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Capitalized amenity value of urban wetlands: a hedonic property price approach to urban wetlands in Perth, Western Australia*

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Up to 60 per cent of potable water supplied to Perth, Western Australia, is extracted from the groundwater system that lies below the northern part of the metropolitan area. Many of the urban wetlands are groundwater-dependent and excessive groundwater extraction and climate change have resulted in a decline in water levels in the wetlands. In order to inform decisions on conserving existing urban wetlands, it is beneficial to be able to estimate the economic value of the urban wetlands. Applying the Hedonic Property Price approach to value urban wetlands, we found that distance to the nearest wetland and the number of wetlands within 1.5 km of a property significantly influence house sales price. For a property that is 943 m away from the nearest wetland, which is the average distance to the wetland in this study, reducing the wetland distance by 1 m will increase the property price by AU$42.40. Similarly, the existence of an additional wetland within 1.5 km of the property will increase the sales price by AU$6976. For a randomly selected wetland, assuming a 20 ha isolated circular wetland surrounded by uniform density housing, the total sales premium to surrounding properties was estimated to be around AU$140 million (AU$40 million and AU$230 million).

Key words: groundwater, hedonic, marginal implicit price, property price, revealed preference.

1. Introduction

The northern Perth metropolitan and peri-urban areas are situated on a vast underground water resource known as the Gnangara Groundwater System. The groundwater system provides the majority of water used for consumptive purposes in the urban area as well as significant environmental amenity in the

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form of lakes and wetlands. A chain of wetlands extends north–south along the Swan Coastal Plain, providing many valuable services such as the protection of water quality in rivers and streams, flood control and storm water detention and habitat for wildlife as well as recreational and landscape amenities. Most of the urban wetlands are appreciated for their aesthetic qualities and other indirect uses because their ecological functions '*have been severely altered to the extent that they now bear little resemblance to their original ecological state*' (Environmental Protection Authority 2006). However, despite their altered state, people may still hold existence, bequest and options values for these wetlands.

At least 80 per cent of all of the wetlands that were once present on the Swan Coastal Plain prior to European settlement have been cleared, filled or developed (WA Department of Environment and Conservation 2008). The drying climate experienced over the past 30 years has led to increased pressure on the aquifer as a source of supplementary water supply for garden irrigation. A 40 per cent reduction in mean run-off into surface water storages has led to outdoor water restrictions for scheme water use, resulting in an increased demand for sinking backyard bores for garden irrigation. As wetland water levels are reflections of the groundwater level, any lowering of the groundwater will potentially impact wetlands (Lund 1995). Excessive extraction of groundwater will result in further decline of water levels of wetlands above the groundwater system. If the trend continues, there is an increased likelihood that the presently unlicensed and unmetered backyard bore use may conflict with the management of urban groundwater levels and wetlands, which may result in a loss of urban wetland amenity value.

These management issues highlight the need for a better understanding of the economic value of maintaining wetlands in both the peri-urban and urban areas. The value of urban wetlands will be useful to policy makers dealing with water use conflicts between maintaining amenity value and consumptive demand for bore water, as well as for the purpose of evaluating supplementary pumping into wetlands and artificial lakes to preserve aesthetic values.

Previous valuation studies of wetlands have come up with a wide range of estimates, in part because of differences in the wetland attributes that are valued and also of differences in methodology (Boyer and Polasky 2004)[1]. The RAMSAR Convention Bureau (Barbier *et al.* 1997) reviewed various economic techniques available for valuing wetlands, in order to provide guidance to policy makers and planners on the potential for economic valuation of wetlands and how such valuation studies should be conducted. One technique introduced by RAMSAR to value environmental amenities that are not sold in the market and do not have direct market value is the hedonic pricing method.

[1] There have been a few meta-analysis studies of wetland values (see Brouwer *et al.* 1999; Boyer and Polasky 2004; Brander *et al.* 2006).

The hedonic pricing method is based on the idea that properties are not homogenous; they differ in respect to a variety of characteristics such as number of bedrooms, bathrooms, lot size, proximity to parks and schools. Property prices can be affected by all these location-specific environmental, structural and neighbourhood characteristics. The method relies on observable market transactions, for instance, property sales data, to place values upon the various characteristics that make up a heterogeneous product (Boxall *et al.* 2005). The hedonic approach can be used to value wetlands as prices of properties near wetlands contain a capitalized amenity value for wetland proximity, so that when the properties are sold, the new buyers have to pay for this amenity value in the form of higher house prices (Loomis and Feldman 2003)[2].

Boyer and Polasky (2004) discussed three studies in the United States that have applied the hedonic method to estimate the value of urban wetlands to nearby properties (Lupi *et al.* 1991; Doss and Taff 1996; Mahan *et al.* 2000). These studies found a significant relationship between sales prices and proximity to wetlands as well as sales prices and size of wetland. Lupi *et al.* (1991) estimated a US$19 increase in property prices if the wetland area increased by 1 ha in Ramsey County, Minnesota. Mahan *et al.* (2000) conducted a study in Portland, Oregon, and found that increasing the size of the nearest wetland by 1 acre increased the residence's value by US$24. They also found that reducing the distance to the nearest wetland by 1000 ft increased the value by US$436. Doss and Taff (1996) studied the effects of proximity to different types of wetlands that are within 1 km of the properties on their prices. They found that the implicit price is positive at the mean distance: moving an additional 10 m towards an emergent-vegetation wetland increases house value by US$136, towards open-water wetlands by US$99 and towards scrub-shrub wetlands by US$145.

