Australian Water Recycling
Centre of Excellence

Economic viability of recycled water schemes—
Technical Report 1

The value of recycled water infrastructure to the residents of Rouse Hill

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The value of recycled water infrastructure to the residents of Rouse Hill

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About the Australian Water Recycling Centre of Excellence

The mission of the Australian Water Recycling Centre of Excellence is to enhance management and use of water recycling through industry partnerships, build capacity and capability within the recycled water industry, and promote water recycling as a socially, environmentally and economically sustainable option for future water security.

The Australian Government has provided $20 million to the Centre through its National Urban Water and Desalination Plan to support applied research and development projects which meet water recycling challenges for Australia's irrigation, urban development, food processing, heavy industry and water utility sectors. This funding has levered an additional $40 million investment from more than 80 private and public organisations, in Australia and overseas.

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Executive Summary

Residential third pipe recycled water infrastructure provides householders with access to recycled wastewater for non-potable uses within the home and in the garden. The wastewater is treated to be 'fit for purpose', managing risks to the environment and to human health.

This recycled water can be seen in some ways as inferior to potable water due to its more limited use and lower quality, and customers tend to expect lower charges than for their potable supply. This contrasts with the fact that supply costs for recycled water can often be higher than for traditional supplies.

At the same time, recycled water contains attributes that are in some ways superior to potable supply – notably, it can have higher reliability than potable supplies, being climate independent and typically being exempt from water restrictions during drought. Recycled wastewater is also perceived to have superior environmental performance than alternative water supply options such as dams and desalination, in that recycled water use reduces wastewater discharge to receiving waters (rivers and oceans), and typically is less energy intensive than desalinated water.

This study

It is commonly perceived by developers that a significant value is retained by a segment of the residential housing market for access to third pipe infrastructure, making those properties with third pipe infrastructure more valuable than similar properties without recycled water access.

If this value exists, a price premium should be evident in property sales data comparing properties with and without recycled water, reflecting the value to users of access to this infrastructure.

The Rouse Hill Recycled Water Plant (RHRWP) is among the first and largest third pipe residential recycled water schemes in Australia, supplying recycled water since 2001 and currently supplying around 20,000 homes in Western Sydney.

This study uses the Hedonic Pricing method to compare properties with and without recycled water access sold in and around the RHRWP, to establish whether a value for recycled water access can be identified, by isolating property attributes which contribute to the property's sale price.

Results

Our analysis finds a relatively small but statistically significant price premium associated with recycled water infrastructure in the Rouse Hill area, increasing property values by 0.716 per cent.

The value held by residents attached to the Rouse Hill Scheme for recycled water infrastructure ranges from $4,266 to $5,204 per property. At the average (median) property value, this produces a value of $4,949 for recycled water infrastructure.

This value can be expected to go some way to justifying the capital costs of third pipe infrastructure, but is unlikely to cover the full costs.

1. Introduction

1.1 Recycled water infrastructure

Residential properties in Australia historically have two water-related utility connections: potable water inflow and sewage outflow. Advances in water treatment technology and the rising cost of producing potable-quality water have led to the installation of residential third pipe schemes as a mechanism for meeting consumer demand. Third pipe schemes allow the delivery of fit-for-purpose (non-potable) recycled water to households in addition to the traditional potable water connection. For many uses around a residential property, non-potable recycled water is a close substitute for potable water.

From the perspective of the household, the availability of recycled water has many benefits. For example, non-potable supplies tend to have a lower unit price and a more permissive use regime compared with potable supplies. The presence of the third-pipe infrastructure provides households with the flexibility to substitute between the potable and non-potable water, allowing the maintenance of outdoor gardens to a standard not otherwise obtainable given budgetary and (potable) water conservation constraints.

While the benefits can be described in a qualitative manner, the quantitative value placed on access to the recycled water infrastructure by households is uncertain. Obtaining an estimate of the value of access to recycled water infrastructure is central to any analysis of the costs and benefits of the infrastructure.

The installation cost of a third pipe scheme is substantial, even when completed during the land development process. The costs of installing the third pipe scheme will be sunk at the time of installation, when the benefits of the scheme are still uncertain. The fundamental question faced by developers and government is whether residents value these benefits more than the significant cost of installing and operating third pipe schemes.

1.2 Heterogeneous Products and Hedonic Pricing

Housing is a heterogeneous product, comprising many individual attributes. No two properties are ever exactly alike, as each consists of unique combinations of location, number of rooms, land area and design. While the heterogeneous product consists of numerous attributes, only a single market price is observed when the property is traded. It is assumed that this price reflects the consumer's valuation of the underlying set of attributes present in the property.

The hedonic model relates the observed market price for the heterogeneous product to the bundle of characteristics which comprises the good. As each unit of the non-homogenous good is comprised of a different bundle of characteristics, there will not be a single uniform market price, even if the market is competitive. By estimating the contribution of each attribute to the observed market price, it is possible to derive an estimate of consumer demand for each attribute rather than the heterogeneous good.

