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PEAK LOAD PRICING AND URBAN WATER MANAGEMENT: VICTORIA, B. C., A CASE STUDY

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The problem of satisfying urban water demands has become a major economic and political issue in several cities of North America and Western Europe in the past two decades, and is certain to do so in many others in the near future. The reasons are not hard to find. Rapidly growing populations, expanding industry, technological innovations and increasing affluence have resulted in a burgeoning of water demands.[1] It has become increasingly difficult to satisfy these growing demands, however, not only because they have exceeded local water supplies, but also because the cost of obtaining new supplies has risen very sharply.

The solution to the impending crisis in urban water management lies in a change from the traditional "extensive" approach to an "intensive" one.[2] The former is characterized by a progressive increase in the distance over which the city's water supply is obtained: as local sources become exhausted, the search for new supplies goes farther and farther afield. In some instances water is brought in from sources hundreds of miles away. Los Angeles, for example, obtains water from the Colorado River, over 200 miles from the city. The inevitable consequences of the "extensive" approach are not only rapidly rising costs, but also conflicts among cities or conflicts with other users competing for the same source of water. The conflict between New York and Philadelpha for the use of the waters of the Delaware River is one illustration.[3] Competition between the city of

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1. U.S. Water Resources Council, The Nation's Water Resources (1968); Resources for Tomorrow Conference, Background Papers (1961); Central Advisory Water Committee, The Growing Demand for Water (1962).

2. Sewell, *The New York Water Crisis,* 64 J. Geography 384 (1966).

3. J. Hirschleifer, et al., Water Supply: Economics, Technology, and Policy 255-284 (1960).

Los Angeles and agricultural interests for the use of waters of rivers in Southern California is another.[4]

In contrast to the supply-oriented, "extensive" approach is a demand-oriented, "intensive" approach. The objective of the latter is to make more efficient use of existing supplies rather than to concentrate solely on furnishing new ones. Various strategies might be used in accomplishing intensive use of existing supplies, such as the imposition of regulations to ensure that water is allocated to its most productive uses, the adoption of water conserving technologies (such as re-cycling, or evaporation control), or the treatment of wastewaters. The most promising of the potential means, however, may be the use of pricing policies to encourage more conservative use.[5]

There are two basic variables which affect the urban demand for water and the resulting costs of supply: the spatial variable and the time variable. With respect to the former, it is generally conceded that the cost of service is an inverse function of population density. The general pricing policy for most water utilities, however, does not account for the spatial variables, so that in practice a suburbanite is charged the same price as a resident of the urban center, even though the cost of supplying the suburbanite is generally much greater.

The present study, however, is addressed to the more immediate of the two factors, the time variable. In the water supply industry there are considerable variations in demand with respect to seasons, time of week, and time of day. For most of the year, water utilities have to satisfy a fairly constant demand for domestic uses such as cooking, washing, and toilet flushing as well as a fairly constant demand for commercial and industrial uses. In the summer months, however, there are heavy additional demands for lawn sprinkling, swimming pools, and air conditioning. (In the Victoria, British Columbia, area average monthly consumption in the summer is about 17,000 gallons per customer whereas in the winter it is approximately 8,000 gallons per customer).

The problem of peak loads is more complex, however, than mere seasonal fluctuations. Water demand is also subject to a decided diurnal effect with peaks occurring at about 7 to 8 a.m. and 5 to 6 p.m. and an off-peak period from 12 to 6 a.m. In addition there is a weekend effect although its exact nature is not predictable because domestic demand is probably increased while commercial and indus-

4. *Id.* at 289.

5. Milman, *Policy Horizons for Future Water Supply,* 39 Land Economics 109 (1963); Howe & Linaweaver, *The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure,* 1967 Water Resources Research 13; Bird & Jackson, *Economic Charges for Water,* in Essays in the Theory and Practice of Pricing (1968).

trial demand are conceivably lowered. The extent to which the former is compensated by the latter varies, of course, both with the nature of the industrial structure and with the settlement patterns and consumption patterns of domestic consumers.

Since the occurrence of peak loads affects the costs of supply, it is essential that these factors be accounted for in an equitable pricing structure. The concept of peak load pricing provides the theoretical framework from which a practical pricing system can be developed.

