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Te Whāriki Subdivision Phases 1 and 2 Methods

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The full case study can be found at:
https://landscapeperformance.org/case-study-briefs/Te-Whariki

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Environmental Benefits

- ***Manages an estimated 6 acre-ft per year or 5% of total runoff from the site in the site's swales and vegetated areas.***

- ***Improves water quality downstream, with on-site sourced total nitrogen reduced by an estimated 10%, total phosphorus by 19%, total suspended solids by 8%, and fecal coliforms by 8% per year.***

Method

The amounts of reduced runoff and pollution loadings were calculated by using the Watershed Treatment Model (WTM) 2013, a spreadsheet-based calculator which can estimate pollution loads sourced from various land surfaces and loading-reduction benefits of various stormwater facilities. The research team collected the required input data from several different channels, including online GIS applications, literature databases, and construction documents. The collected input data and their information sources are shown in table 1.

Table 1. Input data for the Watershed Treatment Model

Watershed Data	
Annual Rainfall (inches)	25.2

Source: Climate-Data.org

Land Use	
High Density Residential (acre)	73.9
Public Open Spaces (acre)	29.9
Roadway (acre)	20.1
Wetlands (acre)	20.5

Source: NZ Primary Parcels; Canterbury Maps Open Data

Hydrologic Soil Group	
A Soils	0%
B Soils	0%
C Soils	7%
D Soils	93%

Source: S-Map Online

Depth to Groundwater	
< 3 ft	0%
3-5 ft	0%
> 5 ft	100%

Source: Canterbury Maps Open Data - Depth to Groundwater

Structural Stormwater Management Practices	
Wetland (acre)	20.5
Dry Swale (acre)	1.5

Source: Canterbury Maps Open Data

Structural Stormwater Management Practice Discount Values	
Capture Discount (D1)	1.0
Design Discount (D2)	1.0
Maintenance Discount (D3)	0.6

Riparian Buffers	
Buffer Length 1 (miles)	0.68
Buffer Width 1 (ft)	29.5
Buffer Length 2 (miles)	2.34
Buffer Width 2 (ft)	19.7

Source: Canterbury Maps Open Data

Riparian Buffer Discount Values	
Maintenance	0.60

Calculations

The collected input data were put into the calculator - Watershed Treatment Model (WTM) - 2013 Off the Shelf Edition for calculation. The calculator then automatically output the result of pollution loads (as shown in table 2) and load reductions of existing stormwater facilities (as shown in table 3).

Table 2. Calculation result - Source loads of existing system to the surface water

	TN (lb/year)	**TP** (lb/year)	**TSS** (lb/year)	**FC** (billion /year)	**RV** (acre-feet /year)
High Density Residential	360.33	53.19	8,407.59	15,639.91	63.27
Public Open Spaces	124.98	18.45	2,916.14	5,424.64	21.94
Roadway	189.96	20.65	11,066.99	7,528.07	30.45
Wetlands	8.20	0.62	0.00	0.00	1.90
Total Surface Water Primary Source Load	**683.46**	**92.90**	**22,390.72**	**28,592.62**	**117.57**
Primary Source Storm Load	679.36	92.72	24,235.72	29,392.12	117.57
Primary Source Non-Stormwater Load	4.10	0.18	205.00	0.00	0.00

TN =Total Nitrogen
TP=Total Phosphorus
TSS=Total Suspended Solids
FC=Fecal Coliform
RV=Runoff Volume

Table 3. Calculation result - Load reductions of existing stormwater facilities

	TN (lb/year)	**TP** (lb/year)	**TSS** (lb/year)	**FC** (billion /year)	**RV** (acre-feet /year)
SSMP - Wetland	21.20	6.58	816.21	970.81	0.00
SSMP - Dry Swale (bioswale, WQ swale)	2.01	0.48	52.70	42.06	0.17
Riparian Buffers	46.53	10.59	1,159.74	1,480.97	5.99
Total Surface Water Reduction	**69.74**	**17.66**	**2,028.65**	**2,493.83**	**6.16**
Storm Reduction	69.74	17.66	2,028.65	2,493.83	6.16
Non-storm Reduction	0.00	0.00	0.00	0.00	0.00

TN=Total Nitrogen
TP=Total Phosphorus
TSS=Total Suspended Solids
FC=Fecal Coliform
RV=Runoff Volume

The research team calculated the contribution rate of each pollution source to the total amount of loadings (see table 4) and the loading reduction percentage of the stormwater facilities (see table 5) based on the output data shown in table 2 and table 3.

Table 4. Contribution rate of each pollution source to the total amount of loadings

	TN (lb/year)	**TP** (lb/year)	**TSS** (lb/year)	**FC** (billion /year)	**RV** (acre-feet /year)
High Density Residential	52.72%	57.25%	37.55%	54.70%	53.82%
Public Open Spaces	18.29%	19.86%	13.02%	18.97%	18.67%
Roadway	27.79%	22.22%	49.43%	26.33%	25.90%
Wetlands	1.20%	0.66%	0.00%	0.00%	1.62%

TN=Total Nitrogen
TP=Total Phosphorus
TSS=Total Suspended Solids
FC=Fecal Coliform
RV=Runoff Volume

Table 5. Loading reduction rate by the stormwater facilities on-site

	TN (lb/year)	**TP** (lb/year)	**TSS** (lb/year)	**FC** (billion /year)	**RV** (acre-feet /year)
Total Surface Water Primary Source Load	683.46	92.90	24440.72	29392.12	117.58
Total Surface Water Reduction	69.74	17.66	2028.65	2493.83	6.16
Percentage of Reduction	**10.20%**	**19.01%**	**8.30%**	**8.48%**	**5.24%**

TN=Total Nitrogen
TP=Total Phosphorus
TSS=Total Suspended Solids
FC=Fecal Coliform
RV=Runoff Volume

The relationship between the different types of land uses and their contribution or reduction to the total pollution loadings and runoff volumes is shown in figure 1.

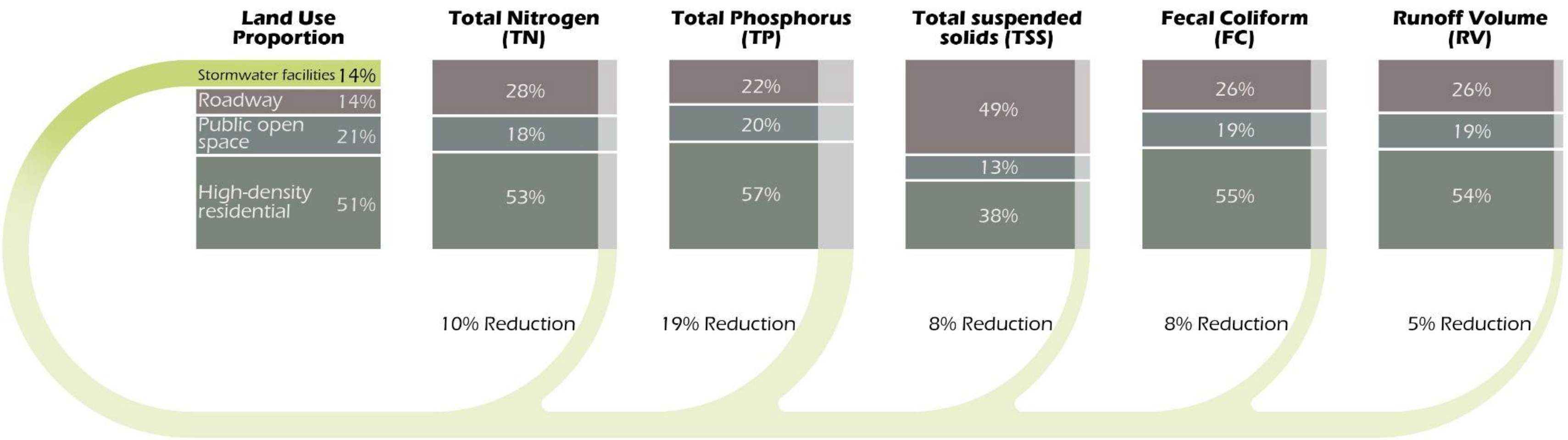

Figure 1. Source loads to the surface water and load reductions of existing stormwater facilities

Sources

Canterbury Maps Open Data: https://canterburymaps.govt.nz/

Canterbury Maps Open Data - Depth to Groundwater: https://opendata.canterburymaps.govt.nz/datasets/depth-to-groundwater/explore?location=-43.628063%2C172.486316%2C12.91

Center for Watershed Protection - Watershed Treatment Model (WTM) - 2013 Off the Shelf Edition: https://owl.cwp.org/mdocs-posts/watershed-treatment-model-wtm-2020-update-for-64-bit-machines/

Climate-Data.org: https://en.climate-data.org/oceania/new-zealand/canterbury/lincoln-213011/

NZ Primary Parcels: https://data.linz.govt.nz/layer/50772-nz-primary-parcels/

S-Map Online: https://smap.landcareresearch.co.nz/maps-and-tools/app/

Watershed Treatment Model (WTM): https://owl.cwp.org/mdocs-posts/watershed-treatment-model-wtm-2020-update-for-64-bit-machines/

Limitations

- The Watershed Treatment Model (WTM) is an estimation tool that is built to provide a general indication of how the system is expected to perform. Most of the default values embedded in the calculator are determined based on a series of studies on similar landscape systems. While these values can help to make the best estimate of the performance of a similar system, they may not accurately reflect the actual performance of a specific development. The actual load sources and loading-reduction performance of the system on-site, therefore, may not be the same as the calculation result.
- Many of the embedded constants adopted by the calculator are specific to North American conditions, which may not reflect the actual conditions in New Zealand. For example, the atmospheric deposition rate of nitrogen adopted by the model is determined based on studies conducted by the National Atmospheric Deposition Program (NADP) in the USA (Caruco 2013). According to the Watershed Treatment Model (WTM) 2013 Documentation, the atmospheric deposition rate of nitrogen was determined as 11.2 lbs/acre/year (about 1255.4 mg/sqm/year) for western and southern US, and 12.8 lbs/acre/year (about 1434.7 mg/sqm/year) for northeastern US (Caruco 2013). However, evidence shows that the atmospheric deposition rate of nitrogen is significantly higher in most areas in the US than in New Zealand (Bobbink et al. 2010). While the nitrogen deposition rate in the majority area in the US is between 1000-2000 mg/sqm/year, the site, Te Whāriki, is situated within an area where its nitrogen deposition rate is between 200-300 mg/sqm/year. Therefore, it can be expected that the nitrogen loadings to the water system on-site would be lower than the calculation result and the load-reduction percentage of the stormwater facilities would be higher than the result.
- As the model was originally built for water quality estimation and management in the

USA, some standards that are specific to the USA are adopted. For example, as one of the required data, Hydrologic Soil Group (HSG) is a type of soil classification system developed by the United States Department of Agriculture. This soil classification system is similar to a sub-system of the New Zealand Soil Classification (NZSC), a New Zealand classification system, but they are not the same. While the soil is categorized into four groups by the HSG, NZSC classified the soil into five groups according to their drainage characteristics. Although the research team has matched the two systems according to their descriptions of the hydrologic characteristics of soils, converting the classification from one system to another will inevitably lower the accuracy of the calculation results.

- ***Increased the number of observed bird species by 400% (fivefold) and the number of observed mollusk, arachnid, and insect species by 165%, as compared to a nearby dairy farm similar to the site's pre-construction condition. The average number of observed species on the site doubled annually from 2017 to 2020.***

Background

Constructed wetlands have been observed to have positive contributions to local species richness (Strand and Weisner 2013). Wetlands, as a major feature in the Te Whāriki subdivision, make up 15% of the total area of the site. Therefore, the subdivision is expected to have a higher level of species richness compared with its pre-construction condition as a dairy farm.

