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ORIGINAL ARTICLE

The amenity value of constructed wetlands

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Abstract

Natural wetlands in urbanised areas provide practical services, including flood control and amenity values such as views, wildlife habitat and recreational opportunities. But cities also construct wetlands to improve flood control and ecosystem services, the value of which might change property prices. This paper reports analyses of property prices that provide estimates of wetlands' localised amenity values in Auckland, New Zealand's largest city. A major challenge is that the selection of sites for wetlands' construction is not random; amenity value is potentially confounded by property and neighbourhood characteristics that vary across space and over time. We use a combination of repeat-sales models, difference-in-differences and matching models to control for unobserved heterogeneity in property and neighbourhood characteristics. The results indicate that local benefit from constructed wetlands ranges from about 5% to 9% depending on the location of the property in areas adjacent to the wetlands or in a larger catchment of interest. Our results have a causal interpretation if the selection criteria are applied uniformly across Auckland and are valuable in assessing the benefits of constructed wetlands.

KEYWORDS

changing neighbourhood conditions, hedonic prices, matching, repeat-sales

JEL CLASSIFICATION

Q25, Q51, Q57, Q58

1 | INTRODUCTION

This paper contributes to the literature that reports the estimates of the amenity value of urban wetlands. Of interest, in this case, is that these wetlands have been constructed. Constructed wetlands, a type of infrastructure built to mimic natural wetland ecosystems in an urban environment, have become increasingly important in resource management and planning as these projects provide practical benefits that vary with the nature of the project. Constructed wetlands reduce the risk of damage to buildings and infrastructure and contribute to storm water collection and flood control, erosion control and groundwater replenishment; supply local amenities: water purification, habitats for native birds, fish, invertebrates and plants; views and recreational opportunities; and contribute to broader public goods: retention of nutrients and sediments, carbon storage and protection against climate-related changes in precipitation patterns (Fernandez & Golubiewski, 2019; Singers et al., 2017).

More generally, constructed wetlands are designed to enhance ecosystem services and resilience, shape the character and ecological infrastructure of cities and perhaps indirectly provide local amenity values (Cortinovis & Geneletti, 2019; Fernandez, 2020; Jarrad et al., 2018; Kuminoff, 2009; Singers et al., 2017). As usual, many of the costs of constructing and maintaining these wetlands can readily be measured because the costs accrue directly to the local agencies that fund the work. However, some costs are more difficult to quantify, such as noise and disruption during construction and costs imposed by restrictions on the development of land around the wetlands to buffer against any adverse effects (Fernandez & Bucaram, 2019; Lewis et al., 2015).

The monetary value of many of the benefits these wetlands deliver is impossible to observe directly. However, we expect the values of localised amenities may affect the sale prices of nearby properties as home buyers compete for properties offered for sale. This amenity value is of academic interest and useful for the local governing body to evaluate projects. This paper contributes to the literature that reports the estimates of this effect using observations on property sales in Auckland, New Zealand's largest city. As we describe in detail later, Auckland is especially well-suited for this type of analysis due to its warm and wet climate, its varied topography and the multitude of wetlands recently constructed in residential areas (Fernandez & Bucaram, 2019).

Our sales data set contains information on all Auckland property sales from 2011 through 2019. We focus on wetlands constructed from 2013 to 2017 to guarantee that we observe sufficient numbers of nearby property sales at least two years before and after wetland construction. Of potential concern, however, is that we do not observe all of the property and neighbourhood characteristics that influence sale prices, and some of these characteristics may change in response to improvements in neighbourhood amenities (Fernandez, Mukherjee, & Scott, 2018; Fernandez, Cutter, et al., 2018). Any such omitted changes could bias the estimates of the amenity effect on property prices (Bin et al., 2009).

To minimise the potential bias, we estimate repeat-sales/hedonic price models to take advantage of the properties that sold more than once. The trade-off is a substantial reduction in the number of observations and potential non-random selection of properties. To treat these issues, we pre-process the data set through coarsened exact matching (CEM) and re-estimate the repeat-sales models before and after wetland construction (Banzhaf, 2020; Dundas, 2017; Haninger et al., 2017). To identify the spatial extent of the effects of constructed wetlands on sale prices, we define treatment groups by proximity to the nearest restored or recently constructed wetland. The distances are set at 300, 600 and 1000 m from the nearest wetland.

Our preferred specification indicates that restoration/construction of wetlands increases property sale prices in the range of 5% to 9% relative to control areas. This percentage effect on sale prices appears also to decrease over time.

The remainder of the paper is organised as follows. Section 2 discusses the literature and provides background information about constructed wetlands. Section 3 details our empirical approach. Section 4 describes the data. Section 5 presents and discusses the results. Section 6 concludes the paper.

2 | BACKGROUND

In this section, we briefly describe the existing literature and also the key characteristics of Auckland and its constructed wetlands.

Recent research includes Jarrad et al. (2018), who estimate the effect of 209 restoration projects in the Johnson Creek Watershed, Oregon. Their estimates indicate that effects vary by area characteristics, distance from the property and project phase. Specifically, in-stream restoration efforts have positive effects on property values, whereas restoration that occurs streamside has mostly negative effects. Polyakov et al. (2017) explore the value of restoring 'urban drains to living streams', an urban restoration project in Perth, Western Australia. They find that properties within 200 metres of the project increase in value once the restored area has become fully established.

Fernandez and Bucaram (2019) find that the effect of proximity to natural wetlands varies with both distance to the wetland and by decile within the sale-price distribution. In addition, although marginal strips along waterways provide amenity benefits, they also restrict development so that the net effect varies by submarket.

