Porirua City Council Riparian Management Strategy

Pauatahanui Stream catchment

NZ0120069

Prepared for
Porirua City Council

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Cardno

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1 Introduction

1.1 Background

Porirua City Council (PCC) is the Territorial Local Authority responsible for regulating land use activities within most of Te Awarua-o-Porirua Harbour catchments.

Te Awarua-o-Porirua Harbour and associated catchments provide a multitude of social, economic, cultural and ecosystem services. Since the 1950s Te Awarua-o-Porirua Harbour and associated waterways have experienced significant anthropological pressures including land reclamation, urban development, intensification of land use and increased influx of contaminates such as nutrients and fine sediment. This has resulted in significant and ongoing environmental and ecological degradation of Te Awarua-o-Porirua Harbour. To slow or reverse further deterioration and restore the mana of Te Awarua-o-Porirua Harbour, it is imperative that the influx of fine sediment and nitrogen originating from the surrounding catchments is reduced by improved riparian management.

PCC has engaged Cardno NZ Ltd. (Cardno) to assist in the development of riparian management plans, identifying which management actions should be implemented where, and which areas should be prioritised for the best results.

This report focuses on the Pauatahanui Stream catchment.

1.2 Scope of works

The scope of the works for the Pauatahanui Stream catchment is to:

- Determine the areas within the catchment that would benefit from riparian management;
- Prioritise areas depending of degree of expected benefit received from riparian management;
- Identify appropriate management actions for management areas;
- Provide cost estimates for riparian management based on the identified management actions; and
- Provide indicative work schedules and identify appropriate plant species for management areas.

2 Catchment Description

The Pauatahanui Stream catchment includes much of the eastern part of the Te Awarua-o-Porirua Harbour catchment. While the total area of the Pauatahanui catchment is 4,289 hectares, only 3,9347 hectares is within Porirua City. The Pauatahanui Stream flows into the Pauatahanui Inlet of the harbour. Pauatahanui Inlet has high ecological value (recognised as Outstanding Waterbodies in the GWRC Natural Resources Plan) and includes saltmarsh, tidal flats, significant habitat for birds and marine species, and is considered rare and representative of natural inner harbour ecosystems.

The mainstem of the Pauatahanui Stream is approximately 9.6 km long. It is approximately 5.2 km from where the stream discharges into the Pauatahanui Inlet of the harbour to the outer harbour. Based on the TOPO50; NZ River Centrelines (LINZ 2020), it includes approximately 148.8 km of stream length (Figure 2-2).

Table 2-1 provides a summary of the land use, land cover and soil types in the Pauatahanui Stream catchment. This catchment is predominantly rural in nature, with more than two-thirds of the catchment particularly the lower and middle catchment, comprising either pasture or exotic plantation forestry (including shelter belts). The upper catchment has pockets of mixed native/exotic shrubland, native scrub and native forest.

A review of historic aerial photography indicates that in the early 1940s landcover of the Pauatahanui catchment mainly consisted of pasture and small areas of indigenous forest. By the late 1980s there were more shelterbelts and areas of plantation forest, and more areas of scrub in the upper catchment. Woody vegetation has continued to increase up to the present day. There are now significantly more life-style blocks in the catchment, and Whitby subdivision and the construction of the Transmission Gully state highway project have urbanised the western parts of the catchment. The historic aerial photos are provided in Figure 2-3.

Table 2-1 provides a summary of land use, landcover and soil types in the Pauatahanui Stream catchment.

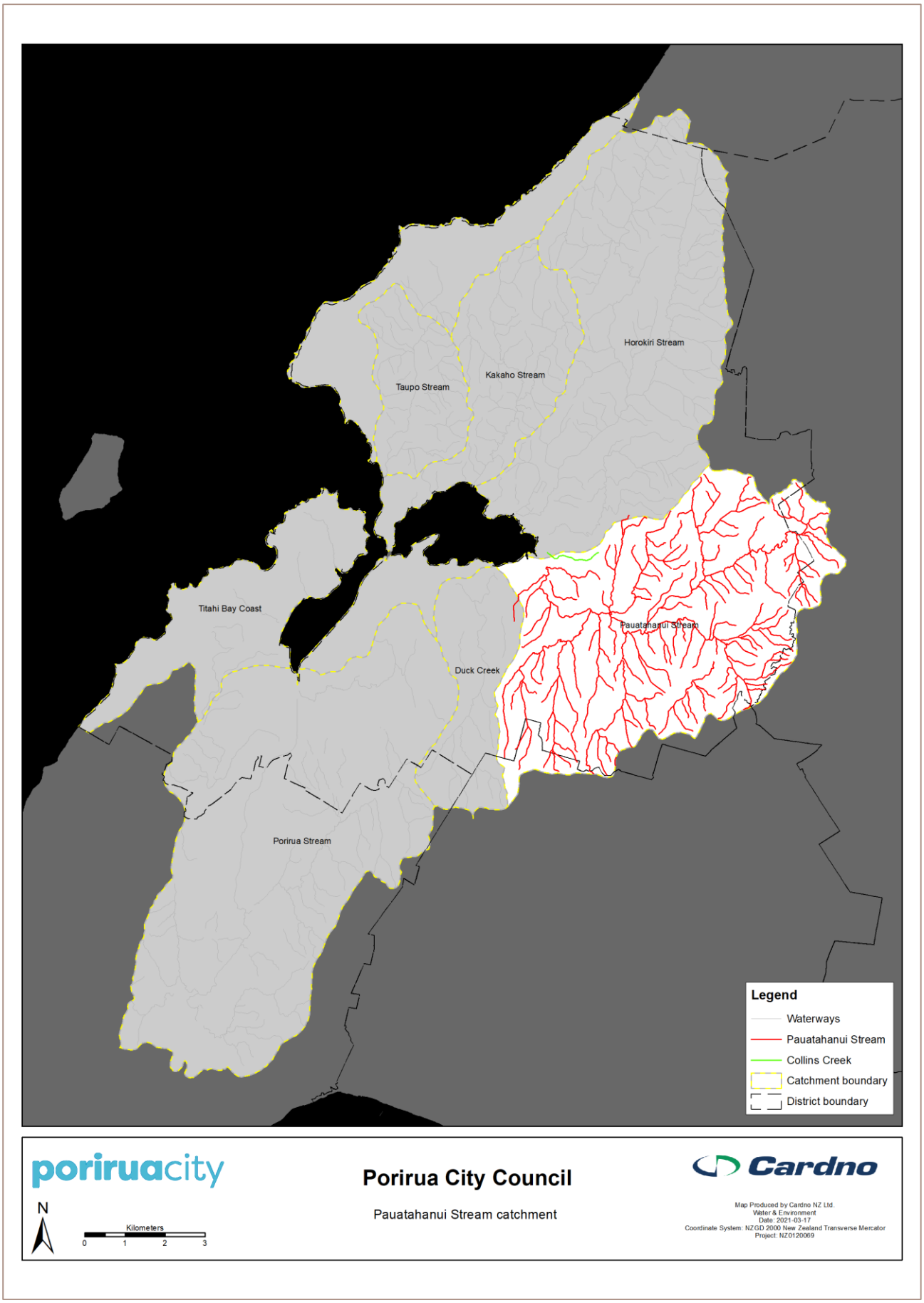

Figure 2-1 Location of the Pauatahanui Stream and Collins Creek within the Te Awarua-o-Porirua Harbour catchment

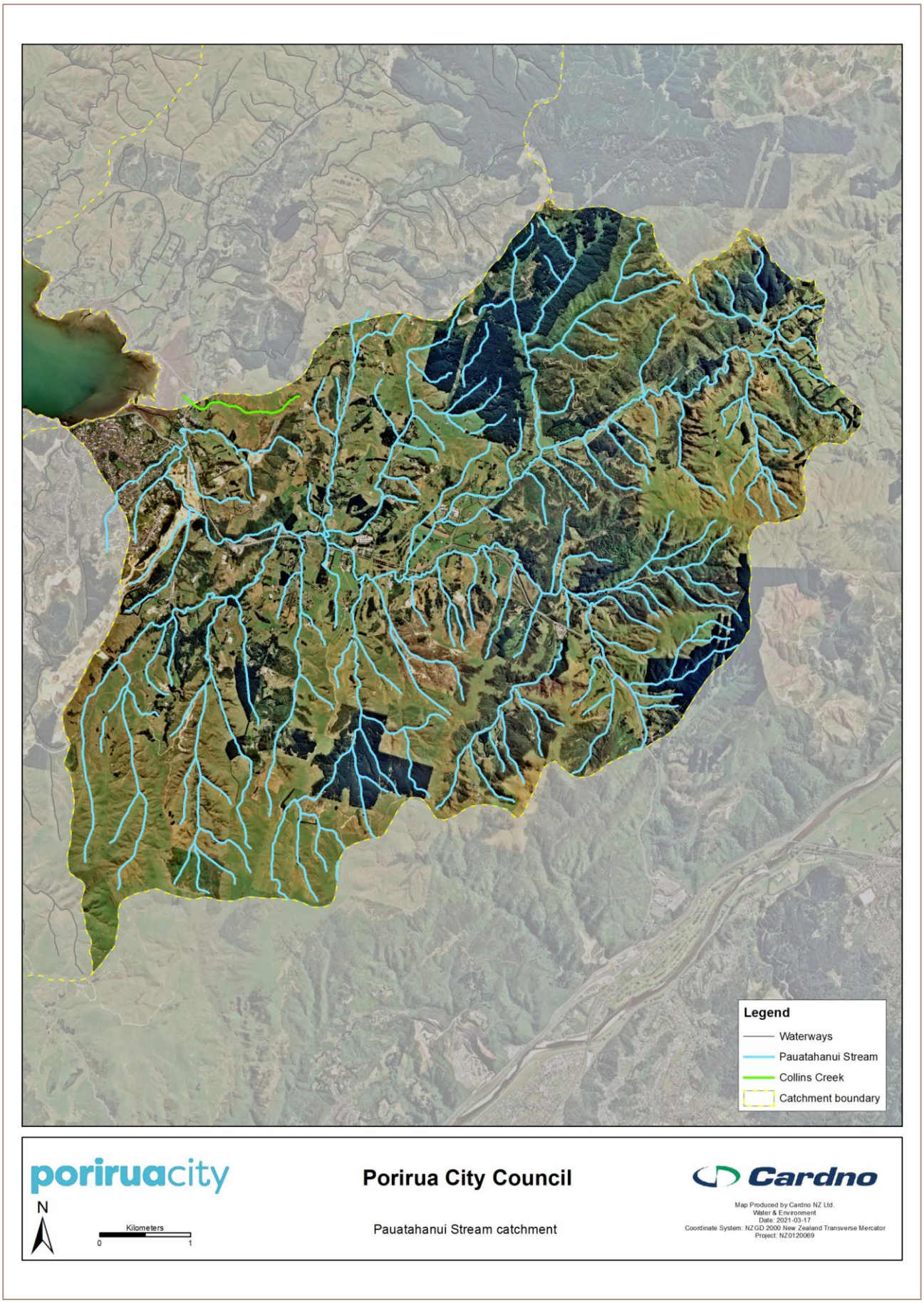

Figure 2-2 Overview map of the Pauatahanui Stream catchment

Table 2-1 Land use, landcover and soil types in the Pauatahanui Stream catchment and riparian buffer.

Category	Description	Catchment		Riparian Zone	
		Area (ha)	Area (%)	Area (ha)	Area (%)
Total		**4,289**		**655**	
Land use (LUCAS[1])	Grassland - High producing	1,570	37%	245	37%
	Grassland - Low producing	808	19%	80	12%
	Natural Forest	599	14%	115	17%
	Grassland - With woody biomass	502	12%	89	14%
	Post 1989 Forest	315	7%	49	8%
	Planted Forest - Pre-1990	310	7%	49	7%
	Settlements	140	3%	18	3%
	Other	34	1%	9	1%
	Wetland - Vegetated non forest	9	0%	0	0%
	Cropland - Perennial	1	0%	0	0%
Landcover (LCDB5.0[2])	High Producing Exotic Grassland	2,470	58%	348	53%
	Exotic Forest	537	13%	80	12%
	Manuka and/or Kanuka	454	11%	79	12%
	Broadleaved Indigenous Hardwoods	384	9%	76	12%
	Gorse and/or Broom	154	4%	25	4%
	Built-up Area (settlement)	104	2%	12	2%
	Forest - Harvested	44	1%	6	1%
	Indigenous Forest	38	1%	6	1%
	Urban Parkland/Open Space	35	1%	6	1%
	Gravel or Rock	26	1%	8	1%
	Transport Infrastructure	17	0%	4	1%
	Low Producing Grassland	14	0%	2	0%
	Herbaceous Saline Vegetation	8	0%	0	0%
	Deciduous Hardwoods	3	0%	3	0%
	Orchard, Vineyard or Other Perennial Crop	2	0%	0	0%
	Fernland	1	0%	0	0%
	Estuarine Open Water	0	0%	0	0%
Soil type (FUND[3])	Typic Firm Brown	1,867	44%	329	50%
	Acidic-Allophanic Firm Brown	822	19%	136	21%
	Allophanic Firm Brown	716	17%	64	10%
	Typic Orthic Brown	713	17%	95	14%

[1] MfE 2012.
[2] Landcare Research 2020.
[3] Landcare Research 2010.

