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Water Pricing Strategy for the City of Albuquerque's Sustainable Water Use

Hirotaka Sato

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for the City of Albuquerque's Sustainable Water Use

by

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Summary

Statement of the Problem

The city of Albuquerque's current water usage is not sustainable. Recent studies done by the city indicate that the aquifer from which the city takes its water is being depleted much faster than the recharge rate. Compounding this are population projections forecasting dramatic rises in urban population out to the year 2060. To address this need, the city has developed a sustainable water strategy based on shifting to renewable water supplies (both surface and ground water), recycling of wastewater and lower quality shallow ground water for industrial and irrigation uses and reducing per capita industrial, commercial and residential consumption. This paper focuses on the last component, reducing per capita consumption and, in particular, develops a residential water pricing strategy that will bring about the required conservation level.

Sustainable water use

The requirement for sustainable water use is that the city uses only renewable water resources. The city has renewable, surface water rights of 69,000 acre-feet per year. These water rights are titled for consumptive use. Currently, the city returns one half of the supplied water to the river through the wastewater treatment plant. Therefore, the city can divert and use twice the titled water rights for supply, 138,000 acre-feet per year.

The city must still rely on ground water for some portion of its water supply. Without a ground water component, the city would need large and more costly treatment facilities to meet seasonal peak demands. However, the amount to be pumped should be limited to the renewable portion of ground water. Renewable ground water is 50,000 acre-feet per year that is replenished by streamflow. To use 88,000 acre-feet of surface water, the city needs water treatment facilities.

However, this measure alone can meet the city's increasing demand for only a few decades depending on the growth scenario. The city requires additional measures for long-term supply. The most viable measure is water conservation.

Water Conservation Goals

Water conservation helps the city's sustainable water use. In particular, selective reduction of consumptive or outdoor use is an effective conservation measure. The city can expand supply water by decreasing the consumptive use portion of its supplied water because the water rights are for consumptive use, not absolute amount. If the city increases its return flow by reducing outdoor water use, the city can use more water for supply as shown in table S-1.

Table S-1 Maximum usable water amount for supply by return flow percentage (acre-feet/year)

	Return flow percentage (%)				
	50 %	55 %	60 %	65 %	70 %
Maximum usable water amount for supply	138,000	154,400	172,500	197,200	230,000
- Renewable ground water	50,000	50,000	50,000	50,000	50,000
- Surface water	88,000	104,000	122,500	147,200	180,000

Using this maximum usable water amount, the per capita consumption target in 2060 by consumptive use and population growth scenario is estimated in table S-2. With the high growth scenario, if consumptive use is 50 percent, per capita water consumption will be 95 gallons per capita per day (gpcd) in 2060 to meet water demand within the present water rights. However, if consumptive use is 70 percent, per capita consumption will be 156 gpcd in 2060.

Table S-2 Estimated per capita consumption target in 2060 within maximum usable water by consumptive use percentage and growth scenario

(gpcd)

Growth Scenario	Population in 2060	Return flow percentage (%)				
		50	55	60	65	70
		Consumptive use (%)				
		50	45	40	35	30
Low	790,600	156	174	195	223	260
Medium	1,016,500	121	136	152	173	202
High	1,316,100	95	105	117	134	156

The city can take two conservation strategies:

- reduce overall per capita water consumption
- reduce outdoor per capita consumption.

The second strategy requires reducing the current large outdoor or summer use and thus managing seasonal water demand. However, this strategy increases the intake water amount and reduces the river water in the reach between intake and sewer discharge points. The city could avoid a temporal large amount of intake by moving the discharge point to the far upstream of the city and pumping treated sewage water. This pumping may only be needed in summer when river flow is small.

In addition, the city's current conservation program requires reducing water consumption to 175 gpcd by 2004 from the present 213 per capita consumption.

Water pricing strategy for sustainable water use

Pricing is central to demand management and adequate pricing can deliver signals of the real value of water to consumers. The sustainable water use requires conservation, especially reduction of outdoor or summer use. By appropriate water pricing, seasonal water demand is manageable and consumptive use can be selectively reduced.

Price-water demand schedules by season (winter, spring/fall, and summer) are developed for Albuquerque. Using these demand schedules, water-pricing policies for the conservation scenario are evaluated. Table S-3 shows one of the most appropriate water pricing schedules according to the population increase for the sustainable water use. The table includes projected per capita demand, residential per capita demand, total water diversion, projected consumptive use, maximum allowable diversion and seasonal residential water demand distribution. Figure S-1 shows projected seasonal residential per capita demand by population increase. Figure S-2 shows estimated seasonal water prices by population increase. Figure S-3 shows the relationship among the projected consumptive use percentage, the projected total water diversion, and the maximum allowable diversion by population increase.

In analyzing the water pricing schedule, the city's conservation goals (175 gpcd) in 2004 and the water price increase incurred by the planned water treatment facilities are considered. In addition, the schedule considers gradual price increase.

In the pricing schedule (Table S-3), winter consumption is set at about 70 gpcd to set winter price at about $1.6 per 1,000 gallons, or the price level for the proposed water treatment plant. On the other hand, summer and spring/fall water prices are raised as population increases so that spring/fall and summer consumptions decrease to the target seasonal water demand. This strategy sends a price signal that summer, outdoor, or consumptive water use is costly and is required to reduce for the sustainable use. The price premium above the winter price is regarded as a sustainable water premium. As population increases, sustainability of water supply reduces. To keep sustainability, water prices for consumptive use must be kept increasing as population increases.

With a population of 1.3 million, equivalent to the population in 2060 for the high growth scenario, the water prices should be set at $1.7 for winter, $1.9 for spring and $2.35 for summer. Even with this population level, still the city has some excess water because the projected total water diversion in 2060 is less than the maximum allowable diversion. Therefore, the city can accommodate more population beyond 2060. Furthermore, the city can grow more by further reducing consumptive use by raising water prices, particularly summer and spring/fall prices. Therefore, this pricing strategy will greatly contribute the City of Albuquerque's sustainable water use.

In conclusion, the city needs additional water resources in near future. Such additional water resources cannot be sought from agriculture nor the aquifer but in the city. Conserved water is an additional precious water resource for the city. Appropriate water pricing plays an important role in water conservation, water use management, and the City of Albuquerque's sustainable water use.

Table S-3 Projected seasonal water demand, total diversion, maximum usable diversion, consumptive use percentage and water price schedule by population increase

Service population (1,000)	477	510 - 540		800	900	1,000	1,100	1,200	1,300
Population growth scenario and target year	Present 1998	City's conservation goal in 2004	All scenarios in 2005	Low growth in 2060		Medium growth in 2060			High growth in 2060
Projected per capita production (gpcd)	211	175	165	155	150	145	140	135	130
Per capita reduction from 1998 (%)	-	17	22	27	29	31	34	36	38
Residential per capita (gpcd)	156	129	126	119	115	111	107	103	99
Projected total diversion (acre-feet/year)	114,100	102,000	96,000	139,000	151,000	162,000	172,000	181,000	189,000
- Surface water	0	0	94,000	94,000	101,000	112,000	122,000	131,000	139,000
- Ground water	114,100	102,000	2,000	45,000	50,000	50,000	50,000	50,000	50,000
Projected consumptive use (%)	50	50	50	45	45	40	40	35	35
Max. allowable diversion (acre-feet/year)	138,000	138,000	138,000	154,000	154,000	172,500	172,500	197,200	197,200
Projected seasonal distribution of residential per capita consumption									
Winter	91	80	77	73	70	74	71	75	72
Spring/fall	146	129	126	119	115	111	107	103	99
Summer	232	179	175	165	159	148	143	132	127
Total	156	129	126	119	115	111	107	103	99
Estimated residential water price (1998 prices)									
Winter	1.07	1.35	1.5	1.6	1.6	1.6	1.7	1.7	1.7
Spring/fall	1.07+α	1.35	1.5	1.6	1.6	1.6	1.7	1.8	1.9
Summer	1.07+α	1.6	1.6	1.80	1.85	2.0	2.1	2.27	2.35

A planned new water treatment plant (Capacity: 94,000 acre-feet/year) ↑ (All scenarios in 2005)

Another new water treatment plant ↑ (900)

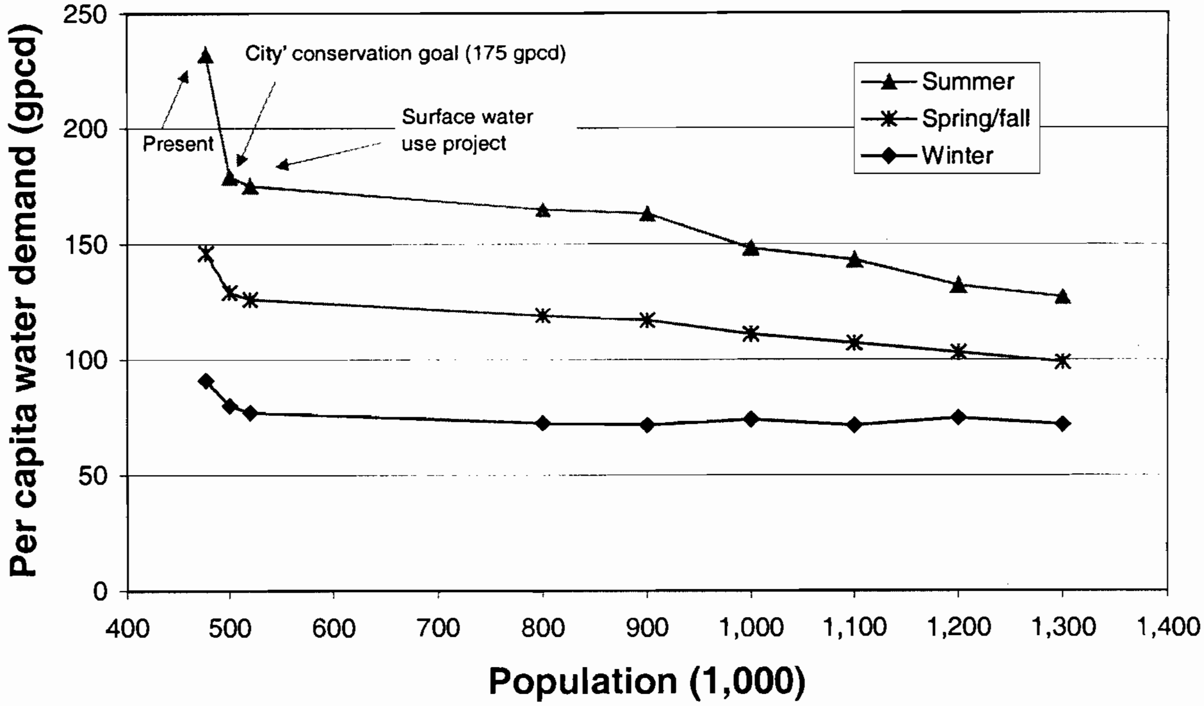


Figure S-1 Projected seasonal residential per capita demand by population increase

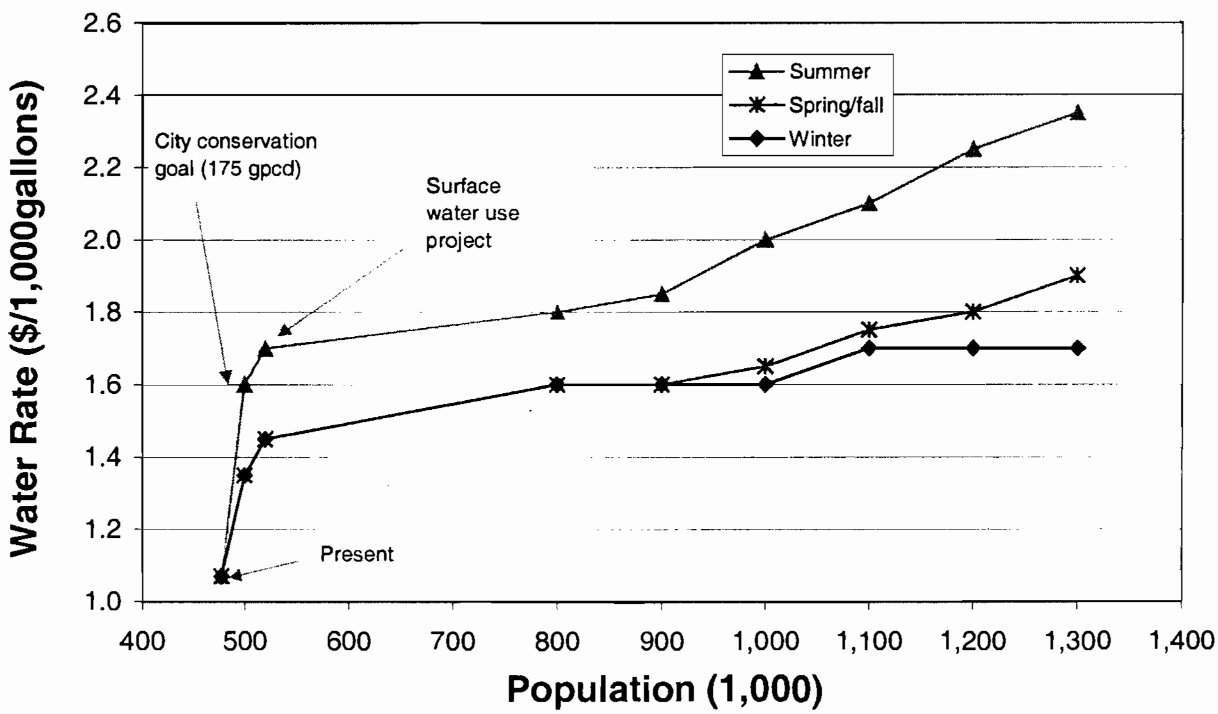


Figure S-2 Seasonal water price projection by population increase

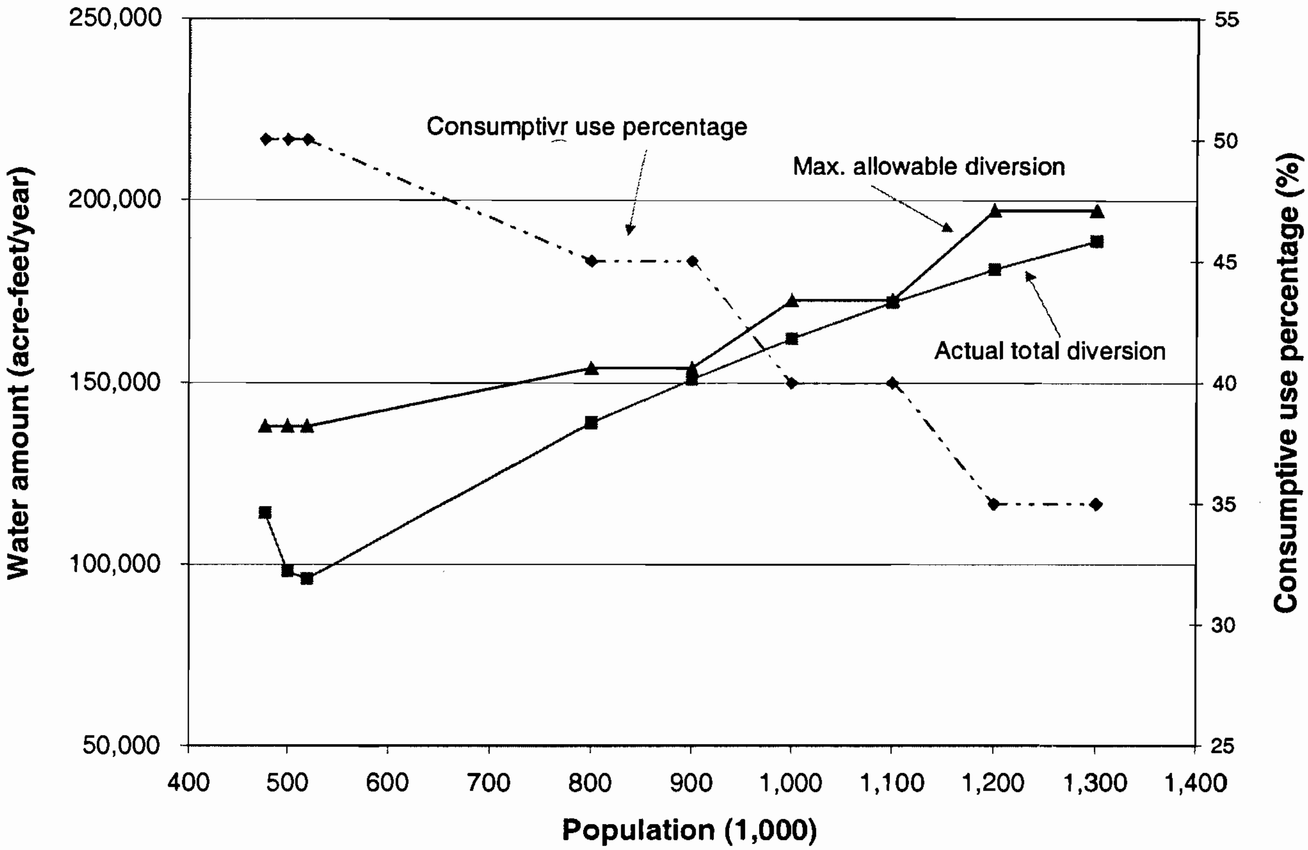


Figure S-3 Projected total diverted water, maximum allowable diversion, and consumptive use percentage

TABLE OF CONTENTS

APPENDIX

LIST OF TABLES

LIST OF FIGURES

CONVERSION FACTORS

1 unit	100 cubic feet	748 gallons
1 acre-feet	325,900 gallons	

ABBREVIATION

gpcd	gallons per capita per day
AWC	Average Winter Consumption
SJC	San Juan-Chama

Introduction

The city faces a problem relying exclusively on mining of the local aquifer for future water supply because of current and future possible large water level declines. These conditions pose many long-term risks to the city water supply (CH2M Hill, 1995). As an increasing demand competes for a decreasing supply of ground water, there will be decreased well yields, high pumping costs, deterioration in water quality as deeper wells are sunk, and inevitably, a subsiding land surface. Therefore, the current city's water use is not sustainable.

The objective of this study is to discuss water pricing strategies that lead to sustainable water use. The study is composed of five sections. Section one examines Albuquerque's sustainable water use, analyzing water demand and supply and focusing on the use of renewable water resources and water conservation. Section two develops water conservation goals through reduction of consumptive or outdoor use. Section three discusses the method to analyze city's pricing policies to manage water demand, estimates water prices to attain the conservation goals, and considers sustainable measures of water rates. The final section discusses conclusions and proposes a sustainable water pricing strategy for the city.

The followings are planning and analysis conditions:

- The planning period is 60 years from 2000 to 2060. (It is the same time span as in a city plan for sustainable water resources management.)
- The planning area is the City of Albuquerque's water service area.
- The planning focus is on water quantity but not quality.
- The planning focus for water pricing policies is on residential water use.

Part I Sustainable Water Use of Albuquerque

Albuquerque must have a reliable long-term supply of water to meet its future needs. This chapter discusses Albuquerque's water supply and demand conditions and proposes measures for sustainable water use.

First, the city's water resources and supply conditions are examined and renewable water resources are identified. Second, the current water use is briefly reviewed. Third, future water demand is projected. Demand projection is an essential part of long-term water supply management. Combined with water supply, water demand forecasts tells us how we should use water resources now and in the future on a sustainable basis. Fourth, the city's long-term water supply plans are reviewed. An impact analysis of city's water supply is reviewed. Finally, a measure for sustainable water use is proposed by considering the city's future demand and supply.

1.1 Albuquerque's Water Resources[1]

(1) Traditional river-aquifer system model (State Engineer (SE) model)

Sand and gravel deposits extending beneath the Rio Grande valley form an aquifer containing abundant good quality water. This aquifer is sole source of drinking water for all communities in the Albuquerque basin, including the City of Albuquerque, and to date has been an economical and efficient source of supply (CH2M Hill, 1995).

There is a hydrologic connection between the Albuquerque basin aquifer and the Rio Grande. As ground water pumping lowers ground water levels near the river, water seeps from the river to recharge the aquifer and helps sustain the ground water supply. In the past, the best technical information available led the city and the State Engineer to conclude that this recharge together with the large size of the aquifer would allow the city to rely exclusively on ground water as its sole source of supply (CH2M Hill, 1995). The State Engineer has used this river-aquifer system model to determine effects of ground water pumping and as the basis for water rights regulation.

[1] This part mainly relays on CH2M Hill (1995).

(2) Water rights along the Rio Grande

Since the early 1900s, water flowing down the Rio Grande past Albuquerque has been fully appropriated for use. In addition to downstream users in New Mexico, the State must also meet commitments to Texas and Mexico. During the relatively dry years of the 1950s' New Mexico failed to meet its commitments to downstream users. During this period of low natural streamflows it was recognized that, because the aquifer and the river are connected, well pumping reduces streamflow in downstream areas, harming those who have a legal right to use the river downstream (CH2M Hill, 1995).

Responding to these concerns, in 1956 the State Engineer ruled and the State Supreme Court later agreed that there could be no more new pumping of the aquifer unless such pumping is compensated for by replacement of water into the river. Since 1956, the State Engineer has required all new wells to have permits and water rights to assure that the river is kept whole. Thus Albuquerque must hold surface water rights to compensate for the effects of ground water pumping on the river. Albuquerque's legal rights to affect flows in the Rio Grande and to offset the effect of ground water pumping are controlled by three elements:

- Vested rights to reduce streamflow (22,000 acre-feet of surface water rights)
- San Juan-Chama water rights (47,000 acre-feet)
- Treated wastewater discharged to the Rio Grande by the city

(3) San Juan-Chama diversion project

In the 1950s, it was recognized that the Rio Grande basin, including the Albuquerque basin, would need additional water to support rapidly growing cities and to supplement irrigation. This led to a plan to augment the streamflow of the Rio Grande by importing water from the Colorado River Basin. Congress authorized a transbasin diversion project, called the San Juan-Chama (SJC) Diversion Project, in 1962 and water was first delivered to the Rio Grande basin from the Colorado basin in 1971.

The City of Albuquerque holds a federal contract to receive 48,200 acre-feet per year of SJC water delivered at the outlet works of Heron Reservoir and 47,000 acre-feet per year at the city excluding estimated conveyance losses to seepage and evaporation.

Based on traditional planning assumptions, Albuquerque's SJC water could compensate for the effects of several decades of future pumping on the river, through recharge to the aquifer.

