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Price Elasticity of Water Demand in a Small College Town: An Inclusion of System Dynamics Approach for Water Demand Forecast

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ABSTRACT: The relationship between water demand and pricing using the price elasticity of water demand in the City of Pullman, Washington, between 2000 and 2006 shows that the current amount of water depletion is not sustainable. Three different economic scenarios were developed by altering variables in regression equations to investigate the influence of individual variables on estimating the final price elasticity of water demand. Single-family households, total residential households, and total population water use of the City of Pullman, Washington were the three different economic scenarios developed for calculating the price elasticity of water demand. The regression results show that the price elasticity of marginal price is inelastic. The exponents for median household income, fixed price, and precipitation had the expected signs in all applied scenarios. An economic model based on the regression equation of price elasticity was developed using a systems dynamic approach. The economic model projected a decline in water demand when the independent variables were assumed to grow linearly over the coming 25 years. When the household size with higher elasticity values was excluded from the regression equation, the developed economic model was able to forecast reasonable water demand. The time series data with exact service connections are recommended to reduce the uncertainty in the computation of the price elasticity of water demand. Further sensitivity analysis is recommended to understand interrelationship of water demand and pricing from the developed economic model using system dynamics approach.

KEYWORDS: price elasticity of water demand, City of Pullman, Palouse Basin region, system dynamics approach, water economics, water demand forecast

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Introduction

Pricing is a crucial element of water-resource economics and planning; it is related to the rapid extraction of groundwater, which is considered to be a potential threat to aquifers in many parts of the world. For example, the significant decrease in groundwater in the Palouse Basin aquifer, which is the only source of drinking water for this region, has compelled researchers to investigate the relationship between water pricing and demand. In this study, the residential price elasticity of water demand is calculated for the City of Pullman. Price elasticity of the water demand is here defined as the relationship between changes in water use because of a change in water price.[1] Price elasticity can be further defined as a measure of willingness to use more water when the price falls, or conversely, to reduce consumption when the price rises,[2] as explained by common supply-and-demand economics. An inverse relation is found between water pricing and consumption. Yoo,[3] Martínez-Espiñeira,[4] and Arbues et al[5] have synthesized some broad perspectives on the price elasticity of water demand in the USA and Europe, demonstrating that water demand is generally inelastic, but can be elastic to some extent, depending on different factors. Arbues et al[5] compiled different variables for the price elasticity of water demand, where marginal price varied between −3.33 and −0.003, average price between +0.332 and −0.067, and income elasticity between +7.829 and +0.051 between 1967 and 1999.

Over past several years many researchers have investigated the price elasticity of water demand for the nearby cities of Pullman, WA, Moscow, ID, Lewiston, ID, and the Palouse Region (Moscow, ID, and Pullman, WA). For example, Lyman[6] used a dynamic model to study the water demand of the City of Moscow. Using a number of climatic variables, price and income determinants, and household characteristics derived from survey data, peak and off-peak effects were analyzed to estimate water demand. The price elasticity of seasonal demand for residential water in Moscow was found to be −0.65 for winter (off-peak) and −3.33 for summer (peak). An analysis of the price elasticity of water demand was carried out by Rode[7] for the City of Lewiston, and he showed that the marginal price, fixed price, and income variables were not statistically significant. The results also show that both short-term and long-term elasticity of the marginal price was −0.3 in the Lewiston Orchards Irrigation District. An effort to study the dynamic aggregate water demand for the Palouse Region (City of Moscow and Pullman) by Peterson[8] was considered inconclusive because of insignificant marginal variables. These results indicate the difficulties calculating the price elasticity of water demand in this region.

Use of the system dynamics approach in water resources planning and management has been accelerated since 1990. Studies by Tidwell et al,[9] Dhungel,[10] Rehan et al,[11] Sahin et al,[12] Mavrommati et al[13] etc., incorporated the system dynamics approach in water economics. Rehan et al[11] presented the simulation results of the water demand forecast using the system dynamics approach with different scenarios like change in annual user fees, without considering the price elasticity etc., in a typical Canadian water utility. System dynamics has been a dynamic tool for sensitivity analysis as well as future projection of resources. Some earlier studies of the Palouse region using a system dynamics approach (Beall et al,[14] Dhungel)[10,15] discuss a participatory system dynamics model for the Palouse Basin Region. For example, a detailed discussion of uncertainty analysis of the Palouse Basin aquifers using system dynamics approach is described in Dhungel.[15] Studies from Beall et al[14] and Dhungel[10] emphasized the need for the economic analysis to cope the future water demand and sustainability of the Palouse Basin Region, though none of these studies conducted detailed economic analysis. The overarching objective here is to understand the price elasticity of water demand of the City of Pullman, WA, and its influence on groundwater extraction and sustainable water use. The decreasing groundwater level in local aquifers is a major concern for basin residents, as the sustainability of the groundwater in this aquifer is vital to the economic and social development of this region. Such an understanding can also help reduce possible conflicts between Washington and Idaho regarding water rights issues in future. The present study incorporates the analyses of water demand forecast of the City of Pullman with the current water-use pattern and pricing structure using a system dynamics approach. The use of a system dynamics approach that affects the price elasticity of water demand is important for understanding the implications for future water-use demand, given current water pricing and demand. This approach further utilizes the developed regression equation of the price elasticity of water demand through the use of the system dynamics approach.

Materials and Methods

Price elasticity of water demand. Flat rate, constant rate, and block rate are the three most commonly used water pricing structures. A single price for an unlimited amount of water is called a flat rate, while uniform rate for each unit of water consumed is constant price.[16] In a block rate type of billing structure, the price per unit of water changes as the volume consumed increases.[16] Generally, the price elasticity of the water demand is calculated using regression analysis with several independent variables, and water use as the dependent variable. The most common independent variables are median household income, average household size, precipitation, and average water price. Because of the limited availability of data, household size must often be estimated indirectly from the population and the number of dwellings.[17] Either annual or seasonal precipitation values can be used in the regression equation for calculating the price elasticity of water demand. Seasonal precipitation is generally taken as the summer period, from May to September, because of the high fluctuation in demand, use, and availability. Foster and Beattie[18] include precipitation as a variable during those months where the average monthly temperature is at least 45°F and 60°F in the northern and southern regions of the United States, respectively. Water demand is directly proportional to temperature and inversely related to precipitation.[19] The common exponential form of a regression equation for calculating the price elasticity of water demand is shown in Eqn. (1):

$$Q = e^{X0} * P_r^{X1} * I^{X2} * P^{X3} * H^{X4} \tag{1}$$

After taking the log of both sides, Eqn. (1) can be written as Eqn. (2). This logarithmic form of regression equation is used to model price elasticity of water demand:

$$\begin{aligned}\ln(Q) = X_0 + X_1 * \ln(P_r) + X_2 * \ln(I) \\ + X_3 * \ln(P) + X_4 * \ln(H)\end{aligned} \tag{2}$$

where Q is the quantity of water consumption, P_r is water price, I is median household income, P is precipitation, and H is average household size (number of people per household). X_0 to X_4 are the unknown least square coefficients estimated from the regression equations. IWR-MAIN[20] (Water Demand Management Suite) has used the following equation to calculate predicted water use for the residential sector (Eqn. (3)):

$$Q = aI^{d1} \quad \mathrm{MP}^{d2} \quad e^{(\mathrm{FC})(d3)} \quad H^{d4} \quad \mathrm{HD}^{d5} \quad T^{d6} \quad R^{d7} \tag{3}$$

where Q is the predicted water use in gallons per day, I is the median household income in \$1000s, MP is the effective marginal price (\$/1000 gal), e is the base of the natural logarithm, FC is the fixed charge (\$), H is the mean household size (person per household), T is the maximum day temperature (Fahrenheit), R is the total seasonal rainfall (inches), a is the intercept in gallons/day, and $d1$–$d7$ are elasticity values for each independent or explanatory variable. For a continuous demand function, price elasticity of water demand (ε) is calculated by comparing the change in the quantity demanded (dQ) to the change in price (dP_r)[1] (Eqn. (4)):

$$\varepsilon = \frac{P_r}{Q} * \left(\frac{dQ}{dP_r}\right) \quad (4)$$

where ε is the price elasticity of demand, P_r is the average water price, Q is the quantity of water demand, dQ is the change in demand, and dP_r is the change in price.