Category	Description	Catchment		Riparian Zone	
		Area (ha)	Area (%)	Area (ha)	Area (%)
	Mottled Immature Pallic	67	2%	7	1%
	Weathered Fluvial Recent	56	1%	14	2%
	Mottled Firm Brown	35	1%	10	1%
	Saline Recent Gley	13	0%	0	0%
	Town	0	0%	0	0%

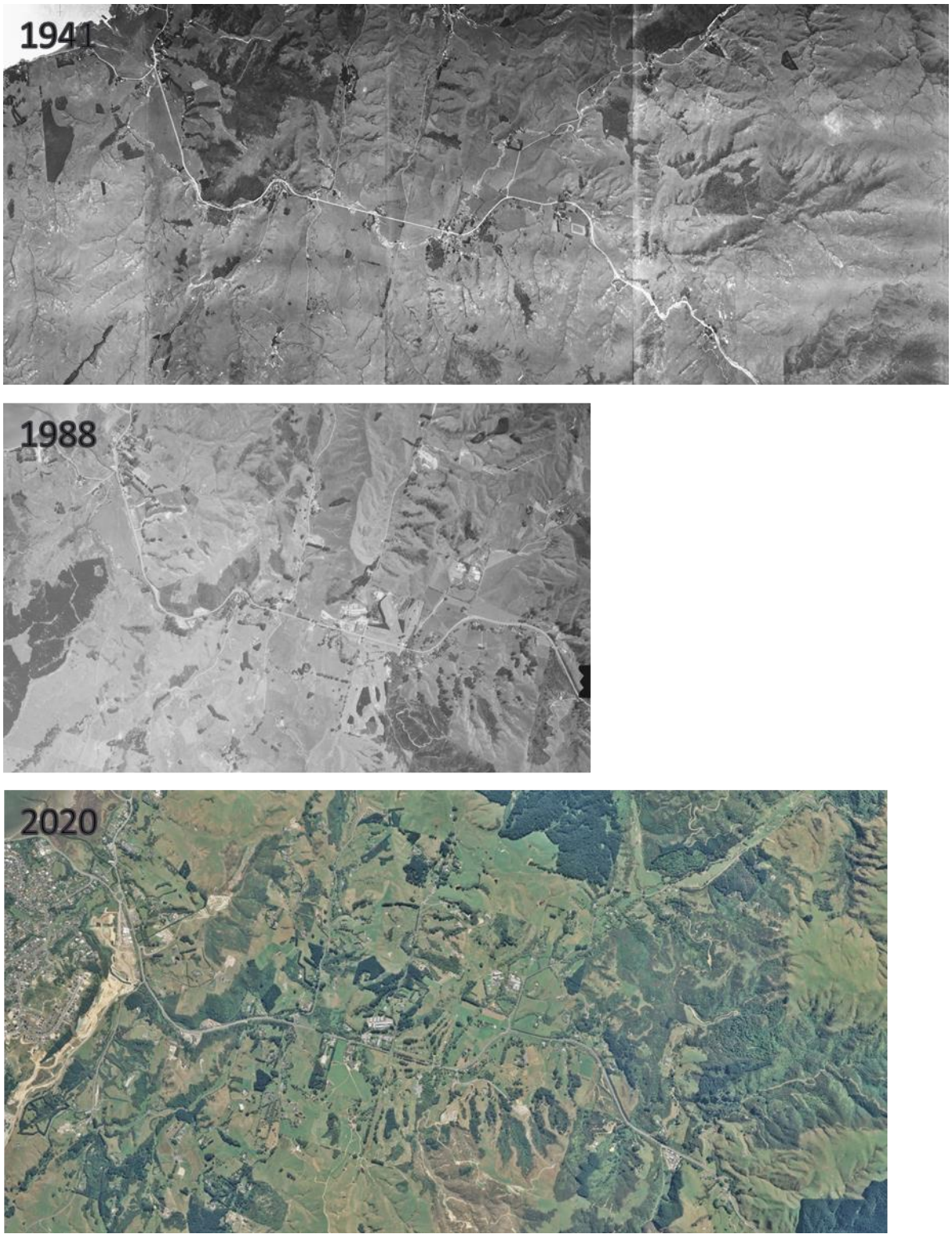

Figure 2-3 Historic photographs of lower reaches of the Pauatahanui catchment

3 Methodology

3.1 Reach prioritisation

Initial riparian management prioritisation of stream reaches was undertaken via a desktop assessment and modelling exercise using ArcGIS desktop 10.7 (ESRI). As part of this analysis a decision was made in consultation with PCC as to which of the following three stream layer sources should be used for analysis:

- River Environment Classification v2.0 (NIWA 2019);
- TOPO50 river centrelines (LINZ 2020); and
- ≥3rd order streams from the Te Awarua-o-Porirua Harbour Whaitua predicted streams.

For the purpose of this analysis the River Environment Classification layer lacked sufficient flow path accuracy and excluded a significant number of streams in the upper catchment. The Te Awarua-o-Porirua Harbour Whaitua predicted stream layer includes stream reaches that have been piped and/or reclaimed and will result in significant overestimation of management requirements within urban areas. The TOPO50 river centrelines was considered the most appropriate stream layer for the project, although the absence of a number of stream reaches in the upper catchments would likely result in an underestimation of the requirements and costs within upper catchments.

The riparian zone within each catchment was drawn by creating a 45-metre-wide buffer around the river centreline (TOPO50; LINZ 2020) based on the assumption that:

- the average width of stream channel is 5 metres; and
- the riparian zone is defined as being 20 metres wide on each side of the stream channel.

The riparian buffer was then divided into approximate 100-metre-long reaches, encompassing both sides of the stream, and attributes from relevant data layers were extracted for each individual stream reach. Priority scores for each reach were calculated based on land use (MfE 2012), land cover (Landcare Research 2020), riparian vegetation (Leathwick et al. 2010), adjacent land slope (Landcare Research 2003) and nitrogen leaching (MfE 2016a) as described in Appendix A. Further data sources were considered for inclusion in the calculation of the priority score; however, the combination of the five layers listed above was found to produce appropriate and informative results.

3.2 Site visits

Several locations were selected for on-site assessments based on the priority score generated during the desktop assessment and input from stakeholders managing the waterways (PCC and Wellington Water). Additional information was collected during the on-site assessment on several stream and riparian aspects including:

- Stream characteristics (wetted width, water depth, streambed substrate, organic matter, etc.);
- Channel and bank characteristics (channel shape, sinuosity, bank stability, ground cover, etc.); and
- Riparian zone characteristics (vegetation types, vegetation density, weed presence, weed density, riparian width, etc.).

The site visits were conducted to verify the accuracy of the reach prioritisation and develop more detailed case studies for specific areas.

3.3 Indicative cost

Indicative costs were estimated for each stream reach with consideration to whether the focus should be on capturing nitrogen and sediment, and whether stock exclusion was required. All costs exclude GST.

Plant numbers

The Ministry for the Environment's Land Use and Carbon Analysis System (LUCAS) and the Land Cover Database 5.0 (LCDB5.0) were used to classify the land use for each stream reach. The likelihood of each land use requiring riparian planting was predetermined and provided in Appendix B. If one of the datasets returned a cover class that did not require planting, a weighting of zero was used. If the LUCAS and LCDB5.0 data differed, an average of the two values was used.

The number of plants required for each reach has not been adjusted for slope, as slope has already been used to determine which stream reaches have higher priorities.

Planting cost estimates are based on a one metre centre-to-centre plant spacing, at a rate of $14.60 NZD per plant[4]. The cost includes site preparation, material costs (eco-sourced plant material at PB3 grade), labour costs and a 3-year maintenance period, but excludes insurances, health and safety costs, any significant pest plant control, bank re-contouring or applying topsoil.

It should be noted that alternative plant spacing has not been included in any of the summary tables in Section 5.

Fencing

Fencing is required to exclude stock. The only land use classes considered to require fencing are Cropland Annual, Grassland High Producing, and Grassland Low Producing.

Each reach polygon has a width of 45m. To estimate the length of the fence, each polygon area was divided by 45 and then doubled. Due to curvatures in the centreline of the stream, this method is approximate only.

Fencing cost estimates are based on the installation of a standard 9-wire post and batten farm fence at a cost of $25.00 NZD per linear metre[5]. This cost includes supply and installation in areas where there is easy access and normal ground conditions, but does not include additional elements such as flood gates, strainers, rail boards, hard to access areas, or post-hole digging in rock.

Verification of costs

The cost estimates have been verified by randomly selecting 40 stream reaches throughout Te Awarua-o-Porirua Harbour (roughly one percent of the total) and comparing the findings of the formulae for planting and fencing requirements to aerial imagery of each polygon, and confirming that the findings are reasonably accurate.

3.4 Treatment descriptions and work schedules

Planting treatments have been broken down into six “functional groups” based on key ecological roles recommended for the Pauatahanui Stream catchment. Based on the priority for each group, a recommended number of species from each “functional group” has been established for each riparian planting polygon. The total species per stream reach was limited to six species. This methodology yielded a total of 28 distinct planting treatments. Each treatment was allocated a code based on the number of species recommended from each of the six “functional groups”.

[4] Unit pricing provided by PCC.
[5] Pricing based on Transmission Gully Project

4 Reach Prioritisation

The results from the reach prioritisation calculations are shown in Figure 4-1 and indicate that stream reaches within the Pauatahanui Stream catchment range from low priority to high, with much of the catchment being a moderate priority for riparian management. Overview maps underlying the reach prioritisation calculations are included in Appendix C.

The results show that pastoral areas in the upper and middle reaches are dominated by high productive exotic grassland on steep terrain with stock access to the majority of stream reaches. This is likely to contribute moderate amounts of nitrogen to waterways. The moderate to steep landforms result in a high risk of sediment erosion (surface runoff), mass movement erosion (slump, slip or landslide) and fluvial erosion (MfE 2001). The combinations of these erosion risks and levels of nitrogen input make it likely that the upper and middle parts of the catchment are the main and likely continuous source of sediment and nutrients. This combination results in much of the catchment having a moderate to high priority classification.

Those parts of the catchment with woody vegetation currently have a lower riparian management priority, but this could change when harvesting of the pine forest commences. Harvesting can increase the risk of sediment movement. It will also take some time for the area to be revegetated, either replanted in forestry species, allowed to regenerate into native vegetation cover or grassed for pasture. Erosion risks will be greater during this period.

The stream reaches in the lower catchment have generally been categorised as low priority. These areas consist mainly of life-style blocks, limited urban settlements, and open-areas and green strips along the streams. The main form of erosion in these areas is likely sediment erosion associated with past and current earthworks, fluvial erosion of infilled soils with low-density riparian vegetation, or erosion associated with flow disturbances/restrictions caused by in-stream structures like bridges and weirs.

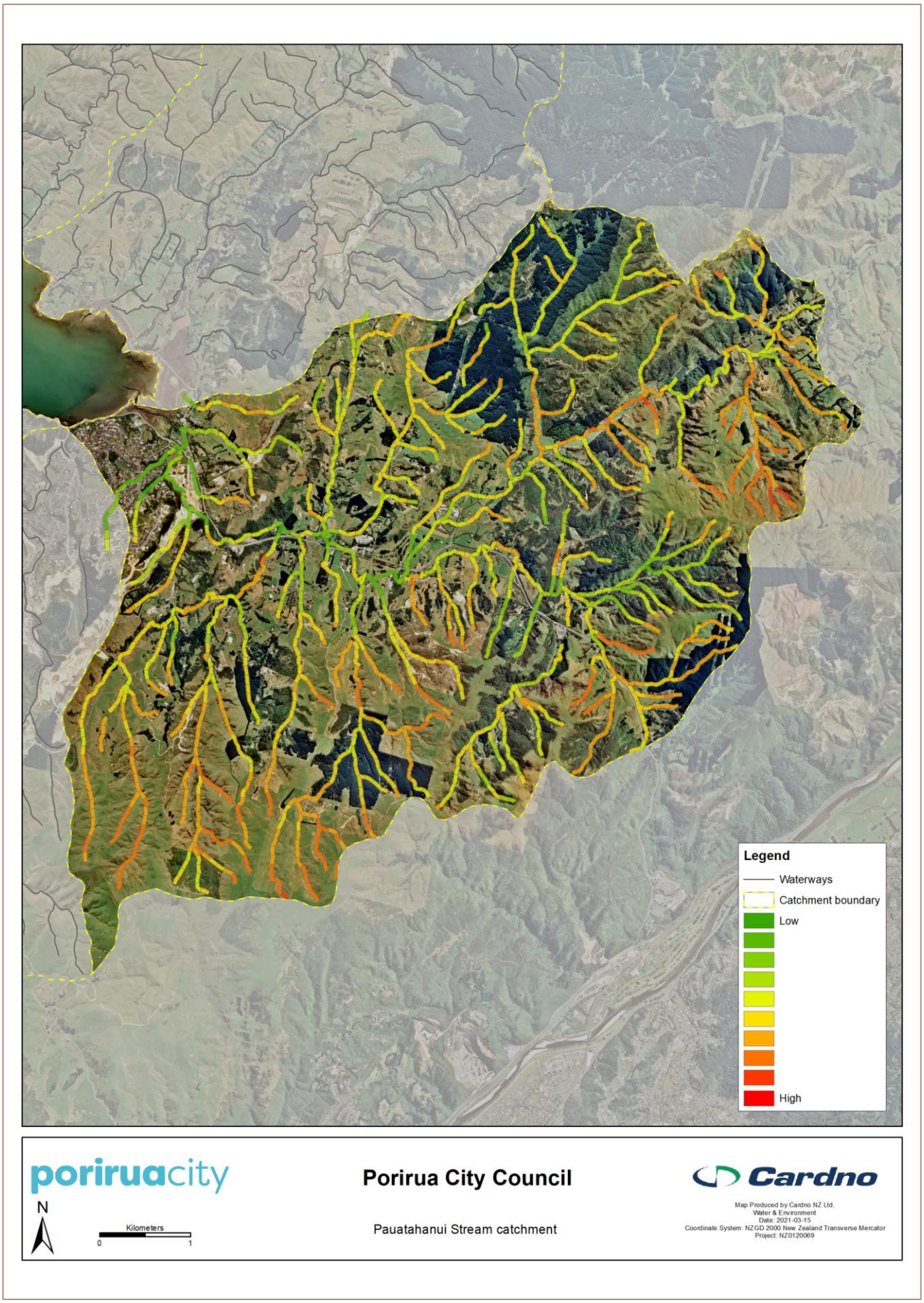

Figure 4-1 Riparian management priority areas within the Pauatahanui Stream catchment.

