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Empirical Study: Impacts of Objective House Factors on Residential Water Usage in Springfield, Missouri

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EMPIRICAL STUDY: IMPACTS OF OBJECTIVE HOUSE FACTORS ON RESIDENTIAL WATER USAGE IN SPRINGFIELD, MISSOURI

A Masters Thesis

Presented to

The Graduate College of

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Natural and Applied Science

By

Ran Qi

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EMPIRICAL STUDY: IMPACTS OF OBJECTIVE HOUSE FACTORS ON RESIDENTIAL WATER USAGE IN SPRINGFIELD, MISSOURI

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ABSTRACT

The study is to examine the objective house factors impacting residential water consumption, to explain how each factor influences water bill in a household, as well as to call attention to use residential water resource more wisely. The results are based on regression data analysis. The Hedonic price model analyzes relations between marginal residential water bill and five independent variables, including: acres, building age, living area, home value, and a south Springfield designation. This study uses data from local households in Springfield, Missouri. Findings can be used in formulating policies related to urban water usage. City Utilities could use the findings from the study as a guide to adjust residential water price with the help of localized data results. The final purpose of this study is to suggest Springfield, Missouri, residential water allocation and pricing policy adjustment. Therefore, residential water resource could be saved and used in a more efficient way.

KEYWORDS: residential water consumption, water usage, regression analysis, Hedonic price model, water resource allocation

This abstract is approved as to form and content

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Arbindra Rimal
Chairperson, Advisory Committee
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INTRODUCTION

Residential water is of critical importance. First, the demand of residential water is a foundation on which governments adjust current water price or make new utilities policies. Therefore, knowing the patterns of residential water consumption would be beneficial to water price and allocation policy-making. Given residents' water usage patterns and the population growth rate, it would be easier for policy makers to adjust the current policies as well as make new policies to allocate water resource more efficiently and make revenue. Second, it would be beneficial to the environment. As is widely recognized, although 72% of the Earth surface is covered by water, less than 1% of the world's fresh water is directly accessible for human uses (Ferrara, 2008). With more efficient water resources allocation and residential usage, it would help save water resource, one of the most essential resources on Earth, and thus protect the environment. Last but not least, utility bills are a constant expense of concern to most households. This research could guide local policy makers in developing policies that can improve water usage behaviors. Hence, local residents could acquire a lifestyle that is both environmentally and economically friendly which is already a trend in major cities all over the world.

This study will estimate the factors that impact residential water bills in Springfield, Missouri. The study findings will suggest practical water pricing policies so that it could be more efficient to allocate resources. The analysis relies on cross-sectional monthly data from City Utilities of Springfield (SCU), Missouri. On one hand, research results could suggest policy makers adjust water price and allocation. On the other hand,

this study will also come up with suggestions for local residents to consume water in an economical and environmentally-friendly way.

Residential water demand has been declining since 2010 in Springfield, Missouri. According to the Annual Operating Budget of City Utilities Springfield (2017), usage of the local water system continues to be much lower than the early 2000s although there is a modest growth in customers. Residential customer growth is estimated to keep increasing slightly through 2018. The annual budget indicated that while there was in an increasing trend of customer growth in 2017, but total water consumption was still much lower than that of two decades ago. In addition, water usage per residential customer in 2015 hit the lowest point in the previous fifteen years. After an increase in 2016, water usage per residential customer is expected to continue to decrease in 2017 based on normal weather. Therefore, it is necessary to analyze factors affecting local residential water demand and to provide a guide for policy makers to adjust current water pricing policies and conduct incentives to encourage residents to save water.

LITERATURE REVIEW

Demand Side Management Studies

Residential water is a common product for customers to utilize in every-day life. Meanwhile, its inelasticity makes it very interesting to study the demand patterns. Scholars and researchers have been analyzing how to monitor residential water demand for decades. Demand side management (DSM) was introduced and applied as a method to detect and oversee residential water demand. Worthington and Hoffman (2007) have illustrated that DSM is an urban water usage management tool.

DSM is also known as energy demand management or demand-side response. This is a modification of consumer demand for energy through various methods such as financial incentives and behavioral change through education. Renwick and Green (2000) used DSM as an urban water resource management tool. They found that DSM stimulated significant discussion among economists, water utility managers, and policymakers. While economists were generally advocating residential water prices that reflect marginal costs as a means of reducing demand during periods of limited water supply availability, others argued that residential demand was price inelastic and thus price was a relatively ineffective DSM policy.

With the increase of using this method to conduct city-wide policies, concerns about DSM dependably have been discussed among economists. Researchers were critical whether DSM could be applied directly in a variety of situations. Hoffman (2009) pointed out that water utility managers, regulators, consumer interest groups as well as policymakers were also cautious about if they needed to adjust DSM when considering

water bill policies. It was argued that sustainable urban water pricing should not be measured under DSM. For instance, Klawitter (2003) argued that water pricing must to be designed to meet the goal of being sustainable. Along with residential water demand, policymakers need to consider maintaining water resources so it could meet the needs of future generations. In the viewpoint of resource use efficiency, water pricing needs to stimulate customers to be conscious of how to use water efficiently. As for water utility managers, they need to pay more attention to full cost recovery including supply costs, opportunity costs and economic externalities. Hence, long-term revenues could be achievable. Additionally, given the thoughts on equity and fairness for different users, regulators are supposed to be careful with price discrimination which is not included in DSM.

Declining Consumption Trend Studies

Rockaway, Coomes, Rivard and Kornstein (2011) claimed that many water utilities across the United States and elsewhere were experiencing declining water sales among households, therefore this gradual erosion in residential consumption may force utilities to raise rates to provide sufficient revenue. Their study pointed out the importance of a clear understanding of the changing water-use patterns. Lots of water utilities have noted that average residential water consumption is decreasing, even though the line chart of customer households continues to climb up (Rockaway, Coomes, Rivard, & Kornstein, 2011). According to the rate sheet from SCU, this similar situation is occurring for local customer households in urban area of Springfield as well. Residents

tend to consume less water per month than people did ten years ago. As a consequence, SCU increases water rates every year to maintain revenue.

There are certain reasons to theoretically explain these declining trends. Rockaway, Coomes, Rivard and Kornstein (2011) stated a key reason appears to be the increased use of water-conserving fixtures and appliances. They showed the improving quality of a house could be a reason why residential water demand has been declining since the 2000s. With the development of technology on water conservation, customers can choose to equip their houses with high-tech supplies such as low-flow toilets and washing machines. Hence, water efficient technologies received more attention. However, these researchers emphasized neither a definitive claim could be stated as to verify these explanations nor the amount each contributes to the observed decline in residential water use. This thesis research critically evaluated local residential water usage data with the aim to detect local water demand trends as well as to assess each factor's relationship to domestic water consumption.

