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Water Resources Planning and Management

Date: October 8, 2012
From: Tom Chesnutt and Gary Fiske
To: Hossein Parandvash
Cc: Lorna Stickel
Re: Task B Technical Memorandum: Retail Demand Modeling

Introduction

This technical memorandum statistically evaluates trends in total PWB retail water usage. This analysis identifies annual and seasonal patterns, removes the effect of weather and the business cycle from identified trends, and identifies factors that contribute toward long term trends. This analysis builds upon Water Demand modeling conducted by the Portland Water Bureau (PWB). Specifically, this application of empirical water demand modeling builds upon the analysis reported in the following documents:

- *Water Management and Conservation Plan for the City of Portland*, Portland Water Bureau, July 2010.
- *Using Structural Time Series Model For Short-Term And Long-Term Water Demand Forecasting*, G. Hossein Parandvash, Portland Water Bureau, 2009.
- *Analysis of Retail Water Consumption by Customer Class: Report Based on Analyses of the Billing and Production Data*, G. Hossein Parandvash, Portland Water Bureau, January 2012

Trends in PWB Retail Water Demand

We apply the statistical model separately documented in a technical appendix "*Appendix A: Statistical Models of Daily Retail Water Demand in Portland*" to examine trends of PWB retail water usage. This model attempts to explain daily production to meet retail demand[1] with a variety of seasonal, weather, and economic variables, and by overall long-term trend terms.

Table 1 shows three comparisons between the estimated trends in two decades, the 1990's and the following decade. The comparisons are based respectively on the raw retail demand data, a "robust" estimate of retail demand, which filters for data quality issues, and after controlling for weather variations and the business cycle.

[1] The daily production to meet retail demand was provided by PWB staff and is calculated by adjusting total production for wholesale sales and changes in local storage.

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Table 1. Estimated Annual Trends in Portland Retail Demand

	Raw Retail Demand	Robust Est. of Retail Demand	After Controlling for Weather and the Business Cycle
1993-1999	-2.56%	-2.59%	-3.35%
2000-2011	-1.46%	-1.31%	-0.89%

One application of the demand model is to demonstrate the effects of deviations of actual weather from normal on retail water demand. Figures 1 and 2 show the average daily maximum air temperature and precipitation patterns over the year, averaged for each day of the year over the period of record (1940-2011).

Figure 1. Mean Daily Maximum Air Temperature: PDX NOAA Station (1940-2011)

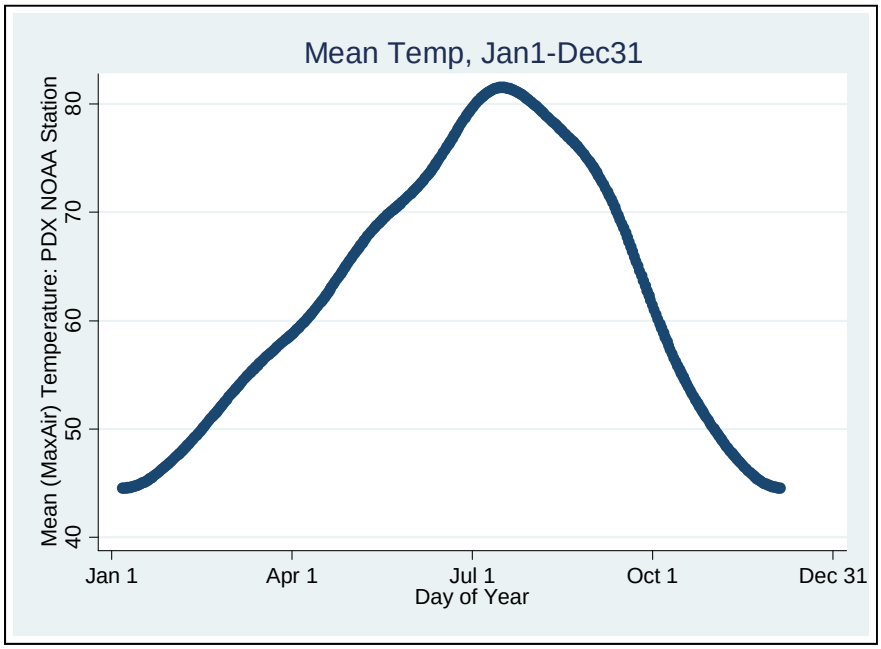


Figure 2. Mean Daily Precipitation: PDX NOAA Station (1940-2011)

