Valuing Urban Wetlands of the Gnangara Mound: A Hedonic Property Price Approach in Western Australia

Sorada Tapsuwan[1], Gordon Ingram[1] and Donna Brennan[2]

[1]Policy and Economic Research Unit, CSIRO Land and Water, Australia.
[2]School of Agricultural and Resource Economics, University of Western Australia

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Sorada Tapsuwan[1], Gordon Ingram[1] and Donna Brennan[2]

[1]*Policy and Economic Research Unit, CSIRO Land and Water, Australia.*
[2]*School of Agricultural and Resource Economics, University of Western Australia*

Abstract

Up to 60% of potable water supplied to Perth in Western Australia is extracted from the Gnangara mound. Many of the urban wetlands above the Mound are groundwater-dependent. Excessive groundwater extraction and climate change have resulted in a decline in water levels in the wetlands. This study estimates the value of urban wetlands in three local government districts in the Perth metropolitan region using the hedonic property price approach. Preliminary results found that proximity to wetlands influences the sales prices of properties. The marginal implicit price of reducing the distance to the nearest wetland by 1 metre, evaluated at the mean sales value, is AU$463. If there is more than one wetland within 1.5 kilometres of a property, the second wetland will help increase the property price by AU$6,081. For a 50 ha wetland, we estimate the total premium of on sales due to wetland proximity is AU$220 million, based on average property characteristics and medium house density. These results will help inform policy makers and land developers on the value of conserving existing urban wetlands, creating new wetland areas and urbanising rural wetlands.

Keywords: groundwater, housing development, aquifer, marginal implicit price

1. Introduction

The majority of the Perth metropolitan and surrounding area is situated on a vast underground water resource that provides the majority of water used for consumptive purposes in the urban area as well as significant environmental amenity in the 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. Recreational uses of wetlands can include swimming, boating, water skiing, and fishing.

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 through increase popularity of backyard bores. If the trend continues, there is an increased likelihood that the presently unlicensed and unmanaged backyard bore use may conflict with the management of urban groundwater levels and associated wetlands, which may cause a loss of urban 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

non-use values are likely to dominate in the urban areas, and are amenable to quantification using hedonic price analysis of property sales data. 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. It will also inform the broader land use planning issues regarding management of the Gnangara Mound area, where urbanisation of areas currently under exotic plantations may improve wetland amenity as well as provide a source of funds for on-ground rehabilitation of degraded groundwater dependent ecosystems in the peri urban area.

Previous valuation studies of wetlands have come up with a wide range of estimates, due in part to differences in the wetland attributes that are valued and also to differences in methodology (Boyer and Polasky, 2004). The RAMSAR Convention Bureau (Barbier *et al.*, 1997) reviewed various economic techniques available to value 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 that can be used to value environmental amenities that are not sold in the market and do not have direct market value, such as wetlands, is the hedonic pricing method.

The hedonic pricing method is based on the idea that properties are not homogenous and can differ in respect to a variety of characteristics. Property prices can be affected by location specific environmental, structural, and neighbourhood characteristics. The model relies on observable market transactions to obtain values of various characteristics of heterogeneous products (Boxall *et al.*, 2005). 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 housings locations and these prices just clear the market (Freeman, 2003).

There have been a number of wetland valuations in Australia applying a variety of estimation techniques both with stated and revealed preferences. In Western Australia, Gerrans (1994) conducted a survey to value the Jandakot wetlands in Perth. He used the double-bounded dichotomous choice contingent valuation (CV) 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 about 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) applied a choice modelling study to estimate the non-use environmental values provided by the Macquarie Marshes, a major wetland in 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 one-off figure of AU$11.39 per household for an extra 1000 hectares of healthy wetlands.

This study applies the hedonic property price approach to value urban wetlands in the Perth metropolitan area. The idea behind using this approach is that 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). We chose the hedonic property price approach because it has an advantage over other assessment techniques in that observed market prices are used to construct the estimates of the wetland value instead of hypothetical market values. Variables on the structural and neighbourhood characteristics, as well as some environmental characteristics are observable by researchers. The limitations of the hedonic technique, however, is that it only allows the estimation of the implicit prices of the characteristics but it cannot be used to estimate the willingness to pay for an environmental attribute due to problems of endogeneity and identification (see Taylor, 2003) unless the second stage hedonic analysis is performed.

