanga over freshwater in its takiwā. This is because of "ongoing degradation of awa (rivers) and moana (lakes) caused by environmental mismanagement" (Te Rūnanga o Ngāi Tahu, 2020).
- Environment Canterbury Regional Council, Christchurch City Council and Waimakariri District Council are releasing their draft long term plans for public consultation in the next couple of months (Christchurch City Council, n.d.-a; Environment Canterbury Regional Council, n.d.-b; Waimakariri District Council, n.d.-a). The proposed rules and budgets allocated to freshwater management and the coastal marine area could affect the health and wellbeing of Brooklands Lagoon. Furthermore, as the National Policy Statement for Freshwater was released in 2020, this will affect how local government monitors, manages and reports on the state of the freshwater in the Waimakariri catchment (Ministry for the Environment, 2020).
- The Christchurch City Council has begun a programme for coastal hazards adaptation planning. Part of this planning which will include Brooklands Lagoon and sandspit will include consultation with the Brooklands community (Christchurch City Council, n.d.-b).
- Any future changes to the Regional Coastal Environmental Plan may affect how Te Riu o Te Aika Kawa is monitored, managed and/or used.
- Any future changes to the Waimakariri River Regional Park Plan may affect the freshwater quality that interacts with the lagoon.
- The Intergovernmental Panel on Climate Change is currently in the process of preparing its sixth assessment report, which may have new findings about estuarine environments as well as future predictions for estuarine environments (The Intergovernmental Panel on Climate Change, n.d.).
- The National Policy Statement for Indigenous Biodiversity is expected to be gazetted by April 2021 and will require local government to control what biodiversity restoration they are undertaking which could include restoration within and around Brooklands Lagoon (Ministry for the Environment, n.d.).
- An independent review into the Resource Management Act 1991 was published in 2020 (Randerson, 2020). The Government announced in February 2021 that it will move to broadly implement the recommendations into new legislation, which will change the way environmental management is carried out in New Zealand, including in estuarine environments such as Brooklands Lagoon. This is because environmental bottom lines will be established.

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Appendices

Appendix 1: Key Place Names Referenced in this Report

Kaiapoi River: The Kaiapoi River is 16 kilometres long and its mouth feeds into the Waimakariri River, approximately 2.5 kilometres from the mouth of the Waimakariri. The Kaiapoi River features both surface and groundwater tributaries. Historically, the Kaiapoi River was the north branch of the Waimakariri River (Environment Canterbury Regional Council, 2007).

Pegasus Bay: To the east of Brooklands Lagoon is Pegasus Bay which is a sandy beach that extends well past the extent of the Lagoon, going as far north as Waipara River, and as far south as the Avon-Heathcote/Ihutai estuary (Environment Canterbury Regional Council, 2020; Wilson, 2015). The te reo name for Pegasus Bay is 'Te Tai o Mahaanui' (Orchard et al., 2012).

Waimakariri River: The Waimakariri River is 161 kilometres long and discharges into Pegasus Bay (Google, n.d.; Statistics New Zealand, 2006). In the lower reaches of the Waimakariri, the southern bank of the river features the single point for water to enter and exit Brooklands Lagoon (Google Maps). The name of this river "refers to the cold (makariri) mountain-fed waters" (Te Rūnanga o Ngāi Tahu, n.d.).

Kaiapoi Oxidation Ponds: The Kaiapoi Oxidation Ponds are used for wastewater treatment from Rangiora, Mandeville, Ohoka, Kaiapoi, Kairaki and The Pines Beach (Waimakariri District Council, n.d.-b). Christchurch City Council carries out bird surveys at the Kaiapoi Oxidation Ponds when they are doing bird surveys at Brooklands Lagoon, and currently this is done monthly (andrewcrossland, 2020, November 26; McClellan & Simpson Grierson, 2016).

MR892: There is a 27.9 hectare Māori reserve known as 'Pūharakekenui Māori Reserve' on the southwest border of Brooklands Lagoon, which was granted by the Crown to Aperahama Te Aika in 1868 after Te Aika and Wi Te Paa saved the life of W. B. D. Mantell, the Land Purchase Commissioner (Christchurch City Council, 2017; Māori Land Court & Ministry of Justice, 2021; Taylor, 1952; Te Rūnanga o Ngāi Tahu, n.d.). Since 2006 the reserve has been managed by Te Hapū o Kāti Urihia Ahuwhenua Trust, who represent the 166 owners of Pūharakekenui Māori Reserve (Māori Land Court & Ministry of Justice, 2021; Te Rūnanga o Ngāi Tahu, n.d.). The Trust have consulted the Christchurch City Council on their plan for the area (Christchurch City Council, 2017). The reserve is "an important tūrakawaewae for manawhenua under the management of Te Hapū o Kati Urihia Ahu Whenua Trust, a legal entity formed to represent the owners" (Orchard et al., 2012, p. 14).