Study area and data. The Palouse Basin spans eastern Washington and northern Idaho. The largest portion is located within Washington's Whitman County and Idaho's Latah County, with a very small area in Benewah County in Idaho. Figure 1 shows the Palouse Basin watershed with major cities and surface water tributaries. The Palouse region is a semi-arid area where precipitation ranges from approximately 59 to 85 cm per year. As elevation increases towards the east, so too does precipitation. The mean temperature of the Palouse Basin decreases from west to east. The precipitation of the Palouse Basin comes either in the form of rain or snow. According to the dominant geologic formations, there are two groundwater aquifers in the Palouse Basin, identified as the Wanapum and Grande Ronde aquifers. Both aquifers have satisfactory groundwater quality for domestic, agricultural, and industrial purposes. The Wanapum aquifer is the shallower of the two at approximately 110 m deep, while the Grande Ronde aquifer is approximately 290 m deep. The shallower Wanapum aquifer is the primary water supply for rural residents of Latah County within the basin limits and in some areas of Whitman County (McKenna);[21] it also supplies approximately 32 percent of Moscow's drinking water (Ralston,[22] Palouse Basin Aquifer Committee (PBAC)).[23] The rest of Moscow's and 100 percent of the City of Pullman's drinking water demands are fulfilled by the Grande Ronde aquifer.

The Palouse Basin area includes three major cities: Moscow, Pullman, and Colfax, as well as other small cities like Viola, Potlatch, etc. (Fig. 1). The City of Pullman is the largest population center in the area, with approximately 31,000 residents in 2014. Half of the city's population is comprised of students attending Washington State University. The population within 7 miles of Moscow and Pullman is denser compared to the rest of the region (ie, Colfax, Viola, and Palouse). Because of the limited availability of data across the basin, the City of Pullman is taken as the representative of the basin, and is used to develop a single price elasticity relationship. This study thus discusses water pricing and demand scenarios of a representative college town where groundwater is the sole source of drinking water.

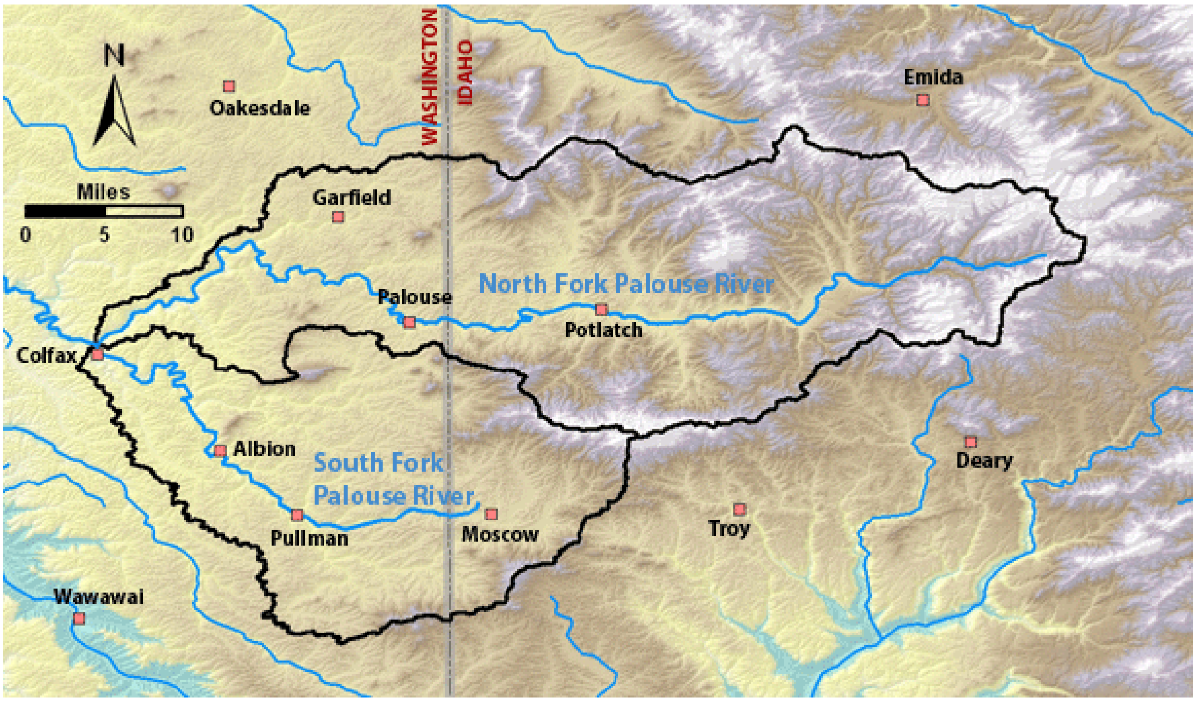

Figure 1. The City of Pullman overlaid with the Palouse basin watershed with major cities, and North Fork and South Fork Palouse River bordered with Idaho and Washington State.
Source: Palouse Basin Community Information System, 2007.

As discussed above, some of the commonly used demographic variables for calculating the price elasticity of water demand are population, per capita water use, median household income, and average size of the household. In addition, precipitation data and water pricing structures are also needed. The population, median household income, and housing units data are obtained from the United States Census Bureau[24] and municipal sources, with a 1% annual population growth rate. Monthly total precipitation data was taken between 2000 and 2006 from Pullman 2 NW, WA (Coop ID: 456789, 46.75 N 117.18 W, elevation 2545 ft.)[25] (see Appendix B)". In summer, more water is needed for irrigation to maintain vegetation if there is inadequate precipitation. A study conducted by Linaweaver et al[26] used evapotranspiration in place of precipitation. Available moisture, or moisture defined by the difference between precipitation and evapotranspiration, can be used as an alternative variable for precipitation. The monthly water price and water extraction data were acquired from the City of Pullman for the years 2000 to 2006 (Appendix B). Table 1 shows the sample data for calculating the price elasticity of water demand of a single-family households. (Appendix B presents the comprehensive data for the City of Pullman's economic analysis). Equation (5) shows the water use per household per 100 cubic feet of single-family households:

$$Q_H = \frac{Q_S}{N_S * 100} \tag{5}$$

where Q_H is water use per household per 100 ft^3, Q_S is the water extraction of single-family households (ft^3), and N_S is the number of single-family households.

Scenarios for the price elasticity of water demand. While calculating the price elasticity of water demand, a regression analysis is carried out based on different population dynamics. Single-family households, total residential households, and total population water use are the three different economic parameterizations developed for calculating the price elasticity of water demand. Total residential households include single, duplex, multiple, group, and mobile homes. These water consumption estimates do not include industrial sites, commercial building, schools, or offices in the area because of lack of data. Based on the three economic scenarios, five different cases are developed by adjusting the variables input into the regression analysis. These scenario adjustments are essential to understanding the influence of individual variables on the regression equation in estimating the final price elasticity of water demand.