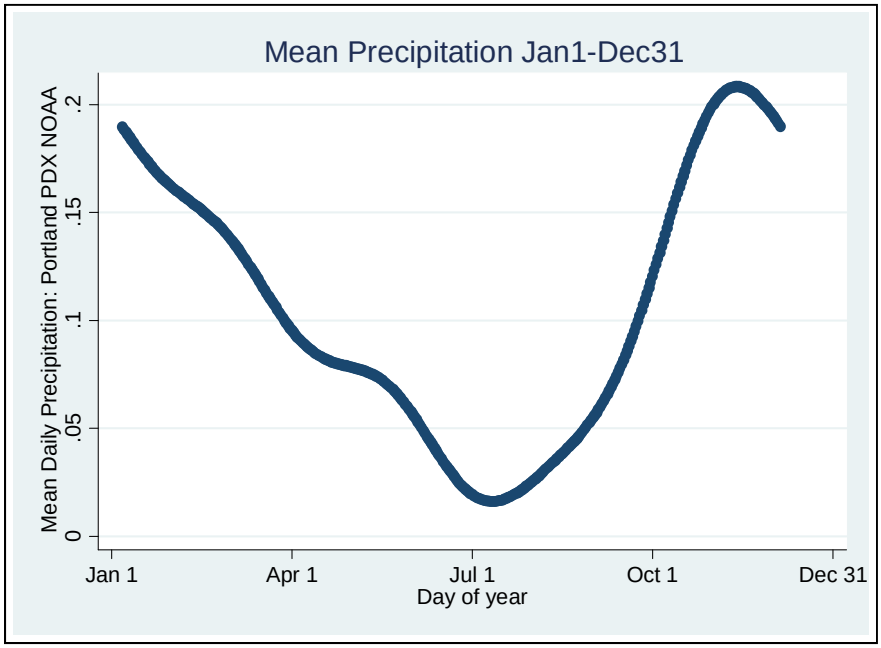


Table 2 expresses this effect of weather in annual volumetric terms and on a percentage basis—how much actual retail demand was higher or lower than what retail demand would have been if weather were normal.

Table 2. Model Predicted Effect of Weather on Retail Demand

Year	Effect of Weather on Retail Water Demand (MG)	Effect of Weather on Water Demand (Percent)
1993	-175	-0.6%
1994	705	2.4%
1995	282	1.0%
1996	73	0.3%
1997	-58	-0.2%
1998	163	0.6%
1999	-73	-0.3%
2000	79	0.3%
2001	25	0.1%
2002	255	1.1%
2003	532	2.2%
2004	301	1.3%

2005	116	0.5%
2006	443	1.9%
2007	85	0.4%
2008	84	0.4%
2009	384	1.7%
2010	-293	-1.3%
2011	-162	-0.7%

Figure 3 shows the historical employment in the Portland metropolitan area from 1993 to 2011 and a trend line fitted to historical employment (Source: Bureau of Labor Statistics). The growth and decline of employment around this trend line is consistent with patterns of the economic business cycle. The departure of employment from its historical trend line was used in the statistical demand model as a proxy measure for the business cycle.