The hedonic pricing method can therefore be used to derive an estimate of the marginal value of recycled water infrastructure to households.

1.3 Current Analysis

Access to recycled water infrastructure is one attribute of residential properties in the suburbs of Western Sydney serviced by the RHWRP. The RHWRP serves an area of 13,300 hectares including the suburbs of Rouse Hill, Stanhope Gardens, Glenwood and Kellyville, or approximately 40,000 people.[1] Recycled water began flowing to over 4,500 homes in the area from August 31, 2001.[2] The region is illustrated in Figure 1 below.

Figure 1: Rouse Hill Recycled Water Area

Source: Sydney Water (http://www.sydneywater.com.au/Publications/Factsheets/RouseHill.pdf)

Consequently, using a hedonic pricing model it is theoretically possible to identify the value of a household's access to the recycled water infrastructure, based on residential property transactions, an understanding of the attributes of each property and whether or not the household has a recycled water connection. This study has used the hedonic pricing method to quantify the value that residential customers place on the availability of recycled water through third pipe infrastructure, using data relating to the Rouse Hill region of Western Sydney.

1 The full list of suburbs containing properties with third pipe infrastructure can be found in Table 1.

2 Sydney Water, 2001. Rouse Hill Area: Community Views on Recycled Water, Post Commissioning. November 2001.

2. Data Sources

2.1 Summary of data sources

In undertaking the hedonic pricing analysis, three data sets were required:

- a database listing residential property sales in the western Sydney region, including information such as the date of sale, nominal sale price, address, and other housing characteristics;
- a list of all properties with a recycled water connection, differentiated by address; and
- mapping data for the western Sydney region, identifying neighbourhood attributes that have an effect on property price such as parks, schools and transport infrastructure.

This chapter sets out the data sources used to perform the hedonic pricing analysis and the adjustments and manipulations performed to the data prior to performing any regression.

2.1.1 Choice of suburbs

The main focus in suburb choice was on minimising differences between properties except for recycled water infrastructure. Suburbs were chosen based upon:

- whether they contained properties with recycled water infrastructure (all suburbs with properties connected to the Rouse Hill Scheme were included);
- location: suburbs in close proximity to the Rouse Hill area were preferred over those further away;
- average property price: suburbs with average property prices similar to those with properties connected to the Rouse Hill Scheme were preferred to those with significantly higher and lower average property prices;
- timeframe of suburb development: suburbs developed over similar timeframe as those with properties connected to the Rouse Hill Scheme were preferred over more established suburbs that may be associated with different socio-economics.

Discussion with Sydney Water officers and numerous real estate agents provided contextual information to inform suburb choice (such as timeframe of suburb development and demographics).

2.1.2 Selection of variables for inclusion

There exist a large number of variables that could be incorporated within the hedonic model, as there is an infinite number of unique attributes associated with a property. Correct specification of the hedonic model requires a prima facie understanding of the consumer utility function. For the purposes of constructing the hedonic model of housing, this analysis has relied on a range of sources, including Tapsuwan (2009), Freeman (2003) and Parsons (1986).

2.2 Property Sales Data

A database of property sales for the western Sydney region was purchased from Australian Property Monitors (APM).[3] The database contained transactions occurring between the years 2000 and 2011 within a set of suburbs selected by MJA. The set of suburbs that was selected contains properties with and without a recycled water infrastructure connection. The objective of the selection process was to obtain a representative sample of property transactions for properties with and without recycled water infrastructure within close geographical proximity to one another.

2.2.1 Removal of transactions occurring before 2005

While data was purchased for an eleven year period, a low number of transactions were reported in 2000 to 2004, and thus these data points were excluded from the database. Between 1,076 and 1,526 transactions were reported per year within the sample set for the years 2005 to 2011. In comparison, fewer than 100 transactions per annum were reported for the years 2000-2004. It is understood that a number of the suburbs chosen for inclusion in the sample set were not fully developed prior to 2005, resulting in the lower number of trades reported.

Transactions occurring before 2005 were removed from the data set for two reasons. The number of observations within the pre-2005 period was insufficient to ensure a statistically significant result was obtained when estimating the time-based dummy variable for those years. Furthermore, while removing the trades resulted in only a minor change to the remaining coefficient estimates, the amendment did improve the overall fit of the regression model. It was therefore decided that the overall low number of data points available prior to 2005 was having a negative effect on the effectiveness of the model, and thus removed.

2.2.2 Property sales type

The property sales database listed transactions for all residential property sales. Transactions were differentiated by property type. Property types included house, townhouse, terrace, villa and cottage. No non-residential or apartment-based properties were included in the database.