5 Indicative Costing

Table 5-1 summarises the total estimated costs per management agency. All costs are exclusive of GST.

A spatial representation of the cost per stream reach has been included in Appendix C.

Figure 5-1 illustrates the landowner and or managing entity of each stream reach. This is based on the Porirua City plans.

Table 5-1 Estimated cost for riparian management for the Pauatahanui Stream catchment

Ownership/managing entity	Estimated cost (excl. GST)	
PCC (private land)	$	52,264,000
PCC (public)	$	14,000
GWRC	$	2,494,000
Transmission Gully	$	961,000
QEII	$	33,000
Hutt City Council	$	4,595,000
Total	**$**	**60,362,000**

Estimated costs are rounded to the nearest thousand dollars so as not to imply a greater level of accuracy than supported by the datasets and analysis tools.

During the verification process[6], it was noted that the “Gorse and or Broom” categorisation within the LCDB5.0 was often inaccurate because the area had already succeeded to native vegetation, and would likely require less riparian planting than the tables indicated.

Additionally, it was noted that in several instances rural settlement/development had not been identified in the LUCAS or LCDB5.0 datasets, which will slightly limit planting areas and reduce plant numbers required in these areas.

[6] The verification process was performed on all Te Awarua-o-Porirua Harbour catchments, not specifically for the Porirua Stream catchment.

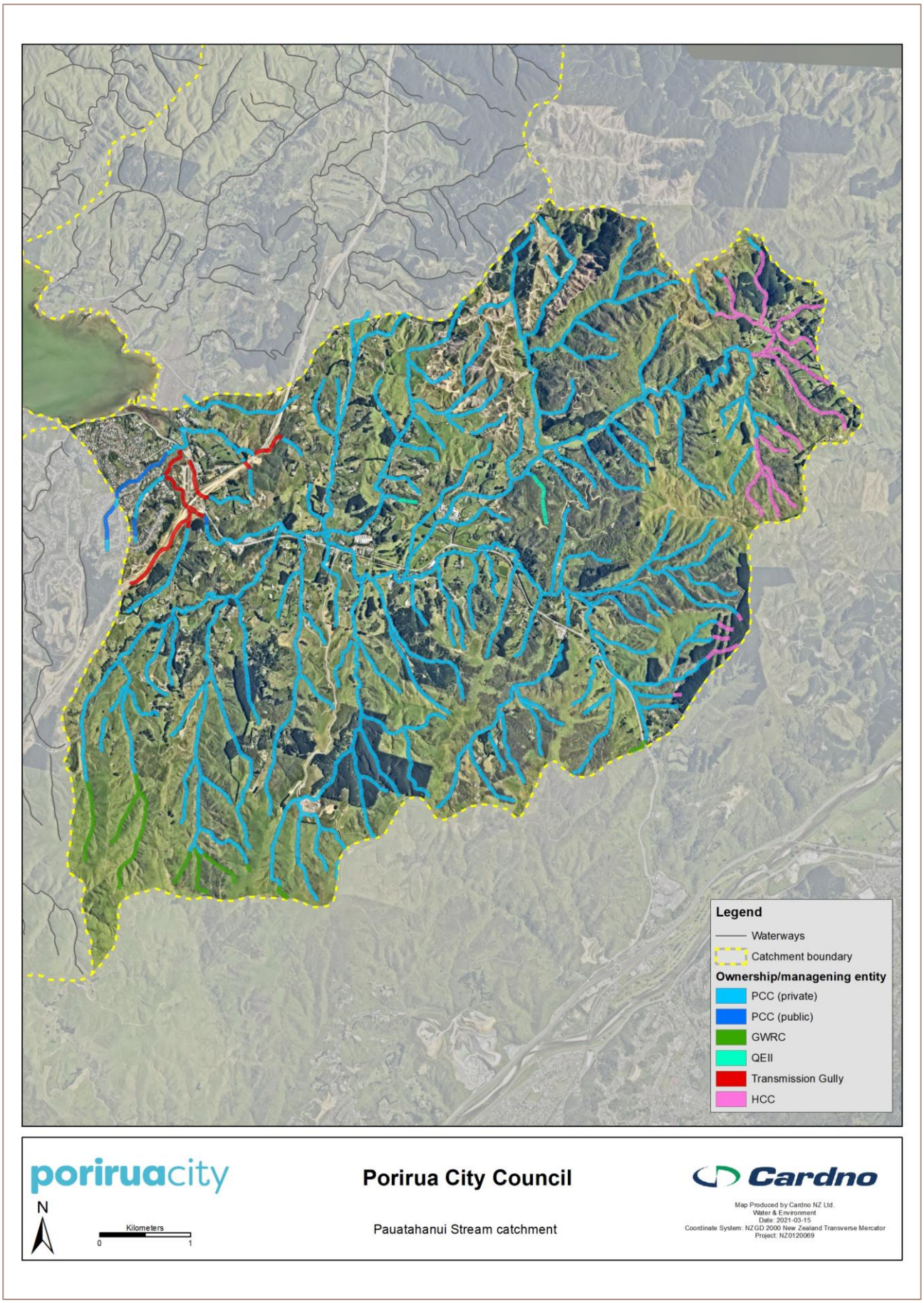

Figure 5-1 Reach ownership and management entity for the Pauatahanui Stream catchment

6 Planting Treatments and Work Schedules

Figure 6-1 illustrates the suggested planting treatment for each individual stream reach. For the purposes of visual representation, the top nine treatments, representing 96 percent of all polygons have been presented. The remaining treatments have been grouped into the “Other treatment” category.

Table 6-1 and Table 6-2 summarise the approximate number of plants required. Suggested plant species for each functional group have been included in Appendix D. Additional maps associated with the planting treatments are included in Appendix C.

Table 6-1 Pauatahanui Stream planting per treatment code.

Treatment code	Number of polygons	Approximate number of plants (x1000)
330000	358	928
132000	207	887
141000	199	834
240000	179	613
231000	121	410
420000	117	306
222000	35	139
321000	30	92
510000	38	63
150000	11	46
123000	4	27
21003	3	13
120003	1	4
33000	1	3
411000	2	3
111003	1	1
110040	2	3
110004	1	1
Total	**1311**	**4373**

Table 6-2 Planting per functional group.

Functional group	Approximate number of plants (x1000)
General revegetation	1434
Erosion control	2296
Nitrogen fixing	576
Freshwater planting	0
Saline planting	1
Lizard habitat	10
Total	**4315**

While the suggested number of species per stream reach has been set at six, it is suggested to vary species composition between reaches to increase biodiversity on a catchment scale. This approach will also enable species substitutions in case of difficulties in sourcing/propagating certain species. Biodiversity could be further enhanced by successional planting 2-5 years after initial planting. Appendix D lists suitable species

for this purpose for each treatment. Note that successional planting has not been included into the estimated costings as this type of planting focusses primarily on increasing biodiversity.

An indicative schedule of works is included in Appendix E. This outlines the required steps and timing associated with planting a stream reach. Note that not all listed items in the schedule of works are relevant to each stream reach and/or project.

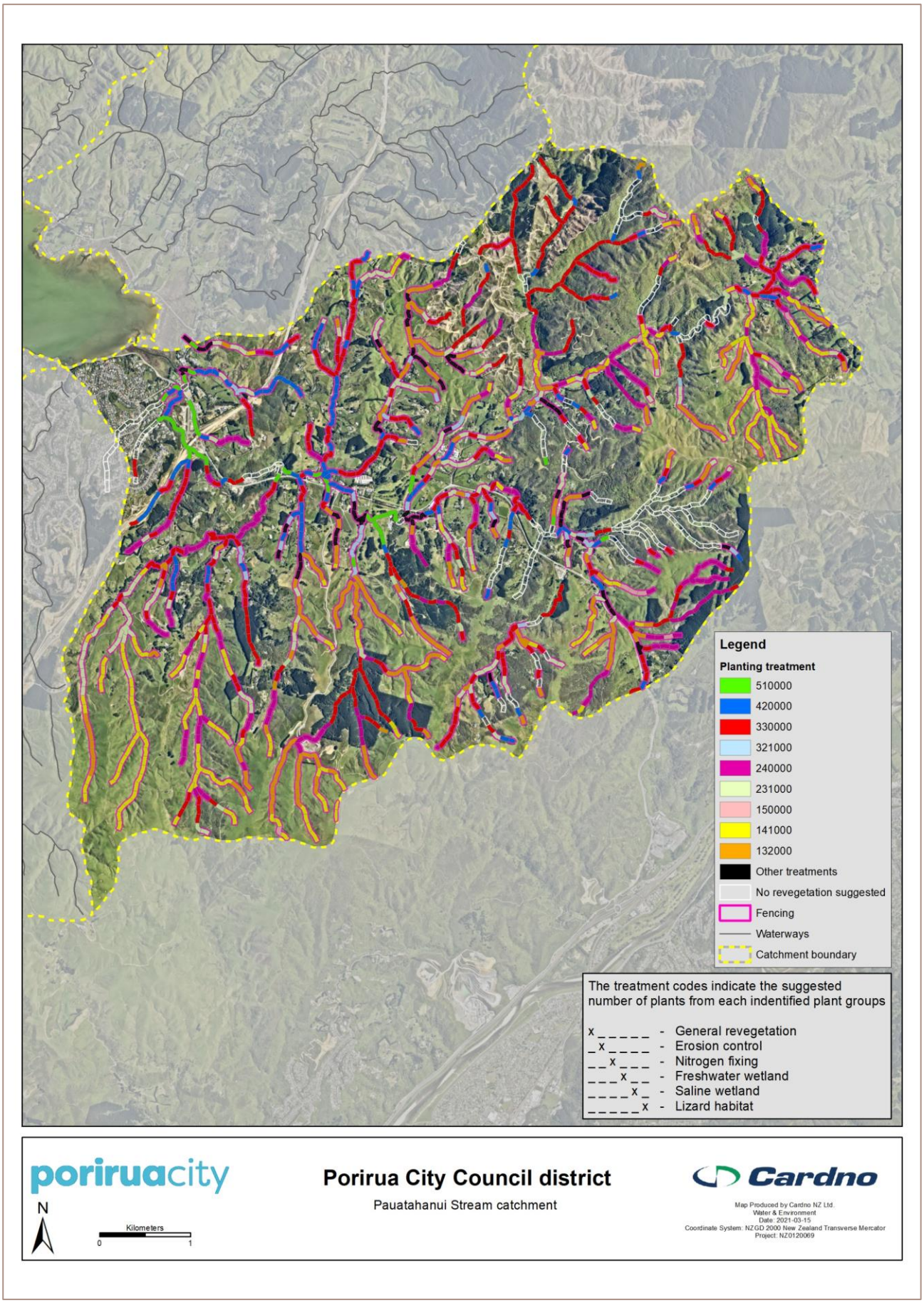

Figure 6-1 Suggested riparian planting treatment and fencing for the Pauatahanui Stream catchment. Fencing lines indicates the stream reaches recommended to be fenced, not proposed fence lines.

7 Discussion and Recommendations

Many of the stream reaches within the Pauatahanui Stream catchment were found to have had relatively unstable banks, were incised and the bed had a high proportion of fine sediment indicative of erosion issues. The combination of relatively steep landforms and moderate to high farm stocking rates have resulted in much of the catchment being a moderate to high priority for riparian management. Erosion issues were also noted near bridge and culvert crossings and where culverts entered the stream .

Riparian management should include excluding stock from waterways and establishing native riparian vegetation where possible.

The benefits of riparian planting will not immediately result in reduced sediment input into Pauatahanui Stream and Te Awarua-o-Porirua Harbour. Plants require time to establish and mature, and soil/bank stability will increase as plant roots develop. Furthermore, sediment entering Pauatahanui Stream is likely to be deposited and re-mobilised by rain events on several occasions especially fine sediment before leaving the catchment. It should be noted that fine sediment plays an ecological role in stream and estuary ecosystems by creating diversity in (micro)-habitat, void filling of the streambed and supplying beneficial low volumes of nutrients, metals and organic matter. Small amounts of sediment input into streams occurs naturally even in fully forested or vegetated ecosystems.

Research by the National Institute of Water and Atmospheric Research Ltd (NIWA 2006) has shown that 0.9 m spacings for shrub species in riparian margins resulted in increased survival and growth of the new plantings, and noted that the average number of self-sown native seedlings across urban and rural sites was 0.88 per m^2. These alternative plant spacings may be considered on a case-by-case basis where it is believed higher density will result in more success especially associated with weed control by shading.

This research also showed that riparian planting should be at least 15 m wide to reduce weed growth in the riparian zone and create a self-sustaining plant community. This is the reason that this project uses a 20 m riparian buffer for the calculations and proposed management treatments. In areas where there is less than 20 m of riparian width, dense shrubs should be planted on the edges of the stream to reduce light entering the riparian zone (NIWA 2006).

