TULAROSA BASIN AND SALT BASIN

REGIONAL WATER PLAN

2000 - 2040

Volume 1

South Central Mountain RC&D Council, Inc.

May 2002

Prepared by

in association with

JOHN SHOMAKER & ASSOCIATES, INC.

LIVINGSTON ASSOCIATES, P.C.
Consulting Engineers

JOHN SHOMAKER AND ASSOCIATES, INC.

Table of Contents

List of Tables

SECTION 6 **PAGE No.**

SECTION 7

SECTION 8

List of Figures

1. INTRODUCTION

1.1 Regional Water Planning Organization

This Draft *Tularosa Basin and Salt Basin Regional Water Plan 2000 – 2040* (Plan) was prepared by the South Central Mountain Resource Conservation and Development Council, Inc., (RC&D) through a grant from the New Mexico Interstate Stream Commission (ISC).

The South Central RC&D Council, Inc. is responsible for completing the Regional Water Plan for the Tularosa Basin and Salt Basin in Otero and Lincoln Counties. Assisting the RC&D with the technical issues surrounding this endeavor is Livingston Associates, P.C., a water resource consulting engineering firm in Alamogordo, New Mexico along with John Shomaker & Associates, Inc., a ground water consulting firm in Albuquerque, NM.

The RC&D Council is a public non-profit organization organized in 1967 to carry out a comprehensive program of resource conservation, economic and community development. The RC&D Council is comprised of representatives of communities, counties, soil and water conservation districts and state and federal agencies in the two-county area. This grass roots approach to solving local problems has been very effective since the inception of the program. The RC&D Council is the centerpiece of the RC&D program which is a federal program administered by the USDA Natural Resources Conservation Service, formerly the Soil Conservation Service. The RC&D program provides a full-time coordinator to assist the Council in carrying out a broad-based Area Plan. The office is located at 409 Central Avenue in Carrizozo, NM, 88301, Telephone (505) 648-2941, Fax (505) 648-2558.

Since the Council is interested in water issues and has been involved in water related projects throughout its 30-year history, it naturally became interested in participating in the regional water planning effort. The Council applied for a planning grant through the Interstate Stream Commission. The grant was approved in March of 1996.

The Council has taken a very active role in the planning process, particularly in coordinating the public meetings, and has worked closely with Livingston Associates to insure a grass roots involvement in the planning process. Additionally, a Steering Committee consisting of the stakeholders and others was developed to include local governments and public citizens in the planning process.

The Council is committed to continuing this process to assist municipalities, counties, and others in the implementation of the final plan recommendations.

1.2 Goals and Objectives of the Regional Water Plan (RWP)

1.2.1 Goals (Vision Statement)

The goal of the Tularosa and Salt Basins RWP is to provide (through the implementation of one or more of the identified water supply and demand alternatives) a sufficient, sustainable water supply (at an economically sustainable price) to meet the agricultural, domestic, water association, municipal, industrial, commercial and other needs of the region, including consideration of the public welfare. The goal is also to make provisions for an adequate water supply to support reasonable growth in population and the economy (agricultural and non-agricultural) over the next forty years, in part through the application of economically viable conservation measures. Included in this goal is the utilization of the regional water resources in a manner that protects and preserves the resource and the environment.

1.2.2 Objectives (Mission Statement)

It is the objective of the RWP to:

a) seek and obtain public input on the plan so that it represents a "grass roots" approach to the solution of the regional water issues,
b) identify and quantify (including yearly and seasonal variations) and estimate the quality of the existing water resources that are economically and practically available to the people of the region,
c) identify the current and projected needs over a forty year time period for water for the region, especially at the local level,

d) quantify the shortfalls in water availability at the regional and local level, including consideration of the quality of the water,
e) identify various alternatives and estimate the cost of implementing those alternatives in order to create a condition in which available supplies equal or exceed the demand over time, and
f) prepare an implementation plan.

1.3 Individuals Involved in the Water Plan Development

Interest in the plan has spanned multiple levels of government, private citizens, farmers, ranchers, developers and various organizations. The South Central Mountain RC&D Council (RC&D) is indebted to their tireless efforts in reviewing technical documents, attending meetings, making presentations and making this plan a locally led endeavor.

The RC&D Council sponsored a meeting on May 5, 1999 to initiate the planning process and form a planning committee. A cooperative agreement was developed to formally recognize committee membership. The following entities and individuals have been involved in the planning efforts:

Committee Chairman:	Tom Springer- Rrepresenting the RC&D Council
RC&D Program:	Howard Shanks- RC&D Coordinator, NRCS
Consultants:	Livingston Associates, P.C.- Eddie Livingston, P.E. John Shomaker & Associates, Inc. – Steve Finch

Communities:

City Of Alamogordo	Kevin Heberle- City Engineer George P. Light- City Surveyor Don Carroll, Mayor Don Cooper, City Commissioner
Village of Tularosa	Demetrio Montoya, Mayor Richard Gutierrez, Planner
Town of Carrizozo	Cathie Eisen, Water Department

Timberon	Gary Scott, Manager, Community of Timberon
Salt Basin	Greg Duggar, Rancher

Counties

Lincoln	Patsy Sanchez, Planning Department Tom Stewart , County Manager
Otero	Monroe Curtis, Planning Dept

Organizations

Alamogordo Chamber of Commerce	Ed Carr, Executive Director
Otero County Economic Development Council	Ed Carr
Otero Soil & Water Conservation District	Eddie Vigil , Supervisor
Tularosa Community Ditch Corporation, Inc.	Norvall Bookout
Sacramento Mountains Watershed Restoration Corporation	Tom Macon Rick Warnock, President
NM Rural Water	Bennie Coker

Agencies-Federal

US Forest Service	Peg Crim, Lincoln National Forest
Natural Resources Conservation Service	Dan Abercrombie, District Conservationist
Bureau of Land Management	Ray Aguilar Ronna Simon
Bureau of Indian Affairs	Gwen Bridge, Hydrologist, Mescalero Apache Tribe
Dept. of Defense- Holloman AFB	Fred Fisher Michael Montoya
US Army	Bob Myers, White Sands Missile Range

Tribal

Mescalero Apache Tribe	Thora Padilla, Office of Environmental Protection

State Agencies

NM Environment Department Jim Edwards, Ruidoso

The following individuals, although they are not representing public entities, have been greatly involved in the planning process:

Leon Beck, Public, Alamogordo
Paul Burnett, Retired Meteorologist, Alamogordo
Norma Cinert, Farmer, Tularosa
Patrick Fudge, Public, Tularosa
John Homan, Businessman, Alamogordo
Jerry Johnson, Real Estate Developer, Alamogordo
Elva Osterreich, Alamogordo Daily News, Alamogordo
Gordon Schweers, Farmer, Alamogordo
Ed Sullivan, Businessman, Alamogordo
Larry November, Public, La Luz Canyon

1.4 Previous Water Planning in the Region

1.4.1 Previous Studies

The water resources of the southeast side of the Tularosa Basin were described in 1915 by Meinzer and Hare. Meeks (1950) discussed the ground water in the Tularosa and Alamogordo areas. In 1958, J.W. Hood described the ground-water resources of the Boles well field 8 miles south of Alamogordo; he also included many aquifer tests and an estimate of recharge to the area. In 1958 Armour Research Foundation of the Illinois Institute of Technology made a general water study of the Tularosa Basin (unpublished consultant's report to Holloman Air Force Base). Herrick and others (1960) discussed the area in a report on the water resources of Tularosa Basin. Herrick and Davis (1965) showed the distribution of potable and inferior water in the area. In 1967, W.C. Balance investigated the ground-water resources of the Holloman Air Force Base well-field areas. McMorries and Associates, in 1967, prepared a water and sewer report for the city of Alamogordo (unpublished consulting engineer's report to the city of Alamogordo). The extent and thickness of the saline-water zones in the area were delineated by McLean (1970), and in 1971 Morris and Prehn presented the potential for desalting ground water for a municipal water supply for Tularosa.

Additionally, in 1982 Herkenhoff prepared an update to the City of Alamogordo Water Master Plan, and the City is currently preparing a 40-year plan. The Village of Tularosa completed a 40-year water plan in 1996, and the Community of Timberon prepared a 40-year water plan in 1997, with a later update. Otero County published a 40-year water plan in 1993 (prior to the ISC Template), and contains valuable information used in this Plan.

Other reports have been prepared for various water-related issues in the Basin, and the reader is encouraged to refer to the bibliography for a detailed list.

The first draft of the Plan was completed and submitted to the ISC in 1997, which primarily discussed water demand issues and public participation.

1.5 Water Plan's Contents

This Regional Water Plan (Plan) follows the outline provided by the ISC in the "Regional Water Planning Handbook" dated December 1994. As required, the report emphasizes the involvement of the public in the planning process and includes the results of the public input. The RWP also provides an estimate of the water supply for the two basins (Tularosa and Salt), an estimate of the current water demand by category of use, a prediction of the demand for water over the next 40 years, and some recommended alternatives for reducing or eliminating the current and long-term shortfalls where they exist.

As a means of further understanding the details of the regional water resource, the Tularosa Basin was divided into three sub-basins: the north, the southeast (hereinafter called the "east" sub-basin) and the southwest (hereinafter called the "west" sub-basin). These sub-basins were further divided for hydrological analysis into major watershed areas since most of the communities in the region depend upon specific canyon-type watersheds for their water supply.

Although, from the standpoint of the estimated basin and sub-basin inflow of water, no water shortages would be predicted for at least 15 to 20 years (and then only in the east basin), in practice several communities are experiencing water shortages at the present time in the summer months. The physical availability of water will be affected by prolonged drought, and continued reduction in storage of fresh ground water by mining (ground water pumping). This Plan therefore addresses water issues at the local (community) level and recommends solutions to these problem areas, some of which have developed into serious socioeconomic issues between and within communities.

In the development of this Plan, we acknowledge that there may be deficiencies and uncertainty in the data and analysis, subject to improvement as additional data may become available.

2. DOCUMENTATION OF PUBLIC INVOLVEMENT IN PLANNING PROCESS

2.1 Interstate Stream Commission Sponsored Water Workshop

A workshop, sponsored by the Interstate Stream Commission (ISC), was held in Carrizozo, NM on July 25 and 26, 1995 for the Tularosa Basin and other regions in Southern NM. The workshop was facilitated by Western Network and was well attended. It dealt primarily with public participation issues. A subsequent workshop was held on September 15, 1995 in Carrizozo with ISC, UNM-BBER and local representatives to discuss population estimates to be used in the water plan.

Several additional workshops and meetings conducted by the ISC and Dialog have been held in Albuquerque and Santa Fe and were attended by members of this region.

2.2 Background Summary of Region Prepared for Public

Prior to the beginning of public meetings, a handout was prepared and made available at public meetings. This handout, along with the ISC brochure, gave background information on the purpose of regional water planning.

A presentation with overhead slides was also prepared for use in presentations at public meetings. The ISC's Regional Water Planning Handbook was also made available. Several news articles were also published during the early stages of the planning process. The original handout was revised and made available at subsequent rounds of public meetings (refer to **Appendix 2.1**). A newspaper insert (14,000 copies) was published and distributed in four local newspapers during the final phase of the planning process.

2.3 List of Stakeholders and Participants

The major stakeholders involved in the development of this plan are listed in the introduction section (Section 1.3). Throughout the development of the Plan, the public has been involved in the process through the establishment of a steering committee, a series of 17 public meetings and several newspaper articles. Participants at the 17 public meetings are listed below. The first series of six public meetings was held between Nov 28, 1995 and December 19, 1995 with 101 people in attendance. The second series of six meetings occurred between March 26, 1996 and April 11, 1996, with 102 in attendance. The third series of 5 public meetings was held between November 30, 2000 and January 25, 2001, with 86 attending. All meetings had similar objectives of providing information specific to communities and receiving feedback from the public. The meetings were held in the communities of Corona, Carrizozo, Tularosa, Alamogordo, Holloman AFB, Orogrande, High Rolls, Boles Acres and Timberon.

Flyers were posted in public buildings, public announcements were made on the radio, and newspaper notices were prepared in order to inform the public about meeting dates and locations. Articles were written by the Alamogordo Daily News covering some of the meetings. An 8-page report summarizing the Plan was inserted into the Alamogordo Daily News and other newspapers in January 2001, and is estimated to have reached more than 10,000 households.

A total of 280 persons attended these public meetings, and provided helpful comments (many of which have been implemented into the planning process). Overall, more than 100 comments were discussed, including a number of comments that were received by mail on a “mail-in” comment form provided by the RC&D Council. To-date, the public has realized the need for future planning of water resources, and welcomed the opportunity to be involved. Additionally, a presentation was made at the New Mexico Chapter of the American Water Resource Association annual conference in Ruidoso, NM. Refer to **Appendix 2.1** for information, articles and dates on the public participation program.

Participants of the first series of meetings:

Corona – November 28, 1995 20 people

Greg Haussler	Hazel Bickford
Hollis Fuchs	Robin Ofuffer
Sue Steans	Robert Bishop
J. Gibbs	Timothy Sanchez
Nolan Vickery	Eddie Livingston
Ellis Hodge	Curtis Schrader
Howard Harkey	Keith Kkessler
Karen Lerner	Teresa Barajas
Van Shamblin	Howard Shanks
Glenn Brimm	Jim Edwards

Tularosa- December 4, 1995 14 people

Linda Julien	Dan Abercrombie	Tom McKean
Adam Kusmak	Stephen E. DuBois	Jim Danlof
Joe M. Danzey	Richard Gutierrez	Nathan Dangeldein
Guenna Rees	Howard Shanks	Eddie Livingston
Jack Rees	Margie Trujillo	

Timberon- December 6, 1995 (Salt Basin) 28 people

Howard Shanks	Dave Ayers
Chris Murtishaw	Ernestine Holler
Mark Clark	Richard Moore
Jack Deaton	Paul R. Davis
Raymond Wilson	Larry Watson
Charla Jean Campbell	Bill Berkebile
Kenneth Bradshaw	Dwight Haisley
Sonny Griffin	Keith Kessler
D.D.	Curtis Schrader
Curtis Reece	Debbie Goss
Ruby Reece	Sid Benson
S. Hollobaugh	Evert Hicks
Helene M. Cook	D. Murtishaw
Butch Haupt	Eddie Livingston

Carrizozo/Nogal - December 8, 1995 8 people

Rene Burton	Carol Schlarb
Greg Haussler	Ruth Armstrong
Keith Kessler	Eddie Livingston
E. Williams	Howard Shanks

Orogrande - December 11, 1995 19 people

Karen Lerner	Al Tengelitsch
Eric Bailey	Mr. & Mrs Edward Johnson
Linda Wilkerson	Joe Bailey
Don Crottzau	Ellen Bailey
Bob Larceval	Don Wilkerson
Leslie Honsberge	Doug Essex
Theresa Kaup	Delta Rumsey
Bear	Earl Johnson
Keith Kessler	Eddie Livingston

Alamogordo - December 19, 1995 12 people

Angie M. Peck	Joe Kenney
David P. Gallagher	Rae Kenney
John Poland	Joe P. Moore
Jean Dodd	Robert D. Bishop
Aubrey Dunn Sr.	Lisa Turner
	Eddie Livingston

Participants in the second series of meetings

Orogrande - March 26, 1996 11people

Eric Bailey	Al Tengelitsch
Joe Bailey	Troy Raines
Doug Essex	Lon Miller
Raul Rojas	Earl Johnson
Don Wilkerson	Eddie Livingston
G. Rojar	

Timberon - March 28, 1996 19 people

Howard Shanks	Debora England
Jean Campbell	Dave Ayers
Grace Meyers	Dwight Haisley
Mary Frances Seidl	Larry Watson
Flo Stapelton	Betty Reece
Rose Marie Setzer	Curtis Schrader
Gloria Spradley	Eddie Livingston
John Stapelton	Yvonne La Rrue
Bob Crislip	Bill Berkebile
Paula Crislip	

High Rolls - April 2, 1996 — 8 people

Mel Pierce	Curtis Schrader
Clint McElhevy	Eddie Livingston
Joe Chambers	Helen Richardson
Phil Haseltine	R.R. Richardson

Carrizozo/ Nogal - April 4, 1996 — 10 people

Howard Shanks	Rene Burton
Keith Kessler	Bettye Martinez
Jim Edwards	Eileen Lovelace
Faustino Gallegos	Van Shamblin
Frances Boling	Eddie Livingston

Tularosa - April 9, 1996 — 36 people

George Hanawalt	Ray Quick
Carol Guilez	John Rees
Chon Guilez	Bill Julien
Lisa Turner	Linda Julien
R. Jackie Sandoval	Gwenna Rees
John Stockert	Bob Carr
Eddie Vigil	J. Howard Blackburn
Robert Baca	James Williams
Norma Cinert	Stephen DuBois
Gladys Nosker	Robert Bishop
Lowell Nosker	Bill Trammell
Sharon Perry	Dan Abercrombie
Bill Hayhurst	Frann E. Bird
Robyn Hayhurst	Joe B. Bird
Tony Tafoya	H.B. Shaw
Joe N. Demanguy	Ken Hughes
Karen Lerner	Stephanie L. DuBois
Fred Utter	Marjorie Trujillo
Eddie Livingston	

Alamogordo -April 11, 1996 — 18 people

Paul Burnett	Charles Walker
Leslie Bond	Thelma Walker
Joe Kenney	Evelyn Cook
Roe Kenney	Alvin Cook
Darrell Burrows	Dennis Cremmins
J. Williams	Barbara Wagner
Roy Quick	Jim Wagner
Sharon Perry	Bill Hornback
Norma Cineret	Bob Fisk
Eddie Livingston	

Participants in the third series of meetings

Tularosa - November 30, 2000 & January 23, 2001 36 people

Howard Shanks
Don Ogden
Pat Fudge
Tom Springer
Norma Cinert
Bob Carr
Melissa Uhles
Joan Price
Bill Mitchell
B. Mitchell
George Hanawalt
Tamiris Duke
Beatrice Gonzales
Judy Dorgen
Margie Trujillo
Michael Dorame
Tom McKean
Beverly Fudge
Paul Troutt
Dave King
Lance Geist
Mary Beth Cicala
Ethel M. Chavez
Gerald Marr
Walt Johnson
Pub Hartwig
Patty Hartwig
Ernest Lopez
Lucy Hill
Pete Gilliland
Dave Dorgen
Carol Torres
Tom Springer
Eddie Livingston
Richard Gutierrez
Coy Webb

Carrizozo / Nogal - December 5, 2000 17 people

Keith Kessler
Tom Roybal
Dusty Voss
Pat Voss
Ralph Meeks
Howard Shanks
Pete Gnatkowski
Rene Burton
Eileen Lovelace
Ruth Armstrong
Dub Williams
Eddie Livingston
Sue Stearns
Van Shamblin
DeAnn Kessler
Tony Sanchez
Jim Edwards

Timberon - January 17, 2001 11 people

Betty Reece
Colleen Gillmonthe
Mary Fran
Ray Lag
Fred Willis
Grace Meyers
Caroline Bompart
Rudy Lidbeck
Howard Shanks
Coy Webb
Gary Scott

Boles Acres - January 25, 2001 7 people

Howard Shanks
Joyce Powell
Marvin Powell
Coy Webb
Wanda Boles
Al Smith
Esther Derimel

Alamogordo - January 18, 2001 **15 people**

Howard Shanks	Rick Warnock
Tom Springer	Innis Lewis
Ralph Kester	Paul Troutt
Lori Shoes	Louis Delan
Gerald Caring	Eddie Livingston
Charlene Garing	Jonna Lynn Schaffer- Salt Basin
Beverly Warnock	Jane Shafer- Salt Basin
	Dale Leith- Salt Basin

2.4 Public Comments

2.4.1 Comments

More than 100 comments from a total list of attendees of about 280 were received, taken into consideration, and incorporated into the plan where appropriate. In addition to verbal and written comments provided by the general public at public meetings held throughout the region, a number of people representing different viewpoints on water issues attended regional water planning committee meetings. These individuals not only provided direct input to the document at the meetings, but, in some instances, were invited to submit a "position" paper incorporating their viewpoint. These viewpoints are included in Appendix 2.2. Four major papers included in Appendix 2.2 are (1) a simplified analysis of the safe yield of water from the Holloman Air Force Base's Boles Well field (a number which appears to be in disagreement with the OSE administrative model that has been run for the same conditions for that area), (2) another perspective on watershed management that includes the construction of small dams in selected canyons in the eastern basin in order to reduce flood damage, while, at the same time, allowing water to recharge the aquifer, (3) a viewpoint held by the Sacramento Mountain Water Restoration Corporation (SMWRC) on the issue of "public welfare", a viewpoint that includes more than just economics in the evaluation of "beneficial" use of water, and (4) a resolution adopted by the SMWRC regarding their position relative to the currently proposed location of a regional desalination plant, about the level of the TDS of the feed water to the plant, and about its alleged impact on the water supply in the mountain areas.

Public comments were recorded at each meeting and documented in a data base contained in **Appendix 2.2.**

3. STRATEGY CHOSEN TO MAXIMIZE PUBLIC INVOLVEMENT

The RC&D Council was successful in receiving the initial grant from ISC for the first phase of the Regional Water Plan in May 1995. This focused on the demand portion of the Plan and initiated the public participation process. The RC&D Council was well suited to sponsor the planning effort due to its involvement with local communities and counties for the past 30 years in the Tularosa Basin. The Council issued a request for proposals on September 25, 1995 and selected a local firm, Livingston Associates,P.C. for development of the regional water plan. The selection of Livingston Associates was an important consideration in the committee's choice due to the firms knowledge of local issues and its accessibility to the public.

The strategy to maximize public participation centered on the formation of a local water planning committee, which was formed during the initial planning process. This committee has been active since 1995 and has held monthly committee meetings. The committee represents the major water users in the Tularosa and Salt Basins and also has a good cross section of individuals representing various water interests in the area. The use of media, primarily newspapers, including newspaper articles, notices, feature stories, and inserts, was the main method of informing the general public. A representative of the Alamogordo Daily News was a member of the planning committee and attended meetings regularly. Other methods included community meetings, and presentations to civic groups.

The final phase of the study began in August 1999 and was completed in December 2001. This phase added a new area to the planning region, which was the Salt Basin. This Basin has become very important due to the potential availability of unappropriated ground water.

In May 1999 a more formal arrangement was established by developing cooperative agreements with the communities within the study area. The final phase of the study began in August 1999 and was completed in December 2001. A list of attendees is included in Section 2.3 of this report. Lincoln and Otero County Commissions were given status reports during this period. Representatives from the Mescalero Apache Indian tribe have attended committee meetings and their Natural Resource Committee was briefed and given copies of the newspaper insert.

As noted above, the committee prepared a newspaper insert for wide distribution within the planning region. Approximately 14,000 copies were inserted into 4 newspapers covering the region. This insert provided readers with the basic outline of the regional water plan and provided readers with an opportunity to comment.

4. BACKGROUND INFORMATION

4.1 Description of Water Planning Region

4.1.1 Location and Boundaries of Planning Region

The location of the planning region for the Draft *Tularosa Basin and Salt Basin Regional Water Plan 2000 – 2040* includes portions of Dona Ana, Lincoln, Sierra, and Socorro Counties that lie within the Tularosa ground water basin, and extends approximately 170 miles from the New Mexico-Texas state line north to Corona. This Plan also includes the Sacramento River area and the Salt Basin, southeast of Alamogordo, which incorporates the water uses of the community of Timberon, Pinion and a few outlying ranches.

4.1.1.1 Tularosa Basin

The Tularosa Basin encompasses approximately 6,500 square miles in south central New Mexico and is an arcuate, down-faulted basin that extends northward approximately 170 miles from near the New Mexico-Texas State line. The basin is bounded on the east by the uplifted Sacramento Mountains and Sierra Blanca Peak and on the west by the uplifted Franklin, Organ, and San Andres Mountains. Chupadera Mesa forms the northern basinal boundary, and a gentle topographic rise separates the basin from the Hueco Bolson to the south. The Tularosa Basin provides a source of both ground water and surface water for the communities of Carrizozo, Nogal, Three Rivers, Mescalero, Tularosa, Alamogordo, and Holloman Air Force Base. Additionally, numerous small rural water systems and domestic well users are supplied. Refer to **Figure 4.1** for a map of the Tularosa Basin. In addition, Bonito Lake, located in the Pecos Valley Watershed supplies a significant amount of water to the communities of Nogal, Carrizozo, Alamogordo and Holloman Air Force Base.

4.1.1.2. Salt Basin

The Sacramento River is located in Otero County, southeast of Cloudcroft and within the Sacramento Mountains. The Sacramento River area provides a source of ground water and surface water to the communities of Timberon and Orogrande. The Sacramento River is part of the Salt Basin. Refer to **Figure 4.1** for a map of the Salt Basin.

The Salt Basin is in the southeastern part of Otero County. The Salt Basin is an extensional basin that widens to the south and is bordered on the north by the Penasco Basin, the east by the Guadalupe/Brokeoff Mountains, and the west by the Hueco Mountains/Otero Mesa. Presently, about 2,500 acres of land in New Mexico, mostly near the Texas State line, is irrigated from wells. The development in New Mexico is a northward extension of a large irrigation development centered around Dell City, Texas, which is a few miles south of the State line. The principal agricultural products are alfalfa, and livestock. The Crow Flats area of the Salt Basin is sparsely settled.

The alkali flats at the bottom of the valley are about 3,614 feet above sea level, and sinkholes are common north of the alkali flats. A long slope, or bajada, lies between the valley floor and the base of mountains bordering the valley. Many isolated bedrock hills stand above the valley floor. The limestone uplands bordering the valley are drained by steep-sided, flat-bottomed canyons. Some smaller closed basins occur within, or adjacent to, the main closed drainage basin. The drainage of the basin is into a series of playas or alkali flats that extend along the valley floor from about 5 miles north to about 50 miles south of the New Mexico-Texas State line (Bjorklund, 1957).

4.1.2 Geography and Landscape

4.1.2.1 Tularosa Basin

- <u>Physical Features</u>

The Tularosa Basin, 6,500 square miles in extent, is an elongated desert valley which comprises about 5 percent of the Rio Grande drainage basin (135,000 square miles). Land-surface altitudes within the basin range from less than 4,000 feet in the barren alkali flats in the south-central part to almost 12,000 feet at the crest of Sierra Blanca Peak. The present topography of the basin results from north-trending, nearly vertical, normal faults which were active in middle to late Cenozoic time. These faults created a structural trough, or graben, that is bounded on the west by the Franklin, Organ, and San Andres Mountains, the Sierra Oscura, and Chupadera Mesa; on the east the graben is bounded by the Hueco and Sacramento Mountains, Sierra Blanca, Tucson Mountain, Patos Mountain, and Gallinas Peak. The basin is bounded on the north by a broad, high topographic divide and on the south by an almost imperceptible divide separating it from the Hueco Bolson in Texas.

The floor of the basin slopes gently southward and contains many depressions, or playas, that have no drainage outlet. These depressions form ephemeral lakes during rainy periods; when dry they commonly become alkali flats.

- <u>Precipitation and Runoff</u>

Mean annual precipitation in the basin ranges from about 10 inches in the central part to about 26 inches on the higher mountain slopes. Maximum rainfall occurs during the winter months (January through March) and during summer thunderstorms from July through September. Significant precipitation also comes from winter snowfall during the months of December through March.

Precipitation on the mountain slopes surrounding the basin runs off in intermittent streams that drain toward the center of the basin, or moves as ground water flow through alluvial deposits in the bottom of stream channels. At the apex of each alluvial fan some of the runoff infiltrates to the ground water body. Runoff passing beyond the toes of the alluvial fans flows out into the basin and evaporates on the playas (“dry lakes” or “alkali flats”), depositing the dissolved solids. Accretion to the ground water body occurs mainly during winter storms. The intense summer thunderstorms produce high runoff of such short duration that little water is recharged to the ground water body.

4.1.2.2 Salt Basin

- <u>Physical Features</u>

The central part of the closed basin is known as Salt Basin, and the Crow Flats area is in the northern part of Salt Basin. The southern part may be topographically separate from Salt Basin, as is the Sacramento River drainage basin in the northern part of the closed basin.

The valley occupied by Crow Flats is quite irregular in shape and ranges in width from about 5 miles to about 12 miles. It is bordered on the east by the Guadalupe and Brokeoff Mountains and on the west by a limestone upland. The valley floor north of the alkali flats or playas is relatively flat and uniform over a width of 2 to 5 miles. On each side of this relatively flat strip is a long, gentle slope between the base of the mountain and the middle of the valley. Such a slope, called a bajada, is formed by the coalescing of alluvial fans at the mouths of the many canyons. The *bajada* is steepest near the mountain and becomes progressively flatter toward the center of the valley. Differences in elevation from the toe to the top of the bajada range from about 500 feet to more than 1,000 feet. A bajada occurs on each side of the valley but it is better developed on the east along the bases of the Guadalupe and Brokeoff Mountains.

The playas or alkali flats, also called salt lakes, are approximately level, stand at an elevation of about 3,414 feet above sea level, and, within the Crow Flats area, are about 0.5 miles wide. They generally are bounded by an abrupt elevation rise of about 10 to 20 feet. An explanation of this feature as suggested by Meinzer and Hare (1915, p. 44-45), and later reiterated by King (1948, p. 137), is that the alkali flats probably are swept clear and extended by wind erosion. Apparently the wind has carried away the dry earth above ground-water level but has encountered an effective downward limit of cutting at the surface of the moist earth above the water table. Some dune and hummocky areas occur on the east side of the playas, where the eolian material has accumulated in hills and around clumps of vegetation. The dune material consists of quartz and qypsum sand.

- <u>Precipitation and Runoff</u>

The average annual precipitation in the Salt Basin is about 9 inches in the valley and about 20 inches on the Guadalupe Mountains east of the valley. Most of the rain falls during the months of May through October, when localized thunderstorms and cloudbursts are common, but the summer precipitation is not adequate for growing crops and must be supplemented by irrigation.

Recharge to the ground water reservoir is principally from the Sacramento River and also from infiltration of precipitation within the basin. The latter is believed to occur mainly from flash floods in the beds of ephemeral streams. Natural discharge occurs by evaporation from the alkali flats, which cover about 37,000 acres in New Mexico and Texas.

Canyons that drain the upland areas are steep sided and flat bottomed, their shape suggesting that at one time they were much deeper than they are today and that they have been partly filled, along with the valley, with material eroded from the highlands. These flat-bottomed canyons and their flat-bottomed tributaries range in length from about a mile to more than 20 miles, and each canyon bottom contains a broad creekbed strewn with cobbles and boulders, indicating the occurrence of many floods. The topography along these drainage courses is mature, although runoff is rapid. The various rock washes do not reach the bottom of the bajada but become obscure as the gradient flattens and floods spread out and lose velocity. The coarse material is dropped on the bajada and only silt, clay, and dissolved minerals are carried to the alkali flats (Bjorklund, 1957).

4.1.3 Climate

4.1.3.1 Tularosa Basin

The climate of the southeast side of the Tularosa Basin is varied, primarily because of the differences in land surface altitude. The precipitation and temperature stations of Alamogordo, Tularosa, and Orogrande reflect an arid climate, and the stations at Mescalero, Mountain Park, and Cloudcroft, in the Sacramento Mountains of the eastern part of the area reflect dry to moist subhumid climates.

Precipitation in the Tularosa Basin occurs during two periods. Winter precipitation, as rain on the basin floor and snow at higher elevations, falls during the period December until March. Summer precipitation usually occurs as intense thunderstorms during the period July through September. Rainfall on the floor of the basin is insufficient for cultivated crops and consequently, surface and ground water is used for irrigation.

Winters commonly are mild and the snowfall is light except in the higher mountainous areas; summers are hot in the lower parts of the basin but are cooler in the mountains. Tularosa and Alamogordo have an average growing season of about 216 days.

4.1.3.2 Salt Basin

The climate of the Crow Flats portion of the Salt Basin is typical of the semiarid Southwest. The winters are generally short and mild and the summers hot and dry. Sunny days are prevalent throughout the year and, although most summer days are hot, the nights generally are cool; temperatures during a year usually range from about 10° to about 106° F. The average annual precipitation is about 9 inches in the valley and about 20 inches on the Guadalupe Mountains east of the valley. Most of the rain falls during the months of May through October, when localized thunderstorms and cloudbursts are common, but the summer precipitation is not adequate for growing crops and must be supplemented by irrigation. Dust storms are common in the spring, and evaporation rates are high during the summer (Bjorklund, 1957).

4.1.4 Major Surface and Ground Water Sources

4.1.4.1 Tularosa Basin

The major surface and ground water sources for the Tularosa Basin are discussed in detail in Section 6.0. Refer to **Figure 4.2** for a map of the major watersheds in the Tularosa Basin and surrounding areas.

4.1.4.2 Salt Basin

The major surface and ground water sources for the Salt Basin are discussed in detail in Section 6.0. Refer to **Figure 4.2** for a map of the major watersheds in the Salt Basin and surrounding areas.

4.1.5 Demographics

4.1.5.1 Tularosa Basin

The major population center in the Tularosa Basin is the City of Alamogordo, with about 32,000 persons (1995 data). The Village of Tularosa, Town of Carrizozo and Holloman Air

Force Base each have current permanent populations of a few thousand. Approximately 50,000 people reside in the Tularosa Basin, with more than 4,000 as rural residents.

4.1.5.2 Salt Basin

Timberon and Pinon are unincorporated communities within the Salt Basin, with a population total of about 450. Rural residents located in the southern portion of the Salt Basin make up only about 50 people.

4.1.6 Economic Picture

4.1.6.1 Tularosa Basin

In 1996 and 2000 respectively the City of Alamogordo and Otero County commissioned Economic Development Strategic Plans in order to provide consistent and concise guidelines for future economic growth. Both plans recognize the need for economic growth in order to provide jobs and raise the standard of living for Alamogordo and Otero County citizens. Juxtaposed against this need for economic growth is the constraint of limited water to support new and expanding businesses. Both of these entities have placed self-imposed constraints on new businesses by not providing encouragement to businesses that are ‘high water users’. Specifically, the Otero County Plan states that it promotes “Industry that does not use large amounts of water in its production processes." It further states that "Exceptions may be made in instances where the water is mostly reprocessed rather than discharged.” The Alamogordo plan is similar, and indicates that there is a short term need to improve water distribution, while a long term water plan is needed which encourages water processing for new sources.

The support the city and county can provide might be, but is not limited to, the following incentives: Industrial Revenue Bonds, tax abatements, and/or infrastructure improvements. In the current highly competitive site selection market, county and city incentives are crucial to successfully recruiting new businesses to a community. Without the support of the county and the city it is unlikely that any manufacturer of any size would locate in Otero County or Alamogordo. The water availability constraint will effectively prevent many high-paying industrial and agricultural manufacturing companies from locating their businesses in Otero

County. Unless new sources of water can be developed, the city and county may be extremely limited in the types and sizes of industry they can support.

In Carrizozo, which is in Lincoln County, water resources are not a limitation. Carrizozo is located at the crossroads of Highway 380 and Route 54. The local economy has limited financial resources, but the town has shown gradual growth over the last few years. New businesses as of this writing include Sierra Blanca Microbrewery, Richmond Tire, and several service stations and restaurants. A new detention center will be completed soon, and a carbon recycling plant has shown interest in locating in the area. Land is affordable, and there has been some residential growth. Water system infrastructure improvements are required to meet the needs of local growth, but water supply is not seen as a limiting factor.

4.1.6.2 Salt Basin

- <u>Timberon</u>

Timberon is a small community located 31 miles south of Cloudcroft. It is situated in the Sacramento Mountains at an elevation from 6,700 to 7,600 feet. The current area of Timberon is 9,350 acres and the permanent population is approximately 280. There are presently 7,653 lots of which only 435 are presently connected to a water meter, which indicates the tremendous potential for future growth. The favorable climate and beauty of the mountains provides a unique attraction for retirees and seasonal residents. The paving of the road from Sunspot also may improve the opportunities for growth. However, water is the limiting factor and there is cause for concern due to the reduction in flows from Carrisa Spring and the difficulty in finding alternative sources.

The community is governed by a water & sanitation board. The district infrastructure includes water production and distribution, roads, airfield, and recreational facilities (golf, tennis, fishing, swimming pool, parks and a community lodge).

The community has a small business section including condominiums, grocery store, post office and real estate offices. A small business involved in utilizing small diameter materials from forest thinning is starting up. The community has received a grant to cost share the cost of thinning lots for fire protection. The community has had several wildfires in the recent past and their fire department is developing plans to deal with wildfires. The community is also developing an economic action plan to improve their economic status.

- Sunspot

There are two observatories located at the head of the Sacramento Watershed approximately 16 miles south Cloudcroft. One is the National Solar Observatory and the other is an astronomical observatory known as Apache Point. The solar facility is a national center for research of the sun. It is federally funded with approximately 65 full-time employees and an annual economic impact to the county of almost $9.5 million. The water supply for both facilities comes from wells nearby and appears adequate for current and future needs.

- Salt Basin

The Sacramento River is a major contributor to the ground water reserves in the Salt Basin. This area consists mainly of desert grassland and shrubland and is used mainly for grazing and military operations. The recent discovery of large natural gas field and the realization that this area also has a tremendous supply of high quality ground water reserves makes the area a sleeping giant in terms of economic development opportunities. The natural gas field lies mostly under federal lands, which limits potential for full development. The water resources, however, are in control of private landowners and the possibility of exporting water from this region is being seriously considered, and the Regional Water Planning Committee is not opposed to the marketing and sale of Salt Basin water inside or outside the Salt Basin.

4.1.7 Land Ownership and Land Use

Land use and ownership data were provided by the New Mexico Water Resource Research Institute (WRRI) at New Mexico State University, and includes acreage by various use and ownership classifications. Refer to **Figure 4.3** for a Land Use map and **Figure 4.4** for a Land Ownership map of the Tularosa and Salt Basins.

4.2 Historical Overview of Water Use in the Region

4.2.1 Tularosa Basin

Between 1861-1862 heavy rains and flooding in the Rio Grande valley drove a group of Mexican farmers to the Tularosa valley. They attempted to locate themselves on the Tularosa River about 15 miles from the present day Village of Tularosa but the Apaches made it impossible to settle there. In 1862, an engineer named Bailey laid out the town for them, which is now the townsite. Trouble with the Indians continued at intervals until 1884. Less than a year later, on April 2, 1863, the first irrigation water flowed through the small community. The second permanent settlement occurred at La Luz between 1863 and 1864.

The first cattle ranches were started in the Basin in the decade between 1870 and 1880 and the most notable was Oliver Lee who began building his empire in the mid 1880's. He established a ranching empire including irrigated lands in the Dog Canyon and Alamo Canyon areas.

In 1897, Oliver Lee sold the water rights from Alamo Canyon to C.B. Eddy. This caused a new epoch in the history of the Basin, for in 1898, Eddy established his railroad and the communities of Alamogordo and Carrizozo flourished. Cattle ranching and irrigated farming grew along with the mining, timber and timber industries. It would seem that water was the necessary element for success, yet it became a problem for the railroad. Loaded with gypsum, it impaired the performance of the steam engines, which literally came to a standstill when using the poor quality water. Mountain water delivered by the Bonito and Sacramento pipelines was to become the new solution to water quality problems. Water development in the canyons continued with ditch works and pipelines utilizing surface water and springs.

The Bonito Canyon pipeline was built in 1907 and the dam was built in 1931 to serve the needs of the railroad for their steam engines and also to supply water to the communities of Carrizozo, Nogal and Ft Stanton. It is located about nine miles north of Ruidoso in the Lower Pecos River drainage. The lake is approximately 45 surface acres with a capacity of 1,090 acre-feet of storage. In 1953, the railroad began changing locomotives from stream to diesel had less and less need for the mountain water. Because it felt obligated to Carrizozo and the neighboring communities, which the Bonito pipeline served, it gave them first opportunity to purchase the pipeline. Carrizozo was unable to afford the maintenance and declined to purchase the pipeline. Ruidoso and Capitan were offered the opportunity to purchase the lake but could not come to terms with the railroad.

In 1954 Alamogordo agreed to purchase the pipeline and lake. This agreement did not set well at first with users of the pipeline due to the fear that Alamogordo and Holloman would take all of the water. The Pecos Valley Conservancy District also became concerned and filed a suit to stop the sale, renewing charges from a 1934 suit. Eventually, a compromise was reached quantifying the amount Alamogordo, and Holloman would receive. Carrizozo, Nogal and Ft. Stanton were also guaranteed their water rights. Terms of the agreement stated that Alamogordo would also be responsible for maintenance, and the bulk of the water would be shared equally between Alamogordo and Holloman Air Force Base. The remainder was to pass over the dam into the Bonito River and into the Pecos Basin. There was also a stipulation that Bonito Lake was never to be closed for public recreation use.

The first part of the Bonito pipeline from Bonito Lake to Nogal has been replaced with a new pipeline. Holloman AFB has received an appropriation from Congress to replace approximately 50 miles of the pipeline between Carrizozo and Tularosa, thus assuring a supply of high quality water to the basin.

The Three Rivers pipeline is located on the Colin McMillan ranch and is still used for agricultural purposes. It was built by Albert Fall to replace an open ditch constructed from the Mescalero Apache boundary to his home.

The water developments within the Basin were the lifeblood of the region and contributed to the quality of life enjoyed by all residents. The railroad made some agreements with the ranchers who had owned the water rights of the Sacramento and Three Rivers lines allowing them water for their own use. However, when the railroad bought the water rights in the Bonito Canyon, no such provision was made and most of the settlers were forced to leave the Bonito Canyon.

Those settling the canyons where springs and surface water were abundant began having disputes over water. The records in the Lincoln, Otero and Dona Ana County Courthouses are full of agreements, affidavits, and contracts regarding land and water deals, as well as many settlements by court actions.

In order to address water disputes, the first comprehensive water law was enacted by the Territorial Legislature in 1905 and then amended in 1907. This law adopted the surface water code and established the position on Territorial Engineer (now the State Engineer). Shortly thereafter, adjudication of rights of the Rio Tularosa, and the La Luz/ Fresnal Stream system were initiated to settle disputes and secure the vested rights of the early settlers who had risked their lives to develop their lands.

The following 30 years brought many sales and trades for water rights. The railroad was still the main appropriator and continued buying up rights and developments by whatever means available. The farmers around Tularosa and La Luz continued using surface rights.

Then, the event that would bring the entire nation together (and greatly impacted the Tularosa Basin) was World War II. The Alamogordo Army Air Field, now known as Holloman Air Force Base and the White Sands Proving Grounds literally turned the small community of Alamogordo into a city overnight. This growth caused an immediate water shortage and it became imperative for Holloman AFB to secure a dependable supply. In 1942 a 5" pipeline was constructed from Alamogordo to HAFB. The end of the war brought temporary relief due to the reduction in personnel. However, Holloman AFB was soon activated for missile development bringing families of the men stationed there. To relieve the situation at Holloman AFB, the Luther Boles well field was purchased and developed. The wells were used in spring and summer and water was purchased from Alamogordo in fall and winter. Alamogordo also began developing additional water sources in 1947 from La Luz Canyon.

The years between 1949 and 1960 saw the greatest activity in commercial irrigated agriculture in the Basin, centered on Tularosa. The Tularosa Ditch was limited on the number of farms it could serve, so many farmers drilled wells and began growing alfalfa, cotton and chili. There were some small dairies as well. The period beginning in the 1970's saw new crops, such as pecans and pistachios, irrigated by drip or sprinklers. Farming is still a viable industry in the Tularosa Basin, but pressures from urban growth and poor economic returns threaten the survival of commercial agriculture.

The Office of the State Engineer declared the Tularosa Underground Water Basin in 1982 and also established administrative criteria for the area between Tularosa and Alamogordo for strict controls of additional withdrawals in that area. The administrative criteria for the rest of the basin (outside the urban areas) are not as strict on receiving approvals for drilling wells.

4.2.2 Salt Basin

In 1897, Oliver Lee constructed a ditch and diversion dam on the Sacramento River for his range and home in 1000-Mile Canyon. The ditch extended to his Upper Juniper Reservoir, thereby providing dependable water for his ranch and home. In 1905, the Southwestern Smelting and Refining Company purchased water from Mr. Lee and built a pipeline to Orogrande for its smelter. Another prominent rancher, W.H. McNew purchased water from Lee and developed an extensive water system for his ranching operations. Both of these pipelines are in existence today, although in a state of disrepair.

Other ranchers began their ranching operations in the Salt Basin during the early 1900's and relied on wells for livestock, domestic use and irrigation of small gardens. The first irrigation well for commercial agricultural purposes was drilled in 1947. Several other wells were drilled in the 60's culminating in a fairly active farming region during the 70's with approximately 6,000 acres under cultivation. The water was of high quality and quantity. Poor prices, high pumping costs and distance to market caused the decline of this endeavor. The ranchers and farmers, recognizing the value of their water, formed an informal organization called the Last Chance Water Company in 1997 with the intention of marketing its water to both in-state and out-of-state users.

The Timberon resort area was established in 1969 by a group of New Mexico businessmen. Judge Paul Moss of Odessa Texas purchased this property originally in 1933. He developed some rather extensive irrigation systems that supplied water from Carrisa Springs to the growing area in the Sacramento Valley where the present day airstrip is located. The area was developed as a resort area and still depends on the springs as their main source of water. The current output of the springs has diminished considerably (650 gpm down to 75 gpm) and the Community of Timberon is drilling wells to supplement this supply.

On September 19, 2000, the Office of the State Engineer declared the Salt Basin, giving the OSE administrative control of water rights issues.

5. LEGAL ISSUES FOR THE REGION

(Note: The majority of Section 5 was taken from the Otero Co. 40-Year Water Plan, 1993)

5.1 Water Laws Relevant to the Region

New Mexico water law broadly states that "all natural waters belong to the public and are subject to appropriation". New Mexico law provides that water may be appropriated, or taken for use, on the basis of three principles.