Towe et al. (2021) use a repeat-sales approach to control for unobserved property and neighbourhood characteristics and instrument for potential endogeneity in selecting wetlands targeted for restoration. They report an average treatment effect of wetland restoration in sale prices of 12% in Baltimore County, Maryland. Richardson et al. (2022) use a quasi-experimental approach and an event-study design for properties sold in Arkansas, USA. They find that prices of properties near wetland restoration sites increase from 6% to 10%.

Although the value of proximity to wetlands has been explored in past work, the context in Auckland is novel. Auckland has a large and growing population that sprawls over a landscape drained by numerous streams and natural wetlands. Drainage is essential because Auckland is relatively wet, with rain falling on an average of 136 days per year with annual total rainfall averaging about 1100 mm. Importantly, the city extends across a peninsula consisting of a dormant volcanic field, which creates variable topography that provides many paths for water to drain ultimately into the sea.

Thus, constructed wetlands can be considered infrastructure replicating and enhancing the services of natural wetlands: detention, fine filtration and biological adsorption to remove contaminants from storm water run-off (Cunningham et al., 2017; Fernandez, 2020; Lewis et al., 2010; Stefanakis, 2019). A constructed wetland usually consists of ponded areas and dense vegetation, which ameliorate erosion, replenish groundwater, provide habitats for native fauna, retain nutrients and sediments, store carbon and provide recreational opportunities (Singers et al., 2017). More generally, constructed wetlands offset natural wetlands lost to agricultural and urban development (Cunningham et al., 2017; Water, 2019).

The Auckland Council (AC) develops and operates the storm water infrastructure primarily to prevent damage from flooding (de Winton et al., 2013). The Auckland Unitary Plan (AUP) includes provisions to increase the use of constructed wetlands as standard practice failed to consider the degradation of natural waterways or the demand for functional neighbourhood green spaces (Cunningham et al., 2017). Constructed wetlands also serve as an adaptation measure to reduce damage from climate change-related changes in precipitation patterns (Fernandez et al., 2017; Fernandez & Golubiewski, 2019).

At the national level, Section 79 of the Local Government Act requires the AUP to set the strategic direction to prevent or minimise the adverse effects of storm water discharges, as they relate to land-use activities that generate storm water contaminants and increase run-off (Cunningham et al., 2017). The National Policy Statement for Freshwater Management (NPSFM) acknowledges the role of constructed wetlands and includes policies to avoid loss and promote restoration of natural inland wetlands. Regional councils must include provisions for restoring natural inland wetlands in their plans.

Planners locate constructed wetlands based on anticipated water flows and treatment requirements and the catchment's topography and natural flow paths, preferably at the base of a catchment in natural gullies and not on or near contaminated land or fill soils. They should not be located above existing or planned properties, or less than 5 m from property lines (Cunningham et al., 2017; Lewis et al., 2015; Water, 2019).

It is also important is that Auckland has a vibrant economy, serving as New Zealand's economic hub. Employment opportunities and household incomes are relatively high. Having developed during the age of cars and highways, employment centres are dispersed across a broad urbanised area, and low-density residential development sprawls further across this topography. Auckland continues to grow rapidly: Population growth averaged 1.73% per annum from 2011 through 2019. Statistics New Zealand forecasts Auckland's population to increase by 40% in the 30 years from 2018 to 2048. This rapid urbanisation puts increasing pressure on both natural systems and infrastructure (Cunningham et al., 2017).

A key characteristic of Auckland is that environmental amenities are widespread across the city, for which residents show appreciation to some extent, considering their flood control services and the potential to generate landscaping and aesthetic values (Fernandez, 2023; Lewis et al., 2010; Samarasinghe & Sharp, 2008, 2010). Samarasinghe and Sharp (2010) show that the release of public information about flood risk mitigates discounts on house prices in flood-prone areas. Constructed wetlands may also play a role in this context.

The amenity value of a constructed wetland is enhanced when it is part of a connected greenway, or series of parks, open spaces or riparian environments, and when they incorporate cultural narratives and design elements distinctive to Auckland's heritage and Māori cultural values. More generally, perceptions about wetlands are driven by its content, composition, structure, context and landscape character (Dobbie, 2013; Dobbie & Green, 2013). If its amenity values are apparent, a constructed wetland will likely become a permanent, well-maintained feature as landowners exercise stewardship (Calhoun et al., 2017; Cunningham et al., 2017; Lewis et al., 2010).

Consequently, any actions or initiatives to construct or restore wetlands have effects on the property market as proximity may result in a healthier environment, increased ecosystem and cultural amenities, and decreased risk of flooding that reduces the likelihood of property damage, safety issues and insurance liabilities (Kanz, 2013).

3 | EMPIRICAL STRATEGY

Our analysis relies on repeat-sales/hedonic sale price models to estimate the value to property buyers of nearby constructed wetlands. We focus on wetlands constructed or restored from 2013 through 2017. This time frame is sufficiently long to guarantee sales occurred at least 2 years before construction and after completion of the wetland. And, the time frame is sufficiently short to reduce the potential for changes in unobserved and temporally correlated confounding factors (Fernandez, Mukherjee, & Scott, 2018; Guignet et al., 2018).

We distinguish three distance bands to construct the treatment groups: very near the wetland (300 m), within a walkable distance from the wetland (600 m buffer) and sufficiently near that the wetland proxies for the character or 'niceness' of a neighbourhood (1000 m buffer; Fernandez, Mukherjee, & Scott, 2018; Netusil et al., 2019). The control groups comprise properties in a band up to five kilometres from the nearest constructed wetland.[1] For example, for the 300-m buffer area, the control group corresponds to properties between 300 and 5000 m from the nearest constructed wetland. These multiple distance buffers allow us to explore

[1]As suggested by a reviewer, we estimated the models using a single control group consisting of properties between 1 and 5 km from the nearest wetland. Nonetheless, the results did not change dramatically.

variation in the monetary magnitude and spatial extent of the wetland effect (Abbott & Allen Klaiber, 2011).