Method

Species observation data were sourced from iNatualist, an online database of species observation records contributed by ecologists and citizen scientists. iNaturalist's observation records are separated into two categories - "Casual" and "Research Grade". Research Grade records are of the highest level of reliability and can be used for research purposes (Boone and Basille 2019). Therefore, only Research Grade observations were adopted in this study. As every Research Grade record in iNaturalist has an attached spatial georeference, the research team was able to identify the location of each observation and collect all the records within the site boundary. In addition to the observation data of Te Whāriki, the research team also collected the observation data of Lincoln University Dairy Farm and Lincoln Wetlands for comparison. These observation data are included in Appendix A-F. As shown in table 6 and 7, 20 bird species and 45 mollusk, arachnid, or insect species were observed in Te Whāriki from 2015 to 2021.

Table 6. Observed bird species in Te Whāriki (2015-2021)

No.	Scientific Name	Common Name	Number of observations
1	Spatula rhynchotis	Australasian Shoveler	13
2	Cygnus atratus	Black Swan	12
3	Aythya novaeseelandiae	New Zealand Scaup	9
4	Fulica atra australis	Australasian Coot	9
5	Porphyrio melanotus ssp. melanotus	Southeastern Australasian Swamphen	6
6	Egretta novaehollandiae ssp. novaehollandiae	Common White-faced Heron	5
7	Cygnus olor	Mute Swan	4
8	Microcarbo melanoleucos ssp. brevirostris	Little Shag	4
9	Anas platyrhynchos	Mallard	2
10	Fulica atra	Eurasian Coot	2
11	Zosterops lateralis lateralis	Tasmanian Silvereye	2
12	Anas superciliosa × platyrhynchos	Pacific Black Duck × Mallard Hybrid	1
13	Cairina moschata domestica	Domestic Muscovy Duck	1
14	Carduelis carduelis	European Goldfinch	1
15	Egretta novaehollandiae	White-faced Heron	1
16	Passer domesticus domesticus	European House Sparrow	1
17	Sturnus vulgaris vulgaris	European Common Starling	1
18	Tadorna variegata	Paradise Shelduck	1
19	Turdus merula	Eurasian Blackbird	1
20	Turdus merula merula	Western European Blackbird	1

Table 7. Observed mollusk, arachnid, and insect species in Te Whāriki (2015-2021)

No.	Scientific Name	Common Name	Number of observations
1	Apis mellifera	Western Honey Bee	10
2	Xanthocnemis zealandica	Red Damselfly	10
3	Pieris rapae	Cabbage White	8
4	Lampona cylindrata	Common White-tail Spider	6
5	Eriophora pustulosa	Knobbled Orbweaver	4
6	Orthodera novaezealandiae	New Zealand Mantis	4
7	Vanessa itea	Yellow Admiral	4
8	Austrolestes colensonis	Blue Damselfly	3
9	Caedicia simplex	Australian Common Garden Katydid	3
10	Danaus plexippus	Monarch	3
11	Phrissogonus laticostata	Apple Looper	3
12	Scopula rubraria	Plantain Moth	3
13	Adversaeschna brevistyla	Blue-spotted Hawker	2
14	Badumna longinqua	Grey House Spider	2
15	Bombus terrestris	Buff-tailed Bumble Bee	2
16	Coccinella undecimpunctata	Eleven-spotted Ladybird Beetle	2
17	Maratus griseus	White-banded House Jumping Spider	2
18	Melangyna novaezelandiae	Large Hover Fly	2
19	Nyssus coloripes	Spotted Ground Swift Spider	2
20	Vespula germanica	German Yellowjacket	2
21	Anachloris subochraria	Golden Grass Carpet	1
22	Anthomyia punctipennis	-	1
23	Arhopalus ferus	Burnt Pine Longhorn	1
24	Chrysodeixis eriosoma	Green Garden Looper	1
25	Cornu aspersum	Garden Snail	1
26	Cryptachaea veruculata	Diamond Comb-footed Spider	1
27	Deroceras reticulatum	Milky Slug	1
28	Dysdera crocata	Woodlouse Spider	1
29	Epiphyas postvittana	Light Brown Apple Moth	1
30	Eristalis tenax	Common Drone Fly	1
31	Ichneutica propria	-	1
32	Lucilia sericata	Common European Greenbottle Fly	1
33	Miomantis caffra	South African Mantis	1
34	Musca domestica	House Fly	1
35	Naupactus leucoloma	White-fringed Weevil	1
36	Nyctemera annulata	New Zealand Magpie Moth	1
37	Opodiphthera eucalypti	Gum Emperor Moth	1
38	Phalangium opilio	European Harvestman	1
39	Pyralis farinalis	Meal Moth	1
40	Sitona lepidus	Clover Root Weevil	1
41	Steatoda capensis	Black Cobweb Spider	1
42	Tegenaria domestica	Barn Funnel Weave	1
43	Uresiphita maorialis	Kowhai Moth	1
44	Vanessa gonerilla gonerilla	New Zealand Red Admiral	1
45	Xanthorhoe semifissata	-	1

In comparison, as shown in table 8 and 9, only four bird species and 16 mollusk, arachnid, or insect species were observed at the Lincoln University Dairy Farm over the same time period. The Lincoln University Dairy Farm is an ideal proxy for the pre-construction condition of the study site, Te Whāriki, as it was previously a dairy farm with very similar landscape characteristics. The Lincoln University Dairy Farm is just 1 mile (1.6 km) away from Te Whāriki.

Table 8. Observed bird species in Lincoln University Dairy Farm (2015-2021)

No.	Scientific Name	Common Name	Number of observations
1	Haematopus finschi	South Island Oystercatcher	1
2	Himantopus leucocephalus	Pied Stilt	1
3	Hirundo neoxena	Welcome Swallow	1
4	Larus dominicanus dominicanus	Southern Black-backed Gull	1

Table 9. Observed mollusk, arachnid, and insect species in Lincoln University Dairy Farm (2015-2021)

No.	Scientific Name	Common Name	Number of observations
1	Apis mellifera	Western Honey Bee	2
2	Phaulacridium marginale	New Zealand Grasshopper	2
3	Xanthocnemis zealandica	Red Damselfly	2
4	Ancistrocerus gazella	European Tube Wasp	1
5	Austrolestes colensonis	Blue Damselfly	1
6	Cassida rubiginosa	Thistle Tortoise Beetle	1
7	Conoderus exsul	Pasture Wireworm	1
8	Cryptachaea veruculata	Diamond Comb-footed Spider	1
9	Cyclosa fuliginata	Sooty Orbweaver	1
10	Dolomedes minor	-	1
11	Dysdera crocata	Woodlouse Spider	1
12	Megadromus antarcticus	Alexander Beetle	1
13	Micromus tasmaniae	Tasmanian Brown Lacewing	1
14	Nyctemera annulata	New Zealand Magpie Moth	1
15	Oxysarcodexia varia	Striped Dung Fly	1
16	Steatoda capensis	Black Cobweb Spider	1
17	Vanessa itea	Yellow Admiral	1

Lincoln Wetlands is a stormwater reserve 1 mile (1.6 km) away from Te Whāriki. As the wetland area of Lincoln Wetlands and Te Whāriki are similar in their landscape characteristics, species richness at Lincoln Wetlands can form a useful comparison with Te Whāriki and helps measure its success in supporting species richness. As shown in table 10 and 11, eight bird species and two mollusk, arachnid, or insect species were observed in Lincoln Wetlands.

Table 10. Observed bird species in Lincoln Wetlands (2015-2021)

No.	Scientific Name	Common Name	Number of observations
1	Anas platyrhynchos	Mallard	1
2	Carduelis carduelis britannica	British Goldfinch	1
3	Cygnus atratus	Black Swan	1
4	Cygnus olor	Mute Swan	1
5	Egretta novaehollandiae ssp. Novaehollandiae	Common White-faced Heron	1
6	Fulica atra australis	Australasian Coot	1
7	Phalacrocorax carbo novaehollandiae	Australasian Great Cormorant	1
8	Tadorna variegata	Paradise Shelduck	1
9	Todiramphus sanctus vagans	New Zealand Kingfisher	1

Table 11. Observed mollusk, arachnid, and insect species in Lincoln Wetlands (2015-2021)

No.	Scientific Name	Common Name	Number of observations
1	Xanthocnemis zealandica	Red Damselfly	2
2	Maratus griseus	White-banded House Jumping Spider	1

The number of observed species in the three sites are summarized below in table 12.

Table 12. Number of observed species in Te Whāriki subdivision, Lincoln University Dairy Farm, and Lincoln Wetlands (2015-2021)

Sites	Number of observed bird species	Number of observed mollusk, arachnid, and insect species	Total
Te Whāriki subdivision (153acre / 62ha)	20 (S_{ba})	45 (S_{ia})	65
Lincoln University Dairy Farm (474acre / 192ha)	4 (S_{bb})	17 (S_{ib})	21
Lincoln Wetlands (42acre / 17ha)	9	2	11

$$S_{ba} = Number\ of\ bird\ species\ after\ construction$$
$$S_{bb} = Number\ of\ bird\ species\ before\ construction$$
$$\approx Number\ of\ bird\ species\ in\ Lincoln\ University\ Dairy\ Farm^{1}$$
$$S_{ba} = Number\ of\ mollusk, arachnid, and\ insect\ species\ after\ construction$$
$$S_{bb} = Number\ of\ mollusk, arachnid, and\ insect\ species\ before\ construction$$
$$\approx Number\ of\ mollusk, arachnid, and\ insect\ species\ in\ Lincoln\ University\ Dairy\ Farm^{1}$$

The two sites studied for comparison (Lincoln University Dairy Farm and Lincoln Wetlands) are different in size to Te Whāriki. From an ecological perspective, an increase in observation area can often result in an increase in observed species (Drakare, Lennon, and Hillebrand 2006). Although several simplified models were suggested by different scholars to simulate the area-species relationship (Scheiner 2003; Williamson, Gaston, and Lonsdale 2001), more comprehensive ecological survey data would be needed to adopt these models and compare the "species density" of the three sites. However, the relative area-species relationships of the three sites can be visualized to show their relative "species density" (as shown in figure 2).

[1] As explained in the previous section, the Lincoln University Dairy Farm is an ideal proxy for the pre-construction condition of the study site. The number of species in Lincoln University Dairy Farm, therefore, can be expected to be similar to the number of species in the study site before construction.

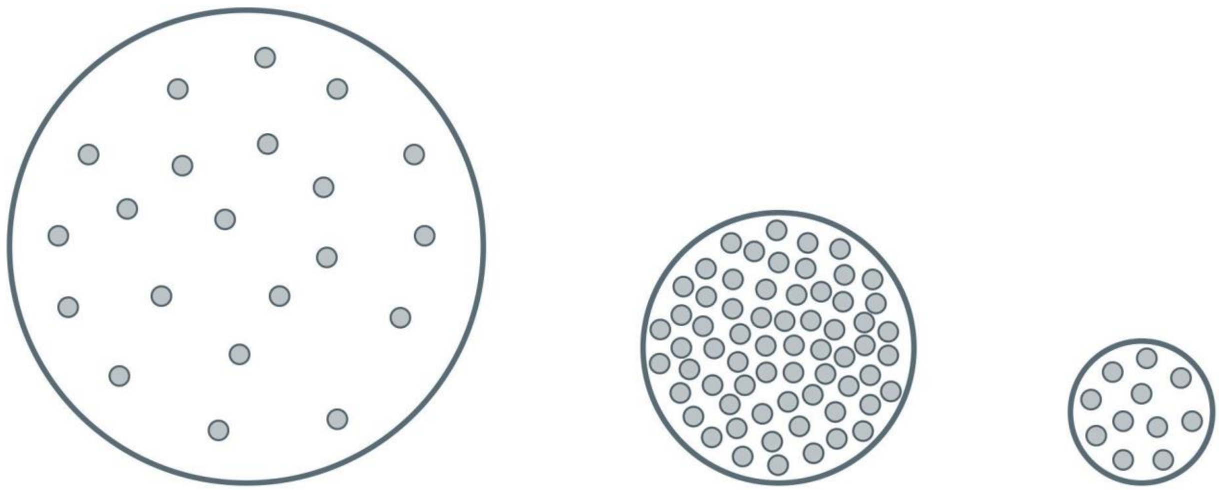

Figure 2. The area-species relationships of the Te Whāriki subdivision and the two sites that were studied for comparison (the outer circles are proportionally scaled to show the relative area of the three sites)

Calculations

The before-after percent change is calculated based on the data in Table 12.

$$Percent\ change\ in\ number\ of\ observed\ bird\ species = \frac{\Delta S_b}{S_{bb}} = \frac{S_{ba} - S_{bb}}{S_{bb}} = \frac{20-4}{4} = 400\%$$

$$Percent\ change\ in\ number\ of\ observed\ mollusk, arachnid, and\ insect\ species = \frac{\Delta S_i}{S_{ib}}$$

$$= \frac{S_{ia} - S_{ib}}{S_{ib}} \times = \frac{45-17}{17} = 165\%$$

Where:

$\Delta S_b = Change\ in\ the\ number\ of\ bird\ species$

$\Delta S_i = Change\ in\ the\ number\ of\ mollusk, arachnid, and\ insect\ species$

The average annual percent change is calculated based on the number of observed species in 2017 (the year that the first phase of Te Whāriki was completed) and 2020 (the latest calendar year with complete annual observation data).