1). All surface and ground water belongs to the public and is subject to appropriation for beneficial use. An appropriator does not own the water, only the right to divert or impound and use it. However, a person who uses water for fishing or rafting is not establishing a right to that water because water has not been diverted from that stream. Surface water is governed by the State's surface water code, enacted in 1907 by the Territorial legislature. With few changes, this law remains in effect today. The surface water code confirmed the validity of all rights, which existed prior to its enactment. In 1931 the New Mexico legislature enacted the ground water code, which closely followed the surface water code, and extended the state engineer's responsibility to include the administration of ground water within declared ground water basins. The state engineer may declare a geographical area a ground water basin when he determines that it has reasonably ascertainable boundaries.

2). Beneficial use is the basis, measure and limit of the right to use water. Agricultural, domestic, recreational, municipal, industrial and other uses are considered beneficial as long as there is no willful waste of the water. In New Mexico all beneficial uses are considered equal regardless of the economic value produced by the use.

3). Priority of appropriation gives the better right. Priority is based upon the date on which construction of works for the beneficial use of water began or on which a notice of intention or an application to appropriate water was filed with the state engineer. The user with the earliest priority date is entitled to receive a full appropriation before those with later, or junior, priorities receive theirs. This concept is referred to as the doctrine of prior appropriation.

The state engineer, who is appointed by the governor and confirmed by the Senate, is responsible for the administration of the State's surface and ground water according to these principles (refer to **Appendix 5** for additional discussion on water rights administration).

State statute 72-14-43, and 44, NMSU 1978 as amended (1993 Cumulative Sup.) authorizes planning for the future water needs of New Mexico and its various regions. The Interstate Stream Commission (ISC) is authorized to appropriate ground water or to purchase water rights on behalf of the various regions of the state. The ISC is also authorized to make grants to the various regions for planning purposes.

Art. XVI sections 1-5, 72-1-1 et seq., NMSA 1978 Comp., as amended establish prior appropriation and beneficial use as the fundamental principles of New Mexico water law. In addition the various regions of the state may differ in important particulars as to the "local water law". For example, the surface waters of Tularosa Creek are subject to a District Court adjudication decree, which impacts that portion of the region and may alter the approach to planning that is required for the communities served by that source. In addition, the Mescalero Apache Tribe's sovereignty must be respected since the Tularosa headwaters originate on tribal lands.

Two new terms have been introduced into the water law arena by the State Legislature. They are: "public welfare" and "conservation". These elements were first introduced by Sporhase v. Nebraska, 458 US. 941 (1982). In Sporhase the Supreme Court of the United States approved these criteria as factors to be considered when any individual state was considering interstate issues concerning water. Public welfare or public interest has played an incidental role in New Mexico's water law. Although the two were ignored administratively, occasionally one or the other would surface in the Courts.

Almost immediately after the Sporhase supra decision, the City of El Paso began its efforts to appropriate New Mexico ground water from the Tularosa Basin's Hueco Bolson for municipal use in El Paso. In two very quick New Mexico Federal Court decisions, the City of El Paso v. Reynolds, 597 F. Sup. 379 (D.N.M. 1983) and City of El Paso v. Reynolds, 597 F. Sup. 694

(D.N.M. 1984), it became clear that public welfare and conservation were going to play a dramatic role in future decisions concerning New Mexico's water future. This action by El Paso became the catalyst for the State to initiate the regional planning process.

It should be noted that there is at this time little definition with respect to these new criteria and that the width and breadth of these doctrines will no doubt be established through much discussion and litigation in the future. However, during the planning process of this region, many public meetings and other opportunities have attempted to identify public concerns and interests.

There are certain special considerations, in addition to the above, that are created by the introduction of the conservation criteria. Simply put, it is not enough to simply conclude, " we need more water". Now we must examine ourselves, our water use patterns, building codes, zoning regulations and land use plans and stewardship abilities to determine whether we are fulfilling our responsibilities to conserve the water we currently hold rights to.

It should be noted that development historically has not necessarily occurred in areas where there is an available water supply. This situation has historically required transportation of water supplies over considerable distances to meet developing water demands. There are several points of diversion within Tularosa Basin which serve for transporting water from the supply source to the areas of demand.

It is fully anticipated that this transportation of water supplies will continue into the future because of the importance and investment in existing ground water and surface water resources such as Bonito Lake, La Luz-Fresnal Canyons, Tularosa Creek, Sacramento River, and the Holloman well fields: Boles, San Andres, Douglas, Frenchy, and Escondido.

5.2 Federal Legal Issues

5.2.1 Federal Reservations

5.2.1.1 Indian Reservations

Mescalero water rights on the Tularosa Creek have not been adjudicated and there is no suit pending at present, but there are potential claims in addition to the presently irrigated acreage and municipal water use at Mescalero.

An adjudication of Tularosa Creek water rights is expected, probably after the final resolution of the adjudication of the Pecos River system and its hydrological related ground water basin. By analogy with the events related to the adjudication of the Rio Ruidoso and associated ground water rights, it can be expected that the Mescalero Tribe will claim a large part, if not all, of the flow of both Tularosa Creek and the Three Rivers system.

The court found that the Mescalero rights in and associated with the Rio Ruidoso were not much more than the amounts historically used, plus an allowance for growth, but the decree has been appealed. Until more definitive action is taken, however, it is uncertain what impact, if any, pending results may have on downstream diversions on the Tularosa Creek.

5.3 Water Rights Administration Policies Specific to the Region

5.3.1 Surface Rights

Most if not all of the surface water in the region has been appropriated. The surface rights on the Sacramento River, Bonito Reservoir, Tularosa Creek, Three Rivers, Caballero Canyon, Alamo Canyon and La Luz/ Fresnal Canyons are filed with the Office of the State Engineer district office in Las Cruces and are available for inspection.

While the principle of riparian rights worked as well in the humid eastern states as it had in England, the Riparian doctrine was not suited to the arid West. New Mexico expressly rejected the Riparian Doctrine, first in its Territorial Supreme Court in 1891 and again in 1945 in the New Mexico Supreme Court.

Instead, New Mexico adopted into its constitution the concept of prior appropriation. Under the definition of prior appropriation, a person who takes water and puts it to a beneficial use is an appropriator. The taking of the water constitutes an appropriation, which includes a priority date. This priority entitles the appropriator to receive his full appropriation before those with junior, or newer, water rights receive their appropriations.

The development of the Appropriation Doctrine had its beginnings in three unrelated movements. The first was the Spanish colonization of the Southwest in which the settlers introduced the acequia system of community controlled irrigation. The second was the Mormon migration to Utah where the religious settlers became the first Anglos to use irrigation on a large scale. When the Mormon church took possession of lands in the region, it also supervised the parceling of land, including the right to water for irrigating the land.

Farther west, a third event also was affecting water rights—the California gold rush. There, miners diverted water from its natural banks to wash away soil clinging to the gold. Gold also lured thousands to the West and Southwest who otherwise wouldn’t have risked the hardships of the arid territory. Whether it was brought about because of mining demands or the accompanying population boom, the Appropriation Doctrine was adopted in seven western states, including New Mexico, in the 25 years following the 1849 gold rush.

An appropriation water right, like equipment or furniture, in considered property and can be owned separately from the land. However, in most states, including New Mexico, the appropriator “owns” only the right to use the water and not the “corpus,” or body, of the water itself.

The federal Desert Land Act of 1877, in recognizing the special needs of arid lands, validated the Appropriation Doctrine. The act provided that water rights on desert land should depend on “bona fide prior appropriation.” The act also provided that all surplus water above actual appropriation and necessary use should be available for public appropriation for irrigation, mining and manufacturing.

The necessity of a man-made diversion, such as a dam or irrigation ditch, is the first of two requirements for establishing a water right in New Mexico. For example, a person who builds a ditch to carry water from the stream to a field is fulfilling the intent of establishing a water right. On the other hand, a person who uses water in a stream for fishing or rafting is not establishing a right to that water because water has not been diverted from the stream. These in-stream uses are allowed, but are not protected by water rights. The act of diverting water, then, sets the stage for the second requirement for water right ownership—beneficial use.

According to New Mexico law:

> Beneficial use shall be the basis, the measure and the limit of the right
> To use of water…Priority in time shall give the better right.

The constitutions of a majority of the western states contain language similar to New Mexico's in determining water rights.

Although the law sets beneficial use as its standard for awarding a water right, and sets penalties for uses that are not beneficial, the law does not specify what those uses are. Generally, nearly all uses are considered beneficial, whether water is used for agriculture, recreation, industry or secondary recovery of oil. New Mexico courts have validated uses such as stock watering as beneficial use. However, the law does classify the "willful waste of surface or underground water to the detriment of another or the public" as a misdemeanor. "Willful waste," then, is not a beneficial use.

In New Mexico, all beneficial uses are considered equal regardless of the economic value produced by the use. The exception to the economic rule is that municipalities, counties and the state may condemn water rights for public purposes at a reasonable price set by the court. This exception allows for population growth and its accompanying demand for more water.

New Mexico Supreme Court Justice Irwin S. Moise said the broad definition of beneficial use is workable because it makes the greatest use of water at the earliest date "when to have held it for future use would result in waste if not loss." He also said the law of supply and demand would take care of changes from one beneficial use to another or better use." (Ref: New Mexico Water Rights, Harris, Linda G., NM Water Resources Research Institute, Misc. Report No. 15, August 1984.)

"Surface water…is governed by the State's surface water code, enacted in 1907 by the Territorial Legislature. With few changes, this law remains in effect today. The surface water code confirmed the validity of all rights which existed prior to its enactment.

Vested surface water rights are those rights which have priority dates established, based on historic use, prior to the enactment of New Mexico's 1907 Surface Water Code. These rights date from the initiation of the claim.

After March 19, 1907, anyone wishing to establish or change a surface water right must apply to the state engineer for a permit to do so. Such an application may be approved if unappropriated water is available and if the new use is not detrimental to existing water rights. In addition, the proposed use must not be contrary to water conservation within New Mexico or detrimental to the public welfare of the State. Most surface water within the State has been appropriated. Following is a summary of the surface water rights for the study area (See **Appendix 5.1**).

5.3.1.1 SACRAMENTO RIVER – In 1965, Alamogordo and the New Mexico Department of Game and Fish applied to the State Engineers Office (SEO) to build a dam on the Sacramento River for recreation. In a 1965 SEO memorandum from M.B. Compton, it is stated that the owner of the Sacramento pipeline (Alamogordo) "is to supply water [368 AFY] through the…pipeline" to the following water right owners: US Army (67.2 AFY), Fairchild (2.8 AFY), Forest Service (0.3 AFY), Moss Ranch (1.7 AFY), Stahmann (44.8 AFY), McNew (16.8 AFY) and Orogrande (234.4 AFY). Compton estimated runoff at the proposed site on the river to be 860 AFY.

5.3.1.2 BONITO RESERVOIR – According to the SEO, there are five holders of Bonito Reservoir water rights: Alamogordo (1,449.02 AFY), Holloman (1,449.02 AFY), Carrizozo (130.31 AFY), Nogal (1.45 AFY) and the Southern Pacific Railroad (57.92 AFY). In terms of available supply, an update of the 1982 water master plan indicates that the entire amount would be available, even in dry years. An agreement between

Alamogordo and Holloman stipulates that Holloman Air Force Base (HAFB) receives its share from November through April, while the City receives its share from May through October.

It should also be noted that Holloman Air Force Base actually owns the Bonito Pipeline, and allows conveyance of flows to Alamogordo under an existing maintenance agreement.

5.3.1.3 TULAROSA CREEK – The Village of Tularosa obtains its primary water supply from Tularosa Creek through its water right of 701.25 AFY, subject to senior rights on the upper stream system. According to the SEO, there are diversions to irrigate approximately 1,000 acres of land upstream from the gaging station (Ref. 33). Included in these diversions are members of the Bent Water Users Association who divert irrigation water from mid-February through early October each year. Using a depletion factor of 2.2 af/ac (Rev. 25), there may be irrigation amounting to at least 2,200 AFY on the creek. With an annual average flow of 7,753 AFY (USGS records from 1948-85), there does not appear to be a shortage on this system.

5.3.1.4 THREE RIVERS – The water rights situation in this stream system is unclear. According to the Bureau of Reclamation (Ref. 38), "a major constraint is potential conflict with Indian use of the water." The Bureau goes on to state that "Although reserved rights have been adjudicated, concern about possible future claims limits the interest in a substantial investment at this time…the water would also be high in total dissolved solids (TDS)." Vigilance relative to any future claims should be exercised for the protection of Otero County residents.

5.3.1.5 CABALLERO CANYON – Permit 2176 (SEO) grants Alamogordo the right to divert 181 AFY from the surface flow in Caballero Canyon. The permit was granted in 1977 and states that any diversions by the City must be measured with a totalizing meter. Proof of completion works and application of the water to beneficial use had to be filed by July 1, 1981. There are no records indicating whether or not the city proved beneficial use by the appointed date.

5.3.1.6 ALAMO CAYON – A compilation of SEO records shows that Alamogordo has rights dating from 1932 and 1937 to 3,078 AFY of water from Alamo Canyon. There are seven rights with earlier priority dates which amount to 1,797.6 AFY. There are four rights with priorities ranging from 1939 to 1983 which amount to 100.18 AFY. The total amount of water rights on the river system is 4,975.78 AFY. It is uncertain what the available supply is for Alamo Canyon. Results of the water yield model simulation performed for this study, as described in Section 6.2.2, indicate that average annual water yields for Alamo Canyon of 3,840 AFY are insufficient to satisfy the total amount of water rights on the system.

5.3.1.7 LA LUZ AND FRESNAL CANYONS – Although most of the rights on the La Luz-Fresnal system are apportioned between each canyon, one right, the largest, applies to both La Luz and Fresnal Canyons. Alamogordo owns a right to 16 cubic feet per second (cfs) from an undefined combination of the two canyons (and personal communication, John Nixon, 1990). This amount is equivalent to about 11,563 AFY. Since there is only one right on the Fresnal with the same priority date (none precede it), an 1866 right for 644.8 AFY, Alamogordo's right is a valuable one for most of the water in the system. Section 6.2.2 shows the average flow in the system to be about 10,500 AFY.

In addition to the 11,563 AFY right on the combined system, there are 6,366.2 AFY of rights in La Luz Canyon and 4,418.82 AFY of rights in Fresnal Canyon. These rights amount to 22,348.02 AFY, whereas a water yield simulation shows that there are only about 10,500 AFY of water available in an average year. Of the total amount of rights, Alamogordo has 12,395.4 AFY, or 55%. With the exception of a few municipal rights, such as High Rolls, the remainder of the rights are assumed to be agricultural. The High Rolls Development Company filed a declaration with the SEO for 9 million gallons per year (27.63 AFY) on June 10, 1982. The High Rolls declaration (number 02861) claims a 1907 priority date.

5.3.2 Ground Water Rights

There are three declared ground water basins in the planning area. The State Engineer's Office (SEO) declared the Tularosa Basin on July 7, 1982, the Hueco Ground Water Basin on September 12, 1980 and the Salt Underground Basin on September 13, 2000.

Ground water rights established in the basin before the date of declaration are not affected by the declarations. These are referred to as pre-basin vested rights. After a declaration, anyone wishing to appropriate ground water, or change the place or purpose of use for a vested right, must apply to the state engineer for a permit to do so. Such applications must meet the same requirements for approval as those for surface rights. If the basin is fully appropriated, no new permits will be granted, except for certain uses exempted by statute such as small domestic and stock watering purposes.

Water rights adjudication is a legal process by which the ownership and extent of water rights are determined through a technical review and legal court order. No adjudication process has been performed in any of the basins in the study area, so all ground water rights are in the form of declarations. There have been no court decrees which define the specific underground water rights of every water right owner declaration within any of the basins. A tabulation of existing declarations is available in **Appendix 5.2**.

"In 1931 the New Mexico Legislature enacted the ground water code, which closely followed the surface water code and extended the state engineer's responsibility to include the administration of ground water with declared ground water basins. The state engineer may declare a geographical area a ground water basin when he determines that it has reasonable ascertainable boundaries".

Some of the applications listed have already been denied (T-0387 for the City of Alamogordo for 22,405 AFY was withdrawn), but are nevertheless identified. The water rights amounts applied for are almost exclusively for irrigation usage and these are for insignificant water amounts (3 to 5 ac ft/acre/year). Two exceptions are File No.'s T-734 through T-734-S-5 for the City of Alamogordo for a total of 6,720 AFY, and File No's T-944 through T-948 for the Department of the Army/Ft. Bliss for a total of 1,075 AFY.

The Salt Basin is the most recently declared ground water basin in the planning region. This action was, in part, a response to the Hunt Building Corporation of El Paso ammended declaration filed with the OSE, claiming a pre-basin intent to pump 45,000 acre feet of ground water from the Salt Basin in New Mexico (just north of Dell City, Texas) for agricultural or municipal and industrial use in New Mexico or Texas. The annual volume of water for the proposed project is claimed to be 45,000-acre feet (not all from New Mexico wells) and includes 17 wells to be developed. Hunt has purchased a farm in New Mexico and has begun developing the existing irrigation systems and started farming.

The Interstate Stream Commission prepared a draft document or resolution relating to implementing a State Appropriation of Water Resources Program to address the issue of unappropriated water within planning regions. The Salt Basin underground water basin was recently declared in September, 2000. Pursuant to N.M.S.A. § 72-12-5, there is no time limit for filing a declaration evidencing a pre-basin water right claim. Accordingly, the full extent of water right claims, for use within or outside the basin, is not known. The Regional Water Planning Committee does not make any recommendations regarding the disposition of water in or from the Salt Basin. Political and market forces and the results of the OSE filings will determine the outcome of the supply and future demand for water. A memorandum from the ISC responding to questions concerning this issue in the Salt Basin is included in **Appendix 5.3.**

The Interstate Streams Commission proposed to the Regional Water Planning Committee that pursuant to NMSA § 72-14-44 (1978), it could reserve water in the Salt Basin on behalf of the Basin. The concept was that the ISC would make an appropriation that would hold the water in place for more than 40 years. After much discussion and at the request of the representative of the Salt Basin, the Regional Planning Committee decided that it did not want the ISC to appropriate and reserve water on behalf of the Salt Basin. Instead, the Regional Water Planning Committee agreed that the residents of the Salt Basin that have lived there for decades and toiled to make a living should have the opportunity to file their declarations and to make new applications to market surplus water, inside or outside the Salt Basin. The Regional Water Planning Committee did not want to interfere with the economic opportunity that presented itself to the residents of the Salt Basin.

5.3.3 Ground Water Basin Criteria

The Tularosa Basin encompasses an area of approximately 6,070 square miles. Due to the size of the basin and geologic diversity, criteria for water rights administration should be developed for specified sub-areas within the basin. This was done for the Alamogordo-Tularosa area on May 19, 1997.

The Alamogordo-Tularosa administrative area is administered using blocks one-half mile square using the grid utilized by the ground water model developed by Thomas M. Morrison of the OSE office. This model is being used to evaluate pending and future applications to determine the effect on existing water rights (see **Appendix 5.3**).

5.4 Local Conflicts

The most recent conflict involves a dispute between a group called the Sacramento Mountain Watershed Restoration Corporation (SMWRC) and the City of Alamogordo over diversion of water from La Luz/Fresnal and Maruchi Canyons. This group has submitted a written request to the OSE office in Las Cruces asking that the City of Alamogordo be enjoined from " further violations of the law" in its diversion of water from these two springs. The SMWRC contends that the City has violated New Mexico statutes and the conditions of a permit issued in September 1995 by the state engineer. The permit approved the addition of 30 new diversion points or spring collection points. The SMWRC further contends, among other requirements, that it be "not detrimental to public welfare or contrary to the conservation of water within the state".

In a letter to Mr. Calvin Chavez, P.E., OSE district engineer in Las Cruces, the SMWRC alleges that the City has caused all the creek systems below the city's collection points to dry up for a period of at least six months during each year and that the city is currently proposing to divert winter flows into an injection well for storage purposes. The letter further alleges that 14 families that depend on a spring within a quarter mile of the lower Maruchi Springs collection point are nearly out of water. Other families in the vicinity have experienced well failures or weakening and some have had to re–drill or have water hauled in. The SMWRC letter contends that the public welfare and conservation provisions in New Mexico water law are the basis for asking the state to enjoin the City from further alleged violations of the law.

A public meeting was held on September 27, 2001 at the Otero County Commission chambers to discuss these issues. Mr. Chavez, along with other OSE representatives, were present and heard over twenty-five presentations made by members of the SMWRC and public.

In response to the above allegations by the SMWRC, Mr. Chavez explained the water rights process, and stated that the City of Alamogordo's water rights in the canyons had been reviewed and were in accordance with the statutes.

The proposed alternative described in Section 8.2 of this report relating to a diversion in the Tularosa River and an off-site reservoir for additional water storage and recreation has caused controversy in the past and continues to be controversial. In the mid 1950's the Tularosa Ditch Corporation, which holds the majority of water rights on the river, proposed a change of the current diversion, near the Village of Tularosa, to a point upstream where a significant quantity of the creek would be diverted into a pipeline and would serve the Village and Ditch needs. A study was completed by the state engineer but no action was taken at that time, due to lack of local interest and support.

In the early 1990's the proposal surfaced again with the addition of a small hydroelectric plant to provide some income and improve the feasibility of the project. A town hall meeting was held in 1993 to explain the project and gain public support. The concept received favorable support from the Village and Ditch Corporation, however, the Rosalio Lopez Ditch Group strongly opposed the project and under the threat of a lawsuit, the project was put on hold again. Since then, the Village and Ditch Corporation have attempted to secure funding for a feasibility study, but have been unsuccessful.

The proposal to utilize excess winter flows from the river will require a detailed study with several alternatives presented. Until this is done, the water planning committee cannot evaluate the alternative discussed in this section. We do support and encourage all users in the Tularosa area to work together to make the best use of the limited water supply provided by the Tularosa River.

6. WATER RESOURCES ASSESSMENT FOR THE PLANNING REGION

The planning region is composed of the Tularosa and Salt Basins (**Figure 1.1**). The Tularosa Basin is hydrologically a closed basin, where surface water runoff originates from the mountains around the perimeter of the basin, recharges the bedrock and basin-fill aquifers, and the remainder flows toward the basin center where it evaporates. The Sacramento Mountains form most of the eastern boundary of the Tularosa Basin Watershed, and has the greatest effect on surface water runoff and ground water recharge in the planning region. The Salt Basin encompasses the watershed area of the New Mexico portion of the Great Salt Basin, which extends several hundred miles into Texas.

The planning region is divided into 4 hydrogeologic areas (**Figure 6.1**), which include the following:

- Northern Tularosa Basin
- Western Tularosa Basin
- Eastern Tularosa Basin
- Salt Basin

The Northern Tularosa Basin includes portions of Lincoln and Sierra Counties north of Otero County. Carrizozo is the largest community in this area, and includes the smaller communities of Ancho, White Oaks, Nogal, and Claunch.

The areas of Western and Eastern Tularosa Basin are divided by the Jarilla Fault (**Figure 6.6**), a north-south trending subsurface structural feature that creates a bedrock high and separates the basin into two parts. The Eastern Tularosa Basin area contains the majority of the population for the planning region, and Alamogordo, the largest city. Most all of the Western Tularosa Basin area is managed by the military, including Holloman Air Force Base, White Sands Missile Range, and Fort Bliss Military Reservation.

The water in the Salt Basin originating in New Mexico flows toward Texas. The portion of the Salt Basin contained in New Mexico is also referred to as the Crow Flats area. The Crow

Flats portion of the basin drains into a series of alkali flats or playas to the south just above the state line (Bjorklund, 1957). The Salt Basin area is dominated by ranching and farming, and sparsely inhabited, with Timberon and Pinon as the only communities in the area. Irrigation with ground water has occurred in the Salt Basin along the New Mexico-Texas border, which is referred to as the Dell City irrigation area.

6.1 Historical Weather Data

6.1.1 Precipitation Monitoring Stations

Precipitation across the Tularosa Basin varies significantly seasonally, annually, and geographically, particularly with respect to altitude. Predominantly, precipitation occurs in showers a few miles wide. These showers often form above the mountains, and produce copious precipitation at higher altitudes. For example, the median annual rainfall at Cloudcroft since 1903 has been about 26 inches. As these showers drift across the Basin, they may occasionally produce brief torrents, but more typically yield only a trace or a few hundreds of an inch of moisture. This is reflected in the lower median rainfall amount recorded in Alamogordo (12 inches), which is less than half that occurring in the mountains surrounding the Basin. The average annual rainfall at Holloman AFB, a few miles more distant from the mountains, drops to 8.5 inches.

The source of moisture that produces these mountain showers stretch across the vast reaches of the tropical oceans. Winds spiral outward from the "Bermuda High", an essentially permanent feature over the Atlantic Ocean, carrying moisture-laden air westward across the Gulf of Mexico and Central America, and northward across Mexico, the Gulf of Mexico, Texas, and other states of the arid southwest. The moist air distilled by the sun from this oceanic source may arrive over the Tularosa Basin and the surrounding mountains from the southeast, south, or southwest. The amount of moisture that may be available to produce precipitation varies depending on features of the global circulation, which change from season to season and year to year resulting in more-or-less random fluctuations in precipitation across the Tularosa Basin. For example, there is no readily discernable indication in the available data that the amount of annual rainfall varies corresponding to the 'sunspot cycle' or any other known phenomenon, except possibly the El Niňo. Consequently, trends do not appear to be predictable in any useful manner.

The occurrence of showery type precipitation is dependent not only on availability of moist air, but also "atmospheric stability," which is governed by how the temperature of the air changes with altitude above the Basin and surrounding mountains, and by larger scale patterns of wind flow. In general, winds blowing upslope produce cooling and condensation of moisture into the clouds that subsequently yield rainfall above the mountains. Hence, precipitation tends to be more copious on windward slopes and above the mountains than over leeward slopes.

The geographic distribution of showers across the Basin and surrounding mountains is affected by the approach of upper atmospheric troughs and frontal systems moving across the region, causing the showers to occur in more organized patterns that may yield precipitation over the entire area.

It is important to note that showers produce rainfall over relatively small areas only a few miles across. Because of this, the amount of rainfall received at one location may be much greater (or less) than the amount of rainfall at another nearby location. As a result, the rainfall record at one location is not a reliable indicator of the rainfall received at other locations only a few miles away. That is, rainfall measurements provide only small-sample statistical information with respect to the amount of water available for use. Although during a given year any one measurement location may show substantially more or less rainfall than may have been received at other nearby locations, such random variations will "average out" over several years for nearby locations at the same altitude with comparable windward or leeward exposures to prevailing wind patterns.

Climatic data are available for only a few locations across the region. Cloudcroft, Alamogordo and Holloman AFB provide representative data for the mountainous areas that supply the bulk of the Basin's water supply, the mountain foothills and the interior of the Basin. Additional climatic data are available for the Main Post area of White Sands Missile Range, with periodic measurements at other temporary locations. **Table 6.1** is a list of the weather stations and summary of climatic data used for this study.

The annual average precipitation in the planning region typically increases with elevation (**Figure 6.2**), and ranges from 7 inches per year (in/yr) along the basin floor to over 25 in/yr on the upper elevations of the Sacramento Mountains. Precipitation records were obtained from Gabin and Lesperance (1977) and the National Oceanic Atmospheric Administration, (NOAA), copies are provided in **Appendix 6.1**.

Precipitation in form of snowpack creates runoff that is important for base flow in streams of the planning area. Many of the higher elevations (above 6,000 ft) receive snow that accumulates in the winter months when evaporation is low; this typically results in a surplus where precipitation exceeds evaporation. The annual average surplus, which is the addition of average monthly surplus precipitation that occurs January through December, is listed for each weather station in **Table 6.1**.

At lower elevations that lack snowpack accumulation (<6,000 ft), precipitation is more seasonal, with heavy rains occurring as thunderstorms during the spring and summer months in response to Monsoonal heating. This precipitation is not adequate to support crops and is therefore supplemented by local irrigation (Bjorklund, 1957).

The average annual rainfall in the Salt Basin is about 9 in/yr in the valley compared to more than 20 in/yr in the Guadalupe Mountains on the eastern edge (Bjorklund, 1957, Ashworth, 1995).

Table 6.1

List of Weather Stations in and Neighboring the Planning Region, and Summary of Weather Station Data

Station	Elevation, ft MSL	Years of Record	Mean Annual Precipitation, in./yr	Mean Annual Potential Evaporation, in./yr	Annual Average Surplus,* in./yr
Alamogordo	4,350		10.31	52.01	0.00
Alto	7,400	6	21.07	31.20	2.50
Ancho	6,115	60	13.34	34.95	0.81
Arabela	5,360	20	19.84	40.79	0.08
Capitan	6,350	54	15.47	32.53	0.62
Carrizozo	5,438	71	11.82	42.67	0.17
Cienega	3,800	8	7.31	53.95	0.00
Cloudcroft	8,827	65	26.16	26.69	5.42
Corona	6,645	67	15.06	35.10	0.69
Farnsworth Ranch	5,400	34	11.23	44.94	0.00
Fort Stanton	6,220	95	14.70	35.22	0.27
Gran Quivira	6,620	38	14.12	37.31	0.50
Mayhill R.S.	6,558	48	20.59	34.95	0.36
Meek	6,380	5	20.80	35.41	2.43
Mescalero	6,785	60	19.24	32.48	1.60
Mountain Park	6,780	52	18.35	32.26	1.66
Nogal (Loma Grande)	8,200	12	23.30	27.96	4.03
Ruidoso	6,838	34	21.43	29.74	2.52
Tularosa	4,443	64	9.67	51.40	0.00
White Oaks	6,310	8	17.95	38.54	2.07
White Sands National Monument	3,995	36	8.12	50.26	0.00

* average annual surplus equals the sum of the monthly average surplus, only for months where average precipitation exceeded calculated potential evaporation

6.1.2 Snowpack Monitoring Stations

The precipitation monitoring station at Cloudcroft, NM measures snowpack. This data is converted to “wet” water in inches.

Record of snowpack data for the Cloudcroft, NM station ranges from 1949 to 1973, then the record contains a 6 year data gap (1974 to 1979, inclusive) and a 2 year data gap (1947 and 1948) until re-established in 1980 to the present. The five-year running average annual snowpack indicates a substantial upward trend from around 50 inches during the mid-50’s to about 110 inches for the mid-80’s. The data then takes a dramatic 50 inch average drop (45%) from 1985 to the present time, implying a similar decline in ground water recharge. Refer to **Figure 6.3** for a graphical representation of the snowpack data. As recorded at the Cloudcroft Weather Station, the approximately 100 year average of snowfall has been 90 inches/year from 1948 to 2000, inclusive, the average has been 76.5 inches/year and the average since 1990 is 64.8 inches/year. The snowfall for 2001 through November is 54 inches, even though the precipitation (rainfall and snowfall) is slightly above the 100-year average.

6.1.3 Drought History

Historically, periods of drought have occurred, particularly the drought of 1953 through 1956. A longer-range perspective of historic period of drought in New Mexico is offered by the correlation of streamflow records with tree-ring data by Ackerly (1999). The work by Ackerly implies that we are currently facing lower average-annual precipitation than most of the twentieth century, and greater frequency, intensity, and duration of droughts.

The record of data for precipitation within the Tularosa Basin spans from 1890 to present. The monitoring station located in Cloudcroft, NM is likely the best indicator of the underground water supply for the Basin; as ground water recharge primarily occurs from mountain high precipitation occurring through snowpack. From 1903 to the present time, annual precipitation in Cloudcroft has varied from a low of 11 inches (1970) to a high of 48 inches (1941). The average for the record over a 90-year time period is about 26 in/yr.

Trends in average annual precipitation for Cloudcroft do not imply the region is currently in a drought, although analysis of the 5-year moving average of cumulative annual snowfall data from Cloudcroft (**Figure 6.3**) shows two drought cycles, one in the 1950's and the other starting in 1990 to current time. The drought periods appear to result in one half of the five-year moving average accumulated snowfall of 80 inches.

The Alamogordo monitoring station correlates well with the Cloudcroft data. The average precipitation is about 12 inches/year. The precipitation has varied as low as 4.85 inches (1952) to 21.87 inches (1941). The precipitation in Alamogordo is about half that of Cloudcroft. Over about the last decade or so the average precipitation in Alamogordo has also decreased by more than 30% to as much as 50%. Refer to **Appendix 6.1** for the Cloudcroft and Alamogordo monitoring station graphical data, and low yield analysis.

6.2 Water Supply

6.2.1 Surface Water

6.2.1.1 Drainage Basins and Watersheds

Surface water in the planning region occurs as seasonal and year-round runoff, and springs. Major drainages and watersheds in the planning area are shown on **Figure 6.1**. No natural or manmade lakes or reservoirs are in the planning region, with the exception of an impoundment on the Sacramento River (Sacramento Lake), which is essentially a manmade berm that has created a marsh; not well maintained for surface-water storage. Water is piped from the Sacramento River to Orogrande. Bonito Lake, located east and outside of the planning region in the Sacramento Mountains, provides water to communities located along the Bonito pipeline (Nogal, Carrizozo, Alamogordo and Holloman Air Force Base). Most of the available surface water in the planning region has been appropriated for use with the exception of surface water in Rinconada Canyon and Sacramento River. Surface water from Three Rivers, Rio Tularosa, La Luz-Fresnal Canyon, Alamo Canyon, and Sacramento River is diverted for irrigation, domestic, and municipal use.

The USGS study (Waltemeyer, 2001) primarily evaluated watersheds that drain into the basin-fill sediments, and not the bedrock aquifer that occupies much of the northern area, therefore estimates of watershed yield using the "surplus-precipitation" method were made for areas not covered by Waltemeyer (2001). Surplus precipitation is that portion of the precipitation remaining after evaporation losses.

As part of developing this water plan, a detailed analysis of each watershed in the planning region (with the exception of the watershed in the San Andres Mountains of the Western Tularosa Basin area) was performed using the method of "surplus precipitation." The value of watershed yield equals the recharge and runoff combined, and can be considered a maximum estimate of potential surface water and recharge for the area.

Surface-water yields calculated from using the "surplus precipitation" method, indicates surplus will occur in the winter months when the potential evaporation is low. However, short-term surplus occurs as runoff resulting from thunderstorms during the summer months. Storm water runoff typically flows to the basin center without watershed infiltration or capture, and evaporates or recharges non-potable (saline) aquifers. Recharge of non-potable (saline) aquifers and the temporary formation of playa lakes from storm water runoff temporarily offsets evaporation of ground water in the basin center.

The analysis of watershed yield was performed by evaluating monthly precipitation and potential evaporation data (see 6.2.2.3) collected from weather stations in the region (**Table 6.1**), to determine the relationship between elevation and annual surplus precipitation. The surplus precipitation was determined for each elevation interval in the watershed, and multiplied by the land area to obtain yield (the sum of recharge and runoff). The sum of the yields for each elevation interval equals the watershed yield. The correlation between elevation and surplus precipitation shows that surplus precipitation does not occur below an elevation of 5,860 ft, because all of the precipitation is lost to evaporation, plant transpiration and interception.

The relationship between surplus precipitation and elevation is as follows:

Surplus precipitation (inches per year) = (land surface elevation - 5,860 ft)/490

In other words, a watershed at elevation 6,350 ft. MSL would have 1-inch/yr. of surplus precipitation

Monthly climatic data used to develop the formula for calculating surplus precipitation can be referenced from **Appendix 6.1**. Estimates of yield for each major watershed in each of the planning area sub-regions are provided in **Tables 6.2** through **6.5**. The total estimated watershed yield for the Tularosa Basin is approximately 132,000 AFY, and the total estimated watershed yield for the Salt Basin is approximately 35,000 AFY.

Drainage basins and watersheds in the planning region typically encompass portions of the mountain ranges, such as the Gallinas, Oscura, San Andres, Sacramento, Organ, and Guadalupe Mountains (**Figure 6.1**). The largest watersheds emanate from the Sacramento Mountains in the Eastern Tularosa Basin area. Summary tables of watersheds and watershed data for each of the sub-areas in the planning region are provided as **Tables 6.2** through **6.5**.

Northern Tularosa Basin

Watersheds in the Northern Tularosa Basin originate from high mesas in the northwestern corner of the area, the Gallinas Mountains in the extreme north, the Oscura Mountains to the west, and the Jicarilla, Patos, and Sierra Blanca Mountains to the east. A list of the watersheds evaluated for this study can be referenced from **Table 6.2**. Most of the watersheds in the Northern Tularosa Basin have a mean elevation greater than 6,500 ft, and average annual precipitation greater than 18 inches per year. Most of the Northern Tularosa Basin area has permeable bedrock exposed at the surface increasing the probability of direct recharge. Meinzer and Hare (1915) noted surface water runoff seeping into sinkholes near Gran Quivira.

Table 6.2

Major Watersheds in the Northern Tularosa Basin, and Summary of Watershed Data and Estimated Yield

Watershed Name	Map ID[2]	Mean Annual Precip, in/yr.	Mean Elevation, ft	Area, mi^2	USGS[1] Estimated Mean Annual Streamflow, AFY	JSAI Estimated Watershed Yield, AFY
Northern Basin						
Oscura Mountains	1	21.3	7,500	14.4	See N3	1,952
Turkey Ridge	2	17.2	6,500	33.5	See Red and Wagon Canyon	2,331
Chupadera Mesa	3	17.2	6,500	59.6	na	4,152
Pajaro & Pinatosa Canyons	4	19.5	7,000	67.7	na	6,860
Largo Canyon	5	18.0	6,600	74.5	na	6,028
Ancho Canyon	6	18.7	6,800	18.7	na	1,730
Pine Canyon	7	18.3	6,700	10.1	na	1,000
Coyote Canyon	8	18.0	6,600	24.0	na	2,066
Lone Mountain	9	20.5	7,070		na	
White Oaks Watershed	10	21.0	7,250	26.3	na	3,315
West Carrizo Mountain	11	22.8	7,800	11.3	na	1,292
Benado Canyon	12	22.5	7,622	16.6	na	2,417
Nogal Canyon	13	18.3	6,750	29.8	na	3,874
Tortolita Canyon	14	21.0	7,300	11.3	na	2,037
Diamond Peak to Godfrey Peak	15,16	21.3	7,500	50.4	na	5,788
USGS basins 1 through 8	15, 16	23.8	na	19.6	649	
N3 (44)	1	15.6	5,125	73.8	3,815	
Red Canyon N2 (45)	2	14.3	5,796	55.6	2,251	
Wagon Canyon N1 (46)	2	13.0	5,400	120.0	5,401	
Northern Basin Total					12,116[3]	44,842

[1] Waltemeyer (2001)
[2] watershed map ID on **Figure 1**
na not available
[3] John Shomaker and Associates, Inc. est. 14,842 AFY and used throughout this Plan

The recharge in the Nogal Arroyo area east of Carrizozo in the Northern Tularosa Basin area has been estimated at 3,000 AFY by Rao (1986). Rao (1986) used Darcy's Law calculations to derive the recharge for this area, but the analysis was performed with limited aquifer data and conservative assumptions were made. Revising Rao's analysis with new aquifer test data from the Nogal arroyo area resulted in a recharge of 5,400 AFY for the shallow aquifer along Nogal Arroyo. The estimated watershed yield for the three watersheds that drain into Nogal Arroyo (Benado, Nogal, and Tortolita Canyons) equals 8,328 AFY (**Table 6.2**). Comparing the Nogal Arroyo recharge (5,400 AFY) to the watershed yield (8,328 AFY) indicates that approximately 65 to 70 percent of the watershed yield becomes recharge. Therefore, using this same percentage, the total recharge to the Northern Tularosa Basin area is approximately 30,000 AFY (65% of 44,842 AFY) and the remaining watershed yield of 14,842 ac-ft/yr is assumed to occur as streamflow (44,842 AFY - 30,000 AFY) which compares closely with the 12,116 AFY estimated by the USGS.

Western Tularosa Basin

Watersheds in the Western Tularosa Basin originate from the San Andres Mountains. These watersheds are typically small in area, steep, and terminate abruptly at the base of the mountains. Annual average precipitation ranges approximately 11 to 16 inches per year for the watersheds in the Western Tularosa Basin area. **Table 6.3** lists the major watersheds in the Western Tularosa Basin area, and summarizes results from Waltemeyer (2001).

Waltemeyer (2001) provides a good analysis of the mean annual streamflow for watersheds in the Western Tularosa Basin area. No independent estimates of watershed yield in the Western Tularosa Basin were performed as part of this study because it was assumed that the estimated mean annual streamflow for this area (9,291 AFY) is equal to the watershed yield, due to the small, steep watersheds. Most of the watershed yield likely becomes recharge at the mountain front.

Table 6.3

Major Watersheds in the Western Tularosa Basin, and Summary of Watershed Data and Estimated Yield					
Watershed Name	**Map ID[1]**	**Mean Annual Precip, in/yr.**	**Mean Elevation, ft**	**Area, mi^2**	**USGS[1] Estimated Mean Annual Streamflow, AFY**
Western Basin					
Oak Canyon (24)		14.85	5,716.73	8.94	203
Soledad Canyon (25)		15.88	6,335.22	15.56	485
Soto Creek (26)		14.32	5,645.93	13.07	319
unnamed (27)		11.91	4,898.37	12.15	217
Bear Canyon (28)		11.80	5,740.51	15.38	290
Little San Nicolas Canyon (29)		12.00	6,154.62	7.35	109
Ash Canyon (30)		13.81	6,352.00	7.60	145
San Andres Canyon (31)		15.63	5,845.00	8.90	217
Mayberry Canyon (32)		15.49	5,695.00	11.53	304
Deadman Canyon (33)		14.33	5,576.00	16.07	427
Lost Man Canyon (34)		12.88	5,954.00	10.18	188
Hembrillo Canyon (35)		12.00	5,669.00	17.17	348
Grandview Canyon (36)		12.00	5,928.00	2.82	29
Sulfur Canyon (37)		12.04	5,770.00	30.29	746
Ash Canyon (38)		12.08	6,352.00	4.30	51
Workman Canyon (39)		12.66	6,141.00	5.99	94
Cottonwood Canyon (40)		13.73	5,791.00	45.29	1,600
Rhoades Canyon (41)		14.57	6,185.00	39.73	1,477
Good Fortune Canyon (42)		15.34	6,227.97	24.02	811
Thurgood Canyon (43)		13.80	5,588.74	37.21	1,231
Western Basin Total					9,291

[1] refer to Waltemeyer (2001) for location of watersheds

Eastern Tularosa Basin

Watersheds in the planning region originating from the Sacramento Mountains in the Eastern Tularosa Basin are listed in **Table 6.4**, along with summaries of watershed data and estimated watershed yield. The watershed yield in the Eastern Tularosa Basin decreases to the south as a result of decrease in mean elevation and total area of the watersheds. Annual average precipitation for these watersheds ranges from 14 to over 20 in/yr.

Recharge to the Eastern Tularosa Basin area (basin fill) was estimated at 14,500 AFY by Morrison (1989). Morrison's estimate was based on the streamflow remaining after diversion that infiltrated at the mountain front. This is a conservative estimate because it does not account for bedrock recharge and/or recharge from the bedrock aquifer into the basin fill as underflow.

Listed in **Table 6.4** is a comparison of estimated watershed yield and estimated or measured base flow for streams in the Eastern Tularosa Basin. Total watershed yield for the Eastern Tularosa Basin is estimated at 77,619 AFY, and total streamflow is estimated at 47,099 AFY. This indicates approximately 60 percent of the watershed yield in the Eastern Tularosa Basin area becomes streamflow (**Table 6.6**). The difference between watershed yield and streamflow (30,520 AFY) may be considered as recharge to the bedrock aquifer to the watershed area above the mountain front.

Table 6.4

Major Watersheds in the Eastern Tularosa Basin, and Summary of Watershed Data and Estimated Yield

Watershed Name	Map ID[2]	Mean Annual Precip, in/yr	Mean Elevation, ft	Watershed area, mi^2	USGS[1] Estimated Mean Annual Streamflow, AFY	JSAI Estimated Watershed Yield, AFY
Eastern Basin						
Three Rivers at Three R.	17	22.0	6,568	86.5	8,326	9,097
Boone and Salinas Draws	18	21.0	7,300	32.7	na	1,261
Rinconada Canyon	19	21.2	6,840	97.5	9,194	10,897
Tularosa Canyon at Tularosa	20	21.2	7,280	157.0	17,520	25,237
Domingo & Rancheria Canyons	21	17.1	6,410	34.4	na	1,249
Cottonwood Wash	22	18.3	6,750	15.4	na	2,149
La Luz Canyon	23	21.1	7,464	65.2	5,285	10,906
Dry Canyon	24	19.4	7,093	9.0	318	1,276
Beeman Canyon	25	15.3	5,930	2.0	na	87
Watershed between Beeman and Marble Canyons	26	15.5	6,015	4.5	na	175
Marble Canyon	27	17.1	6,237	3.5	72	232
Alamo Canyon	28	21.0	7,146	24.9	1,433	3,462
Mule Canyon	29	16.2	6,207	6.7	159	984
San Andres Canyon	30	21.7	7,467	14.8	746	2,532
Dog Canyon	31	20.8	7,392	10.5	442	1,679
Mountain front between Dog and Escondido Canyons	32	16.8	6,327	2.6	na	173
Escondido Canyon	33	19.9	7,083	11.0	434	1,448
Mountain front between Escondido and Bug Scuffle	34	15.5	6,090	8.6	na	585
Bug Scuffle Canyon	35	19.5	6,730	12.3	492	1,190
Grapevine Canyon	36	19.4	6,415	33.5	1,875	2,293
Pipeline Canyon		14.3	5,353	6.1	116	0
Culp Canyon	37	14.3	5,765	23.2	687	707
Eastern Basin total					**47,099**	**77,619**

1 Waltemeyer (2001)
2 watershed map ID on **Figure 6.1**
na not available

Salt Basin

The Salt Basin is a large internally drained basin covering 6,400 square miles, of which 2,400 square miles are in New Mexico and the remaining approximately 4,000 square miles are located just across the state line in Texas (Bjorklund, 1957). Major watersheds within the New Mexico portion of the Salt Basin area include the Sacramento River, Pinon Creek, and Shiloh Draw (**Table 6.5**). The Sacramento River watershed drains the southern end of the Sacramento Mountains, where elevations of the upper watershed range from 8,000 ft to 9,500 ft in elevation. Annual average precipitation in this area exceeds 24 inches per year.