The theory of welfare economics indicates that a system of marginal cost pricing provides a more equitable and efficient solution to public utility pricing than the pricing structures generally in use at present. Without delving deeply into the intricacies of welfare theory (or the theory of the second best), a fairly explicit presentation of the marginal cost pricing principle can be illustrated graphically. In Figure 1 the marginal cost price is Pn—the point where the marginal

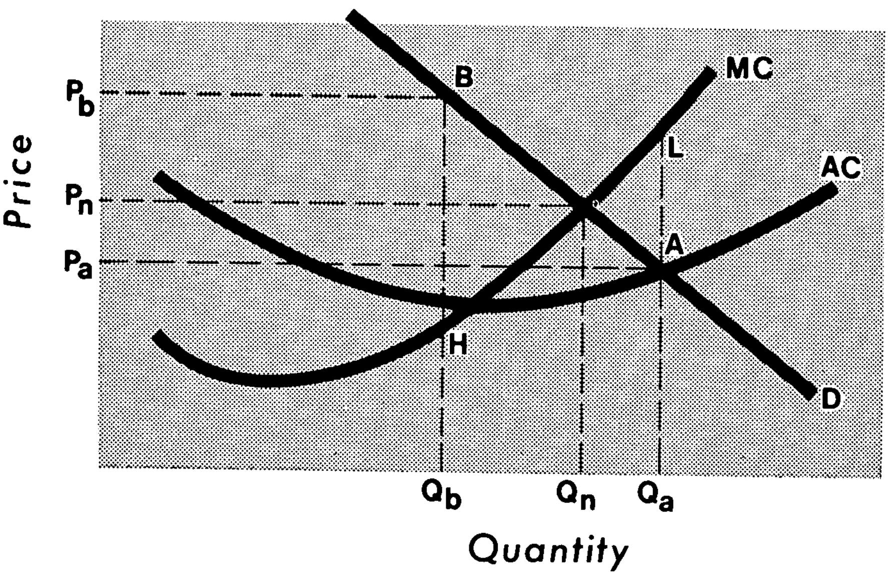

FIGURE 1

cost curve (MC) intersects the demand curve. At any higher price (such as P_b) the value derived from any additional unit of output (BQ_b—the distance under the demand curve) exceeds the incremental cost of an additional unit of ouput (HQ_b—the distance under the MC curve). Therefore, any price lower than P_b (but not lower than P_n) would result in the additional consumer value exceeding the additional cost of production. In a similar manner it can be shown that any price lower than P_n would result in the incremental cost of the additional output exceeding the added value to the consumers.

In most public utilities the pricing policies are generally based on average costs rather than marginal costs. In these circumstances the main pricing objectives are usually limited to ensuring that total revenue exceeds total cost. A consequence of this policy is that output is larger than it would be under marginal cost pricing, the price itself is lower (P_a), and marginal cost (LQ_a) exceeds incremental consumer value (Q_aA).

In simplified terms, the basic principle of marginal cost pricing is that each customer pays for his contribution to the costs of supply. With respect to the peak load problem, this principle means that customers who use the commodity during the peak period would be charged more than off-peak users because the actual costs of supply during the peak period are greater. Specifically, any significant increment in peak demand will necessitate the expansion of the capacity of the supply system, unlike an increment in off-peak demand which would not create an immediate need for expansion. Thus, the peak users would bear the entire responsibility for the capacity costs (the capital costs of capacity expansion) in addition to their share of the short run marginal costs. The off-peak users would be charged only for the short run marginal costs and should bear no responsibility for the capacity costs. This extension of marginal cost pricing to the provision of water supplies is referred to as peak load pricing.

Although the theory of marginal cost pricing and peak load pricing have received a good deal of attention in recent years, few economists have attempted a practical application of the theory. Davis and Hanke attempted such an application to the water pricing structure of the Washington, D.C. area in 1971.[6] They divided water demand into two periods: a peak period from November to April, and an off-peak period from May to October. In order to calculate the off-peak price (WPRICE), some measure of short run marginal cost was required. Average variable cost (or operating cost) was employed as a proxy. This proxy furnishes a reasonable approximation if the cost curves are nearly flat—and therefore, approximately equal. In order to calculate the peak price (SPRICE), they assumed that the current average price (CPRICE) included all the capacity costs spread evenly over the entire twelve month period. According to theory, the capacity costs should be borne fully by the peak users, therefore the difference between the current average price and the off-peak price

6. R. Davis & S. Hanke, Planning and Management of Water Resources in Metropolitan Environments, June, 1971 (mimeo.)

(marginal cost price) is a measure of the capacity costs. The peak price therefore, is equal to the off-peak price plus twice the difference between the current price and the off-peak price (since capacity costs are now spread over six months instead of twelve. In simplified form:

CPRICE = Total revenue/total consumption
WPRICE = Operating costs/total consumption
SPRICE = WPRICE + 2 (CPRICE-WPRICE)

Davis and Hanke concluded their study by simulating the effects of the seasonal prices on demand. They employed a simplified constant elasticity exponential (or log-linear) demand function and Howe and Linaweaver's sprinkling elasticity estimates for the eastern U.S. as well as their own estimates of industrial and domestic elasticity.[7]

For the Victoria study, several refinements were made to the basic Davis and Hanke model. Instead of using the simplified two period—six month case, water demand was broken down into three periods. The rationale for this division is that the Victoria climate appears to have three distinct periods within the year.