In economic scenario 1, the regression analysis is carried out for monthly water use of a single-family household per 100 cubic feet, as a dependent variable. In case 1 of economic scenario 1, all five independent variables are used, whereas in case 2, the regression is carried out without household size. In economic scenario 2, regression analysis is carried out for monthly water use per household per 100 cubic feet with the total residential sector replacing single-family household. In case 3, all the independent variables in the regression equations are used as in case 1 in scenario 1. In case 4, regression analysis is conducted without household size and in case 5 without a fixed price. Finally, in economic scenario 3, the dependent variable is the mean monthly household water use of the total population of the City of Pullman. In this scenario, total water consumption is divided by service area population to compute the proxy of mean household water consumption. The economic scenarios 1, 2, and 3 discussed above are shown in Table 2.

System dynamics model. Computation of the price elasticity of water demand can be limited by different determinants and assumptions (Michelsen et al,[27] Schleich and Hillenbrand,[28] Klaiber et al[29] etc.). Validation of the elasticity values computed from the regression equation is important to compare an accurate interpretation of the relationship among the variables of water demand. Previous studies of the price elasticity of water demand estimate the interrelation between the variables of regression equation, but usually not applied these results in the modeling purpose. The system dynamics approach, utilized in this study, has facilitated the validation of the elasticity values by comparing the estimated water demand from the economic model to the present water extraction trend. The economic model, based on the system dynamics approach, is further applied for conducting a sensitivity analysis to forecast future water demand. Systems thinking for education and Research (STELLA 9[30]) modeling and simulation software is used to develop a system dynamics model to study the sustainability of the Palouse Basin. As mentioned earlier, use of system dynamics approach can be a pertinent approach to utilize the developed regression equation. Appendix A shows a demand model, a simple exponential population forecast model, and an economic model developed using the system dynamics approach. Water demand is forecasted based on the demand model and economic model using a system dynamics approach. The first water demand forecast (demand model, Fig. 2A) is based on population, growth rate, and water use per capita per day (~160 gallons) calculated in billions of gallons (Appendix A—Section 1).

The second is a simple economic model developed from the regression equation (Eqn. (8), Fig. 2B). The multiple regression equation developed from the price elasticity of water demand is used in the economic model, which assumed that the independent variables of the regression equation behave linearly for the projected time period, i.e. until 2025. A trend line is developed from the study period (2000 to 2005) and linearly extrapolated. A shorter time period (2025) is chosen to simulate the water demand forecast based on the economic model because the linear extrapolation of the variables might not be accurate for extended periods of time. The number of households (H) is also linearly extrapolated using a similar approach. In the economic model, population is indirectly calculated inside the model based on the number of households and the average number of people per household

Table 1. Sample data for economic analysis of single-family households, Pullman, Washington.

YEAR (2000)	HOUSEHOLD WATER USE (SINGLE-FAMILY HOUSEHOLDS)/100 ft^3	FIXED PRICE $ (1 INCH WATER METER SIZE)	MARGINAL PRICE ($/100 ft^3)	HOUSEHOLD SIZE	MEDIAN HOUSEHOLD INCOME ($/ANNUM)	PRECIPITATION (INCH/MONTH)
Month	**Q**	**FP**	**MP**	**H**	**I**	**P**
January	6.11	21.93	0.96	2.24	21,662	1.90
February	5.67	21.93	0.96	2.24	21,696	2.66
March	6.57	21.93	0.96	2.24	21,731	2.31
April	5.81	21.93	0.96	2.24	21,765	1.21
May	7.67	21.93	0.96	2.24	21,799	2.14
June	10.92	21.93	1.18	2.24	21,833	1.19
July	16.47	21.93	1.18	2.24	21,867	0.01
August	23.14	21.93	1.18	2.24	21,902	0.04
September	17.78	21.93	1.18	2.24	21,936	1.51
October	8.15	21.93	0.96	2.24	21,970	1.65
November	7.18	21.93	0.96	2.24	22,004	1.86
December	6.05	21.93	0.96	2.24	22,038	1.44

Table 2. Economic scenarios for calculating price elasticity of water demand, Pullman, Washington.

ECONOMIC SCENARIO	CASE	DEPENDENT VARIABLE	INDEPENDENT VARIABLES
1	1	Single-family households water use	Marginal Price (MP), Fixed Price (FP), Median Household income (I), Precipitation (P), Household size (H)
	2		Marginal Price (MP), Fixed Price (FP), Median Household income (I), Precipitation (P)
2	3	Total residential households water use	Marginal Price (MP), Fixed Price (FP), Median Household income (I), Precipitation (P), Household size (H)
	4		Marginal Price (MP), Fixed Price (FP), Median Household income (I), Precipitation (P)
	5		Marginal Price (MP), Median Household income (I), Precipitation (P), Household size (H)
3		Total population water use	Marginal Price (MP), Fixed Price (FP), Median Household income (I), Precipitation (P), Household size (H)

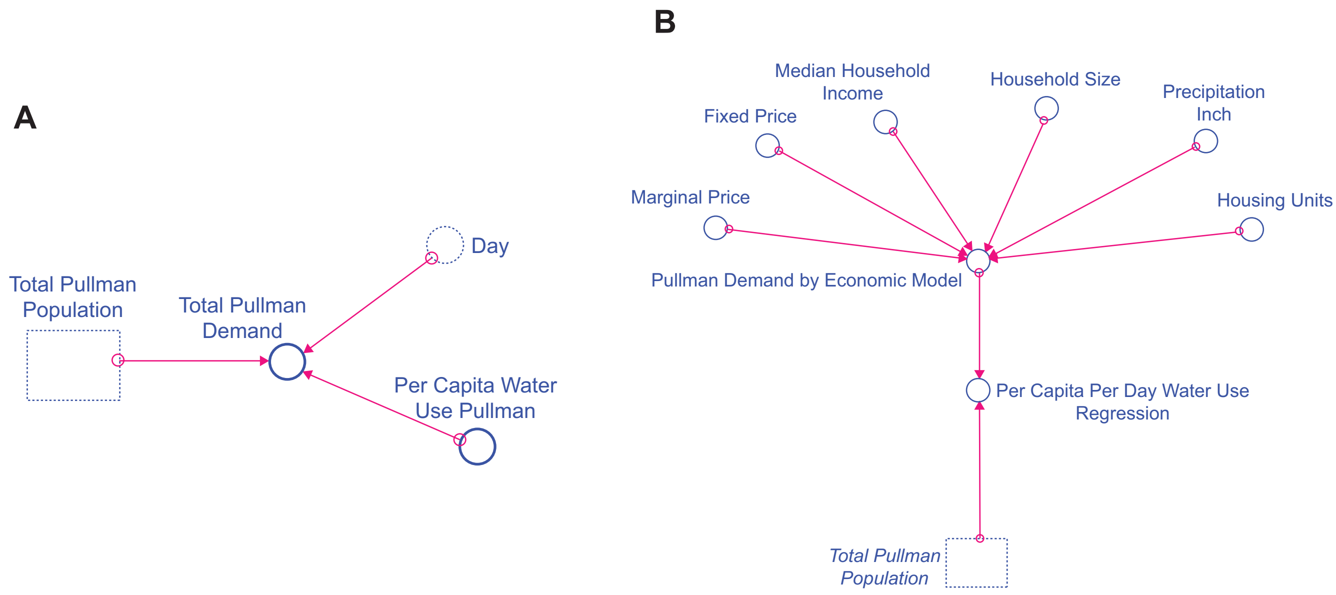

Figure 2. (**A**) System dynamics model for water demand forecast using the demand model, where Total Pullman Demand is in billions of gallons, and Per Capita Water Use Pullman is in gallons per day (~160 gallons). (**B**) System dynamics model for water demand forecast using the economic model, where Pullman Demand by Economic Model ($Q_{Pullman}$) is the total water demand per annum using regression equation (in billions of gallons), Total Pullman Population is the estimated total population of the City of Pullman, Per Capita Per Day Water Use Regression (Q_{c-d}) is in gallons. Housing Units is the total number of households in Pullman (single, duplex, multi, group, and mobile homes).

using linearly extrapolated results. The indirect calculation of population (P_1) in the economic model should closely match the population from the population (P_0) forecast model (Appendix A—Section 2). Any discrepancy in the population forecast between these two approaches can create differences in the water demand forecast.

