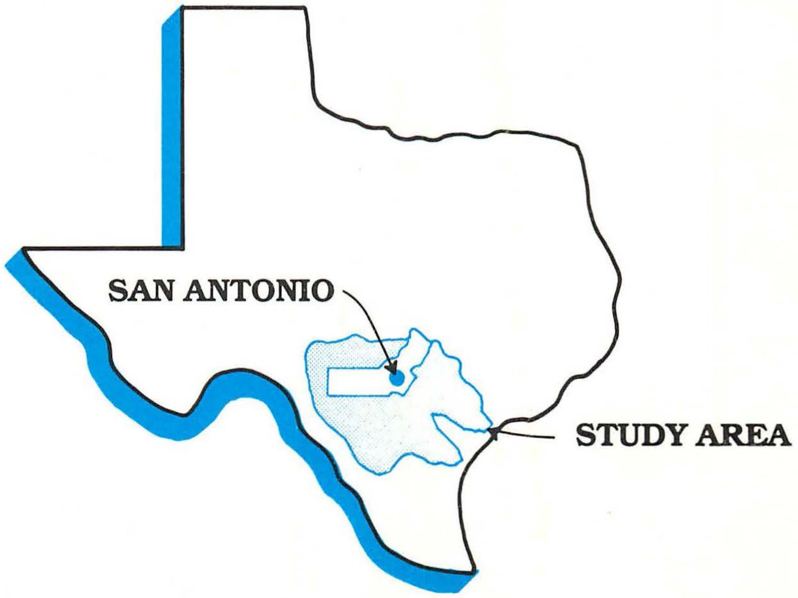
San Antonio

REGIONAL WATER RESOURCE STUDY



REPORT

REGIONAL WATER RESOURCE STUDY

CITY OF SAN ANTONIO
(512) 299-7876
EDWARDS UNDERGROUND WATER DISTRICT
(512) 222-2204

TECHNICAL ADVISORY COMMITTEE

March 21, 1986

Mr. Robert Hasslocher, Chairman
and
Members of the Board of Directors
Edwards Underground Water District

The Honorable Henry Cisneros
and
Members of the City Council
City of San Antonio

Ladies and Gentlemen:

We, the members of the Technical Advisory Committee, are pleased to formally transmit to you the, San Antonio Regional Water Resources Study, Volumes I, II, and III. This transmittal fulfills our charge as outlined in your November 1983, Memorandum of Understanding.

The Technical Advisory Committee recommends that the Sponsors accept the report and initiate Phase I Implementation activities in a manner agreeable to the Sponsors. The leadership demonstrated by the Sponsors will undoubtedly be a model for water resource management state-wide.

Sincerely,

Carl F. Raba, Jr.

Carl F. Raba, Jr., Ph.D., P.E.
Chairman

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SAN ANTONIO REGIONAL WATER RESOURCE STUDY

Sponsors: City of San Antonio
Edwards Underground Water District

April 1986

STATE OF TEXAS
LARRY C. AMANS
59022
REGISTERED
PROFESSIONAL ENGINEER

Larry C. Amans

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ACKNOWLEDGEMENTS

This study was prepared under the direction and with the assistance of the following sponsor representatives:

Rebecca Cedillo	Assistant Planning Director City of San Antonio
Tom Fox	General Manager Edwards Underground Water District
Jean Williams	Project Monitor
Carl F. Raba, Jr.	Chairman, Technical Advisory Committee

Other members of the Technical Advisory Committee are listed on the last page of this report.

CONSULTANTS

Several consultants participated in this study under the overall leadership of CH2M HILL. Those consultants, their chief participants, and their part in the study effort are listed below.

- CH2M HILL--Larry Amans, Project Manager
  Norm Brazelton, Principal-in-Charge
  - Project and report management, water demands, conservation, groundwater resources, wastewater reuse, environmental issues, and development and analysis of alternatives
- PRC Engineering--Glenn Tarbox, Assistant Project Manager
  - Surface water resources data, alternative water resources data (except reuse), and cost estimating
- Arthur Young--George Raftelis, Partner
  Tim Barnes, Manager
  - Financial analysis and implementation planning

- Resource Analysis, Inc.--Ron Lacewell, Professor
  Texas A&M University
  Lonnie Jones, Professor
  Texas A&M University

  - Economic Impacts

- Hooper, Robinson, & Moeller--Bert Hooper, Attorney

  - Legal issues

SAN/M1/50

SUMMARY

EXECUTIVE SUMMARY

PART I--INTRODUCTION

BACKGROUND, GOALS, AND STUDY APPROACH

Recognizing the need for long range water resource planning, the Edwards Underground Water District (EUWD) and the City of San Antonio jointly sponsored a comprehensive eighteen-month study of regional water resources and needs. The sponsors appointed a Technical Advisory Committee to oversee the study, which was conducted by CH2M HILL. This report summarizes the study findings.

The study focuses on regional water needs from the base year of 1980 to the year 2040. The region is divided into a primary area including the counties that overlie the Edwards Aquifer (Uvalde, Medina, Bexar, Comal and Hays Counties) and a secondary area comprised of the remainder of the Nueces, San Antonio and Guadalupe River Basins.

The major goal of the study is to develop three alternative courses of action for regional water resource management, with each representing a potential regional plan that includes provision for needed facilities (wells, pipelines and reservoirs), methods of financing, and the legal and institutional framework necessary for implementation. All alternatives are designed to:

- Protect Edwards Aquifer water quality.
- Assure adequate water supplies to support growth and development.
- Provide water at the lowest equitable cost while minimizing adverse impacts.
- Encourage timely funding while retaining flexibility.
- Minimize restrictions on water use.
- Strengthen the regional water resources planning process.

The three alternatives to the status quo were established by first considering what options were available for environmental protection, water sources, financing, cost recovery and implementation within the framework of the goals set. Options in each of these areas were considered potential "building blocks" that could be used to construct alternatives. The hundreds of possible combinations of options were then screened to obtain reasonable combinations that represent likely possibilities for consideration.

Initial design of alternatives took place under the following guidelines:

- Present Policies (status quo): Use existing water sources and policies only.

- Alternative I: Use any existing or new water sources within the framework of existing laws and institutions.

- Alternative II: Use any water sources except new reservoirs, and allow for new laws and institutions.

- Alternative III: Use existing or new water sources and allow for new laws and institutions.

The building-block elements of facilities, financing methods and legal/institutional provisions that make up each alternative could be modified or exchanged for similar building blocks from other alternatives. This provides the means for arriving at a consensus of regional opinion in seeking to adopt a plan and adds flexibility during the implementation phase.

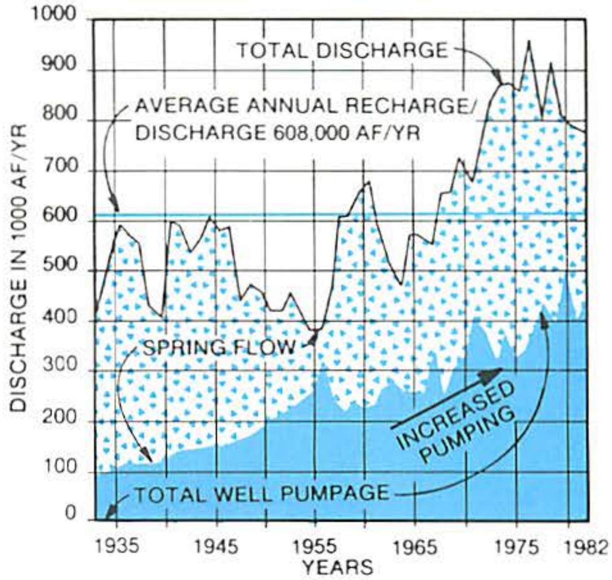
Existing information sources were used on water sources and demand projections. New work centered primarily on the combination of water sources that might be used and on the means for implementing a regional plan.

The first three chapters of the study describe the goals, background, regional setting and approach of the study. Chapter 4 describes potential water sources and forecasts future demand. This is followed by development and analysis of water supply facility alternatives in Chapter 5. Chapter 6 contains recommended action plans and financing options for the three water supply alternatives. The body of the report is followed by 15 appendices in two separate volumes covering technical engineering, economic, legal and financial subjects.

THE HIDDEN COSTS OF PRESENT POLICIES

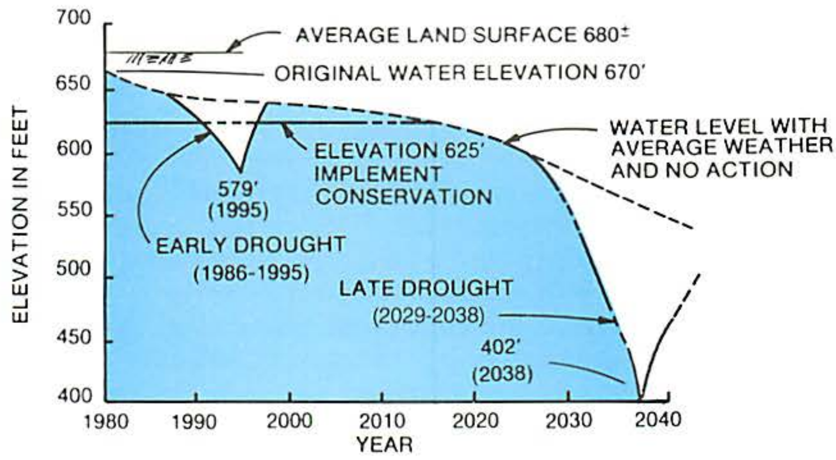
Present policies do not provide for a regional plan to manage water resources. A regionally focused long-term plan and an implementation program for managing water resources are needed in order to assure an adequate water supply for our region's growth and economic development. Population and economic growth will lead to a near doubling of demand for water by the year 2040.

The Edwards Aquifer is now the sole source of water for the City of San Antonio and the primary water source for Bexar, Uvalde, Medina, Comal and Hays Counties. Recharge water entering the aquifer is pumped by many users, and the "overflow" emerges from springs that provide a major portion of the water in the Comal, San Marcos and Guadalupe Rivers. If current practices are continued, this "overflow" will cease permanently after the turn of the century, and the springs will go dry during drought periods before that time. Aquifer water levels will begin to drop, declining by over 140 feet in San Antonio by the year 2040.

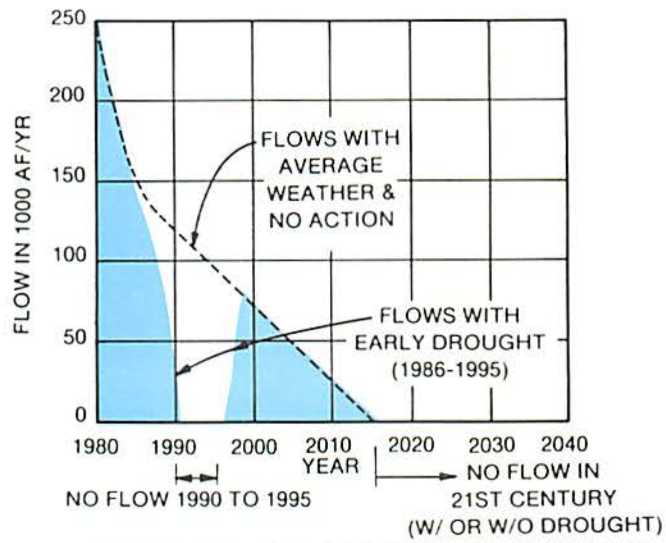


EDWARDS AQUIFER DISCHARGE

Because of the current rates of pumpage, the loss of springflow is not a remote threat. If a drought similar to that of the 1950's began in 1986, Comal Springs would be completely dry from 1990 through 1995; flow at San Marcos Springs would drop to less than half of its historic level. In San Antonio, the aquifer water level would drop below the "Water Watch" level that triggers voluntary conservation measures for 8 consecutive years beginning in 1989, and mandatory conservation measures would be in force from 1992 through 1995. If a drought occurred at a later time, the impacts would be even more severe, since the aquifer would have been more seriously depleted over time.



DROUGHT IMPACT ON WATER LEVELS IN SAN ANTONIO
(Impact is severe now and worse in the future)



DROUGHT IMPACT ON COMAL SPRINGS
(Impact is severe now, springs gone in future)

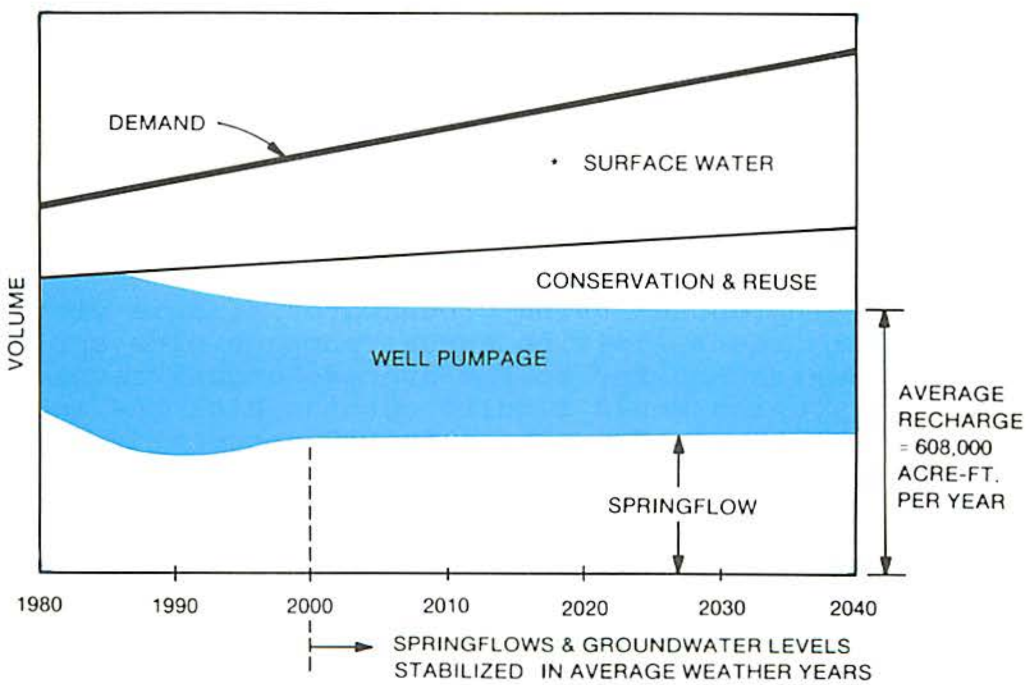
The City of San Antonio, whose wells reach deep into the aquifer, could continue to rely exclusively on groundwater. It is the least expensive water source available. However, in addition to eliminating natural springflows this approach would lead to loss of habitat for endangered species at the springs, lower quality river water, higher pumping costs for users throughout the five-county area, and increased risk of deteriorating groundwater quality in San Antonio and elsewhere. Although the resulting adverse impacts on agriculture and tourism would not cripple the regional economy as a whole, serious local impacts and quality of life issues are raised by continuation of present practices.

Furthermore, exclusive use of groundwater implies incurring increasingly greater risks of litigation, legislation or regulatory action that would preempt the authority of local government officials. The courts or legislators could be in a position to impose water management and use restrictions on the region to prevent adverse regional impacts.

The effect on the local business climate of continuing present policies also merits consideration. Water is a relatively minor part of production costs for nearly all businesses in this area. Water cost increases of the magnitude discussed in this report will not deter new business development. However, lack of assured water availability could have negative consequences. New businesses considering relocation here could perceive the absence of a far-sighted plan as a lack of community leadership and as a signal that the risk of water rationing or other consequences might affect them in the future.

THE ALTERNATIVES

All three alternatives would make use of a combination of water sources--groundwater, surface water and wastewater reuse--to meet growing regional demand. An example of this approach, which is called conjunctive use, appears below.



CONJUNCTIVE USE APPROACH

* SIGNIFICANT AMOUNTS PROVIDED ONLY IN ALTERNATIVES I, & III

Features and cost impacts for each of the three alternatives are shown in the exhibits at the end of this summary. Key differences among the alternatives and present policies are given below.

SELECTED ALTERNATIVES

Alternative	Annual Springflow in 2040 (Acre-Feet)	Annual Withdrawal From Edwards Aquifer in 2040 (Acre-Feet)	Capital Cost (Millions)	Average Monthly Water Cost for San Antonio Customer for Next 50 yrs (in Constant $)	
				$/mo.	% Increase
Present Policies	0	780,000	$120	$10	0%
I	200,000	400,000	$1,720	$17	70%
II	160,000 (artificial)	530,000	$520	$12	20%
III	250,000	350,000	$1,850	$15*	50%*

*The impact is less despite larger capital costs because the cost is spread to all users of the Edwards Aquifer.

No one alternative outlined below may represent the "ideal" solution. Various components from the alternatives may be combined during implementation to create the most appropriate plan.

ALTERNATIVE I

Alternative I proposes using groundwater at safe yield levels. This means limiting annual pumpage plus springflow from the Edwards Aquifer to the average annual rate of replenishment, which would require cutting back the amount of water currently pumped out by about 10 percent.

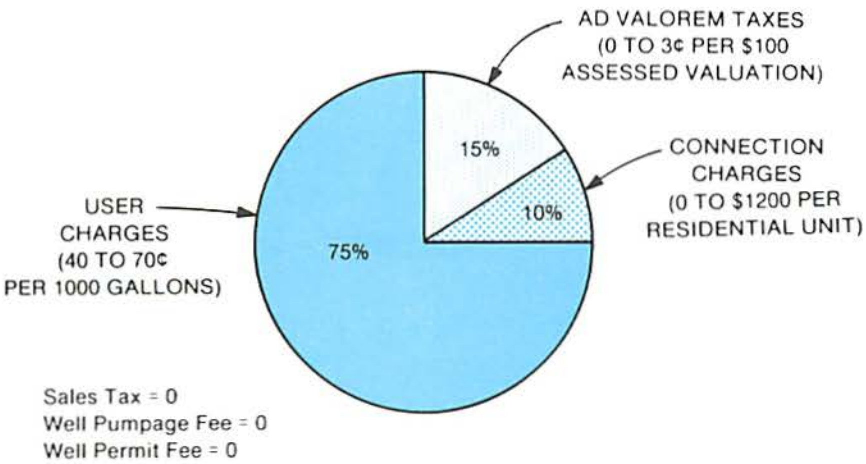
The remainder of the water needed to meet demand would come from conservation, wastewater reuse, existing reservoirs and a total of five new reservoirs scheduled to come on line around 1990, 2010, 2015 and 2020. Construction of the new reservoirs could be delayed if demand does not rise as fast as anticipated. New reservoirs or river diversions would supply from 40 to 50 percent of the water needs of greater San Antonio, New Braunfels, and San Marcos. Secondary area demands could be met from available river flows and, to a lesser extent, from storage in new reservoirs.

An average annual natural springflow of about 200,000 acre-feet per year would result by the year 2040.

Cost recovery for the $1.7 billion in capital costs and operations and maintenance for Alternative I could be financed through the following mechanisms, applied to municipal users in greater San Antonio, San Marcos and New Braunfels throughout the study period:

ALTERNATIVE I

Sources of Revenue for Regional Costs



ALTERNATIVE II

Alternative II meets future demand by overdrafting the Edwards Aquifer. It also relies on continued use of secondary aquifers, mandatory conservation and wastewater reuse programs, and supplies from existing reservoirs.

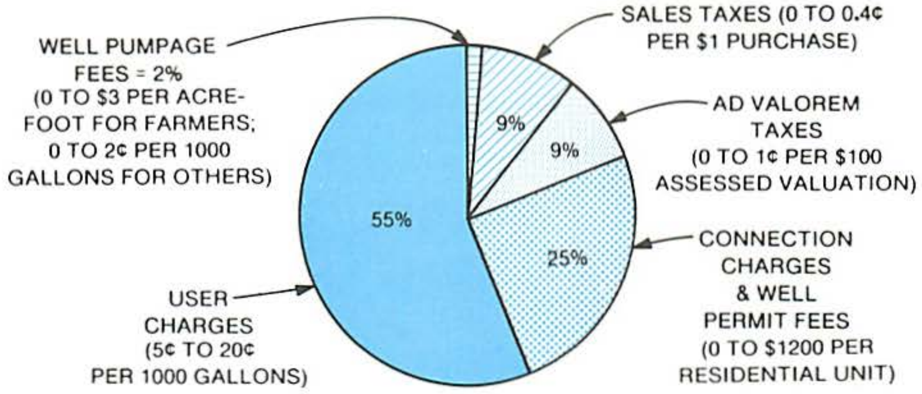
To compensate for the total loss of natural springflow under this alternative, wells would be installed downstream from San Marcos and Comal Springs. These wells would pump up to 160,000 acre-feet of water into the rivers annually, thus providing an "artificial" springflow adequate to maintain river biota and downstream recreation opportunities. Habitat for species living in the springs would be lost as would recreation opportunities at Spring Lake and Landa Lake. Contamination of municipal wells at New Braunfels and San Marcos from the "bad-water" zone could become a serious threat.

On average, water levels would decline about 50 feet by the year 2040 in Uvalde County and New Braunfels, and about 75 feet in San Antonio.

Cost recovery for the $520 million capital investment and for operations and maintenance could be achieved through the following methods, applied to water users throughout the five-county area:

ALTERNATIVE II

Sources of Revenue for Regional Costs



ALTERNATIVE III

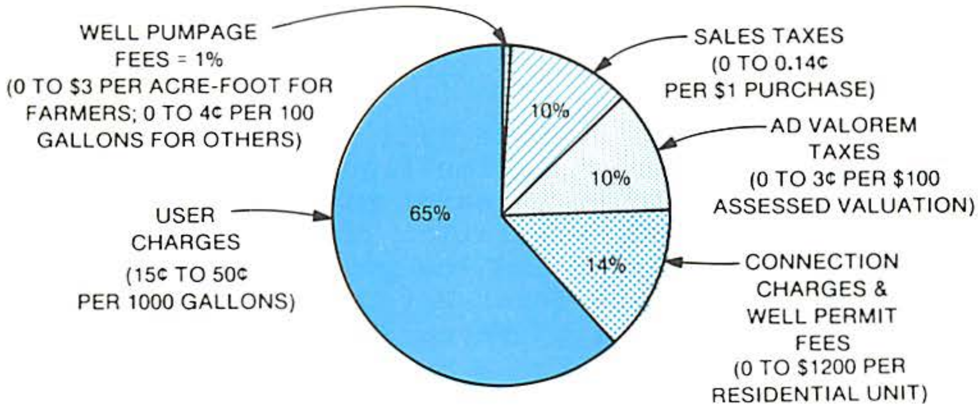
This alternative is similar to Alternative I, except that it provides about 50,000 acre-feet more natural springflows annually for a total average springflow of about 250,000 acre feet. Instead of constructing Cloptin Crossing Reservoir, the larger Lindenau Reservoir would be built. As in Alternative I, new reservoirs or river diversions would supply 40 to 50 percent of the water for greater San Antonio, New Braunfels, and San Marcos. Secondary area demands would be met with available river water and new reservoir storage. Alternative III would be implemented in conjunction with new laws that would maximize financial participation throughout the primary study area.

The current rate of pumpage from the Edwards Aquifer would be reduced by about 20 percent. Other sources used in Alternatives I and II, such as secondary aquifers, reuse, and existing reservoirs, are also part of this alternative.

Recovery of $1.8 billion in capital costs and operating and maintenance costs would occur by applying the following charges to water users throughout the five-county area:

ALTERNATIVE III

Sources of Revenue for Regional Costs



RATING THE FACILITIES ALTERNATIVES

The alternatives are not various ways of producing the same result, but rather provide different results which are not directly comparable. To better evaluate them, a weighting system was established with values for both tangible and intangible factors. Weights were assigned based on professional judgement and provide a reasonable ranking, although assignment of different weights could lead to a reordering of scores. Factors considered included cost, economic impact, environmental impact, reliability of supply, flexibility and ease of implementation.

Alternatives I and III, which both include new reservoirs, received the highest overall ratings, due primarily to the benefits accruing from stabilization of well water levels and springflows. Alternative II, which does not include new reservoirs, fails to provide the benefits of Alternatives I and III, but is considerably less expensive.

Alternative I is comparatively easy to implement but also the most costly to municipal users. Alternative III is harder to implement, but would be less expensive for San Antonio residents since it spreads the cost burden more broadly.

While this simplified rating method provides some insight into the relative advantages of the alternatives, a number of issues merit a more detailed discussion.

PART II--KEY ISSUES

IS THIS MUCH WATER REALLY NEEDED?

An 80 percent increase in water use is projected in the five-county area by year 2040--amounting to an additional 80 billion gallons per year.

To forecast water demand, base data from previous studies were used. Projected population figures were then adjusted downward to reflect lower rates of migration into the area in recent years. Final population figures fall within the range defined by the high and low population projections for 1980 to 2030 made by the Texas Water Development Board (formerly the Department of Water Resources).

Since one of the goals was to identify alternatives that provide adequate water supply to sustain growth, lower demand levels that would result from such measures as restrictive zoning or pumpage limitations were not considered. Lowered demand as a result of conservation was included, as discussed below.

It should be noted that if demand does not increase at the anticipated rate, construction of new facilities could be postponed until the need for additional supply begins to materialize. At the same time, failure to plan for long term needs and to take preliminary steps to provide for them could have negative consequences. Planning must begin now to reserve the availability of potential sources.

ROLE OF WATER CONSERVATION AND REUSE

Under a continuation of present policies, conservation and reuse would not make a significant contribution to meeting future demand, although some programs are already under way. All of the alternatives presented provide for these measures to play an important role in reducing demand or securing adequate supplies.

It is estimated that under existing laws a contribution of about 20 percent of total demand--or less than half of the projected growth in demand--could be achieved. All alternatives include conservation and reuse as important resources, meeting from 15 to 30 percent of total demand by the year 2040.

PURCHASE OF WATER RIGHTS

One consideration not included in the alternatives as described above deserves special mention. Some interest has been expressed in providing for the voluntary purchase of water rights from agricultural interests. Existing rights to withdrawal would be protected, but a cap would need to be placed on the total withdrawals allowed from the Edwards Aquifer as established by new legislation. Purchase for pumpage by greater San Antonio area residents could take a variety of forms including the following possibilities:

- Purchase of a portion (for example, 25 percent) of a farmer's water rights, allowing funds from the purchase to be used for acquisition of water-saving irrigation equipment. Thus, the farmer could use water more efficiently and maintain production levels.

- Option to purchase all of a farmer's water rights in dry years. Purchase might be triggered by a drop in the water table to a predetermined level and/or other predetermined conditions. The farmer would be paid only in the years that the option was exercised, and the purchase price would be a previously agreed upon amount.

- Purchase of a farmer's entire water right through cash payment at time of purchase. This would allow a farmer to switch to dryland farming or to sell the land to others who would be interested in dryland farming.

While this creative option offers benefits for both farmers and city dwellers, the degree of participation it might prompt cannot be predicted. Assuming legislation could be passed to establish the concept of groundwater withdrawal rights, purchases could provide relatively low-cost water supplies. The impact of such a program can be gauged by considering that if 50 percent of all agricultural groundwater pumping ceased, it could provide about 20 percent of the new water supplies needed by the year 2040.

Because of the difficulties in predicting participation in such a program, this type of option is not included in the alternatives outlined below. However, opportunities in this area could be pursued in conjunction with any of the alternatives.

ENVIRONMENTAL IMPACTS

Edwards Aquifer Water Quality

Protecting the high quality of Edwards Aquifer water is vital to the region's future. Regardless of the alternative chosen, the aquifer will continue to be the source of <u>at least</u> 40 percent of all regional water supply for the five counties.

Two measures to prevent contaminants from entering or becoming concentrated in the aquifer are recommended in this report. The first is to limit future withdrawals from the aquifer by providing alternative sources of supply to meet new demand. This would reduce the risk of saline water intrusion in the future.

The second is to modify by special legislative amendment the current Edwards Aquifer recharge zone protection statute to broaden regulated activities and to allow enforcement by the Edwards Underground Water District. Consensus on desirable features of such an amendment would need to be reached in the State Legislature.

Preserving Bays and Estuaries

The potential impact of new reservoirs on species living in the state's bays and estuaries was reviewed. A recently completed study concludes that the reservoirs considered here have an acceptable level of impact on estuary salinity to maintain marine growth.

Although the study included highly detailed computer predictions of bay inflows as if the reservoirs were in place, additional analysis will be needed to update these results when water rights permits for proposed reservoirs are filed with the state.

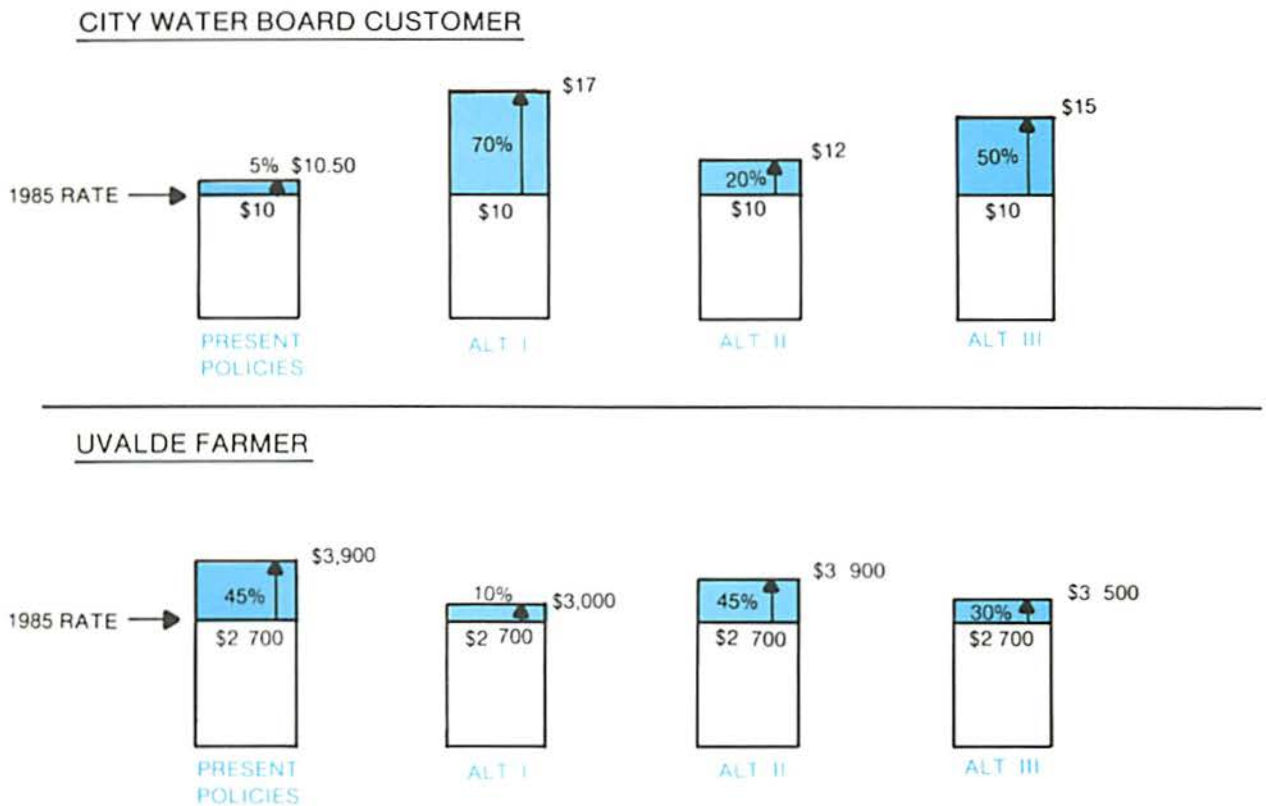
COST IMPACTS

The average water cost increase for residential users generally varies from 20 percent to 70 percent for the sample alternatives. The chart on the next page indicates average increases in costs for San Antonio consumers and a typical Uvalde farmer. Note that adoption of any of the alternatives would reduce or maintain costs for the farmer. This is because in the absence of a plan, the expense of pumping water from greater depths will raise farm pumping costs by an average 45 percent over the next 55 years.

The pattern of cost increases over time for Alternative I is shown on page 14. Although the <u>average</u> cost over the next 55 years for the City Water Board customer is $17/ month compared to $10/month now, water costs (expressed in 1985 dollars) would vary from a low of $11 to a high of $33, excluding normal increases for local utility company improvements and pipe extensions. In practice, costs would be averaged out using smoothing techniques to minimize such sharp fluctuations in rates. In all cases, the least expensive means of boosting supply while meeting other goals have been pursued first.

Additional perspective is provided by viewing how water cost increases would change the area's position relative to other

AVERAGE PROJECTED MONTHLY COSTS THROUGH 2040 (IN 1985 DOLLARS)



parts of the state. San Antonio and New Braunfels currently have water rates that are much lower than those of Houston or Dallas, for example. Assuming the most severe cost impact--a rise of 70 percent--San Antonio would go from being a low-water-cost city to a moderate-cost city. The size of increases required by the water plan alternatives is not likely to deter future development or reduce San Antonio's attractiveness as a site for new businesses.

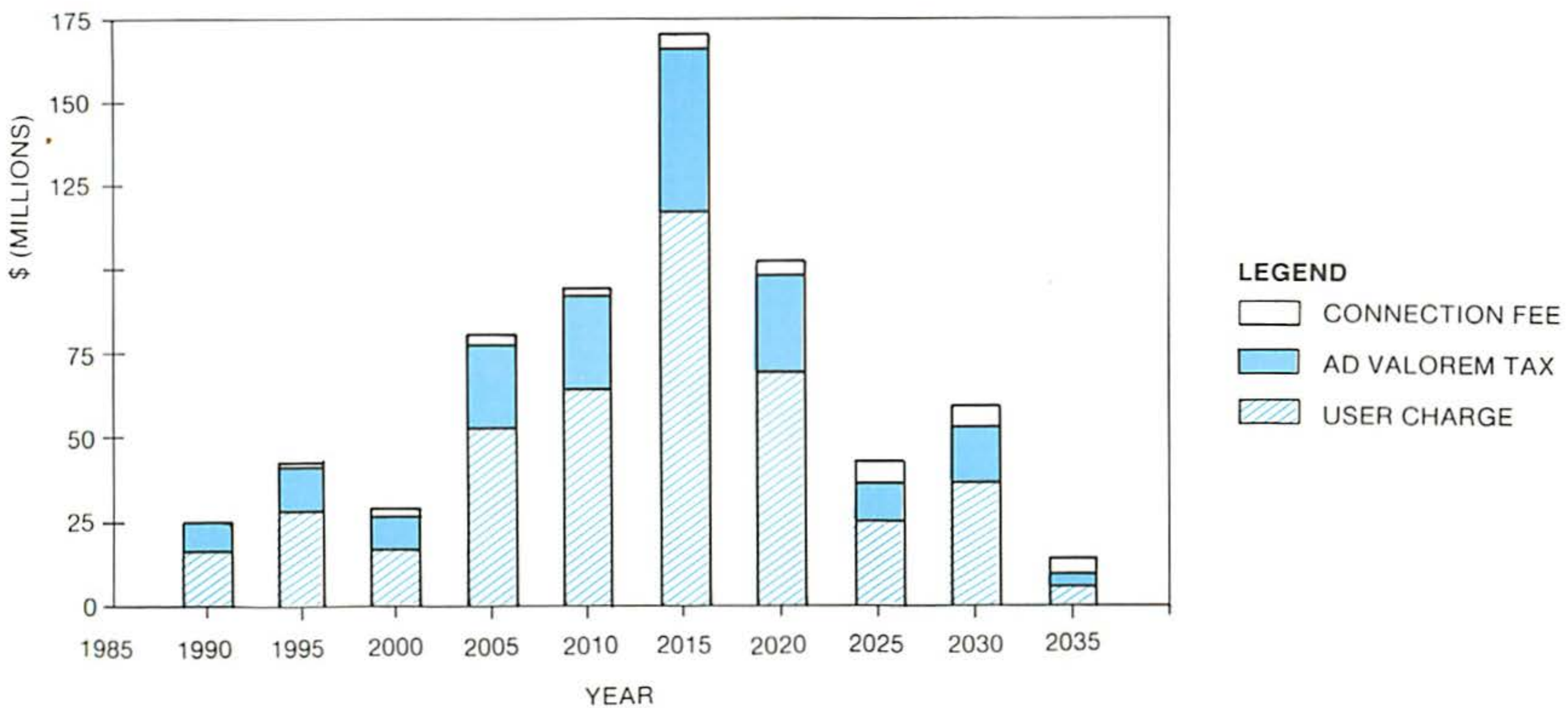
WATER USE AND COST FOR SELECTED CITIES

City	Average Residential Use Per Month (Gal.)	Average Residential Cost Per Month	Cost Per 1000 Gallons
Lubbock	4,500	$10	$2.10
San Antonio (with 70% increase)	11,200	17	1.50
Houston	10,000	15	1.50
Corpus Christi	15,000	21	1.40
Dallas	9,800	13	1.30
San Marcos	8,000	10	1.20
Albuquerque, NM	17,000	15	0.90
New Braunfels	12,500	11	0.85
San Antonio, Current	11,200	10	0.85
El Paso	22,000	17	0.80
Phoenix, AZ	16,000	13	0.80
Uvalde	11,000	8	0.70

ALTERNATIVE 1
COST BUILDUP OVER THE STUDY PERIOD
(IN 1985 DOLLARS)

1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
$10	$15	$18	$15	$23	$24	$33	$23	$14	$16	$11

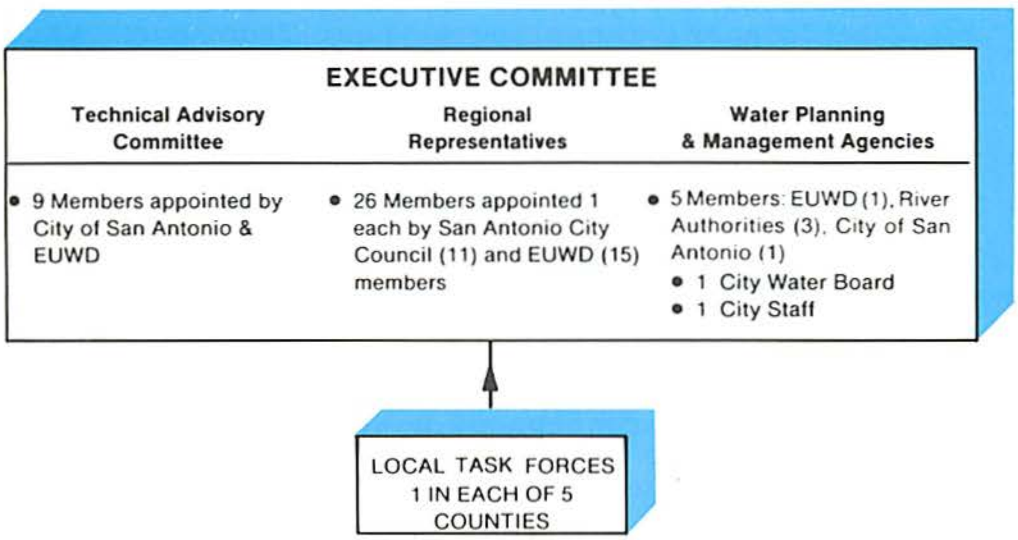
AVERAGE COST PER MONTH FOR TYPICAL CITY WATER BOARD CUSTOMER



PART III--ACTION PLAN

SELECTING AN APPROPRIATE PLAN

The process suggested in this report for selecting the appropriate plan to be implemented focuses on attaining the broadest possible support for a regional water plan. It calls for creation of a 40- member regional task force, plus local citizen task forces in each of the five counties. These groups are charged with reaching a consensus on the elements of the plan. The regional task force would include representatives selected at large from the region, as well as representatives from river authorities and state agencies.



IMPLEMENTATION TASK FORCE

IMPLEMENTATION

Once a consensus has been reached, implementation of the selected plan can begin under existing laws and within the framework of existing institutions. No immediate increase in water costs will occur. Although the adopted plan may call for new legislation, this aspect of it can be pursued simultaneously with other implementation steps.

Powers Of Existing Entities

The wide array of existing water agencies provides the combination of powers needed for implementation:

- The City Water Board (CWB) of San Antonio is empowered to finance, construct, own and operate Applewhite Reservoir and local wells, as well as to implement voluntary conservation measures and to levy user and water availability charges.

- River authorities are empowered to finance, build, own and operate reservoirs, pipelines and filter plants.

- EUWD believes it has the authority to guarantee revenue for bond repayments to be made by river authorities or others. It would do so by entering into long-term contracts with water utilities and others for receipt of a portion of use charges, water availability charges and other fees. These contracts would then be used as proof of ability to ensure payment. Thus EUWD would act as a middleman, funneling payment from users through utilities to the river authorities that would be paying for the facilities.

- Reuse facilities in San Antonio would be under the purview of the City of San Antonio and/or the San Antonio River Authority.

Long Term Resource Management

The need for ongoing oversight, coordination and leadership for regional water planning and implementation of a plan could be met by the creation of a Water Resource Management Board or by modifying the EUWD Board. A general manager and staff reporting to the board would undertake the day-to-day implementation of the plan. While the structure, duties and authority of the board would be finalized by the regional task force, the board's responsibilities can be expected to include:

- Coordinating the plan activities to be undertaken by water resource management agencies in the study area.

- Evaluating and monitoring the adopted regional water plan; possibly also enforcing the terms of agreements.

- Drafting necessary legislative changes and working to obtain approval of them.

- Acting as a liaison with water resource management agencies, city and state governments, and community groups.

- Carrying out public education programs.

- Conducting studies to evaluate appropriate timing of actions and modifications to the plan.

Three alternatives have been developed for constituting a board. As with other elements of the regional plan, variations on these alternatives may be deemed appropriate by the regional task force.

- The existing EUWD Board, which is comprised of three representatives from each of the five counties in the primary study area, could assume the duties and powers outlined above. New legislation would have to be passed to give the EUWD Board additional powers under Alternatives II and III, primarily for the proposed cost recovery methods.

- The EUWD Board, with additional powers as needed, could be restructured to more closely reflect the distribution of the population within the study area. This could be accomplished by electing board members on the basis of population within the five-county area. The resulting board would be comprised of approximately 19 members, 13 from Bexar County and 6 from the other four counties.

- A new Water Resource Management Board independent of existing organizations could be created through the election of members on the basis of population as described above for the restructured EUWD Board.

Either the existing or restructured EUWD Board is suggested as a first choice since it avoids creating another overlapping layer of government. If facilities Alternatives II or III are pursued, the last two management board options--with representation on a "one-person, 1-vote" basis--are the probable choice. This follows the principle of the equal protection clause of the Federal Constitution as applied in current case law to entities which have broad governmental authorities to tax and regulate the conduct of citizens. In addition to mirroring the five-county area's population split, the suggested new board composition also reflects current and projected water usage and revenue collection by geographical area.

Financing Sources And Cost Recovery Powers

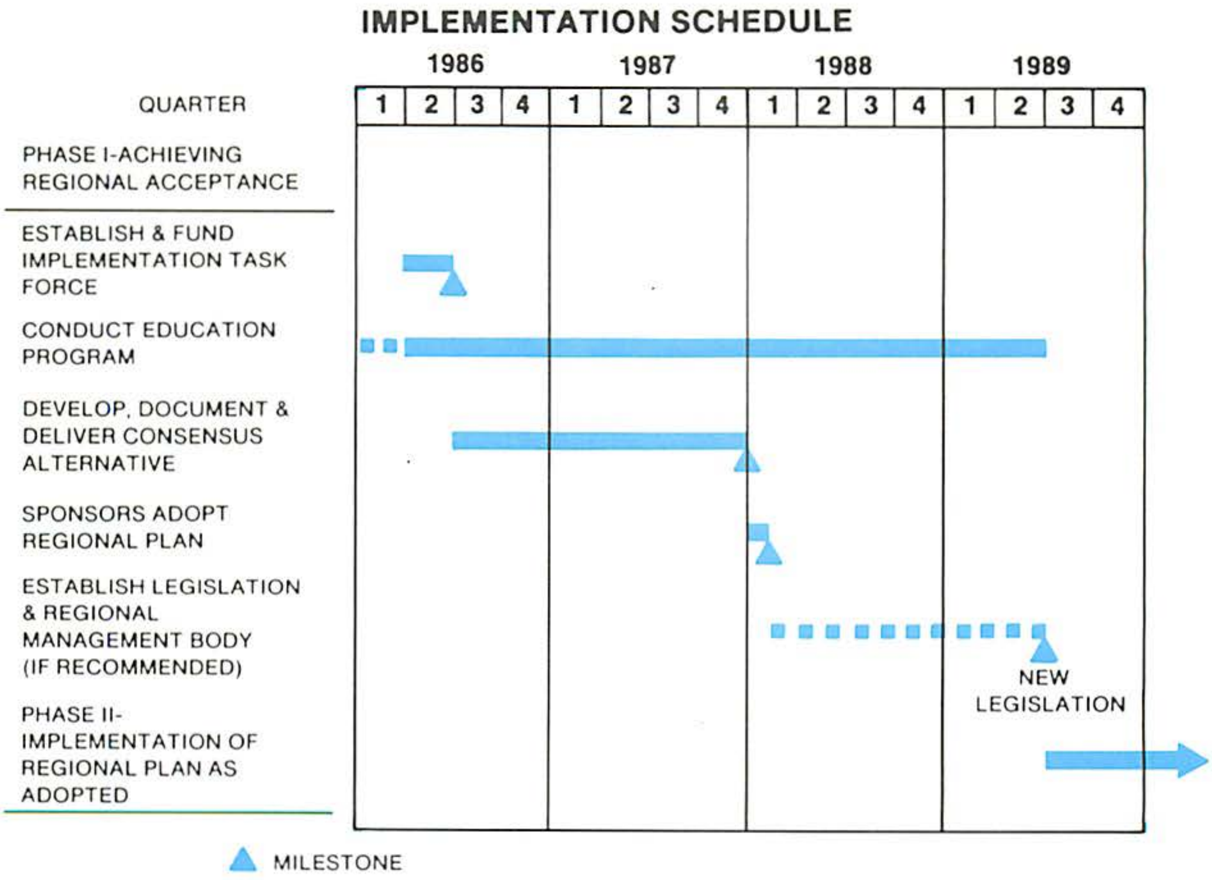
Regardless of the alternative selected, revenue bonds are likely to be the source of almost all funds for construction projects. Prospects are poor for obtaining significant state or federal funding. Proposition 1, which passed in the November 1985 election, is not expected to be a source of funding since the money is targeted for smaller cities and towns that are at the limits of their funding capabilities.

A minor contribution may be provided from grants, sales of power generated at new dams, or sale of excess surface water on a temporary basis until it is needed. Funds from Proposition 2, which was a companion measure to Proposition 1, are also available to help finance the purchase of water-saving irrigation systems by area farmers.

Utilities may not levy sales or ad valorem taxes, well pumpage charges or well permit fees. EUWD can levy a higher ad valorem tax only after it is approved in county elections within the District. The State Legislature would have to pass new laws to permit the use of sales tax, well pumpage fees and well permit charges planned as part of cost recovery for the water plan in Alternatives II and III.

Schedule

The implementation program calls for establishing the regional and local task forces and beginning a series of pub-



lic meetings and education programs during 1986. The task forces would select an alternative to be delivered to the sponsors (EUWD and City of San Antonio) for adoption in the first quarter of 1988. By mid-1989, assuming necessary authorizing legislation has been adopted for Alternative II or III, Water Resource Management Board members could be elected and initial meetings held to begin carrying out the adopted plan. The new board might begin sooner if no new legislation is required or if community consensus is reached more quickly.

It should be noted that regardless of the alternative finally chosen, Applewhite Reservoir construction could move forward under the sponsorship of the City Water Board of San Antonio.

PART IV--CONCLUSION

Public Response to the Study

A series of public meetings were held in San Antonio, New Braunfels, and Hondo at the end of February 1986 to present study findings and sound out public opinion. The following significant concerns were raised which merit careful attention:

- Many Medina and Uvalde County residents object to any new regional fees and to the proposed selection of management board members on a "one-person, one- vote" basis.
- Many Cuero area land owners oppose Cuero reservoir.
- Many residents of the region support more aggressive control of development in the recharge area to protect Edwards water quality.
- In cities, people have asked that "life-line" rates be considered.

Additional public meetings and workshops are an integral part of the proposed implementation plan. Community participation will be actively sought.

What Should Be Done?

Decision-makers can choose among three basic strategies:

- Do nothing and allow present policies to continue.

- o Accept this report and seek consensus on an alternative plan, working within existing political systems and processes to gain maximum regional participation.

- o Accept this report and seek relatively rapid implementation of an alternative plan, even if this means that all users of the aquifer do not share in paying the costs involved.

In choosing a course of action, they should be aware that water resource planning is a critical issue for residents of the study area. A continuation of present policies would eventually lead to loss of natural springs, higher pumping costs because of a drop in aquifer water levels, the danger of saline water intrusion into the Edwards Aquifer and probable legal/administrative action against major Edwards pumpers.

All agree that the Edwards Aquifer is a valuable resource. Water resource planning is broadly understood to be a problem facing the region as a whole, and there is a willingness to work toward solutions that will help ensure the quality of life and prosperity of the region. However, the variety of ways in which consumers would be affected by continued groundwater mining and the diversity of interests affected by water policy have prompted significant differences of opinion among area residents. Concerted efforts will be needed to achieve a consensus regarding what should be done.

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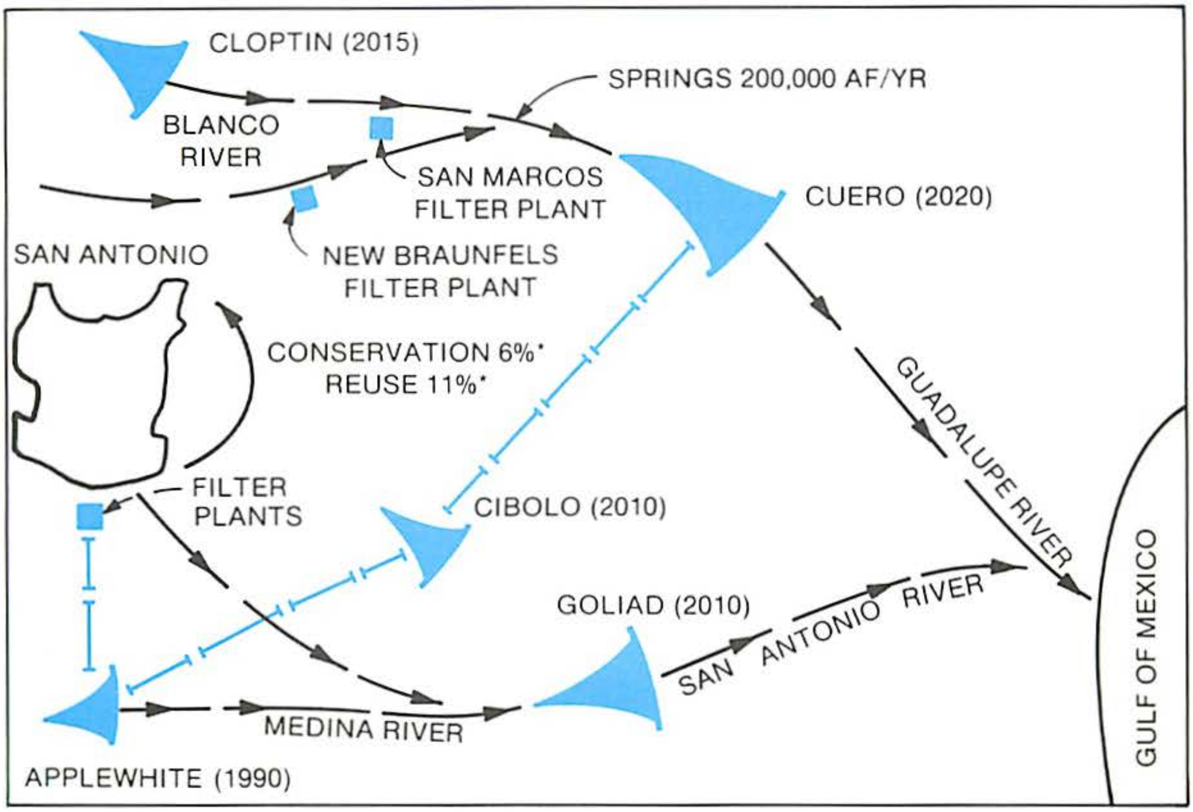
ALTERNATIVE I
No New Laws/Reservoirs



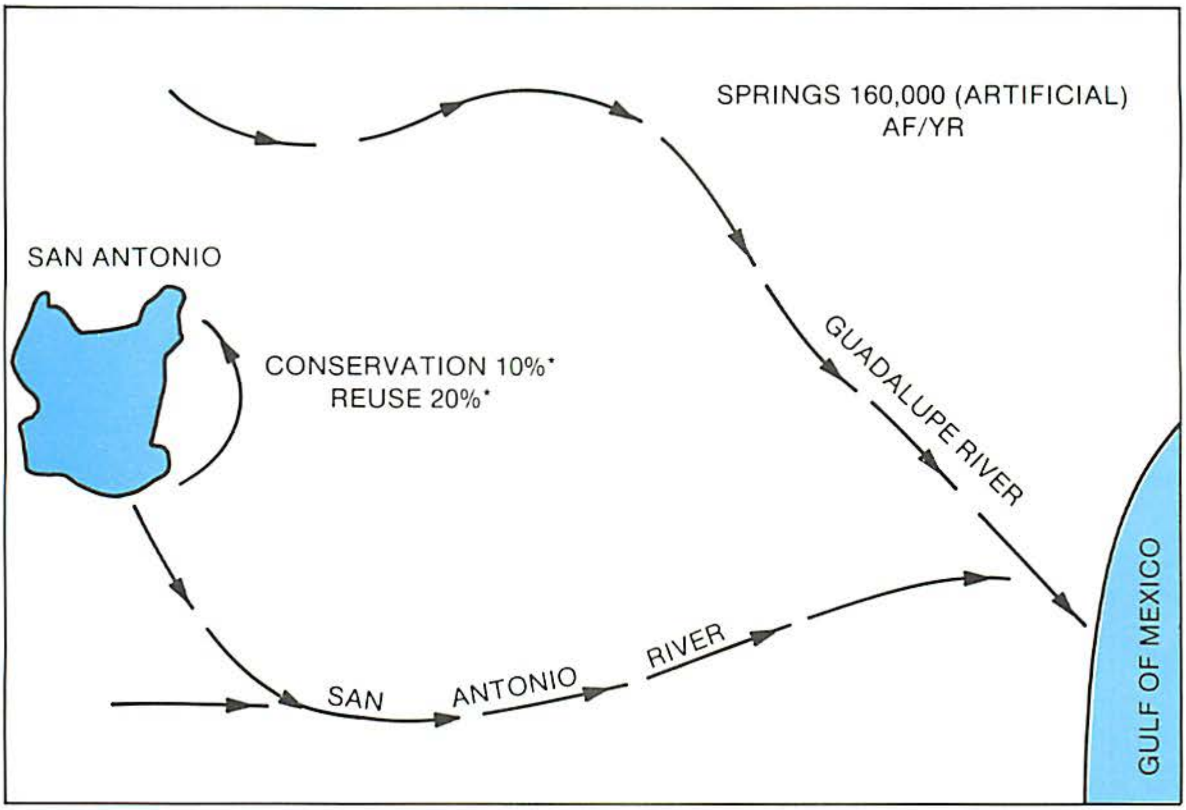
SUPPLY PLAN

* PERCENT OF TOTAL 5-COUNTY DEMAND IN YEAR 2040

FEATURES
- New reservoirs, no new laws
- Edwards pumpage 10% less than current
- Cost $1.7 billion
- Water costs for CWB customers up 70% (average)

PRO'S & CON'S
- Good for maintaining economic growth & springflows
- Protects Edwards water quality
- Voluntary conservation
- Highest water cost increases for participants

ALTERNATIVE II
New Laws/No Reservoirs



SUPPLY PLAN

* PERCENT OF TOTAL 5-COUNTY DEMAND IN YEAR 2040

FEATURES

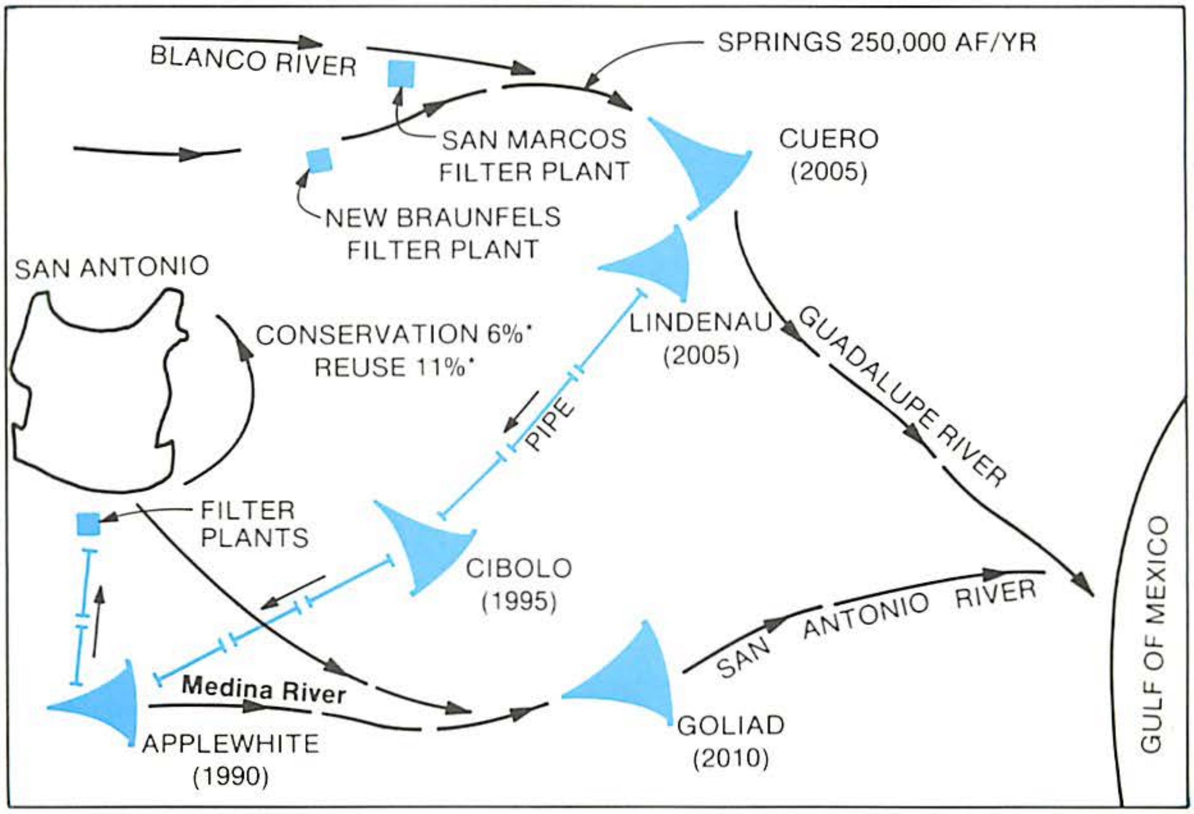
- New laws, no new reservoirs
- Edwards pumpage 50% more than current (15% overdraft)
- Cost $0.5 billion
- Water costs for CWB customers up 20% (average)
- Artificial springflow

PRO'S & CON'S

- Not as good for maintaining economic growth & springflows
- Danger to Edwards water quality
- Mandatory conservation
- Lowest water cost increases for participants

ALTERNATIVE III

New Laws/New Reservoirs (Max)



SUPPLY PLAN

* PERCENT OF TOTAL 5-COUNTY DEMAND IN YEAR 2040

FEATURES

- New reservoirs (maximum), new laws
- Edwards pumpage 20% less than current
- Cost—$1.8 billion
- Water costs for CWB customers up 50% (average)

PRO'S & CON'S

- Best for maintaining economic growth & springflows
- Protects Edwards water quality
- Voluntary conservation
- Medium water cost increases for participants

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CHAPTER 1

Chapter 1
INTRODUCTION AND BACKGROUND

GENERAL

The Edwards Aquifer provides water for municipal, commercial, industrial, agricultural and recreational sectors in the San Antonio area and adjacent region. This high-quality water source is a fundamental contributor to the region's social and economic well-being. But in recent years, state and local officials have raised concerns that regional population and economic growth will soon exceed the aquifer's water supply capabilities. Current water demand, primarily for agricultural irrigation, municipal use, and springflow in the region, is at or near the limit of safe annual yield from the aquifer as defined by the Texas Department of Water Resources (TDWR)[1]. State water resource managers, such as officials from the TDWR, stress the need for new water supply options in the immediate future.

The City of San Antonio and the Edwards Underground Water District (EUWD) are sponsors of this comprehensive regional water resource study. Basic purposes of the study are to review and summarize previous reports on the region's surface and groundwater resources, identify and evaluate alternatives for meeting future demands, and develop a long-term implementation plan for meeting those demands.

STUDY AREA

The Edwards Aquifer extends 175 miles from Brackettville in Kinney County to Kyle in Hays County. It affects many groups of water users including irrigators in the west, the San Antonio metropolitan area, recreational and tourist interests in the New Braunfels and San Marcos areas, and users along the Nueces, San Antonio, and Guadalupe Rivers to the coast, including the bays and estuaries. This is illustrated schematically in Figure 1-1.

Three river basins (Nueces, San Antonio, and Guadalupe) make up the study area, which is divided into primary and secondary sections (see Figure 1-2). The primary study area (region) includes the counties that overlie the Edwards Aquifer, namely, Kinney, Uvalde, Medina, Bexar, Comal, and Hays. Study evaluations are concentrated on this region. Remaining areas of the Nueces, San Antonio, and Guadalupe River Basins comprise the secondary study area.

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[1]On September 1, 1985, the TDWR was reorganized into the Texas Water Development Board and Texas Water Comission. All references to the TDWR in this report are understood to refer to the Texas Water Development Board or the Texas Water Commission as applicable.