During the analysis phase, a dummy variable was introduced identifying each type of property. As the coefficient estimate for all dummy variables except *house* were insignificant, and as fewer than 2.3 per cent of observations were for non-house properties, all non-house transactions were excluded from the database.

2.2.3 Price range

Properties with a sales price of greater than $1.5 million (in real, march 2012 terms) were excluded from the analysis. There were 185 trades with prices greater than $1.5 million, of which only 2.1 per cent had a recycled water connection. These 185 trades can be viewed in the context of the sale price distribution, as illustrated in Figure 2.

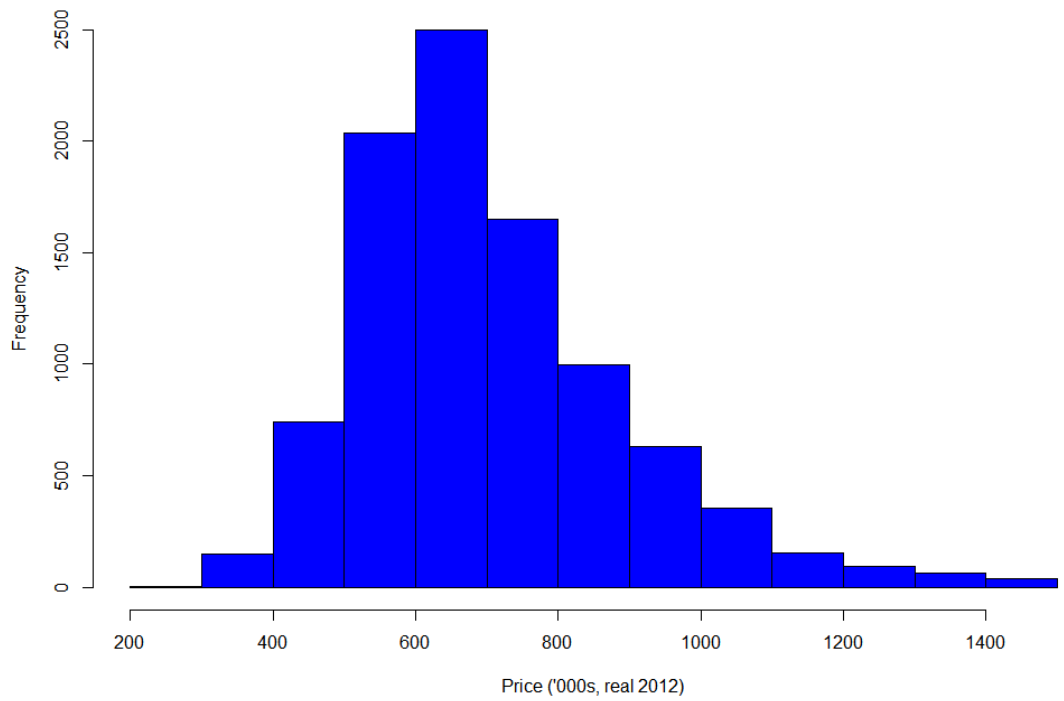
Properties with a sale price in excess of $1.5 million demonstrated a disproportionate number of pools and spas, with 59 and 49 per cent respectively. This compares with 10 and 4 per cent for the wider population.

[3] Disclaimer: This report may contain property sales information provided under licence from the Department of Lands NSW. Copyright 2012 Australian Property Monitors

Additionally, properties that sell at a price significantly higher than the suburb mean are likely to demonstrate a number of unobservable attributes which are not captured within the available database, but are correlated with price. For example, build quality or scenic views are not captured within any available data set, but are correlated with higher prices. With the information available – number of rooms, land area and location – it is impossible to capture these additional sources of variance which affect sale price. This is supported by Figure 5, which shows the fit is poorer for properties with high prices.

It is likely that the inclusion of such properties would lead to misspecification of the underlying hedonic model, potentially biasing the results. For this reason, the $1.5 million upper limit was placed on individual transactions.

Figure 2: Frequency of transactions by price bracket



All sale prices in the database were converted to real (2012) terms using the Australian Bureau of Statistics' Consumer Price Index (Cat 6401.0) for the quarter in which the transaction took place. We also include the dummy variables which will control for any differences between house price inflation and changes in the Consumer Price Index.

2.2.4 Housing Attributes

The property transaction database provided by APM also provided information relating to a range of characteristics about each property. Characteristics included continuous (bounded) variables such as land area, discrete variables such as the number of bedrooms and bathrooms, and dummy variables to specify whether or not a particular characteristic is present. A large number of dummy variables was included in the database but not used in the regression analysis, such as whether the property had a built-in barbeque, billiards room or spa. For many attributes, less than 1 per cent of properties contained the attribute.

A complete list of attributes used in the regression analysis can be found in the following section.