In the three-period model, the off-peak price (WPRICE) was again simply an estimate of the short run marginal cost price. The peak period, however, was first shortened from six months to five months to more adequately reflect the warmer and drier summer season in Victoria. The peak period was then divided into a mid-peak period (May and September) and a peak period (June-August). In order to calculate the mid-peak price (MPRICE) and the peak price (PPRICE), the capacity costs were allocated between them according to their relative contribution to the total period (May-September). Over a ten year period the average contribution of the mid-peak was found to be 30 percent while peak demand contributed 70 percent.

In simplified form:

CPRICE = Total revenue/total consumption

WPRICE = Operating costs/total consumption

$$\text{MPRICE} = \text{WPRICE} + 0.30 \left(\frac{12}{5} \quad (\text{CPRICE-WPRICE})\right)$$

$$\text{PPRICE} = \text{WPRICE} + 0.70 \left(\frac{12}{5} \quad (\text{CPRICE-WPRICE})\right)$$

The results of these calculations of seasonal prices for the period 1967-1970 are reported in Table I.

7. Howe & Linaweaver, *supra* note 5.

TABLE I: SEASONAL PRICES

	1967	1968	1969	1970
		(Cents/1000's gals.)		
Current Avg. Price	34.5	35.2	34.2	34.7
Off-Peak Price	22.0	21.7	22.4	22.2
Peak Price	43.1	44.4	42.2	43.1
Mid-Peak Price	31.0	31.4	30.9	31.2

The next problem encountered in a practical application of peak load pricing is to determine what effect, if any, a change in price would have on consumer demand. From estimations of the price elasticities of demand the resultant effect on such important policy variables as peak demand, off-peak demand, and total revenue can be determined.

A number of attempts have been made in the past decade to estimate the elasticity of demand for urban water.[8] The results of the most significant of these studies are set out in Table II. These studies have shown that in general a log-linear relationship yields a better fit between demand and the various explanatory variables than a linear relationship. The price elasticities derived from the studies range from -.0177 to -1.125, with the average value being -0.40.

Most of the studies have regressed residential or urban demand per capita against such explanatory variables as price, income and some measure of climate. Howe and Linaweaver,[9] however, attempted a more extensive study, using the data collected by the Residential Water Use Research Project at Johns Hopkins University. They estimated price elasticities of -.405 for total residential demand, -.231 for domestic (indoor) demand, -1.12 for sprinkling demand, and -0.683 for maximum day sprinkling demand.

It is worthy of note that only two studies have attempted to estimate price elasticities for specific metropolitan areas. J. A. Rees employed a 14-year time series for Malvern, England, which showed annual residential elasticity to be quite low, -0.13, while summer elasticity was slightly higher at -0.16.[10] Using an 11-year time series, S. T. Wong found the price elasticity in Chicago to be -.0177 while in the suburbs of Chicago it was -.2830.[11]

On an a priori basis one might expect that the elasticity of demand for water in summer would be higher than that in winter. This expec-

8. *See* notes 1-10 in Table 11 *infra.*
9. Howe & Linaweaver, *supra* note 5.
10. Rees, *supra* note 16.
11. Wong, *supra* note 17.

TABLE II
SUMMARY OF URBAN WATER DEMAND STUDIES

Investigator and Area	Type of Analysis	Variables	e_p (Price Elasticity)	R^2
L. Fourt[1] U.S.	cross sectional log-linear	Y = residential demand per capita X_1 =price X_2 =no. of days of rain, June-August X_3 =avg. no. of persons per meter	-0.386	0.683
B. Gardner and S. Schick[2] Utah	cross sectional log-linear	Y =residential demand per capita X_1 =average price X_2 =lot area/capita	-0.766	0.830
J. Bain et al.[3] N. California	cross sectional linear	Y =municipal demand per capita X_1 =average price	-1.099	
C. Howe and P. Linaweaver[4]	cross sectional	Y =domestic demand per capita X_1 =market value of dwelling unit (proxy for income) X_2 =avg. block rate price	-0.231	0.717
	log-linear	Y =sprinkling demand per capita X_1 =net evapotran-spiration X_2 =summer marginal price X_3 =market value per dwelling unit	-1.12	0.729
	log-linear	Y =max. day sprinkling demand per capita X_1 =summer marginal price X_2 -avg. market value per dwelling unit	-0.683	0.564
B. Conley[5] S. California	cross sectional log-linear	Y =municipal demand per capita X_1 =avg. price	-1.025	0.522
S. Gershan[6] S. California	cross sectional log-linear	Y =municipal demand X_1 =avg. price X_2 =median income X_3 =mean daily temp. X_4 =pop. density	-0.31	0.624