Without a precise insight of recent water-consumption patterns, it could be very difficult to develop appropriate pricing structures that would both recoup costs and provide sufficient resources for the future. Mayer, DeOreo, Towler and Lewis (2003) concluded reliable measurements of water savings are essential for long-range projections of the impacts of conservation projects on urban water demands. Discoveries from this study aim to analyze potential factors influencing residential water usage. Hence, it can help reference new more environmentally friendly water consumption patterns.

Schleich and Hillenbrand (2009) analyzed the impact of several economic, environmental and social determinants for the average per capita demand for water and

sewage in Germany. As a developed country, the regional differences of Germany in per capita residential water consumption showed that customer water demand was related to household income, local weather conditions (wet/dry), as well as education level, race and so forth. Economic, environmental and social factors shaped the demand for residential fresh water and sewage were expected to undergo substantial changes in the near future. More specifically, economic growth would lead to higher income levels while water prices may rise in response to increased scarcity; sewage prices may increase because of environmental regulation to control harmful substances, or prices may fall if water markets are deregulated. They also suggested that water utilities should assess their own regional water use characteristics and appropriately adjust to the trend of reduced water sales to residential customers.

METHODS

The research question evaluates if there a relationship between residential water bill consumption and characteristics of a house. The null hypothesis for this study is that there is no relationship between residential water usage and characteristics of a house. The research problem is to estimate relations between residential water bill and objective household features in Springfield, Missouri. Exact monthly residential water bill data is proprietary information for SCU under confidentiality policy with its customers. However, data of monthly domestic water usage is publically accessible and was used in this study to estimate the price. This research problem aimed to analyze how objective factors of a house influence a household's water bill.

This research utilized quantitative methods. Pre-existing statistical data was manipulated by using computational techniques. This research concentrates on gathering numerical data and generalizing it across groups of people with the aim to explain relationships between willingness to purchase residential water and objective characteristics of a household. The goal of this research is to classify features of local residential water consumption and construct statistical models in an attempt to interpret willingness of residents to use water and impacts which objective house factors have on paying for marginal water price.

Pricing Model Hypotheses

Variable Selection. It is essential to determine appropriate variables to organize data and then build up the model. There were a variety of models considered including

regression models, economic models, time series, and even artificial intelligence has been used in analyzing water demand (Jain and Ormsbee, 2002). Most of these models incorporated one or more "predictor" variables that had a known or assumed relationship with domestic water consumption. A wide array of factors was considered for short-term water demand models as independent variables, including weather-related factors, such as temperature and rainfall. However, variables varying from day-to-day cannot completely forecast residential water demand. Long-term factors which could impact residential water usage must also be considered.

Some of the models, especially those focusing on short-term forecasts, included meteorological variables, such as temperature and rainfall, hydrologic conditions including groundwater withdrawals and storm water runoff. Other models focused on the long-term changes in the size and composition of the customer base, or "rate payers", incorporated socio-economic variables including population, household income, house units or households by type (single-family and multi-family), and employment by industry. These variables were assumed to have a direct or indirect relationship with water consumption. For instance, in the Main Water Use Forecasting System, water demand per single-family residential household was a function of both the number of single-family household and the average household size of these households and their income (Henfling and Opitz, 1991).

Model Exploration. Renwick and Green (2000) introduced a model to assess the potential of price and alternative DSM policies. This model could be regarded as an urban water resource management tool, with which an econometric model of residential water demand could be established and estimated. This econometric model incorporated

alternative DSM policy instruments such as water allocations, use restrictions, public education and increasing block rate pricing schedules. Block rate pricing is a city utilities policy. Monthly domestic water consumption is broken into several segments to calculate the bill. Customers pay at a higher rate for each additional segment. Likewise, a household would get a lower water bill if it has fewer blocks. Renwick and Green picked cross-sectional monthly time-series data as samples for eight water agencies in California representing 24% of the state's population of 7.1 million people. Results suggested that both price and alternative DSM policies were effective in reducing demand. However, the extent of the reduction in demand turned out the be different among policy instruments.

Hewitt and Hanemann (1995) developed another model to indicate the residential demand of water. They estimated the residential water demand under block rate pricing with a discrete-or-continuous choice model and compared it to results of regression models. Their empirical analysis used a dataset from a previously published study by Nieswiadomy and Molina (1989) of household level panel data from Denton, Texas. The model was formulated from 1981 to 1985 with summer months only considering an increasing block rate in effect. The result was the discrete-or-continuous choice model produced price elasticity estimates near -1.6, which were much more elastic than previously published results based on regression models where the discrete choice was not excluded.

Most of the studies applied regression models based on data collected during various surveys in regions where water prices increased. This is in part due to the fact that every region has its own conditions affecting residential water consumption and socioeconomic influences. For example, two cities in California and Missouri have

different populations even if they are both ranked as the largest city in its state. Additionally, precipitation is different, sometime opposite, in these two regions as California is facing a drought crisis in recent years.

Regression models are the most popular models for residential water demand. They typically used the form Q = f (P, Z) where P are the price variables and Z are factors such as income, household characteristics, weather, etc. Arbués, Garcıa-Valiñas, and Martınez-Espiñeira (2003) implied the most common forms are linear and logarithmic. There was no agreement about which functional form gives better results. Some researchers viewed it as a good form by looking at which model better suited the database. Billing and Agthe (1980) cited the elasticity in the log model was more useful if the demand was a rectangular parabola, while the elasticity in the linear form was more practical if water demand was linear over a relevant range. The main flaw researchers attribute to the linear model was that at certain price, the demand for water would be zero, which was not in the logical line as a least scale of water usage was needed to survive (Arbués bues, Garcıa-Valiñas, and Martınez-Espiñeira, 2003).

Different estimation methods were tested in Scholar Bollen's study. Bollen (1989) noted the most common methods were Ordinary Least Squares (OLS), Two and Three -Stage Least Squares (2SLS, 3SLS), and Maximum Likelihood (FIML). The choice of a method in analysis was effected by the data set available to the researcher. In other words, the decision on research method depends on the type of data.

A great number of different datasets have been utilized, ranging from individual household data to aggregate data. Lots of the studies used surveys conducted on a sample of households. Researches used three types of data including cross-sectional data

(Chicione and Ramammurthy, 1986), times- series data (Agthe, Billings, Dobra, and Raffiee, 1986), and most commonly cross-sectional-times series data (Renwick and Archibald, 1998). Some models included lagged consumption in their models (Dandy, Nguyen, and Davies, 1997).