Our repeat-sales models incorporate property-level fixed effects and controls for all observed time-constant property or neighbourhood influences. The specification (with no controls) is as follows:

$$P_{it} = \beta_0 + \beta_1 Proximity_{it} + \beta_2 After_{it} + \beta_3 Proximity_{it} \times After_{it} + \delta Trend_{it} + \gamma Y_{it} + \phi_i + \epsilon_{it} \quad (1)$$

P_{it} is the log of the sale price, $Proximity_{it}$ is a dummy variable equal to 1 if the dwelling is within the area defined for treatment (300, 600 or 1000 m), ϕ_i are the property-level fixed effects, $After_{it}$ takes the value of 1 if the property is sold after the restoration or construction of the wetland, $Trend_{it}$ indicates the number of years between the transaction and completion of the wetland, constructed as $Proximity_{it} \times After_{it} \times Number\ of\ Years$, Y_{it} is a vector of sale-year indicators and ϵ_{it} are the residuals. The trend term detects how the effect of the project on sale prices varies over time as the wetland settles, vegetation matures or, alternatively, sets restrictions on development (Fernandez, 2020; Fernandez & Bucaram, 2019; Polyakov et al., 2017; Tapsuwan et al., 2009). We cluster on suburbs to estimate variance and control for serial correlation over time within the cluster.

Importantly, the local authority's decisions about where and when to construct wetlands are not random, and locations where construction occurs may differ systematically from locations where no construction occurs (Haninger et al., 2017). For example, wetland deployment over the period of analysis concentrates in areas other than Central and East Auckland. The model is modified to control for initial characteristics ($Initial_j$) at the j^{th}-neighbourhood level in 2010:

$$P_{it} = \beta_0 + \beta_1 Proximity_{it} + \beta_2 After_{it} + \beta_3 Proximity_{it} \times After_{it} + \delta Trend_{it} + \gamma Y_{it} + Initial_j + \epsilon_{it} \quad (2)$$

A concern is the rapid growth and development of the city in the last decade. Changes in neighbourhood attributes may correlate with the decision to construct wetlands and, consequently, confound the wetland treatment effect (Haninger et al., 2017). As time passes and new areas are developed or rezoned for urban purposes, the neighbourhoods may change in terms of the composition of households (e.g., one-person households vs. three-person family), age profile (e.g., under 15 years vs. above 65), property type (e.g., one-bedroom properties vs three-bedroom properties) or ethnicity (e.g., proportion of European or Māori households). Thus, we add an overall neighbourhood change term that proxies potential changes in the neighbourhood:

$$\begin{aligned} P_{it} = \; & \beta_0 + \beta_1 Proximity_{it} + \beta_2 After_{it} + \beta_3 Proximity_{it} \times After_{it} + \\ & \delta Trend_{it} + \gamma Y_i + Neighbourhood\ Change_j + \epsilon_{it} \end{aligned} \quad (3)$$

We include other covariates for distance to the nearest beach, park and to the central business district (CBD), each of which is interacted with year fixed effects to control for changes in the effect and shifts in the hedonic price function over time (Jarrad et al., 2018).

Nonetheless, unobserved heterogeneity may still be present. To improve the comparability of the control and treated groups, and to mitigate functional form problems and changes in unobservable characteristics related to initial conditions, we pre-process the data set using CEM and re-estimate Specifications 1–3 (Fernandez, Cutter, et al., 2018; Guignet et al., 2018). Coarsened exact matching partitions relevant continuous variables into discrete bins and then matches properties within the same set of discrete attribute bins. It imputes counterfactual observations by pairing treated properties with observationally similar properties from the control group (Collins, 2020). Thus, it ensures that each observed characteristic of matched properties is substantively similar (Blackwell et al., 2009; Iacus et al., 2012). Once properties are matched, we expect more accurate estimates of the average effect of constructed wetlands (Keeler & Stephens, 2020).

As matching variables we use property and parcel characteristics, ecosystem shares by neighbourhood, distances to key destinations (central business district and beaches) and three factors that summarise the initial neighbourhood controls (Fernandez, Mukherjee, & Scott, 2018).

4 | DATA

Information on property sales was compiled from the Valuation and Rates Dataset of the Auckland Council for all recorded transactions from January 2010 through December 2019. The initial data set contains about 280,000 recorded sales. These transactions occurred during a period of generally falling mortgage interest rates and consequent rising property prices. The information in the data set includes sale price, location (latitude and longitude), age of the property, floor area and indicators that the property has a garage and deck.

We dropped observations of about 96,000 transactions of properties located more than 5 km to the nearest wetland; 56,000 that had been traded only once (so repeat-sale models cannot be applied); and transactions with important information missing, for example, floor space or sale date, and observations on sales that were not arms-length. We also discarded properties that sold more than once in a single year or with relatively quick re-sale at a substantially higher price that probably reflects improvements to the property between sales (Dundas, 2017; Jarrad et al., 2018; Muehlenbachs et al., 2015). The resulting sample for analysis comprises 81,461 transactions (Table 1).

All properties are linked to a geo-coded parcel map administered by the Auckland Council. Figure 1 shows the spatial distribution of sales and sale prices across the Auckland region. Figure 2 shows the locations of constructed wetlands. We extracted artificial or storm water wetlands from the indigenous terrestrial and wetland ecosystems guide of the Auckland Council (Singers et al., 2017). We identified 90 wetlands completed from 2012 to 2017. This time frame guarantees that we observe sales at least two years before and after construction.

Next, we classified each sale in terms of proximity to the nearest wetland. We include wetlands within the urbanised area and discard those in the rural fringe with relatively few

TABLE 1 Summary of repeat-sales within each distance band.