Figure 3

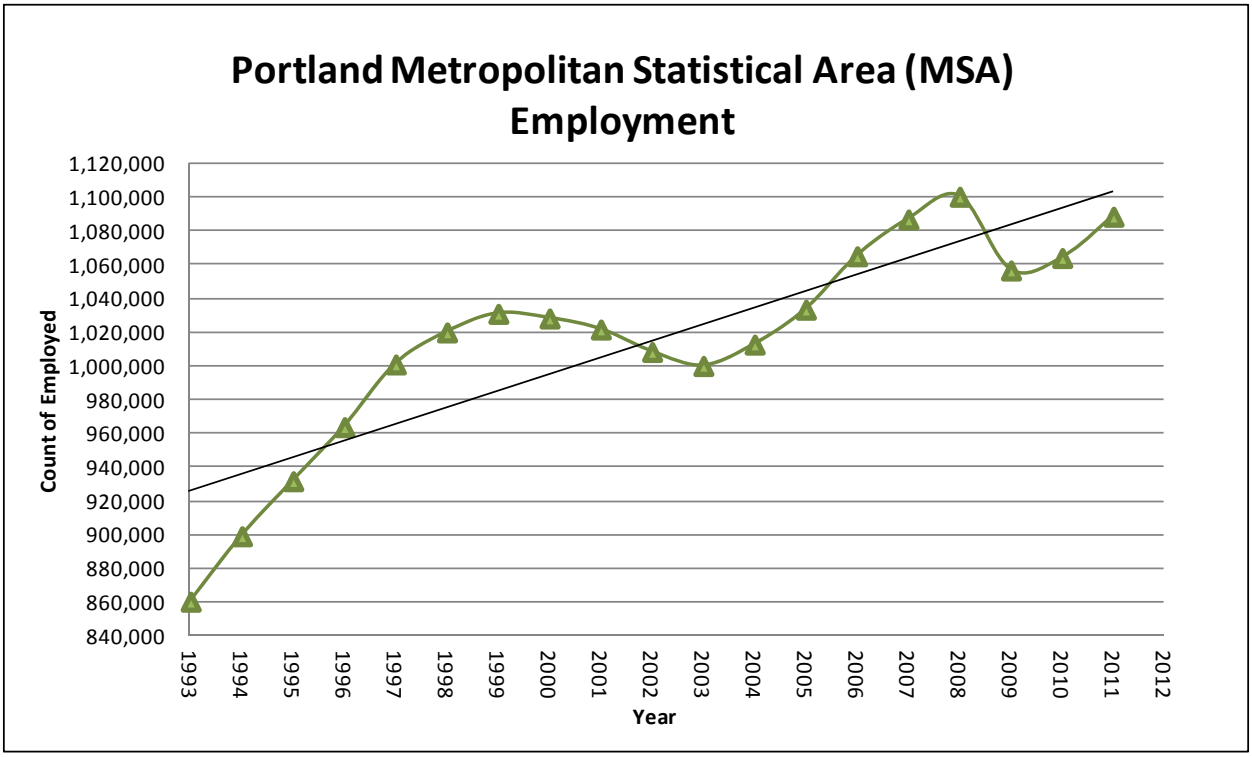


Table 3 shows the effects on annual demand of deviations in total employment from the trend in employment.

Table 3. Model Predicted Effect of Employment on Retail Demand

Year	Effect of Employment on Water Demand (MG)	Effect of Employment on Water Demand (Percent)	Employment Portland MSA§	Trend in Employment, Portland MSA¥	Difference from Trend Employment Portland MSA
1993	-465	-1.6%	860,265	892,507	(32,242)
1994	-62	-0.2%	899,096	904,122	(5,026)
1995	214	0.7%	931,689	915,889	15,800
1996	458	1.6%	963,782	927,808	35,974
1997	727	2.7%	1,000,914	939,882	61,032
1998	769	2.9%	1,019,894	952,114	67,780
1999	711	2.8%	1,030,949	964,505	66,444
2000	530	2.2%	1,028,175	977,057	51,118
2001	320	1.3%	1,021,625	989,772	31,853
2002	60	0.3%	1,008,349	1,002,643	5,706
2003	-166	-0.7%	1,000,051	1,015,691	(15,641)
2004	-159	-0.7%	1,012,681	1,028,909	(16,228)
2005	-84	-0.4%	1,033,424	1,042,300	(8,876)
2006	87	0.4%	1,065,064	1,055,864	9,200
2007	157	0.7%	1,086,894	1,069,605	17,289
2008	158	0.7%	1,100,371	1,083,525	16,846
2009	-382	-1.7%	1,056,644	1,097,626	(40,982)
2010	-420	-1.9%	1,064,018	1,111,910	(47,892)
2011	-329	-1.5%	1,088,534	1,126,381	(37,846)

§Source: Bureau of Labor Statistics for the Portland Metropolitan Statistical Area (MSA).
¥Trend line fitted to Employment in the Portland MSA.

Finally, these estimated effects of non-normal weather and employment different from trend are next used to estimate what retail water demand would have been if weather had been normal and if employment had not differed from its historical trend (that is, if the recession had not occurred.) Actual demand with weather and employment effects removed will be referred to as "normalized" retail water demand.

Table 4 presents the derivation of normalized retail water demand. The first column of raw demand data ("Actual Demand") is processed using robust statistical methods to screen for measurement and data quality issues. The second column of demand data ("Robust Est. Demand") excludes the data flagged as suspect. The robust screen successfully detected anomalous measures in 2003 that were later confirmed to reflect faulty metering of wholesale sales. Next, Demand is normalized for weather. The estimated percentage effect of weather

different from normal ("Effect of Weather on Water Demand (Percent)") explains how weather affected actual demand and is used to estimate the third column of retail demand ("Demand Normalized for Weather (MGD)"). A similar estimate for the effect of employment different than trend is used to estimate the last column of retail demand ("Demand Normalized for Weather and Employment").