TABLE II (Contd)
SUMMARY OF URBAN WATER DEMAND STUDIES

Investigator and Area	Type of Analysis	Variables	e_p (Price Elasticity)	R^2
S. Turnovsky[7]	cross sectional linear	Y =planned domestic demand per capita X_1 =variance of supply X_2 =avg. price X_3 =index of housing space/capita X_4 =% of pop. under 18	-.049 -.406	0.53 0.86
J. Rees[8] Malvern, England	time series linear	Y =daily demand per capita X_1 =time X_2 =price X_3 =rainfall Y =summer demand per capita	-0.13 -0.16	.963 .989 .933 .972
S. Wong[9] Chicago	time series log-linear	Y =demand per capita X_1 =price X_2 =avg. household income X_3 =avg. summer temperature(J-A)	-.0177	.817
Chicago Suburbs			-.2830	.574
A. Grima[10] Toronto	cross sectional linear	Y =residential demand per capita X_1 =income X_2 =size of household X_3 =price X_4 =service charge	Summer -1.07 Winter -0.75	.443 .535

1. L. Fourt, Forecasting the Urban Residential Demand for Water (Agricultural Economics Seminar, 1958).
2. Gardner & Schick, *Factors Affecting Consumption of Urban Household Water in Northern Utah,* Agricultural Experiment Station Bull. 449, Utah State University (1964).
3. J. Bain, R. Caves, & J. Margolis, Northern California's Water Industry (1966).
4. Howe & Linaweaver, *supra* note 5.
5. Conley, *Price Elasticity of the Demand for Water in Southern California,* 1 Annals of Regional Science 180 (1967).
6. Gershan, *Study of Price Elasticity in Southern California* (Department of Water Resources: reported by B. Conley, 1 Annals of Regional Science 182 (1967)).
7. Turnovsky, *The Demand for Water: Some Empirical Evidence on Consumers' Response to a Commodity Uncertain in supply,* 1969 Water Resources Research 350.
8. J. Rees, Factors Affecting Metered Water Consumption, Final Report to the Social Science Research Council (Gr. Brit., 1971).
9. Wong, *A Model on Municipal Water Demand: A Case Study of Northeastern Illinois,* 48 Land Economics 34 (1972).
10. A. Grima, Residential Water Demand: Alternative Choices for Management, 1970 (Ph.D. thesis at the Univ. of Toronto).

tation would seem to follow from the fact that lawn sprinkling, car washing, and filling of swimming pools are non-essential uses, and ones in which major improvements in efficiency of use can be obtained. Price increases, therefore, would likely result in reductions in these demands. The studies undertaken by Howe and Linaweaver[12] and by Rees[13] seem to bear this expectation out.

While the various studies undertaken thus far have helped shed light on the factors underlying the demand for water, and have indicated the potential range of elasticities, they have been carried out in a limited number of geographical locations, and have often suffered from lack of data. Our study was intended to test the conclusions of previous studies in a particular geographical context, and possibly to refine the theory relating to demand analysis.

The city of Victoria, British Columbia, is located on the west coast of North America. It has a population of 200,000 and derives its economic support from the location of provincial government offices in the city, tourism, and a limited range of light industries. Water demands, therefore, are largely residential. The climate is characterized by mild temperatures throughout the year, averaging 41°F in the winter and 59°F in the summer. Precipitation is mainly in the form of rainfall, averaging 27 inches per annum, concentrated in the winter months.

The city is supplied with water from the Sooke and Goldstream watersheds, some 18 miles north of the city (Figure 2). The supply system is managed by the Greater Victoria Water District which supplies water to the city of Victoria, and the municipalities of Oak Bay, Saanich, and Esquimalt as well as a number of outlying communities. The consumption of water in the district in 1971 totalled 6,764 million gallons.

The city's water supply system consists of a number of reservoirs in the watersheds noted above, together with several large diameter pipelines and a distribution system. A major addition was made to the facilities in 1971 through the completion of a 91 inch diameter pipeline with a capacity of 130 million gallons per day. The total capacity of the system, however, is presently limited to 45 million gallons per day because of the smaller capacity of the feeder pipelines into the city.

The Victoria study used similar variables to those employed in previous studies in analyzing the demand for water–namely demand, price, income, average summer temperature, average summer rainfall.

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12. Howe & Linaweaver, *supra* note 5.
13. Rees, *supra* note 16.

