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Market allocation of agricultural water resources in the Salinas River Valley

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MARKET ALLOCATION OF AGRICULTURAL WATER RESOURCES IN THE SALINAS RIVER VALLEY

by

John P. Neagley and Robert T. O'Brien, Jr.

December 1990

Thesis Advisor: T. P. Moore

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Market Allocation of Agricultural Water Resources in the Salinas River Valley

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ABSTRACT

The current drought conditions that the Central California coast has been facing and the increasing threat of saltwater intrusion have forced the Salinas Valley to consider alternatives that provide for conserving and allocating limited groundwater resources. Currently, groundwater resources are treated as a common pool resource where there are no clearly defined property rights for groundwater and there is no regulation of use. This thesis examines the question of how to implement a market system for groundwater in the Salinas Valley. The study compares a free-market approach of water allocation to other centralized water management practices. This study found that, in theory, the establishment of clearly defined groundwater rights and a free market system for groundwater would be an efficient method to allocate agricultural groundwater resources.

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I. INTRODUCTION

Water conservation, water rights, and an efficient allocation of water resources are now central issues in California public policy. These issues are of particular importance in the Salinas Valley, where agriculture has undergone extensive development since the 1920s and is the primary user of water resources. In the Salinas Valley, irrigation water for crop production is obtained almost exclusively from local wells.

> A 1983 water-use survey, by the United States Geological Survey, indicated that mean agricultural water use in the study area (Salinas Valley) was 512,200 acre-ft[1]/year or 91.5 percent of ground-water outflow in the Salinas Valley." [Ref. 1:p. 19]

Because of the proximity of the area to the ocean, large rates of ground-water pumping cause the inflow of seawater into the coastal aquifers. The increased threat of saltwater intrusion and the current drought condition that the central coast has been facing force the Salinas Valley to consider alternatives that provide for conserving and allocating limited ground-water resources.

Economists recognize that the free market provides the most efficient allocation of scarce resources by providing economic incentives to the users [Ref. 2:pp. 64–65]. This thesis examines the question of how to implement a free market system for agricultural groundwater in the Salinas Valley Water District and forecasts the effects this market allocation

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[1]An acre-foot is equal to approximately 333,333 gallons.

would have on water conservation and the allocation of water resources. Specifically, the thesis will cover three major areas: a discussion of the current drought conditions in the Salinas Valley and the importance of the agricultural community to the state and local economy, a brief description of groundwater law and models to privatize groundwater, and a comparison of a free market system of allocating groundwater resources to both a tax system where groundwater is taxed as it is extracted and a maximum standard system where a limit is set on the amount of water that can be extracted.

A. OVERVIEW

The people of the United States have been blessed with an abundance of natural resources, to include a seemingly never-ending supply of fresh water. According to Eugene W. Weber, formerly Chief of Civil Works Planning and Deputy Director of Civil Works for Policy, Office of the Chief of Engineers, Department of the Army, in his review of water usage in the United States:

> Most of the nation was endowed with a generous supply of this vital resource. For many years it was not necessary to plan how to use it but merely to exploit it and reap the blessings of the endowment. From the beginning of our history as a nation, there have been prophetic warnings at infrequent intervals of need for planning ahead. Most of these warnings went unheeded locally and nationally until recent years [mid-1970s]. [Ref. 3:p. 6]

Today, limitations on the water supply for household, agricultural, and industrial use in the United States are a growing problem. Two major threats to existing water supplies are pollution, which reduces the amount of usable water, and overdrafting, which means that demand on a water source is greater than what nature is capable of replenishing. Pollution and overdrafting contribute to declining groundwater levels, which threaten local economies that depend on water from underground sources. Therefore, the planning and managing of this precious resource is critical, not only for economic reasons, but in the long term to sustain life.

Although seven-tenths of the world is covered with water (i.e., about 326,000,000 cubic miles of water), only 2.5 percent of this is fresh water, and more than 75 percent of that is locked up in the polar ice caps. Of all the water on earth, only 0.6 percent is liquid fresh water. Six-tenths of one percent does not sound like much water, but it amounts to approximately 2 million cubic miles. This would be a sufficient amount to sustain the 5.2 billion humans on earth today, but unfortunately this water is not distributed according to human needs. As a consequence, there are more than one billion people in the world with insufficient access to drinking water [Ref. 4:p. 45]. Because of this, water resource management has become a key economic and political issue. But are we doing all we can do? At best, the demand for water is staying the same, while the supply of usable water is declining.

California has been particularly hard-hit when it comes to the amount of available water resources. Hal Rubin of the California State University at Sacramento said that "water has broken more alliances and friendships in California than alcohol." [Ref. 4:p. 48] Back in 1850, when California became a state, the "frontier was still open. California had few people, vast open spaces, and large amounts of natural resources." [Ref

5:p. 1] These early settlers, be they farmers, miners, or housewives, had no need to and did not account for the impact their use of resources made on the environment. But as California developed from a frontier to a modern society, so did the resource accounting and distribution systems. The present demand on California water resources makes the accounting for and distribution of water a very complex process.

> Nature provides the largest portion of California's water during winter and spring, whereas the largest demands occur in the summer and fall. Fifty-five percent of California's water supply comes from the northern one-third of the state, but 75 percent of the use occurs in the central and southern two-thirds of the state. Thus, the water system must store water across time and transport it across space to meet the demands of water users. [Ref. 5:p. 2]

B. GROUNDWATER

Groundwater is the water that occurs below the surface of the Earth, where it occupies all or part of the void spaces in a geological layer or layers. It is also called subsurface water, to distinguish it from surface water which flows overland and in rivers. Both surface and subsurface water are related through the hydrologic cycle, which is the path taken by the water on Earth: from oceans to atmosphere by evaporation, from atmosphere to the ground by precipitation, and ultimately back to the sea by run-off or streamflow.

At present, groundwater is by far the world's most widespread source of fresh water. It is available in nearly every part of the globe, often at depths easily reached by wells. The water supply of most water-bearing rock formations, or aquifers, is replenished to some extent each year. Precipitation seeps below the soil to the water table, that is, into the upper surface of an aquifer that is not confined above by an impervious rock layer.

Of the water withdrawn from streams, lakes, or wells for human use, nearly two-thirds is used for irrigating crops. Irrigation consumes more than any other single use. In the United States, an average of 55 percent of the water used for irrigating crops evaporates or transpires to the atmosphere in the form of water vapor. This 55 percent is classified as consumed because it is not returned directly to streams or groundwater aquifers. Thus, is not available for immediate reuse. In the case of water withdrawn for personal and many industrial uses, nearly all of it may be available for reuse, either directly or after suitable treatment.

For a wide variety of uses, groundwater is more desirable than surface water for at least seven reasons: (1) it is commonly free of pathogenic organisms, and purification for domestic or industrial use is not necessary; (2) its temperature is nearly constant, which is advantageous if the water is used for heat exchange; (3) it is generally free of turbidity and color; (4) its chemical composition is usually constant; (5) groundwater supplies are not seriously affected by short droughts; (6) most of it has not been affected by radiochemical or biological contamination; and (7) it is available in many areas that do not have dependable surface-water supplies because the groundwater has been stored by nature through many years of recharge.

The total amount of groundwater in the United Stated is "vast—about 50 million acre-feet. Even so, the western cities and farms are pumping it out faster than it can be replenished." [Ref. 4:p. 47] This process is called overdrafting. But "overdrafting is not necessarily bad—any more than mining coal or pumping oil is bad. But it is essential to understand that some groundwater supplies are irreplaceable." [Ref. 4:p. 47] In many areas, including California, today's overdrafting is leading to tomorrow's crisis.

C. DESCRIPTION OF THE STUDY AREA

The area selected for study in this thesis is the Salinas Valley, a portion of the lower basin of the Salinas River. The valley is roughly linear, tends northward, and generally has a wedge shape. It is 150 miles long, three miles wide at the upper southeastern end, and approximately 15 miles wide at the lower northwestern end along the Monterey Bay and the Pacific Ocean. The valley floor slopes at a fairly even gradient from the south to the north, with an altitude of 540 feet above sea level at Bradley, 200 feet above sea level at Soledad, 75 feet above sea level at Salinas, and approximately 10 feet above sea level near Monterey Bay. It covers an area of 285,000 acres whose boundaries are dictated by the underlying groundwater aquifer directly related to the Salinas River. Figure 1.1 shows a map of the study area [Ref. 1:p. 5].

The Salinas River runs through the coastal mountains of central California and drains an area of about 4,400 square miles. The river originates near Santa Margarita and flows 120 miles northward to the Pacific coast at Monterey Bay. The lower 70 miles of the river, from San Ardo to Monterey Bay, are in the Salinas Valley. The valley is underlain by permeable, water-bearing alluvium. The alluvium forms a continuous ground-water basin that constitutes the study area for this investigation.

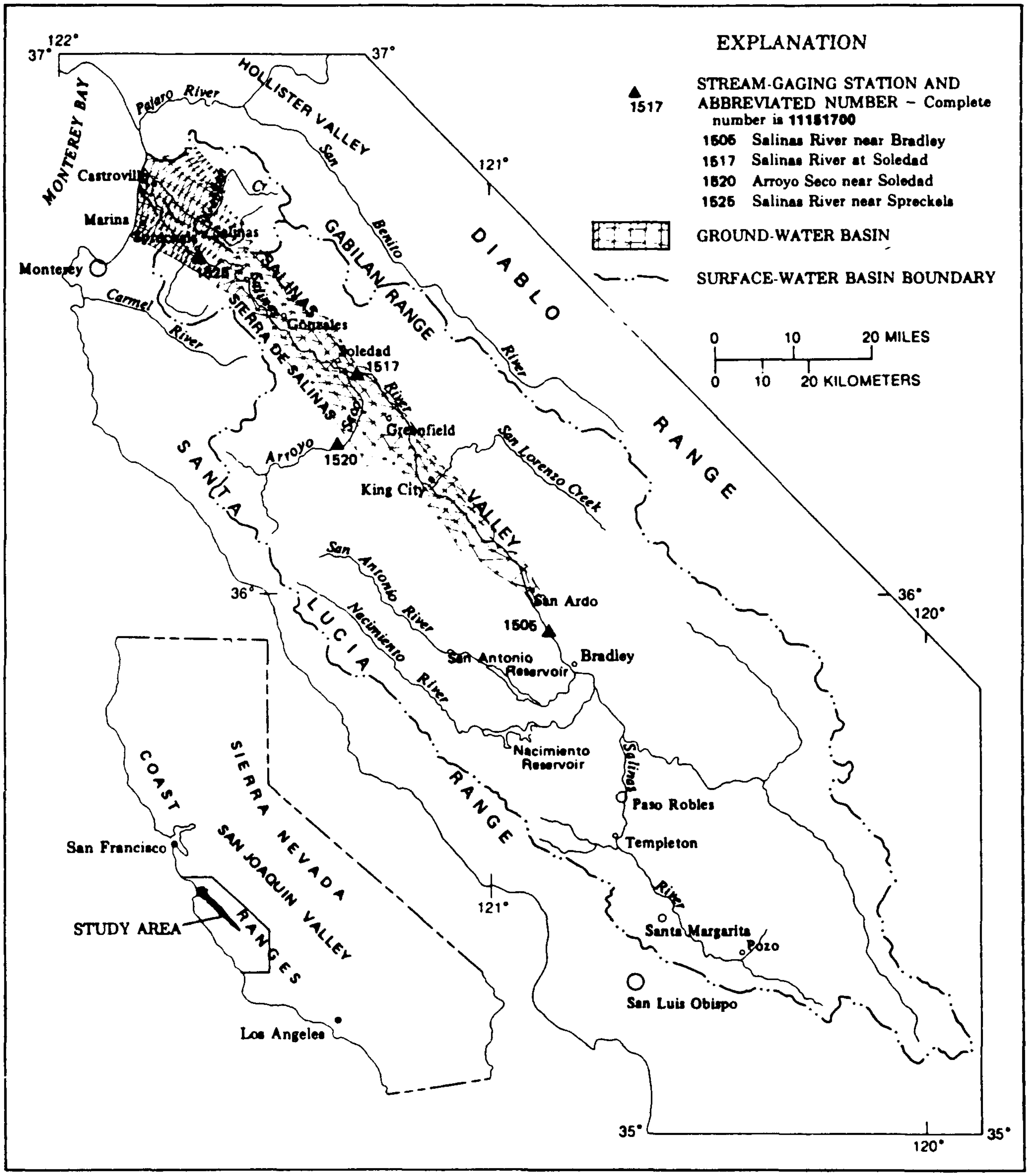

Figure 1.1. **Monterey County and the Salinas Valley Aquifer**

Mountains rise abruptly along both sides of the valley floor. The Diablo Range and the Gabilan Range lie along the northeast edge of the valley, and the Sierra de Salinas and Santa Lucia Range flank the southwest edge. Ridge altitudes average about 2,500 feet on the northeast side and 4,000 feet on the southwest side. The mountains on both sides of the valley decrease to low hills near the coast. The study area lies entirely within Monterey County.

D. MARKET FORMATION, SUPPLY, AND DEMAND

A market is an abstract concept that encompasses the trading arrangements of buyers and sellers that underlie the forces of supply and demand. Therefore, market formation is the creation of the opportunity to trade. In a market, a resource is allocated and priced by means of the supply and demand curves for the resource. To describe supply and demand in the context of groundwater, it is useful to use a model describing a groundwater aquifer. Table 1.1 [Ref. 1:p. 45] represents a static model of the Salinas Valley aquifer. In this model, the supply of water is represented by the inflows into the aquifer and the demand is represented by the outflows. The mean rates of inflows and outflows are described in acre-feet per year. The concept of supply and demand in this context are fundamental to understanding a free market system for water.

A market is continuous if the bidding process between buyer and seller continues over time. This bidding and selling process represents market activity. Market activity is the action of buyers and sellers, while market formulation is the institutional changes that result from the opportunity to trade. Whenever an established price/quantity relationship no longer represents relative economic values, a continuous market allows the price/quantity relationship to change [Ref. 6:p. 10].

TABLE 1.1

ESTABLISHED MEAN ANNUAL WATER BUDGET FOR THE SALINAS VALLEY GROUNDWATER BASIN 1970–81

Budget Item	Rate of Inflow or Outflow	
	Acre-feet/ year	Percentage of total
Inflow		
Recharge from the Salinas River	214,300	38.3
Recharge from the Arroyo Seco	93,600	16.7
Recharge from small streams	23,300	4.2
Other ground-water inflow	13,000	2.3
Percolation of irrigation water	190,300	34.0
Recharge from precipitation	6,100	1.1
Seawater intrusion	18,900	3.4
Total inflow	**559,500**	**100.0**
Outflow		
Agricultural pumpage	512,200	91.5
Municipal pumpage	22,300	4.0
Riparian phreatophyte evapotranspiration*	25,000	4.5
Total outflow	**559,500**	**100.0**

*The process of transferring moisture from the earth to the atmosphere by evaporation and passage of water through a long-rooted plant from the water table or the soil above it.

The distinction between market formation and market activity is important in this study because it emphasizes the role of policy in matters of voluntary behavior. Market activity is voluntary behavior. Policy can only create the opportunity to trade, that is, policy can form a market, but it cannot make economic actors voluntarily trade. Policy cannot make market activity. This study focuses on the policy changes that would be required for the formation of a free market system for agricultural water resources.

E. COMMON POOL RESOURCE

> What is common to many is taken least care of, for all men have greater regard for what is their own than for what they possess in common with others.
>
> *Aristotle*

One cause of the inefficient allocation of groundwater resources in the Salinas Valley lies in the treatment of groundwater aquifers as communal property or "common pool resources." The common-pool problem occurs when a number of overlying property owners are engaged in competitive pumping of water from a common underlying aquifer. The fundamental characteristic of such a situation is that water is no one's property until and unless captured for use [Ref. 7:pp. 63–66]. Each individual considers, in his decisions, only the effect of his pumping upon the water level in his well and not its adverse effects in the wells of his neighbors.

This phenomenon has initially been studied in the case of ocean fisheries [Ref. 8:pp. 124–142], where no fisherman takes into consideration the fact that his catch consists partly of fish which would have been caught by others. This fishery case has an additional dimension in that the rate of fish replenishment is directly related to the quantity of remaining fish.

Because groundwater moves in response to withdrawals, the pumpers are interdependent and hence "externalities"[2] are present. When substantial external effects exist, the calculation of benefits and costs by the individual pumper fails to reflect the total impact of the pumping on society, and a social misallocation of the resources results.

The external effects of groundwater withdrawals are called "technological diseconomies." They are technological because the impact is registered through a physical link between production processes. They are diseconomies because the effects impose a cost on users, rather than a benefit. Under heavy exploitation, groundwater basin management becomes an issue for communities concerned with detrimental external effects such as saltwater intrusion, subsidence of the overlying land surface, and increased pumping costs due to lower water levels.

The "communality" of the resource is a manifestation of the "fugitive" nature of the water resources, namely the lack of direct control. The "common pool" structure of property rights for groundwater fails to include all the significant consequences of private decisions. Typically, the incentives are such that they encourage excessive exploitation. A decision to conserve for future use does not create a property right, and the preserved resource is still subject to the law of capture by others.

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[2] The side effects of an action that influence the well-being of nonconsenting parties. The nonconsenting parties may be either helped (by external benefits) or harmed (by external costs).

F. PREVIOUS STUDIES

Several studies have examined the allocation of water resources. Most of the studies have examined water markets for surface water transfers. The studies conclude that a market allocation of surface water is an efficient way to allocate water resources. The formation of markets for surface water can be facilitated through institutional changes.

Phelps, Moore, and Graubard [Ref. 9:pp. 14–36] concluded that water use throughout California is not efficient because, in part, of the institutional restrictions on water. The current laws in some water districts against transferring water outside the district is one example of these institutional restrictions. The estimated annual social loss due to transfer restrictions was calculated to be between $60 million and $370 million.

Noel [Ref. 10:pp. 28–52] defined six hydrological basins in Yolo County and studied the pumping patterns using an optimal control model. He found that the marginal benefits were not equal among the six basins in the current non-trade environment. Further, Noel found that if transfer were permitted, the most water-deficient basin would be willing to purchase 16,549 acre-feet of water per year from the most water-abundant basin at a price equal to $16.86 per acre-foot. Noel concluded that present groundwater use is inefficient and that inter-basin transfer is a mechanism to improve efficiency in allocation.

Allocation rules which prohibit trade produce greater inefficiencies as the cost of water development increases [Ref. 11:pp. 36–72]. Leveen [Ref. 11:pp. 36–72] found that as the cost of developing additional water supplies increases and the net benefits of newly developed water decrease, the incentive for market activity involving existing water supplies will increase.

Howitt, Mann, and Vaux [Ref. 12:pp. 105-116] used an interregional programming model to examine voluntary transfer of water among five regions defined in their study. Demand and water cost curves for each region were considered under three scenarios: (1) existing institutions and no new water supplies, (2) existing institutions and new water supplies, and (3) existing water supplies with institutional changes to allow trade between the five regions. By comparing the results from the three scenarios, the study concluded that the most economical means of resolving the water scarcity problem in California would be to change institutional arrangements so as to allow voluntary transfer. More benefit would accrue by voluntary trade than by additional water development.

II. BACKGROUND OF THE SALINAS VALLEY

As described in Chapter 1, the Salinas Valley covers an area of 285,000 acres, of which 205,000 acres are currently irrigated cropland. This cropland comprises some of the United States' finest agricultural land. This chapter will describe the 285,000-acre area in terms of its climate, agricultural production, water resources, and water problems.

A. CLIMATE

The Salinas Valley enjoys a mild Mediterranean climate which is attributed to the valley's proximity to the Pacific Ocean. Agricultural areas closer to the coast benefit from normally moderate year-round temperatures: cool, dry summers and mild, rainy winters. Because of the interaction of maritime influences, mountain barriers, and inland heating, the inland climate is more complex. The mountains along the coast tend to hold the marine air away from the interior, which makes solar heating stronger in the middle and southern parts of the valley. As this warmer interior air begins to rise, it draws cooler marine air from the Monterey Bay into the valley. The predominantly west and northwest wind patterns in the summer months, coupled with the northwest-southwest orientation of the valley, further facilitate this circulation. Therefore, the range of temperatures, both daily and yearly, is wider in the inland area. The length of the frost-free season is more than 350 days near the coast and 200-250 days further inland in the valley (see Figure 2.1) [Ref. 13:p. 40].

