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ORIGINAL ARTICLE

Investigating revealed preferences for urban waterway conditions: A hedonic property valuation study

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Abstract

This study examines the impact of urban waterway conditions on property market prices. In general, similar revealed preference studies typically focus on identifying the value associated with changes in attributes such as riparian vegetation or water quality. Using an index that classifies waterways based on the vegetation *and* channel conditions, we analyse both attributes. Our spatial hedonic property price model findings indicate that buyers are willing to pay premiums ranging from 2.7% to 8.5%, depending on vegetation and channel conditions. However, when the proximity to the waterway is accounted for, we found that properties adjacent to the highest-ranked vegetation and channel conditions attract a higher premium of 12.8%. Overall, the implicit marginal effects for the distance–condition interaction variables indicate that for lower-ranked waterway conditions, there is a relative aversion to being adjacent to waterways. The results suggest that there are significant gains to be realised from removing concrete-lined channels and replacing them with stones for banks, or re-creating unmodified channels, even if there is only limited scope for increasing vegetation.

KEYWORDS

channel condition, ecological indices, hedonic price model, riparian vegetation, urban streams

JEL CLASSIFICATION

Q51, Q57

1 | INTRODUCTION

Major cities worldwide have waterways forming a prominent part of their landscape and history. Yet, the urbanisation process has led to the modification of such waterways. Such modifications include the removal of riparian vegetation and the channelisation of waterways. As a result, these changes have undermined waterway health, and the ecosystem services provided by urban waterways (Paul & Meyer, 2001; Towe et al., 2021). The Australian Cooperative Research Centre for Water Sensitive Cities notes that while waterways were historically modified to mitigate flood risk, they were typically designed without consideration of ecological and aesthetic function (CRCWSC, 2016).

In this study, we investigate people's revealed preferences for different quality levels of waterway conditions. We do this by analysing the capitalised value in residential property prices in 11 local government areas (LGAs) in the southern portion of Sydney, Australia. We rely on a vegetation and riparian condition (VRC) index developed by freshwater ecologists to measure urban waterway conditions. The six-level VRC index combines information on vegetation and channel conditions. Channel conditions describe the modifications to waterways. For example, a highly modified waterway has straightened banks and is concrete-lined. A modified waterway is rock-lined and still meandering, and an unmodified waterway is one in a natural state.

Previous hedonic studies have primarily focused on ambient water quality when investigating the capitalised value of freshwater resources in property values (see reviews by Boyle & Kiel, 2001; Brander & Koetse, 2011; Mazzotta et al., 2014; Nicholls & Crompton, 2017). For example, Boyle and Kiel (2001) summarised seven hedonic studies between 1968 and 2000 that use subjective perceptions of water quality, water pH, Secchi disk measures of water clarity, coliform concentrations and other indicators of ambient water quality as explanatory variables in the hedonic equations. None of these past studies considered waterway channel conditions nor the condition of the riparian buffer.

The findings from reviews of the hedonic pricing literature also demonstrate the limited consideration of improvements in waterway riparian and channel condition and their influence on property prices. Brander and Koetse (2011) summarised hedonic studies of urban green space, classified as forest, greenbelt or urban park, which may have freshwater resources as a part of their amenities. These studies did not specifically assess the impact on property values from different waterway conditions. Mazzotta et al. (2014) considered the effects of low-impact development on property values, and of the 36 studies reviewed, only two considered riparian buffers. Nicholls and Crompton (2017) reviewed studies from 1973 to 2017 that specifically investigated the effects of rivers, streams and canals on property values. Across the 25 studies reviewed by Nicholls and Crompton (2017), the common explanatory variables were location with waterway frontage, distance to the waterway and view of the waterway, and only one study considered waterway conditions (i.e., Streiner & Loomis, 1995). Streiner and Loomis (1995) found that property values increased with improved fish habitat and streambank stabilisation projects in place. Thus, findings from previous reviews of the literature indicate that there are few studies and limited evidence on the impact of waterway conditions on property values. Additionally, the studies reviewed by Boyle and Kiel (2001), Brander and Koetse (2011), Mazzotta et al. (2014), and Nicholls and Crompton (2017) are often focused on lakes, not urban rivers and streams, which are the focus of our study.

A few studies have investigated the impact of riparian corridors on property values (e.g., Colby & Wishart, 2002; Mukherjee & Caplan, 2011; Polyakov et al., 2017). These past studies have shown that proximity to riparian corridors and improvement works on the riparian zone generally led to positive impacts on property values. According to findings from these past studies, higher quality waterways generally lead to increased property values. However, these studies did not provide insights into the impact of varying gradients of quality or use indicators that account for the quality of both the riparian vegetation and channel conditions.

To our knowledge, Bark et al. (2009) is the only study that has attempted to comprehensively incorporate waterway quality in a hedonic price property valuation model. This study included explanatory variables to represent the distance to the nearest waterway and four other indices of riparian vegetation volume, diversity of riparian woody species, a 'wetness' index of mesoriparian and hydroriparian species and riparian habitat connectivity with upland riparian vegetation. Results from Bark et al. (2009), although limited in that they are from a single study, indicate that measures of the ecological condition of waterways are valued by people and influence property values.

The most likely explanation for the lack of usage of indicators that account for both riparian vegetation and channel conditions is that, historically, hedonic models have generally relied on accessible measures such as water quality indicators from secondary data sources or proximity to water or water views. An underlying factor for these common measures is that they can be readily elucidated or determined by analysts and property sellers, and buyers. However, these commonly used measures do not reflect all the dimensions of a healthy waterway that are perceived and relevant to people. Furthermore, waterways represent complex ecosystems where riparian and channel conditions are interrelated.