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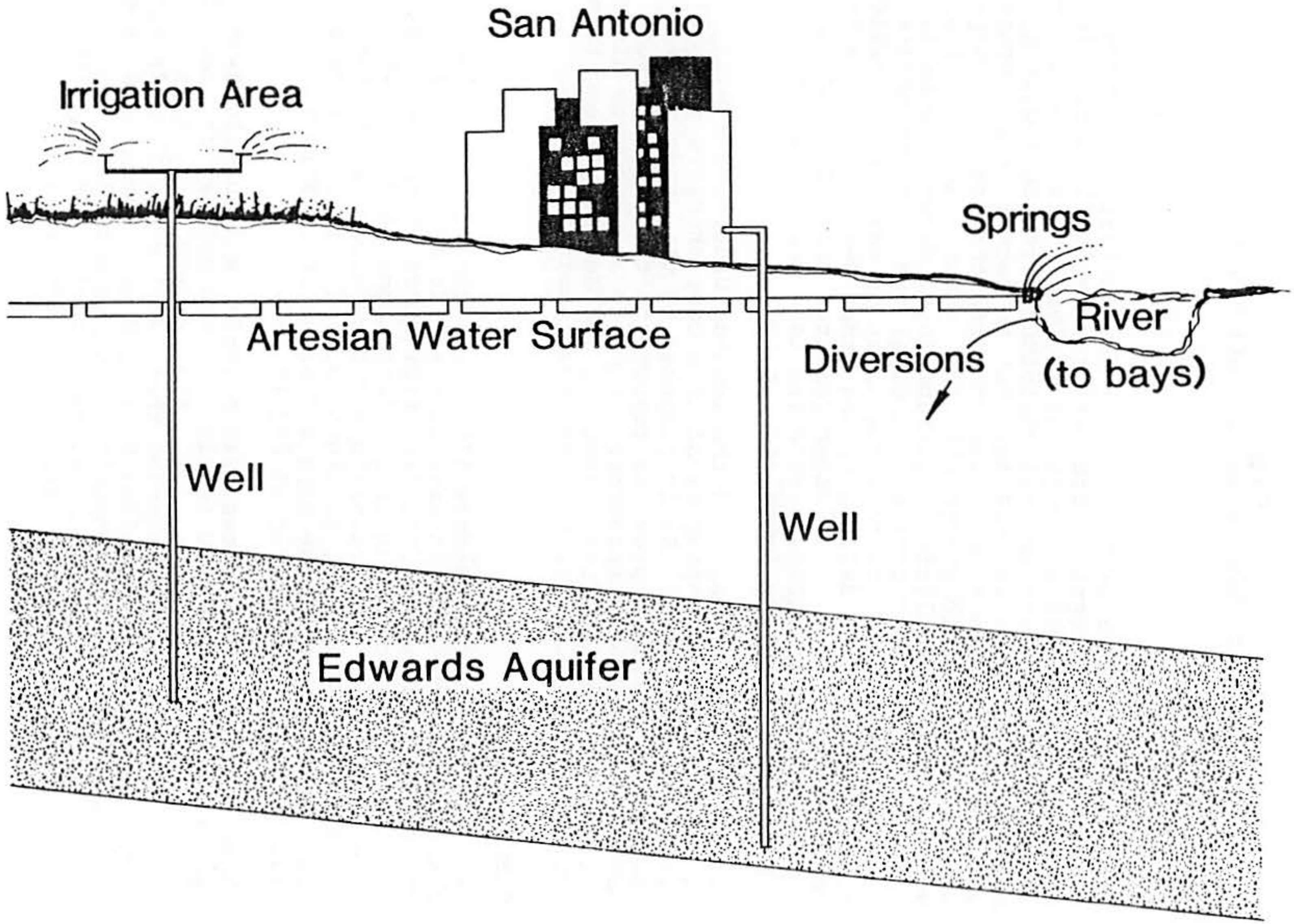

FIGURE 1-1
SCHEMATIC SECTION
OF EDWARDS AQUIFER

CH2M HILL

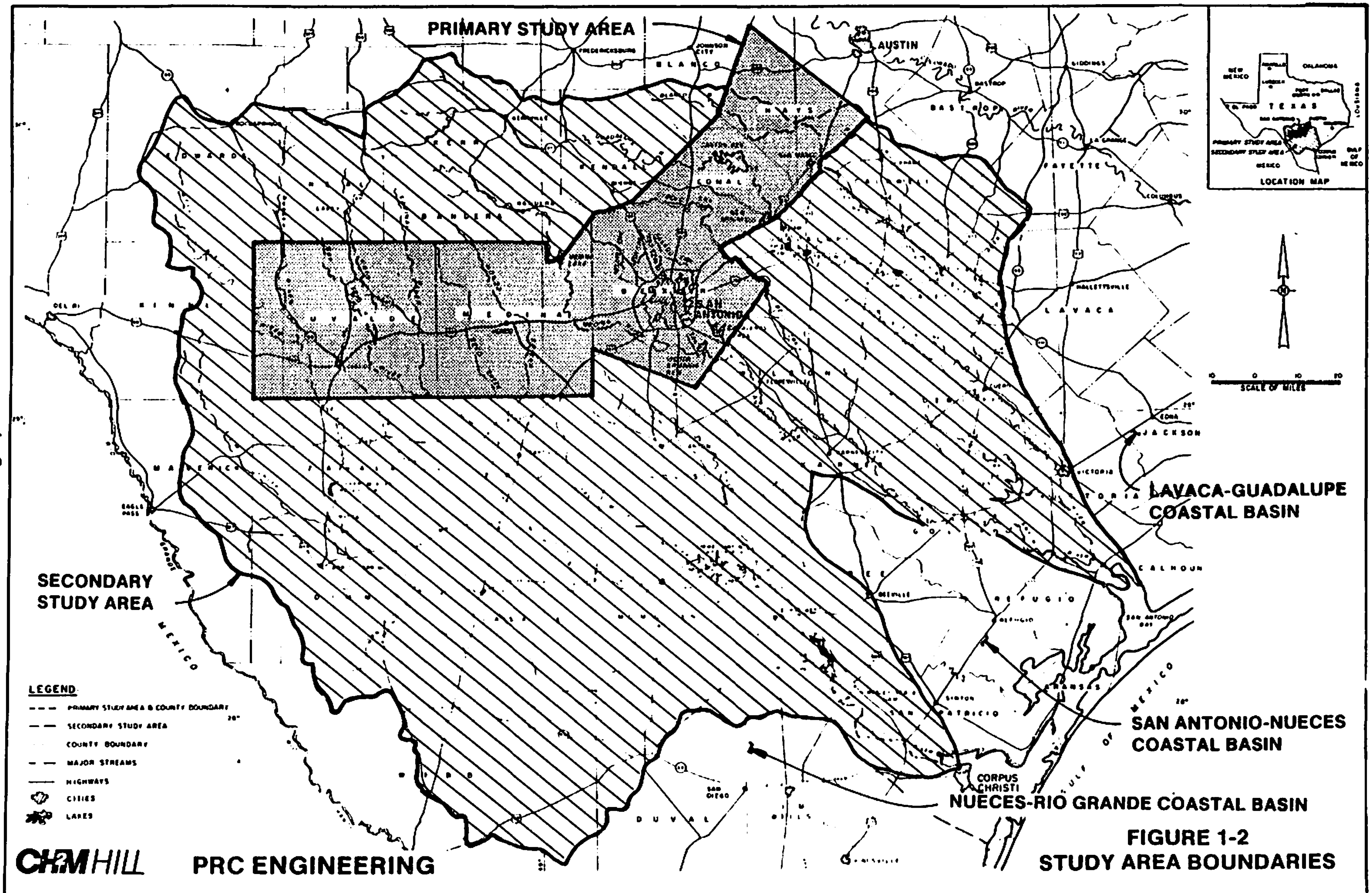

FIGURE 1-2
STUDY AREA BOUNDARIES

These river basins are included because water resources of the basins are interrelated with those of the primary study area. The rivers provide recharge water to the Edwards Aquifer, primarily from the Nueces River tributaries. Spring flows issuing from the Edwards constitute a portion of the Nueces and Guadalupe River flows available for downstream uses. Springflows decline as Edwards well pumpage increases, and San Antonio's wastewater discharge affects flows in the San Antonio River.

SPONSOR GOALS

The preservation of the high quality of Edwards Aquifer water is essential and basic to the purpose of this study. The sponsors have further identified the following principal goals for the study and resulting projects:

- To ensure availability of an adequate and reliable water supply for the region's growth and economic development
- To provide water to residents of the region at the lowest possible equitable cost while minimizing adverse impacts of water development and use
- To encourage timely commitments of funds and other resources for large capital projects
- To ensure that institutional entities protect water resources, remain accountable to the public, and impose minimum legal restrictions on the availability and use of water consistent with achieving these goals
- To maintain planning and decision-making flexibility in meeting future regional water needs
- To strengthen and ensure a reliable long-term water resource planning process for the region

STUDY AUTHORIZATION

In July of 1984 the sponsors approved retaining a consultant to conduct a regional water resource study. A technical advisory committee (TAC), consisting of nine public members interested in water resources planning, was established (1983) to assist in selecting the consultant and to monitor progress of the study. TAC also includes seven ex-offico members (water resources officials from the three river basins, the City of San Antonio, TDWR, and the U.S. Geological Survey). A listing of TAC members is given on the last page of this volume. CH2M HILL, in association with Planning Research Corporation (PRC Engineering) and Arthur

Young, was selected by the TAC in October 1984. Authorization to proceed with the investigations was given in November 1984 with a scheduled completion date of February 1986.

FRAMEWORK OF THE STUDY

The study focuses on regional water needs from the base year of 1980 to the year 2040 with intervals of 1980, 1990, 2000, 2010, 2020, 2030, and 2040.

To the extent possible, the study is based on existing data sources. Major sources of water resource data are files and reports of the Texas Department of Water Resources, U.S. Geological Survey, EUWD, River Authorities, and the San Antonio City Water Board.

REPORT ORGANIZATION

The first three chapters of this report describe study goals, background, regional setting, and approach to the work. Chapter 4 describes potential water sources and forecasts future water demand for the study area.

This is followed by development and analysis of water supply alternatives in Chapter 5. Three alternative approaches to meeting the study area's water demands are compared to the existing or status quo conditions.

Chapter 6 contains recommended action plans and schedules for each of the three water supply alternatives.

Technical appendices are included as Volumes II and III of this report.

The sponsors and/or other entities have the option to select one of the alternatives (or some combination of the alternatives) and implement that plan over the next 50 years. This long-term process includes built-in flexibility that will allow mid-course corrections to meet changing conditions within the overall planning framework of the selected alternative.

OTHER STUDIES

Past

A number of prior efforts relate to this study. Relevant reports are listed at the end of appendices in Volumes II and III. The current study builds upon this previous work while emphasizing the implementation aspects of a regional water supply plan. Particularly significant studies with similar regional emphasis include the following:

- Water for Texas, A Comprehensive Plan, Texas Department of Water Resources, November 1984.

  This study focused on the state's water needs to the year 2030. The state was subdivided into several areas of study, including the south central Texas region, which includes the primary study area. Conjunctive use of groundwater along with new surface water reservoirs was proposed for this area.

- San Antonio-Guadalupe River Basins Study, Texas Basin Project, Special Report, U.S. Bureau of Reclamation, November 1978.

  The purpose of this study was to compile information on current and projected water needs in the two basins and recommend a plan for meeting those needs. Four alternative conjunctive use plans with different combinations of reservoirs were suggested. Both this and the following report recommended that the concept of a master conservancy district be investigated and implemented if found to be a reasonable approach.

- Nueces River Basin for the Texas Basin Project, Special Report, U.S. Bureau of Reclamation, 1983.

  This study was a companion volume to the above USBR report. It recommended the importation of surface water to the Nueces Basin from the San Antonio and Guadalupe Basins along with use of groundwater resources at safe yield levels.

Ongoing

Several related studies were conducted by others concurrent with this regional water resource study. Those studies are described in Chapter 3.

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CHAPTER 2

Chapter 2
REGIONAL SETTING

GENERAL

This chapter summarizes information on the regional setting (physical, environmental, institutional, economic and population) in the study area to provide a basis for the water resource study evaluations. Appendices in Volume II and Volume III give details on the information presented here.

PHYSICAL

Topography

The Nueces, San Antonio, and Guadalupe Rivers drain an area of about 27,200 square miles. The land mass drained by these three rivers is divided into two physiographic provinces. North is the Edwards Plateau of the Great Plains Province, a rough and rugged area covered with rolling hills divided by limestone-walled valleys. South of the plateau lies the Gulf Coastal Plain area, extending to the Gulf of Mexico. The Edwards Plateau and the Coastal Plain are separated by the Balcones Escarpment, a southeastern-facing remnant of the Balcones Fault. The dropoff from the plateau to the plain is a sometimes spectacular and sometimes gradual descent of about 700 feet. The Balcones Escarpment runs about 180 miles along the base of Edwards Plateau, roughly on a line from Brackettville northeast to a little north of San Antonio and on to New Braunfels and San Marcos.

In contrast to most of the Edwards Plateau country of rolling hills and wide flat mesas, portions of the Guadalupe River Basin are characterized by sharp divides. Effects of intensive erosion are apparent on the land surfaces throughout the plateau area. The soils are thin and have a limestone base but are sufficient to provide for the growth of cedar, small oak, mesquite, and extensive ranges of grass.

Geology

Rocks found in the study area are primarily sedimentary material that accumulated along the Ancestral Gulf Basin during the late Mesozoic and Cenozoic Eras. The oldest rocks are of the Cretaceous period. More recent rocks of the Tertiary and Quaternary are also represented.

Principal geologic structures are the Balcones Escarpment and the Luling Fault Zone, both in the Ancestral Gulf Basin. The Ancestral Gulf Basin is indicated by an outcrop pattern of Tertiary rocks. Subsidence in the basin is indicated by the surface slope of the pre-Cretaceous rocks to the southeast from 1,000 feet above sea level in Kendall County to 2,500 feet below sea level in Guadalupe and Bexar Counties and to more than 8,000 feet below sea level in Wilson County.

The Balcones Escarpment, from 4 to 30 miles wide, consists of a series of semiparallel faults extending across the study area from northern Hays County, southwest to Bexar County, then west to Brackettville in Kinney County. The faults are approximately parallel to the fault zone trend in Hays, Comal, and Bexar Counties. In Medina County and northeastern Uvalde County the individual faults occur at small angles to the general fault trend.

The Luling Fault Zone extends from Caldwell County to southeastern Medina County. This zone is located about 10 to 20 miles southeast of the Balcones Escarpment. It is a belt of nearly parallel faults similar to the Balcones Escarpment but not as wide. Faulting is normal, and the downthrow sides are on the northwest side of the fault plains. Fault displacement varies from a few feet (single faults) to a combined displacement of more than 1,500 feet.

Hydrology

Headwaters of the Guadalupe River Basin (total area of 6,070 square miles) lie in Kerr County at an elevation of about 2,360 feet. The river flows east to the City of Gonzales and then south into San Antonio Bay. Blanco and San Marcos Rivers are principal tributaries of the Guadalupe River. Headwaters of the San Antonio River Basin (total area of 4,180 square miles) are in Bandera County at an elevation of 2,360 feet. The river flows southeast to San Antonio Bay near Tivoli. Major tributaries of the San Antonio River are Medina River, Leon Creek, Salado Creek, and Cibolo Creek. Nueces River Basin (total area of 16,950 square miles) headwaters lie in Real and Edwards Counties at an elevation of 2,300 feet. The river flows south to Crystal City, then east into Corpus Christi Bay. Atascosa and Frio Rivers are principal tributaries of the Nueces River. Major tributaries of the Frio River are San Miguel Creek, Hondo Creek, Sabinal River, Dry Frio River, and Leona River.

The source of the three rivers is primarily surface runoff. In addition, Edwards Aquifer natural discharges at San Marcos and Comal Springs supply a substantial baseflow portion of the Guadalupe River. In average rainfall years, springflow accounts for 25 percent of river flow measured at Cuero. The percentage is greater in dry years and reached a maximum of 75 percent in the lowest river-flow year, 1956.

Coastal basins include the Lavaca-Guadalupe located between the Lavaca and the Guadalupe River Basins (total area of 998 square miles); the San Antonio-Nueces between the San Antonio and the Nueces River Basins (total area of 2,652 square miles); and the Nueces-Rio Grande located between the Nueces and Rio Grande River Basins (total area of 10,442 square miles).

Average annual runoff in the Guadalupe River Basin varies from 273 acre-feet per year per square mile at Victoria to 158 acre-feet per year per square mile at Comfort (as of September 1984). The Guadalupe River has an average flow of 1.3 million acre-feet per year at its confluence with the San Antonio River and discharges an average 1.8 million acre-feet per year into San Antonio Bay.

Average annual runoff in the San Antonio River Basin varies from 122 acre-feet per year per square mile at Goliad to 209 acre-feet per year per square mile at Elmendorf (as of September 1984). The San Antonio River discharges an average of 0.5 million acre-feet per year in the Guadalupe River.

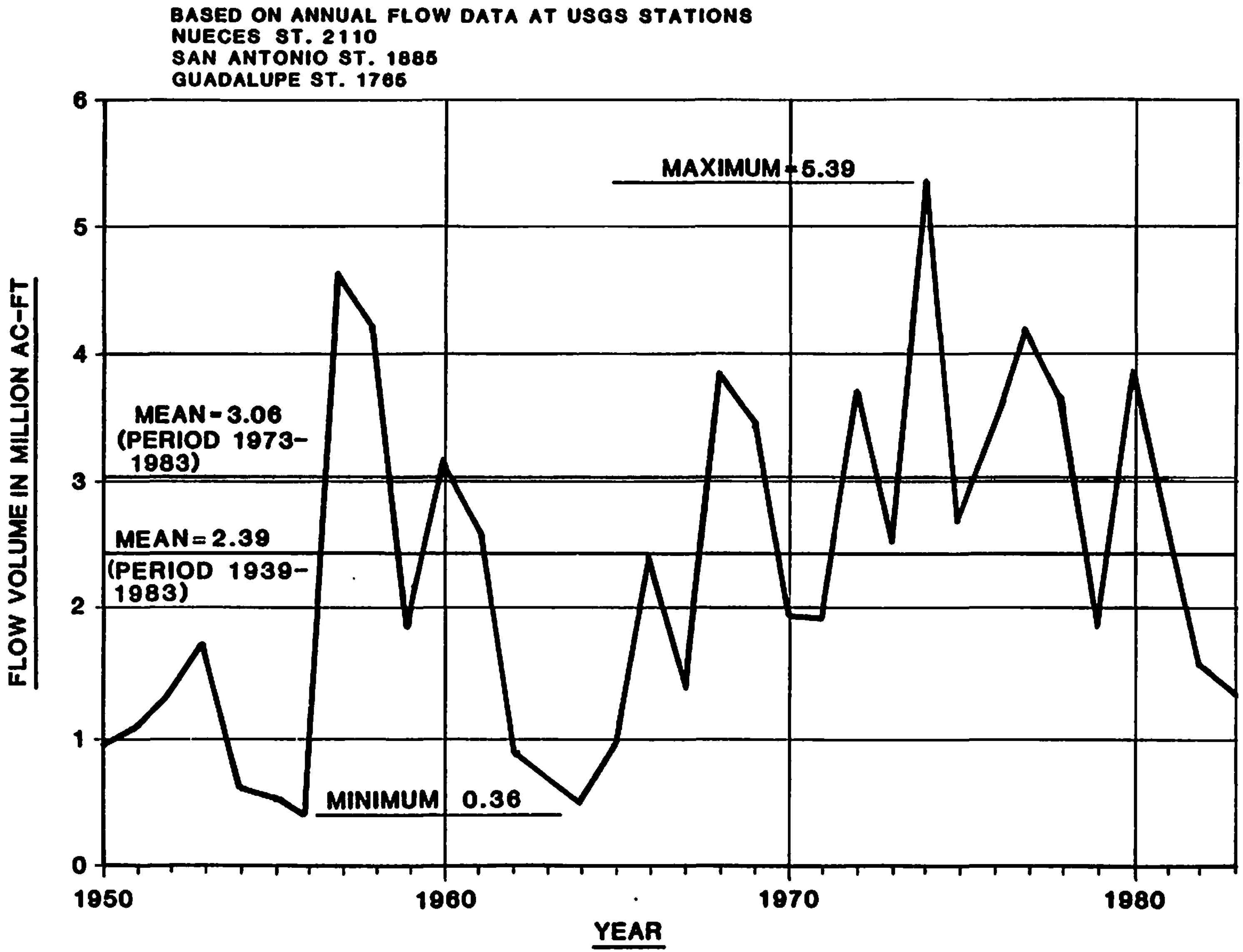
Average annual runoff in the Nueces varies from 145 acre-feet per year per square mile at Laguna to 38 acre-feet per year per square mile at Bracketville (as of September 1984). The Nueces River discharges an average 0.6 million acre-feet per year into Corpus Christi Bay.

Annual streamflows of the three rivers at gauging stations closest to San Antonio Bay are shown in Figure 2-1.

It is important to note that streamflow in recent years (since the early 1970's) has been much higher than the long-term average. Since 1973, the gauged flow of the three rivers has averaged 3.06 million acre-feet (MAF), which is 30 percent higher than the past 45-year average of 2.39 MAF. This surplus has tended to mask the effects that ever-increasing water demands in the area would otherwise have had on springflow, instream flow volumes, the flows reaching the bays, and Edwards Aquifer water levels. The Edwards receives recharge from surface streams and thus has received higher-than-normal recharge in the past decade (see below under "Hydrogeology").

Hydrogeology

Groundwater within the Counties of Uvalde, Medina, Bexar, Comal, and Hays is generally supplied by the Edwards Aquifer. Groundwater for the remaining area within the Nueces, San Antonio, and Guadalupe River Basins is derived from several other principal aquifers: the Carrizo-Wilcox, the Sparta-Laredo, the Queen City-Bigford, the Trinity Group, and the Gulf Coast Aquifer.



NOTE: FLOW VOLUMES SHOWN ARE TOTALS FOR THE THREE RIVERS.

FIGURE 2-1
ANNUAL STREAMFLOWS
NUECES, SAN ANTONIO
& GUADALUPE RIVERS

CH2M HILL

PRC ENGINEERING

Historically the water needs of San Antonio and the surrounding study area have been met by water from the Edwards Aquifer and a system of secondary aquifers. The secondary aquifers include the Trinity Group, located north of the Edwards Aquifer, and the Carrizo-Wilcox, Sparta Laredo, and Queen-City Bigford Aquifers, to the south. Figure 2-2 delineates the Edwards Plateau region, the Texas Hill Country, the Edwards Aquifer, and the Winter Garden area, plus the Gulf Coast region physiographic units and the aquifers found in each. The nomenclature used for the aquifers is that of TDWR.

While the Gulf Coast Aquifer was not specifically included in the Scope of Work for this study, it is important in the overall water balance and can help meet demands in the lower portions of the Nueces, San Antonio, and Guadalupe River Basins. Therefore, its annual available yields, as estimated by TDWR, are included.

Edwards Aquifer

Recharge to the Edwards Aquifer occurs where major streams cross the outcrop area. Streams in the zone can lose up to 100 percent of base flow as infiltration to the aquifer. Discharge from the aquifer occurs through pumpage, primarily for municipal, industrial, and irrigation use, and as spring flow. The Edwards Aquifer supports five major springs in the San Antonio region: Leona, San Pedro, San Antonio, Comal, and San Marcos. Comal and San Marcos account for more than 90 percent of the composite spring discharge. The recharge streams that supply the Edwards Aquifer originate north of the aquifer, in the Texas Hill Country. Baseflows of the recharge streams are generally derived from groundwater discharge in the Hill Country, primarily from the Trinity Group and Edwards (Plateau) Aquifers.

For the period of record 1934-1982, recharge to the aquifer has averaged 608,000 acre-feet per year. Recharge in the last 30 years has been considerably more than the long-term average due to higher than normal rainfall. The 1968 to 1982 period has been particularly wet, resulting in recharge amounts 40 percent above the long-term average. As an example of the demands placed upon the aquifer, total discharge was 786,000 acre-feet in 1982, the most recent year of record. This consisted of 333,000 acre-feet of spring discharge and 453,000 acre-feet of well discharge. Figure 2-3 shows the variability of discharge over this period.

Carrizo-Wilcox Aquifer

The Carrizo-Wilcox Aquifer, where fresh to slightly saline water is available, consists of two geologic units: the Carrizo Sand formation and the underlying Wilcox Group. The

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Table 2-3
TDWR ALTERNATIVES FOR PROTECTING THE
GUADALUPE AND NUECES ESTUARIES

	Estimates of Needed Bay Inflows[e]	
	Guadalupe (Acre-Feet)	Nueces (Acre-Feet)
Alternative I (sustenance)[a]	1,240,000	356,000
Alternative II (maintenance)[b]	1,620,000	397,000
Alternative III (enhancement)[c]	1,830,000	550,000
Alternative IV (viability limit)[d]	755,000	118,000

[a]Estimate based on salinity and inundation needs of each estuary.

[b]Estimate based on salinity, inundation, and fisheries needs to maintain commercial harvests at average levels.

[c]Estimate based on salinity, inundation, and fisheries needs to enhance harvests of selected major commercial species.

[d]Estimate based on monthly limits of bay salinity within which important fish and shellfish can survive, grow, and maintain viable populations.

[e]See text regarding preliminary nature of these estimates.

TDWR emphasizes that data used to develop these estimates represent extremely short periods of time and the alternatives are only a few available to the state. TDWR has noted the need for additional study to improve the accuracy of these estimates.

Springs

The study area has five major springs served by the Edwards Aquifer. For the period of record (1934-1982), the springs have discharged an average of 360,000 acre-feet per year. Records show that all of the springs, with the exception of San Marcos, have ceased discharging at least once during the period of record. This is the result of being discharge points of the Edwards so that when the water level of the Edwards drops, the discharge of the springs is reduced.

The spring discharges support fish life in the rivers, aquatic biota in the springs, recreational activities, the bays and estuaries, and the aesthetic beauty of the study area. These benefits in turn help support the economic growth of the study area.

INSTITUTIONAL

The implementation of a regional water resource plan may require that an agency or some combination of agencies have the following powers:

- Ability to develop an acceptable plan of action to manage both the groundwater and surface water resources necessary to service the demands of the region. There must be a mechanism for responding to changing circumstances and to achieve the cooperation of all agencies in the area carrying out the plan.

- Power to allocate costs and/or recover user fees from participants in payment of operations and capital costs for facilities located both within and outside the primary study area.

- Ability to coordinate or require conservation measures that are consistent across the region and appropriate within the framework of each alternative (i.e., should conservation be mandatory or voluntary?; should construction techniques with respect to conservation be standardized?; etc.).

- Authority to manage groundwater resources through the imposition of pumping limits, the adoption of a pump tax, and/or a requirement that existing and/or new users hold permits controlling the use of groundwater resource.

- Authority to adopt capital funding/revenue mechanisms that allow for sharing of costs on a regional basis according to benefit (i.e., sales tax, ad valorem taxes, water availability charges, well permit fees, etc.).

- Ability to contract using interjurisdictional agreements, joint power agreements, etc. to achieve the goals of the regional water resource program.

Based on a survey (see Appendix B) of agencies both within and outside the study area, certain constraints exist relative to the implementation of a regional water resource plan. These include:

- No agency has the authority to manage both groundwater and surface water resources under a conjunctive use program. Currently, over 200 water purveyors, three river authorities, and the Edwards Underground Water District are involved to varying degrees in the management of these resources in the primary study area.

- Except for the Edwards Underground Water District, which has limited authority, no agency has the power to implement the sharing of costs among institutions and/or individuals within the region. Although contractual arrangements can be developed for the planning and financing of specific components of any alternative, no comprehensive cost sharing mechanism can be implemented by any existing institution.

- Although individual communities or purveyors can adopt conservation measures, no mandatory conservation measures can be imposed on a regionwide basis (i.e., construction techniques to minimize water usage, adoption of pricing structures to encourage conservation, etc.).

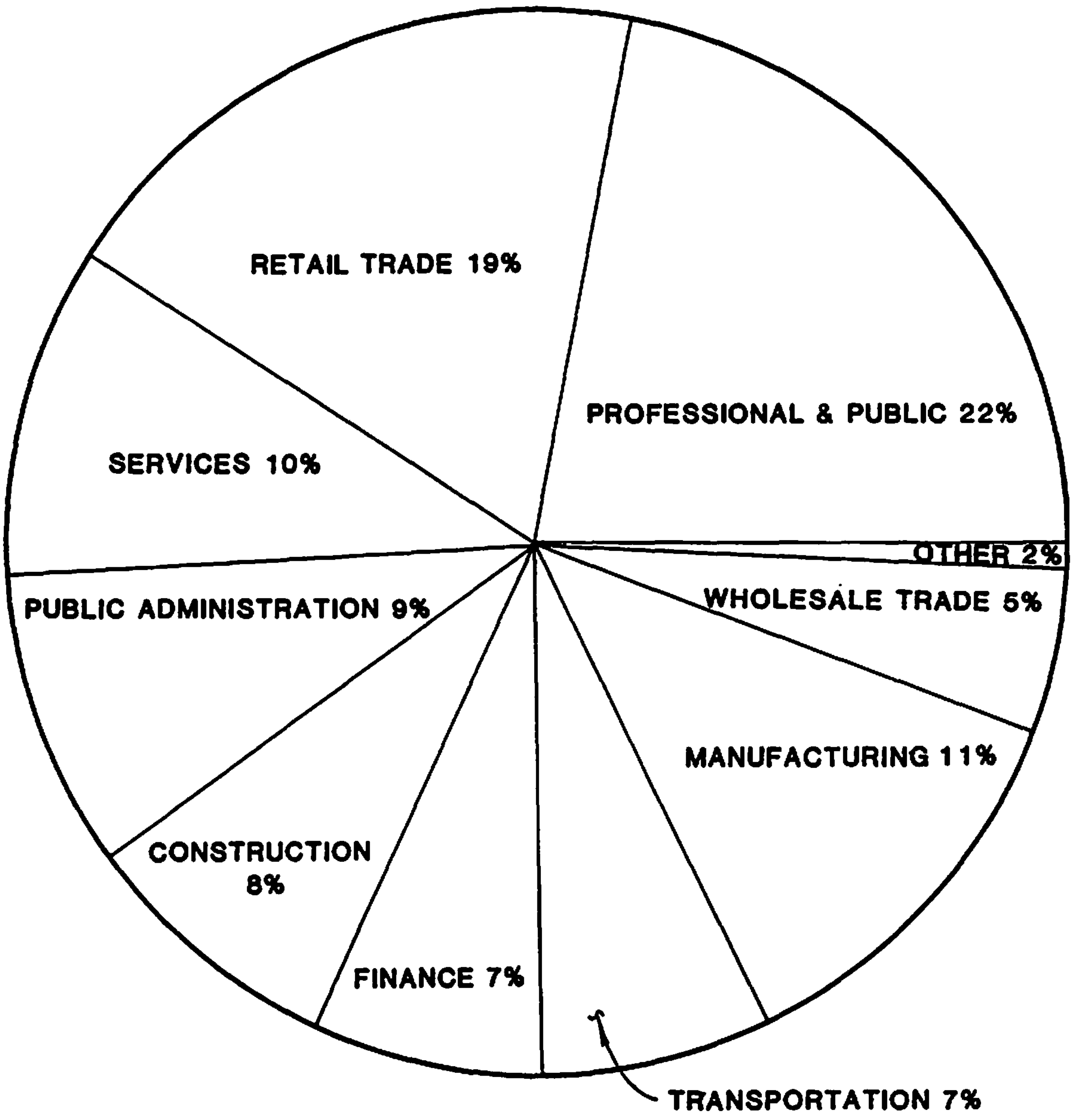
- There is very limited ability to adopt capital funding/revenue mechanisms that provide for sharing of costs on a regional basis (sales tax, ad valorem tax, water availability charges, well permit fees, etc.).

Chapter 6 (Implementation) incorporates a greater discussion of these constraints and identifies an appropriate course of action to address each under the various alternatives.

ECONOMIC

Texas is enjoying a long period of economic prosperity. Since the late 1960's the rate of economic growth in the state has increased while the rate of economic growth in the United States as a whole has slowed. In 1980, the study area attained a proportionately higher level of employment in the service-oriented economic sectors than did the state. Retail trade, finance, professional and public services, business services, and public administration accounted for 67 percent of the employment in the primary study area and 54 percent in the state. Figure 2-4 shows the breakdown of employment by sector for the primary study area.

Within the primary study area, leading economic sectors in Hays, Comal, and Bexar Counties were professional and public services, business and personal services, and retail trade.



NOTE: INCLUDES AGRICUTURE, FOREST & FISHERIES & MINING

FIGURE 2-4

CH2M HILL PRC ENGINEERING 1980 EMPLOYMENT CHARACTERISTICS FOR THE PRIMARY STUDY AREA

Hays County's professional and public services sector is large because residents include state employees working in Austin and residing in Hays County, employees of Southwest Texas University in San Marcos, and County employees. Two-thirds of Bexar County employment stems from the service-oriented sectors: retail trade, finances, services (business, personal, professional, public, and military), and public administration.

Medina and Uvalde Counties also rely heavily on service-oriented sectors, although at lower rates than the other primary study area counties. Medina and Uvalde Counties show a heavy reliance on agriculture, although agricultural employment has been declining.

Five leading economic sectors (within the primary study area) in terms of total output in 1979 are shown in Table 2-4.

Table 2-4
TOP FIVE ECONOMIC SECTORS, 1979
(Primary Study Area)

Sector	Output ($ million)
Financial, Insurance, and Real Estate	1,956
Construction	1,665
Other Services	1,412
Food and Kindred Products	1,406
Wholesale Trade	1,375

An input-output (I-O) model was developed to measure the economic interrelationships ("linkages") among sectors within the primary study area (Bexar, Comal, Hays, Medina, and Uvalde Counties). The model provides a comprehensive set of data that can be used to assess the direct and indirect impacts of changes in the economy. For example, the model provides a basis for evaluating the economic impacts of reductions in production in any given sector as a result of limited supplies or higher costs of water. An I-O model is a tool commonly used by economists to measure such impacts. A detailed description of the I-O model analyses is presented in Appendix D, and the economic impacts are presented in Appendix N, and summarized in Chapter 5.

There are definite "linkages" between sectors in the region, and these are quantified in the appendices. For example, for every thousand dollars of income paid in the irrigated agriculture industry, a total of $2,040 in direct income is paid to workers throughout the primary area in this and related industries. "Ripple effect" indicators, or "multipliers," were developed for all major economic sectors (agriculture, eating and drinking establishments, transportation, etc.) which were then used to measure the overall effect on the primary area's economy for a change in one sector's production due to potential water shortages or higher costs.

The research indicates that the study area business activity is heavily oriented toward wholesale trade, retail trade, finance, and services. These sectors account for more than 48 percent of total sector value of output in the region. Manufacturing accounts for some 27 percent of total sector value of output. The largest contribution to this activity is the food and kindred products sector. Extraction industries such as agriculture and mining make up a relatively small part of the overall study area business activity value (less than three percent). However, these industries are significant in certain counties, especially Uvalde and Medina. The relatively heavy weighting of the trades and services sectors reflects the significance of outside income entering the area through such activities as military spending, recreation, and tourism. These activities are localized primarily in Bexar, Comal and Hays Counties.

HISTORICAL POPULATION

The population of Texas has grown at a faster rate than that of the U.S. during the past 2 decades (see Table 2-6). Total U.S. population has increased 13 percent from 1960 to 1970 and 11 percent during the 1970 to 1980 period. For the same periods, Texas population has increased 17 percent and 27 percent. Much of the state's rapid population growth has been due to in-migration. This demographic shift is related to the overall high rate of economic growth in Texas as compared to other areas. In-migration has comprised approximately 60 percent of the state's total population increase from 1970 to 1980, and supplemental reports of the U.S. Census currently include estimates that 660,000 people migrated to Texas from 1980 to 1982.

Population growth in the primary study area has largely mirrored state growth trends, though significant differences among individual county growth rates are apparent. As indicated in Table 2-6, the population in Hays and Comal Counties has grown faster than that of the central or western sectors, particularly during the 1970 to 1980 period. Extremely high growth rates in the eastern sector reflect a sharply increased level of in-migration.

Table 2-5
HISTORICAL POPULATION CHARACTERISTICS

Year	United States	Texas	Primary Study Area	Bexar Co.	Comal Co.	Hays Co.	Medina Co.	Uvalde Co.
1960	179,323,175	9,579,677	762,647	687,151	19,844	19,934	18,904	16,814
1970	203,302,031	11,195,416	919,864	830,460	24,165	27,642	20,249	17,348
1980	226,545,805	14,229,191	1,111,445	988,800	36,446	40,594	23,164	22,441
			Percent Increase					
1960-1970	13%	17%	21%	17%	22%	39%	7%	3%
1970-1980	11%	27%	21%	19%	51%	47%	14%	29%
			Average Annual Rate of Growth					
1960-1970	1.3%	1.6%	1.9%	1.9%	2.0%	3.3%	.7%	.3%
1970-1980	1.1%	2.4%	1.9%	1.7%	4.1%	3.8%	1.3%	2.6%

Source: U.S. Department of Commerce, Bureau of the Census, General Social and Economic Characteristics, Texas Vol. I. (Washington, D.C.: U.S.G.P.O., 1983).

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Bexar County's rate of population growth was less from 1970 to 1980 than in the previous decade. County population has grown less rapidly in the latter decade than the population of the state at large. Like many Texas counties, Bexar County has attracted relatively large numbers of in-migrants during the latter half of the 1970's, with a continuation of rapid growth exhibited during the early 1980's.

Population in Medina and Uvalde Counties exhibits trends similar to those of other rural areas of the nation. During the 1960 to 1970 period, the rate of population growth in metropolitan areas surpassed growth rates for nonmetropolitan areas. But this trend reversed during the 1970 to 1980 period. Social scientists and others have speculated that this reversal reflects a resurgence of interest in a rural lifestyle.

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CHAPTER 3

Chapter 3
FRAMEWORK OF ANALYSIS

STUDY CONCEPTS AND PLANNING HORIZON

This study focuses on regional water resource management from 1980 to 2040. Population and water demand are forecast for each decade within this planning horizon. As with any planning effort, water demands and regional priorities will vary from what is presented here. The alternative plans are therefore intended to offer flexibility for making changes within an overall planning framework. For instance, an alternative water plan may include a target level of wastewater reuse and a new reservoir as resources to meet future water demands. If greater reuse is actually achieved, the reservoir construction date may be postponed.

STUDY PLAN

Data Sources

Forecasting water demands and evaluating alternative water supplies have been largely based on previous work by others. The major sources of water resources, economic, social, environmental, and geologic data include files and reports of TDWR, U.S. Bureau of Reclamation, EUWD, San Antonio City Water Board, and the local river authorities. Specific references are listed at the end of appendices in Volumes II and III of this report.

Growth and Economic Development Assumptions

Since a stated sponsor goal is to "assure availability of an adequate...water supply for the Region's growth and economic development," options discussed in this report do not consider growth-limiting mechanisms (such as restrictive zoning or groundwater pumpage limitations). An effort is therefore made to satisfy all water demands as fully as possible by optimizing the use of both existing and new sources of water.

Public Involvement

Three groups of public meetings were conducted at the early, intermediate, and final stages of this study. Meetings were held in various central, eastern, and western cities of the primary study area to inform the public of study results and to obtain local input for use in the study. The purpose of this analysis is to formulate and present alternative approaches to water management for the study area. Elected officials will then work through the political process to select one alternative from the "menu" to implement in the coming years. The final form of the selected alternative may vary from those presented herein to reflect a consensus of public opinion.

STUDY TOOLS

Surveys

Conservation. In 1984 the City of San Antonio and the Edwards Underground Water District undertook Operation Water Conservation as a regional program. Operation Water Conservation (the focal point for media coordination, literature, and technical assistance) includes a plan that consists of five phases ranging from awareness programs to emergency water conservation measures. Membership includes cities, counties, river authorities, soil and water conservation districts, and water purveyors in the study area. Members are responsible for policy formulation and implementation. Agencies assisting in educational and advisory capacities include Chambers of Commerce, the Soil Conservation Service, the Texas Department of Water Resources, the Alamo Area Council of Governments, universities, and others. When Operation Water Conservation began, moderate reductions in water use were recorded. A regional survey was designed and implemented to discover how people in the study area responded to Operation Water Conservation and other conservation measures.

The telephone survey was conducted by the Social Research Center at Texas A&M University. A random sample of 303 contacts were made. Survey results were analyzed by using the Statistical Package for the Social Sciences (SPSS) computer program. Questions involved public awareness of the need for conservation, how conservation measures were applied, and attitudes toward water conservation measures.

Detailed survey results are presented in Appendix A, along with a list of the questions asked.

Institutional. Numerous water resource agencies exist within the study area. Each of these agencies has some authorities (which they may or may not currently be using) necessary to implement a long-range water resources plan. To identify applicable authorities, a survey questionnaire was sent to many agencies both within and outside the study area. Entities responding to the survey include the following:

FEDERAL
- U.S. Geological Survey
- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation

STATE

- Texas Department of Water Resources
- Texas Public Utilities Commission
- Texas Agricultural Extension Services
  - Medina County-Hondo
  - Hays County-San Marcos
- Texas Soil and Water Conservation Districts
  - Comal-Hays-Guadalupe
  - Medina Valley
  - Alamo
  - Devils River

RIVER AUTHORITIES

- San Antonio River Authority
- Guadalupe-Blanco River Authority
- Nueces River Authority
- Lower Colorado River Authority

UNDERGROUND WATER DISTRICTS

- Edwards Underground Water District
- High Plains Underground Water Conservation District
- Harris/Galveston Coastal Subsidence District

IRRIGATION DISTRICTS

- Bexar-Medina-Atascosa Water Improvement District No. 1

PUBLIC/PRIVATE WATER UTILITIES

- Lackland City Water Company
- San Antonio City Water Board
- San Fernando Water Company
- City of Uvalde
- City of Alamo Heights
- Atascosa Rural Water Supply Corp.
- East Central Water Supply Corp.
- Kings Point Water Corp.
- Yancy Water Supply Corp.
- Ciblo Creek Municipal Authority
- City of San Marcos
- Bear-Medina-Atascosa Rural Water Supply
- Hill Country Water Works
- Windcrest
- Lackland Heights
- Helotes Park Estates

OTHER INSTITUTIONS

- Alamo Area Council of Governments

Results of the survey are summarized in Appendix B. (A copy of the questionnaire provided to each agency is also included.)

Computer Models

Population. The TDWR population model was used to forecast population growth in the study area. This model is a cohort component model; i.e., each age group for each sex is separately tracked. CH2M HILL modified the TDWR model to incorporate 1980 census data on cohort migration that was not available when TDWR developed its projections. Migration rates into the study area have slowed since earlier projections; therefore, the new population projections are lower than previous estimates by TDWR. The model includes population projections for all cities with populations over 500, plus rural populations for each county. These were aggregated into the desired study area geographic subdivisions of primary and secondary areas, river basins, and major cities. Results are given in Appendix C.

Economic Input-Output. Input-output models are used to identify production transfers among regional sectors or industries and the total output of the region; i.e., the record of sales and purchases of each economic sector and the proportion of total sales among all sectors. The 1979 TDWR model for the state was scaled down to approximate a regional economy and modified to determine linkages between various economic sectors within the primary study area. Results are given in Appendix D.

Demand. TDWR is the only agency in Texas that prepares a comprehensive set of water demand projections for all counties and river basins. TDWR employs a separate econometric model to project water demand for each of the major end-use sectors and develops high-case and low-case projection sets. These models were used to project water use in the study area. Details on how the model was used to forecast demands in each use sector (municipal, industrial, agriculture, steam electric, mining, and livestock) are given in Appendix E and summarized in Chapter 4.

Edwards Groundwater. A computer model was used to identify the Edwards Aquifer's complex response to pumping under alternative management options. The model selected was developed by the TDWR in the 1970's. It predicts flows at five springs plus groundwater levels at 856 cells across the Edwards Aquifer-San Antonio region in response to recharge and pumpage conditions entered by the user. Sizes of the rectangular cells vary from 1.2 to 18.5 square miles. TDWR calibrated the model by trial and error methods until it could accurately predict historic regional water levels and springflows over a 25-year period, 1947 to 1971.

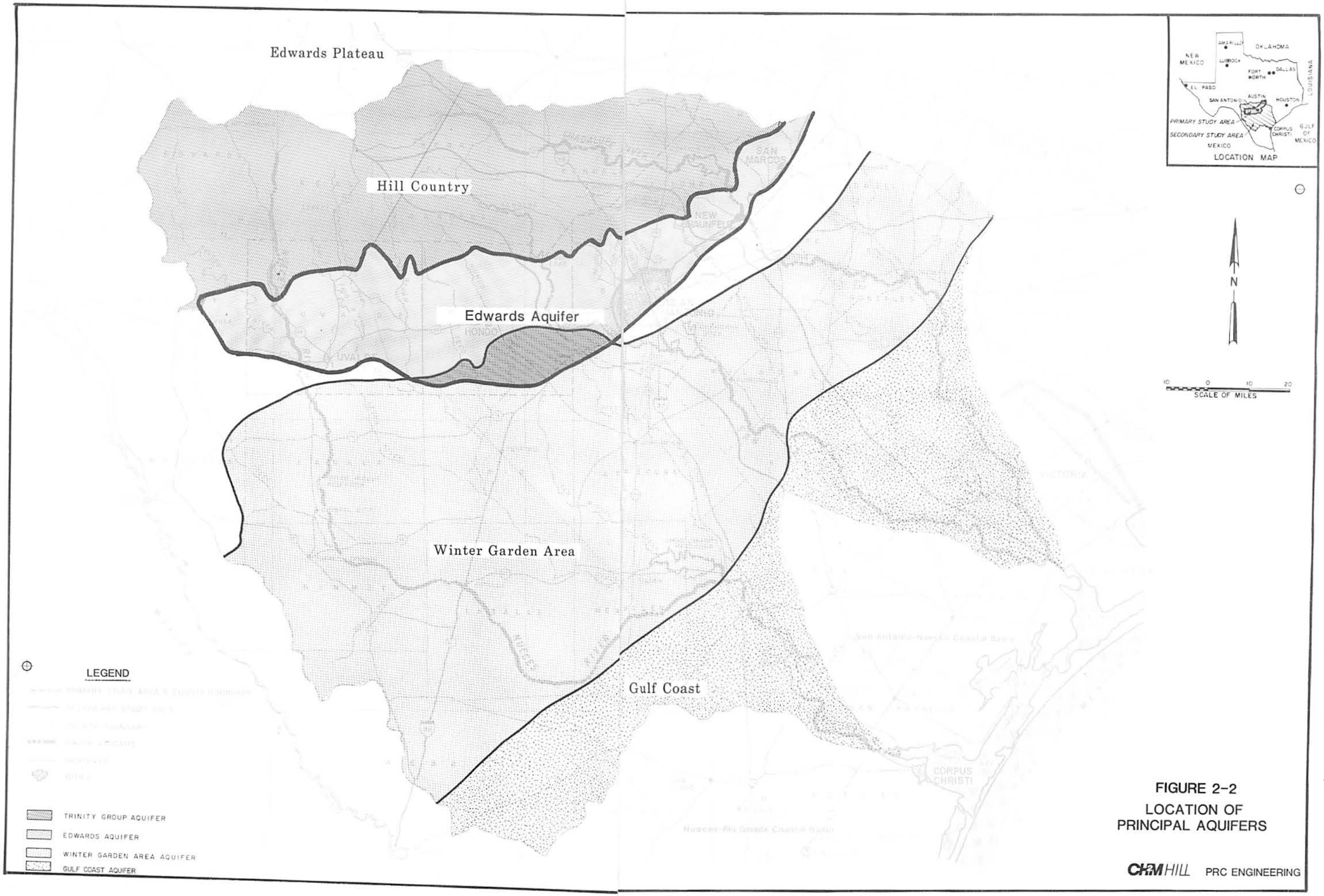
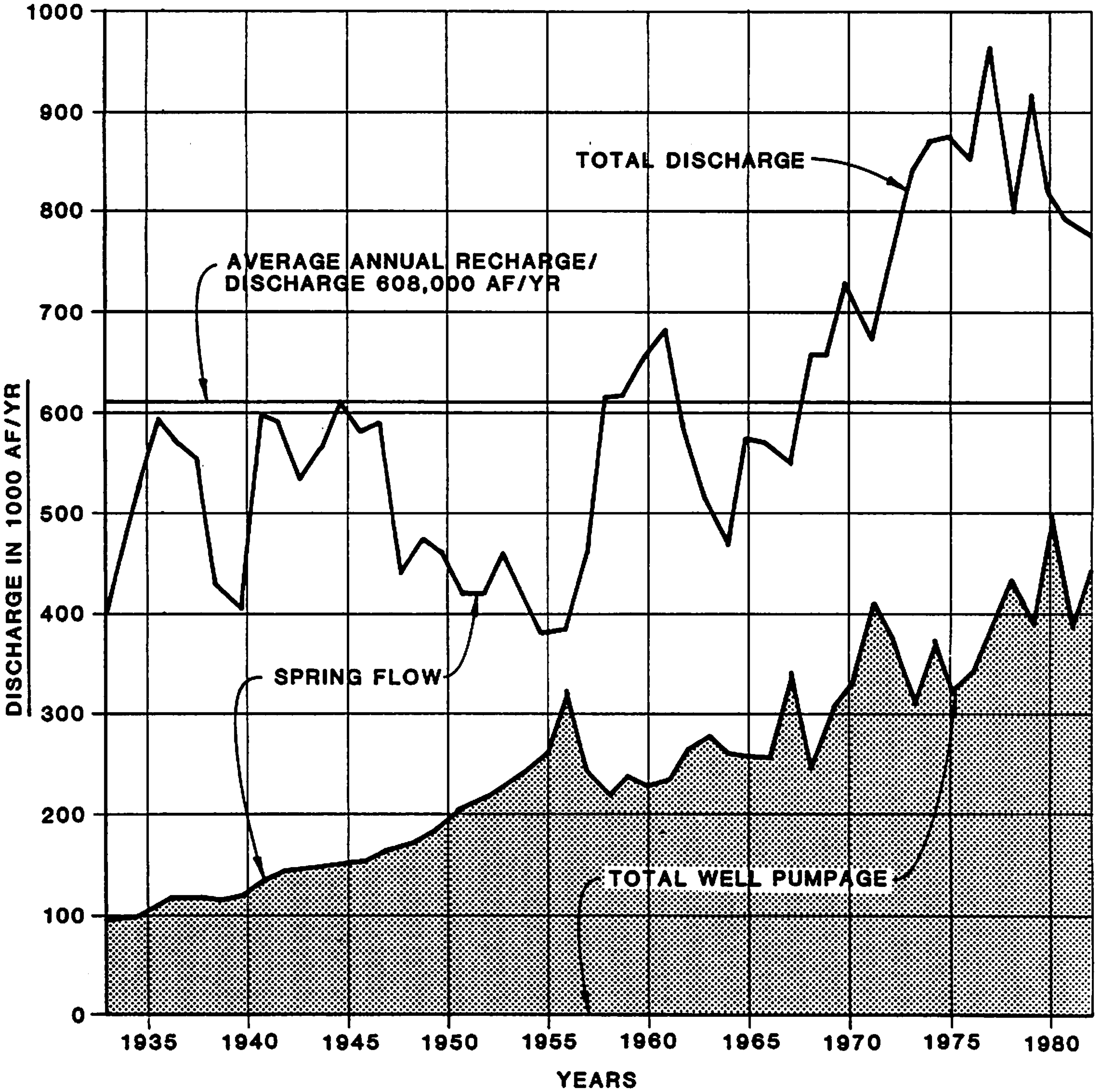


FIGURE 2-2
LOCATION OF
PRINCIPAL AQUIFERS

CH2M HILL PRC ENGINEERING



CH2M HILL PRC ENGINEERING

FIGURE 2-3

ANNUAL DISCHARGE
FROM EDWARDS AQUIFER

Carrizo Sand is the more important of the two units. Estimates prepared by TDWR suggest that average annual recharge to the Carrizo Sand Aquifer is on the order of 100,000 acre-feet per year. Demands currently exceed the average annual recharge rate, so water is being depleted from aquifer storage. TDWR has estimated, however, that across the Winter Garden area, the Carrizo Sand can supply up to 330,000 acre-feet per year to the year 2020, if managed properly. Although regional water levels would fall, TDWR estimates they would not be lowered below acceptable levels. TDWR has estimated that a combined total of about 140,000 acre-feet per year may be available from the Wilcox, Queen City-Bigford, and the Sparta-Laredo Aquifers, although the amount and mechanism of recharge to these aquifers are not precisely known.

Trinity Group Aquifer

The Trinity Group Aquifer has not been studied as extensively as the Edwards or other secondary aquifers. At present, sufficient information for the preparation of a water balance for the aquifer is not available. Recharge to the aquifer has been roughly estimated by TDWR on the order of 200,000 acre-feet per year; however, much of this recharge is believed to be lost to springs and seeps that supply local streams in the area.

Gulf Coast Aquifer

The Gulf Coast Aquifer is of importance to the southern end of the secondary study area. TDWR has estimated the yield of this aquifer to be on the order of 50,000 acre-feet per year.

Climatology

The location of San Antonio on the edge of the Gulf Coastal Plains results in a modified subtropical climate, predominantly continental during the winter months and marine during the summer months. Average temperatures range from 50 degrees in January to the 80's in July and August. While the summer is hot, with daily temperatures above 90° over 80 percent of the time, extremely high temperatures are rare. Mild weather prevails during much of the winter months, with below-freezing temperatures occurring on an average of about 20 days each year.

San Antonio is situated between a semi-arid area of the west and the coastal area of heavy precipitation to the southeast. The normal annual rainfall is about 29 inches. Precipitation is fairly well distributed throughout the year, with heaviest amounts during May in the spring and September in the fall. Precipitation from April through September usually occurs with thunderstorms, with fairly large amounts falling in short periods of time. Most of the winter precipitation occurs as light rain or drizzle. Thunderstorms and heavy rains have occurred in all months of the year. Hail of damaging intensity seldom occurs, but light hail is frequent in connection with the springtime thunderstorms. Measurable snow occurs only once in 3 or 4 years. Snowfall of 2 to 4 inches occurs about every 10 years.

Based on the 1951-1980 period, the average first occurrence of 32°F in the fall is November 24 and the average last occurrence in the spring is March 3. Normals, means, and extremes for San Antonio are given below in Table 2-1.

Table 2-1
NORMALS, MEANS, AND EXTREMES[a]
("Normal" data based on 1951-1980)

	Temperature							Rainfall				
	Normal			Extremes				Normal	Extremes			
	Daily Maximum	Daily Minimum	Monthly Average	High	Year	Low	Year	Per Month	Most	Year	Least	Year
January	58.7	39.0	50.4	89	1971	0	1949	1.55	8.52	1968	0.04	1971
February	63.3	42.4	54.3	92	1959	6	1951	1.86	6.43	1965	0.03	1954
March	71.5	49.8	61.8	100	1971	19	1980	1.33	4.19	1957	0.03	1961
April	80.2	58.8	69.6	100	1982	33	1983	2.73	9.32	1957	0.11	1984
May	86.3	65.5	75.5	101	1967	43	1984	3.67	11.24	1972	0.17	1961
June	93.4	70.2	81.9	105	1980	53	1964	3.03	10.44	1973	0.01	1967
July	96.4	74.3	84.6	106	1954	62	1967	1.92	8.19	1942	T	1984
August	95.4	73.7	84.2	106	1962	61	1966	2.69	11.14	1974	0.00	1952
September	88.0	69.4	79.4	102	1951	41	1942	3.75	15.78	1946	0.06	1947
October	79.2	58.9	70.2	98	1979	33	1980	2.88	9.56	1942	T	1952
November	67.2	48.2	59.5	91	1962	21	1976	2.34	6.01	1977	T	1966
December	61.2	41.4	53.0	90	1955	9	1983	1.38	4.51	1965	0.03	1950
Year	78.4	57.8	68.7					29.13				

"T" - Trace, an amount too small to measure

[a]Weather Service observations are taken at the International Airport, San Antonio, Texas. Latitude 29 Degrees 32'N; Longitude 98 Degrees 28'W; Ground elevation 788 Feet.

Mean annual rainfall and temperatures (1951-1980) for six cities in the study area are given in Table 2-2. Average net reservoir evaporation over the study area is directly related to the rainfall distribution and varies from less than 30 inches to more than 60 inches from east to west.

Table 2-2
MEAN ANNUAL RAINFALL AND TEMPERATURE (1951-1980)

Station	Mean Annual Temperature (°F)	Mean Annual Precipitation (inches)
Corpus Christi	72.2	29.68
Cotulla	71.4	21.65
San Antonio	68.7	29.13
San Marcos	67.0	34.31
Uvalde	69.0	24.10
Victoria	70.2	36.90

ENVIRONMENTAL

Bays and Estuaries

The San Antonio and Guadalupe Rivers join below the town of Victoria, then flow into the Guadalupe Estuary and San Antonio Bay. The Guadalupe Estuary, with 138,000 surface acres, is the third largest inland bay area on the Texas coast. It consists of San Antonio Bay and the minor bays, Espiritu Santo, Hynes, and Mesquite. The Nueces River flows into the Nueces Estuary and Corpus Christi Bay. San Antonio Bay and Corpus Christi Bay are connected by Aransas Bay. The three-bay complex is characterized by large numbers of oyster reefs and relatively low diversity of invertebrates and fish. Its connection with the Gulf of Mexico is indirect, so water level changes caused by streamflow may be greater than those caused by tides. The marshlands act as nurseries for shrimp, oyster, and fish.

An important environmental and economic aspect of water resource development is inflow of freshwater in the bay and estuary system. In its 1984 Water Plan TDWR identifies and illustrates four alternatives for protecting the bays and estuaries. These alternatives and the estimated river flow required are listed in Table 2-3.

The model was run by TDWR personnel for CH2M HILL-generated assumptions of future pumping for the alternative water supply plans studies. Results are given in Appendix H and summarized in Chapter 5.

OTHER ONGOING STUDIES

The following related studies were either ongoing or undertaken during the course of this study:

- Water Conservation Plans--Both the City of San Antonio and EUWD have ongoing water conservation (EUWD) or drought response plans (City) in effect. Staffs of both organizations continue to research new methods for improving these plans. Entities in the region are considering adoption of an ongoing water conservation plan stressing public education and low-water-use landscaping materials.

- Weather Modification--EUWD is carrying out an operational rainfall enhancement project.

- Edwards Aquifer Study--The U.S. Geological Survey in cooperation with the City Water Board is conducting a study concerning properties of the aquifer's framework and groundwater flow within the San Antonio area.

- Bad-water Line Study--The City Water Board, EUWD, TDWR, and USGS have begun an investigation to better define the potential for contamination of the Edwards Aquifer by saline water from adjacent aquifers south of the "Bad-Water Line." Observation wells are being drilled on both sides of the line.

- Edwards Quality of Water Assessment--The U.S. Geological Survey is conducting a study to examine the quality of water in the Edwards Aquifer with respect to several selected nutrients, trace elements and organic constituents. Statistical analysis is being performed in order to relate the distribution of these elements to surface land use and aquifer characteristics.

- Wastewater Reuse--The City of San Antonio received reports in the fall of 1984 from consultants Glass and Koch on potential reuse of City wastewater. Both efforts were preliminary "scoping" studies to explore the possibility of use for irrigation (Glass study) or for powerplant cooling (Koch study). More detailed studies will be undertaken after this regional study targets specific reuse markets to be pursued within the context of an overall water resources plan.

- Guadalupe and San Antonio River Basins Reservoir Study--This study (jointly financed by the City, EUWD, and Guadalupe Blanco and San Antonio River Authorities) focuses on proposed reservoirs on both rivers. A consultant is determining optimum reservoir sizes, costs of reservoirs and delivery systems, and environmental impacts at reservoir sites. Impacts on the San Antonio Bay due to changes in river releases to the bay are also being evaluated.

ALTERNATIVES TO BE CONSIDERED

Three alternative approaches for comprehensive water resource management plans have been identified by the sponsors for consideration in the analysis. These or combinations thereof are to be considered. The present policies or status quo approach to water resource management is also included for comparison. These four approaches have been provided by the sponsors as a framework under which analyses should be made to develop alternatives for comparison. The identified alternatives are summarized as follows:

- Present Policies
    - Existing institutions and policies unchanged from 1980 conditions
    - Existing sources of water utilized, new demands met primarily by overdrafting groundwater aquifers
- Alternative I
    - Existing institutions and laws unchanged, but full use of existing authorities to attempt to meet all future demands
    - New demands met with the following sources as well as groundwater:
        - New reservoirs
        - Conservation
        - Reuse of wastewater
        - Saline water

- Alternative II
  - New laws/institutions, or changes in existing laws/institutions
  - No new surface water reservoirs, new demands met with groundwater, conservation, reuse of wastewater, or saline water
- Alternative III
  - New laws/institutions as necessary
  - New demands met with same sources as Alternative I, including new reservoirs

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CHAPTER 4

Chapter 4
BASELINE CONDITIONS AND FORECASTS

POPULATION FORECAST

Although population growth in Texas will slow over the upcoming years, the rate of growth is expected to exceed national rates. Between 1980 and 2010, the U.S. population is anticipated to increase at an average annual rate of approximately 0.7 percent, whereas state agency projections for Texas are approximately double that figure (primarily due to nationwide migration to sun belt states). Consequently, Texas will assume a greater share of the U.S. population, with approximately 8 percent of the national total living in the state by 2010.

San Antonio is the largest city in the study area. Table 4-1 shows population projections for cities in the study area as well as the largest city in each of the five counties of the primary study area.

Table 4-1
POPULATION PROJECTIONS FOR CITIES

	Source	1990	2000	2010	2020	2030
San Antonio	a	959,706	1,129,659	1,335,796	1,601,836	2,003,020
New Braunfels	a	27,309	31,733	38,836	44,342	50,627
San Marcos	a	33,294	46,957	62,956	77,419	90,740
Hondo	a	6,924	7,963	9,312	10,169	10,850
Uvalde	a	17,462	22,619	28,494	32,653	35,828
Victoria	b	64,677	73,541	80,181	87,362	97,362
Corpus Christi[c]	b	265,017	289,402	316,762	358,454	419,694

[a]CH2M HILL estimate
[b]TDWR high case
[c]Does not include any adjustment for recent designation as U.S. Navy homeport.

Note: Projections do not reflect any potential annexations.

The primary study area is expected to show significant growth, with the largest increases in Hays and Bexar Counties. Bexar County should continue to maintain approximately 87 percent of the total population in the primary study area. Table 4-2 shows the projected population (Texas Department of Water Resources [TDWR] high, TDWR low, and CH2M HILL's estimates) by county in the study area. CH2M HILL estimates include revised and updated information applied to the TDWR model.

ECONOMIC FORECAST

The magnitude and type of future economic activity in the primary study area will be affected to some extent by trends

Table 4-2
PRIMARY STUDY AREA POPULATION PROJECTIONS

Projection	1990	2000	2010	2020	2030	2040[a]
Bexar County						
TDWR High	1,222,196	1,484,245	1,743,566	2,129,224	2,738,831	3,172,543
TDWR Low	1,175,516	1,379,425	1,587,973	1,820,697	2,129,224	2,385,113
CH2M HILL Estimate	1,196,705	1,422,720	1,682,332	2,017,390	2,522,649	2,891,598
Comal County						
TDWR High	51,931	66,778	81,820	94,304	108,693	120,306
TDWR Low	42,796	55,399	65,216	73,703	79,829	84,641
CH2M HILL Estimate	50,564	63,863	78,157	89,237	101,888	112,516
Hays County						
TDWR High	61,064	90,867	126,096	158,826	188,726	213,762
TDWR Low	56,970	75,791	95,945	115,720	132,801	147,627
CH2M HILL Estimate	58,257	84,410	113,169	139,169	163,114	181,561
Medina County						
TDWR High	27,650	32,245	36,286	39,787	42,543	45,002
TDWR Low	26,752	30,407	33,861	36,986	39,787	42,475
CH2M HILL Estimate	26,339	30,365	35,507	38,775	41,371	43,857
Uvalde County						
TDWR High	30,154	38,658	46,854	53,991	59,510	63,822
TDWR Low	28,611	35,256	41,648	48,116	53,991	59,195
CH2M HILL Estimate	27,238	35,015	44,109	50,546	55,462	59,750
Primary Study Area						
TDWR High	1,392,995	1,712,793	2,034,622	2,476,132	3,138,303	3,615,435
TDWR Low	1,330,645	1,576,276	1,824,643	2,095,222	2,435,632	2,719,051
CH2M HILL Estimate	1,359,103	1,636,373	1,953,274	2,335,117	2,884,484	3,289,282

[a]Extrapolated figures based on a modified exponential curve.

Sources: Texas Department of Water Resources, "Texas Department of Water Resources Population Projection (High and Low) 1980-2030," Austin, Texas, 1984, Computer print.

CH2M HILL modification of inputs into TDWR cohort component model.

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in economic activity for the state. Economic forecasters with the Bureau of Business Research at the University of Texas predict that the state's rate of economic growth will not continue to be as high as during the previous 10 years although it will likely outpace that of the U.S. over the next 25 years. Texas's real gross product is projected to grow at an average annual rate of 4.6 percent from 1981 to 2006, as compared to an average annual rate of growth of 5.8 percent from 1971 to 1981. Moderate economic growth is due to (1) a general slowdown in national economic growth overall, (2) moderate growth rates expected for Texas oil and gas industries, and (3) an anticipated leveling of growth in manufacturing because of increasing labor costs, land costs, and environmental constraints.

The economic makeup of the primary study area reflects a service-oriented economy. Figure 2-4 (Chapter 2) shows the high percentage of service-oriented employment sectors. Table 4-3 gives county, study area, state, and national baseline employment characteristics. As shown, the study area employment generally follows national and state characteristics; however, Hays and Bexar Counties have slightly higher service-sector employment. A strong reliance on the service sectors means the study area should not be as prone to major economic fluctuation as a construction- or manufacturing-driven economy.

The economic value of water used by various sectors of the regional economy differs. For agriculture and manufacturing, water is one of the primary inputs required to produce an end product. Because the cost of water is typically minor compared to other inputs for industry, the price of water alone does not dictate many economic decisions, unless the industry is very water intensive as in agriculture. For most industries, the availability and quality of water are more important factors. The impacts of water cost changes under various water resource alternatives are discussed further in Chapter 5.