In the developed economic model, total calculated water demand is converted into per capita daily water use (Q_{c-d}) in the designated years by dividing the population (Eqn. (6)) (Appendix A, Section 3). Q_{c-d} is further compared to the actual per capita daily water use value (~160 gallons). To reduce bias while calculating Q_{c-d}, population computed in the economic model (P_1) needs to be used. In the simulation process, both P_0 and P_1 are used to understand the variations in Q_{c-d}.

$$Q_{c-d} \approx \frac{Q_{Pullman}}{P_1 * 365} \approx \frac{Q_{Pullman}}{P_0 * 365} \qquad (6)$$

where Q_{c-d} is the per capita daily water use, $Q_{Pullman}$ is Pullman water demand per annum from the economic model, P_0 is the total Pullman population from the population model, and P_1 is an indirect calculation of population in the economic model.

Limitations. There are some specific assumptions in this study. Because of a lack of exact service connections, the single-family household data are adopted from the published literature. The household level survey data are precise and effective when calculating price elasticity of water demand. The population, household size, and median household income are generally calculated annually, and some are calculated on a decade basis. There is difficulty in collecting these data on a monthly basis or for smaller time periods, so the data used in these analyses are linearly interpolated to get monthly figures. Because of these difficulties, the monthly time series data are used to calculate the price elasticity of water demand. These types of aggregated time series data have lots of complications, as it is difficult to understand the behavior of individual households. The linearity in the variables in the economic model while forecasting water demand is another key assumption.

Results and Discussion

Price elasticity of water demand. The price elasticity of water demand is calculated based on detailed water-pricing structure and water extraction data from City of Pullman groundwater wells, between 2000 to 2006 (Appendix B). Figure 3 shows the annual water consumption for the residential sector of City of Pullman (single, duplex, multi, group, and mobile homes) and marginal price for the period 2000 to 2006. Figure 3 also shows a constant increase in water consumption, with a slight decrease in 2003. Water consumption in the year 2000 is about 715 million gallons, and reached about 755 million gallons in 2006 with increasing demand. The City of Pullman has both marginal and fixed price water costs. Up to 500 ft^3 for any kind of user class, no marginal price is paid, but certain fixed price is paid whether water is used or not. The City of Pullman has an increasing block rate of marginal water price, varying in the peak (summer) and off-peak (winter) months, and it also differs according to user class. The marginal price increased from \$0.32/100 ft^3 to \$1.19/100 ft^3 between 1971 and 2006 (Table 3). Also, there is more than a

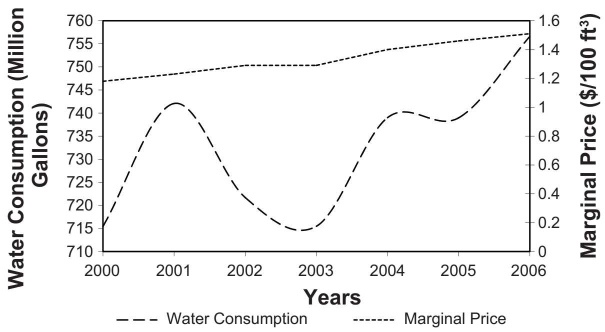

Figure 3. Annual water consumption for the residential sector and marginal price of the City of Pullman, Washington, between 2000 and 2006.

20 percent increase in marginal price between 2000 and 2006 in a single household family size. The fixed price charge also varies according to the user class and size of the water meter (a larger meter relates to a larger service line) (Lamar T and Weppner S[31]). Between 1971 and 2006, the ready-to-serve charge (fixed price) of a one-inch water meter size increased from $2.75 to $26.93. The fixed price increased by approximately 22 percent between 2000 and 2006. A one-inch water meter is taken as the representative in the calculation, assuming that the majority of the single-family households uses this water meter size (Table 3). There is about 6 percent increase in water consumption between 2000 and 2006 in the residential sector of the City of Pullman, Washington. Table 3 shows the detailed water pricing structures of the City of Pullman for the years 1971–2006.

Even if both the marginal and fixed prices are consistently increasing, water consumption of the City of Pullman is also increasing with some seasonal variation within the year. The trends presented in Figure 3 indicate that water consumption and water pricing are hardly related. It is expected that

Table 3. Marginal and fixed price rate structures of the City of Pullman, Washington.

YEAR	MARGINAL PRICE					READY TO SERVE (FIXED PRICE)
	($/100 ft^3)					BASE FEE ($)
	(501–1000) ft^3	(1001–2000) ft^3		(2001–3000) ft^3	OVER 3001 ft^3	
1971	0.32	0.24		0.16	0.12	2.75
	(0–500) ft^3	(500–2000) ft^3		Above 2000 ft^3		
1972	0.44	0.36		0.20		2
	Volume charge above 500 ft^3 ($)					**1 inch water meter size**
1981	0.29					1.8
1981	0.34					5.2
1988	0.51					7.8
1991	0.55					8.46
1992	0.6					9.18
1993	0.65					9.96
1994	0.7					10.81
1995	0.71					10.98
1996	0.75					11.53
	Volume charge above 500 ft^3					**1 inch water meter size**
	Winter (October–May)				**Summer (June–September)**	
1998	0.88					20.09
1999	0.92				1.13	20.99
2000	0.96				1.18	21.93
2000	0.96				1.18	21.93
2001	1				1.23	22.92
2002	1.05				1.29	23.95
2003						
	Winter		**Summer**			**1 inch water meter size**
	(500–800) ft^3	**Over 800 ft^3**	**(500–800) ft^3**	**(801–2000) ft^3**	**Over 2000 ft^3**	
	($/100 ft^3)					
2004	1.1	1.15	1.3	1.4	1.75	24.9
2005	1.14	1.2	1.35	1.46	1.82	25.9
2006	1.19	1.24	1.41	1.51	1.89	26.93

Source: City of Pullman.

once the water consumption trend falls as a result of marginal price increase, the trend will never rise again, unless there are other factors influencing the relation. These facts indicate that because of the constant demand for water and the limited resources, the current price structures of water are not directly influencing water consumption. As the demand for water will grow as the population and industry increase, alternative sources of water will need to be obtained (Dhungel).[10]

Household size exhibits a slightly decreasing trend from 2.24 to 2.21 between 2000 and 2006, while annual median household income increased from \$21,600 to \$24,300. The means of P, H, I, FP, MP, and Q are 1.53 in, 2.23, \$22,993, \$24.18, \$1.17, and 10.04/100 ft^3, respectively. Similarly, the standard deviations of P, H, I, FP, MP, and Q are 1.16 in, 0.01, \$792.6, \$1.51, \$0.17, and 5.41/100 ft^3 (single-family household), respectively (Appendix B). Figure 4 shows the monthly water consumption trend of the residential sector and precipitation of Pullman during the study period. In general, summer water consumption is relatively higher than in winter. The maximum residential water consumption is about 110 million gallons in summer and 40 million gallons in winter.

In the following section, the results of the ordinary least squares (OLS) of the log linear regression (Eqn. (8)) of the economic scenarios are presented. The expected signs of the independent variables are: household size positive, marginal price negative, fixed price negative, median household income positive, and precipitation negative.