Consequently, ecologists generally employ indices of stream conditions to more comprehensively reflect waterway health. In thinking about waterway quality, a holistic approach that includes the waterway channel and the riparian zone along waterways is desirable (Brierley et al., 2002; Findlay et al., 2011; Ladson et al., 1999). Indices of waterway quality conditions have been developed in several contexts to support decision-making. In Australia, for example, the Rapid Riparian Assessment Tool (Findlay et al., 2011) and the River Styles framework (Brierley et al., 2002) are two of several techniques used to assess riparian zone conditions. In the United States, the Department of Agriculture used an index to prioritise watershed restoration activities. This Watershed Condition Classification has 12 waterway condition indicators, including riparian vegetation condition and a channel function indicator (USDA, 2011). In South Africa, the Index of Habitat Integrity grades river health based on 15 characteristics including the degree of modification of the riverbed and channel and remnant vegetation (Kleynhans, 1996).

Coincidentally, there appears to be limited empirical literature on how ecologist-developed indices can be used to analyse people's preferences for different types of waterway conditions. Artell (2014) applied a five-level expert index, ranging from poor to excellent, of the usability of the water for recreation, fishing and consumption. Property values were found to increase with improvements in water quality (Artell, 2014). The author showed that preferences and willingness to pay amounts can vary with quality levels; however, their assessment did not directly address rivers and streams' riparian and channel conditions.

Overall, there is limited empirical literature on people's revealed preferences for different quality levels of urban waterways. Past empirical studies that have assessed people's revealed preferences for waterway health have not adopted common waterway health indices which are commonly used and recommended by ecologists. Nonetheless, past literature posits that it is important that any indicators used in a hedonic model must meet two criteria: relevance and realism to people entering into property transactions (Bingham et al., 1995; Johnston et al., 2002; National Research Council, 2005; Olander et al., 2018; Turner et al., 2010). Relevance implies that the characteristics represent the actual ecosystem under investigation, and realism implies that the characteristics translate into services people enjoy. In this analysis, we have employed the ecologist-developed VRC index as an indicator of urban waterway quality (described in Section 3.2). The VRC index meets the relevance and realism requirements as it is a measure developed to assess waterway ecosystem health and the quality of the waterway does translate into the services enjoyed by

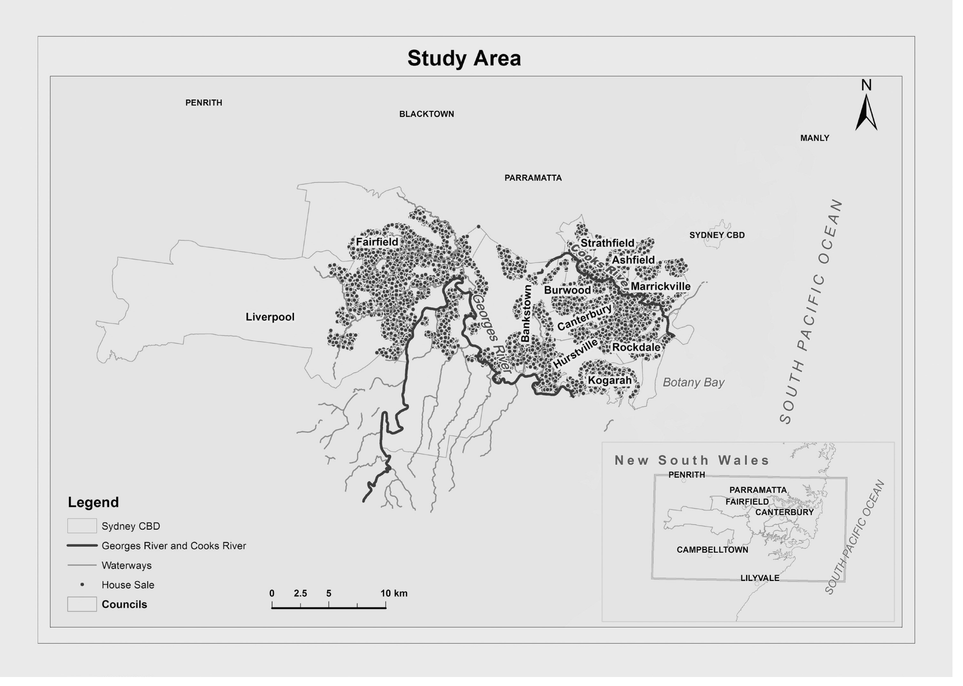

FIGURE 1 Georges River and Cooks River Catchments, Sydney, NSW, Australia. Data sources: Australian Bureau of Statistics, Geoscience Australia, & Greater Sydney Local Land Services. Disclaimer: Map produced for the River Health Project. While care was taken in the creation of this map, Charles Sturt University or its data suppliers cannot accept any responsibility for errors, omissions, or positional accuracy.

people (e.g., nature-based recreation, aesthetic views, birdwatching and urban cooling). The paper proceeds with a description of the study area, data and modelling, with results focused on the importance of vegetation *and* channel conditions as well as distance, before ending with some policy considerations.

2 | STUDY AREA

The study area covers 629 km^2 and comprises 11 councils or LGAs in the southern portion of Sydney, Australia.[1] It contains two main river catchments, the Cooks River and Georges River (Figure 1), and is characterised by high-density development closer to the Sydney Central Business District (CBD) (northeast of study area) and low-density suburban development further away from the CBD. The study area is made up of long time established neighbourhoods.