Total watershed yield calculated for the Salt Basin (New Mexico portion) area is 35,078 AFY (**Table 6.5**), with approximately one-half originating from the Sacramento River. Due to the rock type (solutioned limestone), most all of the 35,078 AFY infiltrates into the ground water system and can be considered as recharge. Meyer (1995) estimated an average annual rate of recharge at 46,897 AFY for the Salt Basin, which includes part of the Diablo Plateau in Texas.

Table 6.5

Major Watersheds in the Salt Basin, and Summary of Watershed Data and Estimated Yield

Name	Mean Annual Precip, in/yr	Mean Elevation, Ft MSL	Area, mi^2	JSAI Estimated Watershed Yield, AFY
Sacramento River	22.8	7,795	135	17,580
Pinon Creek	20.0	7,100	99	8,872
Small un-named watersheds and mountain front	17.2	6,500	124	8,626
Salt Basin Total				35,078

Small un-named watersheds and mountain front areas that potentially yield surface water include portions of Otero Mesa south of the Sacramento Mountains and the Guadalupe Mountains along the eastern margin of the Salt Basin in New Mexico.

The following **Table 6.6** summarizes the recharge in the Tularosa and Salt Basins.

Table 6.6

Estimated average annual recharge for the Tularosa Basin and Salt Basin prior to development	
Component	**Quantity (AFY)**
Estimated recharge to Northern Tularosa Basin area	30,000
Estimated recharge to Western Tularosa Basin area	9,291
Estimated recharge to Eastern Tularosa Basin area	47,099
Total estimated recharge to Tularosa Basin	**86,390**
Total estimated recharge to Salt Basin	**35,078**

6.2.2 Surface Water Sources

Most of the available surface water in the study area has been appropriated for use, except for that part of flood flows which cannot be diverted and thus reaches the basin floor where almost all of it evaporates. Only the large drainage areas on the western slope of the Sacramento Mountains contain streams with any appreciable base flow, derived largely from snowmelt. A small part of the total runoff recharges the alluvial-fill aquifer in the basin through the coarse material at the base of the mountains.

Rio Tularosa

The largest and most important stream in the area is Rio Tularosa. The headwaters of the river originate as spring flow which is derived largely from snowmelt and which appears in the head canyons and tributaries on the Mescalero Apache Indian Reservation in the northern Sacramento Mountains. The large tributaries of the river have springs, but the small tributaries normally contribute only floodflow. The spring flow contributions are a large part of the total flow.

In 1861, immigrants settled along the river about 15 miles upstream from the present community of Tularosa, and in 1862 Tularosa itself was settled (Meinzer and Hare, 1915). Indian hostilities prevented more extensive agricultural development, but after cessation of hostilities towards the end of the century, irrigation along the river increased. By 1905, more than 2,000 acres were being irrigated, about half of which was near Tularosa (Meinzer and Hare, 1915).

In 1909 the waters of Rio Tularosa were adjudicated (Sorensen and Borton, 1967) so that Indians and non-Indian users along the river near Bent would be entitled to domestic and stock water from the river flow at specified times during the irrigation season. The remaining flow was for the benefit of the village of Tularosa and the Tularosa Community Ditch Corp. In 1958 the Armour Research Foundation reported that more than 700 acres of water rights, presumably for irrigation were held by Indians and non-Indian users near Bent; by 1968, the irrigated acreage reported in this area was less than 500 acres. The decrease apparently due to the transfer of some of this land to cabin and housing developments. An additional 400 acres were being irrigated between Tularosa and Bent. Water rights of village of Tularosa were reported by the New Mexico State Engineer (1957) to be 492 acre-feet per year. The Tularosa Community Ditch Corp. had distributed the remaining water for the purpose of irrigating 1,100 acres among shares that ranged from 157 in 1909 to 656 in 1968.

In 1955, the Tularosa Community Ditch Corp. filed an application (under the United States small projects legislation) with the Interstate Stream Commission of New Mexico for construction of a reservoir on Rio Tularosa. The result was a feasibility study by the New Mexico State Engineer (1957) which proposed an off-stream reservoir (4,585 acre-feet storage) in Takalota Canyon, about 4 miles northeast of Tularosa, and a diversion dam on the Rio Tularosa about 5.5 miles upstream from Tularosa. The study called for enough water to irrigate 2,200 acres and 882 to 1,512 acre-feet of water for municipal and industrial purposes on a sliding-scale basis. The total cost of the project at 1957 prices was over $1 million, and the benefit-cost ratio on a 50-year repayment period was 1.27. The project was not acceptable to the local interests, however, and construction did not begin.

Discharge records dating from 1932 for Rio Tularosa were obtained from continuous streamflow-discharge stations of the U.S. Geological Survey. Records for 1932-47 were obtained from the station "Rio Tularosa near Tularosa," 3 miles upstream from Tularosa with a drainage area of 136 square miles (**Figure 6.4**). Records since 1947 were obtained from the station "Rio Tularosa near Bent," 8.5 miles upstream from Tularosa with a drainage area of 120 square miles. **Appendix 6** contains the annual discharges and the estimated base and flood flows at the two stations for their respective periods of record. The streamflow-discharge data for 1932-68 were taken from U.S. Geological Survey publications (U.S. Geological Survey, 1933-61; 1961-64; 1965-68).

The average total annual discharge during 1932-47 at the station near Tularosa was approximately 10,500 acre-feet per year, and that during 1948-68 at the station near Bent was approximately 7,000 acre-feet per year. Assuming that unit runoff and ground water discharge from the small drainage area (16 square miles) between the two stations were the same as above Bent, this small drainage area would yield 1,000 acre-feet per year. If the average annual consumptive use from diversions above Bent for 1948-68 was about 1,000 acre-feet per year, the computed average total annual discharge and the computed average annual base flow during 1948-68 at the station near Tularosa would have been respectively 9,000 and 7,600 acre-feet per year, if the 1,000 acre-feet per year had not been diverted.

If diversions during 1932-47 were approximately 1,000 acre-feet per year, and if these diversions had not occurred, the average total annual discharge at the station near Tularosa would have been 11,500 acre feet per year for this period. The average total annual runoff for the earlier period was approximately 2,500 acre-feet per year greater than the 1948-68 period. This difference was probably caused by a combination of climatic and water-use conditions.

The chemical quality of water in the Rio Tularosa varies with the quantity of flow, the season of the year, and the reach of the river. The best quality water generally occurs at the head-springs area and becomes more mineralized downstream as it receives water from areas underlain by calcareous and gypsiferous material. During the feasibility study on the Tularosa project by the New Mexico State Engineer (1957), water samples of various reaches of the river were collected and analyzed by the U.S. Geological Survey. Dissolved solids ranged from 585 mg/L (milligrams per liter) at the head springs to 1,230 mg/L at the streamflow station near Bent; sulfate content ranged from 128 to 220 mg/L at the two sites. Monthly samples taken at the station near Bent since May 1963 (U.S. Geological Survey, 1964, 1965-67) have shown that the chemical quality generally deteriorates as flow decreases. The quantity and geographic origin of direct runoff or flood flow may also be important.

Alamo Canyon

Other streams of importance in the area are Alamo Creek in Alamo Canyon and La Luz Creek in La Luz Canyon (**Figure 6.5**). Alamo Canyon, which has a drainage area of 25 square miles, debouches from the Sacramento Mountains into the lowlands of the Tularosa

Basin about 3 miles southeast of Alamogordo. When the city was founded in 1898 its original water supply was brought by pipeline from Alamo Creek. Partial discharge records during 1931-37 were obtained at the streamflow station “Alamo Creek near Wood Ranch"”(Sec. 4, T.17 S., R.11 E.) where annual discharge varied from 711 acre-feet (1935) to 1,856 acre-feet (1932). The chemical quality of the water is generally good; it commonly contains about 500 mg/L dissolved solids and about 130 mg/L sulfate. The water rights of Alamo Creek are owned by the city of Alamogordo. The city has extended its pipeline upstream to utilize springs in Alamo Canyon and its tributaries.

La Luz Creek

La Luz Creek is a perennial stream fed by springs along La Luz and Fresnal Canyons and their tributaries. The drainage area of La Luz Creek above the community of La Luz is about 75 square miles. La Luz, located 6 miles north of Alamogordo, was established in 1864, and later the communities of Mountain Park and High Rolls were established upstream along Fresnal Canyon. In 1911, approximately 500 acres of alfalfa and fruit were irrigated with water from the stream (Meinzer and Hare, 1915). By 1969, the irrigated acreage totaled about 700 acres, including some irrigation in Laborcita Canyon north of La Luz Creek. At one time all water rights of La Luz Creek were owned by the La Luz Community Ditch Corp. and irrigators along La Luz Creek; most of the rights are now owned by the city of Alamogordo. The chemical quality of La Luz Creek water deteriorates downstream from the head springs. Armour Research Institute reports a range in dissolved-solids content from 672 mg/L at a spring in Fresnal Canyon to 1,700 mg/L near the La Luz railway station; the sulfate content ranged from 112 to 799 mg/L at these same locations.

Bonito Lake

Surface water from outside the Tularosa Basin is piped in from Bonito Lake on the east side of Sierra Blanca mainly for use by the city of Alamogordo and Holloman Air Force Base. In 1955, the New Mexico State Engineer permitted changes in the purpose and place of use of part of the Rio Bonito water so that most of it could be used by Alamogordo and Holloman Air Force Base. Water from Bonito Lake, superior in chemical quality to water available locally, is mixed with water from local sources at Alamogordo to increase the quantity and improve the quality of the local supply. Additionally, Ft. Stanton, Nogal and Carrizozo hold rights to Bonito Lake water.

6.2.2.2 Stream Flow Data

There are only a few perennial streams in the Tularosa Basin; Salt Creek in the northwestern portion of the basin as well as Three Rivers, Tularosa, La Luz and Alamo Canyons on the eastern side of the basin (Hood, 1958).

Limited stream-flow data are available for the planning region. Detailed records have been kept for the Tularosa Creek, La Luz Creek, and Alamo Canyon, all of these streams are located in the Eastern Tularosa Basin area. Major drainages having ephemeral stream flow, but no records include Temporal Creek (Rinconada Canyon in Eastern Tularosa Basin), Pinon Creek (Salt Basin area) and Indian Creek (in Three Rivers).

The U. S. Geological Survey has measured daily base flow and peak flow for Tularosa Creek at Bent and near Tularosa, and for La Luz Creek. Peak flow for Three Rivers was measured by USGS from 1955 to 1977. Graphs of U.S. Geological Survey stream-flow data are provided in **Appendix 6.2**, and a summary of available surface-water data is presented as **Table 6.7.**

Table 6.7

Summary of Available Surface Water Data in the Planning Region			
Station Name	**Period of Record**	**Annual Mean Streamflow, ac-ft/yr**	**Reference**
Three Rivers near Three Rivers, NM	1956-58	na	USGS database
Indian Creek near Three Rivers, NM	1956-58	na	USGS database
Rio Tularosa at Mescalero, NM	1910-11	na	USGS database
Tularosa Rio near Bent, NM	1948-95	9,495	USGS database
Rio Tularosa near Tularosa, NM	1939-46	11,091	USGS database
Rio La Luz near La Luz, NM	1911-12	8,536	USGS database
Rio La Luz at La Luz, NM	1910-13; 1982-89	8,694	USGS database
Rio Fresnal near Mountain Park, NM	1911-12	1,050	USGS database
Alamo Creek at Woods Ranch, near Alamogordo, NM	1933-50	1,283	USGS database
Salt Creek	1996-99	580	USGS database
Sacramento River near Sunspot, NM	1984-89	2,173	USGS database

Salt Creek watershed includes the mountains along the northwestern part of Tularosa Basin, and discharges to the salt flats in the basin center. Peak flow in Salt Creek occurs during the summer months, and has been measured as high as 70 CFS. Base flow in Salt Creek has averaged 0.8 CFS (580 ac-ft/yr) over the last several years.

Surface-water flow in Three Rivers dramatically varies seasonally and from single rainstorm events. There are no data on base flow for Three Rivers, but a peak flow greater than 4,000 cubic feet per second (CFS) occurred approximately every three years between 1955 and 1970.

Tularosa Creek has an average base flow of approximately 13 CFS (9,495 AFY), with an average peak flow of 750 CFS that occurs approximately three times per year.

Additional data on surface water and spring diversions from La Luz Creek were obtained from the City of Alamogordo files and an aquifer storage and recovery analysis prepared by Livingston Associates and JSAI (1996). In 1995, the City of Alamogordo collected 4,431 ac-ft from spring boxes in the La Luz and Fresnal Canyons, and 1,365 ac-ft from spring boxes in Alamo Canyon. The USGS gauged daily base flow in La Luz Creek from 1982 to 1990, which resulted in an average daily baseflow of 12 CFS or 8,694 AFY.

The monthly spring flows from La Luz Creek and Alamo Canyon vary, and are generally greater in the fall to spring months. In wet years, rainfall and snowpack runoff can be a substantial contributor to the amount of stream flow available for diversion by the spring systems.

The Sacramento River was gauged from 1984 to 1989, at a location in the upper part of the watershed. Daily mean streamflow for the Sacramento River ranged from 2 to 13 CFS between 1984 and 1989. Streamflow in the Sacramento River is related to runoff from snowmelt, and does not show peak flow during the summer monsoon season typical of streams in the lower elevations of the Tularosa Basin.

The U.S. Geological Survey (Waltemeyer, 2001) performed an analysis of selected watersheds in the Tularosa Basin, and estimated mean annual streamflow using basin-climatic characteristics. The purpose of estimating streamflow was to determine the amount of surface water from watersheds in the planning region that could potentially recharge the alluvial aquifer (basin fill) at the mountain front. The USGS method did not consider potential direct recharge in watersheds that supplies the bedrock aquifer in the mountains and highlands.

Total mean annual streamflow for the Northern Tularosa Basin area is estimated (by USGS) to be 12,116 AFY. Total mean annual streamflow for the Eastern Tularosa Basin area is estimated to be 47,099 AFY and total mean annual streamflow for the Western Tularosa Basin area is estimated at 9,291 AFY (See **Tables 6.2, 6.3** and **6.4**). Mean annual streamflow for the Salt Basin was not estimated by the USGS.

Discharges from springs play a significant role in surface water flow in the planning region. A list of all springs in the planning region, inventoried by the USGS, can be found in **Appendix 6.2**.

6.2.2.3 Evaporation Data

Calculated potential evaporation was used in this plan as estimates of evaporation for the water budget. Potential evaporation accounts for water evaporated from the soil, water consumed by plants (evapotranspiration), and precipitation intercepted by plants. Estimates of potential evaporation were obtained from Gabin and Lesperance (1977). In the arid southwest, potential evaporation is best estimated by the procedure developed by Blaney and Criddle (1962), which requires input variables for mean temperature, a climatic coefficient related to the mean temperature, the percent daylight for a particular latitude, and a monthly constant coefficient which reflects the growth stage of alfalfa. The Blaney and Criddle method provides a high estimate of potential evaporation that can be considered conservative for estimating surplus precipitation.

Potential evaporation in the Tularosa Basin ranges from 26 to over 50 inches per year (**Table 6.1**). During the winter months, the potential evaporation at altitudes greater than about 5,860 ft is generally less than precipitation. The evaporation rate in the lower elevations of the Salt Basin area is nine times the precipitation rate. Evaporation in the Salt Flats is highest during the summer months when it averages about 80 inches per year (Ashworth, 1995).

Most all of the surface water and ground water naturally discharges by evaporation in the Alkali Flats and playa lakes in the middle of Tularosa Basin, primarily on the Western side. The total area for the Alkali Flats and playa lakes is approximately 320 square miles. Approximately 60 square miles of the Alkali Flats and playa lakes have a depth-to-ground water less than 20 ft, and may be considered suitable area for evaporation of ground water. Assuming an evaporation rate of 50 inches per year and 60 square miles of land surface that evaporates ground water, the rate of discharge from the center of Tularosa Basin is approximately 160,000 AFY. This rate varies with water table fluctuations at the playa lakes.

6.2.2.4 Storage Reservoirs

The only storage reservoir associated with the Tularosa Basin is Bonito Lake.

Bonito Lake is located approximately 15 miles northwest of Ruidoso, NM within the Lower Pecos Drainage Basin. The lake is owned and operated by the City of Alamogordo as a municipal water supply for Alamogordo, Holloman AFB, Carrizozo, Nogal and Ft. Stanton. Although the Lake is not physically within the Tularosa Basin, a 90-mile long pipeline carries Bonito lake water to Alamogordo and HAFB.

The Lake has a surface area of approximately 100 acres (US Bureau of Reclamation, 1989) with a maximum depth of about 75 feet. The lake was constructed in 1931 and drains a watershed of more than 21,000 acres. Bonito Lake spillway is at an elevation of approximately 7,400 ft. (MSL).

Water quality in the Lake is good, with a total-dissolved-solids (TDS) level of approximately 300 mg/L. The high water quality is due to the volcanic nature of the watershed, where minerals are not easily dissolved. The Bonito Lake drainage is underlain by volcanic rocks cut by numerous stocks, dikes and sills. Rock types are generally acidic and include andesite, latite, trachyte, monzonite, syentite and diorite. Mineralized veins consist of simple fissure fillings of calcite, dolomite and quartz. Gold is the major metal of mining interest, but some silver, zinc and copper have also been produced.

Dissolved solids entering Bonito Lake should be typical of those resulting from weathering of granitic rocks. Some minor contribution should be expected from the mineralized vein system. Some minor contribution from old mining and milling activities is also probable.

Water quality for Bonito Lake is given in **Table 6.9**.

6.3 Surface Water Quality

6.3.1 Water Quality Standards

Table 6.8

Water Quality Standards				
Parameter	**Unit**	**WQCC**	**Unit**	**NMED**
Primary				
Arsenic (As)	mg/L	0.1	mg/L - MCL	0.05
Barium (Ba)	mg/L	1.0	mg/L - MCL	1.0
Cadmium (Cd)	mg/L	0.01	mg/L - MCL	0.010
Chromium (Cr)	mg/L	0.05	mg/L - MCL	0.05
Cyanide (CN)	mg/L	0.2		
Fluoride (F)	mg/L	1.6	mg/L, dependent	1.4 to 2.4
			upon temperature - MCL	
Lead (Pb)	mg/L	0.05	mg/L - MCL	0.05
Total Mercury (Hg)	mg/L	0.002	mg/L - MCL	0.002
Nitrate (NO_3 as N)	mg/L	10.00	mg/L - MCL	10.00
Selenium (Se)	mg/L	0.05	mg/L - MCL	0.01
Silver (Ag)	mg/L	0.05	mg/L - MCL	0.05
Uranium (U)	mg/L	5.00		
Radioactivity:				
Gross Alpha Activity			pCi/l - MCL	15.0
Combined Radium - 226 and Radium - 228	pCi/l	30.0	pCi/l combined - MCL	5.0
Gross Beta Activity			pCi/l - MCL	50.0
Benzene	mg/L	0.01		
polychlorinated biphenyls (PCB's)	mg/L	0.001		
Toluene	mg/L	15.0		
Carbon Tetrachloride	mg/L	0.01		
1, 2 -dichloroethane (EDC)	mg/L	0.02		
1, 1 -dichloroethylene (1, 1 -DCE)	mg/L	0.005		
1, 1, 2, 2 -terachloroethylene (PCE)	mg/L	0.02		
1, 1, 2 -trichloroethylene (TCE)	mg/L	0.1		
Secondary				
Alkalinity			mg/L	30.00 - 500.00
Bicarbonate			mg/L	700.0
Calcium			mg/L	75.0 - 200.0
Carbonate			mg/L	350.0
Chloride (Cl)	mg/L	250.0	mg/L	250.0
Color			units	15.0
Conductance			micromhos	1000.0
Foaming Agents			mg/L	0.5
Hardness			mg/L	250.0
Copper (Cu)	mg/L	1.0	mg/L	
Iron (Fe)	mg/L	1.0	mg/L	0.3
Magnesium			mg/L	125.0

Parameter	Unit	WQCC	Unit	NMED
Manganese (Mn)	mg/L	0.2	mg/L	0.05
Odor			threshold odor number	3.0
Phenols	mg/L	0.005	mg/L	
Sulfate (SO_4)	mg/L	600.0	mg/L	250.0
Total Dissolved Solids (TDS)	mg/L	1000.0	mg/L	
Zinc (Zn)	mg/L	10.0	mg/L	
pH	mol/l	between 6 and 9	mol/l	6.5 - 8.5
Potassium			mg/L	1000.0
Sodium			mg/L	200.0
Total Filterable Residue			mg/L	500.0
Turbidity			T.U.	1.0 - 5.0

6.3.2 Quality of Surface Water Sources

The following **Table 6.9** summarizes the water quality of the surface water sources in the Tularosa and Salt Basins:

Table 6.9

Surface Water Quality in the Tularosa and Salt Basins						
Parameter	Bonito Lake	Three Rivers	Tulie Creek	La Luz/ Fresnal*	Alamo Canyon*	Sacramento River
Sample date		5/85	5/85	3/99		5/85
e-cond.		874	1,664	1,200	1,505	427
TDS	298	678	1,418	830	1,005	296
PH	8.0	8.0	8.0	8.3	7.5	8.0
Calcium	46	122	130	160	194	77
Magnesium	14	21	108	34	73	7
Sodium	12	48	58	76	25	0.5
Potassium	1.0	1.6	1.7	<5.0	0.4	0.8
Barium	0.01				0.05	
Iron	0.82	0.05	0.20	<0.20	<0.25	0.05
Manganese	0.39	0.04	<0.05	<0.05	<0.05	0.03
Bicarbonate	93	146	187	230	378	226
Sulfate	120	299	750	270	558	297
Chloride	11	45	76	100	24	6

* -composite

6.4 Ground Water Supply

Ground water is the primary source of water in the Northern and Western Tularosa Basin areas, whereas surface water and ground water are utilized for supply in the Eastern Tularosa Basin and Salt Basin. Approximately 667 million acre-feet of ground water are estimated to be stored in the planning region, but only approximately 33 million acre-feet (5 percent) of that is considered recoverable fresh water (more than one-half in the Salt Basin). Surface water occurs as runoff from mountain watersheds and as spring flow. All surface waters combined result in a flow of 70,000 acre-feet per year in the planning region; most of this surface water originates from the Sacramento Mountains.

Ground water in the planning region can be divided into two generalized geologic settings: 1) basin fill aquifer, and 2) bedrock aquifer. The majority of the wells in the planning region produce from the basin fill aquifer. The basin fill aquifer is known to have the highest well yields in the planning region, suitable for irrigation. Well yield from the bedrock aquifer varies according to rock type and location, and may range from less than one gallon-per-minute (gpm) to over 1,000 gpm.

Ground water in the Northern Tularosa Basin area is predominately in the bedrock aquifer, although from Carrizozo to the south, the basin fill aquifer is present. Ground water in the Eastern Tularosa Basin area occurs in the basin fill aquifer and in the bedrock aquifer north of Alamogordo. The Western Tularosa Basin area solely contains the basin fill aquifer. The bedrock aquifer in the Salt Basin area is one of the most productive in the planning region. Wells in the Crow Flat area of the Salt Basin produce from the basin fill and bedrock aquifers. A geologic map of the planning region is presented as **Figure 6.6**.

6.4.1 Geologic Data

The Tularosa Basin is located in south-central New Mexico within portions of Lincoln, Otero, Sierra, and Dona Ana Counties. It is a curved, downfaulted basin related to the Rio Grande rift proper. The Rio Grande rift is a north-south trending extensional feature stretching from northern Mexico to southern Colorado (Hawley, 1978). The Tularosa Basin is a closed basin bounded by Chupadera Mesa to the north, the Organ, San Andres and Franklin Mountains to the west, the Sacramento Mountains and Sierra Blanca peak to the east, and the bedrock high to the south (Orr and Myers, 1986). This basin covers an area of approximately 6,500 square miles and extends to the north over 170 miles from the New Mexico – Texas border (Orr and Myers, 1986). The collapse and downfaulting of an over-extended north-south trending upwarp referred to as the Pedernal Ridge (Kelly and Thompson, 1964) (see **Figures 6.7** through **6.15**) formed the Tularosa Basin.

For the purposes of this study, the Tularosa Basin has been divided into four sub-basins based on their hydrogeologic characteristics. The Tularosa Basin proper has been split into a northern and southern portion with its southern portion further divided into eastern and western sections along the north-south trending Jarilla Fault line. The Salt Basin is treated as a separate (and fourth) area of study. The discussion is divided into these four sub-areas.

The geologic units found in the planning region are listed in **Table 6.10**. Also included in **Table 6.10** is a list of each geologic unit, the thickness of the geologic unit, and description.

Table 6.10

Summary of Geologic Units for the Planning Region				
Age	**Symbol**	**Stratigraphic Unit**	**Thickness (ft)**	**Description**
Quaternary	Qa	Alluvium	200 – 500	Basin fill – unconsolidated clay, silt, sands, and gravels
	Qb	Basalt	10 - 50	Basalt lava flows
	Qts	Upper Santa Fe Group	500 – 2000	Basin fill – silts, sands, and gravels
Tertiary	Ti	Intrusives	10 – 100	Igneous intrusives - dikes and sills
	Tps	Galisteo SS	50 – 100	Interbedded siltstones and sandstone
Cretaceous	Kmv	Mesaverde Group	400 – 500	Interbedded sandstone and shale
Triassic	Km	Mancos Shale	150 – 250	Interbedded siltstones and shales
	Trc	Chinle	50 – 100	Interbedded siltstones and shales
	Trm	Moenkopi	50 – 100	Interbedded siltstones and shales
Permian	P	Permian undivided	2000 – 5000	
	Psa/ Pvp	Glorieta/ San Andres/ Victorio Peak	200 - 1000	Sandstone and Limestone
	Py	Yeso Formation	1200 - 1800	Interbedded limestones and shales
	Pa/ Ph	Abo/ Hueco Formations	200 - 500	Mudstones and conglomerates
Pennsylvanian	Pb	Bursum Formation	400 - 600	Interbedded siltstones, sandstones, shales and conglomerates
	IP	Holder Formation	500 - 900	Interbedded limestones and conglomerates
Mississipian -		Gobbler Formation	1200 - 1600	Sandstones and conglomerates
Cambrian	M - C	Lake Valley Formation	350 - 450	Interbedded limestones and shales
		Percha Shale	40 - 80	Black noncalcareous shale
		Fusselman Dolomite	20 - 100	Massive dolomite with chert
		Montoya Formation	190 - 225	Massive dolomite
		El Paso Formation	350 - 450	Dolomitic sandstone
Precambrian		Bliss Sandstone	100 - 150	Quartz sandstone
	pC	Granite		Granites and granodiorites

Northern Tularosa Basin

The northern portion of the Tularosa Basin is located in south-central New Mexico and is centered roughly on the town of Carrizozo. This portion of the basin is confined within the watershed margins of the Tularosa Basin and Townships 1 and 10 South between Ranges 5 and 11 East (near the Otero-Lincoln County border). This portion of the basin is narrow and is at a higher elevation with respect to the rest of the basin.

The subsurface geologic strata that represent the principal water producing units are the alluvial deposits, the upper and lower Santa Fe Formations (in the southern portion of the sub-basin), the Mesaverde Group, the Glorieta Sandstone, the San Andres Limestone, and the Yeso Formation.

The upper Santa Fe Formations are Pliocene to Miocene in age and are undifferentiated in the Northern Tularosa Basin (Hawley, 1978), and, in this report, are referred to as basin fill deposits. The extent of the basin fill deposits is shown on **Figure 6.16**. These units are not present in the northern portion, but have a thickness of up to 2,000 ft in the extreme southern portion of the sub-basin (Reynolds, 1986; McLean, 1970). The basin fill deposits thin to the north, and are generally less than 100 ft thick in the Carrizozo area. This unit is made up of coarse river sediments and valley fill, mainly cobbles, sand, and silt, making it a very productive aquifer where saturated.

Beneath the basin fill and alluvium in the area east of Carrizozo is the Cretaceous-age Mesaverde Group and Dakota Sandstone; these rocks regionally dip to the east (Hendrickson, 1949). These rocks yield water to wells in the Nogal Canyon and Oscura areas; typically less than 50 GPM.

In the Northern Tularosa Basin the Permian-age San Andres Limestone and Glorieta Sandstone are the upper-most lithologic units in the northern portion of the sub-basin (**Figure 6.6**), while it underlies the Santa Fe Group to the south (Griswold, 1959). It is gently folded in the center of the basin and offset at the eastern and western mountain fronts by basin bounding normal faults. The Glorieta Sandstone (250 ft thick) is underlain by 300 ft of San Andres Limestone. The San Andres is composed of highly fractured limestone, which makes it a productive bedrock aquifer. The San Andres limestone is also gently folded in the center and offset by normal faults on the edges of the basin.

The Permian Yeso Formation underlies the San Andres Formation and is exposed in a few areas of the northern sub-basin (**Figures 6.7** and **6.8**). The Yeso typically has a thickness of approximately 1,000 ft and is also gently folded in the central portion of the basin (Griswold, 1959). It is a pinkish-gray to yellow gypsiferous sandstone that is sometimes interbedded with limestone. Wells that produce from the Yeso Formation typically yield less than 10 GPM, but can be higher where secondary porosity occurs from fracturing. The Yeso generally produces ground water high in sulfate and total dissolved solids as a result of leaching gypsum from the formation. The Yeso Formation is almost always associated with the underlying Permian-age Abo Formation in this part of New Mexico. The Abo Formation does not often outcrop within the basin, but drill-hole logs indicate it is present at depth and is approximately 800 ft thick (Griswold, 1959). It is likely deformed in much the same way as the overlying Yeso Formation, but the lack of exposures limits any detailed discussion of its subsurface morphology.

Western Tularosa Basin

The Western Tularosa Basin is bounded on the west by the San Andres Mountains and the bedrock high of the Jarilla Fault to the east. The Jarilla Fault separates the Western Tularosa Basin from the Eastern Tularosa Basin from Township 11 to 26 South down Range 7 East (**Figures 6.9** to **6.12**), expressed by the outcroppings at the Jarilla Mountains, Dos Hermanos, Hurtz Spring, and Tulie Peak. This normal fault has a down-to-the-west orientation, creating two separate half grabens along the length of the basin (Reynolds, 1986). This fault creates the bedrock high that separates the basin into two halves, effectively isolating these two ground water basins from each other. The fault runs through Holloman Air Force Base just west of the playa lake known as Lake Holloman and east of the White Sands Dunes. Springs such as Hurtz Spring are present in several locations along the fault. The TDS of the springs along the Jarilla Fault have TDS content exceeding 3,000 ppm, but is much lower than nearby highly mineralized surface and ground water in the playa flats near Holloman Air Force Base. The west side of the basin is almost entirely occupied by undeveloped lands of White Sands Missile Range/ Fort Bliss/ Holloman Air Force Base.

Quaternary-age alluvial, piedmont, eolian, and pluvial deposits cover the basin surface and are underlain by the Santa Fe Group sediments, all considered basin fill deposits. Many of these basin fill deposits are laden with evaporite deposits, dominantly gypsum sands, which have formed the famous dunes of White Sands National Monument. The basin fill deposits are thickest in the Western Tularosa Basin area, and have been estimated to be over 4,000 ft in places. Ground water in the basin fill is highly mineralized, and the sediments are generally fine grained and yields low quantities of ground water very high in TDS to wells.

In the central portion of the sub-basin, there is little to no data regarding the nature of the lithologic units below the Santa Fe Group other than to say they are likely Permian in age.

The western boundary of the sub-basin is represented by steeply westward dipping Silurian, Pennsylvanian, and Mississippian sedimentary units overlying metamorphic Precambrian rocks.

Eastern Tularosa Basin

The Eastern Tularosa Basin composes the other half graben across the Jarilla Fault. The eastern portion of White Sands Missile Range and Holloman Air Force Base occupy the western side of this sub-basin while the southern portion is largely covered by Fort Bliss. The eastern side of the sub-basin is host to a string of communities oriented north-south along the Sacramento Mountain front, including Alamogordo.

The central basin surficial deposits of the Eastern Tularosa Basin are very similar in character to those found in the western half graben, containing alluvial, piedmont, eolian, and pluvial units. These units are in turn underlain by the Santa Fe Group deposits which are at least 2,500 ft thick and are undifferentiated in the northern part of the sub-basin. The Santa Fe Group is dominated by coarse basin fill material (sand, pebbles, and cobbles with lesser amounts of clay) which act as the primary aquifer upon which mountain front communities in this sub-basin draw their water. These basin fill deposits typically are coarse-grained near the mountain front and become fine grained towards the basin center. Again, due to the depth and lack of exposure, there is very little known about the character of the underlying strata other than to suggest it is likely Permian sedimentary material.

The Sacramento Mountains to the east have a better-understood stratigraphy and structure than that of the central basin. The western side of the Sacramento Mountains is composed of heavily folded and faulted Mesozoic and Paleozoic sedimentary units. The Cretaceous-age Mancos Shale and Dakota Group cap the upper portions of the range in the Three Rivers area. In this area the Mancos Shale is approximately 400 ft thick while the Dakota Group is about 150 ft thick (Griswold, 1959). The Dakota Group is composed mainly of massive to coarsely bedded sandstone, which grade up into the mudstone and shale of the Mancos (Lochman-Balk, 1964). Below the Dakota Group is the Upper Triassic Chinle Formation composed of musdstone and claystone with thin sandstone beds (Lochman-Balk, 1964). The Chinle Formation is approximately 150 ft thick in this part of the Sacramento range (Griswold, 1959). Due to their high shale content, the Mancos and Chinle are not considered viable water bearing units.

Permian-age strata compose the remainder of the known stratigraphic section in the northern portion of the Sacramento Mountains and are heavily faulted and folded within the Sacramento Mountains (**Figures 6.9** to **6.12**). The upper-most Permian unit is the Artesia Group which is approximately 100 ft thick and composed of gypsum, dolomitic limestone as well as red sandstone and siltstone (Griswold, 1959). Beneath the Artesia Group is the San Andres Limestone, which is approximately 800 ft thick and heavily fractured (Griswold, 1959). The Yeso Formation underlies the San Andres in this area and is typically about 1,000 ft in thickness. It is composed of pinkish-gray to yellow silty sandstone and gypsum, with some limestone (Griswold, 1959). The Abo Formation is thought to be the basal Permian strata in this area, determined from well data, but this unit does not crop out in the Eastern Tularosa Basin area. The Abo is approximately 800 ft thick and composed of dark-red to reddish-brown mudstone which can be arkosic and conglomeratic locally (Griswold, 1959).

The Permian-age Bursum Formation is composed of interbedded siltstone, sandstone, shale, and conglomerate, and ranges from 400 to 600 ft in thickness. The potential yield from the Bursum is not well known.

Pennsylvanian-age rocks include the Holder and Gobbler Formations. These rocks yield water to wells in the La Luz – High Rolls area. The Holder Formation primarily consists of limestone and conglomerate, and yields good quantities of water to wells where fracturing and dissolution occur. The City of Alamogordo's La Luz well field produces from limestone of the Holder Formation that underlies the basin fill.

Many of the wells in the bedrock aquifer of the Eastern Tularosa Basin produce water from the Permian-age Yeso and the Pennsylvanian-age Holder Formation, particularly in the La Luz and Tularosa watersheds.

Salt Basin

The Salt Basin is located in the extreme south-central portion of the planning region between Townships 18 and 26 South (state line) and Ranges 11 and 21 East. The Tularosa Basin doubles in width here in its southern extreme – now bordered to the east by the Guadalupe/ Brokeoff Mountains. The Salt Basin is separated from the other portions of the basin by topographic boundaries, namely Otero Mesa and the Cornudas Mountains.

The Salt Basin has been recently declared a state regulated hydrologic administrative basin by the NMOSE, and with this new designation comes a need to better understand the geology and hydrogeology of this remote and poorly understood basin. In order to summarize the present understanding of this area, three cross-sections were drawn across this basin, one at the northern end (**Figure 6.15**), one across the middle (**Figure 6.13**), and one at the southern end of the basin (**Figure 6.14**).

The Salt Basin is an extensional basin that widens to the south and is bordered on the east by the Guadalupe/Broke-off Mountains and on the west by the Hueco Mountains/ Otero Mesa. The basin is structurally defined by north-south trending, high-angle normal faults on its eastern and western margins, resulting in a horst-graben-horst morphology in cross-section across the basin. Faults and associated folds on the eastern side of the basin represent the eastern extent of the Rio Grande Rift portion of the Basin and Range topographic province.

The most common rocks in the Salt Basin include Quaternary-age alluvium, and Permian-age rocks. Tertiary igneous intrusions of both andesitic and basaltic composition are present in the more southwestern side of the basin. Quaternary-age basin fill in the form of alluvium and piedmont deposits as well Santa Fe Group sediments can be more than 500 ft thick, but in most places range from 25-300 ft thick (Bjorklund, 1959). The principal bedrock aquifer units are the San Andres Limestone, Yeso Formation, and Abo (Hueco) Formation, which together make up the bulk of the water bearing strata.

The San Andres Limestone and Yeso Formation cover most of the upper portion of the Salt Basin (**Figures 6.13** to **6.15**). The San Andres Formation is comprised of limestone, with sandstone at the base of the formation. The Yeso consists of sandstone, limestone, dolomite, siltstone, shale, and evaporites (Wasiolek, 1991). The Yeso Formation is approximately 1,000 ft thick in the southern Sacramento Mountains (Kelly, 1971). The lower 500 ft of the Yeso Formation typically consists of siltstone and evaporite deposits. Many of the springs in the southern Sacramento Mountains discharge from the contact between the San Andres and Yeso Formations. Most wells that yield water from the Yeso Formation are completed in the upper 500 ft of the formation in fractured limestone and dolomite where the permeability has been enhanced by solutioning.

Ground water flow in the limestone rocks of the Salt Basin is largely controlled by regional fracture systems (Mayer, 1995). The most significant regional fracture system in the Salt Basin area is referred to as the Otero Break, trending from the Sacramento River to Crow Flats.

6.4.2 Aquifer Characteristics

Described below, for each sub-area of the planning region, are estimates of the most favorable water bearing units and their hydraulic values, recharge, and volume of water stored in the geologic units. Hydraulic data were obtained from pumping test performed on wells.

Water level elevation and depth to water and ground water flow direction maps are provided as **Figures 6.16** and **6.17**, respectively. Depth to water helps identify likely recharge and discharge areas in the planning region.

The estimates of water in storage were made for various ranges in total dissolved solids (TDS) concentration and for the basin fill and bedrock aquifers. **Figure 6.18** is a map of the planning region showing approximate distribution of TDS concentrations in ground water.

<u>Northern Tularosa Basin</u>

Very little hydraulic data are available on the bedrock aquifer in the northern most portion of this sub-area.

Depth to water in the Northern Tularosa Basin ranges from less than 100 ft to over 700 ft below land surface (**Figure 6.17**). Depth to water greater than 500 ft appears to be related to an outcrop of the San Andres Limestone and the increase in land surface elevation in the northwestern portion of the sub-area. Depth to water in the area of the Basin fill aquifer is generally less than 200 ft.

Other than the analysis provided in this report, there are no known estimates of recharge to the aquifers of the Northern Tularosa Basin. The total watershed yield has been estimated at 44,842 AFY, which is the surface water runoff and recharge combined. Due to the high permeability of the basin fill and San Andres Limestone, approximately 70 percent of the watershed yield is estimated to occur as recharge (30,000 AFY). Most all of this water flows to the south, and discharges as springs (Malpais Spring) or evaporates near the center of Tularosa Basin. A portion of this recharge may also occur as deep underflow to the south in the San Andres Limestone or other permeable rocks of the bedrock aquifer.

The estimated total and recoverable volume of ground water stored in the Northern Tularosa Basin area is summarized in **Table 6.11**. More than 85 percent of the total ground water stored in the Northern Tularosa Basin area has TDS concentration greater than 1,000 milligrams per liter (mg/L). Furthermore, approximately 50 percent of the total ground water in storage have a TDS greater than 2,000 mg/L.

Of the 64.8 million acre-feet of estimated ground water stored in the Northern Tularosa Basin area, only 29.7 million acre-feet are considered recoverable. This low recoverability is due to the properties of the bedrock aquifer, and difficulty in extracting water from the bedrock aquifer. It also should be noted that the estimate of recoverable ground water assumes that an infinite number of closely spaced wells could be drilled to extract the ground water, and the estimate does not take into account local variability in hydrogeologic conditions.

Table 6.11

Estimated Total and Recoverable Volume of Ground water Stored in the Northern Tularosa Basin Area						
Total Volume of Water in Storage			Basin Fill	Bedrock	Basin Fill	Bedrock
TDS range, mg/ L	Area Inside Basin Fill, mi^2	Area Outside Basin Fill, mi^2	Total Volume in Storage, AF	Total Volume in Storage, AF	Recoverable Volume in Storage, AF	Recoverable Volume in Storage, AF
>10,000	0	0	0	0	0	0
5,000-10,000	35.64	5.04	1,140,480	161,280	285,120	80,640
4,000-5,000	52.56	31.68	1,681,920	1,013,760	420,480	506,880
3,000-4,000	160.20	146.88	5,126,400	4,700,160	1,281,600	2,350,080
2,000-3,000	42.84	191.16	1,370,880	6,117,120	342,720	3,058,560
1,000-2,000	47.52	953.28	1,520,640	30,504,960	380,160	15,252,480
<1,000	0.00	359.64	0	11,508,480	0	5,754,240
total water			10,840,320	54,005,760	2,710,080	27,002,880

Notes:
Total volume of water stored in basin fill is based on 250 ft average saturated thickness and porosity of 0.2
Total volume of water stored in bedrock is based on 1,000 ft average saturated thickness and porosity of 0.05
Total volume of recoverable water stored in basin fill is based on ability of the aquifer to liberate one half of the total in storage to wells and specific yield of 0.1
Total volume of recoverable water stored in bedrock is based on ability of the aquifer to liberate one half of the total in storage to wells and storage factor equal to 0.05

Western Tularosa Basin

The Western Tularosa Basin consists entirely of basin fill aquifer. Most of the basin fill aquifer in the Western Tularosa Basin area contains saline ground water. Relatively fresh water occurs from White Sands south to the Texas state line. Little information is available on the basin fill aquifer north of White Sands Missile Range (WSMR).

A number of aquifer tests have been performed on wells in the San Andres well field; the water supply for WSMR. **Table 6.12** lists all of the available aquifer test data for the Western Tularosa Basin area. Transmissivity of the basin fill aquifer has been reported to range from 800 to 47,000 ft^2/day, indicating good well production is obtained from the basin fill aquifer. Transmissivity is the rate (hydraulic conductivity) at which water is transmitted through a unit width of aquifer (saturated thickness penetrated by well) under a unit hydraulic gradient, and is generally considered an expression of the aquifer productivity.

Table 6.12

Summary of Hydraulic Data for the Western Tularosa Basin Area

Location	Aquifer	Transmissivity (ft^2/day)	Storativity	Reference
San Andres well field	basin fill	20,000	12%	Balance (1976)
San Andres well field	basin fill	1,200-3,700	9%	Balance (1976)
17S.4E.1.211	basin fill	17,400		McLean (1970)
19S.5E.16.333	basin fill	1,340		McLean (1970)
19S.5E.20.344	basin fill	39,500		McLean (1970)
20S.5E.34.133	basin fill	47,000		McLean (1970)
21S.5E.16.134	basin fill	1,060		McLean (1970)
21S.5E.20.344	basin fill	13,400		McLean (1970)
22S.4E.24.212	basin fill	10,700		McLean (1970)
22S.4E.13.411	basin fill	4,400		McLean (1970)
22S.5E.7.324	basin fill	2,000		McLean (1970)
22S.5E.32.222	basin fill	800		McLean (1970)
22S.6E.8.423	basin fill	2,630		McLean (1970)
17S.4E.2.211	basin fill	1,100		Orr (1986)

Depth to water in Western Tularosa Basin area is generally less than 100 ft (**Figure 6.17**), and the water table is near the land surface in the basin center where ground water discharges by means of evaporation. In the area of White Sands Missile Range Headquarters, depth to water ranges from 200 to 300 ft.

Ground water recharge on this side of the basin is from rainwater and snowmelt in the San Andres Mountains and ground water originating from the Chupadera Mesa/Oscura Mountains areas. The total mean annual streamflow from the San Andres Mountains has been estimated by the USGS at 9,291 AFY, which likely represents the maximum recharge available to the basin fill aquifer. Recharge occurs at the mountain front where surface water runoff infiltrates into the highly permeable basin fill deposits.

Ground water inflow from the Northern Tularosa Basin discharges as springs (Malpais Spring) or evaporates near the center of Tularosa Basin. Based on results from oil and gas exploration of the bedrock aquifer beneath the basin fill (Reynolds, 1986), there may be an upward component of ground water flow in the southern portion of this sub area.

The estimated total and recoverable volume of ground water stored in the Western Tularosa Basin area is summarized in **Table 6.13**. More than 90 percent of the total ground water stored in the Western Tularosa Basin area has TDS concentration greater than 1,000 mg/L.

Furthermore, approximately 50 percent of the total ground water in storage has a TDS greater than 2,000 mg/L. Based on the estimates provided in **Table 6.13**, approximately 6 million acre-feet of fresh water is considered recoverable in the Western Tularosa Basin.

The northern portion of the Western Tularosa Basin may contain fresh water in alluvial fan deposits (Orr and Myers, 1986), however, the limited number of wells drilled in this area make fresh water storage estimates difficult. Orr and Myers, (1986) estimated 10.7 million acre-feet of fresh water in storage in the Western Tularosa Basin.