Table 4. Retail Demand, Robust Estimate and Normalized for Weather and Employment

Year	Actual Demand (MGD)	Robust Est. Demand (MGD)	Effect of Weather on Water Demand (Percent)	Demand Normalized for Weather (MGD)	Effect of Employment on Water Demand (Percent)	Demand Normalized for Weather and Employment
1993	81.60	81.63	-0.6%	82.11	-1.6%	83.39
1994	83.17	83.20	2.4%	81.25	-0.2%	81.42
1995	78.04	81.19	1.0%	80.40	0.7%	79.80
1996	76.04	76.18	0.3%	75.98	1.6%	74.74
1997	75.85	76.29	-0.2%	76.45	2.7%	74.41
1998	74.24	74.33	0.6%	73.88	2.9%	71.72
1999	69.83	69.72	-0.3%	69.92	2.8%	67.97
2000	69.89	69.85	0.3%	69.63	2.2%	68.12
2001	66.32	66.42	0.1%	66.35	1.3%	65.47
2002	62.85	62.99	1.1%	62.32	0.3%	62.16
2003	71.38	64.33	2.2%	62.91	-0.7%	63.35
2004	65.88	65.93	1.3%	65.09	-0.7%	65.54
2005	59.53	60.18	0.5%	59.88	-0.4%	60.09
2006	66.27	66.28	1.9%	65.05	0.4%	64.81
2007	63.83	64.16	0.4%	63.93	0.7%	63.50
2008	63.26	63.20	0.4%	62.97	0.7%	62.54
2009	65.53	65.67	1.7%	64.58	-1.7%	65.67
2010	61.26	61.05	-1.3%	61.85	-1.9%	63.01
2011	59.43	60.40	-0.7%	60.84	-1.5%	61.73
	Percentage Annual Trend					
1993-1999	-2.56%	-2.59%				-3.35%
2000-2011	-1.46%	-1.31%				-0.89%

Figure 4 depicts the annual trends in the actual retail demand in the prior two decades. Retail demand reveals a downward trend from 2000-2011 of 1.5 percent per year that is substantially smaller than in the previous decade, approximately 2.6 percent decline per year. Figure 5 isolates the trend over the last 11 years—the robust screening for data quality problems

reduces the 2000-2011 trend to -1.3 percent per year and controlling for the effects of non-normal weather and the employment cycle further reduces the downward trend. If weather had been normal from 2000 to 2011 and no business cycle had occurred, the long term trend would have been slightly less than one percent per year, 0.9 percent.

Figure 4

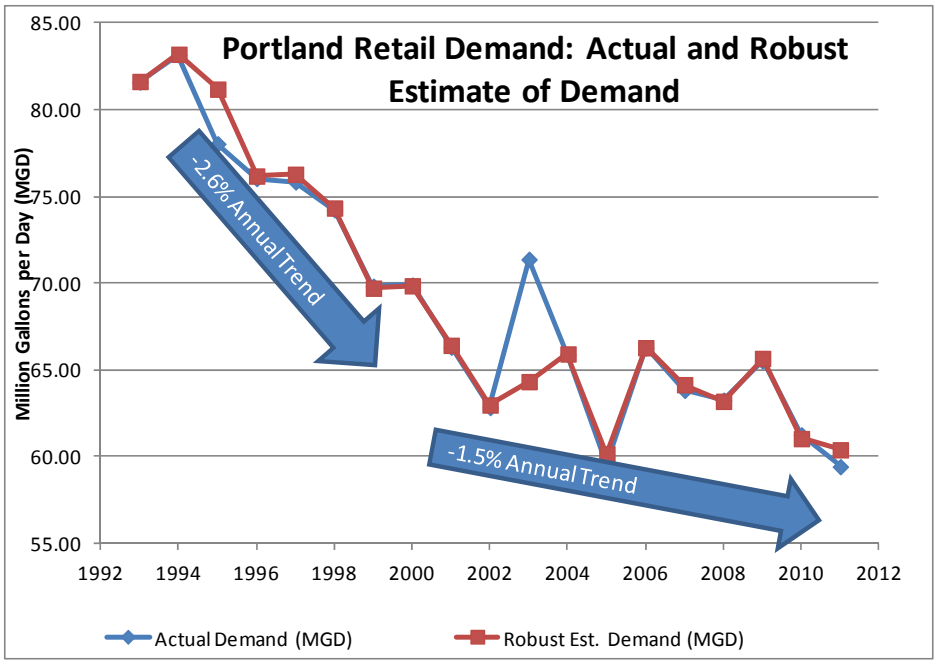
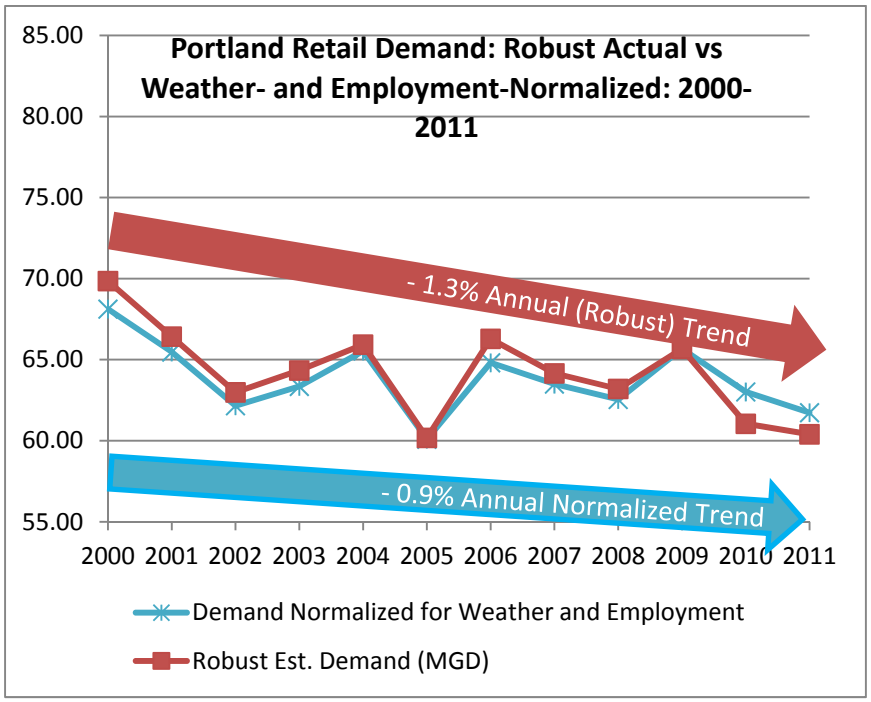