The structure of the paper is as follows. In Section 2 we set out the study area and describe the source of the data used in the hedonic analysis. Section 3 describes the alternative functional forms tested for the property price equation. The modelling results are presented in Section 4 and Section 5 describes the method used for estimating wetland premium to surrounding properties. In Section 6 we draw some conclusions from the analysis and outline directions for further investigation.

2. Study Area and Data

Figure 1 shows the study area, including the locations of the wetlands and the properties sold during the study period, which was selected as July 2005 to June 2006. The study area extends approximately 13 kilometres north-south and 9 kilometres east-west, covering an area of around 86 square kilometres 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 kilometres inland. There are 32 wetlands inside or within a 2 km buffer around the study area. They range in size from 0.3 to 329 hectares. Some of the wetlands are natural and retain some of their original characters, while others are man made or extensively modified.

The study area includes 26 suburbs in three local government districts in the Perth metropolitan area, namely the cities of Cambridge, Vincent and Stirling. It includes beachside suburbs popular with both locals and tourists, inner urban suburbs with café living in the southeast corner and some less affluent areas in the northeast. There is a light industrial and commercial area directly north of the large wetland in the centre of Figure 1 and a large parkland / nature reserve near the two wetlands in the southwest. A major freeway passes through the study area, running approximately from the city centre to just east of the chain of wetlands on the northern boundary of the study area. In and around the study area there are several golf courses, large shopping centres and places of tertiary education, and numerous small parks and reserves.
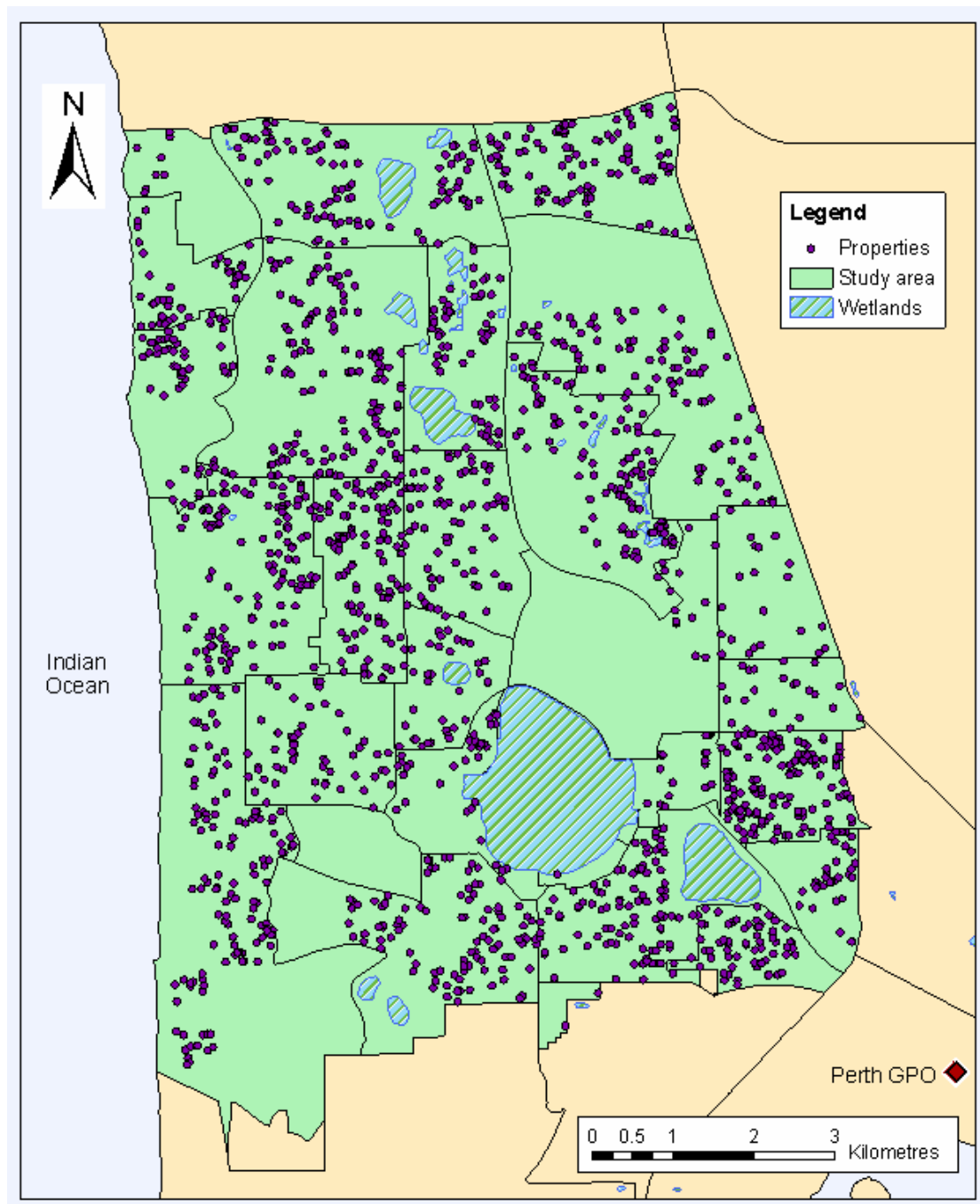
Figure 1. The study area, showing the location of properties sold during the study period, wetlands and suburb boundaries.