WATER DEMAND FORECAST

Study Area Demands

Water demand forecasts were developed using TDWR computer models. CH2M HILL modified runs for the municipal and irrigation sectors and used TDWR high-case projections for other sectors. The methodology for each sector is discussed in Appendix E. Effects of water conservation are treated as an alternative supply in Chapter 5.

Projected water use figures, by end-use sector (Municipal, Manufacturing, Steam Electric, Mining, Irrigation, and Livestock), for the primary and secondary study areas are given

Table 4-3
1980 EMPLOYMENT CHARACTERISTICS

Employment Sector	United States (%)	Texas (%)	Primary Study Area ($)	Bexar Co. (%)	Comal Co. (%)	Hays Co. (%)	Medina Co. (%)	Uvalde Co. (%)
Agriculture	2,760,213 (3%)	182,279 (3%)	6,106 (1%)	3,411 (1%)	347 (2%)	454 (3%)	874 (10%)	1,020 (12%)
Forest & Fisheries	153,376 (1%)	4,899 (<1%)	83 (<1%)	44 (<1%)	7 (<1%)	14 (<1%)	6 (<1%)	12 (<1%)
Mining	1,028,178 (1%)	209,617 (3%)	3,339 (1%)	2,332 (1%)	154 (1%)	103 (1%)	284 (3%)	466 (6%)
Construction	5,739,598 (6%)	545,450 (9%)	34,823 (8%)	29,596 (8%)	1,927 (12%)	1,589 (10%)	1,022 (12%)	689 (8%)
Manufacturing (Nondurable Goods)	8,435,543 (9%)	458,210 (7%)	24,189 (5%)	21,563 (6%)	1,550 (10%)	376 (2%)	250 (3%)	450 (5%)
Manufacturing (Durable Goods)	13,479,211 (14%)	671,057 (11%)	25,840 (6%)	22,292 (6%)	1,375 (9%)	1,502 (9%)	515 (6%)	156 (2%)
Transportation, Comm., Utilities	7,087,455 (7%)	476,436 (8%)	28,766 (7%)	25,944 (7%)	1,059 (7%)	602 (4%)	586 (7%)	575 (7%)
Wholesale Trade	4,217,232 (4%)	331,587 (5%)	22,469 (5%)	20,363 (5%)	615 (4%)	479 (3%)	438 (5%)	574 (7%)
Retail Trade	15,716,694 (16%)	1,046,821 (17%)	80,516 (19%)	72,149 (19%)	2,706 (17%)	3,022 (18%)	1,376 (16%)	1,263 (15%)
Finance, Insurance, Banking, Real Estate	5,898,059 (6%)	377,862 (6%)	28,287 (7%)	26,849 (7%)	888 (6%)	863 (5%)	402 (5%)	285 (3%)
Services (Business and Personal)	8,164,511 (8%)	554,094 (8%)	42,267 (10%)	38,032 (10%)	1,315 (8%)	1,508 (9%)	630 (7%)	782 (9%)
Services (Professional and Public)	19,811,819 (20%)	1,172,129 (19%)	93,554 (22%)	82,256 (22%)	2,854 (18%)	5,321 (31%)	1,483 (17%)	1,640 (20%)
Public Administration	5,147,466 (5%)	281,404 (4%)	39,803 (9%)	36,868 (10%)	848 (5%)	1,076 (6%)	657 (8%)	354 (4%)
TOTAL	97,639,355	6,311,845	431,045	381,699	15,645	16,909	8,526	8,266

Source: U.S. Department of Commerce, Bureau of the Census, General Social and Economic Characteristics, Texas, Vol. II (Washington, D.C.: U.S.G.P.O., 1983).

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in Table 4-4. In the primary study area, the municipal and irrigation water demands are projected to equal about 56 percent and 31 percent, respectively, of the total 1990 demand. Steam electric and manufacturing follow with 6 percent each, then livestock and mining with about one percent each of the total demand. Figures 4-1 and 4-2 show demand projections by major sector for the primary and secondary areas, respectively.

In the secondary study area (see Table 4-4), the largest consuming sector in 1990 is projected to be irrigation, requiring 58 percent of the total demand. Municipal follows with 14 percent.

Several changes are projected to occur on a sector-by-sector comparison (see Table 4-4). The primary study area's municipal and industrial sector use is projected to increase substantially, comprising 85 percent of the total demand in 2040, compared to 53 percent in 1980. Inversely, the irrigation sector's use is expected to drop during early stages of the projection period, with only minor increases occurring during latter stages. This projected decline, 15 percent of the total demand in 2040 as compared to 47 percent in 1980, results because of the substantial growth in municipal and industrial use as well as anticipated improvements in efficiency and cropping pattern changes. It is possible that efficiency improvements may not result in water use reductions as predicted. If so, additional stress will be placed on the Edwards Aquifer supply.

As with the primary study area, major proportional changes in demand, by end-use sectors, are projected to occur in the secondary study area. Municipal and manufacturing sector demand is projected to increase to 64 percent of the total demand by 2040, as compared to 27 percent in 1980. This is due to a large increase in industrial demands forecast to develop primarily near the Guadalupe River between Victoria and the Gulf. Irrigation demand is projected to be about 36 percent of the total demand in 2040 as compared to 73 percent in 1980.

Export Demands

Export of water to adjacent coastal basins is considered a water demand of the study area. Approximately 160,000 acre-feet of surface water were exported in 1980 from the secondary study area to adjacent coastal basins: 60,000 acre-feet to the Lavaca-Guadalupe Coastal Basin (mainly through the Calhoun County canal system, for irrigation), and 100,000 acre-feet to the San Antonio-Nueces and Nueces-Rio Grande Coastal Basins (provided by the Lake Corpus Christi-Choke

TABLE 4-4
WATER DEMAND PROJECTIONS, PRIMARY AND SECONDARY STUDY AREAS

	PRIMARY AREA WATER DEMAND (ACRE-FEET)						SECONDARY AREA WATER DEMAND (ACRE-FEET)					
	1990	2000	2010	2020	2030	2040	1990	2000	2010	2020	2030	2040
MUNICIPAL												
GUADALUPE	41,000	50,874	61,829	71,859	82,011	91,040	10,577	12,282	13,702 (c)	15,022	15,148	16,314
SAN ANTONIO	197,450	242,196	287,845	347,616	440,265	509,980	50,939	58,472	65,232 (c)	72,669	81,317	91,387
NUECES	26,298	31,385	36,682	41,279	45,416	48,438	6,784	7,577	8,453 (c)	8,629	8,388	8,680
TOTAL	264,748	324,455	386,357	460,754	567,692	649,458	68,301	78,332	87,388	96,321	104,853	116,382
MANUFACTURING (a)												
GUADALUPE	7,677	9,800	12,077	15,221	19,028	21,730	57,947	82,525	110,798	144,681	186,700	218,270
SAN ANTONIO	19,061	25,386	32,072	40,175	49,907	56,993	267	376	501	650	837	1,507
NUECES	341	478	622	797	1,015	1,159	3,080	3,975	4,936	6,080	7,472	8,541
TOTAL	27,079	35,664	44,771	56,193	69,950	79,882	61,294	86,876	116,235	151,411	195,009	228,318
STEAM ELECTRIC (a)												
GUADALUPE	0	0	0	0	0	0	26,584	31,584	33,388	35,194	37,000	39,200
SAN ANTONIO	29,285	29,285	29,285	29,285	29,285	29,285	0	6,800	12,438	18,076	23,715	29,015
NUECES	0	0	0	0	0	0	9,101	14,501	19,998	25,498	30,999	35,600
TOTAL	29,285	29,285	29,285	29,285	29,285	29,285	35,685	52,885	65,824	78,768	91,714	103,815
MINING (a)												
GUADALUPE	1,134	1,379	1,604	1,828	2,053	2,250	377	512	520	524	530	650
SAN ANTONIO	617	704	816	928	1,040	1,140	531	592	1,636	2,677	3,717	4,460
NUECES	424	512	597	683	768	842	5,494	6,180	7,888	9,714	11,257	13,858
TOTAL	2,175	2,595	3,017	3,439	3,861	4,231	6,402	7,284	10,044	12,915	15,504	18,969
IRRIGATION (b)												
GUADALUPE	4,448	4,246	1,234	1,234	1,234	1,246	8,461	8,233	8,972	8,972	8,972	8,954
SAN ANTONIO	17,510	16,047	24,314	24,314	25,482	25,725	33,307	31,114	15,943	15,943	15,943	16,775
NUECES	124,600	117,067	98,369	98,446	98,538	99,479	237,012	226,978	205,266	205,266	205,266	204,421
TOTAL	146,558	137,361	123,917	123,994	125,254	126,450	278,781 (d)	266,325 (d)	230,181 (d)	230,181 (d)	230,181 (d)	230,150 (d)
LIVESTOCK (a)												
GUADALUPE	1,080	1,245	1,245	1,245	1,245	1,245	9,480	10,886	10,886	10,886	10,886	10,855
SAN ANTONIO	1,245	1,245	1,245	1,245	1,245	1,245	4,588	5,309	5,309	5,309	5,309	5,355
NUECES	3,367	3,870	3,870	3,870	3,870	3,870	12,209	14,112	14,112	14,112	14,112	14,130
TOTAL	5,692	6,360	6,360	6,360	6,360	6,360	26,277	30,307	30,307	30,307	30,307	30,340
TOTAL												
GUADALUPE	55,339	67,545	77,989	91,387	105,571	117,510	113,426	146,023	178,266	215,279	259,236	294,244
SAN ANTONIO	265,168	314,863	375,577	443,563	547,224	624,368	89,632	102,663	101,059	115,324	130,838	148,499
NUECES	155,030	153,312	140,140	145,075	149,607	153,787	273,681	273,323	260,653	269,299	277,494	285,230
	475,537	535,720	593,707	680,025	802,402	895,666	476,739	522,009	539,979	599,903	667,568	727,974

(a) BASED ON TDWR HIGH CASE PROJECTIONS.
(b) 1980-2000 FIGURES FOR BASINS ARE PROPORTIONED SIMILAR TO TOTAL WATER DEMAND.
(c) 2010 FIGURES REPRESENT PROJECTION OF 2000 FIGURES USING A 1.1% ANNUAL GROWTH RATE.
(d) IRRIGATION FIGURES WERE ADJUSTED USING THE RATIOS OF TDWR HIGH CASE NUMBERS TO THE CH2H HILL ESTIMATES IN THE PRIMARY AREA.

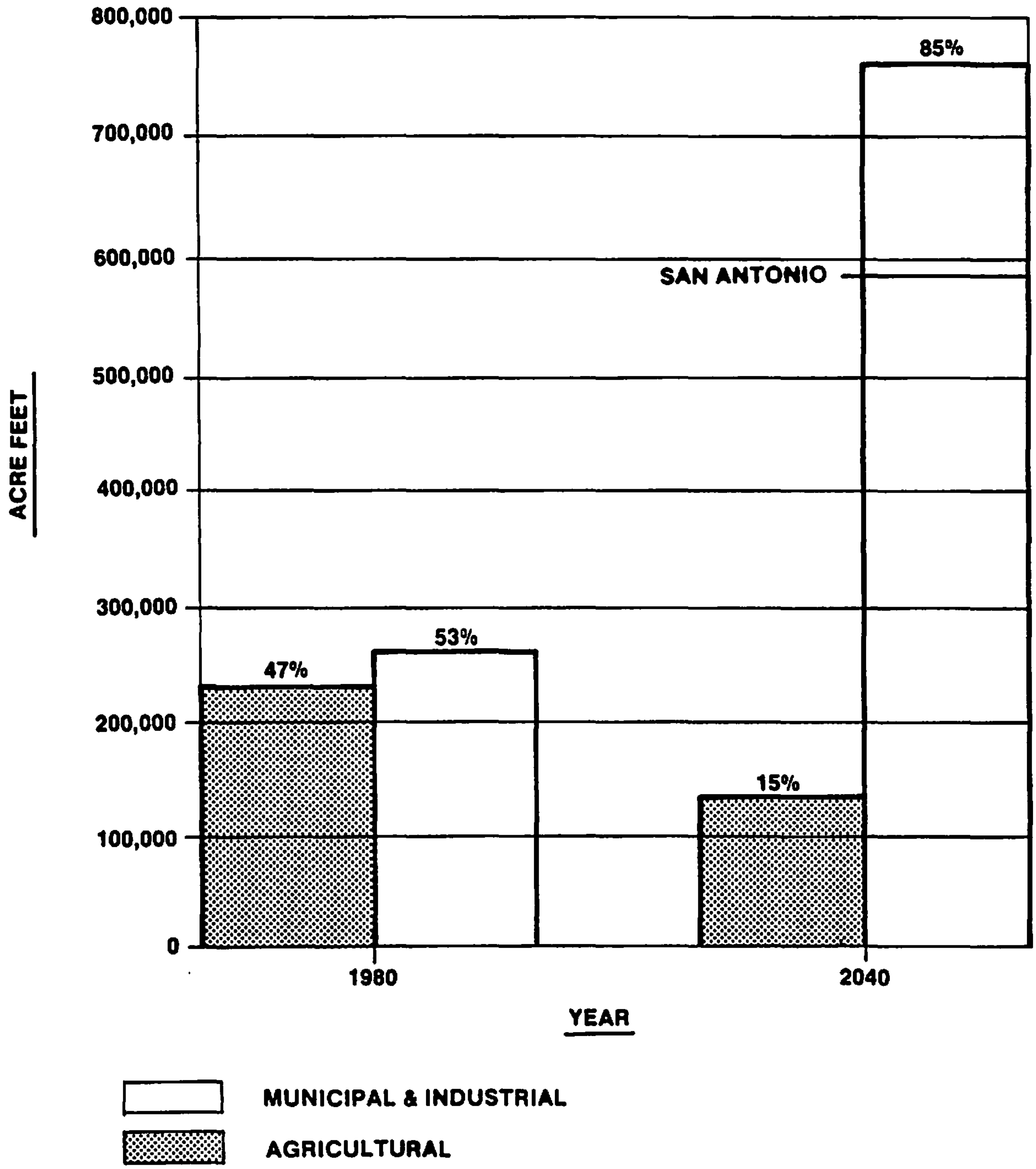

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FIGURE 4-1
PRIMARY STUDY AREA
PROJECTED WATER DEMAND

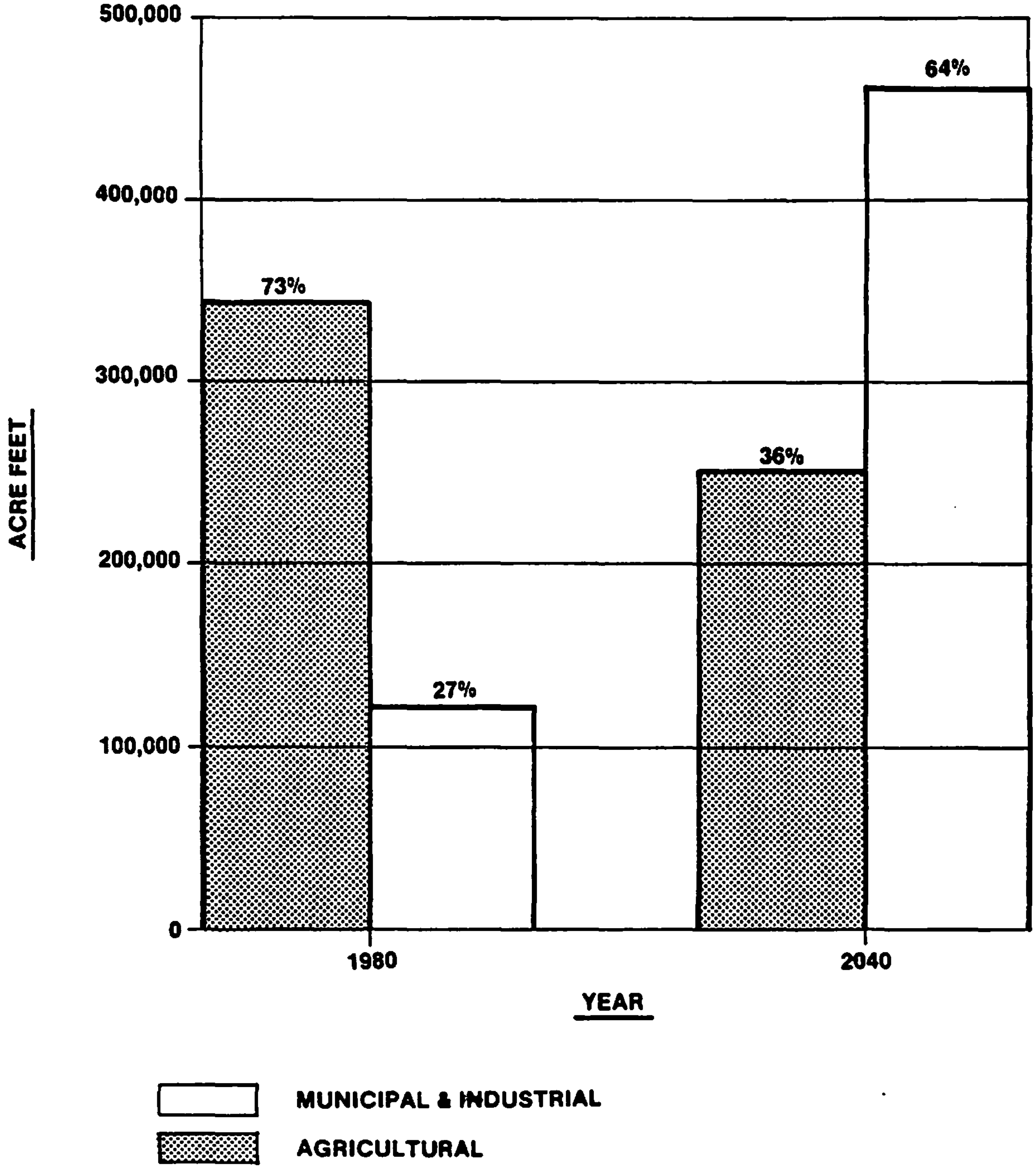

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FIGURE 4-2
SECONDARY STUDY AREA
PROJECTED WATER DEMAND

Canyon system). A summary of projected demands for export of water is presented in Table 4-5.

Spring and Bay Demands

Historical Bay and Estuary Inflow. Average (1939-1983) total freshwater inflow into San Antonio Bay from the Guadalupe River, San Antonio River, ungauged sources, and precipitation on the bay is estimated at 2,690,000 acre-feet per year. The Guadalupe River contributes an average of 1,304,600 acre-feet per year or 49 percent of the total, the San Antonio River contributes an average of 485,400 acre-feet per year or 18 percent, ungauged areas are estimated at 460,000 acre-feet per year or 17 percent, and precipitation on the bay contributes 440,000 acre-feet per year for 16 percent.

Average (1939-1983) total freshwater inflow into the Nueces Estuary from the Nueces River (less diversions), ungauged flows, return flows, and precipitation on the bay surface are estimated at 925,000 acre-feet per year. The Nueces River contributes an average of 550,000 acre-feet per year (603,800 acre-feet per year gauged flow less 53,800 acre-feet per year diversion) or 60 percent of the total. Ungauged areas provide an estimated average of 105,000 acre-feet per year or 11 percent, and precipitation supplies an average of 270,000 acre-feet per year, or 29 percent.

Bay and Estuary Demand. Some studies have sought to determine the required inflow of freshwater in the bay and estuary system to maintain shellfish and finfish production and related bay and marsh organisms. TDWR, in its 1984 Water Plan, identified four alternatives for purposes of illustrating minimum required inflow. The TDWR requirements are by no means mandatory but are only estimates based on limited data. Ongoing and future studies may find that flow requirements are considerably different than these estimates. This issue will be debated and studied for many years to come as a more accurate understanding of the complex estuary systems is obtained. The approach taken in this study is to report the flows reaching the bays after upstream water demands have been satisfied under the various water supply alternatives. Although general comparisons with previously published target flows can be made, these targets are not well enough substantiated to determine if the bays will be helped or impaired by greater or lesser flows.

Historical Springflows. The USGS maintains records of total springflows issuing from the Edwards Aquifer. For the period of record 1934-1982, the average annual springflow was 360,000 acre-feet per year. The highest recorded springflow occurred in 1977, when 580,000 acre-feet were discharged. The next highest was 540,000 acre-feet in 1975. The lowest reported springflow occurred in 1956, during a prolonged

TABLE 4 - 5

COASTAL BASIN EXPORT DEMAND
(Acre-Feet per Year)

FROM Water Supply	TO Coastal Basin	1980	1990	2000	2010	2020	2030	2040a
	LAVACA - GUADALUPE							
Canyon Reservoir	Calhoun County	8,093	10,025	10,980	11,896	12,918	13,657	15,000
Canyon Reservoir	Victoria County	7	9	11	14	17	21	25
Return Flow Goliad	Calhoun County	51,500	63,790	75,770	90,306	107,811	129,534	150,000
BASIN TOTAL		59,600	73,824	86,761	102,216	120,746	143,212	165,025
	SAN ANTONIO - NUECES							
Return Flow Goliad	Aransas County						10,093	12,000
Return Flow Goliad	San Patricio County					20,079	60,812	72,000
Choke & Lake Corpus C.	Aransas County	2,450	5,624	6,731	7,817	9,282	958	1,000
Choke & Lake Corpus C.	Bee County	1,630	3,741	4,463	5,306	5,691	6,684	7,400
Choke & Lake Corpus C.	Nueces County	31	72	87	100	124	150	180
Choke & Lake Corpus C.	San Patricio County	13,188	30,271	37,319	43,994	31,863		
BASIN TOTAL		17,300	39,708	48,600	57,217	67,039	78,697	92,580
	NUECES - RIO GRANDE							
Choke & Lake Corpus C.	Duval County	769	1,059	1,193	1,326	1,450	1,558	1,700
Choke & Lake Corpus C.	Jim Wells County	6,126	8,440	9,902	11,335	13,116	14,885	17,500
Choke & Lake Corpus C.	Kleberg County	2,189	3,016	3,876	4,914	6,548	8,451	11,500
Choke & Lake Corpus C.	Nueces County	77,916	107,339	122,917	140,898	169,582	206,278	240,000
BASIN TOTAL		87,000	119,854	137,888	158,473	190,696	231,172	270,700
REGION TOTAL		163,900	233,386	273,249	317,906	378,481	453,081	528,305
TOTAL EXPORT BY SUPPLY SOURCE								
	Canyon Reservoir	8,101	10,034	10,991	11,910	12,935	13,678	15,025
	Return Flow Goliad	51,500	63,790	75,770	90,306	127,890	200,439	234,000
	Choke & Lake Corpus	104,300	159,562	186,488	215,690	237,656	238,964	279,280

Source = Texas Department of Water Resources 1980 - 2030
a) 2040 Values are extrapolated from 2030 values and might exceed supplies in some cases

drought cycle, when 70,000 acre-feet were discharged. Flows for the period of record are shown graphically in Figure 2-3 (Chapter 2).

Combined flows from the major springs, Comal and San Marcos, average 323,000 acre-feet per year. For Comal Springs, the average flow (1940-1982) was 212,000 acre-feet per year. The low was 28,000 acre-feet in 1956, when the springs were intermittently dry for portions of the year. San Marcos Springs has had an average annual flow of 111,000 acre-feet (1940-1982). The lowest recorded flow occurred in 1956 when 48,000 acre-feet were measured.

Springflow Demand. Few studies have attempted to quantify required flows for the springs. The studies that do address this give the following minimum flow values:

	Annual Avg. AF/yr	Annual Avg. cfs	Minimum Month cfs	Source
San Marcos Springs				
Purpose: 1. Maintenance of biota and recreation	54,000	75	-	1
2. Maintenance of aquatic biota	72,000	100	80	2
Comal Springs				
Purpose: 1. Maintenance of biota and recreation	54,000	75	-	1
Both Springs				
Purpose: 1. Maintenance of biota and recreation (% of historic)	108,000 33%	150	-	1
2. Meeting downstream consumptive water rights diversions (% of historic)	320,000 100%	varies	-	3

Sources:

1. U.S. Bureau of Reclamation, San Antonio Guadalupe River Basins Study, Texas Basins Project, Amarillo, Texas, 1978.

2. Espey, Huston & Associates, Inc., Investigation of Flow Requirements from Comal and San Marcos Springs to Maintain Associated Aquatic Ecosystems, Austin, Texas, 1975.

3. Espey, Huston & Associates, Inc., Water Availability Study for the Guadalupe and San Antonio River Basins, August 1985 file data.

Springflows currently contribute to meeting downstream water rights, bay inflows, and recreation activities (boating, swimming, and inner-tubing) and to maintaining natural vegetation and wildlife in the Guadalupe River and its tributaries fed by the springs--the San Marcos and Comal Rivers. Four endangered species at San Marcos Springs (a plant, two fish species, and a salamander) also depend on relatively constant spring flow quantities, water temperature, and water quality for their existence.

If groundwater pumpage continues to serve as the dominant source for the primary study area, both major springs will go dry by year 2040 (see Chapter 5). There are currently no legal restrictions to prevent this from happening since the springflow originates as groundwater. Pumpers of Edwards groundwater are by state law entitled to pump enough water to meet their needs even if this reduces the amount of groundwater available elsewhere--for instance, at the springs.

Depending on the desires and expectations of local decision-makers, the target amount of springflow could range from zero to the full historic average amount of about 320,000 acre-feet. Various combinations of water supply facilities could be provided to satisfy a portion or all of the above listed concerns (biota, recreation, and water rights) with less than the full historic springflow amounts. These combinations are examined in Chapter 5.

Flow from San Marcos and Comal Springs constitute a substantial portion of Guadalupe River baseflow, which is currently either diverted by downstream users on the Guadalupe River or flows to the bay. The amount attributable to the springs is:

Location	% of River Flow Attributable to Springs Annual Average (1940-1982)	Driest Year (1956)	Driest Month (June 1956)
Cuero (85 miles below Comal Springs)	25%	75%	90%

This shows that although springflows constitute only one-quarter of total Guadalupe River flow on a long-term basis, they contribute a greater share as weather conditions become drier. This is because the springs continue to flow in dry periods, being fed by water previously accumulated in aquifer storage, while the contribution from rainfall runoff drops immediately in response to drier weather conditions.

Drought Effects

The demand estimates presented herein for the primary study area are for assumed average weather conditions to simplify the analysis. In reality, weather conditions differ considerably from year to year, producing variations in water demand--less in wet years, more in dry years. Figure 4-3 illustrates the fact that demands during an extended drought can average about 13 percent greater than the typical year demands over a 1950's intensity drought lasting 10 years. Considering municipal demands only, increases of over 30 percent can occur in any given year of a drought based on TDWR "high-case" projections.

GROUNDWATER

Edwards Aquifer

Characteristics. The Edwards Aquifer (San Antonio region) is one of the more productive aquifers in Texas. It includes about 400 to 700 feet of water-bearing, extensively faulted limestone underlying about 3,200 square miles of land in Kinney, Uvalde, Medina, Bexar, Comal and Hays Counties. The aquifer extends about 175 miles in the east-west direction and varies in width from about 5 to 40 miles. Groundwater flows generally eastward from Kinney, Uvalde, and Medina Counties into Bexar County and then northeastward towards Comal and Hays Counties. Water flows through a network of interconnected cracks and cavernous channels in the limestone, enlarged by the solvent action of the groundwater.

Depth of groundwater varies widely over the 6-county area, ranging from about 350 below ground to 50 feet above ground (artesian condition). Depths vary by location within individual counties as well as seasonally. For illustrative purposes, approximate average depths to groundwater by county are as follows: Kinney and Uvalde--100 feet; Medina--180 feet; Bexar--60 feet; Comal and Hays--100 feet.

Recharge. Recharge to the Edwards Aquifer occurs in the outcrop area of the aquifer, where it is exposed on the land surface. The recharge occurs primarily by infiltration of surface water from numerous streams draining the Texas Hill Country. To a lesser extent, recharge also occurs by infiltration of precipitation falling directly on the outcrop zone. The USGS has estimated that upwards of 80 percent of the recharge to the Edwards Aquifer occurs from streamflow, with the remainder occurring from rain falling directly on the recharge area.

Estimated annual aquifer recharge totals from streamflow and precipitation are available for the period 1934-1982. The average annual rate for this period is 608,000 acre-feet per year. The range is 43,000 acre-feet, which occurred in 1955, to 1,711,000 acre-feet, which occurred in 1958. The recharge in 1981 was 1,448,400 acre-feet, the third highest

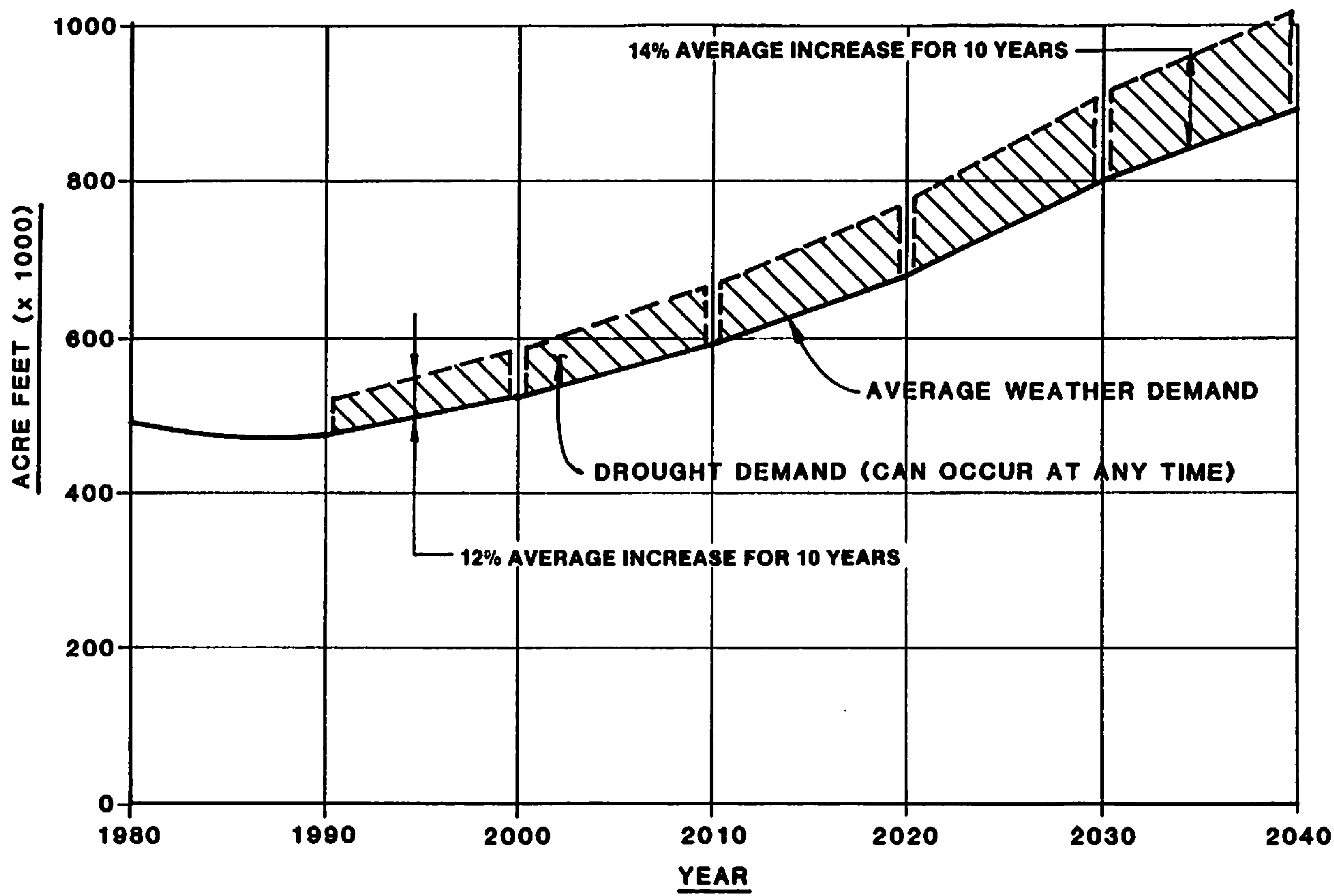

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FIGURE 4-3

PRIMARY STUDY AREA
WATER DEMAND CONSIDERING DROUGHT
(MUNICIPAL, INDUSTRIAL, AGRICULTURAL)

CH2M HILL

value since 1934. Figure 4-4 graphically presents estimated annual recharge for the 1934-1982 period.

The historical recharge amounts can be simplified into two segments. Those beginning in the 1930's and extending through 1956 represent a relatively dry period, while recharge from 1957 to the present represents a much wetter period. Average recharge prior to 1957 was about 410,000 acre-feet per year. Average recharge from 1957 to the present has been about 780,000 acre-feet per year. The 1968 to 1982 period was even wetter at 850,000 acre-feet per year (40 percent above the average).

Discharge. Discharge from the Edwards Aquifer occurs via pumpage from the aquifer and through spring discharge. Five major springs (Leona, San Antonio, San Pedro, Comal, and San Marcos) discharge from the freshwater artesian zone in the aquifer. San Marcos and Comal Springs are the largest, accounting for about 90 percent of the total springflow from the aquifer. A sixth minor spring in the study area, Hueco, is not thought to discharge from artesian pressure but from groundwater in the unconfined (outcrop) portion of the aquifer. The other five major springs issue at points where major faults intercept the aquifer and allow groundwater under artesian pressure to reach the land surface.

Figure 2-3 (Chapter 2) graphically presents the total discharge from the Edwards Aquifer, as measured over the time period 1934 to 1982. Components of both total springflow and total well discharge are shown. During this time, well withdrawals have increased steadily from a low of 102,000 acre-feet in 1934 to a high of 491,000 acre-feet in 1980. In 1982 (most recent records) well discharges were around 453,000 acre-feet.

Major pumpage from the aquifer occurs in Bexar County, where water is withdrawn for municipal and industrial use, and in Uvalde County, where extensive irrigation use occurs. Table 4-6 presents a breakdown of discharge from the Edwards Aquifer by county and by water use. Data shown are for 1982, the most current year of record. The 1982 pumpage in Bexar County was about 65 percent of the total.

The recent wet period has been sufficient to mask the effects on springflows of rapidly escalating groundwater pumping. If recharge during the 1934 to 1982 period had been constant at the average value of 608,000 acre-feet, the aquifer would have discharged to the springs the amount remaining after pumpage. For 1982 this would be:

Calculated spring discharge at 1982 level of pumpage	=	608,000-453,000
	=	155,000 acre-feet/year

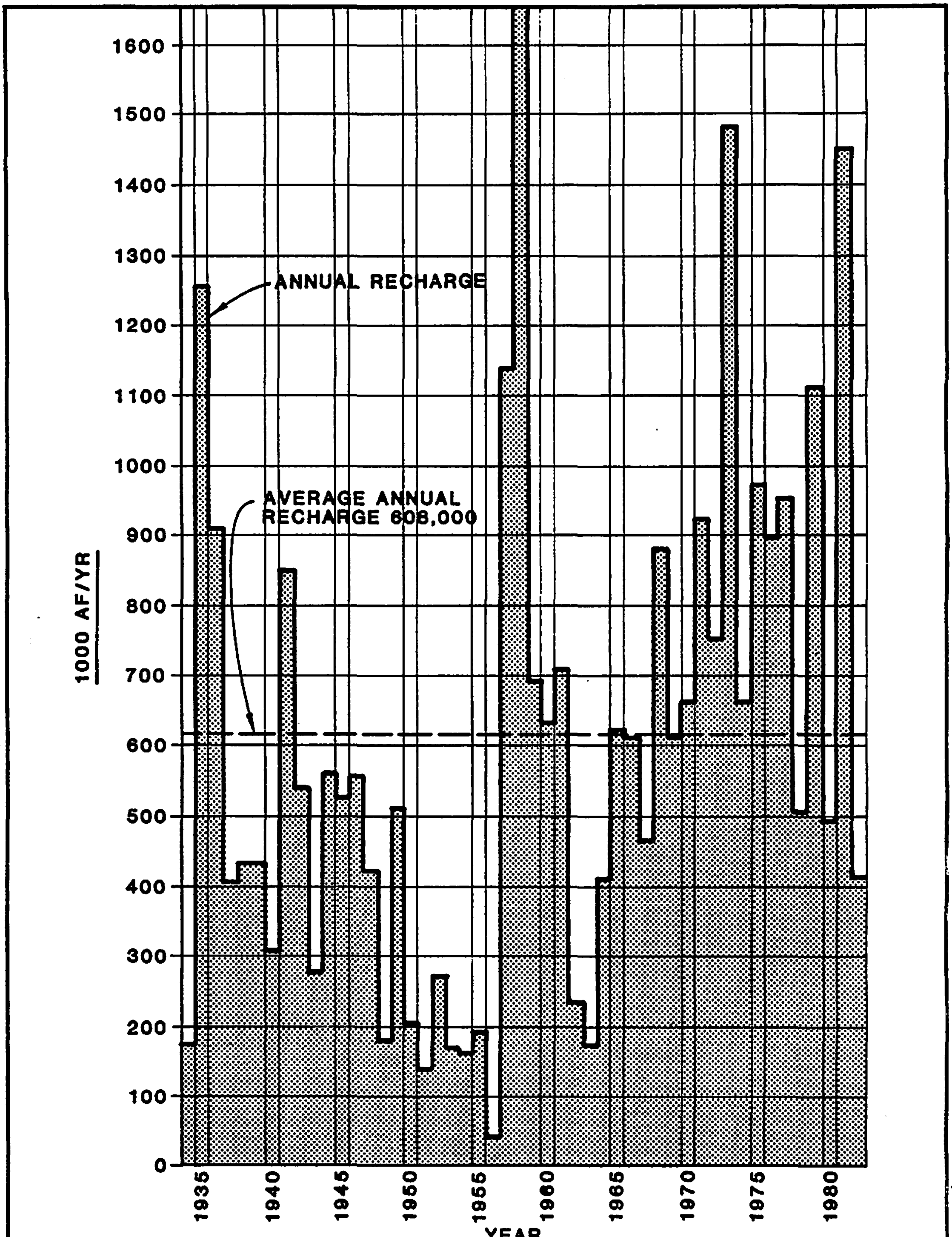

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FIGURE 4-4
ANNUAL RECHARGE TO EDWARDS

Table 4-6

DISCHARGE FROM EDWARDS AQUIFER BY COUNTY AND WATER USE, 1982

County	Springs	Municipal supply and military use	Irrigation	Industrial use	Domestic supply, stock, and miscellaneous use	Total (million gallons per day)	Total (thousand acre-feet per year)
	Million gallons per day						
Kinney	--	--	--	--	0.2	0.2	0.2
Uvalde	29.4	4.8	78.8	--	2.2	115.2	129.0
Medina	--	4.1	25.1	--	.6	29.8	33.4
Bexar	7.8	213.1	11.4	9.7	30.4	272.4	305.1
Comal	176.9	10.0	.2	2.6	.6	190.3	213.2
Hays	83.4	7.8	.6	1.1	1.3	94.2	105.5
Total (million gallons per day)	297.5	239.8	116.1	13.4	35.3	702.1	
Total (thousand acre-feet per year)	333.3	268.6	130.0	15.0	39.5		786.4

Source: Reeves et al (1984)

About 90 percent of this would discharge at Comal and San Marcos Springs for a total of 135,000 acre-feet per year. However, recent historical springflows have been almost triple this amount--345,000 acre-feet per year at Comal and San Marcos from 1978 to 1982--due to the abnormally wet recent years providing a large "bank account" of water that has been steadily draining out at the springs. This has greatly increased the amount of springflow that would otherwise have occurred under average recharge conditions.

If recharge returns to normal or below normal levels, the "bank account" of stored water would eventually be depleted and springflows would be greatly diminished, even if ground-water pumpage did not increase above present levels. These springflow observations are summarized as follows:

	Comal Springs	San Marcos Springs	Both Springs
Actual 1978-1982 springflow (AF/yr) due to recent wet years	235,000	110,000	345,000
Calculated springflow (AF/yr) under average recharge conditions with 1982 level of pumpage	70,000	65,000	135,000

In addition to direct recharge, TDWR estimates an additional quantity of water reaches the Edwards Aquifer as underflow from the Trinity Group Aquifer and Edwards (Plateau) Aquifer Rose Formation. This is estimated to average on the order of 36,000 acre-feet per year.

Aquifer Storage. USGS, TDWR, EUWD, and the City Water Board have been investigating storage characteristics of the limestone that comprises the Edwards Aquifer. Their research suggests that the capacity to store water is determined by the macro and micro voids within the actual rock matrix. The portion of the voids of a rock matrix that will drain (i.e., yield water under gravity or a hydraulic gradient) is termed the specific yield. Estimates of specific yield (using regional water balance studies, geophysical tests, and laboratory examination of recovered core samples) range from 1.7 to 14 percent. A representative average value of 4 percent has been utilized by researchers. The estimated volume of water in storage in the confined freshwater zone of the aquifer, given an area of 2,000 square miles, a thickness of 500 feet, and an average specific yield of 4 percent, is 19.5 million acre-feet. Studies using other methods have developed an estimated value of 15 million acre-feet for the total volume in storage. However, much of this water may not be economically recoverable due to such factors as cost and environmental impacts.

Secondary Aquifers

The Trinity Group and Winter Garden area aquifers are additional principal groundwater resource units to the north and south, respectively, of the Edwards Aquifer. The Carrizo-Wilcox Aquifer, the primary aquifer in the Winter Garden area, coexists with two other aquifers of regional importance, the Queen City-Bigford and the Sparta-Laredo.

Trinity Group. The Trinity Group Aquifer was investigated by TDWR over the time period 1974-1978, within an area of about 5,800 square miles. This area includes the drainage basins of streams that originate and drain to the Edwards Aquifer recharge zone. Figure 2-2 (Chapter 2) portrays the extent and position of the Trinity Group Aquifer relative to the Edwards and Winter Garden area aquifers. The terrain, characterized by sharply dissected divides and incised stream valleys, is the most rugged of the study area.

Recharge to the Trinity Group system over the 2,985 square mile outcrop area may be on the order of 200,000 acre-feet per year. This estimate is an extrapolation, based upon gains in streamflow measured in the Guadalupe River system. The recharge occurs from precipitation on the outcrop.

The key issue regarding the management of the Trinity Group and Edwards (Plateau) Aquifers in the Texas Hill County concerns the role of the aquifers as the source of baseflow for area streams. These streams recharge the Edwards Aquifer. Much of the 200,000-acre-feet-per-year natural recharge from the Trinity Group and Edwards (Plateau) Aquifers is believed to re-emerge as natural stream and springflow. Additional pumpage from the aquifers may result in the capture of this natural discharge, with a corresponding decrease in the baseflow of area streams.

Carrizo-Wilcox. The Carrizo-Wilcox is geographically one of the most extensive aquifers in Texas. It exists in a wide belt extending from the Rio Grande River northeastward into Arkansas and Louisiana. The Carrizo-Wilcox Aquifer consists of four units: the Carrizo Sand, the Wilcox Group, the Sparta-Laredo, and the Queen City-Bigford. Collectively, the hydraulically connected sands of the Carrizo Formation and the Wilcox Group can exceed 2,000 feet in depth.

Annual recharge to the Carrizo Sand is estimated to be on the order of 100,000 acre-feet per year in the Winter Garden area. Withdrawals as of 1970 were around 270,000 acre-feet per year. In areas where pumpage is heavy, significant water-level declines have occurred. Dimmit, Zavala, and eastern Maverick Counties have been subject to the largest declines.

Given the excess of demand over recharge for the Carrizo Sand, TDWR investigated water yield capabilities of the Carrizo Sand under controlled "mining" conditions. The aquifer simulation produced an optimization alternative to regulate pumpage of the aquifer to approximately 330,000 acre-feet per year. To obtain this yield, balanced pumpage is necessary and pumpage would have to be reduced in certain areas while increased in others.

TDWR also estimated water availability under controlled mining conditions for the Wilcox Group, the Queen City-Bigford, and the Sparta-Laredo Aquifers. These estimates indicate approximately 143,000 acre-feet per year of water may be available from these three aquifer units. Individual totals are about 66,000 acre-feet per year from the Wilcox Group, 51,000 acre-feet per year from the Queen City-Bigford Aquifer, and 30,000 acre-feet per year from the Sparta-Laredo Aquifer. The bulk of this yield occurs east of the Frio River, and as with the Carrizo Sand Aquifer, pumpage would have to be optimally located to achieve such yields.

Gulf Coast. The Gulf Coast Aquifer is of importance to the southern end of the secondary study area. TDWR has estimated the yield of the Gulf Coast Aquifer to be on the order of 50,000 acre-feet per year.

Saline Aquifers

An areally extensive resource is contained within the saline aquifers located south of the Edwards Aquifer area. The principal saline resources exist in the Edwards and Glen Rose Formations south of the "bad-water" line, and in the Carrizo Aquifer in the Winter Garden area. Saline resources are defined by TDWR as those waters exceeding 3,000 mg/L total dissolved solids. In the San Antonio area, the "bad-water" line is defined as those waters exceeding 1,000 mg/L total dissolved solids.

The Edwards Formation contains salinities from 1,000 to more than 150,000 mg/L. Thicknesses of the Edwards saline aquifer are estimated to be on the order of 600 to 900 feet. Thicknesses of the Glen Rose saline aquifer are estimated to be between 900 and 2,000 feet.

The Carrizo Wilcox saline aquifer is regarded as one of the state's major potential saline sources of water. The productive characteristics are considered variable but are rated generally excellent by the state. Salinities range from 3,000 to 60,000 mg/L in the area of interest. Net sand thicknesses range from less than 500 to about 1,000 feet, increasing in the down-dip direction.

One of the major considerations regarding investigation or development of saline aquifers is the considerable depths at which they are located. The overall dip of the strata in the region exceeds 100 feet per mile. The Edwards and Glen Rose saline aquifers are found at depths exceeding 1,000 feet immediately down-dip from the "bad-water" line, and the Carrizo-Wilcox is found at depths greater than 5,000 feet immediately down-dip from the fresh to slightly saline isoconcentration line. Further into the saline zone, the depths for both resources can be expected to continue to increase at a rate consistent with the regional dip.

SURFACE WATER

The study area includes the Guadalupe, San Antonio, and Nueces River Basins. Annual streamflows of the three rivers at gauging stations closest to San Antonio Bay are shown in Table 4-7. River flow is highly variable in the study area.

Table 4-7
ANNUAL STREAMFLOWS IN NUECES, SAN ANTONIO, AND GUADALUPE RIVERS
(In Thousand Acre-Feet)

River	Average (1939-1983)	Maximum	Minimum	Ratio (in percent) Maximum/ Average	Ratio (in percent) Minimum/ Average
Nueces near Mathis USGS Sta. 08 211000	603.8	2,537[a]	76[b]	420.2	12.6
San Antonio at Goliad USGS Sta. 08 188500	485.4	1,590[c]	89[d]	327.6	18.3
Guadalupe at Victoria USGS Sta. 08 176500	1,304.6	2,752[e]	232[d]	210.9	17.8
Combined	2,393.8	5,385[c]	362[f]	225.0	15.1

[a]1971; [b]1962; [c]1973; [d]1952; [e]1975; [f]1956

Existing Reservoir Developments

Information on existing reservoirs and dams was obtained through review of feasibility studies, construction reports, and Federal Dam Safety Inspection Program reports. Table 4-8 summarizes statistical data for existing reservoir developments. Locations of surface water developments are shown in Figure 4-5.

Guadalupe River Basin. Canyon Dam and Reservoir is the major existing development in the Guadalupe River Basin. This multipurpose project is owned and operated by the U.S. Army Corps of Engineers. The Guadalupe-Blanco River Authority has a contract with the Corps for 100 percent of the water supply from the project.

Table 4-8
EXISTING RESERVOIR DEVELOPMENTS

Dam and Reservoir	Stream Location	Date Constructed	Purpose	Dam Height (Feet)	Conservation Capacity (Acre-Feet)	Firm Yield (Acre-Feet/ Year)	Average Yield[a] (Acre-Feet/ Year)
Canyon	Guadalupe River	1964	Water Supply and Flood Control	224	386,200	86,000	-
Coleto	Coleto Creek	1981	Powerplant Cooling	65	35,084	-	12,000
H-4	Guadalupe River	1931	Hydropower	42	6,500	0	0
TP-1	Guadalupe River	1928	Hydropower	41	5,900	0	0
TP-3	Guadalupe River	1928	Hydropower	40	5,000	0	0
Salt Water Barrier	Guadalupe River	N/A	Diversion	N/A	N/A	0	0
Calaveras	Calaveras Creek	1969	Powerplant Cooling	70	62,800	-	17,000
Medina	Medina River	1913	Irrigation	164	254,000	39,000	-
Medina Diversion	Medina River	1913	Diversion	62	3,900	0	
Olmos	Olmos Creek	1926	Flood Control	60	12,600[b]	0	0
Victor Braunig	Arroyo Seco	1962	Powerplant Cooling	80	26,500	-	12,000
Choke Canyon	Frio River	1983	Water Supply	116	691,130	139,000	-
Upper Nueces	Nueces River	1948	Irrigation	60	7,590	N/A	N/A
Wesley E. Seale	Nueces River	1958	Water Supply	75	272,352	113,000	-

[a] Average yield based on filling and emptying the reservoir each year
[b] No conservation capacity, flood storage capacity shown
N/A = Not Available

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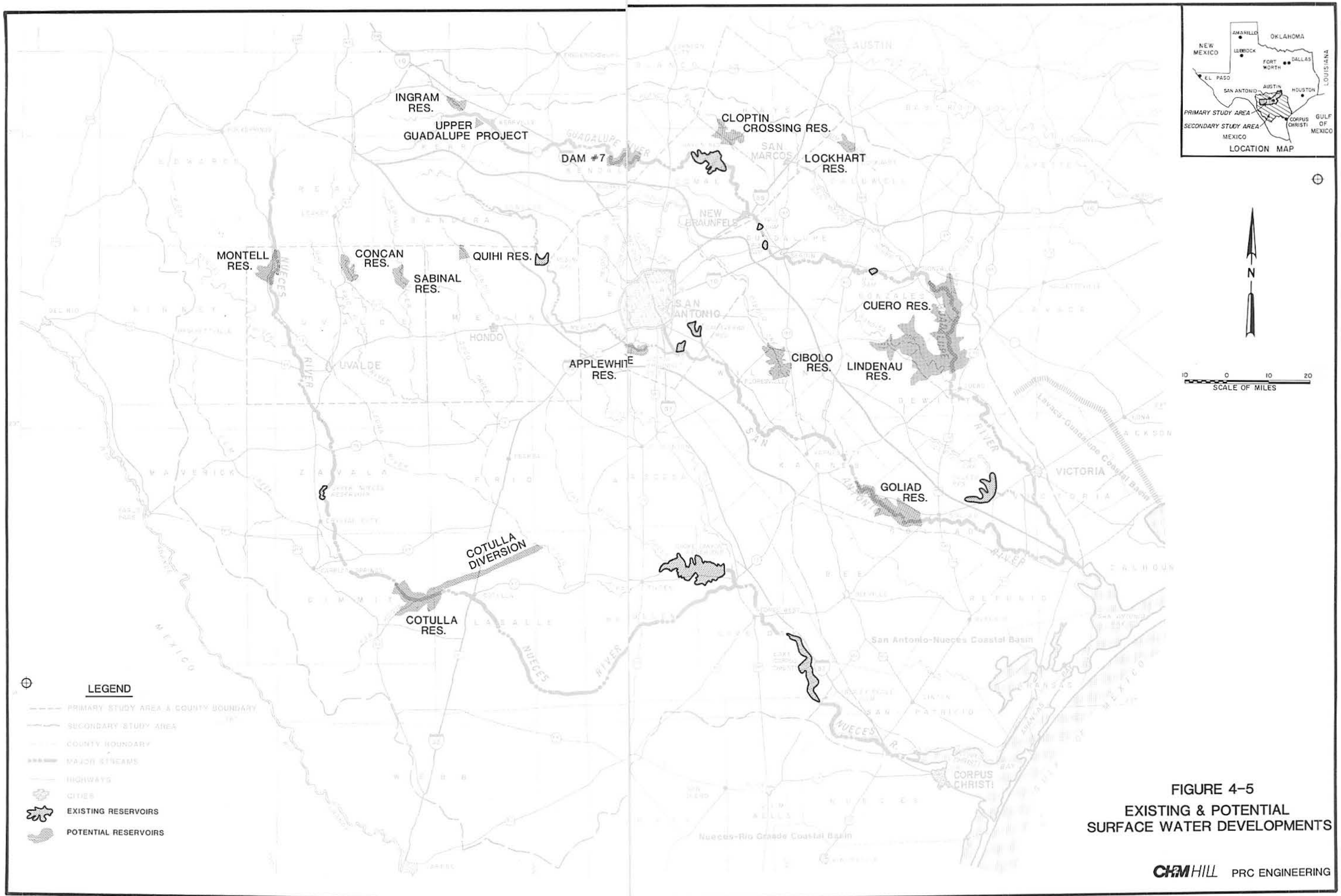

FIGURE 4-5
EXISTING & POTENTIAL SURFACE WATER DEVELOPMENTS

Coleto Dam and Reservoir, built by the Guadalupe-Blanco River Authority, impounds water from the Coleto Creek watershed and diverted water from the Guadalupe River.

H-4 Dam (Lake Gonzales), TP-1 Dam (Lake Dunlap), and TP-3 Dam (Lake McQueeney) are hydropower structures built by the Guadalupe-Blanco River Authority on the Guadalupe River.

Salt Water Barrier and Diversion Dam, at the confluence of the Guadalupe and San Antonio Rivers, is operated by the Guadalupe-Blanco River Authority to prevent salt water intrusion and to divert water to the Calhoun County Canal System.

San Antonio River Basin. Medina Dam and Reservoir, with the Medina Diversion Dam, is currently operated by the Bexar-Medina-Atascosa Counties Water Improvement District No. 1 to deliver water to farmland in the San Antonio and Nueces River Basins. The original purpose of the project was irrigation, but recharge of the Edwards Aquifer proved to be a substantial side benefit.

Calaveras and Victor Braunig Dams and Reservoirs are off-channel projects that divert water from the San Antonio River to supplement limited local runoff. They are operated by the City of San Antonio Public Service Board as cooling ponds for steam electric powerplants.

Olmos Dam and Reservoir is used for flood control and does not have conservation capacity. Flood flows are impounded during a flood event and are later released at an acceptable rate.

Nueces River Basin. Two major reservoirs in the Nueces River Basins are the Choke Canyon Dam and Reservoir and the Wesley E. Seale Dam, which impounds Lake Corpus Christi. The two reservoirs are operated as one system for the municipal and industrial needs of the City of Corpus Christi and the Coastal Bend region.

Upper Nueces Dam and Reservoir is operated by Zavala and Dimmit Counties Improvement District No. 1 for local irrigation.

Potential Surface Water Developments

Table 4-9 summarizes data for potential surface water developments identified in previous studies. Locations of these projects are shown in Figure 4-5.

Guadalupe River Basin. The major development previously proposed for the Guadalupe River Basin is the Cuero project, Stages I and II (or the Cuero and Lindenau Projects). The Cuero system would regulate the Guadalupe River and provide

Table 4-9
POTENTIAL RESERVOIR DEVELOPMENTS

Dam and Reservoir	Stream Location	Purpose	Dam Height (Feet)	Conservation Capacity (Acre-Feet)	Firm Yield (Acre-Feet/Year)	Average Yield (Acre-Feet/Year)
Cloptin Crossing	Blanco River	Water Supply and Flood Control	200	284,100	43,000	-
Cuero (Cuero I)	Guadalupe River	Water Supply and Flood Control	135	1,092,000	145,000	-
Lindenau (Cuero II)	Sandies Creek	Water Supply and Flood Control	105	1,278,000	220,000	-
Upper Guadalupe Project	Guadalupe River	Water Supply	(off-channel)	3,000	3,000	-
Lockhart	Plum Creek	Water Supply	73	50,000	7,960	-
Applewhite	Medina River	Water Supply	93	45,250	-	50,000[a]
Cibolo	Cibolo Creek	Water Supply and Flood Control	110	200,000	25,000	-
Goliad	San Antonio River	Water Supply and Flood Control	108	786,300	132,000	-
Cotulla	Nueces River	Water Supply	82	341,000	18,000	-
Cotulla Diversion	Nueces River	Water Supply	16	N/A	34,000	-
Concan	Frio River	Recharge	164	141,200[b]	-	21,500
Montel	Nueces River	Recharge	158	252,300[b]	-	30,900
Sabinal	Sabinal River	Recharge	114	93,300[b]	-	15,800

[a]Average yield based on filling and emptying the reservoir each year
[b]No conservation capacity, flood storage capacity shown
N/A - Not available

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water to the primary study area. The Cuero Project is a dam on the Guadalupe River, and the Lindenau Project is an off-channel reservoir on Sandies Creek that would require pumping water from the Guadalupe River. Either could be constructed first, but the two reservoirs would operate together after completion, or the Cuero I project could be built alone.

Three local water supply developments have been proposed previously for the Guadalupe River Basin: Cloptin Crossing Reservoir would supply municipal and industrial water to users in Hays County or other downstream users, Lockhart Reservoir would deliver municipal and industrial water to the City of Lockhart, and the Upper Guadalupe Project would provide municipal and industrial water to the City of Kerrville.

<u>San Antonio River Basin</u>. The largest previously proposed project, Goliad Dam and Reservoir, could provide the City of Corpus Christi with municipal and industrial water. Water could also be provided to the Guadalupe River Basin in exchange for water from the Cuero project.

Cibolo Dam and Reservoir could be used to provide San Antonio with municipal and industrial water and to provide a regulating reservoir for a conveyance facility between the City and the Cuero project.

Applewhite Dam and Reservoir includes diversion of Leon Creek to supplement the reservoir inflow. Although water quality in Leon Creek is currently poor due to Kelly Air Force Base industrial waste effluent, it is anticipated that wastewater treatment upgrades will be implemented to remedy the problem. Although a construction permit was issued in 1982, further studies are being conducted under sponsorship of the City Water Board.

If operated alone, Applewhite has an average yield--based on filling and emptying the reservoir each year--of 53,017 acre-feet per year based on historic flows from 1937 to 1969 (Freese and Nichols, 1974). If the recent, wetter weather period is taken into account, the yield averages about 57,000 acre-feet per year for the period 1940-1982 (Espey-Huston, ongoing study in 1985).

A value of 50,000 acre-feet is shown for Applewhite's annual yield to account for a possible decrease due to operational terminal storage requirements at either Applewhite or Cibolo if a coordinated Cuero-Cibolo-Applewhite Reservoir operation is used. A future engineering study will be needed to determine a more exact amount of decrease and which reservoir would be used for terminal storage. As a simplifying assumption for this study, a 7,000 acre-foot decrease is shown at

Applewhite, resulting in 50,000 acre-feet (57,000-7,000=50,000) for purposes of totalling available surface water suppies.

Nueces River Basin. The latest study of the basin, completed by the U.S. Bureau of Reclamation (USBR) in 1983, concluded that Cotulla Reservoir was the most likely development within the basin in the foreseeable future. This reservoir would be operated in conjunction with the Choke Canyon and Lake Corpus Christi. The firm yield obtained is small.

Recharge Reservoirs. The Upper Nueces River Basin offers good potential for recharge of the Edwards Aquifer but probably at the expense of water users downstream. Three recharge projects have been studied by the Corps: Montel Dam and Reservoir on the Nueces River, Sabinal Dam and Reservoir on the Sabinal River, and Concan Dam and Reservoir on the Frio River.

Two of the sites, Concan and Sabinal, have been studied as irrigation projects by the USBR, along with a third site, Quihi Reservoir. The USBR concept was to bypass the recharge zone with a lined conveyance structure to provide irrigation water to downstream users. None of these are considered feasible for irrigation purposes today.

Off-Channel Recharge. Off-channel recharge facilities are areas in which water is diverted from a stream to allow infiltration to the groundwater aquifer. Several types of recharge operations are used in other areas, including ditch and furrow, shallow basins, and deep pits.

The only feasible off-channel recharge sites are where the three rivers or their tributaries cross aquifer outcrops. Recharge reservoirs have been constructed where streams cross the Edwards outcrop. Potential recharge areas for the secondary aquifers are described in the following paragraphs.

The Guadalupe River enters the Carrizo-Wilcox outcrop area near the City of Seguin and passes into the Queen City-Sparta outcrop at the Gonzales-Guadalupe county line. It flows out of the Queen City-Sparta outcrop near the City of Gonzales. The topography along this reach appears feasible for diversions and off-channel recharge sites. Tributaries to the Guadalupe, Plum Creek and San Marcos River, also pass through the outcrop area.

The Medina River enters the Carrizo-Wilcox outcrop in Bexar County and passes out of the Queen City-Sparta outcrop in the middle of Wilson County. The topography appears suitable for diversion and recharge sites along this reach. Cibolo Creek also flows through the outcrops, and diversion and recharge sites may be feasible along its upper reaches north of Stockdale (at intersections of Highways 97 and 123).

The Nueces River crosses only a narrow 10-mile strip of the Carrizo-Wilcox outcrop in the southern part of Uvalde County. The topography appears suitable for off-channel recharge, but available runoff and existing downstream water rights are major constraints to any development.

While a number of recharge areas appear to exist in outcrops of the secondary aquifers, construction of recharge projects does not appear to be feasible. Reasons for this are recharge characteristics of the secondary aquifers, limited availability of water for spreading, large land areas required for spreading, and cost of physical facilities.

EXISTING WATER QUALITY

Typical properties of Edwards Aquifer groundwater are shown in Table 4-10, together with surface water properties for comparison. Both the Edwards Aquifer groundwater and the surface water of major streams in the study area are of good quality, exceeding the standards designated in the Primary and Secondary Drinking Water Regulations of the EPA. Both water sources tend to be hard (i.e., hardness greater than 120 mg/L is considered "hard water"). Edwards groundwater is slightly harder than surface water, which is primarily due to higher concentrations of calcium. There is also a slightly higher level of dissolved solids in the groundwater.

The TDWR has summarized existing water quality in the three river basins, as paraphrased below:

> The Guadalupe River is characterized by excellent quality water; contact recreation activities are practiced throughout the basin. Localized problems with growths of aquatic vegetation in the Guadalupe River between New Braunfels and Gonzales and in the San Marcos River near the City of San Marcos are primarily the result of natural factors. Waters of the lower basin generally contain high nutrient levels, but no aquatic plant growth problems have occurred.
>
> During periods of low flow, portions of the San Antonio River downstream of the City of San Antonio wastewater treatment plants consist almost entirely of treated municipal wastewater. During 7-day, 2-year low-flow conditions, the effluent domination of the San Antonio River to the confluence with Cibolo Creek causes dissolved oxygen sags. The flow in Cibolo Creek is mainly domestic wastewater effluent and has been the site of problem algal growths and fish kills. Leon Creek is dominated by effluent during periods of low flow.
>
> The Nueces River Basin has relatively good surface water quality, and the quality in the less inhabited upper

Table 4-10
EXISTING GROUND AND SURFACE WATER QUALITY

Parameter	Units of Measurement	Typical[a] Standard	Typical Results for: Edwards Groundwater	Typical Results for: Surface Water Major Streams
I. INORGANIC CHEMICALS & RELATED PROPERTIES				
pH		(6.5-8.5)	6.5-8.0	7.1-8.0
Dissolved Solids	mg/l	(1000)	250-450	200-300
Hardness	mg/l	-	250-300	200-250
Non-carbonate hardness	mg/l	-	20-50	10-30
Arsenic (As)	µg/l	50	0-2	0-3
Cadmium (Cd)	µg/l	10	0-1	0
Calcium (Ca)	mg/l	-	80-120	50-70
Chloride (Cl)	mg/l	(300)	10-30	10-30
Chromium (Cr)	µg/l	50	0-15	0
Copper (Cu)	µg/l	(1000)	0-40	0-4
Flouride (F)	mg/l	1.6[b]	0.1-0.5	0.1-0.2
Iron (Fe)	µg/l	(300)	0-500	5-50
Lead (Pb)	µg/l	50	0-10	0-4
Manganese (Mn)	µg/l	(50)	0-50	0-40
Mercury (Hg)	µg/l	2	0-1.5	0
Nickel (Ni)	µg/l	-	0-4	-
Total Nitrate Nitrogen	mg/l	10	1.5-3.0	0.2-3.0
Total Phosphorous (P)	mg/l	0	0-0.1	0.01-0.2
Potassium (K)	mg/l	-	1-2	1-2
Silica (SiO_2)	mg/l	-	10-20	10-15
Sodium (Na)	mg/l	-	3-10	6-10
Sulfate (SO_4)	mg/l	(300)	10-30	10-50
Zinc (Zn)	µg/l	(5000)	0-2000	5-30
II. BIOLOGICAL PROPERTIES				
Biochemical Oxygen Demand		-	0-1	0-1
Total Organic Carbon		-	1-5	1-5
Total Coliform	Colonies/100 ml	-[c]	0-5000	0-50,000
Fecal Coliform	Colonies/100 ml	-[c]	0-150	0-200
III. ORGANIC CHEMICALS				
Aldrin	µg/l	1	0	0
Chlordane	µg/l	3	0	0
DDT	µg/l	50	0	0
Diazinon	µg/l	-	0	0
Dieldrin	µg/l	1	0	0
Endrin	µg/l	0.2	0	0
Heptachlor	µg/l	0.1	0	0
Lindane	µg/l	4	0	0
Malathion	µg/l	-	0	0
PCB	µg/l	-	0	0-0.5
Parathion	µg/l	100	0	0
Silvex	µg/l	10	0	0
Toxaphene	µg/l	5	0	0
2, 4-D	µg/l	100	0	0-0.3
2, 4, 5- T	µg/l	2	0	0

Source: Edwards Underground Water District summary tables.