	Properties	Transactions	Transaction pairs
Within 300 m			
No	35,292	77,177	41,885
Yes	1933	4284	2351
Total	37,225	81,461	44,236
Within 600 m			
No	32,654	71,401	38,747
Yes	4571	10,060	5489
Total	37,225	81,461	44,236
Within 1000 m			
No	28,837	63,045	34,208
Yes	8388	18,416	10,028
Total	37,225	81,461	44,236

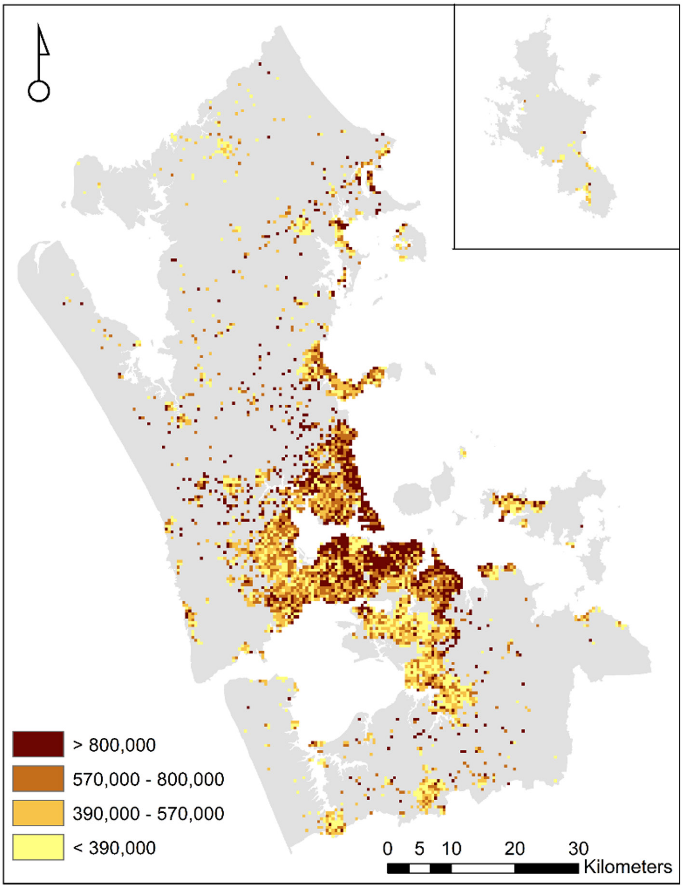

FIGURE 1 Spatial variation in sale prices—January 2011 to December 2019. [Colour figure can be viewed at wileyonlinelibrary.com]

transactions and agricultural influences on the local environment. We distinguish three buffer zones: 300, 600 and 1000 m from the nearest constructed wetland. We calculate the Euclidean distance from each property to the edge of the nearest wetland to sort properties to buffer zones. This allows estimation of the average effect of increased distance to the nearest wetland on sale price. The control groups consist of sales from the edge of the buffer area to five kilometres from the nearest wetlands. We do not explore specific attributes of restored or constructed wetlands (e.g., whether recreation is allowed in the sites; Netusil et al., 2019).

To control for observable neighbourhood characteristics, we match each transacted property to its census statistical area (SA), which represents a suburb, and then to SA characteristics in the nearest of the 2006, 2013 and 2018 censuses. We extrapolate linearly to estimate the value of these variables in years other than census years (Fernandez, Mukherjee, & Scott, 2018). Year 2010 serves as the baseline for initial neighbourhood conditions.

Table 2 provides descriptive statistics of the SA-level variables used for the CEM and other neighbourhood and property characteristics. The mean sale price of about $630,000 reflects the boom phase in the housing market in the aftermath of the global financial crisis. This boom persisted for about a decade. The average floor area is 159 m^2 and the average distance from the nearest wetland is 2.3 km, which contrasts with the average distance to the nearest beach of 5.9 km. Auckland is characterised by a unique landscape with ecosystem features and other environmental amenities scattered across the city (Fernandez, 2023). For example, the

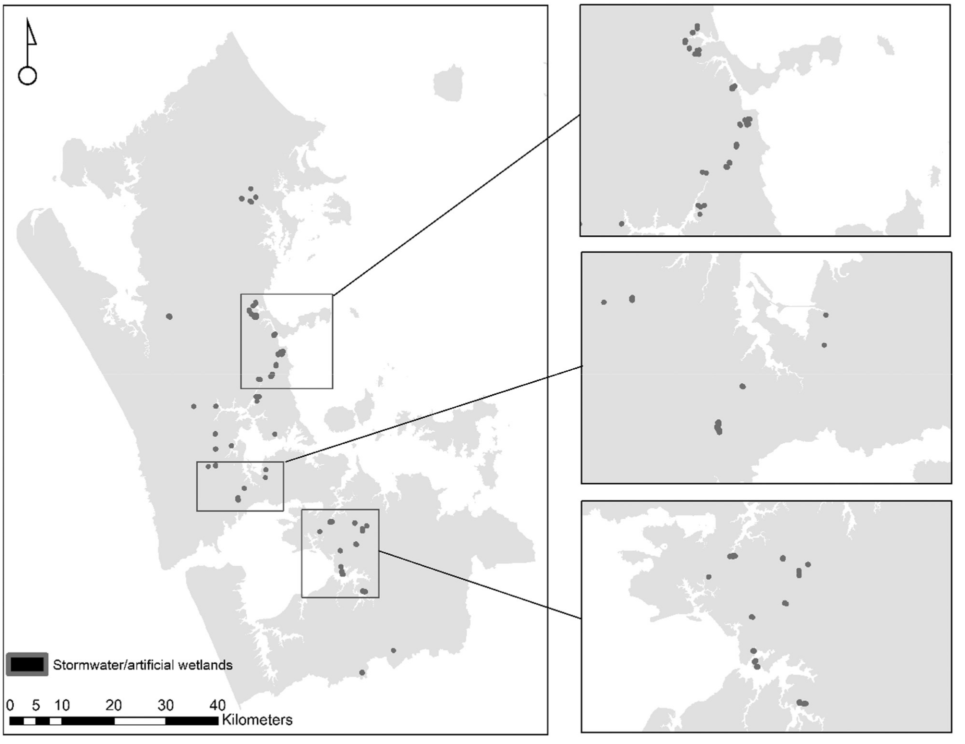

FIGURE 2 Map of constructed wetlands in Auckland. The location of the wetlands comes from the indigenous terrestrial and wetlands ecosystems data set of the Auckland Council (Singers et al., 2017).