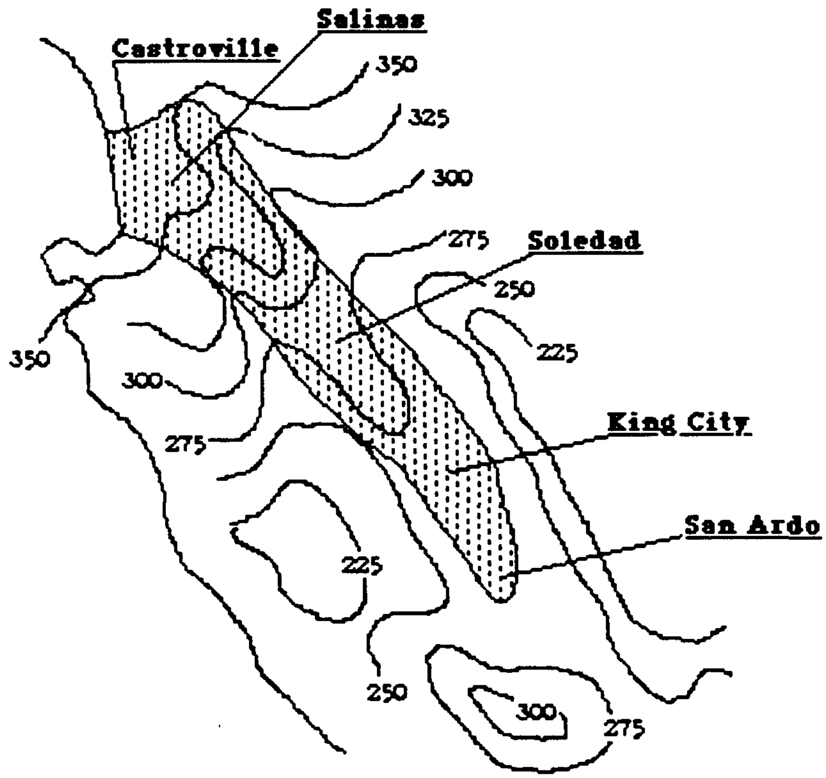

Figure 2.1. **Average Length of Growing Season in Days**

The average annual rainfall is greatest at the north end of the valley and least in the center. Historically, it has varied from a mean of 18 inches per year near the coast to 10 inches per year in Soledad and King City. During the 30-year period ending in 1960, the annual precipitation at Salinas and King City ranged from a low of 5.74 and 3.14 inches, respectively, to a high of 28.10 and 23.81 inches [Ref. 13:p. 41]. The Salinas Valley is currently in the fourth year of a drought [Ref. 14]. During the drought, precipitation amounts have been low, compounding the water supply problems in this area.

In summary, although irrigation is a valley-wide cultivation requirement, the climate in the northern part of the valley allows for the year-round production of a great variety of vegetable crops. In the southern end of the valley, the somewhat more severe climate tends to make it easier to grow hardier crops, such as sugar beets and dry beans.[3]

B. AGRICULTURAL PRODUCTION

Agricultural production is the largest industry in Monterey County, and Monterey County is the number one vegetable-producing county in the nation [Ref. 15:p. 2]. In 1989, Monterey County's agriculture sales exceeded the one billion dollar mark and set an all-time high gross value of $1,205,894,880 [Ref. 16:p. 1]. Because of this, issues that affect the agricultural community also greatly affect the entire Monterey economic community and the nation as a whole.

The large-scale development of agriculture in the Salinas Valley started in 1770 with the establishment of the Spanish missions. In 1899, the world's largest sugar-beet refinery was built near Salinas by Claus Spreckels; it was in large measure the source of prosperity for the region [Ref. 17:p. 78]. Irrigation systems, which eliminated the threat of devastating drought and permitted the introduction of a variety of vegetables, became possible because of the development of new turbine pumps after World War I.

About 80 percent of the floor of the Salinas Valley can be irrigated, with 65 percent currently being irrigated. Although the valley covers only

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[3]According to the Monterey County Agricultural Commission, dry beans consist of large lima, small white, and other dry beans.

one-seventh of the county area, it accounts for virtually all the agricultural production of the county. Monterey County, in turn, produces 95 percent of the artichokes, 55 percent of the broccoli, 35 percent of the cauliflower, 30 percent of the lettuce, and 20 percent of the celery grown in the U.S. The acreage planted and annual values of major crops in Monterey are shown in Table 2.1 [Refs. 16, 18, and 19].

TABLE 2.1

MAJOR CROPS IN MONTEREY COUNTY

1987-1989	Acres			Value ($1,000s)		
	1987	1988	1989	1987	1988	1989
Lettuce	79,792	80,271	76,898	317,395	302,877	330,901
Broccoli	54,810	49,075	50,960	115,951	114,684	122,098
Cauliflower	23,400	20,160	21,391	76,466	69,520	64,411
Grapes	24,814	26,843	26,720	40,276	44,247	60,139
Strawberries	4,065	5,105	5,050	110,462	134,039	102,474
Artichokes	7,660	7,720	8,360	27,880	28,580	25,686
Celery	6,205	4,449	5,085	38,196	33,674	34,456
Tomatoes	4,920	5,940	7,440	28,251	33,094	29,895
Sugar Beets	4,340	3,220	2,830	5,334	4,882	4,495
Carrots	5,095	5,750	5,351	12,769	16,955	18,110
Onions	907	1,295	1,348	6,727	8,892	8,167
Barley	23,200	27,300	21,300	1,877	3,240	2,150
Peppers	1,310	2,720	2,990	4,417	9,622	10,606
Dry Beans	3,283	3,185	3,053	2,274	3,101	2,525
Alfalfa	5,300	3,050	2,970	3,672	2,238	2,300
Potatoes	1,000	1,200	1,000	2,280	3,120	2,600
Total	250,101	246,083	242,749	794,227	812,765	812,846

In terms of annual dollar value, lettuce is by far the leading crop in the Salinas Valley and Monterey County, as shown in Figure 2.2 [Refs.

18:p. 17; 19:p. 17; and 16:p. 17]. The acreage planted in lettuce increased by 13 percent between 1981 and 1989. Broccoli is the second-largest crop, with one-third of the lettuce annual dollar value. Currently, broccoli acreage is two-thirds of the lettuce acreage, although it has increased by about 20 percent during the past 10 years. The acreage of cauliflower has increased at roughly the same rate as lettuce [Ref. 16:p. 24].

Along with many other areas in California, Salinas Valley vineyards have also become important. Twenty years ago, few vineyards existed in the valley; now, they are the fifth largest source of revenue in the county and their acreage is the third largest among irrigated crops [Ref. 16:p. 25]. The production of tomatoes and celery is also increasing, although at a much slower rate. Sugar beets, dry beans, carrots, and potatoes are the most prominent among those crops which have seen decreasing production in the past 20 years [Ref. 20:p. 4].

The growing of crops in the Salinas Valley is highly labor intensive. Field crops and some plots of tomatoes and grapes are all harvested by hand. Vegetables and fruits are manually picked, sorted, and packed, which makes the typical harvesting costs at least half of the total production costs [Ref. 13:p. 43].

The increasing acreage in irrigated and double-cropped vegetables (vegetables grown twice in one year) is a major factor in explaining the overdraft of the underlying groundwater reservoir. A soil survey of Monterey County was conducted in 1978 by the U.S. Department of Agriculture Soil Conservation Service to determine the average application of

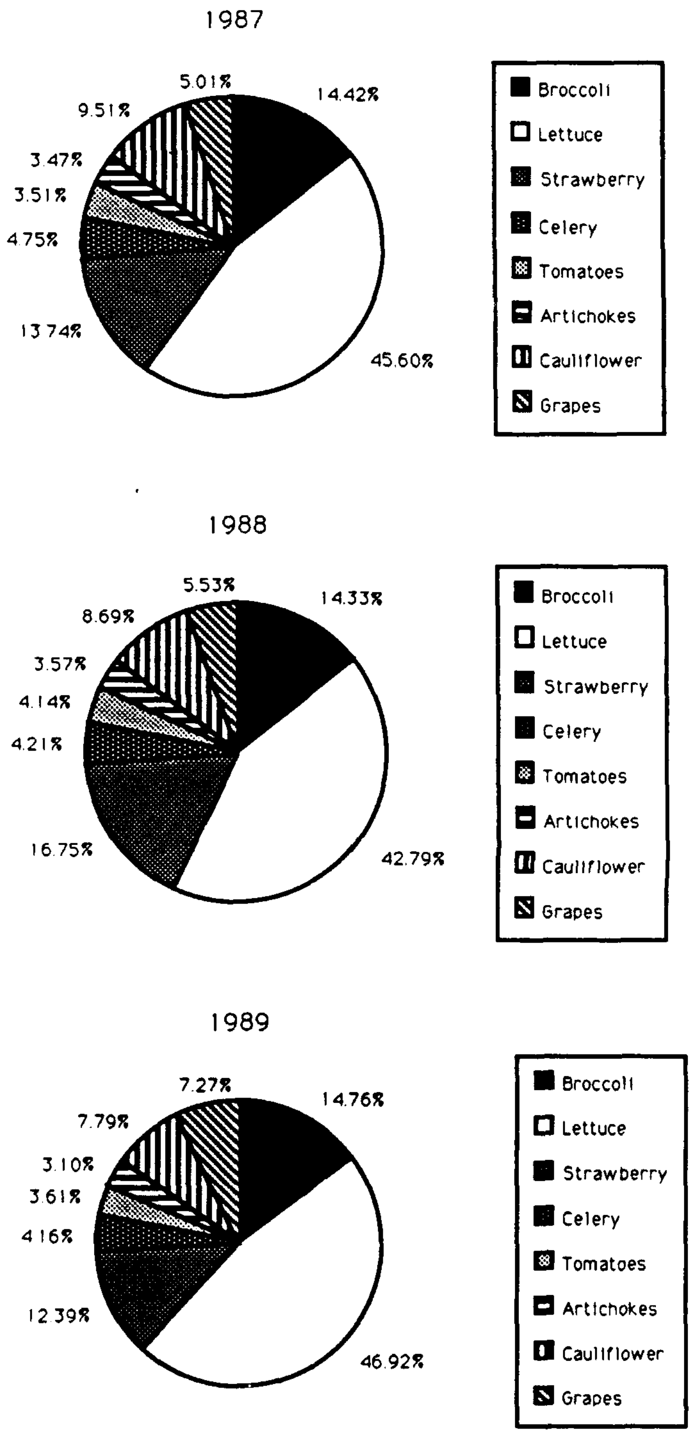

Figure 2.2. **Value of the Leading Crops in the Salinas Valley/Monterey County 1987–1989**

irrigation water by crop in the Salinas Valley. Table 2.2 [Ref. 21:p. 9] shows the results of this survey. The amount of water used to irrigate crops is also related to irrigation efficiency,[4] which varies between 56 percent in the southern part of the valley and 74 percent in the northern part [Ref. 21:p. 7].

TABLE 2.2

WATER CONSUMPTION BY CROPS

Crop	Avg Acre-Feet/ Month/Acre of Crop	Growing Season
Lettuce	2.5	All year
Broccoli	2	All year
Cauliflower	2.5	All year
Artichokes	1.75	All year
Celery	3.5	All year
Tomatoes	2.75	March–October
Carrots	2.75	All year
Potatoes	2.5	Apr.–November
Sugar Beets	3.5	All year
White Beans	2.5	May–October
Alfalfa	3	All year
Grapes	1.5	March–November
Strawberries	5	All year

[4]The amount of water actually needed to grow the plant divided by the total amount of water applied.

C. WATER RESOURCES

In Monterey County, 89 percent of the water used, including almost all of the irrigation water, is pumped directly from an underlying aquifer called the Salinas Valley Aquifer. Of the 659,400 acre-feet per year of water currently used in the county, it is estimated that agriculture consumes 90.5 percent [Ref. 15:p. 2]. Recharging of this aquifer is mainly accomplished through the percolation of water from the Salinas River. This river supplies a natural underground water storage and distribution system for Salinas Valley farmers. Maximizing the yield of groundwater from percolated surface water requires that surface water be controlled so that it flows above the aquifer at a rate as close as possible to the percolation rate.

In 1946, the State Department of Water Resources subdivided the valley floor into four hydrologically interconnected units: Upper Valley, Forebay, East-Side, and Pressure (see Figure 2.3) [Ref. 1:p. 6-7]. The following sections give a brief description of each area [Refs. 22 and 23:p. 2-3].

1. Upper Valley Area

The Upper Valley Area consists of the southern end of the valley and has a gross area of 85,000 acres. It extends from about six miles north of Bradley to about 7.5 miles north of King City. Major urban areas are San Ardo, San Lucas, and King City. In this area, the Sargent, Pine, San Lorenzo, and Pancho Rico Creeks are tributaries to the Salinas River, which originates in the Diablo Mountains. The Nacimiento and

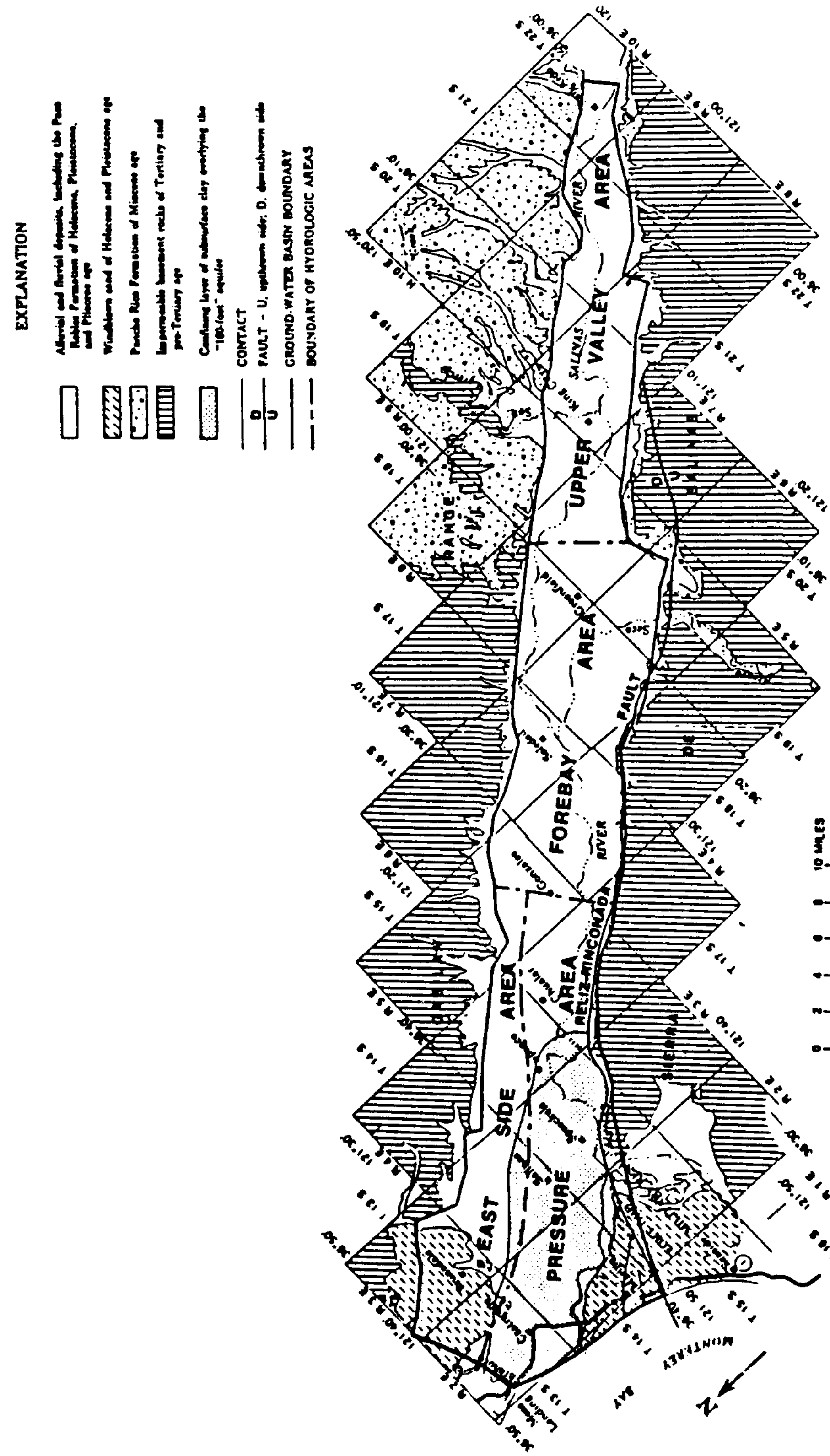

Figure 2.3. **Hydrologic Areas of the Salinas Valley**

San Antonio Rivers, which originate in the Santa Lucia Mountains, join the Salinas River less than two miles south of Bradley. The area's unconfined aquifers are recharged by natural percolation from the Salinas River, the above-mentioned local streams, and precipitation. In addition, releases from two reservoirs, the Nacimiento and San Antonio, are an important souıce of recharge to the Upper Valley Area.

2. Forebay Area

The Forebay Area extends from the northern boundary of the Upper Valley Area to the vicinity of the city of Gonzales and consists of approximately 77,000 acres. The major urban areas within the Forebay area are Greenfield and Soledad. The only tributaries of significance to the Salinas River in this area are Chalone Creek, which enters from the east, and the Arroyo Seco river, which enters from the west. Included in this area is the Arroyo Seco Cone, a highly permeable alluvial sub-area south of Soledad and west of the Salinas River. It is generally the area formed by the fan of Arroyo Seco River and Reliz Creek, both of which originate in the Santa Lucia Mountains. Infiltration from the Arroyo Seco River also recharges the unconfined Forebay aquifers. In addition, the aquifer in the Forebay area is recharged by seepage from natural and regulated flows of the Salinas River, local streams, agricultural return flows, and precipitation.

3. East-Side Area

The East-Side Area extends over 43,000 acres, north from Gonzales to about three miles east of Castroville, and lies generally east of Highway 101. Major urban areas in this area are Santa Rita and the eastern suburbs of the City of Salinas. Tributaries to the Salinas River in this area are the Chualar, Quail, Alisal, Natividad, and Gabilan Creeks, all of which originate in the Gabilan Mountains. The aquifer also receives recharge by groundwater inflow from the Forebay and Pressure areas and by irrigation return flows. However, the groundwater flow from the Forebay is limited due to a reduction in transmissivity at the southern edge of the area.

4. Pressure Area

The Pressure Area extends over 81,100 acres along the western and central portion of the valley, from Gonzales north to the Monterey Bay, and lies west of Highway 101. Major urban areas are Gonzales, Chualar, Salinas, and Castroville. The only major tributary to the Salinas River in this area is El Toro Creek, which originates in the Santa Lucia Mountains. This area's alluvium is characterized by two quasi-continuous clay layers that divide the upper part of the groundwater basin into three horizontal layers and prevent replenishment of the lower layers by deep percolation from above. The three layers of aquifer that are separated by the clay layers have been designated the "180-foot aquifer," the "400-foot aquifer," and the "900-foot aquifer." See Figure 2.4 [Ref. 22] for a visual description of these aquifer layers. The numbers refer to the average depth to water-bearing strata. The pressure area is now primarily recharged by inflow from the Forebay and from seawater intrusion. The East-Side Area appears to have been one of the natural sources of recharge for the Pressure area, but overdrafting of that area has reversed the direction of the underground recharge flow.