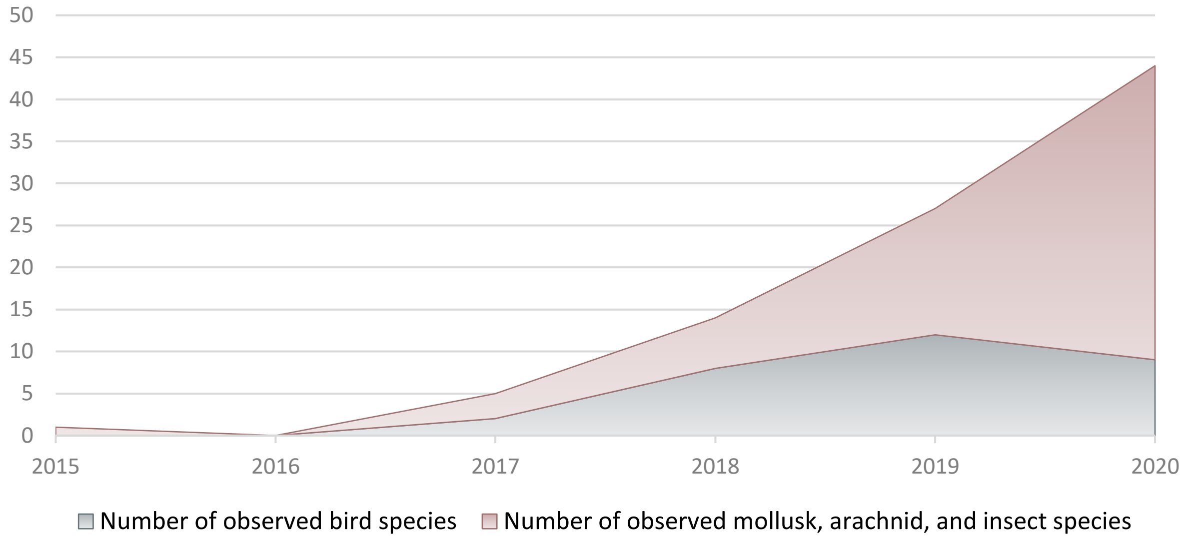

Figure 3 Number of species observed in each one-year period (from 1st January to 31st December) in Te Whāriki subdivision

Sources
iNaturalist: https://www.inaturalist.org/

Limitations
- As explained in the methods section, the observation data were obtained from iNaturalist and were not independently verified by the CSI research team. The way that the observations are reported to iNaturalist means that the number of observed species may be affected by the frequency that the sites have been visited, the likelihood of conducting observations, and observers' ability to identify species, etc. While the dairy farm is expected to be visited less frequently than the study site, the visitor to the dairy farm may be more likely to conduct observation and have a higher ability to identify species - apart from production, the dairy farm is also used for teaching and research.
- Although the researchers have excluded the possible pest species from the observation data to the best of their knowledge, some of the species included may still be possible to be categorized as pests or invasive in the local ecosystem.

- ***Lowers air temperatures of the residential developments around the wetlands during warm, sunny weather. Air temperatures of residential zones around the wetlands are 3º F (1.8º C) cooler on average than an adjacent conventional residential zone as measured during a typical sunny day in April.***

Background
Many recent studies show that water bodies can potentially improve the thermal comfort of the adjacent microclimate by stabilizing the air temperatures around (Manteghi, Limit, and Remaz 2015; Gupta, Mathew, and Khandelwal 2019; Syafii et al. 2016; Wu and Zhang 2019). The air-conditioning effect of water bodies is considered an important type of ecosystem service which

could be provided by landscape developments (Wu and Zhang 2019). In the middle of summer in Lincoln, Canterbury, midday temperatures sometimes reach 86ºF (30ºC) or higher, while night temperatures drop to 50ºF (10 ºC) or lower. Therefore, the wetlands, as a sustainable landscape feature in Te Whāriki subdivision, are expected to be able to stabilize the air temperature of the adjacent residential area and help to create a more comfortable microclimate.

Method

To determine the air-conditioning effect of the wetlands, the air temperature of the residential areas adjacent to the wetlands was compared to the air temperature of a conventional residential area a half mile (0.8 km) away. Two locations were sampled to represent the wetland-front residential areas, while the other two locations were sampled to represent typical residential subdivisions without wetland features (as shown in figure 4 and 5). An ambient thermometer with a resolution of 0.1ºF and a temperature tolerance (margin for error) of ±1ºF was used to measure the temperature of the four sampling points. The measurements were taken at a height about 55 inches above the ground (around the chest height of an average adult) to simulate the temperature perceived by a person. The thermometer was placed on the sampling point approximately 5 minutes before the first reading was taken to make sure its reading became steady. The readings for each sampling point were recorded every two minutes and five readings were recorded for each sampling point over a course of 8 minutes. The intervals between the measurements of each sampling point are around 10 minutes, with the measurements of four locations completed within 80 minutes.

Figure 4. Four locations were sampled to represent the wetland-front residential areas and conventional areas

Sampling point 1

Sampling point 2

Sampling point 3

Sampling point 4

Figure 5. The location of the four sampling points

Calculations

The average air temperatures were calculated based on the readings in Table 13 according to the following equation:

$$\bar{T} = \frac{\sum_{i=1}^{n} T_i}{n}$$

Where:

$\bar{T} = Average\ of\ the\ temperature\ readings$

$n = Number\ of\ temperature\ readings$

$T_i = The\ i'th\ temperature\ reading$

Table 13. Results of temperature measurement

	Wetland-front residential area		Conventional residential area	
	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4
Reading 1	78.4°F / 25.8°C	78.1°F / 25.6°C	80.8°F / 27.1°C	81.5°F / 27.5°C
Reading 2	78.1°F / 25.6°C	77.9°F / 25.5°C	80.8°F / 27.1°C	81.5°F / 27.5°C
Reading 3	78.3°F / 25.7°C	78.3°F / 25.7°C	81.0°F / 27.2°C	81.5°F / 27.5°C
Reading 4	77.9°F / 25.5°C	77.9°F / 25.5°C	81.1°F / 27.3°C	81.3°F / 27.4°C
Reading 5	78.1°F / 25.6°C	78.4°F / 25.8°C	80.8°F / 27.1°C	81.3°F / 27.4°C
Average	78.2°F / 25.6°C	78.1°F / 25.6°C	80.9°F / 27.2°C	81.4°F / 27.5°C
	Wetland-front average: 78.2°F / 25.6°C		**Conventional average: 81.2°F / 27.4°C**	

Sources

Measurements taken on-site by CSI team.

Limitations

- Due to the timeframe of the CSI program, the measurement was conducted in April, which is the mid-fall in New Zealand. The air-conditioning effect of the wetlands, therefore, can be expected to be more significant in summer when the midday temperatures are higher than mid-fall.
- Although various measures (e.g., measuring from the same height, following the same process) were taken by the CSI research team to minimize the impacts of other variables, it is inevitable that the results can still be affected by variables such as wind.

- ***Sequesters 239 tons of atmospheric carbon annually in newly-planted vegetation in the wetland areas. The amount of carbon sequestered annually is equivalent to $6,327 USD (8,952 NZD) of carbon credits on the New Zealand carbon market in April 2021.***

Method

The amount of sequestered carbon was calculated by using the Pathfinder Landscape Carbon Calculator, a web-based application that can estimate the amount of carbon sequestration according to the type and number of plants on site. To obtain this information on vegetation, the planting plans and plant schedule documents of the site were acquired from the landscape architect. To improve the accuracy of the carbon estimation, a range of supporting queries were undertaken, as follows.

Firstly, as three years have passed since the completion of the second stage of the subdivision, it can be expected that there are considerable changes to the condition of the planted vegetation. A vegetation inventory, therefore, was conducted on-site by the CSI team to verify the condition of the plants listed on the planting plan. The type and number of existing planted vegetation on-site were listed in Table 14.

Table 14. The type and number of existing planted vegetation on-site

	Vegetation type													
	TEL (Qty)	TEM (Qty)	TES (Qty)	TSDM (Qty)	TSDS (Qty)	TDL (Qty)	TDM (Qty)	TDS (Qty)	SEL (Qty)	SEM (Qty)	SES (Qty)	SSDM (Qty)	SDM (Qty)	NML (sf)
Phase[2] 1	5	120	35	6	12	12	24	69	496	31	414	3	1	125,202
2A	0	0	0	7	8	2	0	5	0	0	46	0	0	8,097
2B	0	12	5	0	0	3	0	2	0	0	6	0	0	12,407
2C	0	9	0	25	14	0	0	0	0	0	71	0	0	11,704
2D	0	0	6	0	0	7	0	18	19	39	164	0	8	3,595
2E (W)	0	15	0	0	0	0	0	0	702	0	0	0	0	118,393
2E (R)	0	3	5	0	20	0	0	0	0	9	124	41	0	3,117
2F	0	0	0	5	10	0	0	3	0	0	128	0	0	2,158
2G	0	0	0	0	0	0	0	8	0	56	0	0	0	2,502
2G (W)	0	8	2	0	0	0	0	0	502	0	0	0	0	20,405
2H	0	0	0	0	9	0	1	2	0	0	0	0	0	3,346
2H (R)	0	0	0	4	6	0	15	15	0	21	17	0	0	1,298
2I	0	0	0	0	6	0	5	0	0	0	0	0	0	2,769
2J	0	0	0	0	0	0	2	3	0	10	0	0	0	793
2K	0	1	0	11	0	0	0	7	66	17	85	0	0	8,411
2L	0	0	0	8	5	0	0	0	0	47	0	0	0	998
Total	**5**	**168**	**53**	**66**	**90**	**24**	**47**	**132**	**1,785**	**230**	**1,055**	**44**	**9**	**325,195**

TEL=Tree - Evergreen - Large
TEM=Tree - Evergreen - Medium
TES=Tree - Evergreen - Small
TSDM=Tree - Semi-deciduous - Medium
TSDS=Tree - Semi-deciduous - Small
TDL=Tree - Deciduous - Large
TDM=Tree - Deciduous - Medium
TDS=Tree - Deciduous - Small
SEL=Shrub - Evergreen - Large
SEM=Shrub - Evergreen - Medium
SES=Shrub - Evergreen - Small
SSDM=Shrub - Semi-deciduous - Medium
SDM=Shrub - Deciduous - Medium
NML=No-mow Lawn

[2] The second phase was divided into 12 sub-phases, 2A – 2L. The capital letter “W” and “R” following the sub-phases indicate the wetlands and reserves within the sub-phases respectively.

Secondly, as the carbon sequestration rate of deciduous plants is different from evergreen ones, the winter foliage conditions of the plants were checked in winter to make sure the input planting information is specific to the site. For example, *Vaccinium ashei* is classified as a deciduous shrub by many plant databases, but this species is actually evergreen in most areas in New Zealand. According to the plant inventory carried out on-site, *Vaccinium ashei* remains "green" on-site in mid-winter (mid-June).