Table 6.13

Estimated Total and Recoverable Volume of Ground Water Stored in the Western Tularosa Basin Area			
TDS Range (mg/ L)	**Basin Fill Area (mi^2)**	**Basin Fill Total Volume in Storage AF**	**Basin Fill Recoverable Volume in Storage AF**
>10,000	125.28	24,053,760	4,008,960
5,000-10,000	991.80	190,425,600	31,737,600
4,000-5,000	117.36	22,533,120	3,755,520
3,000-4,000	150.12	28,823,040	4,803,840
2,000-3,000	289.44	55,572,480	9,262,080
1,000-2,000	76.68	14,722,560	2,453,760
<1,000	384.56	24,611,840	6,152,960
Total water		**360,742,400**	**62,174,720**

Notes:
Total volume of water stored in basin fill is based on 1500 ft average saturated thickness
And porosity of 0.2
Total volume of fresh water stored in basin fill is based on 500 ft average saturated thickness
And porosity of 0.2
Total volume of recoverable water stored in basin fill is based on ability to dewater 50 percent of the average saturated thickness (500 ft) and specific yield of 0.1

Eastern Tularosa Basin

The Eastern Tularosa Basin area has the longest history of ground water development in the planning region, therefore, most of the available hydraulic data is from this sub area.

Results of pumping tests preformed in the Eastern Tularosa Basin are summarized in **Table 6.14**. Most all the pumping tests were performed on wells completed in the basin fill aquifer. Estimates of transmissivity for the basin fill aquifer range from 60 to 20,000 ft^2/day.

The bedrock aquifer in the Eastern Tularosa Basin primarily consists of the Yeso Formation, and other Permian-age rocks. Wasiolek (1991) reported hydraulic conductivity values of the Yeso Formation to vary from 0.007 to 1.5 feet per day (ft/d). In areas of fracture-enhanced flow near the well, hydraulic conductivity has been reported to be as high as 92 ft/d. Reported hydraulic conductivity values of the Yeso Formation aquifer vary several orders of magnitude as a result of the influences of fracturing.

Table 6.14

Summary of Hydraulic Data for the Eastern Tularosa Basin Area

Location	Aquifer	Transmissivity (ft^2/day)	Storativity	Reference
16.10.5.244	basin fill/bedrock	2,600		Livingston and JSAI (1996)
15.10.36.111	basin fill/bedrock	2,655		Livingston and JSAI (1996)
16.10.5.444	basin fill/bedrock	6,244		Livingston and JSAI (1996)
17.9.25.222	basin fill	2,000	0.0049	Morrison (1989)
17.10.19.144	basin fill	2,340	0.0051	Morrison (1989)
17.10.19.122a	basin fill	1,600	0.001	Morrison (1989)
17.10.19.142	basin fill	1,870	0.0055	Morrison (1989)
17.10.19.142	basin fill	1,730	0.0051	Morrison (1989)
17.10.19.112a	basin fill	1,330	0.0042	Morrison (1989)
17.10.19.112a	basin fill	1,370	0.0025	Morrison (1989)
17.10.19.321a	basin fill	1,400	0.0034	Morrison (1989)
17.10.19.123	basin fill	2,130	0.0051	Morrison (1989)
17.10.19.123	basin fill	8,528	0.0079	Morrison (1989)
17.10.19.123	basin fill	8,020	0.00089	Morrison (1989)
17.10.19.121a	basin fill	600		Morrison (1989)
17.10.19.141	basin fill	720		Morrison (1989)
17.9.25.213	basin fill	2,000		Morrison (1989)
17.10.19.112a	basin fill	1,590	0.0034	Morrison (1989)
17.10.19.112a	basin fill	14,440	0.00043	Morrison (1989)
17.10.18.442a	basin fill	600	0.0012	Morrison (1989)
17.10.18.432a	basin fill	180	0.001	Morrison (1989)
17.10.19.113	basin fill	200	0.04	Morrison (1989)
17.9.24.342	basin fill	2,700		Morrison (1989)
17.9.25.212	basin fill	1,560		Morrison (1989)
17.10.31.424	basin fill	1,160		Morrison (1989)
17.10.32.234	basin fill	20,000		Morrison (1989)
16.8.13.400	basin fill	60		Morrison (1989)
16.9.4.400	basin fill	380		Morrison (1989)
16.9.8.100	basin fill	160		Morrison (1989)
14.9.11.422	basin fill	2,150		Morrison (1989)
14.10.18.424	basin fill	400		Morrison (1989)
14.9.36.422	basin fill	5,000		Morrison (1989)
11S.9E.34	basin fill	6,000	0.019	Morrison (1989)
Boles well field	basin fill	1,330-2,340		Morrison (1989)
Grapevine Canyon	basin fill	1,000-1,330	8-12%	Morrison (1989)
Alamogordo area	basin fill	>1000		McLean (1970)
Alamogordo area	basin fill	20,000		McLean (1970)
Tularosa area	basin fill	2,100-4,200	2.1-16	McLean (1970)
16S.8E.13.400	basin fill	60		Orr (1986)
16S.9E.4.400	basin fill	380		Orr (1986)
16S.9E.8.100	basin fill	160		Orr (1986)
17S.10E.31.424	basin fill	1,160		Orr (1986)
17S.10E.32.234	basin fill	20,000		Orr (1986)

The ground water in this portion of the basin is recharged along the Sacramento Mountain front from rainfall and snowmelt, which infiltrates into the bedrock aquifer or into the alluvial fan at the base of the mountain front. Assuming approximately 60 percent of the total watershed yield becomes recharge, the estimated rate of recharge is 47,099 AFY (**Table 6.6**). The recharge that occurs in the bedrock aquifer likely becomes streamflow or enters the basin fill aquifer as ground water inflow.

Estimates of ground water in storage for different ranges in salinity are provided in **Table 6.15**. Fresh water storage within the Eastern Tularosa Basin area is mainly limited to alluvial fan deposits along the Sacramento Mountain front. This sub-area is estimated to have approximately 7.9 million acre-feet of freshwater in storage, not all of which is deemed recoverable. An equal amount is in storage in the bedrock aquifer.

Based on results from this study, there are approximately 1.9 million acre-feet of recoverable fresh ground water in storage in the Eastern Tularosa Basin area, practically all of it is south of Alamogordo. "Recoverable" in this sense would mean numerous closely spaced wells. The estimate does not account for ground water removed from storage since ground water development began. Provided in **Table 6.15** is a summary of availability of recoverable fresh water south of Alamogordo.

Table 6.15

Estimated Total and Recoverable Volume of Ground Water Stored in the Eastern Tularosa Basin Area						
TDS Range (mg/ L)	Area Inside Basin Fill (mi^2)	Area Outside Basin Fill (mi^2)	Basin Fill	Bedrock	Basin Fill	Bedrock
			Total Volume in Storage (acre-feet)	Total Volume in Storage (acre-feet)	Recoverable Volume in Storage (acre-feet)	Recoverable Volume in Storage (acre-feet)
>10,000	21.60	0.00	2,764,800	0	691,200	0
5,000-10,000	365.52	0.00	46,786,560	0	11,696,640	0
4,000-5,000	173.88	0.00	22,256,640	0	5,564,160	0
3,000-4,000	211.68	18.72	27,095,040	599,040	6,773,760	299,520
2,000-3,000	53.28	54.36	6,819,840	1,739,520	1,704,960	869,760
1,000-2,000	351.00	364.68	44,928,000	11,669,760	11,232,000	5,834,880
<1,000	123.12	477.36	7,879,680	7,637,760	1,969,920	3,818,880
total			158,530,560	21,646,080	39,632,640	10,823,040

Notes
Total volume of water stored in basin fill is based on 1000 ft average saturated thickness and porosity of 0.2
Total volume of water stored in bedrock is based on 1,000 ft average saturated thickness and porosity of 0.05
Total volume of fresh water stored in basin fill is based on 500 ft average saturated thickness and porosity of 0.2
Total volume of recoverable water stored in basin fill is based on ability of the aquifer to liberate one half of the total in storage to wells and specific yield of 0.1
Total volume of recoverable water stored in bedrock is based on ability of the aquifer to liberate one half of the total in storage to wells and storage factor equal to 0.05

Salt Basin

The depth to water in the central portion of the Salt Basin is typically less than 200 ft., while in the adjacent uplands it is often more than 400 ft (Bjorklund, 1959). The depth to water is greater than 1,000 ft in an anomalous zone east of Pinon (**Figure 6.17**).

The aquifer permeability and well yield are affected by degree of fracturing and may vary several orders of magnitude over a short distance. It is likely the degree of fracturing decreases with depth, and is localized around faulted rocks. The Otero Break has been identified by Mayer (1995) as a regional fracture system of high transmissivity, which extends from the Sacramento River to Dell City, Texas. The saturated basin fill deposits of the Crow Flat area, also have high transmissivity and yield water to wells for irrigation. There are no available aquifer test data from the Salt Basin. Mayer (1995) estimated the transmissivity ranges from 80,000 ft^2/d (Otero Break fracture zone) to 800 ft^2/d (Otero Mesa).

Due to the absence of perennial streams in the basin center, ground water recharge in the basin center is mainly infiltration of precipitation during flash flooding of ephemeral channels (Bjorklund, 1959). Therefore most of the total Salt Basin recharge originates from the higher elevations of Sacramento River and Pinon Creek watersheds. Total maximum annual average recharge for Salt Basin is approximately 35,000 AFY.

Estimates of ground water in storage were made for the bedrock aquifer and the Crow Flat basin fill sediments (**Table 6.16**). The estimate of storage in the bedrock aquifer is based on an estimated thickness of 750 ft, which is equivalent to the average thickness of the formations that make up the aquifer.

Of the 60 million acre-feet of water estimated in storage in the Salt Basin, approximately 30 million acre-feet are considered fresh water and only one-half of that is estimated to be recoverable (**Table 6.16**). Most of the ground water in storage is in the bedrock aquifer, particularly in vast undeveloped areas where very little information is available for estimating aquifer properties, making the estimates of ground water in storage lacking supportive data. Eight percent of the ground water stored in Crow Flat is fresh (<1,000 mg/L TDS).

Table 6.16

Estimated Total and Recoverable Volume of Ground water Stored in the Salt Basin Area (New Mexico side)

TDS Range (mg/ L)	Bedrock Aquifer Total Volume in Storage AF	Bedrock Aquifer Recoverable Volume in Storage AF	Basin Fill Alluvial Aquifer Total Volume AF	Crow Flat Basin Fill Aquifer Recoverable AF
>10,000	0	0	0	0
5,000-10,000	0	0	0	0
4,000-5,000	0	0	0	0
3,000-4,000	1,840,320	920,160	0	0
2,000-3,000	12,458,880	6,229,440	512,000	256,000
1,000-2,000	13,219,200	6,609,600	2,176,000	1,088,000
<1,000	29,954,880	14,977,440	230,400	115,200
Total	57,473,280	28,736,640	2,918,400	1,459,200

Total volume of water stored in bedrock is based on 750 ft average saturated thickness and porosity of 0.05
Total volume of recoverable water stored in bedrock is based on ability of the aquifer to liberate one half of the total in storage to wells and confined storage factor equal to 0.05

6.4.3 Well Field Data

Ground water extraction in the Tularosa and Salt Basins can be attributed to 5 different user groups. Irrigated agriculture and public water systems are the largest users, followed by livestock production, commercial and industrial use and domestic use. Well field data from irrigated agriculture and public water systems are presented for each of the four sub-areas of the planning region.

Northern Tularosa Basin

A list of available well data is referenced in **Appendix 6.3**. Most of the wells in the bedrock aquifer produce less than 10 GPM, and are primarily used for stock and domestic supply. A couple of wells in the bedrock aquifer near Ancho, New Mexico have been reported to produce enough water for irrigation. These wells likely produce from the San Andres Limestone. Several wells produce water from the Cretaceous-age rocks in the Carrizozo area (Cooper, 1965). Well yields from the Cretaceous rocks are typically low (<10 GPM), but can range as high as 100 GPM.

The thin basin-fill deposits in the area of Carrizozo and Nogal Arroyo are known to yield several hundred gallons per minute to wells. Most of the high yield wells are completed along Nogal arroyo from Carrizozo to approximately 10 miles east of Carrizozo (Cooper, 1965; Rao, 1986).

Wells are sparsely scattered in the Northern Tularosa Basin Area, with the exception of the area around Carrizozo and Nogal Arroyo. Well field data for the Northern Tularosa Basin would include the two municipal water supply wells in Carrizozo (**Table 6.17**).

Table 6.17

Summary of Carrizozo's Municipal Well Field Data					
Location	**Name**	**Total Depth, ft**	**Aquifer**	**Original Depth to Water, ft**	**Reported Yield, GPM**
T8S R10E 14.221	Town Well 1	200	Basin fill	65	160
T8S R10E 14.223	Town Well 2	215	Basin fill	65	260

Source: Cathie R. Eisen, Level II Water Operator, Town of Carrizozo, 2001

Western Tularosa Basin

The primary well field in the Western Tularosa Basin area is at White Sands Missile Range along the western edge of the basin-fill deposits. The area south of Highway 70 near the White Sands Headquarters is the only area in this sub-region that has fresh ground water. Approximately 10 wells supply water for the White Sands Missile Range Post Headquarters area (Orr and Meyers, 1986). Test wells drilled in this area have penetrated over 5,000 ft of basin fill material (McLean, 1970). Most of the supply wells are completed less than 1,000 ft deep in the fresh water zone of the basin fill deposits. Water supply wells in the area yield approximately 100 to 1,000 GPM (**Table 6.18**); the higher yield wells are commonly due south of Highway 70 along the edge of the basin fill. Specific capacity of municipal supply wells in this area range from 3 to 60 GPM/ft (McLean, 1970).

Test wells have been drilled along the western edge of the basin fill north of Highway 70, but typically result in low yield (<100 GPM) and limited saturated thickness of fresh water (Orr and Meyers, 1986). Test wells drilled by White Sands Missile Range toward the center of the Tularosa Basin have indicated the basin fill becomes finer grained and more saline with distance away from the edge of the basin fill (Orr and Meyers, 1986).

Table 6.18

Summary of Municipal Well Field Data for White Sands Missile Range Post Headquarters Area, Western Tularosa Basin

Location	Name	Total Depth, ft	Aquifer	Original Depth to Water, ft	Reported Yield, GPM
T22S R4E 13.311	Supply Well 13	900	Basin fill	396	1,000
T22S R4E 13.333	Supply Well 11	600	Basin fill	402	366
T22S R4E 13.411	Supply Well 14	810	Basin fill	478	750
T22S R4E 13.424	Supply Well 15	820	Basin fill	458	750
T22S R4E 13.432	Supply Well 16	890	Basin fill	463	660
T22S R4E 23.214	Supply Well 12	570	Basin fill	268	---
T22S R4E 24.212	Supply Well 10	505	Basin fill	397	200
T22S R5E 32.311	Supply Well 4	452	Basin fill	221	33
T22S R5E 32.321	Supply Well 6	338	Basin fill	236	55

Source: McLean (1970)

Many of the water supply wells are known to yield more than several hundred gallons per minute in the basin fill aquifer near the mountain front where sediments are coarse-grained. Test hole drilling by White Sands Missile Range show that the well yield decreases away from the mountain front as the sediments become more fine-grained. The basin fill sediments are thickest in the Western Tularosa Basin than at any other location in the planning region, and well yield could be increased by completion of very deep wells, although water quality would be compromised.

Eastern Tularosa Basin

Many of the wells in this region that have high yields (>100 GPM) are located along the base of the mountain front where sediments are coarse-grained. Some of the most prolific wells produce from the basin fill and bedrock aquifers along the mountain front. One example of production from the basin fill and bedrock aquifers is the City of Alamogordo's La Luz well field, where well yields range from 320 to 1,450 GPM. Irrigation wells that produce several hundred gallons per minute are typically found from Three Rivers south to Alamogordo along the base of the mountain front. Well yield decreases significantly with distance west of the Sacramento Mountain front, potentially from 1,000 to 100 GPM (McLean, 1970).

Over the last twenty years domestic well drilling in the mountain bedrock aquifer between High Rolls and Bent has significantly increased. Well yields in the bedrock aquifer vary drastically from less than 1 GPM to over 100 GPM, and highly depend on local geologic conditions. Well yields in the bedrock aquifer can reduce dramatically by a slight lowering of the water table, because of the decrease in permeability and storage that occurs with depth.

Irrigation and municipal supply wells have been drilled along the edge of the basin fill from Three Rivers to approximately 20 miles south of Alamogordo. These wells are completed in basin-fill aquifer along the eastern edge of Tularosa Basin in a zone about 5 to 10 miles in width. This zone of high well yield contains ground water with a TDS ranging from 1,500 to 5,000 mg/L north of Alamogordo, and TDS less than 1,000 mg/L south of Alamogordo.

A summary of irrigation well data for the Eastern Tularosa Basin is presented in **Table 6.19**. Well yields appear to vary from region to region, but appear to generally decrease to the south. Most of the irrigation wells produce ground water with less than 3,000 mg/L TDS.

Table 6.19

Summary of Irrigation Well Field Data for Eastern Tularosa Basin				
General location	**Average Well Depth, ft**	**Aquifer**	**Average Depth to Water, ft**	**Reported Yield, GPM**
Between Three Rivers and Tularosa (T12S to T13S R9E)	500	Basin fill	250	500 to 1,800
Tularosa irrigation district (T14S R9E)	300	Basin fill	150	200 to 600
Between Tularosa and La Luz (T15S R10E)	350	Basin fill	200	400 to 700
Vicinity of Alamogordo (T16S R10E; T17S R9E)	820	Basin fill	458	100 to 500

Source: McLean (1970), Orr and Meyers (1986), and NMOSE records

There are several municipal well fields in the Eastern Tularosa Basin, particularly for Village of Tularosa, community of La Luz, City of Alamogordo, and Holloman Air Force Base. The Village of Tularosa and community of La Luz have a single well to provide water during peak demand in conjunction with surface water. The City of Alamogordo and Holloman Air Force Base utilize well fields to supply a significant percentage of their water demand.

Alamogordo's La Luz well field data is summarized in **Table 6.20**. All of Alamogordo's La Luz wells produce from the basin fill and underlying bedrock. The variability in well yield is related to the degree of secondary porosity in the bedrock aquifer; the more fractured rock results in higher yield wells.

Table 6.20

List of Well Data for the City of Alamogordo's La Luz Well Field, Otero County, New Mexico

Well	Well No. 2	Well No. 3	Well No. 4	Well No. 5	Well No. 6 repl.	Well No. 7	Well No. 8
Date drilled	1956	1957	1964	1965	1992	1971	1999
Location	15S.10E. 36	16S.10E. 5	16S.10E. 5	15S.10E. 36	16S.10E. 5	16S.10E. 5	15S.10E. 36
Status	Active	active	active	active	active	active	active
Total depth	703	700	780	767	844	750	991
Water level, ft bgl	362	391	440	390	359	336	408
Water column, ft	341	309	340	377	485	414	583
Screen interval, ft bgl	390-703	554-664	417-780	n/a	520-830	542-740	565-985
Pumping level, ft bgl	560	483	516	n/a	500	481	625
Production rate, GPM	320	320	320	460	1450	850	250
Specific capacity, GPM/ft	1.6	3.48	4.22	n/a	10.1	5.86	1.4

ft bgl feet below ground level
GPM/ft gallons per minute per foot
n/a not available

Holloman Air Force Base has four well fields: Boles, San Andres, Douglas and Escondido/ Frenchy (**Table 6.21**). These well fields are located south of Alamogordo along the eastern edge of the basin fill aquifer where well yields are high and water quality is good. The development of the Boles Well Field began in 1947, and by 1976 forty-four test and production wells had been drilled but only 10 are used for water supply (Balance, 1976). The Douglas and San Andres Well Fields were developed by Holloman in the early 1960s. The Douglas Well Field consists of six wells whose yields range from 300 to 700 GPM. The highest yield wells are in the San Andres Well Field, which range from 500 to 1,000 GPM (**Table 6.21**).

Many of the rural population in the Eastern Tularosa Basin depend in individual domestic wells for water supply. The density of domestic wells is greatest around the subdivided lands between Tularosa and Alamogordo, south of Alamogordo, and in the High Rolls area of the Sacramento Mountains. Data on domestic wells is limited to records on file at the NMOSE, and details provided on well records by the Driller. A detailed analysis of domestic wells would provide a better understanding of the ground water yield in the Northern and Eastern Tularosa Basin areas.

Table 6.21

Summary of Municipal Well Field Data for Holloman Air Force Base, Eastern Tularosa Basin

Location	Name	Total Depth, ft	Aquifer	Original Depth to Water, ft	Reported Yield, GPM
Boles Well Field (T17S R9 & 10E)					
Boles	B-2	215	Basin fill	88	280
Boles	B-5	205	Basin fill	86	170
Boles[1]	B-10	261	Basin fill	81	150
Boles	B-15	372	Basin fill	82	200
Boles[1]	B-16	217	Basin fill	73	100
Boles	B-17	202	Basin fill	77	270
Boles	B-26	510	Basin fill	94	300
Boles[1]	B-32	205	Basin fill	61	120
Boles[1]	B-33	180	Basin fill	60	245
Boles	B-34	242	Basin fill	45	188
Boles	B-35	200	Basin fill	78	260
Douglas Well Field (T17S R10E section 31 and T18S R10E sections 6 &7)					
Douglas[1]	D-1	300	Basin fill	---	200
Douglas[1]	D-2	315	Basin fill	180	500
Douglas	D-4	295	Basin fill	130	218
Douglas[1]	D-5	306	Basin fill	141	250
Douglas[1]	D-6	305	Basin fill	139	350
Douglas[1]	D-7	495	Basin fill	173	700
San Andres Well Field (T17S R10E section 32)					
San Andres	SA-1	370	Basin fill	181	478
San Andres[1]	SA-2	510	Basin fill	---	500
San Andres	SA-3	980	Basin fill	---	843
San Andres[1]	SA-4	1,200	Basin fill	316	1,000
San Andres	SA-5	1,140	Basin fill	50	850
San Andres	SA-6	1,140	Basin fill	--	900
Frenchy Well Field					
Frenchy	F-1	1,230	Basin fill	---	1,488
Frenchy	F-2	670	Basin fill	---	413
Escondido	E-1	1,025	Basin fill	---	945

Source: McLean (1970) and Ballance (1976)
[1] well reported to be capped

Salt Basin

Development of ground water for irrigation in the Crow Flat area began in the late 1940's, and several wells were drilled. A good description of the Crow Flats irrigation area can be referenced from Bjorklund (1957). A summary of wells in the Crow Flat area is provided as **Table 6.22**. Well depth, well yield, and depth to water vary dramatically, in part, due to the type of well (i.e. stock versus irrigation). Well depths range from 100 ft to over 1,000 ft, and well yield is reported to be as high as 6,000 GPM. Most of the irrigation wells produce over 1,000 GPM.

Table 6.22

Summary of Wells in the Crow Flat Area, Salt Basin						
File #	**Location**	**Owner**	**Total Depth (ft)**	**Yield (GPM)**	**Pumping level, (ft)**	**Water level, (ft)**
19-297	22S.18E.17.411	George W. Rauch	500	20	450	400.0
19-293	23S.18E.15.112	George W. Rauch	600	600	350	225.0
19-294	23S.18E.2.222	George W. Rauch	500	300	300	300.0
19-298	23S.18E.27.221	George W. Rauch	600	6	500	500.0
19-13	23S.18E.29.111	Lewis	300	15	280	
	23S.18E.30.340	Doyle Pate	300	12R		260.0
19-300	23S.18E.9.133	George W. Rauch	300	20	225	225.0
	24S.17E.8.440	Howell Lewis	745	8R		620.0
19-14	24S.18E.11.33	Lewis	180	15	150	
19-307	24S.18E.11.442	John G. Schafer	180	14	180	110.0
19-309	24S.18E.20.144	John G. Schafer	350	3,000	142	110.0
19-304	24S.18E.29.413	John G. Schafer	200	400	131	110.0
19-308	24S.18E.29.414	John G. Schafer	200	20	180	110.0
19-306	24S.18E.29.424	John G. Schafer	100	10	180	110.0
19-310	24S.18E.29.424	John G. Schafer	425	1100	148	110.0
	24S.19E.18.144	Richard Lewis	480	3,500R		143.0
19-296	24S.19E.18.243	George W. Rauch	450	3,800	150	148.0
	25S.17E.9.110	Howell Lewis	450	12R		435.0
	25S.18E.21.233	Gene Lewis		350R		68.8
	25S.18E.24.111	C.C. Chavez	140	400R		42.4
	25S.18E.25.230	J.D. Lewis	500	597R		55.4
	25S.18E.26.111	Ed Prather	140	840M		56.5
19-228	25S.18E.27.111	Warren	300	650	110	40.0
	26S.17E.21.333	Bryce Dugger	1100	475R		182.5
	26S.17E.28.312	Bryce Dugger	875	475R		193.1
19-280	26S.18E.21.112	Hunt Building Corp.	156	6,000	92	78.0
	26S.18E.21.223	John Gailey	105	2,860M		36.2
	26S.18E.21.331	Frank Gentry	544	1,200R		35.5
	26S.18E.21.411	J.W. Hill	426	2,860M		27.0
	26S.18E.28.113	Frank Gentry	394	3,620M		31.5
	26S.18E.30.122	Ernest Shelton	386	2,000R		89.1
	26S.18E.30.213	Gordon Parks	250	1,720M		63.5
	26S.18E.32.111	Mrs. K. Brownfield	400	600R		32.3
	26S.18E.32.122	Mrs. K. Brownfield	300	3,000R		31.8
	26S.18E.33.111	J.W. Hill	425	400R		26.1
	26S.18E.33.133	J.W. Hill	435	1,200R		27.5

Source: Bjorklund (1957) and NMOSE records

The Crow Flats area of the Salt Basin can yield several thousands of gallons per minute to irrigation wells, but the number of high yield wells that can be sustained is limited by recharge to the aquifer. Most of the high yield wells in Crow Flat produce from the basin fill and bedrock aquifer. The majority of the Salt Basin consists of the bedrock aquifer that typically yields less than 50 GPM to wells. This includes the Otero Plateau along the western margin, the Sacramento Mountains and associated highlands, and the Guadalupe Mountains and associated highlands.

6.4.4. Ground Water Yields By Aquifer

Typically the ground water yield can be considered as limited by the amount of recharge to the aquifer at the expense of streamflow or evaporation in the basin center. Other analyses of ground water yield include utilizing regional ground water flow models to determine the yield (pumping from well fields) that produces an acceptable level of water level decline or mining of the aquifer. Since there is not a regional ground water flow model that can be used for estimating ground water yield for the entire planning area, the analysis of ground water yield below, for each of the sub-regions, is based dewatering 250 ft of the recoverable ground water in storage uniformly in each aquifer over a one hundred year time period (2.5 ft/yr).

The estimate of ground water yield does not take into account dewatering that has occurred since ground water development took place. The analysis of ground water yield is also limited to ground water with TDS content less than 3,000 mg/L, assuming ground water with TDS between 1,000 and 3,000 mg/L TDS can be used for irrigation or treated for municipal supply. Recharge is not considered in the estimate of ground water yield, because in many areas of the planning region, almost all of the streamflow is diverted before entering the ground water system.

Northern Tularosa Basin

Most of the Northern Tularosa Basin contains the bedrock aquifer, with the basin fill aquifer localized around Carrizozo and near the Lincoln-Otero county line. Total recoverable ground water with less than 3,000 mg/L TDS stored in the bedrock aquifer is approximately 27 million acre-feet (**Table 6.11**), of which 6 million acre-feet would equal the upper 250 ft of the aquifer. This would equate to approximately 60,000 acre-feet per year for 100 years.

Estimates of total recoverable ground water with less than 3,000 mg/L TDS stored in the basin fill aquifer is 722,880 acre-feet, most in the Carrizozo area. The basin fill aquifer in the Northern Tularosa Basin is typically less than 100 ft in thickness, and dewatering one half of the thickness would equal approximately 360,000 acre-feet, or 3,600 AFY for 100 years.

Western Tularosa Basin

The basin-fill aquifer is the primary and only known source of water for the Western Tularosa Basin. Estimates of total recoverable ground water with less than 3,000 mg/L TDS stored in the basin fill aquifer is almost 18 million acre-feet (**Table 6.13**), most in the White Sands Missile Range Post Headquarters area. Approximately 9 million acre-feet would equal the upper 250 ft of the aquifer that could be recovered by wells, and also one half of the available ground water with less than 3,000 mg/L in the sub-region. This would equate to a ground water yield of approximately 89,300 acre-feet per year for 100 years.

Eastern Tularosa Basin

The bedrock aquifer in the Eastern Tularosa Basin is confined to the Sacramento Mountains, particularly from Three Rivers to La Luz. Total recoverable ground water with less than 3,000 mg/L TDS stored in the bedrock aquifer is approximately 10.5 million acre-feet (**Table 6.15**), of which 2.6 million acre-feet would equal the upper 250 ft of the aquifer. This would equate to approximately 26,000 acre-feet per year for 100 years. However, this water is available to small wells (domestic type), and would have to be closely spaced to realize the total recovery assumed. Localized drawdowns done to pumping may further reduce this amount.

Estimates of total recoverable ground water with less than 3,000 mg/L TDS stored in the basin fill aquifer between Three Rivers and Orogrande is 14.9 million acre-feet, of which 3.73 million acre-feet would be equal to dewatering the upper 250 ft of the aquifer. This would equal a ground water yield of approximately 37,250 AFY for 100 years. Fresh water in the basin fill aquifer south of Alamogordo is typically less than 500 ft in thickness, and in some areas dewatering 250 ft would remove one half of the thickness or potentially all of the fresh ground water.

Salt Basin

Most of the Salt Basin consists of the bedrock aquifer, and it contains approximately 27.8 million acre-feet of recoverable ground water (**Table 6.16**). The bedrock aquifer is estimated to be 750 ft thick, so approximately 9.3 million acre-feet would equal the ground water yield resulting from dewatering 250 ft of the aquifer with wells. This amounts to a rate of ground water yield of 92,700 acre-feet per year for 100 years.

The Basin fill aquifer in the Salt Basin is confined to Crow Flat, and the estimated recoverable ground water in storage is 1.46 million acre-feet. Spread over a 100 year time period, the ground water yield of the basin fill aquifer equals 14,600 AFY.

6.4.5 Sustainable Yields

The definition of sustainable can be subjective and be based on the priorities for ground water management developed by the community or a governmental entity such as the New Mexico State Engineer. Priorities for ground water management should contain some of the following goals.

- Sustainable long term yields from aquifers
- Effective use of the large volume of water stored in aquifers
- Preservation of ground water quality
- Integration of ground water and surface water into a comprehensive water and environmental management system (Alley et al. 1999).

The U.S. Geological Survey (Alley et al. 1999) defines ground water sustainability the following way:

> "In this report, we define ground water sustainability as development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, or social consequences. …..Furthermore, ground water sustainability must be defined within the context of the complete hydrologic system of which ground water is a part."

For this planning document sustainable yield is based on the availability of water for each sub area of the planning region, as described in this report, and New Mexico State Engineer guidelines for administering ground water in the Tularosa Basin. In general terms, the New

Mexico State Engineer may allow ground water mining to occur so that drawdown will not exceed 100 ft or 2.5 feet per year over a forty-year planning period.

The Regional Planning Committee is not endorsing or advocating this as ground water basin drawdown criteria in the Salt Basin, but is simply using this criteria to estimate sustainable yield there. The NMOSE will set ground water basin criteria based upon the unique and specific characteristics of the Salt Basin if and when such criteria are necessary. Such criteria should be developed with public participation.

It should be noted that the NMOSE criteria for the Tularosa-Alamogordo Administrative area has even more stringent guidelines to insure preservation of fresh water zones.

Sustainable yield, therefore, is the summation of the watershed yield (as defined earlier) and the available ground water in storage (ground water yield) with a total dissolved solid (TDS) range of less than 3,000 mg/L withdrawn at an equal rate over a 100 year period, (but not to exceed the amount allowed by the NMOSE criteria), less any non-salvagible watershed yield. Non-salvagible watershed yield is that portion of the yield lost to the soil (vadose zone) or captured in the bedrock but unavailable.

Summaries of estimated maximum sustainable yields are provided for each of the four sub-regions in **Tables 6.23** through **6.24**. The estimates of sustainable yield do not take into account ground water mined since development began, effects of drought conditions, water-right limitations.

Table 6.23

Estimated sustainable yield for the Northern Tularosa Basin

Component	**Quantity, AFY**
Supply	
Total estimated watershed yield	44,842
Estimated ground water yield from mining entire sub area *	63,600
Losses from Supply	
Non-salvagible watershed yield	14,842
Captured streamflow	1,000
Estimated maximum sustainable yield for Northern Tularosa Basin area	92,600

* Based on the ability to dewater the ground water in storage at an average rate over 100 years, with a TDS less than 3,000 mg/L, uniformly across the Northern Tularosa Basin area.

Table 6.24

Estimated sustainable yield for the Western Tularosa Basin	
Component	**Quantity, AFY**
Supply	
Total estimated watershed yield	9,291
Estimated ground water yield from mining entire sub area *	89,300
Losses from Supply	
Non-salvagible watershed yield	0
Captured streamflow	1,000
Estimated maximum sustainable yield for Western Tularosa Basin area	97,591

* Based on the ability to dewater the ground water in storage at an average rate over 100 years, with a TDS less than 3,000 mg/L, uniformly across the Western Tularosa Basin area.

Table 6.25

Estimated sustainable yield for the Eastern Tularosa Basin	
Component	**Quantity, AFY**
Supply	
Total estimated watershed yield*	77,610
Estimated ground water yield from mining entire sub area **	63,250
Losses from Supply	
Non-salvagible watershed yield	10,511
Captured streamflow	1,000
Estimated maximum sustainable yield for Eastern Tularosa Basin area	119,349

* Includes stream flow and recharge to bedrock aquifer

**Based on the ability to dewater the ground water in storage at an average rate over 100 years, with a TDS less than 3,000 mg/L, uniformly across the Eastern Tularosa Basin area

Table 6.26

Estimated Sustainable Yield for the Salt Basin	
Component	**Quantity, AFY**
Supply	
Total estimated watershed yield	35,078
Inflow from Penasco Basin	8,000
Estimated ground water yield from mining entire sub area *	107,300
Losses from Supply	
Non-salvagible watershed yield	0
Captured streamflow	0
Estimated maximum sustainable yield for Salt Basin area	150,378

* Based on the ability to dewater the ground water in storage, with a TDS less than 3,000 mg/L, uniformly across the Salt Basin area. Much of the ground water in storage is in areas of low well yield, and the estimate does not account for potential rapid dewatering of localized high permeability zones.

6.4.6 Drawdowns by Level of Development

Maps showing historic water-level drawdown contours were developed for the planning area. **Figure 6.19** is a map of historic water level drawdown contours through the year 1950, and **Figure 6.20** is a map of historic water level drawdown contours through the year 1995. Water level drawdown contours were interpreted from hydrographs provided in **Appendix 6.4**.

Drawdown accumulated by the year 1950 was confined to the irrigation district around Tularosa and Boles Acres (**Figure 6.19**). By 1950, a maximum of 10 ft of drawdown was centered around Tularosa, and approximately 1 ft of drawdown noted in area of the Boles Acres.

By 1995, areas of water-level drawdown were observed in the Tularosa irrigation district, City of Alamogordo's La Luz well field, Boles Acres, White Sands (San Andres well field), near the Texas state line in the Western Tularosa Basin area, and in the Salt Basin irrigation district near Crow Flat (**Figure 6.20**). Water-level drawdown has not been observed in the Northern Tularosa Basin.

6.5 WATER QUALITY ISSUES

6.5.1 Assess Quality of Water Sources

<u>Northern Tularosa Basin</u>

The Northern Tularosa Basin has moderate overall TDS concentrations with an area of higher concentration near the White Sands Missile Range boundary. The contours generally follow the basin morphology, concentrating in the lowest portions of the basin near communities. Refer to **Figure 6.21** and **6.22** for salinity and chemical type water maps.

<u>Western Tularosa Basin</u>

This portion of the basin has some of the highest TDS concentrations in the Tularosa Basin. Specifically, a site within the White Sands Missile Range just north of the WSMR headquarters has concentrations in excess of 90,000 mg/L. Refer to **Figure 6.21** and **6.22** for salinity and chemical type water maps.

Eastern Tularosa Basin

The Eastern Tularosa Basin has similar values and distribution of these values as the western portion of the basin. The highest concentrations are found around the Holloman Air Force Base-Alamogordo areas migrating to the west. Refer to **Figure 6.21** and **6.22** for salinity and chemical type water maps.

Salt Basin

The Salt Basin area has the lowest concentrations of TDS within the entire planning region. This area is also sparsely populated with very few developments. The highest concentrations of TDS are near the Alkali Flats area in the extreme southeastern portion of the basin. Refer to **Figure 6.21** and **6.22** for salinity and chemical type water maps.

6.5.2 Sources of Contamination

Ground water contamination in the Tularosa Basin is commonly due to septic tanks, cesspools, and underground (fuel, etc.) storage tank leaks (Water Quality Control Commission, 2000). Of these, underground storage tanks are responsible for 57 percent of the point source contamination represented by approximately 126 sites within the basin. Many of these storage tanks are located under service stations within the City of Alamogordo and are leaking gasoline, diesel, and/or gasoline additives (Water Quality Control Commission, 2000).

Other principal contributors are Holloman AFB, White Sands Missile Range, and Fort Bliss whose fuel distribution tanks have leaked in the past, but many were located over saline (non-potable) ground water. Most all of the leaky underground storage tanks on Holloman Air Force Base have been removed, remediated, and replaced with above-ground storage tanks with containment.

Fuel pipelines and Liquid Petroleum storage and distribution centers also contribute to ground water contamination in the Alamogordo area (Water Quality Control Commission, 2000). ST Services Jet Fuel tanks and supply lines, located east of Highway 54 near Boles Acres subdivision and Holloman's Boles Well Field, has been reported to have leaked. The fuel depot is currently out of service, although remediation is in progress to clean up the leak.

Old and abandoned septic tanks within the Alamogordo area are the principal source of nitrate contamination within the Tularosa Basin (Water Quality Control Commission, 2000). A previous study using data from the 1950's shows a distinct nitrate plume, with values over the state and federal standards, extending south of the City of Alamogordo from an undetermined source (Finch, 2000). A second nitrate plume is noted in the same data set further south near the Alamogordo-White Sands Regional Airport but values there did not exceed the standard (Finch, 2000).

Table 6.27

NMED Underground Storage Tank Bureau Data: Leaking Underground Storage Tank Sites (published in year 2000)

Location	C	EPA	GWPRB	HRMB	I	M	NFA	PI
Alamogordo	3		1		14	1	17	8
Carrizozo	1				2		2	2
Cloudcroft					2			
Coyote					1			
High Rolls								1
Holloman AFB	7						3	1
La Luz								1
Mescalero		2			1			
Orogrande							1	1
Pinon								1
Tularosa					1	1	1	2
White Sands Missile Range	1				2		6	2
C	Cleanup							
EPA	EPA Referral							
GWPRB	Referred to Ground Water Quality Bureau							
HRMB	Referred to Hazardous/Radioactive Materials Bureau							
I	Investigation							
M	Monitoring							
NFA	No Further Action Required							
PI	Pre-Investigation							

Landfills, stock and dairy yards, and agricultural areas can also cause ground water contamination. The City of Alamogordo has one closed municipal landfill, west of Alamogordo and Otero County has closed one landfill near Dog Canyon. The Dog Canyon landfill was closed because of concerns about contaminating the fresh-water aquifer. There is one active landfill (Lincoln-Otero regional landfill) approximately 30 miles south of Alamogordo west of Highway 54.

There are no reported water-supply wells in the Tularosa and Salt Basins that have been contaminated from the potential sources described above. Additionally, because the City of Alamogordo La Luz Well field is substantially distant from these sources, no potential future water resource impacts are anticipated.

7. WATER DEMAND

7.1 Present Uses

7.1.1 Water Use Categories

- **Public Water Supply** Diversions for small community and municipal water supply uses.
- **Domestic Use** Private domestic wells.
- **Industrial** Metered industrial uses, limited data available.
- **Commercial** Metered commercial uses.
- **Irrigated Agriculture** Surface and ground water diversions and depletion, taking into account return flows, categorized by type of use.

7.1.2 Water Diversions by Category of Use

7.1.2.1 Public Water Supply

Water diversions used for Public Water Supply "include all water utilities, publicly or privately owned, which have at least 15 service connections or regularly serve an average of at least 25 individuals daily at least 60 days out of the year. Water used for the irrigation of self-supplied playing fields, golf courses and parks or to maintain the water level in ponds and lakes owned and operated by a municipality which is a public water supplier is also included in this category." This category includes small community water systems, but not individual domestic wells.

Tularosa Basin

A total of 18 public water supply systems are located in the Tularosa Basin with service populations ranging from 36 to over 35,000 persons. A total population of almost 53,000 is currently on a public water supply. Approximately 43% of the current public water supply diversions are from surface water, and 57% from ground water. The City of Alamogordo and

Holloman Air Force Base are the largest public water suppliers in the Basin. The current Public Water Supply Diversions in the Tularosa Basin are approximately 13,700 acre-feet (AFY).

Salt Basin

Public water supplies in the Salt Basin include the Communities of Timberon and Pinon. The current Public Water Supply Diversions for the Salt Basin are approximately 75 AFY.

The following **Table 7.1** summarizes the current (1995, unless otherwise noted) water supply diversions used for Public Water Supply in the Tularosa Basin and Salt Basin:

Table 7.1

Public Water Supply Diversions					
Water Supplier	**Population Served**	**Usage (*GPCD*)**	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Diversion (AFY)**
Tularosa Basin					
Alamogordo PWS	35,969	184	4,726	2,674	7,400
Boles Acres PWS	1,095	129	0	158	158
Canyon Hills WUA	60	160	0	11	11
Carrizozo PWS	1,490	200	130	203	333
Cider Mills Farms	36	155	0	6	6
Dungan MDWCA	50	151	0	8	8
Freemans MHP	43	139	0	7	7
High Rolls	375	90	0	38	38
Holloman AFB	5,786	370	52	2,344	2,397
Karr Canyon Estates	50	153	9	0	9
La Luz MDWCA	2,000	83	46	139	185
Mountain Orchard	90	100	0	10	10
Nogal WCA	42	72	3	0	3
Orogrande MDWCA	72	465	0	38	38
Piney Woods WUA	55	148	0	9	9
Tularosa PWS	3,029	267	907	0	907
WSMR	2,450	797	0	2,187	2,187
TOTALS	***52,692***	***232***	***5,874***	***7,832***	***13,706***
Salt Basin					
Pinion MDWUA	200	198	0	44	44
Timberon WSD	255	106	30	0	30
TOTALS	***455***	***147***	***30***	***44***	***74***

7.1.2.2 Domestic

Domestic uses include self-supplied residences which may be single family homes or multiple housing units with less than 25 occupants, where water is used for normal household purposes such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, watering lawns and gardens and evaporative cooling. This use also includes water used by that segment of the population that is served by small community water systems for which reliable population and water use data are unavailable. This category includes individual domestic wells.

Approximately 8,750 persons are served by self-supplied domestic systems within the Tularosa Basin, and approximately 200 persons in the Salt Basin. The per capita consumption for a domestic well (typically located in a rural setting) is 80 to 100 gallons per day per person (GPCD). Because meters are not required on domestic wells, the per capita consumption is estimated based on previous studies. Typically the per capita consumption is substantially lower than urban usage, because the landscaping component is minimal to non-existent. The per capita consumption values are lower in Lincoln County, due to the higher elevations and cooler climates, therefore minimizing the use of evaporative coolers. The following **Table 7.2** summarizes the water diversions used for Domestic Water Supply in the Tularosa Basin and Salt Basin:

Table 7.2

Domestic Water Supply Diversions			
Water Supplier	**Population Served**	**Gal/Capita/day (*GPCD*) Use**	**Total Diversion (AFY)**
Tularosa Basin	**Lincoln County**		
Rural self supplied homes	784	80	70
Tularosa Basin	**Otero County**		
Rural self supplied homes	7962	100	892
Totals	**8746**	**98 (avg.)**	**962**
Salt Basin			
Rural self supplied homes	200	100	22
Totals	**200**	**100**	**22**

7.1.2.3 Industrial

Industrial uses within the Tularosa Basin are typical served from a public water system. Those industrial uses that are self supplied (i.e.; not already supplied via a public water supply system) consist of three users. The largest industrial user is the Regional Landfill, which is managed by the City of Alamogordo. As shown, all self-supplied industrial users in the Tularosa Basin divert ground water. There are no known industrial uses for water in the Salt Basin.

The following **Table 7.3** summarizes the water diversions used for Industrial use in the Tularosa Basin (there are no industrial uses in the Salt Basin):

Table 7.3

Industrial Use Diversions		
Industrial Water User	**Classification**	**Total Diversion (AFY)**
Otero County		
Regional Landfill	ground water	23
Alexander Molding, Inc.	ground water	2
Sierra Ice (1990 data)	ground water	0
Totals		**25**

7.1.2.4 Commercial

Commercial uses within the Tularosa Basin include businesses, campgrounds, picnic areas and visitor centers. Recreational uses such as golf courses (Timberon) and RV parks are also included. These facilities are considered self-supplied because they derive their water supply from individual wells or surface water, and not from the public water system.