The suggested plant species include several flax species and cabbage trees, which should not be planted directly besides the stream as flax can impede flood flows, or along areas that need to be mowed, as the fibrous leaves wrap around mower blades and weed-trimmer heads.

8 Priority Areas and Suggested Riparian Management

Figure 8-1 to Figure 8-4 illustrates the priority areas for riparian management within the Pauatahanui Stream catchment based on individual reach scores. The areas have been grouped into the following priority categories:

- Moderate-high (Figure 8-1)
- Moderate (Figure 8-2)
- Low-moderate (Figure 8-3)
- Low (Figure 8-4)

Table 8-1 to Table 8-8 describe specific treatments for each of the priority areas including consideration of the stream reach location, characteristics, priority scores, ownership/managing entity and potential management options.

The estimated cost in these tables relate to the planting treatments suggested in Section 6 of this report and exclude any additional or alternative management activities. These areas have been assigned a priority ranging from low to high depending on the expected benefits in sediment and nitrogen input into the Pauatahanui Stream and Te Awarua-o-Porirua Harbour. Considerations of landownership, site access, funding, community involvement and effort required to initiate the proposed riparian management have not been included in the prioritisation.

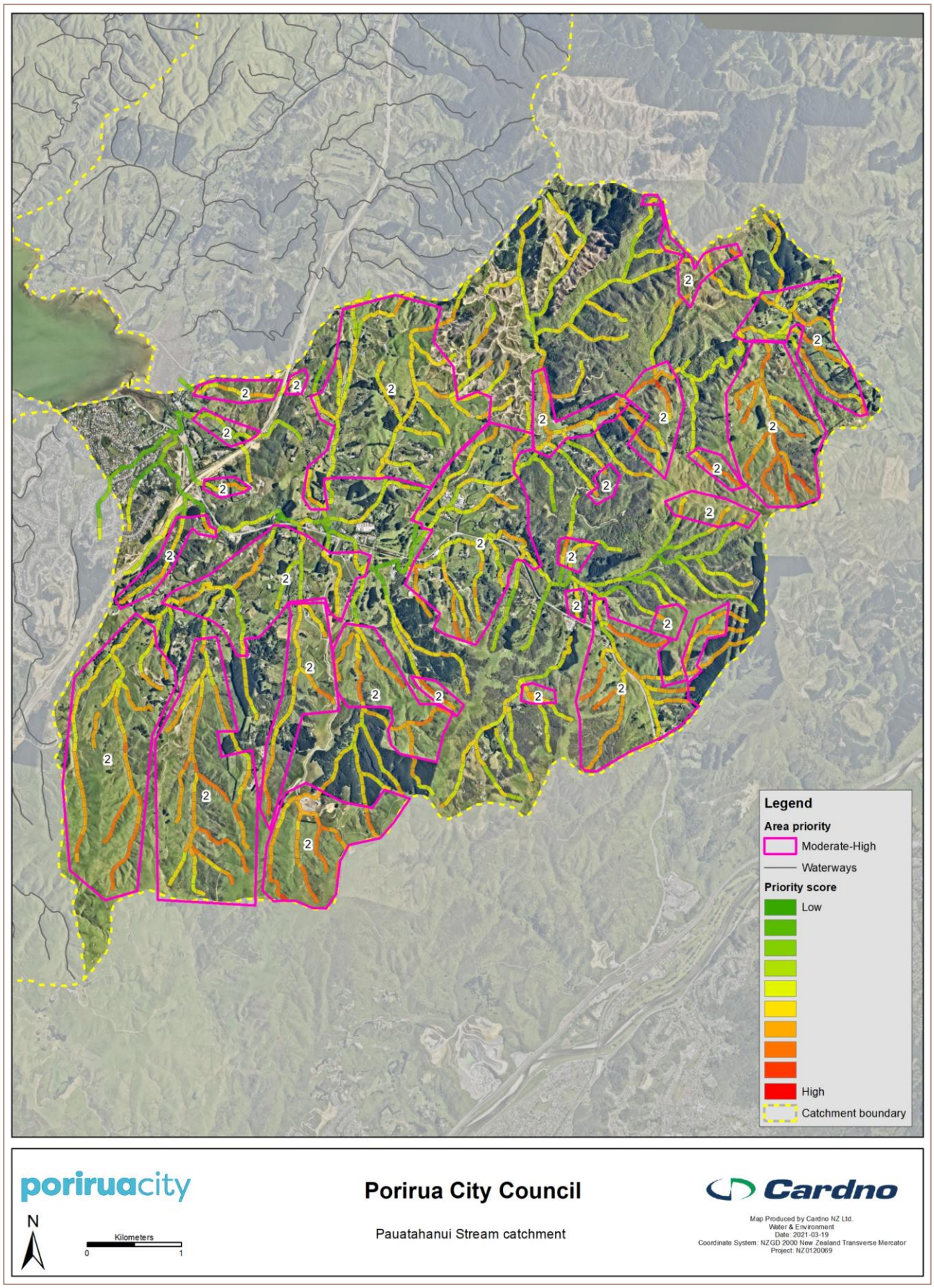

Figure 8-1 Moderate-High priority areas for the Pauatahanui Stream catchment. Numbers indicate the priority area ID and correspond with priority numbers listed in Table 8-1 to Table 8-8

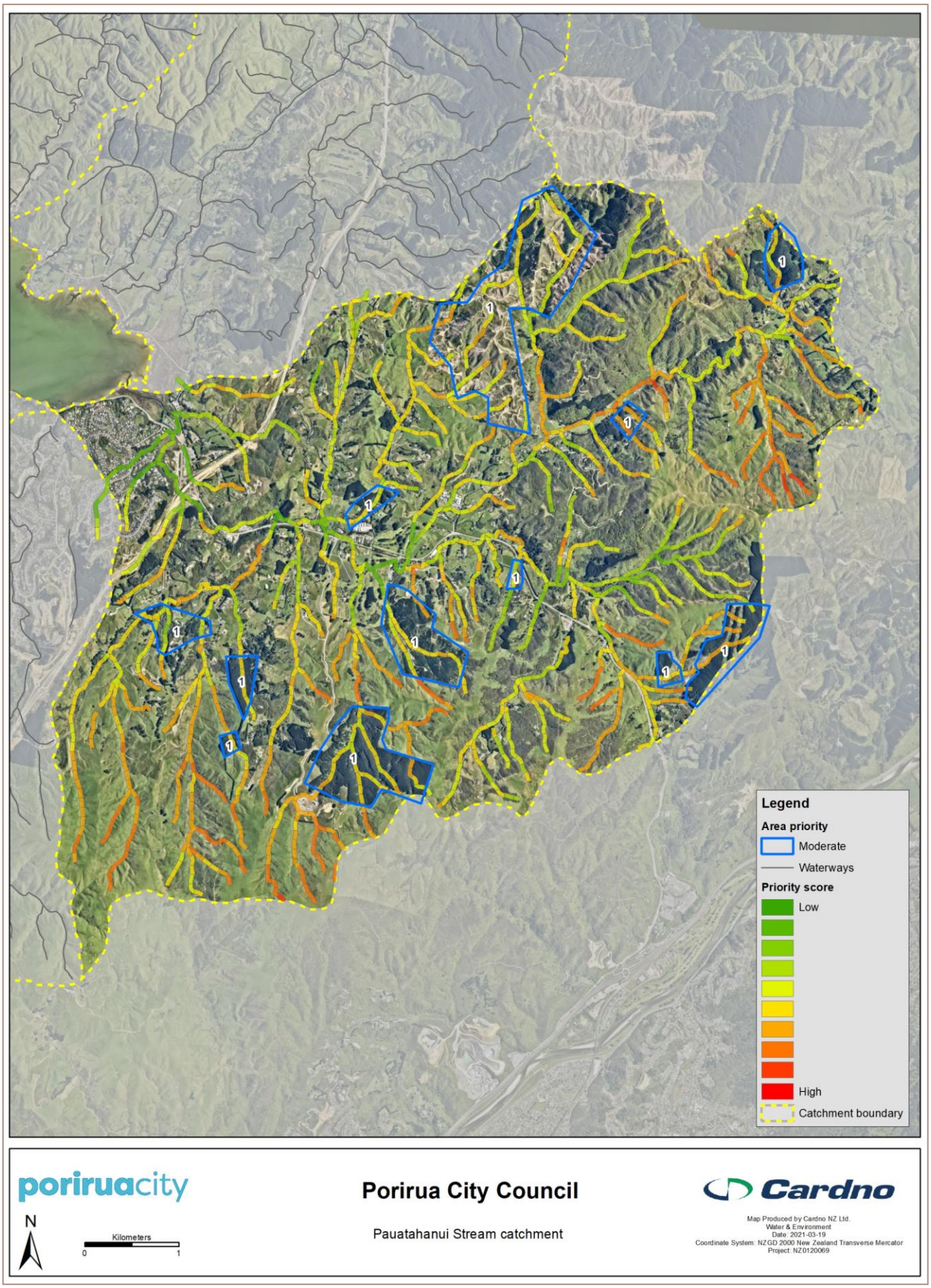

Figure 8-2 Moderate priority areas for the Pauatahanui Stream catchment. Numbers indicate the priority area ID and correspond with priority numbers listed in Table 8-1 to Table 8-8

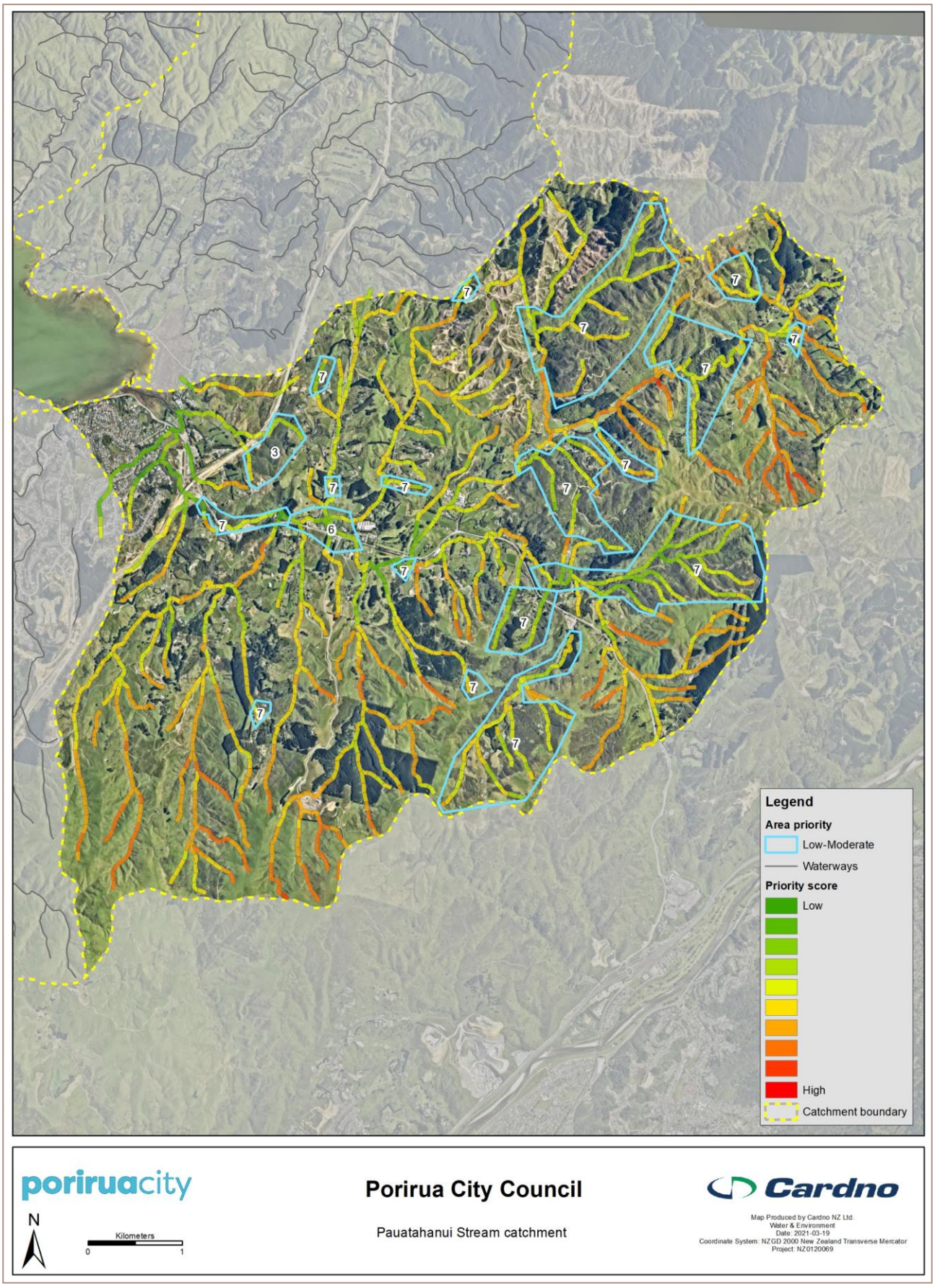

Figure 8-3 Low-Moderate priority areas for the Pauatahanui Stream catchment. Numbers indicate the priority area ID and correspond with priority numbers listed in Table 8-1 to Table 8-8