Figure 5



Determinants of Trends in PWB Retail Water Demand

The remaining long term downward trends illustrated in Figures 4 and 5 result from multiple factors. For example, population has grown over the period, which would be expected to result in positive demand growth. On the other hand, passive conservation would, due to code-mandated replacement of less efficient with more efficient fixtures, be expected to drive demand down. Water and sewer prices, which have increased in real terms, over the period, may have also contributed to the downward trend.

There are likely many other influences on the long-term trend, some of which may be measurable, others not. Figures 6-10 show the historical trends of some of the key potential drivers. Our next analytical step will be to attempt to decompose this trend into its component parts.

Population—PWB provided estimated annual population for the retail area from 1990 forward. Population growth is one of the primary drivers of long term water demand but the amount of water use per person can be a function of land use practices, price, income, and other forces.

Figure 6. Portland Retail Area Population

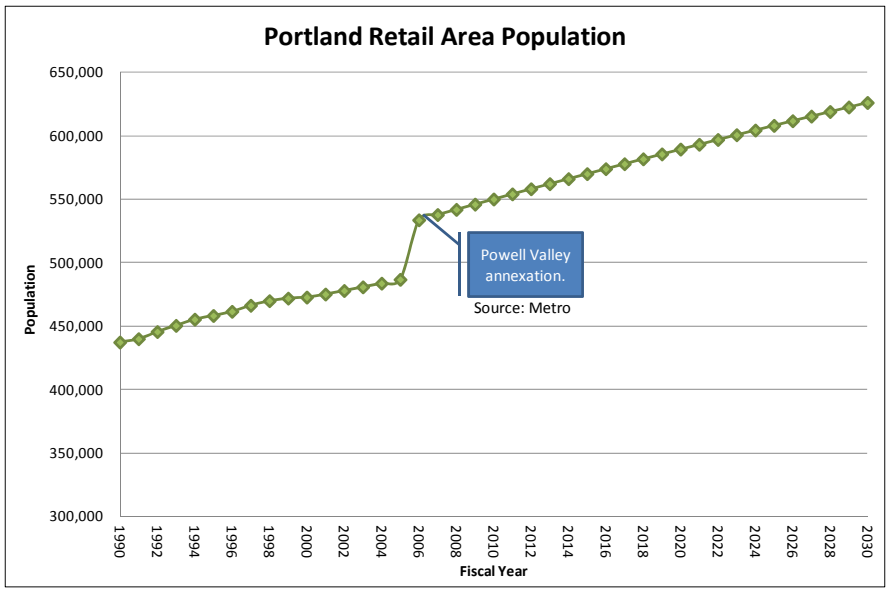


Figure 7. Multnomah County Per Capita Personal Income (PPI)