area of parks (or open spaces other than wetlands) within 300 m of a property averages 18,000 and 251,000 m^2 within 1000 m of the property.

5 | RESULTS

As described earlier, the main empirical challenge involves disentangling the effects on property prices of unobserved changes in property and neighbourhood characteristics from the effects of the establishment of constructed wetlands (Abbott & Allen Klaiber, 2013; Fernandez, Mukherjee, & Scott, 2018). We start by estimating repeat-sales models on data that consist of observations on transactions from 2011 through 2019. The repeat-sales approach controls for unobserved property characteristics that do not change over time. To control for changes in neighbourhood characteristics coincident with the construction of a wetland, we add the neighbourhood controls for which we observe changes. Subsequently, we repeat the exercise with the CEM and compare the results with the unmatched data set. Therefore, we estimate the average direct effect of wetland construction on property prices, removing any indirect effects of other neighbourhood characteristics that influence prices.

Results for the unmatched repeat-sales data set are displayed in Table 3. Our interest is in the coefficient on $Proximity_{it} \times After_{it}$. Given the semi-log functional form, the coefficients are interpreted as semi-elasticities: $(\exp(\beta) - 1) \times 100$ (Halvorsen & Palmquist, 1980).

Estimates from Specification 1 indicate large effects of proximity to newly constructed wetlands on sale prices. Prices of properties within 300 m increase on average by 36% more than properties elsewhere. As expected, this average effect decreases with distance to 19% when

TABLE 2 Descriptive statistics.

	Mean	Std. dev.	Min	Max
SA variables for CEM (levels)				
Proportion study full time	0.123	0.062	0.000	0.689
Proportion not study	0.839	0.066	0.266	1.000
Proportion study part time	0.038	0.009	0.000	0.103
Median income	86,096	24,709	22,826	154,500
Proportion European	0.543	0.210	0.067	0.914
Proportion Maori	0.091	0.064	0.009	0.409
Proportion Pacific	0.095	0.119	0.000	0.774
Proportion Middle East or Latin American	0.020	0.014	0.000	0.123
Proportion Asian	0.236	0.166	0.000	0.795
Proportion other ethnicity	0.015	0.010	0.000	0.100
Proportion one bedroom	0.078	0.115	0.000	0.760
Proportion two bedrooms	0.195	0.121	0.000	0.683
Proportion three bedrooms	0.390	0.145	0.022	0.756
Proportion four bedrooms	0.240	0.123	0.000	0.686
Proportion five+ bedrooms	0.098	0.091	0.000	0.719
Proportion single-family property	0.764	0.089	0.390	0.918
Proportion two family	0.094	0.055	0.000	0.296
Proportion three family	0.013	0.015	0.000	0.125
Proportion multifamily	0.058	0.069	0.000	0.499
Proportion one person	0.071	0.048	0.000	0.344
Proportion under 15 years	0.195	0.058	0.021	0.367
Proportion population age 15–29	0.229	0.089	0.029	0.765
Proportion population age 30–64	0.457	0.047	0.191	0.721
Proportion population age > 65	0.119	0.062	0.013	0.474
Proportion owner-occupier	0.462	0.125	0.083	0.794
Proportion renting	0.396	0.163	0.070	0.883
Proportion in family trust	0.142	0.084	0.000	0.463
Neighbourhood and housing variables				
Sale price	715,632	392,366	120,285	3,285,009
Distance to nearest wetland	2.291	1.399	0.103	5.000
Distance to nearest beach	5.952	5.369	0.020	25.933
Distance to CBD	16.776	9.922	0.637	54.468
Distance to nearest school	0.566	0.351	0.017	5.057
Distance to nearest road	0.685	0.558	0.000	2.831
Slope	2.980	2.304	0.000	19.043
Floorspace (m^2)	159.6	97.3	21.0	11,490
Area of parks 300 m (m^2)	18,137	23,144	0.000	325,379
Area of parks 600 m (m^2)	85,702	84,856	0.000	1,002,198
Area of parks 1000 m (m^2)	251,368	193,004	0.000	1,570,675

Note: All distance variables are in kilometres. Table 5 below provide further description on how differences in means between treated and control units are balanced on the unmatched or CEM-matched data.

TABLE 3 Unmatched results repeat-sales.