The Cooks River is in the inner southwest of the Sydney metropolitan area. Its catchment area covers 100 km^2, and the river's main stem begins as a small stream near Bankstown and flows 23 km in an easterly direction where it enters Botany Bay. Most streams in the Cooks River catchment have been substantially modified and native riparian vegetation cleared (Georges River Combined Councils' Committee, 2013). Many areas alongside the Cooks River support recreational activities through facilities such as cycle paths, riverside walkways, exercise stations, outdoor benches, parks, sports fields as well as pockets of native flora and fauna (Cooks River Alliance, 2014).

[1]The 11 Councils are: Ashfield, Bankstown, Burwood, Canterbury, Fairfield, Hurstville, Kogarah, Liverpool, Marrickville, Rockdale and Strathfield.

The Georges River catchment covers about 1000 km^2, and the river runs 96 km from the southwest of Sydney and meets the South Pacific Ocean at Botany Bay. Around half of the Georges River catchment remains natural, though it contains many tributaries that have undergone significant modification (Georges River Combined Councils' Committee, 2013). Our study focuses on metropolitan riparian conditions, and therefore, the upper reaches of the Georges River catchment (to the southwest of the Sydney CBD) are excluded.

3 | METHODS

3.1 | Hedonic price model

The hedonic pricing method is one of the dominant revealed preference methods that has been used to estimate non-market values for environmental resources. This method assumes that an individual's utility from a good is a function of the characteristics of that good. Empirical work on the hedonic pricing method for housing prices is based on Lancaster's (1966) seminal paper on consumer theory and Rosen's (1974) seminal paper on product differentiation. For this study, we use the commonly adopted model specification of the semi-log model for our initial ordinary least squares regression (Pandit et al., 2014; Plant et al., 2017; Tapsuwan et al., 2009). The base hedonic model specification for our study is:

$$\ln\left(Price_i\right) = \beta_0 + \Sigma\beta_1 S_{1i} + \Sigma\beta_2 N_{2i} + \Sigma\beta_3 L_{3i} + \Sigma\beta_4 LGA_{4i} + \Sigma\beta_5 Yr_{5i} + \Sigma\beta_6 VRC_{6i} + \varepsilon_i \quad (1)$$

where ln ($Price_i$) is a log of the selling price for the ith property in Australian dollars, β_s are regression coefficients, S_{1i} is a vector of structural characteristics, N_{2i} is a vector of neighbourhood characteristics, L_{3i} is a vector of property location characteristics, LGA_{4i} is a vector of council area dummy variables, Yr_{5i} is a vector of the year of property sale fixed effects, the VRC_{6i} are the waterway condition index variables (VRCs are described in Section 3.2), and ε is the error term.

The impact on property prices may decay with increasing distance away from the waterway (Bonetti et al., 2016; Lutzenhiser & Netusil, 2001; McCord et al., 2014). Thus, another model was analysed to account for the effect on distance from different VRC levels.

$$\ln\left(Price_i\right) = \beta_0 + \Sigma\beta_1 S_{1i} + \Sigma\beta_2 N_{2i} + \Sigma\beta_3 L_{3i} + \Sigma\beta_4 LGA_{4i} + \Sigma\beta_5 Yr_{5i} + \Sigma\beta_6 d * VRC_{6i} + \varepsilon_i \quad (2)$$

where d^*VRC_{6i} is the distance and VRC level interaction variable.

An ordinary least squares (OLS) regression with fixed effects LGA and sale year, LGA*sale year interaction variables, and robust standard errors adjusted for 1735 clusters in Statistical Area Level 1 (SA1) was used to gain insights about the spatial relationships and statistical differences between the six VRC levels. Robust standard errors were employed to account for heteroskedasticity in the model's unexplained variation (White, 1980), whereas the clustered robust standard errors were used to account for heteroscedasticity across the SA1 clusters (Cameron & Trivedi, 2010). The Breusch–Pagan (Breusch & Pagan, 1979) and Koenker–Bassett (Koenker & Bassett, 1982) tests indicated the presence of heteroscedasticity. Lagrange Multiplier (LM) tests, using the 4, 8 and 16 nearest neighbours' spatial weights matrices, indicated statistically significant spatial lag (LM_{lag}) and spatial error (LM_{err}) effects. This was confirmed by robust test statistics for spatial lag and spatial error (Anselin & Rey, 2014). However, the LM_{err} and robust LM_{err} test statistics were higher than the LM_{lag} and robust LM_{lag}, respectively, thus suggesting that spatial error dependence is more prominent in the data (Anselin & Rey, 2014; Boxall et al., 2005). Both spatial lag and spatial error models (SEMs) are estimated, with the latter being our preferred model. The spatial lag and SEMs may be formalised as:

$$\text{Spatial lag model}: p = \rho W\text{p} + X\beta + \varepsilon \text{ where } \rho W\text{p} \quad (3)$$

$$\text{Spatial error model}: p = X\beta + \varepsilon \text{ where } \varepsilon = \lambda W\varepsilon + \mu \quad (4)$$

where p is an $n \times 1$ vector of observations on the dependent variable, X is an $n \times k$ matrix of observations on explanatory variables, β is a $\text{k} \times 1$ vector of regression coefficients, W is an $n \times n$ spatial weights matrix, ρ is the spatial autoregressive coefficient, ε is an $n \times 1$ vector of independent and identically distributed (i.i.d.) error terms, μ is an $n \times 1$ random error term that is i.i.d., and λ is the spatial autoregressive coefficient.