This study uses data from multiple sources, but there are essentially two types of data, namely geospatial data and property sales data. The geospatial data consists point (centroid) locations for the properties sold and points of interest, such as schools, shopping centres and parks; polygon (boundary location) data for the wetlands, suburbs and coastline; and digital elevation data. The wetland data was obtained from the WA Department of Water, the elevation data from GeoSciences Australia and all other data from the WA Department of Land Information. The property sales data consists 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 the Department of Land Information. Summary statistics are presented in Table 1.

Table 1. Model variables with their descriptions and statistics.

Variable	Description	Mean	S.D.	Min	Max
Dependent variable					
ADJSALE	The housing sales price adjusted to a June 2006 value in AU$	794,921.70	418,156	95,130.20	4,960,857
Structural attributes					
AREA	Total land area or lot size in square meters	704.25	279.37	91	8,498
BEDS	Number of bedrooms	3.16	0.85	1	6
BATHS	Number of bathrooms	1.45	0.65	1	5
STUDY	Number of studies	0.21	0.42	0	2
CARPARK	Number of park spaces for in garage or carport	0.65	0.78	0	4
DINING	Number of dining rooms	0.64	0.49	0	2
GAMES	Number of game 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
Wetland attributes					
DWETLAND	Number of wetlands within 1.5km of the house	943.35	637.27	2.30	3,244.90
NUMWET	Size of the wetland nearest to property in hectares	2.37	2.36	0	12
Neighbourhood attributes					
DBEACH	Distance in metres to the beach	4,074.76	2,402.60	93.80	8,667.50
DSCHOOL	Distance in metres to the nearest primary or secondary school	572.64	281.19	41	1,803.80
DCITY	Distance in metres to GPO	8,828.44	3,131.24	2,064.90	15,309.70
DFWY	Distance in metres to the nearest freeway entrance	2,197.48	1,431.26	117	7,164.60
ELEV	Elevation of property above sea level in metres	26.14	12.18	4.30	71.40
MEDINC	Median household income of suburb	829.76	170.36	650	1,125.86

The dependent variable of the hedonic price function is the actual sales price of houses recorded. Sale prices were adjusted by the market growth index from the Department of Land Information to a June 2006 level[1]. The average adjusted sales price was AU$794,921. 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 are a set of attributes associated with the property which helps explain the sales price. We have classified the attributes into structural, neighbourhood, and, wetland categories as seen in Table 1. Note that we have

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[1] Except for Jolimont and Leederville where market growth index was taken from the Real Estate Institute of Western Australia (REIWA) 2006.

included in this table only those variables that were found to have a significant effect on sales price.

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, 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 due to financial constraints. Suburb median income level was included as a proxy for neighbourhood wealth. 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 0 bedrooms or bathrooms, and sales values that were unusually high and unusually low. A total of 1,741 observations was used for the analysis.