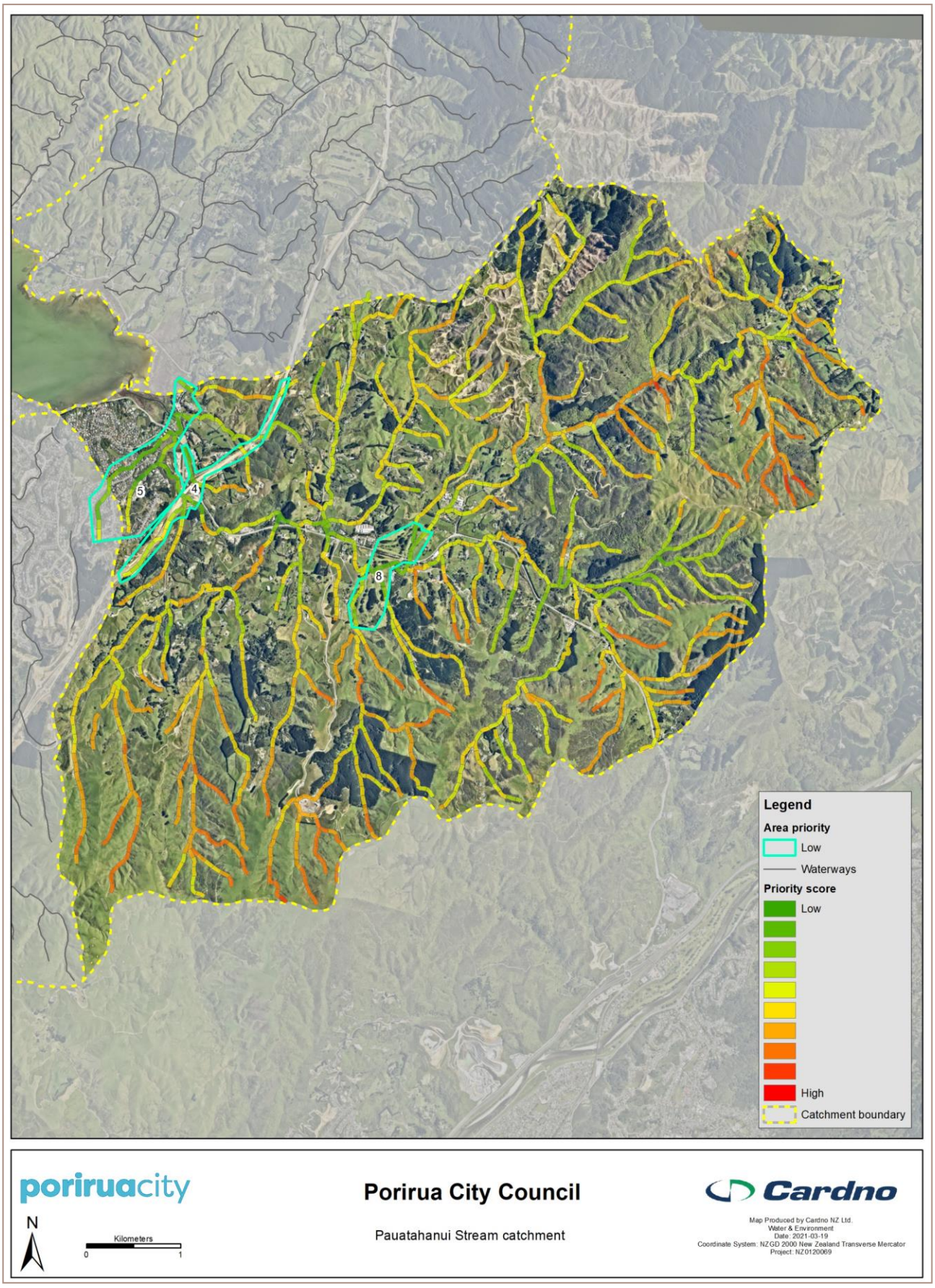

Figure 8-4 Low priority areas for the Pauatahanui Stream catchment. Numbers indicate the priority area ID and correspond with priority numbers listed in Table 8-1 to Table 8-8

Table 8-1 Priority areas 1: Production forests

Attribute	
Management priority	Moderate
Ownership/managing entity	> PCC (Private) > HCC
Approximate riparian planting area	80.9 ha
Estimated planting cost (excl. GST)	$5,488,000
Area characteristics	> Rural area. > Hill terrain with steep gullies. > Utilised for forestry.
Erosion risk(s)	> Sediment erosion (surface runoff) (after harvest). > Fluvial erosion (earthworks, pasture management) (after harvest).
Primary plant functional group(s)	> Erosion control. > General revegetation.
Management strategy	> Riparian revegetation.
Suggested management approach	After harvesting revegetation of at least 5-10 m of riparian margin (exclusion zone for forestry replanting; NES-PF 2017) should be established. In case the land use changes away from forestry, revegetation of a wider riparian zone (20 m) and if appropriate stock exclusion fencing would be advised.

Table 8-2 Priority areas 2: Grasslands

Attribute	
Management priority	Moderate-High
Ownership/managing entity	> PCC (Private) > HCC
Approximate riparian planting area	375.7 ha
Estimated planting cost (excl. GST)	$47,056,000
Area characteristics	> Rural area. > Hill terrain with steep gullies. > Mainly consist of high producing grassland.
Erosion risk(s)	> Sediment erosion (surface runoff). > Mass movement erosion (slump, slip or landslide). > Fluvial erosion (earthworks, pasture management).
Primary plant functional group(s)	> Erosion control. > General revegetation. > Nitrogen leaching.
Management strategy	> Stock exclusion. > Riparian planting. > Additional planting on slopes past riparian zone.
Suggested management approach	The area is currently covered with high producing grassland and likely used for grazing. The streams in the area should be protected by stock exclusion barriers and the riparian zone planted with native species. There are several areas where steep gully banks would ideally be planted outside the 20 m riparian zone. It is recommended that any wetlands are included inside stock exclusion fencing.

Table 8-3 Priority areas 3: Gorse dominated shrubland

Attribute	
Management priority	Low-Moderate
Ownership/managing entity	> PCC (Private)
Approximate riparian planting area	4.1 ha
Estimated planting cost (excl. GST)	$172,000
Area characteristics	> Low rolling gorse covered hills
Erosion risk(s)	> Sediment erosion (surface runoff should the vegetation be cleared).
Primary plant functional group(s)	> General revegetation
Management strategy	> Riparian revegetation > Weed control
Suggested management approach	Work with the landowners to encourage retention of gorse vegetation, which will likely progress to becoming native vegetation over time. This process can be hastened by planting desired native plant species in amongst the gorse, either along lines cut in to the gorse at right angles to the prevailing wind, or by planting groups of native plants in small (created) clearing. The area appears to be mostly fenced already, and fencing should be maintained exclude stock. Some areas of gorse appear to have been sprayed recently.

Table 8-4 Priority areas 4: Transmission Gully project

Attribute	
Management priority	Low
Ownership/managing entity	> Transmission Gully project
Approximate riparian planting area	11.5 ha
Estimated planting cost (excl. GST)	$773,000
Area characteristics	> State Highway construction area. > Peri-urban areas. > Steep hills to lowland flats. > Significant earthworks
Erosion risk(s)	> Fluvial erosion (stormwater) > Sediment erosion (surface runoff)
Primary plant functional group(s)	> General revegetation. > Riparian planting.
Management strategy	> Riparian revegetation. > Bank recontouring/armouring. > Weed control.
Suggested management approach	Riparian planting in this priority area is required as part of the resource consent conditions for the Transmission Gully project.

Table 8-5 Priority areas 5: Urban areas

Attribute	
Management priority	Low
Ownership/managing entity	> PCC (Private) > PCC (Public)
Approximate riparian planting area	17.8 ha
Estimated planting cost (excl. GST)	$504,000
Area characteristics	> Urban and peri-urban on rolling hills. > Areas of manuka-kanuka forest. > Plantation forest.
Erosion risk(s)	> Fluvial erosion (stormwater). > Potential for mass movement erosion (slump, slip or landslide).
Primary plant functional group(s)	> General revegetation
Management strategy	> Riparian revegetation. > Weed control. > Enhancement planting.
Suggested management approach	Maintain existing riparian areas, remove pest plant species and interplant with additional species. Widen riparian vegetated areas where possible. Enhance (potentially enlarge) wetland area at the lower end of the Whitby Walkway. If council owned areas of plantation forest are harvested then revegetate with a diverse range of native plant species. This will assist to increase the diversity of species in the manuka-kanuka forest areas and establish more robust and dense vegetation. If the areas are not intended to be harvested, then selectively fell or poison pines to create canopy gaps to hasten progression towards native vegetation. Encourage private plantation forestry owners to do the same post harvesting, or if not intending to harvest.

Table 8-6 Priority areas 6: State-highway 58

Attribute	
Management priority	Low-Moderate
Ownership/managing entity	> PCC (Private) > NZ Transport Agency
Approximate riparian planting area	7.1 ha
Estimated planting cost (excl. GST)	$785,000
Area characteristics	> Low-lying floodplain. > Confluence of several sub-catchments. > Sediment erosion (surface runoff)
Erosion risk(s)	> Fluvial erosion (stormwater, flood flushing). > Road construction works.
Primary plant functional group(s)	> Wetland construction. > General revegetation.
Management strategy	> Riparian revegetation. > Wetland construction. > Weed control
Suggested management approach	Work with Waka Kotahi (NZ Transport Agency) and private landowners to gradually replace willows and other pest plant species with native wetland species. Creation of a wetland at this location would assist with capturing sediment, reducing sediment input into the harbour.

Table 8-7 Priority areas 7: Native vegetation

Attribute	
Management priority	Low-Moderate
Ownership/managing entity	> PCC (Private)
Approximate riparian planting area	143.0 ha
Estimated planting cost (excl. GST)	$4,193,000
Area characteristics	> Pockets of native vegetation. > Ranging from small to extensive. > Upper to lower catchment. > Some areas also include forestry and other exotic woody vegetation.
Erosion risk(s)	> Fluvial erosion (stormwater).
Primary plant functional group(s)	> General revegetation. > Enrichment planting.
Management strategy	> Exotic vegetation removal. > Riparian planting. > Enrichment planting.
Suggested management approach	Riparian zone in these areas are reasonably well vegetated, but could be enriched to increase canopy density, biodiversity and reduce exotic species.

Table 8-8 Priority areas 8: Golf course

Attribute	
Management priority	Low-Moderate
Ownership/managing entity	> PCC (Private)
Approximate riparian planting area	8.3 ha
Estimated planting cost (excl. GST)	$731,000
Area characteristics	> Golf course. > Flat to rolling, mostly grassed, but with shelterbelts. > Erosion of banks evident.
Erosion risk(s)	> Stream bank collapse. > Fluvial erosion (stormwater). > Sediment erosion (surface runoff).
Primary plant functional group(s)	> Riparian planting (where possible). > Maintaining rough greens where planting not possible.
Management strategy	> Bank recontouring. > Riparian revegetation.
Suggested management approach	Work with the golf course to explore opportunities to create or enhance riparian vegetation, recontour stream banks where possible and provide more room for the stream. Where the greens are currently close to waterways encourage a 3 m to 5 m wide area of rough grass on both sides to capture sediment.

8.1 Wetland opportunity areas

Figure 8-5 illustrates areas within the Pauatahanui Stream catchment with low gradients. Where these areas occur in association with a waterway, there is likely presence of a wetland or potential for creation of a wetland. From Figure 8-5 it becomes clear that the Pauatahanui Stream catchment has several large relatively flat areas including:

- The lower Pauatahanui Stream, between the Pauatahanui Inlet and Bradley Road;
- The Judgeford valley, from Murphys and Flightys Road pass Moonshine Road; and
- The Moonshine Road valley basin.

Besides these three large areas several Pauatahanui Stream tributaries connecting to these areas have flat sections likely suitable for wetland habitat. These include:

- The Bradley Road tributary;
- The Murphys Road tributary;
- The Flightys Road Tributary;
- The Mulhern Road Tributary; and
- An area at the start of Moonshine Hill Road (north east section of the catchment).

The area between the Pauatahanui Inlet and Bradley Road has previously been identified as an historic wetland area (MfE 2016b) and site visits confirm the occurrence of potential wetland habitat in multiple of the other locations listed above.