Other non-market valuation techniques, such as stated preference, have also been applied to value urban wetlands, which attempt to capture both the private amenity value and social use and non-use values. Gerrans (1994) conducted a survey to value the Jandakot wetlands in Perth, Western Australia. He used double-bounded dichotomous choice contingent valuation and found the average household willingness-to-pay for conservation of the wetlands was AU$31.15 per annum. Streever *et al.* (1998) estimated the willingness-to-pay value and examined attitudes towards wetland conservation in New South Wales. Respondents to a questionnaire survey indicated a median willingness-to-pay of AU$100 per household per year for 5 years. Morrison *et al.* (1999) used a choice modelling approach to estimate the non-use environmental values provided by the Macquarie Marshes, a major wetland in

[2] The important assumption is that the individuals have information on all alternatives and must be free to choose a house anywhere in the market (Freeman 2003). The model also assumes that the housing market is in equilibrium, individuals have made their utility-maximizing choices given the prices of alternative housing locations and these prices just clear the market (Freeman 2003).

New South Wales. They found that households were willing to pay AU$0.05 for an extra square kilometre of wetland area. More recently, Whitten and Bennett (2004) applied choice modelling to estimate the social values generated by an array of alternative privately owned wetland management options in the Murrumbidgee River Floodplain (MRF) in New South Wales. On average, respondents to the MRF questionnaire were willing to pay a once-off figure of AU$11.39 per household for an extra 1000 ha of healthy wetlands.

The disadvantage of using stated preference techniques is that the estimated value of environmental amenities is based on a hypothetical market scenario; therefore, the findings are generally open to criticism, particularly when it comes to comparing the hypothetical value to actual willingness-to-pay. The hedonic property price approach, on the contrary, is based on real market transactions that have occurred in a real market setting and therefore could overcome hypothetical bias. Nonetheless, urban wetlands have both public and private use and the hedonic method may not fully capture the public service component of wetlands as this value presumably cannot be fully reflected through property market prices. One of the key considerations in choosing which non-market valuation technique to use is therefore the extent to which amenity (or direct use) values are likely to be the main driver of social values. In this case study, we focus on wetlands in the Perth metropolitan area, which are significantly modified compared with the more natural wetlands of the peri-urban area. Although they may conceivably still have non-use values associated with them (for example, they support various flora and fauna including migratory birds, and there may be heritage, existence and bequest values), the main value is thought to be their recreational and visual amenity. For this reason, and to avoid the problems of hypothetical bias associated with stated preference techniques, we have used the hedonic property price approach. To the authors' knowledge, this is the first paper to apply the hedonic property price approach to estimate the value of urban wetlands in Australia.

2. Study area

Figure 1 shows the study area, including the locations of the wetlands and the properties sold during the study period, July 2005 to June 2006. The study area extends approximately 13 km north–south and 9 km east-west, covering an area of around 86 km^2 north of the Swan River. Most of the area is relatively flat, but there is a line of low hills paralleling the coast about 2–3 km inland. This area was chosen as the study site for a number of reasons. First, there are 32 wetlands inside or within a 2 km buffer around the study area that range in size from 0.3 to 329 ha. Some of the wetlands are natural and retain some of their original character, whereas others are man-made or extensively modified.

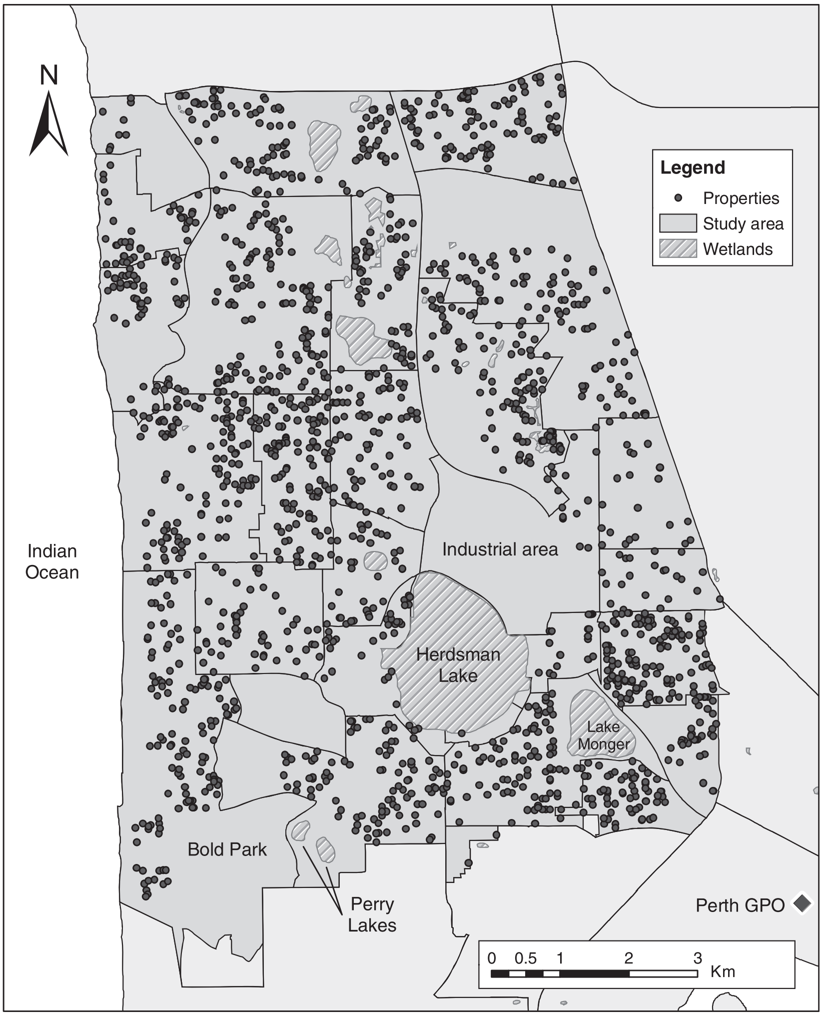

Figure 1 The study area, showing the location of properties sold during the study period, wetlands and suburb boundaries.