[a]Typical standards are given as the maximum contaminant level, unless enclosed in parentheses, indicating a secondary maximum contaminant level.
Maximum contaminant levels indicate those levels set by the U.S. Environmental Protection Agency (EPA) in the National Primary Drinking Water Regulations, and deal with contaminants that may have a significant direct impact on the health of the consumer.
Secondary maximum contaminant levels indicate those levels proposed by EPA in the National Secondary Drinking Water Regulations. These regulations deal with contaminants that may not have a significant direct impact on the health of the consumer, but their presence in excessive quantities may affect the esthetic quality and discourage use of the public water supply.

[b]For maximum daily air temperatures 21.5-26.2 degrees C.

[c]For treated drinking water supplies, the state requirement is less than one colony per 100 ml. Values shown are for raw water, which can be treated and/or chlorinated to meet the standard.

reaches of the basin is very good. As the waters pass from the headwaters to the coastal areas, natural and human activities result in marginal pH levels and dissolved solids problems in some segments. Water quality in the Nueces River Basin is affected by low flow conditions that occur in hot summer months.

ALTERNATIVE WATER SOURCES

Reclaimed Water

Irrigation Return Flows. In 1979, the total irrigated area in the Guadalupe, San Antonio, and Nueces River Basins was about 340,000 acres. Total irrigation water delivered was approximately 510,000 acre-feet (approximately 417,000 acre-feet coming from groundwater). An estimated 60,000 acre-feet of this water shows up as surface return flows with a similar amount being lost to groundwaters. However, this irrigation return flow is spread throughout western portions of the study area making it difficult if not impossible to collect and reuse the runoff economically. In addition, the quantity of return flow is expected to decrease by up to 20 percent in the future as irrigation efficiencies increase. Therefore, for the purposes of this study, irrigation return flows are not considered to be a significant new source.

Municipal Effluents. In 1980, the San Antonio River received approximately 140,000 acre-feet of municipal effluent in Bexar County, primarily from the City of San Antonio. This constituted over 90 percent of the total municipal and industrial (M&I) effluent for the 5-county primary study area and over 70 percent of the M&I return flows for the entire Guadalupe, San Antonio, and Nueces River Basins.

By 1989 the City of San Antonio will have three major (and three minor) renovated or new wastewater treatment facilities in operation when the Wastewater Facilities Improvement Program is complete. The Leon Creek and Salado Creek plants will increase from their present capacity of 24 mgd each to 35 and 36 mgd respectively for a total of 71 mgd (80,000 acre-feet per year). The new Dos Rios I plant will have a capacity of 83 mgd (93,000 acre-feet per year). The Rilling Road plant is scheduled to be retired when Dos Rios I begin operation in 1988. Proposed level of treatment for all three major plants is "advanced secondary," with effluent standards as follows:

Plant	Effluent Standards (in mg/L)					
	Current			Proposed		
	BOD_5	TSS	N	BOD_5	TSS	N
Leon Creek & Salado Creek	20	20	-	10	15	2
Dos Rios I	-	-	-	10	15	2
(Rilling Road)	20	20	-	-	-	-

The abbreviatons of monitored constituents above stand for the following:

BOD_5 = 5-day biochemical oxygen demand,
TSS = total suspended solids,
N = ammonia nitrogen.

Current and projected municipal effluent flows for five cities in the study area are given in the tabulation below in units of acre-feet per year:

City	1980	1990	2000	2010	2020	2030	2040
San Antonio	132,300	138,500	167,400	196,800	234,600	291,600	333,600
New Braunfels	2,600	2,300	2,700	3,300	3,800	4,400	5,000
San Marcos	2,700	3,400	4,900	6,600	8,100	9,500	10,900
Uvalde	0	200	1,100	2,000	2,600	3,100	3,900
Victoria	6,100	6,700	8,800	11,000	13,000	15,100	17,300

Notes: (1) Figures include amounts allocated to V. Braunig and Calaveras Reservoirs.
(2) The City of Uvalde reuses existing effluent. Only 50% of the projected increase in municipal usage is considered as return flows.
(3) 2040 and Victoria values are extrapolated with the primary study area rates of growth.

Based on these projected flows, San Antonio is the only location where large-scale reuse will have an impact on reducing supplies needed from other sources. For that reason, the following discussion of potential uses is limited to the San Antonio treatment plants.

Potential Uses. Reuse of municipal effluents for irrigation is an attractive and efficient use of water resources when the wastewater displaces a higher quality water that is in limited supply. Also, there is the possibility of generating revenue by selling wastewater effluent to new agribusiness entities near the treatment plants. Sales of effluent to these and other user groups are worthy of consideration but are not evaluated in this study since the focus is on largescale applications that increase the overall water supply. For any proposed reuse application, the constraints of health and water quality need to be considered carefully.

Studies have been conducted to identify areas near San Antonio potentially irrigable with effluent; 56,000 acres of irrigable land was determined to be necessary to utilize 84,000 acre-feet of effluent according to a 1984 study by Glass Environmental Consultants. The vast majority of identified suitable land is not currently under irrigation. This alternative was not considered further in this study since it would create a new demand. A second alternative would transport approximately 35,000 acre-feet of effluent to the canal operated by the Bexar-Medina-Atascosa Water Improvement District No. 1, replacing water drawn from the Medina River. This could increase recharge to the Edwards Aquifer by 30,000 to 35,000 acre-feet per year. A third alternative would transport water to western Bexar and eastern Medina Counties to replace pumped groundwater. This system would use approximately 40,000 acre-feet per year, but surface irrigation systems would have to be installed. Costs for these reuse alternatives range from about $190 to $270 per acre-foot.

In considering the potential for industrial reuse of reclaimed wastewater, the most likely major use is for steam electric power plant cooling. Other industrial users are too small and scattered to justify the expense of a distribution system. City Public Service (CPS) already uses approximately 30,000 acre-feet per year of treated effluent. The wastewater treatment plants in southern San Antonio discharge secondary treated wastewater to the San Antonio River, or its tributaries. Water flows down the river a short distance where it is then pumped to Braunig and Calaveras Lakes for use as cooling makeup water. At Braunig Lake, CPS diverts 8,000 acre-feet per year to replace water lost from lake evaporation and from induced evaporation in the power plant. Calaveras Lake currently requires about 22,000 acre-feet per year to meet the cooling water make-up needs of two power plants. San Antonio has an ordinance (#35228) designating the first 37,000 acre-feet of discharge for CPS use, by way of the river or directly from wastewater discharge outlet works. The projected ultimate demand for cooling water at Calaveras Lake and Braunig Lake is about 60,000 acre-feet per year. This amount is the limiting capacity of the lakes for cooling purposes according to CPS representatives. Future energy needs for the San Antonio area are greater than the expanded existing plants can provide, so supplemental energy supplies will come from the South Texas Nuclear Project and/or a potential coal-fired plant in Bastrop County. CPS has a few other small powerplants in San Antonio which are too far from a wastewater effluent source and use too little cooling water to be economically supplied water from this source.

The reuse of effluent for residential irrigation requires dual water distribution systems in which piping completely separate from the potable water distribution system is installed. The effluent is used for lawn and landscape irrigation. This type of system would be most feasible in newly developed areas associated with future treatment plants in the northern part of San Antonio. This approach is listed as an option in the current San Antonio wastewater master plan. In existing neighborhoods, the cost of installing piping under pavement and around existing utilities is often prohibitive. Maximum potential reuse could be 100 percent of the discharge from all new wastewater treatment plants constructed in presently undeveloped areas, or 87,000 acre-feet per year by 2040. Costs for complete dual water systems would be in the order of $500 to $1,000 per acre-foot.

Reuse of treated effluent for park and golf course irrigation would be very similar to residential irrigation. The primary advantage of this alternative is that the distribution system could be less expensive due to fewer distribution points with higher capacities. The amount of water that could be used for irrigation from a proposed wastewater treatment plant in northern San Antonio by the airport would be on the order of 1,300 acre-feet per year with a peak demand of about 350 acre-feet during July. Costs would be in the order of $45 to $55 per acre-foot for parks and golf courses along Olmos Creek if treated wastewater were released to the creek from the proposed treatment plant and then diverted to existing park sprinkler systems with pumps drawing from the creek, followed by in-line chlorination. A permit from the Texas Water Commission would be required in order to implement this reuse option.

With the numerous military facilities located in the San Antonio area, there is potential for development of wastewater reuse at these sites. The wastewater reuse options designated by the U.S. Army Corps of Engineers Research Lab could include irrigation of green areas, wash water for equipment and other facilities, cooling water demands of industrial type operations, and laundries (industrial). Since the military bases are scattered across the city, a fairly extensive distribution system would be required to get treated wastewater to each one from existing treatment facilities. This is complicated to some degree by the location of present wastewater treatment facilities. An alternative is to build treatment plants at the various military installations, similar to the small treatment plant at Kelly Air Force Base. Costs for these reuse options are unknown, but the idea is worthy of further analysis to determine if it is cost-effective to consider this alone or in combination with other alternatives. The total potential military reuse could be about 2,500 acre-feet per year based on an assumed 25 percent of current military water demands being met with treated wastewater. Further studies are needed to more accurately quantify this amount.

Direct reuse (directly from treatment plants to residential use) on a large scale is not likely to occur within the next 20 years. Direct reuse systems need to be proven, and public acceptance must increase. A one-mgd demonstration plant is being tested in Colorado and is the nation's forerunner at this time for direct reuse. The plant produces a volume that is less than one percent of area demand. Costs for water treated in this manner are approximately $800 to $900 per acre-foot. Potential for development of this alternative varies with the availability and cost for developing additional water supplies, and public acceptance.

Indirect reuse differs from direct reuse by virtue of passing through an additional step: it is discharged and mixed with surface or groundwater prior to reuse. The primary reuse option that fits this definition is recharge of an aquifer with wastewater effluent treated to drinking water standards. In order to protect the aquifer, the wastewater treatment plant should incorporate provisions to temporarily store and/or discharge treated water when the plant does not perform up the prescribed standards. Continuous monitoring would be required, similar to the monitoring that has been done successfully at the El Paso treatment and recharge project since June 1985.

Two aquifers in the vicinity of existing and future San Antonio wastewater plants are considered: 1) the Carrizo-Sand Aquifer beginning at the southern tip of Bexar County; and 2) the Edwards Aquifer underlying San Antonio.

The Carrizo San Aquifer's recharge zone lies about 10 miles south of San Antonio's existing major wastewater plants. Effluent could be piped from the plants to the area for recharge by spreading basins or recharge wells. An equivalent amount could be withdrawn from the aquifer by new recovery wells and pumped to San Antonio's water supply system. 70,000 to 108,000 acre-feet per year could be available for this reuse option, with costs estimated to be about $550 to $650 per acre-foot.

Two plans for Edwards Aquifer recharge with wastewater effluent might be considered. The first would be to pipe 70,000 to 108,000 acre-feet per year of treated wastewater from existing southside plants to the recharge zone, or to use recharge wells at some intermediate point. The second plan would be to pipe wastewater effluent from planned northern area treatment plants to recharge zone spreading basins or recharge wells near the plants. The total effluent available for reuse could be up to 165,000 acre-feet per year if all new treatment facilities required to handle the projected 2040 wastewater volumes are included. Costs for this type of indirect reuse option would likely be in the range of $400 to $600 per acre-foot. Total recharge volume could be 78,000 to 165,000 acre-feet per year, depending on the size and location of new treatment plants.

If major recharge projects such as these are pursued, additional engineering feasibility-level studies will be needed to compare these two options in more detail, including items such as costs, institutional and financial alternatives, health risks, and public acceptance. Preliminary observations on these two options are as follows:

- The Edwards recharge option is estimated to be about 20 percent less costly than the Carrizo recharge option. The cost difference is due to the 10 miles of pipeline to and from the Carrizo which is not required for the Edwards option.

- More complete mixing and dilution of effluent is possible in the sand formations of the Carrizo than in the Edwards' fissures and channels in limestone.

- Current Carrizo Sands Aquifer users may perceive a Carrizo recharge plan as a San Antonio disposal operation, arousing "not-in-my-backyard" sentiments.

At this initial planning stage, the Edwards Aquifer recharge option was used to prepare costs for regional water plan alternatives since it is estimated to be less costly. Following more detailed studies and public education/involvement programs, a final aquifer recharge plan may be pursued for the Edwards Aquifer, the Carrizo Sands Aquifer, or a combination of both. If significant dual water system programs are initiated, the amounts to be recharged to either aquifer could be reduced.

Saline Water

Desalination of saline groundwaters might provide a potential potable water supply. The method of treatment most applicable for saline groundwaters in the San Antonio area would be reverse osmosis, in which dissolved salts are removed as water is passed through a cellulose acetate membrane under pressure. Removal efficiencies of 95 percent are obtainable. Desalination of seawater is also a possibility, but transportation costs probably make it infeasible.

The primary disadvantages of this treatment are high energy costs and the need to dispose of the salt brine. Conversion efficiencies of 75 percent might be expected for the saline groundwater, which would mean 100 gallons of feed water would produce 75 gallons of potable water with 25 gallons of brine. The brine would have an approximate fourfold increase in dissolved solids. Disposal of the brines in San Antonio would probably require pumped injection in an alternate aquifer.

Imported Water

Principal constraints on importation of additional long-term supplies of surface water into the study area are as follows:

- Relatively inadequate surface water supplies of river basins adjacent to the study area
- Statutory prohibition against exporting surface water out of the basin of origin unless the exported water is surplus to the amounts needed to meet the in-basin demands for the next 50 years
- Costs of constructing and operating major water conveyance facilities over long distances

The potential exists for importing additional surface water supplies into the study area from one or more of the San Jacinto, Trinity, Neches, Sabine, and Sulphur River, and Cypress Creek basins in the northeast part of the state. However, it is doubtful the required conveyance system would be economically feasible due to the distance involved.

Weather Modification

Successful augmentation of any water supply by cloud seeding depends on the frequency and character of the naturally occurring opportunities. The Gulf of Mexico is the principal source of moisture for the San Antonio area. Warm, moist tropical maritime air masses are frequently carried onshore by southeasterly winds. As these air masses encounter rising terrain or the sloping surface of cold fronts that mark the boundaries of continental air masses, they are cooled by expansion, become unstable, and produce convective clouds that are frequently capable of producing rainfall. Clouds in the San Antonio area vary seasonally. In the winter, layers of stratocumulus clouds frequently inhabit the region. They are not generally considered suitable for seeding. Swelling cumulus clouds that are considered suitable for seeding occur about one day in 4 in the winter and about one day in 3 in the summer.

Available evidence suggests that seeding-produced increases are associated with inefficient, moderate storm systems of the type that produce less than one inch of precipitation. The storms that produce several inches of rainfall are already efficient and are more apt to have their output decreased than increased by seeding. For the present, a 10 percent increase in rainfall represents a good midpoint between the expectation of optimistic seeding operations and pessimistic seeding evaluators.

The Edwards Underground Water District is currently conducting a cloud-seeding program. The program was authorized in July 1985 under a 4-year permit. The target area for the program is located generally in the northern Kinney, Uvalde, and Medina Counties, and in Edwards, Real, Kerr, and Bandera Counties. The goal of the program is to achieve a 10- to 15-percent increase in precipitation over the target area, if possible. The City of Corpus Christi conducted a similar program in the Lower Nueces Basin in 1985.

Vegetation Management

Some of the water currently consumed by brush and timber in undeveloped areas could be made available for other uses if the amount of vegetation were reduced. In the study area, control of woody-type vegetation in upper drainage basins and phreatophytes in downstream channels below the primary study area could increase water supplies.

Phreatophytes are naturally occurring water-loving plants whose roots reach to the water table or the capillary fringe overlying the water table. Because they tap a relatively constant water supply, they are very resistant to drought. In addition, many phreatophytes have a high salinity tolerance and resist floods. The root stems for some of these plants can extend over 30 feet below the surface.

Areas that have potential for increasing water yield have a specific type of vegetative cover, an annual precipitation of more than 20 inches, and slope and soil characteristics with an erosion rate of less than 0.5 acre-foot per square mile per year. Under ideal situations, an additional runoff of up to 2.5 inches per acre per year is possible. Although vegetative management on the Hill Country forest and brushland has some potential, the practicality of this method requires further study before it can be implemented.

A 1967 Soil Conservation Service (SCS) survey estimated that a program to remove 70 percent of the medium and dense brush stands could salvage 1,210,000 acre-feet of water per year in the Neuces River Basin and 646,200 acre-feet per year in Guadalupe and San Antonio River Basins. Therefore, savings may be possible if only a small portion of the stands are removed. Additional studies to develop a current data base appear warranted.

Spraying with herbicides has been tested extensively. This method has shown varying degrees of effectiveness from removal of only a small percentage of old plants to 100-percent removal of seedlings. Both aerial and ground spraying have been used. However, use of herbicides can cause damage to aquatic, avian, and land-based wildlife. In addition, aerial spraying may not be feasible in areas near agricultural lands. Clearing, discing, and mowing on a twice-a-year schedule has been tested and is considered an effective means of controlling phreatophytes. Burning has not been as successful. Biological control of phreatophytes using natural insects or pests of the plants is also a potential means of control.

End-Use Efficiency Conservation

From an institutional and implementations standpoint, water conservation is perhaps the most flexible resource available. It has a short lead time, can be developed in small increments, and is, therefore, treated as a water supply source in the alternatives presented in Chapter 5.

Operation Water Conservation was created to heighten awareness of water usage and waste. The conservation program elements undertaken during the 1984 drought included a public education and awareness campaign and distribution of water kits with water-saving devices. This type of program is especially effective when the public perceives the need for conservation. While these conservation programs can be very effective during drought conditions (during the 1976-1977 drought in California, Marin Municipal Water District reduced usage 50 percent, but afterwards returned to pre-drought usage rates), long-term reductions are typically in the 5- to 10-percent range if public education is continued. The EUWD has estimated savings of approximately 9 percent during the 1984 drought. The City of Phoenix estimated savings of 7 percent from its program.

A survey of water users in the study area showed that people were aware of the importance of water conservation efforts and are willing to limit their water use, at least during critical periods. About a third of the survey respondents had installed the flow restrictors distributed in the water kits, a fairly high implementation rate for a large distribution (over 40,000 kits handed out through July 1985).

Two of the more successful conservation programs in the southwest are operating in Tucson and Phoenix, Arizona. In Tucson, water conservation and peak demand management began in the 1970's. Since then, the City has implemented an increasing block water rate structure, a winter-summer rate differential, a "Beat the Peak" summer demand management program, and a public education program. Together, these programs have reduced per capita use from 205 gallons per day (gpd) in 1973-1974 to 153 gpd in 1983-1984. Beyond pricing programs, media awareness is high with one-time programs such as a rebate program to customers who reduce usage, a "Be Watertight" program, and a residential desert landscaping contest.

The Phoenix project is fairly recent and consists of public awareness programs, distribution of conservation kits, and a new water rate schedule (increasing block). Phoenix has seen water use drop from 267 gpd in 1980 to 233 gpd in 1983. A portion of that decrease is attributable to lower temperature and higher precipitation in 1983. Phoenix has a water conservation coordinator who is responsible for media releases and program compliance and is available for public education appearances.

In Operation Water Conservation, the study area has the beginnings of an effective conservation program. Based on case studies of other conservation programs, a successful program integrates several elements to demonstrate that water savings are necessary. These programs typically include:

- A public education and information program
- Plumbing code requirements for conservation fixtures
- Water conservation kit distribution
- Conservation-oriented rate structure
- Leak-detection program

The major cost of these programs comes from staff time. The City of San Antonio has recently implemented or is now implementing all of these programs. This should be continued and expanded to include other purveyors in the primary study area and to the population centers in the secondary study area. Long-term savings are expected to be in the 5- to 10-percent range. Any savings greater than this during average conditions will require mandatory measures.

If the voluntary programs do not achieve desired conservation results, mandatory measures could be implemented. Typical mandatory measures include (1) demand reduction enforcement programs, such as limits on car washing, lawn watering, etc., (2) retrofit programs where conservation fixtures are required in all homes, (3) restrictions on landscaping, and (4) water rate modifications coupled with dramatic increases for higher water use, etc. These mandatory programs may require home audits, patrols, and intensive program regulation.

The calculation of water demand for irrigation is based on the assumption that irrigation efficiency measures would be implemented. These measures include switching to low energy precision application systems, laser leveling, etc. Industrial water demand calculations also were based on the assumption that conservation measures are being implemented by industry. Wet industries for the most part have already implemented water recycling programs and other water-reducing measures to meet discharge requirements.

Constraints to Conservation

A major constraint to water conservation in the San Antonio area has been the difficulty of coordinating activities of the many water purveyors. The primary study area currently contains over 200 private water purveyors. No one local, state, or federal agency or combination of agencies has "across the board" authority over these private entities.

Another constraint is the lack of building codes in unincorporated county areas. Much of the study area's residential and commercial growth is occuring in these areas. Currently, the only incentives to builders for delivering products meeting acceptable building standards are market-oriented. For example, fire insurance premiums and general property/casualty rates probably combine with consumer taste to impose certain unwritten product construction codes. Water-saving devices and low-water-use landscaping may not be in accordance with consumer taste. Implementation of such measures usually requires mandatory enforcement under building code ordinances. The current lack of building code enforcement in unincorporated areas of the counties is a notable institutional constraint to any water conservation program.

A regulatory constraint is the building code limitation placed by FHA and VA guidelines on landscaping. Under current FHA financing policies, approved homes must feature landscaping (i.e., a defined number of shrubs and trees) not considered conducive to water conservation. Unfortunately, this is a federal policy matter and is unlikely to change in the near future. While these agencies agreed to suspend these closing requirements temporarily during the 1984 drought, that appears to be a one-time only agreement.

Potential Negative Impacts of Water Conservation

There are two potential negative impacts of a successful conservation program. The first is financial. A good program will reduce water sales and thus revenues unless water rates are adjusted upward to compensate for the sales drop.

Secondly, management options are impacted during drought or water shortage periods. A strong ongoing conservation program will delay and possibly eliminate development of physical water resource projects reducing the quantity of carry-over water for dry periods. In addition, when a shortage occurs, emergency conservation measures will not save as much water as if an ongoing program did not exist. The manager can still cut back use, but not as severely as if no conservation program existed.

DEMAND-SUPPLY COMPARISON

Demand

Current and projected primary, secondary, and coastal water demands are shown graphically in Figure 4-6. A summary for years 1980 through 2040 is given in the tabulation below:

TOTAL DEMANDS
(Municipal, Industrial, & Agricultural)
(1,000 acre-feet/year)

	1980	1990	2000	2010	2020	2030	2040
Primary Study Area	493	476	536	594	680	802	896
Secondary Study Area	467	477	522	540	600	668	728
Coastal Basin	164	233	273	318	378	453	528
Total	1,124	1,186	1,331	1,452	1,658	1,923	2,152

Water use is expected to nearly double by 2040.

Supply

A summary of existing water supplies available to demands of the study area are given in Table 4-11.

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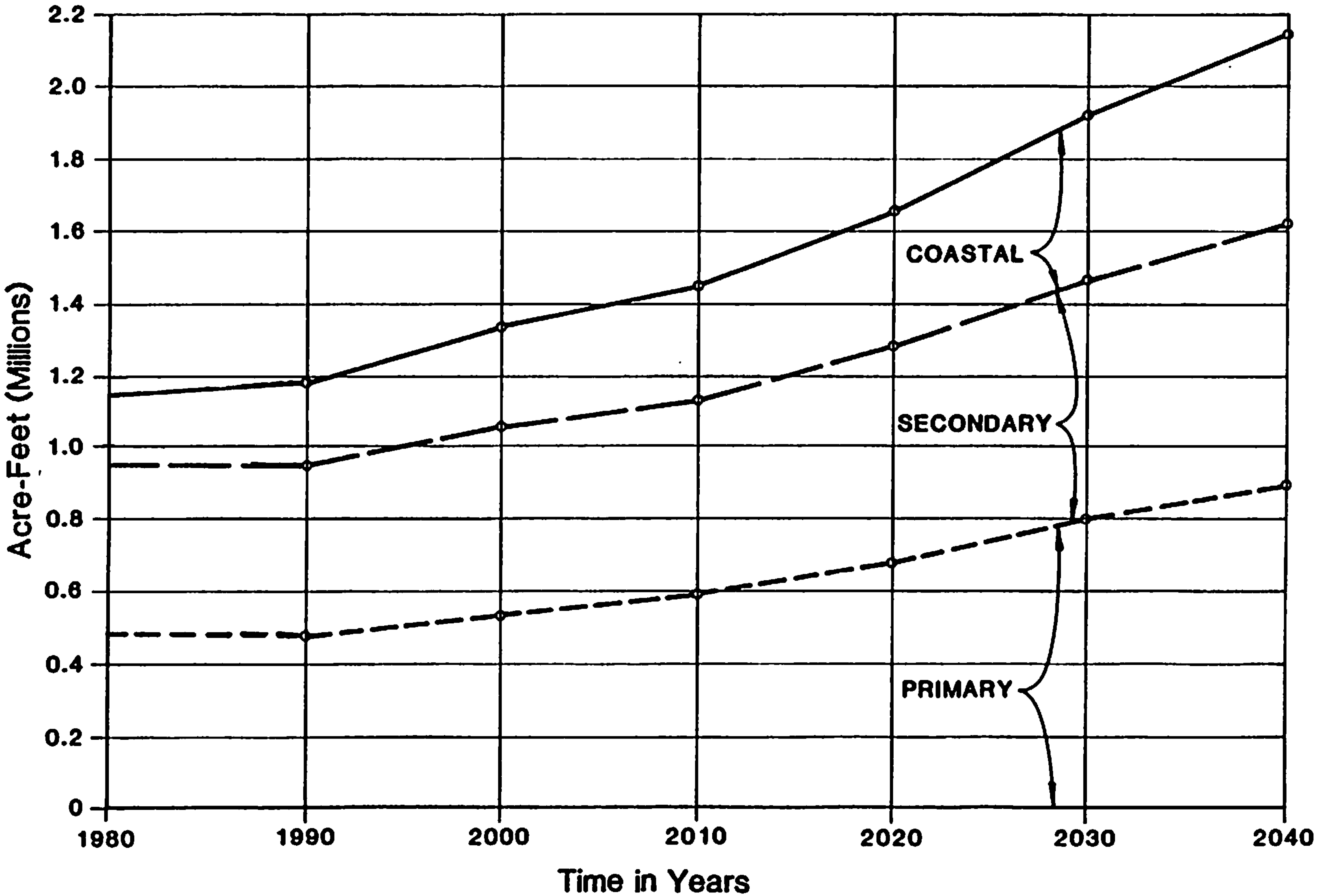

FIGURE 4-6
STUDY AREA WATER DEMAND
(MUNICIPAL, INDUSTRIAL, AGRICULTURAL)

Table 4-11
SOURCES IN 1980
(Acre-Feet)

Existing reservoirs[a]	418,000
River flows[b]	2,394,000
Edwards Aquifer[c]	608,000
Associated aquifers[d]	520,000
Total	3,940,000

[a]Total areal yield of reservoir in each year of the 1947 to 1956 drought, prior to adjusting for required downstream releases.

[b]Average annual gauged flow 1939-1983.

[c]Average annual discharge/recharge 1934-1982. It is possible to pump more than this amount (see discussion below).

[d]Mining occurring in Carrizo Sands.

Estimates of total water demands in the study area depend on the quantity required for bays and estuaries. Average river flows to the bays and estuaries for the 1939-1983 period were 2,340,000 acre-feet (however, bays may not need this much). Adding this to the primary, secondary, and coastal demands (for 1980) gives a total of 3,464,000 acre-feet. Table 4-11 indicates total supplies in 1980 were 3,940,000 acre-feet. Therefore, if river flows occurred at the time the water was needed, the supply more than met demand (return flows and springflows are assumed to be part of the river flows that meet bay and estuary demands).

The above comparison is based on average water year river flows. During below average water years, demands can exceed supplies on a current basis and, in fact, have as early as the 1950's. About the year 2010 demands are expected to exceed current supplies even during an average water year. Alternatives for meeting that future demand include the reservoirs and alternative supplies described in this chapter based on methodology described in Chapter 3. Also, it is possible to provide more water from the Edwards Aquifer than the annual recharge amount listed in Table 4-11. This "mining" of the Edwards is another possible alternative to be considered in lieu of, or in conjunction with, reservoirs and other alternative supplies.

A drought can occur at any time, placing greater stress on the limited water supplies as time passes. Edwards Aquifer water level and springflow declines due to dry periods are becoming more pronounced with time as pumping from wells has increased over the years. The 1984 summer drought produced dramatic groundwater level declines, very little springflow, and almost no flow in the rivers. Since major new water sources such as reservoirs or wastewater reuse take 10 to 20 years to plan and construct, a commitment on whether to proceed with new sources needs to be made in advance of a water shortage.

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CHAPTER 5

Chapter 5
ALTERNATIVES

INTRODUCTION

As stated earlier, current water demands on the Edwards Aquifer are at or near the limit of safe annual yield of the aquifer, as defined by the TDWR. In this chapter, alternatives to continued reliance on the Edwards as a sole source for most of the water demands of the overlying lands are reviewed and evaluated. A brief overview of the problems associated with the Present Policies Alternative--or status quo--is given first to illustrate the need for alternative water management policies. Additional details on the Present Policies Alternative, as compared to other alternatives, are presented later in this chapter in the section, COMPARISON OF SELECTED ALTERNATIVES.

IMPACTS OF CONTINUING PRESENT POLICIES

Lowering of Water Tables

Continuing to rely on wells to meet future water needs will result in the following estimated water table declines:

Community	Estimated Water Table Decline by Year 2040 (to nearest 5 ft)
Uvalde	80
Sabinal	130
Hondo	135
San Antonio	145
New Braunfels	85
San Marcos	30

These declines will have a significant impact on well pumping costs in the future. Present agricultural users will be more financially affected than municipal users since water costs are a more substantial portion of a farmer's total cash outlay. It is estimated that the cost of applying 1 inch of water to an acre of land increases by $0.11 with each additional 10 feet of lift.

Because of the current rates of aquifer pumpage, water table declines during a drought are a present problem that will grow with time if demands continue to be met with groundwater. If a drought similar to that of the 1950's began in 1986, the aquifer water level in San Antonio would drop below the "Water Watch" level that triggers voluntary conservation measures for 8 consecutive years, and mandatory conservation measures would be in force for 4 years from

1992 through 1995. If a drought occurred in later years, its impact would be even more severe, since the aquifer would have been more seriuosly depleted over time. These impacts are shown graphically in Figure 5-1.

Cessation of Springflows

With increased groundwater pumping, springflow will cease permanently in the twenty-first century.

Between now and time of complete cessation, Comal and San Marcos Springs will go intermittently dry with increasing frequency during low-rainfall years. This will have adverse impacts on Guadalupe River water users, instream flows, water quality, recreation opportunities at the springs, the endangered plant and animal species at the springs, and the bays and estuaries. Many agricultural, industrial, and municipal entities between the springs and the Gulf have State permits to divert water from the Guadalupe River which derives part of its flow from Comal and San Marcos Springs. In fact, springflow accounts for 25 percent of river flow in an average year and up to 90 percent in a dry year (measured at Cuero). Loss of springflow will thus cause a significant decrease in river flow. The impact on water diverters will be particularly acute during drought years.

Reduced flow at the springs is not just a problem for twenty-first century planners; it is an immediate concern during dry periods due to increasing rates of aquifer pumpage. If a drought similar to that of the 1950's began in 1986, Comal Springs would be completely dry for 6 years--from 1990 through 1995--and flow at San Marcos Springs would fall to less than half of its historic level. The impact of a future drought on springflow is even more severe, as shown in Figures 5-2 and 5-3.

Instream Flows

Guadalupe River water available for maintenance of plant and wildlife ecosystems and for recreation will be reduced 25 percent in average rainfall years and about 75 percent during a severe drought year such as 1956, due to complete loss of springflow in the twenty-first century. During the driest months of a prolonged drought, river flow could be cut by 90 percent if springflow is lost, leaving almost no water in the river.

Risk of Edwards Quality Degradation

Lowered water levels in the Edwards Aquifer increase the risk of quality degradation due to the following (see Appendix G):

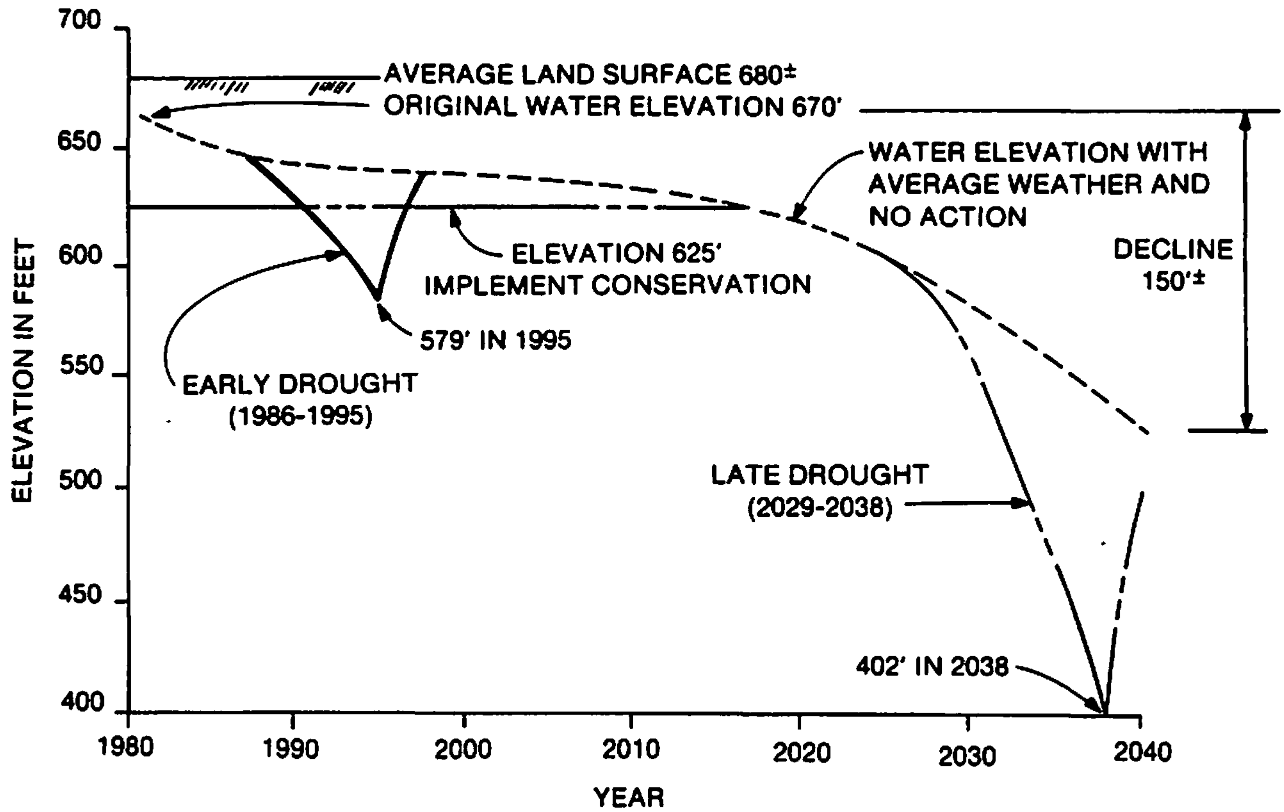

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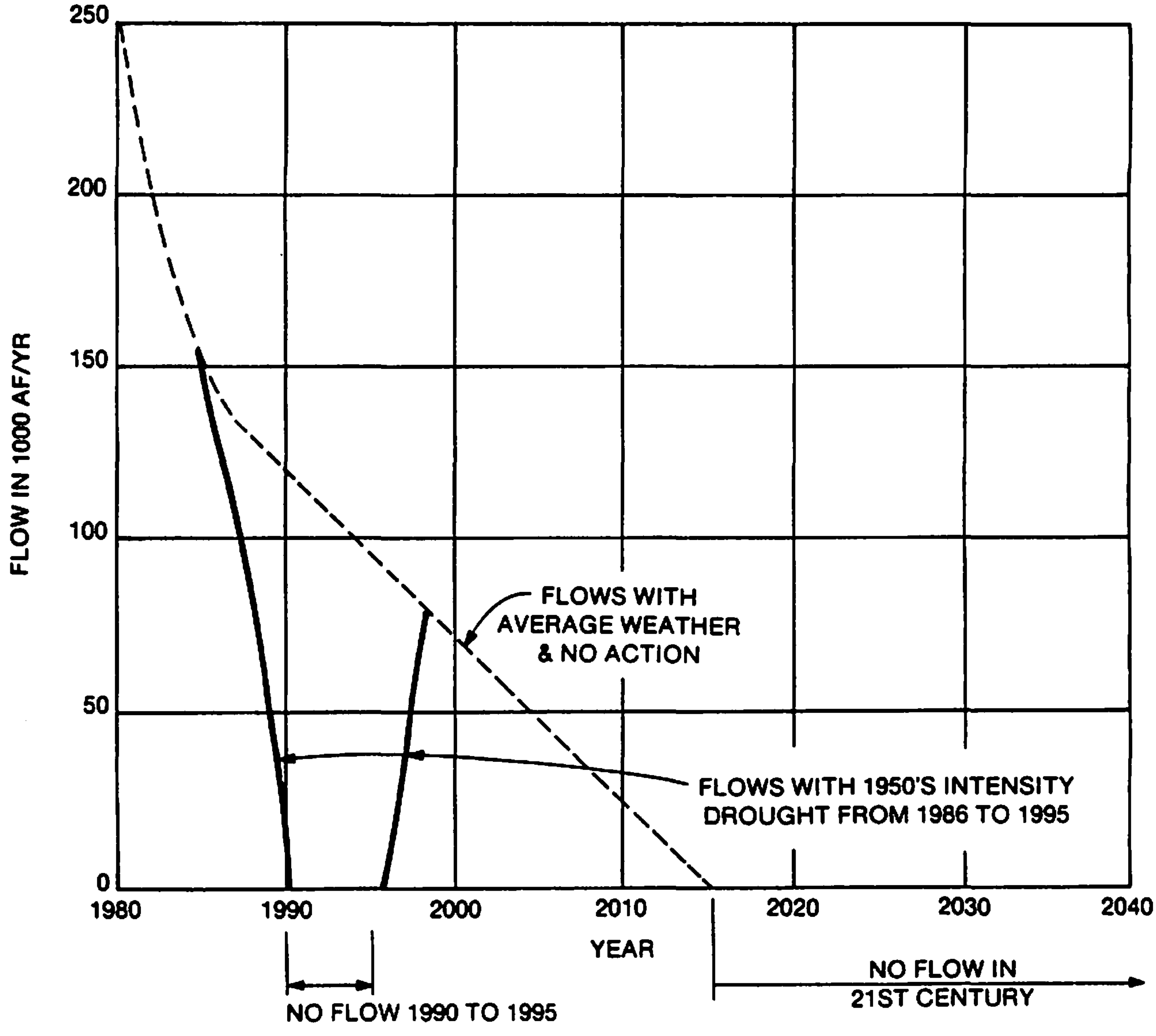
FIGURE 5-1
FUTURE GROUND WATER LEVELS IN SAN ANTONIO



NOTE: 1980 to 1985 FLOWS ARE THEORETICAL AVERAGES FOR COMPUTER MODELING PURPOSES, NOT ACTUAL RECORDED FLOWS.

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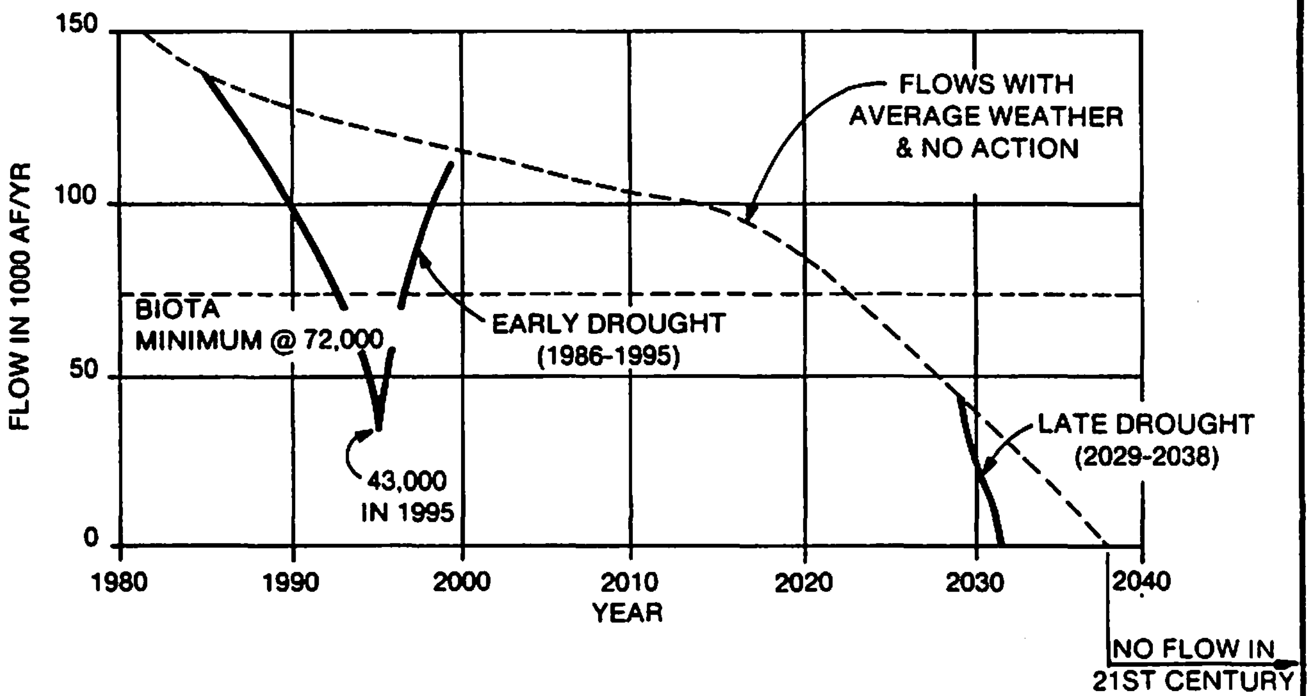
FIGURE 5-2
FUTURE COMAL SPRINGS FLOWS



NOTE: 1980 TO 1985 FLOWS ARE THEORETICAL AVERAGES FOR COMPUTER MODELING PURPOSES, NOT ACTUAL RECORDED FLOWS.

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FIGURE 5-3
FUTURE SAN MARCOS SPRINGS FLOWS
(IMPACT IS SEVERE NOW, SPRING GONE IN FUTURE)

- Saline water intrusion from the "bad-water" zone
- Flow path changes south of the recharge zone that increase the odds of any spilled contaminants in this region getting into the aquifer
- Concentration of any contaminants in the aquifer due to less water in storage for dilution

River Water Quality Degradation

With less water in the Guadalupe River available for dilution, concentrations of treated wastewater currently discharged to the river will increase, causing quality degradation. Mitigation of this impact would entail upgrading of existing wastewater plants discharging to the river at increased cost to communities involved.

Recreation at the Springs

Tourism generated by San Marcos and Comal Springs provides a significant source of income to Comal and Hays Counties. Local income would be reduced with the loss of the springs. In addition to economic impacts, a scenic and pleasing environmental resource would be lost to future generations. Quality of life in this area would thus be lowered in terms of available scenic resources.

Endangered Species

The following threatened or endangered plant and animal species will be lost at San Marcos Springs if springflow ceases:

- Texas wildrice (growing in the San Marcos River downstream of the springs)
- San Marcos Salamander
- San Marcos Gambusia (small fish)
- Fountain darter (small fish)

Limitation of Development in the Secondary Study Area

Without new water sources, the secondary study area's growth potential will be limited. This is particularly true in the lower Guadalupe River Basin where potential industrial demand increases of up to 180,000 acre-feet per year would have no dependable future water source.

Increased Litigation Potential

Those impacted by the above adverse consequences are likely to seek judicial or legislative/administrative relief against the party or parties viewed as causing the problems.

Being the largest single pumper both now and in the future, the City of San Antonio is at risk of being sued or otherwise challenged in a legislative or administrative process. Other current pumpers could also be brought into the process. This risk is growing with time as pumpage increases. Possible parties seeking relief include the following:

- Guadalupe River water rights holders
- Tourist industries at springs and along rivers fed by the springs (Comal, San Marcos, and Guadalupe)
- Farmers in Uvalde, Medina, and Bexar Counties using Edwards Aquifer water
- Other municipalities using Edwards Aquifer water
- Wildlife protection groups concerned about endangered species at the springs and downstream ecosystems
- Marine fishery interests concerned about reduction in flow to the estuaries

Texas law currently treats groundwater as a property right with nearly no obligation of the property holder to other users. However, national and state trends are toward a more equitable distribution of water resources to all users on a sharing basis. Therefore, in the future a successful lawsuit or legislative/administrative action could force reallocation of the area's water supplies on a mandatory schedule. A prudent course of action is to develop a comprehensive water management plan incorporating local input rather than being forced to implement a plan imposed by others. These issues are discussed in more detail in Appendix L.

DEFINITION OF ALTERNATIVES

Three alternative water resource management plans are considered herein as well as the present policies or status quo approach for comparison. The alternatives are defined in Chapter 3 and summarized as follows:

- Present Policies--use existing water sources and existing policies.

- o Alternative I--use any existing or new water source within the framework of existing laws and policies. New reservoirs can be considered.

- o Alternative II--implement new laws/institutions as necessary but build no new reservoirs.

- o Alternative III--consider new laws/institutions as necessary and use any water source including new reservoirs.

DEVELOPMENT OF WATER SUPPLY ALTERNATIVES

Water Sources

In accordance with the study goal to ensure availability of an adequate water supply for growth and economic development in the three river basin area, alternative supply plans were formulated to meet all forecasted demands. Growth-limiting alternatives such as restrictive zoning were therefore not considered.

The first step in developing alternatives was to consider what mix of water supplies would meet forecasted demands in the year 2040. The near doubling of water demands in the study area by the year 2040 requires significant new water supply facilities. The timing of new facilities was determined next, based on the forecast demand buildup and the fact that major new facilities such as reservoirs generally take 15 to 20 years to develop. Lastly, institutional and financial arrangements to implement a coordinated regional plan were considered (Chapter 6).

Within the broad scope of each alternative definition given above, there are many possible combinations or subalternatives. The process used to formulate the alternatives is as follows:

- o Prepare several combinations of the following water supply components to meet the projected demands:

    - Edwards Aquifer groundwater
    - Secondary aquifer groundwater (Carrizo-Wilcox, Trinity Group, and Gulf Coast)
    - Conservation programs
    - Reuse of treated wastewater
    - Saline groundwater

- Recharge reservoirs

- Surface water reservoirs
(Other sources such as cloud-seeding, vegetation management, and imported water from outside the study area are not considered feasible or significant contributors to area water supplies as discussed previously.)

o Compare all combinations within an alternative category (I, II, or III) against one another to determine the most promising one for further study. Use a screening process that considers tangible as well as intangible impacts.

o Compare the selected Alternative I, II, and III plans to each other and to the Present Policies Alternative. Conduct more detailed evaluations to provide sufficient information for the public to make responsible choices among alternatives.

Although several thousand possible combinations of all these components could be made, only a few are actually feasible considering the interrelationships of the limited water resources in the area.

<u>Source Interrelationships</u>

Altering the water flow in one part of the water resource system will produce an impact somewhere else in the system since the total amount of water available is finite. This interdependence is illustrated by the following observations as related to current water use in the San Antonio area:

o Recharge increases available groundwater.

o Groundwater maintains springflows.

o Decreased spring flows reduce river flows.

o Conservation reduces river flows and well pumping.

o Reuse reduces river flows and well pumping.

o Reservoirs partially reduce river flows.

o Increased pumping reduces spring flows.

Each alternative combination was checked to account for all water in the system. For instance, if wastewater is reused, that quantity must be subtracted from the amount that reaches the bays since it will no longer be discharged to the river.

Springflow Considerations

To match projected water demands, varying amounts of water from all sources were arranged in several combinations for each major alternative category. The major factor in determining the total amount of water to be supplied is springflow at New Braunfels and San Marcos. This is illustrated by the following equation for flow into and out of the Edwards Aquifer over time (if outflow does not exceed inflow):

Net average inflow to Edwards Aquifer = Average Pumpage + Average Springflow

If, for example, springflow is to be increased, then pumpage has to be reduced by meeting water demands from sources other than the Edwards Aquifer. Springflow targets were set and the amount of water from new sources was varied accordingly.

Target springflows can range anywhere from zero to the full historic average. The historic average is presented as follows (to nearest 10,000 acre-feet per year at Comal and San Marcos Springs combined):

1934 to 1982 Average = 320,000 acre-feet per year
Wet-Cycle 1978 to 1982 Average = 350,000 acre-feet per year
1982 Average With No Contribution from Wet-Cycle = 135,000 acre-feet per year
(= 600,000 recharge
- 450,000 pumpage) (90% to Comal and San Marcos Springs)

Recent average springflows of 350,000 acre-feet per year are abnormally high due to the large "bank account" of stored water in the Edwards resulting from high recharge during the wet years of the 1970's. Once this bank account of surplus storage is gone, springflows will be cut in half to about 135,000 acre-feet per year even if well withdrawals never increase above present levels.

To avoid the adverse impacts of no springflows detailed earlier, the approach used here was to provide for springflow at a level between the amount available at present pumpage levels (135,000 acre-feet per year) and full historic flow within the limits of available water supplies in the area. The target flows chosen for springs and Edwards pumpage are as follows:

Alternative	Flow in ac-ft/yr by Year 2040 Springs	Pumpage
Present Policies	0	780,000
II	160,000 (artificial)	530,000
I	200,000	400,000
III	250,000	350,000
For comparison:		
Equilibrium average with current pumpage	135,000	450,000
Historic average	320,000	250,000

Alternatives I and III, which include reservoirs as a source, reduce groundwater pumping to 90 percent and 80 percent of 1982 levels, respectively. Alternative III includes what is believed to be the maximum practical development of all water sources in the area--reservoirs, conservation, and reuse. Reaching historic springflow levels of 320,000 acre-feet per year would require development of an additional 100,000 acre-feet per year of new supplies compared to Alternative III. This amounts to a 25 percent increase in new reservoir deliveries to the primary study area compared to Alternative III. With the capital cost of new facilities in Alternative III already at about $1.9 billion dollars (see section COMPARISON OF ALTERNATIVES below), added costs of at least $0.2 to 0.6 billion for another 100,000 acre-feet per year of reuse or water imports are judged unacceptable to consumers in the area.

Without reservoirs in Alternative II, even maximum feasible amounts of conservation and reuse cannot reduce the ever growing demand on the Edwards, resulting eventually in no springflow. With average Edwards recharge projected into the future and Alternative II levels of Edwards pumping, Comal Springs would completely cease flowing in the mid-twenty-first century, and San Marcos Springs flow would be ever-declining, reaching about 95,000 acre-feet per year on average by year 2040.

To maintain flow in the rivers for Alternative II, it was assumed that wells would be installed downstream of the springs to pump a minimum flow amount when natural flows cease. The target amount chosen was 80,000 acre-feet (110 cubic feet per second) per year per spring for a total of

160,000 acre-feet per year. The 80,000 target meets the minimum flow requirement of 72,000 acre-feet per year to maintain aquatic biota below San Marcos Springs (see Chapter 4). An equivalent amount was allocated to Comal Springs.

Although wells pumping into the Comal and San Marcos Rivers could maintain a sizeable flow, such a system would not be as desirable as natural flow. Water could not simply be pumped back into Landa and Spring Lakes (where springflow now originates) because the pumped water would flow back into the ground through the same fissures that now allow spring water to flow up. Lining the lakes to prevent escape of water would destroy the existing natural setting. Therefore, in Alternative II, augmentation wells were assumed to be installed downstream of the current lakes, with exact locations to be determined during subsequent engineering studies if this alternative is adopted. Costs for new recreational lakes at these downstream sites were included in this analysis. However, the natural attractions at the existing spring-fed lakes would be lost.

Another major drawback with continuously pumping river augmentation wells at New Braunfels and San Marcos is the danger of saline water intrusion into municipal wells in the area. The freshwater zone is very narrow in these locations, particulary at New Braunfels. The augmentation wells could be no more than a few hundred feet away from the bad-water line. If Edwards water elvels are lowered over an extended period of time--which would be the case in Alternative II--there is a significant risk that salts, sulfates, and chlorides would migrate from the bad-water zone into municipal wells at New Braunfels and San Marcos. The TDWR states in its 1984 report, "Water for Texas":

> An extreme lowering of water levels below the 1950's leve in the Nueces, San Antonio, and Guadalupe River Basins may cause a significantly large invasion of saline water which not only may contaminate municipal, industrial, and irrigation freshwater supplies but also any flows at Comal, San Marcos, and other springs which are located near the fresh and saline water interface of the aquifer.

<u>Range of Alternative Sources</u>

In addition to the Present Policies Alternative a total of 13 new alternatives were considered, several within each major alternative category. The range of water sources considered is shown in Table 5-1.

Water conservation amounts are based on the assumption of 5-10 percent municipal conservation savings for effective

Table 5-1

RANGE OF ALTERNATIVE WATER SOURCES CONSIDERED

Source	Alternative I	Alternative II	Alternative III
Conservation[a]	5 to 10%	15%	5 to 15%
Reuse[b]	0 to 20%	20 to 30%	0 to 30%
Saline Water[a]	0 to 40%	0 to 20%	0 to 30%
New Recharge Reservoirs	0 to 3	0	0 to 3
New Supply Reservoirs	3 to 5	0	4 to 5
Ground Water Overdraft[c]	0 to 10%	0 to 25%	0
<u>Environmental Flows</u>			
Springflows (1,000 ac-ft/ yr) by year 2040	160 pumped to 200 natural	160 pumped to 230 natural	250 natural
Bay inflows (1,000 ac-ft/ yr) by year 2040, gauged and ungauged	1,700 to 2,300	2,000 to 2,200	1,700 to 2,200

[a]Percent of primary area municipal and industrial demands for cities over 5,000 population

[b]Percent of San Antonio's municipal and industrial demands

[c]Percent of average annual recharge amount

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voluntary programs and 10-15 percent if additional mandatory measures are used including required low-use plumbing fixtures, landscaping controls, watering restrictions and conservation-oriented rate structures. These estimates are achievable on a long-term sustained basis based on experience in other cities (see Appendix K). Although larger use reductions have been recorded during emergency drought conditions in some cities, water use generally returns to previous levels after the emergency is over. Therefore the sustained average of 15 percent for municipal conservation is considered a reasonable upper target level for the future. Over 30 percent conservation is assumed for agricultural use based on TDWR projections.

Wastewater reuse amounting to as much as 30 percent of municipal and industrial demand was assumed, based on existing and planned programs in other cities. San Antonio is considered the only reasonable candidate for a major program of this type in the primary study area since it is the only city with a significant amount of wastewater that can have an impact on total water supply needs. A major reuse program will require additional detailed engineering studies as well as significant public education effort to gain public support. The following reuse projects assumed in this analysis are based on review of available literature as presented in Appendix J:

Reuse Option	Amount in ac-ft/yr by Year 2040
City Public Service (CPS) powerplant cooling water	60,000
Irrigation of central San Antonio parks	1,300
Conveyance to Bexar-Medina-Atascosa Water Improvement District #1 for agricultural reuse in exchange for Medina Lake water recharged to the Edwards	35,000
Edwards recharge from northern San Antonio wastewater plant effluent and/or Residential irrigation in new areas with same effluent	up to 144,000

Maximum reuse potential of 180,000 acre-feet per year for municipal uses and 60,000 acre-feet per year for CPS use was assumed. This amounts to about 70 percent of all wastewater discharged by year 2040, but still allows about the same amount of treated effluent to discharge to the San Antonio River. This is because the reuse quantities will essentially be taken from wastewater plants serving new growth areas.

Recharge of the Edwards Aquifer with treated effluent would only be undertaken after detailed studies demonstrate that it is a safe and reliable process. The water would most likely be recharged through recharge wells after being treated to drinking water quality under careful supervision and monitoring. El Paso has been successfully operating an aquifer recharge project like this since June 1985.

Available Edwards Aquifer Water

Various pumpage amounts were assumed depending upon the alternative examined. For the Present Policies Alternative, nearly all additional demands are met from the Edwards Aquifer without regard to any desired level of pumpage since there are no restrictions to such use. For the other alternatives, an attempt was made to limit Edwards withdrawals by meeting water demands from other sources. Progressive drawdown of the aquifer and its attendant adverse impacts can be prevented by limiting total withdrawals to the approximate average recharge amounts.

The 1934 to 1982 period-of-record average recharge is 608,000 acre-feet per year. For future planning purposes, however, this value will probably be somewhat lower due to additional development in the Hill Country. Much of the 200,000-acre-feet-per-year natural recharge of the Trinity Group Aquifer is believed to re-emerge as natural stream and springflow. Additional pumpage from this aquifer may result in the capture of this natural discharge, with a corresponding decrease in the baseflow of area streams that recharge the Edwards Aquifer. A reduction of an average 8,000 acre-feet per year in recharge to the Edwards was estimated to occur by year 2040 due to additional pumpage from the Trinity Group Aquifer (see section, Hill Country Supply, below). Therefore recharge of the Edwards was assumed to decline from an average 608,000 acre-feet per year in 1980 to 600,000 acre-feet per year in 2040. Increased Trinity Group Aquifer use thus constitutes an area of some vulnerability for Edwards Aquifer users, over which the primary area has little control.

Available Secondary Aquifers Water

Although the yields of secondary aquifers in the study area are not all well quantified, the following values have been used for purposes of estimating year 2040 supplies based on TDWR studies as referenced in Appendix F:

Aquifer	Year 2040 Yield (acre-feet per year)
Carrizo Sand	100,000
Associated Aquifers	143,000
Gulf Coast Aquifer	48,000
Trinity Group Aquifer	26,000
	317,000
Rounded	320,000

Considerably higher levels of pumpage are now occurring in the Carrizo Sand and associated aquifers. However, it was assumed that as these aquifers continue to be overdrafted, pumping would eventually be self-limiting by economic factors when the water depth reaches about 400 feet after the turn of the century. Withdrawals are then assumed to approximately equal the natural rates of recharge shown. The Trinity Group Aquifer has an estimated recharge of 200,000 acre-feet per year, most of which re-emerges as streamflow. The yield of 26,000 acre-feet per year was based on a TDWR-estimated 1980 pumpage of 18,000 acre-feet per year and a projected additional withdrawal of 8,000 acre-feet per year by year 2040 (see next paragraph).

<u>Hill Country Supply</u>

The Hill Country's principal source of water supply is the Trinity Group Aquifer. However, uncertain well yields and cases of less than desirable chemical quality pose a unique problem to the rapidly growing region. For purposes of this study it is assumed that during the planning period of 1980 to 2040 most of the new water supply requirements will be met from other sources to overcome this problem.

Of the approximately 36,000 acre-feet per year additional demand between 1980 and 2040 for lands overlying the Trinity, 28,000 acre-feet per year are estimated to come from other sources as follows:

- 9,000 acre-feet from Canyon Reservoir to Comal and Hays Counties outside of New Braunfels and San Marcos

- 10,000 acre-feet from the Edwards Aquifer to north Bexar County

- 7,000 acre-feet supply to Kerrville from the planned Upper Guadalupe project (potential yield of 9,000)

- 1,000 acre-feet supply to Boerne from a planned Guadalupe River diversion

- 1,000 acre-feet supply to Bandera from an assumed Medina River diversion

The remaining 8,000 acre-feet per year are expected to come from the Trinity for generally dispersed individual well owners who cannot be economically served from new transmission pipelines.

FIRST SCREENING OF ALTERNATIVES

Methodology

Several water source combinations were prepared for comparison. These are presented and evaluated in Appendix M. The particular combinations selected for further detailed comparison are shown in Table 5-2 and described in the following section. They were arrived at by a screening process that scored each combination on the basis of the following tangible and intangible factors:

- Water sufficiency
- Edwards Aquifer overdraft
- Feasibility
- Cost
- Implementation

Other Alternatives Considered

Several alternatives not listed in the screening process were evaluated but deleted from further consideration for various reasons.

Recharge of Imported Surface Water to Edwards. Water could be piped from a new reservoir and recharged to the Edwards Aquifer during wet years of excess river flow. This would require the Edwards water level to be below the mouth of the springs so that recharged water would not escape. Augmentation wells at the springs would be needed to maintain streamflows in the Guadalupe basin. During average and dry years the reservoir (for example, Cuero) would supply water to the primary area in lesser quantities via pumping plants and a pipeline to the greater San Antonio area, but would have additional capacity to pump the higher flood-season flows. The flaws in this arrangement are as follows:

- There is significant risk of saline water contamination of San Marcos and New Braunfels municipal supply wells due to "bad-water"intrusion where Edwards water levels drop due to river augmentation well puming downstream of the springs.

- Endangered species would be lost at the headwater of the springs and recreation opportunities at

Table 5-2

WATER SUPPLY
ALTERNATIVES SELECTED FOR ANALYSIS

Source Required by Year 2040	Amount (Rounded AF/YR) for: Present Policies	ALT. I	ALT. II	ALT. III
Edwards Groundwater Pumpage	790,000	400,000	690,000	350,000
(% overdraft)	(30%)	(0%)	(15%)	(0%)
Secondary Aquifers Pumpage	320,000	320,000	320,000	320,000
(% overdraft)	(0%)	(0%)	(0%)	(0%)
Conservation	0±	50,000	90,000	50,000
(% of municipal demand)		(10%)	(15%)	(10%)
Reuse[b]	0	100,000	180,000	100,000
(% of municipal demand)		(20%)	(30%)	(20%)
New Reservoirs (Deliveries)				
Applewhite	0	50,000	0	50,000
Cibolo	0	25,000	0	25,000
Goliad	0	132,000	0	132,000
Cloptin Crossing	0	43,000	0	0
Cuero I	0	145,000	0	0
Cuero I & II	0	0	0	302,000
Resulting Flows by Year 2040				
San Marcos + Comal Springs	0	200,000	160,000[b]	250,000
Corpus Christi Bay[c]	480,000	480,000	480,000	480,000
San Antonio Bay[c]	1,830,000	1,370,000	1,680,000	1,290,000

[a]Excluding existing and proposed reuse for CPS cooling water

[b]River flow maintained by artifical well pumping

[c]Includes gaged and ungaged flow

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these sites would suffer if natural springflows were not maintained.

- The cost would be significantly higher than other options with conventionally operated reservoirs delivering a firm yield contract amount each year. Additional costs include larger delivery pumps and pipelines, artificial recharge facilities (probably recharge wells) to get the water into the Edwards at a rapid rate, and augmentation wells at the springs.

