Urban Wastewater and Economic Potential for Cotton Growers and Taxpayers

Teddy J. Goldammer, Paul N. Wilson, James C. Wade

ABSTRACT

Wastewater from urban areas can be a valuable source of water and plant nutrients for neighboring agricultural producers, particularly in arid regions of the world. A derived effluent demand function for agricultural producers near Tucson, Arizona, reveals a potential demand of 11,000 acre-feet under present price and delivery system conditions. In this case, wastewater could be exchanged for ground water and both the urban and rural areas would gain.

INTRODUCTION

Water conservation and distribution programs for agricultural regions near urban areas often have ignored a potentially valuable water resource: secondarily-treated effluent or wastewater. Traditionally, urban wastewater was considered to be a nuisance with few productive uses. Emphasis was placed on least-cost disposal methods rather than on potential alternative uses. However, since the passage of the Federal Water Pollution Control Act of 1972 and the Federal Clean Water Act of 1977, wastewater reclamation and effluent reuse have been encouraged.

Effluent is a joint input in the agricultural production process. Both water and fertilizer are supplied to the crop when it is irrigated with treated wastewater. Therefore the effluent serves as a source of water and as a substitute for commercial fertilizers. Sewage effluent may have a higher value in agricultural production than in present alternative methods of disposal.

WASTEWATER DEMAND: THE CASE OF TUCSON, ARIZONA

Adequate supplies of water are critical for survival in a desert environment. Tucson, Arizona, is a desert city of approximately 600,000 people; estimates are that the metropolitan area of Tucson will grow to 1.8 million people by the year 2035. Tucson depends solely on ground water for its water supply. Ground water is pumped from wells with pumping lifts of up to 450 feet. In 1992, Tucson should begin receiving its share of Central Arizona Project (CAP) surface water through the CAP aqueduct. This surface water supply from the Colorado River will supplement, but not replace, the ground water sources.

In the late 1960s, Tucson Water, the municipal water authority, realized that additional supplies of water would be needed to meet the future water demands of a growing metropolitan area. This realization was based strictly on physical relationships, rather than on potential economic scarcity.

In 1968, Tucson began pumping ground water in Avra Valley, an adjacent agricultural area, to supplement its water supplies. In 1971, Tucson was ordered by the court to purchase farmland in Avra Valley from willing sellers in order to claim water rights for municipal use. By law, the city can withdraw the amount of water which was formerly pumped for agricultural purposes, minus any return flows. Presently, the City of Tucson is pumping approximately 5,000 to 6,000 acre-feet of its 60,000 acre-foot water right on 20,000 acres of retired farmland.

Tucson produced approximately 53,000 acre-feet of wastewater effluent in 1985. Raw sewage is treated at two wastewater treatment plants bordering the normally dry Santa Cruz River, which has a

natural northwest drainage. Only ten percent of this wastewater is reused directly by the City of Tucson or Pima County, with the remainder discharged into the Santa Cruz River. Direct reuse is limited to golf courses, some parks and 3,500 acre-feet that is allocated to the Cortaro-Marana Irrigation District, an agricultural area northwest of Tucson.

Table 1 summarizes Tucson's projected net wastewater effluent quantities until the year 2030. The Tohono O'Odham settlement refers to the Southern Arizona Water Rights Act which mandates the City of Tucson to allocate 30,600 acre-feet of wastewater to the Tohono O'Odham Indian Community in 1992. At present, the Indian community has no plans on how to use the effluent on their reservation.

The Cortaro-Marana Irrigation District receives a constant allotment of 3,500 acre-feet over the given planning period. The City of Tucson plans on using a substantial quantity of effluent in landscape irrigation projects such as parks, school yards and golf courses.

It is important to note that, in 1985, only a few thousand acre feet of wastewater were used in landscape irrigation. A problem with direct reuse in unrestricted urban areas is that the effluent must be tertiarily treated substantially increasing the price of the wastewater.

The Cortaro-Marana Irrigation District (CMID) is located 14 miles northwest of Tucson. The CMID, which lies in the floodplains and major tributaries of the Santa Cruz river, consists of 14,700 acres, of which approximately 12,000 acres are irrigated agricultural land. The crops grown in the CMID include upland and Pima cotton, spring and fall lettuce, alfalfa, milo, barley, wheat and pecans, with upland cotton being the principal crop.

The CMID's water supply is from river subflow and percolating ground water. The district has an appropriative water right to pump 29,100 acre-feet annually of the Santa Cruz River's underflow. Other ground water is pumped from a 300 foot depth in the Marana area. Water is distributed in open, concrete-lined canals. The CMID uses approximately 45,000 acre-feet of water per year.