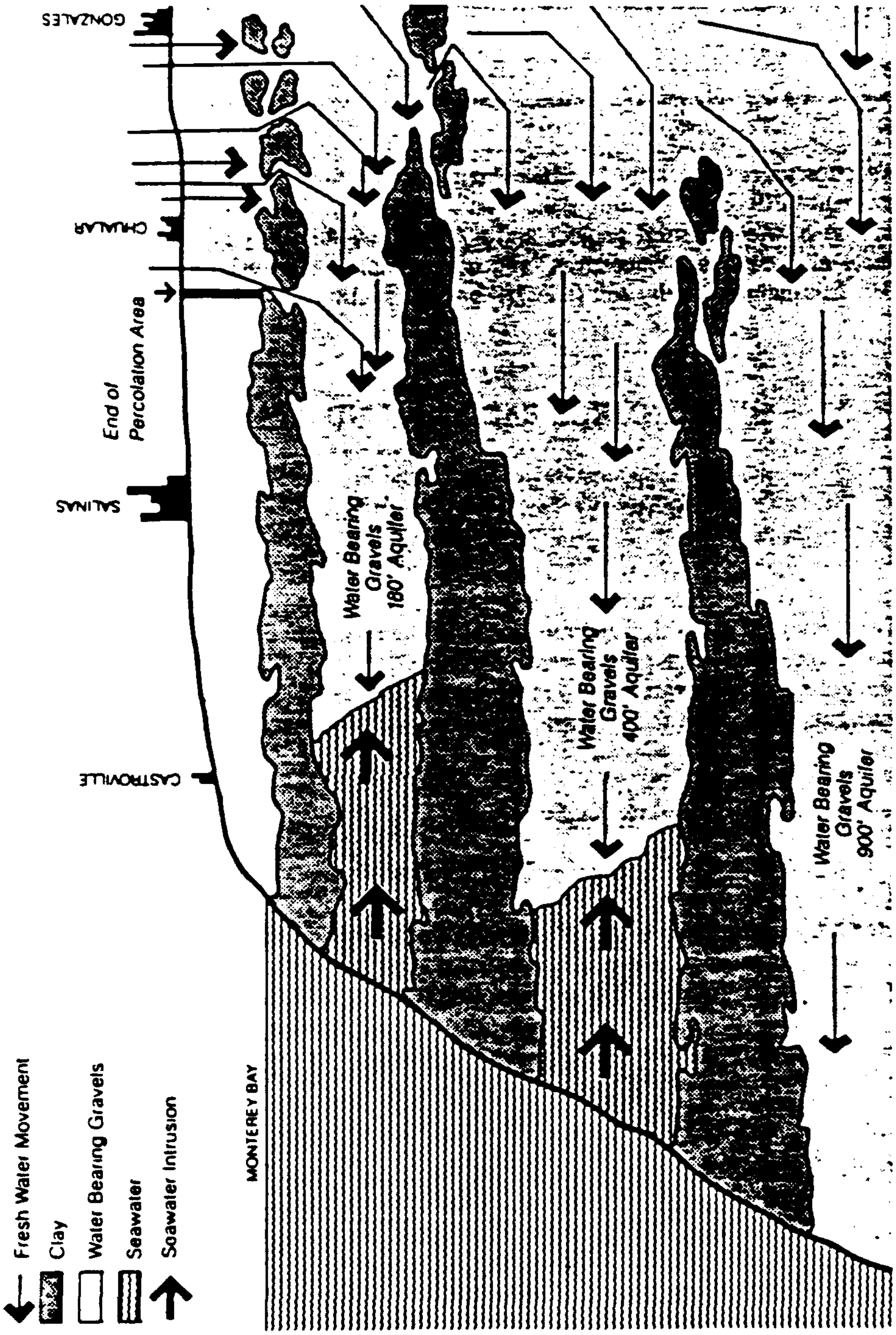

Figure 2.4. **Pressure Area's 180-Foot, 400-Foot, and 900-Foot Aquifers**

D. PROBLEMS

> For several decades, water demand in Monterey County has exceeded the supply, resulting in groundwater overdraft, seawater intrusion, shortages during dry years, and increased water costs. In addition, the municipal and industrial water demand is increasing as the population within the county increases. [Ref. 23:p. 2-1]

Groundwater is essentially the only source of water supply for all Salinas Valley users: municipal, industrial and agricultural. Although the total demand for water has increased continually in the past, the share of irrigation pumping has remained equal to approximately 90 percent of this demand. The water problem in Monterey County is principally linked to the increasing acreage planted with vegetables. Not only do these crops require a large irrigation application during their growing cycle, but their shorter growing cycle also promotes double-cropping.

E. GROUNDWATER OVERDRAFT AND SALT WATER INTRUSION

According to the United States Department of Agriculture, Soil Conservation Service, growers of the Salinas Valley pumped more than 593,460 acre-feet of water from the ground in 1989 [Ref. 15:p. 2]. This is about 36,500 acre- feet more than the estimated mean annual recharge amount and is known as overdrafting. Overdrafting of our underground water supply has resulted in coastal farmers having to pump water from greater depths and in seawater intrusion along the coast. While this overdrafting cannot continue indefinitely, new sources of water are expensive and hard to find.

Using yearly changes in groundwater levels, the Monterey County Flood Control and Water Conservation District[5] estimated the change in the amount of water stored in the aquifer for the 1961–1976 period by multiplying the acreage of each unconfined aquifer area by the estimated specific yield [Ref. 13:p. 57]. Assuming an additional deficit of 16,500 acre-feet because of the increase of irrigated acreage, overdraft estimates have been computed an are presented in Table 2.3 [Refs. 13:p. 57; 15:p. 2].

TABLE 2.3

1989 OVERDRAFT ESTIMATES

Upper Valley	913	acre-feet annually
Forebay	6,570	acre-feet annually
East-Side	11,680	acre-feet annually
Pressure	17,337	acre-feet annually
	36,500	

Salt-water intrusion is a common problem in groundwater formations located near the coast [Ref. 24:p. 25]. It is defined as an increase in the salinity of groundwater over what normally occurs at a given location in the aquifer. This problem is well known along the border between the Salinas Valley and the Pacific Ocean. "The salt water threat has been generally recognized since the 1940's and studied intensively since 1983." [Ref. 25:p. 4]. "By 1944 the pumping overdraft had resulted in

[5]The Monterey County Flood Control and Water Conservation District will change its name to the Monterey County Water Resource Agency, effective 1 January 1991.

salt-water contamination in some wells near the coast." [Ref. 24:p. 107] Seawater is now advancing into the aquifer at a rate which is resulting in "an annual loss of 570 acres of irrigated farm land in the Castroville area. Local officials say that the advancing salt water could reach Salinas within the next 15 years." [Ref. 25:p. 1]

Salt-water intrusion makes it necessary to drill deeper and more expensive wells and causes uncertainty about the future availability of water. It also has reduced agricultural land values in the northern part of the valley. Permanent relief requires overcoming the overdraft and restoring the seaward groundwater slope. To date, most projects that have been considered to solve this problem have been abandoned due to excessive costs [Ref. 22].

F. GROUNDWATER LEVEL

Like most of the aquifers that have been exploited in the western states, water levels have been declining in the Salinas Valley Aquifer.

> In the Upper Valley Area, the water table dropped from 1944 through the late 1950's, then returned to 1944 levels after the construction of the Nacimiento and San Antonio reservoirs. It has remained at virtually the same level since.
>
> The Forebay Area groundwater levels have shown approximately the same patterns as the Upper Valley basin except that, since 1967, they have declined slightly.
>
> The decline in groundwater levels on the East-Side Area has exceeded 40 feet since 1944. Although the variations of storage level are bigger than in the two upstream sub-basins, the water table has been, on average, declining continuously at high rate since the 1960's.
>
> The Pressure Area basin is confined and the piezometric surface has fallen by 25 feet. This is a .5 percent annual average decrease

> and has resulted in an intrusion of seawater from Monterey Bay. [Ref. 13:p. 57]

The extent of the intrusion into both the 180- and 400-foot aquifers is indicated in Figure 2.5 [Ref. 22]. Note that this is the extent of the salt-water intrusion as of 1985. In the Castroville area, a significant number of wells are currently not usable because of the high salinity of the water pumped. In the past, the East-Side Area has been one of the natural sources of recharge for the Pressure area, but overdrafting of that area has stopped this from happening.

G. PROJECTED DEMANDS AND FUTURE SHORTAGES

Water demand for the Salinas Valley has been estimated by the Corps of Engineers for the years 1990 and 2010 [Ref. 23:p. 3-2]. The total water demand has been broken into two components: municipal/industrial and agricultural. The estimates of these two components are described below.

> Estimated municipal water demands for the Salinas Valley have been developed based on Association of Monterey Bay Area Governments (AMBAG) population projections, estimates provided by the Monterey County Flood Control and Water Conservation District municipal demand estimates for Marina and Fort Ord by the Sea-water Intrusion Committee (December 1988), population estimates by the U.S. Bureau of Census (1971), and a survey of water use conducted by the District in cooperation with the County Planning Department (1984). [Ref. 23:p. 3-2]

Estimated population, and municipal, and industrial water demand for the years 1990 and 2010 are shown in Table 2.4 [Ref. 23:p. 3-3].

The total annual estimated agricultural irrigation water demand for the Salinas Valley has been computed by multiplying the estimated

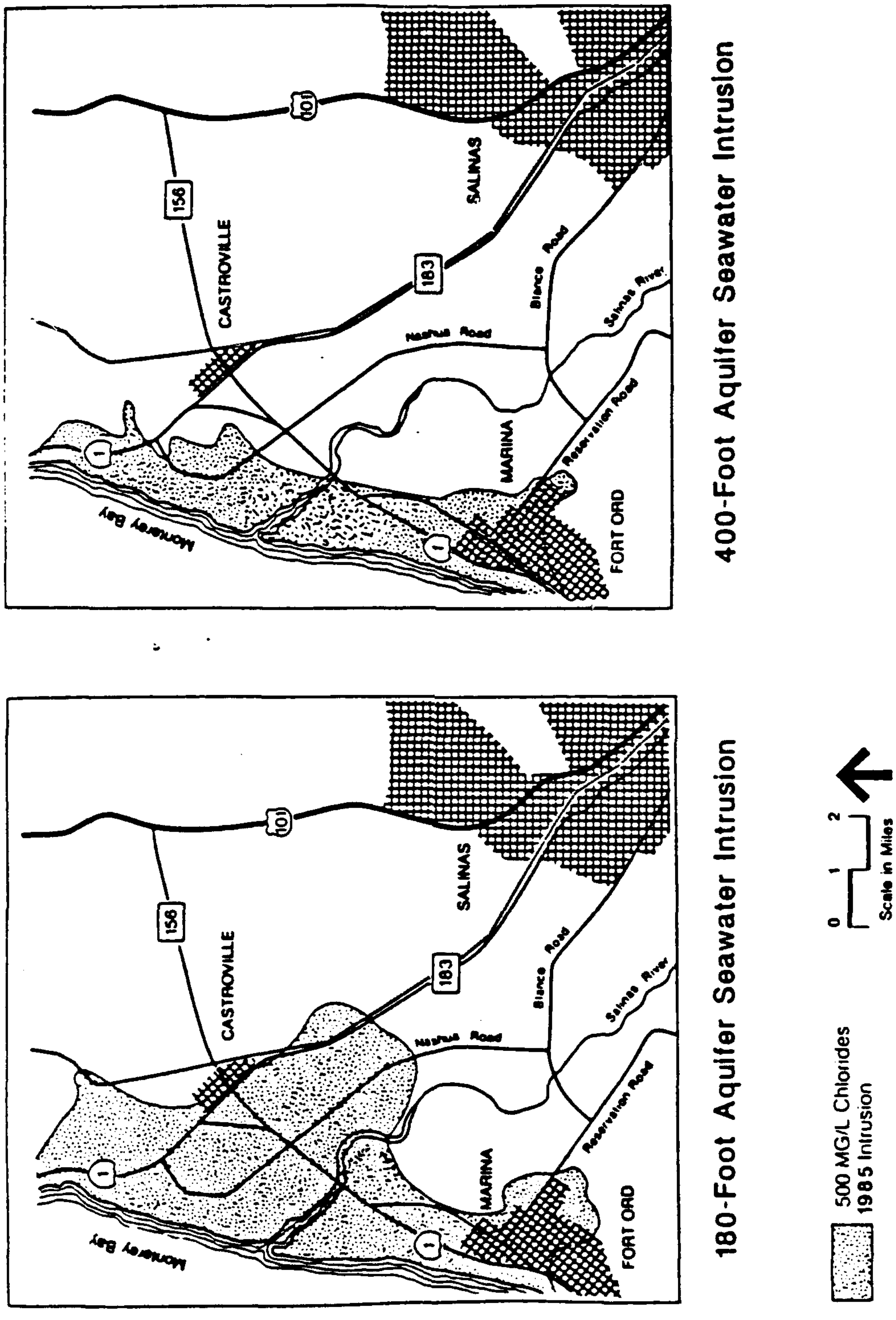

Figure 2.5. **Extent of Salt Water Intrusion**

TABLE 2.4

ESTIMATED MUNICIPAL AND INDUSTRIAL WATER DEMANDS YEARS 1990 AND 2010

Community	Use Per Capita (gal/day)	Year 1990		Year 2010	
		Population	Demand (acre-feet/year)	Population	Demand (acre-feet/year)
Salinas	150	102,627	17,241	145,000	24,359
Castroville	175	5,177	1,015	6,650	1,303
Greenfield	133	7,290	1,086	8,510	1,268
Gonzales	154	5,180	893	6,175	1,065
King City	165	8,581	1,586	15,700	2,901
Soledad	99	8,090	897	9,750	1,081
Marina	N/A	21,012	3,800	37,879	6,400
Fort Ord	N/A	30,460	8,200	32,124	8,200
San Ardo	215	460	111	550	132
Spreckels	201	670	151	800	180
Chualar	150	580	97	700	118
San Lucas	148	202	33	240	40
Unincorporated	140	30,551	4,790	42,122	6,605
Industrial			2,305		2,305
		220,880	42,204	306,200	55,957

irrigated acreage by the estimated average annual per acre water requirement. The estimated irrigation water demands for the years 1990 and 2110 are shown in Table 2.5 [Ref. 23:p. 3-6].

The average annual per acre water demand, irrigated acreage and total annual applied water demands for the Salinas Valley subarea, as set forth in Table 2-5, were estimated by Boyle Engineering in connection with the Salinas Valley Seawater Intrusion Program. Although the potential exists for additional agricultural lands to be developed, particularly in the upper Valley, no increase in irrigation water demands has been projected for the year 2010. This assumes that any increase in water use attributable to the addition of new agricultural lands will be offset by lands being taken out of production for urban use and improved irrigation efficiency [Ref. 23: p. 3-5].

TABLE 2.5

ESTIMATED AGRICULTURAL IRRIGATION WATER DEMANDS YEARS 1990 AND 2010

Subarea	Annual Unit Applied Demand (AF/year)	Year 1990		Year 2010	
		Irrigated Acreage	Demand (AF/year)	Irrigated Acreage	Demand (AF/year)
Salinas Valley	2.5	205,000	511,000	205,000	511,000

The Salinas Valley groundwater model was recently used to estimate groundwater balances for the various units of the Salinas Valley Groundwater Basin. The analysis used 1951 through 1985 hydrological data and forecast water demands from 1986 through 2020. The computer model output included estimates of seawater intrusion and the losses in groundwater storage, which in combination established the need for supplemental water. The analysis was adjusted to develop the 1990 and 2010 supplemental water demands set forth in Table 2.6 [Ref. 23:p.3-8].

H. SUMMARY

Groundwater in the Salinas Valley Aquifer is recharged primarily from the Salinas River through natural streams and controlled releases. Because the volume of water in the Salinas River decreases as it moves

TABLE 2.6

SUMMARY OF WATER DEMANDS

Subarea	Population	Irrigated Acreage	Total Water Demands			Safe Yield Existing Sources (1,000 AF)	Suppl. Water Demand (1,000 AF)
			M & I* (1,000 AF)	Irrigation (1,000 AF)	Total (1,000 AF)		
Year 1990 Estimates							
Salinas Valley	220,990	205,000	42.20	511.00	553.2	515.30	37.90
Year 2010 Estimates							
Salinas Valley	306,200	205,000	56.00	511.00	567.00	518.80	48.20

*Municipal and Industrial

toward the coast, the Upper Valley and Forebay areas have a smaller loss of groundwater storage than the downstream areas. But, because of soil and climate characteristics, the downstream areas possess a comparative advantage in growing vegetables year-round. The combination of more intensive agriculture and less recharge induces an overdraft in the Pressure and East-Side areas, which subsequently leads not only to the destruction of the aquifer by seawater intrusion but also to a dramatic increase in pumping costs.

To a lesser degree, the growth of urban and industrial centers located in the northern part of the county contributes to the increasing overdraft. The district is currently debating a surface-water development project involving a new dam on the Arroyo Seco, which may indicate that major problems confronting the district involve water transfers within the valley. The Arroyo Seco project would provide additional recharge to the northern part of the Forebay, the Pressure, and the East-Side areas. In part, this would result from the increased natural percolation of the

Salinas River north of Greenfield. Two river diversions (pumping plants and pipelines) that direct water toward the critical areas of Castroville and East Side would contribute to the recharge of the Pressure and East-Side Areas as well. The water supply of both sub-areas would be complemented by surface-water delivery networks.

Though it has not yet been decided what course of action will best reduce or eliminate the water problems facing the Salinas Valley, it is certain that any solution involving the construction of water distribution or storage facilities will be tremendously expensive. To do nothing to ease the water crisis, however, would be even more costly to the county, as well as the nation, because of the consequent effects upon vegetable production.

III. PRIVATIZATION OF GROUNDWATER

A. GROUNDWATER MANAGEMENT IN THE SALINAS VALLEY

Centralized management of groundwater by various levels of government has been the dominant policy tool to manage groundwater in the state of California [Ref. 26:p. 76]. The Monterey County Flood Control and Water Conservation District is the central agency for groundwater basin management in the Salinas Valley. Recently, this agency has begun to take on a greater role in the management of groundwater in the Salinas Valley. Centralized management has taken the form of a county-wide water resource management plan that is currently being formulated by members of the Monterey County Flood Control and Water Conservation District[6] In this plan, many new water resource projects are being considered. While it is true that water supplies are scarce and ultimately finite, and that demand has been increasing rapidly, it does not follow that centralized regulation is necessary. This thesis will show that the real issue is whether the agencies responsible for water management provide signals and incentives that correctly reflect the scarcity of water, allowing resource users to respond to changes in supply and/or demand.

The Monterey County Flood Control and Water Conservation District was formed in 1947 by a special act of the California state legislature. Its territory includes all of Monterey County, but specific zones can be cre-

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[6]Hereinafter referred to as the "District."

ated by the District within the county for various local projects and for the purposes of both assessment and the issuance of bonds. Figure 3.1 [Ref. 22] shows the location of the existing zones in the county. The governing body of the District is the Monterey County Board of Supervisors, and voting privileges for bonded indebtedness are attributed to the registered voters in the affected zone. The District has the authority to issue general obligation bonds, allowing the voters in the affected areas to signify approval with a majority vote.

The general administrative costs of the District that accrue to the entire county are financed by annual *ad valorem* assessments upon all properties in the entire county. Water projects established for the benefit of a specific zone, however, are financed by annual *ad valorem* assessments in the zone benefited. The assessments are based on the number of acres owned rather than on water use.

The Monterey County Flood Control and Water Conservation District's primary method for managing the Salinas Valley aquifer is through the controlled release of water from two reservoirs, the Nacimiento and the San Antonio reservoirs. Revenues for this operation are raised by levying an assessment on land owners who receive the most benefit from these releases. These land owners are located closest to the Salinas River and the areas they are located in are designated zones 2 and 2A of the Salinas Valley.