Thirdly, some adjustments were made to the input of the calculator to make the calculation more specific to the site condition. For example, some species on-site, such as *Sophora microphylla* and *Plagianthus regius,* are classified as semi-deciduous. However, semi-deciduous options are not included in the Pathfinder Landscape Carbon Calculator. Although it would be useful to acquire estimated carbon sequestration rates for different types of semi-deciduous plants by either carrying out a comprehensive literature review or setting up experiments, it is beyond the scope of this study. We, therefore, adopted the mean value of the sequestration rates of evergreen plants and the ones for deciduous as our best estimate for the semi-deciduous plants.

Calculations

The information in table 14 was imported into Pathfinder Landscape Carbon Calculator to calculate the amount of carbon sequestration. The calculation results are shown in table 15.

Table 15. Carbon sequestration calculation

Plant type	Quantity		Sequestration rate (kg/unit/year)	Annual carbon sequestration (kg)	Equivalent carbon credit (NZD)[3]
TEL	5	(Qty)	46.87	234.35	8.78
TEM	168	(Qty)	19.11	3,210.31	120.23
TES	53	(Qty)	4.80	254.19	9.52
TSDM	66	(Qty)	22.47	1,483.00	55.54
TSDS	90	(Qty)	5.37	483.28	18.10
TDL	24	(Qty)	51.48	1,235.44	46.27
TDM	47	(Qty)	25.83	1,214.03	45.47
TDS	132	(Qty)	5.94	784.55	29.38
SEL	1,785	(Qty)	1.57	2,803.81	105.00
SEM	230	(Qty)	0.79	180.64	6.77
SES	1,055	(Qty)	0.39	414.30	15.52
SSDM	44	(Qty)	0.88	38.82	1.45
SDM	9	(Qty)	0.98	8.81	0.33
NML	325,195	sf	0.07	23,988.33	898.36
WL	892,980	sf	0.23	202,708.25	7,591.42
Total				**239,042.13**	**8,952.13**

TEL=Tree - Evergreen - Large
TEM=Tree - Evergreen - Medium
TES=Tree - Evergreen - Small
TSDM=Tree - Semi-deciduous - Medium
TSDS=Tree - Semi-deciduous - Small
TDL=Tree - Deciduous - Large
TDM=Tree - Deciduous - Medium
TDS=Tree - Deciduous - Small
SEL=Shrub - Evergreen - Large
SEM=Shrub - Evergreen - Medium
SES=Shrub - Evergreen - Small
SSDM=Shrub - Semi-deciduous - Medium
SDM=Shrub - Deciduous - Medium
NML=No-mow Lawn

Sources

Carbon News: http://www.carbonnews.co.nz/
Pathfinder Landscape Carbon Calculator: https://app.climatepositivedesign.com/

Limitations

- Pathfinder Landscape Carbon Calculator is an estimation tool based on general plant types. Different plant species within the same vegetation classification group (e.g., Tree - Evergreen - Large) may be different in their carbon sequestration rates. The calculation result, therefore, can just indicate an overall scale of carbon sequestration, rather than an accurate value.

[3] The latest Indicative Carbon Prices up to the 30th April 2021 is 37.45 NZ$/ton (Carbon News 2021).

- Herbaceous plants outside the wetlands are not calculated by Pathfinder Landscape Carbon Calculator. Therefore, the actual amount of sequestrated carbon may be larger than the calculation result.

Social Benefits

Overall methods for survey

A questionnaire-based survey was used to obtain data on a range of social benefits at Te Whāriki. The questionnaire is included in Appendix G and was approved by Lincoln University's Human Ethics Committee (Institutional Review Board). The questionnaire was hand-delivered to each residence in the study site (n= 441), as well as a Research Information Sheet (RIS) (Appendix H), consent form (Appendix I), sticker and envelope. A hand-delivered survey was necessary to ensure we covered all of the residents (there is no database of email addresses or similar which would allow an online survey). All households were surveyed to maximize the response rate, and we achieved a rate of 22.68% (108 responses received, among which, 100 were accepted and eight were rejected due to incomplete consent form). Surveyed residents were given a range of options for the return of their questionnaires, including placing the sticker on the letterbox by the specified date to indicate we can collect the form from the letterbox, posting it back to us, scanning and emailing it, or dropping it into our departmental office (which is near the study site). The survey was undertaken in May 2021.

Overall limitations for survey

Although we offered as many means as possible for residents to return the survey, the logistics may have discouraged some from participating. It was interesting to note the efforts that some residents went to in order to get their surveys to us, including dropping them at the main University reception and at the gym.

- ***Encourages physical activity, with 74% of 81 surveyed residents who previously lived in similar residential zones reporting that they have engaged more frequently in physical exercise in and around their neighborhood since they moved to Te Whāriki. On-site observations indicated residents engaged in physical exercise at similar levels to comparable, more traditional, subdivisions.***

Method

Please see the overview above for the Survey method. To supplement the Survey data, a modified SOPARC study, an observational method, was undertaken by students of the masters class in Design Critique, DESN 602 at Lincoln University. The SOPARC method was approved by the University's Human Ethics Committee (Institutional Review Board) with provisos over student safety, and not photographing site users without their consent. The modified SOPARC observation sheets are included in Appendix J.

The System for Observing Play and Recreation in Communities (SOPARC) is documented in McKenzie and Cohen (2006), and this provided the foundation for the method. However, the conventional SOPARC approach only records activity, and not how that activity relates to the setting or levels of engagement. Because the case study investigation is testing the performance of the landscape in supporting physical activity, a modified version of SOPARC, as used in a study of community settings in China (Yin & Ohnoa 2015), was adopted. Yin and Ohnoa's modified SOPARC categorizes activity according to how it relates to the environment as shown in Table 16, and these notational symbols were used by the students in their observations. Further modifications involved using more inclusive terms for identifying users, such as adding an 'other' category for gender, and replacing 'old' with 'senior'. In New Zealand, the retirement age is 65, and this was identified as the threshold for the category of senior. The ethnicity category was not included, as estimating ethnicity through observation is not always possible, and the aspect of ethnicity was not flagged as a particular concern in relation to the performance of the landscape in this context. For a subdivision or park with explicit goals relating to developing ethnic diversity, more consideration of how to identify this aspect would be necessary. Each student conducted observations for two time periods in Te Whāriki, and another two time periods in a comparative location such as a conventional subdivision. The selected time periods were structured in order to make comparisons as meaningful as possible, for example, Te Whāriki on a weekday morning and weekend afternoon, and the comparison site on a weekday morning and weekend afternoon. In some cases, it was possible for students to do their observations of the two sites on the same day, and this helped eliminate the effects of variables such as weather.

Table 16. Categorization of outdoor activities for modified SOPARC
Source: Yin and Ohnoa (2015, 506)

Category	Environmental involvement	Subcategory	Examples	Symbol
Passing-by related codes (Pass)	Participants are little concern about the environmental quality; they use the space as a path to the destinations.	Walking by	Walking, running	
		Cycling by	Cycling	
		Driving by	Driving	
Strolling related codes (Stroll)	Participants may enjoy then environmental quality while strolling through the space on foot.	No pause	Jogging, walking the dog, sightseeing etc.	
		Temporary pause	Short meeting, reading notice etc.	
Staying related codes (Stay)	Participants do some things or stay inside the space, they do the activities supported by the environment.	Sedentary activity	Sitting, standing, playing cards etc.	
		Vigorous activity	Chasing, excising, dancing etc.	

Although visitor counts were low, visitors were observed utilizing the walkways through the site, often walking their dogs. The comparison with other residential subdivisions revealed activity levels were similar or slightly less in Te Whāriki. Higher use numbers were observed in other residential areas where the observed site provided a key connection between different areas, or where there were other activators of space such as playgrounds or commercial activity.

In considering the performance of a residential development, it is not necessarily the numbers of users which are indicators of success. Arguably it is more intangible aspects, such as the quality of the experience, the accessibility of the recreational opportunities to a wide range of users, and safety both in terms of personal safety from crime as well as traffic and other hazards. The SOPARC outcomes can usefully be combined with the survey of residents to add a depth of understanding of how the landscape performs, including comments such as: "We walk the wetlands riverbank regularly. Try for a daily walk" and "We enjoy walking around the wetlands and sometimes going to the park. We didn't go for walks around the neighbourhood before".

Calculations
Survey question #6: Have you engaged more frequently in physical exercise in and around your neighbourhood since you moved to Te Whāriki?

In total, 81 respondents who previously lived in similar types of residential landscapes (i.e., subdivisions) answered this question. Among the 81 respondents, 60 (74%) answered "Yes", while 21 (36%) answered "No".

Sources
On-site observations conducted by students of the masters class in Design Critique, DESN 602 at Lincoln University.

Survey question #6 (see Appendix K).

Limitations
- The SOPARC method has limitations in low-density environments like suburban subdivisions. These areas are unlikely to generate high numbers of observations in terms of recreation and play, reflecting the diffuse nature of physical activity across the study site. Within a one-hour sampling window, only minimal activity might be observed. In our case study, the survey of self-reported changes in physical activity allowed for further evidence of the subdivision's performance.
- Please see the "*overall limitations for survey"* on page 24 for the survey method.

- ***Improves mood and quality of life, with 76% of 79 surveyed residents who previously lived in similar residential zones reporting that they experienced this after they moved to Te Whāriki.***

Method
Please see the "*overall methods for survey"* on page 23 for the survey method.

Calculations
Survey question #6: Did you experience an improvement in your mood and quality of life after

you moved to Te Whāriki?

In total, 80 respondents who previously lived in similar types of residential landscapes (i.e., subdivisions) answered this question. One response was rejected due to invalid answer. Among the 79 valid responses, 60 (76%) answered "Yes", while 19 (24%) answered "No".

Sources
Survey question #6 (see Appendix K).

Limitations:

- Please see the "*overall limitations for survey"* on page 23 for the survey method.

- ***Provides educational opportunities such as plant identification walks and field trips to learn about stormwater systems for various user groups, including students at Lincoln University and Lincoln Primary School.***

Method
The CSI team consulted a range of Lincoln University and local primary (elementary) and high school teaching staff to investigate how the site had been used in educational settings. University staff were selected on the basis of the courses they teach, and the possibility that their teaching would involve use of the site (e.g., field trips, fieldworks, and course projects). The information acquired from the staff who were consulted includes the type of education activities that were conducted on-site, the number of participants, and the time when the education activities were conducted. For the school staff, the approach involved a simplified type of 'snowballing,' where staff identified those who might use the site for teaching activities.

Calculations
Table 17 summarizes the relevant information of the three SoLA courses that involve on-site educational activities in Te Whāriki.

Table 17. The SoLA courses which involve on-site educational activities in Te Whāriki

Code	Course	Educational activities
LASC 206	Landscape Planting Practice	Project work on planting plan
LASC 211	Planting Design and Management	Project work on planting design
LASC 312	Landscape Ecology	Field trip and project work on the landscape systems

The information from the schools was less precise, but also indicated an interest in the educational setting provided by Te Whāriki. The Lincoln High School geography teacher advised Te Whāriki will be an example in the focus on urban design and well-being this year. Lincoln Primary

School used Te Whāriki as the basis for their Inquiry Topic, with the children learning how they can make informed decisions about Lincoln's future over the next 10 to 15 years. The teacher explained that "Many students were not aware of the importance of the wetlands and the importance of keeping these for our environment". They also explored what makes wetlands healthy, identified as many plants and birds as they could, and discussed why all of these things are important.

Sources
Personal communication with Lincoln University teaching staff and staff at the two local schools.

Limitations

- Our investigation is not comprehensive and may reveal only part of the educational opportunities provided by the site. We relied on our networks within the University, and on snowballing within the schools, as administrative staff and teachers passed our request on to one another.