Uvalde County Wells Supplying Greater San Antonio. It is possible that Comal and San Marcos Springs could be kept flowing at the same rates for a longer period even while pumping more groundwater than the average recharge rate by locating new wells in the Uvalde area to serve greater San Antonio. Based on review of groundwater data, this is theoretically possible because the groundwater levels near Uvalde are about 200 feet higher than at the springs, so water could continue to flow to the springs even if levels at Uvalde were locally depressed by new pumping. This approach was rejected at this time because of:

- Political complications arising from objections of residents near the new pumping center. Groundwater levels would be lowered locally to benefit distant users.

- Short-lived benefits after building an expensive 70 mile pipeline since ultimately the overdrafts would dry up springflows when storage was depleted a sufficient amount. By that time, the "window of opportunity" to plan for and construct other supply facilities such as reservoirs might be lost.

Water From Canyon Reservoir to San Antonio. Some past plans have envisioned pumping up to 50,000 acre-feet per year from Canyon Reservoir to San Antonio or diverting this released amount downstream near New Braunfels. This is the full permitted yield of the reservoir. However, since construction was completed in 1964, many delivery contracts have been made for downstream users, currently committing 22,000 acre-feet per year. Also other upstream communities in the river basin, particularly in the Hill Country, who have no dependable source other than the Guadalupe River will be given first priority to the river water. This will diminish the available supply at Canyon. Although the remaining amount available for San Antonio cannot be accurately determined at this time, a reasonable maximum is on the order of 15,000 to 20,000 acre-feet per year. Costs for delivery and treatment of 20,000 acre-feet per year of water from either Canyon Reservoir or the last incremental 20,000 acre-feet per year of potential Cuero Reservoir water are both estimated by the consultant at about $350 per acre-foot. Since there is no significant cost savings for Canyon versus Cuero delivery, and since the best use of the area's resources favors reserving Guadalupe River water for Hill Country use, this alternative was not considered further.

<u>Regulated Limitation of Pumping</u>. Mandatory limits on pumping have been set by court order or legislative action in some areas that have no other alternative or when the parties involved cannot agree on developing other supplies. This is viewed as a less desirable option than the development of a comprehensive resource management plan that uses all economically feasible water supplies as envisioned in this study (see Appendix L). Pumping limitations without any new supplies would stifle the area's growth and economic development, contrary to stated study goals (Chapter 1).

However, if pursued in conjunction with making new supplies available, this idea merits consideration. It could be particularly useful in implementing the groundwater rights purchase program mentioned below. A system could be established based on new legislation, whereby existing pumpage quantities would first be inventoried and permits granted to existing users (existing rights would be "grandfathered"). Permitted water rights could then be voluntarily sold back to the permitting agency--the Edwards Underground Water District or a new area-wide management board--for use in satisfying growing municipal demands. The purchased water would not need to be transported via pipeline; municipal water suppliers in the greater San Antonio area would merely be permitted to withdraw this additional water from their own wells "downstream" of the farmed areas in the west.

This system would require that a limit, or "cap", be placed on pumping from the Edwards aquifer. Otherwise, new wells on new tracts of land near the currently irrigated farm areas could be drilled by others for irrigation purposes to fill the gap in the marketplace left by those farmers who sold their pumpage rights. The limit on total pumpage would need to be set by special legislation and would be equal to the targets set in this Chapter for the alternatives--400,000 acre-feet per year for Alternative I and 350,000 acre-feet per year for Alternative III.

Again, due to the uncertainty of participation in a water rights purchase program, this option is not included in the alternatives described below. However, a program such as this could be developed along with any of the alternatives.

Purchase of Water Rights. Pumping from the Edwards Aquifer could be reduced by buying either surface or groundwater rights.

Run-of-river surface water rights could be purchased on the Guadalupe River and the water pumped to greater San Antonio. A less costly option would be to buy the groundwater rights of nearby Bexar, Medina, and Uvalde County farmers, on a voluntary basis. This could make available for municipal use the water currently used for irrigation. This idea was recently advanced by agricultural interests in Medina and Uvalde Counties. At 130,000 acre-feet of pumpage in 1982, agriculture accounted for 30 percent of Edwards withdrawals.

Existing rights to withdrawal would be protected, but a cap would need to be placed on the total withdrawals allowed from the Edwards Aquifer as established by new legislation. Purchase could take a variety of forms including the following possibilities:

- Purchase of a portion (for example, 25 percent) of a farmer's water rights, such that funds from the purchase could be used for acquisition of water-saving irrigation equipment. Thus, the farmer could use water more efficiently and maintain production levels.

- Option to purchase all of a farmer's water rights in dry years. Purchase might be triggered by a drop in the water table to a predetermined level and/or substandard rainfall amounts for several preceding months. The farmer would be paid only in the years that the option was exercised, and the purchase price would be a previously agreed upon amount.

- Purchase of a farmer's entire water right through cash payment at time of purchase. This would allow a farmer to switch to dryland farming or to sell the land to others who would be interested in dryland farming.

While this creative option offers benefits for both farmers and city dwellers, the degree of participation it might prompt cannot be predicted. Assuming legislation could be passed to establish the concept of groundwater withdrawal rights, purchases could provide relatively low-cost water supplies. The relative impact of such a program can be gauged by considering that if 50 percent of all agricultural groundwater pumping ceased, it would provide about 20 percent of the new water supplies needed by the year 2040 in the primary study area.

Because of the difficulties in predicting participation, this type of option is not included in the alternatives outlined below. However, opportunities in this area could be pursued in conjunction with any of the alternatives.

Recharge Reservoirs. Although recharge reservoirs appear to offer great promise, they did not survive the screening process because:

- The available sites offer small recharge capacity (15,000 to 30,000 acre-feet per year) in relation to primary area demand of 900,000 acre-feet by year 2040.
- Costs are only slightly less than for conventional reservoirs (about 80 percent of the cost), yet they are less reliable because they operate in wet years during the time of least need.
- Water rights issues are a significant impediment. In a 1983 study the Bureau of Reclamation estimated that, based on a preliminary analysis, the yields of Lake Corpus Christi and Choke Canyon Reservoir would have been reduced in 8 out of 31 years of analyzed streamflow data. In the absence of more detailed studies to better quantify the effects, the potential threat to downstream water rights was judged a significant obstacle to developing additional recharge reservoirs at this time.

ALTERNATIVES SELECTED FOR FURTHER ANALYSIS

Alternatives include selections from each of Alternatives I, II, & III screened above, plus the Present Policies Alternative. Alternatives are described in detail below and water deliveries are summarized in Table 5-2.

Present Policies Alternative

Under this alternative, all new water demands would be met from ground water, either the Edwards or the secondary aquifers.

Average Conditions. During average-weather periods, pumpage of the Edwards would increase as follows:

	Estimated Pumpage (Acre-Feet per Year) 1982	2040
Edwards Aquifer	450,000	790,000

The 2040 pumpage value exceeds the average annual recharge of the Edwards by about 180,000 acre-feet (around 30 percent).

The present pumpage from secondary aquifers is in an overdraft condition. The requirement in 2040 to meet projected demands will increase to about 500,000 acre-feet. The aquifers have an estimated safe yield of only about 320,000 acre-feet which was used as the pumpage value for year 2040 assuming future pumpage is economically limited to this amount due to excessive drawdowns.

Several ongoing water supply efforts can help reduce the groundwater overdraft of the Edwards, but not significantly. Applewhite Reservoir is being planned for construction by the City Water Board of San Antonio. Its annual average supply of about 50,000 acre-feet would reduce the overdraft from 30 down to 20 percent of the annual recharge amount, but would not eliminate the overdraft impacts. Weather modification and increased voluntary conservation efforts would also help, but would not make a significant sustained contribution to the area's water supplies.

Average annual gauged and ungauged inflow to the bays at the Gulf would be:

Corpus Christi Bay	480,000
San Antonio Bay	1,830,000

On an average basis, groundwater levels would decline as follows based on TDWR's groundwater computer model (see Appendix H):

	1980 to 2040 Groundwater Decline (feet)
Uvalde County	89
San Antonio	147
New Braunfels	84

Figures 5-4 and 5-5 show resulting springflows and groundwater levels, respectively. Springflows will cease permanently in the early- to mid-twentieth century. Prior to this time, springflows will also cease during dry periods.

Drought Conditions. Under a severe, sustained drought such as occurred here from 1947 to 1956 (drought of record), response of the Edwards Aquifer would be as follows if the drought occurred either early (1986 to 1995) or late (2029 to 2038) in the study period:

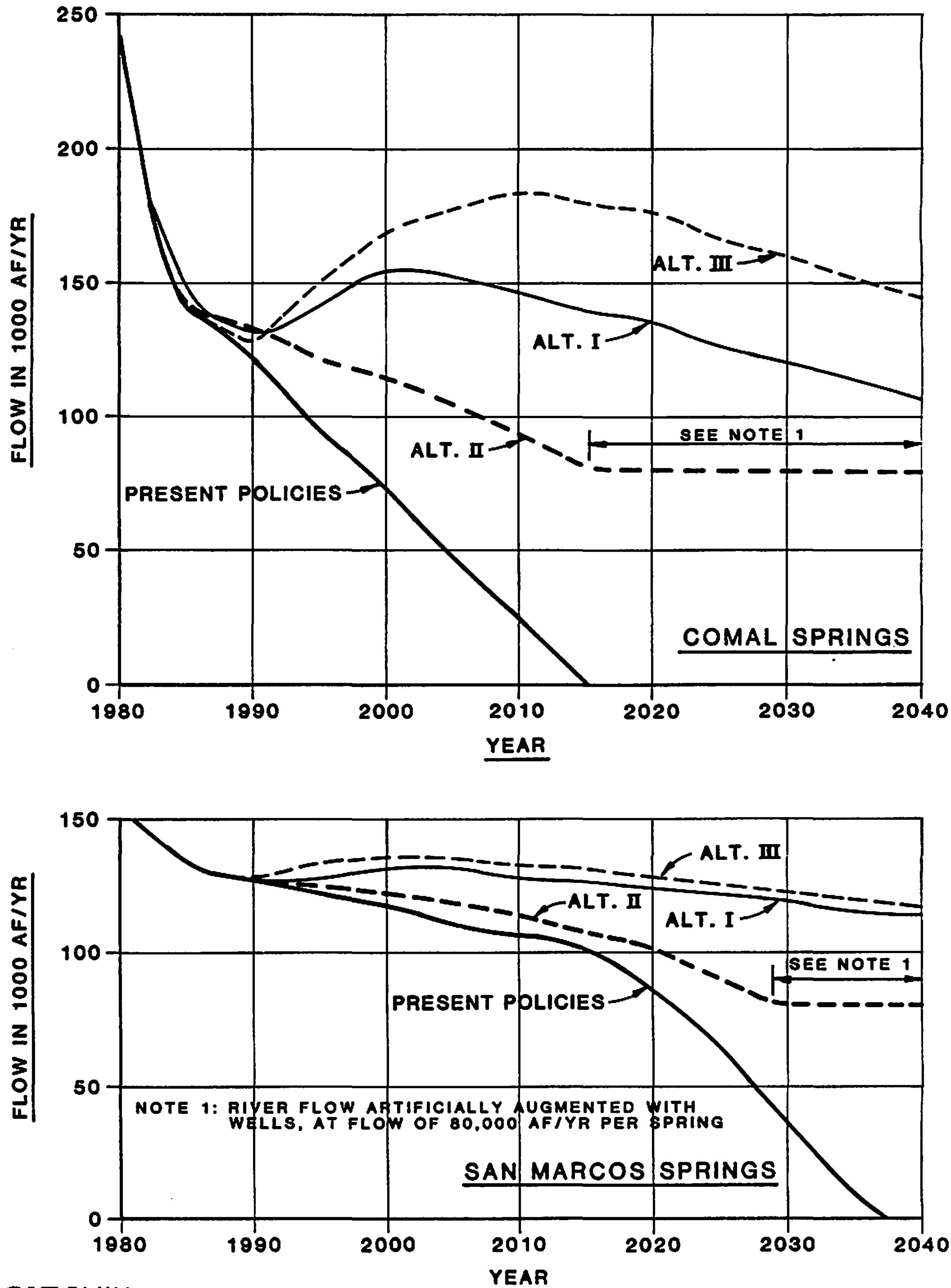

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FIGURE 5-4
ALTERNATIVE SPRINGFLOWS

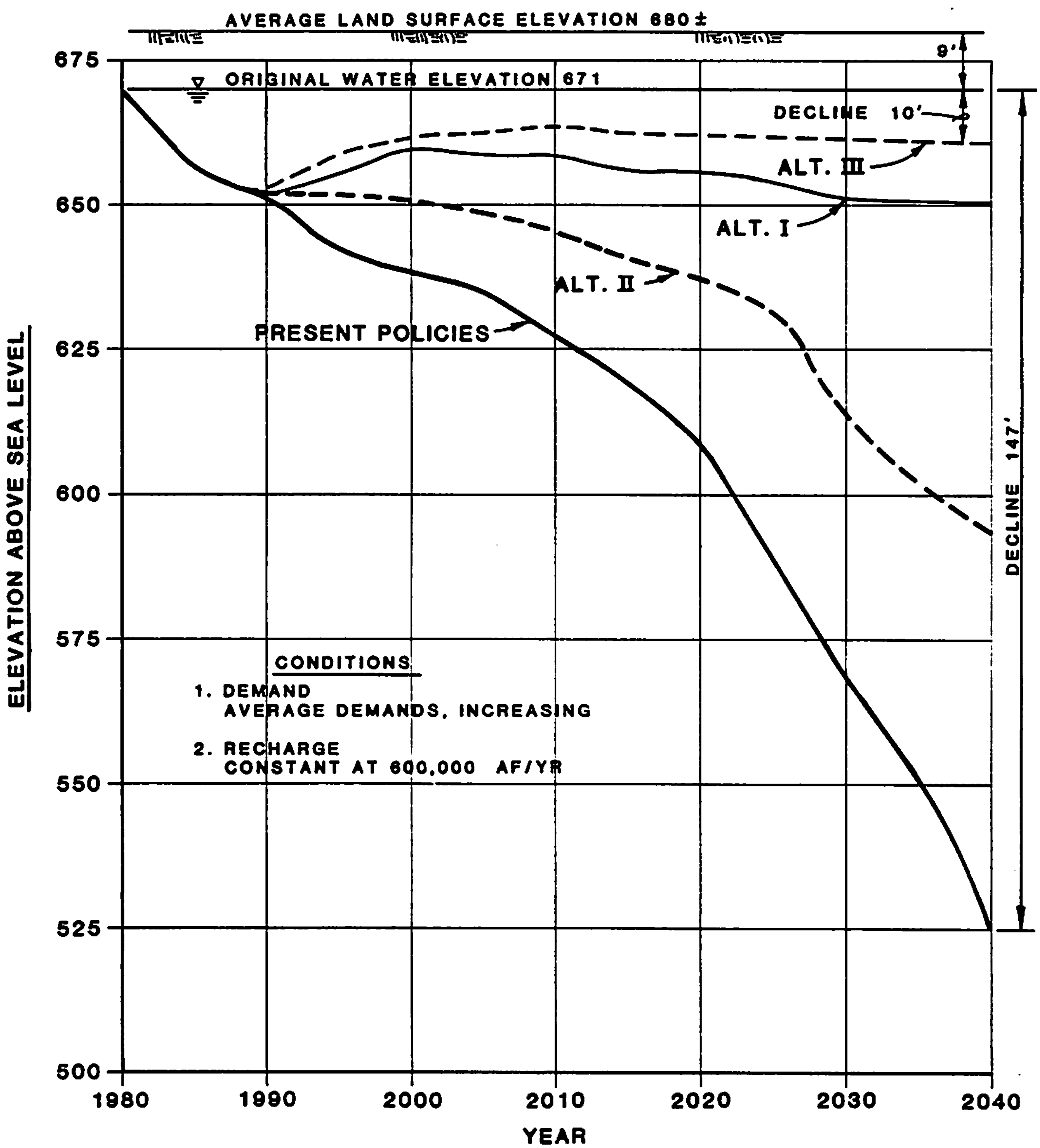

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FIGURE 5-5
ALTERNATIVE WELL WATER LEVELS
IN SAN ANTONIO AREA

Item	Early Drought (1986 to 1995)	Late Drought (2029 to 2038)
Comal Springs-- years of no flow	6	10 (all)
San Marcos Springs-- years of no flow	0	9
Well water level decline in San Antonio in worst year, compared to 1980 levels	90'	270'

This is shown graphically in Figures 5-1 to 5-3 (pages 5-3 to 5-5). The impacts become more severe with time but are already significant today. These impacts were described previously in this chapter. A drought of this magnitude or worse could occur at any time.

Although San Marcos Springs remains flowing during an "early" drought, it will completely cease flowing for 9 out of 10 years during a "late" drought. Water table decline in San Antonio during a late drought is triple the amount experienced during an "early" drought. Declines are significant throughout the primary area, with drops of 210 feet for the Uvalde area, 190 feet for New Braunfels (decline is computed for the worst year of the drought in comparison to 1980 water table levels).

Demands during hot weather drought conditions are projected by TDWR to increase over 33 percent for municipal users. To reduce the drawdown in area aquifers, it is recommended that a program similar to the City of San Antonio/Edwards Underground Water District's Operation Water Conservation be implemented on a cooperative basis throughout the study area.

Alternative I

Alternative I makes use of existing laws and institutions and furnishes water from all economically feasible sources, including new reservoirs. It incorporates a conjunctive use water supply plan, making use of groundwater at safe yield[1] levels and both existing and new surface water reservoirs plus conservation and reuse to supply the remainder. All

[1]Safe yield is here used to mean the average annual rate of replenishment from surface streams and direct rainfall. Greater pumpage would produce the undesirable impacts mentioned under the Present Policies Alternative.

sources would be optimally managed to take advantage of all feasible water resources at the lowest possible cost.

Average Conditions. In summary, projected water demands for the year 2040 would be met from the following sources:

Source	Average Annual Acre-Feet Per Year
Edwards Aquifer Pumpage 400,000 Springflow 200,000	600,000
Secondary Aquifers	320,000 (safe yield)
Conservation	52,000 (10% of M&I demand in primary area cities)
Reuse of Wastewater (in addition to 60,000 acre-feet used by CPS)	100,000 (20% of San Antonio M&I demand. 25% of wastewater flow)
Existing Reservoirs[2] (Corpus Christi, Choke Canyon, Medina, Calaveras, Braunig, Coleto, Canyon)	418,000
New Reservoirs[2]	
Applewhite (in 1990)	50,000
Cibolo (in 2010)	25,000
Goliad (in 2010)	132,000
Cloptin Crossing (in 2015)	43,000
Cuero I (in 2020)	145,000
Local Supplies[3]	89,000
Surface Water Diversions to Secondary Areas and Coastal Basins	390,000

[2]Total areal yield of reservoir in each year of the 1947 to 1956 drought, prior to adjusting for required downstream releases. No adjustments in Goliad Reservoir yields are made to account for future treated wastewater inflow; these amounts are included in the category "surface water diversions."

[3]Small local reservoirs of less than 5,000 acre-feet capacity not specifically named.

Figure 5-6 shows the location of proposed reservoirs and pipelines. Staging of new facilities is shown graphically on Figure 5-7. Facilities were scheduled to meet a target pumpage level for the greater San Antonio area as soon as possible to stabilize well levels and springflows.

"Greater San Antonio" as used here includes the following communities:

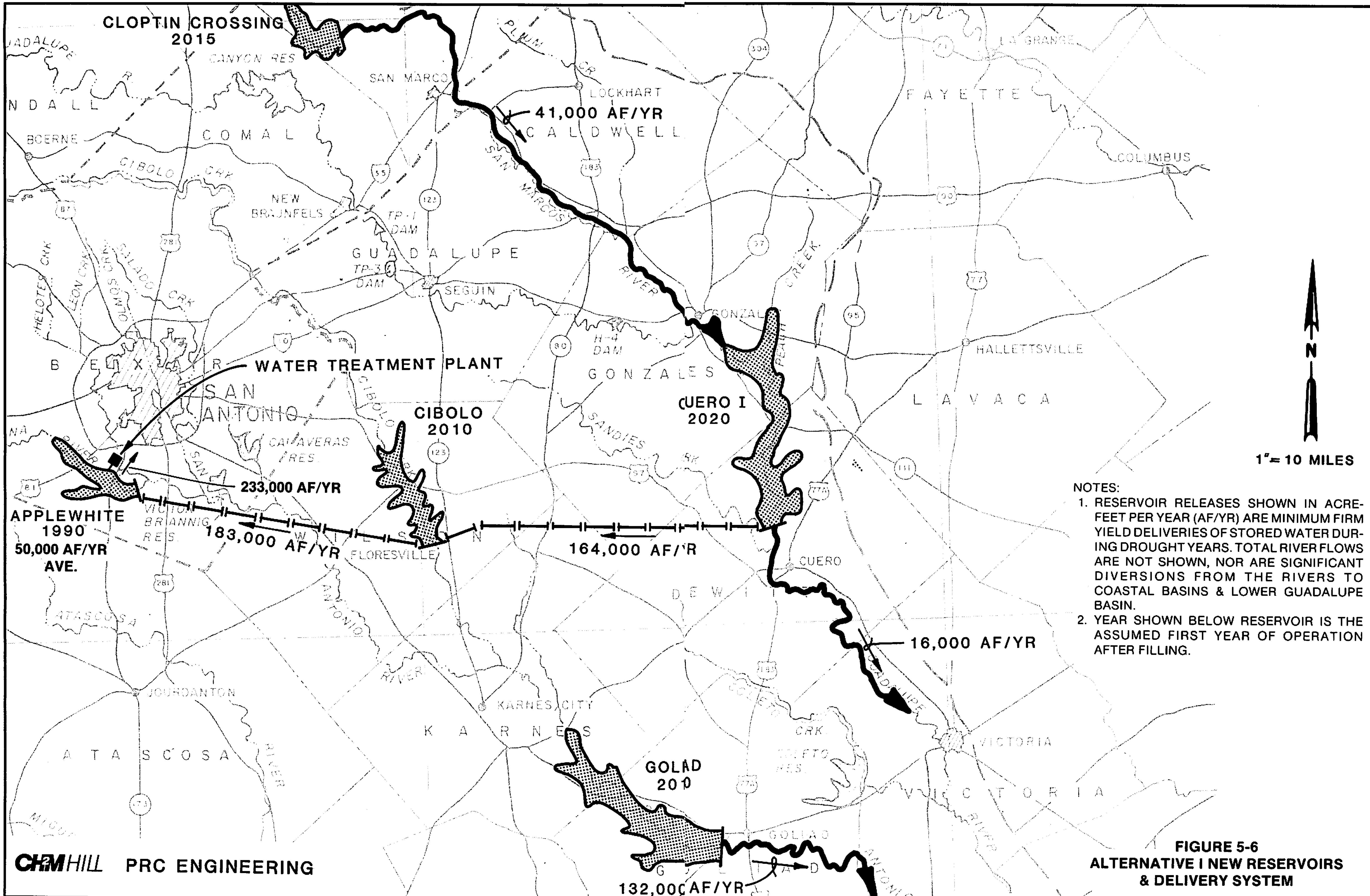
- Alamo Heights
- Balcones Heights
- Castle Hills
- Converse
- Fort Sam Houston
- Hollywood Park
- Kirby
- Lackland AFB
- Leon Valley
- Live Oak
- Lytle
- Olmos Park
- Randolph AFB
- San Antonio (incorporated limits)
- Schertz
- Terrell Hills
- Universal City
- Windcrest
- Shavano Park
- Somerset

Not all of these communities would necessarily be served water by the City Water Board of San Antonio since it may not be economical to extend water mains to all areas and since some areas are served by other private or public water utilities. The goal is to supplement the greater San Antonio area's current groundwater supply with surface water imports in the most economical fashion. Major utilities such as Bexar Metropolitan Water District and Lackland City Water Company could either be provided supplemental surface water directly or could pay an "in-lieu" charge to the regional management entity for the stabilization of water levels afforded by this alternative.

New Braunfels and San Marcos would also receive new surface water supplies as described below.

Note that there is extra capacity in Cuero Reservoir when first built but demand is projected to catch up and exceed that margin by year 2040. The greater San Antonio area would not take delivery of this water until needed to meet the target pumpage value to maintain a designated springflow. However, the greater San Antonio area would be responsible for water supply costs associated with the full allocation of Cuero Reservoir reserved water, whether the water is taken or not. Cost to pump it to San Antonio and treat it is estimated at $160 per acre-foot (excluding capital repayment) compared to $14 per acre-foot for groundwater. During the interim period surface water might be sold to downstream buyers to defray San Antonio costs.

Water from new reservoirs could be obtained through contract among existing entities. Water would be pumped from Cuero I



NOTES:

1. RESERVOIR RELEASES SHOWN IN ACRE-FEET PER YEAR (AF/YR) ARE MINIMUM FIRM YIELD DELIVERIES OF STORED WATER DURING DROUGHT YEARS. TOTAL RIVER FLOWS ARE NOT SHOWN, NOR ARE SIGNIFICANT DIVERSIONS FROM THE RIVERS TO COASTAL BASINS & LOWER GUADALUPE BASIN.
2. YEAR SHOWN BELOW RESERVOIR IS THE ASSUMED FIRST YEAR OF OPERATION AFTER FILLING.

FIGURE 5-6
ALTERNATIVE I NEW RESERVOIRS & DELIVERY SYSTEM

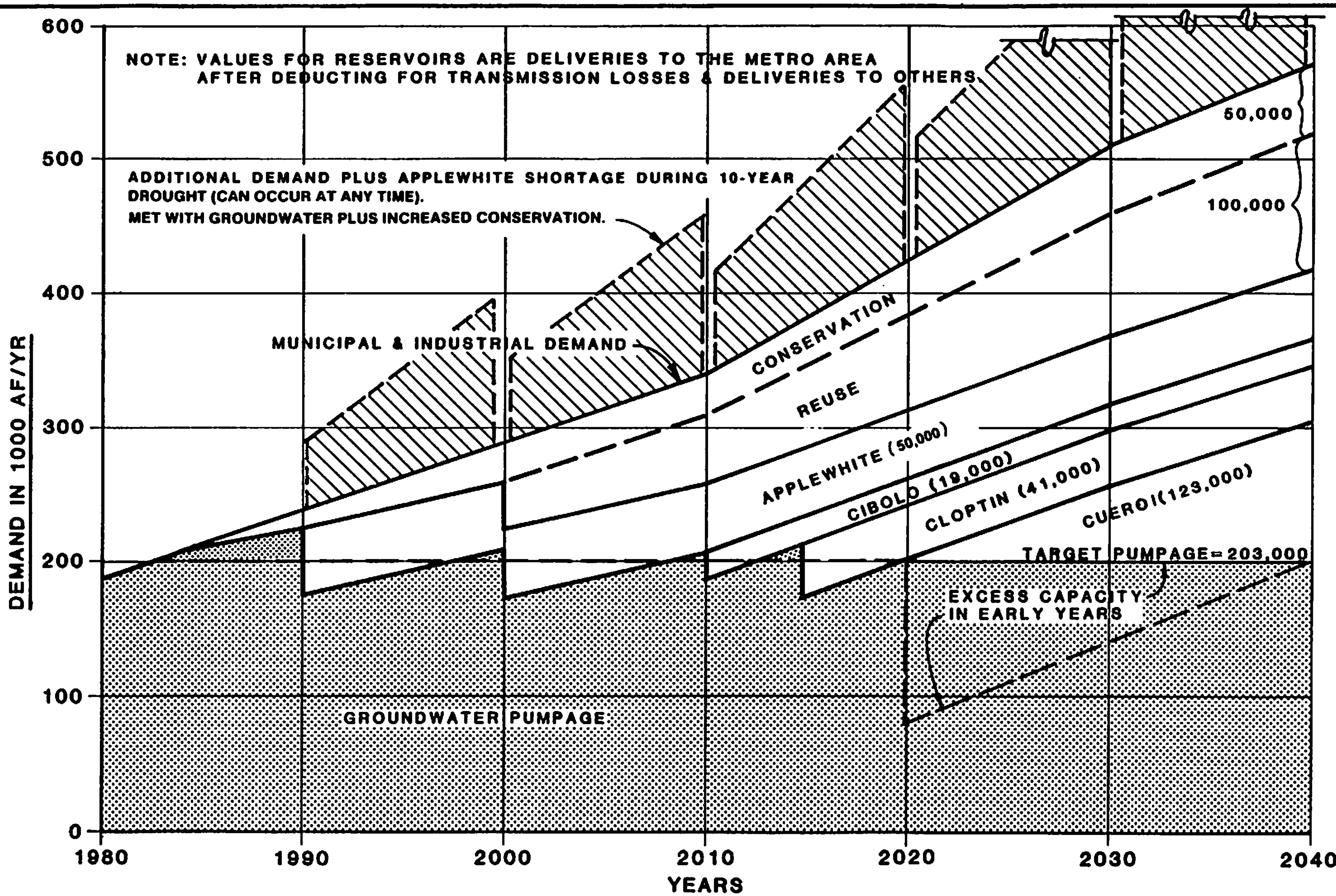


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FIGURE 5-7
ALTERNATIVE I—SUPPLY PHASING PLAN FOR GREATER SAN ANTONIO AREA

Reservoir to greater San Antonio at a maximum rate of 129,000 acre-feet per year (out of 145,000 available) by interbasin transfer contract with the Guadalupe Blanco River Authority. The pipeline would also carry 41,000 acre-feet of water released upriver from Cloptin Crossing Reservoir.

All of the Applewhite Reservoir's annual average yield and 20,000 acre-feet of Cibolo's yield would also be pumped to the city in a common pipeline. Surface water would constitute approximately 40 percent of the greater San Antonio supply by the year 2040.

Since the Guadalupe Basin secondary area's demand of 294,000 acre-feet per year (primarily future industry located near the confluence with the San Antonio River) cannot be met with the remaining water in Guadalupe River reservoirs, the deficit would be supplied from San Antonio River flow (including City of San Antonio wastewater return flows) via regulation at Goliad Reservoir. An additional 41,000 acre-feet would come from river flow when available. The industrial growth is expected to occur along the Victoria Barge Canal, between Victoria and San Antonio Bay.

San Marcos and New Braunfels are assumed to meet about half of their year 2040 municipal and industrial demands with Guadalupe Basin water since they are conveniently located near rivers. Delivery would be via pipeline and pumping plants on the Blanco River for San Marcos and at Lake Dunlap or a new diversion dam on the Guadalupe River for New Braunfels. Firm storage capacity could be provided by Cloptin Crossing and Canyon Dam, respectively. For New Braunfels, the selection of the most cost-effective diversion site would depend on the relative costs of the new diversion dam compared to the longer pipeline from Lake Dunlap, about 15 miles away. This supplemental surface water would be used to reduce demands on the Edwards in order to maintain natural spring flow and to provide additional insurance against saline water intrusion into existing well fields near the bad-water line. Wells would continue to be used for summer peaking periods and for dry years when demands are higher than normal.

Major demands in the secondary study area and coastal basins are assumed to be met primarily with available river flow. The one notable exception is the Guadalupe River secondary area which is allocated new reservoir storage in Goliad Reservoir (all of the firm yield) and about 10 percent of Cuero I's firm yield. It must be recognized, however, that there may be comptetition from coastal basin water users (such as Corpus Christi) for the available firm reservoir supplies. Actual allocation of reservoir supplies to lower basin users may therefore differ from the assumptions given here.

Natural flow from the Edwards at San Marcos and Comal Springs is perpetuated at the following rates on an average basis:

Spring	Simulated Flow (Acre-Feet Per Year) 1985	2040	60-Year Average
Comal	145,000	95,000	140,000
San Marcos	130,000	105,000	130,000
	275,000	200,000	270,000

This is accomplished by substituting new surface water supplies and treated wastewater effluent for Edwards water otherwise pumped by current and future users.

Since computer model studies indicate that both springs could go dry during a sustained drought, provision would be made to install augmentation wells to keep each river flowing at a target 80,000 acre-feet per year, or 110 cubic feet per second. Actual installation of these wells could be postponed until needed. However, early in the planning period well sites should be located and arrangements made for a temporary or permanent power source so that wells could be drilled and pumping begun in a minimum amount of time.

Groundwater levels predicted for this alternative (see Appendix H) are as follows, assuming average recharge to the Edwards:

	1980 to 2040 Groundwater Decline (feet)
Uvalde County	22
San Antonio	19
New Braunfels	4

Water levels decline in the first 10 years or so before alternative supplies are delivered, but then rise to a stabilized level as shown on Figure 5-5 for water levels in the San Antonio area. Note that average-recharge conditions are shown here only as a means of comparing alternatives and showing trends; actual water levels will vary considerably from year to year based on actual weather conditions.

Average annual inflow to the bays at the Gulf would be:

San Antonio Bay	1,370,000 acre-feet
Corpus Christi Bay	480,000 acre-feet

Operational Strategies. There are several ways to operate a conjunctive use system of reservoirs and groundwater in the primary study area. A typical conjunctive use operation would be to take more water from surface streams in wet years, allowing groundwater levels to rise. Then in dry years, the stored "bank account" of groundwater could be drawn on. In the case of the Edwards Aquifer, however, the situation is complicated by the presence of the springs. If Edwards storage is allowed to build during wet periods by relying more heavily on reservors, the stored water will spill out at the springs, although not instantaneously as with a surface reservoir. A possible operational approach here would be to take a slightly greater than normal amount from wells following a wet year, thereby shaving the peak off the expected higher springflow that year that otherwise would have been surplus to the system. A lesser amount could be taken from wells if springflow were down in a prior time period. The concept is worth investigating with the currently available computer models of the Edwards and of the Guadalupe/San Antonio River system. However, one problem is that springflows and recharge do not always follow a predictable pattern.

Another concept to consider when contracting for reservoir supplies is "risk management." Under this concept, the buyer agrees, for example, to take a 10 percent shortage 5 percent of the time instead of a guaranteed delivery every year. Various sets of percentages could be agreed upon. The cost to the buyer would then be less since the water is not as valuable if not available 100 percent of the time.

Thought also needs to be given to the operation of the interconnected reservoir delivery system to greater San Antonio. If Applewhite is kept near full to maximize emergency storage, it would then have little capacity to impound Medina River storm flow, which could pass over the spillway and be lost for municipal use purposes. A possible operational strategy would be to vary the level in response to storm activity. The reservoir could be kept near full during non-rain periods. Then, before normally heavy rainfall periods, the inflow from Cuero/Cibolo could be halted, allowing the pumpage from Applewhite to the filter plant to lower the lake level in readiness for the storm inflow. Although some streamflow would be unavoidably lost due to prediction inaccuracies, the system operation could be varied to optimize yields. Cibolo Reservoir could also be used as a terminal storage facility alone or in conjunction with Applewhite to maximize Applewhite yield since water from the latter does not have to be pumped as far and is therefore less costly to deliver.

Drought Conditions. Under a 1950's type drought, response of the Edwards Aquifer would be as follows if the drought recurred in the decade 2030 to 2040:

	Groundwater Decline in Worst Year Compared to 1980 (feet)
Uvalde County	103
San Antonio	135
New Braunfels	81

Augmentation wells pumping 80,000 acre-feet per year at each spring would need to pump for 9 years at Comal and 6 years at San Marcos to avoid dropping below the target minimum flows that would otherwise occur.

Impacts from the same intensity drought occurring earlier--say, from 1986 to 1995--would be similar to but slightly less severe than those described for the Present Policies Alternative since some water supply contirubtions would be made by Applewhite Reservoir and some increased conservation efforts during this early period. A slight lessening of drought impacts would be expected throughout the study period as new water supplies become available. The new water supplies meet the requirements of projected growth and duce pumping from the Edwards by 10 percent. However, they are not sufficient to totally eliminate the adverse consequences that an extended, severe drought can have on this area.

Reservoirs could continue to deliver water at the amounts shown above since their firm yield amount is computed based on a drought period simulation. Alternatively, if the "risk management" approach is adopted, a slight shortage might be taken in reservoir deliveries, with more being taken from the Edwards in a given year or years.

A drought response conservation program would be in effect in San Antonio and is recommended throughout the study area as well.

Alternative II

Alternative II attempts to meet water demands with all sources except new reservoirs, and employs new laws and institutions as needed to better manage the area's water resources. Future demands are met by overdrafting the Edwards Aquifer because without new reservoirs, even the maximum feasible conservation/demand management and waste-water reuse programs cannot keep pace with the doubling of water demand in the study area by year 2040.

The following sources would supply projected year 2040 water demands:

Source	Average Annual Acre-Feet Per Year
Edwards Aquifer Pumpage 529,000 Springflow 160,000[4]	689,000
Secondary Aquifers	320,000
Conservation	92,000 (15% of M&I demand in primary area)
Reuse of Wastewater (in addition to 60,000 acre-feet used by CPS)	180,000 (30% of San Antonio M&I demand; 50% of wastewater flow)
Existing Reservoirs (Corpus Christi, Choke Canyon, Medina, Calaveras, Braunig, Coleto, Canyon)	418,000
New Reservoirs	0
Local Supplies	89,000
Surface Water Diversions to Secondary Areas and Coastal Basins	520,000

Due to the projected major new demands in the Guadalupe secondary area and the absence of reservoirs or other available supplies, these and San Antonio secondary area demands would have to be met primarily with non-firm available river flows (about 50 percent) as summarized below:

Source	Water Supplies (Acre-Feet Per Year)	%
Secondary Aquifers	120,000	30
Firm Yield of Existing Reservoirs	90,000	20
Non-Firm River Flow	230,000	50
Total (Guadalupe and San Antonio Secondary Study Area)	440,000	100%

[4]Artificially pumped from new wells into the rivers downstream of springs.

Although river flow in <u>average</u> years is sufficient to meet the demands, there would be shortages in any year with less than average rainfall.

The Gulf Coast Aquifer is not believed capable of supporting the predicted high industrial demands near Victoria, since the total safe yield throughout the aquifer's entire area is only 48,000 acre-feet per year.

Staging of new facilities is shown on Figure 5-8 for the greater San Antonio area. The first increment of reuse water (35,000 acre-feet per year exchange with Bexar-Medina-Atascosa Water Development District #1) is planned for around year 2000 with other reuse projects in north San Antonio (Edwards recharge and/or residential irrigation) implemented in stages in conjunction with wastewater treatment plant construction. A reuse program of this magnitude would require significant education and facilities planning effort to gain public acceptance and support. The full 30 percent recycle goal could not be achieved immediately but would be phased in over a period of 15 to 20 years.

On an average basis, groundwater levels would decline as follows (see Appendix H):

	1980 to 2040 Groundwater Decline (Ft)
Uvalde County	49
San Antonio	76
New Braunfels	49

Under this alternative, springflow will decline over time due to increasing Edwards overdraft. To keep springflows above the biota/recreation maintenance levels, permanent augmentation wells would have to be installed after the turn of the century assuming theoretical average recharge each year. In reality a drought prior to these dates would most likely trigger the well installations.

As described earlier in the section, "Springflow Considerations," the augmentation wells would maintain river flows at a minimum level but would not perpetuate the existing Spring Lake and Landa Lake at the springs. Although new manmade lakes downstream of the present lakes would be constructed under this plan as a mitigation measure, it is believed that tourism would greatly decline due to the loss of the natural springs attraction. Impacts of this artificial pumping are summarized as follows:

- Loss of natural springs recreation attraction.

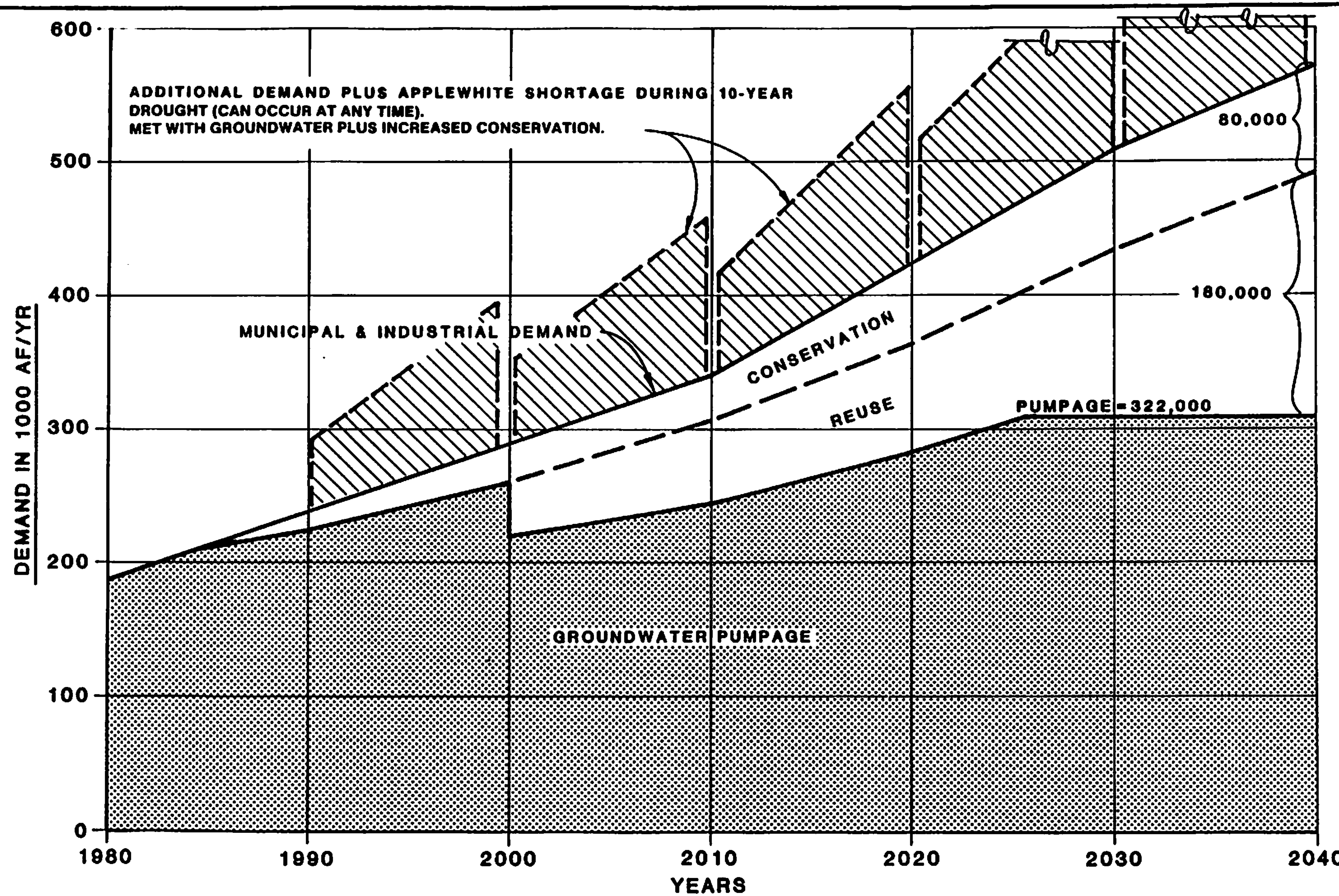

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FIGURE 5-8
ALTERNATIVE II—SUPPLY PHASING PLAN
FOR GREATER SAN ANTONIO AREA

- Significant threat of saline water intrusion into municipal wells due to proximity to the "bad-water" zone.

Average annual inflow to the estuaries at the gulf would be as follows in year 2040:

San Antonio Bay	1,680,000 acre-feet
Corpus Christi Bay	480,000 acre-feet

<u>Drought Conditions</u>. Response of the Edwards to the drought of record occurring in the decade 2030 to 2040 is predicted as follows:

	Groundwater Decline In Worst Year Compared to 1980 (Ft)
Uvalde County	145
San Antonio	211
New Braunfels	169

Spring augmentation wells would continue to pump into the rivers just as in normal years.

Impacts from the same intensity drought occurring earlier--say, from 1986 to 1995--would be nearly identical to those described for the Present Policies Alternative since no significant new water sources (primarily reuse) would be available in this time frame. Drought effects between now and the year 2040 would continue to become more severe because Edwards Aquifer water levels will continue to fall as more water is pumped out each year than is naturally recharged.

A drought response conservation program would be in effect in San Antonio and is recommended throughout the study area as well.

<u>Alternative III</u>

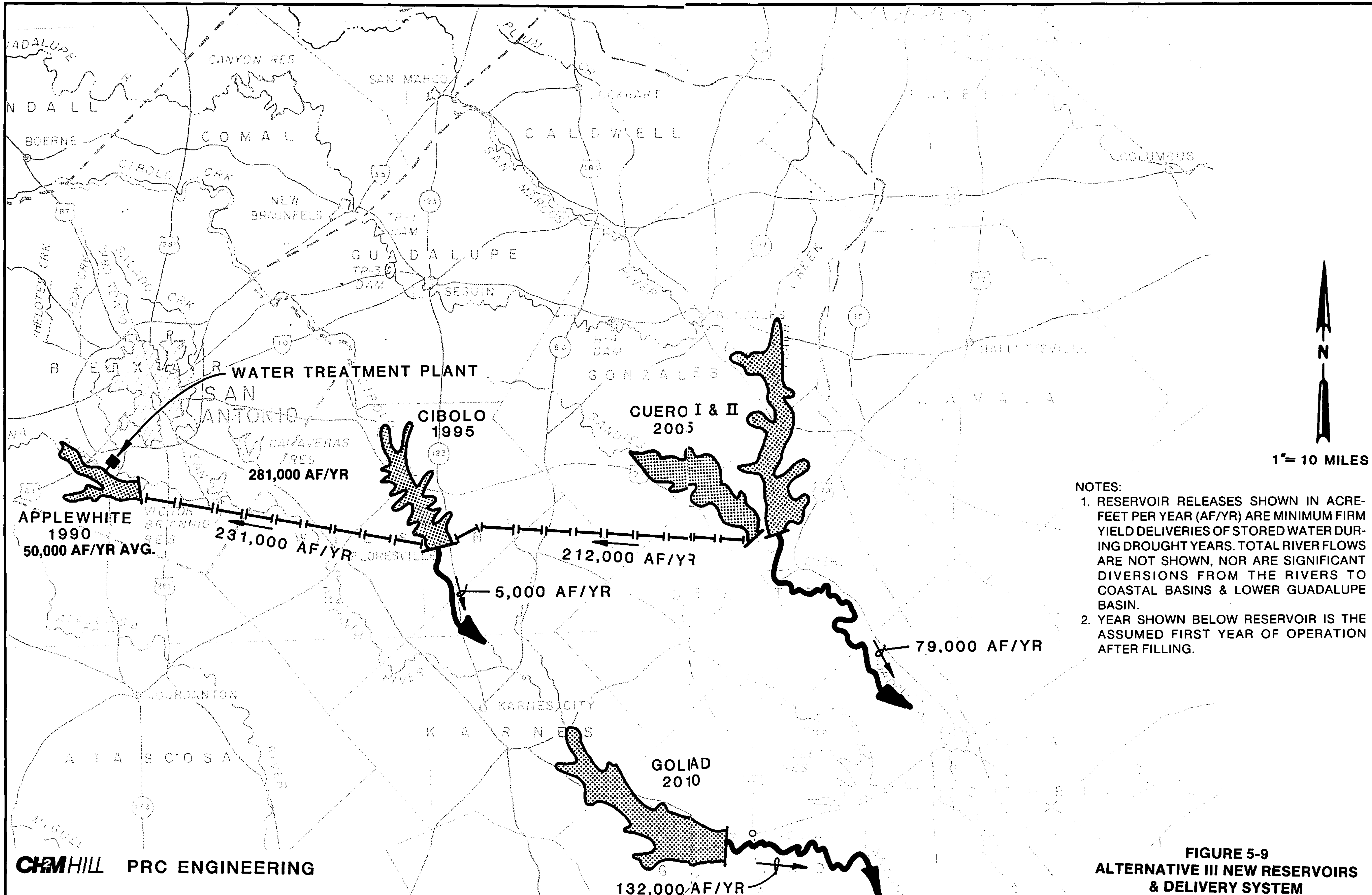
Alternative III furnishes water from all economically feasible sources, including new reservoirs, and employs new laws and institutions as needed to better manage the area's water resources. Alternative III is similar to Alternative I except that it has about 100,000 acre-feet per year more reservoir capacity (Cuero I and II reservoirs used instead of Cuero I plus Cloptin) and will be implemented with new laws to maximize primary area financial participation. As in the other alternatives, all sources would be optimally managed to take advantage of lowest cost water sources first and construct reservoirs only as necessitated by increasing demand.

In summary, projected water demands for the year 2040 would be met from the following sources:

Source	Average Annual Acre-Feet Per Year
Edwards Aquifer Pumpage 350,000 Springflow 250,000	600,000
Secondary Aquifers	320,000 (safe yield)
Conservation	52,000 (10% of M&I demand in primary area cities)
Reuse of Wastewater (in addition to 60,000 acre-feet used by CPS)	100,000 (20% of San Antonio M&I demand. 25% of wastewater flow)
Existing Reservoirs (Corpus Christi, Choke Canyon, Medina, Calaveras Braunig, Coleto, Canyon)	418,000
New Reservoirs	
Applewhite (in 1990)	50,000
Cibolo (in 1995)	25,000
Cuero I & II (in 2005)	302,000
Goliad (in 2010)	132,000
Local Supplies	89,000
Surface Water Diversions to Secondary Areas and Coastal Basins	350,000

Figure 5-9 shows the location of proposed reservoirs and pipelines. The staging of new facilities is shown graphically on Figure 5-10. Facilities were scheduled to meet a target pumpage level for the greater San Antonio area as soon as possible to stabilize well levels and springflows.

Note that as in Alternative I, there is excess capacity in Cuero I and II reservoirs reserved for greater San Antonio that might be sold as interim water if buyers are present, but that cannot be projected with any certainty at this time. As with Alternative I, the reservoir's water supply would be shared with GBRA, with GBRA reserving about 80,000 acre-feet per year, or about 25 percent of the capacity. The unit cost to both entities (as estimated by the



NOTES:
1. RESERVOIR RELEASES SHOWN IN ACRE-FEET PER YEAR (AF/YR) ARE MINIMUM FIRM YIELD DELIVERIES OF STORED WATER DURING DROUGHT YEARS. TOTAL RIVER FLOWS ARE NOT SHOWN, NOR ARE SIGNIFICANT DIVERSIONS FROM THE RIVERS TO COASTAL BASINS & LOWER GUADALUPE BASIN.
2. YEAR SHOWN BELOW RESERVOIR IS THE ASSUMED FIRST YEAR OF OPERATION AFTER FILLING.

FIGURE 5-9
ALTERNATIVE III NEW RESERVOIRS & DELIVERY SYSTEM

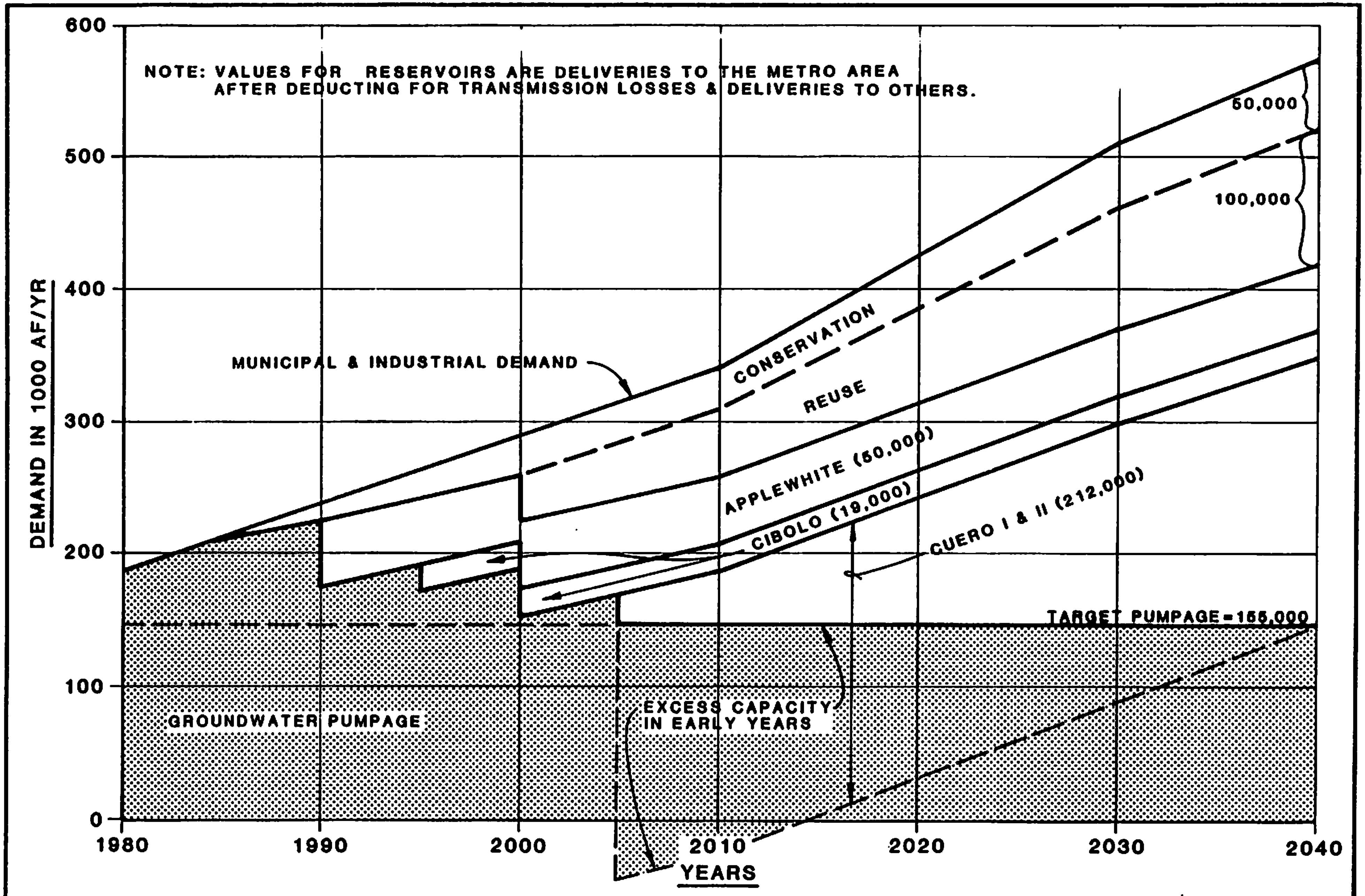


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FIGURE 5-10
ALTERNATIVE III—SUPPLY PHASING PLAN FOR GREATER SAN ANTONIO AREA

consultant) is less--about $185 per acre-foot compared to about $215 per acre-foot for Alternative I (transmission and treatment costs excluded).

Water from new reservoirs could be obtained by contract from existing entities--Cuero and Lindenau (Cuero I and II) water from the Guadalupe Blanco River Authority, and Cibolo/Goliad water from the San Antonio River Authority. Water would be pumped from Cuero II Reservoir to San Antonio at a maximum rate per year of 212,000 acre-feet via an interbasin transfer contract. A common pipeline would also carry water from Cibolo and Applewhite Reservoirs. Surface water would constitute approximately 40 percent of the City's supply by the year 2040.

San Marcos and New Braunfels would be supplied about half of their 2040 needs with nearby Guadalupe River basin surface water as in Alternative I.

Major demands in the secondary study area and coastal basins are assumed to be primarily with available river flow. The one notable exception is the Guadalupe River secondary area which is allocated new reservoir storage in Goliad Reservoir (all of the firm yield) and about 25 percent of Cuero I and II's firm yield. It must be recognized, however, that there may be competition from coastal basin water users (such as Corpus Christi) for the available firm reservoir supplies. Actual allocation of reservoir supplies to lower basin users may therefore differ from the assumptions given here.

Natural flow from the Edwards would be maintained at San Marcos and Comal Springs at the following rates on an average basis:

	Simulated Flow (Acre-Feet Per Year)		
	1985	2040	60-Year Average
Comal	145,000	140,000	165,000
San Marcos	130,000	110,000	125,000
	275,000	250,000	290,000

As shown in Figure 5-4, this is the highest springflow provided by any of the alternatives. It is made possible by delivering more water to greater San Antonio from a larger reservoir system thereby freeing up more groundwater to emerge as springflow.

Model studies show that both springs can go dry or below the targeted minimum flow during a sustained drought like that in the 1950's. Therefore, provisions would be made to install augmentation wells to maintain 80,000 acre-feet per year below each spring, just as in Alternative I. However, if no drought of this magnitude occurs, the wells would not be installed.

Groundwater levels predicted for this alternative (see Appendix H) are as follows, assuming average recharge to the Edwards:

	1980 to 2040 Groundwater Decline (feet)
Uvalde County	18
San Antonio	10
New Braunfels	2

As in Alternative I, water levels decline for 10 years but then rise to a stabilized level (Figure 5-2).

Average annual inflow to the bays at the Gulf is estimated as follows:

San Antonio Bay	1,290,000 acre-feet
Corpus Christi Bay	480,000 acre-feet

Operational Strategies. Operations would be similar to those stated for Alternative I since both have most of the same reservoirs, pipelines, and reuse facilities.

Drought Conditions. Under 1950's type drought occurring from 2030 to 2040, the Edwards Aquifer's response is projected to be as follows:

	Groundwater Decline in Worst Year Compared to 1980 (Ft)
Uvalde County	93
San Antonio	113
New Braunfels	64

Augmentation wells pumping 80,000 acre-feet per year at each spring would need to pump for 8 years at Comal and 6 years at San Marcos Spring to avoid dropping below the target minimum flows that would otherwise occur.

Impacts from the same intensity drought occurring from 1986 to 1995 would be the same as described earlier for Alternative I; i.e. less severe than those indicated for the Present Policies Alternative. Between 1995 and the end of the study period, a slight lessening of drought impacts would be expected as new water sources reduce pumping from the Edwards by 20 percent compared to current pumping. This alternative provides the most "drought protection" of the alternatives. However, even with the maximum amount of new water supplied under this alternative, the adverse consequences of an extended, severe drought will still be significant.

Reservoir operation would be similar to that described for Alternative I.

A drought response conservation program would be in effect in San Antonio and is recommended throughout the study area as well.

<u>Differences in Alternatives</u>

In terms of physical supply facilities, Alternatives I and III are similar. Both include interbasin transfer of Guadalupe River water to the San Antonio basin, with re-transfer of lower San Antonio River flows back to the Guadalupe basin to meet water needs at the confluence of the two rivers. Both include the same conservation and reuse plans, which meet 10 and 20 percent of municipal demands, respectively. The major differences are:

- o Alternative I has a smaller amount of new reservoir development. It uses the smaller Cuero plus Cloptin Reservoirs (total 188,000 acre-feet yield) versus Cuero I and II in Alternative III (302,000 acre-feet yield).

- o Alternative I will be implemented and financed using mechanisms available under existing laws and institutions. Alternative III will use new laws to maximize area-wide financial participation via such mechanisms as higher taxing limits and/or new well permit fees in addition to other sources available under existing laws such as water user charges and water availability charges ("hookup charges") from new water users.

In both Alternatives I and III, water demands in the primary study area can be 100 percent satisfied with firm supplies from surface or groundwater sources. With the larger surface water development in Alternative III, Guadalupe secondary study area demands in year 2040 can be 100 percent met with firm yields of surface and groundwater. By contrast, Alternative I includes slightly more risk in that 15 percent of Guadalupe secondary study area demands must be met with non-firm river flows, which are largely unavailable during a drought. Alternative III reservoirs provide additional firm supplies for water demand growth beyond year 2040, amounting to about 20,000 acre-feet per year.

The larger reservoir development in Alternative III also has lower unit costs for surface water due to economies of scale. The cost comparison is as follows:

	Unit Cost to Greater San Antonio of Treated Surface Water[5] (per acre-foot)	Unit Cost to Guadalupe Basin Users for Raw Water[6] (per acre-foot)
Alt. I	$660	$215
Alt. III	610	185
Difference	$ 50 (8%)	$ 30 (14%)

Alternative III thus provides more water to supply future Guadalupe basin needs (80,000 acre-feet per year from Cuero I and II versus 16,000 acre-feet per year from Cuero I) and at 14 percent lower cost.

Reservoirs in Alternatives I and III allow Comal and San Marcos Springs to flow naturally most of the time whereas springs will cease to flow under Alternative II; river flow immediately downstream of the springs can only be maintained by pumping continuously from new wells.

Alternative II differs significantly from I and III in that no major new reservoirs are to be built. Fifteen percent overdraft of the Edwards and 50 percent supply of San Antonio and Guadalupe River secondary area needs from non-firm river flows result from non-development of reservoirs in addition to cessation of natural springflows. On the other hand, costs are only one-fourth of those for Alternatives I and III, and land disturbance due to reservoir construction is less.

Resulting year 2040 springflows, new reservoir allocations to Greater San Antonio, and City of San Antonio wastewater return flows to the river are summarized in Table 5-3 for comparison of the various alternatives.

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[5] Includes capital repayment, operation, and maintenance costs of Cuero project to cover: proportionate share of reservoirs; transmission pipes and pumps; and water filtration plants in greater San Antonio.

[6] Includes capital repayment, operation and maintenance costs of Cuero project (cost of raw water at the reservoir).

Table 5-3

ESTIMATED FLOWS IN YEAR 2040
ASSUMED IN THIS STUDY
(1,000 acre-feet per year)

	ALTERNATIVE				
	Present Policies	I	II	III	Historic
City of San Antonio Wastewater Return Flow to River	275	175	95	175	105
Average Springflow					
o Comal	0	95	80*	140	212
o San Marcos	0	105	80*	110	111
Total	0	200	160	250	323
Reservoir Allocation to Greater San Antonio					
o Applewhite	0	50	0	50	
o Cibolo	0	20	0	19	
o Cloptin	0	43	0	0	
o Cuero I	0	129 (89%)	0	0	
o Cuero I & II	0	0	0	223 (74%)	

*Supplied by artificial pumping.

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In all alternatives, the largest or near-largest source of water for the primary study area is the Edwards Aquifer. This is shown graphically in Figure 5-11 for year 2040 quantities. The alternatives would draw on several sources of water, thereby reducing the Edwards contribution from 85 percent to a lower value of 40 to 60 percent in an effort to diversify sources, protect groundwater quality, and maintain natural springflows.