(4) The new river-aquifer system model (USGS model)

In the 1980s, several events occurred which began to raise concerns about the traditional water model. Pumping of the aquifer caused some wells to experience unexpectedly large declines in water levels in spite of the previous studies by the State Engineer, which had predicted significantly less declines (CH2M Hill, 1995). Also, the water drilling on the rapidly growing west side showed that areas of highly productive aquifer are scarce (CH2M Hill, 1995).

Recent studies implemented or funded by the city have identified potentially serious problems with the traditional approach to water management. The new results show that the thickness of the good-quality aquifer is much less than that concluded by the 1960s studies (CH2M Hill, 1995) and that the river provides much less recharge to the aquifer than previously thought. The earlier studies underestimated ground water level declines because they overestimated river recharge to the aquifer.

The research conducted by the USGS (Kernodle et al., 1995) demonstrated that more than half the water pumped was not being replenished by the Rio Grande and that the rate of increases in river recharge were less than thought by the State Engineer. Thus a large portion of the City's supply is coming from the depletion of the aquifer, i.e., non-renewable aquifer stocks.

(5) Comparison of traditional and new river-aquifer system models

a. River-aquifer system

Figure 1-1 compares the traditional SE and the new USGS model of the river-aquifer system in the Albuquerque basin. In the traditional model, the aquifer has plenty of water and is easily replenished from the river. However, in the new model, the thickness of the good-quality aquifer is much less and the river provides less recharge to the aquifer.

b. River-aquifer water budget

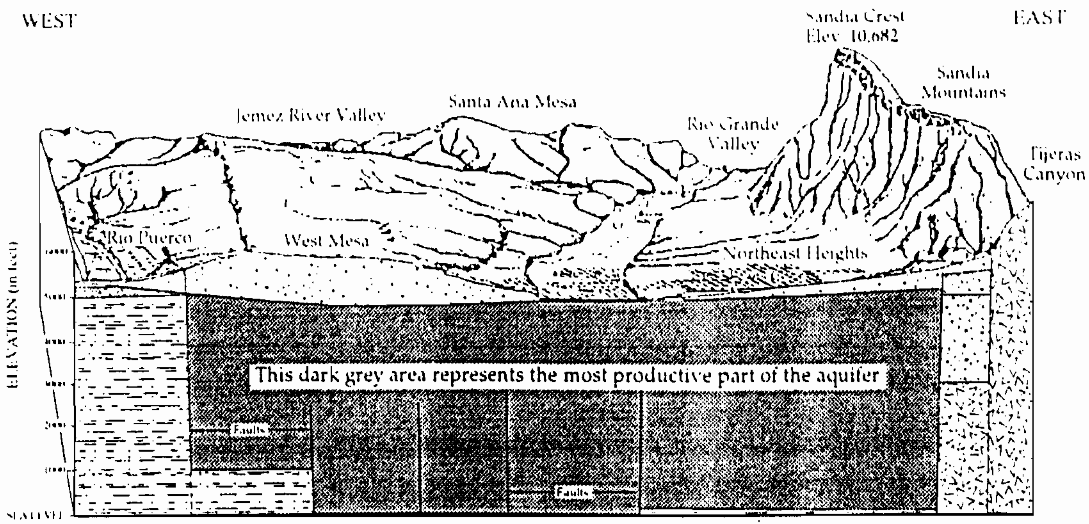
Table 1-1 compares river-aquifer water budgets of the SE and the USGS models in 1994. In the USGS

model, more water is coming from aquifer storage. Consequently, the ground water levels have declined more than was thought. It is observed that water levels of many city wells have declined, and particularly wells in east Albuquerque, which have declined by nearly 100 feet since the 1960s (Kernodle et al., 1995). The SE model did not forecast such large ground water drawdown (CH2M Hill, 1995).

Table 1-1 River-aquifer water budget in 1994 using State Engineer (SE) and USGS models (acre-feet / year)

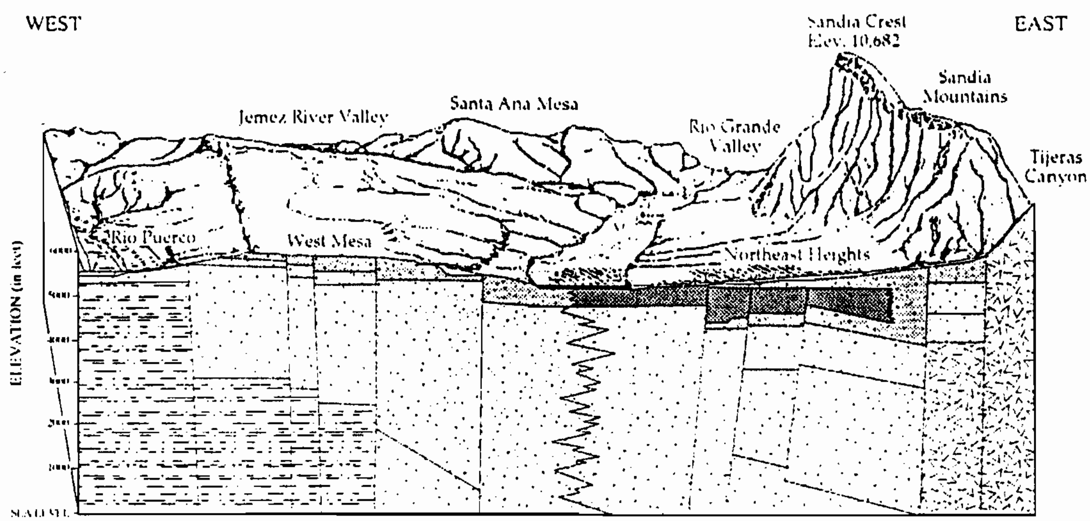
	SE Model	USGS Model
Ground water pumping	123,000	123,000
Surface water diversion	0	0
Reduction in streamflow caused by City wells	82,000	53,000
Reclaimed wastewater return to river	62,000	62,000
Net effect of pumping on river	20,000	-9,000
Albuquerque's local surface water rights	22,000	22,000
Local water rights unused	2,000	31,000
Aquifer storage loss	41,000	67,800

Source: Compiled using CH2M Hill (1995) and Kernodle et al. (1995)



1950s Conceptual View of the Aquifer

This is a 1950s representation of what the aquifer looked like – the dark grey area represents the most productive part of the aquifer – in essence, everything under Albuquerque and the West Mesa.



1990s Conceptual View of the Aquifer

We now know that the productive dark grey area of aquifer is much less extensive than previously thought. The light grey areas also have water in them – however, the lighter the grey, the less productive these areas are.

Figure 1-1 New concept model of the aquifer

(Taken from Figure 1-4 CH2M Hill, 1995)

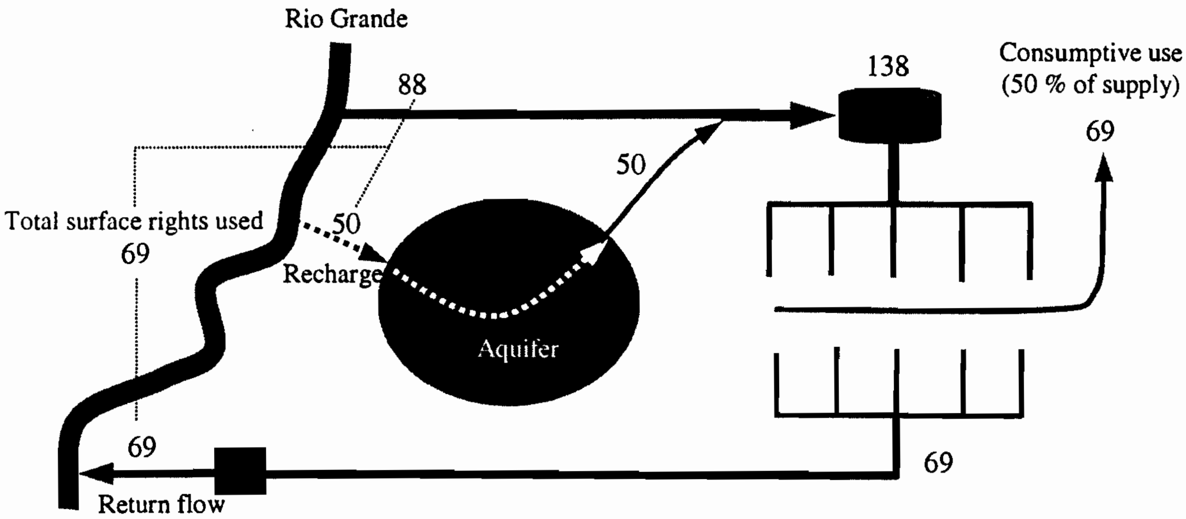
(6) Renewable water resources

The city has total surface water rights of 69,000 acre-feet per year including 22,000 acre-feet local surface water and 47,000 acre-feet San Juan-Chama surface water. These rights are for consumptive use of water. Return flow to the river is not counted in consumptive use rights.

In 1995, the city supplied 125,139 acre-feet and returned 63,821 acre-feet to the river (Wilson & Lucero, 1997). The city returns about one half of total supplied water to the Rio Grande through the city's wastewater treatment plant. Therefore, maximum allowable diverted water amount is 138,000 acre-feet per year, which equals twice the city's total surface water rights. These are renewable water resources.

According to the city's Water Resources Planning (City of Albuquerque Public Works Department), total rechargeable ground water is about 50,000 acre-feet per year. The USGS computer model (Kernodle et al., 1995) shows 67,800 acre-feet of the total ground water withdrawal in 1994 of 123,000 acre-feet comes from aquifer storage. Therefore, 55,200 (123,000 - 67,800) acre-feet per year can be considered replenished. However, actual replenished water is uncertain. Further studies would be necessary for more accurate estimation of replenished water amount. This study assumes that ground water pumping of 50,000 acre-feet per year is replenished from the river and thus renewable.

Figure 1-2 illustrates the water balance of the city's renewable water supply. Total diversion is 138,000 acre-feet per year, which equals twice the city's surface water rights. This includes 50,000 acre-feet ground water and 88,000 acre-feet surface water. This is based 50 percent return flows to the river.



(Unit: 1,000 acre-feet/year)

Figure 1-2 Water balance in the maximum renewable water supply (50 % return flow)

1.2 Current Water Use

Figure 1-3 shows water use of the City of Albuquerque in 1995. The city provides water with the service population of 470,000 in 1995 and consumes 125,000 acre-feet per year. The per capita consumption is 237 gallons per day. Of the total supplied water, 49 percent returns to the river through the wastewater treatment plant. Fifty-one (51) percent is consumptive use. All supplied water (125,000 acre-feet) comes from ground water. If the renewable ground water is 50,000 acre-feet, 75,000 acre-feet comes from aquifer stock or ground water depletion.

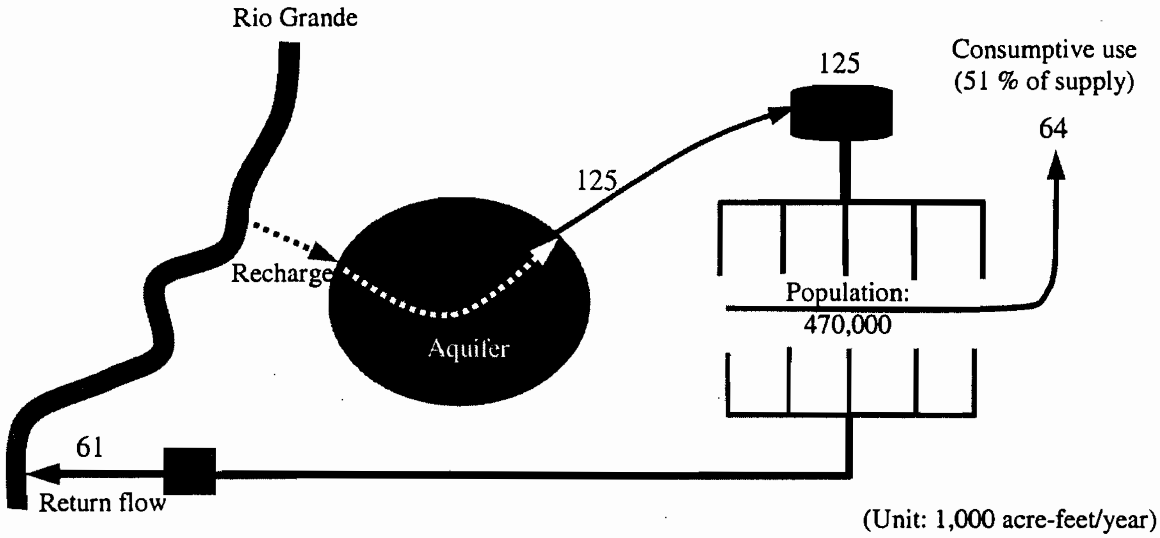


Figure 1-3 Water use balance of the City of Albuquerque in 1995

1.3 Water Demand Projection

This part reviews existing water demand projections, the past per capita consumption and population trends. Then, future water demand by high, medium, and low growth scenario is developed.

(1) Existing water demand projection of Albuquerque

Table 1-2 compares three existing water demand projections for the city of Albuquerque in 2060. Water demand in 2060 ranges from 142, 000 to 288,000 acre-feet per year. The 1991 City Projection in the table estimated the smallest water demand in 2060 among the projections. The demand of continued current trends with assumed conservation of 30 percent of the CH2M Hill projection is used as the baseline or most probable scenario in the City of Albuquerque's water resources management strategy.

Table 1-2 Comparison of existing water demand projections in 2060

(acre-feet/year)

	1991 City Projection	CH2M Hill	1997 City Projection
Total water demand with water conservation	-	203,000	approx. 185,000
Total water demand without water conservation	175,000	288,000	approx. 264,000
Total water demand for lower growth with conservation		142,000	
Remarks	The original figure is 154,000 acre-feet excluding system losses. Total demand is calculated using 12 % losses of the total production.	Total demand is estimated by assuming continued current trends and 30% conservation.	Thirty percent of conservation is assumed.
Source	Water Conservation Office, City of Albuquerque.	CH2M Hill, 1995	Water Resources Management Strategy (1997)

(2) Per capita water demand

Table 1-3 and figure 1-4 show per capita daily water consumption by customer class from 1989 to 1998.

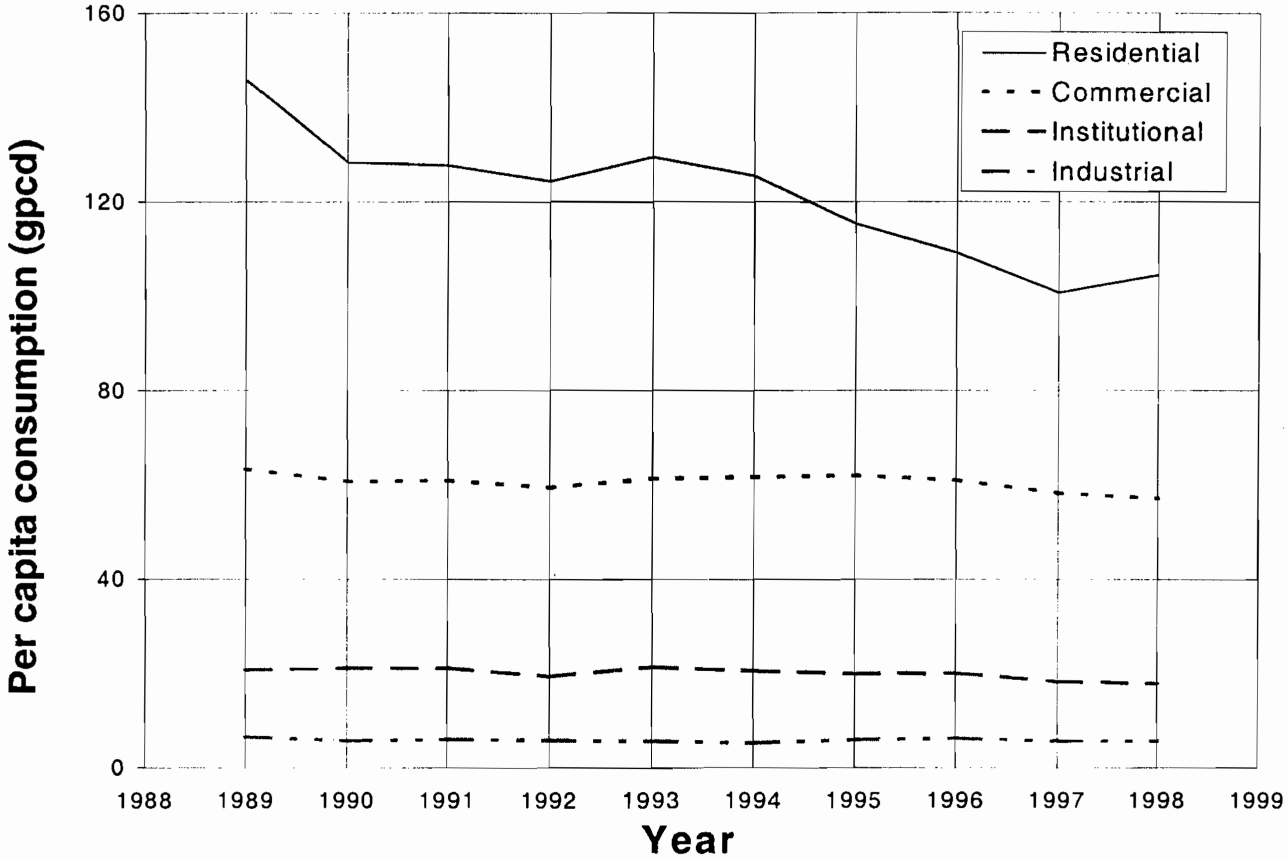
Table 1-3 Per capita daily water consumption by customer class from 1989 to 1998

(gpcd)

Year	Residential	Commercial	Industrial	Institutional	Flat rate customer	Sub-total	Loss	Total production
1989	145.9	63.4	6.6	20.8	2.6	239	40	279
1990	128.4	60.8	5.8	21.2	2.5	219	30	249
1991	127.7	61.0	6.1	21.2	2.5	218	25	243
1992	124.4	59.5	5.9	19.4	2.4	212	25	237
1993	129.5	61.4	5.7	21.4	2.4	220	28	248
1994	125.5	61.7	5.3	20.6	2.4	215	31	246
1995	115.3	62.0	6.0	20.0	2.3	206	31	237
1996	109.2	61.1	6.3	20.1	1.6	198	28	226
1997	100.8	58.3	5.7	18.3	0.7	184	26	210
1998	104.5	57.2	5.7	17.9	0.1	185	28	213
Ave.	121.1	60.6	5.9	20.1	2.0	210	29	239

Source: Water conservation office, City of Albuquerque

Note: Residential per capita is calculated from total population but not residential population.



Note: Per capita residential consumption is caliculated from total population rather than residential population. Therefore, this per capita residentia consumption is less than actual residential per capita consumption.

Figure 1-4 Yearly average daily per capita consumption by customer class

In 1994, 58.2 percent of water consumption was residential, 28.6 percent commercial (multi-family residents are categorized commercial because of common meters), 9.6 percent institutional, and 2.5 percent industrial. If multi-family residents, which are categorized commercial, are included in residential, residential water consumption accounts for very large part of the city's water consumption.

Water consumption in 1989 was very high because of an extremely dry year. Between 1989 and 1993, average total water consumption was about 250 gpcd. In 1994, the city adopted its water conservation strategy and implemented voluntary conservation measures. The conservation plan together with water price increase has showed success; consumption has steadily declined from 250 gpcd to 210 in 1997. However, water consumption in 1998 increased slightly to 213 gpcd.

After implementing the city's water conservation strategy, most water saving comes from residential customers, who reduced per capita consumption by 20 percent between 1994 and 1998. On a per capita consumption basis, commercial, industrial and institutional water consumption has remained stable for the last 10 years.

Reductions in per capita consumption appear to have stabilized in 1998. It may be difficult to reduce consumption further using only city's current voluntary water conservation measures. If no further conservation measures are taken, water consumption should keep the current per capita consumption and pattern. The average per capita water consumption between 1997 and 1998 (table 1- 4) is used for future water demand projection.

Table 1-4 Per capita water consumption by customer class for demand forecast

	Residential	Commercial	Industrial	Institutional	Loss	Total
Per capita daily consumption (gpcd)	103	58	6	18	27	212
Percentage (%)	48.6	27.4	2.8	8.5	12.7	100

Note: Per capita consumption for residential is calculated from total population, but not residential population. System losses are about 12 percent of total production.

(3) Water demand projection

a. Past population

Table 1-5 compiles the past populations and water service populations for Bernalillo County and the City of Albuquerque. In the 1960s and 1970s, the area's population increased rapidly due to strong economic growth and the "sunbelt" phenomenon. In the 1980s, a weaker economy slowed the growth to about 1.5 percent per year. Recent data indicate that the growth rate has increased again with the county and the city growing 1.65 percent per year from 1990 to 1995, and the water service population growing 1.78 percent per year from 1995 to 1998. Growth in the county was slightly slower than in the city.

Table 1-5 Past population and city water service population in Bernalillo County and City of Albuquerque

	Bernalillo County(1)		City of Albuquerque(1)			Service Population(2)		
	Population	Annual Increase	Population	Annual Increase	% to County	Population	Annual Increase	% to County
1960	262,199		201,189		77			
1970	315,774	1.88	244,501	1.97	77			
1980	420,262	2.81	332,336	3.02	79	355,087		85
1990	482,120	1.43	384,915	1.53	80	424,503	1.86	88
1995	523,030	1.64	417,772	1.65	80	452,707	1.30	87
1998						477,240	1.78	88

Source: (1) Bureau of Business and Economic Research (BBER), University of New Mexico.
(2) Water Conservation Office, City of Albuquerque

b. Population projection

Table 1-6 shows existing projections of future population. Each projection is for a different geographic area. The first four projections in the table assume a declining growth rate for study period and the last projection assumes about 9,000 as an annual increase. As a result, all projections have declining growth rates. However, there is no guarantee that the growth rate in the study area will decline and it is possible for the population to keep increasing at the current rate, especially if the area thrives economically.