2.2.5 Final data set

Following all of the aforementioned exclusions, a total data set of 9,399 transactions were utilised to estimate parameters within the hedonic model. A summary of the suburbs selected and the resulting number of transactions per suburb is listed in Table 1.

Table 1: Number of transactions per year by suburb, 2005 - 2011

Suburb	Year							
	2005	2006	2007	2008	2009	2010	2011	Total
Beaumont Hills	64	54	78	66	85	110	89	546
Kellyville	191	206	234	181	232	232	228	1,504
Castle Hill	266	268	301	255	348	294	300	2,032
Kings Langley	73	81	103	64	68	53	65	507
Stanhope Gardens	45	60	70	77	130	92	87	561
Quakers Hill	137	160	206	183	201	183	242	1,312
Kellyville Ridge	35	39	58	53	79	95	92	451
Glenwood	126	145	176	154	193	155	171	1,120
Acacia Gardens	16	22	41	32	46	33	39	229
Bella Vista	43	41	51	47	66	69	53	370
Rouse Hill	73	63	69	78	124	81	96	584
Parklea	7	21	16	17	25	19	30	135
The Ponds	0	0	0	0	10	4	34	48
Total	**1,076**	**1,160**	**1,403**	**1,207**	**1,607**	**1,420**	**1,526**	**9,399**

Source: Property Transaction Database

Out of the total sample set of 9,399 sales, 15.6 per cent of properties were sold more than once, while 5.3 per cent were sold more than twice.

2.2.6 Access to recycled water infrastructure

The property sales database did not contain an attribute relating to recycled water infrastructure. As such, this was introduced into the database. A database listing all properties with access to recycled water infrastructure was provided by Sydney Water. The list contained property number, street address and suburb.

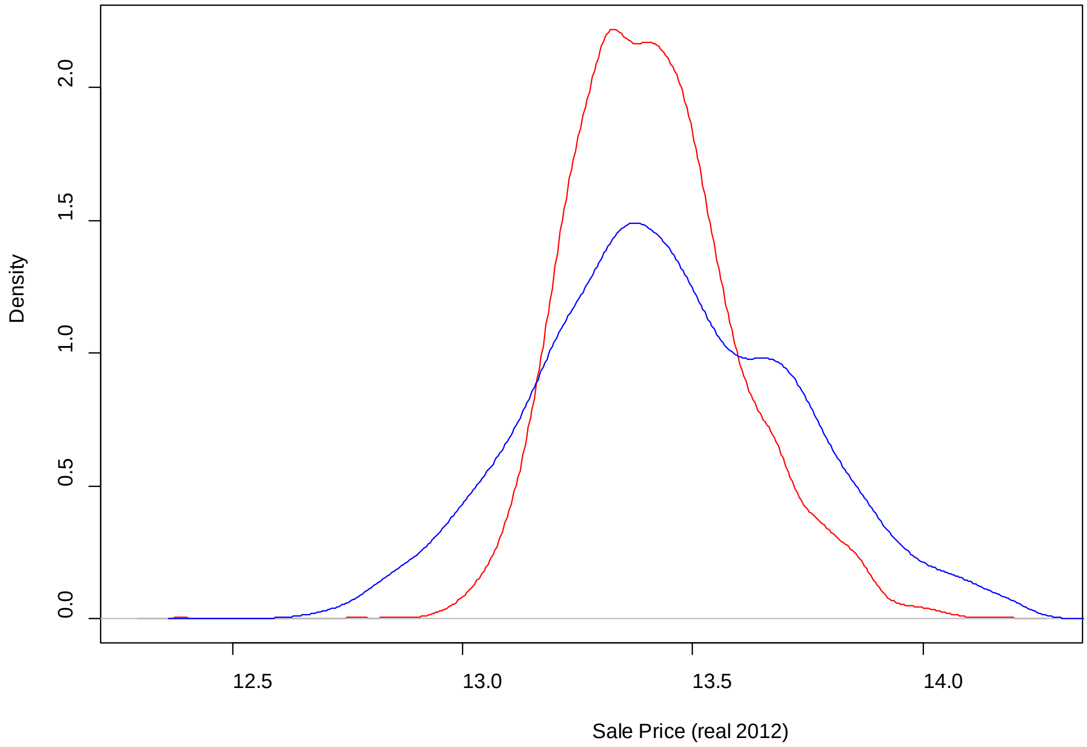
A fuzzy search algorithm was used to reconcile the list provided by Sydney Water with the addresses of each property within the transaction database. The algorithm matched street addresses on a number of characteristics, allowing the alphanumeric string for subdivisions (for example, house “1B”) or other variations to be matched to a unique street address, as listed in the Sydney Water database. Most properties sales could be perfectly matched with information from the Sydney Water database. From those which could not be perfectly matched between the two datasets, a selection was manually checked for accuracy. All properties that were checked manually were correctly identified.