A linear-programming model of the CMID was developed to estimate the potential demand for wastewater effluent in this agricultural region. The model was constructed to maximize returns above cash costs subject to relevant agronomic and water supply and demand constraints. The cropping pattern was assumed to be the average number of acres for the 1980-1984 period for upland and Pima cotton, barley, milo, wheat and alfalfa. Input coefficients were obtained from published crop budgets and research reports. Nitrogen and phosphorous in the wastewater was allowed to substitute for commerically purchased fertilizer. Wastewater was a substitute for ground water within the bounds of the fertilizer and water blending constraints. By parametrically varying the price of wastewater effluent, holding the prices of all other inputs constant, a derived demand for wastewater was estimated.

Two scenarios were evaluated. The first assumed that the CMID could accept delivery of 18,600 acre-feet of wastewater at a price of $13.17 per acre-foot. This price represents the current $5.00 charge for effluent and an additional $8.17 per acre-foot to renovate and expand the CMID's water distribution system. In addition, it was assumed that the CMID would only demand effluent in quantities which would not create an oversupply of nitrogen for the crops. Under these assumptions, the CMID demands 11,385 acre-feet of wastewater up to a price of $20.00 which is the cost of ground water (Figure 1). As the wastewater price increases above the ground water price, effluent is still demanded because of the fertilizer value of the wastewater. The net benefits to the agricultural producers in scenario one are $111,000. These benefits can be attributed to a lower water price and commercial fertilizer savings.

The second scenario assumes a blending ratio of 40 percent in the summer months and 90 percent in the winter months, based on the experience of the Buckeye Irrigation District in Phoenix, Arizona. The blending assumption is more realistic because a single distribution system is incapable of delivering irrigation water of varying ground-wastewater blends depending on the crop. Hence the blending ratio cannot be varied for each crop and some crops will receive more nitrogen than is agronomically recommended. Under these conditions, the CMID uses 18,600 acre-feet of wastewater at price equal to or less than $20.00. Additional effluent would be demanded if the CMID distribution system were modified to carry more water.

WATER MARKET POTENTIAL?

It can be shown that by trading effluent for ground water, the City of Tucson could save more than $1 million per year versus purchasing agricultural land in Avra Valley (Table 2). The assumptions are that the City of Tucson trades 18,000 acre feet of wastewater to the CMID for ground water. The exchange ratio is based on the relative prices of effluent, assumed to be $15.00 acre foot, and the marginal cost of pumping gound water in the CMID of $45.00 or $20.00 per acre foot. For example, if CMID ground water is priced at $20.00 per acre foot, CMID could trade 13,500 acre feet of ground water for 18,000 acre feet of effluent and the city of Tucson would save $1,761,750 per year with Avra Valley water priced at $0.30 per 100 cubic feet. A conservative estimate of the current cost of Avra Valley water is $.32 per 100 ft^3. Therefore, by allocating water to its most appropriate and productive use, both the City of Tucson and the CMID gain economically.

However, it would be naive to assume that a market for effluent will develop because there is an economic justification for water transfers. The first obstacle for more efficient water management is the desire by farmers to receive "inexpensive" effluent. Since in the case of Tucson, the city is "losing" the effluent by discharging it into the river, any price above the current price of $5.00 per acre-foot is perceived by the producer as windfall for the city. In bargaining with the city, the farmer will attempt to reduce the city's gain as a result of any transfer. This bargaining position can threaten the prospects of any contractual agreement.

The urban water authority is the second obstacle facing water transfer options. City water managers must guarantee their constituencies water supplies over long planning horizons (e.g. 50 years). When water supply is uncertain due to weather, demand and institutional concerns, the water manager uses water reserves to manage supply risk rather than rely on a water market. In the case of Tucson, retired agricultural land in Avra Valley acts as a water bank and reduces supply uncertainty.

A second reason the urban water authorities may block the development of water transfers is the engineering emphasis of most water departments. Revealed preferences by these decision makers indicates support for the construction of pipelines, aqueducts, and recharge projects to manage water supplies efficiently. Economic considerations, other than construction costs, often play a minor role in the evaluation of supply alternatives. Thirdly, the urban water authority may view the agricultural region as a competitor for a scarce resource. Municipal policy may discourage any effort to perpetuate agricultural production in the region or increase agricultural land values.

State-enforced water laws are a third constraint to the development of water exchanges. Transfers of surface (e.g. effluent) water and ground water between water management areas or districts may be prohibited under current regulations. Therefore, cities and agricultural producers willing to cooperate would have to lobby for changes in the state's water code to implement water exchanges. The economic incentives to initiate this lobbying effort, however, may be in the best interests of both the urban water authority and the adjacent agricultural region.

Table 1: Projected Net Wastewater Effluent in Acre-Feet, Tucson, Arizona

Year	*Projected Effluent*	*Tohono O'Odham Settlement*	*Marana Allotment*	*Cortaro-Landscape Irrigation*	*Potential Demand of Net Effluent*
1990	61,000	30,600	3,500	23,000	3,900
2000	79,000	30,600	3,500	28,000	16,900
2010	101,000	30,600	3,500	33,000	33,900
2015	111,000	30,600	3,500	35,500	41,400
2020	122,000	30,600	3,500	38,000	49,900
2025	133,000	30,600	3,500	40,500	58,400
2030	144,000	30,600	3,500	43,000	66,900

Source: CH2M-Hill/Rubel and Hager, 1983.