Table 1-6 Existing population projections

	Bernalillo[1]		City[2]		BBER Medium growth[3]		BBER High growth[4]		Continued current growth trends[5]	
	Population	Annual increase	Population	Annual increase	Population	Annual increase	Population	Annual increase	Population	Annual increase
1995	523,030		417,772							
1998	545,493	1.41								
2000	558,589	1.19	446,871	1.19	531,711		538,517		504,500	
2005	594,317	1.25	475,454	1.25						
2010	621,940	0.91	497,552	0.91	589,134	1.03	607,339	1.20	595,600	1.67
2015	650,784	0.91	520,627	0.91						
2020	679,538	0.87	543,630	0.87	647,133	0.94	678,907	1.11	686,600	1.43
2025	709,487	0.87	567,590	0.87						
2030	740,646	0.86	592,517	0.86	700,997	0.80	754,343	1.05	777,700	1.25
2040					752,294	0.71	834,370	1.01	868,800	1.11
2050					803,191	0.65	920,537	0.98	956,300	0.96
2060					852,953	0.60	1,006,485	0.89	1,041,600	0.86

Source: (1) Bureau of Business and Economic Research (BBER), University of New Mexico.
(2) City population is calculated as 80 percent of County population (City of Albuquerque Planning Department)
(3) Population of "Water Management Area" within Bernalillo County. The medium projection assumes that migration rates will start at the high level experienced in 1970s and early 1980s and then decline over the study period (BBER, 1993).
(4) Population of "Water Management Area" within Bernalillo County. The high projection assumes a continuation of the high level of migration observed in the late 1970s and the early 1980s (BBER, 1993).
(5) "Equivalent" City-supplied population calculated from trend in water use in Figure 41, Simulation of Ground-Water Flow in the Albuquerque Basin, Central New Mexico, USGS, 1995 (CH2M Hill, 1995).

The future population scenarios are formulated taking into account past trends and existing projections:

- High growth scenario assumes the current growth rate (1.65%) for the study period,
- Medium growth scenario assumes the growth rates of "continued current growth trends", and
- Low growth scenario assumes the growth rates of "BBER medium growth".

Table 1-7 and figure 1-5 shows projected water service populations by scenario.

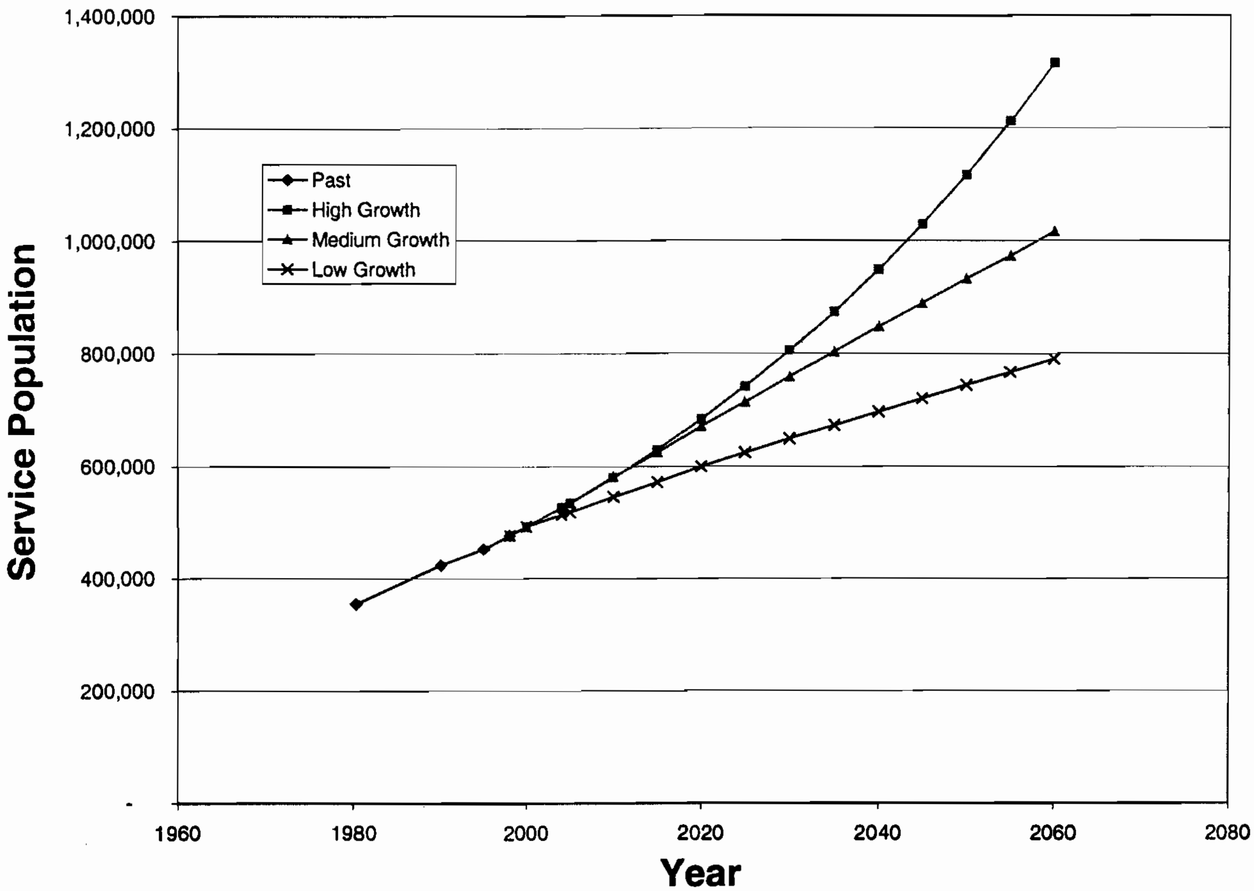


Figure 1-5 Population projection in water service area of Albuquerque

Table 1-7 Population projections by scenario

Year	High growth		Medium growth		Low growth	
	Population	Annual Increase	Population	Annual Increase	Population	Annual Increase
1998	477,240		477,240		477,240	
2000	493,100	1.65	493,100	1.65	493,100	1.65
2010	580,700	1.65	582,000	1.67	546,300	1.03
2020	683,900	1.65	670,800	1.43	599,900	0.94
2030	805,500	1.65	759,500	1.25	649,700	0.80
2040	948,700	1.65	848,100	1.11	697,300	0.71
2050	1,117,400	1.65	933,100	0.96	744,700	0.66
2060	1,316,100	1.65	1,016,500	0.86	790,600	0.60

c. Water demand projection

c.1 Total water demand

Total projected water demand is calculated in table 1-8 and figure 1-6 from the projected population multiplied by the planned per capita water consumption (212 gpcd).

Table 1-8 Projected city water demands

(acre-feet/year)

Year	High growth	Medium growth	Low growth
1998	114,100	114,100	114,100
2000	117,200	117,200	117,200
2010	137,800	138,100	129,800
2020	162,300	159,200	142,400
2030	191,100	180,400	154,300
2040	225,200	201,300	165,700
2050	265,400	221,500	176,700
2060	312,300	241,500	187,800

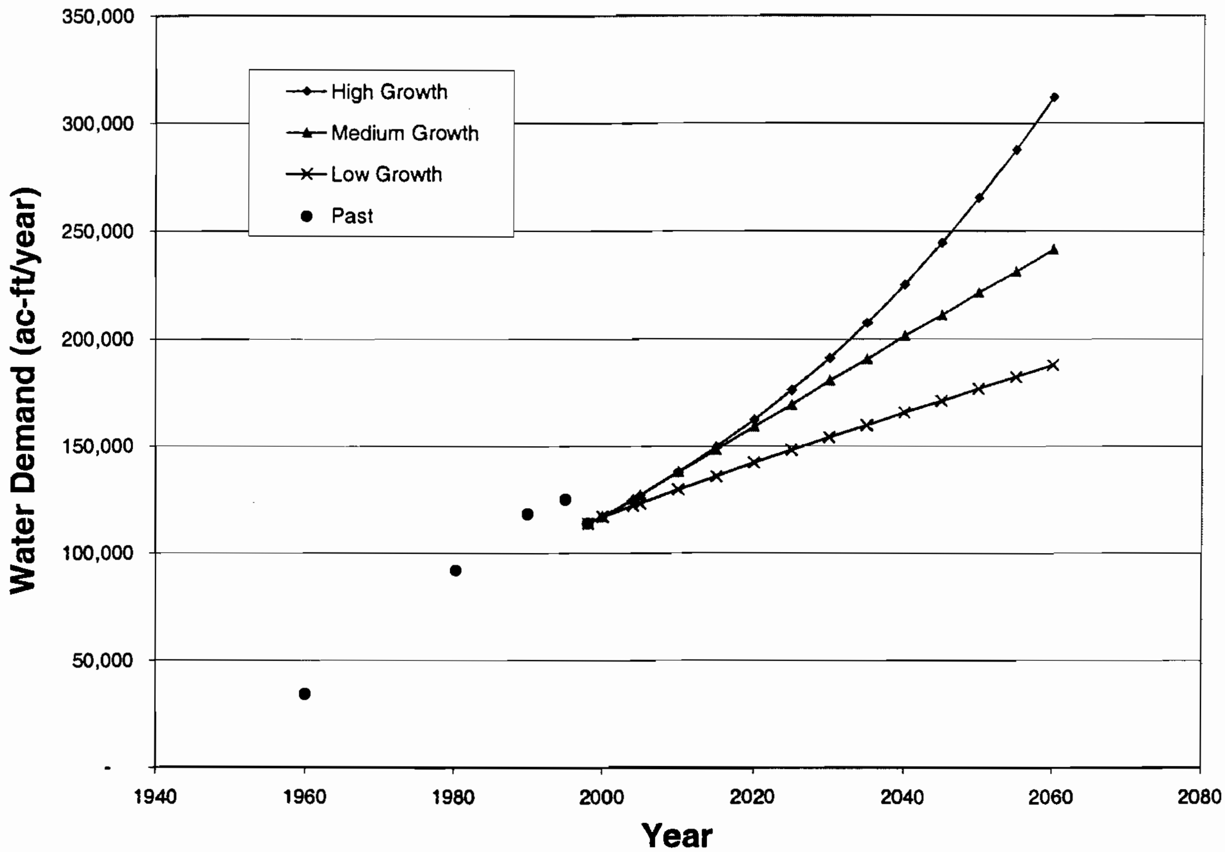


Figure 1-6 Water demand projection of Albuquerque water service area

c.2 Water demand by customer category

Total water demand is distributed according to the percentage of the present distribution of per capita water consumption (table 1-4) and water consumption by customer class in 2060 is obtained in table 1-9.

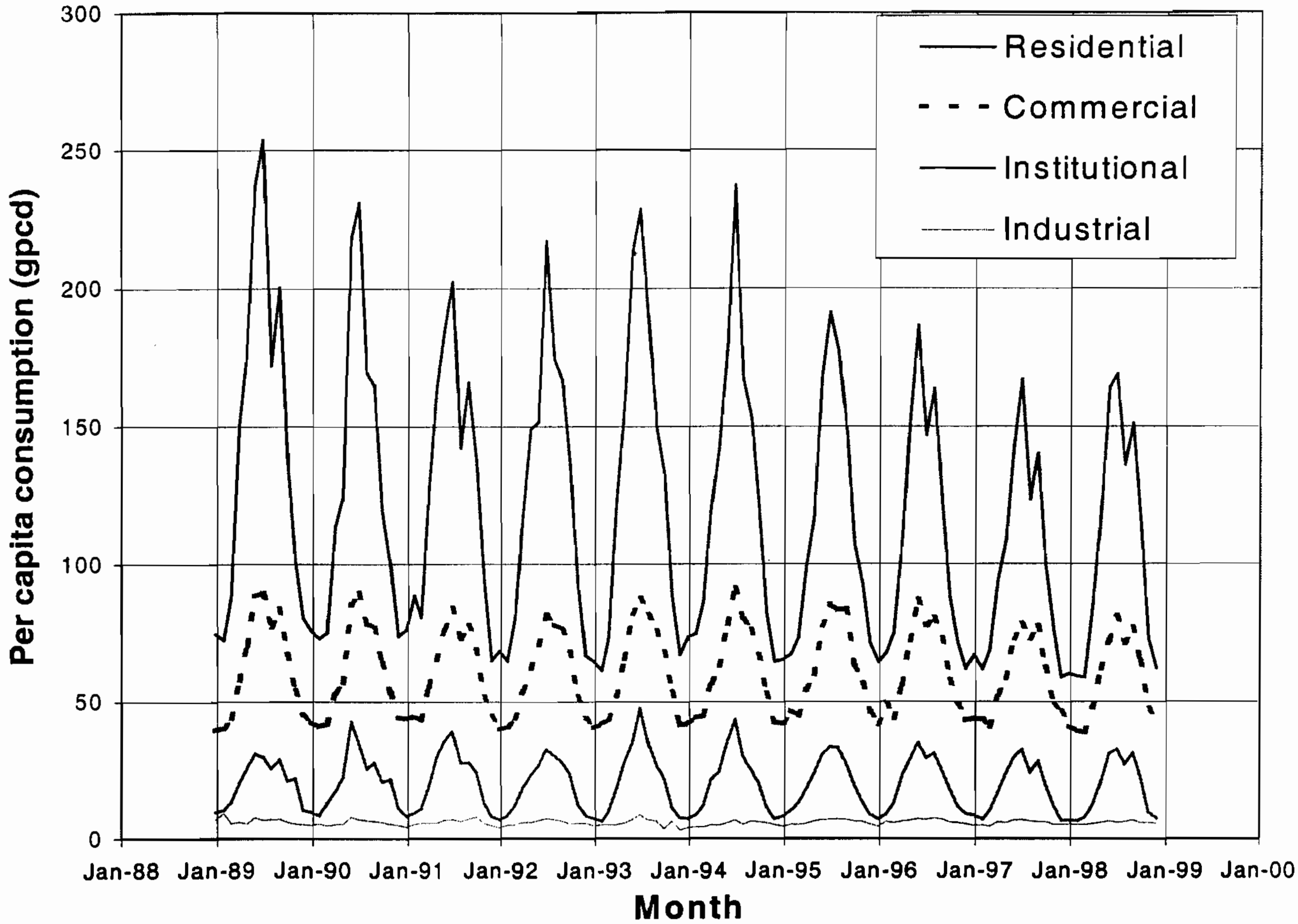
Table 1-9 Water demand by customer category and growth scenario in 2060 (acre-feet/year)

	Residential	Commercial	Industrial	Institutional	Loss
High growth	151,780	85,570	8,740	26,550	39,660
Medium growth	117,370	66,170	6,760	20,530	30,670
Low growth	91,270	51,460	5,260	15,960	23,850

c.3 Monthly demand

Table 1-10 and figure 1-7 show a monthly variation of average water consumption by customer class between 1997 and 1998. The largest consumption occurs in the summer months and the lowest consumption occurs in winter months. From the analysis of the seasonal water consumption pattern, three seasons can be recognized: winter use (December to March), spring/fall use (April, May, October and November), and summer use (June to September).

Institutional consumption has the largest monthly variation; the largest consumption month is as much as five times the lowest consumption month due to outdoor uses or careless uses in summer. Industrial consumption is very stable throughout the year; there is almost no monthly variation. The largest consumptions in residential and commercial are about 3 and 2 times the lowest consumption, respectively. Projected monthly demand can be calculated from the projected total water demand and these monthly ratios.



Note: Per capita residential consumption is caliculated from total population rather than residential population. Therefore, this per capita residential consumption is less than actual residential per capita consumption.

Figure 1-7 Monthly average daily per capita consumption by customer class

Table 1-10 Monthly variation of water consumption (ratios to annual average consumption) by customer category (average of 1997 and 1998)

(%)

	Residential	Commercial	Industrial	Institutional	Total production
Jan	0.052	0.062	0.074	0.036	0.052
Feb	0.050	0.060	0.074	0.031	0.052
Mar	0.052	0.058	0.071	0.042	0.066
Apr	0.073	0.073	0.084	0.068	0.078
May	0.092	0.087	0.085	0.102	0.106
Jun	0.125	0.105	0.095	0.140	0.125
Jul	0.137	0.115	0.092	0.150	0.119
Aug	0.105	0.104	0.091	0.117	0.110
Sep	0.118	0.111	0.093	0.137	0.107
Oct	0.087	0.091	0.087	0.096	0.078
Nov	0.060	0.069	0.079	0.049	0.056
Dec	0.049	0.064	0.077	0.032	0.050
Total	1.000	0.999	1.002	1.000	0.999

Source: City of Albuquerque Conservation Office

1.4 City of Albuquerque Water Resources Management Strategy

(1) Development of a long-term water supply plan

The new USGS model made it clear that the city's water management strategy of exclusive reliance on the local aquifer was not sustainable. The current and future possible large water level declines was posing many long-term risk to the city's water supply (CH2M Hill, 1995). As increasing demand competes for a decreasing supply of ground water, there will be decreased well yields, high pumping costs, deterioration in water quality as deeper wells are sunk, and inevitably, subsiding land surfaces.

The city realized a need to formulate a long-term water supply plan that stops excessive aquifer pumping, uses its surface water, reduces water consumption, and provides for future needs (CH2M Hill, 1995). The city proactively responded to ground water depletion and formulated a Water Conservation Strategy in

1995 and a Water Resources Management Strategy in 1997 to protect the aquifer. The city is now in the process of implementing these water supply plans.

(2) Water Conservation Strategy (City of Albuquerque, 1995)

The city's per capita consumption was very high compared to other desert cities. The 5-year average consumption between 1989 and 1993 (baseline) was 250 gallons per capita per day (gpcd). To reduce consumption, the Long-Range Water Conservation Strategy was adopted in 1995. The conservation goals of the plan are:

- Achieve a 30 % reduction in water usage by 2004 from the baseline 250 gpcd to 175 gpcd in 2004.
- Reduce summer outdoor usage by 25 %
- Reduce year-round indoor usage by 33 %
- Reduce peak day usage by 20 % by 2004.

These goals include all classes of water use. The plan mainly focuses on education and public awareness of water conservation.

(3) Water Resources Management Strategy (City of Albuquerque, 1997)

The city's Long Term Plans call for combining surface and ground water supplies, and using its San Juan-Chama and Rio Grande surface water rights as a direct water supply. Under this strategy (figure 1-8), the city will fully use its surface water rights by taking water directly from the river, treating it, and delivering it to customers; pumping of ground water will be reduced by an equivalent amount (CH2M Hill, 1995). To use the city's surface water, the city must construct an infiltration gallery to take water from the stream and a water treatment plant (capacity of 940,000 acre-feet per year). The construction cost of the project is estimated $190 million and the project is planned to be completed in 2005. However, the city must still relay on ground water for some portion of water supply. Without a ground water component of supply, the city would need extremely expensive water storage facilities and large and costlier treatment facilities to meet seasonal peak demands. The city plans to pump from the aquifer to meet seasonal peak demands and as a drought reserve. However, the city will use only the renewable portion of ground water that is replenished from the river. The conjunctive use of water sources will protect the aquifer and can attain efficient and sustainable water supply. However, under this strategy, the city needs additional water resources beyond 2040. The city's Water Resources Management Strategy is not sustainable plan beyond 2040.

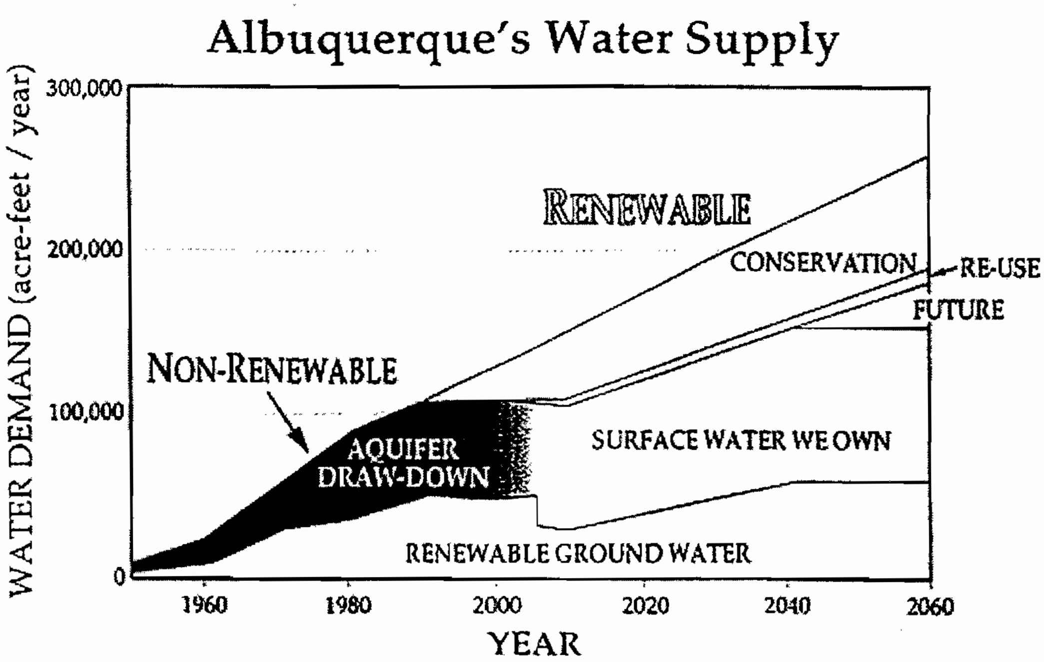


Figure 1-8 City of Albuquerque water resources management strategy
(Taken from City of Albuquerque Public Works Department, May 1997)

1.5 Impact of City Water Supply

This part evaluates possible impacts of city's water supply from ground water and surface water.

(1) Ground water

a. Ground water use in the Albuquerque basin

Table 1-11 shows ground water withdrawals of the city and other users in the Albuquerque basin from Cochiti to San Acacia. In 1994, the city withdrawal accounted for 72 percent of total withdrawal in the basin. Even without the city pumping, other users' pumping would affect the water system in the basin although their effect is less than the city's.

Table 1-11 Ground water withdrawal in the Albuquerque basin of the Middle Grande Valley (acre-feet/year)

	1960	1979	1994	2020	2060		
					High gr.	Medium gr.	Low gr.
City pumping	34,300	86,400	123,000	177,000	218,300	147,500	93,800
Other users	27,200	34,600	47,500	74,300	-	-	-
Total	61,500	121,000	171,000	251,000	-	-	-

Note: Ground water withdrawals until 2020 are compiled from Kernodle et al., 1995.
Ground water withdrawal of the city in 2020 is city water demand of current growth scenario.
Ground water withdrawals in 2060 are calculated by subtracting SJC water from total demand.

b. Ground water depletion

It is already observed that water levels of many city wells have declined, especially wells in east Albuquerque, which have declined by nearly 100 feet since the 1960s (Kernodle et al., 1995). Future ground water withdrawals and ground water drawdowns of several scenarios are compiled in table 1-12.

Table 1-12 Future ground water withdrawals and ground water drawdown

Scenarios	City pumping amount in the planned year (acre-feet/year)	Periods (years)	Average drawdown in Albuquerque area (feet)	Maximum drawdown (east/west) (feet)
Current trend	177,000 (2020)	26	65	164 / 258
30-percent conservation	98,700 (2020)	26	28	55 / 91
Continued local ground water development without conservation	288,000 (2060)	65	200	420
Continued local ground water development with 30% conservation	203,000 (2060)	65	130	340
Direct use of SJC water with 30% conservation	109,000 (2060)	65	60	310

Source: compiled from CH2M Hill (1995) and Kernodle et al., (1995).