	Specification 1		Specification 2		Specification 3	
	Coefficient	***p*-value**	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**
Panel A: 300 m						
Dummy distance × Dummy after construction	0.306	0.000	0.295	0.000	0.238	0.000
	[0.0689]		[0.070]		[0.053]	
Linear trend	−0.001	0.951	−0.000	0.978	−0.011	0.483
	[0.015]		[0.014]		[0.016]	
Adjusted *R* squared	0.333		0.433		0.343	
Panel B: 600 m						
Dummy distance × Dummy after construction	0.178	0.007	0.161	0.019	0.129	0.000
	[0.066]		[0.068]		[0.036]	
Linear trend	0.007	0.457	0.008	0.351	−0.003	0.625
	[0.009]		[0.009]		[0.007]	
Adjusted *R* squared	0.334	0.433	0.474			
Panel C: 1000 m						
Dummy distance × Dummy after construction	0.072	0.133	0.072	0.163	0.049	0.075
	[0.048]		[0.052]		[0.028]	
Linear trend	0.007	0.438	0.006	0.484	0.001	0.751
	[0.009]		[0.009]		[0.006]	
Adjusted *R* squared	0.459		0.432		0.473	
Observations	81,461					
Initial neighbourhood characteristics	No		Yes		No	
Neighbourhood change	No		No		Yes	
Years	Yes		Yes		Yes	

Note: Standard errors in parentheses.

sales of properties out to 600 m from the wetland are included and becomes insignificant at a distance of 1000 m.

These estimates may, however, pick up the effects on sale prices of any omitted neighbourhood characteristics. Specification 2 includes initial neighbourhood conditions with results similar to those in Specification 1. Specification 3 adds controls for changes in neighbourhood conditions over time, which as expected reduces the estimated effect of a constructed wetland compared with Specifications 1 and 2. Arguably, wetlands on their own increase prices on average by 27%, 14% and 5% for properties within 300, 600 and 1000 m, respectively. That is, wetlands provide a localised amenity value where properties closest to the wetland experience a large positive effect that outweighs any nuisance usually associated with public open spaces (e.g., lack of privacy and noise; Cheung & Fernandez, 2020).

Also of interest is that none of the coefficients on the linear trend (i.e., the number of years since wetland deployment) is significant in any of the specifications. That is, the percentage effect of the new amenity on property prices appears to remain constant over time.

Next, we introduce CEM as a pre-processing stage to treat potential bias due to changes in the demographics of neighbourhoods. The CEM algorithm constructs strata based on the

TABLE 4 Number of observations.

	Treated		
	No	Yes	Total
Treated = 300 m distance to nearest wetland			
All	77,177	4284	81,461
Matched	4026	4204	8230
Unmatched	73,151	80	73,231
Treated = 600 m distance to nearest wetland			
All	71,401	10,060	81,461
Matched	9717	4961	14,678
Unmatched	61,684	5099	66,783
Treated = 1000 m distance to nearest wetland			
All	63,045	18,416	81,461
Matched	13,283	10,022	23,305
Unmatched	49,762	8394	58,156

ranges of the matching variables, coarsens the variables into these ranges and then forms each unique combination of ranges into strata (Fernandez, Mukherjee, & Scott, 2018; Iacus et al., 2012; Keeler & Stephens, 2020). Table 4 shows the number of strata by treatment group and reveals how few control observations are comparable with treatment observations. For example, in the 1000 m buffer, about 75% of the control observations are unmatched. Thus, the matching process imposes a trade-off: The comparability of the control and treatment groups increases, but the number of observations decreases considerably.

Table 5 shows that the individual and multivariate balance statistics improve significantly with the CEM approach, as expected. The L1 statistics compare the balance across the distribution of the treated and untreated variables by observing the differences in the corresponding (multivariate) histograms. The multivariate L1 distance improves by 30% in all specifications (Fernandez, Mukherjee, & Scott, 2018; Iacus et al., 2012). That is, the matched treatment and control data sets, as expected, compare much better on observable characteristics.

Table 6 presents estimates of Specifications 1–3 and using the matched data set, which tells a story somewhat different from that of the estimates in Table 3.

Similar to Specification 1 in Table 3, the effect of a constructed wetland decreases monotonically with buffer size, from 36% for the 300 m buffer to 10% for the 1000 m buffer. Even so, for Specification 2, the introduction of neighbourhood controls produces similar results to Specification 1 and, by implication, to Specifications 1 and 2 in Table 3. Nonetheless, all the linear trends are now negative and significant, except for the 1000 m buffer. That is, the matching reveals that the percentage effect of wetlands on sale prices decreases over time.

For Specification 3, the percentage effect of proximity to wetlands decreases substantially compared to Specification 2. But, compared with the results in Table 3 for the unmatched data set, the treatment effect decreases further for properties within 300 m from 27% to 19%, and the linear trend becomes negative and significant. In absolute value, the magnitude of the linear trend is twice and seven times higher in the 300 m buffer compared with the 600 m and 1000 m buffers, respectively.

Figure 3 plots the estimated wetland effects in combination with the linear trends. Notably, after 3 years, the effect for properties within 300 m is statistically equal to those in the 1000 m buffer area. As time passes, the amenity value of wetlands decreases faster for properties closest to the wetland, perhaps because households gradually perceive the nuisance associated with public open spaces or maintenance work (Albouy et al., 2020).

TABLE 5 Imbalance improves with coarsened exact matching.