3.2 | Data

3.2.1 | Vegetation and riparian condition index

The VRC index has six levels (VRC1 to VRC6), which are based on riparian buffer width, vegetation contiguity and the waterway channel modification. A higher index number represents a higher level of VRC for the waterway segment. The index data were supplied by the Sydney Metropolitan Catchment Management Authority (SMCMA) and were developed by ecologists using remotely sensed spatial data sourced from government departments and vetted through a series of 13 local land managers and community representatives in 2007 (Earth Tech, 2007).

Table 1 provides descriptions of the six-level VRC index. Channel modification status ranges from highly modified to unmodified. Riparian condition status ranges from little to no vegetation to extensive vegetation with continuous canopy. Figure 2 shows aerial images of VRC1 and VRC6 waterway segments. A total of 260 km of waterways were categorised into

TABLE 1 Classification of waterway characteristics using the vegetation and riparian condition (VRC) index.

VRC level	Channel condition	Vegetation condition	Percent of properties near each VRC level
VRC1	Highly modified channel	• Little to no buffer; • Little to no canopy; and • The number and frequency of road crossings is undefined.	35.3
VRC2	Modified channel	• Little to no buffer; • Discontinuous canopy; and • The number and frequency of road crossings is undefined.	14.4
VRC3	Modified channel	• Buffer greater than 10 m for 30% of length; • Discontinuous canopy; and • Road crossings >100 m apart.	7.8
VRC4	Unmodified channel	• Buffer greater than 10 m for 30% of length; • Weeds evident; • Discontinuous canopy; and • Road crossings occur at intervals of >500 m.	16.3
VRC5	Unmodified channel	• Buffer greater than 20 m for 70% of length; • Semi-continuous canopy; and • Road crossings no less than 500 m apart.	23.7
VRC6	Unmodified channel	• Buffer greater than 50 m for 70% of length; • Continuous canopy; and • Road crossings that are no less than 2 km apart.	2.5

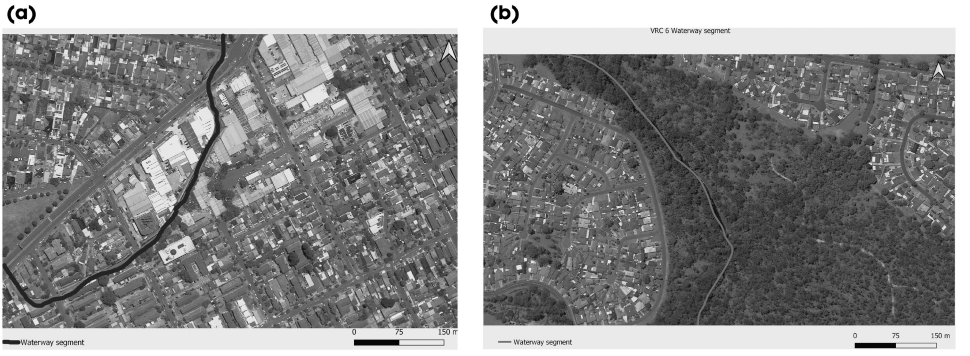

FIGURE 2 Aerial images of a VRC1 (a) waterway and a VRC6 (b) waterway in the study area.

the six VRC levels. Across all the six VRC levels, a higher proportion (35.3%) of the properties in our sample data were located closer to the lowest waterway health conditions (VRC1) and the least number (2.5%) of properties were found to be closest to the highest waterway health condition (VRC6).

3.2.2 | Property information

Our modelling was undertaken with an initial sample of 31,287 single-family property sale records and a final sample of 29,749 records. A summary of the continuous variables used in the hedonic model is provided in Table 2. Property price and structural data were obtained from CoreLogic RP Data for the period of January 2003 through December 2013. The data were cleaned to remove erroneous entries (e.g., commercial sales) and missing values (e.g., missing lot and structural characteristics). Potential non-arm's length transactions and outliers were removed by trimming the bottom and top 1% of the sample based on the selling price (Ham et al., 2012). Property prices were adjusted to 2013 dollars using the Australian Bureau of Statistics consumer price index (ABS, 2014b).

There was a high incidence of missing values for the age of the house variable (77%). This is not uncommon for Australian real estate data supplied by private data vendors (Plant et al., 2017). We imputed the missing values to avoid removing these property observations from the data and to retain house age as an explanatory variable. Given that the housing stock in urban neighbourhoods and suburbs tends to be built around the same time (Plant et al., 2017; Randolph & Freestone, 2012; Thompson, 2007), we calculated the average house age within each Statistical level 1 (SA1) unit. SA1 is defined by the Australian Bureau of Statistics as the smallest unit for processing and releasing Australian census data and has an average population of 400 people (ABS, 2014a). The calculated average house age at SA1 level was applied to properties with a missing age value. Other Australian studies have adopted an estimate of the suburb house age to fill missing house age data (e.g., Plant et al., 2017). Our approach is like the *k*-means clustering-based imputation, which uses an average from a portion of the data (Luengo et al., 2012; Rahman & Islam, 2015).

Digital elevation model data were sourced from the state of New South Wales Land and Property Information Office. These data were used to extract individual elevations above sea level for each property. The location of each property in the final data set is shown in Figure 1. Proximity of properties to location features was calculated using ESRI's ArcMap. The NSW Bureau of Crime Statistics and Research supplied property crime and violent

TABLE 2 Continuous variables definitions and summary statistics ($N=29{,}749$).