COMPARISON OF ALTERNATIVES

Cost

Summary. The total capital costs of the required additional major facilities for the Present Policies and Alternative I, II, and III, as well as their annual O&M costs, are presented below:

TOTAL CAPITAL AND ANNUAL COSTS

Alt.	Capital Cost (1985 $)	Annual O&M Cost (Incl. Energy) in Year 2040 (1985 $)
P.P.	$118,000,000	$10,050,000
I	$1,723,000,000	$45,350,000
II	$521,000,000	$39,520,000
III	$1,852,000,000	$51,200,000

The costs shown above cover all projects proposed herein. Although most of this cost will be recovered from the five-county primary study area, there are two major projects in Alternatives I and III that will be financed partially or wholly by future secondary study area (or coastal basin) beneficiaries. All of Goliad Reservoir's costs, and from about 10 percent (Alternative I) to 30 percent (Alternative III) of Cuero I or Cuero I and II Reservoir's costs would be repaid by future customers of the San Antonio River Authority and Guadalupe-Blanco River Authority, respectively. Financing options presented in Chapter 6 for primary study area repayment of costs are thus based on the following adjusted totals after deducting applicable Goliad and Cuero costs:

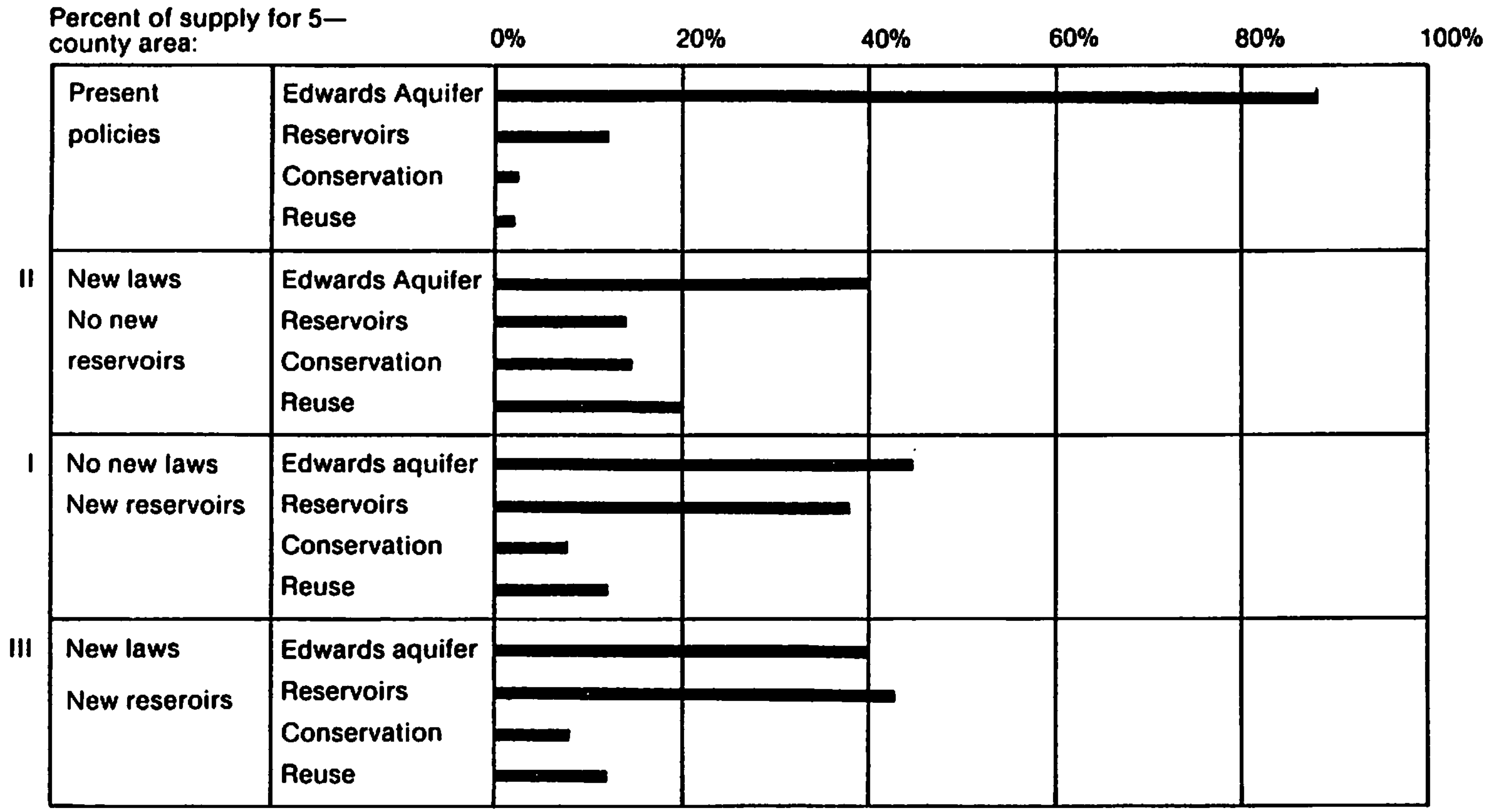

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FIGURE 5-11
WATER SOURCES FOR ALTERNATIVES

PRIMARY STUDY AREA
CAPITAL AND ANNUAL COSTS

Alt.	Capital Cost (1985 $)	Annual O&M Cost (Incl. Energy) in Year 2040 (1985 $)	Equivalent Annual Cost (1985 $)
P.P.	$ 118,000,000	$10,050,000	$ 2,600,000
I	$1,463,000,000	$44,190,000	$41,000,000
II	$521,000,000	$39,520,000	$ 9,900,000
III	$1,492,000,000	$49,840,000	$77,000,000

Since capital costs have been assumed to be paid on a 20-year loan basis, and because the planning period for the study is 50 years, the annual payment required for the financing of the proposed water supply development will not be evenly distributed each year. For this reason an "equivalent annual cost" is also shown for the purposes of comparison. It is the amount that would have to be deposited in an escrow account earning 9.5 percent interest, from which all capital and O&M costs would be paid each year through year 2040.

Comparison of Alternatives. The Present Policies Alternative has no major surface water supply development projects. Additional wells are used to meet the increasing demand of the metropolitan areas of San Antonio, San Marcos, and New Braunfels. The capital costs remain low because the cost of providing additional wells is the least expensive method of developing additional water supplies.

Alternative II is similar to the Present Policies Alternative but includes an extensive program of wastewater reuse. The wastewater treatment and recharge represents the additional cost of this alternative.

Alternative I and III have significantly larger costs because each includes major surface water supply development projects to reduce the demand on the underground water supplies. Alternative III replaces two of the proposed projects considered in Alternative I, Cloptin Crossing and Cuero I, with the larger Cuero I and II project.

The major difference in "equivalent annual cost" between alternatives I and III is due to the staging of the different projects. Alternative III has projects scheduled earlier in the planning period than Alternative I, and will require large capital expenditures sooner, as shown below.

SCHEDULE OF CAPITAL COSTS

Project Name	Capital Cost (Million $)	Proposed On-Line Date Alt. I	Alt. III
Cibolo	200	2010	1995
Cloptin Crossing	130	2015	
Cuero I	270	2020	
Cuero I and II	490		2005

An inflation factor was not included in the equivalent annual cost values due to the inability to forecast inflation rates. However inflation will likely continue throughout the study period which will increase the costs shown.

If inflaction is included in the analysis, the gap between Alternative I and III equivalent annual costs narrows. This is shown in the tabulation below. With no inflation, Alternative III costs nearly twice as much as Alternative I. But at 9.55% inflation, the costs are identical. Rising costs due to inflation have a greater impact on Alternative I since major cost items (Cloptin Crossing and Cuero I Reservoirs) are constructed 10 to 15 years later than the comparable Cuero I and II project in Alternative III.

IMPACT OF INFLATION ON COSTS

Inflation Rate (Percent)	Equivalent Annual Cost Ratio (Alt.III/Alt.I)
0.0	1.9
5.0	1.4
6.0	1.3
7.0	1.2
8.0	1.1
9.55	1.0

TABLE 5 - 4

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
CUMULATIVE COSTS FOR ADDITIONAL FACILITIES
BY YEAR 2040

PRESENT POLICIES

ITEM	YIELD (AF/Y)	CAPITAL COST ($)	ANNUALIZED ($/Y)	O & M ($/Y)	ENERGY ($/Y)
1.WELLS					
a. San Antonio	348,000	$110,000,000	$12,480,000	$770,000	$8,630,000
b. New Braunfels & San Marcos	24,000	$8,000,000	$910,000	$50,000	$600,000
c. Spring Augmentation					
2. WASTEWATER REUSE					
a. Treatment & Recharge					
3. DAM & RESERVOIRS					
a. Applewhite					
b. Cibolo					
c. Cloptin Crossing					
d. Cuero I (Guadalupe River)					
e. Cuero I & II (I & Lindenau)					
g. Goliad					
4. CONVEYANCE					
a. Cuero - Cibolo					
b. Cibolo-Applewhite					
c. Applewhite - San Antonio					
d. Blanco River - San Marcos					
e. Guadalupe R. - New Braunfels					
5. FILTER PLANTS					
a. San Antonio					
b. San Marcos					
c. New Braunfels					
TOTALS		$118,000,000	$13,390,000	$820,000	$9,230,000

Assumptions : 9.5 % Interest Rate
20 Yearly Payments
January 1985 Dollars

TABLE 5 - 5

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
CUMULATIVE COSTS FOR ADDITIONAL FACILITIES
BY YEAR 2040

ALTERNATIVE I

ITEM	YIELD (AF/Y)	CAPITAL COST ($)	ANNUALIZED ($/Y)	O & M ($/Y)	ENERGY ($/Y)
1.WELLS					
a. San Antonio	65,000	$21,000,000	$2,380,000	$140,000	$770,000
b. New Braunfels & San Marcos	8,000	$3,000,000	$340,000	$20,000	$90,000
c. Spring Augmentation (standby)	160,000	$13,000,000	$1,480,000	$40,000	$150,000
2. WASTEWATER REUSE					
a. Treatment & Recharge	100,000	$220,000,000	$24,960,000	$13,200,000	$3,300,000
3. DAM & RESERVOIRS					
	50,000*				
a. Applewhite	53,000	$82,000,000	$9,310,000	$300,000	
b. Cibolo	25,000	$200,000,000	$22,700,000	$800,000	
c. Cloptin Crossing	43,000	$130,000,000	$14,750,000	$700,000	
d. Cuero I (Guadalupe River)	145,000	$270,000,000	$30,640,000	$500,000	
e. Cuero I & II (I & Lindenau)					
g. Goliad	132,000	$230,000,000	$26,100,000	$1,100,000	
4. CONVEYANCE					
a. Cuero - Cibolo	161,000	$220,000,000	$24,960,000	$1,000,000	$7,600,000
b. Cibolo-Applewhite	180,000	$190,000,000	$21,560,000	$900,000	$5,700,000
c. Applewhite - San Antonio	233,000	$37,000,000	$4,200,000	$100,000	$2,900,000
d. Blanco River - San Marcos	11,000	$9,000,000	$1,020,000	$70,000	$260,000
e. Guadalupe R. - New Braunfels	5,000	$5,000,000	$570,000	$40,000	$170,000
5. FILTER PLANTS					
a. San Antonio	233,000	$84,000,000	$9,530,000	$3,100,000	$1,600,000
b. San Marcos	11,000	$6,000,000	$680,000	$400,000	$100,000
c. New Braunfels	5,000	$3,000,000	$340,000	$240,000	$60,000
TOTALS		$1,723,000,000	$195,520,000	$22,650,000	$22,700,000

Assumptions : 9.5 % Interest Rate
20 Yearly Payments
January 1985 Dollars

*This is an average yield based on a yearly fill-and-drain operation. Other yields are "firm yields" available each year during the drought of record (1947 to 1956).

TABLE 5 - 6

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
CUMULATIVE COSTS FOR ADDITIONAL FACILITIES
BY YEAR 2040

ALTERNATIVE II

ITEM	YIELD (AF/Y)	CAPITAL COST ($)	ANNUALIZED ($/Y)	O & M ($/Y)	ENERGY ($/Y)
1.WELLS					
a. San Antonio	264,000	$85,000,000	$9,650,000	$580,000	$6,550,000
b. New Braunfels & San Marcos	24,000	$8,000,000	$910,000	$50,000	$600,000
c. Spring Augmentation (permanent)	160,000	$18,000,000	$2,040,000	$350,000	$1,890,000
2. WASTEWATER REUSE					
a. Treatment & Recharge	180,000	$410,000,000	$46,530,000	$24,100,000	$5,400,000
3. DAM & RESERVOIRS					
a. Applewhite					
b. Cibolo					
c. Cloptin Crossing					
d. Cuero I (Guadalupe River)					
e. Cuero I & II (I & Lindenau)					
g. Goliad					
4. CONVEYANCE					
a. Cuero - Cibolo					
b. Cibolo-Applewhite					
c. Applewhite - San Antonio					
d. Blanco River - San Marcos					
e. Guadalupe R. - New Braunfels					
5. FILTER PLANTS					
a. San Antonio					
b. San Marcos					
c. New Braunfels					
TOTALS		$521,000,000	$59,130,000	$25,080,000	$14,440,000

Assumptions : 9.5 % Interest Rate
20 Yearly Payments
January 1985 Dollars

TABLE 5 - 7

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
CUMULATIVE COSTS FOR ADDITIONAL FACILITIES
BY YEAR 2040

ALTERNATIVE III

ITEM	YIELD (AF/Y)	CAPITAL COST ($)	ANNUALIZED ($/Y)	O & M ($/Y)	ENERGY ($/Y)
1. WELLS					
a. San Antonio	17,000	$5,000,000	$570,000	$40,000	$200,000
b. New Braunfels & San Marcos	8,000	$3,000,000	$340,000	$20,000	$90,000
c. Spring Augmentation (standby)	160,000	$13,000,000	$1,480,000	$20,000	$90,000
2. WASTEWATER REUSE					
a. Treatment & Recharge	100,000	$220,000,000	$24,960,000	$13,200,000	$3,300,000
3. DAM & RESERVOIRS					
a. Applewhite	50,000*	$82,000,000	$9,310,000	$300,000	
b. Cibolo	25,000	$200,000,000	$22,700,000	$800,000	
c. Cloptin Crossing					
d. Cuero I (Guadalupe River)					
e. Cuero I & II (I & Lindenau)	302,000	$490,000,000	$55,600,000	$1,000,000	
g. Goliad	132,000	$230,000,000	$26,100,000	$1,100,000	
4. CONVEYANCE					
a. Cuero - Cibolo	209,000	$240,000,000	$27,230,000	$1,100,000	$10,200,000
b. Cibolo-Applewhite	228,000	$210,000,000	$23,830,000	$1,000,000	$7,700,000
c. Applewhite - San Antonio	281,000	$40,000,000	$4,540,000	$100,000	$3,500,000
d. Blanco River - San Marcos	11,000	$9,000,000	$1,020,000	$70,000	$260,000
e. Guadalupe R. - New Braunfels	5,000	$5,000,000	$570,000	$40,000	$170,000
5. FILTER PLANTS					
a. San Antonio	281,000	$96,000,000	$10,890,000	$4,100,000	$2,000,000
b. San Marcos	11,000	$6,000,000	$680,000	$400,000	$100,000
c. New Braunfels	5,000	$3,000,000	$340,000	$240,000	$60,000
TOTALS		$1,852,000,000	$210,160,000	$23,530,000	$27,670,000

Assumptions : 9.5 % Interest Rate
20 Yearly Payments
January 1985 Dollars

*See footnote on Table 5-5

Detailed Costs. Tables 5-4 through 5-7 present in more detail the cumulative costs of the different components required for the Present Policies and Alternatives I, II, and III, respectively.

Cost Estimating Procedures

1. The costs prepared for the analysis of the alternatives represent only capital and O&M costs related to additional major facilities required by year 2040 to meet the projected water demands. In order to keep all estimates consistent, costs of new wells and/or other local supply facilities are not included, except in those areas receiving alternative water supplies (the greater San Antonio area, New Braunfels, and San Marcos).

2. Costs for major transmission lines have been estimated, but local distribution system costs are not included.

3. All costs are in January 1985 dollars. Where updating of published cost data was necessary, the Engineering News Record Construction Cost Index for Dallas, Texas was used as a cost escalator.

4. Sources of cost data:

   Well and pumping costs were obtained from the City Water Board of San Antonio current figures.

   Costs for Water and Advanced Secondary Wastewater Treatment were obtained from costs curves prepared by the Environmental Protection Agency.

   The cost of Applewhite Reservoir was determined from a 1983 report by Freese and Nichols. The costs of the Cloptin Crossing and Goliad Reservoirs were updated from the 1978 Texas Basin Report by the USBR. The costs of the Cibolo, Cuero I, and Cuero I and II projects were updated from an ongoing study conducted by Espey, Huston & Associates.

   The costs for the conveyance structures and the treatment facilities were obtained from the 1978 Texas Basin Report by the USBR and prorated to the proposed capacities.

5. All construction costs were modified to include an allowance of 40 percent to cover contingencies, engineering, administration, and financing.

6. For all major construction projects, capital expenditure was assumed to occur 5 years before the proposed online date.

7. Energy cost was assumed at 6 cents per kilowatt hour.

Financial Impacts

Chapter 6 includes a discussion of the financial impacts on various classes of customers using five different combinations of cost recovery methods. Recovery methods include the following:

- User charges (water bills)
- Water availability charges (hookup charge for new customers)
- Property taxes
- Sales taxes
- Well permit fees (similar to hookup charge)
- Well pumpage fees (charge to independent well owner per volume of water used)

Although the calculated water cost for each customer class varies slightly with each combination of the above methods, an average of the five combinations is presented in Table 5-8 for comparative purposes. The costs shown are average yearly water costs from 1985 to 2040, in 1985 dollars, to pay for current service plus new regional facilities. Costs do not include the effects of inflation or standard utility company rate increases to pay for local system improvements. Actual rates in the future will be higher due to these factors. Also, the rates will vary upward and downward as total bonded indebtedness of phased regional projects increases and decreases. This variation is presented in Chapter 6.

For comparison of alternatives, the discussion here will focus on residential customer rate impacts since this class represents the largest number of water users in the primary study area. Note, however, that the trends presented here are not necessarily valid for all customer classes. For instance, a City Water Board customer's costs are higher for Alternative I than for II. But for a farmer, costs are higher under Alternative II due to imposition of new taxes and well pumpage fees that are not allowable under Alternative I assumptions of no new laws.

For residential customers in cities affected by all alternatives, cost increases (average of next 55 years) compared to Present Policies costs are summarized as follows:

Table 5-8

SUMMARY OF CUSTOMER IMPACTS
(Monthly Costs in Current Dollars, No Inflation)

Water Beneficiary	Existing Costs	AVERAGE IMPACT OVER THE STUDY PERIOD (Total $ and % Increase)			
		Present Policies Costs	Alt. I	Alt. II	Alt. III
Average Residential Customer					
City Water Board	$ 10	$ 10+	$ 17	$ 12	$ 15
		5%	70%	20%	50%
Lackland City Water Co.	17	17+	17	19	21
		5%	0%	10%	25%
New Braunfels	10	11	16	12	14
		10%	60%	20%	40%
San Marcos	12	13	18	14	16
		8%	50%	15%	35%
Uvalde	7	8	7	9	12
		15%	0%	30%	70%
Large Industrial Customer					
Customer on CWB	9,800	10,100	18,200	12,000	15,300
		3%	85%	20%	55%
Customer with Well	1,400	1,900	1,500	2,900	5,200
		30%	7%	110%	270%
Average Farmer					
Bexar County	540	840	580	780	650
		55%	8%	45%	20%
Uvalde County	2,700	3,900	3,000	3,900	3,500
		45%	10%	45%	30%
Rural Domestic Well Owner	1.20	1.60	2.10	2.80	5.50
		35%	75%	135%	360%
Large Institutional Water Beneficiary					
CWB Customer	12,500	12,900	22,800	15,200	19,300
		3%	80%	20%	55%

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Alternative	Cost Increase
I	50 to 70%
II	20%
III	30 to 50%

Alternative I has the most impact, followed by III, II, and Present Policies.

Note that Alternative I cost increases are greater than those for Alternative III even though Alternative III has higher project costs. This is because Alternative III has a broader customer base to pay the bills, which more than offsets the higher costs. With new laws possible in Alternative III, funds are collected from all utility customers plus farmers and independent well owners (individuals and industries).

Economic Impacts

Economic impacts are described in detail in Appendix N and are summarized below. The factors examined include agricultural productivity, recreation and tourism, industrial productivity, real property values, and business development and investment prospects.

Agricultural Productivity. Economic output by irrigated agriculture in the primary study area exceeds $24 million, which is 0.1 percent of total 5-county output. Considering interrelationships with other sectors, however, irrigated agriculture is estimated to be responsible for about $67 million of total regional business activity. Irrigation is important to crop production in Bexar, Medina and Uvalde Counties. Its impact on economic activity in Bexar County is about 0.1 percent compared to 5 to 10 percent in Medina, and Uvalde Counties. For the approximately 116 thousand irrigated acres in the primary study area, evaluation of no irrigation was included to provide insight into the overall effect, recognizing that an elimination of irrigation is not a part of any alternative. Without irrigation it was estimated that per acre net returns would decline by 55 to 64 percent and gross returns by 29 to 48 percent, over the three counties.

Evaluation of Alternatives I, II, and III for 2040, as compared to continuation of present policies, using the projection of a 40 percent improvement in irrigation efficiencies, leaves irrigation farmers theoretically in business for all cases. In 2040, with continuation of the present policies, pumping lift was estimated to be about 120 feet greater in Bexar and Medina Counties and from 45 to 110 feet greater in Uvalde County. The effect of the water alternatives in 2040, as compared to continuation of present policies, was a reduction in pumping lift. Gross revenue is projected to be relatively unchanged across all scenarios in 2040. Due to less pumping lift and less unit water use assumed under for Alternatives I, II and III, net returns would be greater than continuing with the present policies. Net returns are greatest for Alternatives I and III. However, the differences are small, ranging from an increase of .04 percent to 7 percent across the counties comparing the alternatives to continuation of present policy. The major impacts of Alternatives I to III are in Medina and Uvalde Counties where farmers' net returns for both counties are from about $800,000 to $1,200,000 per year greater than with continuation of present policies.

The above values are based on an assumed 40 percent improvement in irrigation efficiencies. The implications of no change in irrigation efficiency over the study period were also evaluated. Using 1980 as a base, net returns to irrigation farmers in Medina and Uvalde Counties are estimated at $18.3 million. Following present policies to 2040 would reduce this value to $16.1 million (12 percent decline). Comparable returns for the alternatives are estimated at $17.2 million (6 percent decline) for Alternative II, and $17.9 million (2 percent decline) for Alternatives I and III. Thus, the alternatives have estimated net returns greater than continuation of present policies to 2040 but less than estimated net returns in 1980. The additional energy cost of pumping irrigation water in Uvalde County due to the increase lift in 2040 as compared to 1980 would be approximately $16 per acre foot under continuation of present policies, $6.50 per acre foot for Alternative II, and $2.80 per acre foot for Alternatives I and III.

General conclusions for returns to agriculture indicate the following:

- No significant difference in total gross returns for various alternatives, all of which are slightly higher than current conditions if irrigation efficiencies increase by about 40 percent as projected by the TDWR.

- Farmers' net returns (profits) rise slightly under all alternatives compared to current conditions, if irrigation efficiencies increase, with the greatest increase for Alternatives I and III (9 percent in Uvalde County) and least for continuation of present policy (3 percent in Uvalde County).

- If irrigation efficiencies remain at current levels (no significant new conservation efforts), farmers' gross returns remain about the same but net returns (profit) may decrease up to 12 percent under continuation of present policies. This has serious implications for economic viability of individual farm firms.

Recreation and Tourism. Spring-related recreational and tourism activities in Comal and Hays Counties are similar, consisting of visitations at park facilities, camping, canoeing, tube floating, scuba diving, and other activities. For the communities of New Braunfels and San Marcos, the spring-related activities provide an economic base industry, attracting new revenue from outside the area each year. Principal types of expenditures include food, auto, lodging, and amusements. The combined economic impacts of recreational expenditures are summarized within the following ranges:

	Total Output Effects ($ million)		Total Employment Effects (number)		Total Income Effects ($ million)	
	Low	High	Low	High	Low	High
Comal Springs	30	47	988	1,600	6	10
San Marcos Springs	15	26	656	1100	4	6
Total	45	73	1,644	2,700	10	16

Total output related to the springs is estimated to range from $45 to $73 million or approximately 5 percent of total output from Comal and Hays Counties. Compared to statistics acquired from the New Braunfels and San Marcos Chambers of Commerce and elsewhere, spring-related business activity accounts for more than one-half of all recreation and tourism activity in both areas and for 7 to 8 percent of total employment in the sub-area.

Results from a comparison of alternatives may be summarized as follows:

- Continuation of present policies is a "worst case" alternative for recreation and tourism related to Comal and San Marcos Springs, reducing related economic activity by up to 90 percent compared to 1985 conditions.

- Alternative II reduces economic activity in Comal and Hays Counties by up to 75 percent compared to 1985 conditions.

- Alternatives I and III have the least negative effect on recreation and tourism related economic activity with reductions of 10 to 40 percent of current activity.

- The reservoirs in Alternatives I and III will provide recreational opportunities in the secondary area resulting in business activity about 4 times as great as the current activity at the springs.

Decreases in spring-related economic activity result for all alternatives compared to today's level of activity because the springs cannot maintain flowing at current high rates once the "bank account" of extra aquifer storage due to recent wet weather is depleted. This topic is discussed in Chapter 5 section, "Springflow Considerations."

Industrial Productivity. The study area economy reflects a structure that is heavily oriented toward services and trade activities rather than manufacturing and extractive industries, as shown in the following figures (which do not include households):

	Value of Output ($ million)	Percent of Total
Agriculture, Fisheries, & Forestry	187	1
Mining	358	2
Construction	1,666	11
Manufacturing	4,206	27
Transportation	590	4
Communications	160	1
Utilities	948	6
Wholesale Trade	1,375	9
Retail Trade	1,449	9
Financial, Insurance, & Real Estate	1,956	12
Education Services	667	4
Services	2,269	14
Total	15,831	100

The economic sectors that contribute the most to area employment and personal income also use relatively little water in their production process. All manufacturing sectors use only 17 thousand acre-feet of groundwater or about 4 percent of total pumpage to produce 27 percent of the economic output. Notable exceptions are the food and kindred products, textile and apparel, glass, stone, and clay products sectors. These are relatively heavy water users, pumping about 90 percent of all water used by manufacturing. Most other manufacturing sectors use much less than one acre-foot of water per one million dollars of output. Among the non-manufacturing sectors, only the eating and drinking establishments and health services sector use a significant amount of water relative to value of output. Results of the industrial productivity analysis are summarized as follows:

- None of the alternatives for water supply considered in this study are expected to have a significant effect on industrial output since most industry is not water intensive.

- Among the sectors most heavily affected are food and kindred products, textile and apparel, glass, stone, and clay products, eating and drinking establishments, and health services.

- Any policy alternative that limits water availability to industry may be expected to have a significant detrimental impact on area business activity, employment, and personal income.

- Any alternative that ensures the long-term, continuous supply of water, even if it increases the cost, may be expected to benefit the productivity and stability of industry and the economic base it provides the area.

Real Property Values. Factors affecting real property values are varied and complex. Among these is a direct relationship between an economy's health and the property values. Three sectors of the economy affected by water price and availability were evaluated--agricutlure, recreation at local springs, and industry.

All of the 2040 alternatives maintain irrigated land values at about the same level for Bexar County. For Alternative I and III, irrigated land values are 11 to 13 percent greater than continuation of current policy and for Alternative II, 6 to 9 percent greater in both Medina and Uvalde Counties.

The value of irrigated land in Medina and Uvalde Counties is projected to be slightly higher in 2040 than in 1983 assuming a 40 percent improvement in irrigation efficiency under any of the alternatives. However, if no improvement in irrigation efficiency is assumed, the 2040 values for irrigated land as compared to 1983 values would be about 11 percent less for continuation of present policies, 6 percent less for Alternative II, and 2 percent less for Alternatives I and III. The productive value of irrigated land in 2040 is very sensitive to the level of irrigation efficiency with significant efficiency improvements necessary to offset the effect of increasing pump lift.

Increases in irrigated land values result in further increases in property values of agricultural support industries, an increase in the property tax base and a decrease in the tax rates to meet current public service demands. However, since irrigated land is less than 4 percent of total taxable property value, the predicted reduction in County tax rates (or <u>increases</u> if irrigation efficiencies do not change) is less than one percent for Alternatives I, II, and III as compared to continued present policies in 2040.

Recreation-induced reduction in real property values due to reduced springflow at Comal and San Marcos Springs would occur in Comal and Hays Counties under each alternative compared to the 1980 situation. A continuation of present policies to 2040 has the greatest impact with county-wide property values dropping as much as 5 percent in Comal and 3 percent in Hays Counties. However, since the reduction in property values is such a small portion of the total tax base, the effect is less than a 3 percent tax rate increase. Each of the other alternatives have lesser impacts on property values. Although for the counties in aggregate the effect of reduced springflows is relatively small, property adjacent to the springs and associated rivers would be disproportionately affected. The impact of a doubling of unemployment in these counties would affect workers and soften the market for homes and apartments. A major local impact would also be expected on food service, amusements, lodging, and service stations.

Industrial-induced property value losses depend upon whether a water shortage results in a higher price for water or a water-use constraint. Increases in price or pumping lifts are not projected to impose serious problems on industry in the primary study area and, therefore, the impacts on real property values are expected to be minimal. However, constraints on water availability would impact all industry dramatically, affecting the rate of use of industrial plants, reducing returns on investment, and reducing plant value. Plant shutdowns, even if temporary, would affect employment and income and result in reduced values of apartments, residential and commercial property, and urban land. Thus, with water availability, even if at a higher price, little effect on industrial property values is expected.

<u>Business Development and Investment</u>. Business investment in a community is influenced by many factors. Water is one of these. Approximately one-fourth of the economy of the

primary study area would be affected either by increased water price or reduced availability. Most of the impact would fall in irrigated agriculture, mining, and water-sensitive manufacturing sectors such as food and kindred products, textile and apparel, and glass, stone, and clay products. Over 90 percent of the recent business investment has occurred in services, transportation, trade, finance-insurance-real estate, and government. In these sectors, water is a relatively minor part of production costs. However, lack of water availability could be expected to have serious negative consequences to the local business investment climate. This is partially because it would reflect a negative local image of the community in terms of a desire to plan for systematic and orderly business growth. Considering the nature of the growth industries in the primary study area, of major importance to business investments are community factors relating to taxes, amenities, and perceptive leadership. Among the alternatives considered, Alternatives I and III offer the most favorable water climate for continued business development and investment within the area. Continuation of present policies and Alternative II impact severely on springflow, the consequences of which extend beyond the loss of recreational and tourist economic activity to one of a poor image for leadership in the region.

Water Availability

The physical availability, or reliability, of combined groundwater and surface water resources to meet study area demand is greatest for Alternative III, followed by I, II, and Present Policies (least available). This is illustrated in the following tabulation:

Alternative	Edwards Aquifer Discharge in Excess of Recharge (%)	% of Consumptive Demands[5] Met With Firm Supplies[6]
Present Policies	30%	60%
II	15	65
I	0	85
III	0	90

[5] Consumptive demands = municipal, manufacturing, steam electric, mining, irrigation, and livestock demands.

[6] Firm supplies = reservoir supplies available each year during drought of record plus groundwater supplies limited to average annual recharge amount.

Under Alternatives II and Present Policies, withdrawals from the Edwards Aquifer in excess of the annual recharge amount will cause progressive drawdown of groundwater levels: over 140 feet in San Antonio by year 2040 for Present Policies and about 75 feet for Alternative II. This will necessitate deeper and deeper wells for many users and diminish the "bank account" of water available to future generations. Dry years and droughts will have more severe impacts on springflows as water tables decline over time. Also, the increased pump lift and lower (or zero) springflows associated with these alternatives increases the probability of legal/administrative conflicts over the dwindling supply of water. Alternatives I and III will maintain well water levels at close to their present values.

Available firm supplies of surface water remain constant for Alternatives II and Present Policies but increase substantially under Alternatives I and III. Firm yields (water available at all times, even during the drought of record) from both existing and proposed major reservoirs (larger than 5,000 acre-feet-per-year yield) are as follows:[7]

Alternative	Yield in Acre-Feet Per Year
Present Policies	420,000
II	420,000
I	810,000
III	930,000

Without major new reservoirs on the Guadalupe River, the large projected industrial demands (an additional 180,000 acre-feet per year by year 2040) cannot be met. Groundwater supplies in the area are insufficient to meet this much new demand. Growth in the Guadalupe basin will thus be limited since industry will not locate in an area unless it has guaranteed water supplies. Although flows in the Guadalupe River during average-weather years would be more than sufficient to supply these demands, these flows are largely unavailable during a drought. Only reservoirs can provide the needed supply by capturing wet-weather flow and saving it for critical dry-period needs.

[7] Included are average yields from Applewhite Reservoir and power plant cooling water reservois--Coleto @ 12,000, Calaveras @ 17,000, and Braunig @ 12,000 acre-feet per year.

With Alternatives I and III, natural springflow at Comal and San Marcos Springs will be maintained at all times, except during times of drought. Average flows of the two springs combined, from 1980 to 2040, are projected as 270,000 and 290,000 acre-feet per year for Alternatives I and III, respectively. Under Alternatives II and Present Policies, springflow will eventually cease in the twenty-first century, and no flow during dry periods will occur with increasing frequency as Edwards groundwater levels decline. Flow in the Comal and San Marcos Rivers will be artificially maintained at a minimum level under Alternative II with new wells discharging into the river downstream of the existing springs.

Environmental Considerations

The following environmental issues were considered in comparing alternatives:

- Water Quality
- Recreation
- Wildlife Habitat and Vegetation
- Endangered Species
- Bays and Estuaries
- Archeological and Cultural Resources

Relative impacts of the four alternatives are summarized in Table 5-9 and discussed in the following paragraphs.

The environmental ranking system was designed to reflect the major concerns of the study sponsors (City of San Antonio and Edwards Underground Water District) and residents of the primary study area as perceived by the consultant. Weights were assigned to various criteria with these concerns in mind based on the consultant's professional judgment. Different relative weightings may be given to the criteria by various reviewers, in some cases resulting in other overall rankings.

Water quality was assigned the highest relative weight (30 points) because of the overriding concern of area residents for longterm maintenance of Edwards groundwater quality. Protection of bays and estuaries was selected as the next priority consideration (25 points) because of its critical importance to the study area environment and the State as a whole. Wildlife concerns, both protection of habitat and endangered species, were ranked at the same level (a total of 25 points) to reflect values traditionally expressed by the general public. Recreation, ranked next highest (15 points), is a major influence on Hays and Comal Counties' economies, and on perceived quality of life in the study area. Archeological and cultural resources were assigned the lowest weight (5 points) because of the potential for mitigation of adverse effects.

Table 5-9
ENVIRONMENTAL RANKING OF ALTERNATIVES

Environmental Issue	Relative Weight	Alternative PP	I	II	III
Water Quality					
Groundwater	15	2	15	4	15
Guadalupe River	8	1	7	3	8
San Antonio River	7	1	3	5	3
	30	4	25	12	26
Recreation					
Comal & San Marcos Springs	6	0	5	2	6
Guadalupe River	3	0	2	1	3
San Antonio River	3	3	2	1	2
Reservoirs	3	0	2	0	3
	15	3	11	4	14
Wildlife Habitat & Vegetation					
Bottomland Forest Habitat & Vegetation	4	4	1	4	0
Habitat & Vegetation in Rangeland, Pasture, & Cropland	6	6	1	6	0
Aquatic Habitat (reservoir)	3	0	2	0	3
Shoreline Habitat (reservoir)	2	0	1	0	2
	15	10	5	10	5
Endangered Species					
San Marcos Gambusia, Fountain Darter, & Texas Wildrice	6	0	5	4	6
San Marcos Salamander	4	0	2	0	4
	10	0	7	4	10
Bays & Estuaries					
Guadalupe	15	15	11	13	10
Nueces	10	10	10	10	10
	25	25	21	23	20
Archeological & Cultural Resources	5	5	3	5	2
TOTAL	100	47	72	58	77

Source: CH2M HILL, 1986.

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Values for each of the alternatives were determined on the basis of existing information cited in the following section. This analysis is preliminary in nature, intended only to assess relative impacts among alternatives, not the total environmental impacts of all considered projects. If and when facilities are actually constructed, more comprehensive and detailed environmental assessments will be needed for specific projects. For reservoirs, further environmental studies would be needed, as a minimum, in support of an application for a Corps of Engineers dredge and fill permit (Section 404 Permit). These studies would incorporate data on the effects of reservoir construction on the social environment, population, housing, noise, air quality, visual resources, agriculture in the secondary study area as a whole, and other issues which are beyond the scope of this study.

Water Quality. The environmental effects of each alternative will be considered with respect to groundwater and surface water.

Groundwater quality will be potentially adversely affected by those alternatives that place the highest demand on the aquifer and/or have the greatest amount of recharge associated with reuse of treated wastewater effluent. Maintenance of high quality Edwards groundwater is best served by Alternatives I and III, while Alternative II can have an adverse impact, and the Present Policies Alternative rates lowest of all. High pumping demands can promote groundwater degradation by:

- Potential saline intrusion from the bad-water zone as water levels drop
- Concentration of contaminants as aquifer storage and the "flushing" action of springflows decreases
- Increasing contamination potential as some areas adjacent to the recharge zone change from pressurized artesian conditions (the pressure keeping contaminants out) to free water table conditions

The Present Policies Alternative places the greatest demands on the aquifer, and therefore has the highest potential for groundwater degradation. Water tables are predicted to drop over 140 feet by 2040 if present policies are continued. This compares to 76 feet for Alternative II, 19 feet for Alternative I, and 10 feet for Alternative III. These values are for the City of San Antonio area. Declines in other areas are predicted to be less. Once the springflows stop permanently in 30 to 50 years (and intermittently before then), the aquifer becomes a "collection" reservoir for all upgradient natural stream inflow and any spilled contaminants, with pumped wells being the only outlet.

Alternative II is somewhat better than Present Policies because pumping is reduced and a minimum pumped "flushing" flow at the springs will be maintained. Groundwater drop in San Antonio is 50 percent of that for present policies but is still significant. This alternative also includes the largest proposed amount of wastewater reuse, which may partially be attained by aquifer recharge (up to 144,000 acre-feet per year) although some of this may be used for residential landscape irrigation. Although the reuse water can be treated to very high standards, it is still perceived as a lower quality water source than naturally recharged stream water.

Alternatives I and III have little or no impact on groundwater quality because they incorporate target pumping levels that, when combined with springflow, do not exceed the average yearly recharge to the aquifer. Both alternatives include an increment of recharged treated wastewater--up to 64,000 acre-feet per year. However, this amount, equal to 10 percent of average recharge, is small in relation to other quantities considered in the total water balance of the aquifer. Therefore, it is judged to have a relatively negligible effect on groundwater quality.

Surface water quality is affected in the Guadalupe and San Antonio Rivers. The Nueces River is not affected to a significant degree by any of the alternatives and is omitted from this review.

In the San Antonio basin, water quality declines as City of San Antonio wastewater return flow increases. Although the water will soon be treated to advanced secondary standards, the resulting effluent is still of lower quality than the receiving waters. Present Policies has the highest ratio of wastewater flow to total flow, giving it the lowest rating (see table below). Alternatives I and III have lower volumes of return flow, so they have less impact. Due to high amounts of wastewater reuse, Alternative II has the lowest ratio of wastewater return flow to total flow so it has the least impact on stream quality.

Alternative	Flows by Year 2040 (acre-feet per year) Springflow[7]	Return Flow to S.A. River[8]
Present Policies	0	275,000
I	200,000	175,000
II	160,000	95,000
III	250,000	175,000

[7]Flow at Comal and San Marcos Springs combined

[8]Treated wastewater effluent released to San Antonio River

Guadalupe River water quality is related to springflow volume, especially during dry years when springflow can constitute up to 90 percent of the base flow of the river. Present Policies Alternative produces no springflow by year 2040. Alternative II has the next level of continuous flow at 160,000 acre-feet per year, followed by Alternative I at 200,000 acre-feet per year and Alternative III at 250,000 acre-feet per year.

The impact of Alternative II on water quality in the Guadalupe River basin is complicated by the requirement to pump well water continuously to replace springflow. Higher than desirable salt, sulfate, and chloride levels could be found in the Comal and San Marcos Rivers if augmentation wells begin drawing water from the bad-water zone, a possibility due to the closeness of the wells to this zone. A temporary spring augmentation plan (Alternatives I and III) during droughts only is not expected to encounter the same problem. In all cases where pumping into the river is considered, an NPDES discharge permit must be obtained. These permits may require water discharged into the stream to be equal in quality to the existing receiving water quality. If demineralization of the well water were required to meet permit requirements, the cost for Alternative II could be approximately $60 million more per year, assuming that half the water would be treated and blended with the remaining well water before discharge to the river. An additional environmental problem is disposal of the brine generated by the demineralization process. It would have to be hauled away for disposal or injected by deep wells into a saline aquifer. These costs are not included in cost estimates for Alternative II presented earlier in Chapter 5.

Abbreviated quality standards for the San Marcos and Comal Rivers are given below:

Quality Indicators	San Marcos River	Comal River
Chlorine	25 mg/L	25 mg/L
Sulphate	25 mg/L	30 mg/L
TDS	380 mg/L	400 mg/L
Dissolved oxygen	6 mg/L	5 mg/L
Temperature	80°F	---

Reducing springflows in the Guadalupe River reduces the river's capacity to assimilate wastewater effluent, which could ultimately have an impact on downstream dischargers. The state would likely require that some or all of the effluent dischargers along the Guadalupe River below the springs upgrade their wastewater plant standards to maintain current water quality if less river water is available for dilution. The estimated cost to upgrade downstream treatment plants (from the Springs to Cuero) to discharge quality requirements of 10 mg/L of BOD, 15 mg/L of suspended solids (SS) and 3 mg/L of ammonia nitrogen is about $23 million (capital cost in 1985 dollars, plus 40 percent to cover contingencies, engineering, and administration (Ref. 1)). If more stringent discharge standards of 5 mg/L BOD, 5 mg/L SS, and 2 mg/L of ammonia nitrogen are required, the cost of modifying downstream treatment plants is increased to about $29 million. These costs are not reflected in the estimated cost of alternatives presented earlier in this chapter. Again, Alternative III would provide the least adverse impacts, followed in order by Alternatives I, II, and Present Policies.

Recreation. Benefits are divided by type of water-based recreation resource as follows:

- o Comal and San Marcos Springs
- o Guadalupe River
- o San Antonio River
- o New reservoirs

All four alternatives have a recreation impact on the springs and rivers, while Alternatives I and III also have impacts associated with the development of new reservoirs. Recreation benefits increase in relation to springflows and available reservoirs, so Alternative III provides the most recreation benefits, followed closely by Alternative I, with minimal benefits for Alternatives II and Present Policies.

The recreation impact at Comal and San Marcos Springs is related to the level of springflow and reflected in predicted economic activity for the various alternatives (see Appendix N). Approximate estimates of future annual income at the two springs for the various alternatives are summarized from Appendix N as follows (in 1985 dollars):

Alternative	Predicted Approximate Range of Annual Income (millions)
Present Policies	$2 to $5
I	10 to 13
II	4 to 8
III	10 to 14

Alternative III has the highest income and flows (over 250,00 acre-feet per year for both springs by year 2040) and is thus assigned the maximum weighting factor for beneficial recreation impact. Alternative I receives a slightly lower rating. Alternative II has considerably less beneficial impact. The Present Policies Alternative has the lowest beneficial recreation benefit at the springs with no flow predicted in the future.

In the Guadalupe River, associated recreation impacts are somewhat more complex than those impacts associated with springflow. In the upper reaches of the river, springflow constitutes a major portion of river flow, but its influence decreases somewhat moving downstream near the Gulf. However, since the majority of recreational activity occurs upstream near the springs, springflow constitutes the major indicator of total recreation activity in the river basin.

The Present Policies Alternative benefits comparatively from recreational activity downsteam on the Guadalupe River because no new reservoirs are in place to diminish river flows. However, because of the cessation of springflow, this alternative rates the lowest in overall recreation benefit.

Alternative II is an improvement over Present Policies, but the increase is small because springflows are maintained at a minimal level (total Comal and San Marcos springflow is 160,000 acre-feet per year), with downstream recreation benefits essentially the same.

Alternatives I and III have the highest potential for river based recreation. Although these two alternatives have lower downstream recreation potential due to river flow losses at reservoirs, the upstream recreation potential, driven by springflows, is much higher, so these two alternatives result in the highest total recreation potential. Since Alternative III has slightly larger springflow (total springflow of 250,000 acre-feet per year) than Alternative I (total springflow of 200,000 acre-feet per year), it has a slightly higher recreation potential.

Recreation potential along the San Antonio River is related to total river flow. There are no major springflows to act as a recreational catalyst in the upstream portions of the river. The major considerations are thus the flow reductions resulting from diversion and recycle of wastewater effluent (reuse) and evaporative losses from reservoirs.

Present Policies results in the highest river flows and highest recreational potential (San Antonio wastewater return flow is 275,000 acre-feet per year). This is followed by Alternatives I and III, which have the second highest level of constant effluent flow (175,000 acre-feet per year). Alternative II includes the largest amount of reuse, which reduces effluent flow to the lowest level (95,000 acre-feet per year); therefore, it has the lowest recreation benefit.

Alternatives I and III have recreational benefits that can be related to total visitor days associated with the reservoirs included in each alternative (see Appendix N). Alternative III rates highest with an estimated 2.1 million visitor days in the first year of operation of all reservoirs, followed by Alternative I with an estimated 1.7 million visitor days. Both Present Policies and Alternative II include no reservoirs, so these alternatives have no new reservoir recreation potential.

Wildlife Habitat and Vegetation. Wildlife habitat and vegetation will be lost in the areas inundated by new reservoirs and traversed by transmission pipelines in Alternatives I and III. On the other hand, aquatic habitat will increase due to the new lakes as reservoir-stocking programs are initiated. Terrestrial habitat and vegetation are assigned a slightly higher value than aquatic habitat, because terrestrial habitat in this area is likely to support a higher variety of plant and animal organisms. Therefore Alternatives II and Present Policies are more favorable than Alternatives I and III.

Acres of habitat associated with each reservoir are as follows (Ref. 2 and 3).

Reservoir	Approximate Acres of Existing Habitat Lost = Acres of Aquatic Habitat Gained	
	Alt. I	Alt. III
Applewhite	2,500	2,500
Cibolo	16,700	16,700
Cloptin Crossing	6,100	--
Cuero I	41,500	41,500
Cuero II	--	26,900
Goliad	27,800	27,800
TOTAL	94,600	115,400

The total acres of habitat and number of animals estimated to be lost due to reservoir inundation are given in Table 5-10. Values are from a U.S. Fish and Wildlife Service 1974 study. Although the acreages and number of animals lost appear to be quite high, the average percent of total basin habitat and animals lost is a rather small 2 to 4 percent. With the exception of one species (swamp rabbit), percentage losses in the two river basins do not exceed the following values for any given species:

	Max. % Loss for Alternative	
	I	III
Habitat	3	5
Number of Animals	4	6

Bottomland forest is most subject to inundation and would sustain the greatest impacts of any of the affected habitat

Table 5-10
HABITATS AND NUMBER OF ANIMALS LOST DUE TO RESERVOIRS

Species	Total for Entire River Basins	Alternative I Lost Due to Inundation	Alternative I Percent of Basins	Alternative III Lost Due to Inundation	Alternative III Percent of Basins
White-Tailed Deer					
Acres of habitat	5,213,500	107,150	2.1	158,000	3.0
Number of animals	574,700	6,085	1.1	9,210	1.6
Javelina					
Acres of habitat	1,709,000	1,270	0.1	1,270	0.1
Number of animals	10,800	1[a]	1[a]	1[a]	1[a]
Turkeys					
Acres of habitat	3,432,200	93,050	2.7	143,900	4.2
Number of animals	69,700	250	0.4	1/	1/
Bobwhite Quail					
Acres of habitat	6,151,200	107,150	1.7	158,000	2.6
Number of animals	1,271,000	28,120	2.2	41,095	3.2
Mourning Dove					
Acres of habitat	8,067,500	135,900	1.7	194,200	2.4
Number of animals	4,800,000	72,665	1.5	103,840	2.2
Jackrabbit					
Acres of habitat	5,644,400	107,150	1.9	158,100	2.8
Number of animals	298,200	4,593	1.5	5,625	1.9
Swamp Rabbit					
Acres of habitat	73,000	8,325	11.4	18,885	25.9
Number of animals	13,800	1,660	2.5	3,770	27.3
Cottontail Rabbit					
Acres of habitat	7,779,900	107,150	1.4	158,000	2.0
Number of animals	929,200	22,960	2.5	41,035	4.4
Fur-Bearers (all)					
Acres of habitat	8,577,700	107,150	1.2	158,000	1.8
Number of animals	2,720,200	107,150	3.9	158,000	5.8
Squirrel					
Acres of habitat	3,568,700	107,150	3.0	103,170	2.9
Number of animals	266,400	8,610	3.3	8,780	3.3
Waterfowl					
Acres of habitat	375,000	9,546	2.5	19,713	5.3
Number of animals	varies	1,074	varies	2,218	varies
Total Number of Listed Animals	10,953,800	253,367	2.3	373,573	3.4

Source: U.S. Bureau of Reclamation, San Antonio-Guadalupe River Basins Study, 1978, based on U.S. Fish and Wildlife Service study in 1974.

[a] Animals or harvest negligible

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types (forest, rangeland, pasture, and cropland). It is also the habitat with the highest habitat value. Alternative I reservoirs affect about half as much of this land as does Alternative III.

Alternatives I and III would both inundate about 10 percent of 1,130 miles of river system in both the San Antonio and Guadalupe basins. Although native aquatic species in these sections of river will decline in population, this loss is offset by the increase in aquatic species associated with the reservoirs which are highly valued in recreation fisheries (Ref. 4). Aquatic resources will thus be improved by Alternatives I and III, while no change in these resources will occur for Alternatives II and Present Policies.

Vegetation will be lost in areas inundated by reservoirs or cleared for transmission pipeline construction. The loss of vegetation in transmission pipeline rights-of-way is temporary; these areas will be vegetated after construction. The number of acres lost for Alternatives I and III will be about 95,000 and 116,000, respectively. No acres are lost for the Present Policies Alternative and a relatively negligible amount at reuse facilities sites in Alternative II.

<u>Threatened and Endangered Species</u>. The following four threatened or endangered species, which are dependent on springflow, could be affected by the various alternatives considered:

- o San Marcos Gambusia (small fish)
- o Fountain darter (small fish)
- o San Marcos salamander
- o Texas wildrice (in the San Marcos River downstream of springs)

Although the fountain darter and San Marcos salamander have been reported in the past to occur in the Comal River and springs (Ref. 5), the most recent field investigation effort (Ref. 6) did not yield any samples of these two species. Therefore, the following statement was made concerning the habitat of the Comal River:

> Both direct channel modification and extensive development along the banks has taken place over the entire length of the Comal River. This, together with the natural variability of the springs, has resulted in a highly altered biological community. The overall diversity has been reduced and the unique endemic species once found here are no longer in evidence.

Consequently, the balance of this review of the four listed species will focus on their occurrence at San Marcos Springs and in the San Marcos River.

The Present Policies Alternative, which depletes springflow, will essentially eliminate these four species. Therefore, the three other alternatives, which include natural and/or artificial springflow, are their best hope of survival. A possible mitigation measure if springflows cease is to re-establish these species at other locations. Although reestablishment of the fountain darter has been successfully accomplished in the past, reestablishment of the other species elsewhere would be extremely difficult or unlikely due to the rarity of these species and/or their dependence on the unique chemical and temperature characteristics of San Marcos springwater (based on U.S. Fish and Wildlife Service's 1984 study, "The San Marcos Recovery Plan for San Marcos River Endangered and Threatened Species"). Continuation of natural springflow (Alternative I and III) is therefore the best option, followed by pumped, artificial springflow (Alternative II).

The following species--San Marcos Gambusia, fountain darter, and Texas wildrice--occur primarily downstream from Spring Lake at San Marcos Springs (Ref. 10). If augmentation water pumped downstream of Spring Lake meets the same temperature and quality conditions that exist in the natural springflow water, these species may be indifferent to whether the springflows are natural or artificial. However, since they are very sensitive to changes in these parameters (Ref. 11), augmentation water does potentially pose a threat. Even though augmentation wells near the springs in Alternative II will be drawing from the same part of the aquifer that now provides natural springflow, there is no guarantee that the pumped water will have exactly the same chemical and temperature characteristics, due to variations within the aquifer. If continued heavy augmentation pumping draws water from the nearby "bad-water" zone of the aquifer, the higher levels of salts, chlorides, and sulfates from that zone could be detrimental to the endangered species. Even if the lower quality pumped water were treated to meet state water quality standards, it would be difficult if not impossible to maintain the same exact chemical/temperature characteristics that existed in the natural springflow state. Therefore, there is greater risk to endangered species with Alternative II than with Alternatives I or III, which both provide natural springflow.

The minimum annual average flow for biota maintenance recommended in a previous report is 72,000 acre-feet per year (Ref. 12). Alternatives I and III will maintain an average of over 110,000 acre-feet per year and 120,000 acre-feet per year of natural flow, respectively, at San Marcos springs throughout the study period. The minimum requirement is thus satisfied during years of average or greater recharge to the Edwards. A drought that causes springflows to drop below the maintenance level of 72,000 acre-feet per year would require temporary pumping to the river from wells. The same risk to the biota with respect to temperature and quality under Alternative II augmentation well pumping conditions is also present during droughts for Alternatives I and III, but to a much lesser degree because augmentation water would be mixed with natural spring water only temporarily during droughts. No major changes in Edwards water quality or the position of the "bad-water" line were detected during the severe but temporary historic drought of the 1950's (Appendix G), so no significant quality effects due to temporary pumping are anticipated in the future for Alternatives I and III.

Since under Alternative III the spring has slightly higher flow and is less likely to go dry during a drought than it is under Alternative I, Alternative III has a higher benefit. Alternative II has less environmental benefit because flow volumes are lower and totally comprised of pumped flow rather than natural springflow.

The San Marcos salamander is very sensitive to natural springflow because it lives in the upper reaches of Spring Lake and in the vegetation near the lake-bottom fissures that constitute San Marcos Springs. An extended cessation of natural springflow will almost certainly eliminate this species. Artificial river augmentation from wells downstream of Spring Lake will not preserve the necessary habitat. Therefore, Alternative III is the best option when considering maintenance of the San Marcos salamander's habitat. Under a worst case simulation of a 1950's intensity drought occurring during the study years 2030 to 2040, the lowest estimated yearly San Marcos springflow was about 4,000 acre feet, which would likely maintain water in Spring Lake to preserve the salamander's habitat.

Alternative I is less reliable for the salamander's protection since San Marcos Springs could go dry for up to 2 years if a drought of the intensity experienced in the 1950's occurs again. The Present Policies Alternative is only marginally superior to Alternative II since natural flow at San Marcos Springs can be maintained only slightly longer on average, until year 2037 as opposed to year 2031. The springs will very likely be intermittently dry long before this when a drought occurs. Alternative II accelerates depletion of natural springflow once river flow augmentation by pumping from the aquifer is begun.

Other endangered species that have habitat requirements that occur in the study area, but are not known to occupy any of the specific areas affected by the various alternatives, are given below (Ref. 7 and 8).

Other Endangered Species

American alligator	Interior least tern
Attwater's greater prairie chicken	New Braunfels snakewood
Bald eagle	Peregrine falcon
Eastern brown pelican	Red wolf
Eskimo curlew	Texas blind salamander
Houston toad	Whooping crane

Of these species, the Bald eagle may benefit slightly from an increase in lake-shore habitat associated with the reservoirs of Alternatives I and III (Ref. 9).

Bays and Estuaries. Bay and estuary systems are very complex, so that the relationship between inflow and estuary finfish and shellfish production is not readily determined. One of the main complications is the high variability in bay and estuary conditions. Several studies have been undertaken as a means to provide a better understanding of the complex relationships that exist. Studies by the TDWR have resulted in target inflow volumes, but these targets are not well enough substantiated to determine if the bays will be helped or impaired by greater or lesser flows. The TDWR made the following comments in January 1984 to the Texas Joint Committee on Water Resources regarding the results of its most recent estuary studies:

> Additional studies of key ecological processes and field testing of the mathematical relationships already developed among the important environmental factors should be performed in order to verify the accuracy of current estimates of the need for freshwater inflow to the estuaries.

Regarding the information available for analysis, the TDWR continued, "we do not believe that adequate information is yet available."

The effort in this study is therefore directed toward rating the potential estuary impacts of the various alternatives in relation to each other, rather than in relation to some standard. Consideration is given to Corpus Christi Bay (Nueces Estuary) and San Antonio Bay (Guadalupe Estuary).

Corpus Christi Bay inflows remain relatively constant under all alternatives, so all alternatives rate equally high. Inflows to the San Antonio Bay vary with the alternative chosen, so benefits were assigned relative to resultant flow. Present Policies has the highest estuary inflow

(1,830,000 acre-feet per year gauged and ungauged) and was assigned maximum benefits. Alternative II has inflow of 1,680,000 acre-feet per year (gauged and ungauged), so it receives the next most favorable rating. Bay inflows under Alternatives I and III are reduced by diversion of surface water from reservoirs to demand centers and water loss to evaporation, so that estuary inflows are 1,370,000 acre-feet per year and 1,290,000 acre-feet per year respectively. Benefits assigned to these two alternatives are therefore the lowest by comparison.

The remaining flow in the rivers reaching the bays is substantial in all alternatives, averaging about 1,500,000 acre-feet per year, which is about the same as the total amount required for all upstream study area water needs by year 2040. Espey, Huston and Assoc. (Ref. 13) noted in its 1985 study that the reservoirs considered here have an acceptable level of impact on the estuaries, based on maintaining an adequate bay salinity to promote marine growth. This conclusion was based on a very detailed examination of historical fish harvests and salinities plus computer predictions of monthly bay inflows with reservoirs in place. However, additional computations will still be needed to finalize inflow impacts when exact reservoir sizes are agreed upon during water purchase negotiations and water rights permit applications.

Texas water law currently contains safeguards for bay and estuary inflows. First, if any new reservoir within 200 river miles of the coast is constructed with State financial assistance, 5 percent of the firm annual yield of the reservoir is appropriated to the Texas Parks and Wildlife Department for release to the bays and estuaries (Texas Water Code Section 16.1331). This could apply to Goliad and Cuero Reservoirs if State financial assistance is used, as is currently assumed.

Second, the Texas Water Commission must include in all water rights permits issued for sites within 200 miles of the coast, "to the extent practicable when considering all public interests, those conditions considered necessary to maintain beneficial inflows to any affected bay and estuary system" (Texas Water Code Section 11.147). The "200 river mile" provision covers all reservoirs in the alternatives presented herein. However, it is not known at this time how much, if any, additional releases from firm annual yields would be required. Amounts would be determined during the water rights permitting process.

These provisions could reduce firm yield values for some of the reservoirs in this study. However, reservoir yields have not been adjusted in this study to provide additional downstream relases for the estuaries since the final impact of these provisions is uncertain and since the reservoir yield estimates could easily vary by more than 5 percent based on the dam crest height assumed and the levels of springflow and wastewater return flows assumed.

Archeological and Cultural Resources. Based on the number of known archeological sites listed below (Ref. 14), Alternative III will have the most adverse impact, followed by Alternative I. Alternatives II and Present Policies will have no adverse impacts. (NA in following tabulation indicates data not available.)

Reservoir	Number of Sites: Alt. I	Number of Sites: Alt. III
Applewhite	NA	NA
Cibolo	54	54
Cloptin Crossing	NA	NA
Cuero I	350	350
Cuero II	-	11
Goliad	NA	NA
KNOWN SITES (WITHIN FLOOD POOL)	404	415
ADDITIONAL POSSIBLE SITES FROM FIELD RECONNAISSANCE	43	70

Sites are known to exist within both the Guadalupe and San Antonio basins in areas subject to reservoir development for Alternatives I and III. The greatest impacts are associated with the Cuero I reservoir, which has been thoroughly studied, and is included in both alternatives.

The existence of significant archeological and cultural resources should not prevent reservoir construction; however, the identification of any sites will necessitate the development and execution of mitigation plans in order to obtain State and Federal permits (Ref. 15).

Summary of Environmental Impacts. As shown in Table 5-10, Alternative III is the most favorable in terms of environmental impacts, followed closely by Alternative I. Alternative II is next best, and Present Policies Alternative is least favorable. The alternatives with reservoirs (I and III) receive lower rankings with respect to habitat disturbance, archeological site disturbance, and flows to the bays. However, these factors are more than offset by the benefits that the increased water supply affords in the areas of water quality, recreation, and endangered species. Less dependence on the Edwards Aquifer in Alternatives I and

III results in stabilization of groundwater levels and improved springflows, which lead to the higher ranking.

Implementation

Factors determining the ease with which a given alternative can be implemented include the following:

- General resistance to change
- Cost impacts on the water consumer
- Potential legal/administrative challenges by other parties who share the area's common water resources and who may be adversely impacted by a plan
- Public attitudes regarding efficient resource utilization
- Perceptions of equity by general public and impacted agencies
- Public acceptability of proposed levels of wastewater reuse

Although the ease of implementation is difficult to predict given all the variables involved, some general observations can be made. The Present Policies Alternative is initially the easiest to implement since it requires no changes. Other alternatives require new approaches to water policy in this area and will meet with varying levels of resistance at first until people are convinced of a plan's merits.

With regard to public reaction to water cost increases, Present Policies will generate the least resistance since cost increases will be minimal. Alternative II has slightly more cost impact. Alternatives I and III have considerably more impact on water rates. Average residential water costs would rise about 30 to 70 percent above current levels to pay for regional facilities, not counting the standard water utility increases to cover system improvements and inflation. As discussed above, Alternative I results in slightly higher increases for most customer groups than does Alternative III.

The potential legal/administrative challenges by various groups impacted by Alternatives II and Present Policies are a disincentive to ultimate adoption of these alternatives. Even though no plan is immune to challenges or lawsuits, Alternatives I and III are judged to have the least potential for challenges since all competing demands for water quantity and quality protection are best satisfied. Most efficient overall resource utilization is also provided by these alternatives.

All financial plans for the alternatives include consideration of the principal of equity, i.e., those who benefit should pay for water resource planning and new facilities. However, various user groups will likely object, at least initially, that the cost sharing is not equitable under any new revenue plan. For example, farming interests could object to various Alternatives II and III financing options, which include well pumpage fees and well permit fees. City of San Antonio residents could insist that all groundwater users, including farmers, should share in the cost of any new programs related to the common resource, the Edwards Aquifer. Thus Alternatives I and Present Policies, which require no new area-wide financial participation, are judged easier to implement at the outset than Alternatives II and III.

Wastewater reuse plans will likely be viewed at first with some skepticism until public education programs convince people of the benefits and safety of such a plan. Alternative II plans include a significantly higher amount of reuse than other alternatives--180,000 acre-feet per year versus 100,000 acre-feet per year for Alternatives I and III. Therefore Alternative II is judged most difficult to implement with regard to this issue.

Each individual or group will have a different perception of which alternative will be easiest to implement, depending on the relative emphasis given to each of the above factors. For purposes of ranking the alternatives, it is assumed here that Alternatives I and Present Policies get equally high rankings as easiest to implement, Present Policies because it requires no changes and Alternative I because it will best avoid the potential legal challenges and does not have the obstacle of convincing so many new participants in area-wide financing. Alternative III is judged next easiest to implement because it accomplishes essentially the same results as Alternative I but requires area-wide financial participation. Alternative II is considered most difficult to implement because it could 1) incur legal/ administrative challenges due to lowered groundwater levels and reduced springflow, 2) generate opposition to area-wide financial participation particularly when it provides fewer benefits than Alternatives I or III, and 3) develop greater public resistance to wastewater reuse plans.

Flexibility

A comprehensive water resource plan should be flexible enough to meet unexpected changes in demand and to be able to transfer water supplies readily between areas of water surplus and deficit. If, as predicted, the population of greater San Antonio rapidly escalates, it would be desirable to have water and plant capacity locally available to meet the additional demands. At the same time, the plan should not be too dependent on any one source of water but should provide a mixture of ground and surface water from different locations for maximum flexibility.

The Present Policies Alternative provides the least flexibility since resources are not coordinated on an area-wide basis and the dependence on groundwater limits the options available for many areas. At the other extreme, Alternative III includes the most new reservoirs, which represent an irreversible commitment once they are built. They can, of course, be delayed right up until the start of construction date if demands do not develop as projected.

Alternatives I and III provide for the best coordination and balance of resources and the best arrangement for adapting to changing needs and desires of people in the study area. With groundwater levels stabilized and with surface water supplies expanded, the ability to rely on either resource in times of emergency or changing need patterns is strengthened. Adequate surface water is available to replace some well sources that may become unusable, while well water can be used as backup for emergency demands if surface water systems break down.

Alternative I, with $130,000,000 less in reservoir costs and fewer acres inundated, is judged to rate slightly higher than Alternative III in terms of irreversible commitments of financial and land resources. Alternative II, and lastly the Present Policies Alternative are considerably less flexible because they do not provide as diversified a mix of alternative water sources to meet emergency conditions or unexpected rapid growth.

Summary Comparison

Determining the best water resource management alternative requires local decision-makers to consider which solution would impose the least adverse environmental impacts, promise the best overall economic solution, maximize water availability and flexibility, and require the fewest tradeoffs among the various benefits and costs associated with implementation. The preceding sections of this chapter include analyses of identified economic and environmental criteria. Results of those analyses are summarized below, followed by an overall comparison.