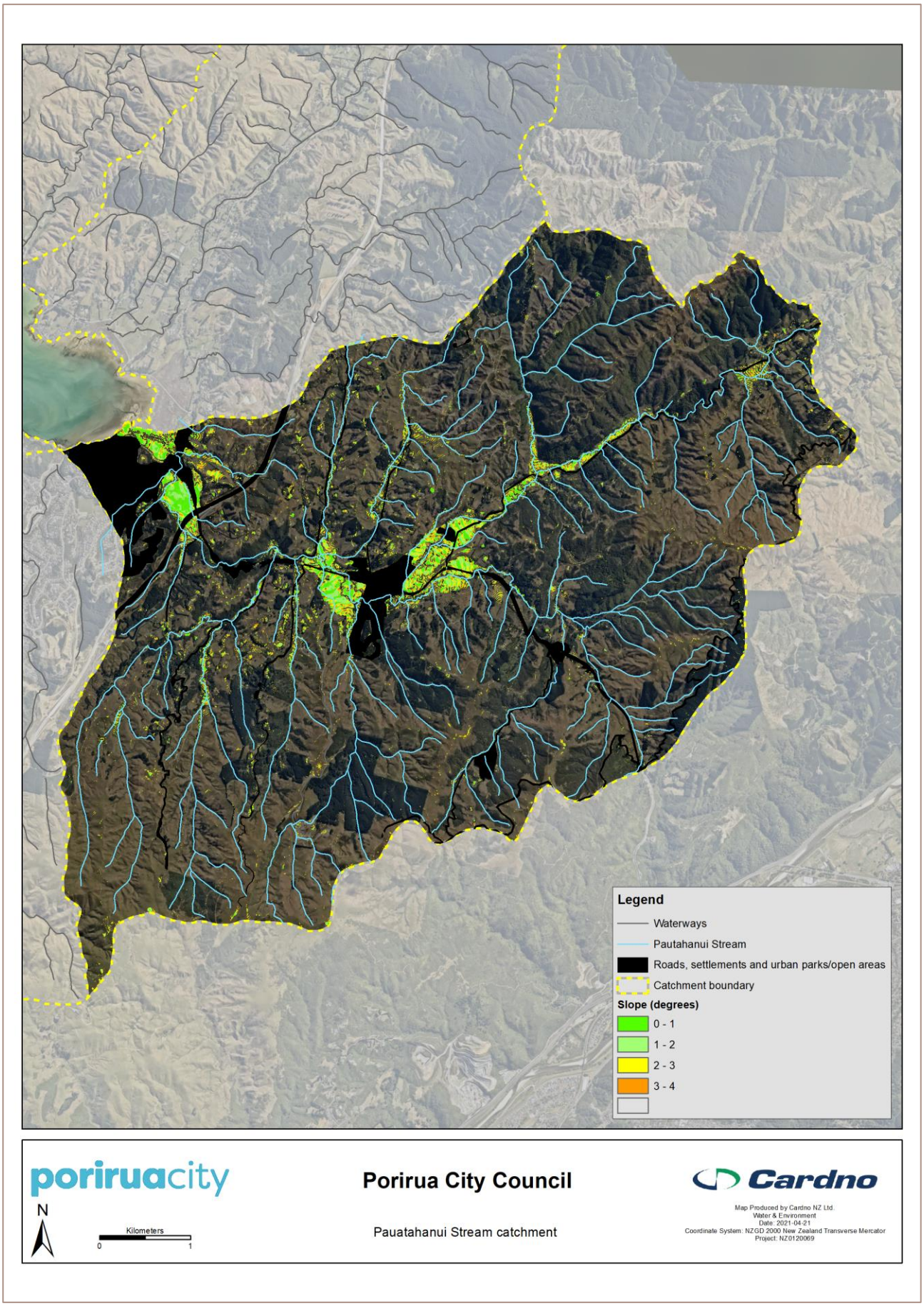

Figure 8-5 Overview of potential wetland areas in the Pauatahanui Stream catchment

9 References

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APPENDIX A

PRIORITY SCORING

Priority Score

$$Priority\ Score_{Final} = the\ greater\ of\ Attribute\ Priority\ Score_{Land}\ or\ Attribute\ Priority\ Score_{nitrogen}$$

$$Priority\ Score_{Land} = \frac{\left(\frac{Attribute\ Priority\ Score_{land\ use} + Attribute\ Priority\ Score_{land\ cover} + Attribute\ Priority\ Score_{rapirian}}{3}\right) + Attribute\ Priority\ Score_{slope}}{2}$$

$$Priority\ Score_{nitrogen} = Attribute\ Priority\ Score_{nitrogen}$$

Land use (LUCAS)

$$Attribute\ Priority\ Score_{Land\ use} = \frac{Sum(Category_{\ area} \times Priority_{value})}{Total\ area}$$

Table 1 LUCAS categories and associated priority values.

Category	Priority value
Crop	1.0
Grassland High producing	0.9
Grassland Low producing	1.0
Grassland With woody biomass	0.8
Natural Forest	0.0
Other	0.0
Planted Forest Pre 1990	0.5
Post 1989 Forest	0.7
Settlements	0.3
Wetland Open water	0.0
Wetland Vegetated non-forest	0.0

Land cover (LCDB 5.0)

$$Priority\ Score_{land\ cover} = \frac{Sum(Category_{area} \times Priority_{value})}{Total\ area}$$

Table 2 LCDB 5.0 categories and associated priority values.

Category	Priority value
Broadleaved Indigenous Hardwoods	0.0
Built up Area settlement	0.3
Deciduous Hardwoods	0.0
Estuarine Open Water	0.0
Exotic Forest	0.5
Fernland	0.3
Flaxland	0.2
Forest Harvested	0.6
Gorse and or Broom	0.4
Gravel or Rock	0.7
Herbaceous Freshwater Vegetation	0.0
Herbaceous Saline Vegetation	0.0
High Producing Exotic Grassland	0.9
Indigenous Forest	0.0
Lake or Pond	0.0
Low Producing Grassland	1.0
Manuka and or Kanuka	0.2
Orchard, Vineyard or Other Perennial Crop	0.2
Short-rotation Cropland	1.0
Transport Infrastructure	0.0
Urban Parkland Open Space	0.1

Riparian vegetation (FENZ)

$$Attribute\ Priority\ Score_{Riparian} = 1 - \left(\frac{1}{[FENZ\ SegHisShad]} \times \left([FENZ\ SegRipShad] \times \left([FENZ\ SegRipNati] + \left((1 - [FENZ\ SegRipShad]) \times 0.60\right)\right)\right)\right)$$

Adjacent Land Slope (LENZ Slope)

$$Attribute\ Priority\ Score_{Slope} = \frac{Sum(Category_{area} \times Priority_{value})}{Total\ area}$$

Table 3 LENZ Slope categories and associated priority values.

Category	Priority value
Flat 0-3%	0.00
Gentle 3-6%	0.25
Moderate 6-12%	0.50
Steep 12-25%	0.75
Very Steep 25-45%	1.00

Nitrogen Leaching (Nitrogen Leaching 2011)

$$Attribute\ Priority\ Score_{nitrogen} = \frac{Sum(Category_{area} \times Priority_{value})}{Total\ area}$$

Table 4 Nitrogen leaching categories and associated priority values.

Category	Priority value
0-3 kg nitrate-N/ha/yr	0.00
3-6 kg nitrate-N/ha/yr	0.20
6-12 kg nitrate-N/ha/yr	0.40
12-25 kg nitrate-N/ha/yr	0.60
25-50 kg nitrate-N/ha/yr	0.80
>50 kg nitrate-N/ha/yr	1.00

APPENDIX B

COSTING WEIGHTINGS

Table 1 LUCAS category weightings for plant number estimations

LUCAS Category	Weighting (as % of area)	Notes
Cropland Annual	100%	
Cropland Perennial	0%	Not represented in riparian margins.
Grassland High producing	100%	
Grassland Low producing	100%	
Grassland With woody biomass	0%	Stream-adjacent areas generally characterised by regenerating native bush and scrub with little intervention required except in specific cases.
Natural Forest	0%	Existing native forest.
Other	0%	Generally characterised by existing road corridors & other infrastructure.
Planted Forest Pre 1990	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Post 1989 Forest	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Settlements	0%	Generally private land or existing native vegetation.
Wetland Open water	0%	Open water.
Wetland Vegetated non-forest	0%	These areas appear generally well vegetated.
Broadleaved Indigenous Hardwoods	0%	Existing native forest.

Table 2 LCDB5.0 category weightings for plant number estimations

LCDB5.0 Category	Weighting (as % of area)	Notes
Built up Area settlement	0%	Generally private land or existing native vegetation.
Deciduous Hardwoods	0%	Generally good existing canopy coverage.
Estuarine Open Water	0%	Minimally represented in riparian margins.
Exotic Forest	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Fernland	0%	Generally good existing canopy coverage.
Flaxland	0%	Generally good existing canopy coverage.
Forest Harvested	50%	Generally characterised by existing road corridors & other infrastructure.
Gorse and or Broom	25%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Gravel or Rock	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Herbaceous Freshwater Vegetation	25%	Generally private land or existing native vegetation.
Herbaceous Saline Vegetation	25%	Open water.
High Producing Exotic Grassland	100%	These areas appear generally well vegetated.
Indigenous Forest	0%	Existing native forest.
Lake or Pond	0%	
Low Producing Grassland	100%	
Manuka and or Kanuka	0%	Generally good existing canopy coverage.
Matagouri or Grey Scrub	0%	Not represented in riparian margins.
Orchard Vineyard or Other Perennial Crop	0%	Comprises only 2480m2 of the total riparian area.
Sand or Gravel	0%	Not represented in riparian margins.
Short rotation Cropland	100%	
Surface Mine or Dump	0%	Not represented in riparian margins.
Transport Infrastructure	0%	Existing native vegetation present where possible.
Urban Parkland Open Space	50%	Reduced to a narrower planting martin go allow some access to streams and maintain safety in parks & open spaces.

Table 3 LUCAS category weightings for fencing

LUCAS Category	Weighting (as % of area)	Notes
Cropland Annual	100%	
Cropland Perennial	0%	Not represented in riparian margins.
Grassland High producing	100%	
Grassland Low producing	100%	
Grassland With woody biomass	0%	
Natural Forest	0%	
Other	0%	
Planted Forest Pre 1990	0%	
Post 1989 Forest	0%	
Settlements	0%	
Wetland Open water	0%	
Wetland Vegetated non-forest	0%	
Broadleaved Indigenous Hardwoods	0%	

APPENDIX C

ADDITIONAL MAPS

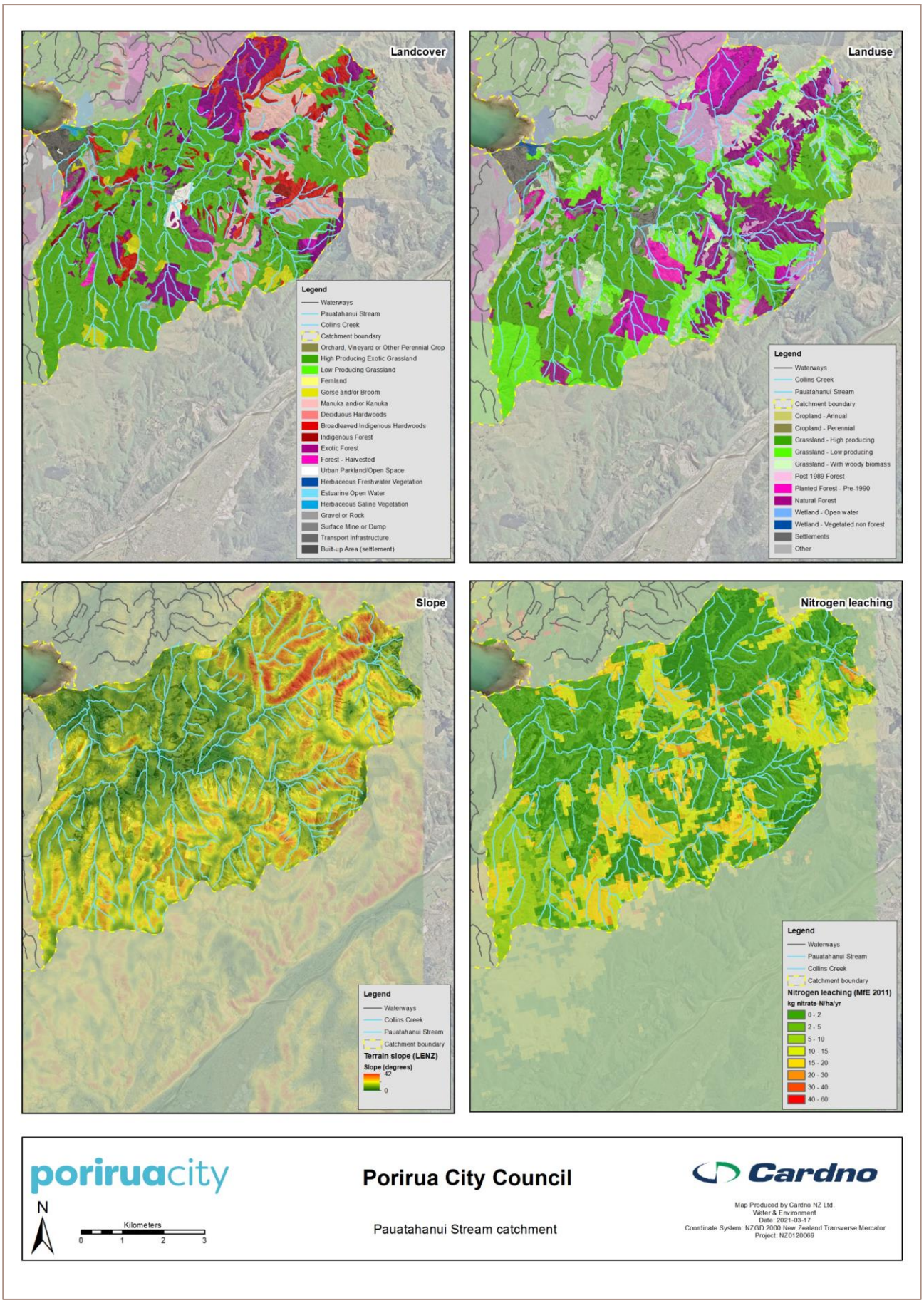


Figure 1 Overview of data layers used in the priority area calculations.