A dummy variable was introduced into the property sales database based on whether the property appeared in the Sydney Water list. In total, 34.4 per cent of properties listed in the transaction database were identified as having a recycled water connection.

The correlation between the presence of recycled water infrastructure and other exogenous and endogenous variables was examined. Figure 3 illustrates the kernel density estimate for properties with and without access to recycled water infrastructure. A two sample t-test was then used to determine whether the difference in the two sub-sample distributions was statistically different from zero.

The means were different (p=0.035), with a real price difference of $48,753. The majority of this difference is accounted for by the sub-sample of properties with access to recycled water infrastructure having a different composition, in terms of the number of rooms, location and land area. However, it has been accepted that there still remains a component of the difference between the two means which cannot be explained by the set of attributes available.

Figure 3: Kernel density plots for properties with recycled water (red) and without (blue)



Source: MJA analysis from Sydney Water and property sales database.

2.3 Map database for neighbourhood attributes

Proximity of a property to neighbourhood attributes such as parks, schools, shops and major roads will all have an effect on the value of a property. In hedonic regression analysis, location effects have traditionally used the suburb as the smallest unit of spatial disaggregation. The rationale for not considering neighbourhood attributes at a greater level of spatial resolution are generally technical in nature: analysing each property on the basis of its exact geographical location and proximity to neighbourhood features requires extensive data on the geographic characteristics of a town or city, and the exact geographical coordinates of those characteristics. Historically, such features have not been readily available.

2.3.1 Neighbourhood Attribute Data Sources

Advances in freely-available online mapping information provide a means to access information on the physical attributes surrounding a property. The OpenStreetMap (OSM) project provides users with ready access to a rich database of geographical features for most Australian towns and cities. The OSM database was therefore used to identify the neighbourhood attributes surrounding residential properties.

The OSM database was provided in Extensible Markup Language (XML) format, from which the relevant attribute characteristics and their locations can be extracted. Modules available in the R Software package, with modifications by MJA, were used to automate the extraction and analysis of mapping data from the OSM XML database.

2.3.2 Proximity Measurement

The proximity between a property and nearby attributes was calculated as the great circle distance between two coordinates. The great circle distance is the shortest distance between two points on the surface of a sphere. Over relatively short distances, the great circle distance will approximate the distance travelled over the surface of the Earth (which is not perfectly spherical).

Use of the great circle distance makes an implicit assumption that it is the physical proximity of a property to the attribute which influences price. Assuming that all transport takes place over the road network, it is possible that the great circle distance is not correlated with the distance between two points when using the road network. The fundamental question is therefore whether it is physical proximity or travel time between a property and neighbourhood attribute which affects property price.

The great circle distance was used as a measure of proximity for two reasons. Firstly, it is expected that physical distance is itself only a proxy for the variable which affects household utility. For example, the disutility from a major road is likely to result from excessive noise pollution. Ideally, average noise levels (measured in decibels) would be recorded. Given the practical limitations of obtaining all such relevant data, using a proxy variable which is highly correlated must suffice. In this regard, great circle distance is believed to be a better approximate to the road-based distance.

Secondly, and from a more practical perspective, the time taken to complete a road routing computation is significantly greater than the time take to complete a comparable great circle distance computation. The great circle calculation is a simple trigonometric problem while road routing requires the use of the travelling salesman algorithm (or something similar) to find the shortest route between two points. For large datasets with many attributes, the additional processing time is prohibitive. Consequently, all distances are measured in meters using the great circle method.

2.3.3 Neighbourhood attribute list

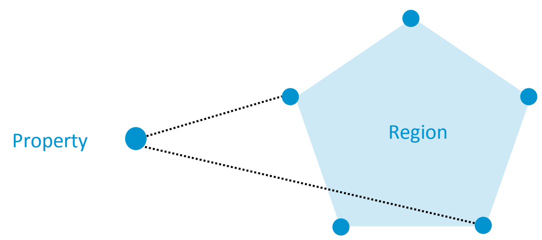
The OSM database contains a large set of location-based attributes. Attributes include schools, hospitals, retail areas, industrial parks, roads and lakes. Only a subset of the full attribute list is included in the analysis, for the reason that not all attributes within the OSM feature set appear within the selected sample region, and many attributes are highly correlated with others.

For example, all retail buildings exist on land classified for retail use (although the opposite is not true), therefore selecting the retail land classification will capture all retail buildings. Some attributes were used on the basis of an ex-post expectation that they would not influence property prices, or would have changed significantly over the period 2005 to 2012 (see section 2.4.4 for further discussion of this point)

For the purposes of estimating the proximity of a residential property to an attribute, attributes were classified as either nodes (single points) or regions (collections of nodes defining a closed set). Each node is referenced by latitude and longitude coordinates. Attributes are not prevented from intersecting or overlapping other attributes.