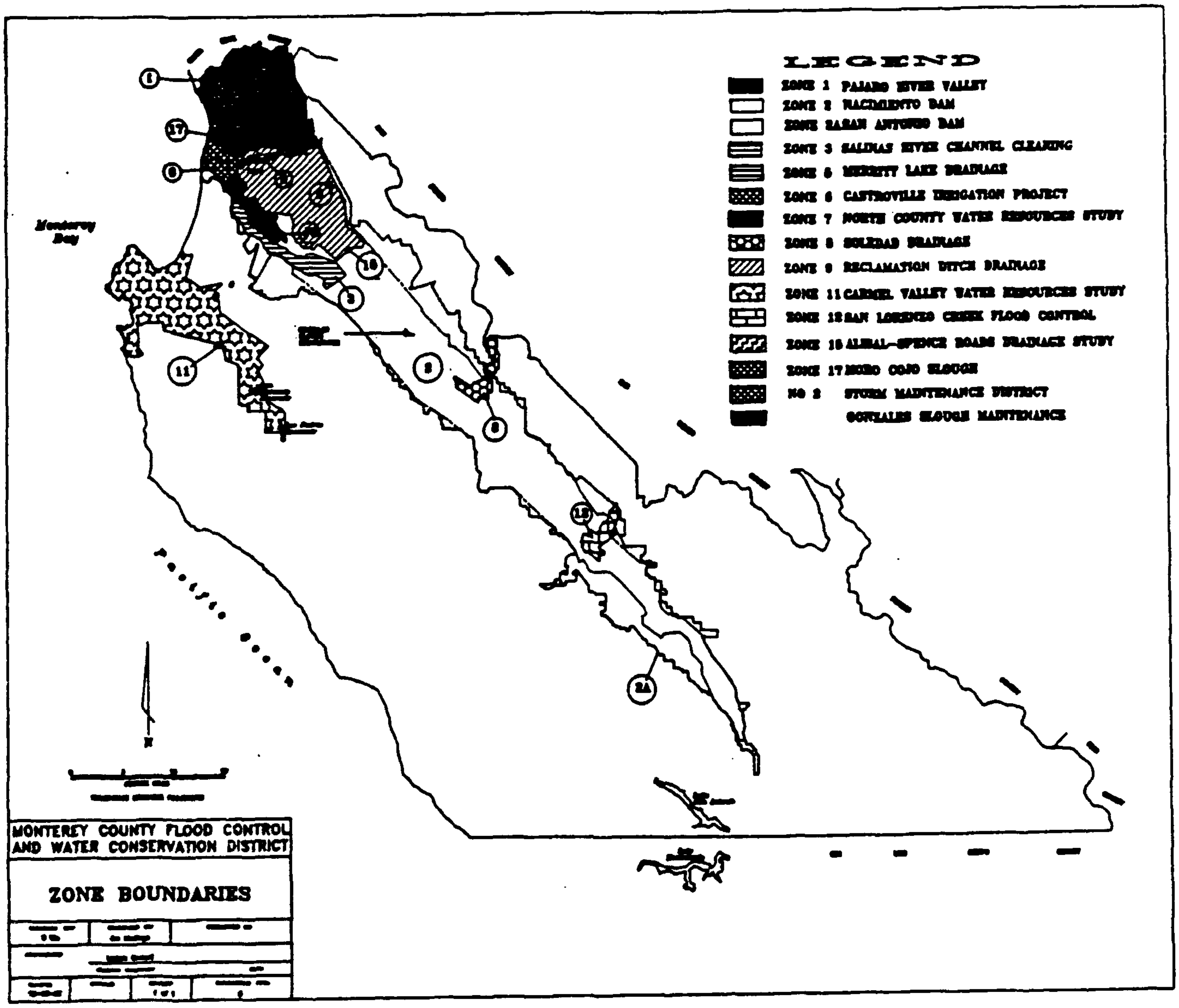

Figure 3.1. **Zones of The Monterey County Flood Control and Water Conservation District**

B. OPERATION OF THE NACIMIENTO AND SAN ANTONIO RESERVOIRS

In 1954, the District appropriated the unappropriated water of the Nacimiento River for the "joint and common benefit of all users without recognition for separate rights for different uses either in the amount of use or the priority right," [Ref. 27:p. 3]. In 1956, they built the Nacimiento dam. Considerable pride in the Salinas Valley is attached to the fact that the project was completely financed with local funds through a $7 million bond issue, approved by the voters in the Salinas Valley in April 1955 by a margin of 11 to one.

In 1963, a $12.9 million bond issue for the construction of a dam on the nearby San Antonio River was approved. The bond is being repaid by property taxes in the area of the Salinas Valley defined as zone 2A— this zone encompasses a major portion of the valley floor that can be irrigated, as shown in Figure 3.1.

The Monterey County Flood Control and Water Conservation District provides recharge of the Salinas Valley aquifer by releasing water from the Nacimiento and San Antonio reservoirs into the Salinas River. This allows water to percolate into the aquifer through the river bed. These reservoirs have a capacity of 350,000 acre-feet each. The dams are operated for the benefit of the property owners in Zones 2 and 2A of the Monterey County Flood Control and Water Conservation District (Figure 3.1). These benefits include flood control, water conservation, and recreation.

During the winter months, when heavy rains can cause flooding in the Salinas Valley, the dams provide flood protection by controlling two of the three largest tributaries of the Salinas River. Space for flood storage is kept in both reservoirs. This space is designated as the conservation pool. The size of the conservation pool is indicated by the number of feet from the base of the reservoir to the spillway lip. The conservation pool for the San Antonio Reservoir is 771 feet and the conservation pool for Nacimiento Reservoir is 767 feet. The District releases a certain amount of water during the winter months if the reservoirs fill up too much. As spring approaches, the chance of a large flood diminishes. Then the amount of flood storage needed decreases and the reservoirs are allowed to fill up to the conservation pool level, if there is enough precipitation.

The amount of flood storage needed in the winter is determined by the amount of water that flows into the reservoirs. The average annual flow into Lake Nacimiento is 190,000 acre-feet, while 67,000 acre-feet flow into lake San Antonio [Ref. 22]. Therefore, Lake Nacimiento receives approximately three times the inflow of San Antonio Lake. Releases from the conservation storage are made at a three-to-one ratio, Nacimiento releasing three times as much water as San Antonio. The outlet pipe for Nacimiento is smaller than the outlet pipe for San Antonio, so Nacimiento cannot release large amounts of water as quickly as San Antonio can. This reduces the District's flexibility to release water from Nacimiento and necessitates a fairly constant release in order to maintain Nacimiento's conservation pool.

Replenishment of the Salinas Valley groundwater basin is another primary benefit derived from the operation of the Nacimiento and San Antonio dams. During the late spring, summer, and early fall, the Salinas River would normally be dry. During these seasons, the District releases water from both dams to keep the Salinas River flowing and recharge the aquifer without wasting water to the ocean. Water is released into the

Salinas River and is allowed to flow to a point just north of Spreckels. Spreckels lies above the edge of a heavy, impermeable buried clay layer. Water released from the reservoirs which flows above this clay layer cannot percolate into the aquifer through the layer. Therefore, the District regulates releases so that flows stop north of Spreckels to maximize the amount of water that percolates into the aquifer. Percolation rates vary throughout the year between 250 to 600 cubic feet per second. Evaporation and transpiration loss is estimated between 27 and 41 cubic feet per second [Ref. 22].

The amount of water released from both reservoirs is determined by the amount needed to replenish the groundwater supply and the amount available for release. The Nacimiento Reservoir maintains a minimum pool of 670 feet and the San Antonio Reservoir maintains a minimum pool of 662 feet. The minimum pool is set to a value greater than zero for environmental reasons (e.g., to keep the aquatic life alive). When water is below the minimum pool level, no water is released. The appendix contains graphs of the reservoir levels at the end of each month from 1957 to April of 1990. Current reservoir levels are below the minimum level required before water can be released.

There has been a steady drop in the water available to release from 1986 to the present (accounting for seasonal changes). This steady drop has complicated the central control model by limiting the amount of water and number of releases the District can perform.

C. WATER STANDBY/AVAILABILITY CHARGES

The Monterey County Flood Control and Water Conservation District receives revenue for the support of the Nacimiento and San Antonio dams through standby (sometimes called availability) charges levied on land owners in zones 2 and 2A. These standby charges are currently limited by district ordinances to no more than $10 per acre or per parcel smaller than an acre. A recent proposal to change the Monterey County Flood Control and Water Conservation District Conservation Act would increase the maximum standby charge to $25 per acre [Ref. 28:p. A4]. Standby charges are assessed on the property tax bill at the rates described in Table 3.1. The rates charged are based on the type of land use rather than on any consumptive use. This is an important distinction when evaluating the effectiveness of the current centralized management system. The rates levied on land owners merely provide revenue to the District to maintain reservoirs, collect data, and pay for support staff. These rates do not alter consumer behavior because they provide no economic incentive to the users to reduce consumption. The rates affect the users' fixed costs and total cost but not their variable costs. Figure 3.2 describes consumer behavior in this situation.

Assuming landowners are maximizing their profits, they want to produce where total revenue exceeds total cost by the greatest possible amount. Total cost and total revenue are shown graphically in Figure 3.2. The difference between total cost and revenue is maximized when the two curves are parallel, as shown in Figure 3.2 at output level Q_1. To maximize profits, producers also want to select combinations of inputs

TABLE 3.1

WATER STANDBY OR AVAILABILITY CHARGES 1989-90, 1990-91

Land Use Factors	Zone 2		Zone 2A	
	1989-90	1990-91	1989-90	1990-91
A	.72/acre	1.10/acre	2.40/acre	8.90/acre
B	1.44/acre	1.10/acre	4.80/acre	8.90/acre
C	.06/acre	.12/acre	.22/acre	.88/acre
D	.02/acre	.02/acre	.02/acre	.10/acre

Factor A = Irrigated agricultural, residential, commercial, and institutional land
Factor B = Industrial land
Factor C = Dry farm, grazing, and vacant land
Factor D = River channels and land subject to frequent flooding

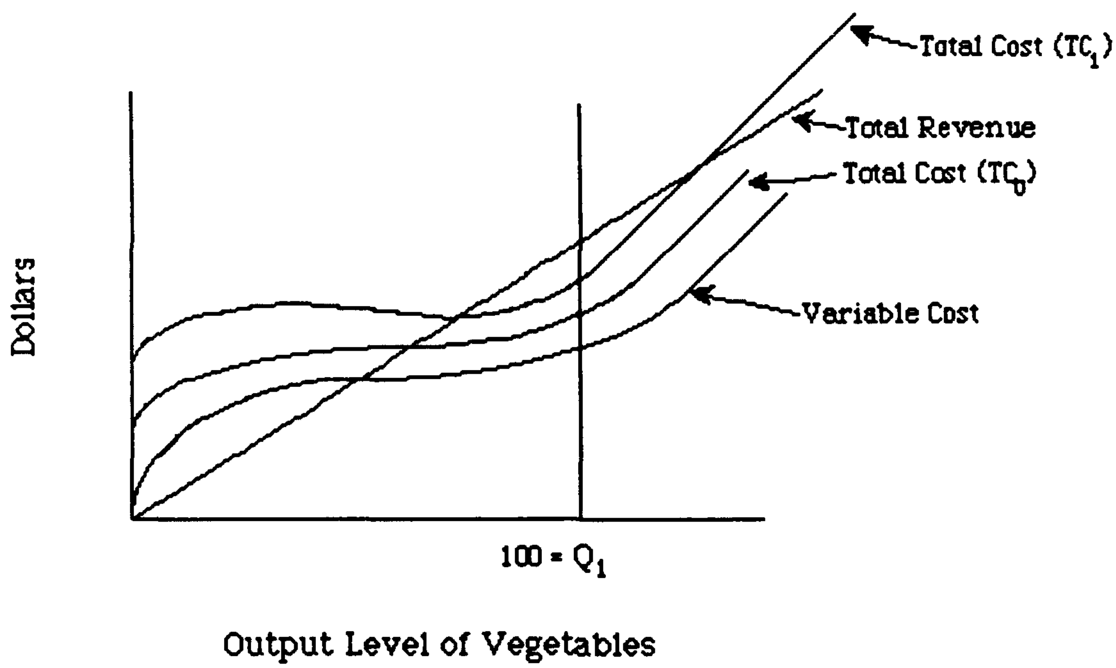

Figure 3.2. **Effect of Standby Charges on Consumer Behavior**

that minimize the cost of producing this level of output. The isoquants in Figure 3.3 show the possible combination of variable inputs (in this case water and fertilizer) capable of producing a fixed output. The isocost line shows the different combinations of inputs that have the same total cost (i.e., the slope of this line equals the price of water divided by the price of fertilizer). Total costs increase as new isocost lines shift out from the origin. Thus, the cost-minimizing combination of inputs occurs where the isocost line is tangent to the isoquant line representing the selected level of output.

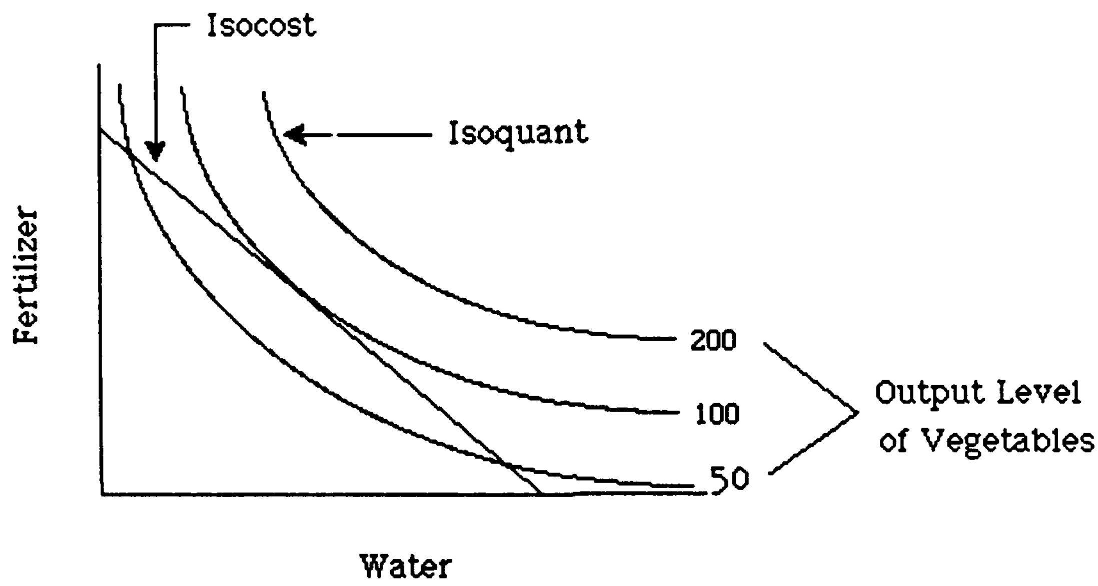

Figure 3.3. **Isoquants For Vegetable Output**

A standby charge levied on owners causes the total cost curve to shift from TC_0 to TC_1 in Figure 3.2 but the optimal quantity Q_1 does not change because these two total cost curves are parallel.[7] The distance between the total cost and the total revenue curve decreases when

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[7]The optimal remains the same with one exception. The optimal quantity changes to zero when the standby charge is great enough to place the total cost curve completely above the entire revenue curve.

standby charges are applied, representing a reduction in profits when fixed costs increase. The combination of variable costs represented by the isoquants does not change because neither the level of output nor the relative price of the inputs has changed. Therefore, the units of water used with an increase in fixed costs do not change. Thus, the standby charge does not provide an economic incentive for farmers to reduce the consumption of water.

Intuitively, this makes sense. Producers select the combination of variable inputs so as to maximize the difference between total revenues and operating costs. This maximizes net operating revenues, with which fixed costs must be paid. Any revenues remaining after paying fixed costs represent the producer's profits. An increase in fixed costs will reduce profits but will not affect the combination of variable inputs that maximizes the difference between total revenues and operating costs. Thus, changes in fixed costs will not affect water usage.

Under a central control model, a more economically efficient assessment would be a replenishment assessment or groundwater charge. A replenishment assessment or groundwater charge is a charge levied on water users who extract groundwater, both retail water purveyors and individual water users, and is based on annual water use. This charge would change the slope of the total cost curve and the isocost line, leading to a smaller output and less water intensive production process. Such a charge ultimately requires that meters be installed on all wells, public and private, and that the amount of water pumped from each well be reported to the District.

A replenishment assessment can be an important charge as part of an overall water basin management approach. Varying the magnitude of replenishment assessment helps to influence the variable cost, and therefore the use of groundwater relative to water from other sources.

Neither the District nor the county has the power to establish a replenishment assessment, and no such power is included in the amendments to the District Act that were proposed in 1990.

D. PRIVATIZING THE SALINAS VALLEY GROUNDWATER BASINS

The majority of the initial research on groundwater allocation focused on the development of optimal control techniques for maximizing the net present value of the resource [Ref. 29:pp. 33–34]. Recognizing the practical difficulties of implementing optimal control models, the hesitance of most groundwater regulatory agencies to use incentive-oriented management techniques that affect consumer behavior and therefore the supply and demand for water resources, and other problems inherent to bureaucratic control, has spurred interest in creating private property rights for groundwater. Establishing groundwater rights is fundamental to creating a market system for agricultural water resources because it establishes a commodity that can be defined, valued, and traded.

E. GROUNDWATER RIGHTS: A HISTORICAL PERSPECTIVE

As long as groundwater was relatively abundant, it made little sense for the early American settlers to devote much effort to devising institutions to govern its allocation. As with many of our property institutions, the simplest rules were adopted from those of England. The

English rule of absolute ownership first used to establish property rights in water gave the overlying landowners complete freedom to allocate groundwater without liability. Since the early English courts knew little about the hydrology of groundwater, they avoided the issue of classifying groundwater as property in the same sense as rocks and minerals on or under an individual's land. "It was in the light of this scientific and judicial ignorance that the overlaying land owner was given total dominion over his 'property,' that is, a free hand to do as he pleased with the water found within his land, without accountability for damage." [Ref. 30:p. 272] This form of property rights worked well as long as third-party injuries were rare—that is, as long as groundwater was not scarce. [Ref. 31:p. 225]

1. Reasonable Use Doctrine

As the demand for water grew and individuals began to compete for water and land use, the English rule of absolute ownership had to be modified. The United States courts softened the English rule with the American rule of reasonable use. Under this law, overlaying landowners had coequal rights to the groundwater, subject to reasonableness. The judicial determination of reasonableness is related to the demand of adjacent landowners on the common supply. This aspect of the reasonable-use doctrine can create uncertainty in the long run. The determination of reasonableness is subject to the whim of the court and can change with various economic and social conditions. As water has become more scarce, uncertainty has increased as more uses have been successfully challenged as unreasonable. [Ref. 31:p. 227]

2. Correlative Rights Doctrine

The common-law rule of absolute ownership and reasonable use of groundwater was rejected for California in 1903 and replaced with the correlative rights doctrine. The correlative rights doctrine differs from the reasonable use doctrine in two basic respects. First, in the event that the demand for groundwater exceeds the supply, then all overlaying land owners must reduce their use on a coequal basis. Second, in cases where supplies are in excess of the reasonable needs of overlaying landowners, then water may be put to use in areas that don't overlay the aquifer itself. [Ref. 31:p. 228]

3. Current Water Rights Doctrines

In general, the water doctrines that exist today have evolved as a result of the changes in benefits and costs of defining and enforcing property rights. There are three predominant methods for allocating groundwater today. The arid western states follow the appropriation doctrine[8] (except for California, which uses the correlative doctrine). The more humid eastern states, with their higher annual precipitation, allocate groundwater according to the reasonable use doctrine. [Ref. 31:p. 228]

While the increasing relative scarcity of groundwater has brought pressure for the establishment and revision of groundwater

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[8]The fundamental principle of the water right under the appropriation doctrine is expressed in the phrase "First in time—first in right." The rights of water users depending on a common source of supply are not equal but are ranked in a hierarchy established by the date at which the uses were first initiated.

rights, this pressure has not resulted in an efficient institutional arrangement, that is, a set of property rights that gives users the market incentives to put groundwater resources to their highest valued use. For this to happen, property rights must be well defined, enforced, and transferable. Definition and enforcement are necessary to give individuals the incentive to use water efficiently. In order for exchange of water rights to take place, traders must have some idea of what rights are included. Less will be paid for rights not well defined and enforced, and in the extreme no trade will occur. [Ref. 31:p. 229]

Consider the impact of one person's pumping groundwater on another's pumping cost. If the rights being purchased cannot be exercised at the original pumping costs (that is, those pumping costs before the sale), the buyer will have an incentive to pump more water in the short term. If water rights are defined as a fixed quantity of water, the buyer of water rights will want to pump more water in the near term, where his pumping costs are known and these costs are reflected in the price of the water he has purchased. If the buyer of the water rights waits to pump the water he has just purchased, his pumping cost may increase because of the activities of pumpers around him. This increased cost was not reflected in the original purchase price of the water rights. Without property definition and enforcement, pumpers have this incentive, which can promote excessive depletion of the groundwater basin. [Ref. 31:p. 230]

The transferability of property rights ensures that individuals will take into account the opportunity costs of their actions. As long as individuals are free to buy and sell water rights, market prices will emerge, making owners aware of the cost of wasting water. If rights are not transferable, the fact that water has more valuable alternatives (that is, water has different marginal values for different uses) makes little difference; the owner will not be able to sell his water to those who have the higher valued uses. [Ref. 31:p. 232]

The public institutions that have evolved to govern groundwater, like the Monterey County Flood Control and Water Conservation District, have typically defined groundwater rights in ways that are deficient both in terms of certainty and transferability. The groundwater rights in the Salinas Valley are not tradable, although they do run with the land and the land can be traded. Therefore, the only way to reflect the value of water rights is through the price of the overlaying land. Since the value of a parcel of land has other considerations besides water rights, the purchase price of the land does not purely reflect the value of the water rights to which the land owner would be entitled.