Variable	Definition	Mean	Standard deviation	Min	Max
Price (2013 $Au)	Sales price in 2013 Australian dollars	633,149	256,736	202,833	2,408,168
Age	Age of house at the time of sale (years)	49.57	27.10	0.34	212.34
Beds	Number of bedrooms	3.36	0.85	1.00	10.00
Baths	Number of bathrooms	1.55	0.71	1.00	6.00
Area	Area of land parcel (/100 m^2)	5.38	1.93	0.43	19.98
Elevation	Metres above sea level (/100 m)	0.30	0.16	0.01	0.91
Neighbourhood variables					
Children	Percentage of the population under 18 years	24.50	5.43	0.00	38.75
Pcrime	Previous year property offences per 1000 persons in a suburb	34.67	21.55	4.76	164.92
Vcrime	Previous year violent offences per 1000 persons in a suburb	9.43	5.80	0.00	49.54
Non-English	Non-English-speaking population (%) per SA1	33.89	12.43	0.00	76.40
Unemployed	Average unemployment rate (%) per SA1	6.83	4.24	0.00	38.95
Location variables					
CBD	Distance from Sydney Central Business District (km)	18.95	8.88	2.40	34.18
SchoolD	Distance from a school (km)	0.48	0.25	0.02	1.96
WaterwayD	Distance from a waterway (km)	0.51	0.27	0.00	1.00

offences data. Other neighbourhood data were sourced from the Australian Bureau of Statistics.[2]

Binary location variables represent the presence of selected characteristics within specified buffers around a property (Table 3). The sizes of the buffers vary by characteristic. For example, there were no properties located within 100 m of a beach and very few were located near a beach in the study area, so a 2.5 km buffer is used. In contrast, 100 m and 500 m buffers are used for bushlands as there were several properties located within these distance bands.

Each property was assigned a VRC level based on the condition of the closest waterway segment. The VRC condition was based on the assigned waterway condition for a 750 m

[2]Property offences comprise breaking and entering non-dwellings, motor vehicle theft, stealing from a motor vehicle or retail store, dwelling or person, stock theft and other theft and fraud. Violent offences comprise homicide, assault, sexual and robbery offences.

TABLE 3 Binary variable definitions and summary frequencies ($N = 29{,}749$).

Category	Description	Proportion of properties for category (%)
beach2500	Number of properties within 2.5 km of a beach	3.50
bush100	Number of properties within 100 m of a bushland	3.46
bush500	Number of properties between 100 m and 500 m from a bushland	22.38
hospit2500	Number of properties within 2.5 km of the hospital	48.73
indust500	Number of properties within 500 m of an industrial area	30.01
mroad100	Number of properties within 100 m from a major road	5.40
mroad500	Number of properties between 100 m and 500 m from a major road	26.31
railst100	Number of properties within 100 m from a train station	0.13
railst500	Number of properties between 100 m and 500 m from a train station	10.62
railst1000	Number of properties within 1 km from a train station	23.99
railway100	Number of properties within 100 m of a railway line	3.88
railway500	Number of properties between 100 m and 500 m from a railway line	20.50
wbody500	Number of properties within 500 m of a waterbody (e.g., lake, bay)	3.97
adjlot	Lots that are adjacent to the waterway corridor	5.08
Georges	Number of properties located in the Georges River catchment	64.95
Cooks	Number of properties located in the Cooks River catchment	35.05

segment. The 750 m length was derived from 375 m upstream and another 375 m from the downstream length. Distances between waterway segments and properties were measured using Euclidean distance, as has been done in other studies (e.g., Fernandez et al., 2018; Landry et al., 2022 and Towe et al., 2021). Properties that did not have a waterway segment within 1 km were excluded from the initial data collection, as hedonic studies typically show that the effects of proximate environmental amenities occur within 1 km distance (e.g., Bark et al., 2009; Colby & Wishart, 2002; Geoghegan et al., 1997; Jarrad et al., 2018; Kadish & Netusil, 2012; Polyakov et al., 2017; Sander & Haight, 2012 and Towe et al., 2021).[3] This implies that the impact of our modelled estimates will be for changes in the VRC index, but not for the presence or absence of waterways.

4 | RESULTS

We report results from six models with the same variable list but differing specifications for the model and VRC variables.

4.1 | Influence of vegetation and riparian condition

Initial modelling showed that there was no statistically significant difference between VRC2 and VRC3 coefficients and between VRC4 and VRC5 coefficients. Therefore, these four VRCs were combined to form two VRC levels, VRC2a = VRC2 + VRC3 observations

[3]For example, Colby and Wishart (2002) found that 75% of benefits accrued to properties located within 800 m of a riparian corridor.

and VRC3a = VRC4 + VRC5. The original VRC6 is now renamed to VRC4a in line with the new merged VRC levels. The test results revealed the presence of omitted variables bias within the models. To mitigate this bias, we took measures by incorporating fixed effects for LGAs and the year of sale in all subsequent models. This approach serves to control for unobserved variables that exhibit variation across LGAs and sale years. Furthermore, we implemented robust standard errors adjusted for 1735 clusters at the SA1. This adjustment accounts for the clustering effect at the SA1 level, enhancing the robustness of the estimated results.