Secondly, the study area includes 26 suburbs that range from affluent beachside suburbs popular with both locals and tourists to inner urban suburbs in the southeast corner and to some less affluent areas in the northeast. Thirdly, there is a mixture of land uses: residential, light industrial and commercial. The light industrial area is located directly north of Herdsman Lake, the largest wetland in the study area. Fourthly, there is a large parkland/nature reserve, named Bold Park, that lies to the west of the Perry Lakes, which represents the neighbourhood 'green space'. There is also a major freeway that passes through the study area, running approximately from the city centre (near the Perth GPO) to just east of the chain of wetlands on the northern boundary of the study area. Finally, in and around the study area, there are other amenities such as golf courses, large shopping centres and places of tertiary education and numerous small parks and reserves.

3. Hedonic property price function

The general specification of the hedonic property price regression equation is:

$$\ln(ADJSALE_i) = \beta_0 + \sum \beta_j S_{ji} + \sum \beta_k N_{ki} + \sum \beta_l W_{li} + \sum \beta_m SUB_{mi} + \varepsilon_i \quad (1)$$

for $i = 1, 2, \ldots, n$ and where ln ($ADJSALE_i$) is the natural logarithm of the sales price of house i, β are the various regression coefficients, S_{ji} is the j^{th} structural variable for house i, N_{ki} is the k^{th} neighbourhood variable for house i, W_{li} is the l^{th} wetland variable for house i, SUB_{mi} is the suburb dummy m for house i, ε_i is the error term for house i, with $E(\varepsilon) = 0$ and $V(\varepsilon) = \sigma^2 > 0$.

The dependent variable is the actual recorded sales price. Because of recent exponential demand for houses in the Perth metropolitan area arising from the mining boom in Western Australia, the Perth property market has experienced significant growth over a short period of time. To adjust for market growth over time, sale prices in this study were adjusted by the market growth index from Landgate to a June 2006 value[3]. The average adjusted sales price was AU$794 922. Actual sales prices are preferred over other forms of prices such as assessed, appraised, or census tract estimates because actual sales closely reflect the equilibrium market price (Mahan *et al.* 2000).

For each property sale, there is a set of attributes associated with the property that help to explain the sales price. We have classified the attributes into structural, neighbourhood and wetland categories as seen in Table 1. Note that we have included in this table only those variables that were found to have a significant effect on sales price, and that suburb dummy variables were not listed.

4. Data sources

There are essentially two types of data used in this study, namely geospatial data and property sales data. The geospatial data consist of point data (centroids) for the properties sold and points of interest, such as schools, shopping centres and parks; line data for the coastline; polygon data for the wetland and suburb boundaries; and digital elevation data. The wetland data were

[3] Except for the suburbs of Jolimont and Leederville, for which Landgate growth index data were unavailable. For these suburbs, the market growth index from the Real Estate Institute of Western Australia (Real Estate Institute of Western Australia 2006) was used to make the adjustment.

Table 1 Model variables with their descriptions and statistics, excluding suburb dummy variables

Variable	Description	Mean	SD	Min	Max
Dependent variable					
ADJSALE	House sales price in AU$ adjusted to June 2006 value	794 922	418 156	95 130	4 960 857
Structural attributes					
AREA	Total land area or lot size in square metres	704	279	91	8498
BED	Number of bedrooms	3.16	0.85	1	6
BATH	Number of bathrooms	1.45	0.65	1	5
STUDY	Number of studies	0.21	0.42	0	2
CARPARK	Number of parking spaces in garage or carport	0.65	0.78	0	4
DINING	Number of dining rooms	0.64	0.49	0	2
GAME	Number of games rooms	0.15	0.36	0	2
AGE	Age of the house in years	39.42	22.26	1	106
ROOF	Dummy variable for tiled roofing (1 if tiled, 0 otherwise)	0.84	0.37	0	1
Neighbourhood attributes					
DBEACH	Distance in metres to beach	4074.76	2402.60	93.80	8667.50
DCITY	Distance in metres to city GPO	8828.44	3131.24	2064.90	15 309.70
DFWY	Distance in metres to nearest freeway entrance	2197.48	1431.26	117	7164.60
ELEV	Elevation of property above sea level in metres AHD	26.14	12.18	4.30	71.40
Wetland attributes					
DWETLAND	Distance in metres to the edge of the wetland nearest the property	943.35	637.27	2.30	3244.90
NUMWET	Number of wetlands within close proximity to the property	2.37	2.36	0	12

obtained from the WA Department of Water, and the other spatial data from Landgate, the WA government agency responsible for property and land information. The property sales data consist of the property sales price and characteristics of the property, such as land area, and the number of bedrooms and bathrooms. These data were also acquired from Landgate. Summary statistics for the variables used in the study are presented in Table 1. Note that this study considered only the sale of free-standing houses with land; data on units, villas, apartments, retirement villages and vacant land were excluded from the analysis as they were not detailed enough to permit a reliable hedonic analysis.