Panel A: Treated = 300 metres to nearest wetland				
	Unmatched		**Matched**	
Multivariate L1 balance	**0.984**		**0.676**	
Univariate balance	**L1**	**Mean difference**	**L1**	**Mean difference**
Area parks radius of 300 m around the property	0.130	−397.117	0.068	331.489
Slope	0.188	0.178	0.086	−0.028
Floorspace	0.410	65.264	0.122	6.871
Share of area of neighbourhood on ecosystems	0.485	0.044	0.001	0.000
Factor 1	0.567	0.415	0.000	0.000
Factor 2	0.504	−0.299	0.000	0.000
Factor 3	0.490	0.341	0.000	0.000
Distance to CBD	0.519	5.831	0.066	−0.041
Distance to nearest beach	0.511	1.398	0.092	−0.012
Panel B: Treated = 600 metres to nearest wetland				
	Unmatched		**Matched**	
Multivariate L1 balance	**0.963**		**0.617**	
Univariate balance	**L1**	**Mean difference**	**L1**	**Mean difference**
Area parks radius of 600 m around the property	0.105	−1210.552	0.103	2738.746
Slope	0.140	0.162	0.037	−0.011
Floorspace	0.325	52.000	0.063	5.383
Share of area of neighbourhood on ecosystems	0.478	0.044	0.002	0.000
Factor 1	0.465	0.327	0.000	0.000
Factor 2	0.411	−0.205	0.000	0.000
Factor 3	0.442	0.362	0.000	0.000
Distance to CBD	0.463	4.775	0.072	−0.063
Distance to nearest beach	0.425	0.864	0.063	−0.040
Panel C: Treated = 1000 metres to nearest wetland				
	Unmatched		**Matched**	
Multivariate L1 balance	**0.924**		**0.597**	
Univariate balance	**L1**	**Mean difference**	**L1**	**Mean difference**
Area parks radius of 1000 m around the property	0.112	23,949.237	0.041	422.459
Slope	0.122	0.265	0.052	−0.006
Floorspace	0.227	34.492	0.064	2.089
Share of area of neighbourhood on ecosystems	0.442	0.040	0.001	0.000
Factor 1	0.375	0.230	0.000	0.000
Factor 2	0.373	−0.139	0.000	0.000
Factor 3	0.336	0.339	0.002	−0.001
Distance to CBD	0.406	4.599	0.032	−0.015
Distance to nearest beach	0.330	1.361	0.063	−0.003

Note: Factors 1–3 refer to the three extracted factors from applying factor analysis to the SA variables described in Table 2. Mean difference refers to the difference in means between treated and control units on the unmatched or CEM-matched data.

TABLE 6 Matched results repeat-sales.

	Specification 1		Specification 2		Specification 3	
	Coefficient	***p*-value**	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**
Panel A: 300 m						
Dummy distance × Dummy after construction	0.313	0.000	0.267	0.000	0.177	0.000
	[0.023]		[0.022]		[0.022]	
Linear trend	−0.041	0.000	−0.023	0.000	−0.0271	0.000
	[0.005]		[0.005]		[0.005]	
Adjusted R squared 300 m	0.373		0.4748		0.529	
Observations: 8230						
Panel B: 600 m						
Dummy distance × Dummy after construction	0.260	0.000	0.242	0.000	0.125	0.000
	[0.019]		[0.018]		[0.018]	
Linear trend	−0.019	0.000	−0.008	0.009	−0.007	0.016
	[0.003]		[0.003]		[0.003]	
Adjusted R squared 600 m	0.353		0.439		0.386	
Observations: 14,678						
Panel C: 1000 m						
Dummy distance × Dummy after construction	0.099	0.000	0.098	0.000	0.049	0.000
	[0.014]		[0.014]		[0.014]	
Linear trend	−0.008	0.001	−0.003	0.216	−0.002	0.365
	[0.002]		[0.002]		[0.002]	
Adjusted R squared 1000 m	0.342		0.440		0.371	
Observations: 23,305						
Initial neighbourhood characteristics	No		Yes		No	
Neighbourhood change	No		No		Yes	
Years	Yes		Yes		Yes	

Note: Standard errors in parentheses.

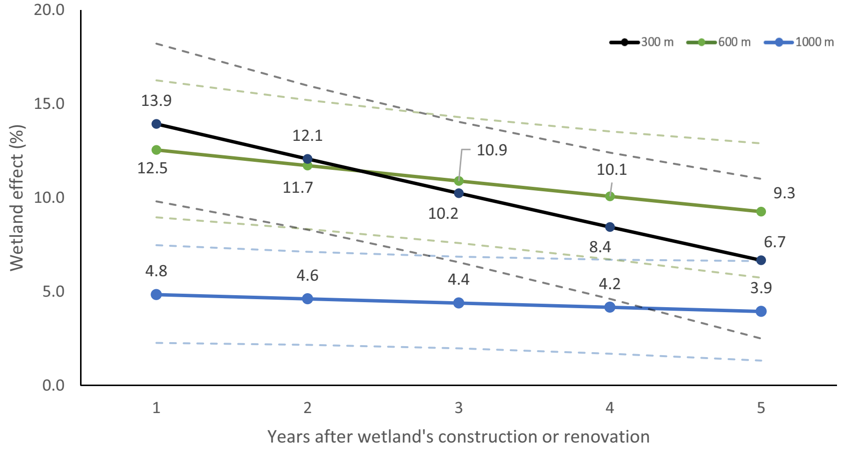

FIGURE 3 Wetland effect over time. Dashed lines depict the 95% confidence interval of the wetland effect by treatment group. [Colour figure can be viewed at wileyonlinelibrary.com]

Hence, controlling for neighbourhood change mitigates endogeneity in both the matched and unmatched data sets. Results in the matched data set suggest that any changes in neighbourhood conditions are more pronounced in areas close to wetlands than in the rest of the catchment.

We do not, however, observe the process the Auckland Council used to decide where to construct or restore an artificial wetland. General guidelines or principles exist for design and deployment, but controlling for every selection effect is impossible. This may imply that our results should be interpreted as the effects on property prices only where wetlands are more likely to be constructed. However, assuming that the selection criteria are applied uniformly across Auckland, our results have a causal interpretation and are valuable in assessing the benefits of constructed wetlands (Richardson et al., 2022).

A back-of-the-envelope calculation shows that using the effects of Specification 3 applied to the most recent sale price of properties within the treatment groups, the amenity effect of constructed wetlands amounts to NZ$617 million.[2] This is a sizable amenity value, which should be confronted with construction and maintenance costs to get a reasonable estimate of the net benefit of constructed wetlands to Auckland homebuyers.