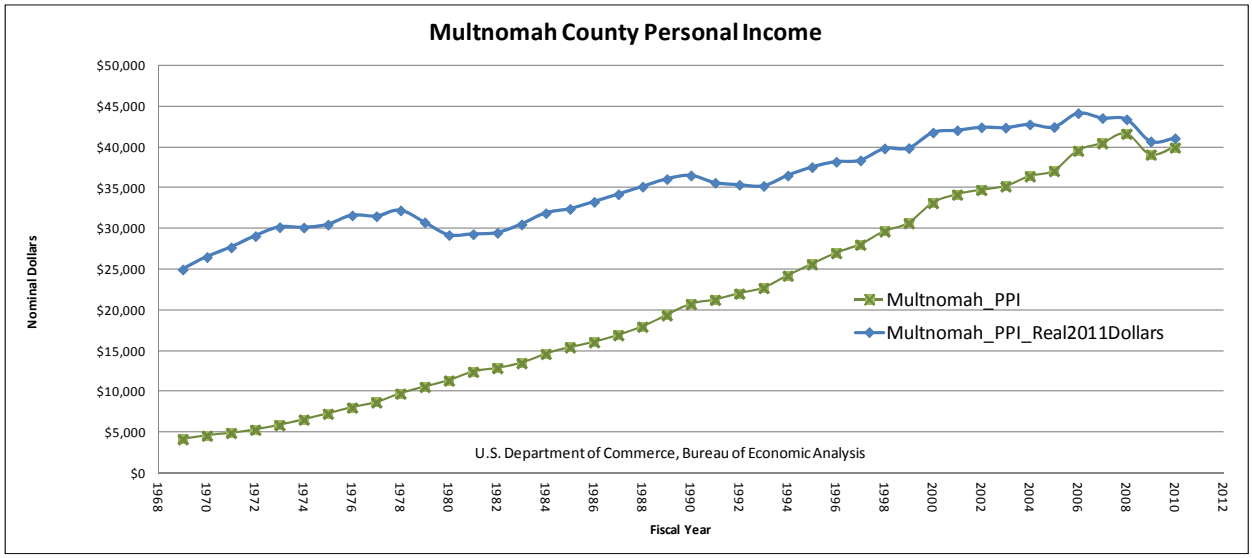


Figure 8. Water Price in Real FY2012 Dollars per CCF

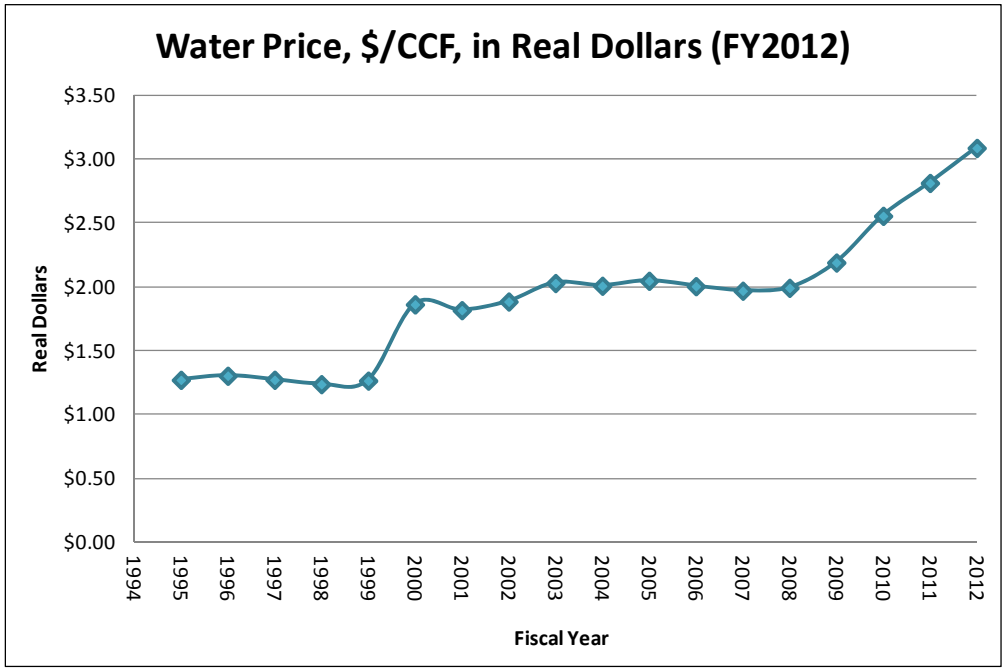


Figure 9. Sewer Price in Real FY2012 Dollars per CCF

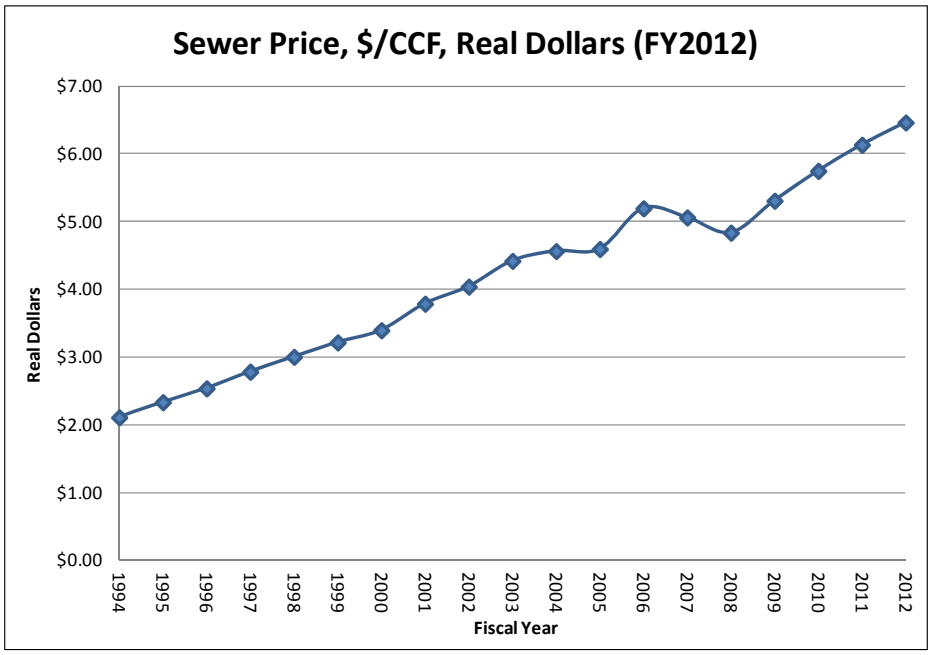
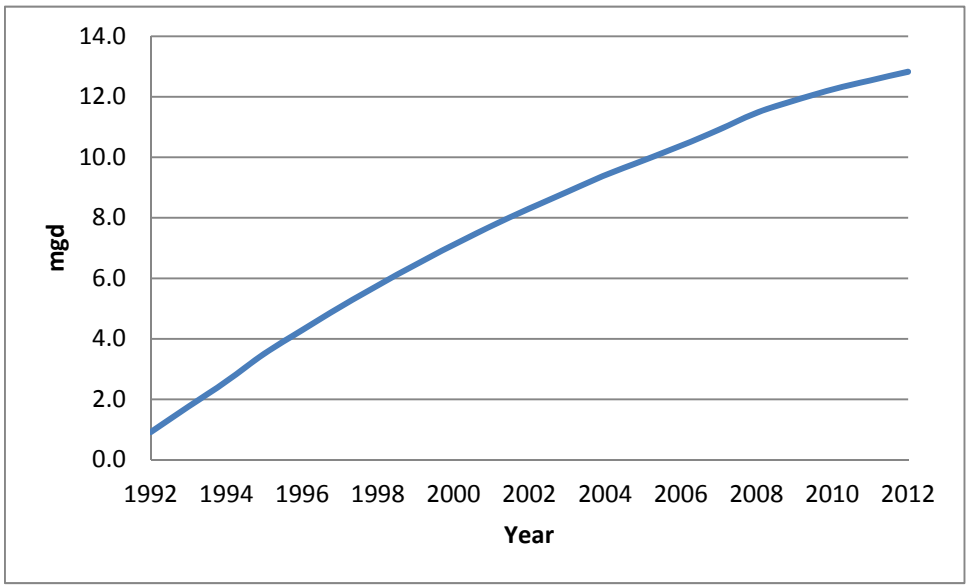


Figure 10. Estimated Cumulative Daily Passive Conservation Savings



Decomposition of Trends in PWB Retail Water Demand

The decline in PWB retail water demand occurs despite the approximate 1.45 percent annual rate of population growth from 2000 through 2011 forward. Figure 11 depicts trends in per-capita daily retail demands over this period. The bottom curve in Figure 10 shows the per capita normalized retail water demand--that is, reflecting normal weather and no recession. Per capita normalized demand declines from 144 gallons per capita per day (gpcd) in 2000 to 111 gpcd in 2011, an average annual decline of 2.31 percent.