The ArcInfo geographic information system (GIS) and Matlab were employed to process the spatial data for the hedonic model. The distance to the nearest wetland was defined as the distance measured from the centroid of the property lot to the edge of the nearest wetland. Distance to points of interest, such as neighbourhood parks, train stations, shops and golf courses, were calculated using the distance measured from the centroid of the property lot to the centroid of the point of interest, instead of the edge. This is because cadastral information was not obtained at the time because of financial constraints. Distance and other spatial data forming the neighbourhood and wetland attributes for each property were attached to the property sales record.

The explanatory variables were checked for missing observations or unrealistic values, such as houses with zero bedrooms or bathrooms, and sales values that were unusually high or low. A total of $n = 1741$ observations of house sales were used for the analysis.

5. Estimation method

A step-wise regression approach was used to select variables with statistical significance and variance inflation factor of less than 10. The approach is iterative and starts with an initial list of candidate explanatory variables in linear form on the right hand side of Equation (1). The right hand side is then modified in several ways: excluding variables found not to have a significant effect on the sales price, including additional candidate variables and testing them for significance and modifying the functional form of the explanatory variables. Different functional forms are suggested by inspecting scatter plots of the variables and reviewing equation forms used in previous hedonic studies.

During the regression development, a larger set of structural, neighbourhood and wetland attributes than those listed in Table 1 was included in the intermediate models. Structural attributes such as the type of wall material and numbers of family rooms, meal areas and tennis courts were not significant. Neighbourhood variables capturing the closest distance to different classes of points of interests, namely schools, TAFEs and universities, parks, golf courses, train stations and commercial areas, were likewise dropped from the model as they were found to be insignificant. Distance to train stations and freeway entrances were highly collinear and in the end were collapsed into one variable (*DFWY*) as most train stations in the study area are at the same location as freeway entrances. This is due to the nature of the infrastructure design in the northern suburbs of Perth, where train lines run in between the two sides of the freeway.

Several additional wetland attributes were also considered for inclusion in Equation (1). For instance, the distances to two iconic local lakes, Herdsman Lake and Lake Monger (Figure 1), were included in the model to determine whether there is any preference to live near these two particular lakes. It was found that these variables were not significant, and hence they were dropped.

Similarly, the size of the nearest wetland in hectares was also in an earlier version of the model, but this variable was also dropped as the variable was not statistically significant.

In the final form of the hedonic pricing function, most right-hand side variables appear in a linear form, but there are some exceptions. Land area (*AREA*) appears as both linear and squared terms. The number of bedrooms (*BED*) and elevation (*ELEV*) appears only as squared terms, as the linear terms were not statistically significant. It is helpful to define additional variables that reflect these dependencies: $AREA2 = AREA^2$, $BED2 = BED^2$ and $ELEV2 = ELEV^2$. The distance to the beach (*DBEACH*) and the nearest wetland was found to have a different functional form as discussed below.

The theoretical expectation for *DBEACH* is that a property very close to the beach will have a much higher sales price than a property slightly further away. Consider two properties, one with beach frontage and view, and its rear neighbour that has neither. Intuitively, one would expect the beach front property to have a higher premium for being closer to the beach and having the view compared with the property behind. This indicates a significant drop in marginal sales value for being further away from the beach or a steep downward sloping curve for *DBEACH*. However, for properties that are further away from the beach, for example, properties that are 1 km away, the premium of being close to the beach no longer varies significantly from property to property. This indicates a more gentle downward sloping curve. Hence, a suitable functional form would have an inverse relationship between *ADJSALE* and *DBEACH* with a varying slope. By observing the data, the most suitable functional form uses both linear and inverse power law terms:

$$\ln(ADJSALE_i) = \ldots + \beta_{DBEACH} \times DBEACH_i + \beta_{INVBCH} \times \frac{1}{DBEACH_i^{\gamma}} + \ldots \quad (2)$$

This form of *DBEACH* dependence allows ln(*ADJSALE*) to diminish with distance quite rapidly when close to the beach and to decrease at a slower rate when further away. The exponent γ was found by running a series of regressions in STATA using do loops for different values of γ. The value of γ that gave the smallest root mean square error was chosen. The best fit occurred for $\gamma = 0.48$. For convenience, a new variable $INVBCH = 1/(BEACH^{\gamma})$ was defined, so that Equation (2) becomes linear in *DBEACH* and *INVBCH*.

The theoretical motivation for *DBEACH* also applies for distance to the wetlands (*DWETLAND*). The shifted inverse relationship provides a gradual downward sloping curve suited to our *a priori* expectation that as distance to wetland increases, property price decreases but at a slower rate. Therefore, the most suitable form for *DWETLAND* was found to be:

$$\ln(ADJSALE_i) = \ldots + \beta_{DWETLAND} \times DWETLAND_i + \beta_{INVWET} \times \frac{1}{\alpha + DWETLAND_i} + \ldots. \quad (3)$$

A non-zero value of α in Equation (3) allows the curve to intersect the y-axis instead of increasing to infinity, that is, ln($ADJSALE$) remains bounded as $DWETLAND$ approaches zero. The curve showed best fit at $\alpha = 275$. The values of α and γ were determined concurrently using nested do loops. As above, it is convenient to define a new variable $INVWET = 1/(\alpha + DWETLAND)$, and then Equation (3) becomes linear in $DWETLAND$ and $INVWET$.