Pūharakekenui / Styx River: Pūharakekenui is a spring-fed river that covers approximately 70 km² and runs for 24.8 km from Harewood and Bishopdale to its mouth at Brooklands Lagoon (Christchurch City Council, 2017; Te Rūnanga o Ngāi Tahu, n.d.; The Styx Living Laboratory Trust, n.d.).

River Tide Gates: Large double-hinged river tide gates were installed under the Harbour Road Bridge in Brooklands/Kainga in 1981 and remain in good condition (Hicks & Duncan, 1993). They affect the way that the lower floodplain of the Pūharakekenui is influenced by tidal inflows from Brooklands Lagoon, which can go up the river (Christchurch City Council, 2017). It has been noted by Te Rūnanga o Te Ngāi Tahu that these gates alter the connection that the upper reaches of Pūharakekenui have with the lower reaches "the awa and Te Riu O Te Aika Kawa beyond" (Orchard et al, 2012, p. 16). A 2013 report states that the river tide gates "are effective at controlling the flow of saltwater upstream" (Coates, 2013, p. 86).

* When discussing rivers in the wider area, please note that this is as they are in their current state. The rivers have changed over time in their geomorphological formation, including the fact that some of the original tributaries of the Waimakariri River are now accepted as being their own rivers today (e.g., Kaiapoi). Some of these changes are discussed throughout this historical synthesis.

Appendix 2: Key points from Knox and Bolton (1978) and references therein

- Effluents being discharged into the lower reaches of the Waimakariri River and its tributaries included waste from two meat works, effluent via an oxidation pond system, an array of contaminants from a fellmongery, waste from a freezing company and discharges from a woollen mill.
- High tide had changed from being approximately 4 feet deep in 1938 to approximately 1 foot deep in 1978.
- The following fish species frequented Brooklands Lagoon: Lemon sole, river flounder, sand flounder (tinplater), stargazer, kahawai, whitebait
- The following bird species were recorded within Brooklands Lagoon over a 12 month period: Pukeko, NZ shovellers, greys/mallards/hybrids, paradise ducks, grey teal, pied stilts, white-faced herons, white herons, bar-tailed godwits, black-backed godwits, black-backed gulls, harrier hawks, white-backed magpies, kingfishers, pied fantails, welcome swallows.
- Human activities in and around Brooklands Lagoon led to noticeable changes "in the lagoon and its surroundings" (p. 103). These activities included recreational uses of the lagoon, such as power boating, water skiing, fishing, shooting, driving landrovers, motorbikes, and walking with or without dogs, dumping of waste such as entire bodies of cars, and the "construction of permanent and holiday residences" (p 103).
- The distribution and species richness of some vegetation found in Brooklands Lagoon had decreased due to the Waimakariri River no longer discharging into the ocean via the lagoon. In particular, sediment was accumulating in the lagoon where the river used to sweep through and smothering the top layers of the lagoons' benthic habitat.
- "If the spread of scirpus americanus [*Schoenoplectus punges*) continues at its present rate it will not be long before the mudflat between the lagoon edge and the island is replaced by continuous salt marsh" (p. 41).
- When it flooded, the Waimakariri River was depositing silt into Brooklands Lagoon because the water became stationary when in the lagoon.
- The deposition of sediment and silt from the Waimakariri River had the potential to "lead to short-term drastic changes in the estuarine ecosystem" (p. 105).
- Human impacts to the estuarine environment affect the water quality of the estuary more than anything else.
- That a management plan for Brooklands Lagoon needed to be implemented.
- Even though the water level in Brooklands Lagoon was dependent on high or low tide, it had "no direct connection to the sea" (Knox and Bolton, 1978, p. 3).
- Further toward the south end of Brooklands Lagoon had a longer exposure to air and less exposed to water, thus meaning that the mudflat at the southern end of the lagoon had more air exposure than anywhere else in the lagoon.
- At low tide, all mudflats in the lagoon were exposed, and only small channels in the lagoon contained water.
- The main water channel in Brooklands Lagoon extended from its mouth "to approximately one-third of its length" (p. 5). The channel narrowed beyond this, and smaller channels fed into the main water channel.
- The stagnant water and extensive maritime vegetation at the southern end of the lagoon was "a wildlife refuge for wading birds and numerous water fowl" (p. 5).