If the city continues local ground water development, the average drawdown of ground water will be 200 feet in 2060 and the maximum drawdown will be 420 feet. Even with the direct use of SJC water with 30

percent conservation an average drawdown of 60 feet and a maximum of 310 feet will occur because the ground water withdrawal exceed renewable ground water portion (50,000 acre-feet per year).

c. Possible impacts

Heavy pumping and large water level declines will pose many long-term risks to the city's water supply. There will be decreased well yields, high pumping costs, deterioration in water quality as deeper wells are sunk, and inevitably, a subsiding land surface.

One of the most significant effects of continued mining of the aquifer is the potential for subsidence of the land surface. Water level declines reduce the pore pressure within aquifer materials and aquifer compaction results. There is some threshold value of drawdown and once this value is exceeded, subsidence may occur. The threshold value for Albuquerque is unknown, but USGS (1985; Bureau of Mines and Mineral Resources) studies in the Southwest and Albuquerque have suggested that water level decline of about 85 to 300 feet may be equivalent to the threshold level (CH2M Hill, 1995). In any event as ground water levels decrease, the risks and degree of land subsidence will increase. Additional drawdown through 2060 may be sufficient to cause compaction of the aquifer and subsidence, causing damage to urban structures such as streets, buildings, structures, underground infrastructures, and housing.

(2) Surface water

a. Surface water system of the Middle Rio Grande Basin

Table 1-13 shows a draft version of Middle Rio Grande Basin surface water budget. In this water budget, riparian evapotranspiration is the biggest water user. The second is consumptive agriculture use. There is currently no direct use of surface water for municipal use.

Table 1-13 Middle Rio Grande Basin surface water budget (draft version)

(1000 acre-feet/year)

	Average amount	Variability
Annual inflow		
Rio Grande at Otowi gage	1,100[1]	400-2,900[2]
Tributary inflow[3]	140	
Tributary recharge to ground water plus mountain-front recharge	80	
Ground water inflow[4]	30	
Storm drain inflow, Albuquerque	6	
Municipal wastewater, Albuquerque	60	
Total	316	
Annual outflow from Otowi to San Acacia		
Recharge to aquifer[5]	60	
Open-water evaporation[6]	60	± 30
Agriculture: crop and valley-floor turf	100	± 30
Riparian evapotranspiration[7]	135	± 60
Total	335	
Total annual outflow below San Acacia	310	
Annual outflow to Texas and Mexico[8]	771	182 - 1,800

Notes: (1) Average annual flow at Otowi gage 1910 - 1993.
(2) Minimum and Maximum annual flows at Otowi during 1973 - 95.
(3) All gaged tributaries: Santa Fe, Galisteo, Jemez, Puerco, Salado.
(4) Deep ground water inflow from north and northwest.
(5) From river, drains, ditches; principally into Albuquerque's coalesced cones of depression.
(6) From river, canals, drains and farm fields.
(7) Includes all non-crop vegetation in the valley.
(8) The interstate compact requires that New Mexico flow 707,000 acre-feet per year to Texas.
Source: Third Middle Rio Grande Water Assembly, March 27, 1999 (handouts)

b. Possible impacts

If the city changes water supply source from ground water to direct diversion of stream water. The maximum consumption of the river water would be 69,000 acre-feet per year (total surface water rights of the city). The outflow of the river system will be 129,000 acre-feet per year including the return flow (60,000 acre-feet per year) in the surface water budget shown in table 1-13. This will be the single largest outflow in the Albuquerque basin and could affect the interstate compact between New Mexico and Texas, which requires New Mexico to deliver 707,000 acre-feet per year to Texas on average.

There may also be some impact to the river ecosystem. In particular, the river reach between the diversion point and the wastewater discharge point could be impacted severely. Listing of the Rio Grande Silvery Minnow and the Southwest Willow Flycatcher as endangered species has the potential of immediately impacting Albuquerque's surface water uses (CH2M Hill, 1995).

1.6 Sustainable Water Use

Currently, the City of Albuquerque uses ground water as its sole source of water supply, which amounts to 114,100 acre-feet per year in 1998. The city's use of this source is not sustainable because the city is mining ground water significantly, and the ground water level is dropping. The drawdown will further increase in the future as demand increases. This situation poses significant future risks and costs to the city such as surface land subsidence, depletion of quality water, high costs of pumping and treatment.

The city's first requirement for sustainable water use is the use of renewable water resources. In 1997, the city adopted "Water Resources Management Strategy," and decided to make the shift to renewable water use, which is more sustainable water use, taking the costs, legal, environmental and other factors into consideration. The city evaluated that the future costs incurred by ground water depletion overweighed the present costs of using renewable water. Although there may be some impacts of the city's direct diversion on the river ecosystem and the interstate and international compacts the city possesses the rights to the water.

The city has renewable, surface water rights of 69,000 acre-feet per year, and can use maximum 138,000 acre-feet per year assuming 50 percent of return flow to the river. However, this renewable water resource alone does not meet the future city water demand. For example, the city needs to supply 188,000 acre-feet in 2060 with the low growth scenario and 312,000 acre-feet in 2060 with the high growth scenario. The shift to renewable water use alone does not meet sustainable water use.

The city requires additional measures for long-term supply. Another possible supply side measure is to acquire new surface water rights from agriculture. However, it seems very difficult under the present political climate. There are three major competitors for surface water rights: environmentalists and federal agencies representing endangered species of the Rio Grande, the Middle Rio Grande Conservancy District (MRGCD) represented by farmers, and municipalities including the City of Albuquerque. The federal

government may try to buy water rights for the endangered species. MRGCD tries to keep water for farmers and is creating a water bank to save water but saved water in the bank is used only for farmers and not for city users.

The city needs to manage its water supply within the present surface water resources. There are three measures that the city can take:

- Limited or managed growth and managed water demand;
- Recycling or reuse and increase of water supply; and
- Conservation and reduction of water demand.

A limited growth policy is not currently considered. However, perpetual growth is impossible and someday the city will or must stop growing in part because of its resources limitation. However, the city expects to and could grow beyond several decades in the future.

The city may start to recycle wastewater for industrial and irrigation use but recycling is very expensive and only a small amount for specific uses are viable considering current recycle technologies and costs. The quality of the treated water is also the limited factor to use.

Currently, the city is implementing a water conservation strategy to reduce water consumption because the present city's per capita consumption (213 gpcd in 1998) is very high, compared to other desert cities such as Tucson (165 gpcd), Santa Fe (120 gpcd), Rio Rancho (160 gpcd), and El Paso (167 gpcd). The city has a lot of room to conserve water. The city's goal for per capita consumption is 175 gpcd by 2004.

Table 1-14 shows projected water demand by growth scenario if the city's per capita consumption goal (175 gpcd) is attained as scheduled in 2004. The present water rights can meet water demands by 2045, 2026 and 2020 for low, medium and high growth scenario, respectively. After those years, the city needs additional measures.

Table 1-14 Projected water demand by growth scenario with the city's conservation goal

Year	per capita consumption (gpcd)	Projected water demand by growth scenario (acre-feet/year)		
		High growth	Medium growth	Low growth
2000	208	114,900	114,900	114,900
2004	175	103,200	103,300	100,700
2010	175	113,800	114,100	107,100
2020	175	134,000	131,500	117,600
2030	175	157,900	148,800	127,300
2040	175	185,900	166,200	136,600
2050	175	219,000	182,900	145,900
2060	175	257,900	199,200	154,900

Note: 175 gpcd is the city's water conservation goal in 2004.

Assuming that the city takes further conservation measures, table 1-15 shows the per capita consumption schedule the city must attain to meet future water demand within the present water sources. The city needs to reduce per capita water consumption by 2060 to 154, 121, and 94 gpcd for low, medium, and high growth scenario, respectively. (These numbers are calculated with 50 percent of return flow, or 50 percent consumptive use of the supplied water. If the city increases return flow percentage through outdoor water conservation, the city would need a more modest conservation schedule.)

Table 1-15 Per capita consumption schedule to be achieved within the present water sources (gpcd)

Year	Growth scenario		
	High growth	Medium growth	Low growth
2000	208	208	208
2010	175	175	175
2020	175	175	175
2030	153	162	175
2040	130	145	175
2050	110	132	165
2060	94	121	154

Note: It is assumed that 50 percent consumptive use of supplied water.
The schedule includes the city's conservation goals (175 gpcd) in 2004.

Per capita water demand of 154 gpcd would be achievable, considering other desert cities' per capita

consumption. However, 94 gpcd for the high growth scenario in 2060 would be outside of the experience of most desert cities.

The measure that should or could be taken, including acquisition of water rights, depends on economical, social and environmental costs and benefits. Under current water circumstances, water conservation would be less costly and the most viable option that the city could take. However, social costs of conservation will increase as conservation requirements become more sever. At some point the marginal cost of conservation will exceed the marginal cost of other measures and a switch to other measures should occur.

This study focuses on water conservation as the most viable measure that the city can take for the sustainable water use. The next section discusses a conservation strategy and goals.

Part II Water Conservation for Albuquerque's Sustainable Water Use

In the previous section, water conservation is considered as the most viable measure that the city can take for the sustainable water use. First, this section overviews water conservation. Second, it examines how much the City of Albuquerque can potentially reduce water consumption. Third, it proposes an effective conservation measure, that is, a selective reduction of consumptive use. Finally, this section addresses how much water the city needs to conserve.

2.1 Water Conservation

(1) Water conservation trends in the United States

As cities in the United States continue to grow and their demands on the available water resources increase, additional water resources are becoming increasingly rare and the development of additional supplies to meet their future demands has become very costly. Environmental concerns about increased water use have intensified during the last two decades to the point where the development of new supplies is politically infeasible, and the prospects for financing major construction programs are discouraging for many water agencies (Baumann and Boland, 1998). Many new considerations surrounding water resource development have forced municipalities to extend their perspective beyond traditional water resource development projects.

As alternative ways of increasing water supply, many municipalities in the United States have increasingly been paying attention to demand management or water conservation, and pricing policies as a way of dealing with both higher costs (economically, politically, and environmentally) in a long-term water supply plan and imminent shortages. A great necessity currently challenging municipalities is lowering their consumption of their existing water resources. Lowered consumption sustains current resource levels and ensures their availability for future generations.

(2) Water conservation measures

Various conservation methods can be identified including technical (long-term improvement in technical efficiency that seems to occur "naturally"); voluntary (changes in consumer behavior); coercive (responses brought about by utility actions, including changes in the pricing structures); and mandatory (such as penalties, fines, and user restrictions) (Beecher et al. 1994).

Many municipalities are now using various conservation measures including landscape ordinance, landscape watering restrictions, xeriscaping, water audits, education, low flow fixtures, leak detection, and conservation rates. In emergency circumstances such as drought, mandatory water rationing or water allocation with penalties is used.

2.2 Potential Water Savings

Table 2-1 shows estimated potential water consumption with water conservation. Albuquerque can reduce its total water production to 97 gpcd and residential water consumption to 73 gpcd. Detail of the analysis of potential water savings are discussed in Appendix A.

Table 2-1 Estimated potential per capita water consumption with conservation (gpcd)

	Residential	Resident. (total)	Commer.	Industrial	Institut.	Total consump.	Total with loss
Indoor use	36.1	25.8	18.2	2.4	3.1	49.5	49.5
Outdoor use	37.1	24.3	7.7	0.2	5.4	37.6	47.7
Total	73.2	50.1	25.9	2.6	8.8	87.1	96.8

Note: Residential per capita consumption is calculated from residential population but resident. (total) per capita consumption is calculated from total population.
Loss is 10 percent of total water production.

Table 2-2 shows percentages for water savings from the water consumption needed in 1998 to achieve the potential water savings. The City of Albuquerque can still save water by about 46 percent from the present water use.

Table 2-2 Percentage of water savings from 1998 water use to achieve potential water savings, Albuquerque

(%)

	Residential	Commercial	Industrial	Institutional	Total consumption	Total consumption with loss
Indoor use	42.6	44.0	47.1	45.6	43.6	43.6
Outdoor use	57.9	47.2	28.6	47.8	53.5	49.2
Total	48.9	45.0	45.6	48.6	47.4	46.2

Note: These water saving percentages are calculated from 1998 consumption.

2.3 Strategic Conservation for Albuquerque

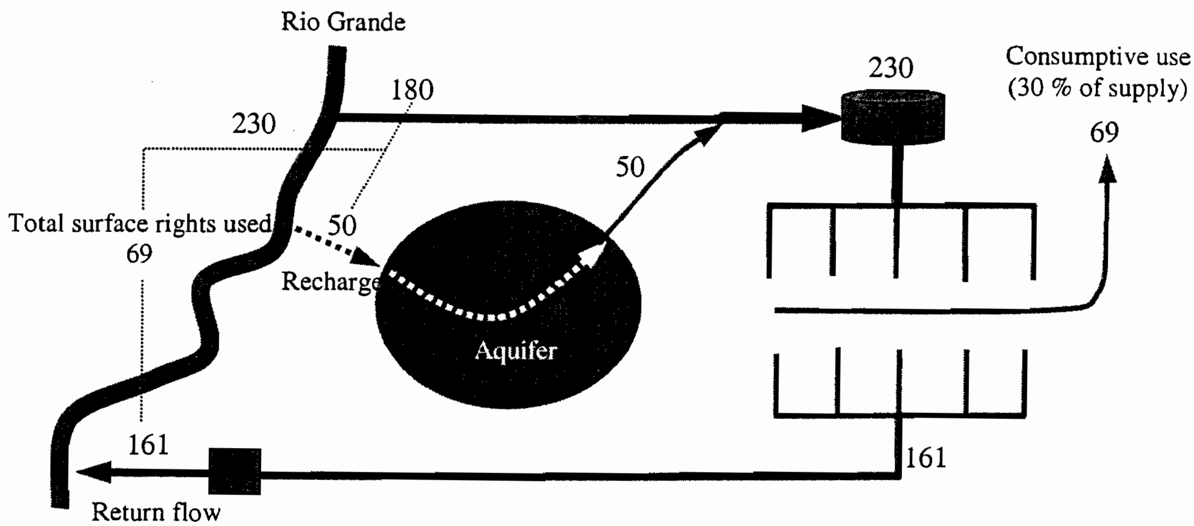
The city's maximum diverted water amount for supply is 138,000 acre-feet per year. This number is calculated using the current 50 percent return flow to the river, or 50 percent consumptive use of the supplied water. If the city reduces outdoor consumption, the percentage of return flow will increase and that of consumptive use will decrease. Thus, the city can use more surface water to supply.

Table 2-3 shows the maximum diverted water amount for supply within the present water resources assuming several return flow percentages. Although it is impossible, if the city attains 100 percent return flow, the city's water use is perpetually sustainable[2]. If the city returns 70 percent of total water supply to the river, the city can use 230,000 acre-feet per year, on a sustainable basis (Figure 2-1). The city borrows 230,000 acre-feet from the river and returns 70 percent, 161,000 acre-feet, per year. The city consumes only 69,000 acre-feet per year, which equals the total water rights that the city has.

[2] It may not sustainable, as water diversion from the river increases because of water quality issues.

Table 2-3 Maximum usable water amount for supply by return flow percentage (acre-feet/year)

	Percentage of return flow (%)				
	50 %	55 %	60 %	65 %	70 %
Maximum usable water amount for supply	138,000	154,400	172,500	197,200	230,000
Renewable ground water	50,000	50,000	50,000	50,000	50,000
Surface water	88,000	104,000	122,500	147,200	180,000
Return flow	69,000	85,400	103,500	128,200	161,000



(Unit: 1,000 acre-feet/year)

Figure 2-1 Water balance in the maximum renewable water supply (30 % consumptive use)

Reduction of consumptive use or increases of return flow can expand the city's water supply. Table 2-4 shows calculated per capita consumption in 2060 by growth scenario if the city can increase its return flow percentage. With 50 percent return flow, the city must reduce per capita water consumption to 94 gpcd in 2060 for the high growth scenario; however, with 70 percent reduction, the city's per capita goal is 157 gpcd in 2060 for the high growth scenario.

Table 2-4 Estimated per capita production in 2060 within maximum usable water rights by consumptive use percentage and growth scenario

(gpcd)

Growth Scenario	Population in 2060	Return flow (%)				
		50	55	60	65	70
		Consumptive use (%)				
		50	45	40	35	30
Low	790,600	156	174	195	223	260
Medium	1,016,500	121	136	152	173	202
High	1,316,100	94	105	117	134	156

Overall reduction of water consumption increases the city's water supply amount for the future growth. However, more efficiently, consumptive use reduction would relieve conservation burden and contribute to increase the city's water supply for the future generations. Therefore, consumptive use management is an important water management tool.

The city's water use consists of two major uses: indoor and outdoor. Indoor use is virtually nonconsumptive as almost all of the water used indoor returns to the river through the wastewater treatment plant, while outdoor use is significantly consumptive through evaporation and evapotranspiration. In winter, most of the supplied water is used indoors while in summer, a considerable amounts of water is used outdoors for landscaping, pools, or cooling. Therefore, to manage consumptive use, outdoor use or summer water use must be managed.

Water deliveries are lowest in the winter months, when very little water is used on gardens or for cooling, suggesting that the amount of water used indoors year-round is roughly equal to the amount delivered in the least delivery month and any water delivered in excess of the least delivery month quantity is considered outdoors. Using this principle, total indoor consumption was estimated 62,900 acre-feet in 1995 (Figure 2-2). This consumption is very similar to the return flow amounts from the city's wastewater treatment plant in 1995, 61,300 are-feet.

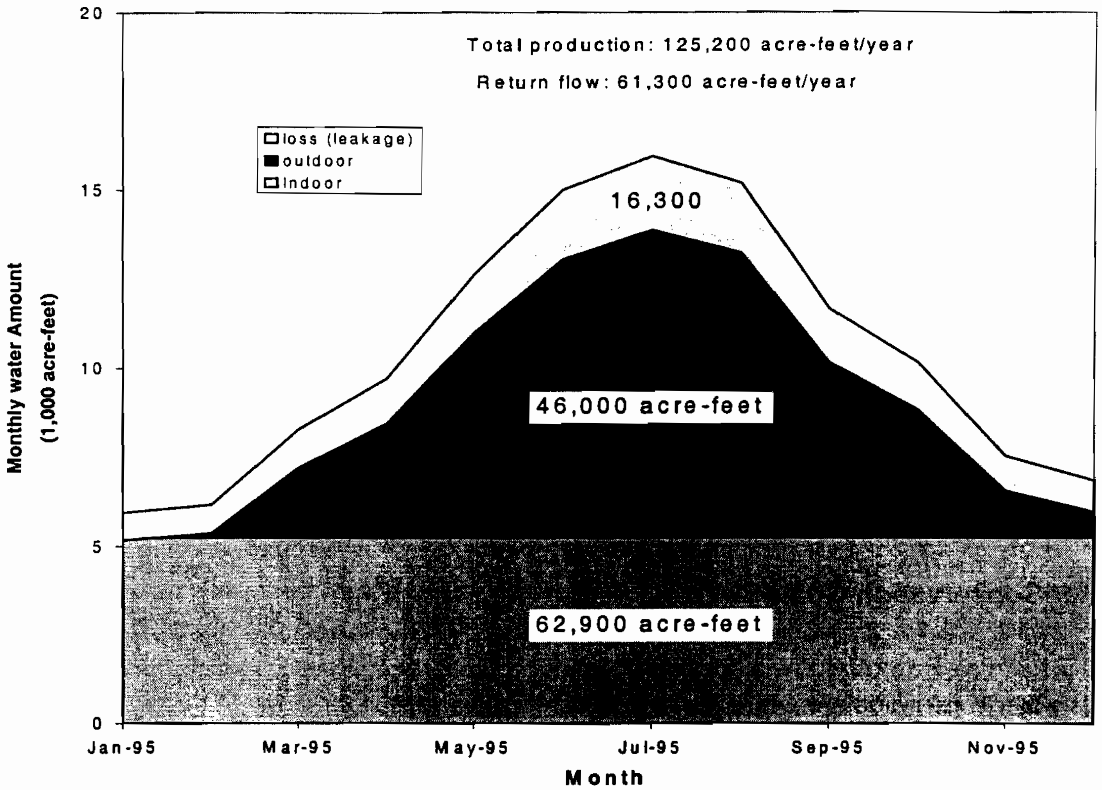


Figure 2-2 Annual water consumption in 1995 by indoor and outdoor use

The wastewater treatment plant receives flows from indoor and industrial use only. The flow of sewage into the wastewater treatment plant usually shows virtually no seasonal variation, indicating that indoor use varies little over the course of the year.

Therefore, the amount of water used indoors year-round is roughly equal to the amount delivered in the least delivery month and any water delivered in excess of the least delivery month quantity is considered outdoors. Table 2-5 shows the estimated current indoor and outdoor per capita water consumption by customer class.

Table 2-5 Indoor and outdoor per capita water consumption by customer class

(Average of 1997 and 1998)

(gpcd)

	Residential	Resident. (total)	Commercial	Industrial	Institutional	Total consumption	Total with loss
Indoor use	89.0	60.5	41.4	5.1	6.8	113.6	113.6
Outdoor use	67.3	42.0	16.3	0.7	11.3	70.3	97.8
Total	156.3	102.5	57.6	5.7	18.1	183.9	211.3

Note: Residential per capita consumption is calculated from residential population but resident. (total) per capita consumption is calculated from total population.
Losses are 12 percent of total water consumption.

2.4 Water Conservation Goals

(1) City's water conservation program goal by 2004

Per capita consumption goals of the city's conservation program are 175 gpcd in 2004. Current per capita consumption is 211 gpcd, so the city must reduce water use by 17.2 percent. Table 2-6 shows per capita consumption goals for the city water conservation program by indoor and outdoor use. Residential per capita consumption should be reduced to 130 gallons per day from the present 156 gallons.

Table 2-6 Per capita consumption goals for the city water conservation program by customer class and indoor and outdoor use

(gpcd)

	Residential	Total consumption	Total production
Indoor use	73.6	87.6	-
Outdoor use	55.8	66.4	-
Total	129.4	154.0	175*

Note: Residential per capita consumption is calculated from residential population.
Same reduction percentage (17.2 %) is applied to both outdoor and indoor uses.
* includes 12 % of loss.