Our Model 1 is an OLS model with fixed effects LGA and sale year, LGA × sale year interaction variables, and robust standard errors adjusted for 1735 clusters in SA1, and it includes VRC binary variables without considering the effect of distance away from the waterway. Model 2 and Model 3 are a SEM and a spatial lag model based on the same variables used in Model 1. Models 4–6, are OLS, error model and spatial lag, respectively but these have distance–VRC interaction variables based on the distance between properties and waterways. Our results for the first three models are presented in Table 4. The explanatory power of the spatial models is higher than the OLS, as shown by the higher adjusted R^2 and lower akaike information criterion test statistics values. The SEM had higher explanatory power and is therefore referenced to explain the effect of independent variables on property selling prices.

The regression results indicate that more bedrooms, more bathrooms, larger land parcels and newer houses contribute positively to the selling price of a property, as expected. Property prices are lower in areas with higher numbers of children and those areas with a higher unemployment rate. Property prices closer to the CBD and those closer to waterways command a price premium. Reported neighbourhood violent crime has a significant negative effect on property prices. However, property offences are higher in neighbourhoods with higher property prices. These findings are similar to those of Li and Saphores (2012) and Lynch and Rasmussen (2001).[4]

Table 5 provides the estimated implicit marginal effects for Models 1 to 3. The regression results for our variables of interest, the VRC levels, are compared with a property nearby a waterway with VRC1 characteristics. Given that the VRC levels are dummy variables, the relative implicit marginal effect of the VRC levels from the OLS and SEM models were calculated using the formula $(\exp^{\beta}-1)*100$, as per Halvorsen and Palmquist (1980). The total effect on the dependent variable from the spatial lag model consists of two parts, the direct effect βi and the indirect effects driven by the spatial multiplier, $\beta i\ (1-\rho)$ (Anselin & Rey, 2014).

Modelling results indicate that homebuyers were willing to pay 2.74% more for a property nearby VRC2a characteristics or the equivalent of AU$15,711 at the median property price of AU$573,378. Homebuyers were willing to pay 5.47% more for a property nearby waterway characteristics, corresponding to VRC3a, and 8.51 for VRC5 characteristics. These results indicate that buyers generally have a preference for higher quality VRC.

4.2 | Assessment of distance decay

Models 4 to 6 were used to estimate the effect size and statistical significance of VRCs on property prices based on four distance bands: adjacent to the waterway (*AdjVRCi*), at less than 100 m but not adjacent to the waterway (*d100VRCi*), equal or greater than 100 m but less than

[4]A possible explanation is that people living in more wealthy areas are likely to report more petty crimes than those in poorer areas (Lynch & Rasmussen, 2001). Another explanation is that criminals are more likely to steal in wealthier neighbourhoods with higher valued items.

TABLE 4 OLS and spatial regression results ($N = 29{,}749$).

Variable	Model 1—OLS	Model 2—SEM	Model 3—Spatial lag
Beds	0.0781*** (0.0014)	0.0722*** (0.0012)	0.0740*** (0.0013)
Baths	0.1063*** (0.0016)	0.0927*** (0.0015)	0.0958*** (0.0015)
Area	0.0392*** (0.0006)	0.0409*** (0.0006)	0.0343*** (0.0005)
Age	−0.0016*** (0.0001)	−0.0016*** (0.0001)	−0.0010*** (0.0001)
Elevation	0.1120*** (0.009)	0.1427*** (0.0141)	0.0574*** (0.0083)
Pcrime	0.0009*** (0.0001)	0.0003*** (0.0001)	0.0005*** (0.0001)
Vcrime	−0.0101*** (0.0003)	−0.0067*** (0.0004)	−0.0061*** (0.0003)
Children	−0.0017*** (0.0002)	−0.0014*** (0.0004)	−0.0012*** (0.0002)
Non-English	0.0001 (0.0001)	0.0003 *** (0.0002)	−0.0001 (0.0001)
Unemployed	−0.0087*** (0.0003)	−0.0087*** (0.0004)	−0.0051*** (0.0003)
CBD	−0.0151*** (0.0006)	−0.0164*** (0.0009)	−0.0101*** (0.0005)
SchoolD	0.0321*** (0.004)	0.0421*** (0.0065)	0.0105*** (0.0037)
StreamD	−0.0185*** (0.0039)	−0.0171*** (0.0063)	−0.0143*** (0.0036)
VRC2a	0.0319*** (0.0032)	0.0270*** (0.005)	0.0204*** (0.0029)
VRC3a	0.0565*** (0.0033)	0.0533*** (0.0053)	0.0338*** (0.0031)
VRC4a	0.0802*** (0.0068)	0.0817*** (0.0105)	0.0497*** (0.0062)
λ		0.4627*** (0.006)	
ρ			0.3465*** (0.0049)
Adjusted R^2	82.15%	84.79%	84.71%
Akaike information criterion	−26,466	−26,482	−26,466

Note: *Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level.

TABLE 5 Estimated implicit marginal effects.