Cost and Financial Impacts. Continuing with the present policies is the least expensive since the lowest cost resource, groundwater, would continue to be the major source. Alternative II follows closely behind Present Policies because the next lowest cost resource, wastewater reuse, is added. Alternatives I and III are significantly more expensive due to the addition of higher cost surface water. Although Alternative III is almost double the cost of Alternative I in terms of equivalent annual cost, it is about 20 percent less than Alternative I in terms of customer costs for the area's largest user group, San Antonio's residential customers. This is because Alternative III's higher costs are spread over a much larger customer base, covering the entire primary study area. For Alternative I, with no new laws to spread the financial burden, City of San Antonio customers will likely bear nearly the full cost of new surface water sources. Considering lowest cost water rates as the most appropriate cost indicator to the consumer, Present Policies Alternative rates highest, followed closely by Alternative II, with Alternative III third and Alternative I last.

Economic Impacts. The alternative providing the most water to the area ranks highest in making water available to maintain or increase primary area agricultural production, industrial production, recreational activity, real property values, and business development and investment. The ranking in terms of most beneficial economic impacts is Alternative III, followed by I, II, and Present Policies.

Water Availability. With new reservoirs in addition to groundwater, conservation and wastewater reuse sources, Alternatives I and III provide the most water to meet all competing needs. Alternative III ranks highest, followed closely by I. Alternatives II and Present Policies are a distant third and fourth place, respectively, because in both cases the Edwards Aquifer is overdrafted at rates greater than the annual recharge rate and the lower Guadalupe River basin will have minimal firm supplies of water to meet expected demands.

Environmental Impacts. Six factors were considered in the environmental analysis: water quality, recreation, wildlife habitat and vegetation, endangered species, bays and estuaries, and archeological and cultural resources. Alternatives I and III, by providing the most water, have the most beneficial impacts on water quality, recreation, and endangered species. When considering habitat/vegetation, estuaries, and archeological resources, Alternatives II and Present Policies have the least adverse impacts due to the absence of reservoirs. Overall, the benefits for alternatives with reservoirs were judged to more than offset the benefits of those alternatives without reservoirs, so the greatest environmental benefit accrues to Alternative III, followed by I, II, and Present Policies.

Implementation. The Present Policies Alternative would be easiest to implement since it requires no change from current water supply conditions. With the lowest cost, it would probably be favored initially by most ratepayers. The public may, however, react adversely to the unfavorable impacts and ultimate legal/administrative challenges that result from lowered water tables and reduced springflows, and therefore prefer Alternative I, which prevents these problems. Present Policies and Alternative I are thus given equally high ratings. Alternatives II and III are judged more difficult to implement because area-wide agreement must be reached on new laws that will spread the cost of facilities to all who currently overlie the Edwards Aquifer. Alternative II is judged the most difficult to implement because rates of nearly all users will be raised as in Alternative III, but the benefits will be minimal compared to Alternatives I and III.

Flexibility. Alternatives I and III have the most flexibility due to a balanced mix of several water sources that can best meet emergency conditions or unexpected rapid growth. Alternatives II and Present Policies, on the other hand, place a greater dependence on groundwater, thus magnifying drought impacts on this source and limiting the options in responding to drought or demand increases.

Overall Comparison

Three tabulations below present an integrated evaluation of the alternatives based on all of the screening criteria considered. In order to rank the importance of comparative factors, relative weights have been assigned to each of the above evaluation criteria. The only difference between the tabulations is the spread of relative weights to the factors. Each alternative is then rated with a number that represents its share of the relative weight assigned to each criteria. The water rate (cost) and environmental impacts were ranked in accordance with relative values given in this chapter. The remaining numbers shown were developed by rating an alternative at 10 to 100 percent of the weight, in increments of 10 percent, with 100 percent the highest rating. Therefore, a rating of 30 percent multiplied by a weight of 20 gives a score of 6 out of 20 possible points. Water rates, implementation, and environmental impacts are always given a significant relative weighting because they are generally paramount in the minds of the public that will ultimately choose one plan or the other through its public officials.

Scoring of Alternatives--Ranking 1

Evaluation Criteria	Relative Weight	Present Policies	I	II	III
Water Rates	30	30	16	26	20
Economic Growth	10	5	8	7	10
Water Availability	10	1	9	4	10
Environmental Impacts	20	9	14	12	15
Implementation	20	20	20	6	12
Flexibility	10	1	10	4	8
TOTAL	100	66	77	59	75

Scoring of Alternatives--Ranking 2

Evaluation Criteria	Relative Weight	Present Policies	I	II	III
Water Rates	40	40	22	34	26
Economic Growth	5	2	4	3	5
Water Availability	10	1	9	4	10
Environmental Impacts	20	9	14	12	15
Implementation	20	20	20	6	12
Flexibility	5	0	5	2	4
TOTAL	100	72	74	61	72

Scoring of Alternatives--Ranking 3

Evaluation Criteria	Relative Weight	Present Policies	I	II	III
Water Rates	30	30	16	26	20
Economic Growth	5	2	4	3	5
Water Availability	10	1	9	4	10
Environmental Impacts	30	14	22	17	23
Implementation	20	20	20	6	12
Flexibility	5	0	5	2	4
TOTAL	100	67	76	58	74

The numerical rankings indicate both Alternatives I and III have the best combination of beneficial impacts. Alternative I ranks slightly higher than III due to expected easier implementation. Alternatives II and Present Policies rank lower in all cases because of less favorable ratings on economic growth, water availability, environmental impacts, and flexibility. Placing a very heavy emphasis on the "water rates" criteria (40 percent in Ranking 2) brings the Present Policies Alternative into a tie for second place, but it still falls behind Alternative I due to lower ratings on nearly all other criteria. All three rankings result in a near tie for highest rating between Alternatives I and III because Alternative III's higher ranking on water rates and environmental impacts is offset by Alternative I's higher chance of implementation.

It is recognized that this ranking system, like any other, is subjective, and that other relative weights and values could be applied to various elements to result in other overall rankings. This analysis is not to be construed as a recommendation of one alternative over another. The purpose of this study is to present sufficient information about regional water resource issues and alternatives so that a responsible course of action can be selected by local decision-makers after a period of public review and comment.

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3. U.S. Dept. of the Interior, Bureau of Reclamation, Special Report on San Antonio Guadalupe River Basins Study: Texas Basin Project, Amarillo, Texas, November 1978.

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5. U.S. Fish and Wildlife Service, San Marcos Recovery Plan. Albuquerque, New Mexico, 1984.

6. Espey, Huston and Associates, Inc., Investigation of Flow Requirements from Comal and San Marcos Springs to Maintain Associated Aquatic Ecosystems, Guadalupe River Basin. Austin, Texas, February 1975.

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8. U.S. Dept. of the Interior.

9. Ibid.

10. U.S. Fish and Wildlife Service.

11. Espey, Huston and Associates, Inc., Investigations of Flow Requirements from Comal and San Marcos Springs to Maintain Associated Aquatic Ecosystem, Guadalupe River Basin.

12. Ibid.

13. Espey, Huston and Associates, Inc., Water Availability Study for the Guadalupe and San Antonio River Basins.

14. Ibid.

15. Ibid.

CHAPTER 6

Chapter 6
IMPLEMENTATION

INTRODUCTION

In Chapter 5, physical alternatives were developed which were based upon the three major study assumptions - 1) surface water reservoirs with the existing laws and institutions, 2) new laws and institutions only, and 3) surface water reservoirs with new laws and institutions. These alternatives, as well as the present policies alternative, were evaluated in terms of cost effectiveness, economic impact on the primary and secondary study areas, political feasibility, and other non-economic factors. As the next step in the study process, it is important to evaluate the implementation considerations related to each of the physical alternatives. In such a diverse environment as the five-county study area, it is essential that an effective implementation plan be developed which allows for the selection of a preferred physical alternative, achieves regional acceptance of that alternative, and provides a vehicle by which laws and institutions are in place to effectively construct facilities and administer the regional program.

Purpose of Chapter

In selecting the appropriate alternative and developing an effective implementation plan, it is important to consider the complex political climate, the diverse water beneficiaries affected, and special interest groups which will react to the study alternatives. As a result, an approach has been developed in this chapter which has as its objectives: 1) identification of a preferred alternative and achieving regional acceptance of that alternative, and 2) successfully implementing the alternative.

In addition to the political environment, it is important that the implementation plan address the technical aspects of the preferred long-range water resource alternative. In this chapter, the following implementation issues are addressed:

- Institutional Issues

  The appropriate agencies need to be identified which have sufficient powers to implement and administer the regional program. Existing institutions will be first considered as the mechanism for implementation. Where the powers of existing institutions are inadequate, an expansion of the powers of these institutions is recommended. In some cases, new institutions with appropriate powers to effectively deal with the regional program may need to be considered. An important institutional issue will deal with the appropriate structure of the Implementation Task Force. This Task Force will be the principal vehicle for selecting an appropriate course of action and gaining regional acceptance of this course of action.

- Legal Issues

  Under Alternatives II and III, new laws and institutional powers have been included as a part of the regional water implementation plan. To be implemented, the selected alternatives will have to receive strong support by the state legislature. The steps necessary to achieve regional acceptance and gain this support have also been included as a part of the implementation plan.

- Financing

  An essential step in implementation is the development of an appropriate plan for financing capital facilities and programs, and recovering related costs from water beneficiaries. This chapter evaluates in detail: 1) funding mechanisms for financing capital facilities and programs, 2) alternative methods of recovering relevant annual operating and capital revenue requirements, and 3) the financial impact on water beneficiaries of alternative financial planning scenarios.

Overview of Chapter

This chapter has been organized into three (3) sections:

- A. Summary of Findings, Conclusions, and Recommendations

  In this section, the process that was used in developing the findings, conclusions and recommendations is described. This section also provides a comprehensive overview of the results of the analysis. Presented are the key characteristics which affect the development and implementation of a regional water plan; legal and institutional considerations; and alternative financial planning scenarios with related impacts on water beneficiaries.

- B. Institutional and Legal Considerations

  In the second section, the factors in the five-county study area which affect the institutional recommendations for each physical alternative are discussed. In addition, existing legal constraints regarding institutional powers and financing vehicles available are presented.

- C. Implementation Plan

  The third section provides an overview of the implementation process, objectives of the implementation plan, key considerations in developing an implementation plan, and a description of the various implementation phases. In addition, the Water Resource Management Board and the Implementation Task Force are discussed in detail. The proposed plan for selecting a preferred course of action and gaining regional acceptance for this course of action is identified. Finally, a detailed description of the implementation plan for each physical alternative is provided.

Reliance on Financial, Engineering and Operating Data

A significant amount of financial and engineering data has been incorporated in the analysis. Input was provided by personnel from the three river authorities, City Water Board, the Edwards Underground Water District, New Braunfels Utilities, the City of San Marcos, the City of Uvalde, the Lackland City Water Company, and the appraisal offices in each of the five counties in the primary study area. In our opinion, this data appears reasonable. However, cost and revenue projections employed in the analysis should not be construed as statements of fact. The accuracy of any financial projection is dependent upon the occurrence of future events which cannot be assured. Financial projections may be affected favorably or unfavorably by many factors such as water usage, governmental regulations or controls, and general economic conditions.

In addition, financial impacts have been projected in real terms. That is, no inflationary components have been included in prices, interest rates or bond coupon rates. The reader should keep in mind, therefore, that the projected charges and related customer impacts are expressed in 1985 dollars. As a result, costs, charges, and related customer impacts will be higher once inflation has been incorporated.

The financial impact on water beneficiaries provides a major criteria for evaluating the feasibility of a physical alternative. It is important to emphasize that the purpose of the analysis is to provide sufficient detail for decision making purposes. Before a financial plan is adopted and implemented, it will be necessary to perform additional analysis at greater levels of precision. More refined estimates of the following variables will be required in this analysis:

- Water Demand
- Program Costs
- Capital Costs
- Annual O&M Requirements
- Staging of Construction Programs

More detailed analyses will facilitate the development of rate and charge structures and cost allocation schedules and will enable bond financing requirements to be properly addressed.

A. SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

RESULTS OF EVALUATING PRESENT POLICIES AND THE ALTERNATIVES

Table 6-1 summarizes the major points of each alternative to be considered during the implementation process including capital costs, financial impacts, major facilities, revenue sources, new laws, and institutional responsibilities. For each alternative, five possible financing scenarios have been identified which would recover revenue requirements. Figure 6-1 and Table 6-2 summarize revenue requirements for each of the alternatives over the study period as presented herein. These costs can vary based on actual timing of projects and on whether "smoothing" technique are used to levelize some of the wide swings in costs. Revenue requirements are those dollars that need to be collected each year to pay operating and maintenance costs, debt service (principal and interest) and the debt coverage required on revenue bonds used to finance identified capital improvements. Specifically excluded from the costs to be recovered from the primary study area are the following: 1) all costs of Goliad Reservoir, 2) approximately 10 to 30 percent of Cuero I or Cuero I & II reservoir costs. These costs are to be repaid by future SARA & GBRA customers. Figures 6-2 through 6-4 summarize, for each of the alternatives, dollars to be collected from the region during selected years based on the financial planning scenarios detailed in Appendix O.

Tables 6-3 and 6-4 summarize the average and maximum impacts upon water beneficiaries. Detailed impact schedules for each financing scenario are provided in Appendix O. Average impact represents the average change in costs from the existing levels to the particular financing scenario for a water beneficiary. Maximum impact occurs during a peak period sometime during the 50-year horizon. The five financial planning scenarios were based upon different combinations of methods in recovering annual revenue requirements. These methods are described in Appendix O. As can be seen in Tables 6-4, the maximum impact on certain water beneficiaries is severe. It is important to note that through improved facility staging, financial smoothing, and numerous other smoothing techniques, the regional plan should attempt to approach the average impacts as presented in Table 6-3. As more fully discussed in Appendix O, some consideration should be given to the use of "lifeline" rates to soften the impact of rate increases to those who may have difficulty in affording the indicated water costs. The use of such rates, which should be studied during future rate-setting processes, has not been included in this analysis of overall impacts.

The average impact of the five scenarios for each water beneficiary is evaluated. In addition, the average impact of each scenario is identified after water availability and well permit revenues have been used as an offset. Appendix O also

SAN ANTONIO REGIONAL WATER RESOURCE STUDY

TABLE 6-1

SUMMARY OF IMPLEMENTATION CONSIDERATIONS FOR EACH ALTERNATIVE

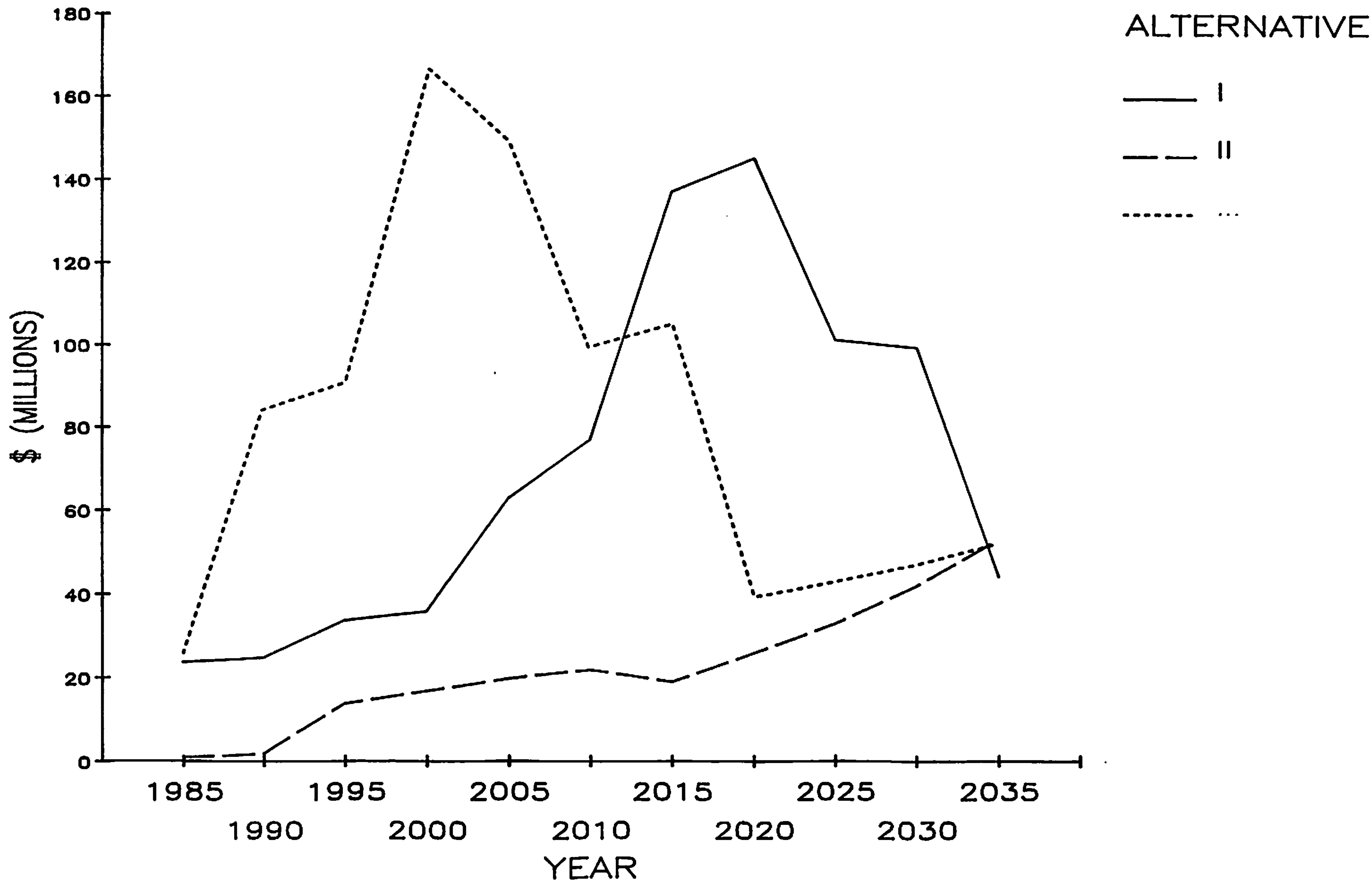
Alternatives	Total Capital Cost (1985 $)	Major Facilities	Financial Impact on Avg. Residential Customers** (Monthly Costs - 1985 $)	Revenue Services Considered	New Legislation	Institutional Responsibilities
I. Use any existing or new water sources within the framework of existing laws and institutions.	$1,723,000,000	Dam & Reservoirs* • Applewhite • Cibolo • Cloptin Crossing • Cuero I • Goliad Wastewater Reuse 100,000 acre-feet per year	Average $17/month 70% increase Maximum $30/month 200% increase	• Water availability charges • Ad valorem taxes • User charges	• None - plan accomplished using existing laws and interjurisdictional agreements.	• River Authorities - design, finance, construct and operate reservoirs and associated conveyance and treatment facilities. • EUWD - administer cost recovery system and act as trustee and arbiter under terms of interjurisdictional agreement. • City of San Antonio - finance, construct, own and operate wastewater reuse facilities (Alternative - San Antonio River Authority). • Water Purveyors - development of local supply wells and construction of local system improvements.
II. Use existing water sources, but allow for new laws and institutions	$521,000,000	Wastewater Reuse 180,000 acre-feet per year	Average $12/month 20% increase Maximum $14/month 40% increase	• Water availability charges • Well permit fees • Well pumpage fees • Sales taxes • Ad valorem taxes • User charges	• Adoption of plan by state legislature and authoriza- for EUWD/WRMB to enforce provisions of plan. • Establishment of increased groundwater protection powers for EUWD. • Mandatory conservation requirements. • Broader powers and requirements to establish necessary revenue programs (availability charges, sales tax, etc.).	• River Authorities - limited additional duties (no new reservoirs). • EUWD - Administer cost recovery system, well permitting program and mandatory conservation program. • City of San Antonio - finance, construct, and operate wastewater reuse facilities (Alternative - San Antonio River Authority). • Water Purveyors - development of local supply wells and construction of local system improvements.
III. Use existing or new water sources and allow for new laws and institutions.	$1,852,000,000	Dam & Reservoirs* • Applewhite • Cibolo • Cuero I & II • Goliad Wastewater Reuse 100,000 acre-feet per year	Average $15/month 50% increase Maximum $28/month 180% increase	• Water availability charges • Well permit fees • Well pumpage fees • Sales taxes • Ad valorem taxes • User charges	• Adoption of plan by state legislature and authorization for EUWD/WRMB to enforce provisions of plan. • Establishment of increased groundwater protection powers for EUWD. • Broader powers and requirements to establish necessary revenue programs.	• River Authorities - design, finance, construct and operate reservoirs and associated conveyance and treatment facilities. • EUWD - administer cost recovery system and well permitting program. • City of San Antonio - finance, construct, and operate wastewater reuse facilities (Alternative - San Antonio River Authority). • Water Purveyors - development of local supply wells and construction of local system improvements.

* Plus associated conveyance and treatment facilities.

** City of San Antonio Water Board Customer - percentage increase as compared to existing cost per month of $10.

FIGURE 6-1

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
REVENUE REQUIREMENTS*
PER YEAR
(1985 $)



*Revenue requirements include: operating and maintenance c[illegible]s, [illegible]t service and [illegible]t c[illegible]rage

TABLE 6-2

Revenue Requirements in Five-Year Increments*
($000's)

	Five-Year Increment Beginning										
	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
ALTERNATIVE I											
Operating & Maintenance Costs	$ 328	$ 1,855	$ 9,455	$11,555	$12,955	$18,355	$ 21,955	$ 29,900	$ 34,400	$40,400	$44,400
Capital Requirements**	23,464	23,465	24,449	24,489	50,157	58,366	115,357	115,368	66,184	58,775	-0-
Total	$23,792	$25,320	$33,904	$36,044	$63,112	$76,721	$137,312	$145,268	$100,584	$99,175	$44,400
ALTERNATIVE II											
Operating & Maintenance Costs	$ 852	$ 1,404	$ 7,604	$10,004	$12,504	$14,904	$ 17,804	$ 23,004	$ 27,604	$33,704	$40,004
Capital Requirements**	203	261	6,429	7,056	7,315	7,481	1,636	3,394	5,429	8,566	12,747
Total	$ 1,055	$ 1,665	$14,033	$17,060	$19,819	$22,385	$ 19,440	$ 26,398	$ 33,033	$42,270	$52,751
ALTERNATIVE III											
Operating & Maintenance Costs	$ 697	$ 2,993	$14,293	$ 17,793	$ 23,933	$30,533	$ 34,833	$ 38,833	$ 43,433	$46,633	$51,433
Capital Requirements**	24,796	80,766	76,765	149,402	124,605	68,636	68,636	-0-	-0-	-0-	-0-
Total	$25,493	$83,759	$91,058	$167,195	$148,538	$99,169	$103,469	$ 38,833	$ 43,433	$46,633	$51,433

* 1985 dollars.

** Debt service (principal and interest payments) and coverage.

NOTE: Operating and maintenance costs include additional regional administration costs as described in Appendix O.

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
ALTERNATIVE I
DOLLARS COLLECTED FROM REGION
PER YEAR — SELECTED YEARS

FIGURE 6-2

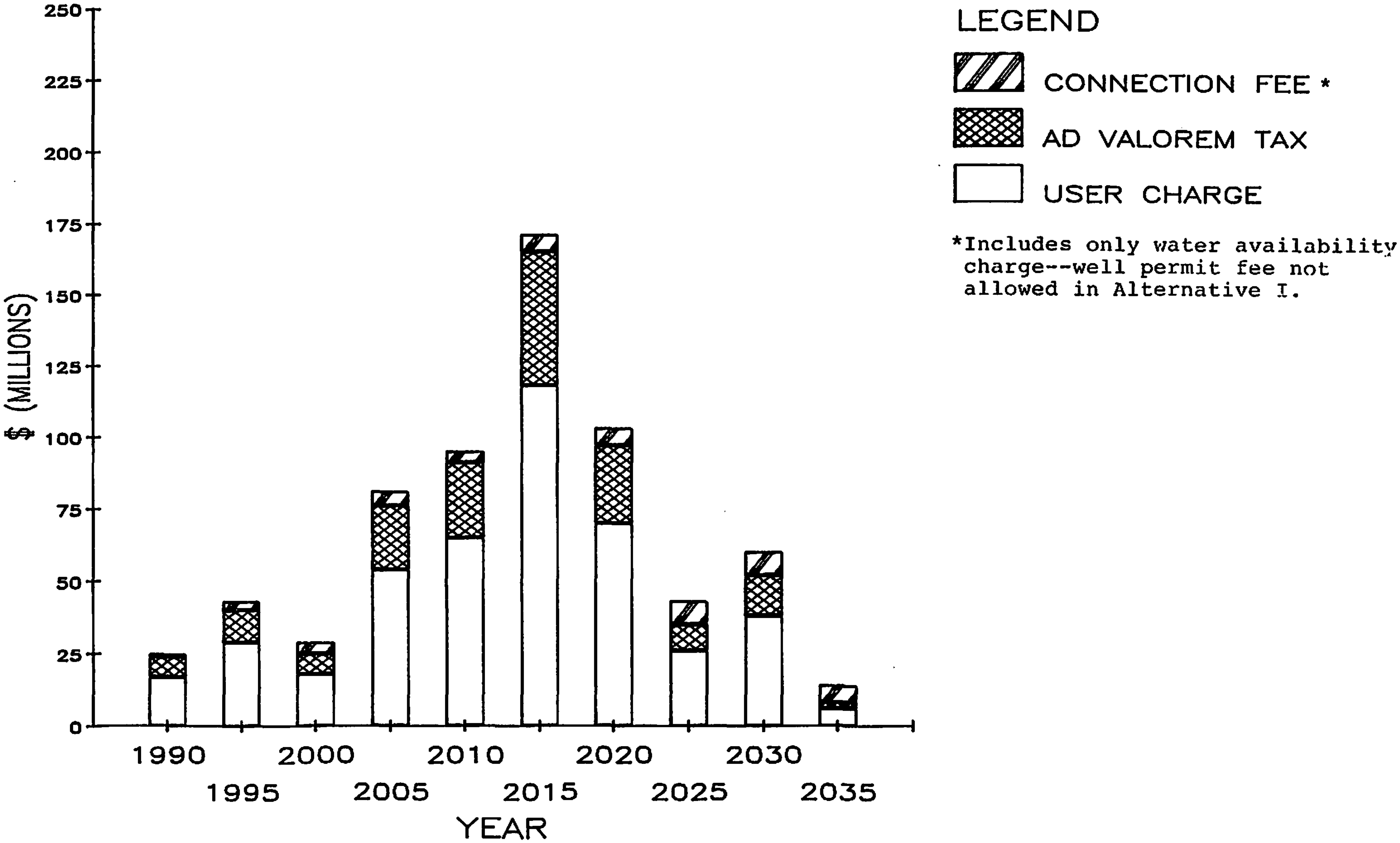


FIGURE 6-3

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
ALTERNATIVE II
DOLLARS COLLECTED FROM REGION
PER YEAR — SELECTED YEARS

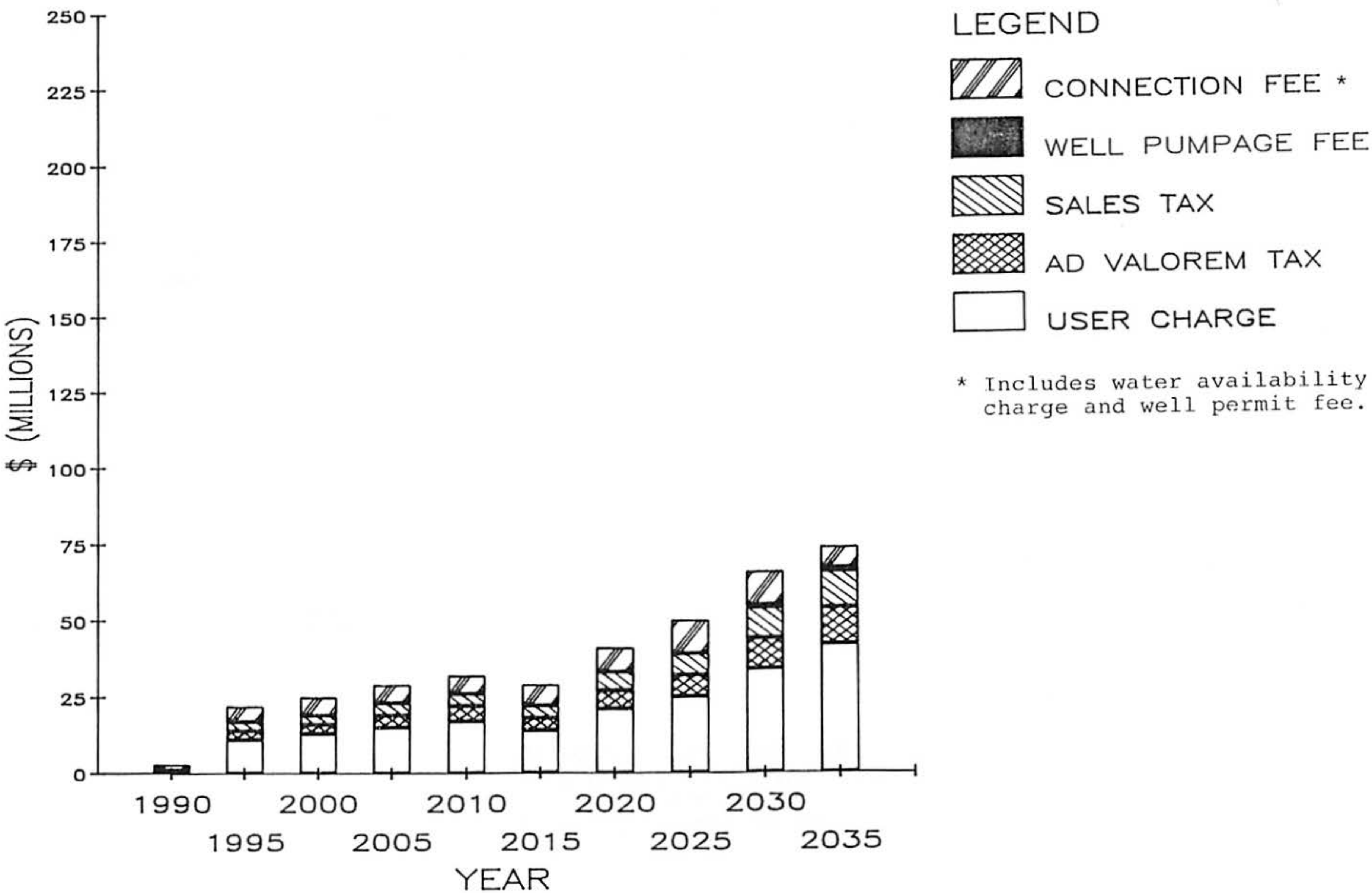
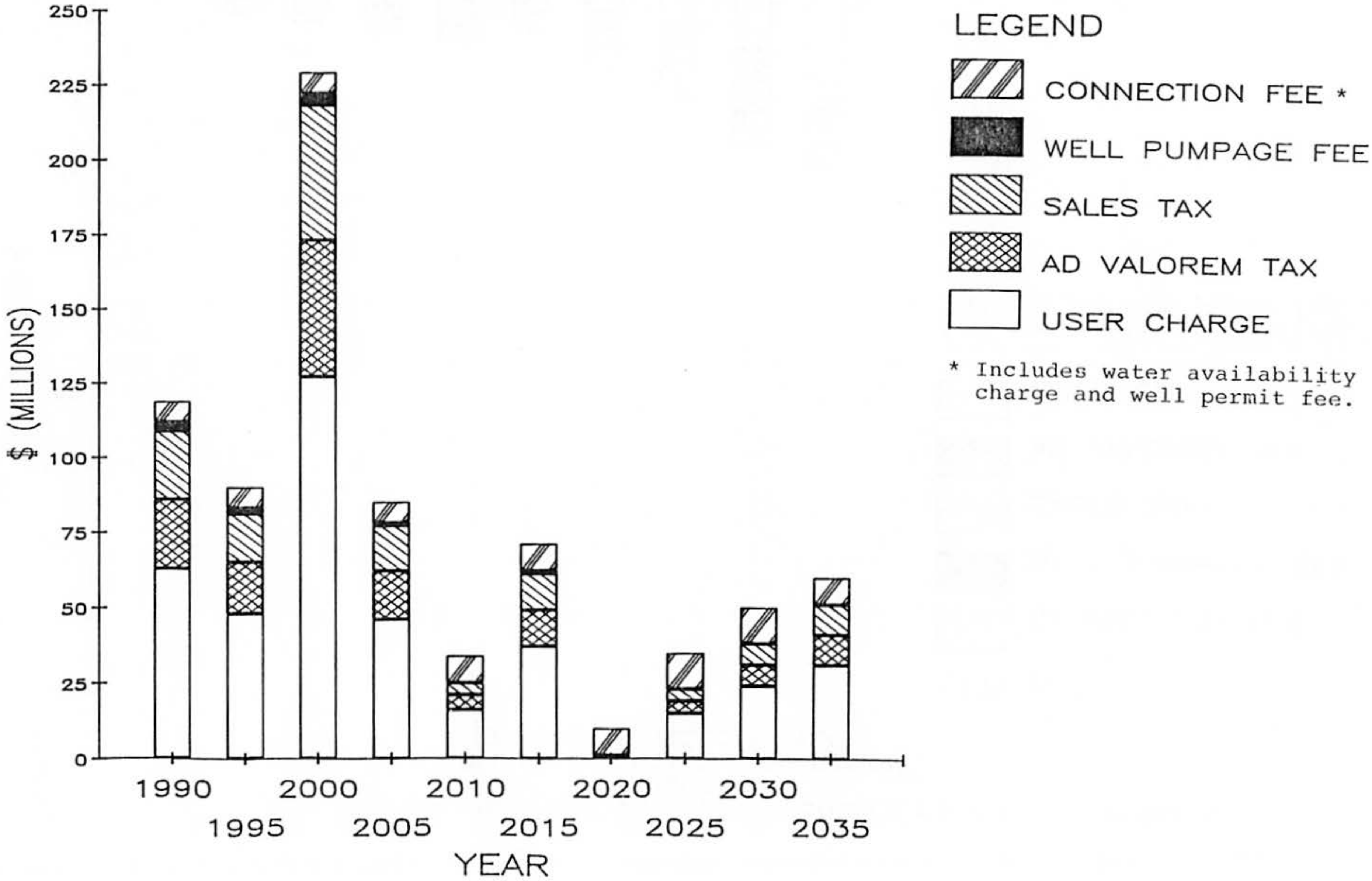


FIGURE 6-4

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
ALTERNATIVE III
DOLLARS COLLECTED FROM REGION
PER YEAR — SELECTED YEARS



SAN ANTONIO REGIONAL WATER RESOURCE STUDY

TABLE 6-3

Customer Impact Table

Average Monthly Cost (1985 $) Over Study Period to Year 2040

Water Beneficiary	Existing	Present Policies	I Average Cost	I % Increase	II Average Cost	II % Increase	III Average Cost	III % Increase
AVERAGE RESIDENTIAL CUSTOMER								
City Water Board	$10	$10+	$17	70%	$12	20%	$15	50%
Lackland City Water Co.	17	17+	17	0%	19	10%	21	25%
New Braunfels	10	11	16	60%	12	20%	14	40%
San Marcos	12	13	18	50%	14	15%	16	35%
Uvalde	7	8	7	0%	9	30%	12	70%
LARGE INDUSTRIAL CUSTOMER*								
Customer A on CWB	9,800	10,100	18,200	85%	12,000	20%	15,300	55%
Customer B with Well	1,400	1,900	1,500	7%	2,900	105%	5,200	270%
AVERAGE FARMER								
Bexar County	540	840	580	8%	780	45%	650	20%
Uvalde County	2,700	3,900	3,000	10%	3,900	45%	3,500	30%
RURAL DOMESTIC WELL OWNER	$1.20	$1.60	$2.10	75%	$2.80	135%	$5.50	360%
LARGE INSTITUTIONAL WATER BENEFICIARY								
CWB Customer	12,500	12,900	22,800	80%	15,200	20%	19,300	55%

NOTE: Projected charges and related customer impacts are expressed in 1985 dollars. Actual charges and related customer impacts will be higher.

*Data on property values and sales taxes paid were not available.

SAN ANTONIO REGIONAL WATER RESOURCE STUDY

TABLE 6-4

Customer Impact Table

Maximum Monthly Cost (1985 $) Within Study Period to Year 2040

Water Beneficiary	Existing	Present Policies	I Maximum Cost	I % Increase	II Maximum Cost	II % Increase	III Maximum Cost	III % Increase
AVERAGE RESIDENTIAL CUSTOMER								
City Water Board	$10	$10+	$30	200%	$14	40%	$28	180%
Lackland City Water Co.	17	17+	17	0%	20	20%	33	95%
New Braunfels	10	11	27	170%	13	30%	26	160%
San Marcos	12	13	33	150%	16	30%	28	135%
Uvalde	7	8	7	0%	10	40%	22	215%
LARGE INDUSTRIAL CUSTOMER*								
Customer A on CWB	9,800	10,100	31,900	225%	13,600	40%	28,600	190%
Customer B with Well	1,400	1,900	1,500	7%	4,100	193%	15,100	980%
AVERAGE FARMER								
Bexar County	540	840	600	10%	780	45%	650	20%
Uvalde County	2,700	3,900	3,000	10%	3,900	45%	3,500	30%
RURAL DOMESTIC WELL OWNER	$1.20	$1.60	$4.00	230%	$3.95	230%	$16.20	1250%
LARGE INSTITUTIONAL WATER BENEFICIARY								
CWB Customer	12,500	12,900	39,700	220%	17,200	40%	35,600	185%

NOTE: Projected charges and related customer impacts are expressed in 1985 dollars. Actual charges and related customer impacts will be higher.

*Data on property values and sales taxes paid were not available.

provides an additional financing scenario for each alternative, defined as the "new water/old water" methodology. This financing approach, as discussed more fully in Appendix O, attempts to allocate regional water costs more to growing areas than the other financial planning scenarios.

Present Policies

A detailed discussion of the impacts of continuing under the present policies is presented in Chapter 5. Since implementation of the present policies involves no more than continuation of current practices and institutions, little of this chapter is devoted to the present policies. In the evaluation of the financial impact of the physical alternative on water beneficiaries, however, consideration is made of the financial impact of the present policies when compared with the physical alternatives. A comparison is then made of the financial impact under the three physical alternatives with the existing present policies over the same 50-year base period.

The major observation under the present policies alternative is that the energy cost (unadjusted for inflation) to pump water from the aquifer will increase on average approximately 75 percent. This occurs due to the lowering of the water table, which requires water to be pumped from greater depths. As a result, water beneficiaries with a high percentage of costs related to pumping (agricultural and independent well owners/operators) will experience a greater impact than water beneficiaries with a lower percentage of pumping costs (customers of water purveyors).

Under the present policies alternative, water purveyors will continue to drill wells in an unregulated fashion; new well owners and operators will continue to size and locate wells in an unregulated manner; no comprehensive plan for constructing surface water reservoirs will be implemented; conjunctive use permitting will not be implemented; and mandatory conservation will not be enforced in the region.

Alternative I

Alternative I leaves the existing institutions and laws unchanged, but makes full use of existing powers to address future demands. Alternative I provides for the development of surface water reservoirs, raw water conveyance systems, surface water treatment plants, and wastewater reuse facilities.

Under Alternative I, existing laws and institutions allow for only three feasible cost recovery methods: user charges, ad valorem taxes, and water availability charges. Not allowed under this alternative would be the use of well pumpage charges, well permit fees, and region-wide sales taxes. Interjurisdictional agreements would have to be consummated with all municipal water purveyors. Under such agreements, purveyors would pass relevant revenues to the Edwards Underground Water District which would administer the cost recovery program. In order to obtain revenue bond financing of the regional water facilities, it would be necessary that these agreements be legally binding. Revenues collected by the District would then be passed to agencies involved in constructing and operating regional facilities.

It is unlikely that all water purveyors will agree to voluntarily participate and sign interjurisdictional agreements. As a result, the financial analysis was performed assuming an agreement between the Edwards Underground Water District and three water purveyors - the City Water Board, New Braunfels Utilities, and the City of San Marcos. These utilities were included because it is anticipated that they will experience significant future demand, have a vested interest in the maintenance of spring flows, and will likely be motivated to more aggressively address their long-term water resource needs.

As presented in Tables 6-3 and 6-4, the impacts on water beneficiaries include the following observations:

- The average increase in monthly water costs for affected residential customers ranges from 50 to 70 percent when compared with existing costs. The City Water Board residential customer is more severely impacted since he uses relatively more water than customers of the other utilities surveyed, and he has higher assessed property values.

- The maximum impacts on affected water beneficiaries range from 7 percent for a industrial customer on a well to 230 percent for a rural domestic well owner. The maximum impact on an average residential customer is significant, ranging from 150 percent to 200 percent.

- Even without the consideration of property taxes, the large industrial customer on the City Water Board's system has the largest average impact of 85 percent.

- Domestic well owners, who currently have very low water costs, are significantly impacted through the imposition of the ad valorem tax. Larger customers on wells are not significantly impacted.

- The imposition of a $600 Water Availability Charge reduces the average increase for all users by approximately 9 percent.

Alternative II

Under this alternative, the Edwards Underground Water District's responsibilities will be expanded significantly. New laws would be passed to give the District well permitting regulatory powers, mandatory conservation authority, and the responsibility for coordinating and administering the financial plan of the water resource alternative.

In developing equitable cost-recovery methodologies, it has been assumed that new laws would need to be passed. These new laws will allow the Edwards Underground Water District:

- to levy well pumpage charges and well permit fees on a regionwide basis.
- to levy a regionwide sales tax.
- to enforce mandatory regionwide conservation measures, including conservation pricing structures.

The financial impacts upon various water beneficiaries as presented in Tables 6-3 and 6-4, respectively, are summarized below:

- o Except for customers on wells, the average impact upon water beneficiaries is not significant, with the impact ranging from 10 percent to 45 percent.
- o Residential customer average impacts range from 10 to 30 percent.
- o Excluding the rural domestic well owner whose water costs are very low, the industrial customer with a well system is most heavily impacted, with an average percent increase from existing costs of 105 percent.
- o Because of the lower water table and increased pumping costs, the average farmer is more significantly impacted under this alternative then under either Alternative I or III. However, even this alternative has cost increases that are no greater than under present policies.

Alternative III

The third alternative allows for new laws and institutions to be created and for water demand to be met by a range of sources, including surface water reservoirs. Chapter 5 details the major capital projects under Alternative III.

The implementation of Alternative III will require that laws be passed and new institutions created. The new laws that will be created are very similar to those required under Alternative II. The exception to this is that mandatory conservation will not be required.

Alternative III has the broadest institutional impact on the various water resource entities. This impact occurs because of the need for new laws and the requirements for the river authorities, the Edwards Underground Water District, the City Water Board, all other water purveyors, the City of San Antonio, and the five counties in the area to be actively involved in the implementation of the regional water plan. The other two alternatives involve either new laws or active involvement by the various water resource entities, but not both. The Edwards Underground Water District will have the same broad powers as outlined in Alternative II, with the exception of mandatory conservation.

As shown in Tables 6-3 and 6-4, the financial impacts for Alternative III are:

- The average residential customer has an average impact between 25 percent and 70 percent. However, maximum impacts for these same customers range from 95 percent to 215 percent.

- Water beneficiaries on well systems are more significantly impacted in Alternative III than in the other alternatives.

- Except for farmers, the maximum impacts significantly affect all water beneficiaries. These maximum impacts range from 100 percent for a Lackland City Water Company residential customer to 1,250 percent for a rural domestic well owner.

Figure 6-5 depicts, for each alternative, projected changes in the average residential bill for a City Water Board customer (1985 $) over the study period.

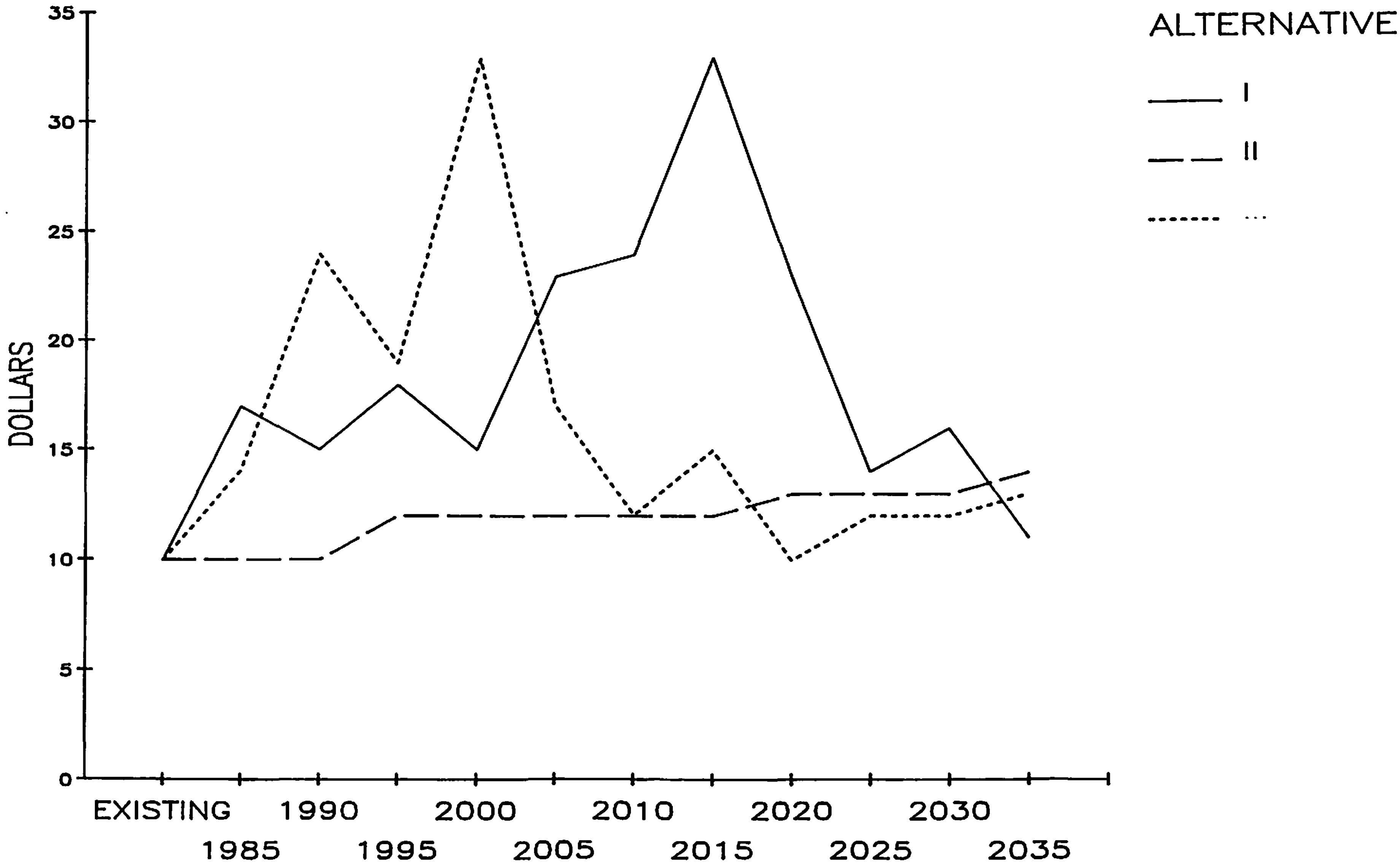
Comparison of Texas and National Water Rates

Table 6-5 presents a comparison of San Antonio, New Braunfels, San Marcos, and Uvalde average residential water costs with selected Texas cities. At current rates and at rates that have risen by the average increase presented earlier, the four cities within the study area compare favorably with other Texas cities that rely on surface water (i.e. Corpus Christi and Dallas).

Table 6-6 compares San Antonio water costs at various usage levels with other comparable cities throughout the United States. The cities were identified based upon discussions with the San Antonio Economic Development Foundation as being competitors with San Antonio for economic development. As the table shows, at current rates San Antonio charges a comparable amount for water. With an average 70 percent increase (worst case) San Antonio will charge as much as or more than the cities studied. Both Tables 6-5 and 6-6 present costs at current rates. Of course, the other cities will experience increased

FIGURE 6-5

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
CITY WATER BOARD RESIDENTIAL CUSTOMER
AVERAGE MONTHLY BILL (11,200 GALLONS)
(SELECTED YEARS)



CHARGES ARE EXPRESSED IN 1985 DOLLARS. ACTUAL CHARGES WILL BE HIGHER.

SAN ANTONIO REGIONAL WATER RESOURCE STUDY

WATER USE AND COST FOR SELECTED TEXAS CITIES

CITY	AVERAGE RESIDENTIAL USE PER MONTH (gal.)	AVERAGE RESIDENTIAL COST PER MONTH	COST PER 1,000 GALLONS
Uvalde (current)	11,000	$ 8	$0.70
El Paso	22,000	17	0.80
San Antonio (current)	11,200	10	0.85
New Braunfels	12,500	11	0.85
San Marcos (current)	8,000	10	1.20
Uvalde (with 70% increase)	11,000	14	1.28
Dallas	9,800	13	1.30
Corpus Christi	15,000	21	1.40
New Braunfels (with 60% increase)	12,500	18	1.45
Houston	10,000	15	1.50
San Antonio (with 70% increase)	11,200	17	1.50
Sam Marcos (with 50% increase)	8,000	15	1.90
Lubbock	4,500	10	2.10

SAN ANTONIO REGIONAL WATER RESOURCE STUDY TABLE 6-6

WATER USE AND COST OF OTHER SELECTED CITIES

(in alphabetical order)

CITY	RESIDENTIAL 7,500 Gallons Per month (5/8" meter)	RESIDENTIAL 22,500 Gallons Per month (5/8" meter)	COMMERCIAL 374,000 Gallons Per month (2" meter)	INDUSTRIAL/INSTITUTIONAL 7,480,000 Gallons Per month (4" meter)	INDUSTRIAL/INSTITUTIONAL 11,220,000 Gallons Per month (8" meter)
Albuquerque, New Mexico	$ 9	$18	$261	$ 4,763	$ 7,302
Charlotte, North Carolina	6	17	256	5,101	7,651
Colorado Springs, Colorado	17	44	695	1,386	20,782
Denver, Colorado	7	17	187	3,194	4,791
Greensboro, North Carolina	6	17	34	2,596	3,596
New Orleans, Louisiana	15	39	560	8,825	13,120
Omaha, Nebraska	6	15	199	3,974	5,615
San Antonio, (current)	8	22	495	10,420	15,652
San Antonio (with 70% increase)	14	37	842	17,714	26,608
Tucson, Arizona	12	36*	464	7,832	11,785
Tulsa, Oklahoma	10	25	338	6,734	10,100

* Winter Rates

costs over time. These increases have not been included in the analysis which tends to overstate projected San Antonio rates by comparison. Therefore, the future residential, commercial and industrial rates for other cities could be comparable.

The comparison of rates with other communities should be carefully evaluated. Each community has its own unique circumstances with respect to 1) available water resources, 2) timing of construction of capital facilities and issuance of bonds, and 3) water demand. Although it is certainly a factor, it should be noted that relative to labor availability, location of markets, etc., water costs are not a primary concern in attracting new development. Also, the impacts that are shown will occur over an extended period of time and measures may be taken to minimize certain peaks that occur in this initital analysis.

IMPLEMENTATION

Methodology for Achieving a Regional Decision (Phase I Implementation)

As detailed in Section C of this chapter, the Phase I implementation plan provides the methodology for achieving a regional decision on the preferred course of action. The Phase I implementation plan applies across all alternatives. During this phase, an implementation task force will be formed and a comprehensive public education and information effort will take place. In addition, extensive reviews of the proposed alternatives will occur through the involvement of an Implementation Task Force Executive Committee, local task forces and the participation of a broad range of community and technical representatives at a regional water symposium. The major activities that will occur during Phase I are described in detail in Section C.

Program/Facilities Implementation Plan (Phase II)

Having achieved a regional decision during Phase I, the next phase is to document an action plan to secure the region's water future. This phase incorporates the financing, construction, and operation of capital facilities as well as the startup of expanded conservation and public education programs. This phase, which will extend to the end of the study period (year 2040) will set in place the mechanism for responding to changing conditions, both during the study period and beyond. Implementation schedules for each of the alternatives are included in Section C of this Chapter.

Implementation Task Force

The first step in moving forward will be the establishment of an Implementation Task Force. This task force, a broad-based group of individuals representative of the constituency within the study area, will have the primary responsibility for taking the results of this study to the public and educating the citizens, politicians, policy makers, and water resource management agencies regarding the alternatives. This will include describing the advantages and disadvantages and receiving comments regarding the alternative courses of action. While this group will not be charged with making the decision as to which alternative to follow, it will play a key role in insuring that the region makes an informed decision. The Task Force will also function as the sounding board for receiving input that may result in modifications to the alternatives that are under consideration. A potential structure of both the Implementation Task Force Executive Committee and Local Task Forces are further described in Section C. It is important to point out that other structures may address the objective of the project sponsors more effectively. However, it is felt that the proposed structure achieves the proper balance between regional representation and geographical resource use.

Water Resource Management Board

As more fully described in Section C, the implementation task force will be responsible for determining the need for and role of a regional water management agency. Three basic alternatives for the Board have been developed:

1. Existing EUWD Board--Make use of the existing EUWD Board structure, but provide for assumption of additional duties and powers.

2. Restructured EUWD Board--Assumes a Board structured to more closely reflect the distribution of population, resource use, and water resource revenue within the study area.

3. New Management Board--Assumes creation of a new Board to operate as an agency separate from the existing EUWD Board.

The responsibility of the Board would include, among others, the cordination of activities among the various water resource management agencies and the evaluation and monitoring of the adopted regional water plan. The structure, duties, and powers of the Board would be finalized during the first phase of the implementation process.

B. INSTITUTIONAL AND LEGAL CONSIDERATIONS

An important part of the development of a program of action for the study area is the consideration of factors affecting institutional alternatives. A discussion of these factors, together with an analysis of existing legal constraints, is presented below.

FACTORS CONSIDERED IN DEVELOPING INSTITUTIONAL ALTERNATIVES

As a result of discussions with project staff members, the survey of existing institutions and powers, and presentations to the public, TAC and project sponsors, seven important factors affecting the development of institutional alternatives have been identified. These factors are:

- Public Image of the Regional Water Plan
- Use of Powers of Existing Institutions
- Experience of Existing Institutions
- Legal Constraints
- Implementation Considerations
- Flexibility and Response to Change
- Regional and Local Equity

Public Image of the Regional Water Plan

In the development of any mechanism for regional cost-sharing or assignment of planning/enforcement responsibilities, a key factor will be the selection of agencies which will be considered by participating entities as being those best able to act in the interest of the region as a whole. As an example, two agencies might have similar capabilities and/or experience with respect to the construction and/or operation of a water treatment facility. However, if the facility is proposed as a part of the regional program to meet growing water demands, the associated capital and operating costs will be shared by a number of entities. In such a situation, consideration must be given to the public image of the responsible agency. For example, a more positive public image might be achieved if it was operated by an agency with a regional focus such as a river authority versus an agency such as a major water purveyor whose responsibilities are more localized.

Use of Powers of Existing Institutions

Making full use of powers of existing institutions will be a consideration in determining the appropriate implementing agency. As discussed in Section C, the study area contains several entities such as the Edwards Underground Water District and the river authorities which have broad powers in carrying out both operating programs and capital improvements. Obviously, it will be beneficial to make use of those broad powers, where appropriate, versus the creation of new entities or the expansion of powers through legislative action.

Experience of Existing Institutions

As determined previously, another factor similar to that of making full use of existing powers is the experience of existing institutions. For example, it is obvious that in almost all instances, the river authorities are best suited to take the lead in the planning, engineering, financing, and construction of surface water reservoirs. Making use of the experience of existing institutions will result in the most efficient and cost-effective solution, regardless of the alternative chosen.

Legal Constraints

The fourth factor, which will be addressed in greater detail later in this section, is legal constraints that are placed on the study area. For example, in considering the imposition of a water availability charge or in suggesting modifications to existing conservation programs such as requiring the use of water saving devices, a key consideration will be legal precedence. Also, the likelihood of obtaining changes in the law will be a key determinant in the implementation of the selected alternative.

Implementation Considerations

The feasibility of implementation is always a key determinant in the success of any plan, but particularly so with the magnitude of costs and impacts of the physical alternatives described in Chapter 5. In evaluating the institutional alternatives, one must evaluate whether a particular approach is achievable. An institutional alternative which would achieve a higher degree of equity but which is politically unpopular or would require extensive legislative changes may not be implementable. Thus, it may be more appropriate to consider institutional arrangements which still allow for an acceptable degree of equity, but which offer a more practical and achievable approach.

Flexibility and Response to Change

Many assumptions have been made in the development of each alternative. Actual amounts for items such as population growth, water demand, construction cost estimates, etc. will obviously differ from the assumptions made in Chapter 5 over the 50-year study period. A key consideration in the adoption of any plan of action will be the ability to adopt to changing circumstances. This may include modifications to both operating programs and capital improvement plans.

Regional and Local Equity

One of the most important factors in developing institutional alternatives will be the establishment of institutions which maximize the equity of the solution, both on a regional and local basis. Thus, the development of institutional alternatives has to take into account the ability to treat similar classes of customers and/or beneficiaries uniformly, the ability to charge customers in a manner that accurately reflects the costs of facilities/programs that benefit them, and to recognize the interrelationship of ground and surface water resources.

LEGAL CONSIDERATIONS

The purpose of the remainder of this section is to identify those legal constraints which appear to limit the ability of the people in the primary study area to implement an effective regional program for the conjunctive development and use of the groundwater and surface water resources that are reasonably available to the primary study area. The issues addressed are those that have been identified in the process of evaluating what could be accomplished under Alternative I in the study, which is based on a continuation of the present legal and institutional structures. These issues then become matters which are potentially the subject for new legislation or institutional changes necessary to implement Alternative II or Alternative III.

In certain instances, some of which are noted below, interpretations and opinions may differ as to whether the necessary authority exists which would permit the accomplishment of a particular objective. With respect to those matters, further legal analysis should be undertaken so that a more accurate evaluation may be made as to whether the exercise of a particular power or authority could be expected to withstand a legal challenge. If the evaluation is that a legal challenge would likely be successful, then it may be necessary to consider other courses of action, such as seeking legislative or other institutional changes. This would of course mean that the particular power or authority would not be available under Alternative I, which is based on proceeding under existing laws. It is also possible that some of the questioned powers and authority may be exercised through the establishment of institutional agreements or contracts.

Non-Tax Revenue Sources

Several non-tax sources of revenue have been considered to assist in underwriting the costs of financing the regional water development program. These include charges on groundwater withdrawals, permit fees for wells, water availability charges, and user charges. There is presently no governmental entity in the area that has the authority to assess and collect charges for the withdrawal of groundwater or to charge and collect well permit fees. It is noted, however, that these powers have been granted by the legislature to and are presently exercised by the Harris-Galveston Coastal Subsidence District as a part of the District's subsidence control program. Therefore, there is a legislative precedent for granting these powers where the legislature deems it appropriate.

Water availability charges are designed to recover all or part of the capital cost of providing water supply systems and facilities to serve a particular area, and are collected from those who use the water provided through the facilities. At the present time, this type of charge is typically levied against water users occupying newly developed areas, so that the new development underwrites all or a substantial part of the cost of water supply facilities required to accommodate the new growth. The charge can be based on the cost of existing facilities, as well as on the projected cost of additional facilities, required to meet the demand generated by the new growth. Although there are certain restrictions on how much and what part of the capital costs of facilities required to serve new growth can be imposed on the new customer, the concept has almost uniformly been upheld by the courts where the prescribed criteria have been satisfied.

User charges are the most common method of generating revenues from water systems, and they may be used both for ordinary operation and maintenance expenses as well as for retirement of debt incurred to construct facilities. User charges customarily are collected from the individual water customers by the water purveyor. No general legislation would be required before water availability charges or user charges could be established and assessed in the usual water customer purveyor relationship.

It might be possible to establish water availability and user charges throughout the primary study area through a series of interjurisdictional agreements or a master agreement among all purveyors of water, both groundwater and surface water. For there to be a comprehensive institutional network throughout the area for the establishment and collection of such charges, it would obviously require participation by all, or at least the major, water purveyors in the region benefited by the regional water resource program. The difficulties in achieving such an objective are apparent. Moreover, there would likely be severe complications in obtaining the approval of the utility regulatory bodies for uniformity of rates.

Should an attempt be made to establish a network of interjurisdictional agreements in the face of the complications noted above, it is thought that the Edwards Underground Water District might serve as the coordinating and management agency between the owners of the water supply reservoirs, the purveyors of surface water obtained from the reservoirs, and the purveyors of groundwater. However, there is a question whether the powers of the District are broad enough to authorize it to fill that particular role, without additional legislative authorization. If it were determined that the District could not perform this particular function, then the owners of the reservoirs and the water purveyors could contract directly with each other, should they elect to do so.

Tax Revenue Sources

The question has been raised as to whether or not sales taxes could be levied in the region as a source of funding for the regional water supply and development program. Currently, sales taxes are a revenue source for the state, and also for individual municipalities which elect to impose an additional sales tax on a local option basis. Without additional legislative authority, the state portion of the sales tax would not be available to assist in funding a project of the type proposed here. Also, there is no authority for individual municipalities to levy an additional local sales tax specifically for water resource development, such as has been granted for mass transportation purposes. Therefore, additional legislation would be required.

Ad valorem taxes on property are also a potential source of revenue that has been considered under Alternative I. The Edwards Underground Water District, whose boundaries are overlapping with the primary study area, is the only local or regional agency that presently has ad valorem taxation powers throughout the primary study area. Under the act creating the District, the District is authorized to levy a total tax of $.25 per $100 valuation. Of this amount, the District is authorized to levy a tax of up to $.02 per $100 valuation on all property in the District upon a favorable two-thirds majority vote of the Board of Directors of the District each year it is levied.

The additional $.23 tax provided for the District may only be levied on a county-by-county election basis. That is, before any part of the additional $.23 tax may be levied in a given county, the Board of Directors of the District, including a majority of the Directors from the county in question, must authorize an election to be held within the county. The voters in the county must then, by a majority vote, approve the levy of the additional tax of up to $.23. All taxes collected in each county are required to be kept in a separate fund, and expenditures of the tax monies from a given county may be made only upon a majority vote of the members of the Board of Directors of the District, which must include a favorable vote of a majority of the Directors from the county in question.

The Edwards Underground Water District is authorized to dedicate and pledge taxes and other revenues to projects which have as their purpose the "conserving, protecting, recharging, or benefiting underground water-bearing formations within the District and waters therein..." Because the construction of surface water reservoirs would benefit groundwater reservoirs by reducing the water demand on and withdrawals from the underground reservoirs, it is thought that the Edwards District may be able to use its tax revenues to finance, or serve as the basis for the issuance of bonds to finance, the construction of surface water reservoirs and treatment and conveyance facilities. However, because of the strong orientation of the Edwards District Act toward the protection and preservation of groundwater, consideration should be given to clarifying the District's authority in this respect before undertaking a major program involving surface water as well as groundwater. This could be accomplished through a request for an opinion of the State Attorney General, through some type of declaratory judgment action in court, or through additional legislation.

Conservation Measures

There is at present no local or regional agency in the primary study area with authority to adopt and implement mandatory water conservation measures throughout the area. Possible conservation measures include requiring water-saving fixtures and establishment of a water pricing structure for individual customers to discourage excessive use.

Many individual purveyors of water, and particularly public agencies, may be able to establish and enforce water conservation measures. Some private water purveyors, including both proprietary water supply companies and non-profit organizations, may have difficulty enforcing water conservation measures in the absence of adequate enforcement powers. However, the Texas Public Utility Commission currently authorizes private water purveyors to use pricing structures to discourage excessive water usage, and it is anticipated that this same practice will be observed by the Texas Water Commission as it takes over the regulation of private water utilities in this state, effective March 1, 1986.

Municipalities have rate setting powers with respect to private water utilities operating entirely within their boundaries. Therefore, a city could, for example, approve a proposal by a water purveyor operating within the city limits to accomplish water conservation through a pricing structure.

Governmental agencies operating water utilities, in the absence of some limiting special legislation, should be able to impose water rationing and other water conservation measures, including a pricing structure, to discourage excessive water usage.