- ***Reduces the level of perceived undesirable noise on site. 56% of 82 survey respondents who previously lived in similar residential zones report that Te Whāriki is quieter than the subdivision they lived in before, while only 10% report that it is louder.***

Method
Please see the "*overall methods for survey"* on page 23 for the survey method.

Calculations
Survey question #7: How noisy or quiet does Te Whāriki feel, compared to where you lived previously?

In total, 82 respondents who previously lived in similar types of residential landscapes (i.e., subdivisions) answered this question. One response is rejected due to invalid answer.
Among the 81 valid responses, 45 (56%) answered "Quieter", 28 (35%) answered "Similar", and 8 (10%) answered "Noisier".

Sources
Survey question #7 (see Appendix K).

Limitations:

- Please see the "*overall limitations for survey"* on page 23 for the survey method.

- ***Produces fruits and herbs for resident consumption, with 30% of 100 surveyed residents reporting that they have harvested from the public areas. 9% report that they harvest more than 3 times per year on average.***

Method
Please see the "*overall methods for survey"* on page 23 for the survey method.

Calculations
Survey question #10: Have you ever harvested any fruit or herbs from the public areas of Te Whāriki?

In total, 100 respondents answered this question. Among the 100 responses, 9 (9%) answered "Yes, more than 3 times per year on average", 10 (10%) answered "Yes, at least once per year on average", 11 (11%) answered "Yes, at least once since moving to Te Whāriki", and 70 (70%) answered "No".

Sources
Survey question #10 (see Appendix K).

Limitations:
- Please see the "*overall limitations for survey"* on page 23 for the survey method.

- ***Offers improved aesthetic and amenity value according to 53% of 81 surveyed residents who previously lived in similar residential zones.***

Method
Please see the "*overall methods for survey"* on page 23 for the survey method.

Calculations
Survey question #8: How do you feel about the aesthetic / amenity values of Te Whāriki, compared to where you lived previously? (For example, wetlands, street-centre swales, public green spaces, playgrounds, trees and other planting).

In total, 83 respondents who previously lived in similar types of residential landscapes (i.e., subdivisions) answered this question. Two responses are rejected due to invalid answers. Among the 81 valid responses, 43 (53%) answered "Better", 30 (37%) answered "Similar", and 8 (10%) answered "Worse".

Sources
Survey question #8 (see Appendix K).

Limitations:
- Please see the "*overall limitations for survey"* on page 23 for the survey method.

- ***Promotes alternative transportation modes, with 55% of 78 surveyed residents who previously lived in similar residential zones reporting that they make fewer trips by car since they moved to Te Whāriki.***

Method
Please see the "*overall methods for survey"* on page 23 for the survey method.

Calculations
Survey question #12: How has your vehicle use changed since you moved to Te Whāriki? (Please tick all that are applicable)

In total, 78 respondents who previously lived in similar types of residential landscapes (i.e., subdivisions) answered this question. Among the 78 responses, 43 (55%) answered "Fewer trips by car", 19 (24%) answered "More use of 'micro-transport' (biking, scooter, skateboard, etc.)", and 37 (47%) answered "More journeys on foot".

Relevant comments from respondents include: "It's great to be able to walk to the shops. One of reasons we bought here".

Sources
Survey question #12 (see Appendix K).

Limitations:

- Please see the "*overall limitations for survey"* on page 23 for the survey method.

Economic Benefits

- ***Supports a growing number of businesses adjacent to the site, with 15 more businesses established within 150 ft (46 meters) of Te Whāriki from when the first phase was completed in 2017 through July 2021. 73% of 100 surveyed residents report that they visit adjacent businesses more than twice per week.***

Method
Please see the "*overall methods for survey"* on page 23 for the survey method.
Information about the newly established businesses was collected through on-site observation. Table 18 indicates all the businesses established within a 150-feet (46-meter) distance to the Te Whāriki subdivision after 2017 (the time when the first phase of the subdivision is completed) was developed, as shown in table 18.

Table 18. Businesses established within a 150-feet (46-meter) distance to the Te Whāriki subdivision since 2017

No.	Business Name	Business Type
1	BloomKitchen	Restaurant
2	Domino's Pizza Lincoln	Restaurant
3	Fond Farewells Pet Cremation Service	Cremation service
4	GLO Nail & Beauty	Beauty salon
5	Liquorland Lincoln	Bottle shop

6	Mexicali Fresh Lincoln	Restaurant
7	Mike Pero Real Estate	Real estate agents
8	Motus Lincoln Physiotherapy	Physiotherapist
9	Mughlal Indian Cuisine	Restaurant
10	NomNom Kitchen	Restaurant
11	Robert Harris Café	Café
12	Sushiya	Restaurant
13	The Flaming Rabbit	Restaurant
14	We Cook	Restaurant
15	WeCare Health	Pharmacy and healthcare center

Calculations

Survey question #11: Do you regularly use the local businesses within Te Whāriki? (e.g., New World supermarket, Robert Harris café, Flaming Rabbit, WeCare Pharmacy, Motus Lincoln fitness centre, Domino's Pizza, Challenge gas station, Liquorland, etc.).

In total, 100 respondents answered this question. Among the 100 responses, 73 (73%) answered "Yes, at least twice per week", 24 (24%) answered "Yes, at least weekly", two (2%) answered "A little, at least monthly", and one (1%) answered "No, tend to go beyond Te Whāriki to other commercial areas".

Sources

Survey question #11 (see Appendix K).

Limitations

- Please see the "*overall limitations for survey*" on page 23 for the survey method.
- While familiarity with the Te Whāriki context allows for some commentary on commercial development, any more conclusive statements are limited by not having data about the previous numbers of business or the usage patterns of residents.

Cost Comparison

- ***The design, consenting (acquiring legal permission), and construction of the wetlands was estimated to cost approximately $18 million USD in total ($21 USD per sf), while its maintenance is estimated to cost between $174,382 to $309,057 USD per year. Although the cost of acquiring (i.e. designing, consenting, and constructing) and maintaining the wetlands is expected to be higher than other stormwater facilities, the wetlands are considered to have multiple benefits as illustrated above. Also, approximately 52% of survey respondents who previously lived in similar environments (subdivisions) report that the wetlands are one of the reasons they chose to live in Te Whāriki. The presence of the wetlands is the***

second most commonly cited reason for them to move to Te Whāriki. Besides the tangible benefits outlined above, the wetlands are also closely related to other intangible aspects of sustainability such as cultural value.

Method

Acquiring the exact cost of the stormwater facilities in Te Whāriki has proven to be difficult due to a range of practical reasons, including the inconsistency of the parties involved (as explained in the lessons learned section - the continuity of the landscape development), the involvement of multiple professional parties and the potential conflict of interests between these parties.

The research team, therefore, made their best estimate based on recent research that studied the costs of a series of stormwater facilities installed around New Zealand. By studying the cost of 28 constructed wetlands around New Zealand, Ira and Simcock (2019) report that the median total acquisition cost of the 28 cases is 325 NZD/sqm, or 21 USD/sf, while their average cost is around 500 NZD/sqm, or 32 USD/sf, as shown in figure 6 (currency converted based on the rate at 1/7/2021). The costs of designing, consenting, and constructing these wetlands are included, while the land costs are excluded (Ira and Simcock 2019).

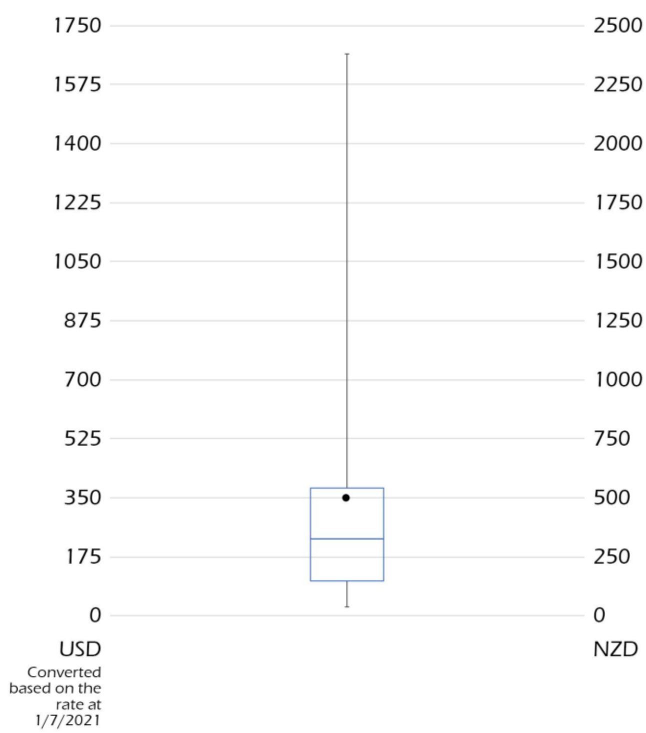

Figure 6. Cost of wetland developments (incl. design, consenting, and construction costs): Cost per wetland surface area ($/sqm) (n=28). Adopted from Ira and Simcock (2019, 28)

According to Ira and Simcock (2019), the median total cost of 4 example green roofs is around 220NZD/sqm, or 14 USD/sf.

Apart from the acquisition costs, constructed wetlands also require a considerable amount of maintenance. The maintenance cost of the Te Whāriki wetlands was calculated based on the wetland maintenance cost-estimating method developed by Ira and Simcock (2019, 37-38). This cost-estimating method is shown in Appendix L

Please see the "*overall methods for survey*" on page 23 for the survey method.

Calculations

The estimated total acquisition cost of the Te Whāriki wetlands is calculated according to Ira and Simcock's report. The median total cost of the 28 cases was adopted as the estimated unit cost of the Te Whāriki wetlands.

$$\begin{aligned} Total\ acquisition\ cost &= Estimated\ unit\ cost \times total\ units = 21USD/sf \times 892{,}980sf \\ &= 17{,}752{,}580USD \end{aligned}$$

The estimated maintenance cost of the Te Whāriki wetlands is calculated in table 19, 20, and 21 for three maintenance scenarios based on their maintenance frequency, namely high amenity, functional, and bare minimum.

Table 19. Estimated cost for routine maintenance activities of the Te Whāriki wetland (NZD/year)

			High Amenity			Functional			Bare Minimum		
Maintenance activities	**Unit**	**Amount**	**Unit cost**	**Frequency**	**Total cost**	**Unit cost**	**Frequency**	**Total cost**	**Unit cost**	**Frequency**	**Total cost**
Routine general maintenance	sqm	82,961	0.24	12	238,928	0.24	4	79,643	0.6	1	49,777
Removing debris	per wetland	16	48	12	9,216	48	4	3,072	164	1	2,624
Inspections	per visit	1	300	1	300	300	1	300	480	0.5	240
Scheduled routine mechanical maintenance	per wetland	16	384	1	6,144	384	1	6,144	660	0.5	5,280
Make good from vandalism	per wetland	16	25.2	2	806	25.2	1	403	97.8	0	0
Weed management	sqm	82,961	0.3	4	99,553	0.3	2	49,777	0.35	0.5	14,518
Aquatic weed management	sqm	82,961	0.29	2	48,117	0.29	1	24,059	0.53	0.5	21,985
Additional visits for initial Aftercare of Plants	sqm	82,961	0.3	0	0	0.3	2	49,777	0.35	2	58,073
Total					**403,065**			**213,174**			**152,496**

Table 20. Estimated cost for corrective maintenance activities of the Te Whāriki wetland and their costs (NZD/year)

			High Amenity			Functional			Bare Minimum		
Maintenance activities	**Unit**	**Amount**	**Unit cost**	**Frequency**	**Total cost**	**Unit cost**	**Frequency**	**Total cost**	**Unit cost**	**Frequency**	**Total cost**
Corrective structural maintenance	per wetland	16	12,000	1/10	19,200	12,000	1/10	19,200	18,804	1/5	60,173
Replacement of parts	per wetland	16	1,200	1/20	960	1,200	1/20	960	7,200	1/10	11,520
Replanting the wetland zone	sqm	82,961	11	1/50	18,251	11	1/50	18,251	15	1/50	24,888
Desilting and disposal of sediment from forebay	cbm	\	105	1/25	\	105	1/25	\	310	1/20	\
Desilting and disposal of sediment from main pond	cbm	\	105	1/50	\	105	1/50	\	310	1/50	\
Council inspections	per inspection	1	105	1/3	35	105	1/3	35	120	1/3	40
Total					**38,446**			**38,446**			**96,621**

Table 21. Estimated total maintenance cost of the Te Whāriki wetland (NZD/year)

	High Amenity		Functional		Bare Minimum	
	NZD	**USD**	**NZD**	**USD**	**NZD**	**USD**
Cost for routine maintenance activities	403,065	282,145	213,174	149,222	152,496	106,747
Cost for corrective maintenance activities	38,446	26,912	38,446	26,912	96,621	67,635
Total maintenance cost	441,511	309,057	251,620	176,134	249,117	174,382

(Currency converted based on the rate at 1/7/2021)

The percentage of the surveyed residents who reported that the wetlands and landscape features are one of the reasons for them to move to Te Whāriki is calculated below:

Survey question #3: Why did you move to Te Whāriki? (Please tick all that are applicable)

In total, 83 respondents who previously lived in similar types of residential landscapes (i.e., subdivisions) answered this question. Among the 83 responses, 52 (63%) answered "Away from the hustle and bustle", 43 (52%) answered "Wetlands and landscape features", 37 (45%) answered "Others", 31 (37%) answered "Convenient for commuting", 25 (30%) answered "Housing price", 23 (28%) answered "Accessibility to commercial facilities", and 12 (14%) answered "Proximity to educational facilities". These percentages are illustrated in figure 7.