3. Estimation Method

A statistical software package, STATA, was used to perform a least square regression to estimate the hedonic price function. The Box-Cox regression procedure indicated that the log-linear functional form best fits the data. The general specification was:

$$\ln P_i = \beta_0 + \sum \beta_j (S)_{ji} + \sum \beta_k (N)_{ki} + \sum \beta_l (W)_{li} + \varepsilon_i \qquad (1)$$

for i = 1,2,…n and where

> $\ln P_i$ is the natural log of the sale price of house i
> S_{ji} is the jth structural variable for house i
> N_{ki} is the kth neighbourhood variable for house i
> W_{li} is the lth wetland variable for house i
> ε_i is the error term for house i, with $E(\varepsilon_h) = 0$ and $V(\varepsilon_h) = \sigma^2 > 0$.

A larger set of structural, neighbourhood and wetland attributes than those listed in Table 1 was included in the original model. A step-wise regression approach was used to select variables with statistical significance and variance inflation factor (VIF) of less than 10. Proximity to two iconic local lakes (Herdsman and Monger) were included in the original model to determine whether there is any preference to live near these two lakes but the two variables were not significant, hence were dropped. The size of the wetland was also in the original model to capture whether property prices will be affected by wetland size, but this variable was dropped due to insignificance as well. A variable capturing the distance to a number of points of interests; namely preschools, schools (grade school and high school), TAFEs and universities, golf courses, train stations, and commercial areas were dropped from the model as they were found to be insignificant or collinear with other variables.

A number of models were estimated with different forms of DWETLAND to see which form of DWETLAND best fits the data. We found

$$\ln P_i = \beta_0 + \sum \beta_j (S)_{ji} + \sum \beta_k (N)_{ki}$$

$$+ \beta_1 (\text{DWETLAND}) + \beta_2 \frac{1}{(\alpha + \text{DWETLAND})} \qquad (2)$$

$$+ \beta_3 \text{NUMWET} + \varepsilon_i$$

gave the best fit as the 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 slow rate. The parameter added to DWETLAND allowed the curve to intersect the y-axis instead of increasing up to infinity. The parameter, α, value was estimated by running a do-loop of the regression for a range of values from 5 to 1,000. A matrix of output results recorded the root mean square error (RMSE), adjusted – R^2, and the parameter estimates for every do-loop. We chose the model that produced the lowest root mean squared error. The parameter value was found to be $\alpha = 275$. Concurrently, an inverse relationship between sales and DBEACH was also explored. The hedonic model performed better when DBEACH was in the form

$$\ln P_i = \beta_0 + \beta_1 (\text{DBEACH}) + \beta_2 \frac{1}{(\text{DBEACH}^\gamma)} + \sum \beta_j (N')_{ji}$$

$$+ \sum \beta_k (S)_{ki} + \beta_1 (\text{DWETLAND}) + \beta_2 \frac{1}{(\alpha + \text{DWETLAND})} \qquad (3)$$

$$+ \beta_3 \text{NUMWET} + \varepsilon_i$$

where, N` is the neighbourhood characteristics bar distance to the beach and γ is the integer of the inverse of DBEACH. From the do-loop results, the model performed best when $\gamma = 0.48$. This inverse form of DBEACH was chosen as it allowed ADJSALES to diminish quite rapidly at closer distances and to decrease at a slower rate at larger distances. This is due to the expected relationship that a property very close to the beach or possibly with beach view with have a much higher sales prices than a property slightly further away and does not have beach view.

4. Results

Results of the preliminary analysis are presented in Table 2. The Breusch-Pagan test found significant evidence of heteroskedasticity at the 5% level therefore a robust regression estimate was obtained to deal with heteroskedasticity problems. All the variables included in the model were significant at the 1% or 5% level except for DFWY which was significant at the 10% level. The inverse of (α+DWETLAND) and NUMWET both have the expected signs. A plot of DWETLAND against ADJSALES is shown in Figure 2.