Model Settlement. This research uses Hedonic pricing model to examine how the various measures were constructed and impacted the residents monthly water consumption. This study aims to reveal how the price of residential water in the city of Springfield, Missouri, is related to characteristics of a home.

The Hedonic pricing model is suitable for this study considering the characteristics of the chosen variables in the research. Hedonic models have been applied in residential water usage studies. Griliches (1957) first used Hedonic pricing model for his thesis on hybrid corn. He studied the diffusion of an innovation as it was affected by various economic forces. It led him to try alternative frameworks for the analysis of technical change in his work on the demand for fertilizer in agriculture.

Hedonic hypothesis reflects the willingness of customers to purchase a product. Rosen (1974) supposed that goods were valued for their utility-bearing attributes or characteristics. He pointed out Hedonic prices were defined as the implicit prices of attributes and were analyzed by economic agents digging the inter price features observed prices of differentiated products and the specific amounts of features related with them. In this study, Hedonic price theory could be used to tell the story of residential water with characteristics of the price.

Hedonic regression analysis could help with the research for this thesis. Household water consumption is composite with both objective and subjective

characteristics. For instance, a new house with economically-friendly amenities tends to use less water than those with an old, sometimes even leaking appliances. As for subjective factors affecting domestic water usage, a very common example could be found in different lifestyles including the amount of times a person takes a shower per week, the amount of water used when cooking, and so forth. All these characteristics are based on individual feelings, tastes, or opinions on water consumption. Sirmans, Macpherson and Zietz (2005) noted that Hedonic regression analysis was typically applied in estimating the marginal contribution of individual characteristics. This thesis is focused on the objective factors and trying to explain their relationships with household water usage respectively. The Hedonic pricing model enables a researcher to detect local consumers' willingness of using water which is directly reflected on the monthly utility bill. Therefore, this thesis used anonymous data from SCU and then calculated the marginal bill of household water consumption.

Empirical Design

In order to undertake this analysis, it was critical to obtain residential customer records. SCU made customer-based files available for this study. SCU created and maintained the data collection of residential water customers located in the associated Green County Parcel (GCP). Their records contained the monthly residential water usage from 2013 to 2017. This was a cross-section study with 12 months' data in 2017. To match the household information, it was necessary to have more independent variables. Building age was added to track the house condition. A dummy variable was created for location (south or north of Springfield, with south equaling one) to track the community

condition. In a word, added independent variables were building age, home value (U.S. dollar), GCP acres (size of parcel) and GCP living area (square foot), and a south/north dummy.

Home value was tracked on Beacon Schneider Geospatial website. Schneider Geospatial was the provider of Geography Information System (GIS) and e-government solutions to Green County and recognized in GIS mapping technology. Beacon, as one of the solutions, provided access to obtain appraised home values.

The dummy variable was the south area of Springfield. By decoding zip codes, the geographic area of a house was discovered and distinguished as value of one or zero in this study. A dummy variable equaled one in the model if a house was located in the south urban district or zero for the north urban district.

The original data from SCU had more than 85,000 rows of data for both commercial and residential types of water usage. This study focused on residential water only in the city of Springfield. The research was based on two sets of random data. The second set of data functioned as a selected subset helping reduce occasional errors and obtain robustness in the model. Given the availability of finance and labor, two thousand random data were divided in half. The size of each set was 1,000 households. The first set of data was used as the sample in running the models; while the second set of data functioned for robustness check.

The method of sample selection was the Random function in Excel. All 85,460 observations were included and run in Random function. Then 1,000 data with south dummy variables (all south dummies summed up to 645) were selected as the first set of the sample. With the same method, a second set of data with 488 south dummy sum-up

was generated with a balance between south and north areas. To note, Random function in Excel could merely change the order of observation numbers, not including monthly marginal usage of residential water, home value, acres, age, living area as well as dummy. Therefore, all those variables were manually matched with observation numbers after running the Random function.

The dependent variable was designed as the willingness of residents to purchase water. The Hedonic pricing model required marginal price of residential water usage on the left side of the equation. Customer confidentiality policies, however, only allowed for access to monthly water service rates. The residential water service rates (Appendix A) sheet provided details about how residential water bills were generated. Residential water price is the sum of customer charges and commodity charges. Customer charges were fixed throughout the year; commodity charges were the result of monthly usage multiplied by rate for the season (winter/summer period) and household area (inside/outside the city of Springfield, Missouri). All data in this study is inside the Springfield urban area.

Model Preparation

Block rate pricing creates a variety of formulas to calculate water bills in different rate levels. Increasing blocking tariffs are set along with the amount of domestic water usage (centum cubic feet, CCF). In block rate pricing, the bill would be charged at a higher rate in every next block of water usage. For instance, if there is a household with eight CCF water consumption, under block rate pricing, it is more expensive for the second block of three CCF water usage than the first five CCF. As shown in Appendix A,

SCU puts increasing block rates only from June to October while keeping a flat rate from November to May. The flat rate of Springfield residential water is \$2.63 while the fixed charge is \$16.90. Bills from November to May as well as residential water consumption within five CCF from June to October share the same computation:

(1) $$P = 16.90 + 2.63(MU)$$

Where P stands for residential water price; MU stands for monthly water usage.

As for summer seasons (June to October), \$2.63, \$3.25, and \$4.00 are three different water service rates. Residential water would be billed under formula (2) when the amount is between 5 CCF to 15 CCF. Formula (3) applies to water usage beyond 15 CCF:

(2) $$P = 16.90 + 5(2.63) + 3.25(MU - 5)$$

(3) $$P = 16.90 + 5(2.63) + 10(3.25) + 4(MU - 15)$$

Marginal price is the outcome of average yearly water price divided by yearly water consumption. Hedonic pricing model is hereby utilized. Thus, this study can analyze the price-quality relationship of residential water (Combris, Lecocq, and Visser, 1997). As mentioned above, Rosen (1974) has demonstrated under which market situations the implicit price can be interpreted as how consumers value a product’s one additional unit of the characteristic. If the estimated implicit price shows to be not significantly different from zero, then this characteristic can be concluded as not valued by consumers. In other words, in a market, the quality of a product is not regarded as considerable or relevant impact of purchasing if the Hedonic price has a low, near-to-zero estimation. Residential water demand is reflected by house condition and household demography. The dependent variable is initiated under formula (4).

(4) $$HP = YR\_P \div YR\_C$$

Where HP is Hedonic price, YR_P is average yearly residential water price, and YR_C is yearly residential water consumption.