A portion of this downward trend can be explained by passive conservation attributable to the 1992 plumbing code. The second line from the bottom in Figure 10 shows what the per-capita demand would have been in the absence of passive conservation. The downward trend is reduced from 2.31% to 1.42% annually.

Another portion of the trend can be explained by the increase in real water and sewer prices over the period. This is estimated by multiplying the increase in the real price of water and sewer service by a price elasticity derived from the literature.[2] The third line from the bottom shows what the expected trend would have been in the absence of both passive savings and price effects. The downward trend is further reduced to 0.80% per year.

This residual trend remains unexplained. There are additional factors that drive usage down that we cannot explain. These may include behavioral changes, changes in land use patterns, changes in plant materials, market-driven passive savings associated with fixtures and appliances that are not covered by the 1992 plumbing code changes, water conservation messaging at both regional and local level, and other conservation programs since 1992.

Thus, Figure 11 can be used to summarize the decomposition in trends in PWB retail water demand from 2000 to 2011:

- After adjusting for weather and employment cycle Portland per capita retail demand declined 33 gallons per capita per day (from 144 gpcd to 111 gpcd).
- About 12 gpcd or 36 percent of the decline was estimated to have occurred from quantified passive conservation due to the 1992 plumbing code.
- Another 9 gpcd or about 27 percent of the decline was estimated as the predictable customer response to the increase in the real price of water and sewer service.
- The remaining 12 gpcd of decline is attributable to other not yet quantified factors.

[2] Price elasticities from Renwick and Green (2000) "Do Residential Water Demand Side Management Policies Measure Up? An Analysis of Eight California Water Agencies". This study isolated a purer response to price by separately controlling for conservation programs and drought response. These summer and non-summer elasticities were reweighted using PWB retail demand shape to yield an annual average elasticity of -0.1345.

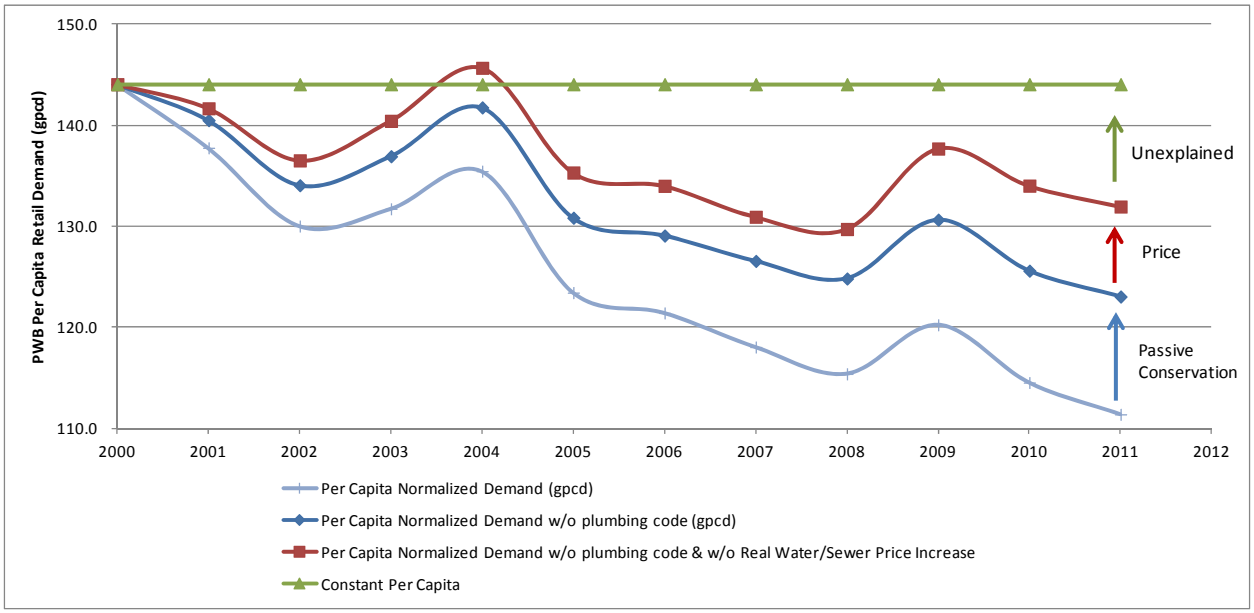



Figure 11. Decomposition of Portland Per-Capita Retail Demand Trend