(2) Conservation goals for the city's sustainable water use in 2060

Managing consumptive use is a variable tool for Albuquerque's sustainable water use. If return flow percentage of total supply increase, that is, consumptive use percentage decreases, the city can divert more water for supply. Table 2-7 shows per capita consumption goals for the high growth scenario of Albuquerque in 2060 by consumptive use percentage and outdoor and indoor use. With 30 percent consumptive use, the city needs the per capita consumption of 156 gpcd in 2060. Residential customers must reduce water consumption to 120 gpcd under the 30 percent consumptive use scenario as shown in table 2-8.

Table 2-7 Per capita consumption goals for the high growth scenario in 2060 by consumptive use

	Consumptive use (%)	Per capita consumption (gpcd)			
		Total water production	Total consumption*	Indoor	Outdoor
50 % consumptive use	50	94	84.6	47.0	37.6
40 % consumptive use	40	117	105.3	70.2	35.1
35 %consumptive use	35	134	120.6	87.1	33.5
30 % consumptive use	30	156	140.4	109.2	31.2

Note: *without loss (10 % of total production).

Table 2-8 Residential per capíta consumption goals for the high growth scenario in 2060 by consumptive use

(gpcd)

	Residential per capita consumption (gpcd)		
	Indoor use	Outdoor use	Total
50 % consumptive use	40.0	31.9	71.9
40 % consumptive use	59.8	29.8	89.6
35 %consumptive use	74.0	28.5	102.5
30 % consumptive use	92.9	26.5	119.4

There are many measures to reduce city's water consumption. Water pricing is one of the most effective conservation management tools. The next part discusses water pricing measures to attain these conservation goals for the city's sustainable water use.

Part III Analysis of Water Pricing and Water Demand

In the previous section, water conservation goals are established for the sustainable water use. There are many measures to reduce city's water consumption. Water pricing is one of the most effective conservation management tools. This section discusses the method to analyze city's pricing policies to manage water demand and evaluates water prices to attain the conservation goals.

First, general and the city's water pricing objectives are discussed. Second, conservation-oriented water rates are briefly mentioned and an example of how conservation-oriented water rates reduce water consumption in Tucson is reviewed. Third, price responsiveness for water demand is reviewed. Fourth, seasonal price-demand schedules for the city are created using water rates and consumption of other cities in the desert climate. Five, using these price-demand schedules, future pricing policies for managing the city's water demand are analyzed and evaluated. Six, sustainable measures for water rates are discussed.

3.1 Water Pricing Objectives for Albuquerque

(1) Water pricing

Water resources today are not priced to reflect their true value. This result is people continuing to use supplies without considering that one day they will have exhausted their supply of water resources completely (Stumpf, 1995).

Without adequate pricing signals, customers have little basis on which to make informed choices about how to use water efficiently. Deficiencies in pricing can also undermine the effectiveness of other conservation programs. By contrast, effective price signals will induce water customers to modify their water use in ways that reflect the actual value of water (Chesnutt and Beecher, 1998).

Pricing is central to demand management. High water prices encourage water resource conservation, while low water prices encourage more water use and more expensive water supply development. For most cities in the United States, appropriate water pricing or higher prices measures are now essential toward their sustainable water use.

As shown later in this section, Tucson achieved a low level of per capita water consumption (165 gpcd) mainly by raising price. Likewise, cities around Albuquerque such as Santa Fe, Rio Rancho and El Paso that achieve low per capita consumption always have higher water prices.

In addition, appropriate water pricing measures reduce costs of water conservation measures. Water conservation measures are not free. For example, the city of Albuquerque estimates that to meet the conservation goal of reducing per capita consumption by 30 percent over 10 years will cost $65 million (Brown et al., 1996). In 1997, the city of Albuquerque spent 2.2 million dollars on conservation mainly for rebates programs of low flow fixtures. Appropriate water pricing measures will effectively reduce the costs burden of water conservation program to the utility in the long-run.

(2) Water pricing objectives

Water rates include many pricing objectives. There are numerous water prices and rate structures for urban water utilities, each having objectives. There are three major objectives of water rates which are:

1. to generate revenue (cost recovery) – rates generate revenue that permits a utility to cover its costs.
2. to allocate costs – rates serve to allocate costs among different types of use and user.
3. to provide incentives – rates provide price signals to customers which may serve as incentives for them to use water efficiently, encouraging them to modify their behavior in particular direction (Hanemann, 1998).

For most utilities, generating revenue to meet the utility's revenue requirements is the primary role of a water rate structure. The task of allocating costs is difficult because of the complicated nature of water utility costs and user characteristics. Recently, incentive pricing is becoming important as utilities consider the promotion of conservation, system load management, and economic efficiency.

A well-designed rate structure can help the utility manage its supplies more efficiently, encourage consumers to make wise choices, and earn enough revenue to manage the utility. In reality, it is not an easy task for the utility to meet all objectives simultaneously. Therefore, prioritization and balance of objectives is needed.

(3) Albuquerque water rates

a. Albuquerque pricing objectives

The city's Water Resource Management Strategy (1997) establishes several pricing objectives. The Strategy recommends that rates be established to:

1) be equitable;
2) achieve a stable and predictable revenue stream;
3) recover costs;
4) provide a conservation incentive;
5) be increased gradually; and
6) be affordable for low-income individuals.

b. Current water rate structures of Albuquerque

The city's water rates consist of fixed monthly charge by meter size, commodity charge (uniform rate), and summer surcharge. Water rates in 1998 are shown in table 3-1.

Table 3-1 Water rates of the City of Albuquerque (effective in May 1998)

	Rates
Commodity charge including:	\$0.803 /unit (\$1.074/1,000 gallons),
New Sustainable Water Supply Program	\$0.088 /unit (\$0.118 /1,000 gallons)
New Water Resources Management Program	\$0.075 /unit (\$0.100 /1,000 gallons)
New Facility Rehabilitation Program	\$0.03 /unit (\$0.040 /1,000 gallons)
State water conservation surcharge	\$0.0244 /unit (\$0.033/1,000 gallons)
Summer surcharge	\$0.21 per unit is added to the base commodity charge, for each unit exceeding 200% of the average winter consumption (AWC) during April through October[3]. Winter months are December, January, February, and March.

Note: 1 unit = 100 ft^3 = 748 gallons.
Source: Water & Sewer Rate Ordinance. City of Albuquerque Public Works Department. Bill Number F/S 0-7. Effective July 1, 1998.

[3] For residential customers on service sizes 1 through 4, the AWC will be calculated by service size. For all residential customers on service size 5 through 9 and all other customer classes, the AWC will be calculated for each account.

Customer Classification

- Residential: Single-family, townhouses, duplexes or triplexes.
- Commercial: Multi-family residential, mobile home parks served by common meter(s), retail, offices, hotels, motels, and shopping centers.
- Industrial: Manufacturing or process facility, which is engaged in producing a product.
- Institutional: Government buildings, hospitals, schools, and other facilities that provide public and quasi-public services.

Table 3-2 shows evolution of the city's water prices from 1981 to 1998.

Table 3-2 Change in water prices of the City of Albuquerque

($/1,000gallons)

	July 81	Sept 82	Sept 88	July 90	July 91	July 93	Apr 94	Jan 95	July 97	May 98
Commodity charge	0.535	0.628	0.695	0.695	0.735	0.762	0.762	0.912	0.952	1.106
Seasonal surcharge	-	0.281	0.281	0.281	-	0.281	0.281	0.281	0.281	0.281
Switch point as of AWC*	-	500	400	400	-	400	200	200	200	200

Note: * A summer surcharge is added to the base commodity charge, for each unit exceeding switch point (%) of the average winter consumption (AWC) during April through October.

(4) Water pricing objectives for Albuquerque

The City of Albuquerque's sustainable water use requires water conservation, particularly reduction of consumptive or outdoor use. Therefore, this study mainly focuses on pricing measures to reduce water consumption. In addition, this study also discusses the city's other pricing objectives.

3.2 Conservation-Oriented Rates

(1) Trend of water pricing of urban water sector

As costs for the water supply industry rise, water becomes scarce, and concerns about both equity and

efficiency grow, rate-design alternatives receive increasing attention. Traditional rate structures such as decreasing block rates have been criticized because they do not send adequate pricing signals. A trend in the water sector in recent years is the decline in the use of decreasing-block rates, matched by expanded use of uniform and increasing-block rate structures (Beecher et al. 1994). Further, many water utilities incorporate seasonal variations within their uniform or increasing-block rate structures. Recently, many utilities use these conservation-oriented rates.

Throughout the United States, increasing numbers of water utilities are implementing a variety of conservation-oriented rate structures reflecting their water resource conditions and supply system. According to survey results reports by the American Water Works Associations (AWWA), more than 60 percent of US water utilities have some form of conservation-oriented rate structure (Cuthbert and Lemoine, 1996). The most aggressive rate structures are typically found among utilities in area where water resources are limited and new resources are expensive or difficult to obtain, particularly in the western and southern United States (Cuthbert and Lemoine, 1996).

(2) Conservation-oriented rate structures

The idea behind conservation-oriented pricing is to charge customers for the full cost of water service, including the cost of new supplies and over the long term to bring supply and demand into balance. Prices are important because they send signals that guide consumer and water agency decisions (Chesnutt and Beecher, 1998).

Conservation-oriented rate structures include uniform commodity rates, seasonal rates, increasing-block rates, and excess-use rates. These rates feature pricing information that can provide water users with appropriate pricing signals and promote conservation. Recently, many water utilities are creating elaborate and complicated conservation-oriented rate structures such as Feebate rates (a combination of fees and rebates (Collinge, 1996)). In emergencies such as droughts, water rates such as specific water allocations with penalties for non-compliance is used. Appendix B discusses uniform rate, increasing-block rates, seasonal rates, excess use rates and fee and rebate rates.

3.3 Example of Conservation Rates and Water Management Rules in Tucson

(1) Water rates and water consumption

Figure 3-1 shows per capita water production and water rates in mean-use block between the 1966 and 1982 fiscal years in Tucson. Until 1976, the rate schedules were designed simply to cover revenue needs. Water conservation was not a goal of the Tucson Water Department. Until 1974, the water rate was a two-step declining rate schedule. The first increasing-block rate was introduced in 1974 but the step to the second block was very modest.

A major change occurred in 1976 when the Water Department changed its pricing policy from a cost-recovery to a conservation-oriented rate structure. The Department introduced a many-step increasing block rate. Consistent with this change, the per capita water production fell from about 190 gallons per day to 158 gallons; the per capita consumption dropped 17 percent in one year. Further increases in water rates lowered per capita consumption to 148 gallons per day in 1978/79. However, after that, despite the increase in water rates, per capita consumption increased.

(2) Real and nominal prices

Table 3-3 and figure 3-1 shows the relationship between real prices and nominal prices for marginal water prices in mean-use block and per capita water production. During the period between 1966 to 1981, nominal prices continued to increase but real prices had increasing trend until 1978 and 1979 but after that real prices had declined. The trend of real prices fit with the trend of per capita water production. Martin (1984) analyzed water production, and water price and price elasticity for this period and concluded that decreasing real prices encourage increasing water use. Increasing real prices encourage less water use.

As a result of real price increases and water problem awareness caused by the political furor of 1976, water consumption in Tucson fell to a low of 148 gpcd. Since that time, real water prices have fallen, and although the water is a subject in the news almost every day, per capita daily use has risen to 166 gallons in 1981/82.

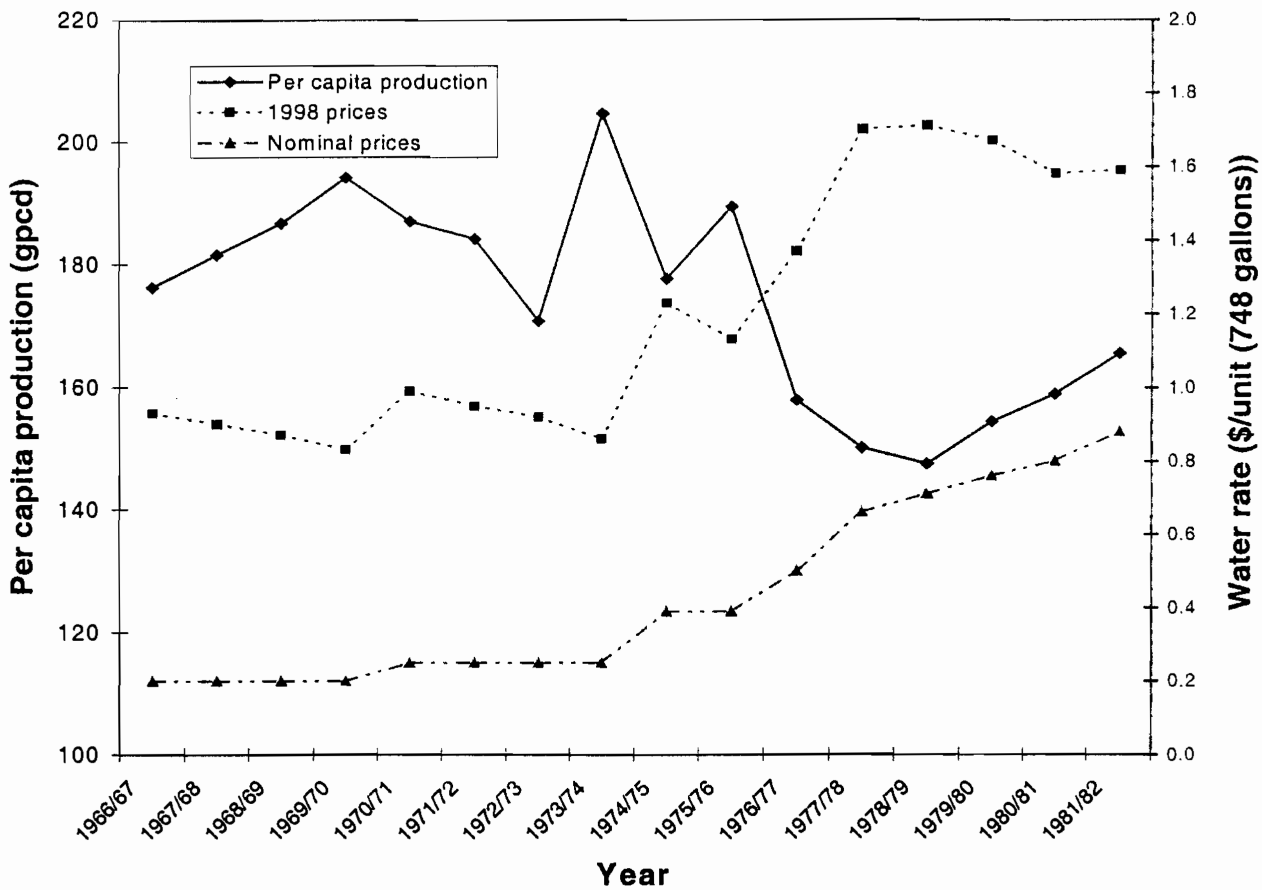


Figure 3-1 Water rates in mean-use block and per capita production in Tucson (1966 to 1982)

Table 3-3 Per capita water production and marginal water rate per unit in mean-use block, Tucson, 1973-1982

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Per capita production (gpcd)</th><th colspan="2">1979 prices ($/unit)</th><th colspan="2">Nominal prices ($/unit)</th></tr>
<tr><th>summer</th><th>Winter</th><th>Summer</th><th>Winter</th></tr>
<tr><td>1973/74</td><td>205</td><td colspan="2">0.92</td><td colspan="2">0.25</td></tr>
<tr><td>1974/75</td><td>178</td><td colspan="2">0.86</td><td colspan="2">0.39</td></tr>
<tr><td>1975/76</td><td>189</td><td colspan="2">1.23</td><td colspan="2">0.39</td></tr>
<tr><td>1976/77</td><td>158</td><td colspan="2">1.13</td><td colspan="2">0.50</td></tr>
<tr><td>1977/78</td><td>150</td><td>1.70</td><td>1.42</td><td>0.66</td><td>0.55</td></tr>
<tr><td>1978/79</td><td>148</td><td>1.71</td><td>1.43</td><td>0.71</td><td>0.59</td></tr>
<tr><td>1979/80</td><td>154</td><td>1.67</td><td>1.43</td><td>0.76</td><td>0.65</td></tr>
<tr><td>1980/81</td><td>159</td><td>1.58</td><td>1.43</td><td>0.80</td><td>0.71</td></tr>
<tr><td>1981/82</td><td>166</td><td>1.59</td><td>1.43</td><td>0.88</td><td>0.79</td></tr>
</table>

Source: Constructed from Martin (1984).
Note: 1 unit = 100 ft^3 = 748 gallons
1998 prices are adjusted by CPI.

In case of the Albuquerque, figure 3-2 shows the nominal prices and the real prices adjusted by 1998 CPI and yearly per capita water productions. Water productions apparently respond to real prices rather than nominal prices.

(3) Peak and off-peak consumption

Since 1976, the Water Department has used increasing-block rates, aimed at reducing peak consumption in summer. This has resulted in significant reduction of per capita consumption in peak months. Interestingly, per capita consumption in the least month also decreased such that the peak month to least month ratio remained constant because the winter rates also increased as much as the summer rates did.

(4) High volume users

Starting in 1982, rates were adjusted in a way to make it more expensive to consume above-average amounts of water, but left water bills for customers using average or below-average amounts mostly unaffected. This rate change further encouraged large volume users to reduce water use; water consumption of large volume users decreased from 8 percent to 6.6 percent (Cuthbert, 1989). At the same time, the peak usage months of June-July was 11 percent lower than in 1982, however nonpeak winter months were unaffected. It suggests that the rate structure was effectively and selectively curtailing discretionary outdoor use during the peak season.

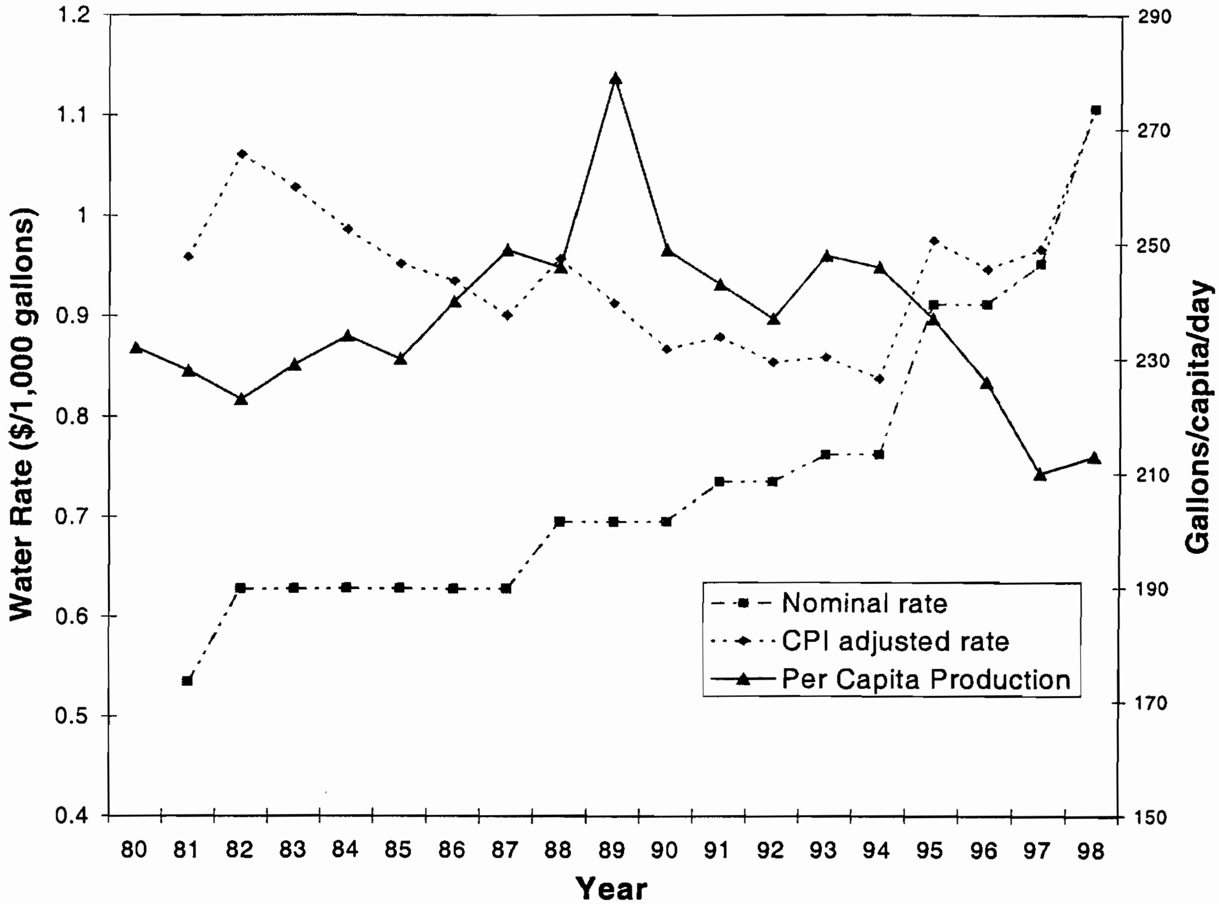


Figure 3-2 Water rates and per capita production in Albuquerque (1981 to 1998)

3.4 Analysis of Price Responsiveness

(1) Water rate design

Stevens, Miller, and Willis (1992) conducted a cross-sectional analysis of 1988 water demand for eighty-five communities in Massachusetts. Employing an average price variable, price elasticities were calculated for three rate structures: uniform rates, decreasing-block rates, and increasing-block rates. For uniform rates, price elasticities ranged from -0.10 to -0.43. For decreasing-block rates, price elasticities ranged from -0.40 to - 0.69. For increasing-block rates, price elasticities ranged from -0.42 to -0.54. This study implied that price elasticities are not substantially affected by type of rate design and that the level of rates is more important than rate structure in affecting water usage.

(2) Water price level

Martin and Thomas (1986) conducted a cross-sectoral analysis of residential water demand, using 1978-79 data for four cities including the desert cities of Tucson and Phoenix, Arizona. A comparison of demand data from the four cities indicates that residential water demand tends to become more price-elastic with higher water prices and lower water demands.

(3) Customer class

There are numerous studies for residential price elasticity but few studies for other customer classes' price elasticity. One study shows that each user class responds differently to water price changes. The analysis of William and Suh (1986) indicated that industrial water demand is more price-responsive than residential water demand. Scheider and Whitlatch (1991) conducted a pooled time-series/cross-sectional analysis of water demand for metropolitan Columbus, Ohio. The analysis, employing data for 1959-1976, covered sixteen communities served by the Columbus water system. Table 3-4 shows estimated short-run and long-run price elasticities for four customer classes and total demand. The conclusion of this analysis was that both short-run and long-run price elasticities vary substantially over customer classes and residential elasticities are more inelastic than other classes in both short- and long-runs.