When calculating the great circle distance between a residential property and a neighbourhood attribute defined as a region, the minimum distance between a boundary node of the region and the property was used. As illustrated in Figure 4, the difference in distance between a property and the various boundary nodes of a region can be significant. A great circle distance is therefore calculated for all nodes within the region, and the minimum distance recorded for the purpose of further analysis.

Figure 4: Calculating great circle distances between properties and regions



Source: MJA

It is likely that in some instances the method of calculating the proximity via the aforementioned methodology will lead to inaccuracies. For example, if a motorway intersects the shortest distance between a residential property and parkland, the true distance to the parkland will be significantly greater than the estimate. However, given the technical limitations and complexities in calculating proximities for such a large number of data points, it is accepted that some level of inaccuracy was inevitable.

2.3.4 Changes in mapping attributes over time

The great circle calculation for the distance between each residential property and attributes of each class (in meters) was added to the database of property transactions. While the list of transactions extended between 2005 and 2011, the mapping data exists only as a snapshot of the region in 2012.

It is therefore possible that some attributes which are now present on the mapping database were not present (or present in a different form) at the time of the property transaction. There is, unfortunately, no way to overcome this data limitation. It has therefore been assumed that no significant changes in the geographical layout of the region have occurred since 2005.

2.3.5 Collinearity in neighbourhood attributes

In an early form of the model, a range of location variables were independently included in the model. However, examination of a correlation matrix and visual inspection of scatter-plot diagrams illustrated the significant degree of covariance between some variables. For example, all parks are surrounded by grassed areas within the OSM database, resulting in a high degree of collinearity between the two variables.

When collinearity was identified, the relevant variables were collapsed into a single variable. This was achieved by replacing all instances of the collinear variables in the database with a common variable name. Given the final set of variables used in the analysis, the impact of any such modifications were negligible, as only the ‘retail’ variable was highly collinear with another variable (car parking).

3. Methodology

3.1 Database development

Given the data sources identified in section 2, a property transaction-based database was created on which the hedonic regression could take place. All information pre-processing was undertaken in the R statistical package.

3.2 Functional Form

Economic theory provides some guidance in regards to the functional form of the hedonic model, given that neither the functional form nor the distribution of the error term is known a priori (Mäler & Vincent, 2003). Alternatives used in past studies include linear, quadratic, double-log, semi-log and Box-Cox transformation. Freeman (2003) proposes that, in choosing a functional form, the economist generally selects parameter values that result in the ‘best fit’ to the available data. While the degree to which the model fits the underlying data is an important consideration, additional factors must also enter into consideration.

Maximising the predictive capacity of the regression may not be an appropriate objective when estimating a hedonic model. If the intention of the hedonic model is limited to estimating the price of the heterogeneous product, then using a functional form that minimises the error term may be appropriate (Cassel & Mendelsohn, 1985). However, both generally, and in the context of the current analysis, the objective is to accurately estimate the implicit price of each characteristic, and not the price of the heterogeneous commodity.

Table 2: Variables used and functional form

Variable	Units	Form
Period	Year	Time-based dummy
Recycled Water Connection	Dummy	Dummy
Parking spaces	Number of spaces	Factor
Number of rooms	Rooms	Factor
Number of bedrooms	Rooms	Factor
Number of bathrooms	Rooms	Factor
Railway station (distance)	Meters	Quadratic
Hospital (distance)	Meters	Quadratic
Leisure (public parks and gardens)	Meters	Quadratic
Motorway (distance)	Meters	Quadratic
Primary road (distance)	Meters	Quadratic
Secondary road (distance)	Meters	Quadratic
School (distance)	Meters	Quadratic
Water (lakes, distance)	Meters	Quadratic
Retail land (distance)	Meters	Quadratic
Industrial Land (distance)	Meters	Quadratic
Suburb by area	Meters squared	log

Source: MJA

Given the lack of clear evidence for one functional form over another, the specification used represents a balance between a method that maximises the fit of the model, a-priori expectations for consumer utility functions and forms used in similar types of analysis in the past. Adoption of a different specification set (for example, linear only) resulted in a reduction to the model's goodness-of-fit and also decreased the statistical significance of a minority of variable coefficients.

A listing of the form utilised for each parameter is set out in Table 2.The period parameter is a time-based dummy variable to capture changes in the value of residential properties that is not associated with particular attributes. This is often referred to as a pure measure of changes in house-price values, as it is not associated with any single attribute of the property.

The suburb by area parameter is the product of the suburb-level dummy variable and the land-area of the property in meters squared. The purpose of creating such a variable is to allow the formation of a measure of the value of each square meter of land that is differentiated by suburb.

3.3 Estimation of the hedonic model

The hedonic model regression was performed using standard Ordinary Least Squares (OLS) methods to generate coefficient estimates. The model was estimated with the log of (real) sale price used as the dependent variable, meaning that all parameter coefficient estimates are measured in per cent terms.