While the Edwards Underground Water District does not now appear to have authority to mandate water conservation measures within the primary study area, it could continue to educate the public as to the need for and the value of implementing conservation measures and coordinate the development, on a cooperative basis, of an area-wide approach to water conservation.

Regulation of Drilling and Pumping of Water Wells

Regulation of the spacing and drilling of water wells and the withdrawal of groundwater in the primary study area may be desired in order to accomplish the conjunctive use of groundwater and surface water to serve the area. Currently, there is no agency in the primary study area vested with these powers. While the Edwards Underground Water District exercises jurisdiction over the entire area, the District's act does not authorize the District to require and issue permits for the drilling of water wells or to regulate the production of groundwater. The Texas Legislature has granted these powers to underground water conservation districts created pursuant to general law. Therefore, there is a legislative precedent for the grant of these powers to groundwater districts. It would, of course, take additional legislation to extend these powers to the Edwards District.

Institutional Responsibilities Under Alternative I

Under Alternative I, the Edwards Underground Water District would be assigned responsibilities in connection with contracting for the construction, management, and operation of water reservoirs, conveyance and treatment facilities; in administering cost recovery systems for the regional water program; and in entering into water supply contracts with water purveyors with respect to the surface water supply developed by other parties. The Edwards District Act could be interpreted as empowering the District to carry out these institutional responsibilities involving surface water resources by virtue of its authority to enter into agreements with other public and private entities for the purpose of conserving, protecting, recharging or benefiting groundwater reservoirs, since as previously noted the substitution of surface water for groundwater usage benefits groundwater reservoirs by reducing the demand on the groundwater. However, the powers and authority of the District appear to be directed almost entirely to groundwater considerations. Its authority with respect to surface water matters arises by implication from provisions such as the one noted above. It is beyond the scope of this study to attempt to resolve the uncertainty with respect to the District's role in surface water matters. Should they prove to be of concern when implementation of the plan is proposed, they can be addressed and resolved during that phase of the program.

It should be noted that some of the institutional responsibilities proposed for the Edwards Underground Water District might be performed by other governmental entities in the region. For example, river authorities, municipalities and water purveyors could probably enter into contracts to accomplish many of the same objectives. However, what would be lacking would be a single governmental entity with jurisdiction over the primary study area that could act in a coordinating and management capacity for the regional water resource program.

Selection of Governing Bodies for Management Entities

An important legal and political consideration for any management entity involved in the program is the manner in which the membership of the governing body of the entity is selected. The manner of selection of the governing body is to a great extent determined by whether the management entity is or will be a governmental agency (such as a political subdivision of the State or, by way of example, an agency created by mutual agreement of two or more political subdivisions under the Texas Interlocal Cooperation Act), or a non-governmental entity (such as a private corporation, a public utility or an association made up of representatives from both governmental and non-governmental entities).

If a particular management entity is a governmental agency, the constitution and selection of its governing body likewise will be determined by the law under which it is created. However, the Federal constitutional provision guaranteeing every citizen equal protection of the laws, which is the basis for the "one person, one vote" principle, may come into play in the selection process. Under the one person, one vote principle, where the members of a public body are elected from separate geographical regions, such as precincts or districts, the population of every geographical region is required to be as equal as reasonably practical. The equal protection clause has also been invoked in some instances to require election of the members of a governing body by districts or precincts, rather than at large, so as not to dilute the voting strength of a particular segment of the population.

A rather narrow exception to these principles has been recognized in the case of a governmental agency that has a special, limited purpose, whose special purpose activities have a disproportionate effect on its constituents (that is, its major effect is on one group or class of people), and that has limited governmental authority. Governmental authority is considered limited if the agency cannot impose ad valorem or sales taxes, does not have the authority to regulate the conduct of its citizens, and does not exercise normal governmental functions. One court case has held that the one person, one vote principle may not apply to a governmental agency whose purpose is to provide a service that can be and sometimes is provided by a private or quasi-public corporation and which has only incidental governmental powers (Thompson vs. Board of Directors of the Turlock Irrigation District, 247 CA2d 587, 55 Cal. Reptr. 689 (1967)). The exception has been applied in the case of water districts which develop and deliver water supplies, but which do not regulate the use of the water or exercise any other significant governmental functions.

Using these criteria, it appears probable that the role projected for either the Edwards Underground Water District or a new Water Resource Management Board as a governmental agency with an elected governing body would invoke the one person, one vote principle. This assumes the District or the Board would exercise the implementation, management, regulatory and enforcement powers recommended in Alternative II or Alternative III. Should the law governing the District or the Board provide for at-large election of the members of the governing body, it is also possible that an attempt to force districting for the election of the members of the governing body could be successful under certain circumstances.

Conclusion

Under present legal and institutional structures, it would be very difficult to organize and implement a comprehensive water resource program for the primary study area of the type proposed by this study. Some of the obstacles include the lack of a state policy or legal structure fostering the conjunctive use of surface water and groundwater and the absence of a regional governmental agency with the powers necessary to coordinate and manage the project and provide adequate financing or financial support on an area-wide basis. Thus, it appears that legislation will be required to accomplish the goals of the study.

C. IMPLEMENTATION PLAN

This section contains an overview of the process to be used in achieving a regional decision and in developing an ongoing process for implementation of the physical alternatives. Included in this section are:

- Objective of the Plan
- Key Considerations in Developing the Plan
- Description of Implementation Phases
- Discussion of the Proposed Implementation Task Force
- Discussion of the Proposed Water Resource Management Board

OBJECTIVE OF THE PLAN

The objective of the implementation plan is to first provide a methodology to achieve a regional decision regarding which alternative is to be implemented. Having achieved a regional decision, a framework is provided outlining the key steps and responsibilities to achieve the desired solution. Key components of the implementation plan are:

- Description and Schedule of Tasks--provides task title, subtasks (where appropriate), detailed description of the task, and timing of activities.

- Assignment of Responsibility--identifies for each task and/or subtask the responsible party or parties to accomplish the activities identified.

- Methodology of Achieving Regional Decision--describes method by which the region is to consider the alternatives and select the preferred alternative.

- Development of Flexible Plan to Adapt to Change--discusses the mechanism which allows for response to changes in assumptions such as water demand, construction cost estimates, or more refined data regarding the Edwards Aquifer and surface water resources. In addition, the plan should be flexible to allow for modification of the implementation process if deemed appropriate by the sponsors.

- Identification of Irrevocable Commitments of Money and Resources--outlines critical dates at which time the region is faced with making irrevocable commitments of money and resources. Among these might be signing of long-term water supply contracts, issuance of bonds, the awarding of construction contracts, etc.

- Identification of New Laws--under Alternative II and III, identifies: 1) new laws necessary to achieve implementation, and/or 2) interjurisdictional agreements. Identifies key interjurisdictional agreements, parties to the agreement, and objective of the agreement such as to achieve equitable cost-sharing, to secure a long-term source of supply, or to assign responsibility for acting to administer revenue collection programs, regional planning efforts, etc.

KEY IMPLEMENTATION CONSIDERATIONS

A number of key considerations have been identified as a result of interviews with the major agencies involved in water resources management, meetings with the project sponsors, TAC, and public hearings held during the course of the study. These considerations include:

Existing Power/Agencies

As discussed earlier, a full understanding of existing powers and agencies that can be used in the implementation of each of the alternatives is essential.

Politics and Vested Interests

While politics and vested interests of various groups within the area should not dictate the development of the implementation plan, clearly for the plan to be practical and widely accepted, an awareness of the politics surrounding ground and surface water issues should be maintained. This is particularly important in Texas, given the well-developed body of law that surrounds water rights, the free-capture rule, etc. Also, within the primary and secondary study areas, there is an extremely diverse set of individuals/groups who have a vested interest in any changes that may occur under present policies or any of the three alternatives. As an example, the primary study area contains 1) predominately agricultural communities to the west, with large usage of water for irrigation, 2) a growing major population area in the center (City of San Antonio and surrounding communities), and 3) communities to the east which surround the springs and which are impacted substantially by the recreational and tourist activities occurring at these sites. An evaluation of politics and these vested interests will be necessary to determine whether public officials are willing to act to achieve changes necessary to implement the plan and whether the public is willing to pay the costs and adopt changes in water consumption patterns, building techniques, etc., necessary for plan implementation.

Area Wide Management

Because the primary study area is predominately dependent on groundwater as a source of supply, and that supply has historically been abundant, effective coordination and use of groundwater and surface water resources has never been an issue. This is evident in the establishment of resource management agencies such as the Edward Underground Water District, which is charged with the task of managing groundwater resources and the river authorities, which are responsible for surface water supply development and water quality in streams and rivers. Conjunctive use management practices provide for the combined use of ground and surface waters. These practices are more widely used in other states such as Florida, which manages both surface and groundwater resources by actions of five regional water management districts, but are largely unused in Texas because of the widely disparate laws with respect to surface and groundwater resources. As stated in the Texas Water Plan (November, 1984), "with proper modification of Texas law and water management practices, conjunctive use, defined as use of water from ground and surface sources, separately or in combination, in such a manner that the availability of these sources is maximized, has the potential for increasing available water supplies in the State." It also points out, however, that "...groundwater, unlike surface water, is the property of the overlying landowner and its use is subject to very few limitations." The proposed implementation plan must work within the guidelines of these current limitations or suggest appropriate legislative changes.

Feasibility of Implementation

An assessment of the feasibility of implementation must be made in designing any plan to move forward. In addition, evaluation of the ability to achieve implementation through interjurisdictional cooperation versus mandatory legislative requirements must be made to determine the need for new laws.

Staging of Activities to Address Water Demand

Inherent in the development of the implementation plan is the identification and scheduling of necessary activities to satisfy identified water demands and to meet targeted spring flows. In developing the implementation plan, the schedule of capital improvements as identified in Chapter 5 served as a key determinant in the timing of activities. The actual timing of events could change if there are significant changes in water consumption patterns or levels of demand.

IMPLEMENTATION PHASES

In developing the implementation plan for each of the alternatives, the tasks, scheduling,and responsibilities are divided into two phases. These two phases are:

- Phase I--This phase includes the identification of tasks and parties responsible for achieving a regional decision from among the identified alternatives. To achieve a regional decision, the decision making group is defined and then a format to execute the decision is described. Phase I covers a more limited time frame than Phase II which serves as the ongoing program of activities.

- Phase II--Having achieved a regional decision during Phase I, the next phase is to document an action plan to secure the region's water future. This phase incorporates the financing, construction, and operation of capital facilities as well as the startup of expanded conservation and public education programs. This phase, which will extend to the end of the study period (year 2040), will set in place the mechanism for responding to changing conditions, both during the study period and beyond.

IMPLEMENTATION TASK FORCE

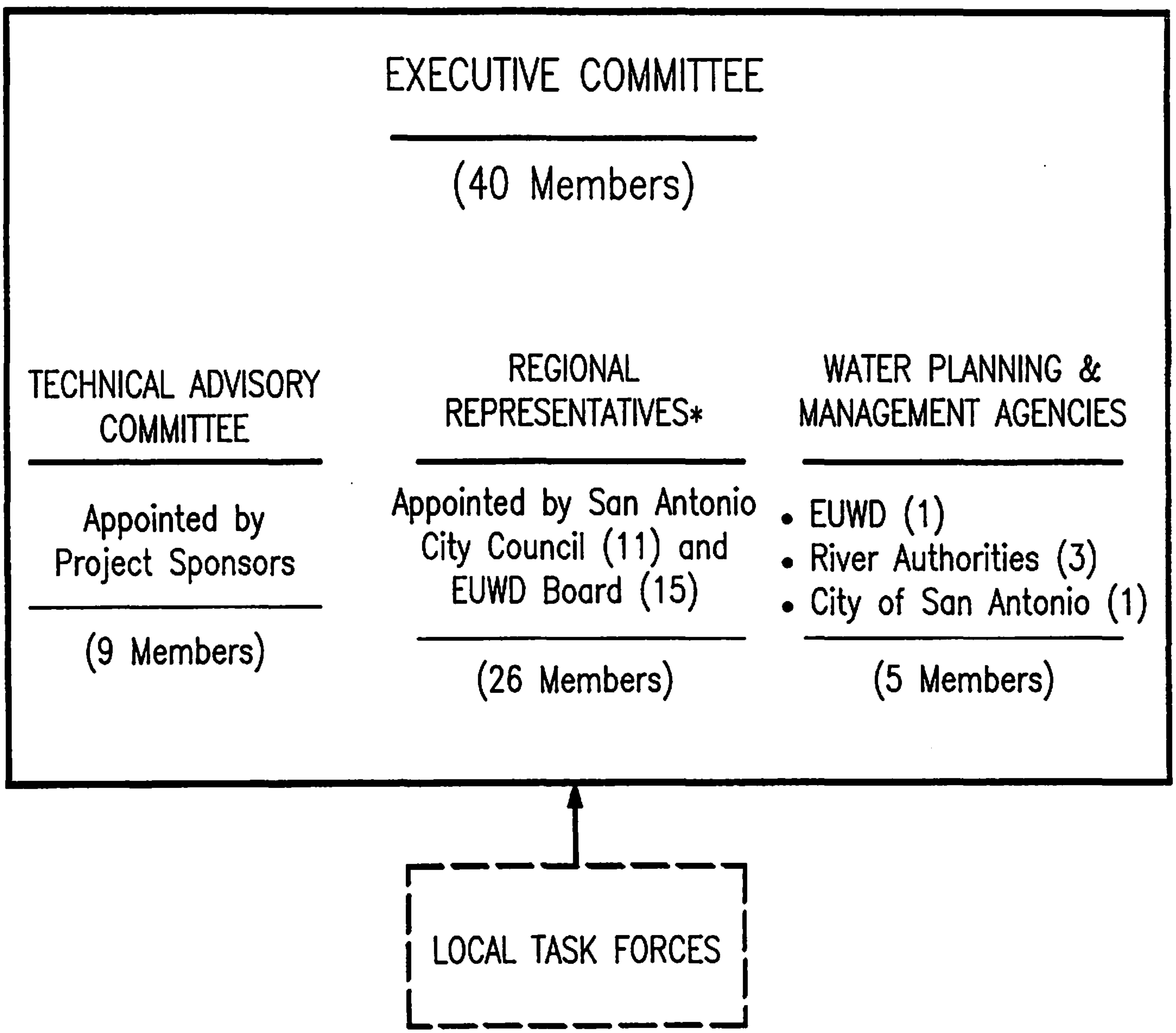
The first step in moving forward with any alternative is the suggested establishment of an Implementation Task Force. This task force, which should be a broad-based group of individuals representative of the constituency within the study area, will be charged with taking the results of this study to the public and educating the citizens, politicians, policy-makers, and water resource management agencies regarding the alternatives. This will include describing the advantages and disadvantages and receiving comments regarding the alternative courses of action. This group will also be charged with presenting the consensus views to the project sponsors. It will also receive input that may result in modifications to the alternatives that are under consideration.

As illustrated in Figure 6-6, it is recommended that the nine members of the existing Technical Advisory Committee be incorporated in the formation of the Implementation Task Force Executive Committee. This would insure that the task force has the individuals that are best able to relate to the public the comprehensive evaluation process that was used in determining the alternatives. It would also contain those who are most familiar with the broad range of issues facing the region and provide continuity during implementation.

The members of the governing bodies of the project sponsors [City Council - (11 members) and Edwards Underground Water District - (15 members)] would appoint one representative each to the Executive Committee from the general public. Representatives would come from different geographic areas and represent a broad spectrum of interests.

FIGURE 6-6

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
Proposed Implementation Task Force



* One appointee per City Council/EUWD Board Member

In order to obtain the input of those agencies which will play a critical role in the management of water resources regardless of the alternative selected, it is recommended that one representative from each of the following agencies be included on the Implementation Task Force. These agencies are:

- o Edwards Underground Water District
- o Nueces River Authority
- o San Antonio River Authority
- o Guadalupe-Blanco River Authority
- o City of San Antonio

It is recommended that each of the agencies be given the freedom to choose its representative, be it the manager, head of the governing body, or some other representative. The technical, legal, financial, and operating experience embodied in these agencies will be critical in the formation of a regional decision.

In order to insure that the Executive Committee functions efficiently, it is suggested that a temporary steering subcommittee be in place from the beginning, composed of the technical advisory committee and the water planning and management agency representatives. The steering subcommittee would organize the meetings, provide leadership over the Executive Committee, and be the focal point of the implementation process.

There are several options available for selecting the Chairperson of the Executive Implementation Task Force. The members of the committee itself may nominate and vote on the Chairperson. Alternatively, the City Council and EUWD Board may each prepare a list of candidates and work together to identify an individual that is suitable to both (this approach was used to identify the Chairman of the TAC). The Chairperson will coordinate the activities of both the Executive Committee and the Steering Subcommittee.

The 40-member Executive Committee would be augmented on the local level by a Local Task Force within each of the five counties. These task forces, which would likely operate on a less formal basis than the Executive Committee, would provide the forum by which the regional representatives could obtain comments on the proposed alternatives. These local task forces would be responsible for conducting public meetings, public education forums and, in general, for providing the Executive Committee with the concerns and preferred action of the local community. The local task forces would incorporate representatives such as:

- o Water Purveyors
- o Mayors
- o Chambers of Commerce

- Agricultural Community
- Citizen Action Groups
- County Commissioners Court
- Development/Homebuilders Association
- Manufacturers/Industrial Association

The composition of these local task forces should be somewhat flexible and might include as many as 25 to 75 members per county.

PHASE I IMPLEMENTATION PLAN (All Alternatives)

The Phase I implementation plan provides the methodology for achieving a regional decision. The first objective of Phase I will be to determine a consensus plan of action. This plan of action will include:

- Capital facilities
- Financing plan
- Institutional responsibilities
- Proposed legislation.

The second objective of Phase I will be to gain regional acceptance of the preferred plan of action.

Because the regional decision has not yet been made, the Phase I implementation plan will relate to all alternatives. During this phase, a comprehensive public education and information effort will take place. In addition, extensive reviews of the proposed alternatives will occur through the involvement of the Implementation Task Force Executive Committee, local task forces, and participation of a broad range of community and technical representatives at a regional water symposium. The major activities that will occur during Phase I, are described in detail below:

Task	Task Title
I	Establish Implementation Task Force Executive Committee
II	Establish Local Task Forces
III	Conduct Public Meeting/Education Program
IV	Conduct Regional Water Symposium
V	Conduct Executive Committee/Local Task Force Meetings to Develop Preferred Plan of Action
VI	Establish Legislation and Water Resource Management Board (as recommended)

In Appendix O, the following items are provided for each task:

- o Task title
- o Objective of each task
- o Subtasks detailing activities to occur during each task

Figure 6-7 depicts the proposed schedule and provides timing for subtasks, responsibilities and gives an estimate of manhours. The manhour estimates include both the direct efforts of the parties involved as well as any other assistance that may be required in the development of the public information program, preparation of the regional water symposium program, and other Phase I implementation activities. As shown, the Phase I implementation effort could occur over an approximately three year period and is estimated to require 30,000 manhours. Based on the involvement of 300-400 individuals, this translates into approximately 100 manhours of effort per individual.

PROGRAM/FACILITIES IMPLEMENTATION PLAN (PHASE II)

After a consensus plan of action is selected during Phase I, it is necessary to implement this plan of action. Interjurisdictional agreements would be consummated, cost recovery mechanisms would be implemented, facilities would be constructed, and other key implementation activities would be addressed. Figure 6-8 summarizes the major activities for each alternative. Figures 6-9, 6-10, and 6-11 provide a time-phased work schedule of these activities over the 50-year study period. In addition, these figures identify the key agencies responsible for implementing each activity. In Appendix O, a comprehensive work plan is provided which presents a detailed discussion of each major activity.

DESCRIPTION OF INSTITUTIONAL RESPONSIBILITIES

During Phase II, the key institutions involved in implementing the adopted course of action will be:

- o River Authorities
- o Edwards Underground Water District
- o City Water Board of San Antonio
- o Other Water Purveyors
- o City of San Antonio
- o Water Resource Management Board

River Authorities

Under Alternatives I and III, the respective river authorities will be responsible for designing, financing, constructing, owning, and operating the reservoirs (excluding Applewhite) and the associated raw water conveyance and treatment facilities. Responsibilities for individual facilities are shown in Table 6-7.

FIGURE 6-7
page 1 of 2

SAN ANTONIO REGIONAL WATER RESOURCE STUDY

PROPOSED PHASE I IMPLEMENTATION SCHEDULE

CALENDAR YEAR (Quarters): 1986 (1, 2, 3, 4); 1987 (1, 2, 3, 4); 1988 (1, 2, 3, 4); 1989 (1, 2, 3, 4)

Task · Subtask	Task/Subtask Description	Executive Committee	Local Task Forces	Water Agency Governing Bodies	EUWD	River Authorities	CWB	City of San Antonio	WRMB
		RESPONSIBILITY AND ESTIMATED MAN HOURS							
I.	<u>Establish Implementation Task Force Executive Committee</u>								
I.1	Appointments made to ITF Executive Committee and funding established.								
I.2	Conduct initial meeting(s) of ITF Executive Committee.	400							
I.3	Prepare list of potential representatives on Local Task Forces.	100							
II.	<u>Establish Local Task Forces</u>								
II.1	Advertise formation of Local Task Forces using major newspapers, community service spots on TV and radio, letters to governing bodies, Chambers of Commerce, etc.	20			40				
II.2	Prepare letters of invitation and mail out to potential representatives identified in Task I.	200			120				
II.3	Conduct initial meeting(s) of Local Task Forces.		1500						
III.	<u>Conduct Public Meeting/Education Program</u>								
III.1	Prepare summary of regional water resource plan.	400							
III.2	Distribute copies of summary to Executive Committee and Local Task Forces and advertise availability.	80			40				
III.3	Formulate program and schedule of public information/education activities including, among others, activities such as: • Prepare flyers, brochures summarizing need for development of plan, TV and radio public service announcements, press releases, special feature articles. • Meetings with legislative delegates, mayors and other elected officials to describe plan and alternatives. • Conduct site visits for Executive Committee (springs, potential reservoir or reuse sites).	200	500	100	240	240	80	120	
III.4	Implement public meeting/education program.	4000	4500		1000	1500	500	750	
IV.	<u>Conduct Regional Water Symposium</u>								
IV.1	Develop symposium program and list of speakers.	300	240		600	200	120	120	
IV.2	Prepare invitation lists and mail out invitations.	80	40		80	20	20	20	
IV.3	Hold regional water symposium.	400	1000	400	240	320	160	160	
	Subtotal - Manhours	6,180	7,780	500	2,360	2,280	880	1,170	0

LEGEND

- Δ Indicates key meeting or deliverable dates
- TAC San Antonio Regional Water Resource Study Technical Advisory Committee
- Executive Committee · Implementation Task Force Executive Committee
- Water Agency Governing Bodies Governing bodies of River Authorities, EUWD and CWB
- EUWD · Edwards Underground Water District
- CWB City Water Board of San Antonio
- WRMB Water Resource Management Board

FIGURE 6-7
page 2 of 2

SAN ANTONIO REGIONAL WATER RESOURCE STUDY

PROPOSED PHASE I IMPLEMENTATION SCHEDULE

Task - Subtask	Task/Subtask Description	Calendar Year (Quarters)
V.	**Conduct Executive Committee/Local Task Force Meetings to Develop Preferred Plan of Action**	
V.1	Conduct Executive Committee meetings.	(Δ Monthly Meetings) 1986 Q4 – 1988 Q1
V.2	Conduct Local Task Force meetings.	1986 Q4 – 1987 Q4
V.3	Execute Committee develops, documents and delivers consensus alternative.	Δ end of 1987 Q4
V.4	EUWD and City Council adopt preferred plan of action.	Δ 1988 Q1
VI.	**Establish Legislation and Water Resource Management Board (as recommended)**	
VI.1	Draft legislative changes recommended in adopted plan of action and secure approval.	1988 Q1 – 1989 Q2
VI.2	New legislation adopted and regional management body structure established.	Δ New Legislation, 1989 Q2
VI.3	Establishment of WRMB.	Δ 1989 Q3

Calendar years shown: 1986, 1987, 1988 and a fourth year, each divided into quarters 1–4.

RESPONSIBILITY AND ESTIMATED MAN HOURS

Task	Executive Committee	Local Task Force	Water Agency Governing Bodies	EUWD	River Authorities	CWB	City of San Antonio	WRMB
V.	2300	2600		380				
VI.	800	800	240	240	720	240	480	
Subtotal - Manhours	3,100	3,300	240	600	720	240	480	0
Total - Manhours	9,280	11,080	740	2,960	3,000	1,120	1,650	0

SUMMARY OF PHASE I IMPLEMENTATION EFFORT

Total Effort = 29,830 Manhours
OR 3,729 Mandays
OR 14.3 Manyears
Averages approximately 100 hours per person

LEGEND

- Δ - Indicates key meeting or deliverable dates
- TAC - San Antonio Regional Water Resource Study Technical Advisory Committee
- Executive Committee - Implementation Task Force Executive Committee
- Water Agency Governing Bodies - Governing bodies of River Authorities, EUWD and CWB
- EUWD - Edwards Underground Water District
- CWB - City Water Board of San Antonio
- WRMB - Water Resource Management Board

FIGURE 6-8

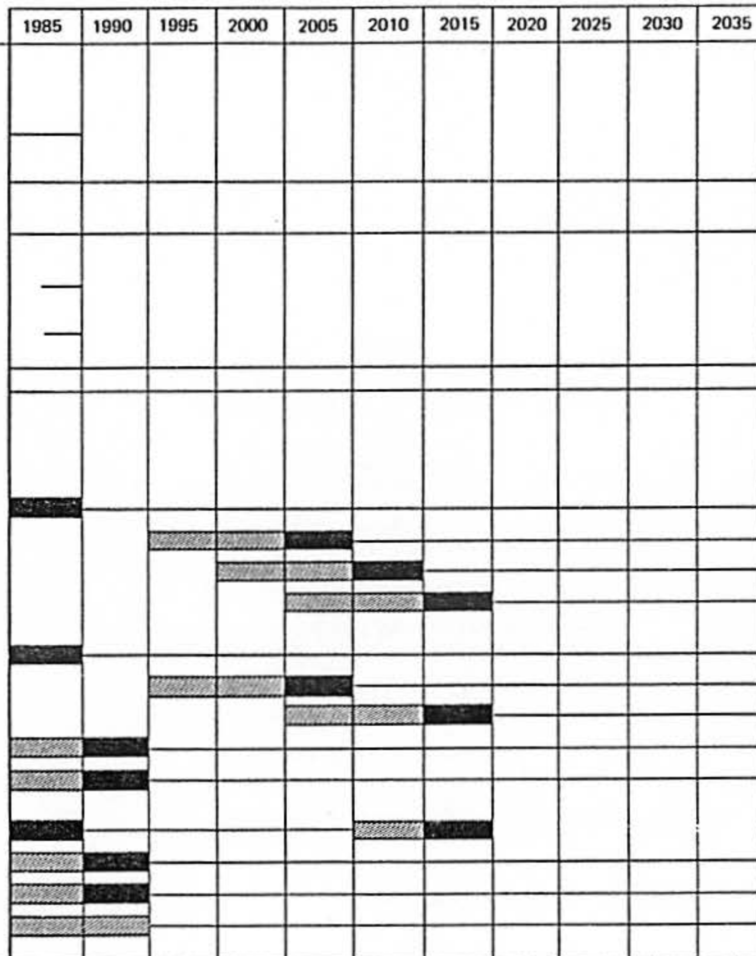
SAN ANTONIO REGIONAL WATER RESOURCE STUDY

SUMMARY OF MAJOR ACTIVITIES UNDER EACH ALTERNATIVE

ALTERNATIVE I	ALTERNATIVE II	ALTERNATIVE III
1. Conduct Additional Preliminary Planning/Engineering/Water Quality Studies	1. Conduct Additional Preliminary Planning/Engineering/Water Quality Studies	1. Conduct Additional Preliminary Planning Engineering/Water Quality Studies
2. Coordination and Improvement of Voluntary Municipal and Conservation Programs	2. Development of Mandatory Municipal and Conservation Program	2. Coordination and Improvement of Voluntary Municipal and Conservation Programs
3. Continuation of Regional Water Resource Management Activities	3. Continuation of Regional Water Resource Management Activities	3. Continuation of Regional Water Resource Management Activities
4. Development of long-term Water Supply Contracts and Operating Agreements	4. Development of long-term Water Supply Contracts and Operating Agreements	4. Development of long-term Water Supply Contracts and Operating Agreements
5. Adoption of Revenue/Cost Recovery Mechanisms - Water availability charges - User charges - Ad valorem taxes	5. Adoption of Revenue/Cost Recovery Mechanisms - Water availability charges - User charges - Well permit fees - Well pumpage fees - Ad valorem taxes - Sales taxes	5. Adoption of Revenue/Cost Recovery Mechanisms - Water availability charges - User charges - Well permit fees - Well pumpage fees - Ad valorem taxes - Sales taxes
6. Development of Local Water Supply Wells/System Improvements/Spring Augmentation	6. Development of Local Water Supply Wells/System Improvements/Spring Augmentation	6. Development of Local Water Supply Wells/System Improvements/Spring Augmentation
7. Development of Surface Water Reservoirs - Applewhite - Cibolo - Goliad - Cloptin - Cuero I	7. (Not Applicable)	7. Development of Surface Water Reservoirs - Applewhite - Cibolo - Goliad - Cuero I & II
8. Develonment of Raw Water Conveyance Facilities - Applewhite to San Antonio - Cibolo to Applewhite - Cuero I to Cibolo - Blanco River to San Marcos	8. (Not Applicable)	8. Development of Raw Water Conveyance Facilities - Applewhite to San Antonio - Cibolo to Applewhite - Cuero II to Cibolo - Guadalupe River to New Braunfels
9. Development of Water Treatment Facilities - San Antonio - San Marcos - New Braunfels	9. (Not Applicable)	9. Development of Water Treatment Facilities - San Antonio - San Marcos - New Braunfels
10. Development of Reuse Facilities	10. Development of Reuse Facilities	10. Development of Reuse Facilities

FIGURE 6-9

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
PROPOSED PHASE II IMPLEMENTATION SCHEDULE
ALTERNATIVE I (No New Laws - Surface Water Reservoirs)



Task	Task Description	SARA	GBRA	EUWD	CWB	CITY OF S.A.	PURVEYORS	WRMB
I	Conduct Additional Planning/Engineering/Water Quality Studies	●	●	●	●	●	●	●
II	Continuation/Improvement of Municipal Conservation Programs		●	●	●	●	●	●
III	Continuation/Improvement of Agricultural Conservation Programs			●				●
IV	Development of Necessary Interjurisdictional Agreements	○	●	●	●		●	
V	Adoption of Revenue/Cost Recovery Mechanism			●	●	●	●	
VI	Development of Water Supply Wells				●		●	
	Development of Spring Augmentation Wells		●					
VII	Development and Operation of Surface Water Reservoirs and Related Raw Water Conveyance and Water Treatment Facilities							
	Surface Water Reservoirs							
	– Applewhite				●			
	– Cibolo	●						
	– Cloptin		●					
	– Cuero I		●					
	Raw Water Conveyance Facilities							
	– Applewhite to San Antonio	●						
	– Cibolo to Applewhite	●						
	– Cuero I to Cibolo		●					
	– Blanco River to San Marcos		●					
	– Guadalupe River to New Braunfels		●					
	Water Treatment Facilities							
	– San Antonio	●						
	– San Marcos		●					
	– New Braunfels		●					
VIII	Development of Reuse Facilities	●				●		

LEGEND

Ongoing Program ———
Preconstruction Activities*
Construction

*Includes all activities to evaluate feasibility, obtain permits, secure financing, engineer and design facilities, conduct facility siting and land acquisition.

LEGEND

SARA - San Antonio River Authority
GBRA - Guadalupe-Blanco River Authority
EUWD - Edwards Underground Water District
CWB - City Water Board
City of S.A. - City of San Antonio
Purveyors - Other Water Purveyors
WRMB - Water Resource Management Board

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
PROPOSED PHASE II IMPLEMENTATION SCHEDULE
ALTERNATIVE II (New Laws/No New Surface Water Reservoirs)

FIGURE 6-10

Task	Task Description	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	Responsibility: SARA	GBRA	EUWD	CWB	CITY OF S.A.	PURVEYORS	WRMB
I	Conduct Additional Planning/Engineering/Water Quality Studies												●	●	●	●	●	●	●
II	Continuation/Improvement of Municipal and Agricultural Conservation Programs (Mandatory Provisions)														●	●	●	●	●
III	Develop Necessary Contracts and Operating Agreements												●	●	●	●	●	●	
IV	Adopt Revenue/Cost Recovery Mechanisms														●	●	●	●	●
V	Development of Supply and Spring Augmentation Wells													●		●		●	
VI	Development of Reuse Facilities												●				●		

LEGEND
Ongoing Program
Preconstruction Activities*
Construction
*Includes all activities to evaluate feasibility, obtain permits, secure financing, engineer and design facilities, conduct facility siting and land acquisition.

LEGEND
SARA - San Antonio River Authority
GBRA - Guadalupe-Blanco River Authority
EUWD - Edwards Underground Water District
CWB - City Water Board
City of S.A. - City of San Antonio
Purveyors - Other Water Purveyors
WRMB - Water Resource Management Board

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
PROPOSED PHASE II IMPLEMENTATION SCHEDULE
ALTERNATIVE III (New Laws - Surface Water Reservoirs)

FIGURE 6-11

Task	Task Description	SARA	GBRA	EUWD	CWB	CITY OF S.A.	PURVEYORS	WRMB
I	Conduct Additional Planning/Engineering/Water Quality Studies	●	●	●	●	●	●	●
II	Continuation/Improvement of Municipal Conservation Programs			●	●	●	●	●
III	Continuation/Improvement of Agricultural Conservation Program			●				●
IV	Develop Necessary Contracts and Operating Agreements	●	●	●	●	●	●	
V	Adoption of Revenue/Cost Recovery Mechanism			●	●	●	●	●
VI	Development of Water Supply Wells				●		●	
	Development of Spring Augmentation Wells		●					
VII	Development and Operation of Surface Water Reservoirs and Related Raw Water Conveyance and Water Treatment Facilities							
	Surface Water Reservoirs							
	– Applewhite				●			
	– Cibolo	●						
	– Cuero I & II		●					
	Raw Water Conveyance Facilities							
	– Applewhite to San Antonio	●						
	– Cibolo to Applewhite	●						
	– Cuero II to Cibolo		●					
	– Blanco River to San Marcos		●					
	– Guadalupe River to New Braunfels		●					
	Water Treatment Facilities							
	– San Antonio	●						
	– San Marcos		●					
	– New Braunfels		●					
VIII	Development of Reuse Facilities	●						

Schedule columns: 1985, 1990, 1995, 2000, 2005, 2010, 2015, 2020, 2025, 2030, 2035

LEGEND

Ongoing Program

Preconstruction Activities*

Construction

*Includes all activities to evaluate feasibility, obtain permits, secure financing, engineer and design facilities, conduct facility siting and land acquisition.

LEGEND

SARA - San Antonio River Authority
GBRA - Guadalupe-Blanco River Authority
EUWD - Edwards Underground Water District
CWB - City Water Board
City of S.A. - City of San Antonio
Purveyors - Other Water Purveyors
WRMB - Water Resource Management Board

SAN ANTONIO REGIONAL WATER RESOURCE STUDY TABLE 6-7

SUMMARY OF RESPONSIBILITIES — RIVER AUTHORITIES

	ALTERNATIVE	
	I	III
1. SURFACE WATER RESERVOIRS*		
• CIBOLO	SARA	SARA
• GOLIAD	SARA	SARA
• CLOPTIN	GBRA	N/A
• CUERO I	GBRA	N/A
• CUERO I & II	N/A	GBRA
2. RAW WATER CONVEYANCE FACILITIES		
• APPLEWHITE to SAN ANTONIO	SARA	SARA
• CIBOLO to APPLEWHITE	SARA	SARA
• CUERO to CIBOLO	GBRA	GBRA
• BLANCO RIVER to SAN MARCOS	GBRA	GBRA
• GUADALUPE RIVER to NEW BRAUNFELS	GBRA	GBRA
3. WATER TREATMENT FACILITIES		
• SAN ANTONIO	SARA	SARA
• SAN MARCOS	GBRA	GBRA
• NEW BRAUNFELS	GBRA	GBRA

* CITY OF SAN ANTONIO WOULD BE RESPONSIBLE FOR THE CONSTRUCTION OF THE APPLEWHITE DAM & RESERVOIR.

SARA — SAN ANTONIO RIVER AUTHORITY
GBRA — GUADALUPE—BLANCO RIVER AUTHORITY
N/A — NOT APPLICABLE

Under Alternative II, the activities of the river authorities will be much more limited in comparison with Alternatives I and III since no surface water reservoirs, conveyance, or treatment facilities are to be built to benefit the primary study area.

The activities of the river authorities are dependent upon the needs of the regions they serve. As such, planning, construc tion, and operation of the facilities in Alternative I or III will be dependent upon the river authorities receiving suitable long-term water supply contracts. These contracts must demonstrate such need and provide sufficient credit support and revenue sources to secure a satisfactory bond rating and interest rate on any revenue bonds issued and to generate funds for repayment of such debt. They will also define the terms and conditions of water deliveries, how operating costs will be recovered, and how modifications to the contract can be made.

The river authorities, in coordination with the regional management agency, will be responsible for complying with all federal, state, and local regulatory requirements such as the following:

- o Environmental Impact Statements
- o State and Federal Permits
- o Easements and Right-of-Ways

The river authorities will also be responsible for coordinating water planning activities with the City of San Antonio, water purveyors, the Edwards Underground Water District, the State, and the Water Resource Management Board.

Edwards Underground Water District

The role of the District would be greatly expanded its role with respect to coordination and management of many of the activities affecting the region's water resources, particularly under Alternatives II and III. These activities will include:

- o Administer Cost Recovery System. The interjurisdictional agreements and/or operational agreements and contracts established during the implementation of the alternatives will provide for regular transfers of water availability and user charges from the respective jurisdictions to the District and receipt of ad valorem tax funds collected by the counties on behalf of the District. These funds will then be allocated between the river authorities, the District itself, the City of San Antonio, and the City Water Board for capital costs and operations of regional facilities.

  The District would be the party responsible for negotiating the terms and conditions of the interjurisdictional agreements and/or contracts; would be a party to the agreements; and act as a trustee and arbiter under the terms of the agreement. In fulfilling the trustee role, the District would serve as a "financial clearinghouse" to receive and transmit funds to the parties as discussed in the cost recovery system described above. The District would require annual financial audits and report the results of such audits to the participating agencies. The District would act to coordinate preparation of any separate long-term water supply or operating contracts necessary to provide the required security for the river authorities or the City of San Antonio to issue revenue bonds to construct identified regional facilities.

- Serve as Staff Support to the Water Resource Management Board. If established as a separate entity, the Water Resource Management Board will be responsible for a broad range of activities. As such, this body will require administrative and technical support that is funded as a part of the cost of the regional plan. In addition, it is anticipated that the District would provide technical assistance to the WRMB.

- Continue Administration and Coordination of Conservation Programs. Under Alternative I and III, the District would continue in its current role in promoting conservation activities within the region and coordinating voluntary enhancements to programs as described in the detailed work plan (Appendix O). Alternative II would include the coordination and enforcement of mandatory conservation provisions as outlined in the detailed implementation plan (also described in Appendix O).

- Coordinate with State for Grants and Other State Financial Participation. As a part of the plan, the District would develop and maintain contacts with the Texas Department of Water Resources, the respective legislative representatives and other state and water resource management agencies in the region. These contacts would allow the District to be aware of all possible state grants and loan programs and any direct state financial participation.

City Water Board of San Antonio

The City Water Board would continue with its plan to finance, construct, own, and operate the Applewhite Reservoir. In that regard, the Board would be responsible for meeting regulatory requirements associated with the reservoir.

Based on the terms defined in the interjurisdictional agreements (Alternative I) and long-term water supply contracts or legislation (Alternative II and III), the City Water Board would be responsible for implementing required user and water availability charges and remitting such funds to the Edwards Underground Water District.

As is currently the case, the City Water Board would be entirely responsible for financing, constructing, and operating local water supply wells and associated transmission/distribution systems. The Board would also adopt and implement voluntary conservation measures to achieve the desired level of demand reduction (and mandatory provisions under Alternative II).

Other Water Purveyors

All municipal purveyors in the primary study area would adopt voluntary conservation measures as described in the detailed work plan. Under Alternative II, all municipal purveyors in the primary study area would adopt mandatory conservation measures as described in the detailed work plan. As with the City Water Board, these water purveyors would be responsible for development of local supply wells and construction of local system improvements. They would also incorporate the availability charges and user charges as defined in the terms of the interjurisdictional agreements (Alternative I) or in the legislation (Alternative II and III).

City of San Antonio

The major responsibility that may rest with the City as a result of the adoption of any of the alternatives would be the financing, construction, ownership, and operation of the identified wastewater reuse and recharge facilities. If the facility is constructed as a single unit with integrated components it may be very difficult or impractical to segregate ownership, and/or transfer of the effluent through 1) treatment to normal secondary/tertiary treatment standards and 2) treatment down to drinking water standards for injection into the aquifer. In such case, it may be most feasible to charge the City of San Antonio, currently responsible for wastewater treatment, with the responsibility for the reuse facilities. The facility costs, both capital and operating, would be incorporated as a part of the regional cost recovery system and the Edwards Underground Water District would reimburse the City for its respective portion of the costs of operations and debt service associated with treatment and recharge operations that go beyond the normal standards required for stream discharge.

As an alternative, the San Antonio River Authority could handle this responsibility. This would be more positive in terms of public image as a regional agency would be responsible for ownership and operation of these regional facilities. It is recommended that this decision be finalized as additional reuse studies are conducted and the feasibility of various options are investigated.

Regardless of the decision, the responsible institution will need to achieve compliance with all regulatory requirements for the reuse facilities and develop the cost recovery mechanisms with the Edwards Underground Water District in its role as the trustee for regional cost-sharing.

Water Resource Management Board

One of the decisions to be reached by the ITF is whether a regional management board should be established, and if so, its composition. Three basic alternatives for structuring this board have been developed, but variations in these proposed alternatives could be considered during the implementation process. The three options, as illustrated in Figures 6-12 through 6-14, are:

1. Existing EUWD Board--This alternative makes use of the existing EUWD Board structure but provides for the assumption of additional duties/powers as defined below. The existing board structure is comprised of three elected representatives from each of the five counties in the study area.

2. Restructured EUWD Board--Under this alternative, the membership of the EUWD would be structured to more closely reflect the distribution of population, resource use, and water resource revenue generated within the study area. On the basis of population, the total membership might be on the order of 19, based roughly on the number of state legislative districts covering the area.

3. New Management Board--This alternative assumes the creation of a new Water Resource Management Board which would operate as a agency separate from the existing EUWD Board. As with the second alternative, the membership of the new board would be based upon the election of members based upon population.

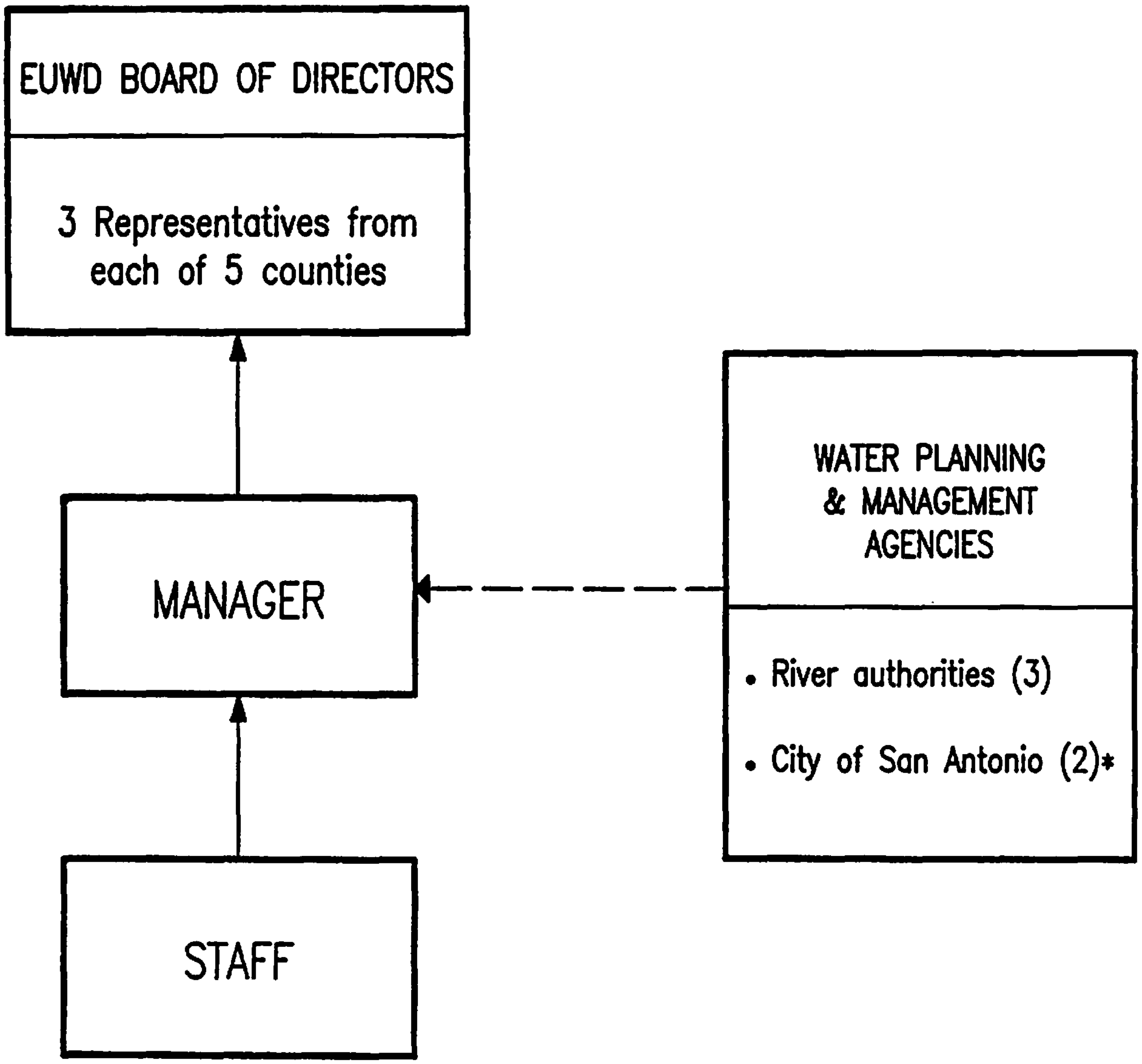
For all options, there would be a manager and staff reporting to the Board. The manager would receive technical input and coordinate the programs and activities of the Board through representatives of the major water planning and management agencies in the study area. For all alternatives, this would include one representative from each of the river authorities and two from the City of San Antonio (one each from the City Water Board and City staff). If a new Board was to be implemented, an additional representative would be appointed from the Edwards Underground Water District.

The responsibilities of the board would include:

- Coordination of activities among the various water resource management agencies in the study area.

FIGURE 6-12

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
Proposed Water Resource Management Board
-Option 1 of 3-
Existing Edwards Board

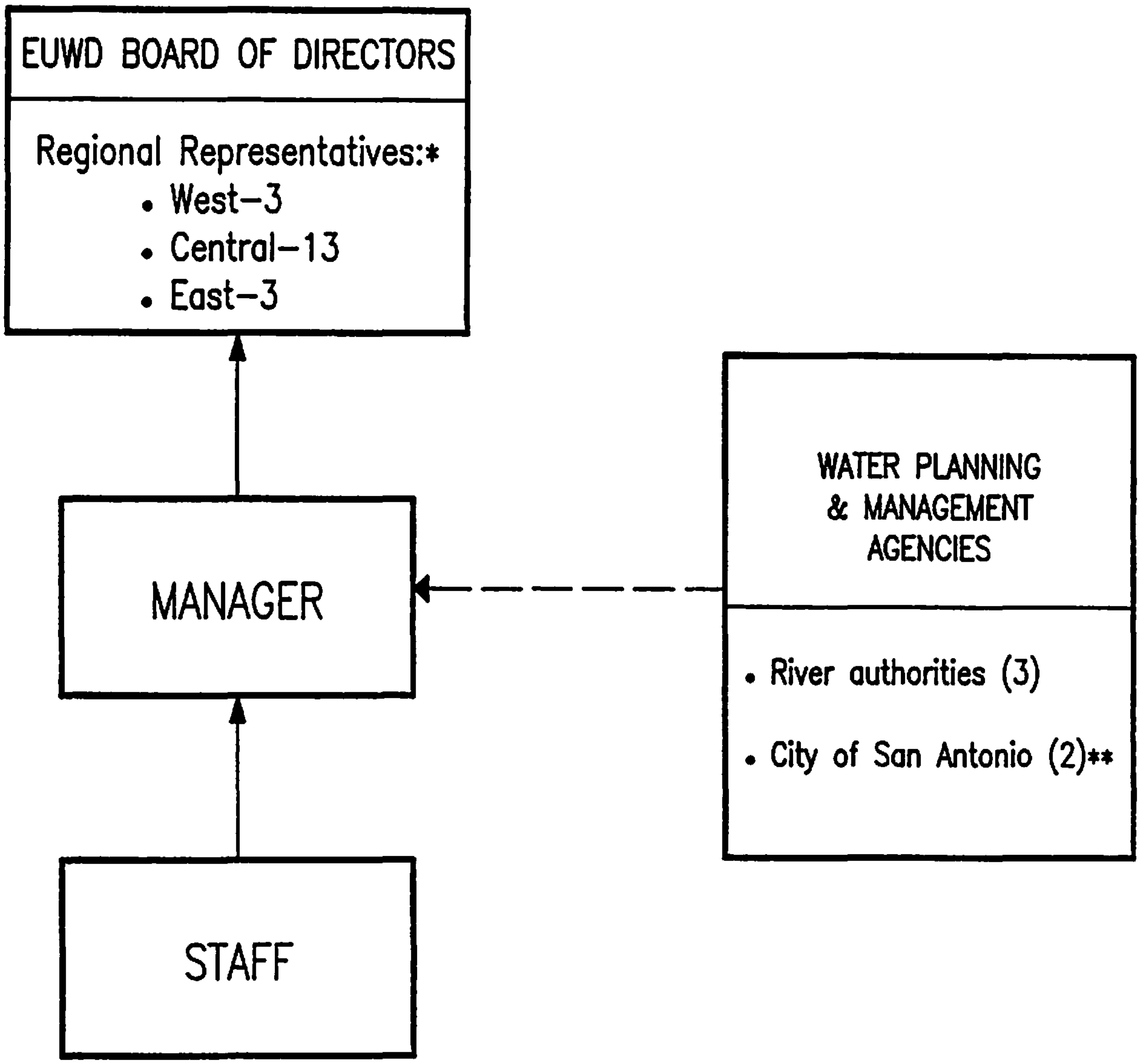


* 1-City Water Board

1-City Staff

FIGURE 6-13

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
Proposed Water Resource Management Board
-Option 2 of 3-
Restructured Edwards Board



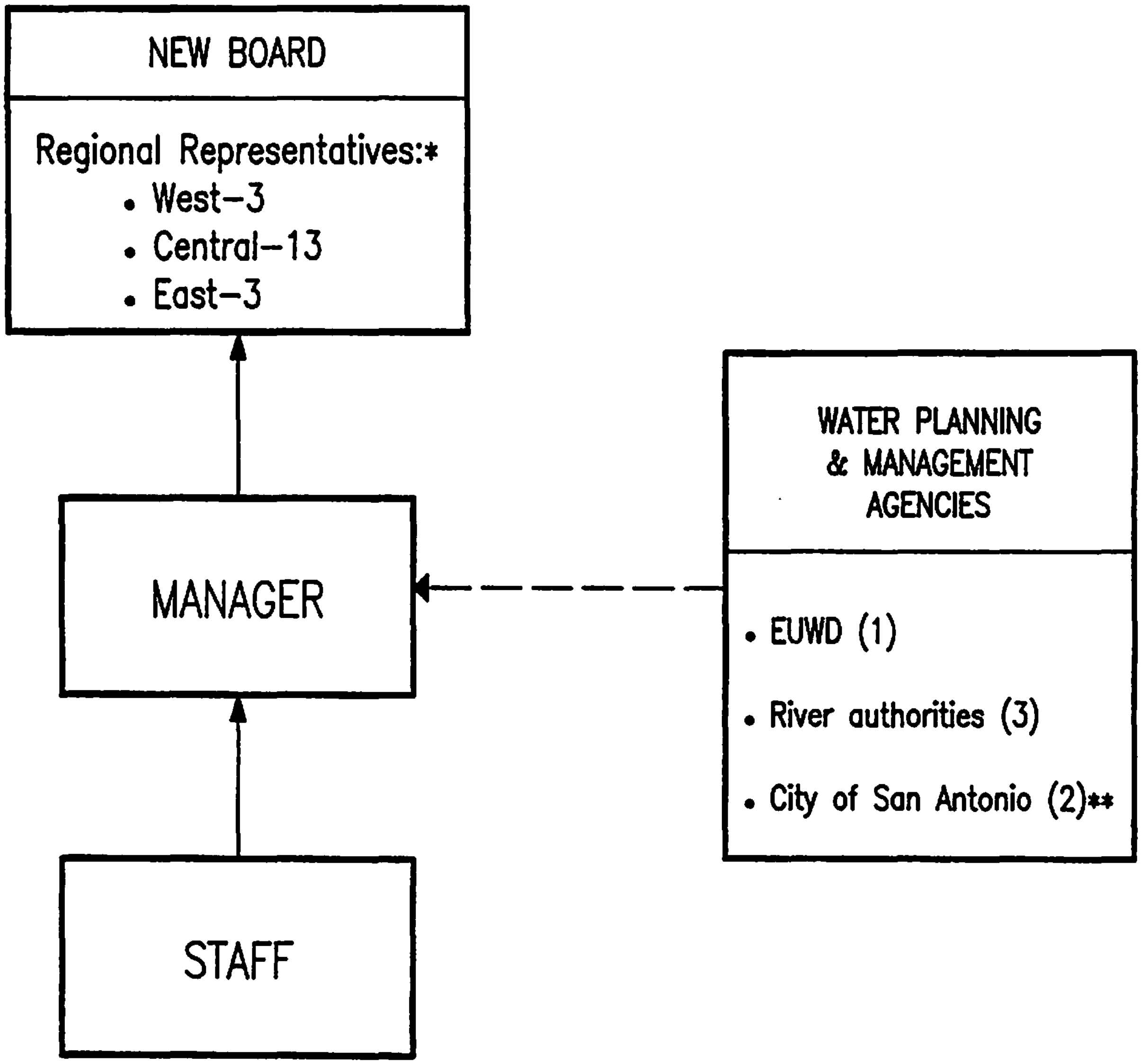
* Elected representatives from the five-county study area, based on population. Number shown is approximate.

** 1-City Water Board

1-City Staff

FIGURE 6-14

SAN ANTONIO REGIONAL WATER RESOURCE STUDY
Proposed Water Resource Management Board
-Option 3 of 3-
New Board



* Elected representatives from the five-county study area, based on population. Number shown is approximate.

** 1-City Water Board
1-City Staff

- Evaluation and monitoring (and possible enforcement) of the adopted regional water plan.

- Drafting of necessary legislative changes and efforts to achieve approval.

- Continuing liaison with water resource management agencies, governing bodies of cities and counties, and civic and community groups.

- On going efforts with respect to public education and awareness.

- Authority to conduct special studies necessary to evaluate timing of actions, necessary modifications to adopted water plan, etc.

The structure, duties, and powers of the Water Resource Management Board will be finalized during the first phase of the implementation process. This effort will insure that the defined structure, duties and powers provide an effective board for consideration of regional issues and that it promotes effective regional water resource management.

REQUIREMENTS FOR NEW LAWS AND/OR INTERJURISDICTIONAL AGREEMENTS

By definition, Alternative I will not require the passage of new laws. Interjurisdictional agreements among the identified municipal water purveyors will be required to secure financing for the identified projects and to provide for associated cost-sharing and coordination of activities.

The implementation of Alternative II would require the following legislation:

- Adoption of the water plan by the state legislature and authorization for the Edwards Underground Water District and/or the Water Resource Management Board to enforce the provisions of the plan.

- Establishment of increased groundwater protection powers for the Edwards Underground Water District, possibly including powers to limit pumpage, restrict size and spacing of wells, to control development over recharge areas, and to enforce mandatory conservation requirements.

- Granting of broader powers and requirements to establish necessary revenue programs including water availability charges and well permit fees, well pumpage fees and sales taxes.

The implementation of Alternative III would require basically the same legislation as Alternative II, except for the mandatory conservation requirements that apply only to Alternative II.

IRREVOCABLE COMMITMENTS OF MONEY AND RESOURCES

The entire planning process is structured to maintain maximum flexibility for as long as possible. However, as summarized in Table 6-8, the construction of capital facilities and development of programs does require irrevocable commitments of money and resources. These commitments are subdivided into 1) programmatic and/or institutional commitments and 2) commitments associated with capital improvements. With respect to programmatic or institutional commitments, irrevocable commitments are assumed to occur when new entities are created, when legislative changes are made, and when contracts of interjurisdictional agreements are signed. Although, in the strictest sense, these actions are not irrevocable, they do signal events that may be very difficult or costly to modify. For capital improvements, these commitments occur at the time that bonds are issued and construction contracts are awarded. For most individual components of the alternative (i.e., surface reservoirs, etc.) these occur in a discrete fashion. However, for well development and construction of reuse facilities, these commitments are spread over the study period. For these facilities, the time of the commitment reflects the first major investment in the ongoing program.

GROUNDWATER QUALITY PROTECTION

Protection of the high quality of Edwards Aquifer water is vital to the overall water supply of the area. As discussed in Appendix G, the primary recommendations to guard against entry or concentration of contaminants in the aquifer are to:

- Limit future pumping withdrawals by developing alternative sources of water for new demands. This objective is met in Alternatives I and III using conservation, reuse, and reservoirs as the new sources.

- Modify by special legislative amendment the current Edwards Aquifer recharge zone protection statute to broaden regulated activities and to allow enforcement by the Edwards Underground Water District, if the State agrees this is advantageous. The current statute is Chapter 313, Rules of the Texas Water Commission. Initiation of such an amendment would most likely rest with the District.

The first measure will reduce the risk of potential contamination from one or more of the following potential sources:

- Salt water intrusion from the "bad water" zone if Edwards water levels drop significantly over a sustained period of time.

TABLE 6-8

Irrevocable Commitment of Money and Resources

	ALTERNATIVE					
	I		II		III	
	TIMING*	CAPITAL COSTS	TIMING*	CAPITAL COSTS	TIMING*	CAPITAL COSTS
A. PROGRAMMATIC/INSTITUTIONAL COMMITMENTS						
1. Establishment of Water Resource Management Board	1989	-	1989	-	1989	-
2. Completion of interjurisdictional/operational agreements	1989	-	1989	-	1989	-
3. Adoption of legislation	-	-	1989	-	1989	-
B. CAPITAL IMPROVEMENTS						
1. Surface Water Reservoirs						
• Applewhite	1987	$ 82,000,000	N/A	-	1987	$ 82,000,000
• Cibolo	2005	200,000,000	N/A	-	1990	200,000,000
• Goliad	2010	230,000,000	N/A	-	2010	230,000,000
• Cloptin	2010	130,000,000	N/A	-	N/A	-
• Cuero I	2015	270,000,000	N/A	-	N/A	-
• Cuero I & II	N/A	-	N/A	-	2000	490,000,000
2. Raw Water Conveyance Facilities						
• Applewhite to San Antonio	1987	37,000,000	N/A	-	1987	40,000,000
• Cibolo to Applewhite	2005	190,000,000	N/A	-	1990	210,000,000
• Cuero to Cibolo	2015	220,000,000	N/A	-	2000	240,000,000
• Blanco River to San Marcos	1990	9,000,000	N/A	-	1990	9,000,000
• Guadalupe River to New Braunfels	1990	5,000,000	N/A	-	1990	5,000,000
3. Water Treatment Facilities						
• San Antonio	1987	84,000,000	N/A	-	1987	96,000,000
• San Marcos	1990	6,000,000	N/A	-	1990	6,000,000
• New Braunfels	1990	3,000,000	N/A	-	1990	3,000,000
4. Reuse Facilities	1995	220,000,000	1995	$410,000,000	1995	220,000,000
5. Wells **	As Needed	37,000,000	As Needed	111,000,000	As Needed	21,000,000

* The years shown indicate the proposed start of construction. These dates assume finalization of necessary financing and conclusion of engineering feasibility studies. For reuse facilities and spring augmentation wells, these dates indicate the beginning of an ongoing construction program. For example, the construction of reuse facilities will occur over a 40 year period beginning in 1995 with total costs extending over this time frame.

** Spring augmentation wells and new municipal wells in Greater San Antonio, New Braunfels, and San Marcos.

- Concentration of any contaminants in the aquifer due to less water in storage for dilution.

- Change of artesian (pressure) to water table (non-pressure) conditions in some areas south of the recharge zone which increase the odds of any spilled contaminants in this region getting into the aquifer.

Regarding recharge zone protection, there is already a Texas statute (Chapter 331) regulating wastewater management, hydrocarbon storage, animal feedlot operations, and disposal of industrial/hazardous wastes in the Edwards recharge area. However, some additional provisions addressing the following items are recommended below to strengthen and broaden the current safeguards against development impacts.

Source of Contamination	Danger	Guidelines for New Regulations
Construction site soil erosion contaminants	Clogging of recharge paths plus contaminants on the soil	City of Austin ordinances and design manuals
Storm water	Nutrients, bacteria, and soil contributing to clogging of recharge paths	City of Austin ordinances and design manuals
Solid waste landfills	Contaminated drainage water	TDWR staff or consultant
Hazardous materials handling and storage	Poisonous and carcinogenic substances	TDWR staff or consultant

Construction site soil erosion can be reduced with sediment traps/barriers and detention basins. The City of Austin has detailed procedures in place to protect against construction site soil erosion as well as stormwater runoff in the recharge zone of the Edwards Aquifer-Austin Region. Stormwater management criteria include detention; sedimentation; and, in high density areas, filtration. Sanitary landfill operations should be restricted or prohibited in the recharge zone. Activities involving manufacture, storage, or handling of hazardous materials in excess of a minimum quantity should be prohibited in the recharge zone.

Standards should also be extended to cover the "buffer zone." This area, extending across Bexar, Comal, and Hays Counties, is just south of the recharge zone and varies from 1 to 5 miles in width, as defined by the Edwards Underground Water District. In this area are outcroppings of fractured rock that can provide a pathway for contaminants to enter the Edwards if these areas change from artesian to water table aquifer conditions.

Aquifer protection is a regional concern. Therefore implementation of a protection program should be carried out by the Texas Department of Water Resources or delegated by it to the Edwards Underground Water District. The district has the necessary jurisdictional boundaries and is mandated in its authorizing legislation with protecting Edwards water quality.

Similar regulations may also be required for the Trinity Group Aquifer in the Hill Country due to similar recharge conditions and current active land development in that area. However, no aquifer protection district exists for that area and detailed studies of the aquifer have not yet been made.

CONSERVATION PROGRAMS

Detailed tasks for the development of both municipal and agricultural conservation programs are provided in Appendix O. Under Alternative I, the current voluntary municipal conservation programs are continued and necessary enhancements are made to achieve demand reductions. Under this alternative, the conservation goal is a 10 percent reduction in normal municipal and commercial water demand in primary study area communities. The municipal conservation program would include 1) a public information program, 2) possible incentive programs to encourage water purveyors and developers to conserve water, and 3) the voluntary adoption of conservation-oriented rate structures. The agricultural conservation program, designed to achieve over 30 percent savings in applied irrigation water, would include both information and education programs, soil moisture monitoring services, and on-farm demonstration and lecture programs.

Under Alternative II, the conservation program includes continuation of the voluntary programs plus adoption of mandatory conservation measures to achieve desired demand reductions. The programs could include targeted per capita water use goals and a system of warnings and penalities for observed water wastage.

The conservation program under Alternative III is similar to that provided for in Alternative I.

San Antonio Regional
Water Resource Study

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