The model was tested for neighbourhood fixed-effect and it was found that the model displayed a suburb effect. This occurs when premium sales prices are attached to suburb names or the 'feel' of the suburb, such as Wembley Downs, being known as the 'soccer mum' suburb, because it is popular with young, affluent families with children. It is also expected that suburbs with or adjacent to wetlands would exhibit a premium compared with suburbs that are further away from wetlands.

A total of 25 dummy variables representing each suburb in the data set were created to capture the qualities of the suburbs that are attached to the suburb itself and that are not represented by the structural, neighbourhood and wetland variables. It is expected that a number of these suburb dummy variables would be significant.

By combining the existing explanatory variables in Table 1 with the newly defined variables, *AREA2*, *BED2*, *ELEV2*, *INVBCH* and *INVWET*, the hedonic pricing function can be written in the strictly log-linear form of Equation (1). The Breusch–Pagan test was applied to the regression equation and found significant evidence of heteroskedasticity at the 5 per cent level. Therefore, a robust regression estimate was performed to deal with the heteroskedasticity problem.

A randomly drawn subsample (20 per cent of sample) was set aside for specification test. The remaining observations were used to determine the specification. The determined specification was then tested on the omitted 20 per cent of the sample. The specification with the inverse function for *DBEACH* and *DWETLAND* was compared against a general semi-log specification and a spline regression (where *DBEACH* and *DWETLAND* were each given five knots). The in-sample fit and out-of-sample forecast mean squared error (MSE) of the three specifications were compared. It was found that the spline function performed slightly better than the two other specifications for in-sample predictions. However, the specification with the inverse function for *DBEACH* and *DWETLAND* performed significantly better for out-of-sample forecast than the spline function and the general semi-log specification, as the MSE was significantly smaller.

Table 2 Regression results

Variable	Coefficient	SE	*t*-ratio	95% CI on coefficient	
DWETLAND	3.56E-05	2.35E-05	1.5100	−1.05E-05	0.0001
INVWET	140.0336*	20.8841	6.7100	99.0725	180.9948
DBEACH	3.14E-05*	1.42E-05	2.2100	3.50E-06	0.0001
INVBCH	17.9577*	0.9810	18.3100	16.0336	19.8818
DCITY	-4.41E-05*	1.18E-05	−3.7400	−0.0001	−2.10E-05
DFWY	3.62E-05*	1.27E-05	2.8500	1.13E-05	0.0001
NUMWET	9.66E-03**	5.22E-03	1.8500	−5.69E-04	0.0199
AREA	0.0006*	0.0000	14.2800	0.0005	0.0007
ROOF	−0.0576*	1.64E-02	−3.5200	−0.0897	−0.0255
AGE	−0.0022*	0.0004	−5.5800	−0.0030	−0.0014
BATH	0.0855*	0.0110	7.7600	0.0639	0.1071
DINING	−0.0394*	0.0124	−3.1800	−0.0637	−0.0151
GAMES	0.0258**	0.0145	1.7900	−0.0025	0.0542
STUDY	0.0695*	0.0140	4.9700	0.0421	0.0969
CARPARK	−0.0210*	0.0067	−3.1600	−0.0340	−0.0080
AREA2	0.0000*	0.0000	−6.5600	0.0000	0.0000
ELEV2	8.91E-05*	9.37E-06	9.5100	7.08E-05	1.08E-04
BED2	0.0088*	1.25E-03	7.0500	0.0064	0.0113
SUBURB2	0.2951*	0.0601	4.9100	0.1772	0.4130
SUBURB3	0.4052*	0.0786	5.1600	0.2511	0.5594
SUBURB4	0.6134*	0.0848	7.2400	0.4472	0.7796
SUBURB5	0.4393*	0.0638	6.8900	0.3142	0.5644
SUBURB6	0.5793*	0.0773	7.5000	0.4278	0.7309
SUBURB7	0.2233*	0.0710	3.1500	0.0841	0.3625
SUBURB8	0.3057*	0.0570	5.3700	0.1940	0.4174
SUBURB9	0.0941*	0.0470	2.0000	0.0020	0.1862
SUBURB10	0.3709*	0.0574	6.4600	0.2583	0.4836
SUBURB11	0.6792*	0.1284	5.2900	0.4273	0.9311
SUBURB12	0.1053**	0.0633	1.6600	−0.0189	0.2296
SUBURB13	0.3797*	0.0577	6.5900	0.2666	0.4927
SUBURB14	0.3153*	0.0888	3.5500	0.1411	0.4895
SUBURB15	0.4431*	0.0671	6.6000	0.3114	0.5748
SUBURB16	0.4721*	0.0761	6.2000	0.3228	0.6214
SUBURB17	0.1673*	0.0713	2.3500	0.0274	0.3071
SUBURB18	0.4878*	0.0713	6.8400	0.3479	0.6277
SUBURB19	0.3055*	0.0487	6.2700	0.2099	0.4011
SUBURB20	0.4547*	0.0765	5.9400	0.3045	0.6048
SUBURB21	0.0971**	0.0574	1.6900	−0.0155	0.2097
SUBURB22	0.2509*	0.0848	2.9600	0.0846	0.4173
SUBURB23	0.4369*	0.0767	5.7000	0.2864	0.5873
SUBURB24	0.4232*	0.0795	5.3200	0.2672	0.5792
SUBURB25	0.5033*	0.0842	5.9800	0.3381	0.6685
SUBURB26	0.4686*	0.0683	6.8600	0.3347	0.6025
CONSTANT	12.1294	0.1844	65.7700	0.0000	11.7677

Adj. R-squared = 0.7512; root MSE = 0.2118; n = 1741.
Additional parameter values: α = 275, γ = 0.48.
*Significant at the 5% level; **Significant at the 10% level.