Table 2: Annual Benefits Accruing to the Tucson Water Authority by Trading 18,000 Acre Feet of Wastewater for Alternative Quantities of Ground Water.

Avra Valley Water Cost (per 100 ft3)1	Ground Water Traded (Acre Feet)2	
	5,940	13,500
	Cost Savings($)	
$0.30	775,170	1,761,750
$0.40	1,033,560	2,349,000
$0.50	1,291,950	2,936,250

1. Cost of land and pumping. Does not include land maintenance costs or costs of the distribution system to get the rural water into the municipality.

2. Determined by the effluent/ground water price ratio where the marginal cost of pumping ground water is $45 and $20. These costs represent the marginal cost of pumping in the Marana area and the cost of CMID water to the growers respectively.

ADDITIONAL LITERATURE

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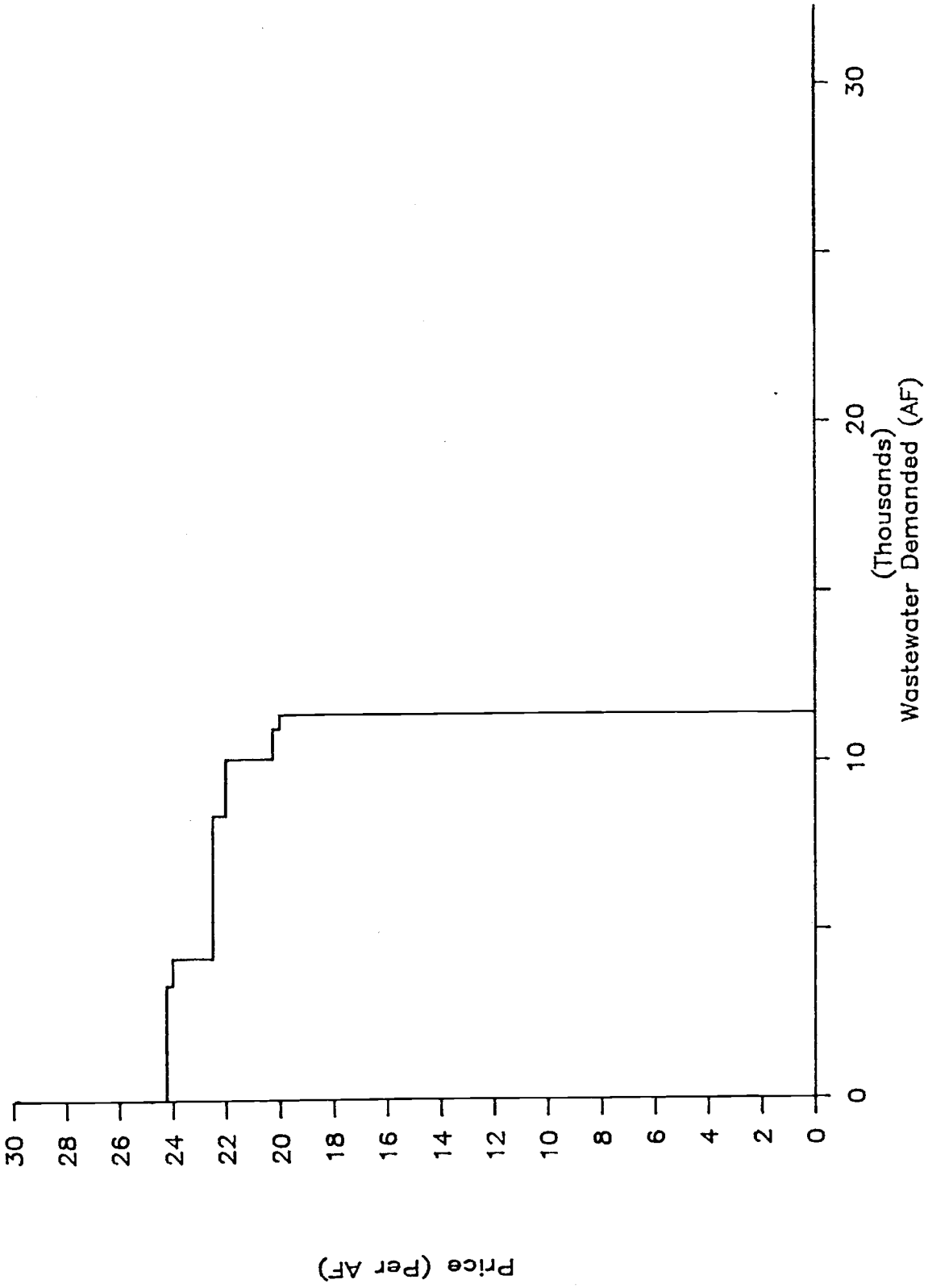

Figure 1: Derived Demand for Wastewater Under Agronomic and Supply Constraints, CMID, 1986.