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

AGE is positively related to sales. The distance to the beach is negatively related to the sales price as expected and is significant at the 1% level, as well as the coefficient of the inverse relationship of DBEACH to sales. The coefficient of distance to primary and secondary schools and freeway entrances are all positive. The positive relationship implies that the closer the property is to these places, the lower the prices. This can be due to the inconvenience of having traffic congestions around schools and freeway entrances.

Table 2. Regression results

Variables	Coefficient	Std. Err.	T - ratio	[95% Conf.	Interval]
DBEACH	-4.21E-05††	5.32E-06	-7.91	-0.0000525	-0.0000317
DCITY	-8.23E-05††	2.94E-06	-28.02	-0.0000881	-0.0000765
DSCHOOL	0.0000717††	2.20E-05	3.26	2.85E-05	0.0001149
DFWY	1.63E-05	9.43E-06	1.73	-2.17E-06	3.48E-05
DWETLAND	0.0000584††	0.0000191	3.05	0.0000209	0.0000959
INVWET	1.73E+02††	1.82E+01	9.48	1.37E+02	2.09E+02
NUMWET	7.65E-03†	3.22E-03	2.38	1.34E-03	1.40E-02
AREA	4.83E-04††	3.70E-05	13.06	4.10E-04	5.55E-04
ROOF	-6.19E-02††	1.60E-02	-3.88	-9.32E-02	-3.06E-02
AGE	-1.35E-03††	3.83E-04	-3.52	-2.10E-03	-5.96E-04
BATHS	9.20E-02††	1.13E-02	8.16	6.99E-02	1.14E-01
DINING	-0.039671††	0.0125338	-3.17	-0.064254	-0.0150878
GAMES	0.0381667†	0.0150296	2.54	8.69E-03	0.0676448
STUDY	7.87E-02††	1.44E-02	5.46	5.04E-02	1.07E-01
CARPARK	-2.11E-02††	6.82E-03	-3.1	-3.45E-02	-7.74E-03
AREA2	-1.97E-08††	4.05E-09	-4.86	-2.76E-08	-1.17E-08
ELEV2	0.000104††	7.79E-06	13.34	0.0000887	0.0001193
BED2	8.79E-03††	1.23E-03	7.15	6.38E-03	1.12E-02
MEDINC	2.80E-04††	4.68E-05	5.97	1.88E-04	3.71E-04
INVBCH	17.73623††	7.88E-01	22.51	16.19096	19.28149
CONSTANT	12.88491	0.0780702	165.04	12.73179	13.03804
Adj R-squared	0.7264				
Root MSE	0.2194				
N=1741					

† significant at the 5% level
†† significant at the 1% level

Figure 2 shows the effect on sales prices of the average property as the distance to the wetland increases. The plot of ADJSALE and DWETLAND shows a decline in sales prices as the distance to the wetland increases and levels off as it reaches the three kilometre mark, which is the maximum DWETLAND distance of this study area, before increasing again. This constant decrease is counter-intuitive as one would expect a diminishing impact of wetland on sales prices.

Table 3 reports the marginal implicit prices of the model variables. At the mean of sales price, the distance to the wetland was found to be 245 metres. This indicates that, a property which is 245 metres away from the wetland will experience a reduction in sales prices of approximately AU$463 if the property were to be one