6. Results

The final regression coefficients β in Equation (1) and regression statistics are presented in Table 2. All the model variables, including suburb dummy variables, were significant at the 5 per cent level except for *DFWY* and *GAME*, which were significant at the 10 per cent level.

The area of the land, the number of bedrooms, bathrooms, studies, car parking spaces (garage and carport combined), dining rooms and game rooms, the age of house and type of roofing material were all found to have a significant influence on sales prices. Tiled roofs were not preferred over other types of roofing, such as metal, iron and aluminium, as indicated by the negative sign of the *ROOF* coefficient. Extra bedrooms, bathrooms, studies and game rooms all increase sales price. Counter-intuitively, extra car parking spaces and dining rooms were found to negatively influence sales. Older houses sell for cheaper than newer houses, as the coefficient of *AGE* is negative.

As expected, sales price is inversely related to the distance to the beach, as captured in *DBEACH* and *INVBCH*, and both variables are significant at the 1 per cent level. The coefficient of the distances to the freeway entrance is positive. The positive relationship implies that the closer the property is to the freeway, the lower the price. This may appear counter-intuitive as one would expect being near freeways would allow easy access and convenience, therefore should be increasing property prices. A similar effect has been found in Mahan *et al.* (2000) regarding the negative effect of living near commercial zones because of congestion and noise. Freeway entrances pose similar problems, particularly for properties with very close proximity, i.e. those that are next door to freeway entrances. However, the relationship may not be linear, as houses that are relatively close to freeway entrances but are far enough to be removed from congestion and noise may have higher values than properties that are much further away. It was found that both proximity to the city and elevation increase sales price as expected. This concurs with the findings of Mahan *et al.* (2000).

The effect of wetland proximity on sales price appears through three variables: *DWETLAND*, *INVWET* and *NUMWET*. The coefficients of *DWETLAND* and the inverse distance variable $INVWET = 1/(\alpha + DWETLAND)$ are both positive with *DWETLAND* not significant, but *INVWET* being significant at the 1 per cent level. Figure 2 shows the net effect of distance to the nearest wetland, combining the effects of *DWETLAND* and *INVWET* on sales price. The significant inverse relationship between distance to urban wetlands and sales price was also found by Lupi *et al.* (1991), Doss and Taff (1996) and Mahan *et al.* (2000). There is a rapid decline in value in the first few hundred metres from the wetland edge, which is possibly related to the amenity value of wetland frontage or convenience of easy walking access to the wetland. The value continues to fall, but at a slower rate, with increasing distance until a minimum sales price is reached at around 1.7 km from the wetland. Beyond about 1.7 km, there is a slight increase in value up to around 3 km, which is the maximum wetland distance encountered in the study. The variable *NUMWET* accounts for the number of wetlands near a property. It

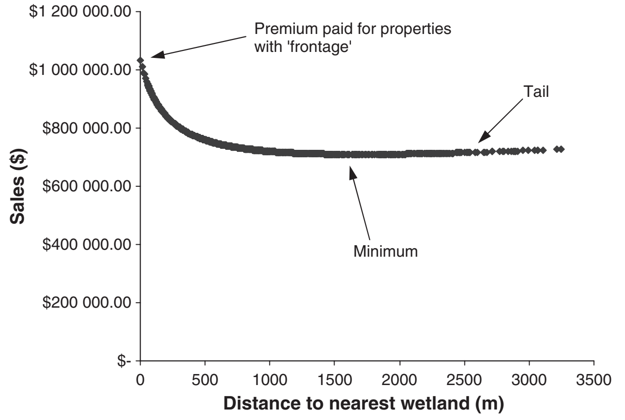

Figure 2 The effect of distance to the nearest wetland on the estimated sales price, holding all other variables constant at their average values for the study area.

has a positive coefficient, meaning that being in close proximity (within 1.5 km[4]) to multiple wetlands increases property values.

It is noteworthy that the distance to the nearest park was not a significant explanatory variable for the house sales price. This was surprising, as it might be expected that proximity to a park could attract a premium. There are a number of possible explanations. For example, we did not distinguish between types of parks, which range between local neighbourhood parks that are small and numerous, and larger tracts of greenspace that include active and passive recreational amenity. Moreover, the distance to park data was calculated using the park's centroid rather than the more correct polygon data for the park boundaries, and this contributes to inaccuracies in the calculated distance, particularly for large parks. This preliminary result, that there is no amenity value for parks, implies that if a neighbourhood wetland were to dry up and leave a passive greenspace in its place, then the total premium of the amenity of the wetland would be lost, because there is no value associated with the greenspace left behind. However, more detailed analysis of the value of parks and public greenspace may be required in order to properly compare the values of public open space attributes, including wetlands and alternative landscapes.