The following **Table 7.4** summarizes the water diversions used for commercial use in the Tularosa and Salt Basins:

Table 7.4

Commercial Use Diversions		
Commercial Water User	**Classification**	**Total Diversion (AFY)**
Camper Ranch (1990 data)	Ground water	0.15
Carrizozo Golf Association	Ground water	293.2
Mountain Springs Ranch RV Park	Ground water	2
Alamo Rosa Fuel Stop	Ground water	4.22
Alamo West Fire Dept. (1990 data)	Ground water	0.02
Bubby's	Ground water	0.5
Christ Community Church (1990 data)	Ground water	0.11
Consolidated Bottling (1990 data)	Ground water	0.09
Fosseen - Warehouse	Ground water	0.06
Four Square Gospel Church (1990 data)	Ground water	0.58
Hannis, Phillip Blaine	Ground water	0.69
Ikard & Nelson	Ground water	0.1
KC's Log Cabin Rest	Ground water	2
Macon, Joyce & Agold, Harold	Surface Water	13.61
Melendres, Joe – Fitness Center (1990 data)	Ground water	1
Misc. Businesses	Ground water	10
Nickels Bar and Lounge	Ground water	0.5
Oliver Lee State Park (1990 data)	Ground water	1.58
Oro Vista Fire Department (1990 data)	Ground water	0.81
Polson & Grady Elec. Cont. (1990 data)	Ground water	0.3
Rio Benito Trading (1990 data)	Ground water	0.74
Sagebrush Investors	Ground water	0.47
Schaffer, Jean (1990)	Ground water	0.23
Schureman, Earl	Ground water	0.68
Scott Able 4-H Camp	Ground water	2
Southwest Engineering (1990)	Ground water	0.14
Three Rivers Petroglyph Site	Ground water	1
Treasure Rockhound RV Park	Surface Water	5.99
Deerhead Campground (USFS)	Ground water	1
Karr Canyon Campground (USFS)	Ground water	1
Slide Group Area (USFS)	Ground water	0.2
Valenti Real Estate Services (1990)	Ground water	0.08
Waste Management of Alamogordo (1990)	Ground water	1.76
White Sands Missile Range	Ground water	218.9
White Sands National Monument	Ground water	8.94
Total Tularosa Basin		**575**
Salt Basin		
Timberon Golf/Country Club/Lake	Surface Water	472.61
Total Salt Basin		**473**

7.1.2.5 Irrigated Agriculture

Values for irrigated agriculture water use were derived from information provided to the Office of the State Engineer, and compiled in an inventory report.

Tularosa Basin

In 1995, approximately 6,345 acres were under irrigation in the Tularosa Basin. Various methods for irrigating cropland were tabulated into three categories; flood, drip and sprinkler. Both ground water and surface water are used for irrigation. As shown, about 79% of the irrigated agriculture diversions are from ground water, and 21% from surface water in the Tularosa Basin.

Salt Basin

In 1995 there were approximately 2,485 acres irrigated in the Salt Basin, and all use ground water. Irrigation methods include both flood and sprinkler.

The following **Table 7.5** summarizes the water diversions for Irrigated Agricultural use in the Tularosa Basin and Salt Basin:

Table 7.5

Irrigated Agricultural Diversions					
Type of Irrigation	**County**	**Irrigated Acreage**	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Diversion (AFY)**
Tularosa Basin					
Flood	Lincoln	475	0	2,265	2,265
Flood	Otero	985	5,693	915	6,608
Sub-total		**1,460**	**5,693**	**3,180**	**8,873**
Drip	Lincoln	75	0	170	170
Drip	Otero	1,895	0	6,303	6,303
Sub-total		**1,970**	**0**	**6,473**	**6,473**
Sprinkler	Lincoln	65	0	107	107
Sprinkler	Otero	2,850	0	11,830	11,830
Sub-total		**2,915**	**0**	**11,937**	**11,937**
TOTAL TULAROSA BASIN		**6,345**	**5,693**	**21,590**	**27,283**
Salt Basin					
Flood	Otero	325	0	1,338	1,338
Sprinkler	Otero	2,160	0	8,833	8,833
TOTAL SALT BASIN		**2,485**	**0**	**10,171**	**10,171**

7.1.2.6 Livestock

Water use figures for livestock are developed using the number of livestock reported by various state and federal agencies and per capita water requirements determined by research. For 1995, approximately 48,000 cattle, hogs, horses, chickens and sheep are included in the Tularosa Basin. This water-use category includes both surface and ground water diversions. Approximately 64% of the livestock diversions are obtained from ground water, and 36% from surface water.

The following **Table 7.6** summarizes the water diversions for livestock use in the Tularosa Basin (data not available for Salt Basin):

Table 7.6

Livestock Use Diversions				
Water Use		**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Diversion (AFY)**
Livestock	*Lincoln County*	75	82	157
Livestock	*Otero County*	74	184	258
Totals		***149***	***266***	***415***

7.1.2.7 Stockpond Evaporation

Stockpond withdrawals include water lost through evaporation. Values for stockpond evaporation were obtained from 1980 data compiled by the Office of the State Engineer Office and used in previous reports. These data are not available for current OSE inventories. The number of stock ponds was reported by various agencies, and an assumed surface area of one acre was used in the evaporation computations.

The following **Table 7.7** summarizes the water diversions associated with stockpond evaporation in the Tularosa Basin (data not available for Salt Basin):

Table 7.7

Stockpond Evaporation Diversions			
County	**No. of Stockponds**	**Net Evaporation (ft)**	**Ground Water (AFY)**
Lincoln	630	3.33	2,098
Otero	510	3.66	1,867
Totals	**1,140**		**3,965**

7.1.2.8 Fish, Wildlife, and Recreation

There are limited fish, wildlife and recreational water uses in the Tularosa Basin, and these are not inventoried by the OSE.

7.1.2.9 Mining

Mining uses in the Tularosa Basin reported to the OSE include one sand-and-gravel operation, which utilizes ground water. The following **Table 7.8** summarizes the water diversions associated with mining uses in the Tularosa Basin:

Table 7.8

Mining Use Withdrawals		
Mining Water User	**Classification**	**Total Diversion (AFY)**
Otero County		
Sand and Gravel Washing	ground water	20
Totals		**20**

7.1.2.10 Summary Total All Uses

The current diversions within the Tularosa Basin total approximately 47,000 acre-feet (AF). Approximately 75% of the total diversions are from ground water, and about 25% are from surface water supplies. Irrigated agriculture uses account for the majority of the diversions within the Basin (58%), and public water systems using 29%.

For the Salt Basin, current use is about 10,700 acre-feet (AF), with more than 95% from ground water.

The following **Table 7.9** summarizes the current water diversions associated with all use categories in the Tularosa Basin and Salt Basin (see **Fig. 7**.):

Table 7.9

Summary of Present Diversions				
Use	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Diversion (AFY)**	**Percent (%)**
Tularosa Basin				
Public Water Systems	5,874	7,832	13,706	29
Domestic (self supplied)	0	962	962	2
Irrigated Agriculture	5,,693	21,590	27,283	58
Livestock	149	266	415	1
Commercial	0	575	575	1
Industrial	0	25	25	0
Stockpond Evaporation	0	3,965	3,965	8
Mining	0	20	20	0
Total Tularosa Basin	**11,716**	**35,235**	**46,951**	**100**
Great Salt Basin				
Public Water Systems	30	44	75	1
Domestic (self supplied)	0	22	22	0
Irrigated Agriculture	0	10,171	10,171	95
Commercial	473	0	473	4
Total Salt Basin	**503**	**10,238**	**10,741**	**100**

7.1.3 Water Depletions by Category of Use

7.1.3.1 Public Water Supply

Depletions for a public water supply indicate the amount of water that is totally lost out of the system, in other words, that quantity which is not directly returned to either surface or ground water. Data available indicate that approximately 45% to 60% of all public water supply withdrawals are assumed as depletions from the Tularosa Basin.

The following **Table 7.10** summarizes the water depletions by the Public Water Supply in the Tularosa Basin and Salt Basin:

Table 7.10

Public Water Supply Depletions					
Water Supplier	**Population Served**	**Depletion Factor**	**Surface Water (AF)**	**Ground Water (AF)**	**Total Depletions (AF)**
Tularosa Basin					
Alamogordo PWS	35,969	0.50	2,363	1,337	3,700
Boles Acres PWS	1,095	0.50	0	79	79
Canyon Hills WUA	60	0.50	0	5	5
Carrizozo PWS	1,490	0.45	59	91	150
Cider Mills Farms	36	0.50	0	3	3
Dungan MDWCA	50	0.50	0	4	4
Freemans MHP	43	0.50	0	3	3
High Rolls	375	0.50	0	19	19
Holloman AFB	5,786	0.60	31	1,407	1,438
Karr Canyon Estates	50	0.50	4	0	4
La Luz MDWCA	2,000	0.50	23	70	93
Mountain Orchard	90	0.50	0	5	5
Nogal WCA	42	0.45	2	0	2
Orogrande MDWCA	72	0.50	0	19	19
Piney Woods WUA	55	0.50	0	5	5
Tularosa PWS	3,029	0.50	454	0	454
WSMR	2,450	0.50	0	1,094	1,094
TOTALS	***52,692***		***2,936***	***4,140***	***7,076***
Salt Basin					
Pinon MDWUA	200	0.50	0	22	22
Timberon WSD	255	0.50	15	0	15
TOTALS	***455***		***15***	***22***	***37***

7.1.3.2 Domestic

Water uses associated with depletions is the same for self-supplied domestic homes as it is with those on a public water system, therefore the depletion factor remains the same for domestic uses. Data available indicate that approximately 45% of self-supplied domestic ground water withdrawals are assumed as depletions from the Tularosa Basin.

The following **Table 7.11** summarizes the water depletions by the Domestic Water Supply in the Tularosa Basin and Salt Basin:

Table 7.11

Domestic Water Supply Depletions					
Water Supplier		**Population Served**	**Depletion Factor**	**Ground Water (AFY)**	**Total Depletion (AFY)**
Tularosa Basin	*Lincoln County*				
Rural self-supplied homes		784	0.45	32	32
Tularosa Basin	*Otero County*				
Rural self-supplied homes		7,962	0.45	401	401
TOTALS		**8,746**		**433**	**433**
Salt Basin					
Rural self-supplied homes		200	0.45	9.9	9.9
TOTALS		**200**		**10**	**10**

7.1.3.3 Industrial

The depletions for the industrial uses in the Basin vary from 100% at the landfill and Sierra Ice to 60% for Alexander Molding, Inc.

The following **Table 7.12** summarizes the water depletions by Industrial use in the Tularosa Basin:

Table 7.12

Industrial Use Depletions				
Industrial Water User	**Classification**	**Depletion Factor**	**Ground Water (AFY)**	**Total Depletion (AF)**
Otero County				
Regional Landfill	ground water	1.00	23	23
Alexander Molding, Inc.	ground water	0.60	1	1
Sierra Ice (1990 data)	ground water	1.00	0	0
TOTALS			**24**	**24**

7.1.3.4 Commercial

Because most commercial users do not directly meter their discharges, computation of depletions is difficult. Where meter data are not available, depletions are usually determined as a percentage of diversions, depending on use. Depletions for uses similar to domestic (ie; drinking, restrooms, etc.) are given domestic depletion factors (45%). Other commercial uses are assigned values associated with their individual use. Golf course (irrigation) depletions are given a factor of 92%.

The following **Table 7.13** summarizes the water depletions by commercial use in the Tularosa Basin and Salt Basin:

Table 7.13

Commercial Use Depletions				
Commercial Water User	**Classification**	**Depletion Factor**	**Ground Water (AFY)**	**Total Depletion (AFY)**
Camper Ranch	Ground water	0.45	0.07	0.07
Carrizozo Golf Association	Ground water	0.92	269.74	269.74
Mountain Springs Ranch RV Park	**Ground water**	0.45	0.90	0.90
Alamo Rosa Fuel Stop	Ground water	0.45	1.90	1.90
Alamo West Fire Dept.	Ground water	0.45	0.01	0.01
Bubby's	Ground water	0.45	0.23	0.23
Christ Community Church	Ground water	0.45	0.05	0.05
Consolidated Bottling	Ground water	0.45	0.04	0.04
Fosseen - Warehouse	Ground water	0.45	0.03	0.03
Four Square Gospel Church	Ground water	0.45	0.26	0.26
Hannis, Phillip Blaine	Ground water	0.45	0.31	0.31
Ikard & Nelson	Ground water	0.45	0.05	0.05
KC's Log Cabin Rest	Ground water	0.45	0.90	0.90
Macon, Joyce & Agold, Harold	Ground water	0.45	6.12	6.12
Melendres, Joe - Fitness Center	Ground water	0.45	0.45	0.45
Misc. Businesses	Ground water	0.45	4.50	4.50
Nickels Bar and Lounge	Ground water	0.45	0.23	0.23
Oliver Lee State Park	Ground water	0.45	0.71	0.71
Oro Vista Fire Department	Ground water	0.45	0.36	0.36
Polson & Grady Elec. Cont.	Ground water	0.45	0.14	0.14
Rio Benito Trading	Ground water	0.45	0.33	0.33
Sagebrush Investors	Ground water	0.45	0.21	0.21
Schaffer, Jean	Ground water	0.45	0.10	0.10
Schureman, Earl	Ground water	0.45	0.31	0.31
Scott Able 4-H Camp	Ground water	0.45	0.90	0.90
Southwest Engineering	Ground water	0.45	0.06	0.06
Three Rivers Petroglyph Site	Ground water	0.45	0.45	0.45
Treasure Rockhound RV Park	Ground water	0.45	2.70	2.70
Deerhead Campground (USFS)	Ground water	0.45	0.45	0.45
Karr Canyon Campground (USFS)	Ground water	0.45	0.45	0.45
Slide Group Area (USFS)	Ground water	0.45	0.09	0.09
Valenti Real Estate Services	Ground water	0.45	0.04	0.04
Waste Management of Alamogordo	Ground water	0.45	0.79	0.79
White Sands Missile Range	Ground water	1.00	218.9	218.9
White Sands National Monument	Ground water	0.45	4.02	4.02
TOTAL TULAROSA BASIN			**517**	**517**
SALT BASIN				
Timberon Golf/Country Club/Lake	Surface Water	0.92	434.80	434.80
TOTAL SALT BASIN			**435**	**435**

7.1.3.5 Irrigated Agriculture

7.1.3.5.1 Private Use by District and Area

- Crop Consumption

The total depletion of water used by irrigated agriculture includes both the consumptive irrigation requirement (CIR) of the crop and incidental depletions (ID). The ID includes such factors as evaporation from canals and laterals; transpiration by phreatophytes; water supply pipe leakage; sprinkler spray evaporation and drift; evaporation and runoff from irrigated fields and wetted crop canopies.

The ID depends on the method of irrigation used, and the relative "on-farm" efficiency. For the data reviewed, the on-farm efficiencies for the three irrigation methods are as follows:

- Flood irrigation: 60%
- Drip irrigation: 85%
- Sprinkler irrigation: 65%

The following **Table 7.14** summarizes the water depletions by Irrigated Agriculture use in the Tularosa Basin and Salt Basin:

Table 7.14

Irrigated Agricultural Depletions						
Type of Irrigation	**Depletion Factor**	**County**	**Irrigated Acreage**	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Depletion (AFY)**
Tularosa Basin						
Flood	*60%*	Lincoln	475	0	1,359	1,359
Flood	*60%*	Otero	985	3,416	549	3,965
sub-total			**1,460**	**3,416**	**1,908**	**5,324**
Drip	*85%*	Lincoln	75	0	145	145
Drip	*85%*	Otero	1,895	0	5,358	5,358
sub-total			**1,970**	**0**	**5,502**	**5,502**
Sprinkler	*65%*	Lincoln	65	0	70	70
Sprinkler	*65%*	Otero	2,850	0	7,690	7,690
sub-total			**2,915**	**0**	**7,690**	**7,759**
TOTAL TULAROSA BASIN			**6,345**	**3,416**	**15,169**	**18,585**
Salt Basin						
Flood	60%	Otero	325	0	803	803
Sprinkler	65%	Otero	2,160	0	5,741	5,741
TOTAL SALT BASIN			**2,485**	**0**	**6,544**	**6,544**

The consumptive irrigation requirement (CIR) of a crop is that quantity of irrigation water that is actually consumed or used by crops for growing or evaporated from the soil in a specific period of time. This volume of water is exclusive of rainfall. Excess water used for soil leaching is not considered in the CIR value. Extensive research has been performed to develop CIR values for specific crop types and irrigation methods.

For the Tularosa Basin and Salt Basin, the consumptive irrigation requirement (CIR) for each irrigation method depends on the location, and are as follows in **Table 7.15**:

Table 7.15

Consumptive Irrigation Requirement			
Type of Irrigation	**County**	**Irrigated Acreage**	**Consumptive Irrigation Requirement (ft)**
Tularosa Basin			
Flood	Lincoln	475	2.62
Flood	Otero	985	2.99
sub-total		**1,460**	
Drip	Lincoln	75	1.92
Drip	Otero	1895	2.83
sub-total		**1970**	
Sprinkler	Lincoln	65	1.07
Sprinkler	Otero	2,850	2.70
sub-total		**2,915**	
Salt Basin			
Sprinkler	*Otero*	2,160	2.66
Flood	*Otero*	325	2.47
sub-total		**2,485**	

7.1.3.6 Livestock

All of the livestock water diversions are considered depletions because there is no return flow into the Basin. The following **Table 7.16** summarizes the water depletions by Livestock in the Tularosa Basin (data not available for Salt Basin):

Table 7.16

Livestock Use Depletions				
Water Use	**County**	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Depletion (AFY)**
Livestock	*Lincoln*	75	82	157
Livestock	*Otero*	74	184	258
Totals		***149***	***266***	***415***

7.1.3.7 Stockpond Evaporation

All of the stockpond evaporation is considered depletions to the Tularosa Basin.

The following **Table 7.17** summarizes the depletion associated with stockpond evaporation in the Tularosa Basin (data not available for Salt Basin):

Table 7.17

Stockpond Evaporation Depletions				
County	**Total Evaporation (AF)**	**Depletion Factor**	**Ground Water (AFY)**	**Total Depletion (AF)**
Lincoln	2,098	1.00	2,098	2,098
Otero	1,867	1.00	1,867	1,867
Totals	**3,965**		**3,965**	**3,965**

7.1.3.8 Fish, Wildlife, and Recreation

There are limited fish, wildlife and recreational water uses in the Tularosa Basin, and the depletions are not determined.

7.1.3.9 Mining

The following **Table 7.18** summarizes the water depletions associated with mining (sand and gravel operations) in the Tularosa Basin:

Table 7.18

Mining Use Depletions				
Mining Water User	**Classification**	**Depletion Factor**	**Ground Water (AFY)**	**Total Depletion (AFY)**
Otero County				
Sand and Gravel Washing	ground water	0.20	4.00	4.00
TOTAL			***4.00***	***4.00***

7.1.3.10 Summary Total Depletion All Uses

The following **Table 7.19** summarizes the potential water depletions in the Tularosa Basin and Salt Basin:

Table 7.19

Summary of Present Depletions				
Use	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Depletion (AFY)**	**Percent (%)**
Tularosa Basin				
Public Water Systems	2,936	4,140	7,076	23
Domestic (self supplied)	0	433	433	1
Irrigated Agriculture	3,416	15,169	18,585	60
Livestock	149	266	415	1
Commercial	0	517	517	2
Industrial	0	24	24	0
Stockpond Evaporation	0	3,965	3,965	13
Mining	0	4	4	0
TOTAL TULAROSA BASIN	**6,500**	**24,518**	**31,018**	**100**
Great Salt Basin				
Public Water Systems	15	22	37	1
Domestic (self-supplied)	0	10	10	0
Irrigated Agriculture	0	6,544	6,544	93
Commercial	435	0	435	6
TOTAL SALT BASIN	**450**	**6,576**	**7,026**	**100**

7.1.4 Public Water Supply Systems by Community

7.1.4.1 Present Water Use Data

7.1.4.1.1 List Domestic Uses

The following **Table 7.20** summarizes the water Diversions used for Public Water Supply in the Tularosa Basin and Salt Basin (1995 data unless noted):

Table 7.20

Public Water Supply Diversions					
Water Supplier	**Population Served**	**Usage (*GPCD*)**	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Diversion (AFY)**
Tularosa Basin					
Alamogordo PWS	35,969	184	4,726	2,674	7,400
Boles Acres PWS	1,095	129	00	158	158
Canyon Hills WUA	60	160	0	11	11
Carrizozo PWS*	1,490	200	130	203	333
Cider Mills Farms	36	155	0	6	6
Dungan MDWCA	50	151	0	8	8
Freemans MHP	43	139	0	7	7
High Rolls	375	90	0	38	38
Holloman AFB	5,786	370	52	2,344	2,397
Karr Canyon Estates	50	153	9	0	9
La Luz MDWCA	2,000	83	46	139	185
Mountain Orchard	90	100	0	10	10
Nogal WCA	42	72	3	0	3
Orogrande MDWCA	72	465	0	38	38
Piney Woods WUA	55	148	0	9	9
Tularosa PWS	3,029	267	907	0	907
WSMR	2,450	797	0	2,187	2,187
Domestic Wells	8,746	98	0	962	962
TOTALS	***61,438***	***213***	***5,874***	***8,794***	***14,668***
Salt Basin					
Pinion MDWUA	200	198	0	44	44
Timberon WSD	255	107	30	0	30
Domestic Wells	200	100	0	22	22
TOTALS	***655***	***132***	***30***	***67***	***97***

* Estimated. Cathie Eisen, 2001

7.1.4.1.2 Average Daily Water Consumption

The average daily water consumption for public water supplies is computed by dividing the annual diversion by 365 days per year and converting to gallons per day. As shown in the table below, the average daily consumption of water in the Tularosa Basin, from public water supply, is more than 13 million gallons. Approximately 40% of the public water supply is derived from surface water supplies, and 60% from the ground water. For the Salt Basin, the average daily public water consumption is almost 87,000 gallons.

The following **Table 7.21** summarizes the Public Water Supply Data for the Tularosa Basin and Salt Basin:

Table 7.21

Public Water Supply Data					
Water Supplier	**Population Served**	**Usage (*GPCD*)**	**Surface Water %**	**Ground Water %**	**Total Diversion (GPD)**
Tularosa Basin					
Alamogordo PWS	35,969	184	32	18	6,606,294
Boles Acres PWS	1,095	129	0	1	141,071
Canyon Hills WUA	60	160	0	0	9,579
Carrizozo PWS*	1,490	200	1	1	297,283
Cider Mills Farms	36	155	0	0	5,589
Dungan MDWCA	50	151	0	0	7,570
Freemans MHP	43	139	0	0	5,964
High Rolls	375	90	0	0	33,817
Holloman AFB	5,786	370	0	16	2,139,627
Karr Canyon Estates	50	153	0	0	7,660
La Luz MDWCA	2,000	83	0	1	165,514
Mountain Orchard	90	100	0	0	9,035
Nogal WCA	42	72	0	0	3,044
Orogrande MDWCA	72	465	0	0	33,478
Piney Woods WUA	55	148	0	0	8,133
Tularosa PWS	3,029	267	6	0	809,923
WSMR	2,450	797	0	15	1,952,428
Domestic Wells	8,746	98	0	7	858,920
TOTALS	***61,438***	***213***	***40***	***60***	***13,094,929***
Salt Basin					
Pinion MDWUA	200	198	0	46	39,566
Timberon WSD	255	107	31	0	27,166
Domestic Wells	200	100	0	23	20,000
TOTALS	***655***	***132***	***31***	***69***	***86,732***

All figures rounded
* Estimated. Cathie Eisen, 2001

7.1.4.1.3 Per Capita Water Withdrawal Rates

As shown in **Table 7.21** above, the per capita water use varies substantially throughout the public water system. These use rates vary from just over 70 gallons per person per day (*GPCD*) in Nogal to around 465 *GPCD* in the Orogrande water system. The average water use per person in the Tularosa Basin is 213 gallons per day (*GPCD*). Typically, any type of landscape irrigation will increase the per capita consumption by as much as 100% over the typical domestic uses (drinking/cooking, bathing, washing, etc.). Additionally, in larger systems where there are commercial/industrial or irrigation (parks, etc.) uses, the per capita consumptive values are higher than their rural counterparts because the non-domestic use is averaged into the figures. For example, the City of Alamogordo overall water use is 184 GPCD, whereas the residential-only water use is about 110 GPCD. For Holloman AFB, the per-capita values shown are higher than the actual of 249 GPCD, because almost 50% of the water users live off-base, but consume water on-base. For the Salt Basin, the average daily per capita public water use is about 132 GPCD.

7.1.5 Return Flows

Return flows are the theoretical amounts of water that could return to the ground water supply, and are determined by subtracting the depletions from the diversions. Return flow can be thought of as “recharge” to the ground water system. Many factors contribute to the determination of potential return flows, including wastewater effluent disposal, septic tanks, seepage from irrigation canals, excess irrigated water from flood irrigation and others.

The following **Table 7.22** summarizes the potential return flows into the Tularosa Basin and Salt Basin:

Table 7.22

Summary of Potential Return Flows				
Use	**Surface Water (AFY)**	**Ground Water (AFY)**	**Total Return Flows (AFY)**	**Percent (%)**
Tularosa Basin	2,938	3,692	6,630	42
Public Water Systems	0	529	529	3
Domestic (self supplied)	2,277	6,421	8,698	55
Irrigated Agriculture	0	0	0	0
Commercial	0	58	58	0
Industrial	0	1	1	0
Stockpond Evaporation	0	0	0	0
Mining	0	16	16	0
TOTAL TULAROSA BASIN	**5,216**	**10,717**	**15,932**	**100**
Salt Basin				
Public Water Systems	15	22	7,690	94
Domestic (self-supplied)	0	13	157	2
Irrigated Agriculture	0	3,627	0	0
Commercial	38	0	333	4
TOTAL SALT BASIN	**53**	**3,661**	**8,180**	**100**

Approximately 33% of the return flows are from surface water diversions, and 67% from ground water diversions.

7.2 Future Water Uses in 40-Year Planning Horizon

7.2.1 Methodology to Project Future Water Needs

7.2.1.1 Public Supply and Domestic Water Needs

Water use for domestic purposes was determined using per capita consumption rates and projections in populations. Current per capita daily demand (GPCD) figures were used to project future demands, and allowances for conservation were quantified in a separate computation. Only the larger, incorporated community water system demands are shown individually, while the rural water system users, along with the individual domestic well users, are combined into a single category.

7.2.1.2 Irrigated Agriculture Water Needs

Future water needs for the irrigated agriculture sector were projected using average water application rates and consumptive use (CIR) figures for the region. Individual crop types were not separated, as the type of crop grown throughout the region may vary from year to year. The amount of acreage expected to be under irrigation was also estimated using projections based on the previous 20-year irrigation practices and public input on the desire to continue to increase agriculture-based input to the economy.

7.2.1.3 Commercial Water Needs

Water requirements for future self-supplied commercial, industrial and mining operations uses were projected using the approximate growth rate for public supply purposes. It seems that any growth in commercial activity must follow the population growth patterns.

7.2.2 Future Water Demands

7.2.2.1 Population Projections

Population projections for the planning period were developed using the University of New Mexico Bureau of Business and Economic Research (UNM-BBER) study prepared for the ISC, or available data from other studies. The data were extrapolated, where necessary, to project out to year 2040. The City of Alamogordo and Holloman Air Force Base data were obtained from a 40-Year Water Plan under development for the City of Alamogordo (projections prepared by UNM-BBER). The Village of Tularosa data were obtained from a 40-year water system master plan recently completed for the Village of Tularosa. The Timberon data were obtained from a water plan recently completed by the Timberon Water and Sanitation District. The data for the Town of Carrizozo were obtained from public input. WSMR population assumes current levels. Data for the population served by small water systems and self-supplied domestic wells were developed using OSE figures and averaged projected growth rates from the UNM-BBER study. In all cases, the most recent population projections were used as applicable, whether UNM-BBER or local available study.

The following **Table 7.23** summarizes the projected future populations in the Tularosa Basin and Salt Basin (see also **Appendix 7.2**):

Table 7.23

Projected Populations for 2000, 2020 and 2040				
	Population			
Area/Year	**1995**	**2000**	**2020**	**2040**
Tularosa Basin				
Alamogordo	30,136	35,969	46,366	56,137*
Holloman Air Force Base	5,547	5,786	5,234	5,234
Tularosa	3,029	3,512	6,594	12,162*
Carrizozo†	1,056	1,490	1,490	1,490
Rural Water Systems	2,450	2,450	2,450	2,450
Rural Domestic Wells	8,746	9,400	11,280	13,160
TOTAL TULAROSA BASIN	**54,932**	**62,807**	**78,454**	**96,513**
Salt Basin				
Timberon	255	331	593	837
Pinion MDWUA	200	210	250	290
Rural Domestic Wells	200	200	240	280
TOTAL SALT BASIN	**655**	**741**	**1,083**	**1,407**

*From separate studies
† Assumed

7.2.2.2 Public Water Supply

The average daily per capita water consumption (*GPCD*) in the Public Water Supplies of the Basin varies greatly from system to system. The major water systems are shown separately to account for the variation of per capita consumption rates. The small community water systems are grouped together. It is assumed that the current per capita use rates will continue into the planning period; however, conservation measures could reduce these values by 20% or more.

The per capita consumption for domestic wells varies from the northern portion of the Basin (80 GPCD) to the southern areas (100 GPCD). An average value of 98 GPCD was used for future water use in self-supplied domestic wells for the Tularosa Basin and 100 GPCD for the Salt Basin.

The following **Table 7.24** summarizes the projected annual Public Water Supply diversions in the Tularosa Basin and Salt Basin:

Table 7.24

Projected Public Water Supply Diversions				
		Diversion (AFY)		
Area /Year	***GPCD***	**2000**	**2020**	**2040**
Tularosa Basin				
Alamogordo	165	7,400	8,570	10,375
Holloman Air Force Base	370	2,397	2,169	2,169
Tularosa	267	907	1,972	3,637
Carrizozo	200	333	334	334
WSMR	800	2,195	2,195	2,195
Rural Water Systems	108	508	610	711
Rural Domestic Wells	98	1,032	1,238	1,445
TOTAL TULAROSA BASIN		**14,772**	**17,088**	**20,867**
Salt Basin				
Pinion MDWUA	198	73	132	186
Timberon	137	32	38	145
Rural Domestic Wells	100	22	27	31
TOTAL SALT BASIN		**128**	**197**	**262**

AF/AN – acre-feet/annum

7.2.2.3 Industrial, Commercial and Mining

As the majority of industrial and commercial users are being served from a public water system, it is assumed that those relying on wells would continue to increase at a small rate throughout the planning period.

The following **Table 7.25** summarizes the projected annual industrial, commercial and mining water diversions in the Tularosa Basin:

Table 7.25

Industrial, Commercial and Mining Projected Water Diversions			
	Diversion (AFY)		
Use/Year	**2000**	**2020**	**2040**
Tularosa Basin			
Industrial	25	30	35
Commercial	575	600	625
Mining	20	20	20
TOTAL TULAROSA BASIN	***620***	***650***	***680***
Salt Basin			
Commercial	500	550	600
TOTAL SALT BASIN	***500***	***550***	***600***

7.2.2.4 Irrigated Agriculture

The amount of irrigated agriculture lands was assumed to remain within the range of current practice (1975 – 1990), with the assumption that as some agricultural lands are converted to subdivisions, others that are now fallow will be brought into production.

The following **Table 7.26** summarizes the projected annual irrigated agriculture water diversions in the Tularosa Basin and Salt Basin:

Table 7.26

Irrigated Agriculture Projected Water Diversions			
	Diversion (AFY)		
Use/Year	**2000**	**2020**	**2040**
Tularosa Basin			
Irrigated Acreage	6,000	6,650	7,000
Diversion (Acre-Feet/Acre)	4.5	4.7	5.0
TOTAL TULAROSA BASIN	**27,000**	**31,325**	**35,000**
Salt Basin			
Irrigated Acreage	2,550	2,675	2,805
Diversion (Acre-Feet/Acre)	4.0	4.0	4.0
TOTAL SALT BASIN	**10,200**	**10,700**	**11,220**

7.2.2.5 Livestock and Stock Pond Evaporation

It is assumed that the current livestock water use and stock pond evaporation rates will continue into the planning period.

The following **Table 7.27** summarizes the projected annual livestock and stock pond water diversions in the Tularosa Basin:

Table 7.27

Livestock and Stock Pond Evaporation Projected Water Diversions			
	Diversion (AFY)		
Use/Year	**2000**	**2020**	**2040**
Livestock	415	415	415
Stockpond Evaporation	3,965	3,965	3,965
TOTAL TULAROSA BASIN	**4,380**	**4,380**	**4,380**

7.2.2.6 Fish, Wildlife and Recreation

There are limited fish, wildlife and recreational water uses in the Tularosa Basin. Future water uses for these categories were not estimated.

7.2.2.7 Summary Total all Uses

The following **Table 7.28** summarizes the projected annual water diversions in the Tularosa Basin and Salt Basin (see **Fig. 7.2**):

Table 7.28

Summary of Projected Future Water Diversions			
	Diversion (AFY)		
Use/Year	**2000**	**2020**	**2040**
Tularosa Basin			
Public Water Systems	14,772	17,088	20,867
Irrigated Agriculture	27,000	31,255	35,000
Others	5,000	5,030	5,060
TOTAL TULAROSA BASIN	**46,772**	**53,373**	**60,927**
Salt Basin			
Public Water Systems	128	197	262
Irrigated Agriculture	10,200	10,700	11,220
Commercial	500	550	600
TOTAL SALT BASIN	**10,828**	**11,447**	**12,082**

For the planning horizon of 2000 to 2040, water use in the Tularosa Basin may grow from more than 43,000 acre-feet per year to approximately 64,000 acre-feet per year, and water use in the Salt Basin may grow from 10,800 acre-feet per year to over 12,000 acre-feet per year.

7.2.3 Future Water Depletions

Based on average current depletion factors previously discussed, the following Table **7.29** shows potential future depletions.

Table 7.29

Summary of Projected Depletions			
	Depletion (AFY)		
Use/Year	**2000**	**2020**	**2040**
Tularosa Basin			
Public Water Systems	7,386	8,544	10,434
Irrigated Agriculture	17,550	20,316	22,750
Others	4,250	4,276	4,301
TOTAL TULAROSA BASIN	**29,186**	**33,135**	**37,485**
Salt Basin			
Public Water Systems	58	89	118
Irrigated Agriculture	6,630	6,955	7,293
Commercial	325	358	390
TOTAL SALT BASIN	**7,013**	**7,401**	**7,801**

7.2.4 Future Water Return Flows

The future projected return flows are indicated below in Table **7.30**.

Table 7.30

Summary of Projected Potential Return Flows			
	Return Flow (AFY)		
Use/Year	**2000**	**2020**	**2040**
Tularosa Basin			
Public Water Systems	7,386	8,544	10,434
Irrigated Agriculture	9,450	10,939	12,250
Others	750	755	759
TOTAL TULAROSA BASIN	**17,586**	**20,238**	**23,443**
Salt Basin			
Public Water Systems	70	108	144
Irrigated Agriculture	3,570	3,745	3,927
Commercial	175	193	210
TOTAL SALT BASIN	**3,815**	**4,046**	**4,281**

8. WATER PLAN ALTERNATIVES

8.1 Water Supply vs. Future Demands

8.1.1 Graphical Analysis of Supply vs. Demands

<u>Tularosa Basin</u>

As previously described in Section 6, the total annual sustainable yield for to the east portion of the Tularosa Basin is approximately 129,000 AFY. The total projected water demands for the same area approach 60,000 AFY by the year 2040. The quality of the water (that can be practically recovered) ranges from less than 1,000 mg/L TDS in the bedrock portions of the Sacramento Mountains and alluvial material south of Alamogordo to more than 3,000 mg/L TDS generally west of an arbitrary Highway 54 north-south divide.

Sustainable yield for the entire Tularosa Basin approaches 300,000 AFY, whereas the total projected demands (2040) in the entire Tularosa Basin are approximately 62,000 AFY. Refer to **Figure 8.1** for the Total East Basin water balance. Refer to **Figure 8.10** for the Entire Tularosa Basin water balance. (Note :Fig. 8.2 to 8.9 do not include using ground water in storage)

Although this general water budget appears to indicate a surplus in sustainable yield in the system of almost 70,000 AFY in the Eastern Tularosa Basin, this can be misleading. The areas of surplus recharge may not necessarily follow the areas of demand, and periods of drought can reduce watershed yield 50 percent below the annual average (see Section 6.1.3). Furthermore, water quality has a major role in the actual suitability of the resource for use in either irrigated agriculture or as a potable supply for domestic wells and public water systems. Therefore, to provide a better level of supply vs. demand budgeting, the Eastern Tularosa Basin water budget is further sub-divided into "reaches" based on supply and demand centers, usually by watersheds, and a water budget prepared for each of the reaches.

Because it is difficult to estimate the ground water yield for each sub-reach without a detailed groundwater flow model, the surface water yield only is shown on **Figures 8.2** to **8.9**. An additional 63,250 AFY of ground water yield is also available but not detailed. A summary of each sub-reach water balance follows.

Three Rivers to Rinconada Canyon

The total surface water supply (inflow) to the area from Three Rivers to Rinconada Canyon is approximately 18,000 AFY on the average, and potentially less than 9,000 AFY during periods of drought. Demands in this reach are mainly irrigation of pecan orchards and alfalfa, which total about 2,500 AFY by the year 2040. A surface water "surplus" of 7,500 to 15,500 AFY is available, with a water quality of 1,000 to 3,000 mg/L TDS. The majority of ground water in this area is greater than 2,000 mg/L TDS. Lower TDS water comes from the Armijo springs at the headwaters of the Three Rivers. Refer to **Figure 8.2** for the Three Rivers to Rinconada Canyon water balance.

Rinconada Canyon to La Luz Canyon

The total surface water supply (inflow) to the area from Rinconada Canyon to La Luz Canyon averages approximately 33,000 AFY, and may be as low as 16,000 AFY during periods of drought. Demands in this reach are mainly irrigation around Tularosa, domestic wells and the public water systems of the Village of Tularosa and La Luz. These demands will total about 33,000 AFY by the year 2040. A current "surplus" of about 17,000 AFY is expected to decrease to less than 1,000 AFY in the future, based on total diversions. Refer to **Fig. 8.3** for the Rinconada Canyon to La Luz Canyon water balance.

However, in this reach of the watershed, return flows may be applicable to the water budget. As water is pumped (or diverted from Rio Tularosa) and enters the irrigation network, a portion is not used by the crop and is returned to the ground water system. The actual amount which returns is not quantifiable, but some estimates have been attempted and are discussed in Section 7. Since the return flows can be thought of as supply, only the net depletion needs to be evaluated in the water budget for this area. Based on using only the depletions (as demands), the water balance is a somewhat better picture. **Figure 8.4** indicates the budget based on depletions, and shows that on the average there is a potential surplus of sustainable supply varying from 22,000 AFY in the year 2000 which reduces to about 17,000 in the year 2040.

Additionally, water conservation may be an important factor in reducing water demands and depletions. As discussed in more detail later in this Section, an overall reduction in demands of up to 20% may be practical over the planning period. Reaching a 20% level of conservation is assumed to require 40 years. This reduction should be across the board, in both the M&I category as well as irrigated agriculture. If such a savings can be accomplished, then (based on the diversion) a reduction in demands of more than 7,000 AFY by year 2040 is possible. The net demand by then would be about 26,000 AFY versus an average supply of about 33,000 AFY. Additionally, evaluating only the depletions (and conservation) would indicate an even better picture in this reach. Refer to **Figure 8.5** for the water budget using conservation in this reach.

The water quality in the area ranges from 1,500 to more than 3,000 mg/L TDS. The quality of the majority of ground water in this area is greater than 2,000 mg/L TDS. Refer to **Figure 8.3, 8.4** and **8.5** for the various Rinconada Canyon to La Luz Canyon water balances.

La Luz Canyon to Alamo Canyon

The total surface water supply (inflow) to the area from La Luz Canyon to Alamo Canyon averages approximately 12,000 AFY (which includes importation of Bonito Lake water). Demands in this reach include the Alamogordo public water system, domestic wells and rural water systems. There are also some irrigated agriculture and commercial uses. These demands will total about 20,000 AFY by the year 2040. A current deficit exists in surface water supply, indicating reliance on ground water mining.

However, in this reach of the watershed, the majority of return flows are not applicable to the water budget. Water is pumped (or diverted from the La Luz/Fresnal and Alamo Canyon diversions) and enters the Alamogordo public water system where it is consumed. The return flow enters the wastewater system and is treated at the reclaimed water treatment plant. These treated reclaimed waters are re-used on the golf course and city parks. Some of the current uses for reclaimed water is for irrigation of parks and golf courses, dust control, industrial uses, and construction which offsets the demand on the potable water supply.

Figure 8.6 indicates the water budget based on the total diversions. **Figure 8.7** shows the potential effects of water conservation. The achievement of a 20% level of conservation potentially reduces demands to about the supply amounts in the year 2040. The actual amount reduced by conservation will probably be somewhere between the two values. The City of Alamogordo has observed a substantial reduction in water use due to conservation and re-use efforts over the last few years, and in some months greater than 4-million gallons per-day.

The water quality in the area ranges from less than 1,000 mg/L (in the canyons) to more than 4,000 mg/L TDS. The quality of the majority of ground water in this area is greater than 2,000 mg/L TDS.

Alamo Canyon to Escondido Canyon

The total surface water supply to the area from Alamo Canyon to Escondido Canyon is approximately 3,000 AFY. Demands in this reach are mainly domestic wells, Holloman AFB wells and some irrigation of orchards, all of which are expected to reach a demand of about 3,000 AFY by the year 2040. A surplus supply may be available (ground water), with a water quality of <1,000 to about 3,000 mg/L TDS. However, this area is a part of the NMOSE Tularosa Basin Administrative Area, and is administratively limited. The majority of available water rights in this area are used, and approval for additional appropriation of ground water by the NMOSE is highly unlikely. Past pumping has caused some accumulated drawdown (**Figure 6.20**), indicating recharge does not offset pumping. The majority of ground water in this area has a quality of less than 1,000 mg/L TDS. Refer to **Figure 8.8** for the Alamo Canyon to Escondido Canyon water balance.

Escondido Canyon to Culp Canyon

The total surface water supply to the area from Escondido Canyon to Culp Canyon is approximately 5,000 AFY. There are currently small demands from domestic and stock wells in this reach. Therefore, a surplus of more than 5,000 AFY may be available, with a water quality of <1,000 to about 3,000 mg/L TDS. However, this area is also a part of the NMOSE Tularosa Basin Administrative Area, and is administratively limited (see discussion above). The majority of ground water in this area is less than 1,000 mg/L TDS. Refer to **Figure 8.9** for the Escondido Canyon to Culp Canyon water balance.

Salt Basin

Sustainable supply to the Salt Basin is approximately 150,000 AFY as previously discussed in Section 6. The demands in the Salt Basin include primarily irrigated agriculture and domestic/stock wells in the lower flats, and Timberon and Pinon communities in the higher elevations. A demand of almost 12,000 AFY will be required by the year 2040. Refer to **Figure 8.11** for the Salt Basin water balance.

8.1.1.1 Water Balances at the Local Level

Background

Although the hydrologic data indicate that the average, annual sustainable supply of water into the Tularosa Basin in terms of the planning region as a whole, in terms of the three individual sub-basins and in terms of selected drainage canyons within the eastern sub-basin is adequate at the present time to meet all demands, a significant fraction of this supply is not, in general, recoverable for use by municipalities, by small communities, or by small water associations from a practical and cost effective standpoint. Inflow is defined here as the total amount of precipitation that becomes surface water and/or enters the underground aquifer. The inflow will, of course, vary from year to year depending upon the precipitation, particular the snowfall levels. Capture of the water is made difficult by the diffuse nature of the source, by the fact that a significant amount of underground water flows down the western slopes of the Sacramento Mountains in limestone beds in solution or fracture zones which are difficult to find, and by the fact that the water becomes more saline as it spreads out into the valley alluvial fill, principally along the alluvial fans.

In order to evaluate the potable water supply relative to demand, an analysis has been made of the actual supplies available to some selected population centers in the basin. The analysis is based upon current well field and surface water yields. In this case the definition of a potable water supply is that amount of water that can cost-effectively be captured, and that has a TDS value of 1,000 mg/L or less. In addition, it assumes that the water that can be economically recovered would require only treatment by sedimentation/filtration and disinfection, at most, to render it safe for human consumption (no TDS reduction).

From this standpoint, most population centers in the Tularosa Basin have an average, annual, sustainable water supply that is only slightly larger than the demand or, in some cases (especially under drought conditions), less than the demand. This fact implies (and it is obvious from an analysis of the daily supply and demand data kept by various municipalities) that a shortfall already exist in the summer months. It is this shortfall that must be addressed by the Regional Water Plan through the application of one or more of the alternatives that are identified and evaluated in Section 8.2. Some of these alternatives are already used in order to meet the water needs of the community on a seasonable basin. One of these alternatives is blending, wherein the existing supply of potable water (which generally has a moderately low TDS load) is blended with well water which usually has a TDS of greater than 1,000 ppm. The blended water will then generally meet potable requirements.

Location of Critical Water Supply Conditions

The population centers where the water situation is critical at the present time are Timberon, Orogrande, Tularosa, and, most significantly because of the population density, the area around the City of Alamogordo which consists of the City itself, Holloman Air Force Base, Boles Acres, La Luz Canyon, other populated canyons, and some small county subdivisions. Two other communities where conditions may become critical in the near future are Carrrizozo and Nogal which depend to a great extent on their limited water rights to water in the Bonito pipeline. Since all of the water in the pipeline is appropriated, there is no flexibility in this source and water for the summer months and for the future must come from other sources unless the water in the pipeline or water rights can be bought. However, it should be noted that water from Bonito Lake is not a "guaranteed" supply, in that it is subject to drought conditions which may limit or reduce the available flows.

Water Supply Conditions for the City of Alamogordo and the Surrounding Area

Table 8.1 lists the estimated annual, average supply of potable water for the Alamogordo area by source and compares it to the current demand and the anticipated demand for the year 2040. Five currently utilized sources are identified, and the amount of water that can be withdrawn from each on a sustainable basis is estimated. The total is about 14,700 AFY, a value which is only slightly above the estimated annual average water demand of about 13,290 AFY for the area for the year 2000 and well below the estimated need of 21,000 AFY for the year 2040. The demand includes estimated domestic and commercial requirements as well as the needs for the City itself, small public water suppliers, and other nearby communities, all of which depend on basically the same water supply and recharge area.