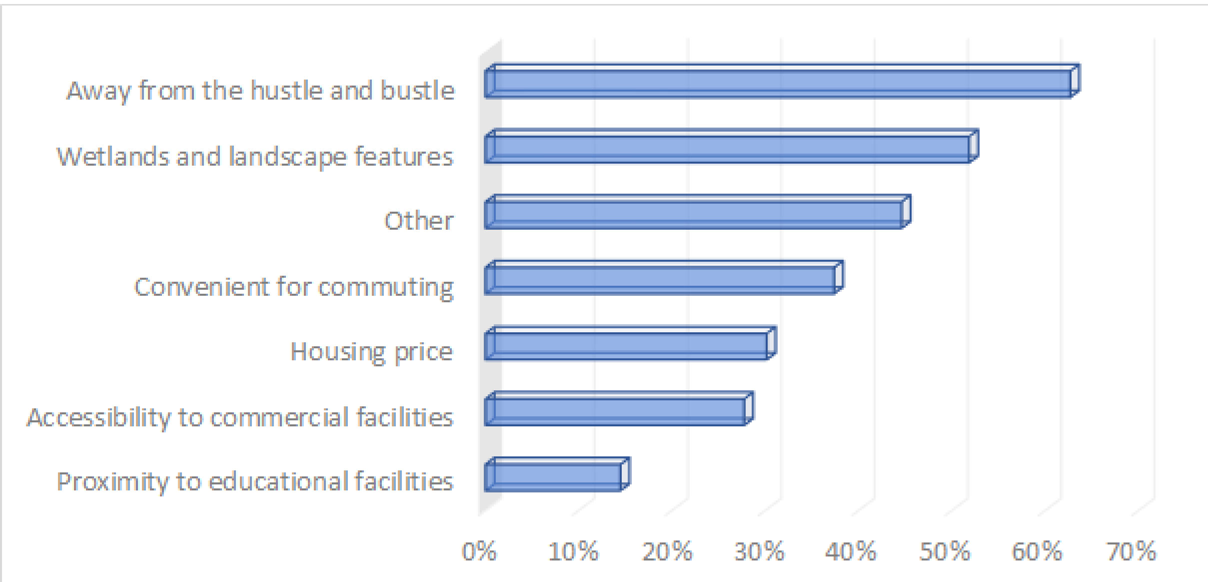

Figure 7. Percentage of the reasons for respondents who previously lived in similar types of residential landscapes to move to Te Whāriki (n=83)

Sources

Survey question #3 (see Appendix K).

Limitations

- The cost-calculating model adopted is an estimation tool developed based on the cost information of a range of existing stormwater facilities. This means that the calculation result is only intended to provide a general indication for the possible cost of a stormwater facility, rather than the actual cost for a specific facility.
- The volume of desilting of disposal of sediments is required for the calculation. However, the research team failed to acquire this information from multiple channels. Therefore, the cost required for desilting was not included in the calculation.
- Please see the "*overall limitations for survey"* on page 23 for the survey method.

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Appendix A – Species observation records in Te Whāriki (Bird species)

Date of observation	Scientific Name	Common Name
2017-08-30	Porphyrio melanotus ssp. Melanotus	Southeastern Australasian Swamphen
2017-12-14	Carduelis carduelis	European Goldfinch
2018-01-02	Fulica atra australis	Australasian Coot
2018-04-29	Aythya novaeseelandiae	New Zealand Scaup
2018-06-20	Cygnus atratus	Black Swan
2018-06-22	Fulica atra	Eurasian Coot
2018-06-25	Anas platyrhynchos	Mallard
2018-07-11	Fulica atra	Eurasian Coot
2018-07-17	Aythya novaeseelandiae	New Zealand Scaup
2018-07-17	Cygnus olor	Mute Swan
2018-07-17	Zosterops lateralis lateralis	Tasmanian Silvereye
2018-07-19	Cygnus atratus	Black Swan
2018-07-26	Microcarbo melanoleucos ssp. Brevirostris	Little Shag
2018-08-15	Cygnus olor	Mute Swan
2018-11-30	Aythya novaeseelandiae	New Zealand Scaup
2018-11-30	Cygnus olor	Mute Swan
2019-01-03	Fulica atra australis	Australasian Coot
2019-02-18	Cygnus atratus	Black Swan
2019-02-20	Fulica atra australis	Australasian Coot
2019-03-23	Tadorna variegata	Paradise Shelduck
2019-04-01	Porphyrio melanotus ssp. Melanotus	Southeastern Australasian Swamphen
2019-04-01	Porphyrio melanotus ssp. Melanotus	Southeastern Australasian Swamphen
2019-04-02	Porphyrio melanotus ssp. Melanotus	Southeastern Australasian Swamphen
2019-04-04	Anas platyrhynchos	Mallard
2019-04-04	Cygnus atratus	Black Swan
2019-04-04	Egretta novaehollandiae ssp. Novaehollandiae	Common White-faced Heron
2019-04-09	Cygnus atratus	Black Swan
2019-04-09	Egretta novaehollandiae ssp. Novaehollandiae	Common White-faced Heron
2019-04-09	Fulica atra australis	Australasian Coot
2019-04-18	Aythya novaeseelandiae	New Zealand Scaup
2019-04-30	Aythya novaeseelandiae	New Zealand Scaup
2019-04-30	Cygnus atratus	Black Swan
2019-04-30	Cygnus atratus	Black Swan
2019-04-30	Cygnus olor	Mute Swan
2019-04-30	Spatula rhynchotis	Australasian Shoveler
2019-05-23	Microcarbo melanoleucos ssp. Brevirostris	Little Shag
2019-05-23	Spatula rhynchotis	Australasian Shoveler

2019-05-27	Turdus merula	Eurasian Blackbird
2019-06-12	Aythya novaeseelandiae	New Zealand Scaup
2019-06-12	Spatula rhynchotis	Australasian Shoveler
2019-07-25	Egretta novaehollandiae	White-faced Heron
2019-09-02	Passer domesticus domesticus	European House Sparrow
2019-09-27	Fulica atra australis	Australasian Coot
2019-11-04	Egretta novaehollandiae ssp. Novaehollandiae	Common White-faced Heron
2020-02-05	Fulica atra australis	Australasian Coot
2020-03-18	Porphyrio melanotus ssp. Melanotus	Southeastern Australasian Swamphen
2020-03-29	Cygnus atratus	Black Swan
2020-04-02	Egretta novaehollandiae ssp. Novaehollandiae	Common White-faced Heron
2020-04-02	Fulica atra australis	Australasian Coot
2020-04-06	Cygnus atratus	Black Swan
2020-04-13	Fulica atra australis	Australasian Coot
2020-06-17	Cygnus atratus	Black Swan
2020-06-17	Microcarbo melanoleucos ssp. Brevirostris	Little Shag
2020-06-17	Zosterops lateralis lateralis	Tasmanian Silvereye
2020-06-18	Cygnus atratus	Black Swan
2020-06-18	Fulica atra australis	Australasian Coot
2020-06-30	Cairina moschata domestica	Domestic Muscovy Duck
2020-07-10	Aythya novaeseelandiae	New Zealand Scaup
2020-07-31	Aythya novaeseelandiae	New Zealand Scaup
2020-10-26	Sturnus vulgaris vulgaris	European Common Starling
2020-10-30	Microcarbo melanoleucos ssp. Brevirostris	Little Shag
2020-10-31	Cygnus atratus	Black Swan
2021-02-03	Anas superciliosa × platyrhynchos	Pacific Black Duck × Mallard Hybrid
2021-02-03	Aythya novaeseelandiae	New Zealand Scaup
2021-02-03	Egretta novaehollandiae ssp. Novaehollandiae	Common White-faced Heron
2021-02-03	Porphyrio melanotus ssp. Melanotus	Southeastern Australasian Swamphen
2021-02-19	Turdus merula merula	Western European Blackbird

Appendix B – Species observation records in Te Whāriki (Mollusk, arachnid, and insect species)

Date of observation	Scientific Name	Common Name
2015-03-01	Pieris rapae	Cabbage White
2017-03-16	Pieris rapae	Cabbage White
2017-04-16	Bombus terrestris	Buff-tailed Bumble Bee
2017-08-30	Danaus plexippus	Monarch
2018-03-28	Naupactus leucoloma	White-fringed Weevil
2018-04-07	Lampona cylindrata	Common White-tail Spider
2018-04-08	Eriophora pustulosa	Knobbled Orbweaver
2018-04-15	Apis mellifera	Western Honey Bee
2018-04-20	Melangyna novaezelandiae	Large Hover Fly
2018-09-12	Eriophora pustulosa	Knobbled Orbweaver
2018-09-13	Lampona cylindrata	Common White-tail Spider
2018-11-22	Adversaeschna brevistyla	Blue-spotted Hawker
2019-01-08	Adversaeschna brevistyla	Blue-spotted Hawker
2019-01-08	Austrolestes colensonis	Blue Damselfly
2019-01-08	Xanthocnemis zealandica	Red Damselfly
2019-01-08	Xanthocnemis zealandica	Red Damselfly
2019-01-08	Xanthocnemis zealandica	Red Damselfly
2019-01-15	Xanthocnemis zealandica	Red Damselfly
2019-01-15	Xanthocnemis zealandica	Red Damselfly
2019-02-20	Xanthocnemis zealandica	Red Damselfly
2019-03-01	Pieris rapae	Cabbage White
2019-03-02	Pieris rapae	Cabbage White
2019-03-04	Pieris rapae	Cabbage White
2019-03-12	Orthodera novaezealandiae	New Zealand Mantis
2019-03-28	Nyssus coloripes	Spotted Ground Swift Spider
2019-03-28	Pyralis farinalis	Meal Moth
2019-04-03	Lampona cylindrata	Common White-tail Spider
2019-04-13	Scopula rubraria	Plantain Moth
2019-05-07	Sitona lepidus	Clover Root Weevil
2019-05-12	Cryptachaea veruculata	Diamond Comb-footed Spider
2019-05-14	Caedicia simplex	Australian Common Garden Katydid
2019-05-23	Coccinella undecimpunctata	Eleven-spotted Ladybird Beetle
2019-05-28	Coccinella undecimpunctata	Eleven-spotted Ladybird Beetle
2019-08-21	Austrolestes colensonis	Blue Damselfly
2019-09-27	Xanthocnemis zealandica	Red Damselfly
2019-11-20	Vanessa itea	Yellow Admiral