metre further away from the wetland. If there is more than one wetland within 1.5 kilometres of a property, the second wetland will help increase the property price by AU$6,081. An extra bedroom will increase the average house price by AU$72,715.
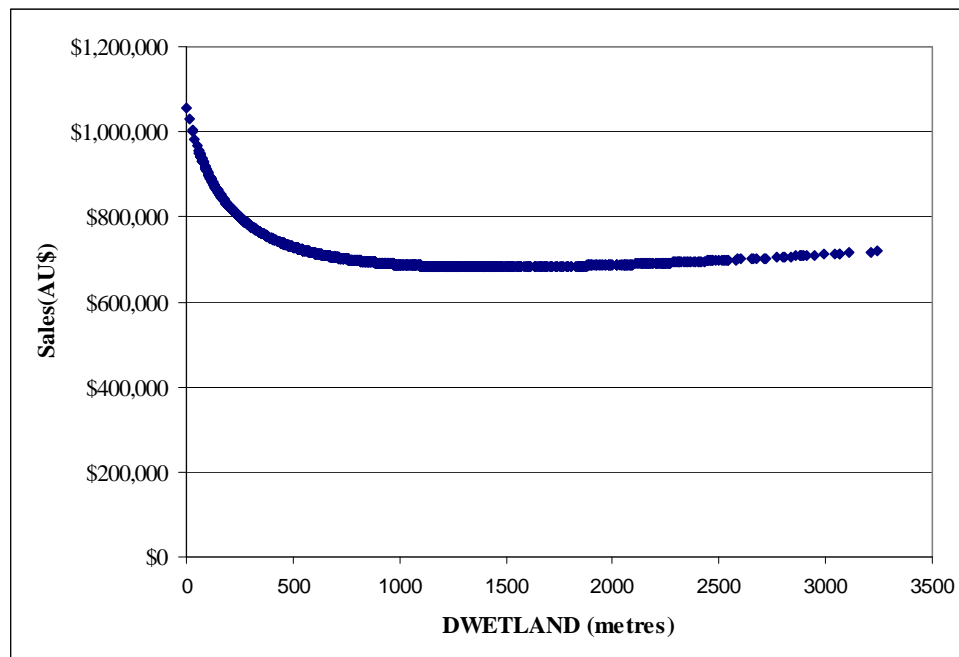

Figure 2. A plot of estimated sales and distance to wetland (holding other variables constant)

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

Variables	At the mean of SALES	95% C.I. Upper bound	95% C.I. Lower bound
DBEACH	-418.93	-393.615	-444.247
DCITY	-65.42	-70.03	-60.81
DSCHOOL	57.00	22.66	91.34
DFWY	12.96	-1.72	27.66
DWETLAND	-463.02	-387.397	-538.636
NUMWET	6,081.71	1065.20	11098.30
AREA	351.33	280.57	422.17
ROOF	-49,210.42	-74085.43	-24335.41
AGE	-1,071.40	-1668.70	-474.01
BATHS	73,163.96	55572.02	90755.89
DINING	-3,1535.26	-51076.90	-11993.62
GAMES	30,339.54	6906.76	53772.32
STUDY	6,2538.95	40056.18	85021.80
CARPARK	-16,786.84	-27420.51	-6153.17
ELEV	7,625.75	6503.883	8747.613
BED	72,715.52	52767.47	92663.57
MEDINC	222.18	149.21	295.07

5. Wetland premium on property prices

The total premium in sales price due to wetland proximity ΔP_T can be estimated from the hedonic price function, equation (3). Essentially, ΔP_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 a 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 (Figure 3). With some simplifying assumptions, namely approximately circular wetlands and uniform housing density within the premium zone, the total premium due to a wetland can be estimated by:

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

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
$\Delta P(r)$ is the sales price premium at location r, that is, the difference between the sales price of a property at radius r and the sales price of an identical property located far from the wetland (that is, at $r = R^*$)
n $\neq n(r)$ is the number of houses per unit area

The edge of the premium zone, located at the minimum in the price – wetland distance curve, is found by setting $\partial P/\partial r = 0$, which yields:

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

where $\alpha = 275$.

Note that the edge of the premium zone occurs at a distance $R^* - R = 275 + \sqrt{\beta_{INVPWET}/\beta_{DWETLAND}} = 1450$ metres from the edge of a wetland, irrespective of the size of the wetland or the values of any of the explanatory variables in the hedonic price function.

Now, the total premium can be found by using the relationship DWETLAND = (r-R) and substituting equations (3) and (5) into equation (4). Unfortunately this integral does not have an analytical solution, but it is readily evaluated by numerical methods.