Table 8.1

LA LUZ TO DOG CANYON RECHARGE AREA[(1)] WATER SUPPLY/DEMAND

(ESTIMATED ANNUAL AVERAGE SUSTAINABLE POTABLE WATER SUPPLY) [(2)]
(YEAR 2000)

SOURCE	AMOUNT (ACRE-FEET/YEAR)
1. La Luz/Fresnal Stream System	7,366 [(3)]
2. Alamo Canyon	1,100 [(6)]
3. Bonito Lake	2,898 [(7)]
4. HAFB Well Field	1,679 [(14)]
5. Boles Acres	1,417 [(8)]
TOTAL	14,460

(ESTIMATED ANNUAL AVERAGE POTABLE WATER DEMAND

LOCATION	AMOUNT (ACRE-FEET PER YEAR)	
	YEAR 2000	YEAR 2040
1. City of Alamogordo	7,400 [(9)]	10,375 [(9)]
2. HAFB	2,502 [(9)]	2,502 (9)
3. Boles Acres	158 [(10)]	221 [(13)]
4. La Luz/Laborcita Canyons	500 [(11)]	700 [(13)]
5. La Luz MDWCA	185 [(10)]	259 [(13)]
6. Domestic	481 [(4)]	673 [(13)]
7. Commercial	100 [(5)]	140 [(13)]
8. Other Public Water Supplies	98 [(12)]	137 [(13)]
TOTAL	11,424	15,007

(1) Includes all of the La Luz canyon recharge area (65 square miles), in addition to the area southward to and including the Dog Canyon recharge area (9 square miles). Includes the major communities of Alamogordo, Holloman Air Force Base, the Community of La Luz, the residents of the La Luz and Laborcita Canyons, Boles Acres, and the residents of Fresnal Canyon (High Rolls and Mountain Park)

(2) Potable Water is defined as water that has a total TDS content less than or equal to 1,000 ppm, is safe for human consumption, and requires no more than a sedimentation/filter removal step for turbidity control and a chlorination step.

(3) See report by John Shoemaker and Associates, Inc. (JSAI), dated March, 2001, page 9. See also "Detailed Flow Study of La Luz/Fresnal Stream System", Daniel Engineering Company, March 16, 1982. The latter document estimates the flow at about twice the JSAI value, but is generally considered an overestimate.

(4) Estimate based on assumption that one half of the population (7,962) that is using domestic water supplies is located in the area whose water supply is from the La Luz to Dog Canyon recharge area (inclusive).

(5) Estimate of commercial use requiring potable water within the La Luz to Dog Canyon recharge area (inclusive).

(6) 1999 Data from City of Alamogordo

(7) City of Alamo & HAFB Water Rights

(8) Estimated from well field data

(9) Table 7.24

(10) See Draft RWP, page 27, Dated Approximately May, 2001

(11) Personal Communication

(12) Sum of use by entities not covered above. See Draft RWP, page 12, Dated Approximately May, 2001

(13) Assume a 40% growth in population between 2000 and 2040.

(14) See S. D. Theodosis, "Water Supply Program Projections, Holloman AFB, December, 1967, Page 5

Insofar as the City itself is concerned, in the summer months, blending of Bonito pipeline water and other surface waters with well water in the 1200 to 1400 mg/L TDS range is already practiced. This option, and a strong conservation program based on a conservation education effort, a restriction of water use to a certain time-of-day and day-of-use, lining and covering the reservoirs with plastic, and an extensive use of reclaimed water in parks, has made it possible to offset the shortfalls in supply to date. Efforts are also underway to store water available from the La Luz/Fresnal canyon sources in the winter months in the underground basin fill aquifer so that it can be recovered in the summertime.

Although these efforts have made it possible for the City and Holloman Air Force Base to solve the water shortfall in the near term, other measures will be needed in order to meet their future demands. Steps need to be taken now since it usually takes several years to implement an offset option.

The shortfall issue in the Alamogordo area is further complicated by the fact that the residents in La Luz and adjacent canyons depend on the same source of water and the same watershed area as does the City of Alamogordo. In the 1940's and 1950's, the City, as legally permitted, diverted the springs in the canyons and installed a collection system and a transmission line from the source to the city. In recent years the City has improved the collection system so that losses are reduced and a higher water quality can be achieved. Higher water demand in the canyons area caused by a substantial increase in the tree and shrub density in the watershed area, the drilling of domestic wells (approximately 482), and because of a diminished water supply available throughout the area caused by drought conditions has diminished, and at certain times completely stopped the flow of water down the streambeds in the canyons.

The City also has water rights and available water from Fresnal and Alamo Canyons in the Sacramento Mountains, but all of the sources have experienced a reduction in flow due to drought and are needed to meet demands.

The Bonito pipeline has become unreliable due to an increasing number of failures in recent years. A contract to replace the pipeline is currently underway. Some sections of the old pipeline are being saved in order to serve as a potential conveyance for water that may become available from north of Tularosa.

Water Supply Conditions in Carrizozo, Nogal, and the Surrounding Area

Table 8.2 shows the amount of water available to these two communities. Both have small amounts of water rights to the water in the Bonito pipeline. However, as can be seen from the estimated demand for the year 2000 and from the projected demand for the year 2040, the Bonito pipeline supply alone is insufficient in terms of water rights to that supply. Carrizozo has wells which have been utilized to augment the Bonito pipeline water and blending has been done. The City of Carrizozo is also in the process of drilling additional wells. Nogal, on the other hand, has been purchasing from the City of Alamogordo additional water in the pipeline, over and above their existing water rights, in order to meet ongoing demand. Whether or not this remedy can continue is open to question as the demand for water in the Alamogordo area continues to increase as noted above. Nogal plans to construct a well to offset the future water demands. They should pursue a long-term agreement with the City of Alamogordo or other entity to purchase water from Bonito Lake or ground water sources nearby.

Table 8.2

CARRIZOZO RECHARGE AREA WATER SUPPLY AND DEMAND

ESTIMATED ANNUAL AVERAGE SUSTAINABLE POTABLE WATER SUPPLY
(YEAR 200)

SOURCE	AMOUNT (ACRE FEET PER YEAR)
1. Bonito Lake (Carrizozo)	130.0
2. Bonito Lake (Nogal Water Assoc.)	1.5
Total	131.5

ESTIMATED ANNUAL AVERAGE POTABLE WATER DEMAND

LOCATION	AMOUNT (ACRE-FEET PER YEAR)	
	YEAR 2000	YEAR 2040
1. Village of Carrizozo	330	330
2. Nogal Water Association	5	15
Total	335	345

Water Supply Conditions in the Village of Tularosa and the Surrounding Area

Table 8.3 shows the water supply and demand condition for the Village of Tularosa. As can be seen, the demand of 1,050 AF for the year 2000 for water is only slightly less than the supply on average. During the summer months, the demand will sometimes exceed the amounts of water to which the Village has water rights in Tularosa Creek, even though water appropriated to others may still be available in the creek. To date, the Village has purchased water from the Tularosa Community Ditch Corporation in order to meet its needs, but the current water situation is sufficiently severe that the Village has placed a moratorium on new connections outside of the Village. The Village has one well within the Village limits which has a capacity of 450 GPM, but the TDS in the water is greater than 1,000 ppm; consequently, blending with water from Tularosa Creek is used. Consideration is being given to drilling another well with similar capacity. The Village presently services 1,171 water hookups. Of these, 71 are outside the Village limits. The Village expects to expand the Village limits in the near future and include additional hookups.

Table 8.3

TULAROSA RECHARGE AREA WATER SUPPLY AND DEMAND

ESTIMATED ANNUAL AVERAGE SUSTAINABLE POTABLE WATER SUPPLY
(YEAR 2000)

SOURCE	AMOUNT (ACRE-FEET PER YEAR)
1. Tularosa Creek	965

ESTIMATED ANNUAL AVERAGE POTABLE WATER DEMAND

LOCATION	AMOUNT (ACRE-FEET PER YEAR) YEAR 2000	YEAR 2040
1. Village of Tularosa	948*	2,476**

*See page 4-2 of the Village of Tularosa Comprehensive Water Study, September 1996

** Linear Extrapolation of Data from the Year 2000 to the Year 2040, op.cit.

The Village of Tularosa has a unique situation in which a 49 square block area in the older section of the Village has, by court decree, rights to 1,200 AFY of surface water for irrigation of gardens and orchards. (Refer to **Appendix 5**)

The Village has taken steps to improve water conditions in the Village by obtaining funding for the construction of a new, 2.0 MGD water filter plant, with the capability of increasing capacity to 4.0 MGD. The latter improvement will require the Village to seek additional water rights to meet the demands of future growth. Once the new plant is built, and if the moratorium is lifted, it is estimated that enough water could be provided to support a population in the range of 8,000 to 14,000 within the Village limits in terms of the water treatment system.

The Village of Tularosa has recently completed a total rehabilitation of the water storage tanks serving the community, but an additional capacity of 3-million gallons is needed to meet future growth.

The Village of Tularosa is currently in the process of applying for additional water rights through the Office of the State Engineer.

Water Supply Conditions in Timberon and Orogrande

Timberon has experienced a severe reduction in the spring flows and well capacity in the area in the last year or so. Springs that historically provided 600 GPM are now producing only 65 GPM. Two existing wells now produce only 40 and 22 GPM from depths of 450 to 480 feet, respectively. To date, three new wells have been drilled, but no significant flow rates have been achieved. There are plans to continue well drilling.

The current demand for water for Timberon is about 680 AFY. Current supply is about 220 AFY; therefore severe water use restrictions are in place, particularly for golf courses and swimming pools. Timberon is expecting to grow significantly in population in the next 40 years as a result of the construction, currently going on, of a paved highway to the community. The population grew 15% in the last year and one-half and is expected to continue this rate of growth as a result of the paved highway access. Thus a severe water shortage exists at this time and would be projected to only get worse if steps are not taken to offset the shortfall.

Although there would not appear, from a geographical standpoint, to be a connection between the water issues in Timberon and Orogrande, in fact Orogrande's water supply comes via pipeline from the same watershed as that for Timberon. A 42 mile long pipeline has historically provided Orogrande's water from the Sacramento River Basin. The drought conditions in the Sacramento River basin that are impacting the Timberon water supply are affecting the supply of water to Orogrande as well. The amount of water held in the Sacramento Lake, which tends to be a cienega at best, has diminished significantly in recent years. In addition to Orogrande's water rights to the pipeline water, three other entities have water rights also. These are the BLM, the Johnson Ranch, and the Circle Cross Ranch. This pipeline was constructed in the 1920's and, although sections have been replaced, is basically in poor condition in terms of leaks and collapses. It is in need of constant repair. There are, in addition, problems with scale buildup so that flow becomes restricted.

Orogrande has water rights to 100,000 gallons per day (112 AFY), but only about 20,000 gallons per day (22 AFY) is available from the pipeline if it is operating. Since Orogrande is located in the central area of the Tularosa Basin, their only other practical water supply at present is well water, but that water tends to be high in TDS, of the order of 2,000 ppm or more. The flow from wells is typically only about 25 GPM.

Recommended Solutions to Water Shortfall

See Section 8.3.3 and following for recommended solutions to the water issues described above. See **Table 8.4** below for potable water supply and demands.

ESTIMATED ANNUAL AVERAGE POTABLE WATER SUPPLY
(YEAR 2000)

SOURCE		AMOUNT (AFY)	
Carrisa Springs		75 (current)	600 (historical)
Supplemental Wells		62 (current)	0 (historical)
	Total	137 (current)	600 (historical)

ANNUAL AVERAGE POTABLE DEMAND

SOURCE	AMOUNT (AFY)	
Carrisa Springs	220* (Year 2000)	800* (Year 2040)

*Information provided by the TWSD on 11-17-01
Population = 350 (2000) and 4,500 (2040)

8.2 Future Water Supply Alternatives

8.2.1 Water Management Alternatives

The water resources in the Tularosa and Salt Basins can be extended with proper management tools. These tools include educational, institutional and governmental programs which protect and enhance the water resources in the Planning area. Some suggested water management alternatives are:

8.2.1.1 Public Education

Management begins with education. An aggressive public educational campaign on water conservation and supply protection would extend the water supplies, both in the mountain areas as well as the communities.

8.2.1.2 Water Conservation and Reuse

Water conservation plans should be developed by each community. Conservation goals should be established and progress monitored. Incentives should also be developed to accompany the plan.

8.2.1.3 Restrictions on Development

The mountain areas in the Planning Region have limited water resources. A detailed study on the sustained yields and levels of development would help administrate growth and protect water resources. This would require a ground water flow-model and hydrologic study. As a minimum, developers should be required to obtain water rights for subdivisions, even for those proposing domestic wells. The Office of the State Engineer could set up a special Administrative Area, where limitations on water use and density of development are specified. County ordinances can be developed to regulate water use.

8.2.1.4 Supply Blending

In areas where low TDS water is available (<500 mg/L), this can be blended with higher TDS ground water (>1,000 mg/L) to increase the quantity of supply. There will be some trade-off in water quality, however. This may not be acceptable to the public in all cases.

8.2.1.5 Special Administrative Areas

Some areas in the Planning Region may benefit from a Special Administrative Area administered by the NMOSE or Otero County. The Sacramento Mountain communities is one area where tighter restrictions on water use may benefit. This option should be evaluated further.

8.2.1.6 Water Quality Monitoring Programs

A program should be developed to monitor the quality of the various water resources in the Tularosa and Salt Basins.

8.2.1.7 Water Level Monitoring Programs

Monitoring stations should be installed to monitor the ground water levels in the Tularosa and Salt Basins, to augment the USGS database.

8.2.1.8 Stream Gage Monitoring Programs

Stream gages should be re-established on the major stream systems in the Tularosa and Salt Basins.

8.2.1.9 Climate Monitoring Programs

Additional climate monitoring and data collection systems should be established in the Planning Region.

8.2.1.10 Water Planning Committee

The Water Planning Committee should continue to meet on a regular basis to implement the recommendations in this Plan.

8.2.2 Water Development Alternatives

Whereas the Water Management Alternatives outline managerial methods to extend the life of the supply, the following Water Development Alternatives actually create “wet water” for the Region. Some of these develop currently unusable water (due to quality i.e. desalination) while other alternatives increase supply in the Basin (rainfall/snowpack augmentation, watershed management).

8.2.2.1 Watershed Management

One of the major alternatives for offsetting the shortfall between the demand for water and the supply of water in the Tularosa Basin, especially around Alamogordo and Tularosa, relates to watershed management. Since the recharge for a major part of the ground water supply and for springs in the Basin occurs on the western slopes of the Lincoln National Forest in the Sacramento and Capitan Mountains, it is essential to understand the role that plant life plays in the ground and surface water yields from these forested regions. Although there still exists some differences of opinion among hydrologist and forest scientists as to how much of an increase in water yield can be achieved by the removal, replacement, and control of vegetation, the preponderance of the studies and field work performed to date seem to indicate that improvement of water yield is achievable through environmentally acceptable watershed management at elevations in this area above about 6,000 feet.

The increase in yield depends, in part, on the specific type of vegetation now occupying the watershed, the topography, the geology, and the soil types; consequently, it is essential that data collection be initiated in the very near future for this watershed so that existing calculational models, which have been calibrated for other specific areas, can be run in order to estimate the change in yield. The possibilities for developing new and significant amounts of water by watershed management are sufficiently high that one cannot fail to investigate this option in detail. Unfortunately, proving the effects is time consuming and difficult since the “before” and “after” conditions can be overwhelmed by the variability in precipitation from year to year. Nevertheless, the potential in this area is so large that it cannot be overlooked.

Prompt action is also suggested in view of the fact that forest management issues have reached the national level as a result of the catastrophic fires that took place in the western U.S. this last summer. The steps to be taken to reduce the fire hazard in our national forests and to restore the forest to a healthier state more akin to pre-settlement conditions are very similar to those needed to improve the water yield. There exists therefore a window of opportunity to work with the Federal Government to fund forest restoration work in our area. This opportunity should not be lost, because the potential exists to obtain “new” water that is currently being lost and may be increasingly lost to evapotranspiration as the basal area of the forest watershed continues to increase as a result of the suppression of natural fires.

A conservative estimate of the yield of water from forest management on the western slopes of the mountains around Alamogordo is found to be about 5,000 acre-feet per year, based upon an assumed reduction of basal area of the existing forested areas of about 30%.

Watershed restoration and management would be applied to approximately 269,000 acres of watershed lands above 6,000 feet in elevation along the eastern Tularosa Basin from Rinconada Canyon to Dog Canyon. Potential additional water yields range from nil to around 2 in/year, depending on ground elevation (according to Garrett, 2001). From this analysis, approximately 15,000 AFY in additional watershed yield may be expected. This is added to the watershed in the form of water for vegetation, runoff, stream and spring flows and some ground water recharge. Costs associated with this alternative are estimated at approximately $230/AF. This cost is based on an average cost of $350 per acre on the average for clearing, exclusive of maintenance, but the costs can vary from actually being a profitable operation (timber harvest) to costs as high as $800 per acre if all of the slash must be removed and the cuttings have no economic value.

Additional water yields from tree thinning alone may not be adequate to realize the full potential of ground water recharge. The construction of small retention dams beginning in the upper watershed is recommended in combination with reseeding to reduce surface runoff and enhance ground water recharge. Erosion control measures, including streambank protection, may also be needed to reduce sedimentation.

The construction of small retention ponds in the upper watershed tributaries would enhance ground water recharge to the bedrock aquifer. This would be of great benefit to the mountain communities (domestic wells) as well as spring and stream users. Additionally, retention ponds can be used to reduce peak flows from summer storm runoff, thereby reducing flood potential and allowing recharge of this water (which typically runs-off rapidly without recharge). Improved meadows are also an important feature at watershed restoration.

The committee strongly encourages cooperation between all agencies and entities in implementing and funding a comprehensive watershed restoration program. These agencies should include as a minimum, the Natural Resources Conservation Service, the Forest Service, and other USDA agencies which also have authority involving watershed and flood prevention issues.

The Otero County Commissioners have taken an active role in addressing watershed and forest restoration issues. They have proposed a Lincoln National Forest Demonstration Program, supported by the Forest Service, which advocates accelerated implementation of watershed restoration activities. This program, the County Partnership Restoration Program (CPRP), has just received special funding from the US Department of Agriculture to implement forest and watershed restoration projects on the Lincoln National Forest in New Mexico and to other natural forests in Arizona and Colorado. Additional input to the subject prepared by the County of Otero is shown on Pages 8-48 and 8-49 of this Section.

The Interstate Stream Commission also recognizes the importance of watershed restoration and recently adopted a policy supporting the implementation of environmentally sound restoration practices which will enhance the recharge of underground aquifers. It should be also noted that the Mescalero Apache Tribe has an active watershed and forest management program on their nearby reservation.

An effective watershed restoration program includes an analysis of the entire watershed and addresses other issues such as erosion, land uses, water quality, plant diversity, noxious weeds, brush control, management of livestock and wildlife and protection of cultural resources and endangered species. These issues should not be overlooked when planning and implementing watershed restoration programs. This should include a comprehensive monitoring program to document the short term and long term changes to the ecosystem.

The costs mentioned above are estimated at approximately $230/AF. These costs can vary widely due to location, terrain and specific prescriptions. For example, costs for brush control in Pinion-Juniper areas usually are $ 65.00 - $ 80.00 per acre while costs in urban interface areas for tree thinning can run as high as $ 1000.00 per acre!

It should be noted that watershed restoration will increase the water yield within the watershed, however the quantity of water actually reaching the ground water system to wells or spring system for domestic diversion is difficult to estimate. Additionally, this alternative is subject to drought conditions, so the amounts realized may vary widely.

8.2.2.2 Rainfall Augmentation

Clouds are comprised of water droplets that form as water vapor condenses or sublimates around extremely small particles such as sea salts that are carried naturally by the winds throughout the atmosphere. Only a small part of the available moisture in clouds is transformed into precipitation that reaches the surface. Scientists have found through experimentation that adding particles to natural clouds may, under the right conditions, cause or increase the amounts of rain or snow. The particles may be similar to naturally occurring sea salts, or may be ice crystals. The process of adding particles to clouds is called cloud seeding, whether the particles are delivered from aircraft or from ground-based sites.

Scientists and engineers have conducted cloud seeding experiments and operations in many countries around the world over several decades. Weather modification activities to enhance water supplies have been conducted for a wide variety of users including government agencies, water resource managers, hydroelectric power companies, and agricultural interests. While some experiments have yielded inconclusive results, others have been quite successful. Scientists have learned that cloud seeding is a complex operation that requires much thought and careful planning to obtain desired results. Successful cloud seeding efforts may augment rain volumes by as much as 130 percent as shown by experiments conducted in West Texas. A modest increase of 5 to 20 percent appears reasonable.

It is an obvious, but important fact, that cloud seeding will not produce rainfall from a cloudless sky. Cloud seeding is not a viable alternative for producing near-normal rainfall during a drought because the meteorological conditions are not generally favorable. The objective of a cloud seeding program would be to increase the amount of average rainfall so as to increase the long-term average annual supply of both surface and ground water in storage. The quantities of water added during the wetter months and years would then be available in long-term storage to meet needs during drier months and years. Thus, the cloud seeding alternative is one that would be even more useful when coupled with expanded storage capacity, such as watershed retention ponds. Flood control measures may also need to be considered when attempting cloud seeding operations.

The great advantage of the cloud seeding alternative is its potential to tap into nature's 'water cycle' to bring additional fresh water from nature's own source, the oceans. The winds carry a supply of pure water vapor distilled from the oceans surfaces above the Sacramento Mountains, where natural processes produce up to 25 inches or more of rainfall on the average annually. The geographical location of the Sacramento Mountains (within the flow pattern of water vapor carried to our area from the oceans) facilitates capturing additional water from this infinitely renewable source in order to replenish the Basin's streams and stores of high quality ground water.

Using cloud seeding to increase precipitation over 154,000 acres in the Sacramento Mountains portion of the eastern Tularosa Basin would potentially yield an additional 22,000 AFY in watershed runoff. Specifically, the region from Rinconada Canyon south to La Luz Canyon, and Alamo canyon to Dog Canyon would be targeted. This additional watershed yield would provide increased water supply that will be used up in vegetation, evapotranspiration (ET), stream and spring flow and some ground water recharge. The Sacramento River watershed in the Salt Basin would also benefit from additional precipitation, yielding added flows to streams and springs in an estimated amount of 4,000 AFY. Costs associated with this alternative are estimated at approximately $4/AF. (See **Table 8.5**)

Although there is potential for additional watershed yield with this option, the actual amount of water reaching the ground water and spring systems as additional available supply is difficult to estimate, and should not be considered a "guaranteed" supply for planning purposes. Additional studies are needed to fully evaluate this alternative.

8.2.2.3 Snowpack Augmentation

As discussed in Section 6, the majority of recharge to the ground water system is derived from snowpack on the western slope of the Sacramento Mountains. By increasing the amount of winter precipitation in the form of snowpack (as discussed in 8.2.2.2), additional ground water recharge may be possible. Using the cloud seeding technologies during the winter months to augment snowfall on 154,000 acres at elevations above 7,000 feet in the Eastern Tularosa Basin may yield an additional 1,700 AFY in ground water recharge. This would be an important added resource for the mountain communities, increasing supply to domestic wells.

The Sacramento River watershed in the Salt Basin would also benefit, yielding added flows to springs in an estimated amount of 500 AFY. However, there are high uncertainties associated with the amount of “wet” water which would actually be realized under this option.

First, this method requires watershed management (reduction in tree density) to be most efficient, which could take decades to fully realize. Second, the amount of potential added snowpack is not well documented, and may not improve significantly. Third, the actual amount of water added to the ground water system (spread out along the eastern portion of the Tularosa Basin) is uncertain. Although this option should be a part of the overall management plan, it should be studied further. In as much as the costs associated with implementing this option are relatively low, it should be noted that the probability of realizing any real significant amount of “wet” water within the planning horizon (40-years) is somewhat minimal, except possibly on a local basis. Costs associated with this alternative are estimated at approximately $44/AF (See **Table 8.5**).

As in the option above, there is potential for additional watershed yield with this option. However, the actual amount of water reaching the ground water and spring systems as additional available supply is difficult to estimate, and this option should not be considered a "guaranteed" supply for planning purposes.

8.2.2.4 Desalination

As discussed in Section 6, there is an abundance of recoverable and un-appropriated brackish ground water in the Tularosa Basin. Technologies exist which can remove the minerals and produce potable quality water. The concept of desalination has been previously addressed in the Tularosa Basin, once as a supply for the Village of Tularosa (Morris and Prehn, Jr., 1971) and again in conjunction with a nuclear generating energy-water complex in the Tularosa Basin (Lansford, et. al., 1976). Additionally, the City of Alamogordo pursued funding in the mid-1970's to establish a 5 MGD desalination plant, but the total funding was not available and the city discontinued further efforts towards its development. The subject re-surfaced as an option in a study of Alamogordo's water supply alternatives in 1986 (US Bureau of Reclamation, 1986).

A study is currently being prepared which again evaluates the feasibility of desalinating water in the Tularosa Basin as a major water supply for the City of Alamogordo and other potential regional users (Livingston, et. al., 2002). The use of reverse osmosis (RO) technology would convert brackish ground water with a quality of up to 4,000 ppm TDS down to potable standards of 800 ppm TDS, matching the spring water quality. The overall recovery of the system is expected to be above 80%, meaning that less than 20 out of every 100 gallons of feed water will be disposed of as concentrated brine solution. Disposal of the concentrate may be through evaporation ponds or beneficially used. The project is scheduled to produce from 4 million gallons per day (MGD) initially to 16 MGD in the future. For this planning document, 10,000 AFY is used as a cost comparison basis. The costs associated with this alternative are estimated at approximately $211/AF (See **Table 8.5**).

Desalination can be implemented to provide a reliable supply for planning purposes. Desalination also may provide a regional supply to the area. Some residents have expressed concern over perceived impacts of a desalination plant, however, the desalination project will have to comply with regulations regarding water rights (via the NMOSE), concentrate disposal (via the NMED) and others. Water table monitoring in the well fields is also recommended. The removed salts are anticipated to be beneficially re-used, but the details on quantity and use are currently under development.

8.2.2.5 Underground Aquifer Storage and Recovery

One alternative for capture of additional renewable surface water supplies is underground Aquifer Storage and Recovery (ASR). With this technology, excess or off-peak stream flow may be diverted to a special well for injection into the aquifer for storage. Then, when peak demand periods come again, the well or additional recovery wells may be used to pump this stored water into the distribution system for consumers. Like an immense underground tank, water may be stored, thus minimizing the risk of evaporation or contamination. Storage volumes may be very high.

The State of New Mexico recently promulgated rules for allowing municipalities and other governmental entities to store water in underground aquifers for later recovery and use. Among other requirements, the rules state that the water rights must be owned, and the physical storing and recovery of water must not be detrimental to public welfare. Additionally, the stored water remains the property of the entity which placed it there.

The City of Alamogordo prepared a feasibility study which evaluated aquifer storage and recovery (ASR) as a water supply option (Livingston, Shomaker, 1996). The study investigated using the excess winter spring flows from the La Luz/Fresnal Canyon system (those which the City has rights to) and storing them in the La Luz well field after treatment. A pilot project was performed where 21 million gallons of treated spring water was injected in the well field. The study concluded that the aquifer was capable of storing and holding injected water with little mixing of the poorer quality ground water, while actually increasing the water table levels around the well field. The City is currently pursuing a full-scale ASR program. This option may be available to other communities, depending on the properties of the nearby basin-fill aquifer. The costs associated with this alternative are estimated at approximately $98/AF (See **Table 8.5**). This option is also dependent on a number of wet winters (with "excess" spring flows to recharge) to be fully reliable.

8.2.2.6 Flood Control Aquifer Recharge

The City of Alamogordo is developing flood control projects for the north and south parts of the city. The US Army Corps of Engineers (USCOE) is the lead agency, and has provided matching funds for design and construction of the South Diversion Channel, which is currently under construction. The flood control for the north part of the city is under evaluation, and may potentially be a diversion channel or detention basin/channel outfall. If the flood flows originating in the drainage watersheds northeast of Alamogordo can be captured and diverted into a detention basin, then the basin can be used for ground water recharge. The initial location for the flood control detention basin is at the southeast corner of Highway 82 and Florida Ave., just south of the City of Alamogordo La Luz well field. The recharged flood flows may help replenish the aquifer around the well field, as well as the numerous domestic wells in the vicinity.

Previous studies have evaluated a similar concept (USBR, 1986). Although this option requires additional analysis (computer modeling of the aquifer and actual flood flow estimates), shallow ground water recharge using spreading basins and recharge pits is currently used elsewhere. The USCOE does not have final estimates of potential flood volumes, a rough estimate using previous numbers (USBR, 1986) indicates that about 500 to 1,000 AFY may be potentially recharged. Because the majority of the cost of the flood control portion of the project would be paid through federal grants, the recharge cost component would be relatively small. This option could be pursued as part of the overall watershed management. This option may be pursued by a co-operative agreement between the stakeholders in the local area. However, as with other options which rely on the precipitation to produce additional water for the Basin, flood control and diversion/recharge is not a guaranteed supply. Drought can limit the effectiveness of such an option, and the quantity of water actually reaching the ground water system is unknown. The costs associated with this alternative are estimated at approximately $240/AF (See **Table 8.5**).

County-wide flood control projects may also benefit from similar concepts, and may tie into watershed restoration (and flood control enhancement). Some requirements for these are included in USC Title 6, Chapter 18 and Title 33, Chapter 5, where cooperative efforts are needed between agencies.

8.2.2.7 Tularosa Creek Reservoir

The Tularosa Community Ditch Corporation (TCDC) is a community ditch association or acequia that provides water to agricultural users in the Tularosa area from a diversion of Tularosa creek water. The Ditch Corporation owns a majority (87%) of the flows in Tularosa Creek. The Village of Tularosa also obtains its water from the same source from which it depends almost entirely for its municipal water supply and regularly purchases water from TCDC at a minimal rate. Even though the water in the river system is fully appropriated, there are times when the flows are underutilized, primarily in the winter months when demands for irrigation and municipal use are at it's lowest.

The Village and the TCDC are planning a cooperative effort to divert the unused water into a pipeline for transport to a reservoir and stored for later use. This concept is not new and the original study, completed by the state engineer's office dates back to 1957. Since then there have been additional studies by the Natural Resources Conservation Service and a local engineering firm. The latter studies have included the concept of a small hydroelectric plant to offset some of the costs of the project. It is anticipated that there would also be some recreation and wildlife benefits resulting from the construction of a reservoir, although there would be no guarantee of a permanent pool of water in the reservoir.

The water planning committee recommends that this project is included in this plan and listed as a potential alternative for the Tularosa area with the understanding that it cannot be fully evaluated until a detailed study is completed. Both the Village and the TCDC have attempted to obtain funding for a feasibility study numerous times, but have been unsuccessful. The public, including those entities or individuals directly affected by this project, should be involved in the planning process.

8.2.2.8 Reclaimed Water

Reclaimed water is a resource that utilizes treated wastewater effluent for beneficial use, such as golf course and green space irrigation. This resource is considered a “water supply” because it offsets potable water use for the same demands. New regulations of the NM Environment Department require a higher (tertiary) level of water treatment and disinfection to eliminate pathogens and bacteria.

The City of Alamogordo currently operates a reclaimed water system. The system uses approximately 3-million gallons of treated wastewater effluent (reclaimed water) each day (3,360) on their golf course, parks and ball-fields. This reclaimed water is a beneficial use of resources because it offsets the need for an equal amount of potable water for the same uses. The City is currently developing plans to expand the system to use the full potential of reclaimed water (Boyle, 2001).

In some places (El Paso, TX, Orange County, CA, etc.) reclaimed water is treated to better-than-drinking-water standards and re-injected into the ground water aquifer for additional treatment (and storage), and later pumped into the distribution system. For Alamogordo, however, the quality of its wastewater effluent would have to be improved further at considerable cost. In addition, the current water production well fields are sufficiently far away that pumping costs would be substantial. Additionally, use on the green spaces is one application for the reclaimed water in this case.

Holloman AFB treats its wastewater and discharges the effluent into a playa lake for evaporation. The lake is located over very poor quality ground water (more than 10,000 mg/L TDS), and therefore is of no concern to the fresh aquifer system. A reclaimed water system may be of benefit to HAFB, as it would offset potable use on landscaping.

Other communities in the Tularosa Basin should take advantage of reclaiming wastewater for beneficial use. The Village of Tularosa, for example, beneficially uses effluent for irrigating alfalfa fields, thus offsetting demand for ground or surface waters. The larger municipal systems (HAFB, Carrizozo) may potentially use reclaimed water as a resource. Studies are needed to evaluate the feasibility, costs and benefits for other communities. The US Bureau of Reclamation has a reclaimed water system funding program. The costs associated with this alternative are estimated at approximately $150/AF (See **Table 8.5**).

8.2.2.9 Residential/Commercial Water Conservation

Residential water use may be ideally segregated into indoor and outdoor demands, though a single connection and meter typically serves both uses. In communities with affluent populations or areas with dense housing units, outdoor landscape irrigation may be appreciably higher. Experience shows that basin residents in established housing areas typically have greater per capita water use relative to mountain residents and rural communities.

There are often many ways in which industrial and commercial water demands can be reduced with relatively little capital investment and without reducing the competitive position of the product produced. One of the most cost-effective is to try to reuse water in the production process. Another is to find ways to reduce the amount of water needed, or to find ways to eliminate the use of water altogether in selected steps in the production process. Some of the latter options can be expensive and take considerable time to implement. Some financial assistance can sometimes be obtained since a reduction in the amount of water consumed can reduce community infrastructure costs.

Probably the most effective conservation measure that can be taken in our communities is education and awareness training. Education goals should include: (1) bringing to the attention of the general public the value of water, (2) emphasizing the fact that precipitation is low on the average and can vary dramatically from year to year in the southwest, and (3) making people aware of the fact that we are mining potable water resources as demands increase. This increased awareness will encourage people to use water more wisely and effectively.

In addition to education, there are a number of actions that can be taken by municipalities that will result in decreases in the demand for water without causing undue harm to individuals, businesses, or the economy. Some of these have been in use in various communities for many years and have been shown to be effective. One of these is regulating the time of day during which outdoor watering can be done by the homeowner. This option is especially appealing since it does not put a financial burden on the citizens. Since anywhere from 35% to 40% of our water consumption is related to outdoor watering of lawns and other plants, this option can be very effective. It has been shown that a reduction of 5% in water use can be realized by this technique. The City of Alamogordo has implemented such a plan. Xeriscaping may be costly, but this technique has been estimated to reduce outdoor water use by as much as 50%. We have historically tended to use more water to accomplish a given task than is actually needed. This is especially true when it comes to domestic outdoor irrigation, where there is a tendency to apply more water than the plant actually needs to grow optimally. In addition, water has tended to be underpriced as a commodity, a situation which causes people to be less mindful of the value of water and the importance of saving water.

Another relatively low-cost option applying to indoor water use is to install low-flow fixtures in the home, to repair leaking faucets and fixtures, and to carry out an audit of water consumption to see where water can be saved without sacrificing results. Savings of the order of 10% can be achieved by this method of water conservation.

Because evaporative air conditioners use a significant amount of water, the City of Alamogordo is considering adopting an ordinance requiring new homes to be constructed with refrigerated air conditioning. Incentives for homeowners to replace their existing evaporative coolers with high efficiency evaporative coolers or refrigerated air may also be effective.

Proposed Actions

This plan therefore recommends the following prioritized action plan for methods to be researched and implemented for residential and commercial conservation in Tularosa Basin communities:

1. Public Education – develop and distribute water conservation facts, goals, and action plans to all community and municipal water system contacts for dissemination to local news outlets and inclusion in regular billings and Board meetings. Set goals and repeat distribution with updates and monitoring data to show progress. Provide accolades/rewards for low water users or good conservation practices in newsletters and reports.
2. Metering and stepped rate structures – Implement metering (use NM statewide water meter contract and/or seek state/federal grant funds for installation) and fair rate structures, and phase out single annual fees that allow unmonitored water waste and unfair water use. Rate increases may be justified. *Based on study of previous programs in NM, implementation of items 1 and 2 may result in up to 20% water use reductions.*

3. Recordkeeping and water system audits to identify water use that is not accounted for – Perform water balances to determine unaccounted water quantities. If the difference between supply and demand (pumped vs. sold) is greater than 10%, implement metering checks and flow isolation to determine leaks or broken meter problems. These water waste issues result in lost revenue, thus correction of these problems is a win-win scenario.
4. Leak detection and repair – After system water audits are concluded and leaks are suspected, implement systematic pipeline replacement (aged 25-years and older is suspect) and potholing or leak detection practices. Isolation of system pressure zones with zone meters may also help narrow the search.
5. Pressure reduction – Where possible, reduce subsystem pressures to near 50 psi by adding pressure reducing valves or separating system units. Reduced pressures mean reduced flow and repair cost.
6. Indoor plumbing fixture and appliance ordinances, audits, and retrofit/rebate programs – Ordinances may be implemented by incorporated municipalities, or Board-initiated mandates may be issued by community systems. Either way, some reliable monitoring method and some fair weight of law consequence must be enacted. Monetary rewards or fines are typical methods, and inspections by a water system representative may be justified. However, this may only be effective if implemented on a voluntary basis for existing homes, and included in County building codes for new homes.
7. Landscape irrigation ordinances, audits, and retrofit/rebate programs (xeriscaping) – see 6
8. Water waste ordinances and fines – see 6. This item will require staff to respond to reports of water waste, to document findings, and to file reports to water wasters and system operations/enforcement staff. Enforcement may require legal actions.
9. Require use of refrigerated air conditioning on new home construction and incentives for replacement of existing evaporative air conditioners with refrigerated air units.

Implementing these measures may conserve up to 20% of the future domestic water demands, or approximately 4,400 AFY. The costs associated with this alternative are estimated at approximately $41/AF.

8.2.2.10 Agricultural Use Water Conservation

Since the largest water demand in the Tularosa and Salt Basins is agricultural use, there are also some conservation measures that may be implemented by farmers to reduce water demand. The above methods are not necessarily applicable to farm irrigation practices. Some applicable methods include the use of LEPA, drip, and sprinkler systems; lining ditches with concrete or laying pipe to carry irrigation water to the fields; and laser leveling fields. The New Mexico Office of the State Engineer (OSE) monitors irrigation water use by crop and irrigation method every 5 years. In their 5-year reports, the OSE also describes methods of conserving water relative to off-farm and on-farm conveyance and use (Brian Wilson, OSE TR 49, September 1997). Many of the applicable proposed methods are summarized here.

Improving Off-farm (surface water) Conveyance Efficiency:

- Install canal liners (e.g. clay, concrete, soil cement, pipelines)
- Control weeds and vegetation in conveyance structures
- Monitor flows to determine unaccounted water or losses
- Improve/automate flow regulation structures
- Schedule water deliveries

Improving On-farm Irrigation Efficiency:

- Install ditch linings or piping
- Land leveling
- Optimum tillage
- Improve flow regulation structures
- Monitor soil moisture
- Recover runoff and tailwater
- Select/improve proper application method (flood, sprinkler, drip)
- Schedule irrigation to meet crop demands

Proposed Action

High Efficiency Sprinklers - Most of the cropland in the Tularosa Basin is irrigated by sprinklers. Several farmers have center pivots, however side roll sprinklers are much more common. Irrigation efficiencies of 65% are common when growing high water use crops such as alfalfa. A gross application of 5 acre feet is needed for optimum yields. With new LEPA sprinkler systems an irrigation efficiency of 85% to 90% is achievable.

Land Leveling - Most farms need to be re-leveled. The economics of farming have not allowed most farms to be re-leveled since the 1970's. Farms in the Tularosa area have about 1½% slope. Irrigation efficiencies average about 40% and could be increased to 60% with precision leveling and proper lengths of run. Raising hay requires a gross application of 4-5 acre feet per year.

Soil Moisture Monitoring - Nut orchards have become a popular crop. Several hundred acres of pistachios have been planted in the Basin in the last 30 years. All growers initially used drip irrigation and graduated to micro-sprayers or micro sprinklers as the trees began to reach a productive age. The consumptive use of these trees will continue to increase until the trees reach maturity. Gross application rates will increase for the next 25 years until they stabilize at about 5 acre feet per year. The use of gypsum blocks and tensiometers could improve the irrigation efficiencies by 15% or more.

High Efficiency Drip Systems - Most of the pecan orchards are in the vicinity of Tularosa. Impact sprinkles are used in many of the mature orchards. Micro sprinklers are sprayers that are generally used in immature blocks of trees. Producers with about 900 acres with larger pecan trees have installed buried polyethylene pipe with emitters on a set spacing. Consumptive use will increase for the next 30 years because less than half of the pecan orchards have reached maturity. As with pistachios, irrigation efficiencies could be increased by 15% with current technology.

Implementing these measures may conserve up to 20% of the future water demands, or approximately 10,000 AFY. The costs associated with this alternative are estimated at approximately $100/AF (See **Table 8.5**).

8.2.2.11 Development of Fresh Ground Water Wells

The largest fresh water area in the eastern Tularosa Basin is from Alamo Canyon south to Culp Canyon. Besides a number of domestic wells, the well fields for Holloman AFB are located in that area. As discussed in Section 6, fresh water is also in storage within the basin fill alluvial aquifer in that same area, and some additional appropriation of ground water for municipal supply may be possible. An evaluation is needed to determine potential additional diversions, if any. Impacts to existing water rights also needs to be evaluated, which may limit any additional diversions. For purposes of evaluation of this alternative (or any other one involving increased pumping or new wells for fresh water in aquifer storage) a somewhat arbitrary assumption is made that 4,000 AFY could be diverted.

It should be noted that at the request of the Planning Committee the OSE ran the water rights administrative computer model in this area to divert 4,000 AFY and indicated that it was not feasible. Refer to **Appendix 8.2** for an explanation on the OSE model run. Additionally, HAFB recently drilled an exploratory well in the Grapevine Canyon area, which revealed a poorer water quality than expected there. The costs associated with this alternative are not applicable. (See **Table 8.5**).

8.2.2.12 Summary of Development Alternatives

The following Table summarizes the Water Development Alternatives

Table 8.5

Summary of Water Supply Alternatives

Alt. No.	Alternative Description	Potential Diversion (AFY)	Water Quality (TDS)	Capital Cost (M)	Annual O&M (M)	Water Cost ($/1000 Gals)	Water Cost ($/AFY)
1	Watershed Management*	15,000	<1,000	$100	$0.01	$0.71	$230
2a	Rainfall Augmentation*	22,000	<1,000	$1.0	$0.03	$0.01	$4
2b	Snowpack Augmentation*	1,700	<1,000	$1.0	$0.03	$0.14	$44
3	Brackish Water Desalination	10,000	<800	$15	$1.0	$0.65	$211
4	Aquifer Storage And Recovery (ASR)	2,000	<1,000	$2.0	$0.1	$0.30	$98
5	Flood Control Diversion Recharge	500	<1,000	$2.0	$0.01	$0.74	$240
6	Tularosa Creek Reservoir	3,000	1,500	n/a	n/a	n/a	n/a
7	Reclaimed Water Reuse	1,000	1,500	$2.0	$0.05	$0.46	$150
8	Municipal/ Industrial Water Conservation	4,400	<1,000	$6.0	$0.03	$0.13	$41
9	Irrigated Agriculture Water Conservation	5,000	<3,000	$4.0	$0.38	$0.31	$100
10	Fresh Water Wells	4,000	<1,000	n/a	n/a	n/a	n/a

n/a not applicable

* - not considered a reliable supply for planning purposes

8.3 Evaluation of Water Supply Alternatives

8.3.1 Evaluation of Water Management Alternatives

The following Table summarizes the evaluation of Water Management Alternatives

Table 8.6

Evaluation of Water Management Alternatives							
Alternative	**Technical Feasibility**	**Political Feasibility**	**Legal Feasibility**	**Financial Feasibility**	**Social and Cultural Impacts**	**Suggested Implementation Schedule (year)**	**Physical, Hydrological, Environmental Impacts**
Public Education	High	High	High	Medium	Low	Ongoing	Low
Water Conservation and Reuse	High	High	High	Medium	Low	Ongoing	Low
Special Administrative Areas	High	Medium	Low	Medium	High	2005	Low
Supply Blending	High	High	High	Medium	Medium	Ongoing for some areas	Low

8.3.2 Evaluation of Water Development Alternatives

The following Table summarizes the evaluation of Water Development Alternatives

Table 8.7

Evaluation of Water Development Alternatives

Alternative	Technical Feasibility	Political Feasibility	Legal Feasibility	Financial Feasibility	Social and Cultural Impacts	Suggested Implementation Schedule (year)	Physical, Hydrological, Environmental Impacts
Watershed Management	High Studies indicate highly feasible	High Would benefit mountain communities	High	High Costs are shared with USFS grants	Low Improves fire safety/ water	2002 Some small projects ongoing	Low Helps forest health, watershed and fire safety
Rainfall/ Snowpack Augmentation	High Has history of use in eastern NM	High Would benefit mountain communities	High	High Costs are low and may be shared	Low None expected	2004 funding sources need to be identified	Medium Increased runoff may cause floods
Brackish Water Desalination	High Pilot study shows feasible	High Regional support	High	Good Funding may be available	Low None expected	2005 funding sources need to be identified	Low No impacts expected
Aquifer Storage and Recovery	High Pilot study shows feasible	High Benefits domestic users and Alamo	High	High Costs are low	Low None expected	2002 Alamo project has been started	Low No impacts expected
Alamogordo Flood Control Aquifer Recharge	High Is used in other areas	High Benefits domestic users and Alamo	Medium	High Part funding may be available	Low None expected	2010 Corps of Engrs. to complete design	Low No impacts expected
Tularosa Creek Reservoir	Needs to be studied	Fair Some opposition from Creek residents	Needs further evaluation	Needs further evaluation	Medium Some view socio/econ impacts	2003 Study and funding sources need to be identified	Needs further evaluation
Reclaimed Water Reuse	High Is used in other areas	High Conserves water	High	High USBR funding is available	Low None expected	2003 Begin study for HAFB and Carrizozo	Low No impacts expected
Municipal/ Industrial Conservation	High Is used in other areas	High Conserves water	High	High Costs are low	Low None expected	2003 Begin educational pgm	Low No impacts expected
Agricultural Conservation	High Is used in other areas	High Conserves water	High	Fair Needs funding	Low None expected	2004 Begin educational pgm	Low No impacts expected
Fresh Water Well Fields	Needs to be studied	N/A	Low OSE Areas	N/A	N/A	2003 Begin detail study	Low No impacts Expected

8.3.3 Recommended Actions to Offset Shortfall

Alamogordo Area

In the next 5 to 10 years the most economical option to meet the current and future water demands for the City of Alamogordo (and indirectly those of the residents in the surrounding areas) would be desalination of the brackish water in the alluvial fill aquifer in the Eastern Tularosa Basin. As already noted in this plan, very large quantities of water in the 2,000 to 10,000 ppm are available and would last hundreds of years. The City of Alamogordo is planning to build a desalination plant capable of meeting the current shortfall in water demand for the city itself, as well as other potential users within the Region. It is conceivable that the desalination plant could be used to satisfy regional water supply problems. The costing of this option would have to be developed in detail for each participating entity. This scenario could also be of help to the City in getting funding for the plant since it would be supported by a much broader political base (military and civilian). The city-operated desalination plant could be designed to facilitate future expansion as demand in the Region increases over the next 40 years.