			Model 3—Spatial lag (%)		
Variable	Model 1—OLS (%)	Model 2—SEM (%)	Direct effect	Indirect effect	Total effect
Beds	8.12	7.49	7.61	3.70	11.32
Baths	11.22	9.71	9.86	4.80	14.66
Area	4.00	4.17	3.53	1.72	5.24
Age	−0.16	−0.16	−0.11	−0.05	−0.16
Elevation	11.85	15.34	5.91	2.87	8.78
Pcrime	0.09	0.03	0.06	0.03	0.08
Vcrime	−1.00	−0.67	−0.62	−0.30	−0.93
Children	−0.17	−0.14	−0.12	−0.06	−0.19
Non-English	0.01	0.03	−0.01	−0.01	−0.02
Unemployed	−0.87	−0.87	−0.52	−0.25	−0.77
CBD	−1.50	−1.63	−1.04	−0.51	−1.55
SchoolD	3.26	4.30	1.09	0.53	1.61
WaterwayaD	−1.83	−1.70	−1.47	−0.71	−2.18
VRC2a	3.24	2.74	2.10	1.02	3.12
VRC3a	5.81	5.47	3.48	1.69	5.18
VRC4a	8.35	8.51	5.12	2.49	7.60

500 m (*d500VRCi*) and those located 500 m or greater from the waterway (*d501VRCi*). Each of the VRC variables interacted with these four distance bands.

Our OLS and spatial regression results in Table 6 show that all VRC2a coefficient estimates are positive and significant, indicating that the VRC2a waterway segments are preferred more than VRC1 segments at the different distance categories. As per the SEM model, the effect on price from proximity to the VRC2a segments, properties that are located between 100 and 500 m command a higher premium than those at distances of less than 100 m (including those adjacent), or greater than 500 m from the waterway. Thus, the distance and VRC2a interaction coefficients indicate a distance-decay pattern from 100 to 1000 m and an aversion for being too close (i.e. adjacent to the waterway). A similar pattern was estimated for VRC3a, but the differences in magnitude at the different distances were less than those of VRC2a (See Figure 3). For

TABLE 6 OLS and spatial regression results ($N=29{,}749$).

Variable	Model 4 —OLS	Model 5—SEM	Model 6—Spatial lag
Beds	0.0780*** (0.0014)	0.0722*** (0.0012)	0.0738*** (0.0013)
Baths	0.1063*** (0.0016)	0.0927*** (0.0015)	0.0958*** (0.0015)
Area	0.0391*** (0.0006)	0.0409*** (0.0006)	0.0342*** (0.0005)
Age	−0.0016*** (0.0001)	−0.0016*** (0.0001)	−0.0010*** (0.0001)
Elevation	0.1196*** (0.0090)	0.1470*** (0.0141)	0.0652*** (0.0083)
Pcrime	0.0010*** (0.0001)	0.0003*** (0.0001)	0.0005*** (0.0001)
Vcrime	−0.0101*** (0.0003)	−0.0068*** (0.0004)	−0.0060*** (0.0003)
Children	−0.0017*** (0.0002)	−0.0014*** (0.0004)	−0.0011*** (0.0002)
Non-English	0.0001 (0.0001)	0.0003* (0.0002)	−0.0001 (0.0001)
Unemployed	−0.0087*** (0.0003)	−0.0088*** (0.0004)	−0.0051*** (0.0003)
CBD	−0.0151*** (0.0006)	−0.0165*** (0.0009)	−0.0101*** (0.0005)
SchoolD	0.0298*** (0.0040)	0.0402*** (0.0065)	0.0086** (0.0037)
StreamD	−0.0114* (0.0051)	−0.0117 (0.0078)	−0.0100** (0.0047)
AdjVRC2a	0.0278** (0.0097)	0.0211** (0.0108)	0.0126 (0.0088)
d100VRC2a	0.0477*** (0.0125)	0.0471*** (0.0133)	0.0352*** (0.0114)
d500VRC2a	0.0405*** (0.0040)	0.0323*** (0.0059)	0.0250*** (0.0036)
d501VRC2a	0.0182*** (0.0036)	0.0141** (0.0055)	0.0118*** (0.0033)
AdjVRC3a	0.0545*** (0.0063)	0.0490*** (0.0077)	0.0277*** (0.0058)
d100VRC3a	0.0502*** (0.0112)	0.0602*** (0.0121)	0.0358*** (0.0102)
d500VRC3a	0.0570*** (0.0037)	0.0539*** (0.0056)	0.0325*** (0.0034)
d501VRC3a	0.0564*** (0.0037)	0.0543*** (0.0056)	0.0315*** (0.0034)
AdjVRC 4a	0.1236*** (0.0200)	0.1204*** (0.0218)	0.0863*** (0.0183)
d100VRC4a	0.1128 (0.0895)	0.0986 (0.0857)	0.0723 (0.0818)
d500VRC4a	0.0762*** (0.0096)	0.0723*** (0.0138)	0.0471*** (0.0087)
d501VRC4a	0.0777*** (0.0089)	0.0770*** (0.0134)	0.0495*** (0.0081)
λ		0.4630*** (0.0060)	
ρ			0.3457*** (0.0049)
Adjusted R^2	82.15%	84.78%	84.70%
Akaike information criterion	−26,482	−26,466	−26,466

Note: λ is the spatial error parameter and k = number of nearest neighbours. *Significant at the 10% level, ** Significant at the 5% level, *** Significant at the 1% level.

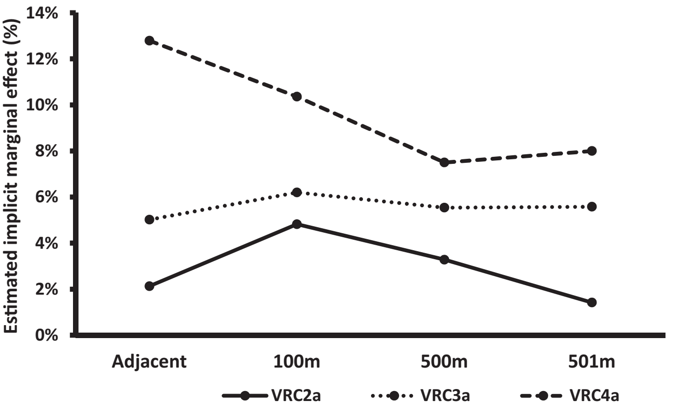

FIGURE 3 Illustration of the effect of vegetation and riparian conditions at different distances.