Economic scenario 1. In case 1 of scenario 1, the results show high elasticity values for household size and median household income (Table 4). In this case, the household size had an elasticity of about 355, while that of the median household income is about 41. The elasticity of marginal price and fixed price is about +2.98 and −6.94, respectively, while precipitation is −0.09. In case 2, price elasticity of marginal price still has high elasticity, ie +2.96. In case 2, the elasticity of precipitation, household income, and fixed price is −0.09, 5.83, and −7.18, respectively. Most of the attained elasticity values of independent variables are larger than those published in the literature. The coefficient of determination (R^2) in both cases is 0.77. The F statistics are about 50.6 and 63.5 for case 1 and 2, respectively (Table 4). The constant term of the regression equation in case 1 and 2 becomes negative with larger numbers. The t stat and probability value (P-value) are also shown in Table 4. The negative and positive values in Tables 4 and 5 are the expected signs of the variables in the regression equations. It is difficult to explain the higher elasticity values for these independent variables, which is possibly because of the weak relationship among the variables.

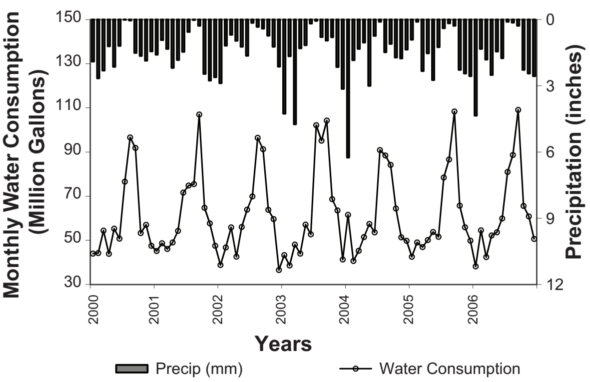

Figure 4. Monthly water consumption of the residential sector and precipitation of the City of Pullman, Washington, between 2000 and 2007.

Economic scenarios 2 and 3. In economic scenario 2, the results show that there is a slight decrease in the price elasticity of marginal price in all cases compared to economic scenario 1, but it still attains a positive sign. The elasticity of the marginal price of case 3, 4, and 5 is +1.6, +1.58, and +1.62, respectively (Table 5). The fixed price elasticity is about −5.07 and −5.21 for case 3 and 4, respectively. The R^2 is 0.68 in both case 3 and 4, and 0.62 in case 5 (Table 5). As in economic scenario 1, the constant term of the regression equation has larger negative values in these economic scenarios. The rest of the results of the regression analysis are presented in Table 5. The trend of the elasticity of median household income is similar in both scenarios 1 and 2. In general, these two scenarios show similar elasticity trends among all applied independent variables. The results of economic scenario 3 are not statistically different from scenarios 1 and 2, so the results are not presented or discussed.

The results of all the above scenarios show a positive sign in the marginal price (case 1 to 5). The fixed price, median household income, and precipitation signs obtained the expected signs in all cases. In all scenarios, the elasticity of household size is high. Equation (7) shows the results of the multiple regression equations in logarithmic form for case 3 of economic scenario 2, and Eqn. (8) in exponential form.

$$\ln(Q) = 1.6*\ln(MP) - 5.07*\ln(FP) + 24.32*\ln(I) + 188.72*\ln(H) - 0.048*\ln(P) - 377.22 \tag{7}$$

$$Q = MP^{1.6} * FP^{-5.07} * I^{24.32} * H^{188.72} * P^{-0.048} * e^{-377.22} \tag{8}$$

The +1.6 marginal price elasticity of demand means that a 1% increase in marginal price will increase water use by 1.6%, while −5.07 fixed price elasticity means a 1% increase in fixed price will decrease water use by 5.07%. The results show that the marginal price does not directly influence water demand, while fixed price has a large impact in all cases. The result of this study contradicts the results of Lyman,[6] where marginal price shows elasticity to water demand in the City of Moscow, ID. The studies by Rode[7] and Peterson[8] were inconclusive because of the insignificant marginal variable and other independent variables in the city nearby the City of Pullman, WA. The regression equations (7) and (8) are chosen in the economic model to forecast water demand, as this scenario represents the total residential household of the City of

Table 4. Regression coefficients for price elasticity curve for single-family and residential households.

CASE 1	COEFFICIENTS	STANDARD ERROR	*t* STAT	*P*-VALUE	*F* STATISTICS
Single-family households					
Constant	−672.76	836.94	−0.80	0.4241	50.64
Marginal Price (−)	2.98***	0.29	10.12	0.0000	
Precipitation (−)	−0.09*	0.03	−3.54	0.0007	
Household size (+)	355.04	464.82	0.76	0.4475	
Median Household income (+)	41.06	46.27	0.89	0.3778	
Fixed Price (−)	−6.94***	1.93	−3.60	0.0006	
Case 2					
Constant	−33.90	29.73	−1.14	0.2579	63.52
Marginal Price	2.96***	0.29	10.12	0.0000	
Precipitation	−0.09***	0.03	−3.56	0.0007	
Median Household income	5.83	3.53	1.65	0.1030	
Fixed Price	−7.18***	1.90	−3.79	0.0003	
Total residential households					
Case 3					
Constant	−377.22	513.66	−0.73	0.4649	34.23
Marginal Price	1.60***	0.20	8.19	0.0000	
Household size	188.72	284.98	0.66	0.5098	
Precipitation	−0.05*	0.02	−2.63	0.0102	
Median Household income	24.32	28.43	0.86	0.3950	
Fixed Price	−5.07***	1.33	−3.81	0.0003	

Notes: ***, **, and * denote signifance at the 0.1%, 1%, and 5% levels, respectively.

Pullman and elasticity of marginal and the fixed price attained smaller values compared to the other cases.

In the next section, the results of the developed economic model using a regression equation are discussed. This study incorporates a system dynamics approach in price elasticity of water demand in order to forecast demand.

System dynamics model. The first part of this section shows the results of the demand model (Fig. 2A). Using a growth rate of about 1% per year, the total forecasted population of Pullman will be about 31,000 in 2025, and about 65,000 in 2100 (can vary with students enrollment). Cheng Q and Chang N[32] synthesized the various approaches to forecast short-and long-term municipal water demands since 1960s. They characterized these approaches as the regression analysis, the time series analysis, the computational intelligence approach, the hybrid approach, and the Monte Carlo simulation approach. Figure 5 shows a water demand projection for the Palouse Basin cities, using a demand model based

Table 5. Regression coefficients for price elasticity curve for residential households.

MARGINAL PRICE	FIXED PRICE	MEDIAN HOUSEHOLD INCOME	HOUSEHOLD SIZE	PRECIPITATION	CONSTANT	COEFFICIENT OF DETERMINATION	*F* STATISTICS
ln(MP)	ln(FP)	ln(*I*)	Ln(*H*)	Ln(*P*)	C	R^2	F
Expected signs of the variables							
−	−	+	+	−			
Economic scenario 2							
Case 3	**General case**						
1.6	−5.07	24.32	188.72	−0.048	−377.22	0.68	34.23
Case 4	**Without household size**						
1.58	−5.21	5.56		−0.048	−37.33	0.68	42.98
Case 5	**General case without Fixed Price**						
1.62		32.50	359.32	−0.048	−612.17	0.62	33.43

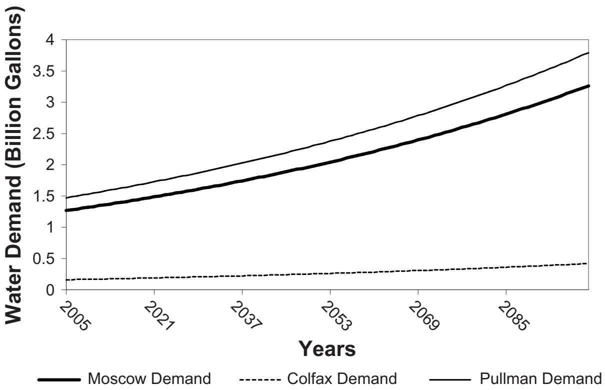

Figure 5. Water demand forecast by the demand model for the major cities of the Palouse Basin region using system dynamics approach between 2005 and 2100.

on a system dynamics approach (Appendix A—Section 1). In the year 2000, the PBAC estimated that approximately 160 gallons of water per person per day are used in the Palouse Basin, encompassing all the cities. The estimated demand in the initial year (2005) was 0.16 billion gallons for Colfax, 1.27 billion gallons for Moscow, 0.04 billion gallons for Potlatch, 0.02 billion gallons for Viola, and 1.47 billion gallons for Pullman. The exact water extraction in 2005 from major cities was 1.05, 1.38, and 0.266 billion gallons for Moscow, Pullman, and Colfax, respectively.