Table 3-4 Estimated price elasticity of water demand

Investigator and data	Class	Price elasticity	
		Short-run	Long-run
Williams and Suh, 86 systems, 1976	Residential Commercial Industrial	-0.48 -0.36 -0.74	
Schneider and Whitlatch, 16 Columbus, OH communities from 1959 to 1976	Residential Commercial Industrial Government Total demand	-0.11 -0.24 -0.11 -0.44 -0.12	-0.26 -0.92 -0.44 -0.78 -0.50

Source: Reproduced from Table 3-4, Beecher et al. 1994.

(4) Indoor vs. outdoor use, winter vs. summer, and off-peak vs. peak

Howe and Linaweaver (1967) performed a cross-sectional analysis of residential water demand incorporating thirty-nine urban areas to analyze indoor and outdoor use. Table 3-5 shows the results. This analysis suggests that domestic demand is highly price-inelastic and that irrigation demand is price-inelastic in the west but is price-elastic in the east.

Howe (1982) disaggregated residential water demand into winter and summer components. As shown in table 3-5, summer usage is less responsive to price changes.

Table 3-5 Estimated price elasticity of water demand

Investigator and data	Class	Price elasticity
Howe and Linaweaver, 39 urban areas	Total residential Residential domestic Sprinkling, west Sprinkling, east	-0.41 -0.23 -0.70 -1.57
Howe Regional US	Residential winter Residential summer, west Residential summer, east	-0.06 -0.43 -0.57

Source: Reproduced from Table 3-4, Beecher et al. 1994.

Gibbons (1986) analyzes summer and winter price elasticities for Tucson, Raleigh, and Toronto with

prices and average residential water use in table 3-6. This analysis suggests that winter demand is highly price-inelastic and that summer demand is price-elastic. Tucson, which is located in the dry area, has very large summer consumption compared to the other two cities. Both winter and summer demands in Tucson are more inelastic than in Raleigh and Toronto, which are located in humid areas.

Table 3-6 Price elasticity of water demand in Tucson, Raleigh, and Toronto.

Locality	Date of Data	Season	Price (1998$/ gallons)	Elasticity of demand	Average water use (gals/ household /month)
Tucson, AZ	1979	Winter	1.42	-0.23	7,140
		Summer	1.64	-0.70	12,420
Raleigh, NC	1973	Total	2.51	-0.27	
		Winter	2.51	-0.31	5,910
		Summer	2.43	-1.38	6,660
Toronto, Ont.	1967	Total	1.56	-0.93	
		Winter	1.56	-0.75	4,010
		Summer	1.56	-1.07	4,950

Source: Gibbons, 1986.

Lyman conducted a time-series analysis of water demand for thirty households in Moscow, Idaho for 1983-1987. As shown in table 3-7, this analysis indicates that both short-run and long-run peak water demand is more price-elastic than off-peak demand. Furthermore, the study found that the price sensivity of peak demand affects off-peak demand when consumers purchase and use more water-efficient appliances (Beecher et al., 1994).

Table 3-7 Off-peak and peak price elasticity

Category	Price elasticity (%)	
	Short-run	Long-run
Off-peak	-0.40 - -0.43	-0.63 - -0.71
Peak	-1.38 - -2.02	-2.60 - -3.33

Source: Lyman, 1992.
Note: 30 households, Moscow, ID (1983 – 1987)

The price elasticities measured as indoor, winter and off-peak as a group are lower than elasticities measured as outdoor, summer and peak as a group. This is because off-peak demand occurs in winter and measures indoor demand and vice versa.

(4) Short-run vs. long-run

Long-run responsiveness to changes in price is greater than short-run responsiveness as show in table 3-4 and table 3-7. This can be attributed partly to the assumption that consumers in the long run have more opportunity to change water use methods.

(5) Household class

To identify the incidence of conservation burden among household classes during a severe California drought, Renwick and Archibald (1998) researched two communities located along the central coast, Santa Barbara and Goleta. Table 3-8 shows price elasticity by income class.

Table 3-8 Price elasticity of demand for water by Income Class

Income class	Price elasticity
Total sample	-0.33
<$20,000	-0.53
$20,000 - $59,999	-0.21
$60,000 - $99,999	-0.22
>$99,999	-0.11

Source: Table 4, Renwick and Archibald, 1998

Households with lower incomes responded more to higher water prices than wealthier household groups. In particular, low income households were more than five times as price responsive as relatively wealthy households reflecting the fact that their water bill typically constitutes a large share of the household budget. These results suggest that price policy will achieve a large reduction in residential demand in lower income households than in higher income households.

3.5 Water Demand Schedule for Albuquerque

Many studies have been conducted to select an appropriate price elasticity of water demand. Unfortunately, the results of these studies differ significantly as we vary location, climatic and weather conditions, classes of customers, and other unique factors associated with one service area versus another.

An important problem in comparing the results of most studies is that the definitions of the price and quantity variables used in the models and the range and means of price and quantity data typically disappear from tables of comparison (Martin and Thomas, 1986).

If the City of Albuquerque needs aggressive water conservation in the future, future level of water demand is outside of the range of previously observed variations of demand. Therefore, to analyze future price policies for Albuquerque, water demand schedules for the city must be estimated from cities that have the similar service area conditions as Albuquerque.

Albuquerque's sustainable water price policy must consider management of indoor and outdoor water use or seasonal water use. Therefore, water demand schedules must be built for seasonal demand as well as overall demand.

Residential water demand schedule is analyzed here. Because there is no study about demand schedules other than residential water demand, water demand schedules for other customer classes are not conducted in this study.

However, analysis of residential water demand schedules is important because about 60 percent of water use is for residential customers (single-households, duplex, etc.) in Albuquerque and If apartment customers are included, water use of residential customers would account for more than 70 percent.

(1) Overall residential demand schedule

Martin and Thomas (1986) studied residential water demand schedules using the five cities of Coober Pedy, Kuwait, Perth, Tucson, and Phoenix, located in desert climates[4]. Table 3-9 shows water price and

[4] Perth, Western Australia, has a relatively wet climate with an average of 30 in., but 85-95% of its rain falls in the winter months from May to October. Summers are hot and evaporation is high with 11in. in the midsummer month of January.

consumption data and figure 3-3 shows a residential water demand schedule constructed from Kuwait, Perth, Tucson, Phoenix and Albuquerque. Cooper Pedy provides an opportunity to observe an upper point on a demand curve for residential water in an arid climate. As for the demand schedule (freehand smooth curve), Perth is to the left of the curve, since it has a wetter environment than the other cities. Kuwait is shown to the right of the curve, since per capita income is much higher than the other areas. Price elasticities of the demand curve are about – 1.0 at 50 gpcd, - 0.7 at 100 gpcd, and –0.63 at 170 gpcd. As the price rises, water demand becomes more price-elastic. However, if the price rises beyond $5.0/1,000 gallons or the demand reduces below 50 gpcd, the price-elasticity decreases. Therefore, this study does not use price elasticity to estimate water reduction. Instead, water demand schedules estimated for other cities is used for Albuquerque.

Table 3-9 Residential water consumption in six cities

	Average per capita (gpcd)	Price per 1000 gals (1998 price)	Per capita income (US dollars)	Annual rainfall (inch)
Coober Pedy, South Australia (1980-1984)	13.2	89.70	8,876 (1982)	5
Kuwait (mean, 1973-1981)	49.0	6.83	20,578 (1981)	5
Perth, Western Australia (1981/1982)	76.1	2.10	9,252 (1982)	34
Tucson, Arizona (1978/1979)	98.0	2.29	8,872 (1982)	11
Phoenix, Arizona (1979)	157.0	0.76	9,893 (1982)	8
Albuquerque (1994)	191.0	0.829		9
Albuquerque (1998)	157.0	1.067		9

Source: Author's construct using Table 1, Martin and Thomas (1986).
Note: Prices are adjusted by CPI.

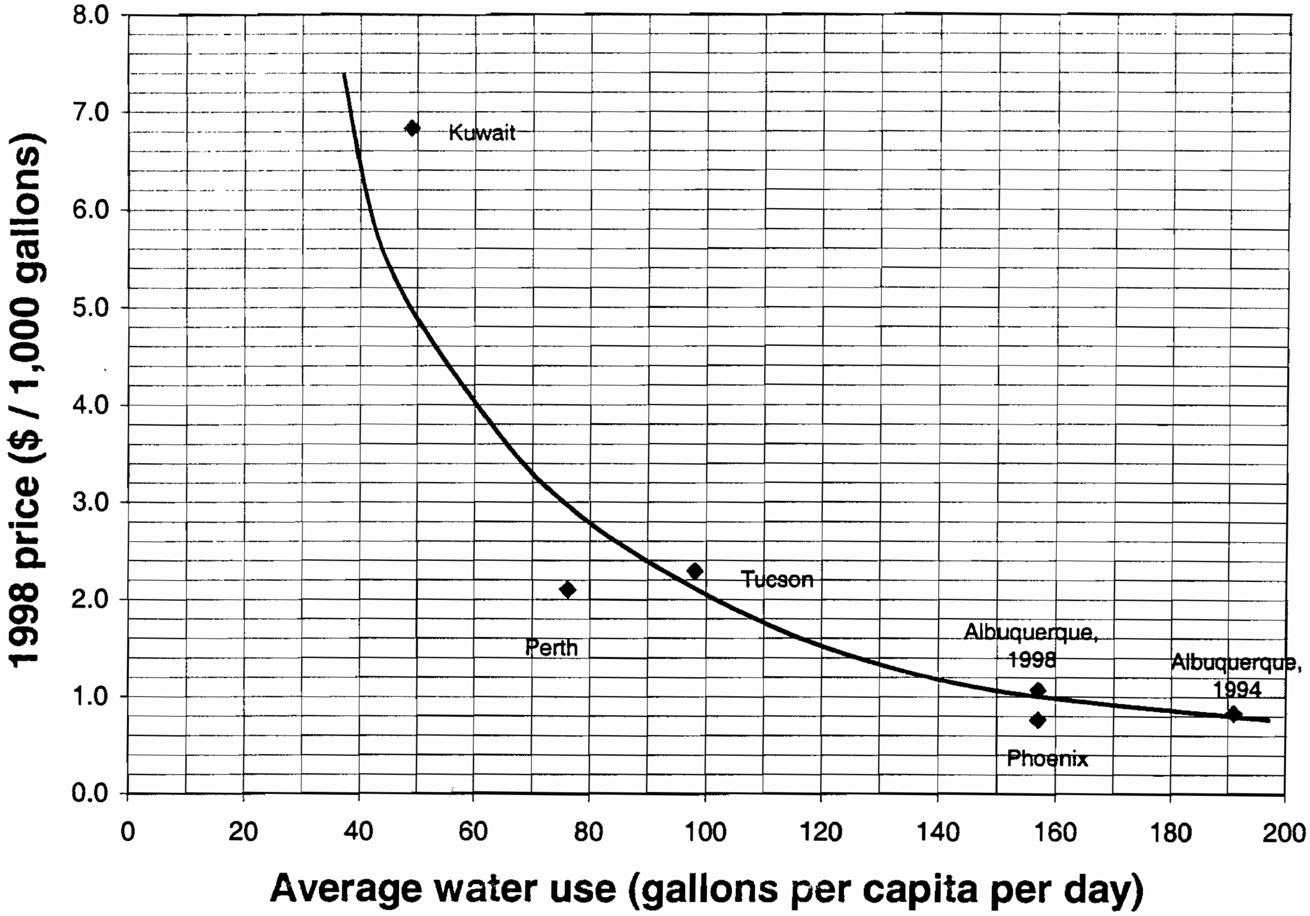


Figure 3-3 Estimated overall residential water demand schedule for Albuquerque

(2) Seasonal residential demand schedule

Table 3-10 shows residential water consumptions and water rates in Raleigh, Tucson, and Albuquerque in winter, spring/fall, and summer. Figure 3-4 shows estimated seasonal residential water demand schedules (freehand hand smooth curves) for winter, spring/fall and summer constructed these data. A convergence point of these three curves may be $5 or $6 on the upper left part of the curve. It means that outdoor water use would disappear at this price level.

Table 3-10 Residential water consumption by winter, spring/fall, and summer in three cities

	Winter		Spring/fall		Summer	
	Per capita consum. (gpcd)	1998 price ($/1000gal)	Per capita consum. (gpcd)	1998 price ($/1000gal)	Per capita consum. (gpcd)	1998 price ($/1000gal)
Tucson, AZ, 1974	85	1.71	127	1.71	196	1.71
Tucson, AZ, 1975	81	1.56	120	1.56	178	1.56
Tucson, AZ, 1976	76	1.90	104	1.90	148	1.90
Tucson, AZ, 1977	69	1.96	90	1.96	130	2.32
Tucson, AZ, 1978	63	1.95	90	1.95	136	2.35
Tucson, AZ, 1979	65	1.93	97	1.93	124	2.26
Raleigh, NC, 1973	56	2.51	-	-	63	2.43
Albuquerque, 1994	114	0.83	178	0.83	296	0.83/1.14
Albuquerque, 1998	91	1.09	146	1.09	234	1.09/1.37*

Source: Author's construct using Table 1-2, Gibbons (1986) and Martin (1984).
Note: Prices are adjusted by CPI.
(1) Albuquerque rates have excess use surcharge for more than 200 % of winter average use during summer.
(2) Tucson water rates were many step-increasing block rates. For the analysis, a marginal water rate in mean-use block is used.
(3) Raleigh's summer water use cannot be compared because it is located in wet summer climate. Per capita consumption for Raleigh is calculated from per household consumption by assuming 3.5 person per household.

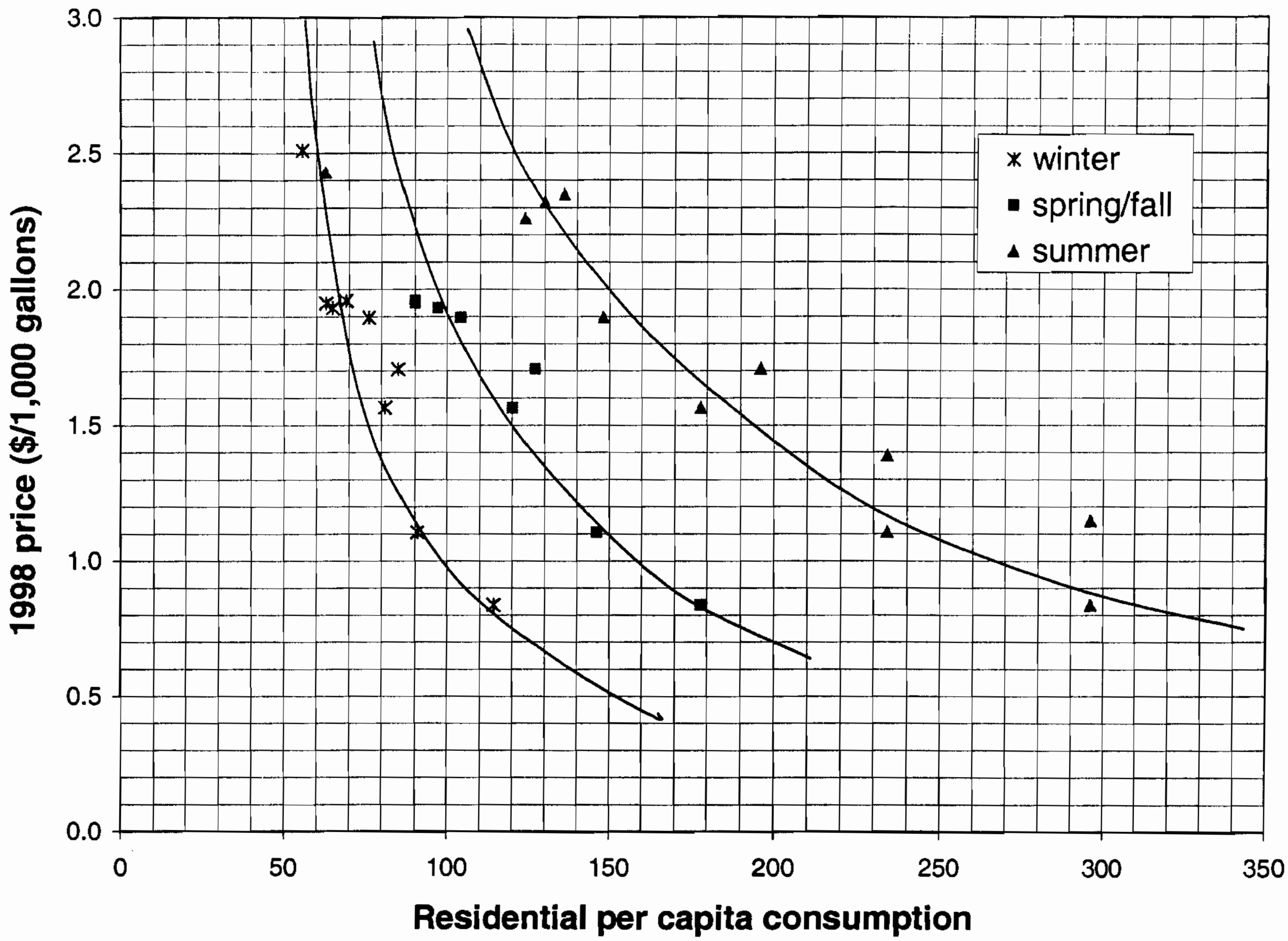


Figure 3-4 Estimated residential winter, spring/fall and summer water demand schedules for Albuquerque

3.6 Analysis of Water Price Level for Albuquerque's Sustainable Water Use

The estimated demand schedules for Albuquerque are used to analyze Albuquerque's water pricing policies for water conservation scenarios.

(1) Residential water price level for sustainable water use scenarios

a) Residential water price level in 2060

Table 3-11 shows the water conservation goal in 2060 by the growth scenario with 50 percent consumptive use. The table includes estimated residential water price levels for the scenarios from figure 3-3 (overall residential water demand schedule). With the low growth scenario, residential water price should be $1.6/1,000 gallons in 2060. This is a moderate water price increase from the present $1.1. With the medium and high growth scenario, residential water price should be $2.5 and $ 3.3, respectively in 2060. With the high growth scenario, water price levels must be more expensive because more reduction of water consumption is required.

Table 3-11 Conservation goal in 2060 and estimated residential water price level by population growth scenario (50 percent consumptive use)

	Total water production (gpcd)	Total water consumption (gpcd)	% of reduction from 1998[1]	Residential per capita demand[2]	Estimated residential water price ($/1,000 gallons)
Low growth	154	140	26	116	1.7
Medium growth	121	109	43	89	2.5
High growth	94	85	55	70	3.3

Note: (1) Percentage of reduction from average consumption of 1997 and 1998.

(2) Calculated from residential population.

b) Residential water price level in 2060 for the high growth scenario

This section discusses water demand management in 2060 with the high growth scenario by focusing on consumptive use management. Table 3-12 summarizes per capita residential water demand goals in 2060

by different consumptive use percentages. The table also includes indoor and outdoor residential water demand and projected seasonal water demands calculated by assuming that:

1) winter months are December through March, spring/fall months are April, May, October and November, and summer months are June through September form the analysis of current water consumption of Albuquerque.
2) indoor demand equals winter demand; and
3) one thirds and two thirds of total outdoor demand are consumed in spring/fall and summer demand, respectively, that is, spring/fall demand is winter (indoor) demand plus one thirds of outdoor demand.

Table 3-12 Per capita residential water demand goals in 2060 for the high growth scenario by consumptive use scenario and indoor and outdoor use and seasonal water demand

Scenario name	consumptive use (%)	Projected per capita residential water demand (gpcd)					
		Indoor	Outdoor	Total	Winter	Spring/ fall	Summer
1998 consumption	50	89	67.3	156.3	91	146	232
1. 50 % consumptive use	50	40.0	31.9	71.9	40	72	104
2. 40 % consumptive use	40	59.8	29.8	89.6	60	90	119
3. 35 % consumptive use	35	74.0	28.5	102.5	74	102	131
4. 30 % consumptive use	30	92.9	26.5	119.4	93	119	146

Note: One thirds and two thirds of total outdoor use are distributed to spring/fall and summer demand, respectively. Winter is December through March, spring/fall is April, May, and November, and summer is June through September.

Table 3-13 shows estimated residential water prices for the high growth scenario in 2060 from figure 3-3 (overall residential water demand schedule) and figure 3-4 (seasonal residential water demand schedule). The water prices with the 35 and 30 percent consumptive use scenarios reduced costs such that they may be feasible. In particular, the 30 percent consumptive use scenario can be attained only by increasing summer and spring/fall water prices by $0.4 and $0.9 per 1,000gallons, while the winter price is kept at the current level.

Table 3-13 Estimated residential water prices for the high growth scenario in 2060

Scenario name	Estimated residential water prices ($/1000 gallons)			
	Winter	Spring/fall	Summer	Overall
1998 water rates	1.094 (base) 0.278 in summer (for excess use more than 200 % of AWC)			
1. 50 % consumptive use	> very high	2.8	2.7	3.3
2. 40 % consumptive use	2.25	2.18	2.4	2.5
3. 35 % consumptive use	1.55	1.9	2.3	2.05
4. 30 % consumptive use	1.08	1.5	2.0	1.7

Note: AWC (Average Winter Consumption)
These prices are estimated from demand curves in figure 3-3 and figure 3-4.

(2) Water price level for city's conservation goal in 2004

The city is now implementing a water conservation program in which the overall per capita water demand goal in 2004 is 175 gpcd. Residential per capita demand must be reduced by 17.2 percent from the current water consumption. Table 3-14 shows projected per capita residential water demand schedules in 2004 for the city's conservation goal by indoor and outdoor water reduction scenario. The scenarios include 1) the same reduction ratio for indoor and outdoor use, 2) 10 % indoor use reduction, and 3) 5 % indoor use reduction from 1998 water consumption.

Table 3-14 Projected per capita residential water demand schedules in 2004 for the city's conservation goal by indoor and outdoor water reduction scenario

Scenario	water use reduction from 1998 (%)		Projected residential per capita water demand (gpcd)					
	Indoor	Outdoor	Indoor	Outdoor	Total	Winter	Spring/ fall	Summer
1998 consumption	-	-	89	67.3	156.3	91	146	232
1. Same reduction	17.2	17.2	73.6	55.8	129.4	74	129	185
2. 10 % indoor use reduction	10	26.6	80.1	49.3	129.4	80	129	179
3. 5 % indoor use reduction	5	33.4	84.6	44.8	129.4	85	129	174

Note: One thirds and two thirds of total outdoor use are distributed to spring/fall and summer demand, respectively.