The Village of Tularosa could also elect to participate in the desalination project, especially since one of the more favorable plant locations would be near the Village of Tularosa. A pipeline will be necessary to serve the Village, the length depending on the actual location of the desalination plant. In addition, there may be some pumping costs, again depending on the exact location of the plant. The Village is also investigating the feasibility of constructing a reservoir north of the Village in order to capture appropriated, but unused, water flowing down Tularosa Creek in the winter. This water would be stored for use in the summer months. This water requires treatment to meet drinking water standards.

Beginning now, watershed management and cloud seeding should also be implemented to help alleviate the water issues in the La Luz, Maruche, Cottonwood, Fresnal, and other canyon watersheds that provide water to the area. Consideration must also be given to getting permission from the Mescalero Indian Tribe to implement cloud seeding that may affect precipitation on Indian land. In addition, any watershed management proposed for land owned by the Mescalero Tribe would need the approval of the Tribe.

The costing of the watershed management and cloud seeding options would have to be developed in detail for each participating entity. One option for the La Luz/Fresnal community is to form a rural water association and purchase existing water to meet their current and future needs.

Timberon/Orogrande

Relative few options are available to the Community of Timberon to solve its water issues. The most promising, but long-term, is watershed management. Although this alternative is usually viewed as an area-wide project, it would appear that a much more manageable approach would be to thin the watershed that appears to supply water to the springs and wells in the immediate vicinity of the community. There seems to be a close correlation, for example, between the flow of water out of Monument Springs in Monument Canyon and the availability of water in Timberon at Carrisa Springs. It therefore might be particularly effective to treat the Monument Canyon watershed. However, since the community largely lies in the Sacramento Canyon through which the Sacramento River runs, forest thinning should also be implemented in that recharge area. Timberon is currently drilling wells in the area, and if successful, may provide adequate water for the near-term.

Another option for Timberon could be wells and a pipeline from the northern Salt Basin. The pipeline might be about 15 miles in length and have a capital cost in the neighborhood of $4,000,000. There would, of course, be ongoing maintenance and pumping costs since the elevation difference is about 450 feet.

A third option would be aggressive watershed restoration and cloud seeding for the Monument Canyon and Sacramento Canyon areas.

For Orogrande, a small desalination plant is one option. The cost of replacing the pipeline should be compared to desalination. Several wells may be required to supply brackish water to a desalination plant. However, desalination is more reliable during drought than Sacramento River flows. A watershed management program in the Sacramento Canyon, as described above, would also have the potential of providing more water to Orogrande, but the current pipeline would have to be refurbished and the time frame for watershed management to yield any appreciable flows may be unacceptable. Water may also be piped in from an outside source at potentially considerable expense.

Carrizozo/Nogal

The most economical alternative for Carrizozo to meet its future demand for water would appear to be drilling of additional wells and blending with their treated Bonito Lake water. With an average ground water quality of about 1,200 mg/L TDS, a ground-water-to-surface-water blending ratio of around 40:60 would provide a blended water quality of approximately 800 mg/L TDS.

The community of Nogal would appear to have access to good quality ground water in sufficient quantities for current and reasonable growth if the NMOSE would permit additional appropriations. Another option is to disband the Nogal Water Association and have each resident install a domestic well. The latter approach is not very desirable in terms of water conservation. Another possibility is to adopt the strategy that is recommended for the La Luz Canyon area residents. In this case, the regional desalination plant would be made larger in capacity in order to allow the Nogal residents to purchase additional water from the Bonito pipeline which runs nearby.

8.4 Drought Management Plan

8.4.1 Trigger Criteria for Drought Action

Definition of Drought

Drought as defined in the *New Mexico Drought Plan, 1998*, is a multi-faceted, indistinct event resulting from numerous factors. Four interrelated types of drought must be considered in developing an action plan.

1. Meteorological drought is a period of substantially diminished precipitation.
2. Agricultural drought is decreased soil moisture, which impacts crop needs, and usually follows a period of meteorological drought.
3. Hydrological drought is a deficiency in surface water or ground water supplies, and is a latter impact of meteorological drought as measured by streamflow, snowpack, lake/reservoir levels, or ground water depth.
4. Socioeconomic drought is a result when physical water shortages impact human health, quality of life, or production of goods and services.

Need for a Plan

The state has implemented a drought plan in an effort to plan for and minimize impacts of natural shortages of water supply on the citizens in New Mexico. Regional plans are required in conjunction with, and as part of state-funded water management plans. The short period of drought in 1996 prompted the state's initial plan, and a proactive effort toward drought management was initiated in 1998 to develop actions to monitor, assess, prepare for, and mitigate drought occurrences. The statewide plan encourages the development of local plans and monitoring groups, and is part of the basin 40-year plan outline. Prudence dictates that a staged plan of action be in place for local governments to respond appropriately to minimize drought period impacts. And, since statewide monitoring is often focussed on much more general conditions, local plans are needed to specify local trigger mechanisms such as reservoir and lake-levels, streamflows, or ground water levels.

Existing Drought or Conservation Plans in the Tularosa Basin

There are several existing plans for emergency water conservation that have been developed by local governments in the Tularosa Basin. Available plans include the City of Alamogordo, Otero County, the Village of Tularosa, and Timberon community. Holloman AFB currently defers to the City of Alamogordo plan. In an effort to maintain a level of continuity, the proposed basin-wide plan should not overrule local plans, but enhance them. In addition, local monitoring conditions (e.g., trigger reservoir elevation trends) are very site specific, so local plans may be needed to develop correct responses. Please refer to example plans from the Village of Tularosa and the City of Alamogordo included in **Appendix 8.1.**

Differing complexity and specificity is evident in the examples due to differing local conditions and irrigation or water use practices. Plans may be very similar in content and water conservation actions, but trigger mechanisms must be specific to the water system being monitored. For instance, a 'Palmer Index' number for the basin near Alamogordo or Tularosa may not necessarily be an accurate indicator of water supply problems for springs and streamflow originating in the higher elevations of the Sacramento Mountains (Timberon). The following proposed plans are therefore presented as regional guidance, and local entities and water system managers will be required to develop their own trigger criteria for phased water conservation action plans.

Proposed Administrators of the Regional Drought Plan

Administration of drought management plans could entail emergency actions that impact human health and quality of life. Local public officials or water system managers must have governing body support in decision making, and weight of law in enforcing some more critical elements of late stage water use restrictions. Administrators are proposed to include City or Village managers or mayors, who will make recommendations based on data provided by water system operators, with confirmation votes required in special session by governing commission or City council members. Water system President/Board decisions will be binding for smaller communities. An RC&D representative or state liaison is recommended as a coordinator of local communities and point of contact for state drought management officials.

Proposed Trigger criteria of the Regional Drought Plan

Directly measurable triggers affecting water system performance are likely to differ for each community. However, the state plan introduces use of the Palmer Drought Severity Index (PDSI), the Surface Water Supply Index (SWSI), and the Standardized Precipitation Index (SPI), for establishing trigger criteria for each stage of drought. The New Mexico Climate Center provides monitoring data and archives of monthly indices for 8 climatic zones in New Mexico. Zones applicable to the Tularosa Basin are 6 and 8, which make up the Central Highlands and south plains. These data may be reviewed at www.weather.nmsu.edu. The climatic zones are evidently being further divided into sub-groups to further delineate drought conditions, but for now the average condition of the entire zone is the display shown on the web page. To make use of the state's drought index and monitoring, local governments within the basin should understand the basis and use of local monitoring to check the state results prior to implementing use restrictions.

PDSI

The PDSI, Palmer Drought Severity Index, classifications range from –6.0 to +6.0 indicating extreme drought to extreme wet conditions, respectively. The PDSI is calculated based on precipitation, temperature, and soil moisture using available local data (weather stations, extension service monitoring). PDSI classifications range as follows:

Table 8.8 Palmer Drought Index Classifications

PSDI Classification System	
4.00 or more	Extremely Wet
3.00 to 3.99	Very Wet
2.00 to 2.99	Moderately Wet
1.00 to 1.99	Slightly Wet
0.50 to 0.99	Incipient Wet Spell
0.49 to –0.99	Near Normal
-1.00 to –1.99	Mild Drought
-2.00 to –2.99	Moderate Drought
-3.00 to –3.99	Severe Drought
-4.00 or lower	Extreme Drought

PSDI's for the Tularosa and Salt Basin (climate regions 6 and 8 on the web page) have ranged from close to –7.0 extreme drought conditions to over 12.0 extreme wet conditions in records viewed from 1895 to 1998, per the *1998 New Mexico Drought Plan.*

The August 2000 drought conditions indicated drought conditions were worsening over much of New Mexico, with average rainfall at 70% of normal. Climate region 6 had –1.7 to –4.0 PSDI's, with the August PSDI calculated at –3.9. This indicated an EMERGENCY drought condition for much of our region, based on the state monitoring group evaluation. Region 8, though not truly representative of the Tularosa Basin and including only a small portion of our area, also retained EMERGENCY status but with PSDI's of +2.2 and +1.0 for July and August 2000. Conditions through January 2001 indicate drought conditions are, with region 6 PSDI at –0.8 and WARNING status, and region 8 PSDI at +2.8 and NORMAL status. 10-month running totals are –31.3 and –6.1 respectively, so drought conditions are still evident in deep soil and likely shown in reduced ground water levels.

SWSI

Another index, the SWSI or Surface Water Supply Index, uses a similar scale and condition assessment rationale. Inputs for this category are snowpack, streamflow, precipitation, and reservoir storage. However, only 'major reservoirs' in New Mexico are monitored and it is unclear from the *New Mexico Drought Plan* if the Alamogordo or Bonito Lake reservoir systems are included as monitoring sites.

SPI

The final index used to assess drought conditions by the state is the SPI, or Standardized Precipitation Index, which quantifies precipitation deficit over time. SPI is the difference of mean precipitation from current precipitation for a particular time scale divided by the standard deviation. A drought condition exists any time the SPI is continuously negative and reaches –1.0 or less. Extreme Drought is defined with an SPI of –2.00 or less.

Recommended New Mexico Drought Plan Triggers

Putting it all together, the New Mexico Monitoring Work Group evaluates monitoring data with these indices and confers with local work groups to 'ground truth' the data before posting an evaluation on the web site. The drought stages are defined as follows:

Table 8.9 Drought Stage Trigger Characteristics

Drought Stage	Characteristics
Normal	PDSI between -.9 and +5, six month SPI positive.
Advisory	One month average PDSI between -1.0 and -1.9 not exceeding 2 months -1.0. Six month SPI declining and <0.25 for 2 consecutive months.
Alert (mild drought)	PDSI between -1.0 and -1.9 over 2 months or between -2.0 and -2.9 for 1 month. 6-month SPI between 0 and -0.99.
Warming (moderate drought)	PDSI between -1.0 and -1.9 over 9 months, -2.0 to -2.9 for at least 2 months, or -3.0 or less for at least 1 month. 6-month SPI declining between -1.0 and -1.49.
Emergency (severe to extreme drought)	PDSI between -2.0 and -2.9 over 9 months, -3.0 to -3.9 for at least 2 months, or -4.0 or less for at least 1 month. 6-month SPI declining between -1.5.
Receding Drought - Emergency Stage	After Emergency Stage, PDSI improves to > -2.0 for 2 consecutive months. Six month SPI moves in + direction for 2 consecutive months.

Receding Drought - Warning Stage	After Warning Stage, PDSI improves to > -1.5 for consecutive months. Six month SPI rises in + direction between -1.0 and -1.49 for 2 consecutive months.
Receding Drought - Alert Stage	After Alert Stage, PDSI improves to > -1.0 for 2 consecutive months. Six month SPI rises in + direction between 0.0 and -0.99 for 2 consecutive months.
Receding Drought - Advisory Stage	After Alert Stage, PDSI improves to 0.0 or greater, with the ten-month total PDSI > -10.0. Six month SPI month SPI > 0.0.

These triggers follow an increasing intensity pattern, and each stage is determined using the data specified in this section. If individual communities choose to accept these criteria as triggers for their local drought management ordinance, then local monitoring requirements may need to be revised and coordinated with the state monitoring group. Contact Charles Caruso, New Mexico Office of the State Engineer, Drought Planning Team, (505) 827-6196, or e-mail at ccaruso@seo.state.nm.us.

Recommendation

Since drought management actions may include mandatory conservation, rationing, and/or increased water fees, each community must have legal authority and basis for conservation program initiation. Coordination and communication as a region is also key. ***It is therefore our recommendation that the state's criteria be conditionally adopted for Tularosa Basin drought planning, assessment, and management. Conditions for this action are (1) that a Tularosa Basin liaison is established to coordinate with water system managers and authorities in each community, and (2) that local monitoring stations and climatic sub-areas be established***. In this way regular reports could be provided from local systems to the liaison, who would, in turn, send monthly reports in for evaluation by the state drought monitoring work group. Assessments based on local data could then be posted regularly on the web site for agency and system user viewing and decision-making.

In this manner, existing community drought management systems and monitoring may continue, but may be enhanced by greater coordination and accountability. Ultimate drought stage adoption and ordinance activation would still be the responsibility of local officials. Some additional needs noted during this review can be directed to specific communities for further action:

Table 8.10 Recommended Tularosa Basin Community Criteria Development Actions

Community/System	Recommended Criteria Development Action(s)
City of Alamogordo	Establish drought monitoring contact, incorporate spring/stream flow criteria, snowpack monitoring point/criteria, soil moisture monitoring point/criteria, ground water (drought reserve) monitoring criteria, and precipitation monitoring point/criteria for better forecasting. Develop rate increases based on water scarcity/waste.
Holloman AFB	Establish drought monitoring contact, Detail a plan to possibly coincide with City of Alamogordo criteria (similar watershed effects), and establish restrictions for each drought stage specific to squadrons, shops, housing, tenants, etc.
Village of Tularosa	Same as City of Alamogordo, and as with Holloman AFB establish drought management actions linked to criteria
Timberon, WSMR, Carrizozo, Boles Acres, La Luz, Canyon Hills, High Rolls, Cider Mills, Enchanted Valley, Orogrande, Nogal, Dungan, Karr Canyon Estates, Mountain Orchard, Pineywoods	Establish drought monitoring contact, incorporate snowpack monitoring point/criteria, soil moisture monitoring point/criteria, and precipitation monitoring point/criteria for better forecasting. Develop water waste policy with fines for violations. Develop and/or provide water conservation and drought management plans incorporating the above criteria applicable to your systems.

Phased water management strategy and actions

This section describes long-term conservation measures and provides a recommended outline of phased water use reduction actions to match each drought stage. Proper water system management, fees/metering, and conservation are the first modes of defense against drought impacts.

long-term water resource conservation guidance

State and federal water resources management and drought planning guidelines describe a multi-point progressive action plan to implementing water saving measures. As discussed in more detail in this Plan, these may be implemented on an as-needed basis in reaction to drought conditions, or put into practice in advance as standard operating procedure to prudently reduce use. Main categories of conservation are domestic, commercial, and agricultural use; with water quality protection guidelines included. Measures can include:

Example progressive water conservation measures

- Water Measurement and Accounting (metering)
- Water rate structure
- Customer Information and Education services
- Water conservation officer
- Audit and Incentive Programs (Leak Detection/Repair)
- Landscape Programs (xeriscape, Irrigation practices)
- Wastewater/Graywater reuse programs
- Plumbing and Low-flow fixture regulation and replacement programs
- Conjunctive use
- Agricultural Water Conservation

Implementation of many of these measures often results in significant water savings. Thus, a long-term water use reduction program using some of these example methods is recommended first for Tularosa Basin water systems to increase water use efficiency *and thus decrease vulnerability to drought conditions. The 1993 Otero* County 40-year *Water Plan* indicates that at that time 11 of 23 water systems in the County were metered. All 11 of these communities should develop criteria and a plan to enforce restrictions in the event of drought. Remaining un-metered communities could implement metering to provide a basis for protection of valuable and limited water resources. And, moving progressively down the above listing, once metered, many communities then have the capability to control water rates in a structure that encourages water use efficiency (such a plan is in place for communities like High Rolls and Timberon). Thence, system managers may provide educational and water conservation tips and updates to customers in each billing or as a mailer to inexpensively pass the word about being good stewards of limited water resources – most people want to do the right thing. Other measures can then be implemented with capital investments as they are deemed worthy for additional water use savings to reach established per capita or system reduction goals.

Recommended Drought Plan Management Strategy – Phases and Actions

Once long-term and planned water use reduction measures are developed, communities are better prepared for unplanned drought conditions. However, a drought contingency plan is required to limit impacts of these inevitable events. As stated above, certain measurable trigger criteria can be monitored to determine when a drought plan must be implemented. Once triggered, water system managers or public officials must have guidelines as to which water-conserving tactics must be implemented at each drought stage. The state development guidelines for the 40-year water plan recommend a four-phased approach:

- Phase I – Water Shortage Advisory (voluntary conservation)
- Phase II – Water Shortage Watch (level 1 mandatory conservation)
- Phase III – Water Shortage Warning (Level 2 mandatory conservation)
- Phase IV – Water Shortage Emergency (Rationing)

Keeping with the NM Drought Plan format, these phases make up groupings of the drought stages discussed prior, or:

- Phase I – Advisory, approaching or incipient drought
- Phase II – Alert, mild drought
- Phase III – Warning, moderate drought
- Phase IV – Emergency, severe drought

Appropriate actions must be taken in each phase or stage to increase the consumer awareness, incentivize/mandate water use reductions and water waste elimination, and provide for protection of priority uses. The following table summarizes drought stages, characteristics (per state criteria), and proposed actions. Actions are adopted primarily from the City of Alamogordo Plan, with suggested rate increases by category as described in the Timberon community plan.

Table 8.11 Recommended Drought Management Strategy Outline

Drought Stage	Drought Criteria Characteristics	Recommended Actions
Normal	PDSI Between -.9 and +5, six month SPI positive.	Even/Odd Spring/Summer irrigation, before 8AM & after 8PM.
Advisory	One month average PDSI between -1.0 and -1.9 not exceeding 2 months -1.0. Six month SPI declining and < 0.25 for 2 consecutive months.	Brief City Mgr./Board/Council; News ads; Insert in billings/mailer requesting conservation.
Alert (mild drought)	PDSI between -1.0 and -1.9 over 2 months or between -2.0 and -2.9 for 1 month. 6-month SPI between 0 and -0.99.	Stage 1 rationing - Public Announcements;Irrigation limited to twice/week;No pool filling.
Warning (moderate drought)	PDSI between -1.0 and -1.9 over 9 month, -2.0 to -2.9 for at least 2 months, or -3.0 or less for at least 1 month. 6-month SPI declining between -1.0 and -1.49.	Stage 2 rationing - Public Announcements; irrigation limited to once/week; no car washing; no-pool make-up water or filling; no deck/walkway/driveway washing; additional $1 surcharge per 1000 gallons used over baseline.
Emergency (severe to extreme drought)	PDSI between -2.0 and -2.9 over 9 months, -3.0 to -3.9 for at least 2 months, or -4.0 or less for at least 1 month. 6-month SPI declining between -1.5 and -2.0	Stage 3 rationing - Public Announcements; irrigation prohibited but for reclaimed water; continue Stage 2 add $2 surcharge per 1000 gallons used over the baseline up to 20,00 gal, and $.50 more for each 10,000 gal increment above baseline.

Note that each progressive stage retains the restrictions from the previous stage. Water waste prohibitions apply at all stages, including:

- Restricted nonessential water use – car washing by bucket and hose w/nozzle
- Prohibited water waste – directed irrigation (no street watering), repair leaks (no geysers), no refilling of swimming pools, evaporative cooler bleeder lines <1/8"

Each stage must be verified by local and state monitoring, coordinated with the state liaison, local water system manager, and local governing body, and carefully watched to allow quick response to changing conditions. During drought periods, emergency water supplies may be needed, including emergency wells, interbasin transfers, trucked water (National Guard), etc. Plans for these eventualities should be made in advance.

Suggested Drought Plan Ordinance

The City of Alamogordo water conservation ordinance provided in **Appendix 8.2** might serve as an example for communities that currently have no existing drought plan. Each community (including tribal governments) must prepare a legal basis from which to implement water rationing should drought conditions warrant such actions.

Otero County has indicated additional input as follows:

> "Otero County has taken the lead in Forest and Watershed Restoration. Flood Prevention and Control and Disaster Management are the responsibility of the County to protect the health and welfare of the citizens.
>
> Watershed management is considered as the best option for water in this basin. Records clearly indicate a drought at the beginning of the 20th century. Alamogordo's stream flow records from the La Luz and Fresnal Creeks show that flows were almost twice as high then as now. Less annual precipitation then and more stream flow than now clearly shows that we presently have an unhealthy stream system.
>
> Otero County is of the opinion that more emphasis should be put on improving watershed conditions to increase the yield of water. Best available science and data (ie: Garrett study) indicates improving watershed conditions through watershed management will increase the yield and have positive benefits to all aspects of a healthy forest as well as positive social economic impact. The cost table should reflect that increasing water yield through proper forest and watershed management will benefit the forest holistically. The County believes the reference is the watershed enhancement selection questioning the benefits to the watershed yield should be removed.

With Forest and watershed restoration already underway, retention dams, ponds and meadows will be developed to prevent flooding due to the increased water yield, which will be realized. These flood prevention measures need to be in place and adequate to prevent erosion and damage. They need to be developed to maximize aquifer recharge to realize the benefits without creating flood damage and erosion as a result of the increased water yield.

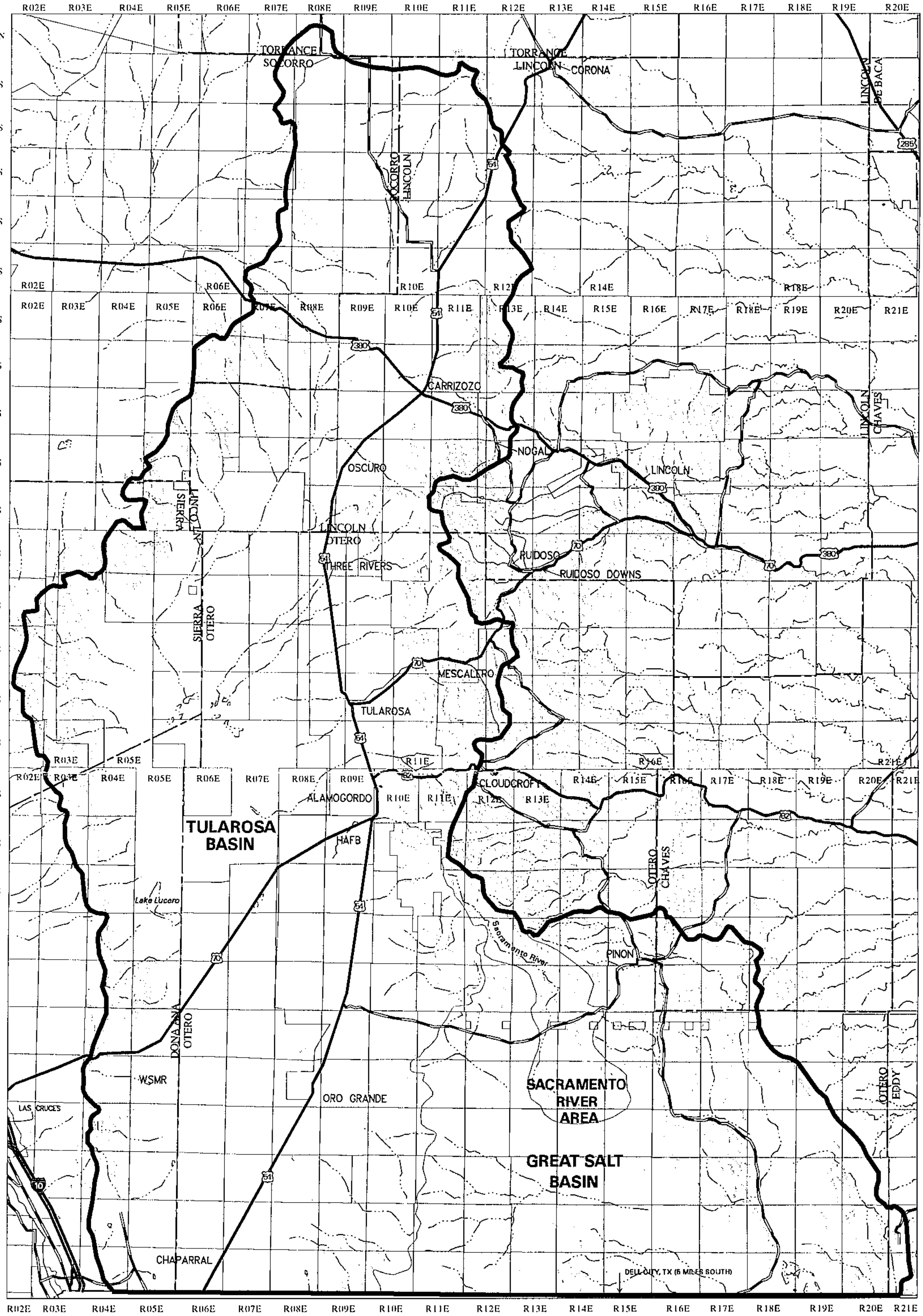
All flood prevention and control projects and measures must be developed with County participation and approval. U.S. Code Title 16, Chapter 18 "Watershed Protection and Flood Prevention" and Title 33, Chapter 15 "Flood Control" requires collaborative interdisciplinary cooperation between all local, state and Federal Government Agencies. Considering the work being done on the Forest and Watershed Restoration, critical attention and effort to flood prevention must occur simultaneously or sooner. Present runoff creates flood hazards for the areas surrounding the base of the watersheds. The increase to Forest and watershed restoration requires restoration of meadows and open fields as surface water detention areas to reduce the runoff. Construction of retention ponds at different elevations to capture the runoff and accomplish flood and erosion prevention enhances our entire ecosystem and increase the volume of water recharged into the aquifers.

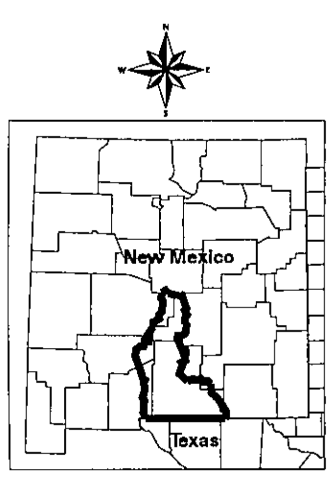
Concerning cloud seeding, planning, implementation and control procedures must be submitted to and approved by the County(s) to be impacted and to the appropriate government agencies. Flood prevention measures must be in place and adequate to prevent flood damage and erosion to properties.

The County believes this plan should recommend and address adequate monitoring of the Alamogordo City Desalination Plan to determine and evaluate cumulative effects on rural residents and agriculture water users".

F I G U R E S

Tularosa Basin, Sacramento River Area and Great Salt Basin Regional Water Plan
Planning Region





Produced by New Mexico Water Resources Research Institute, June 2000

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. Shaded relief provided by RGIS and is based on 1:250,000 Digital Elevation Models (DEMs) created by the U.S. Geological Survey. Boundary of the Tularosa, Sacramento, and Great Salt Basins Water Planning Region is based on surface drainage divides.

Horizontal accuracy: At the scale of 1:900,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 762 ground meters, of their true location.

Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.

Explanation

- State Line
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State Highway
- Township/Range
- Planning Region
- Sub-region Boundary

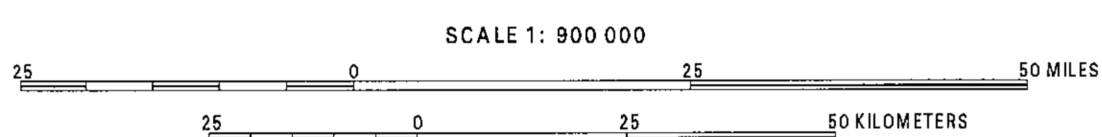
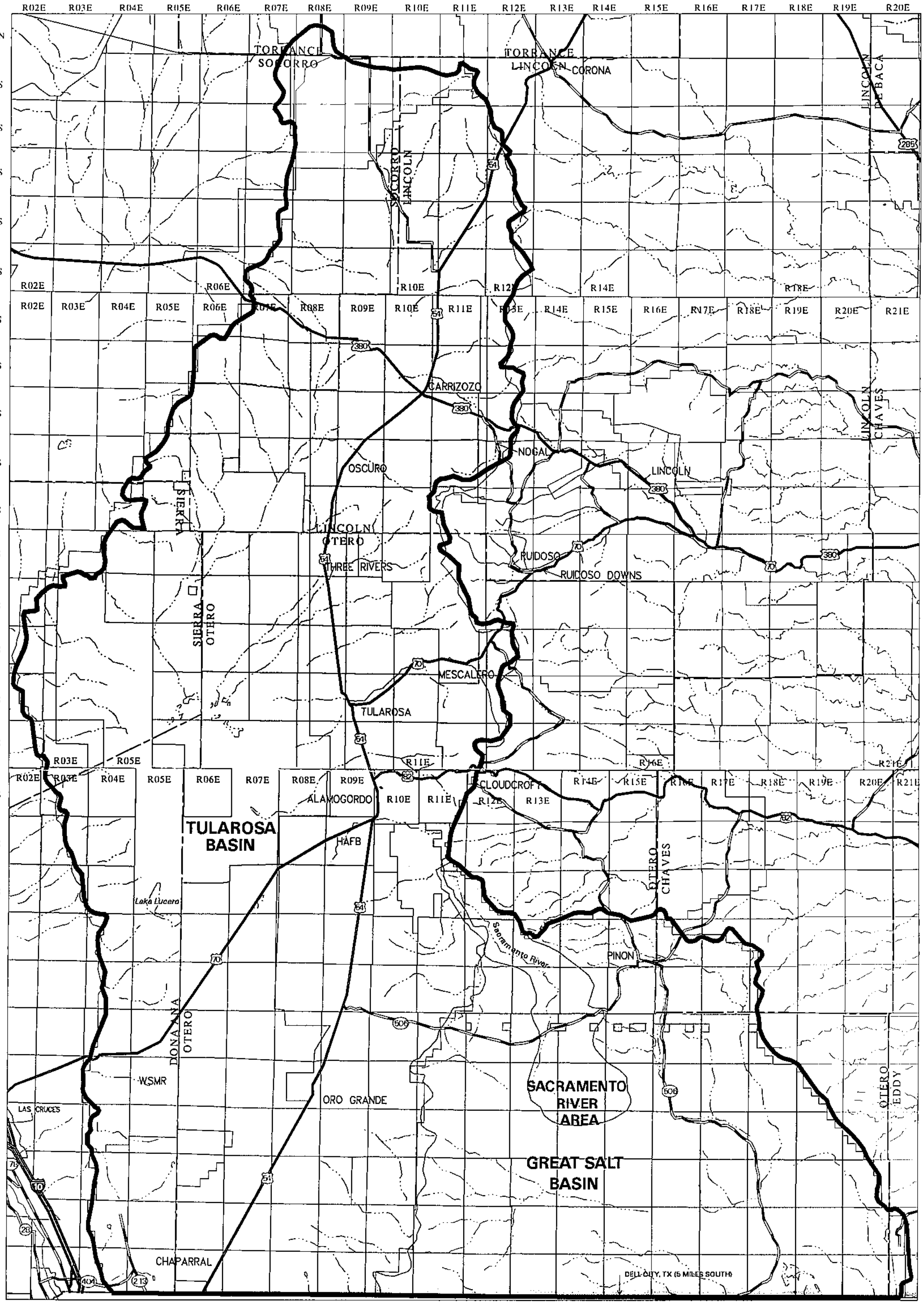
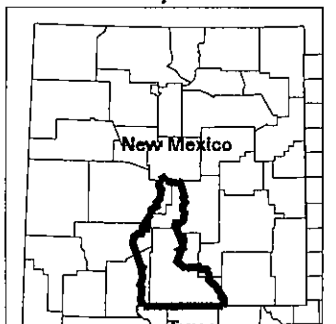


Figure 1.1 – Planning Region

Tularosa Basin, Sacramento River Area and Great Salt Basin Regional Water Plan
Underground Water Basins in the Region





Produced by New Mexico Water Resources Research Institute, June 2000

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. The Underground Water Basin boundaries are based on the New Mexico Office of the State Engineer (OSE) administrative groundwater basins. The cadastral accuracy of the OSE administrative basins and the county boundaries where verified by the use of 1:100,000 Public Land Survey System (PLSS) from RGIS. Boundary of the Tularosa, Sacramento, and Great Salt Basins Water Planning Region is based on surface drainage divides.

Horizontal accuracy: At the scale of 1:900,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 762 ground meters, of their true location.

Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.

SCALE 1: 900 000

25 0 25 50 MILES

25 0 25 50 KILOMETERS

Explanation

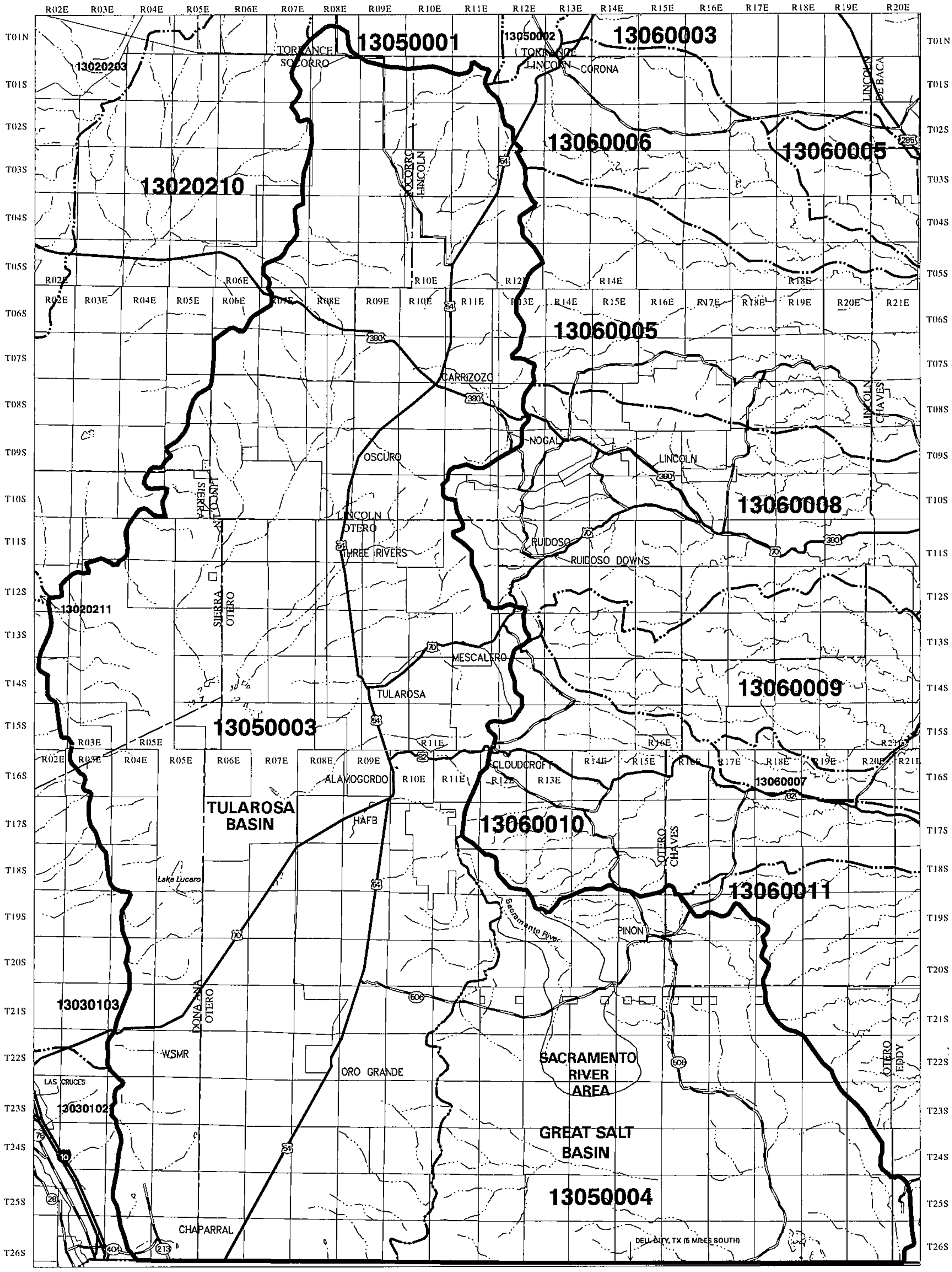
- State Line
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State/Other Highway
- Township/Range
- Planning Region
- Sub– region

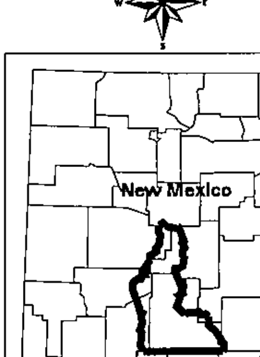
- Undeclared GW basin
- Tularosa GW basin
- Hueco GW basin
- Roswell GW basin
- Rio Grande GW basin
- Hondo GW basin
- Rio Penasco GW basin
- Carlsbad GW basin
- Lower Rio Grande GW basin
- Fort Sumner GW basin
- Salt GW basin

Figure 4.1 – Underground Water Basins

Tularosa , Sacramento River Area and Great Salt Basin Regional Water Plan

Watersheds





Produced by New Mexico Water Resources Research Institute, June 2000

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. Watershed boundaries based on USGS 1:500,000 and 1:100,000 scale maps, data provided by the RGIS program. Boundary of the Tularosa, Sacramento, and Great Salt Basin Water Planning Region is based on surface drainage divides.

Horizontal accuracy: At the scale of 1:900,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 762 ground meters, of their true location.

Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.

SCALE 1: 900 000

25 0 25 50 MILES

25 0 25 50 KILOMETERS

Explanation

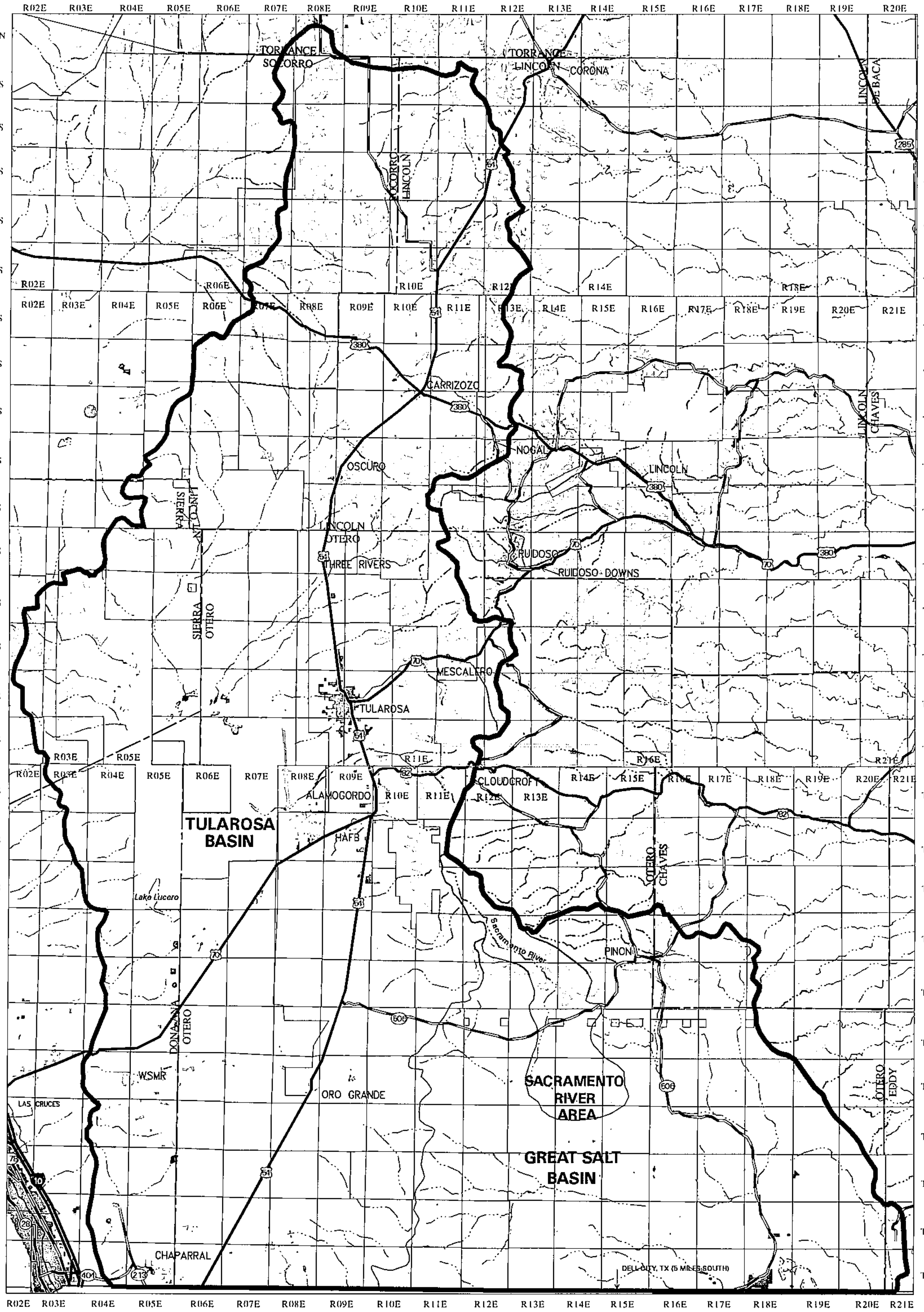
- Watershed Boundary
- State Line
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State/Other Highway
- Township/Ramge
- Planning Region
- Sub–region

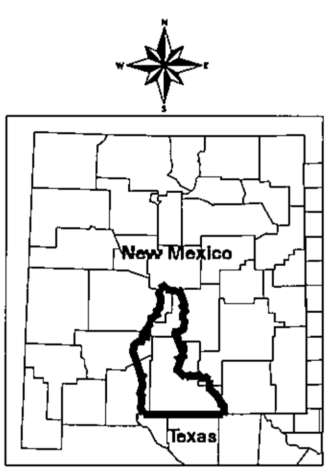
Hydrolgic Unit Code	Name	Area (sq. mi.)
13020203	Rio Grande-Albuquerque	3200
13050001	Western Estancia	2400
13050002	Eastern Estancia	517
13060003	Upper Pecos	4870
13020210	Jornada Del Muerto	1800
13050003	Tularosa Valley	6720
13060006	Gallo Arroyo	745
13060005	Arroyo Del Macho	1870
13020211	Elephant Butte Reservoir	2110
13060007	Upper Pecos-Long Arroyo	2700
13060008	Rio Hondo	1680
13030103	Jornada Draw	1260
13060009	Rio Felix	994
13060010	Rio Penasco	1080
13060011	Upper Pecos-Black	4360
13030102	El Paso-Las Cruces	2400
13050004	Salt Basin	7900

Figure 4.2 - Watersheds

Tularosa Basin, Sacramento River Area and Great Salt Basin Regional Water Plan

Landuse in the Region





Produced by New Mexico Water Resources Research Institute, June 2000

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. Landuse coverage developed by USGS/EPA at 1:250,000 scale. Boundary of the Tularosa, Sacramento, and Great Salt Basins Water Planning Region is based on surface drainage divides.

Horizontal accuracy: At the scale of 1:900,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 762 ground meters, of their true location.

Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.