4. Mutual Prescription Doctrine

In some instances, California has been evolving toward providing public institutions the power to establish groundwater property rights. The California State Supreme Court ruled (1972) in favor of the mutual prescription doctrine. Under this doctrine, a basin is to be adjudicated[9] and a safe level of extraction determined. A share of the

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[9]Adjudication of the aquifer means that the courts will decide on a legal and safe level to which water can be extracted. Pumpers will be forced to adhere to the level of pumping that will result in this level.

rights is then allocated to each of the groundwater users in the basin on the basis of their known or estimated extraction, prior to adjudication. Since such a system eliminates a part of the common pool problem, provides an institution for reducing tenure uncertainty, and (by defining ownership) allows for the possibility of transferring water rights. The mutual prescription doctrine is currently being applied to the Tehachapi basin. The Tehachapi basin is located in Kern County approximately 35 miles southeast of Bakersfield, California, and 100 miles north of Los Angeles. The mutual prescription doctrine was adopted in Kern County in 1971 as a result of a severe overdraft problem. [Ref. 31: pp. 242-243]

5. Riparian Rights

Riparian rights apply to surface water and do not transfer well to groundwater. Riparian rights define the water rights o. landowners adjacent to streams, rivers, or other sources of surface water. All owners of riparian lands have a legal right to a certain use of water in the stream, while non-riparian land owners generally have no water rights. No riparian rights exist for the Salinas or the Arroyo Seco River. Riparian rights establish a rule of capture, so that the absolute or reasonable use doctrine does not apply to overlying landowners.

There are subtle relationships between surface water and groundwater. Some surface-water flows are controlled so as to replenish groundwater. Generally, this benefits surface-water users by making water available more consistently over time. However, if groundwater levels have been pumped down, the surface-water flows can percolate into the groundwater faster, potentially reducing the amount of water reaching downstream surface-water users. An example of this is the Carmel River today.

Finally, if groundwater levels are pumped down and drought conditions occur, the vegetation along the surface-water channel can die. Besides the obvious negative æsthetic effect, this can harm those holding riparian rights by:

a. Damaging floodplain agricultural activities.

b. Allowing increases in future channel erosion, which can destroy adjoining structures.

c. Reducing the volume of flood water that can be retained by the channel, thus increasing the risk of flood damage.

Under California's current correlative rights doctrine, landowners have little or no incentive to conserve. If they do not pump the water, someone else will. The cost of water is a function of the pumping cost and pumpers clearly anticipate that pumping cost will increase in the future. Clearly the potential exists for altering the property rights that govern groundwater allocation to make them more efficient.

F. A MODEL FOR GROUNDWATER USE

Anderson [Ref. 31:pp. 229-230] describes a simplified model of a groundwater basin. The basin is much like a tub filled with saturated coarse sand; a stream of water is flowing in (net natural recharge) and water is being pumped out from the porous medium in the tub. A static model describing the recharge and outflow of water in the Salinas Valley aquifer was developed by Yates [Ref. 1:pp. 6-23]. Table 1.1 in Chapter 1 describes the output of this model. The Salinas Valley groundwater basin is a single unit without divisions, so this model will be used to describe conditions in the Salinas Valley. If the incoming flow matches the pumping, the level of saturation of the sand is stable. Otherwise, the level will rise or fall as the difference between recharge and pumping is positive or negative. The natural recharge to the aquifer is a random variable, and as a practical matter the amount of water being pumped is a random variable reflecting variations in irrigation demand caused by fluctuations in seasonal precipitation and temperature.

Three variables determine the economic value and allocation of groundwater over time, the annual rate of pumping, the total stock of groundwater at the beginning of the year, and the amount of recharge each year. The annual rate of pumping determines the amount of water used per year in production. The annual pumping rate in the Salinas Valley in 1989 was estimated to be 659,400 acre-feet per year, 90 percent of which (593,460 acre-feet) was consumed by agriculture [Ref. 15:p. 2]. Total recharge in the aquifer was estimated to be 622,900 acre-feet, resulting in an overdraft of 36,500 acre-feet.

Anderson [Ref. 31:pp. 229–231] defined the role of stocks as twofold. Their most direct and fundamental role is to provide the physical basis for water to be used in production, particularly when water supplies fluctuate rapidly. Their second role is related to pumping costs; higher stocks imply lower pumping costs because there is less of a lift requirement. This implies users would place a future value on the stocks left in the aquifer which is equal to the present value of the stocks currently being used for production.

While an important part of the stock value of groundwater is related to pumping costs, Anderson [Ref. 31:p. 234] describes two other sources of value. First, because they are bowl-shaped, most aquifers lose part of their spatial distribution function as stocks decline. As the surface area of the aquifer water table decreases, the land surface area overlaying groundwater is reduced. Wells on the old perimeter before stocks were depleted go dry, and water has to be transported from elsewhere to the land lying near the old perimeter. In coastal areas like the Salinas Valley, saltwater intrusion can occur as stocks decline. For example, in parts of the Salinas Valley adjacent to the ocean, saltwater has intruded up to five miles inland in the aquifer, beneath nearly 13,000 acres of land [Ref. 15:p. 2].

Further loss of efficiency is encountered whenever the cone of depression created around the pump intersects the edge or bottom of the aquifer, because pumping capacity is reduced as stocks are drawn down. This problem is especially critical for irrigated agriculture, where timing of water delivery is extremely important. Since the intercessional storage and spatial distribution functions of the aquifer can be adversely affected as draw-down occurs, stocks have a value in addition to their direct impact on pumping costs. [Ref. 31:p. 234]

Second, when recharge and irrigation demand are a random variable, stocks have a contingency or insurance value. Shortages of water can cause a reduction in production to a point where water has a relatively high marginal value, creating a large opportunity value for stored water. A direct relationship exists between marginal value of stocks and the variability of the net additions to stocks in an aquifer. This variability has more impact on the marginal value of stocks at low rather than high levels. When stock and flow rights are clearly defined, the insurance value of groundwater stocks will allow individuals to place a future value on water remaining in the aquifer. This means that future water will probably be available for individual use. Therefore, overdraft is less likely to occur because individuals will want to preserve their right to use stock in the future. [Ref. 31:p. 234]

G. FULL STOCK-FLOW RIGHTS

The most fully defined property rights in groundwater would establish full stock and flow rights [Ref. 32:pp. 7-10]. The estimated stock of the water in the aquifer would be allocated as a once-and-for-all property right that could be exercised at any time. The amount of groundwater flow rights would be allocated each year based on a percentage of total annual recharge. If the long-term recharge rate should change, these flow rights would be adjusted accordingly. As long as surface drainage is not a problem, carryover of unused flow rights from year to year would be allowed.[10] The property rights would be allocated to individuals in proportion to their pumping during some base period. Using the Salinas Valley groundwater basin and a base year of 1989, the deeds or water

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[10]Surface drainage is only a problem if unused flow rights are not returned to the aquifer. Unused flow rights would be lost if they did not percolate back into the aquifer.

rights using Smith's [Ref. 32:p. 7-10] model would be determined as follows:

1. Individual proportions of the flow in acre-feet would be a function of the total use in 1989, which was 659,400 acre-feet. Let the amount used by the i^{th} individual be x_i acre-feet. Then the proportion of total use by individual i in 1989 would have been $x_i/659{,}400$, which is denoted p_i.
2. The flow right would be based on a fraction of long-run average net recharge to the basin, which has been estimated at 622,900 acre-feet. Therefore, the property right of individual i to an annual flow is $r_i = 622{,}900p_i$ thousand acre-feet per year in perpetuity.
3. The stock right would convey a right to a share of the basin's stock, which was estimated to be approximately 1.05 million acre-feet in 1989. The share of this stock granted to individual i would also be p_i, giving a right to pump from the stock no more than a total of $R_i = 1.05p_i$ million acre-feet at any time in the future.

The initial allocation of water rights is arbitrary and primarily a question of equity. To assign the water deed by the appropriative doctrine usually means that potential claimants must show evidence of use. If the base period is a future known period, individuals may maximize their pumping during this period in order to receive a maximum allocation. Under this scheme, individuals who had adopted conservation methods prior to the base year would be penalized because their consumptive rates would be lower.

To keep this from occurring, the base year could be derived from an average of the previous ten years or some other large period of time, making the process fairer. Another possibility could be to devise a system to compensate individuals who have adopted conservation methods prior to the base year through "water credits." These credits would give conservation-minded farmers additional flow rights and penalize individuals who were wasteful of water. Measuring and rating conservation methods to assign water credits would involve some subjectivity. Therefore, great care would have to be taken in assigning water credits, if such a system were used.

Another alternative to the initial allocation of water rights would be to assign water deeds to land owners in proportion to land overlaying the aquifer. This method of allocation would avoid the incentive to waste water in establishing a priority right. Water rights would be sold with land. New users[11] who did not exist before the base year when the initial allocation was performed must acquire, through purchase, existing stock and flow rights. This would only be economically efficient if a market were established for exchanging groundwater rights.

H. ENFORCEMENT OF WATER RIGHTS

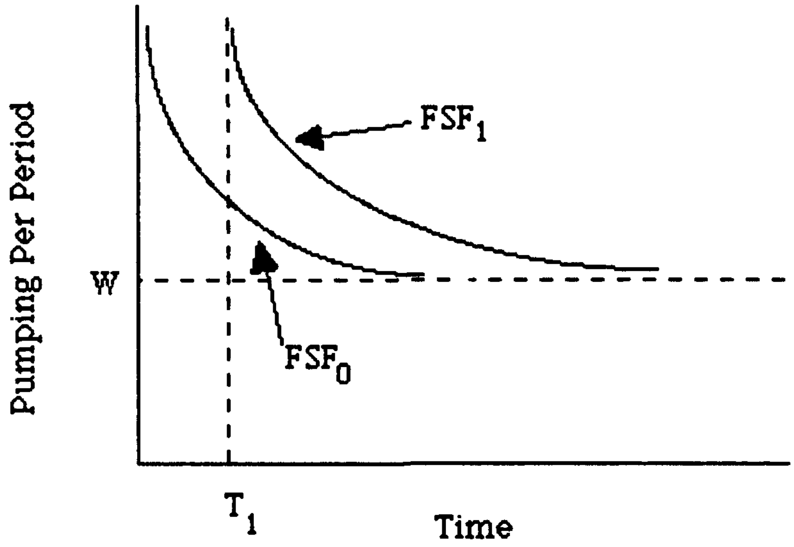
Enforcement is critical for groundwater rights to be an effective alternative to centralized management. Several methods could be devised to enforce private water rights. Pumps could be metered. Each owner of a right could begin with an initial stock. At the end of the year, an adjustment would be made to the owner's stock account by subtracting the amount pumped and adding the appropriate share of aggregate natural recharge. Because the latter component is a random variable from year to year, observed stream flows or other sources of recharge would be

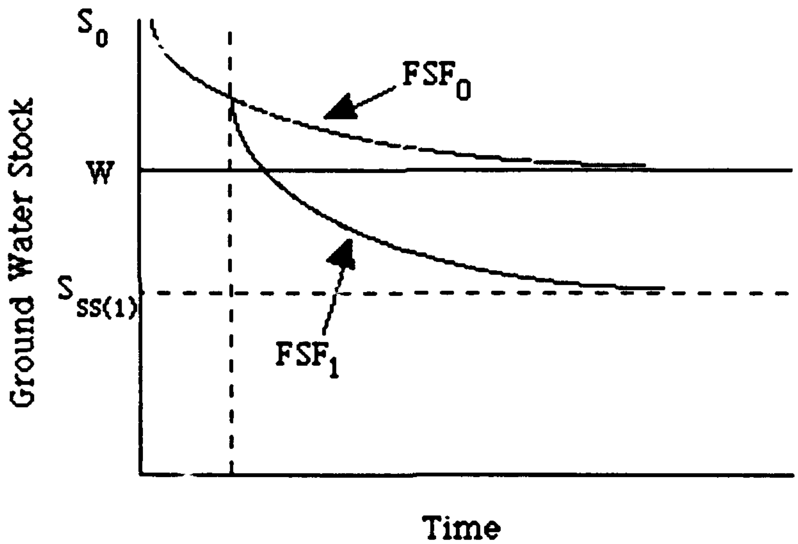
[11]New users are defined as users whose land doesn't overlie the aquifer, or old land owners who changed uses to something that requires more water than they own.

used as an estimate. In the Salinas Valley, return flows from irrigation would be of consequence. They would be applied to reduce the subtraction from pumping. A method to maintain the integrity of the meters and to maintain control over the construction of new wells would have to be devised. With additional manning, the Monterey County Flood Control and Water Conservation District could undertake the responsibility of monitoring wells, estimating return flows, and adjusting stock and flow accounts. Legal authority would have to be granted to levy fines on violators for pumping more than the amount owned.

I. THE EFFECT OF STOCK AND FLOW RIGHTS

Fractor [Ref. 33:pp. 405–412] has shown that an advantage to privatizing groundwater rights through the establishment of stock and flow rights is the consequent flexibility in the face of changing economic conditions. In Figure 3.4, the initial stock of ground water is larger than the stock that would exist in the long-run steady state (where use equals recharge). Time paths for groundwater pumping and groundwater stock in the case of increased water demand with full stock-flow rights (FSF) are illustrated in Figure 3.4. Suppose the demand for water increases. The pumping per period would increase from FSF_0 to FSF_1. This increase in pumping reflects the increase in water demand. Groundwater stock would decrease from FSF_0 to FSF_1. In this case, the stock would be used because FSF_1 is below the periodic recharge level. The full stock-flow rights would allow for complete adjustment to this increased demand. Because the entire resource has been adjudicated, we would simply see





Legend

FSF_0	=	Full stock-flow rights prior to demand change
FSF_1	=	Full stock-flow rights after demand change
S_0	=	Initial stock
S_{ss}	=	Steady state stock
W	=	Periodic recharge
T_1	=	Time of demand change

Figure 3.4. **Time Paths for Groundwater Pumping and Stocks With Full Stock-Flow Rights: Increased Water Demand**

water shifting from the future to the present and some previously unused stock rights will be exercised. We implicitly assume that some stock rights will still exist at the steady state. A steady state for stock rights means that the "stock" of water in the aquifer remains relatively constant because individuals will exercise their flow rights first. Given that the marginal cost of extraction likely rises at an increasing rate as the stock diminishes, economic exhaustion will occur before physical exhaustion of the groundwater stock. Individuals will stop pumping prior to the physical exhaustion because their pumping cost will increase to a point where it is no longer worth pumping. If there are no other alternative sources of water (e.g., surface water or desalinization of sea water), then the uses will be forced to use less water or go out of business entirely.

IV. WATER MARKETS AND MARKET ACTIVITY

A. PROPERTY RIGHTS AND MARKETS

The force driving the actions of economic agents, which manifest themselves in markets and the price mechanism, is a search for the wealth created by the scarcity problem. Markets are based on a system of property rights for those resources and goods that are scarce. The rights to property allow the owner to exclude users, husband resources and enhance wealth. However, there is no private market activity involving these property rights unless they are transferred. Thus, the presence of private transferability distinguishes the market solution from the other methods of allocating water. [Ref. 31:p. 102]

Property right theories have had considerable success in explaining the development in markets and other institutional arrangements across a broad range of situations [Ref. 26:p. 347]. Demsetz [Ref. 34] has studied the relationship between institutions and market formation. Two fundamental principles can be distilled from Demsetz's work. The first is that, as property rights become more valuable, more effort will be devoted to the property definition and protection of property rights. Demsetz shows that Canadian Indians developed property rights for hunting grounds as the value of beaver pelts increased due to an emerging fur trade. Anderson and Hill [Ref. 35:p. 163] extend this idea by applying their theory of the supply and demand of property rights activities to western cattle ranching. They point out that as the value of land and horses (a determinant of demand for the associated property rights) rose and fell, there was a corresponding rise and fall in the expenditure of resources on property rights definition and enforcement. Similarly, as the cost of property rights to land fell with the introduction of barbed wire, more fencing was used to define and enforce property rights. [Ref. 31:p. 250]

Demsetz's second point is that enforcement costs are a function of the structure of the property right. Because of the difficulties in defining stock and flow rights, the enforcement costs for these rights would be high. Umbeck [Ref. 36:p. 421] shows that during the California gold rush, the earlier contract choice of sharing the product of a claim was abandoned as the mining population (and stealing) increased, thereby increasing the cost of enforcing this type of agreement. Therefore, the ability to clearly define water rights and monitor the exchange of these rights is essential to a market. [Ref. 31:p. 252]

Property rights for water would become more valuable in two cases: if the current supply of water in the aquifer is decreased, or if the demand for water increased. The supply of water could decrease under two conditions. First, if the recharge rate decreased during the year, the yearly allocation of water recharge would be smaller. Thus, the water available would have more value. Second, if demand for water increases (perhaps as a result of an introducing a highly valued, water-intensive crop), the stock of water would decrease because farmers would be more likely to exercise their stock rights. This would increase both the values of flow rights and the remaining stock rights.

To recognize the efficiency of a free market system for water, it is useful to look at two aspects of water allocation. The first aspect is the effect of water management methods in evaluating the external costs of water extraction. These costs are the externalities which individuals must bear as a result of independent pumping. The second is the relative economic efficiency of each allocation method. The allocation efficiency is measured by evaluating each method in terms of maximizing societal benefits. Societal value in markets is reflected through the pricing system. Therefore, in this case, societal benefits are equated with net revenue maximization (total revenue minus social costs).

B. TAX APPROACH TO WATER ALLOCATION

One alternative to a free market for water is the water tax approach. Figure 4.1 shows the private marginal cost curves for a broccoli grower, PMC_1, and society's marginal cost, SMC_1, to illustrate the economics of this approach. The difference between the social marginal cost curve and the private marginal cost curve for the broccoli grower is the social cost resulting from the pumping actions of the broccoli grower. The broccoli grower creates a social or external cost because his pumping affects the pumping cost of the individuals around him. The individuals on the edge of the aquifer are most affected by others' pumping, so the social cost to them is the greatest. If we could determine the amount of the external or social cost for each water consumer, we could set the tax at this level. The revenues generated by the tax could be used to compensate secondary parties harmed by pumping water from the aquifer or to finance a wide range of water projects, including applied research on better methods of improving water conservation.

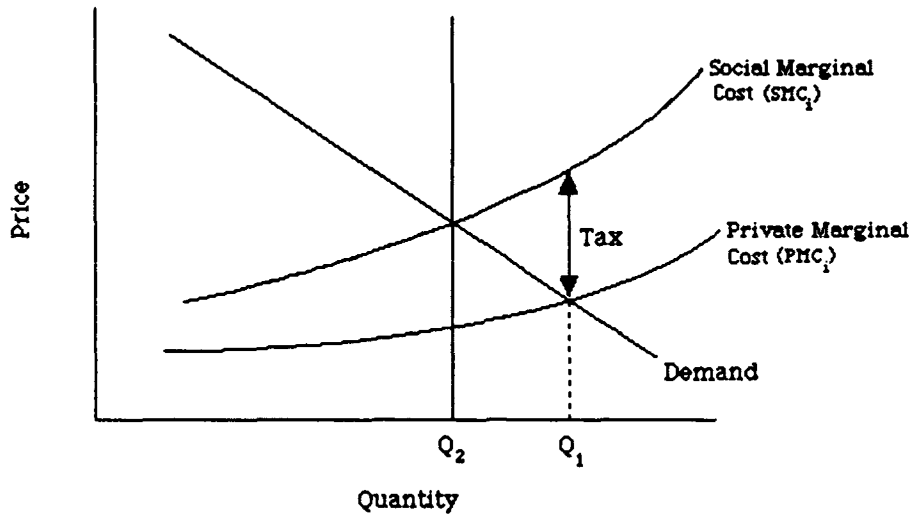


Figure 4.1. **Broccoli Grower's Marginal Cost Curves**

The tax approach would promote efficient allocation by altering several economic incentives in a highly desirable way. First, the water tax would increase the cost of producing water-intensive crops, causing the supply of these crops to decline. Second, the water tax would give farms an economic incentive to use agricultural methods that consume less water (e.g., reduce double cropping, switch to less-water-consumptive crops). A properly set tax would approximate the ideal price and output conditions, as in Figure 4.2. In Figure 4.2, the supply curve S_2 is the ideal, reflecting the social and private cost of pumping water, and incorporating conservation methods that are chosen to minimize the sum of those costs. S_1, however, reflects purely the private costs and production techniques chosen to minimize only the private costs. Thus, the ideal output is Q_2 and the optimal cost (and price) is P_2. But when the producer is not responsible for social costs, we can expect the larger output, Q_1, and the much larger social marginal cost, MC_S, even though the buyers only pay P_1 for water pumping.