Table 3-15 shows estimated residential water prices by scenario from figure 3-3 and figure 3-4. With the same reduction ratio scenario, winter water prices must be raised, compared to other seasonal water prices. Ten and five percent indoor reduction scenarios need more moderate water price increases for winter.

Table 3-15 Estimated residential water prices for Albuquerque's sustainable water use scenarios

Scenario	Estimated residential water prices ($/1000 gallons)			
	Winter	Spring/fall	Summer	Overall
1998 water rates	1.094 (base) 0.278 in summer (for excess use more than 200 % of AWC)			
1. Same reduction (17.2 %)	1.6	1.35	1.6	1.4
2. 10 % indoor use reduction	1.38	1.35	1.65	1.4
3. 5 % indoor use reduction	1.25	1.35	1.7	1.4

Note: Winter Average Consumption (AWC)
These prices are estimated from demand curves in figure 3-3 and figure 3-4.

(3) Preliminary estimate of water price level for San Juan-Chama water direct use

The city has the plan to be directly using SJC water by 2005. To do this, the city will incur capital costs for diversion and treatment facilities. It will also raise operation and maintenance costs of the water system. Table 3-16 shows the costs of the SJC project.

Table 3-16 Costs for San Juan-Chama water direct use

($ millions)

	Capital costs	Operating & Maintenance costs
San Juan-Chama water direct use	140	15

Note: Project costs are developed at a reconnaissance level and based on costs from 2000 through 2035.
Source: CH2M Hill, 1995.

The present rate ($1.1/1,000 gallons) includes charges for the Water Resources Management Program, the Sustainable Water Supply Program and the Facility Rehabilitation Program. The basic portion of the rate covering the O&M costs of the water supply is estimated at $0.816/1,000 gallons, and total consumption

in 1998 is estimated at 32 billion gallons. Therefore, total revenue from the basic portion of the rate is $26 million ($0.816 x 32 millions gallons). The total O & M costs including the SJC project are estimated at $41 million ($15 + $26 million). Assuming a 35 year-payment schedule for the project capital costs, annual payments will be $4 millions. Therefore, total annual revenue requirement that must come from the basic portion of the rate charge will be $45 million. This revenue is equivalent to 1.7 times the basic portion of the present revenue and therefore the water price for the project needs to increase by 1.7 times, that is, $1.4. If the Water Resources Management Program charge ($0.116), the Facility Rehabilitation Program charge ($0.0397), and the state water conservation charge ($0.0323) continue to be charged to the customers in the future, the total charge will be nearly $1.6 /1,000 gallons. This equals a 50 percent increase from the present rates.

If the water price is raised to this level, residential per capita consumption would be 122 gallons per day from both figure 3-3 and figure 3-4. Twenty-two percent of residential water use reduction is expected by the price increase by the SJC project. If all customer classes attain this reduction level, overall per capita water consumption will be 165 gpcd.

3.7 Evaluation of Sustainable Water Use Scenarios from Water Price Setting

1) The San Juan-Chama water direct use project must raise the water price level to $1.6/1,000 gallons. This water price level will decrease the residential water consumption to 122 gpcd or by 22 percent and overall consumption to 165 gpcd. The SJC project will contribute to Albuquerque's sustainable water use through the project's price setting.

2) With the high growth scenario, the water price level should be $3.2/1,000 gallons.

3) If reducing consumptive use (outdoor water use) helps expand supply water from the river, water prices could be set at cheaper levels. Water prices for the four scenarios by consumptive use percentage are analyzed for the high growth scenario. The scenario of 40 percent consumptive use raises overall residential water prices to $2.5/1,000 gallons. For the scenario of 35 percent consumptive use, overall residential price is about $2.0 and the winter, spring/fall and summer prices are $1.6, $1.9, and $2.3. This scenario lessens the water conservation burden through the year. Further, with the scenario of 30 percent consumptive use, water prices are set at more moderate price increases to attain the conservation goal, keeping the winter water prices at the present level.

4) To achieve the city's water conservation goals in 2004, overall residential water prices should be set at $1.4/1,000 gallons and one of the seasonal water price scenarios shown in table 3-15 should be implemented. Ten percent indoor and 27 percent outdoor reduction or 5 percent indoor and 33 percent outdoor reduction is preferable from the price setting.

The San Juan-Chama project requires a price increase of $1.6. The water prices for the conservation goal in 2004 are less than the water prices for the SJC project. The water prices for the project will reduce water consumption below the city's conservation goals.

3.8 Considerations for Albuquerque's Sustainable Water Rate Strategy

(1) Prioritization of rate objectives

There are many objectives to be considered in setting water rates. Conflicts and tradeoffs among these objectives are numerous and difficult to avoid. A well-designed rate structure can minimize some of the conflicts, but prioritization or balance of objectives is essential.

(2) Rate structure design for Albuquerque's sustainable water use (conservation incentive)

To manage Albuquerque's sustainable water use through conservation measures, the city needs to reduce water consumption and to manage the consumptive uses, or outdoor uses. To manage this water use, the city needs to control seasonal water consumption. Therefore, the important rate requirement for the city's sustainable water use is the incentives for outdoor or summer use reduction.

A high water rate level itself is important to encourage conservation. Even if the rate structure is decreasing or uniform, a high water rate level would encourage conservation.

Setting a low level for the lower block and off-peak period does not encourage water conservation for low or medium water volume users. In some cases, such rate structure increases water consumption for low and medium volume users. Water rates for low volume use and off-peak use should be set at an appropriate level.

A conservation-oriented rate structure can be designed to distribute the burden among customer groups. Seasonal, increasing-block, and excess-use rate structures are major types of the conservation-oriented rate structure that municipalities often use to reduce water consumption for high volume use, peak use, or outdoor water use. An excess-use rate structure is currently used by Albuquerque.

(3) Equity

Equity could be attained by using a cost-of-service principle. The rate structure should assure that each customer or customer class pays its proportionate share of the cost of providing service. To incorporate a cost-of-service principle into the city's rate design, cost-of-service analysis for the water supply system is necessary. However, using a cost-of-service makes water rates complicated. Also it is a difficult task to define equity for a variety of water use of customers.

The most important equity consideration is peak water users. Peak demand is considerably more expensive to meet, because it necessitates the construction and maintenance of seldom-used system capacity, infrastructure that is used only during the relatively brief periods of peak demand. Large volume customers who greatly contribute to peak demand should be charged at a higher price.

Similarly, according to the City of Albuquerque, the highest 10 percent household water consumption accounts for 27 percent of total residential water supplies, while the bottom 50 percent account for 24 percent of total residential water supplied. The middle 40 percent accounts for 49 percent of the total residential water. The highest 10 percent residents use 5 times as much water as the bottom 50 percent residents. The existence of this distinctive pattern of household water use raises an issue about the design of conservation-oriented water rates.

By incorporating some instruments such as an increasing-block structure in the rates, these conservation burdens can be distributed more equitably among water users.

(4) A stable and predictable revenue stream

Revenue instability is the most frequently cited problem with various forms of conservation rates. For stable and predictable revenue streams, the rate structure should be simple. A uniform rate structure stabilizes revenue. A seasonal uniform rate structure would also stabilizes revenue.

(5) Cost recovery and revenue neutral

Given the current rate level in Albuquerque, residential demand schedules estimated in this study are inelastic so that any increase in water rates raises the revenue over the present revenue. The conservation-oriented water rates tend to overcollect. Excess revenue should be used for water conservation programs and education efforts. Also it can be used for rebates for low volume customers.

(6) Affordable for low-income households

Some municipalities use lifeline volume allowance for no charge to make water bills affordable for low-income households who use low water volume. However, it is very difficult to establish lifeline allowance volumes.

In New Mexico, poorer households tend to be larger. Large families inevitably use relatively larger water volume because of larger household size even if per capita consumption of such households is small. Lifeline allowances need to consider household size. Increasing block rates would punish low-income large households as well as high water use customers.

In another example, the single professional maintains his water use below the lifeline in all months while the low-income large household greatly exceeds the lifeline amount (Mee, 1998).

Renwick and Archibald (1998) researched two communities located along the central coast of California. This research shows that low-income households are more price responsive than relatively wealthy households, reflecting the fact that their water bill typically constitutes a large share of the household budget. It indicates that pricing policies achieves a larger reduction in residential demand in lower income households than in higher income households. Conservation burden incurred by a water rates increase tends to be imposed on low-income households.

It is difficult selectively to relieve conservation burdens to low income families. Pricing policy should be incorporated with other income adjustment policies such as food stamp, or water stamp programs.

(7) Public acceptance

The single most important factor in determining the design of a conservation-oriented rate structure is not the amount that water use declines but rather the level of public acceptance it receive. If customers are not willing to accept the consequence of a conservation-oriented rate structure, the program will not succeed. The changes in Tucson's block rate structure from a moderate step of block rates to an aggressive block rate induced political crisis. Very expensive bills for high water consumers due to aggressive increasing-block steps in Tucson induced a recall movement of city council members. Uniform rates or a moderate increasing block steps can avoid such a crisis.

The rate structure should be simple enough so that consumers can understand the incentives and utility staff can easily explain. Tucson and Phoenix shifted to simpler rate structures and fewer blocks. For Tucson, the first conservation-oriented rates had seven blocks but now has three. Phoenix recently adopted a three-season (summer, winter, spring-fall), uniform commodity rate structure, with each season being four months.

Gradual rate increases are a good strategy to earn public acceptance.

(8) Commercial, industrial, and institutional customer classes

The other customer classes – commercial, industrial, and institutional – are considerably more heterogeneous than the single families. Therefore, the switchpoint of block rate structure should be based not on some absolute level of use that would be the same for all users within the class but rather on a relative level of use, namely usage in the winter.

Price elasticity varies substantially over customer classes and demand of other classes is more elastic than residential. To attain the city's conservation goals, therefore, water rates for other customer classes can be set at lower rates than residential rates.

(9) Inflation adjustment

Customers respond to real, not nominal prices. It is necessary to periodically increase water rate levels to adjust for inflation. An across-the-board increase is required. If inflation adjustment is not implemented, water consumption will increase again.

Part IV Sustainable Water Pricing Strategy

This section discusses conclusions and proposes a sustainable water pricing strategy under various population projections. First, the city's sustainable water use and conservation goals are summarized. Second, one of the appropriate water price schedules according to future population increase is proposed for the city's sustainable water use. In addition, the requirements for the acceptable water rate structures are suggested.

4.1 Sustainable Water Use

The requirement for sustainable water use is that the city uses only renewable water resources. The city has renewable surface water rights of 69,000 acre-feet per year. These water rights are titled for consumptive use. Currently, the city returns one half of the supplied water to the river through wastewater treatment plant. Therefore, the city can use about twice the titled water rights for supply, 138,000 acre-feet per year.

The city must still relay on ground water for some portion of its water supply. Without a ground water component, the city would need expensive water storage facilities and large and more costly treatment facilities to meet seasonal peak demands. The city will use pumping from the aquifer to meet seasonal peak demands and as drought reserve. However, the amount to be pumped should be limited within renewable portion of ground water. Renewable ground water is 50,000 acre-feet per year that is replenished from the streamflow. The renewable water resources are:

- 50,000 acre-feet/year ground water, and
- 88,000 acre-feet/year surface water.

To use surface water, the city needs water treatment facilities.

However, this measure alone can meet the city's increasing demand for only one or two decades depending on the growth scenario. The city requires additional measures for long-term supply. The most viable measure that the city can take for several decades is water conservation. Conserved water can be used for future growth and generations.

4.2 Water Conservation Goals

Water conservation helps the city's sustainable water use. In particular, selective reduction of consumptive or outdoor use is an effective conservation measure. The city can expand supply water by decreasing the consumptive use portion of its water supply because the water rights are for consumptive use, not absolute amount. If the city increases its return flow by reducing outdoor water use, the city can use more water for supply. Table 4-1 shows the maximum usable amount in 2060 within the present water rights by return flow percentage.

However, this strategy increases the intake water amount and reduces the river water in the reach between intake and sewer discharge points. The city could avoid a temporal large amount of intake by moving the discharge point to the far upstream of the city and pumping treated water (figure 4-1). This pumping may need only summer when river flow is small.

Table 4-1 Maximum usable water amount for supply in 2060 by return flow percentage (acre-feet/year)

	Return flow percentage (%) of total diverted water				
	50 %	55 %	60 %	65 %	70 %
Maximum usable water amount for supply	138,000	154,400	172,500	197,200	230,000
- Renewable ground water	50,000	50,000	50,000	50,000	50,000
- Surface water	88,000	104,000	122,500	147,200	180,000

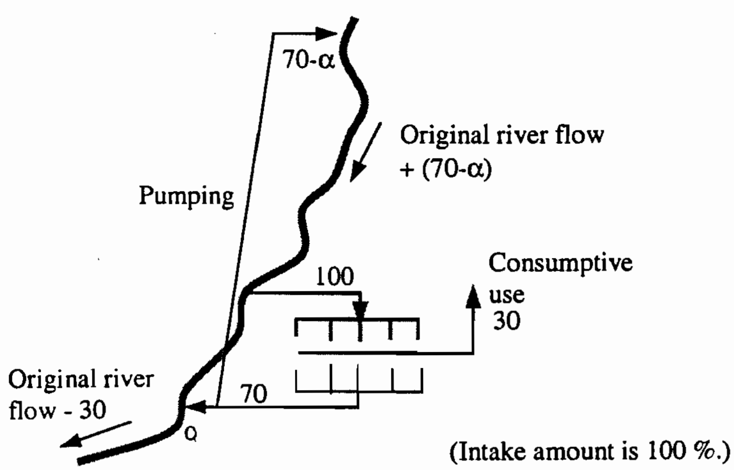


Figure 4-1 Potential solution for city's large intake (30 % consumptive use)

Using the maximum usable water amount, table 4-2 shows the estimated per capita consumption targets in 2060 by consumptive use and growth scenario. With the high growth scenario, if consumptive use is 50 percent, per capita water consumption will be 95 per day in 2060 to meet water demand within the present water rights. However, if consumptive use is 70 percent, per capita consumption will be 156 per day in 2060.

Table 4-2 Estimated per capita consumption target (gpcd) in 2060 within maximum usable water by consumptive use percentage and growth scenario

Growth Scenario	Population in 2060	Return flow percentage (%)				
		50	55	60	65	70
		Consumptive use (%)				
		50	45	40	35	30
Low	790,600	156	174	195	223	260
Medium	1,016,500	121	136	152	173	202
High	1,316,100	95	105	117	134	156

The city can take two conservation strategies:

- reduce overall per capita water consumption
- reduce outdoor per capita consumption.

The second strategy requires reducing current large amount of outdoor or summer use and thus managing seasonal water demand.

In addition, the city's current conservation program requires reducing water consumption to 175 gpcd by 2004 from the present 213 gpcd in 1998.

4.3 Water pricing Strategy for Sustainable Water Use

Pricing is central to demand management and adequate pricing can deliver signals of the real value of water to consumers. The sustainable water use requires conservation, especially reduction of outdoor or summer use. By appropriate water pricing, seasonal water demand is manageable and consumptive use can be selectively reduced.

To analyze water pricing, price-water demand schedules by season (winter, spring/fall, and summer) are estimated for Albuquerque. Using these demand schedules (figure 3-3 and figure 3-4), pricing policies for the conservation scenario are evaluated. Table 4-3 shows one of the most appropriate water pricing schedules according to the population increase for the sustainable water use. The table also includes projected per capita demand, residential per capita demand, total water diversion, projected consumptive use, maximum allowable water diversion and seasonal residential water demand distribution. Figure 4-2 shows projected seasonal residential per capita demand by population increase. Figure 4-3 shows seasonal residential water price projection by population increase. In analyzing the water price schedule, the city's conservation goals (175 gpcd) in 2004 and the water price increase incurred by the planned water treatment facilities are considered. In addition, the schedule considers gradual price increase.

To find appropriate price schedules, the following scheme is taken:

(1) set projected per capita consumption and consumptive use percentage and calculate percentage of overall per capita demand reduction;
(2) calculate total water use and maximum allowable diversion equivalent to the projected consumptive use;
(3) compare total water use and maximum allowable diversion and modify projected per capita and consumptive use percentage to fit total water use within the maximum allowable diversion;
(4) estimate residential per capita demand from the percentage of overall per capita reduction;
(5) project seasonal residential per capita demand;
(6) estimate seasonal water prices to achieve the projected residential per capita demand;
(7) start over if estimated water prices are considered not appropriate; and
(8) try this flow chart several times to find an appropriate water price schedule.

In the projected schedule, winter consumption is set at about 70 gpcd to set winter prices at about $1.6 per 1,000 gallons, the price level for the proposed water treatment plant. On the other hand, summer and spring/fall water prices are raised as population increases so that spring/fall and summer consumptions decrease to the target seasonal water demand. The strategy in this price schedule setting is to raise summer and spring/fall water prices. This strategy indicates that summer, outdoor, or consumptive water use is expensive. This sends a price signal that such use is expensive and is not sustainable use for Albuquerque. The price premium above the winter price is regarded as a sustainable water premium. As population increases, sustainability of water resource reduces. To keep sustainability, water prices for outdoor use must be kept increasing as population increases.

With a population of 1.3 million, equivalent to the population in 2060 for the high growth scenario, the water prices should be set at $1.7 for winter, $1.9 for spring and $2.35 for summer.

Even with this population level, still the city has some excess usable water because the projected total water use (diversion) in 2060 is less than the maximum allowable water diversion. Therefore, the city can accommodate more population beyond 2060. Furthermore, the city can grow more by further reducing consumptive use by raising water prices, particularly summer and spring/fall prices. Therefore, this pricing strategy will greatly contribute the City of Albuquerque's sustainable water use.

The projected demand shows that an additional water treatment plant is necessary once the population reaches between 800,000 and 900,000.

In addition to conservation objective, the water rates should stabilize utility revenue, and be accepted by public and thus include some consideration of equity. The following measures would meet these requirements:

- Seasonal rate structure
- Periodic inflation adjustment
- Simple moderately increasing block rate structure, if necessary
- Gradual change of the rate structure
- Excess-use rate structure for commercial, industrial, and institutional customer classes
- Adding spring/fall rates to increase demand controllability

4.4 Conclusions

In conclusion, the city needs additional water resources in near future. Such additional water resources cannot be sought from agriculture nor the aquifer but in the city. Conserved water is an additional precious water resource for the city. Appropriate water pricing plays an important role in water conservation, water use management, and the City of Albuquerque's sustainable water use.

Table 4-3 Projected seasonal water demand, total diversion, maximum usable diversion, consumptive use percentage and water price schedule by population increase

Service population (1,000)	477	510 - 540		800	900	1,000	1,100	1,200	1,300
Population growth scenario and target year	Present 1998	City's conservation goal in 2004	All scenarios in 2005	Low growth in 2060		Medium growth in 2060			High growth in 2060
Projected per capita production (gpcd)	211	175	165	155	150	145	140	135	130
Per capita reduction from 1998 (%)	-	17	22	27	29	31	34	36	38
Residential per capita demand (gpcd)	156	129	126	119	115	111	107	103	99
Projected total diversion (acre-feet/year)	114,100	102,000	96,000	139,000	151,000	162,000	172,000	181,000	189,000
- Surface water	0	0	94,000	94,000	101,000	112,000	122,000	131,000	139,000
- Ground water	114,100	102,000	2,000	45,000	50,000	50,000	50,000	50,000	50,000
Target consumptive use (%)	51	45 - 50	45- 50	45	45	40	40	35	35
Max. allowable diversion (acre-feet/year)	138,000	138,000	138,000	154,000	154,000	172,500	172,500	197,200	197,200
Projected seasonal distribution of residential per capita consumption									
Winter	91	80	77	73	70	74	71	75	72
Spring/fall	146	129	126	119	115	111	107	103	99
Summer	232	179	175	165	159	148	143	132	127
Total	156	129	126	119	115	111	107	103	99
Estimated residential water price (1998 prices)									
Winter	1.07	1.35	1.5	1.6	1.6	1.6	1.7	1.7	1.7
Spring/fall	1.07	1.35	1.5	1.6	1.6	1.6	1.7	1.8	1.9
Summer	1.07+α	1.6	1.6	1.80	1.85	2.0	2.1	2.27	2.35

A planned new water treatment plant (Capacity: 94,000 acre-feet/year) ↑

Another new water treatment plant ↑

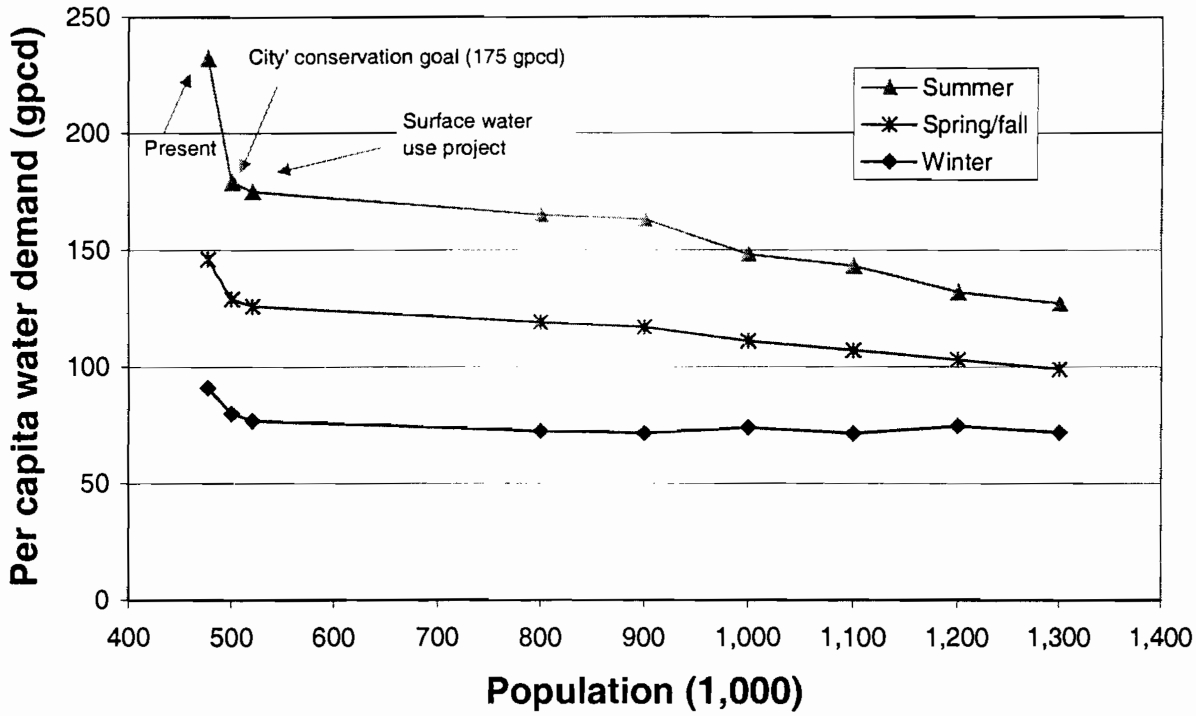


Figure 4-2 Projected seasonal residential per capita demand by population increase