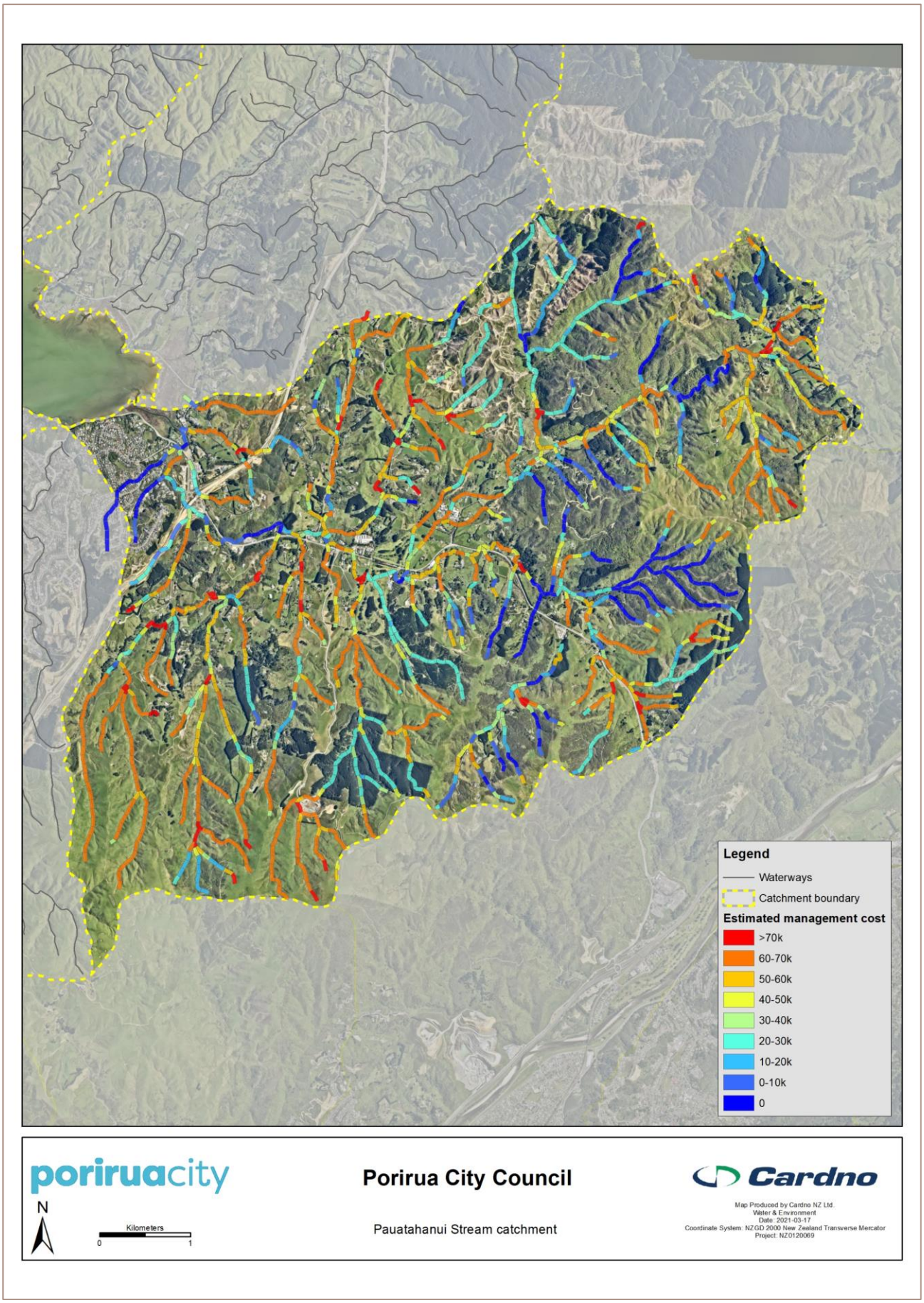


Figure 2 Overview of estimated management cost per reach section.

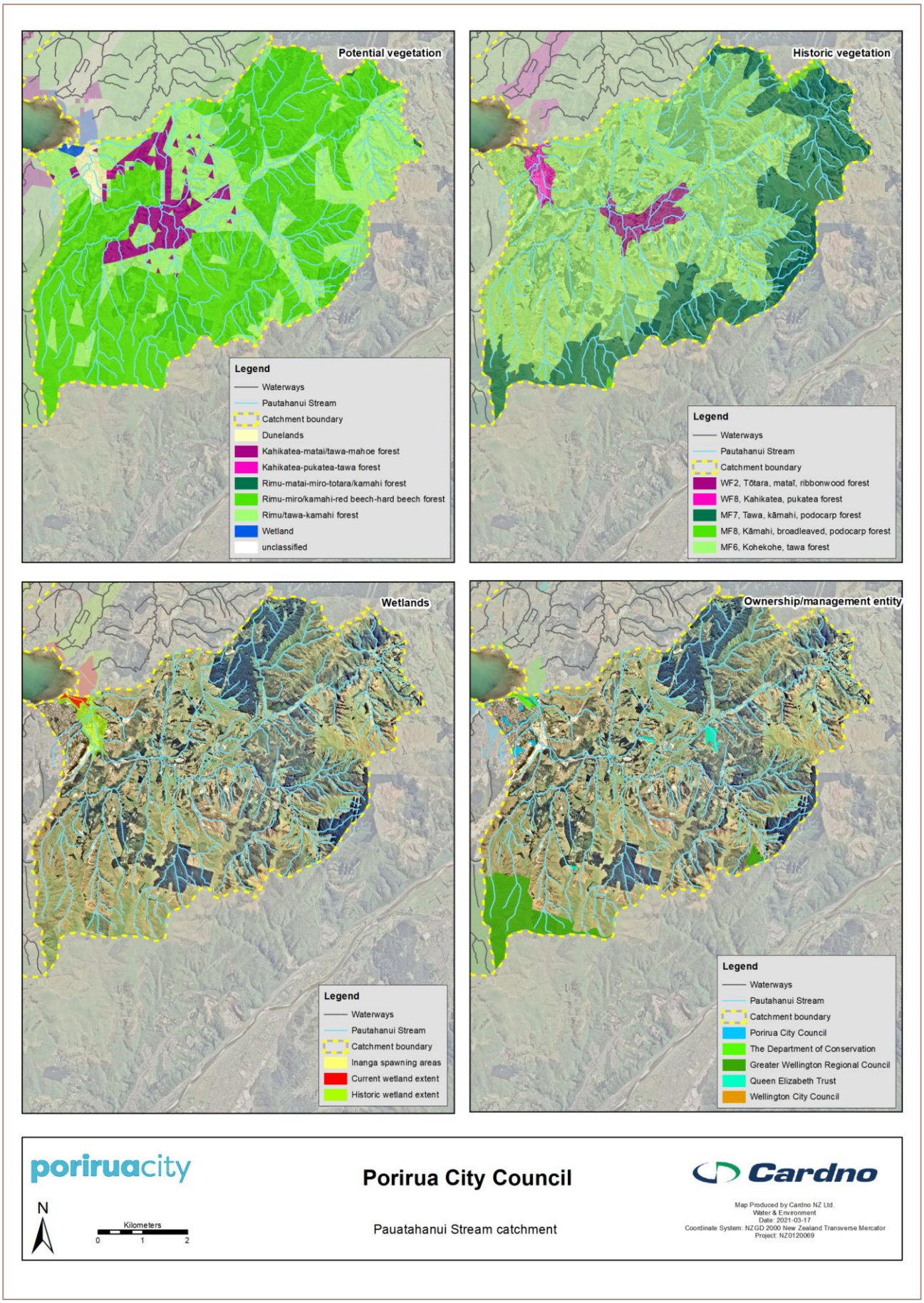


Figure 3 Overview of data layers used in the treatment area calculations.

APPENDIX D

PLANT LISTS

Table 1 Functional groups –✓ indicates preferred species. Any species designated with a (*) are on the national or Wellington regional threatened species list and should be planted where possible.

Scientific name	Common name	General Revegetation	Erosion Control	Nitrogen Fixing	Freshwater Wetland	Saline Wetland	Lizard Habitat
*Aciphylla squarrosa**	Spaniard				✓		✓
Apodasmia similis	Oioi				✓	✓	
Aristotelia serrata	Makomako	✓	✓				
Austroderia toetoe	Toetoe		✓			✓	
Baumea articulata	Jointed baumea				✓	✓	
Carex secta	Purei					✓	
Carmichaelia australis.	Broom			✓			
Carpodetus serratus	Putaputaweta	✓					
Coprosma propinqua	Mingimingi						✓
Coprosma repens	Taupata					✓	
Coprosma robusta	Karamu	✓	✓				
Coprosma tenuicaulis	Hukihuki				✓		
Cordyline australis	Ti kouka	✓			✓	✓	
Coriaria arborea	Tutu		✓	✓			
Austroderia fulvida	Toetoe	✓			✓		
Cypress ustulatus	Giant umbrella sedge				✓	✓	
*Discaria toumatou**	Matagouri			✓			✓
Fuchsia excorticata	Tree fuchsia	✓					
Griselinia littoralis	Kapuka	✓					
Veronica stricta	Koromiko	✓					
Juncus kraussii	Sea rush					✓	
Juncus pallidus	Giant rush					✓	
Knightia excelsa	Rewarewa		✓	✓			
Kunzea robusta	Kanuka	✓	✓				✓
Laurelia novae-zelandiae	Pukatea				✓		
Leptospermum scoparium	Manuka	✓	✓	✓			✓
Melicytus ramiflorus	Mahoe	✓	✓				
*Muehlenbeckia astonii**	Shrubby tororaro						✓
Muehlenbeckia axillaris, or M. complexa var. complexa.	Muehlenbeckia						✓
Myoporum laetum	Ngaio	✓					
Myrsine australis	Red mapou	✓	✓				
Olearia paniculata	Akiraho	✓	✓				
Olearia solandri	Coastal tree daisy		✓			✓	
Ozothamnus leptophyllus	Tauhinu		✓				
Phormium cookianum	Wharariki		✓				✓
Phormium tenax	Harakeke				✓	✓	✓

Scientific name	Common name	General Revegetation	Erosion Control	Nitrogen Fixing	Freshwater Wetland	Saline Wetland	Lizard Habitat
Pittosporum eugenioides	Tarata	✓					
Pittosporum tenuifolium	Kohukohu	✓					
Plagianthus divaricatus	Salt marsh ribbonwood					✓	
Plagianthus regius subsp. regius	Manatu	✓			✓	✓	
Poa cita	Silver tussock						✓
Pseudopanax arboreus	Whauwhaupaku	✓					
Pseudopanax crassifolius	Horoeka	✓					
*Pseudopanax ferox**	Fierce lancewood	✓					
Sophora microphylla	Kowhai			✓			
*Streblus banksia**	Turepo	✓					
Typha orientalis	Raupo					✓	

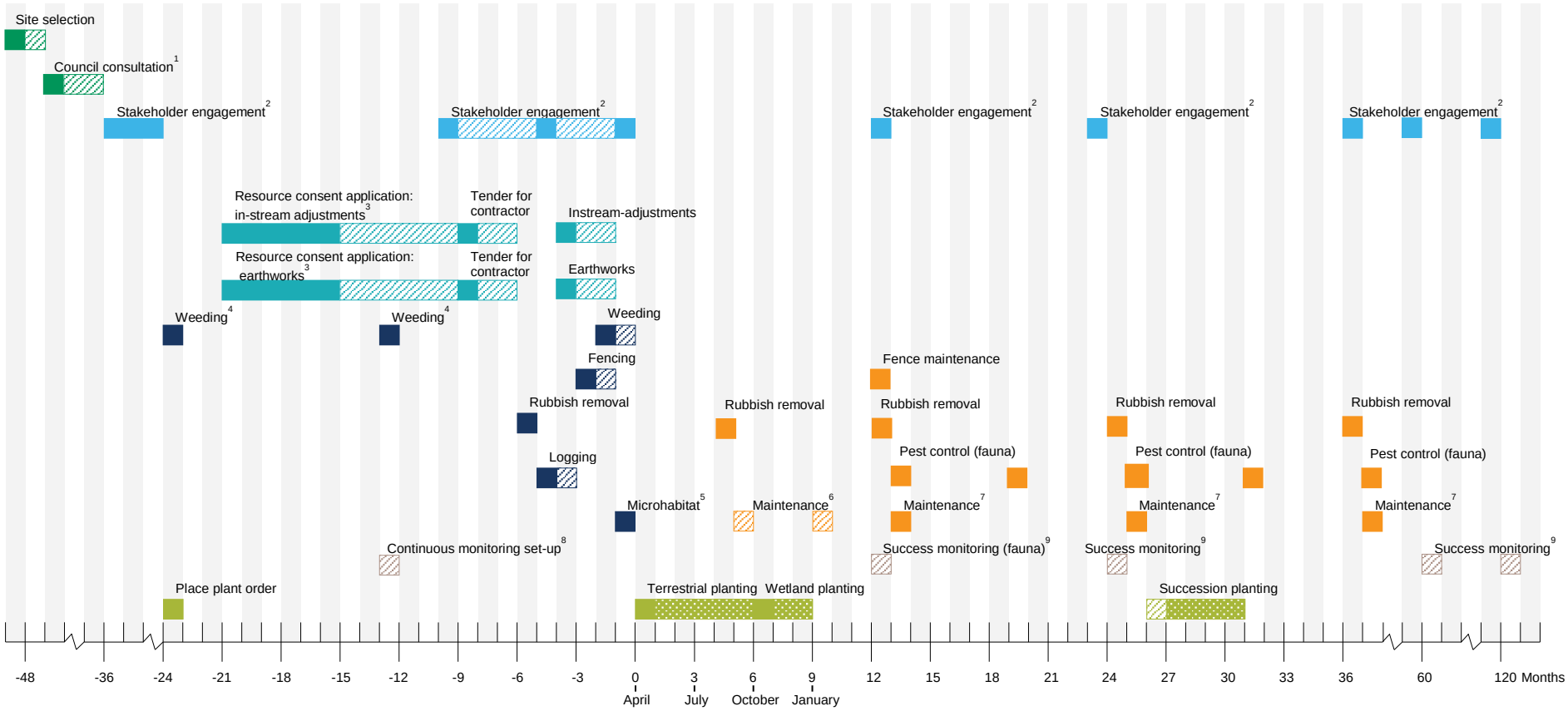
Table 2 Functional groups –for successional planting 2 to 5 years after initial planting.