6.1 Marginal implicit prices and elasticities

From the hedonic property price function estimated in Equation (1), the partial derivative with respect to any of the variables (i.e. property characteristic) gives the marginal implicit price (MIP) of that characteristic. In other words, an MIP is the additional amount that must be paid by any purchaser to move

[4] A distance of 1.5 km is approximately 1–2 min drive at an average speed of 60 km/h or 15–20 min walk at the average walking speed of 4.83 km (or 3 miles)/h.

Table 3 Marginal implicit prices and elasticities of structural, neighbourhood and wetland variables

Variable	MIP at the mean of the variables	Elasticity at the mean of the variables (%)
DWETLAND	−42.40	−0.06
DBEACH	−151.73	−0.03
DCITY	−31.84	−0.39
DFWY	26.13	0.08
NUMWET	6975.67	0.02
AREA	401.65	0.42
ROOF	−41 550.77	−0.05
AGE	−1609.97	−0.09
BATH	61 703.99	0.12
DINING	−28 438.99	−0.03
GAME	18 646.70	0.004
STUDY	50 142.84	0.01
CARPARK	−15 160.67	−0.01
ELEV	3362.45	0.12
BED	40 152.12	14.72

to a property with a better level of a particular characteristic, while the levels of all other attributes are held constant. For example, if two houses have similar characteristics, except for one is closer to the beach than the other, the one closer to the beach will be more expensive as there is an MIP associated with being closer to the beach. Table 3 reports MIPs for the model variables. This allows one to estimate, for example, that an extra bedroom will increase the average house price by AU$40 152, holding every other characteristic equal. In addition, shown in Table 3 are the elasticities of the sales price with respect to the model variables. Elasticity is defined as the percentage change in the sales price for a percentage change in the model variable under consideration. Note that the MIP reported for *DBEACH* in Table 3 includes contributions of both *DBEACH* and *INVBCH*.

In graphical terms, the MIP for the distance to the nearest wetland is the slope of the curve in Figure 2. Very close to the wetland, the MIP is highly negative, but then approaches 0 at around 1.7 km, before becoming slightly positive at longer distances. The MIP reported in Table 3 for *DWETLAND* was evaluated at a distance of 943 m, which is the average wetland distance of the sample, when all other variables take on their mean values given in Table 1. At this distance from the wetland, a property will experience a reduction in sales price of approximately AU$42.40 if the property were to be 1 m further away from the wetland. As the average property is worth $790 000 and is 943 m away from the wetland, a 1 per cent increase in wetland distance, in other words moving 9.4 m away from the wetland, will reduce the property price by 0.06 per cent. This translates to around AU$474. From the results for *NUMWET*, it can be stated that if the property has more than one wetland nearby, the presence of a second wetland will increase the property price by AU$6976, as households have more options as to which wetland they want to visit. Contrary to Lupi *et al*. (1991), Doss and Taff (1996) and Mahan *et al*. (2000), we did not find any significant relationship between sales price and size of wetland.

6.2 Total sales premium of a wetland

Consider a neighbourhood wetland that may be drying because of reduced rainfall and lowering groundwater table. If the wetland were to dry up and be replaced by terrestrial vegetation, what will be the aggregate reduction in sales prices of nearby properties, assuming that the terrestrial vegetation provides no benefit to these nearby properties?

The hedonic price function, in Equation (1), can be used is to estimate the total premium in sales price, P_T, for a particular wetland, based on wetland proximity. Essentially, P_T is the integral with respect to land area of the product of the sales price premium and the housing density. The integral is evaluated within an annular *premium zone* surrounding the wetland of interest, which we assume to extend from the edge of the wetland out to a distance corresponding to the minimum in the price – wetland distance curve in Figure 2, which is about 1.7 km. To gain an appreciation for the premium calculation, it is helpful to consider a simplified case, namely an isolated circular wetland surrounded by housing of uniform density. With these assumptions, the total premium of a wetland can be estimated by:

$$P_T(R) = \int_R^{R*} P(r)\, n\, 2\pi r\, dr \qquad (4)$$

where $R = (A/\pi)^{1/2}$ is the effective radius of a wetland of area A, R^* is the radius at the outer edge of the premium zone, $P(r) = (ADJSALE|_r - ADJSALE|_{r=R^*})$ is the sales price premium at radius r, that is, the difference between the sales price of a property at radius r and the sales price of a property having identical attributes except that it is with located at the edge of the premium zone, that is, at $r = R^*$; other distance attributes being assumed to remain unchanged, $n \neq n(r)$ is the housing density, defined as the number of houses per unit land area.

The edge of the premium zone, located at the minimum in the price–wetland distance curve (Figure 2), may be found from Equation (1) by setting $\partial ADJSALE/\partial r = 0$, which yields:

$$R* = R - \alpha + \sqrt{\beta_{\mathrm{INVWET}}/\beta_{\mathrm{DWETLAND}}} \qquad (5)$$

By substituting values in Equation (5), it may be seen that the edge of the premium zone occurs at a distance $D^* = (R^* - R) = 1708$ m, or about 1.7 km from the edge of a wetland as observed from Figure 2. Note that the edge of the premium zone always located at this distance, irrespective of the size of the wetland or the values of any of the explanatory variables in the hedonic price function. However, the size of the premium zone, measured in terms of area, will increase as the size of the wetland increases.

The housing density values, n, can be determined from GIS analysis of the study region, by counting the number of all residential properties located within the premium zone of each wetland and then dividing by the area of the premium zone, excluding the area of the wetland itself. The median, lower and upper quartile values of n were found to be 5.3, 4.5 and 6.6 properties per hectare, respectively. Note that n is less than the reciprocal of the land area for each property ($1/AREA$) because, although n includes the property land area, it also includes the area of nearby roads and verges, any parkland surrounding the wetland, and the area of any other features, such as schools and shopping centres, within the premium zone.