Empirical Model

The dependent variable, residential water Hedonic price, is the result of average yearly residential water price divided by yearly residential water consumption. The purpose is to establish a Hedonic model to explain local residents' water consumption quality, or the willingness of paying marginal water price. Hereby, the Hedonic regression model was built up with Hedonic price on the left side and home value, GCP acres, age, GCP living area as well as south dummy variable on the right side of equation below:

(5) $$HP = \alpha + \beta_1(HV) + \beta_2(Acres) + \beta_3(BA) + \beta_4(LA) + \beta_5(South)$$

Where HP denotes Hedonic price; HV, BA and LA denote home value, building age, living area and south, respectively. α is the constant (intercept); while β_1, β_2, β_3, β_4 and β_5 are coefficients of independent variables in equation (5).

There is another independent variable called home value per square foot. It is established to accurately describe how much the household pays for the living area. The variable is a division of home value and living area, therefore, is computed to define the quality of a house. This new independent variable is the ratio of home value and living area of a house, which is named as home value per square foot in equation (6):

(6) $$HVPSF = HV \div LA$$

Where HVPSF is home value per square foot and HV, LA are home value and living area respectively.

Now the new explanatory variable, HVPSF, ousts both home value and living area. Therefore, there is a new Hedonic price equation below:

(7) $$HP = \alpha + \beta_1(HVPSF) + \beta_2(Acres) + \beta_3(BA) + \beta_4(South)$$

It was a dynamic result-exploring adventure. As an initiative study, results in this study were figured out step-by-step, model-by-model. Results were refined from process of model modifications rather than one solid model. The dynamics of adapting model allowed more thoughtful results helping answer the research problem more properly. Therefore, both equation (5) and (7) were analyzed in this study.

Variable Definitions

Statistical tests and analyses helped understand the outcome of this study. A summary of the data used for the estimation of regression models described characteristics of variables (Table 1). As the dependent variable in both equation (5) and (7), Hedonic price had a mean of $8.16 per CCF and a standard deviation of $7.80 per CCF. It indicated that the marginal residential water price in the city of Springfield was $8.16 per CCF. The maximum and minimum values were $70.23 per CCF and $3.49 per CCF, respectively.

There are six independent variables in total. Home value, living area, building age and acres were named as “original independent variables” since they were chosen directly from original file provided by SCU. All independent variables described features of a house. This study is attempting to discover relationships between marginal residential water price and objective house characteristics.

South was the binary variable in this study. The value equaled one if the household was located in the south region of Springfield; and zero if the household was living in the north side of Springfield. Approximately 64% of households were scattered in category 1, with the remaining 35.5% in category 0.

Home value per square foot was the result of home value divided by living area in equation (7). In this project, it was named as “combined independent variable”. The average home value per square foot (sq. ft.) calculate from the sample equaled to $51.14 per sq. ft. with a standard deviation of $22.35 per sq. ft. The maximum value of home value per square foot was $307.64 while the minimum was $7.24 per sq. ft.

Home value described the appraised value of a house or apartment in 2017. The average home value in the sample was $90,307.86 with a standard deviation of $79,354.10. The most expensive house in the sample was evaluated as $277,400, and the cheapest was $21,000.

Living area was defined as house area including any square footage under air conditioning. The average square footage of living area was 1,609.37 with a standard deviation of 2,189.26 sq. ft. The largest living area in the sample had 7,908 sq. ft.; while the narrowest living area had 568 sq. ft.

Building age reflected house condition as “new” or “old”. In the sample, the average building age was 56.18 years with a standard deviation of 31.93 years. The oldest house had 90 years of history, and the newest house was built for only 4 years.

The last original variable was acres. The average acres of a house in the sample were 0.32 with a standard deviation of 0.80 acres. The maximum acres were 19.60 while there are houses with 0.07 acre in the sample.

RESULTS

A number of OLS models were run with 992 valid observations. Hedonic price was the dependent variable along with five original independent variables including home value, acres, age, living area and south dummy variable for the first two models; with combined independent variable, home value per square foot, for the latter two models.

Model Results

Model One was a regression model with original independent variables. R-squared was 0.02 and adjusted R-squared was 0.01. Among original independent variables, coefficients of acres, building age, living area and south were all positive while home value was negative (Table 2). However, t-ratios of original independent variables were statistically insignificant except home value with a t-ratio of -1.691 (significant level, $\alpha \leq .05$).

Model Two was a semi-log regression model with original independent variables. R-squared and adjusted R-squared slightly increased from 0.01 to 0.06 in Model Two. Along with constant and home value, acres became statistically significant with a t-ratio of 1.907 at a significant level of 5% (Table 3). Coefficients of acres and building age remained positive. However, coefficients of both living area and dummy variable changed into negative.

Model Three was a regression model with an independent variable called home value per square foot which combined home value and living area. Home value per

square foot was introduced as a combined independent variable to solve collinearity problems. R-squared and adjusted R-square were both 0.01, which was similar to results in Model One. Coefficient of home value per square foot was negative (Table 4). Acres and building age showed as positive. In Model Three, home value per square foot was the only statistically significant independent variable with a t-ratio of -2.598 at $\alpha \leq .05$. Coefficient of south binary variable changed into negative, but was not statistically significant enough to note.

Model Four was a semi-log regression model with the combined independent variable, home value per square foot. Model Four had R-squared and adjusted R-squared of 0.02. Similar to results in Model Three, home value per square foot and south were negative while acres and building age were positive (Table 5). In addition, home value per square foot remained being the only statistically significant independent variable with a t-ratio of −2.780 ($\alpha \leq .05$).

Diagnostic Tests

Collinearity and heteroscedasticity were detected in the sample. It was necessary to solve these statistical problems with the aim to get more accurate results. Belsley-Kuh-Welsch collinearity diagnostics were used to test for and correct collinearity. Collinearity detection was conducted at the same time when generating models. Table 6 contains results before and after combining home value and living area as one independent variable. Before the combination, variance inflation factors of home value and living area were 3.472 and 3.294 respectively even though they were still below 10. However, variance inflation factors of all four independent variables in Model Three and Four were

not larger than 10 and dropped down around 1.0 which was the minimum possible value. Heteroscedasticity was detected and corrected in sample data under four different tests (Table 7).

Robustness Check

The second set of data was used to keep robustness in this study. There were 995 valid observations. As the dependent variable both equation (5) and (7), Hedonic price distribution of data for robustness check had a higher mean value of 13.35 than that of sample (Table 8). However, the range of values was larger than sample data with a standard deviation of 23.57. The maximum and minimum values of Hedonic price were 205.43 and 3.51 respectively.