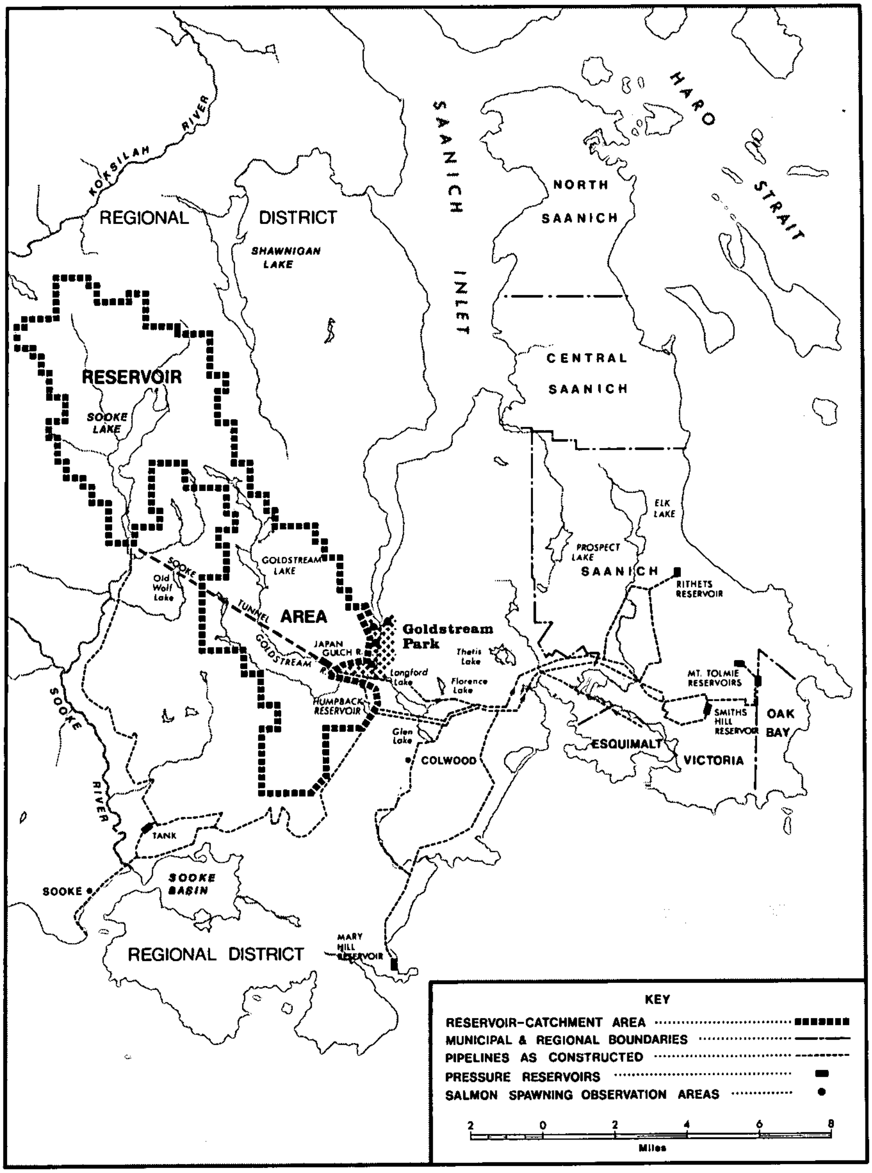
KOKSILAH RIVER
REGIONAL DISTRICT
SHAWNIGAN LAKE
SAANICH INLET
HARO STRAIT
NORTH SAANICH
CENTRAL SAANICH
RESERVOIR
SOOKE LAKE
ELK LAKE
PROSPECT LAKE
SAANICH
RITHETS RESERVOIR
GOLDSTREAM LAKE
Old Wolf Lake
SOOKE TUNNEL
AREA
Goldstream Park
JAPAN GULCH R.
GOLDSTREAM R.
Thetis Lake
Longford Lake
Florence Lake
HUMPBACK RESERVOIR
MT. TOLMIE RESERVOIRS
SMITHS HILL RESERVOIR
OAK BAY
Glen Lake
COLWOOD
ESQUIMALT
VICTORIA
SOOKE RIVER
TANK
SOOKE BASIN
SOOKE
REGIONAL DISTRICT
MARY HILL RESERVOIR
KEY
RESERVOIR-CATCHMENT AREA
MUNICIPAL & REGIONAL BOUNDARIES
PIPELINES AS CONSTRUCTED
PRESSURE RESERVOIRS
SALMON SPAWNING OBSERVATION AREAS
2 0 2 4 6 8
Miles

FIGURE 2

The data are set out in Table III. The dependent variable was based on figures for total municipal demand which is a combination of residential, commercial and industrial demand. The exact measure employed in the Victoria study was demand per customer (or service) rather than the more popular demand per capita because accurate annual population statistics were incomplete for this region whereas data on the number of customers and total annual demand statistics were available for the period 1954-1970. As well as measuring an annual demand function, an attempt was also made at measuring seasonal demand functions.