The OLS regression specification follows that of Hansen (2009), in adopting a general form of:

$$P_{i,t} = \sum_{T=1}^{T} D1_{i,t}\alpha_t + X_{i,t}\beta + \varepsilon_{i,t}$$

Where:

- $P_{i,t}$ is the log of the price of house i when sold at time t;
- $D1_{i,t}$ is a vector of dummy variables with a value of one if the house sold in time t and zero otherwise;
- $X_{i,t}$ is a vector of house characteristics for house i when sold at time t; and
- $\varepsilon_{i,t}$ is a white noise term.

The OLS regression was performed using the R (http://www.r-project.org) statistical software with the LM-TEST module for OLS regression analysis.

As noted in section 4.2, heteroscedasticity was identified within the sample. Consequently, the OLS specification was adjusted to use a weighted least squares method (WLS), with individual weights based on the predicted variance. All subsequent parameter estimates are reported using the WLS method.

4. Results

4.1 Coefficient Estimates

Using the aforementioned WLS model, parameter estimates were obtained for the hedonic model. Estimates are illustrated in Table 3 below. As previously noted, the log of the sale price (in real 2012 dollars) was used as the dependent variable. Therefore, the coefficient estimates represent a per cent change per unit of the attribute.

Table 3: Coefficient estimates and statistical significance

Variable	Estimate	Significance[4]
Intercept	10.980	
Period – 2006	-2.527×10^{-02}	
Period – 2007	-2.136×10^{-02}	
Period – 2008	-6.714×10^{-02}	
Period – 2009	-7.323×10^{-02}	
Period – 2010	-5.531×10^{-02}	
Period - 2011	-8.359×10^{-03}	
Recycled Water	7.341×10^{-03}	0.022
Rooms – 3	0.290	
Rooms – 4	0.352	
Rooms – 5	0.341	
Rooms – 6	0.355	
Rooms – 7	0.374	
Rooms – 8	0.397	
Rooms – 9	0.398	
Rooms – 10	0.400	
Rooms – 11	0.401	
Rooms – 12	0.394	
Rooms – 13	0.386	
Rooms – 14	0.163	0.086
Bedrooms – 2	-0.115	
Bedrooms – 3	-9.938	
Bedrooms – 4	-2.457	
Bedrooms – 5[5]	NA	-
Railway Station (Squared)	0.080	
Railway Station	0.178	

4 For significance, p<0.0001 unless otherwise specified.

5 The number of bedrooms equal to five is not defined to prevent singularities.

Variable	Estimate	Significance[4]
Hospital (Squared)	9.425×10^{-10}	0.014
Hospital	3.036×10^{-2}	
Motorway (Squared)	-2.789×10^{-10}	
Motorway	8.536×10^{-10}	0.039
Primary Road (Squared)	0.018	0.822
Primary Road	1.964×10^{-9}	
Secondary Road (Squared)	9.389×10^{-10}	
Secondary Road	-3.027×10^{-8}	
School (Squared)	6.182×10^{-5}	
School	1.882×10^{-10}	
Lake (Squared)	6.496×10^{-3}	
Lake	1.392×10^{-2}	
Retail (Squared)	8.365×10^{-9}	
Retail	2.117×10^{-2}	
Industrial (Squared)	1.698×10^{-9}	0.011
Industrial	2.737×10^{-3}	0.483
Suburb - Acacia Gardens	0.137	
Suburb - Beaumont Hills	0.146	
Suburb - Bella Vista	0.197	
Suburb - Castle Hill	0.764	
Suburb - Glenwood	0.150	
Suburb - Kellyville	0.152	
Suburb - Kellyville Ridge	0.141	
Suburb - Kings Langley	0.147	
Suburb - Parklea	0.139	
Suburb - Quakers Hill	0.125	
Suburb - Rouse Hill	0.122	
Suburb - Stanhope Gardens	0.141	
Suburb - The Ponds	0.147	
Intercept	0.109	