We implement a battery of robustness checks. As shown in Appendix S1: Table A1, we add housing controls to Specification 3 of Table 6. These controls decrease the treatment effect slightly. The linear trend estimate at the 1000 m buffer also changes sign. Although the coefficient is small, this may suggest that amenity value increases as the constructed wetland settles and vegetation matures (Polyakov et al., 2017; Tapsuwan et al., 2009).

To test whether wetland construction/restoration spills over to affect prices of control properties, we remove all treated observations so the data contain only control group transactions. Next, we falsely assign treatment to control properties. The results in Table A3 indicate that the net effect of treatment on control group property does not differ significantly from zero, which supports our assumption that the control groups are serving their function (Dundas, 2017).

Although the CEM approach has been applied in the related literature to mitigate selection bias and to create valid treatment–control comparisons through pairing on observable covariates, it is still an open question whether properties within the treatment areas systematically differ from those in the control groups or in the proximity (Richardson et al., 2022). We re-estimate Specifications 1–3 from Table 6 using nearest neighbour matching as the pre-processing stage to compare properties in the control and treatment groups. Results in Table A3 show all treatment effects are positive and significant though differ somewhat from those in Table 6. Nonetheless, these matching results also support the finding that constructed wetlands introduce amenity value and have a positive treatment effect.

Finally, we re-estimate Specification 3 from Table 6 using an event-study design in a difference-in-differences setting to allow impacts to vary nonlinearly over the years. Figure A1 plots the results for the three treatment groups and those of Table 6 including the linear trend. The treatment effects change relative to the number of years since construction of the nearest wetland and, within the range of significant coefficients, the results are consistent with those using the linear trend in Table 6.

6 | CONCLUDING REMARKS

Restoration or construction of wetlands may induce new development on land previously in open space or in run-down areas (Lewis et al., 2015), or encourage local government to designate areas as buffers where restrictions on development are in place to avoid adverse

[2]Average prices are NZ$734,516, NZ$722,394 and $713,574 and the number of properties are 1933, 2638 and 3817 for areas within 0–300, 300–600 m and 600–1000 m from the nearest wetland, respectively.

effects (Fernandez & Bucaram, 2019). Thus, the net effect of constructed wetlands on property prices likely depends on the construction phase and the extent the project incorporates landscaping or aesthetic values in addition to ecological functions (e.g., flood control; Jarrad et al., 2018; Lewis et al., 2010; Polyakov et al., 2017; Tapsuwan et al., 2009).

This paper reports estimates of the impact of constructed wetlands on property prices in Auckland, New Zealand's largest city. We use repeat-sales/hedonic price models to control for fixed characteristics and to identify treatment effects, but at the risk of picking up the effects of unobserved changes in neighbourhood attributes motivated by the amenities that wetlands provide (Fernandez, Cutter, et al., 2018; Haninger et al., 2017; Mastromonaco & Maniloff, 2018). The empirical challenge is then to disentangle neighbourhood changes from geographically broad treatment effects (Fernandez, Mukherjee, & Scott, 2018). Therefore, our analysis involves a combination of property-level fixed effects, difference-in-differences and matching estimators (Collins, 2020; Fernandez, Mukherjee, & Scott, 2018; Guignet et al., 2018; Haninger et al., 2017; Keeler & Stephens, 2020; Richardson et al., 2022).

Our results indicate that increases in property prices range from 5% to 9% depending on the location of the property in the areas adjacent to the wetlands or across a larger catchment of interest, and on how many years have passed after the wetland's deployment. Overall, households value easy access to and/or the associated ecological functions of constructed wetlands. Nonetheless, as time passes, the effect decreases faster for properties closest to the wetland perhaps because households gradually perceive the nuisance associated with proximity to open spaces (e.g., nuisance, lack of privacy and maintenance works), which offset the amenity value of the wetland itself (Albouy et al., 2020).

Although the estimated effect (the response to construction or restoration) may be of interest for the purpose of land value capture or property taxation, we go a step beyond. Our results suggest causal identification of the marginal willingness to pay (MWTP) for living in a location proximate to a constructed wetland (Bishop et al., 2020; Haninger et al., 2017; Kuminoff & Pope, 2014).

This paper leaves open some questions that seem worth exploring in future research. First, limitations in data availability preclude study of changes in household demographics, which can feed back to influence sale prices. Second, constructed wetlands vary in several characteristics, the value of which could potentially be estimated. However, preliminary estimates using wetlands characteristics were unreliable. Third, in the aftermath of the global financial crisis, Auckland's housing market entered a boom phase that ended in 2017 but revived in 2020 with changes in monetary policy to mitigate the effects of the COVID-19 pandemic and lockdowns. This paper does not incorporate these recent factors (Cheung & Fernandez, 2021; Fernandez & Martin, 2021). Fourth, we do not explore interactions with rental or labour markets. This may be an interesting avenue of research that could be addressed through, for example, equilibrium sorting models for which our results provide valuable input (Binner & Day, 2015, 2018). Lastly, although we incorporate a linear trend to estimate treatment effects over time, we do not extrapolate beyond the short run. Nonlinearities, feedback or other neighbourhood effects over time (e.g., gentrification; Haninger et al., 2017) may influence this paper's implications.

Regarding policy or urban planning, constructed wetlands may have the unintended effect of making properties less affordable. Results associated with the 1000 m buffer indicate that amenity values spread over a relatively large catchment area. Planners should consider this trade-off and explore other affordability instruments while preserving a baseline level of environmental amenities. Also, as constructed wetlands are a cost-effective alternative for storm water management, our results may be used to explore their role as a component of a comprehensive strategy to manage urban streams, their interaction with other WSD approaches (Irwin et al., 2018; Jarrad et al., 2018) and to inform land use, urban planning, investments regulation and development decisions (Du & Huang, 2018).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the Auckland Council. Restrictions apply to the availability of these data, which were used under license for this study.

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