Model Five was a regression model with original independent variables, but using the second data set. Similar to results of the sample, R-squared and adjusted R-squared remained low at 0.03 in Model Five. Negative coefficients of home value and south echoed results in the sample; while positive coefficients displayed for other three original independent variables (Table 9). Meanwhile, home value was statistically significant with t-ratios of −2.670 at $\alpha \leq .05$. Acres was another statistically significant independent variable in the model with a t-ratio of 2.600 at $\alpha \leq .05$.

Model Six was a semi-log regression model with original independent variables. Both R-squared and adjusted R-squared jumped up from 0.02 to 0.10 in Model Six (Table 10). Home value, acres and building age were still the most statistically significant. South dummy variable and building age became slightly significant statistically with t-ratios of −1.830 and 1.704 respectively when $\alpha \leq .05$. Living area became the only statistically

insignificant with a t-ratio of −1.143 at $\alpha \leq .05$. Coefficients kept the same signal except for living area. This change of coefficient did not draw much attention since living area was statistically insignificant in this model.

Model Seven was a regression model with the combined independent variable, home value per square foot. R-squared and adjusted R-squared were both at 0.03. Home value per square foot was the only negative coefficient in the model (Table 11). Besides the constant, home value per square foot, acres and building age were statistically significant with t-ratios of −2.171, 2.496 and 2.292 respectively at a significant level of 5%. South dummy variable changed into statistically insignificant with a t-ratio of 0.2867 ($\alpha \leq .05$).

Model Eight was a semi-log regression model with the combined independent variable. Both R-squared and adjusted R-squared increased to 0.09. All four independent variables were statistically significant (Table 12). Coefficients of home value per square foot and south were negative while the other two independent variables were positive.

DISCUSSION

The research problem was to explain relationships between residential water consumption represented by average monthly water bill and objective characteristics of a household in Springfield, Missouri. Home value, acres, age, living area and south dummy variable were chosen to be independent variables. Results from regression analysis showed that there were impacts of those variables on the residential water bill. In the following sections, results from the study created a basis of discussing service rates policy adjustment at SCU. In addition, discussion on water resource allocation in this section is expected to raise attention of customers to maintain their house condition and save water.

Understanding how a water utility charging policy works was the first step to figure out the water price. According to Reynaud, Renzetti and Villeneuve (2005), there were different types of pricing of a water utility: flat rate, constant or uniform rate, increasing block rate or decreasing block rate. Hewitt (2000) described that utilities in the United States tend to practice increasing block rate pricing systems under drier weather conditions. Missouri is a mid-west state where the annual precipitation is 43.11 inches. In a list of average total yearly precipitation for each state (Appendix B) in 2017, Missouri was the 24th where all states were ranked from the wettest at number 1 to the driest state at number 50. Therefore, local weather is not the driest among the states. Results and discussion in this study support SCU's increasing block rate water policy.

Average monthly water bill was observed to be steady in this study. Gunatilake, Gopalakrishnan and Chandrasena (2001) found that water consumption did not

immediately respond to price changes. Therefore, the function was limited to change water usage and water conservation by changing pricing policies. However, Dalhuisen, Florax, De Groot and Nijkamp (2003) revealed that residential water demand was relatively price-elastic under increasing block rate pricing. This feature of water usage offered an opportunity to increase revenue by setting up increasing tariffs on different levels of water consumption. It was also pointed out that such different water policies included purpose of social equality and accommodated the poorer heads of communities as residential water had no substitute (Gunatilake, Gopalakrishnan and Chandrasena, 2001). Increasing block rate systems divided water consumption into blocks. The charging rate of the initial block was at the lowest level and gradually increased as a response to increased water consumption. Increasing block rate would not only accommodate residents with low water consumption, but also help city utility department make revenue as the more water is consumed, the higher rate tariff would be imposed on the household water bill (Gunatilake, Gopalakrishnan and Chandrasena, 2001).

Selecting reasonable explanatory variables was the next essential step after figuring out the dependent variable in this study. The reason why this study added home value and living area ratio was that both independent variables were measuring the same thing. As displayed in the results section, both sample sets led to very similar results, including coefficients, standard errors, t-ratios, as well as p-values. It could be calculated that home value is around 100-scale difference with living area. In other words, home value could be approximately assessed by living area times 100. With that being said, one could conclude that home value and living area were highly related.

Home value and living area ratio exclusively reflected the quality of a household,

leaving alone district and surroundings which would affect the appraisal value. The ratio demonstrated the value paid on the living area of a house so that research could be more accurate in demographic point of view. For instance, a house with a large family crowded together in a small and cheap house may consume more water than that with a retired couple living in a big and expensive house. In this scenario, the crowded large family has lower value-living area ratio than the couple does. Therefore, the quality of this couple's house is better than the large family even though the living area of both houses are the same. Hence, the ratio shows the quality of a household by taking into account both value the home and living area. The higher the ratio is, the more likely it is that this household has higher income to purchase an expensive house.

Expensive houses generally include modern toilets and appliances with water saving and energy conservation features. Lee, Tansel and Balbin (2011) analyzed long-term observations of impacts of water conservation incentives on water demand. Those incentives included rebates and unit exchange programs for showerheads, toilets and clothes washers. Their study displayed water savings in residential water use efficiency. Water demand significantly decreased in the first two years and was continuously decreasing in the third or fourth year. High efficiency toilets and clothes washers had the highest potential in saving water. According to Mohadjer and Rice (2004), the reduction in leaking due to toilet replacements was 44 % average water savings under New York City's Toilet Rebate Program. The costs for water efficient toilets widely varies based on model, manufacturer, and other features. However, generally, water efficient toilets and clothes washers are more costly than traditional ones. Therefore, a household which can

afford expensive high-tech appliances usually does a much better job on water conservation.

Model Explanation

Explanation of Regression Models. Model One, Three, Five, and Seven contained the geometric means of explanatory variables. Model One explained a low variability of the response data around its mean. Coefficient of home value was negative, meaning that the higher a house value was, the lower a household had to pay for its monthly water bill. Here are two implications. Higher house value requires higher ability to pay it off, which indicates a higher household income to access more efficient facilities, such as clothes washer, dish washer, taps, showerheads as well as toilets. Besides, potentially a higher level of education to be aware of water resource saving. On the other hand, lower house value implies more household population to consume water. One scenario could be that a six-person family squeezing in a cheap house tends to use more water than that of a retired couple living in an expensive house equipped with water conservation appliances.

Coefficient of home value per square foot was negative in Model Three after combining home value with living area. It suggested that the higher a house value per square foot was, the less marginal price a household would pay for monthly water bill. Coefficient of south dummy variable, south, changed into negative as that of home value per square foot in Table 4. It revealed that if a household located in the south of the city, this household tended to pay less marginal water bill.