The second part of this section discusses the results of the economic model. Figure 6 shows the linear extrapolation of the variables up to the year 2025 using system dynamics approach (except precipitation, which uses a constant mean areal precipitation of entire Palouse Basin). Areal mean precipitation was computed between 1971 and 2000 (consistent with widely available climate normals). The Parameter-elevation Regressions on Independent Slopes Model (PRISM)[33] precipitation maps (developed at Oregon State University) were utilized in this study. Linear extrapolation of the marginal price, fixed price, median household, and household numbers shows an increasing trend, while the household size shows a decreasing trend (Fig. 6). The constant term of the regression equation was also kept constant while forecasting water demand from the economic model (Appendix A-Section 3). This might create bias in the simulation, which probably needs to be adjusted after analyzing the final water demand forecast. Appendix A in section 3 shows the equations of the trend line used in the economic model.

The forecasted population in the economic model (P_1) is about 23,000, which is 7,000 less than the population forecast model (P_0) at the end of the simulation period (2025) based on the total residential households. This indicates that these variables of the regression equation may not necessarily behave linearly. The economic model projects about 0.75 billion gallons of water consumption for the City of Pullman in 2005 based on the total residential households (Eqn. (8)), about half of that in the demand model. Because of the lack of the exact number of service connections in different user classes and variability in the coefficients of regression equation, the water demand obtained from the economic model may have differed from that of the demand model in 2005. The water demand projected from the demand model, as well as the actual water extraction, shows a constant increase in water demand for the City of Pullman (Fig. 5). Figure 7 shows the annual water demand forecast using an economic model using Eqn. (8) (in billions of gallons). The results of the economic model project a decreasing water demand in the coming 20 years. At the end of the simulation period, the water demand unrealistically declined to 0.3 billion gallons. Per capita per day water use ($Q_{c\text{-}d}$) decreased from 81 gallons to 26 gallons when P_0 is used, and to 32 gallons when P_1 was used at the end of the simulation period. This projection indicates that the applied regression equation is unable to simulate realistic water demand forecast. As discussed earlier, there can

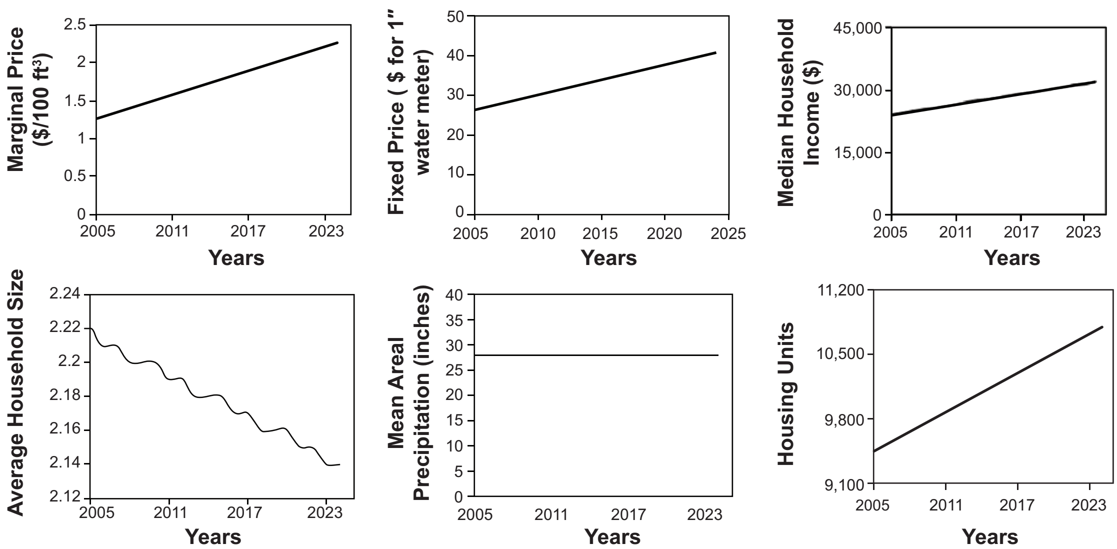

Figure 6. Linear extrapolation of independent variables for regression equation using system dynamics approach between 2005 and 2025.

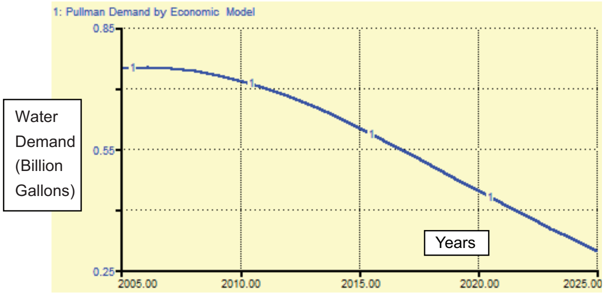

Figure 7. Water demand projection by the economic model for the City of Pullman using system dynamics approach between 2005 and 2025 (Scenario 2- Case 3).

be various uncertainties regarding linear extrapolation of the regression equation variables and the computed elasticity of the variables. The linear extrapolation of fixed price reached \$41 (Fig. 6) at the end of the simulation period, with a high elasticity value. This high elasticity can be one of the reasons for the rapid declining trend in water demand. As discussed above, the population of the economic model projected a smaller number than the population forecast model.

Figure 8 shows the results of a scenario where all the variables of the regression equation 8, as in the previous scenario, kept the fixed price of water constant at \$26.93. This sensitivity analysis is important in understanding the role of the high elasticity value of fixed price in the economic model. With this change, the economic model predicted an increasing trend in water demand (Fig. 8) similar to the demand model (Fig. 5). The water demand increased up to 2.45 billion gallons in 2025 with an over-prediction of water demand while compared to the demand model. Finally, Figure 9 shows the simulation results of scenario 2- case 4 where the household size is excluded from the regression equation in the economic model (Eqn. 9). In case 4, the income elasticity and constant term in the regression equation is significantly smaller than scenario 2- case 3 (Eqn. 8).

$$Q = MP^{1.58} * FP^{-5.21} * I^{5.56} * P^{-0.048} * e^{-37.33} \qquad (9)$$

Both the economic and demand models projected similar water demand trend during the extended simulation period, ie 2100 years. This result confirmed that the developed economic model and the approach utilized in this study can play a vital role in understanding and validating the regression equation of the price elasticity of water demand. It should be noted that the developed economic model fundamentally differs from the demand model. The high elasticity value of the household size in the regression equation (Eqn. 8) is one of the reasons why the economic model has difficulty to forecasting reasonable water demand. The water demand from the economic (Eqn. 9) and demand model are about 2.6 and 3.8 billion gallons, respectively at the end of the simulation period.

Based on the limited simulation analysis, it is challenging to generate a realistic water demand forecast for all the scenarios because of the possible weak relationship among the variables of the regression equation. To understand the future implication of water demand and pricing of this region, a set of sensitivity analysis can be done by using economic scenarios (case 1 to 5 and possibly others) and adjusting the elasticity values in the regression equation. The main objective here is to demonstrate a system dynamics approach as an appropriate tool to develop an economic model which need to be further explored in the areas where water pricing and demand has a strong relationship.