The use of annual time series data necessitated the calculation of a common price for the entire region for each year, which is difficult to achieve because of the institutional framework in Victoria and because of the declining block rate structures. The Greater Victoria Water District sells water at wholesale rates to its owner-municipalities: Oak Bay, Saanich, and Victoria City-Esquimalt. The district also sells water at retail rates to an outside area. As a result, each of these four areas have their own completely independent price structures, all with declining block rates, but with uniform rates for all uses—residential, commercial, and industrial.

In order to arrive at some reasonable measure of price for the whole region it was necessary to construct a weighted price index. The average consumption per customer for the bi-monthly billing period was applied to each of the four price structures to obtain an average price for each area. For example, if the average consumption was 25,000 gallons per customer, and the price was 30 cents per 1000 gallons for the first 20,000 gallons and 25 cents per 1000 gallons for the next 50,000 gallons, then the average price per customer would be calculated as follows:

$$\text{PRICE}=\frac{(20{,}000\ \text{gal.}\ \times \frac{30\ \text{cents}}{1000\ \text{gal.}})+(5{,}000\ \text{gal.}\ \times \frac{25\ \text{cents}}{1000\ \text{gal.}})}{\text{average consumption}}$$

After an average price for each area had been calculated for each of the years 1954-1970, a weighted sum was computed to determine the regional price. The weight used was the percentage contribution of the individual municipal demand to the total regional demand. Thus in 1970, the relative contributions to total demand were: Victoria, 51.88 percent; Saanich, 28.9 percent; Oak Bay, 9.83 percent; Outside, 9.38 percent. Since the respective prices in that year were 28.9 cents, 39.4 cents, 35.3 cents, and 32.1 cents, the regional price was calculated as follows:

TABLE III: REGRESSION DATA

Consumption Unit = 1000's of Imperial Gallons
Price = 1961 constant dollars

Year	Annual Cons/ Cust.*	Annual Price ($ 1961)	Peak Cons/ Cust. (June-Aug.)	Peak Price	Off-Peak Cons/ Cust. (Oct.-Apr.)	Off-Peak Price	Mid-Peak Cons/ Cust. (May, Sept.)	Mid-Peak Price	Dispos. Income/ Return ($ 1961)	Peak Avg. Temp. (°F)	Mid-Peak Avg. Temp. (°F)	Peak Avg. Rain (inches)
1970	149.2	.267	57.09	.252	66.20	.268	25.87	.258	4263	59.0	54.1	0.14
1969	147.3	.271	54.00	.253	67.06	.275	26.21	.258	4275	59.5	56.6	0.31
1968	133.1	.278	49.79	.261	61.62	.284	21.67	.268	4296	58.9	55.5	1.17
1967	139.5	.287	56.76	.271	58.52	.289	24.19	.277	4313	60.4	56.4	0.29
1966	129.5	.296	50.60	.278	57.71	.300	21.20	.287	4368	57.8	55.3	0.76
1965	126.6	.304	53.58	.285	54.39	.308	18.59	.293	4284	58.7	53.5	0.61
1964	118.5	.308	42.28	.289	54.54	.311	21.74	.298	4134	57.9	53.5	0.99
1963	126.3	.303	46.30	.282	56.32	.308	23.65	.293	4106	58.5	57.2	0.81
1962	122.6	.308	46.83	.286	55.00	.315	20.80	.299	4056	57.7	54.6	0.80
1961	129.3	.310	54.45	.289	53.89	.315	20.94	.297	3965	60.9	55.1	0.62
1960	129.2	.308	53.11	.285	56.13	.314	20.01	.301	3923	59.1	54.8	0.38
1959	130.6	.217	50.12	.158	59.39	.223	21.14	.171	3825	59.5	54.5	0.82
1958	150.4	.222	60.90	.165	61.70	.228	27.83	.180	3834	62.1	57.4	0.37
1957	140.8	.225	48.58	.165	65.03	.231	27.16	.179	3762	58.5	58.1	0.89
1956	140.4	.231	47.65	.170	66.61	.233	26.10	.186	3699	58.7	56.2	1.01
1955	133.4	.233	48.63	.169	63.03	.225	21.73	.171	3539	57.3	53.5	1.11
1954	136.6	.223	50.38	.162	62.34	.227	23.30	.173	3444	56.9	55.6	1.09

*Cons/Cust.=Consumption per Customer

$$\text{Regional price} = .5188\,(28.9) + .2891\,(39.4) + .0983\,(35.3) + .0938\,(32.1)$$
$$= 32.8\text{c}/1{,}000 \text{ gallons}$$

This price variable was then deflated by the regional consumer price index in order to obtain a price for water relative to other goods and services in 1961 constant dollars.

Annual data on disposable income were available for the Victoria region. However, since annual population data were incomplete, the income measure used was disposable income per tax return rather than per capita income. As with price, average income was also deflated by the regional consumer price index.