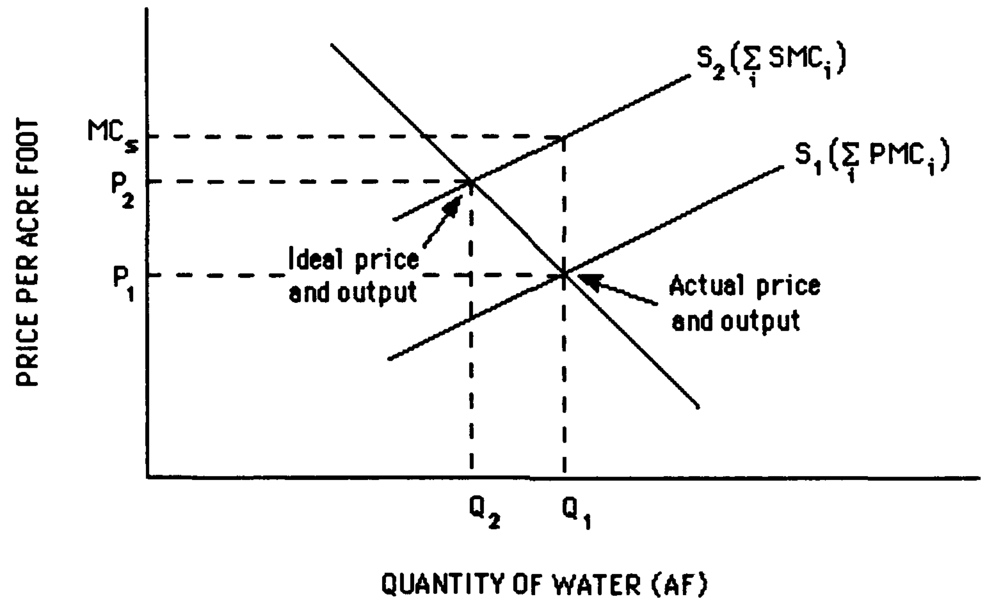


Figure 4.2. **Supply, Externalities, and Minimum-Cost Production**

Third, since farms would be able to lower their tax bills by reducing water consumption, a market for innovative water conservation techniques would exist. As long as it was cheaper for the firm to incorporate water conservation techniques than to pay the water tax, the farm would opt for improved water conservation. Entrepreneurs would be induced to develop low-cost irrigation and water conservation devices and market them to firms that would now have a strong incentive to reduce their water consumption.

The water tax is appealing because it can, in theory, be efficient, but there are three common objections. First, an efficient tax is one based on the external pumping costs incurred by other water consumers. Without knowing what these external costs are, an efficient tax cannot be figured or implemented. Determining external costs is difficult. Farmers pumping at different locations in the valley will be affected by external costs in different degrees. Farmers closer to the edge of the aquifer will absorb a greater social cost because their pumping cost will be most affected by others' pumping. To be truly equitable, a tax would have to be calculated for each farmer based on the degree to which his pumping affected other farmers' pumping. The revenue from the tax would have to be distributed differently to each farmer, based on the external effect of others' pumping on his own pumping costs. This problem could be somewhat alleviated if the valley were divided into zones based on the external costs imposed and the external effect absorbed by each farmer.

A second objection to the water tax alternative is that it requires monitoring the amount of water pumped. But any efficient strategy requires the monitoring agency to know how much is being pumped, so this objection does not weaken the tax option relative to other strategies. A more telling, third objection is a political one: to switch from a situation in which the pumper does not pay any external costs to one in which external costs are paid to the tax collector by pumpers would involve a huge transfer of wealth.

C. MAXIMUM WATER CONSUMPTION STANDARD

Although economics suggests that the water tax approach would be more efficient than other centralized water management practices, a maximum water usage standard is often suggested [Ref. 24:p. 53]. In this case, the regulatory agency forces all pumpers to reduce their pumping to a designated level. Pumpers who are unable to meet the standard are required to terminate pumping, or are penalized for continued pumping.

The problem with this approach is that it is inflexible, especially when changes occur in water demand. Figure 4.3 illustrates this condition for changes in demand. Suppose the quantity of water being pumped were fixed at q_1 and demand for water increased from d_1 to d_2 as a result of a market change (for example, vegetable producers in Florida had unseasonably cold weather, so the demand for vegetables from the Salinas Valley increased). Pumpers would be willing to pay higher pumping costs p_2 to pump the additional water, but they are unable to because of the quantity is fixed at q_1. Conversely, if demand decreased, from d_1 to d_3, the pumpers would have no incentive to reduce water consumption.

D. WATER MARKETS: A CASE COMPARISON

We can examine the effects of each one of these methods in terms of economic efficiency by presenting a simple case of two different farms, each using different amounts of water and producing different crops. Figure 4.4 illustrates the farms' total annual revenue curves. The total annual revenue curves show the amount of revenue gained as a function of the amount of water used for production. The total revenue curve

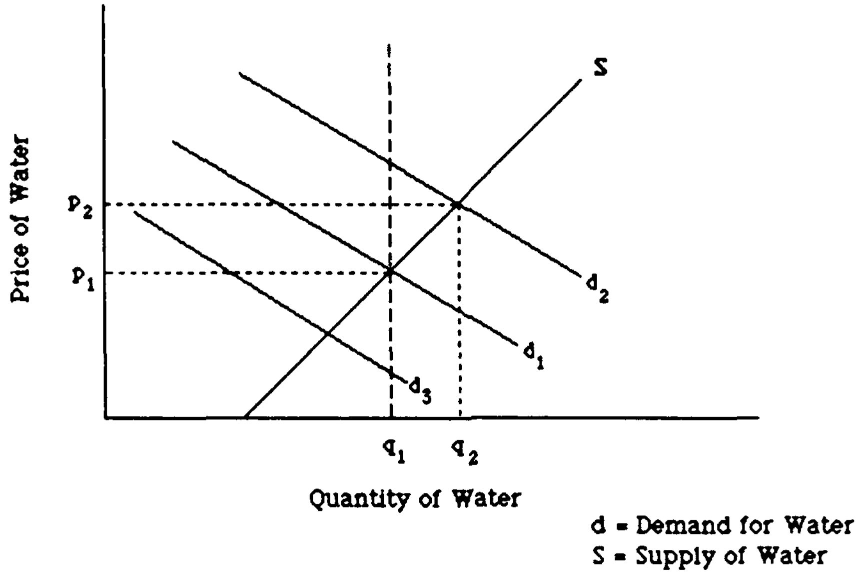


Figure 4.3. **Maximum Water Consumption Standard Approach With Changes in Demand**

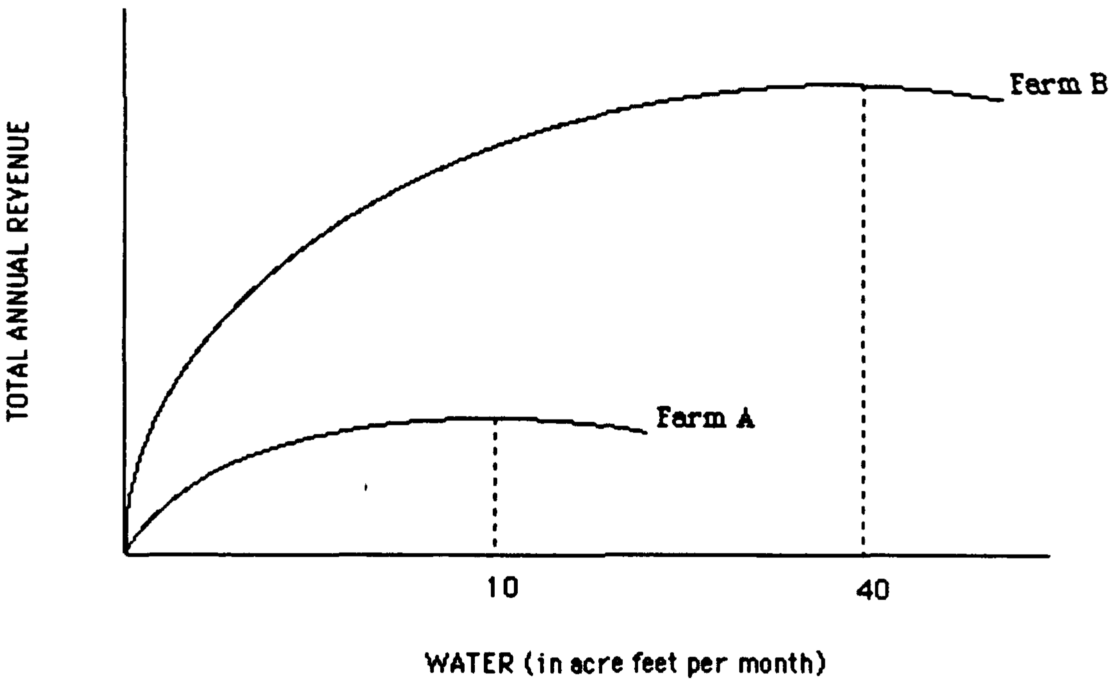


Figure 4.4. **Total Revenue for Farms A/B**

shows that farm A would maximize revenues at 10 acre-feet of water a month and farm B would maximize revenue at 40 acre-feet per month. Water used in excess of these amounts would cause revenues to decrease because additional water would not increase crop output, but total pumping costs would continue to increase.

To compare the efficiency of each farm with regard to water use, each farm's marginal net revenue curve must be examined. Marginal net revenue in this case is defined as the additional revenue generated with each additional increment of water used. Figure 4.5 depicts the marginal net revenue curves for farms A and B. Mathematically, these curves are derived from the total revenue curve by taking the first derivative of each total revenue curve. In this case, the equations for the marginal net revenue are: $MNR_a = 10 - w$ and $MNR_b = 4 - .1w$, where w = acre-feet of water. The marginal net revenue curves still show that both farms maximize their revenue when 10 and 40 acre feet per month, respectively, are used. The slopes of the marginal net revenue curves are different showing that the value of an additional increment of water varies between farms. The slopes of these curves are based on the type of crop farmed, the efficiency of the farm's irrigation system and water conservation methods, the market price of the crops farmed, and the fertility of the soil.

When the supply of water is greater than the sum of all farms' optimal usage values, farms A and B will choose to use 10 and 40 acre-feet of water a month. If a drought occurs, one policy to reduce water

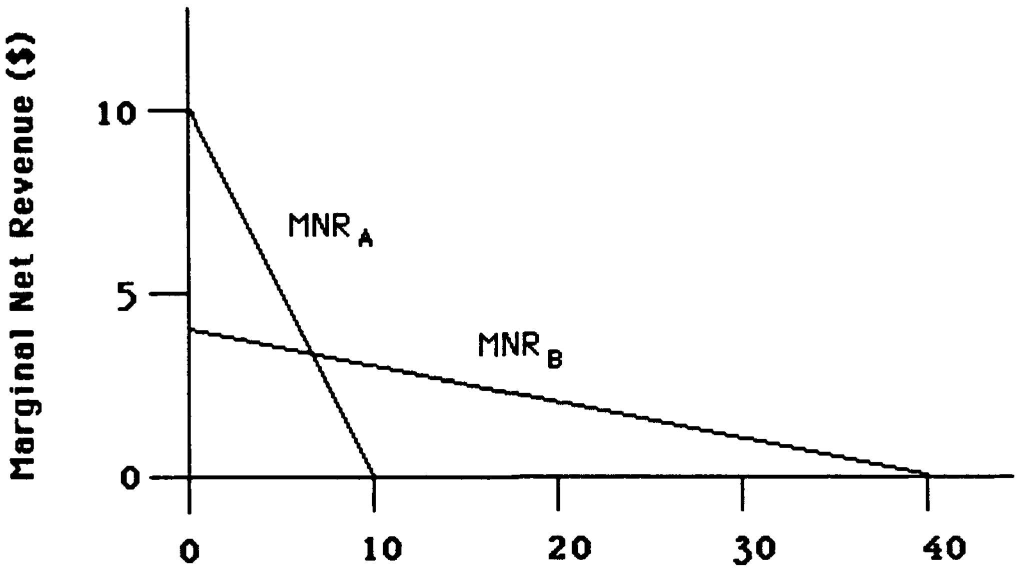


Figure 4.5. **Marginal Net Revenue for Farms A and B**

consumption may be to set a limit for each farmer. For example, an institutional action may have each farmer reduce water consumption by 10 percent. At this level of reduction, farm A would consume nine acre-feet of water and Farm B would consume 36 acre-feet of water. Figure 4.6 illustrates this. The total revenue is determined by calculating the to area under the marginal net revenue curves. The total revenue generated under these conditions would be $128.7. This represents the area under the marginal net revenue curve between 0 and 9 for farm A and 0 and 36 for farm B.

The purpose of any water management policy should be to maximize the total net revenues of water. This is one of the characteristics of a market. The market transmits information through the price system about the value society places on goods and services. Maximizing total

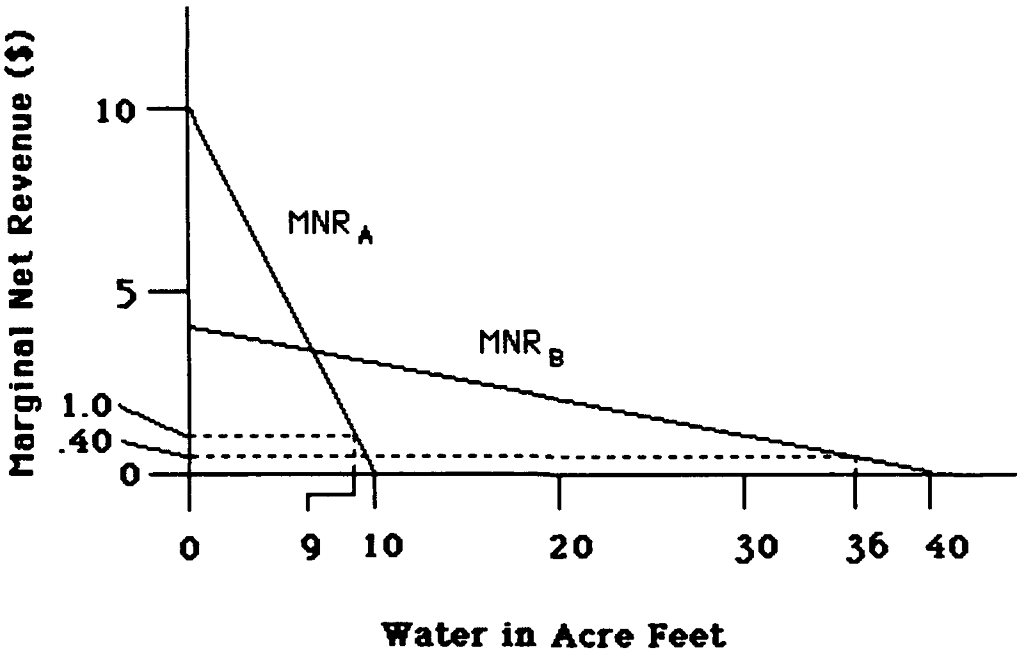


Figure 4.6. **Marginal Net Revenue for Farms A and B Water Limitation (Reduction by 10%)**

net revenue would indicate that the water was being used in a way that society most valued. Under the trading of water rights condition, changes in social marginal costs and marginal net revenue would be realized by individuals willing to trade and the market would make this correction.

The 10 percent reduction does not maximize the total net revenue for each farm at that level of water consumption. Each farm's net revenue is not maximized because farm A and farm B have different marginal values for water. Assume that now farm A and farm B own water rights for nine and 36 acre-feet of water, respectively. Under these conditions, the farms will try to use water where their net marginal revenues are equal to each other. Recalling that $MNR_a = 10 - W$ and $MNR_b = 4 - .1W$, and that farm A and B own water rights that total to 45 acre feet (W_a +

W_b = 45 acre-feet). We can solve for W_a and W_b when marginal net revenues are equal. In this simple case, farm A's and farm B's marginal net revenues are equal when farm B uses 35.45 acre-feet of water and farm A uses 9.55 acre-feet of water, as shown in Figure 4.7. Therefore, to obtain the same 10 percent reduction, Farm A would be willing to buy .55 acre-feet of water from farm B and farm B would be willing to sell that same amount to farm A. This assumes there are no transaction costs. Total revenue generated by the two farms when they operate at these points after the exchange is $128.9. At this level of water use, the total net revenues are maximized and neither party can realize any gains from further exchanges of water rights.

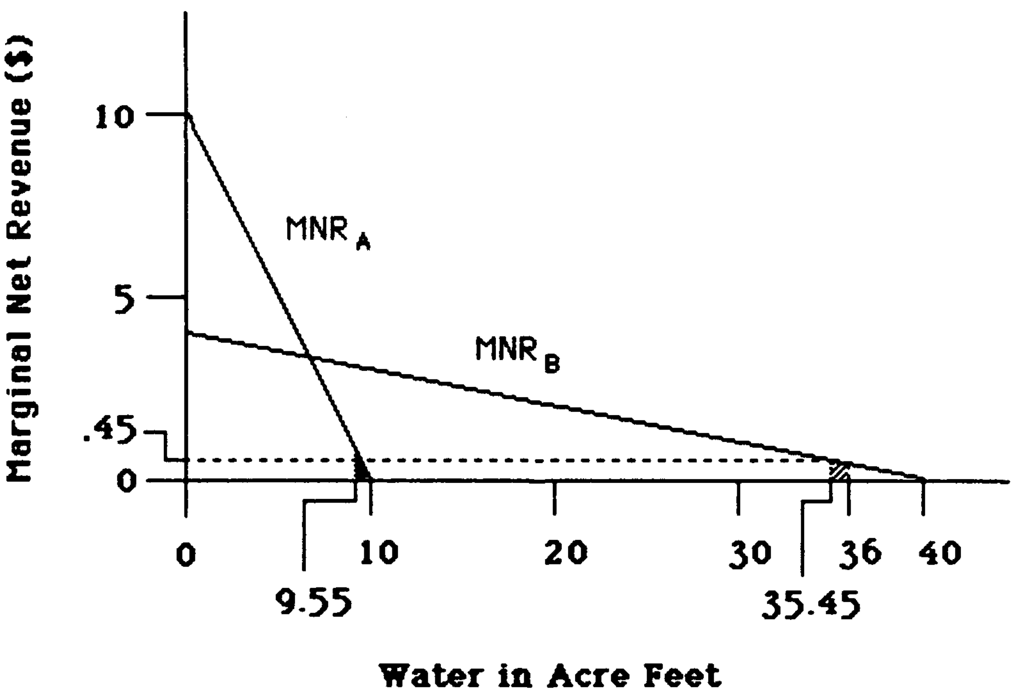


Figure 4.7. **Marginal Net Revenue for Farms A and B ($0.45 Tax Applied)**

The tax approach to water allocation can also provide net revenue maximization. If the institution setting the tax could perfectly predict the revenues for all parties, it could set a tax that would maximize net revenues. In this example, a tax set at $.45 per acre-foot would cause farms A and B to use water at the same level as they did when water rights were traded. The problem with the tax approach is twofold. First, there are more than two farms in the Salinas Valley. Since each farm's net revenue must be known to the tax agency, it would be very difficult to get the data needed to determine the tax at which net revenue maximization occurs. Second, the tax approach is inflexible when there are changes in the social marginal cost of water (supply) or the marginal net revenue (demand). For example, if either farm changes its net revenue curve (by changes in crop type or improved irrigation methods), the tax would have to be recalculated. The optimal tax rate should equal the external costs associated with the quantity of water pumped. As the demand for water increases and farmers start pumping more water, the optimal tax should increase. Thus, the tax would have to be recalculated, unless it were stated as a function of the total quantity of water pumped. Changes in supply introduce similar problems. As the supply of water decreases, external pumping costs increase for a given quantity of water pumped. Thus, the optimal tax would increase and so have to be recalculated.