Conclusions and Recommendations

The constant extraction of water from the Palouse Basin aquifer can lead to unsustainable groundwater aquifers. The price elasticity of water demand of the City of Pullman, WA, was computed using different regression equations. The results confirm that the current water pricing structures do not directly influence water consumption and demand. Five different scenarios were developed, each altering different independent variables in the regression equations. The price elasticity of the marginal prices had positive values in all scenarios, indicating that current price does not directly influence demand of water. The fixed price had negative values in all scenarios, and the rest of the independent variables had expected signs in the regression

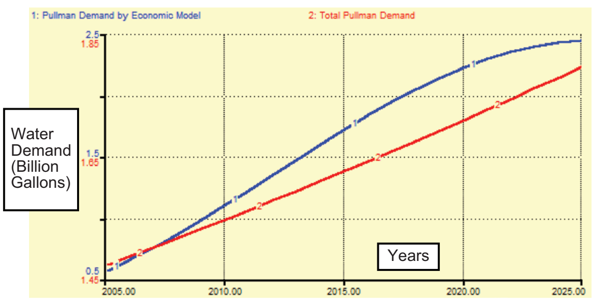

Figure 8. Water demand projection by the economic and demand model for the City of Pullman using system dynamics approach with constant fixed price in linear regression equation between 2005 and 2025 (Scenario 2- Case 3).

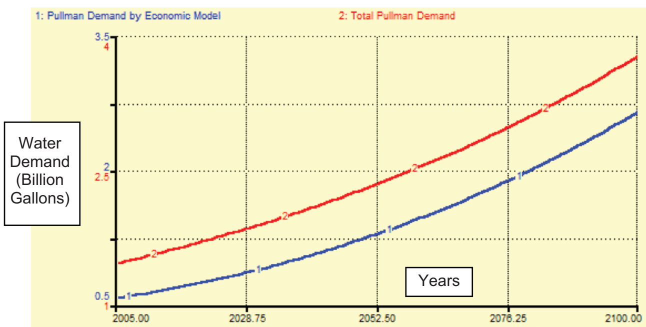

Figure 9. Water demand projection by the economic and demand model for the City of Pullman using system dynamics approach between 2005 and 2100 (Scenario 2- Case 4).

output. An economic model was developed using a system dynamics approach based on the regression equation of price elasticity and the linear extrapolation of the variables. This study showed a complicated interrelationship among water pricing, water demand, and other independent variables of a regression equation. The increasing block rate structures of water pricing for different user classes and the time period of the analysis can also add uncertainty to the results. It may be possible that people might not be aware of the water demand and pricing structures in Pullman, where more than half of the population are students. The use of a price elasticity-based regression equation in system dynamics was demonstrated to be a relevant approach to develop the economic model.

The results of these analyses indicated the complications that arise when calculating the price elasticity of water demand in a small college town with limited exact household data. The water demand forecasted from the system dynamics approach had difficulties predicting a reasonable trend for all scenarios, which probably indicates the weak inter-relationship among the regression variables, needs for a better regression equation, and extrapolation approach of the variables. Further sensitivity analysis is needed using the regression equation of the economic scenarios to understand the interrelationship between water demand and pricing (economic scenarios 1–3). There may be numerous reasons for the inelasticity of the marginal price. The housing and water-use patterns can be complex in this type of city where groundwater is the sole source of drinking water. The time series data with exact service connections are recommended to reduce the uncertainty in the price elasticity of water demand.

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Author Contributions

Conceived and designed the experiments: RD, FF. Analyzed the data: RD. Wrote the first draft of the manuscript: RD. Made critical revisions: RD, FF. All authors reviewed and approved of the final manuscript.

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Supplementary Data

Appendix A.

Section 1—Pullman water demand forecast (demand model)

Per_Capita_Water__Use_Pullman = 160 {160 gallons)
Pullman_Demand_by_Demand_Model = Pullman_Population* Day*Per_Capita_Water__Use_Pullman/1000000000
Total_Pullman_Demand = Total_Pullman_Population*Day* Per_Capita_Water__Use_Pullman/1000000000 {billion gallons)

Section 2—Pullman population forecast model

Single-family households

Pullman_Population(t) = Pullman_Population(t – dt) + (Birth) * dt
INIT Pullman_Population = 10764 {For 2005}
Birth = Pullman_Population*Pullman_Growth_Rate_Only

Total population

Total_Pullman_Population(t) = Total_Pullman_Population(t – dt) + (Birth_4) * dt
INIT Total_Pullman_Population = Population_Pullman
Birth_4 = Total_Pullman_Population*Population_Growth_Rate_Pullman
Population_Growth_Rate_Pullman = 0.01{1/yr}
Pullman_Growth_Rate_Only = 0.0128 {%}

Section 3—Water demand forecast by economic model

Household_Size= –0.004*TIME+10.24
Fixed_Price = 0.7658*TIME-1509.9 {$ (1 inch water meter size)}
Housing_Units = 71.6*TIME-134184 {no.}
Marginal_Price = 0.0527*TIME-104.45 {$ / 100 ft^3}
Median_Household_Income = 410.42*TIME-799212 {$ / per annum}
Per_Capita_Per_Day_Water_Use_Regression =
Pullman_Demand_by_Economic_Model*1000000000/(Total_Pullman_Population*365)
Precipitation_Inch = 27.92 {inch}

Scenario 2- Case 3

Pullman_Demand_by_Economic_Model = (Marginal_Price^1.6*Fixed_Price^-5.07*Precipitation_Inch^-0.048* Household_Size^188.72*Median_Household_Income^24.32*EXP(-377))*100*7.481* Housing_Units *12/1000000000 {billion gallons}

Scenario 2- Case 4

(Marginal_Price^1.58*Fixed_Price^-5.21*Precipitation_Inch^-0.048*Median_Household_Income^5.56*EXP(–37.33))*100*7.481*Households*12/1000000000

(Multiplier 7.481 converts cubic feet to gallon)

Appendix B. Comprehensive data set of City of Pullman for Economic analysis.