As for data of robustness check, more explanatory variables became statistically

significant. Acres was at same level of statistical significance as home value was in Model Five. Coefficient of acres was positive, indicating that a household tended to consume more water if it possessed more acres with the house. Usually, large front lawn and back yard with garden, landscaping, and/or swimming pool could come along with large acres of a house. Entertainment sections of a house consume large amount of water in order to take care of the lawn and garden, as well as to fill up and maintain a swimming pool.

Each independent variable except south binary variable was statistically significant in Model Seven. There was also a better goodness-of-fit. Against results of previous models, coefficient of south dummy variable changed into positive. However, both t-ratio and p-value shows south displayed a statistically insignificant role in this model. Therefore, this coefficient change of south could be neglected.

Explanation of Semi-Log Regression Models. Exponentiated regression coefficients were introduced to interpret what happened to residential water bill itself for a one-unit increase of explanatory variables. A linear relationship was hypothesized between log transformed residential water usage and a group of predictor variables in Model Two, Four, Six, and Eight. Written mathematically, the relationship follows the equation below:

(8) $$\text{Log}(Y) = \beta_0 + \beta_1 X_1 + \ldots + \beta_k X_k$$

where Y is residential water Hedonic price; $X_1, \ldots, X_k$ are predictor variables in equation (5) and (7); and $\beta_0, \beta_1, \ldots, \beta_k$ are coefficients of explanatory variables.

In Model Two, coefficient of home value was −7.73741e-07 so that its exponentiated coefficient equaled: exp (−7.73741e-07) = −1.000001. Therefore, exp

($-7.73741\text{e-}07*10^5$) = −0.1 which means residential water Hedonic price would decrease 0.1% for a 100,000-dollar increase in home value holding other independent variables constant. For acres, residential water Hedonic price would increase about 5.9% with one acre increase, when other independent variables were held at a fixed value, since exp (0.0572452) = 1.059. Home value per square foot was created as a new predictor variable with a coefficient of -0.0026 in Model Four. In this model, exp (home value per square foot) = exp (−0.0026) = −1.002603 meaning that residential water Hedonic price would decrease 0.26% if home value per square foot increases by one dollar increase, holding other independent variables constant. Likewise, exp (−0.0026*10) = −1.02603 implying that residential water Hedonic price would decrease 2.6% when there is a ten-dollar increase in home value per square foot, holding other independent variables constant. Model Four indicates that there is a negative relationship between residential water Hedonic price and home value per square foot. Each predictor variable was more statistically significant in both Model Six and Model Eight. In Model Six, residential water Hedonic price would increase 6.4% with one acre increase of a house holding other independent variables constant, since exp (acres) = exp (0.0616) = 1.0635. South as a dummy variable had an exponentiated coefficient of −0.87, exp (−0.087) = −1.090897, meaning that if a house was located in the south region of Springfield, Missouri, residential water Hedonic price were assumed to decrease 9.1% holding other independent variables at fixed values. The least statistically significant variable was building age with a coefficient of 0.0033 in Model Six. Hence, exponentiated coefficient was exp (build age) = exp (0.0033) = 1.0033, indicating that residential water Hedonic price would increase about 0.33% for a one-year increase in building age of a house. For

a ten-year increase in building age, in other words, it was expected to have a 3.3% increase in residential water Hedonic price, as exp (0.0033*10) = 1.033.

Data Limitations

It was important to make it clear that results of this study may not apply to all residents. Results were more concentrated on finding the trends of local residential water consumption. Statistical results showed that a series of OLS regression models lacked the direct impact on residential water usage. Data of explanatory variables did not fit the regression line very well. According to Analysis of Variance (ANOVA), the data in semi-log regression model were closer to the fitted regression line. Both R-squared and adjusted R-squared increased from 0.02 to 0.06 and 0.01 to 0.05 respectively. This result hints that semi-log regression model may be a better model.

There was also data loss in this study. The raw data provided by SCU was a pooled time-series data monthly water consumption and cross-section of factors detecting observations of (up to) 86,000 households from 2013 to 2017. This study used 2,000 observations divided into two sets for analysis: those randomly selected with monthly water usage data in the year of 2017. Nine hundred and ninety-two observations with non-zero values were used out of 1,000 samples; and second set of data had that of 995. Mathematics in calculating Hedonic price of residential water caused data loss. Total water consumption of a household was the denominator when computing Hedonic price in equation (4). Hence, all data with zero water usage in 2017 was considered non-valid values and therefore eliminated. Eight observations were deleted in experiment one and five in the data for robustness check.

Low R square values were calculated in both the sample data and the second set of data. The semi-log regression model has a R-squared of 0.06, indicating that semi-log regression model explained 6% of the variability of the response data around its mean. This low data fitness may be due to the limited sample size. There were more than 85,000 original data points provided by SCU. Due to the lack of labor, only 2.35% data was selected in this study. As a potential consequence, both experiments showed a low coefficient of determination in models. Among all models in this study, Model 6 had the best goodness-of-fit with a (adjusted) R-squared of 0.1, meaning that 10% of variability of the response data around its mean was explained in this model. In addition, the original data provided by SCU only included communities which joint GCP in 2017, leaving the rest of 167,391 total population out of study. Results indicate that demographic data is more important in determine residential water usage than characteristics of a home.

Beside lack of labor, shortage of financial support was another limitation to access more demographic data such as household population, income, education level, gender and race. Focus groups and social survey such as questionnaires needed significant financial support to carry out. For example, stamps and envelopes for mailing questionnaires was a large money request as sample size was large in this study. As a consequence, this study comprised to concentrate on objective factors of a house which could directly reachable from the database in SCU. Aitken, Mcmahon, Wearing and Finlayson (1994) revealed that number of residents, clothes washing machine loads and property value accounted the majority (60% of 264 samples) of residential water usage variation. It could explain the reason why models in this study have poor fit. Without household population and direct indoor water consumption value, appraised house value,

acres, building age, living area and location were very poor predictors of residential water consumption in this study.