Given the three potential methods of water allocation, the tax approach, the maximum water consumption approach, and the market approach, the market approach provides the most efficient allocation of scarce water resources under continually changing conditions.

E. WATER PRICING AND WATER MARKETS

Water prices in a free market organize economic activity in three ways: (1) they transmit information, (2) they provide an incentive to adopt those methods of production that are least costly and thereby use available resources for the most highly valued purpose, and (3) they determine who gets how much of the resource. A market for water rights would be efficient because it would consider the marginal value of water to each user. In such a market, water users would exchange water rights until their marginal benefits are equal. As shown in the previous section, if farmer A can benefit more from using an additional unit of water than farmer B, farmer A would be willing to purchase that unit from B. For farmer B to be willing to sell that unit to farmer A, he must at least receive his marginal value for water. In a market, this is how water prices would be determined. Further, the kinds of crops that require a lot of water would become more expensive and would carry higher prices than those that required less water, so consumers would be induced to buy more of the latter. The advantage of the market system over the tax system is that not only does the market encourage conservation (because unused water rights can be sold and a profit can be made), but the water is allocated to its most profitable use. In an agricultural area with limited water resources, like the Salinas Valley, society is better off if the limited supply of water is used on the most productive soil and crop combinations in order to maximize agricultural output. The market will make this allocation by transmitting information through the prices for goods produced with water resources and the prices of tradable water rights themselves. Economic order emerges as the unintended consequence of the actions of many people, each seeking his own interest. The price of water will reflect the scarcity of the resource to those owning the water rights.

F. ROLE OF WATER EXCHANGES

The formation of a water exchange or organized market can enormously facilitate the transmission of information. A formal water exchange would provide an institution through which farmers could buy and sell water rights. It would also provide an institution for enforcing those rights. Water accounts for each water user could be kept. As exchanges took place, water accounts between the traders would be adjusted to reflect their new balances. A water exchange could also provide an institution which would reallocate flow rights every year. As discussed previously, flow accounts would be calculated and credited each year based on the amount of recharge for the year. Stock rights would remain relatively constant and only change when stock rights were exercised. When stock rights were exercised, this transaction would be recorded in the user's stock account. Prices for water would be tracked and set each day on the water exchange. Flow and stock rights would be traded much like commercial stock on a stock exchange. The exchange would provide a clearing house for potential buyers and sellers of water rights and also provide uniformity so that all exchanges would occur under the same conditions and so that there would be no abuse of rights or black markets for water.

It would be possible to account for water rights using a single account—one which holds the initial stock amount and is simply added to by flow replenishments and deducted from by metered pumping. However, having a separate stock account would make it easier to determine the aquifer level at a given time. The separate stock account also would provide a baseline figure or safety level for water in the aquifer.

G. BARRIERS TO A MARKET SYSTEM

A new way of doing business, especially one which would require a significant departure from current procedures, does not get implemented without encountering barriers. The major barriers associated with the implementation of a groundwater market system are: the task of making the initial allocation of water rights equitable, the lack of laws and institutions to administer the program, and the potential unwillingness of voters in the Salinas Valley to accept this type of change.

1. Initial Allocation of Rights

The initial method used to allocate stock and flow rights may be fundamental to the success of a groundwater market system. The initial allocation of these rights would be one of the most difficult and critical tasks to be accomplished in the establishment of a free-market system for water rights. Parties in the Salinas Valley receiving a comparatively small initial allocation of water rights might perceive that the state, by moving to a groundwater market system, has given something of substantial value to those who initially receive larger water allocations. In fact, there would not be any new wealth created by the initial allocations. Careful assignment of initial water rights could even allow the current distribution of that wealth to remain unchanged. Breaking the tie that currently exists between land and water will create new wealth only through the elimination of inefficient water use. It is important to understand that most of the potential wealth arising from water use already exists; it would only be made more visible by a water market.

2. Legal and Political Barriers

Currently, the Monterey County Flood Control and Water Conservation District has no legal authority to establish a free market system for water. Such authority would require political reforms at the state level. In addition, the Monterey County Flood Control and Water Conservation District, or some other institution, would have to:

a. Collect data on water use.

b. Establish and maintain data on the number of wells.

c. Provide a physical market for the exchange of water rights.

d. Provide a means for the enforcement of these rights.

e. Collect data necessary to estimate annual aquifer replenishment flow.

f. Collect data necessary to estimate irrigation returns to the aquifer, and to monitor the quality of those returns.

As mentioned previously, the Monterey County Flood Control and Water Conservation District could do this, but not without a substantial increase in staffing and authority. Obtaining this additional staff would be difficult under the current constrained fiscal environment.

With a water market system, an exchange would have to be established so there would be a way to trade water rights. This would be similar to the stock market, but would be specifically for water rights trading. Once again, the Monterey County Flood Control and Water Conservation District could do this, but not without a substantial increase in staffing.

The members of the local farming community will probably oppose any change in the current management of water if they think it will mean that they have to pay any more for their water than the present standby charges. Since the Salinas Valley farmers are currently not paying anything for groundwater itself (standby charges pay for water distribution, not water), any new distribution system, whatever its cost, would probably be seen as a potential reduction in farm profits.

A water market system might not be politically palatable either. Although the average citizen might feel that the program was in the best interest of the community, the strong and wealthy growers carry substantial influence in this largely agricultural community. Strong agricultural lobbyists could make it very uncomfortable for any politician supporting legislation that was perceived to have the potential of making crops more costly to grow.

3. Constituents' Acceptance

Although most private residents of the Salinas Valley realize that something has to be done to conserve water, they will probably not be receptive to a program that might require them to pay higher taxes to get the agricultural industry to conserve water. These higher taxes would be required to support additional government personnel to operate and monitor the market. Most private residents feel that they are already doing their part in the crusade to conserve water.

Many cities that get their water from the aquifer in the Salinas Valley have already imposed an across-the-board percentage cut in water use or have raised the price per gallon to discourage excessive use. Some cities, such as Marina, have formed a "water conservation task force" to determine additional means to conserve water through home, business, landscaping, and local government agency conservation measures. Requiring the local residential property owner to pay additional taxes to support the market system might seem unfair because he is already doing his share, and it is the agricultural growers that are using the lion's share of the valley's water and causing the problems.

V. SUMMARY

This thesis examined the groundwater resources problem in the Salinas Valley and analyzed a market alternative for allocating these resources in the agricultural community. The thesis covered three major areas: a discussion of the current drought conditions in the Salinas Valley and the importance of the agricultural community to the state and local economy, a brief description of groundwater law and models, and finally a comparison of a free-market system of allocating groundwater resources to both a tax system (where groundwater is taxed as it is extracted) and a maximum water consumption standard system (where a limit is set on the amount of water that can be extracted).

The Salinas Valley, which covers an area of 285,000 acres, enjoys a mild Mediterranean climate and benefits from normally moderate year-round temperatures. Agriculture is the number one industry in the Salinas Valley and has a significant impact on the county as a whole. In terms of annual dollar value, lettuce is by far the leading crop and has contributed to making Monterey County the number one vegetable producing county in the nation. Because agriculture has a great impact on the entire county, and because Monterey County is the largest vegetable-producing county in the United States, issues that affect the agricultural community also greatly affect the entire Monterey economic community and the nation as a whole.

Groundwater is essentially the only source of water for the Salinas Valley. For several decades, water demand in Monterey County has exceeded the supply, resulting in groundwater overdraft, seawater intrusion, shortages during dry years, and increased water costs. The water problem in the Monterey County is principally linked to the increasing acreage planted with vegetables. These crops not only require a large irrigation application during their growing cycle but their short growing cycle and the favorable local climate also promote double-cropping.

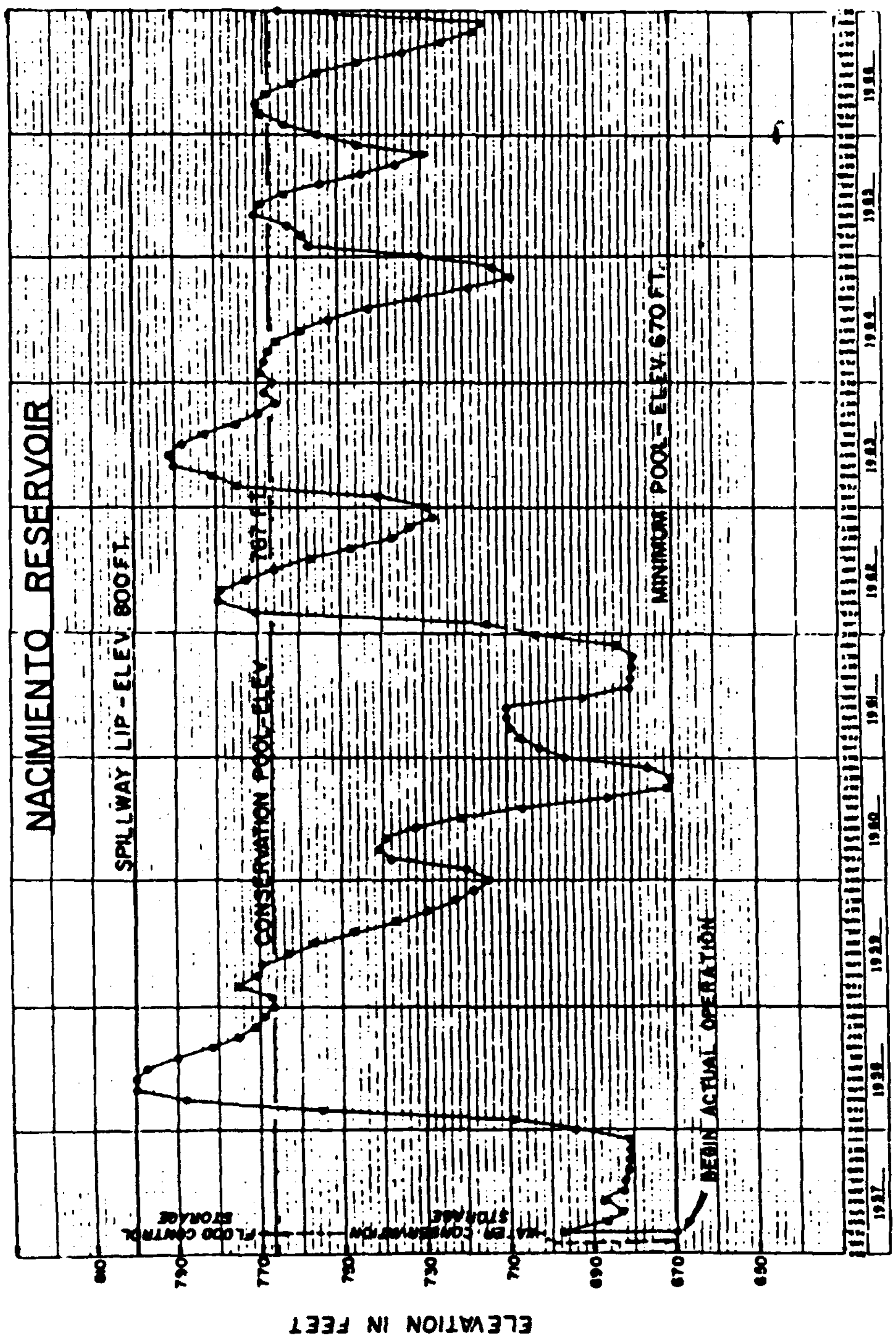
This study identified several obstacles in the formation of marketable groundwater rights. A market for groundwater requires that groundwater rights be clearly defined and enforceable. Defining and enforcing groundwater rights is difficult because of the inherent uncertainty in measuring aquifer stock levels and natural recharge. A second obstacle in establishing groundwater rights is the requirement to monitor groundwater pumping by water rights holders. These two obstacles must be overcome before accurate stock and flow rights can be defined and before a market for water rights can be established.

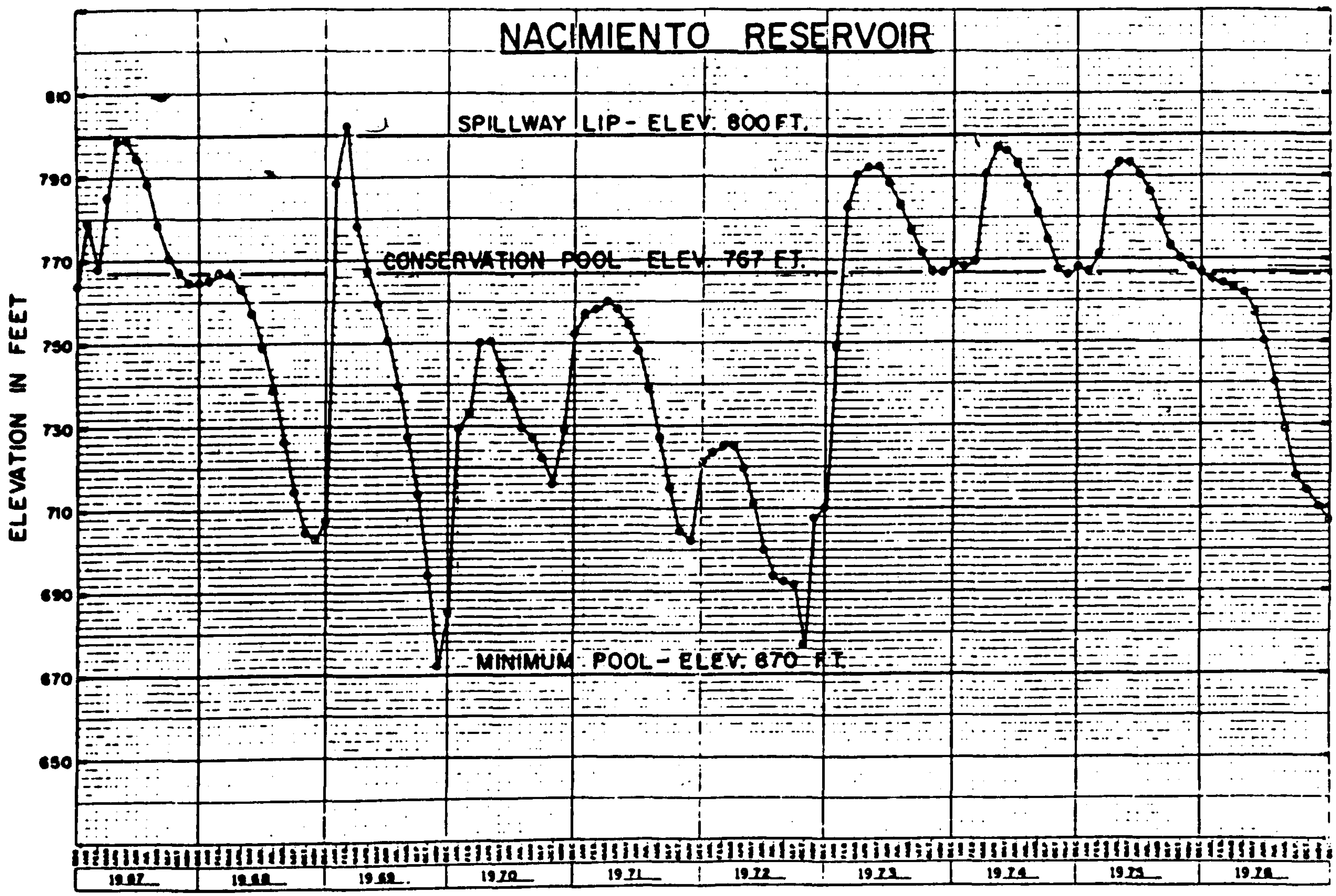
Our assessment of the implementation of a market system for groundwater in the Salinas Valley has shown that, in theory, a market system is more efficient than the current management techniques being used by centralized government agencies. This thesis compared two aspects of water allocation under three different management alternatives. The three market alternatives are: a free-market system for groundwater rights; a tax approach; and a maximum water consumption standard approach. Two aspects of water allocation were compared under each of these management alternatives: the external cost imposed on society resulting from groundwater extraction and the relative economic efficiency of each allocation method. Given the three potential methods of water allocation, the market approach provides the most efficient allocation of scarce water resources under continually changing conditions of supply and demand.

A water market system is not the only way to proceed in the valley's quest to conserve its precious resource, water. It is not even the easiest to establish and operate. But it is the most efficient and, if properly run, the fairest. In some ways, whatever decisions the policy makers and leaders of the communities within the valley make to manage this problem are not as important as just making a decision. According to the Monterey County Flood Control and Water Conservation District [Ref. 37:p. 1A], as of November 1990, the Salinas Valley water table had plummeted to the lowest levels in its recorded history. The signs seem to be that the situation is not ge ing better, so some sort of action must be taken. Water marketing could play a significant role in fairly providing future water supplies for the Salinas Valley.