Scientific name	Common name	Rimu/tawa/kamahi forest	Rimu/miro/kamahi/podocarp forest	Wetland/sheltered coastal forest
Beilschmiedia tawa	Tawa	✓	✓	✓
Dacrycarpus dacrydioides	Kahikatea		✓	✓
Dacrydium cupressinum	Rimu	✓	✓	
Dysoxylum spectabile	Kohekohe	✓	✓	✓
Melicytus ramiflorus	Mahoe		✓	
Metrosideros robusta	Northern rata		✓	
Podocarpus totara	Totara	✓	✓	✓
Prumnopitys taxifolia	Matai		✓	✓
Rhopalostylis sapida	Nikau palm		✓	✓
Weinnmania racemosa	Kamahi	✓	✓	

APPENDIX

E

SCHEDULE OF WORKS



Legend

Site selection	Engagement	Major works	Site preparation
Minimum time	Minimum time	Minimum time	Minimum time
Additional time	Additional time	Additional time	Additional time

Planting	Maintenance	Success
Required	Required	Recommended
Optional	Optional	
Extended planting season		

Notes

[1] Required for major works (size, intensity and/or sensitivity)

[2] e.g. landowners, guardians, community groups, developers, landholdings, other councils

[3] Notifiable consent applications are likely to require additional time

[4] Weed control of difficult species such as vines or blackberry

[5] Placement of fauna microhabitat like logs and rocks

[6] Maintenance consisting of plant release and monitoring of plant survival rate

[7] Maintenance consisting of plant release and infill planting

[8] Continuous or baseline monitoring (e.g. turbidity, nutrients)

[9] Planting success (e.g. survival, canopy) and/or treatment success (e.g. water quality)

APPENDIX

F

SITE IMAGES

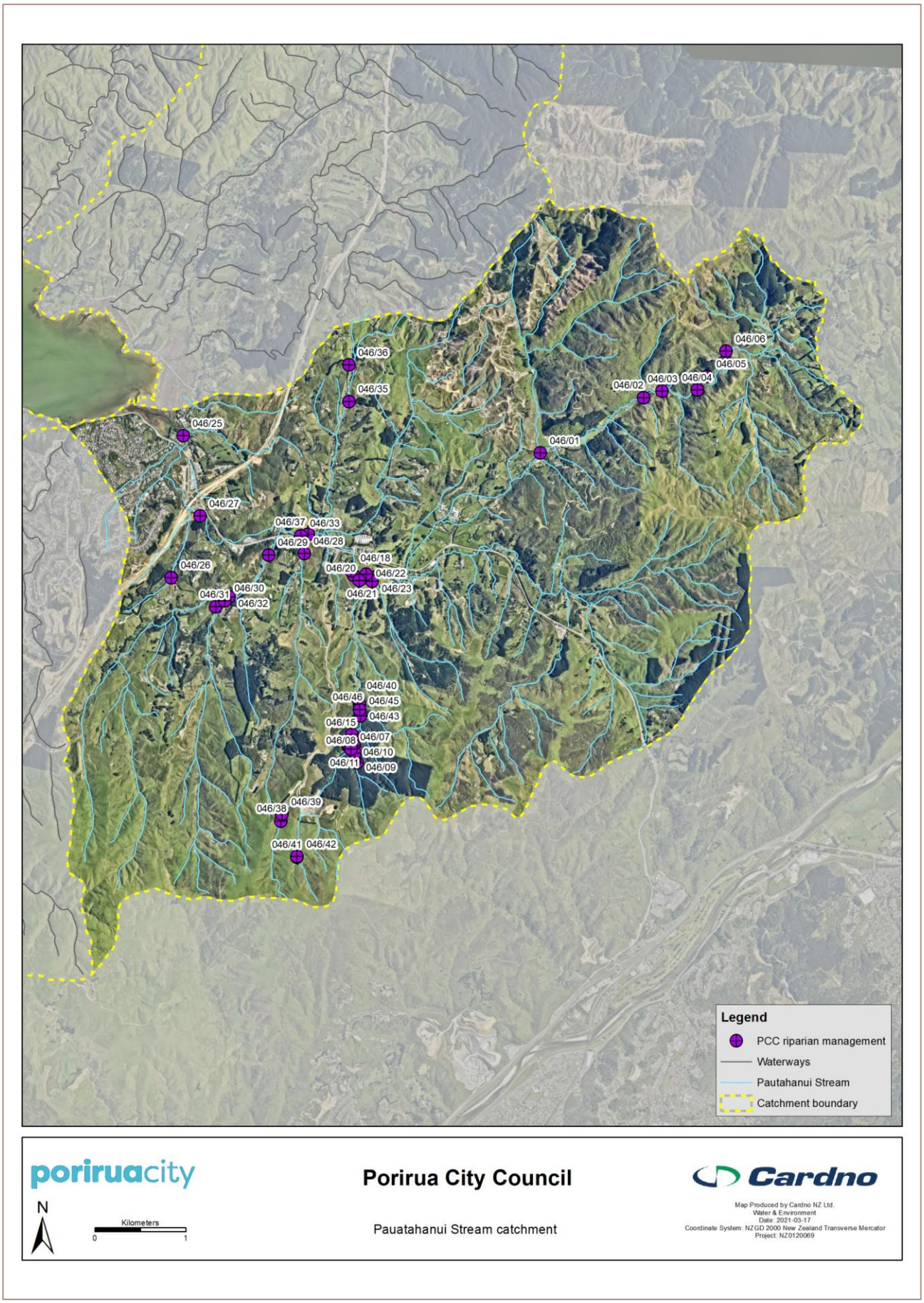


Figure 1 Transect locations within the Pauatahanui Stream catchment.

Plate 1: Transect046/01– Recently planted willows along the riparian margin. Stabilised erosion on the true left bend.

Plate 2: Transect 046/02 – Stream section largely runs through a long grass paddock with patches of willows for riparian shading.

Plate 3: Transect 046/03 – Eroded stream banks, mainly gravel and cobble substrates, likely caused by stock access and flood events. Native vegetation present on the true left bank however this does not extend to the stream bank.

Plate 4: Transect 046/04 – Rock baskets helping to prevent further erosion of the road side, however this likely needs to be remodelled in the future. Good established riparian vegetation on the true right.

Plate 5: Transect 046/05 – Established native riparian vegetation and a range of instream habitats for aquatic life present.

Plate 6: Transect 046/06 – Patches of native and exotic vegetation along the stream margin. Recent erosion along both the true left and right banks, this looks to have somewhat stabilised since but further erosion at the site is highly likely. The site could benefit from stock exclusion if stock are currently able to access.

Plate 9: Transect 046/07 – Looking upstream, established riparian vegetation providing stream shade. Vegetation consists of largely exotic pines (some have fallen) with small patches of early native vegetation.

Plate 10: Transect 046/08 – Stream section which runs sub-surface for approximately 20 metres. Established riparian vegetation providing good stream shade (both native and exotic)

Plate 11: Transect 046/09 – Stream returning to the surface. True left bank very unstable and appears to have recently slipped, resulting in sediment discharge.

Plate 12: Transect 046/10 – Fallen pines across stream banks. Presence of woody debris and a variety of instream habitats for aquatic life.

Plate 13: Transect 046/11 – Presence of undercut banks on true right side. Established vegetation on true right and grass/farm track on true left. Approximately 5 meters downstream is the confluence with the stream captured in Transect 046/07 to 046/10

Plate 14: Transect 046/12 – Riparian vegetation consists of native and exotic (pines, eucalyptus), good stream shading and a variety of instream habitats present.

Plate 15: Transect 046/13 – Vegetated stream banks which are mostly stable, some sections of undercut banks.

Plate 16: Transect 046/14 – Patches of mixed native and exotic riparian vegetation, creating moderate to high instream shading. True left stream bank could likely benefit from planting, however if left this is likely to regenerate.

Plate 17: Transect 046/15 – Patches of exotic and native riparian vegetation. Good instream habitat for aquatic life.

Plate 18: Transect 046/16 – Perched culvert under farm access track, gravels and rocks have been placed under the culvert to help improve fish passage. Stream banks could benefit from riparian planting, however native and exotic vegetation surrounds the site so it is likely this will regenerate if left alone.

Plate 19: Transect 046/17 – Transect located at the top of a small waterfall. Established native riparian vegetation at the site.

Plate 20: Transect 046/18 – Pauatahanui mainstem. There is likely stock access at the site. Willows creating instream shading, these could be replaced in time with native planting.

Plate 21: Transect 046/19 – Pauatahanui mainstem, riparian shading created by planted willows which could eventually be replaced by native vegetation. Stock access, should be prevented with fencing

Plate 22: Transect 046/20 – Pauatahanui tributary upstream of transect 046/019. Recontouring of the true left bank could prevent potential bank erosion. Stream section would benefit from stock exclusion and native riparian planting.

Plate 23: Transect 046/21 – Transect located within the Judgeford Golf Course. Downstream and upstream sites are subject to erosion and have previously been remediated by using concrete blocks. The stream section should be planted and given room to move.

Plate 24: Transect 046/22 – Erosion present on the border of Judgeford Golf Course and private property.

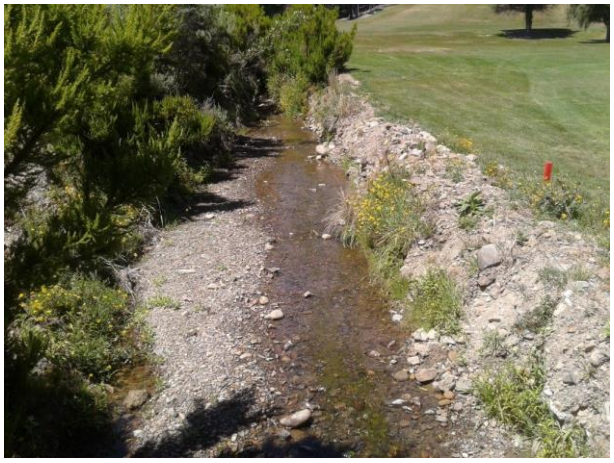


Plate 25: Transect 046/23 – Stream bank erosion on both sides. Ideally the stream banks along this reach would be recontoured and planting should be customised.

Plate 26: Transect 046/25- Pauatahanui mainstem near Pauatahanui shops and Pauatahanui Wildlife walk. Salt water influence. Existing and sufficient riparian shading.

Plate 27: Transect 046/26 – Wetland characteristics, the stream section could benefit from planting with wet tolerant species.

Plate 28: Transect 046/27 – Pauatahanui mainstem at Bradey Road. An abundance of blackberry and weeds present, which could be replaced with native species to improve instream shading.

Plate 29: Transect 046/28 – Stream section runs through private property, eucalyptus trees within the stream margin provide good instream shading, however stock exclusion fencing is appropriate

Plate 30: Transect 046/29 – Downstream requires control of blackberry. Pines along the stream margin provide good shading, however should be replaced with native vegetation in the future. Good instream habitats providing habitat for aquatic life.

Plate 31: Transect 046/30 – Twin culverts, gravel stream bed and good riparian shading upstream.

Plate 32: Transect 046/31 – Private property which is farmed. Areas of stock damage, therefore stock exclusion fencing would benefit the site. Overall there is good stream shading from adjacent pines and *Carex spp* along the stream banks.

Plate 33: Transect 046/32 – Upstream bridge channel has been blocked by gravels. True right side should be planted and excluded from stock.

Plate 34: Transect 046/33 – Extensive weed control required on the true left side, approx. 3 metres of blackberry before reaching the stream channel. On the true left side there is a path connecting SH58 and Flightys Road, removal of weeds and planting of natives will enhance the ascetics of the area. Stock should be excluded from the true right side as this is currently farmed.

Plate 35: Transect 046/35 – Private property. The stream section is heavy damaged due to stock. The section should be excluded from stock and wet tolerant species planted in and around the existing *Carex spp.*

Plate 36: Transect 046/36 – Pines along the riparian margin providing good instream shading. These trees, in time should be replaced with natives to enhance biodiversity along the reach. The section is within private land but could be excluded from stock.

Plate 37: Transect 046/37 – Stream section along Flightys Road. Weeds along the section to be removed and planted.

Plate 38: Transect 046/38 – Stream section located within private property. Evidence of stock damage. Wetland

characteristics, additional planting could incorporate wet tolerant species.

Plate 39: Transect 046/39 – Wetland characteristics, erosion from stormwater drain and stock damage. Low riparian shading. Area would benefit from bank recontouring, planting and stock exclusion fencing.

Plate 40: Transect 046/40 – Meandering stream section throughout farmland. Evidence of damage from stock. Planted willows along the stream banks will stabilise some sections prone to erosion, however stock should be excluded.

Plate 41: Transect 046/41 – Downstream stream section runs through pines, upstream displays wetland characteristics. Stream section should be excluded from stock as damage is evident.

Plate 42: Transect 046/42 – Stream section recently planted and largely excluded from stock.

Plate 43: Transect 046/43 – Stream bank erosion largely stabilised by native riparian planting.

Plate 44: Transect 046/44 – Wide and incised stream channel, consisting of largely boulders and gravels. Good riparian shading from exotic and native species.

Plate 45: Transect 046/45 – Wide stream channel within farmland. Suggest to exclude stock from the waterway to prevent damage and plant riparian margins.

Plate 46: Transect 046/46 – No stock access, stream shading by exotic and patches of native species. Undercut banks on the true right providing instream habitats for aquatic life.

About Cardno

Cardno is a professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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