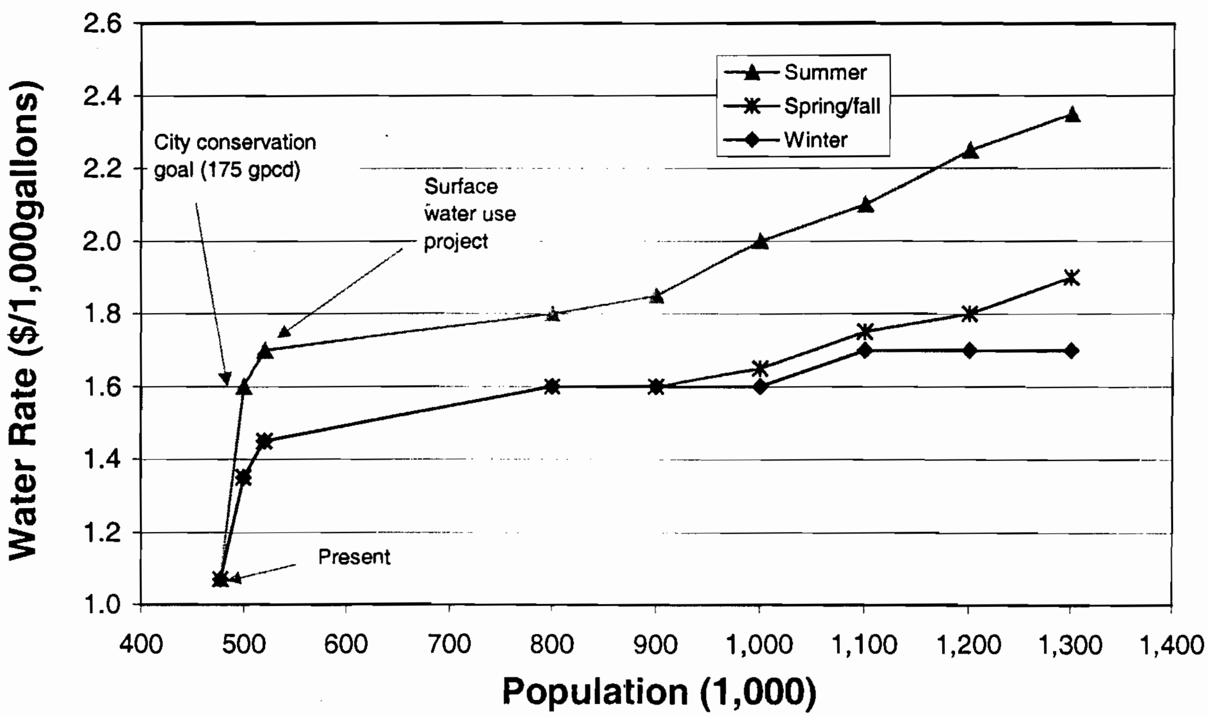


Figure 4-3 Seasonal water price projection by population increase

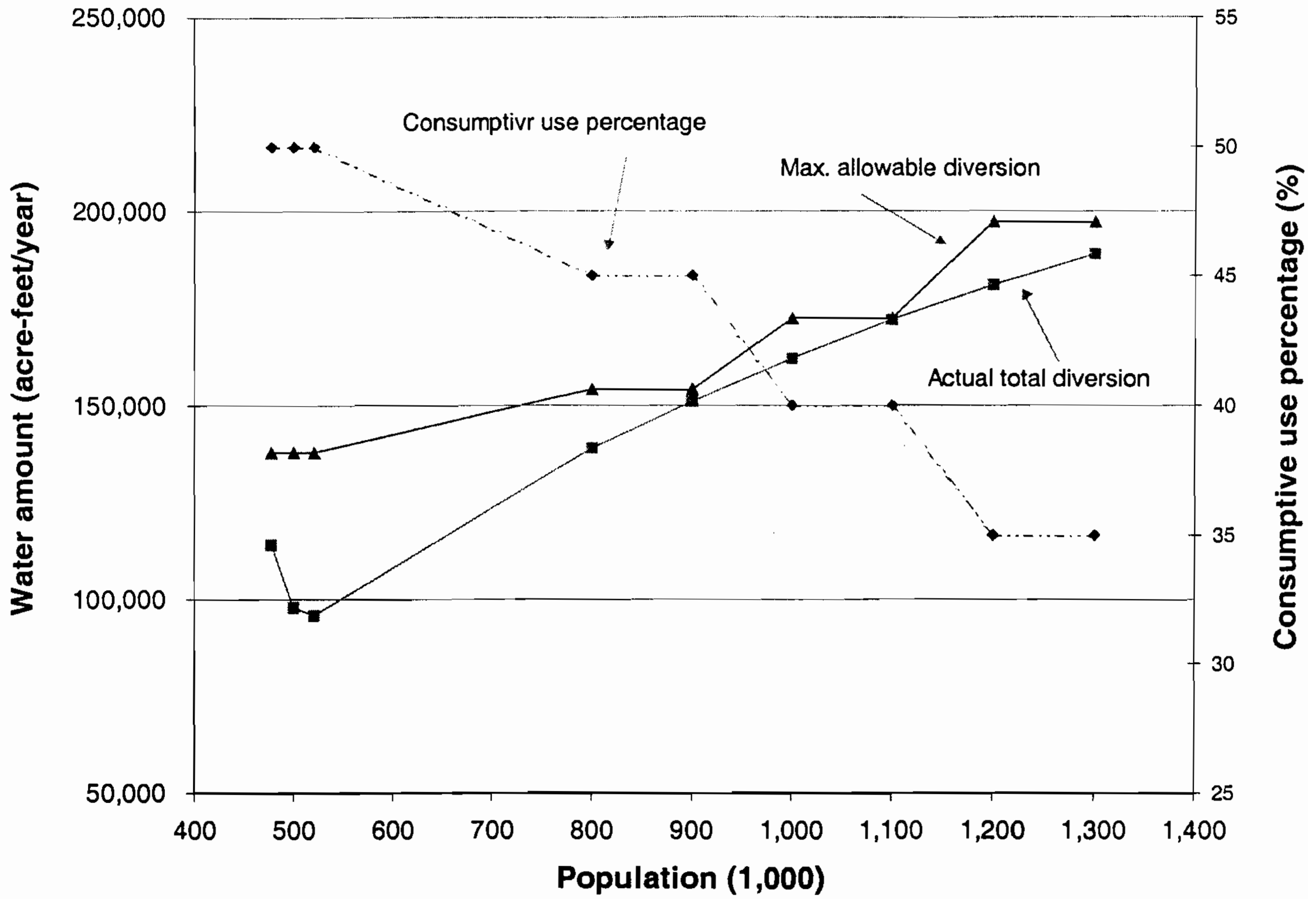


Figure 4-4 Projected total water diversion, maximum allowable diversion, and consumptive use percentage

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Appendix A Analysis of potential water saving for Albuquerque

A-1. Analysis of potential water savings

(1) Residential

Residential water use consists of two uses: indoor and outdoor uses. Indoor use means the nonconsumptive use of water for general sanitary and cooking purposes, while outdoor use means the consumptive use of water for watering lawns and gardens, filling swimming pools, and for feeding evaporative coolers.

Indoor use

Cotter and Croft (1974) researched indoor water use at selected subdivisions in Albuquerque and Las Cruces during the period 1971-73. The residences monitored in this study were predominantly middle income family homes served by municipal water and sewage systems. Indoor water use for all of the homes included in the study averaged 79 gpcd. It is frequently mentioned that off-peak water use represents indoor water use. Off-peak water use of single families over the city was 98 gpcd in December 1994, before adoption of a conservation program in 1995 and 92 gpcd in January 1998. This number is slightly larger than that of Cotter and Croft's research. It indicates that a household uses a little water for outdoor even in winter or that water consumption behavior has slightly changed since the early 1970s.

Table A-1 shows potential water savings indoor. If a household uses efficient fixtures and recycled evaporative cooling or no water-use cooling equipment, the household can reduce indoor water consumption to 35 gpcd. The 1994 residential per capita consumption in Albuquerque was 98 per day. The city's residential customers can reduce water indoor use by 63 percent.

Table A-1 Per capita consumption of efficient and conventional fixtures and evaporative cooling

	Per capita consumption
Efficient indoor fixtures	35.2 gpcd
Conventional indoor low-flow fixtures	73.4 gpcd
Evaporative cooling	20.0 gpcd

Source: Beecher et al. (1994), Brown and Caldwell (1984)

Note: fixtures include toilets, showerhead, faucets, washing machine, and dishwasher.

Outdoor use

Outdoor water use varies widely depending upon the climate. In dry areas like Albuquerque, outdoor water use generally account for 50 percent to 70 percent of the total residential water use (Wilson and Lucero, 1997). According to the City of Albuquerque's metered water record, average peak water use of single families over the city was 253 gpcd in July 1998. In a peak month, an average household uses about 3 times more than in the off-peak month. Assuming that annual outdoor use is estimated by subtracting water consumption in the least use month from total annual consumption, outdoor water use accounts for 48 percent (92 gpcd) of total residential water use (191 gpcd) in 1994.

Most of outdoor water is used for landscaping. The California Department of Water Resources estimated potential water saving for outdoor use in 1989. It indicated that the household can save 50 percent of water use by using high efficient landscaping. Albuquerque's conservation education material, "How to Save Water At Home (1996)", demonstrates that the water wasteful yard, the so-called Midwest yard, uses 88,000 gallons per year but the water-wise yard, the so-called Southwestern yard, uses 29,000 gallons. Assuming 2.5 persons per household, the Midwest yard and Southwest yard use 96 gpcd and 32 gpcd, respectively.

In arid climate and water scarce areas, outdoor water use in an average household can be reduced to less than 32 gpcd, or water consumption of the Southwest yard; about 60 percent of outdoor water use can be saved.

(2) Commercial

Hauck (no data) studied water savings for a water audit of Albuquerque Manor retirement home (commercial customer). Albuquerque Manor used 21 million gallons of water in 1996. After the water audit for its facility, he estimated that water could be saved by 57 percent in the facility including 58 % saving for irrigation use. The details of the water savings are shown in table A-2.

Table A-2 Estimated water savings and fraction of total use in Albuquerque Manor retirement home

Water use sub-division	Estimated water used in 1996 (1000 gallons)	Estimated water saved by conservation program (1000 gals/year)	Water conservation measures
Toilets	4,750	2,580	Ultra low flow toilets
Sinks	2,250	1,335	Install low flow faucets
Showers	1,500	NA	NA
Dishwasher	250	50	Optimize use of Dishwasher
Garbage disposals	800	800	Discontinue using GD
Ice machines	1,000	850	Air cooled machine retrofit
Washing machines	7,500	5,250	Laundry re-use/recycle
Evaporative coolers	250	NA	NA
Irrigation use	1,410	814	Improve irrigation efficiency
Miscellaneous	930	NA	NA
Total	20,715	11,679	

Source: Hauck (no date)

c. Industrial

The California Department of Water Resources estimated in 1989 that potential industrial water saving is 10 to 20 percent. However, table A-3 shows more potential savings in industry sector. The mean water saving of selected companies in San Jose is 53 percent in table A-3.

Table A-3 San Jose, California: Industrial Water Conservation

Company	Before conservation (1000 m^3/year)	After conservation (1000 m^3/year)	Water saving (%)
IBM	420	42	90
California Paperboard Corp.	2,473	689	72
Gangi Bros. Food Processing	568	212	63
Hewlett-Packard	87	42	52
Advanced Micro Devices	2,098	1,318	37
Tandem Computers	125	87	30
Dyna-Craft Metal Finishing	193	140	27

Source: Table 11-1, Postal. 1997.

A-2. Potential water savings for Albuquerque

For sustainable water use of the City of Albuquerque, saving outdoor, consumptive-use water is the important objective. Nonconsumptive water use flows into the sewer where it is treated and used again and returned to the river where it is originally diverted.

It can be identified that all uses that do not return water to the system through sewer flows as outdoor use. The flow of sewage into sewage treatment plant usually shows almost no seasonal variation, indicating that indoor use varies little over the course of the year. Water deliveries are lowest in December, January, or February, the three months when very little water is used on gardens or for cooling, suggesting that the amount of water used indoors year-round is equal to deliveries in the least delivery month. Thus, any water delivered in excess of the least delivery month quantities in the other months of the year is used outdoors.

Table A-4 shows the estimated outdoor and indoor water consumption per capita by consumer class in 1994 before Albuquerque adopted its conservation program. In the estimation, it is assumed that indoor use equals water consumption in the least delivery month in 1994, that is, December. Outdoor consumption is calculated by subtracting the estimated indoor water use from annual average water consumption. In 1994, about half of total water produced is used for outdoor water.

Table A-4 Estimated outdoor and indoor per capita water consumption by consumer class in 1994

	Residential	Resident. (total)	Commerc.	Industrial	Institut.	Total consump.	Total with loss
Indoor use (gpcd)	97.9	64.4	42.4	5.0	7.2	118.9	118.9
Outdoor use (gpcd)	92.7	60.7	19.2	0.3	13.4	93.7	126.2
Total (gpcd)	190.6	125.1	61.6	5.3	20.6	212.6	245.1
% of indoor use	51.4	51.5	68.8	94.3	35.0	55.9	48.5

Note: Residential per capita consumption is calculated from residential population but resident. (total) per capita consumption is calculated from total population.

Loss is 12 percent of total indoor and outdoor consumption.

Potential water savings for Albuquerque are estimated in table A-5. Table A-6 shows estimated potential water consumption with water conservation measures using water consumption in 1994 before Albuquerque adopted a water conservation program. Albuquerque can reduce total water production to 97 gpcd and residential water consumption to 76 gpcd.

Table A-5 Potential water savings by consumer class and indoor and outdoor use for Albuquerque

(%)

	Residential	Commercial	Industrial	Institutional
Indoor use	63	57	53	57
Outdoor use	60	60	60	60

Note: These percentage should be applied to water use prior to the adoption of a conservation program of Albuquerque.

Table A-6 Estimated potential per capita water consumption with conservation (gpcd)

	Residential	Resident. (total)	Commer.	Industrial	Institut.	Total consump.	Total with loss
Indoor use	36.1	25.8	18.2	2.4	3.1	49.5	49.5
Outdoor use	37.1	24.3	7.7	0.2	5.4	37.6	47.7
Total	76.2	50.1	25.9	2.6	8.8	87.1	96.8

Note: Residential per capita consumption is calculated from residential population but resident. (total) per capita consumption is calculated from total population.
Loss is 10 percent of total water consumption.
Water consumption in 1994 is used for baseline consumption because Albuquerque started water conservation program in 1995.

Appendix B Conservation-Oriented Water Rate Structures

(1) Uniform rates

This rate-setting approach involves the determination of a single quantity charge for all customers without any recognition given to class differences in demands or seasonal cost differentials. Uniform rates are based on the assumption that every unit of water is of equal cost and value.

Advantages:

- Financial sufficiency – A system of uniform rates will generate a relatively dependable stream of revenues.
- Rates are based on traditional cost-of-service practice – This approach determines rates based on the estimated cost of providing service to the customer.
- Simplicity – This approach is easily understood by customers.

Disadvantages:

- Less conservation-oriented – This approach is not as conservation-oriented as the other alternatives being considered because all units are priced at the same level regardless of class, peaking ratios, or time (season) of use.
- Equity – Although uniform rates are generally perceived to be fair by the consumer, one could argue that the uniform rate structure does not consider class or individual customer peaking differences and therefore does not allocate costs based on the demands placed upon the system.

(2) Increasing-block rates

The primary objective of establishing increasing-block rates is to reduce water use, particularly from the large volume customers who are charged progressively higher rates. The reasons for targeting reductions in use by large volume customers under this design include potentially greater price elasticity responsiveness, cost-effectiveness of significant identifiable reductions, and the perceived ability of large customers to internalize costs through economic decision making.

Under this approach, the structure would be applied separately to each customer class. Rates under this method can be better designed to encourage large volume customers to reduce usage by setting the usage

block(s) to reflect the unique characteristics of each class.

An increasing block rate schedule is economically efficient if it can be shown that large consumers have higher peak to average rations than small customers. For example, if a large consumer's peak hourly usage is three times the average hourly usage and a small customer's peak hourly usage is only twice the average hourly usage, then the large consumer is placing more of a burden (per gallon used) on the system. In such a case it would be economically efficient for the larger customer to pay a higher price for water through an inclining block rate schedule.

Advantages:

- Rates are based on the indicated cost-of-service – If large volume customers have relatively high peak-to-average ratios and residential customers have significant variations in seasonal patterns, the increasing-block rate design may correspond more directly to cost.
- Conservation oriented – Increasing block rates are primarily intended to encourage water use reductions, particularly from large volume customers as a class or large volume customers within a class. (Increasing usage by small users because of corresponding bill reductions may partially offset the large customer volume reductions.)

Disadvantages:

- Financial Sufficiency – Increasing block rates can result in revenue erosion as large users seek alternatives and can cause instability because rates may not precisely correspond to the utility's costs.
- Equity – It is difficult to design an increasing block schedule that accurately reflects cost causation patterns of the many and varied customers in a given class and may therefore be considered inequitable.
- Customer impacts – The adverse impact of increasing block rates on large volume customers is an essential consideration.
- Diversity of customer usage pattern – Since the approach is based on the peaking characteristics of each customer class, these characteristics are key to the resulting rates produced through the cost of service. The rates do not reflect each customer's different demand characteristics, but rather are estimates of class demand factors based on the review of monthly usage data, limited historical customer class sampling, and academic research.

(3) Seasonal rates

This rate-setting approach assesses a quantity charge which varies by season. The nonseasonal rate is a lower rate which represents the base costs associated with the water system. The seasonal rate adds to this cost the cost of meeting peaking requirements of the system. The essential issues with respect to considering a seasonal rate are: (1) the extent to which the utility consistently exhibits readily identifiable seasonal demands significantly greater than average; and (2) the presence of relatively significant and easily identifiable cost differentials for meeting peak demands exists as compared to the off-peak demands.

Advantages:

- Rates are based on cost-of-service – This approach determines rates based on the estimated cost of providing service to customers using traditional cost allocation principles.
- Equity to customer classes – A seasonal rate structure improves equity (when compared to the uniform approach) because the customers who cause the higher costs to meet peak seasonal demands are charged accordingly.
- Conservation oriented – If properly designed and implemented, seasonal rates convey a signal to the consumer concerning the importance of efficient utilization of resources. Because outdoor use is the most price elastic type of water use, seasonal pricing can be an effective tool in promoting water conservation.

Disadvantages:

- Financial Sufficiency – Seasonal rates are generally not as stable as uniform rates. Depending on the extent of the peak-seasonal differential, the level of rate increase being imposed, and customer response, seasonal rates can result in a majority of the utility's revenues being generated in the seasonal months.
- Customer impact – One of the underlying concepts of seasonal rates is that there is no attempt to distinguish, via price, between the type of water use occurring during the seasonal period, i.e., all water use in the seasonal period is charged at the higher seasonal rate. So while customers with higher peak to average usage ratios contribute more to the recovery of extra of peaking costs, all customers

pay the higher rates for all usage in the seasonal period. This can have a negative impact on customers using very little water for discretionary purposes. These customers tend to have fewer opportunities to reduce water demands.

(4) Excess use rates

This structure is another approach for implementing seasonal rates but amounts to a surcharge for all consumption in excess of a customer's nonpeak use. The quantity charge calculated under this approach is based on an established percentage of each customer's average water consumption (AWC). The first block rate would be charged for usage up to some percent of AWC. This generally corresponds to base level or non-discretionary water usage and can be defined in a community specific manner. A second and/or third higher charge would be assessed for water usage above certain percentages of AWC, possibly corresponding to seasonal and marginal cost concepts. For purposes of this analysis and for determining AWC, the period of November through February was selected because it represented the four-month period where system-wide water use was at its lower point.

Advantages:

- Rates are based on the indicated cost-of-service – This approach calculates rates based on the cost of providing different levels of service, as opposed to costs by class. Block one or base usage reflects the cost of meeting basic water use demands, primarily indoor/domestic use. The second block is based on the costs of meeting peak demands or seasonal usage, while the third block can be related to marginal cost pricing principles.
- Conservation oriented – The rate structure allows individual customers to determine their own average water usage and then assesses charges based on this level of use as compared to usage during other periods. The rates are structured to provide disincentives to water usage during peak demand periods; rates reflect the cost of meeting differing demand levels.
- Equitable to individual customers – Since the rate and pricing approach results in a total water bill which is reflective of each individual customer's average and peak demand characteristics, this approach is deemed to be very equitable in terms of the price reflecting the cost to serve. The approach does not rely on assumptions concerning customer class peaking characteristics and is therefore considered fair and equitable to each customer.

Disadvantages:

- Customer impact differences – Customer impacts are based on the amount of water consumed relative to each customer's AWC or percent thereof. This can result in widely varying impacts among customers in the same class. A customer with relatively low water usage (during the November to February time period) and a fairly high peak in the summertime will receive a higher percentage increase than a customer with relatively steady usage at a high level throughout the year.
- There is no disincentive to the customer not to over-use water during the winter averaging period to increases their allotment for the irrigation system.

(5) Feebate

Collinge (1996) proposed a revenue-neutral "feebate" system to help utilities achieve water conservation goals. The system consists of three parts: (1) a flat rate structure designed to achieve revenue neutrality while recovering the utility's fixed and average variable costs; (2) an entitlement (allotment) program providing a baseline amount of water to each customer at the standard rate based on variables independent of ongoing usage, summing to the utility's intended supply amount; and (3) feebates in the forms of offering penalties assessed to customers using water above their allotment and rebates to customers using water below their allotment.

Allotments for any given month will depend on projected availability of water for that month. The feebates will also be changeable, because it will be adjusted up or down monthly to approximately meet the water use target. The feebate's value will depend on the elasticity of demand for water and on the quantity reduction needed to meet the target.

This approach gives low-volume users the same incentives to conserve as high-volume users. The system represents an opportunity for the water utility to simultaneously meet goals of revenue neutrality, efficiency, and equity.