2019-11-26	Lucilia sericata	Common European Greenbottle Fly
2019-12-06	Vanessa itea	Yellow Admiral
2020-01-28	Nyctemera annulata	New Zealand Magpie Moth
2020-02-06	Uresiphita maorialis	Kowhai Moth
2020-02-21	Danaus plexippus	Monarch
2020-02-22	Pieris rapae	Cabbage White
2020-02-22	Scopula rubraria	Plantain Moth
2020-04-09	Vanessa gonerilla gonerilla	New Zealand Red Admiral
2020-04-11	Vanessa itea	Yellow Admiral
2020-04-13	Caedicia simplex	Australian Common Garden Katydid
2020-04-21	Steatoda capensis	Black Cobweb Spider
2020-04-22	Melangyna novaezelandiae	Large Hover Fly
2020-04-24	Lampona cylindrata	Common White-tail Spider
2020-04-24	Vespula germanica	German Yellowjacket
2020-04-25	Apis mellifera	Western Honey Bee
2020-04-25	Austrolestes colensonis	Blue Damselfly
2020-04-25	Caedicia simplex	Australian Common Garden Katydid
2020-04-25	Dysdera crocata	Woodlouse Spider
2020-04-27	Apis mellifera	Western Honey Bee
2020-04-27	Deroceras reticulatum	Milky Slug
2020-04-27	Eriophora pustulosa	Knobbled Orbweaver
2020-04-28	Danaus plexippus	Monarch
2020-04-28	Orthodera novaezealandiae	New Zealand Mantis
2020-04-29	Anachloris subochraria	Golden Grass Carpet
2020-04-29	Apis mellifera	Western Honey Bee
2020-04-29	Apis mellifera	Western Honey Bee
2020-04-29	Apis mellifera	Western Honey Bee
2020-04-29	Phalangium opilio	European Harvestman
2020-04-29	Pieris rapae	Cabbage White
2020-04-29	Tegenaria domestica	Barn Funnel Weave
2020-04-30	Lampona cylindrata	Common White-tail Spider
2020-04-30	Maratus griseus	White-banded House Jumping Spider
2020-04-30	Maratus griseus	White-banded House Jumping Spider
2020-04-30	Scopula rubraria	Plantain Moth
2020-05-01	Bombus terrestris	Buff-tailed Bumble Bee
2020-05-01	Lampona cylindrata	Common White-tail Spider
2020-05-02	Cornu aspersum	Garden Snail
2020-05-02	Musca domestica	House Fly
2020-05-02	Phrissogonus laticostata	Apple Looper
2020-05-02	Vespula germanica	German Yellowjacket
2020-05-03	Anthomyia punctipennis	-

2020-05-03	Apis mellifera	Western Honey Bee
2020-05-03	Miomantis caffra	South African Mantis
2020-05-03	Nyssus coloripes	Spotted Ground Swift Spider
2020-05-03	Phrissogonus laticostata	Apple Looper
2020-05-04	Apis mellifera	Western Honey Bee
2020-05-04	Chrysodeixis eriosoma	Green Garden Looper
2020-05-04	Ichneutica propria	-
2020-05-04	Xanthorhoe semifissata	-
2020-08-15	Apis mellifera	Western Honey Bee
2020-08-15	Eristalis tenax	Common Drone Fly
2020-10-15	Xanthocnemis zealandica	Red Damselfly
2020-11-25	Xanthocnemis zealandica	Red Damselfly
2020-11-25	Xanthocnemis zealandica	Red Damselfly
2020-12-19	Opodiphthera eucalypti	Gum Emperor Moth
2021-01-04	Arhopalus ferus	Burnt Pine Longhorn
2021-01-13	Vanessa itea	Yellow Admiral
2021-02-07	Pieris rapae	Cabbage White
2021-02-19	Apis mellifera	Western Honey Bee
2021-03-17	Orthodera novaezealandiae	New Zealand Mantis
2021-03-17	Orthodera novaezealandiae	New Zealand Mantis
2021-03-25	Badumna longinqua	Grey House Spider
2021-04-04	Badumna longinqua	Grey House Spider
2021-04-04	Epiphyas postvittana	Light Brown Apple Moth
2021-04-04	Eriophora pustulosa	Knobbled Orbweaver
2021-04-04	Phrissogonus laticostata	Apple Looper

Appendix C – Species observation records in Lincoln University Dairy Farm (Bird species)

Date of observation	Scientific Name	Common Name
2016-12-07	Larus dominicanus dominicanus	Southern Black-backed Gull
2016-12-15	Himantopus leucocephalus	Pied Stilt
2017-01-10	Haematopus finschi	South Island Oystercatcher
2017-02-09	Hirundo neoxena	Welcome Swallow

Appendix D – Species observation records in Lincoln University Dairy Farm (Mollusk, arachnid, and insect species)

Date of observation	Scientific Name	Common Name
2016-12-16	Dysdera crocata	Woodlouse Spider
2017-01-10	Conoderus exsul	Pasture Wireworm
2017-01-20	Apis mellifera	Western Honey Bee
2017-01-20	Dolomedes minor	-
2017-01-20	Steatoda capensis	Black Cobweb Spider
2017-01-20	Xanthocnemis zealandica	Red Damselfly
2017-02-09	Austrolestes colensonis	Blue Damselfly
2017-02-18	Xanthocnemis zealandica	Red Damselfly
2017-03-01	Phaulacridium marginale	New Zealand Grasshopper
2017-03-08	Cassida rubiginosa	Thistle Tortoise Beetle
2017-03-08	Cryptachaea veruculata	Diamond Comb-footed Spider
2017-03-08	Oxysarcodexia varia	Striped Dung Fly
2017-03-08	Phaulacridium marginale	New Zealand Grasshopper
2017-03-08	Vanessa itea	Yellow Admiral
2017-03-17	Cyclosa fuliginata	Sooty Orbweaver
2018-03-05	Nyctemera annulata	New Zealand Magpie Moth
2018-03-13	Megadromus antarcticus	Alexander Beetle
2018-03-15	Micromus tasmaniae	Tasmanian Brown Lacewing
2018-04-27	Apis mellifera	Western Honey Bee
2019-01-24	Ancistrocerus gazella	European Tube Wasp

Appendix E – Species observation records in Lincoln Wetlands (Bird species)

Date of observation	Scientific Name	Common Name
2019-01-03	Cygnus olor	Mute Swan
2019-04-08	Cygnus atratus	Black Swan
2019-04-08	Fulica atra australis	Australasian Coot
2019-04-08	Tadorna variegata	Paradise Shelduck
2019-06-23	Todiramphus sanctus vagans	New Zealand Kingfisher
2020-10-06	Anas platyrhynchos	Mallard
2020-10-09	Carduelis carduelis britannica	British Goldfinch
2020-10-09	Egretta novaehollandiae ssp. Novaehollandiae	Common White-faced Heron
2020-10-09	Phalacrocorax carbo novaehollandiae	Australasian Great Cormorant

Appendix F – Species observation records in Lincoln Wetlands (Mollusk, arachnid, and insect species)

Date of observation	Scientific Name	Common Name
2019-06-28	Maratus griseus	White-banded House Jumping Spider
2020-10-09	Xanthocnemis zealandica	Red Damselfly
2020-10-09	Xanthocnemis zealandica	Red Damselfly

Appendix G – Survey Questionnaire

LINCOLN UNIVERSITY TE WHARE WĀNAKA O AORAKI | LANDSCAPE ARCHITECTURE FOUNDATION

Instructions

In the envelope delivered to your letterbox you will find:

- This questionnaire
- Research Information Sheet
- Consent Form
- Letterbox sticker

You can participate in the survey by following the steps below:

Step 1: Read through the Research Information Sheet included in the envelope before you decide to participate in this survey.

Step 2: If you are comfortable with the information provided, you can then sign the Consent Form included.

Step 3: Fill in the questionnaire attached.

Step 4: Return the questionnaire and the consent form as per the instruction below:

If you are comfortable with us collecting the completed questionnaire and Consent Form from your letterbox, please

- put this questionnaire and the Consent Form back into the envelope,
- put the envelope back into your letterbox,
- unlock your letterbox on **Sunday, 9th May 2021** (we will collect the envelopes that evening),
- and put the sticker on your letterbox (this will help us to identify the letterboxes with envelopes to be collected. We will clean the sticker for you when we collect your envelope on Sunday, 9th May 2021).

Alternatively, if the weather is fine, please feel free to leave it on top of your letterbox with something to weigh it down.

Or you can scan and email your questionnaire and Consent Form to the researcher: jacky.bowring@lincoln.ac.nz

Or contact the researcher by email if you would like an electronic copy of this form and the Consent Form to fill in and email back.

Or you can drop your completed survey into the School of Landscape Architecture at Lincoln University, or post it to the address on the Research Information Sheet.

_ _ _ _ _ _

Please enter a self-selected 6 digit or letter code to allow for the identification of your questionnaire if you wish to withdraw. Record this code on the Research Information Sheet so you have a record of it.

LINCOLN UNIVERSITY

TE WHARE WĀNAKA O AORAKI

Research Survey

Questionnaire

A case study investigation of the Te Whāriki subdivision

1. **What type of place did you live in before you moved to Te Whāriki?**
   - ○ Rural subdivision
   - ○ Rural non-subdivision (e.g., farm)
   - ○ Urban subdivision
   - ○ Urban non-subdivision (e.g., apartment)
   - ○ Other ______________________________

2. **Which option below describes your residential situation?**
   - ○ I'm the owner of this property
   - ○ I'm renting
   - ○ Other ______________________________

3. **Why did you move to Te Whāriki? (<u>Please tick all that are applicable</u>)**
   - ☐ Convenient for commuting
   - ☐ Accessibility to commercial facilities
   - ☐ Wetlands and landscape features
   - ☐ Housing price
   - ☐ Away from the hustle and bustle
   - ☐ Proximity to educational facilities
   - ☐ Other ______________________________

4. **Compared to where you lived before, has moving to Te Whāriki improved your experience of using the landscape elements of your neighbourhood? (For example, wetlands, street-centre swales, public green spaces, playgrounds, trees and other planting).**
   - ○ Yes
   - ○ No

   Please add further comments about your answer:

   ____

5. **Have you engaged more frequently in physical exercise in and around your neighbourhood since you moved to Te Whāriki?**
   - ○ Yes
   - ○ No

   Please add further comments about your answer:

   ____

6. **Did you experience an improvement in your mood and quality of life after you moved to Te Whāriki?**
   - ○ Yes
   - ○ No

   Please add further comments about your answer:

   ____

7. **How noisy or quiet does Te Whāriki feel, compared to where you lived previously?**
   - ○ Noisier
   - ○ Quieter
   - ○ Similar

   Please add further comments about your answer:

   ____

8. **How do you feel about the aesthetic / amenity values of Te Whāriki, compared to where you lived previously? (For example, wetlands, street-centre swales, public green spaces, playgrounds, trees and other planting).**
   - ○ Better
   - ○ Similar
   - ○ Worse

   Please add further comments about your answer:

   ____

9. **Do you know that there are fruit trees and herbs in the public areas of Te Whāriki?**
   - ○ Yes
   - ○ No

   Please add further comments about your answer:

   ____

10. **Have you ever harvested any fruit or herbs from the public areas of Te Whāriki?**
    - ○ Yes, more than 3 times per year on average
    - ○ Yes, at least once per year on average
    - ○ Yes, at least once since moving to Te Whāriki
    - ○ No

    Please add further comments about your answer:

    ____

11. **Do you regularly use the local businesses within Te Whāriki? (e.g., New World supermarket, Robert Harris café, Flaming Rabbit, WeCare Pharmacy, Motus Lincoln fitness centre, Domino's Pizza, Challenge gas station, Liquorland, etc.).**
    - ○ Yes, at least twice per week
    - ○ Yes, at least weekly
    - ○ A little, at least monthly
    - ○ No, tend to go beyond Te Whāriki to other commercial areas

    Please add further comments about your answer:

    ____

12. How has your vehicle use changed since you moved to Te Whāriki? (Please tick all that are applicable)

☐ Fewer trips by car
☐ More trips by car
☐ More use of 'micro-transport' (biking, scooter, skateboard etc)
☐ More journeys on foot
☐ Other ____

Please add further comments about your answer:

____

13. What are the reasons for your changed vehicle use? (Please tick all that are applicable).

Reasons for changed vehicle use	Resulted changes in vehicle use		
	More	Similar	Less
Walkability or ease of using alternative transport (e.g., biking)	☐	☐	☐
Availability of public transport or other alternative shared transport (e.g., shared scooter such as Lime, Flamingo etc.)	☐	☐	☐
Opportunities for carpooling	☐	☐	☐
Change in commuting distance (including to university)	☐	☐	☐
Accessibility to shopping and other services	☐	☐	☐
Change in distance for taking children to school	☐	☐	☐

14. Please feel free to add any further comments about your experiences of the public areas of Te Whāriki:

Thank you for contributing to the survey.