Figure 3 shows how the total premium due to the presence of a wetland changes with wetland size and housing density, assuming all other explanatory variables are at their mean values. The housing density values, n, were determined from GIS analysis of the study region, with the range describing the lower quartile, median and upper quartile values. Note that the n calculation included any buffer area from the edge of the wetland to the first row of houses, so n will be small compared to the reciprocal of the local average property area.
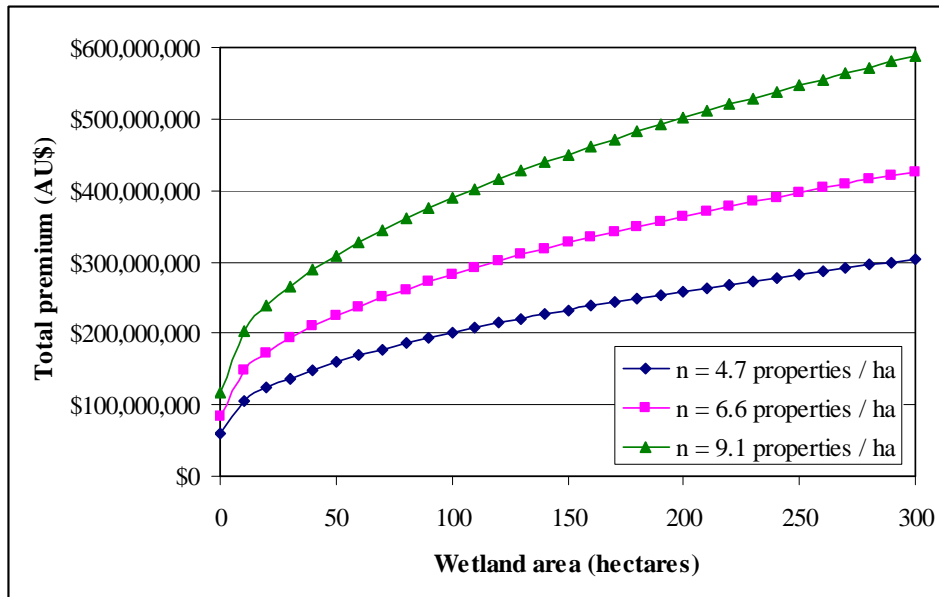
Figure 3. Total premium in sales price due to wetland proximity as a function of wetland size for low, medium and high density housing.

The total premium in sales price for a 50 hectare wetland was approximately AU$220 million for properties with all other attributes at their mean values. It should be noted however, that this total premium is not the social willingness-to-pay for the wetland. It is merely an indicator of the possible loss to the capitalized amenity value of properties near the wetlands, if the wetland were to disappear, due to a fall in the groundwater table for instance. We plan to investigate the loss of consumer surplus due to the disappearance of wetlands in a second stage hedonic analysis.

6. Conclusion

A hedonic property price approach was used to value wetlands in part of the Perth metropolitan area. A number of functional forms for the DWETLAND variable were evaluated. Preliminary results showed that the model incorporating an inverse of DWETLAND plus a parameter α performed better than any other forms of DWETLAND tested. Similarly, the variable DBEACH was found to have an inverse relationship with ADJSALES. Results from the model indicated that proximity to wetland and number of wetlands within 1.5 kilometres of a property has a statistically significant impact on sales prices. This is consistent with findings from previous studies by Lupi *et al.* (1991), Doss and Taff (1996), Morrison et al. (1999) and Mahan *et al.* (2000). For a property that is approximately 245 metres away from the wetland, reducing the distance to the nearest wetland by 1 metre will increase the property price by AU$463. Similarly, the existence of an additional wetland within 1.5 kilometres of the property will increase the sales price by AU$6,081. The total premium in sales price for a wetland of 50 hectares was AU$220 million.

Preliminary results of this study have shown that the existence of urban wetlands helps improve sales prices of surrounding properties. A number of new housing developments have created artificial wetlands as wetlands add the extra environmental appeal to properties, thus, helps increase the sales price. Urbanising around existing wetlands not only will improve surround property prices, but could also help increase

recharge into the wetlands from run-offs as well. With continuing reduction in rainfall from climate change coupled with increasing demand for groundwater supply, there is sense of urgency to advocate for the importance of preserving urban wetlands, not only for environmental benefits but for economic gains as well.

It should be noted that this study was only done in a local scale and to truly appreciate the value of all the wetlands linked to the Gnangara Mound, a larger scale study must be conducted. A spatial hedonic analysis could also be carried out to study the spatial dependency of house prices 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, wetland view, as well as performing a second stage hedonic analysis to estimate the willingness-to-pay function.

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