APPENDIX

RESERVOIR LEVELS




NACIMIENTO RESERVOIR
SPILLWAY LIP - ELEV. 800 FT.
CONSERVATION POOL - ELEV. 767 FT.
MINIMUM POOL - ELEV. 670 FT.
ELEVATION IN FEET
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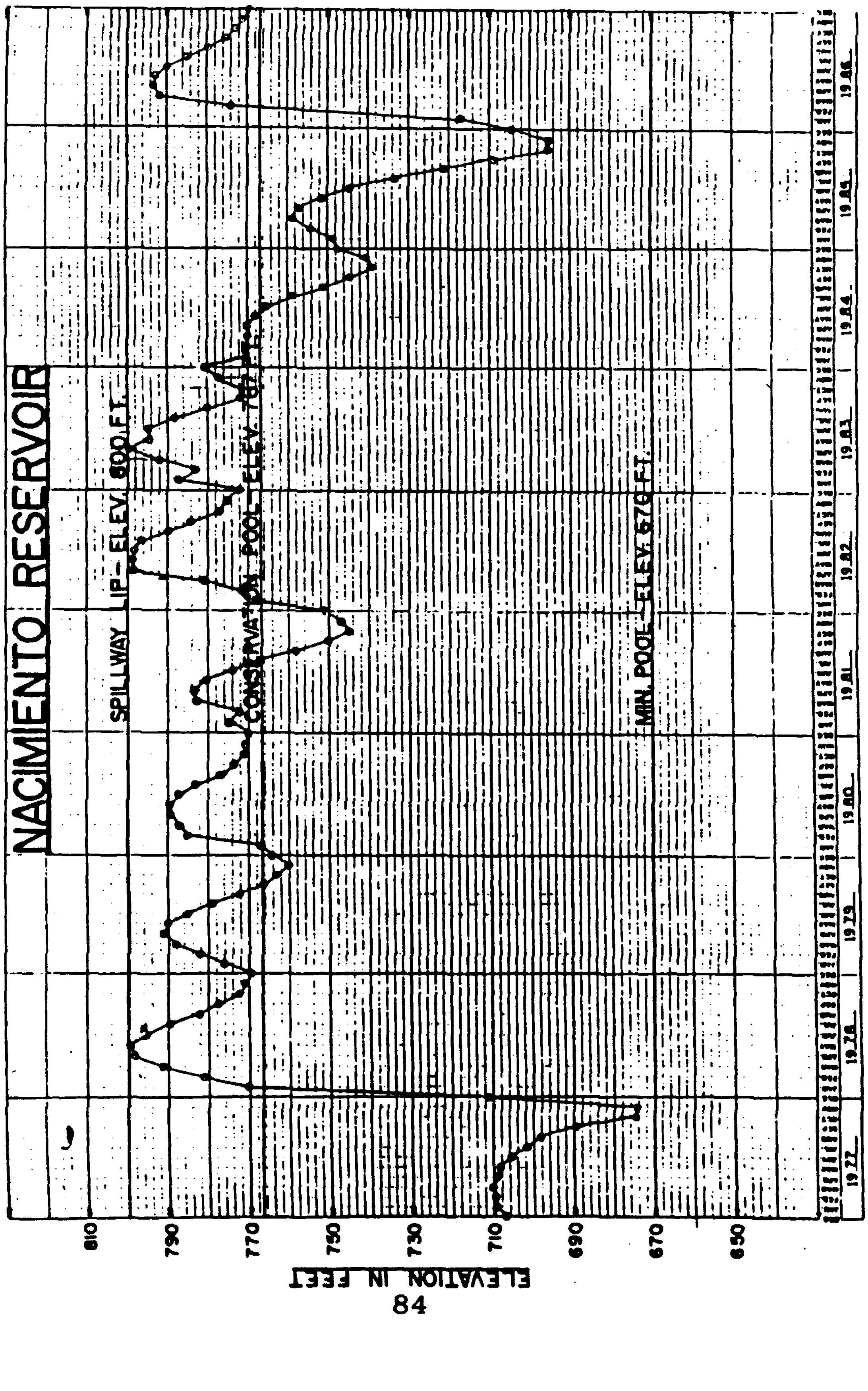
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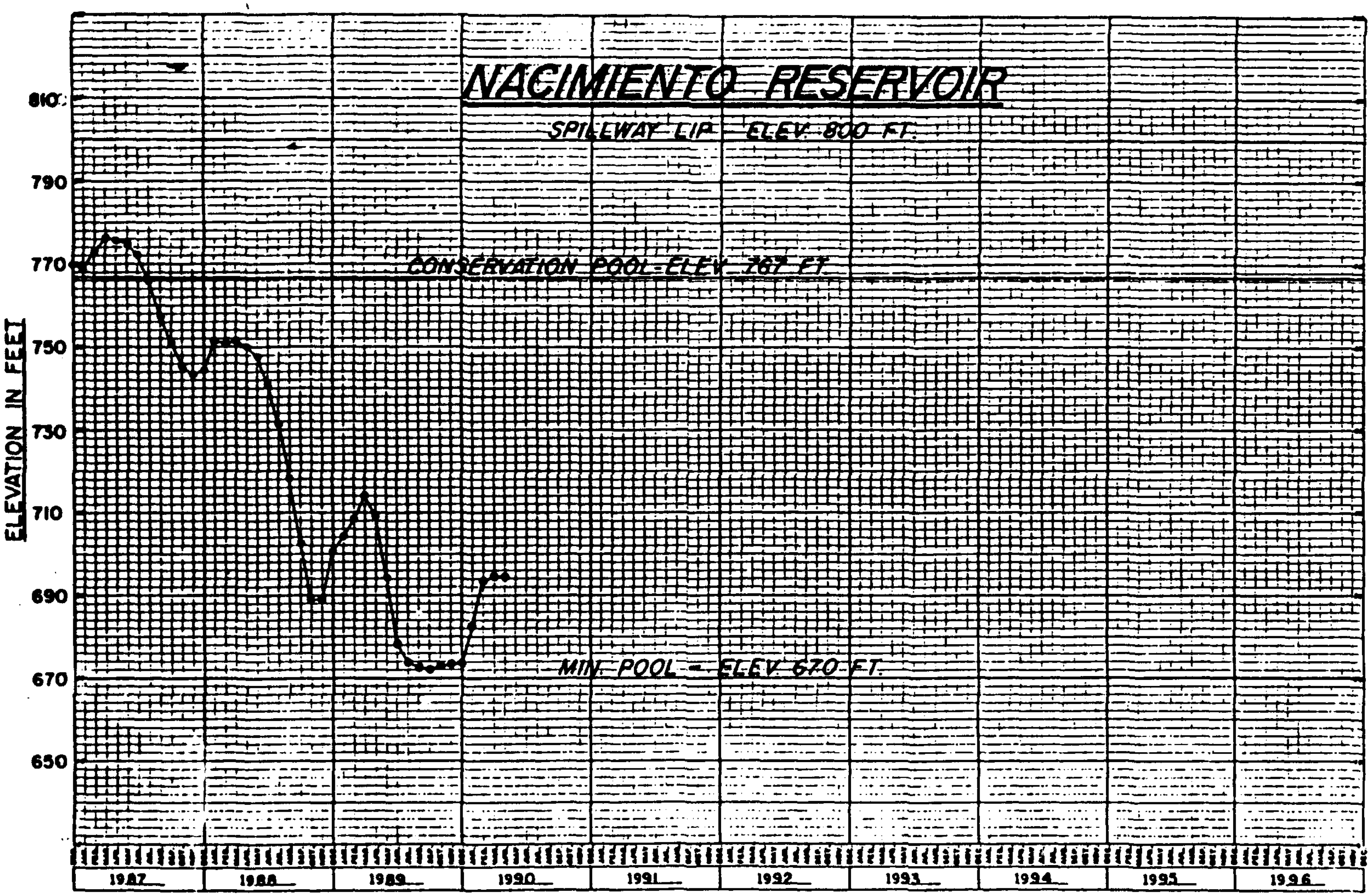
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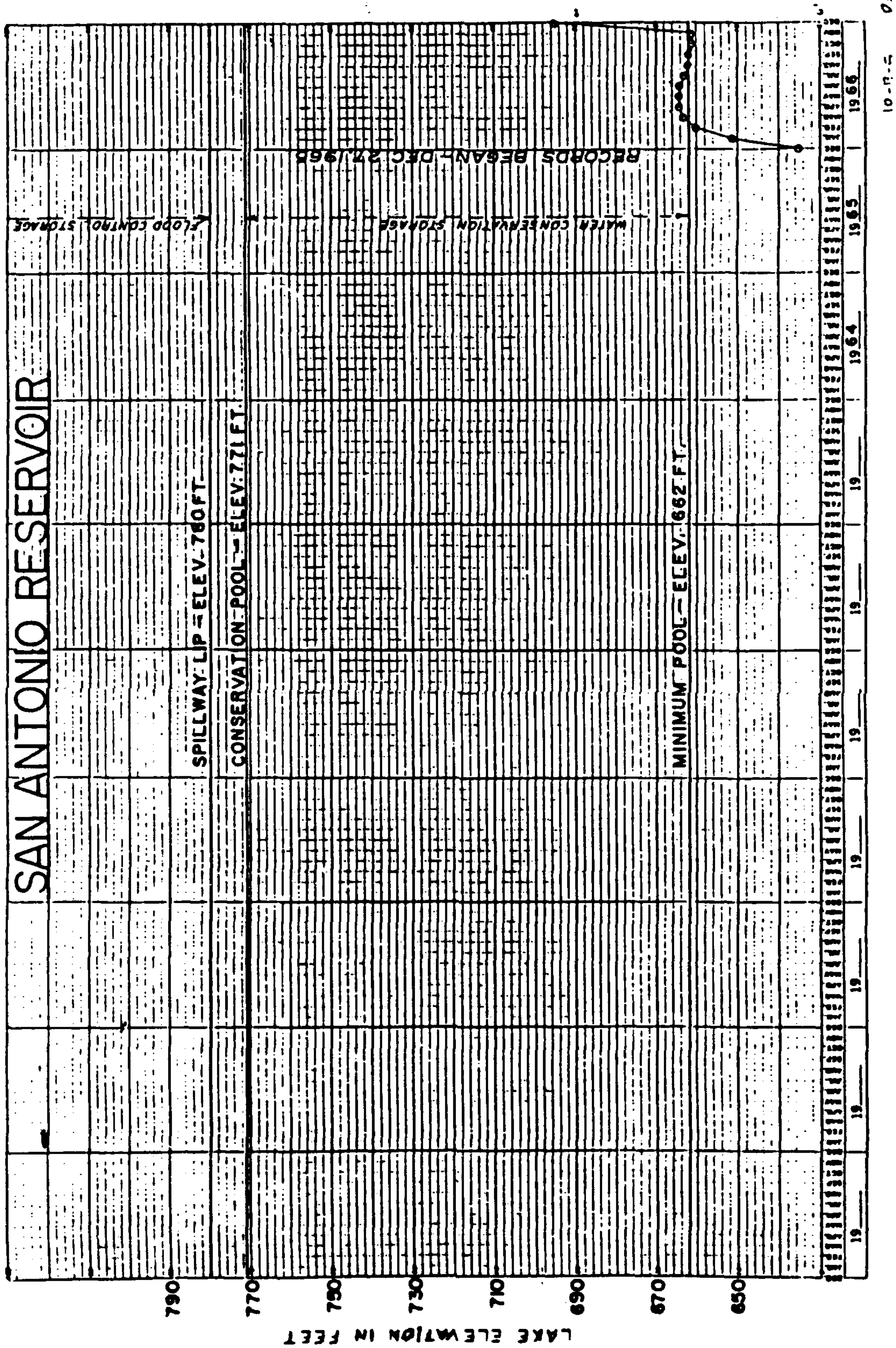
SAN ANTONIO RESERVOIR
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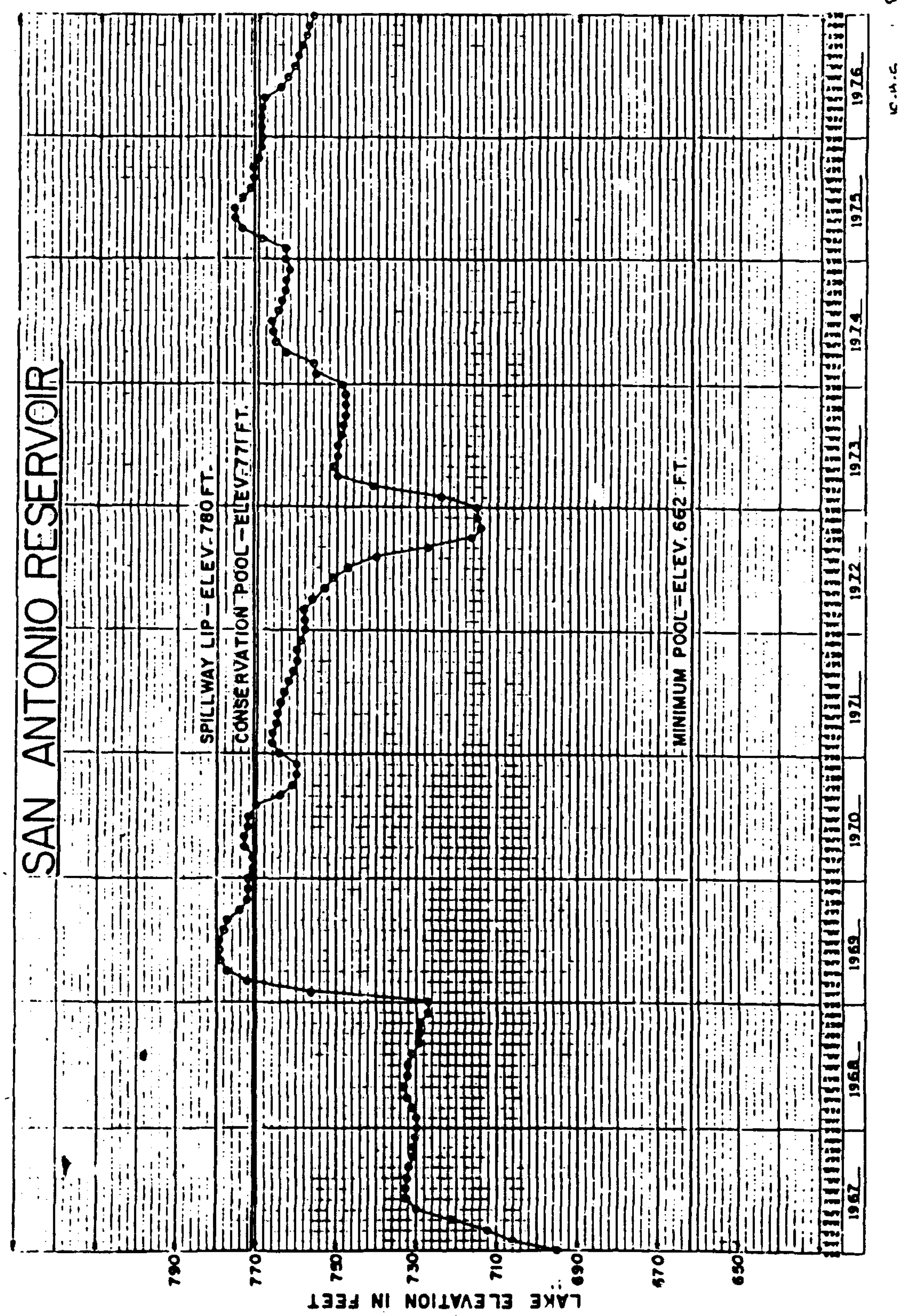
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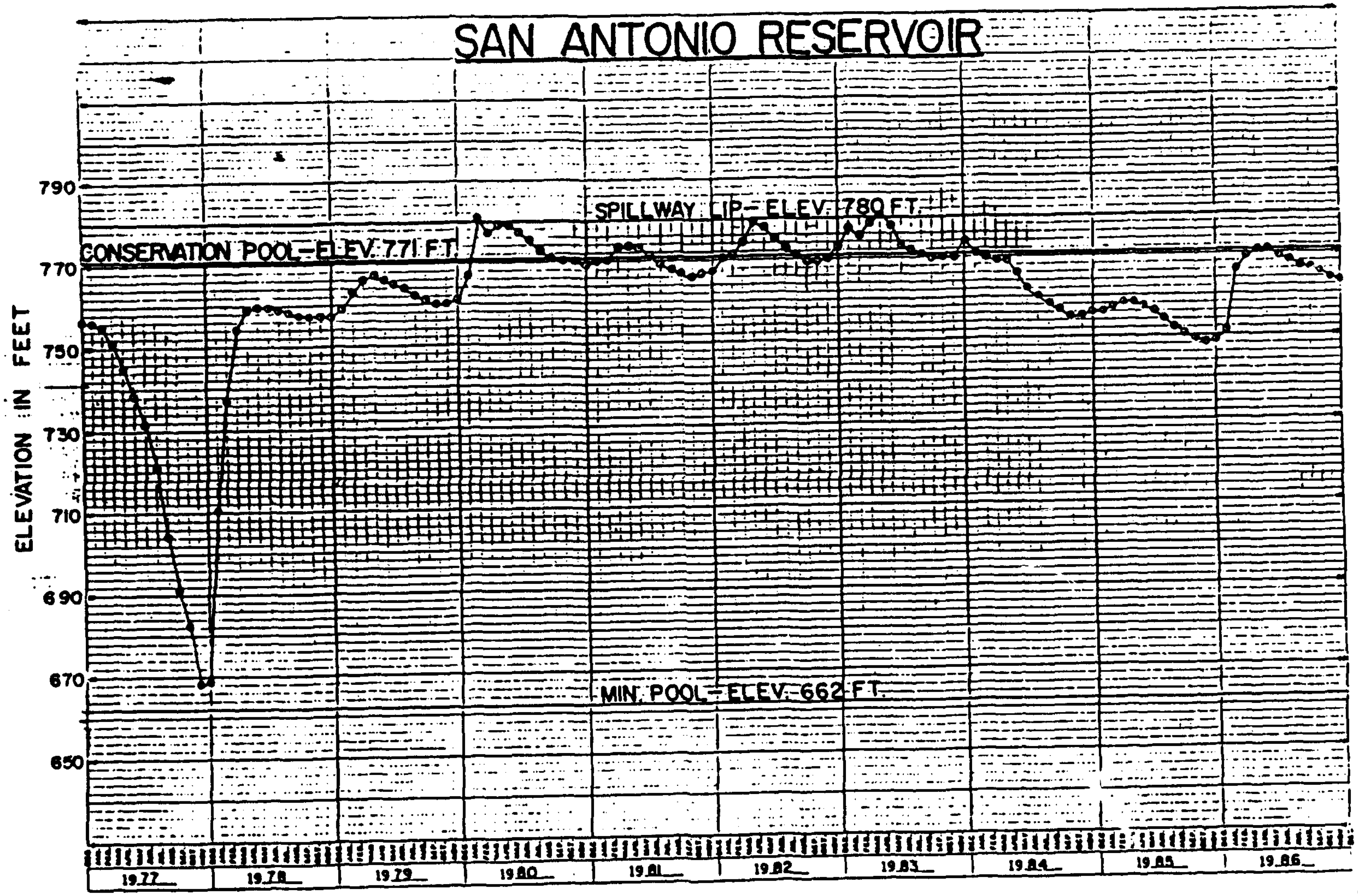

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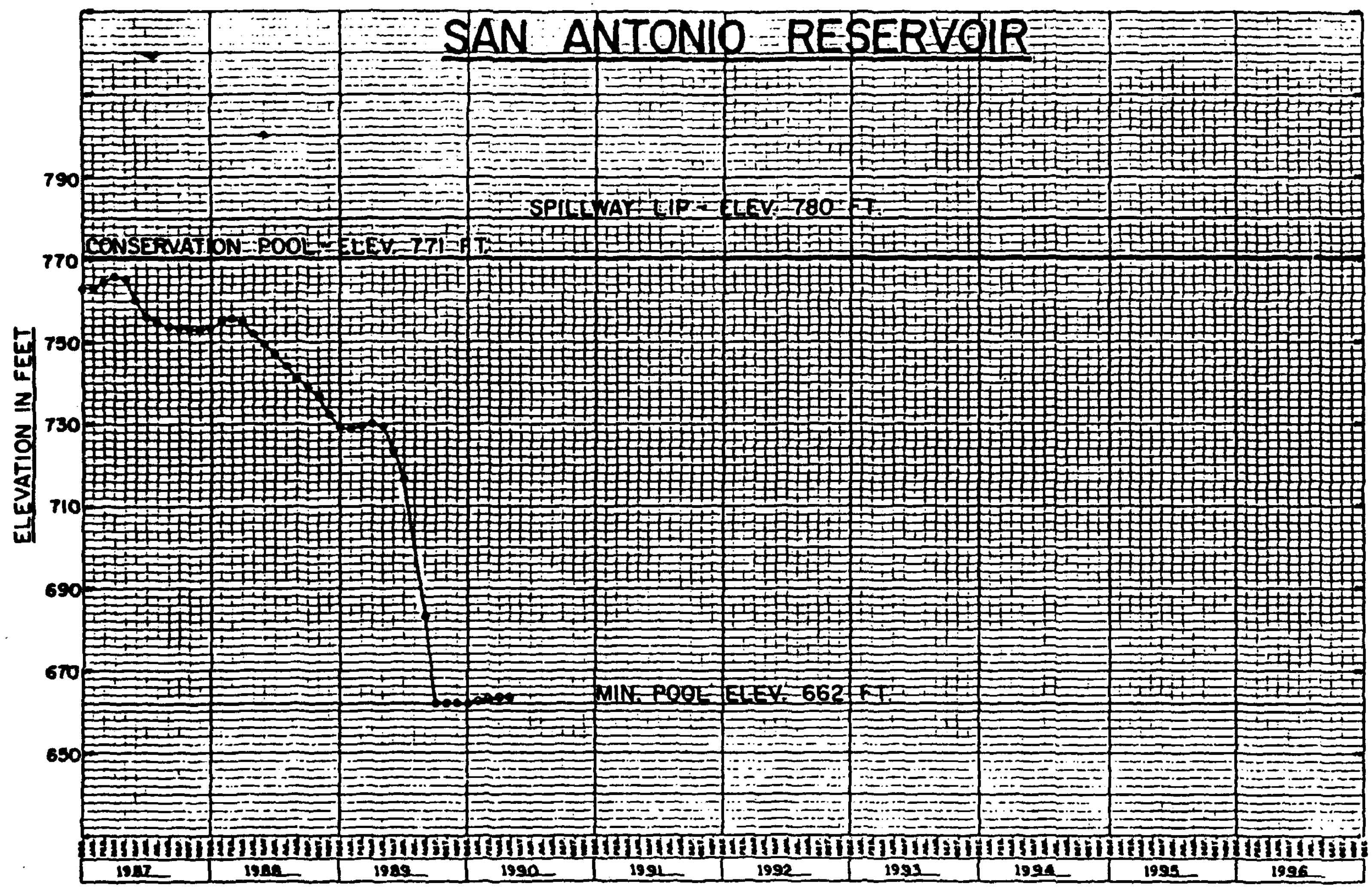
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