Appendix H – Research Information Sheet (RIS)

LINCOLN UNIVERSITY TE WHARE WĀNAKA O AORAKI

LANDSCAPE ARCHITECTURE FOUNDATION

Research Information Sheet

Lincoln University

Faculty of Environment, Society and Design

We invite you to participate in a research project: "Evaluating the performance of a New Zealand rural residential landscape development – A case study investigation of the Te Whāriki subdivision."

What is the aim of this project?

This project aims to examine and document how Te Whāriki subdivision achieves its design goals and contributes to sustainability.

Who are we surveying?

We invite all the Te Whāriki residents to participate in this survey. We hope one person in each household will complete the questionnaire. However, participation in this research is voluntary, and there is no obligation to take part.

What will you be asked to do?

Your participation will involve completing the attached questionnaire, which will take 10 to 15 minutes to complete. The survey asks various questions about your attitudes and perceptions toward the landscape components of Te Whāriki.

How will your data be used?

The results of the project will be published on the website of the Case Study Investigation research programme and will possibly be submitted for publication in academic journals. (Previous case studies from around the world can be viewed here: https://www.landscapeperformance.org/case-study-briefs)

Your identity and data will remain private. No one will have access to this information, other than the two researchers of this project and the Human Ethics Committee in the event of an audit. To further ensure anonymity, consent forms and individual survey data will be seen only by the two researchers and will be securely stored in Lincoln University. Only aggregated data will be presented in any publications, and no information will be reported in a way that might identify any individual participant.

Can you withdraw from the project?

You may decline to answer any question in the survey without affecting your ability to participate in the project. You may also withdraw from the project, including withdrawing any information you have provided, at any time up to 23rd May 2021. You can do this by contacting the research team: Jacky Bowring or Hanley Chen, using the contact details set out below. You will need to advise the six digit or letter code that you have written at the bottom of this sheet – which is a record of the same code you have written on your questionnaire.

What if you have any questions?

If you have any queries or concerns about your participation in the project, please contact the research team as below, or the Head of the School of Landscape Architecture, Dr Gillian Lawson (ph. 03 423 0461, Gillian.lawson@lincoln.ac.nz); we would be happy to discuss any concerns you have about participation in the project.

Researcher:
Professor Jacky Bowring
School of Landscape Architecture
Faculty of Environment, Society and Design
Landscape Architecture Building
PO Box 85084, Lincoln University
Lincoln 7647, Christchurch
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Hanley Chen
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Faculty of Environment, Society and Design
Room 111, School of Landscape Architecture
Lincoln University
Lincoln 7647, Christchurch
Hanley.Chen@lincolnuni.ac.nz
Ph. 02 102873235

This project has been reviewed and approved by the Lincoln University Human Ethics Committee.

_ _ _ _ _ _ Record the 6 digit or letter code you have written on your questionnaire, in case you need to refer back to it.

PLEASE KEEP THIS SHEET FOR YOUR REFERENCE

Appendix I – Consent form

LINCOLN UNIVERSITY TE WHARE WĀNAKA O AORAKI

LANDSCAPE ARCHITECTURE FOUNDATION

Consent Form

Name of Project: Evaluating the performance of a New Zealand rural residential landscape development – A case study investigation of the Te Whāriki subdivision

1. I have read and understood the description of the project above.
2. I have been given sufficient time to consider whether or not to participate in the project and to ask questions.
3. I have been given a copy of the Research Information Sheet to keep.
4. I understand that I may withdraw from the project, including withdrawal of any information I have provided, up to 23rd May 2021.
5. I understand that my anonymity will be preserved.

☐ *I consent to participate in the project.*

☐ *I consent to publication of the results (which may include my anonymised information).*

Name:

Signed:

Date:

Please follow the same instructions as for the questionnaire for returning this form (leave out for collection, scan and send, post, or request an electronic version to fill in and email).

PLEASE RETURN THIS SHEET

Appendix J – Modified SOPARC sheets

SOPARC Activity Observation Sheet LASC 410/DESN 602 2021
Physical Environment Check Sheet

Location (subdivision / suburb name)				
Place (name of park/street etc)				
Date		Observation time	from	to
Weather				
Observer				

Tick	Item	Content	
	Grassed area		
	Seating		
	Water (tap/ drinking fountain)		
	Water (wetland/pond)		
	Play equipment		
	Paved areas		
	Paths		
	Shelter		
	Other		
Notes:			Plan of physical environment

SOPARC Activity Observation Sheet LASC 410/DESN 602 2021 Activity Observation Sheet				
Location (subdivision / suburb name)				
Place (name of park/street etc)				
Date		Observation time	from	to
Weather				
Observer				

No.	Gender			Est. age	Activit y	Notes	Diagram/map
	F	M	O				

Codes for estimated age:
CY – Child Youth 0-19 years
A – Adult 20-65 years
S – Senior – 65 plus

Appendix K – Survey result

	Count	Percentage
Q1 What type of place did you live in before you moved to Te Whāriki?		
○ Rural subdivision	22	22%
○ Rural non-subdivision (e.g., farm)	5	5%
○ Urban subdivision	61	61%
○ Urban non-subdivision (e.g., apartment)	3	3%
○ Other ________________________________	9	9%
Q2 Which option below describes your residential situation?		
○ I'm the owner of this property	91	91%
○ I'm renting	9	9%
○ Other ________________________________	0	0%
Q3 Why did you move to Te Whāriki? (Please tick all that are applicable)		
☐ Convenient for commuting	31	31%
☐ Accessibility to commercial facilities	23	23%
☐ Wetlands and landscape features	43	43%
☐ Housing price	25	25%
☐ Away from the hustle and bustle	52	52%
☐ Proximity to educational facilities	12	12%
☐ Other ________________________________	37	37%
Q4 Compared to where you lived before, has moving to Te Whāriki improved your experience of using the landscape elements of your neighbourhood? (For example, wetlands, street-centre swales, public green spaces, playgrounds, trees and other planting).		
○ Yes	65	65%
○ No	17	17%
○ Yes & No	1	1%
Q5 Have you engaged more frequently in physical exercise in and around your neighbourhood since you moved to Te Whāriki?		
○ Yes	60	60%
○ No	21	21%
Q6 Did you experience an improvement in your mood and quality of life after you moved to Te Whāriki?		
○ Yes	60	60%
○ No	19	19%
○ Yes & No	1	1%
Q7 How noisy or quiet does Te Whāriki feel, compared to where you lived previously?		
○ Noisier	8	8%
○ Quieter	45	45%
○ Similar	28	28%
○ Noisier & quieter	1	1%

Q8 How do you feel about the aesthetic / amenity values of Te Whāriki, compared to where you lived previously? (For example, wetlands, street-centre swales, public green spaces, playgrounds, trees and other planting).

○ Better	43	43%
○ Similar	30	30%
○ Worse	8	8%
○ Better and similar	1	1%
○ Better and worse	1	1%

Q9 Do you know that there are fruit trees and herbs in the public areas of Te Whāriki?

○ Yes	54	54%
○ No	29	29%

Q10 Have you ever harvested any fruit or herbs from the public areas of Te Whāriki?

○ Yes, more than 3 times per year on average	8	8%
○ Yes, at least once per year on average	8	8%
○ Yes, at least once since moving to Te Whāriki	9	9%
○ No	58	58%

Q11 Do you regularly use the local businesses within Te Whāriki? (e.g., New World supermarket, Robert Harris café, Flaming Rabbit, WeCare Pharmacy, Motus Lincoln fitness centre, Domino's Pizza, Challenge gas station, Liquorland, etc.).

○ Yes, at least twice per week	62	62%
○ Yes, at least weekly	18	18%
○ A little, at least monthly	2	2%
○ No, tend to go beyond Te Whāriki to other commercial areas	1	1%

Q12 How has your vehicle use changed since you moved to Te Whāriki? (<u>Please tick all that are applicable</u>)

☐ Fewer trips by car	43	43%
☐ More trips by car	16	16%
☐ More use of 'micro-transport' (biking, scooter, skateboard etc)	19	19%
☐ More journeys on foot	37	37%
☐ Other ______________________	12	12%

Appendix L – Wetland maintenance activities and unit costs. Adopted from Ira and Simcock (2019, 28).

ROUTINE MAINTENANCE	Frequency (Per Year)			Unit	2018 Costs	
	High Amenity	Functional	Bare Minimum*		Low	High
Routine General Maintenance (tree and shrub trimming/lifting, mowing access track**, maintaining healthy vegetation cover, fertilising, removing litter including dog pooh), includes plant and weed assessment	12	4	1	m^2	$0.24	$0.60
Removing debris (e.g. litter, dead vegetation) from outlet and inlet /forebay structures, reinstating any scour/erosion	12	4	1	per wetland	$48	$164
Inspections (e.g. botulism issues, QA, inspection of embankments, spillways, outfalls, overall functioning of facility, integrity of fences and stakes if present)	1	1	0.5	per visit	$300	$480
Scheduled Routine Mechanical Maintenance (pumps, outlets)	1	1	0.5	per wetland	$384	$660
Make good from vandalism (trim /replace plants, remove graffiti)	2	1	0	per wetland	$25.20	$97.80

ROUTINE MAINTENANCE	Frequency (Per Year)			Unit	2018 Costs	
	High Amenity	Functional	Bare Minimum*		Low	High
Weed Management	4	2 - late spring & summer to prevent seeding	0.5	m^2	$0.30	$0.35
Aquatic weed management	2	1	0.5	m^2	$0.29	$0.53
Additional visits for initial Aftercare of Plants (for first 2 to 4 years until 'completion' standard is achieved), includes initial tree form prune and canopy lift that ensures adequate light to retain dense groundcover and achieves safe sightlines (canopy base at 2–4-m height depending on specification) ***	0	2	2	m^2	$0.30	$0.35

*Use high rate if "bare minimum" frequency is selected
**mowing relates to access tracks only (other mowing is associated with non-functional components of the wetland system)
***intensity of initial aftercare more dependent on initial weed pressure, plant density and growth rates, i.e. high intensity / frequency where weed pressure is high and growth rates slow
Note: rates and activities assume no watering or mulch replacement is needed as wetland has reached the completion criteria

CORRECTIVE MAINTENANCE	Frequency (Number of Years Between Each Event)			Unit	2018 Costs	
	High Amenity	Functional	Bare Minimum		Low	High
Corrective Structural Maintenance (repairs to pumps, concrete components, dam embankments/baffles, erosion)	10	10	5	per wetland	$12,000	$18,804
Replacement of parts (grates, trash screens)	20	20	10	per wetland	$1,200	$7,200
Replanting the wetland zone*	50	50	50	m^2	$11	$15
Desilting and disposal of sediment from forebay*	25	25	20	m^3	$105	$310
Desilting and disposal of sediment from main pond*	50	50	50	m^3	$105	$310
Council Inspections – cost to private wetlands	3	3	3	per inspection	$105	$120

*Actual frequencies are dependent on the sediment and contaminant load being captured and removed by the wetland