YEAR	MONTH	WATER EXTRACTION (SINGLE-FAMILY HOUSEHOLDS)	TOTAL EXTRACTION	MEDIAN HOUSEHOLD INCOME	PRECIPITATION	HOUSEHOLD SIZE	FIXED PRICE	MARGINAL PRICE (SINGLE-FAMILY HOUSEHOLDS)	MARGINAL PRICE (TOTAL RESIDENTIAL)	HOUSING UNIT (SINGLE-FAMILY HOUSEHOLDS)	TOTAL HOUSEHOLDS	TOTAL POPULATION
		ft^3	ft^3	$	IN	PERSON	$ (1 INCH WATER METER SIZE)	$ / 100 ft^3	$ / 100 ft^3	NO		
		Q_S	Q_T	I	P	H	FP	MP_S	MP_T	N_S	N_T	
2000	January	1964268	5877889	21662	1.90	2.24	21.930	0.96	0.96	3217	9022	24664
2000	February	1826063	5915316	21696	2.66	2.24	21.930	0.96	0.96	3223	9028	24653
2000	March	2122005	7274413	21731	2.31	2.24	21.930	0.96	0.96	3228	9034	24641
2000	April	1879279	5865495	21765	1.21	2.24	21.930	0.96	0.96	3234	9040	24630
2000	May	2484217	7392175	21799	2.14	2.24	21.930	0.96	0.96	3239	9046	24619
2000	June	3543088	6785373	21833	1.19	2.24	21.930	1.18	1.18	3245	9052	24608
2000	July	5354343	10236314	21867	0.01	2.24	21.930	1.18	1.18	3250	9058	24596
2000	August	7534448	12913743	21902	0.04	2.24	21.930	1.18	1.18	3255	9064	24585
2000	September	5798750	12277019	21936	1.51	2.24	21.930	1.18	1.18	3261	9070	24574
2000	October	2661299	7126734	21970	1.65	2.24	21.930	0.96	0.96	3266	9076	24563
2000	November	2347824	7625634	22004	1.86	2.24	21.930	0.96	0.96	3272	9082	24551
2000	December	1981549	6355439	22038	1.44	2.24	21.930	0.96	0.96	3277	9088	24540
2001	January	2015734	6040603	22073	1.59	2.24	22.920	1.00	1.00	3283	9094	24571
2001	February	1954427	6507531	22107	0.93	2.24	22.920	1.00	1.00	3288	9100	24602
2001	March	1838650	6162655	22141	1.33	2.24	22.920	1.00	1.00	3293	9106	24633
2001	April	2082449	6552777	22175	2.19	2.23	22.920	1.00	1.00	3299	9111	24663
2001	May	2400214	7254617	22209	1.83	2.23	22.920	1.00	1.00	3304	9117	24694
2001	June	3806614	9575364	22244	1.46	2.23	22.920	1.23	1.23	3310	9123	24725
2001	July	5084948	10000424	22278	0.56	2.23	22.920	1.23	1.23	3315	9129	24756
2001	August	5310093	10092392	22312	0.02	2.23	22.920	1.23	1.23	3321	9135	24787
2001	September	7169385	14301170	22346	0.28	2.23	22.920	1.23	1.23	3326	9141	24818
2001	October	3654611	8653608	22380	2.46	2.23	22.920	1.00	1.00	3332	9147	24848
2001	November	2517910	7710475	22415	2.76	2.23	22.920	1.00	1.00	3337	9153	24879
2001	December	1997526	6353920	22449	2.61	2.23	22.920	1.00	1.00	3342	9159	24910
2002	January	1803846	5191996	22483	2.88	2.23	23.950	1.05	1.05	3348	9165	24943
2002	February	1895084	6254505	22517	1.18	2.23	23.950	1.05	1.05	3353	9171	24975
2002	March	2145152	7467159	22551	0.69	2.23	23.950	1.05	1.05	3359	9177	25008
2002	April	1810296	5694853	22586	0.96	2.23	23.950	1.05	1.05	3364	9183	25040
2002	May	2490631	7493009	22620	1.23	2.23	23.950	1.05	1.05	3370	9189	25073
2002	June	3901991	8544395	22654	1.64	2.23	23.950	1.29	1.29	3375	9195	25105
2002	July	4746682	9344955	22688	0.15	2.23	23.950	1.29	1.29	3380	9201	25138
2002	August	7112037	12889648	22722	0.33	2.23	23.950	1.29	1.29	3386	9207	25170
2002	September	6022030	12204097	22757	0.41	2.23	23.950	1.29	1.29	3391	9213	25203
2002	October	3502139	8531498	22791	0.73	2.23	23.950	1.05	1.05	3397	9219	25235
2002	November	2625739	7974815	22825	1.23	2.23	23.950	1.05	1.05	3402	9225	25268
2002	December	1552390	4890887	22859	2.13	2.23	23.950	1.05	1.05	3408	9231	25300

2003	January	2011543	5790131	22893	4.26	2.23	23.950	1.05	1.05	3413	9237	25350
2003	February	1820444	5159663	22928	1.66	2.23	23.950	1.05	1.05	3418	9243	25401
2003	March	1963734	6423445	22962	4.74	2.23	23.950	1.05	1.05	3424	9249	25451
2003	April	1827297	5881315	22996	1.30	2.23	23.950	1.05	1.05	3429	9255	25502
2003	May	2389655	7634149	23030	1.16	2.23	23.950	1.05	1.05	3435	9261	25552
2003	June	3015584	7045600	23064	0.18	2.23	23.950	1.29	1.29	3440	9267	25603
2003	July	7462948	13653907	23099	0.06	2.23	23.950	1.29	1.29	3446	9273	25653
2003	August	7139747	12717461	23133	0.79	2.23	23.950	1.29	1.29	3451	9279	25703
2003	September	7251902	13935037	23167	0.95	2.23	23.950	1.29	1.29	3456	9285	25754
2003	October	3930321	9179868	23201	0.80	2.22	23.950	1.05	1.05	3462	9290	25804
2003	November	2890490	8496825	23235	2.15	2.22	23.950	1.05	1.05	3467	9296	25855
2003	December	1763475	5524555	23270	3.14	2.22	23.950	1.05	1.05	3473	9302	25905
2004	January	2803937	8227001	23304	6.25	2.22	24.900	1.15	1.15	3478	9308	25851
2004	March	1880474	6048229	23372	1.33	2.22	24.900	1.10	1.10	3489	9320	25744
2004	April	2365776	6880936	23406	1.04	2.22	24.900	1.10	1.10	3494	9326	25691
2004	May	2818361	7675988	23441	3.00	2.22	24.900	1.15	1.15	3500	9332	25637
2004	June	3092558	7166852	23475	0.74	2.22	24.900	1.40	1.30	3505	9338	25584
2004	July	6508931	12149175	23509	0.10	2.22	24.900	1.40	1.40	3511	9344	25530
2004	August	6769112	11822464	23543	1.48	2.22	24.900	1.40	1.40	3516	9350	25476
2004	September	5068512	11253858	23577	1.10	2.22	24.900	1.40	1.40	3522	9356	25423
2004	October	3340810	8615017	23612	1.72	2.22	24.900	1.40	1.40	3527	9362	25369
2004	November	2119393	6865902	23646	1.76	2.22	24.900	1.10	1.10	3533	9368	25316
2004	December	2064986	6656884	23680	1.36	2.22	24.900	1.10	1.10	3538	9374	25262
2005	January	2091674	5688958	23714	0.91	2.22	25.900	1.14	1.14	3543	9380	25270
2005	February	1976143	6552983	23749	0.10	2.22	25.900	1.14	1.14	3549	9386	25278
2005	March	1925580	6279214	23783	2.33	2.22	25.900	1.14	1.14	3554	9392	25286
2005	April	2162333	6704528	23817	1.53	2.22	25.900	1.14	1.14	3560	9398	25294
2005	May	2437734	7191515	23851	2.74	2.22	25.900	1.14	1.14	3565	9404	25302
2005	June	3142420	6898329	23885	1.25	2.22	25.900	1.46	1.35	3571	9410	25310
2005	July	5649439	10486832	23920	0.39	2.22	25.900	1.46	1.46	3576	9416	25317
2005	August	6689646	11578011	23954	0.17	2.22	25.900	1.46	1.46	3581	9422	25325
2005	September	7420095	14488590	23988	0.28	2.22	25.900	1.82	1.82	3587	9428	25333
2005	October	3679684	8785338	24022	2.28	2.22	25.900	1.46	1.46	3592	9434	25341
2005	November	2394268	7474327	24056	2.44	2.22	25.900	1.14	1.14	3598	9440	25349
2005	December	2200781	6663322	24091	2.56	2.22	25.900	1.14	1.14	3603	9446	25357
2006	January	1956031	5104705	24125	4.35	2.22	26.930	1.19	1.19	3609	9452	25365
2006	February	2108831	7290017	24159	1.33	2.22	26.930	1.19	1.19	3614	9458	25373
2006	April	2164533	6979413	24227	2.51	2.21	26.930	1.19	1.19	3625	9469	25389
2006	May	2480851	7169488	24262	1.45	2.21	26.930	1.19	1.19	3630	9475	25397
2006	June	3862594	8008863	24296	1.75	2.21	26.930	1.51	1.51	3636	9481	25405
2006	July	5963238	10824949	24330	0.10	2.21	26.930	1.51	1.51	3641	9487	25412
2006	August	7133752	11855159	24364	0.14	2.21	26.930	1.51	1.51	3647	9493	25420