The remaining two explanatory variables were temperature and rainfall. For the peak period the measures used were average temperature and average rainfall per month for June, July and August. For the mid-peak period, figures relating to the average temperature and rainfall for the months of May and September were employed.

In the first regression analysis a log-linear relationship of the following form was used:

$$\log Q = a + b \log P + c \log I + d \log T + e \log R$$

where Q = consumption/customer
a = constant term
P = average price ($1961)
b = price coefficient = price elasticity
I = disposable income/tax return ($1961)
c = income coefficient = income elasticity
T = average temperature (June, July, August)
d = temperature coefficient
R = average rainfall (June, July, August)
e = rainfall coefficient

Separate demand functions were estimated for annual, peak, off-peak, and mid-peak demands. The results are summarized in Table IV.

The results obtained for the annual demand function were encouraging. The price elasticity of -0.395 was highly significant as well as being similar to the estimates of most previous studies. However, when an attempt was made to break down demand into seasonal components, peculiar results were obtained. The peak demand function indicated that temperature and rainfall were significant variables but that price had no effect on summer demand. (Both temeprature and rainfall variables were used because it was found that the exclusion of either one led to a significantly reduced R^2.) On the other hand, it was found that off-peak demand had a price elasticity of -0.579. The weather variables were eliminated from the off-peak function. R^2 did not change significantly when they were excluded.

TABLE IV: LOG-LINEAR DEMAND FUNCTIONS

Demand Function		Estimated equations and standard errors									R^2	Durbin-Watson
Annual demand	lnQ =	1.656 (2.407)	-	0.395 lnP* (0.093)	+	0.191 lnI (0.197)	+	0.272 lnT (0.472)	-	0.066 lnR* (0.019)	.804	1.670
Peak demand	lnQ =	-2.528 (3.694)	-	0.065 lnP (0.089)	-	0.049 lnI (0.332)	+	1.650 lnT* (0.723)	-	0.091 lnR* (0.028)	.743	1.671
Off-peak demand	lnQ =	0.845 (2.164)	-	0.579 lnP* (0.127)	+	0.504 lnI (0.246)					.630	1.170
Mid-peak demand	lnQ =	-11.96* (4.66)	-	0.252 lnP** (0.150)	+	0.277 lnI (0.550)	+	3.097 lnT* (0.899)	+	0.040 lnR (0.058)	.674	1.398

*Using a two-tailed t-test, these coefficients are significant to the 95% level of confidence.
**90% confidence level.
All other coefficients are below the 85% confidence level.

These results appear to be a direct contradiction of the findings of Rees and of Howe and Linaweaver, and more importantly, they are exactly opposite to what might be predicted a priori.

Various explanations might be offered for this apparent anomaly. A plausible one is that price does in fact have more influence on winter demands than on those in summer, which may result from the nature of the price structure which is the declining block type. Since more water is consumed during the summer months, the average price paid is likely to be lower as progressively lower block rates are reached. In the Victoria region this situation is compounded by the fact that the largest municipality (accounting for approximately 50 percent of total demand) has a promotional summer rate to encourage sprinkling by which any amount used in the summer above the winter average is charged 24.1c/1000 gal. compared to the first block rate (37,380 gallons) of 28.9c/1000 gal. The differences between peak and off-peak prices are shown in Table III. The result of the lower summer prices may be that the demand functions are linear (instead of log-linear with constant elasticity) and that summer demand is in the very inelastic portion of its curve while winter prices, being higher, are in the less inelastic portion of the winter demand curve.

A possible factor contributing to the low summer price elasticity might be Victoria's highly significant tourist trade. Summer visitors staying in hotels, motels, and other tourist accommodation are not subject to a direct price for water and therefore their elasticity is zero, which contributes to the downward pressure on the summer price elasticity.

The previous demand functions were re-run in linear form, using the same variables:

$$Q = a + bP + cI + dT + eR$$

The regression equations and related statistics are reported in Table V.

On a purely statistical basis it is difficult to determine whether the linear or the log-linear demand function is the more suitable. The linear function for annual demand shows a slight decrease in both the R^2 value and the Durbin-Watson statistic from the previous log-linear relationship. For the remaining linear functions—peak, off-peak and mid-peak demand—the R^2 values and the Durbin-Watson statistics have all increased slightly.