The total sales premium can now be found by substituting Equations (1) and (5) into Equation (4) and performing the integration. This integral does not have an analytical solution, but it is readily evaluated by numerical methods. The parametric bootstrap method of Krinsky and Robb (1986) was used to estimate the 95 per cent confidence interval (CI) on the total sales premium.

Figure 3 shows how the total sales premium because of the presence of a wetland changes with wetland size and housing density, assuming all other explanatory variables remain at their mean values. As wetland size increases, the total premium increases because of two effects: an increase in the area of the premium zone and an increase in the number of properties very close to the wetland (frontage), which is related to the wetland perimeter. Even small wetlands contribute a large premium to the neighbourhood. Based on an average density of 5.3 properties per hectare, the total premium in sales price for a 20 ha wetland, which is approximately the mean size of wetlands in the study area, is approximately AU$140 million, or between AU$40 million and

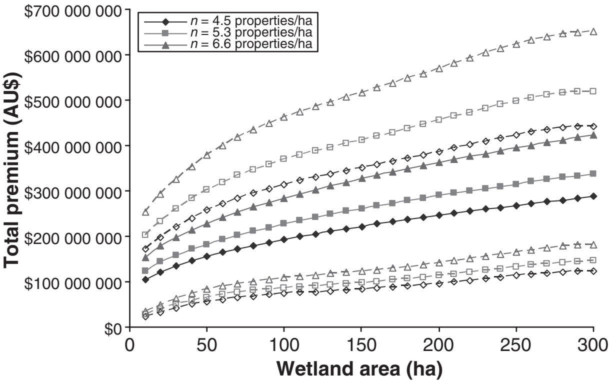

Figure 3 Total premium in sales price based on wetland proximity as a function of wetland size for lower quartile, median and upper quartile housing densities (dashed lines show the 95% confidence intervals).

AU$230 million (the 95 per cent CI). The point estimates for the total sales premium constructed under the inverse distance specification lie within the 95 per cent CI of the total sales premium constructed under the spline specification for all wetland size and housing density. For a wetland the size of Lake Monger (see Figure 1), approximately 70 ha, the premium is around AU$200 million, or between AU$80 million and AU$330 million. As seen in Equation (4), the total premium is directly proportional to the housing density n, so increasing the density by 10 per cent will also increase the total premium by 10 per cent. However, the premium calculations do not take into account any change in the *AREA* variable for each property, so the change in total premium with n shown in Figure 3 will likely be smaller in reality. The values in Figure 3 should be treated as indicative only, because they apply for hypothetical case of an isolated circular wetland surrounded by houses at the median housing density that have all other attributes at the mean values found in the study (Table 1). It should also be noted that the estimate of the total sales premium is based on the fact that the terrestrial vegetation that replaces the wetland does not provide any premium to property prices.

7. Discussion

As anticipated, both the distance to the nearest wetland (*DWETLAND*) and the number of wetlands within close proximity (*NUMWET*) significantly influence house sales price, along with a number of other property-specific and neighbourhood attributes. The functional form suggests that wetland distance influences sales price within a premium zone extending approximately 1.7 km from the edge of a wetland. For a property that is 943 m away from the nearest wetland, which is the distance corresponding to the mean sales price in the study, reducing the wetland distance by 1 m will increase the property price by AU$42.40. Similarly, the existence of an additional wetland within close proximity of the property will increase the sales price by AU$6976. The hedonic price function, when combined with information on housing density and wetland size, can be used to estimate a total premium on house sales because of the presence of a nearby wetland. For a given wetland, assuming a 20 ha isolated circular wetland surrounded by uniform density housing, the total sales premium to surrounding properties was estimated to be between AU$40 million and AU$230 million, all other variables being held at their mean values.

This study has shown that there is a significant relationship between property prices and distances to wetlands. A number of new housing developments have created artificial wetlands to add extra environmental appeal to their properties. In the case of Perth, Western Australia, urbanizing around existing wetlands not only will improve surround property prices, but could also help raise the water level in wetlands from increased run-off and groundwater recharge. With the continuing reduction in rainfall because of climate change in Perth, coupled with the increasing demand for groundwater supply, there is sense of urgency for advocating the importance of preserving urban wetlands, not only for environmental benefits but also for economic gains.

It should be noted that the value of urban wetlands captured in this study is only the capitalized amenity value for wetland proximity on nearby property prices and not a willingness-to-pay. Hence, the estimated value should be taken with caution that it is merely the lower bound of the wetland services as other non-use values placed on the wetlands have not been incorporated in the estimation. Additionally, this value is merely a snapshot in time and there is a chance that wetland values may change in the future. In order to capture wetland values that are not revealed in the market place, other valuation methods, such as stated preference or second-stage hedonic analysis, may be required to supplement this study. A spatial hedonic analysis could also be carried out to study the spatial dependency of house prices, in which prices of nearby properties are used to explain the price of any specific property, in order to improve the accuracy of the parameter estimates. Accuracy could also be improved by obtaining cadastral information and constructing explanatory variables that capture wetland quality, auxiliary wetland amenities (such as park benches and playgrounds) and wetland view or frontage. Nonetheless, the estimates in this study should at least provide some insight to policy makers of the impact on surrounding property values if wetlands were left to dry.

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