Furthermore, there are limitations running the Hedonic pricing method. First, information was limited for residents who used water on daily basis. Available data was designed to analyze Springfield residential water Hedonic price. However, the model required all residents had prior knowledge of potential positive and negative externalities they might face when consuming water. For instance, residents should have known that a level of increased charging rate during a severe drought would cause and how it would affect them. However, residents would also need to be aware when they are getting close to the next block rate, which is not always the case in real life. Second, the measurement was not always valid in this study. Key importance was to increase the quality of measures used in independent explanatory variables when setting models up. If a location of a house was not in a rich neighborhood of south urban area, for example, this could result in an inaccurate coefficient generated in regression analyses. Third, market limitations are reflected in data. The model ideally designed that a variety of different residential water price policies were up on the table for individuals to choose the particular water price, with a combination of characteristics residents desired. However, in reality it may be the case that City Utilities has already chosen a set of residential water price policy. Espey, Espey and Shaw (1997) found that population density, household size and temperature did not significantly influence the estimate of residential water price elasticity, while pricing structure and season were found to significantly affect the estimate of its price elasticity. Thesis study illustrated that residential water price could not be elastic when the pricing frame was set up already. Fourth, multi-

collinearity between home value and acres was detected in this study. It is likely that expensive houses are usually to be found with large acres while economic houses are found with small acres in the real estate market. In this case, it would be impossible to split out home value and acres accurately. Last but not least, the price changes could not take effect right away on residential water consumption. The model assumed that market price, residential water price in this study, adjust immediately to changes in attributes. However, there would most likely be a lag associated with the price change in reality.

Summary

Results indicated that Hedonic residential water price was relatively low in a larger and newer household located in South Springfield, Missouri. Houses located in the southern region of Springfield are large, new and more expensive as there are more high-income neighborhoods than the north side of the city. In addition, Lake Springfield in the south city area adds more home value on houses located in the south urban Springfield, Missouri. Results discovered that households with expensive houses consume water more efficiently therefore ending up with relatively economic monthly water bills.

Sample data was far small compared with 86,000 original observations. This gap mainly caused result variations in this research. Robustness check supported that the sample data was statistically good to present.

This initial study on local residential water demand was a dynamic study. With available data in hand, the best fitted model was found with the goal to explain more variability of the response data around the mean value. Semi-log regression model with home value per square foot variable turned out to be the final model.

SCU could adjust water rates based on current residential water consumption patterns. This study supports that increasing block rate pricing could both accommodate residents who consume small amount of water and charge higher rates for larger residential water usage. This study finds that a household with a higher home value per square foot tends to obtain smaller Hedonic water price. High home value per square foot means the living area is costly, which indicates this is a house in good condition. Therefore, the house would face less risk of water leaking. Besides, a high quality of the living area requires high financial pay-off ability. Further, higher income households indicate potentially higher education level. Those residents have conservational awareness through education. For low-income households, they tend to use less water so they could pay less marginal residential water bill. Based on abilities of paying water bill off, it is efficient to impose tariffs on larger water usage. In this way, SCU can maintain revenue under the declining water demand trend.

Discoveries of this study is supposed to help SCU adjust current water service and come up with more suitable local residential water price policies. The residential water usage continues to be much lower than the early 2000s even though there is modest growth in residential customer growth projected to continue to increase slightly through 2018, according to Annual Operating Budget of City Utilities Springfield, Missouri (2017). This budgeting report implied that it was in an increasing trend of customer growth in 2017, but consumption was still much lower that the early 2000s. Water use per residential customer in 2015 was the lowest in the previous 15 years. After an increase in 2016, use per customers is expected to continue to decline in 2017 based on normal weather.

Studies on Springfield, Missouri, residential water usage should be an ongoing academic process and this thesis was only the first of many. This study is hoping to encourage scholars to think critically and further on analyzing local residential water consumption factors. Of course, more demographic characteristics are needed to describe the households more precisely. For instance, without house population, it was difficult to estimate house condition with the building age in hand only.

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Table 1. Descriptive Statistics

Variable	Unit	Mean	Standard Deviation	Maximum	Minimum
Hedonic price	U.S. dollar/CCF[1]	8.16	7.80	104.03	3.49
Home value	U.S. dollar	90,307.86	79,354.10	1,161,800	1,1000
Living area	Square foot (sq ft)	1,648.65	799.62	7,908.00	568.00
Home value per square Foot	U.S. dollar/sq ft	51.14	22.35	307.64	7.24
Building age	Year	45.51	30.01	90.00	41.00
Acres	N/A	0.33	0.70	19.60	0.07
South [2]	N/A	N/A	N/A	1	0

[1] 1 CCF = 100 cubic feet =748.05 U.S. liquid gallons
[2] Value = 1 if a house is located in south of Springfield; = 0 if a house is located in north of Springfield

Table 2. Results of Model One

Variable	Coefficient*	Standard Error	T-ratio	P-value
Constant	8.2573	1.1839	6.97	<0.0001
Home value	−1.35417e-05	8.00940e-06	−1.69	0.0912
Living area	0.0002	0.0009	0.21	0.8301
Building age	0.0092	0.0091	1.02	0.3074
Acres	0.9474	0.6949	1.36	0.1731
South	0.098	0.4853	0.20	0.8401

* Indicates significance at 0.05 level

Table 3. Results of Model Two

Variable	Coefficient*	Geometric Coefficient	Standard Error	T-ratio	P-value
Constant	2.0982	8.1512	0.0595	35.24	<0.0001
Home value	−7.73741e-07	−0.1	4.26287e-07	−1.82	0.0698
Living area	−7.18473e-05	−0.9999	4.54164e-05	−1.58	0.114
Building age	0.0005	1.0005	0.0005	1.01	0.3148
Acres	0.0572	1.0589	0.03	1.91	0.0568
South	−0.012	−0.9881	0.0306	−0.39	0.6948

* Indicates significance at 0.05 level

Table 4. Results of Model Three

Variable	Coefficient*	Standard Error	T-ratio	P-value
Constant	9.168	0.828943	11.06	<0.0001
Home value per square foot	−0.0334	0.0129	−2.60	0.0095
Building age	0.01	0.0092	1.06	0.2891
Acres	0.8305	0.6204	1.34	0.1810
South	−0.0236	0.5174	−0.05	0.9637

* Indicates significance at 0.05 level

Table 5. Results of Model Four

Variable	Coefficient*	Geometric Coefficient	Standard Error	T-ratio	P-value
Constant	2.0696	7.9219	0.0533	38.85	<0.0001
Home value per square foot	−0.0026	−0.9974	0.0009	−2.78	0.0055
Building age	0.00056	1.00056	0.0005	1.1	0.2716
Acres	0.0387	1.0395	0.0264	1.46	0.1435
South	−0.0465	−0.9546	0.0327	−1.42	0.1549

* Indicates significance at 0.05 level

Table 6. Diagnostic Test on Collinearity

Model One and Two			Model Three and Four
Independent variables	Variance Inflation Factors		Independent variables
Home value	3.472	1.133	Home value per square foot
Living area	1.118		
Building age	1.006	1.092	Building age
Acres	3.294	1.005	Acres
South	1.069	1.041	South

Table 7. Diagnostic Test on Heteroscedasticity

Test	Test statistic	P-value	Degree of freedom
White test	38.31	0.0054	991
White test (squares only)	12.68	0.18	991
Breusch-Pagan test	298.98	0.00	991
Koenker test	8.77	0.12	991