VRC4a, property buyers are willing to pay more with decreasing distances from the waterway segment; that is, there is a distance-decay function from adjacent properties through to those located up to 500 m, after which there is a slight increase (the d100VRC4a was not significant across all three models). These findings provide some evidence that the VRC effect will differ with distance from the waterway. Overall, the distance–VRC interaction coefficients indicate that for lower-ranked waterway conditions (VRC2a and VRC3a), there is a relative aversion to being adjacent to waterways. However, there is a preference for being located adjacent to waterways with highly ranked waterway conditions (VRC4a).

5 | CONCLUSIONS

Our findings indicate that buyers have a positive willingness to pay for higher quality urban riparian vegetation and channel conditions. While previous work has demonstrated the value of riparian vegetation in urban contexts, these studies have focused solely on the condition of riparian vegetation and not on the condition of the buffer and channel. This is despite the inclusion of buffers and channels as fundamental components of ecological indices of catchment and riparian conditions (Brierley et al., 2002; Findlay et al., 2011; Kleynhans, 1996; USDA, 2011). Our findings demonstrate that ecologist-developed indices that rely on relevant indicators that are perceived by buyers can be employed in non-market valuation studies to estimate the implied premiums for different quality levels.

This is of practical importance, as environmental managers establishing restoration priorities and justifying expenditure through the application of cost–benefit analysis will be required to identify the economic value of achieving changes in ecological indicators of waterway health. Access to estimates of the economic values of ecological indicators would be expected to substantively simplify this process, as it means that links between secondary indicators commonly used in hedonic pricing studies (such as improved fish habitat, or connected vegetation) do not need to be mapped to the different ecological conditions. Moreover, the analysis is less reductionist and includes a fuller picture of the various ecological conditions rather than only focusing on a narrow set of variables to represent environmental quality, which may also be a source of omitted variable bias.

There was evidence that households were prepared to pay significant premiums to avoid being located near highly modified channels with little or no vegetation (e.g., VRC2a vs VRC1). This implies that there are large gains to be realised from removing concrete-lined channels and replacing them with stones for banks, or re-creating unmodified channels, even if there is only limited scope for increasing vegetation. This implication is aligned with the recommendation of Davies et al. (2011) that traditional concrete channels should be removed and replaced with more environmentally appropriate solutions. However, while the value of removing concrete banks and improving channel conditions is high, the costs of such works may also be high, highlighting the need to identify benefit–cost ratios for each of these potential changes.

Generally, there was an aversion to being located adjacent to VRC2a, and VRC3a compared with a further distance away (though noting that these are preferred to VRC1). A declining distance-decay pattern was observed particularly for properties located further than 500 m—this was observed for all VRC2a and VRC3a. Based on the results for VRC2a and VRC3a, the coefficients of the distance–VRC interaction variables indicate a relatively high preference for being located within 500 m but not adjacent to the waterway segments.

These implicit marginal effects from the distance-VRC estimates indicate that monotonically declining distance functions cannot be assumed in all instances and that there is evidence across multiple VRCs of an optimal distance from the waterway (and not always being adjacent to the river), whereafter values decline. The estimated preference patterns reflect past studies on the effect of distance from urban environmental assets. For example, Lutzenhiser and Netusil (2001) found a mixed distance effect, with a general decay in effect but the highest effect being on non-adjacent properties. Similarly, Bonetti et al. (2016) found an aversion for proximity to streams with poor quality streams and a preference for proximity to canals with better water quality, while McCord et al. (2014) found an initial increase in effect with increased distance followed by a decrease in effect for detached properties located further than 500 m.

The findings suggest that policymakers should involve land developers in urban areas to recognise the value of healthy VRCs. For greenfield developments, the results indicate that land developers could preserve natural riparian areas within their development estates and compensate for potential revenue loss by selling at a premium. In Australia, the responsibility for managing urban natural environments lies with governments and government agencies, which regularly invest in revegetation and stream renaturalisation works (e.g., Polyakov et al., 2017). Therefore, for brownfield development, there is an opportunity for the government to engage in negotiations for co-funding improvement works (such as through a levy paid by local landowners), considering that the renaturalisation efforts can provide substantial benefits to those who own these properties separate from what is enjoyed by the broader public. However, it is noted that there are likely to be contextual factors to consider, including the history and causes of degradation, perceived property rights and community socio-demographic profile and consequent ability to pay.

Overall, the findings from this study indicate that there is an opportunity for land managers to partner with ecologists and developers in the preservation and restoration of urban waterways and riparian corridors. Such a partnership has important and mutually beneficial outcomes for the resilience of urban environmental assets while supporting the preferences of urban residential communities. The indices developed by ecologists provide a way for policymakers and ecologists to enhance the design of restoration works but it is important that the use of such indices is augmented by information about community preferences. For example, while residents value trees, it is also important to ensure that the bank channel is restored.

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CONFLICT OF INTEREST STATEMENT

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study cannot be shared with any third party due to a confidentiality agreement between the authors' institution and the data vendor, CoreLogic (www.corelogic.com.au/). Data requests should be addressed to CoreLogic.

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