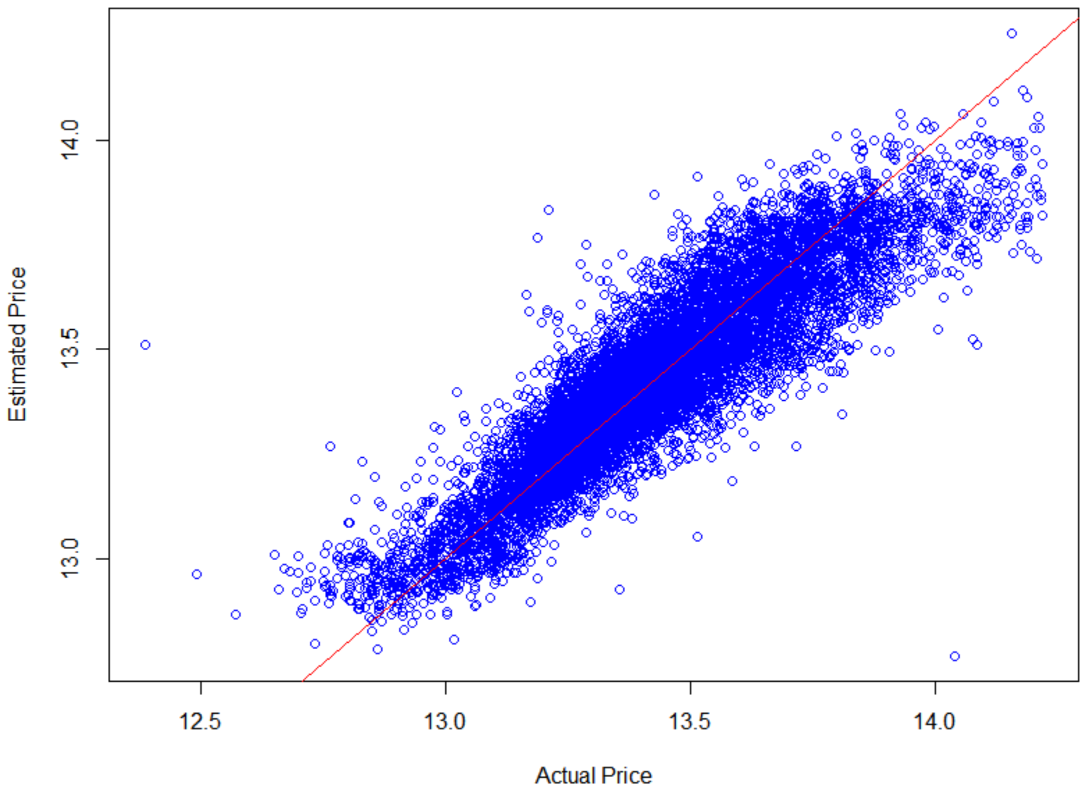
The correlation coefficient (R^2) value for the above model was 0.817.

4.2 Heteroscedasticity

Application of the Breusch-Pagan test identified the presence of statistically significant heteroscedasticity within the hedonic model. Indeed, the figure below illustrates the severity of heteroscedasticity in the final OLS regression undertaken.

A number of unsuccessful attempts were made to reduce the heteroscedasticity through modification of the functional form of variables. Consequently, the WLS method was used as opposed to the simpler OLS approach.

Figure 5: Plot of predicted versus actual (log) prices using OLS



Note: The red line is the point where estimated log price equals actual (log) price.

4.3 Recycled water infrastructure values

As the hedonic model is estimated in log form, it is necessary to convert the coefficient estimate in order to produce a dollar-value estimate. This is undertaken by multiplying the recycled water connection dummy variable coefficient estimate by the mean house price. As the WLS regression uses a logarithmic form, it is also necessary to multiply the median price by a scaling factor (see Wooldridge, 2008, p.189) to correctly estimate the value of the recycled water infrastructure. Following Wooldridge (2008), a constant factor is found by regressing the predicted (real) price onto the actual real sale price using OLS, with no intercept term. Using this approach, the estimated scaling factor was 1.00783.

Table 4 below provides an indicative house price range for the region, from which an estimate of the value of recycled water can be formed in dollar terms. The use of a range for the mean house price is appropriate given the continuing evolution of property prices in the region.

Table 4: Recycled Water Infrastructure value estimate in real $ (2012)

Point	Median House Price	Recycled Water Value
Lower quartile	581,215	$4,266
Median	674,238	$4,949
Upper quartile	709,008	$5,204

Source: Property database and MJA estimates.

The value held by residents attached to the Rouse Hill Recycled Water Scheme for recycled water infrastructure ranges from $4,266 to $5,204 per property. We estimate the average (median) property retains a value of $4,949 for recycled water infrastructure.

5. Conclusion

In order to assess the costs and benefits of installing third pipe schemes to deliver non-potable water, it is necessary to estimate the value of that service to households. Hedonic pricing is one method that allows the capitalised value of the recycled water connection to be separated from the sale price of a property.

Based on transactions of residential properties in the suburbs of Western Sydney between 2005 and 2011, and information on neighbourhood attributes in the region, an estimate of the value of the Rouse Hill recycling scheme per household can be formed. While the estimate is dependent on the median house price in the region, the result is believed to be both statistically significant and a robust indicator of the value of recycled water infrastructure to households. At 0.716 per cent of the average property in Western Sydney, or $4,949, the estimate is not insignificant, but is likely to be less than the cost of installing or retrofitting third pipe infrastructure into suburbs.

Importantly, this reflects one of many values for recycled water in a community. In addition, there may be values held by the broader Sydney society for water recycling in addition to this ‘use value’ to residents.

6. References

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