Table 8. Descriptive Statistics for Robustness Check

Variable	Unit	Mean	Standard Deviation	Maximum	Minimum
Hedonic price	U.S. dollar/ccf	13.35	23.57	205.43	3.51
Home value	U.S. dollar	80,146.89	76,044.95	1,009,900.00	6100.00
Living area	Square foot (sq ft)	1,609.37	2,189.26	63,900.00	288.00
Home value per square Foot	U.S. dollar/sq ft	62.66	493.74	15,618.56	1.00
Building age	Year	56.18	31.93	150.00	4.00
Acres	N/A	0.32	0.80	22.00	0.00
South	N/A	N/A	N/A	1	0

Table 9. Results of Model Five for Robustness Check

Variable	Coefficient*	Standard Error	T-ratio	P-value
Constant	9.8029	1.5385	6.37	<0.0001
Home value	−2.31513e-05	−8.67054e-06	−2.67	0.0077
Living area	1.90735e-05	0.0001	0.15	0.8835
Building age	0.0888	0.0253	3.5	0.0005
Acres	1.2114	0.4659	2.6	0.0095
South	−0.0053	−1.5999	−0.003	0.9973

* Indicates significance at 0.05 level

Table 10. Results of Model Six for Robustness Check

Variable	Coefficient*	Exponentiated Coefficient	Standard Error	T-ratio	P-value
Constant	2.1764	8.8149	0.0633	34.41	<0.0001
Home value	−1.78931e-06	0.1	3.64955e-07	−4.9	<0.0001
Living area	−2.31886e-06	0.1	2.57757e-06	−0.90	0.3685
Building age	0.0033	1.0033	0.0008	4.24	<0.0001
Acres	0.0616	1.0635	0.0132	4.66	<0.0001
South	−0.087	−0.9167	0.0476	−1.83	0.0676

* Indicates significance at 0.05 level

Table 11. Results of Model Seven for Robustness Check

Variable	Coefficient*	Standard Error	T-ratio	P-value
Constant	16.015	4.0478	3.96	<0.0001
Home value per square foot	−0.1445	−0.0666	−2.17	0.0302
Building age	0.0632	0.0276	2.29	0.0221
Acres	1.0549	0.4227	2.5	0.0127
South	0.4858	1.6944	0.29	0.7744

* Indicates significance at 0.05 level

Table 12. Results of Model Eight for Robustness Check

Variable	Coefficient*	Geometric Coefficient	Standard Error	T-ratio	P-value
Constant	2.267	9.6504	0.1207	18.78	<0.0001
Home value per square foot	−0.005	−0.995	0.0018	−2.78	0.0055
Building age	0.0035	1.0035	0.0009	3.86	0.0001
Acres	0.0437	1.0447	0.0165	2.66	0.0081
South	−0.1048	−0.9005	0.0489	−2.14	0.0323

* Indicates significance at 0.05 level

APPENDICES

Appendix A. Residential Water Service Rate for Springfield, Missouri

Council Bill No. 2016-252 WATER RATES

General Oedinance 6318 Sheet No. 1

CITY UTILITIES OF SPRINGFIELD, MISSOURI
RESIDENTIAL WATER SERVICE RATE

Availability

Available within the corporate limits of the City of Springfield, Missouri, and the adjacent territory served by City Utilities for residential domestic housekeeping purpose, where adequate capacity is available from City Utilities' water distribution system to serve such water requirements. Availability is subject to the General Terms and Conditions Governing Water Service and the Utility Service Rule and Regulations.

Monthly Charges

The following charges are applicable to bills prepared during the months shown:

	Until 10/2018	Until 10/2019	Thereafter
Customer Charge			
Per month	$ 16.90	$ 17.70	$ 18.50

Commodity Charge

Note: One hundred cubic feet of water equals 1 CCF of water, and 1 CCF equals 748 gallons of water.

	Until 10/2018	Until 10/2019	Thereafter
(Winter Period: November through May)			
Charge per CCF	$ 2.63	$ 2.73	$ 2.83
(Summer Period: June through October)			
Charge per CCF for the first 5 CCF	$ 3.25	$ 3.36	$ 3.47

Charge per CCF for the next 10 CCF…………..	$ 4.00	$ 4.06	$ 4.12

Outside City Charge

All charges shall be ten percent (10%) more per service outside the corporate limits of the City of Springfield, Missouri.

APPROVED BY CITY COUNCIL November 28, 2016 APPROVED BY BOARD OF PUBLIC UTILITIES
EFFECTIVE Cycle 1, October 2017 OF SPRINGFIELD, MO October 27, 2016

Supersedes rate schedule effective Cycle 1, October 2013.

Appendix B. Average Total Yearly Precipitation for Each State

State	Inches	Millimetres	Rank
Hawaii	63.7	1618	1
Louisiana	60.1	1528	2
Mississippi	59	1499	3
Alabama	58.3	1480	4
Florida	54.5	1385	5
Tennessee	54.2	1376	6
Georgia	50.7	1287	7
Arkansas	50.6	1284	8
Connecticut	50.3	1279	9
North Carolina	50.3	1279	9
South Carolina	49.8	1264	11
Kentucky	48.9	1242	12
Rhode Island	47.9	1218	13
Massachusetts	47.7	1211	14
New Jersey	47.1	1196	15
Delaware	45.7	1160	16
West Virginia	45.2	1147	17
Maryland	44.5	1131	18
Virginia	44.3	1125	19
New Hampshire	43.4	1103	20
Pennsylvania	42.9	1089	21
Vermont	42.7	1085	22
Maine	42.2	1072	23
Missouri	42.2	1071	24
New York	41.8	1062	25
Indiana	41.7	1060	26
Illinois	39.2	996	27

State	Inches	Millimetres	Rank
Ohio	39.1	993	28
Washington	38.4	976	29
Oklahoma	36.5	927	30
Iowa	34	864	31
Michigan	32.8	833	32
Wisconsin	32.6	829	33
Texas	28.9	734	34
Kansas	28.9	733	35
Oregon	27.4	695	36
Minnesota	27.3	693	37
Nebraska	23.6	599	38
Alaska	22.5	572	39
California	22.2	563	40
South Dakota	20.1	511	41
Idaho	18.9	481	42
North Dakota	17.8	452	43
Colorado	15.9	405	44
Montana	15.3	390	45
New Mexico	14.6	370	46
Arizona	13.6	345	47
Wyoming	12.9	328	48
Utah	12.2	310	49
Nevada	9.5	241	50

Source retrieved from
https://www.currentresults.com/Weather/US/average-annual-state-precipitation.php