The first part of Table VI shows some representative calculations for the price elasticities based on the current pricing structure. The range of these elasticities over the seventeen year period are as fol-

TABLE V: LINEAR DEMAND FUNCTIONS

Demand Function		Estimated equations and standard errors									R^2	Durbin-Watson
Annual demand	Q =	152.62*	-	227.16P*	+	0.0091	+	0.313T	-	15.84R*	.788	1.569
		(78.02)		(47.05)		(0.007)		(1.214)		(5.38)		
Peak demand	Q =	-9.135	-	24.67†	+	0.0011	+	1.179*	-	9.129R*	.763	1.732
		(41.016)		(19.37)		(0.004)		(0.649)		(2.856)		
Off-peak demand	Q =	65.88*	-	128.23P*	+	0.0071*					.641	1.206
		(10.60)		(27.29)		(0.004)						
Mid-peak demand	Q =	-49.53*	-	25.23P**	+	0.002I	+	1.282T*	+	1.08OR	.699	1.553
		(19.27)										

*95% confidence level
**90% confidence level
†85% confidence level
All other coefficients are below the 85% confidence level.

lows: annual demand (-.318 to -.568); peak demand (-.067 to -.168); off-peak demand (-.449 to -.744); mid-peak demand (-.161 to -.396).

TABLE VI: PRICE ELASTICITIES

	1967	*1968*	*1969*	*1970*
At Current Prices				
Peak demand	-.116	-.128	-.113	-.109
Off-peak demand	-.628	-.590	-.526	-.513
Mid-peak demand	-.288	-.310	-.247	-.250
At Seasonal Prices				
Peak demand	-.199	-.237	-.204	-.197
Off-peak demand	-.395	-.367	-.358	-.355
Mid-peak demand	-.324	-.368	-.298	-.303

The second part of Table VI shows representative calculations for the corresponding price elasticities based on the seasonal pricing structure. If our earlier hypothesis (that the high off-peak price was responsible for the off-peak elasticity exceeding the peak elasticity) is correct, then using seasonal prices which have a higher peak price and a lower off-peak price, the peak elasticity should be the larger of the two. As can be seen from Table VI, the predicted result is not the case although the gap between the two values has narrowed considerably. The statistical results still indicate that price has a greater effect on winter demand than it does on summer demand.

Three possible conclusions might be derived from the above analysis: (1) the results of the regression analysis are incorrect and, in fact, summer elasticity is greater than winter elasticity, or (2) the results are correct and serve to illustrate the peculiar behavior of Victoria residents with respect of water use,[14] or (3) the results are correct and serve to illustrate the strong effect that the summer tourist trade has on the demand for water in Victoria. The authors are inclined to accept the latter two explanations; that summer demand for water in Victoria is influenced by the large tourist trade and the apparent preference of the residents of the city for green lawns, flowering trees, shrubs, and herbacious borders. The residents have tried consciously in fact to develop a reputation for the city as that of the City of Gardens.

CONCLUSIONS AND IMPLICATIONS

In order to determine the effects of the proposed peak load pricing structure on the Greater Victoria Water District, a simulation program was developed. The price elasticities derived from the linear

14. From a general observation of the residents one could easily conclude that they suffer from an acute case of the "green lawn syndrome." In its most severe form this affliction results in sprinkling use becoming a more "essential" good than domestic use.

demand functions were used to determine the demand and revenue changes that would have occurred had the seasonal prices been in effect over the period 1967-1970. The results are summarized in Table VII.

TABLE VII: SIMULATION OF PRICE CHANGES

	Percent Change Using Seasonal Prices			
	1967	*1968*	*1969*	*1970*
Total demand	6.7%	7.6%	6.7%	7.1%
Peak demand	-5.8	-7.3	-5.6	-5.4
Off-peak demand	19.9	20.6	17.9	18.9
Mid-peak demand	-0.3	-0.7	-0.2	0.5
Revenue (from water sales)	-4.0	-6.9	-5.6	-5.0

The simulation results showed that seasonal prices would have a somewhat different impact on demand and revenue in Victoria than they would have in Washington, D.C. The results of the Davis and Hanke study indicated that dual seasonal pricing in Washington would result in a 4.4 percent increase in off-peak demand (compared to approximately 18 percent in Victoria), an 8.3 percent decrease in peak demand (compared to 6 percent), a 2.6 percent decrease in total demand (compared to an increase of approximately 7 percent), and a 1.2 percent decrease in revenue (compared to 5 percent).

The results of the Victoria study show that the demand for water for residential purposes is moderately inelastic, ranging from -.318 to -.568 when considered on an overall annual basis. This finding tends to confirm results of previous studies. The finding that peak period elasticities are lower than off-peak elasticities is somewhat surprising, and merits further inquiry.

The application of seasonal prices would have some implications for the Victoria water supply system. Although it would stimulate a reduction in peak demands (ranging from -7.3 to -5.4 percent), it would result in a more continuous use of a larger proportion of the facilities. Most importantly, reducing the peak demands would serve to postpone further additions to the city's water supply system. In a community where demands for capital for other public goods—such as schools, parks, hospitals, and transit systems—are growing rapidly such postponement would have very important implications for the city's finances and its ability to provide other essential services.