SCALE 1: 900 000

25 0 25 50 MILES

25 0 25 50 KILOMETERS

Explanation

- Stateline
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State/Other Highway
- Township/Range
- Planning Region
- Sub–region

- No Data
- Urban
- Agricultural Land
- Rangeland
- Forest Land
- Water
- Wetland
- Barren Land
- Tundra

…ure 4.3 – Land Use

Tularosa Basin, Sacramento River Area and Great Salt Basin Regional Water Plan

Landownership in the Region

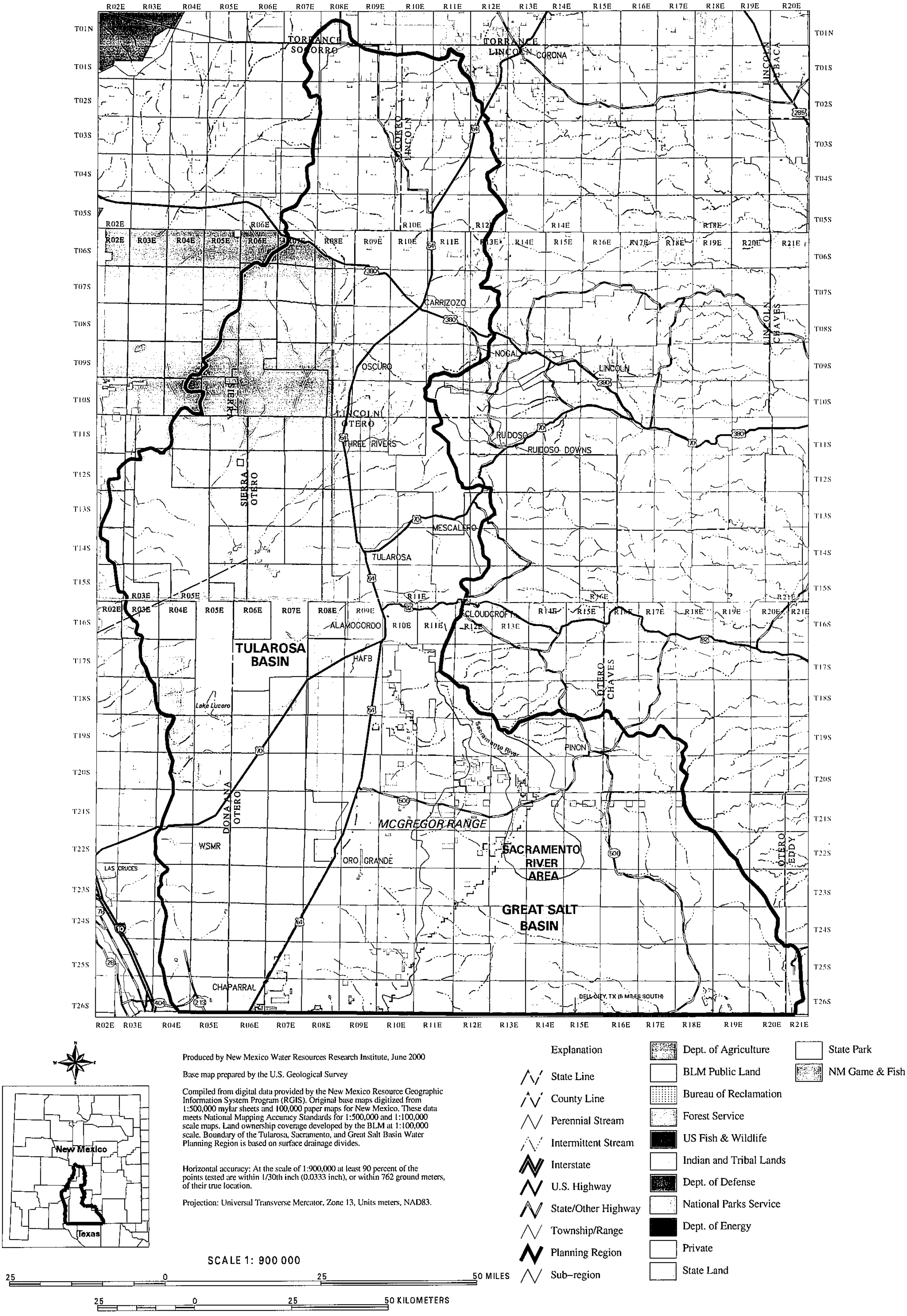
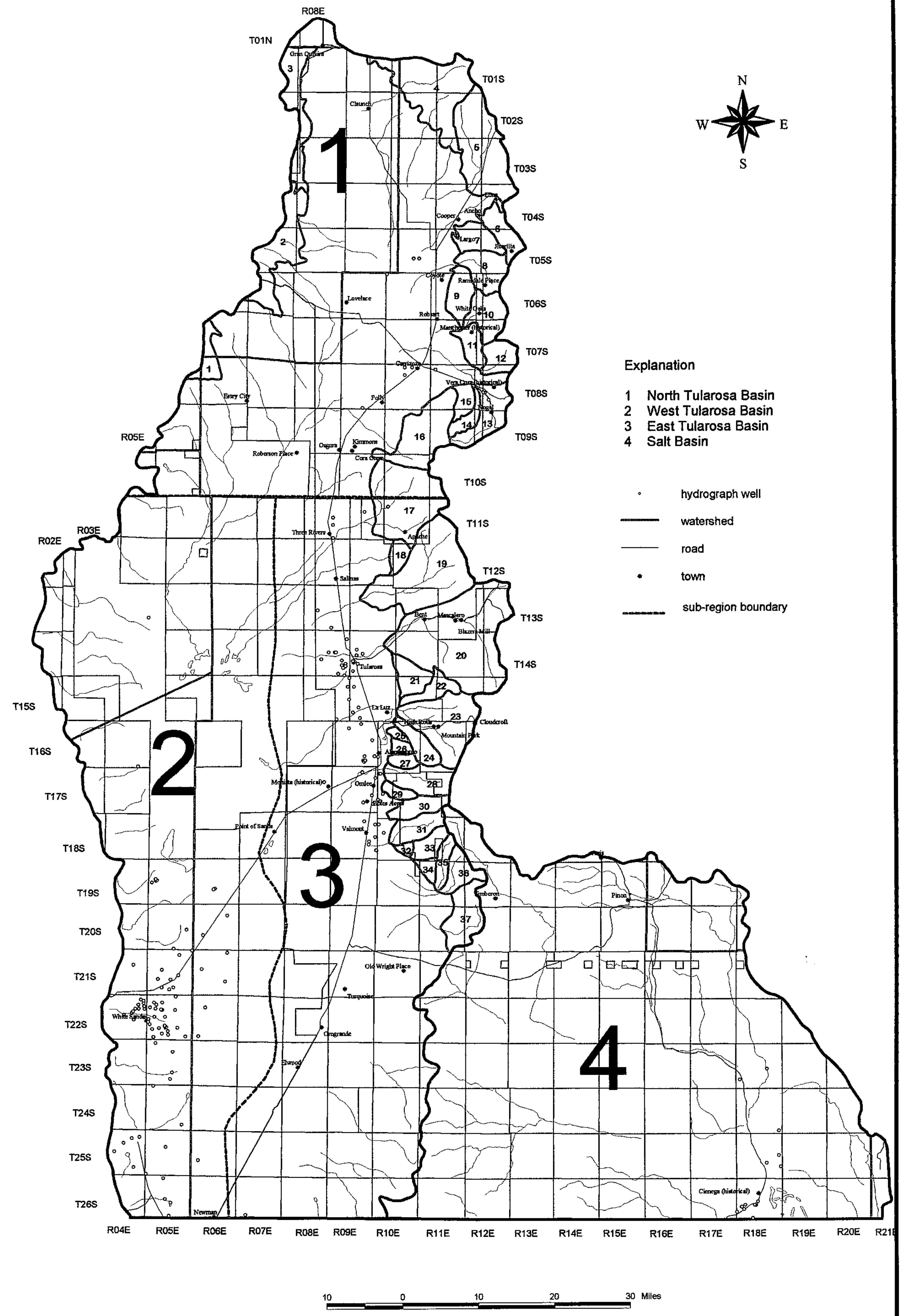


Figure 4.4 – Land Ownership



Map of the Tularosa and Salt Basins showing sub-regions, hydrograph well locations, major watersheds, and geographic details.

JOHN SHOMAKER & ASSOCIATES, INC.

Figure 6.1 – Hydrogeologic Areas Map

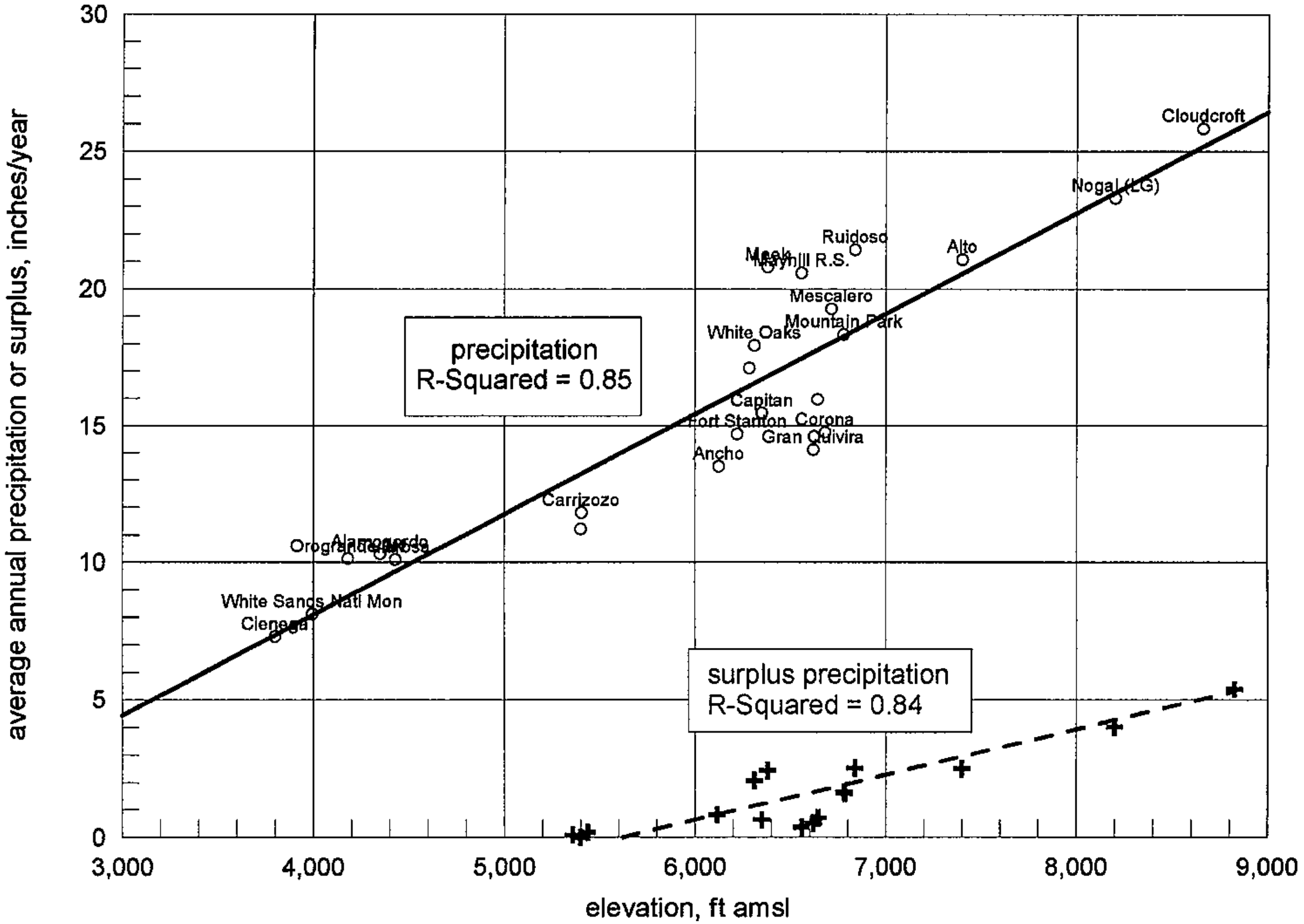


Figure 6.2 - Graph of precipitation and surplus versus elevation for the planning region.

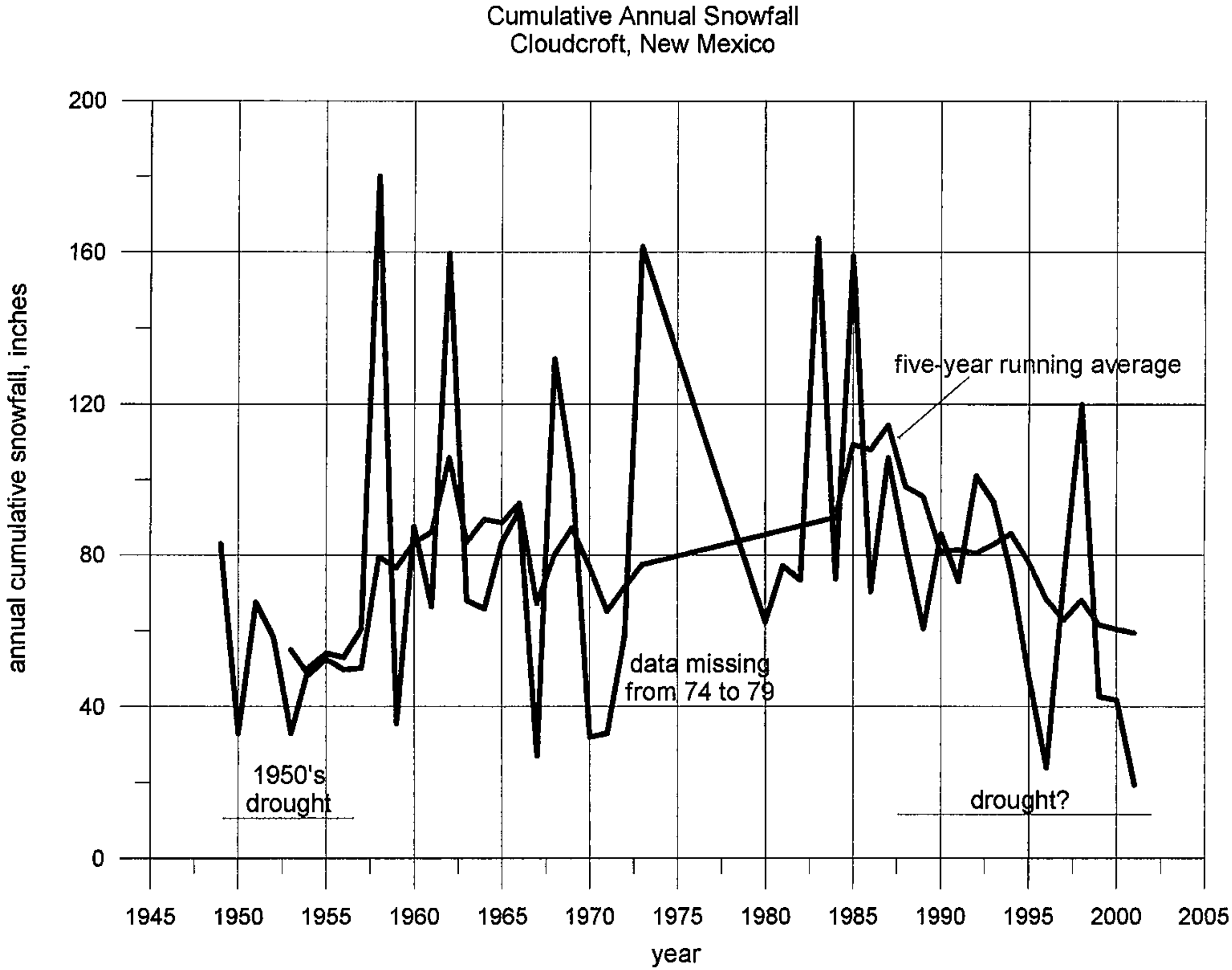


Figure 6.3 Graph of annual cumulated snowfall, Cloudcroft, New Mexico.

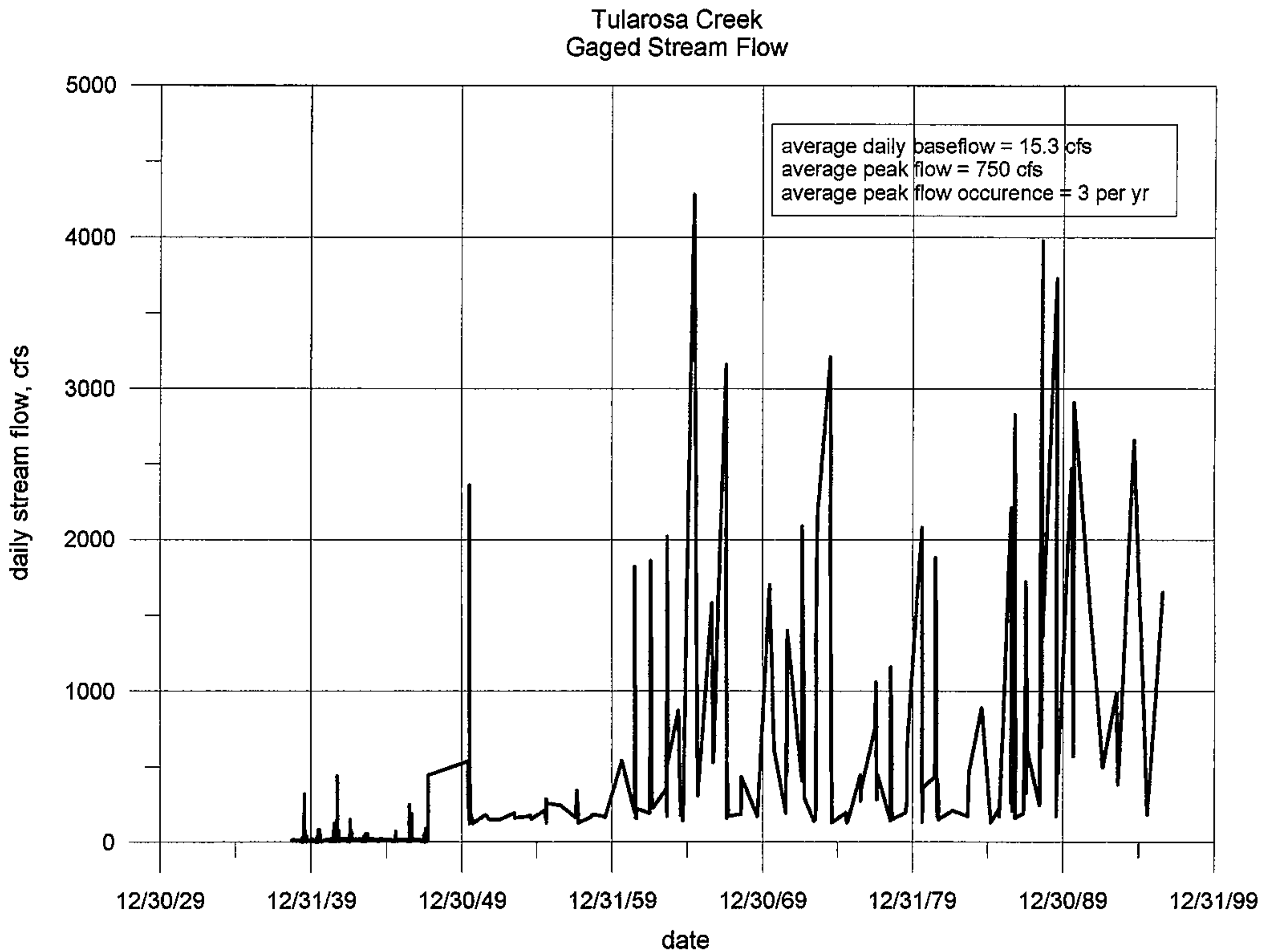


Figure 6.4 - Rio Tularosa, Eastern Tularosa Basin area (data obtained from USGS)

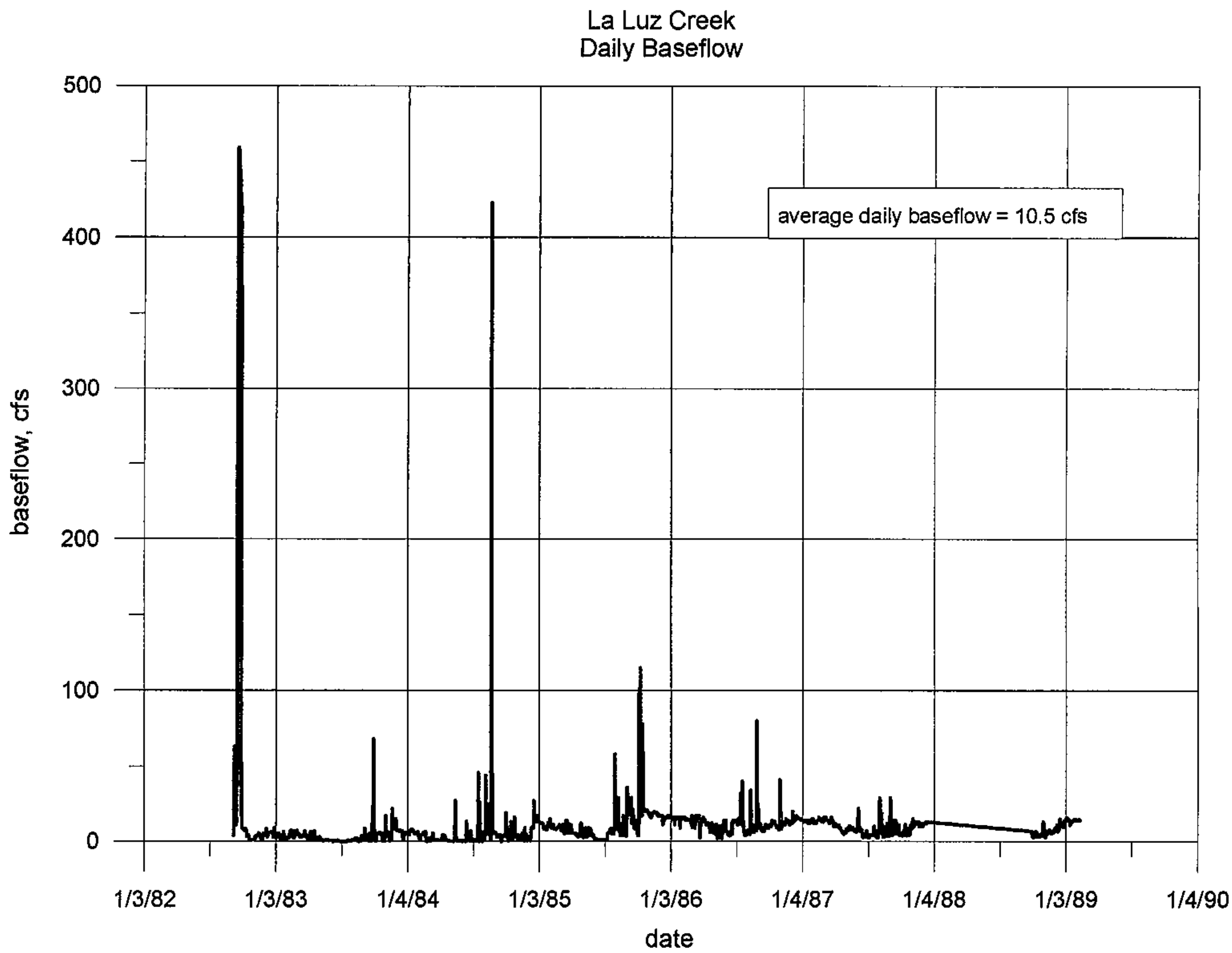


Figure 6.5 - La Luz Creek, Eastern Tularosa Basin area (data obtained from USGS)

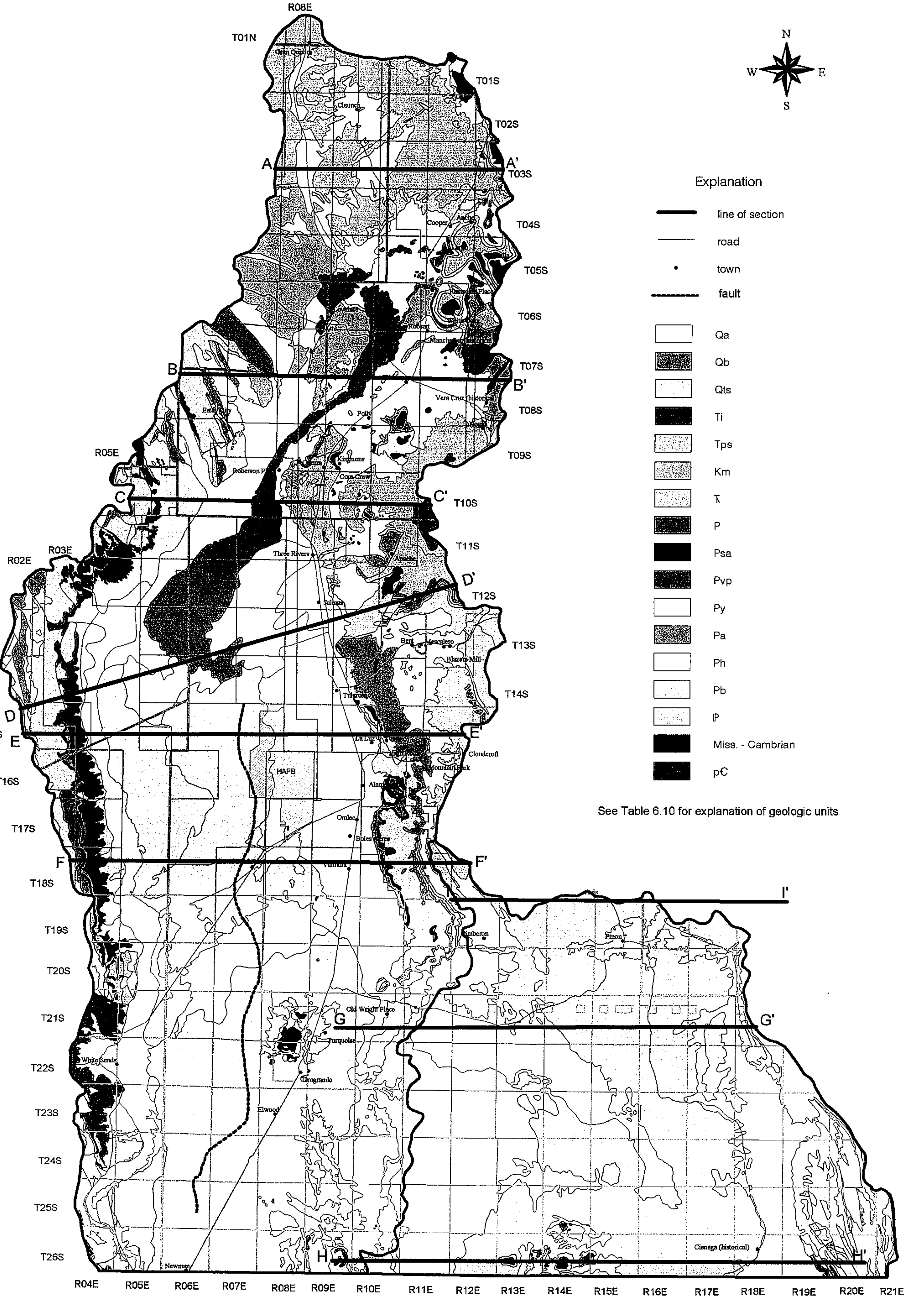


Figure 6.6. Map of the Tularosa and Salt Basins showing regional geology and lines of section.

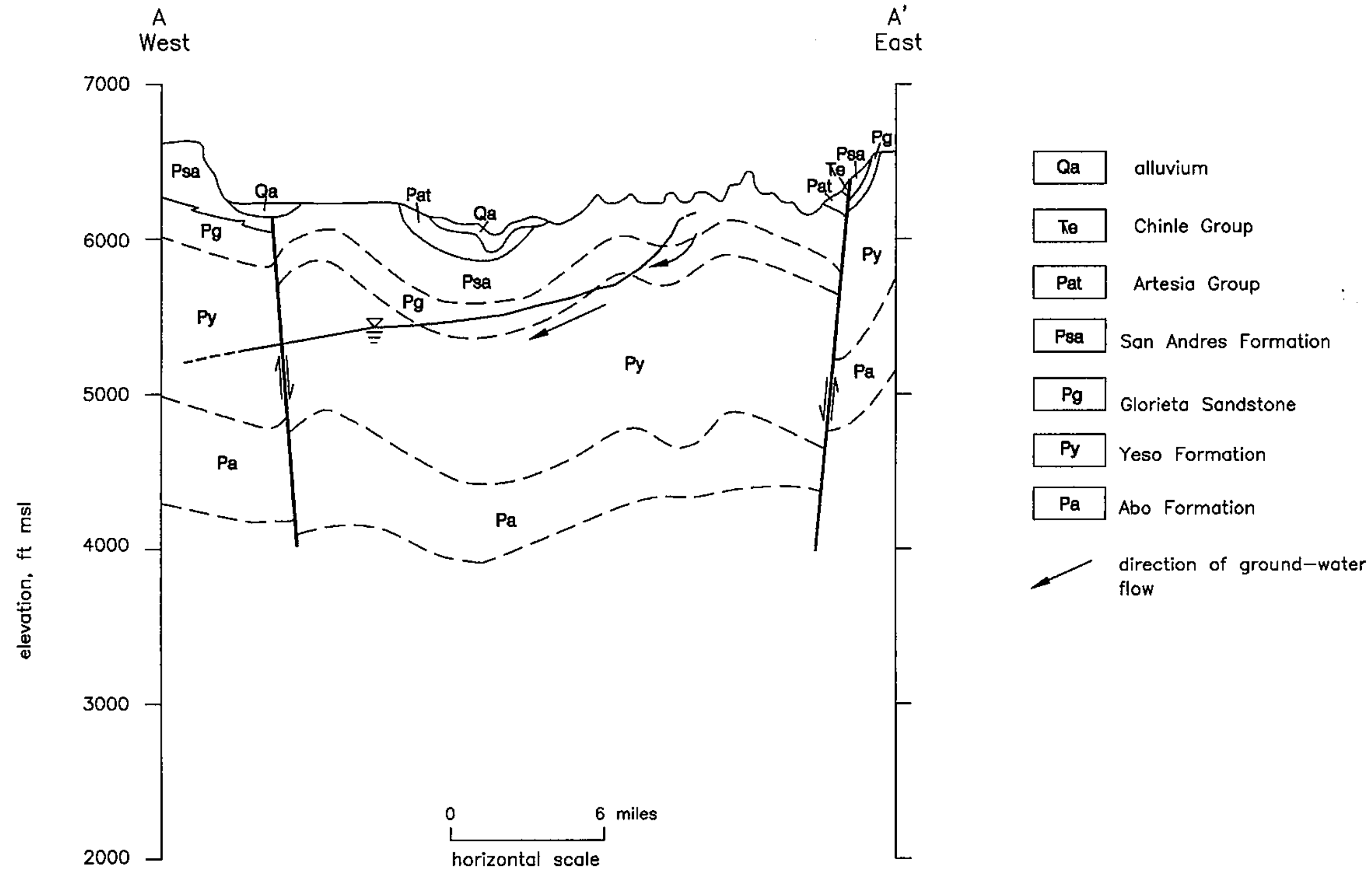


Figure 6.7. Hydrogeologic cross-section, A-A', North Tularosa basin. See Figure 6.6 for line of section.

JOHN SHOMAKER & ASSOCIATES, INC.

Figure 6.7 – Section A-A

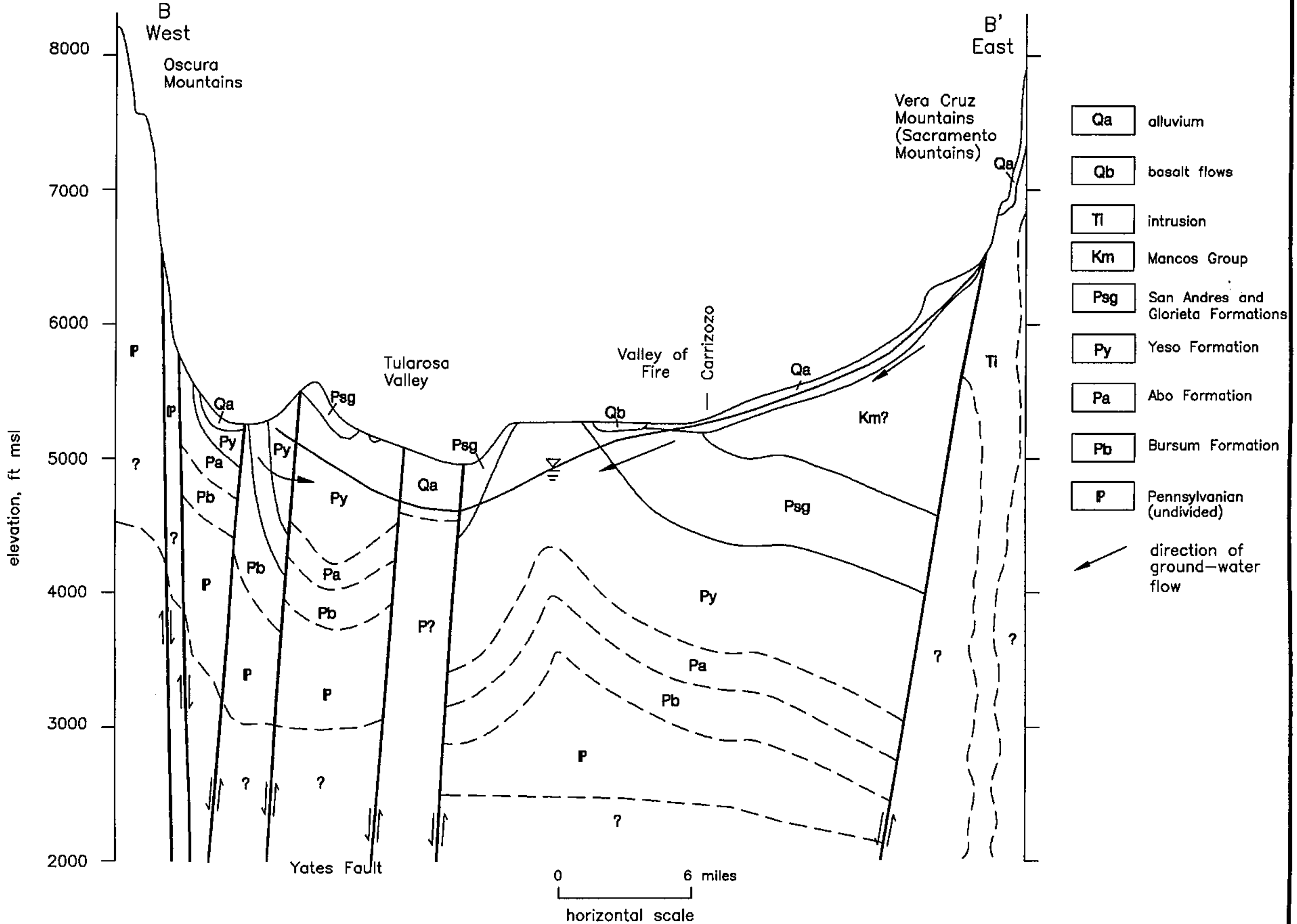
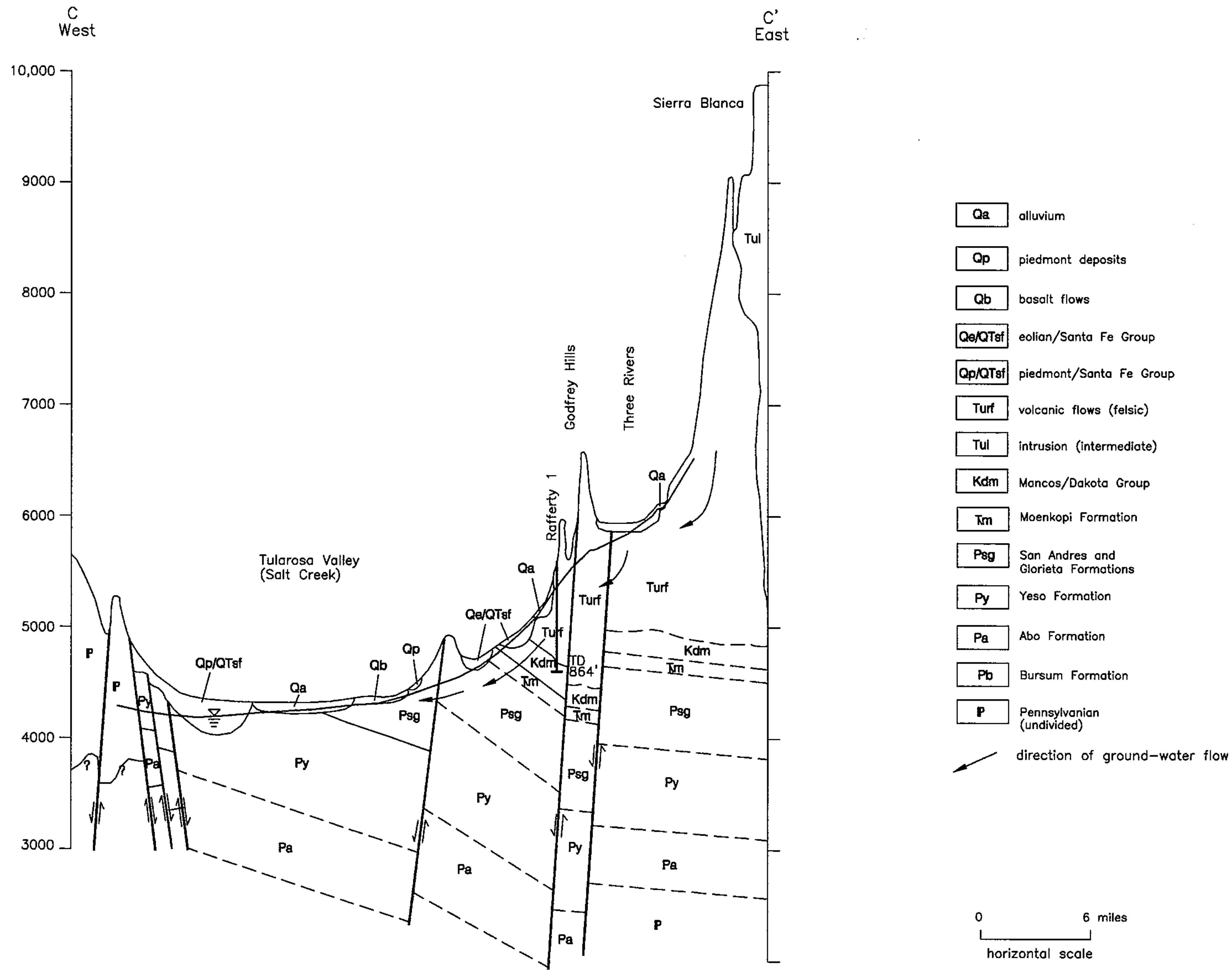


Figure 6.8. Hydrogeologic cross-section, B-B', North Tularosa basin. See Figure 6.6 for line of section.

JOHN SHOMAKER & ASSOCIATES, INC.

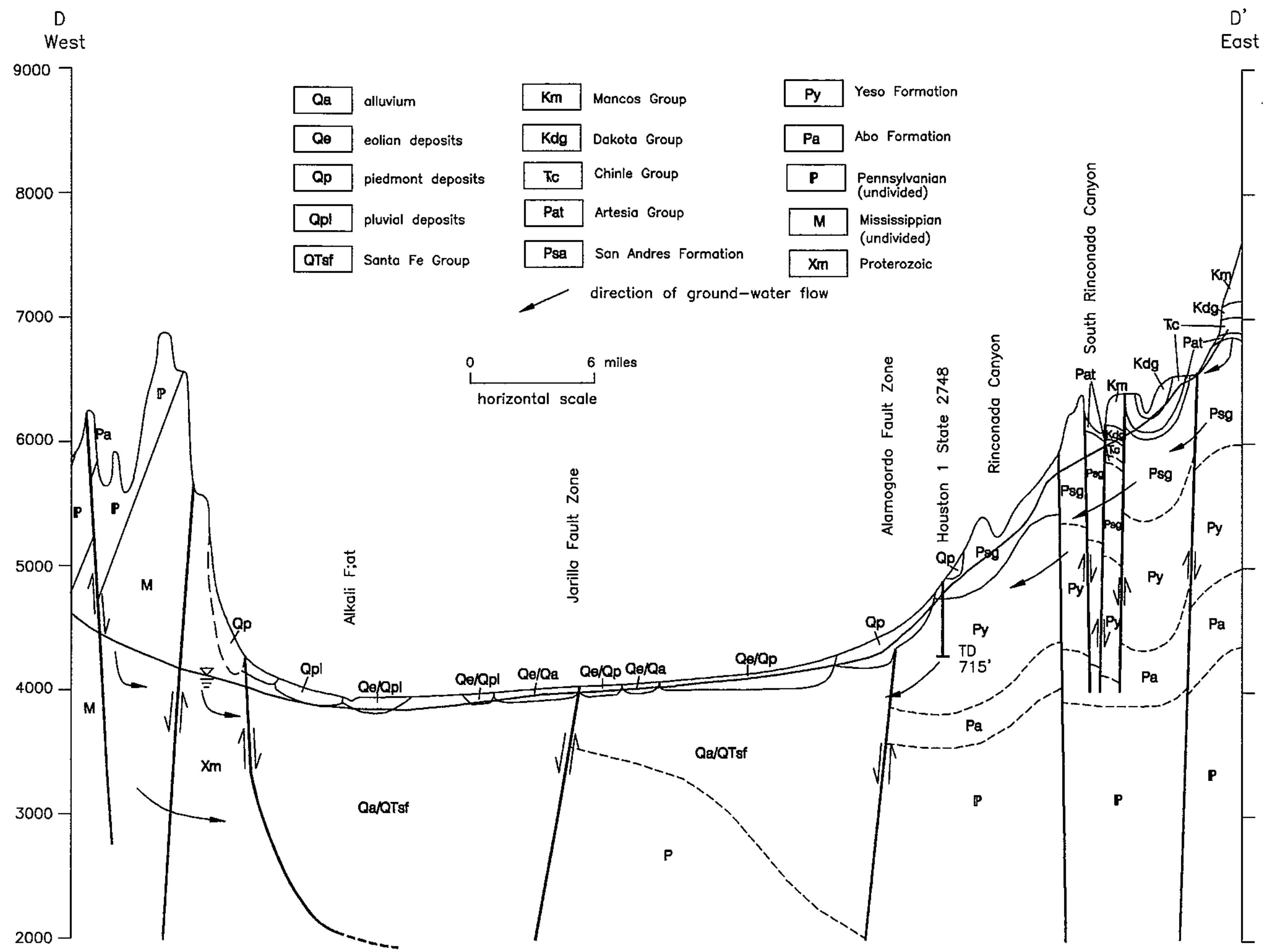
Figure 6.8 – Section B-B



Hydrogeologic cross-section, C–C', Tularosa basin. See Figure 6.6 for line of section.

JOHN SHOMAKER & ASSOCIATES, INC. 03/08/02

Figure 6.9 – Section C-C



Hydrogeologic cross-section, D–D', Tularosa basin. See Figure 6.6 for line of section.

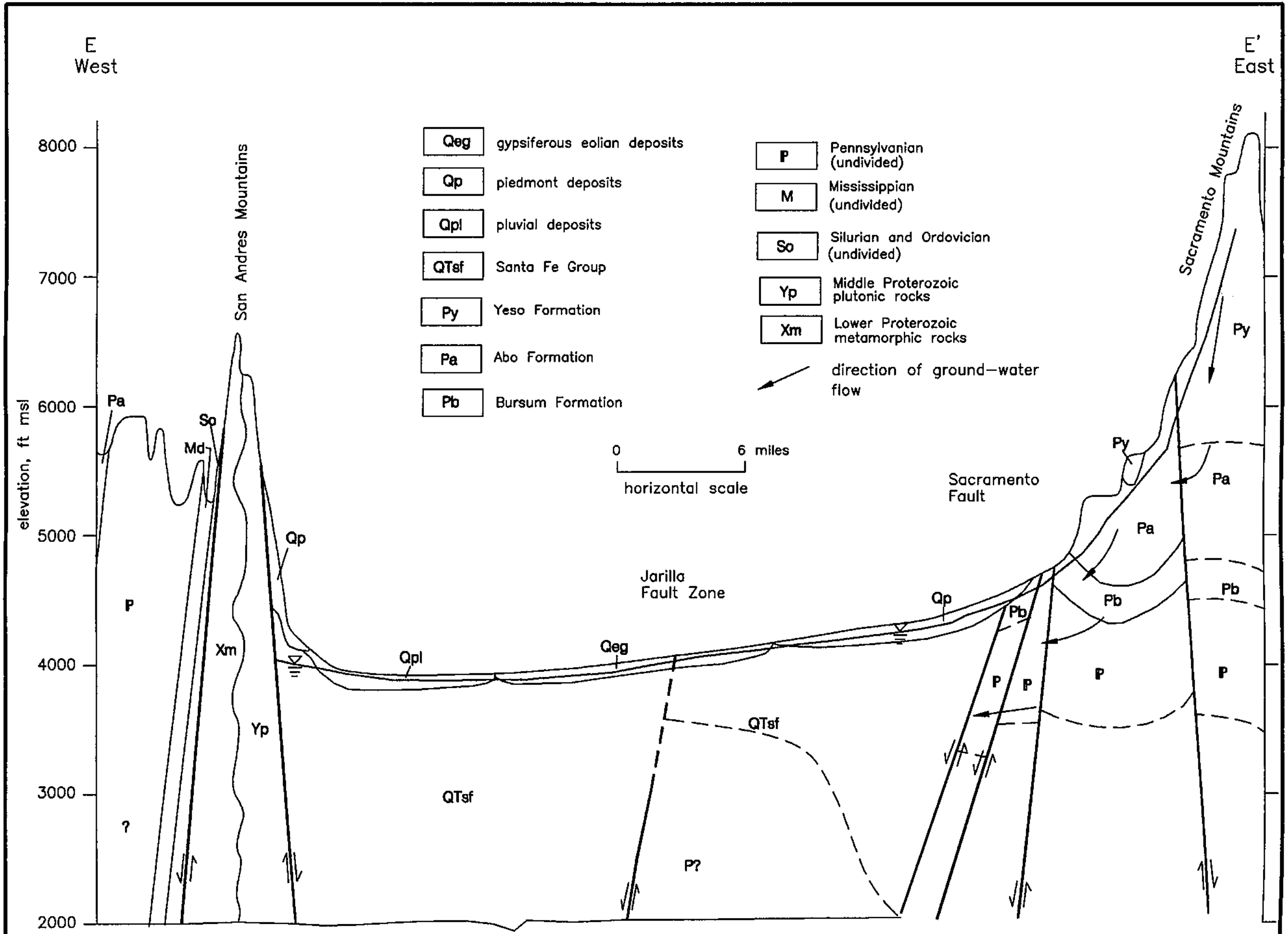


Figure 6.11. Hydrogeologic cross-section, E–E', Tularosa basin. See Figure 6.6 for line of section.

JOHN SHOMAKER & ASSOCIATES, INC.

Figure 6.11 – Section E-E

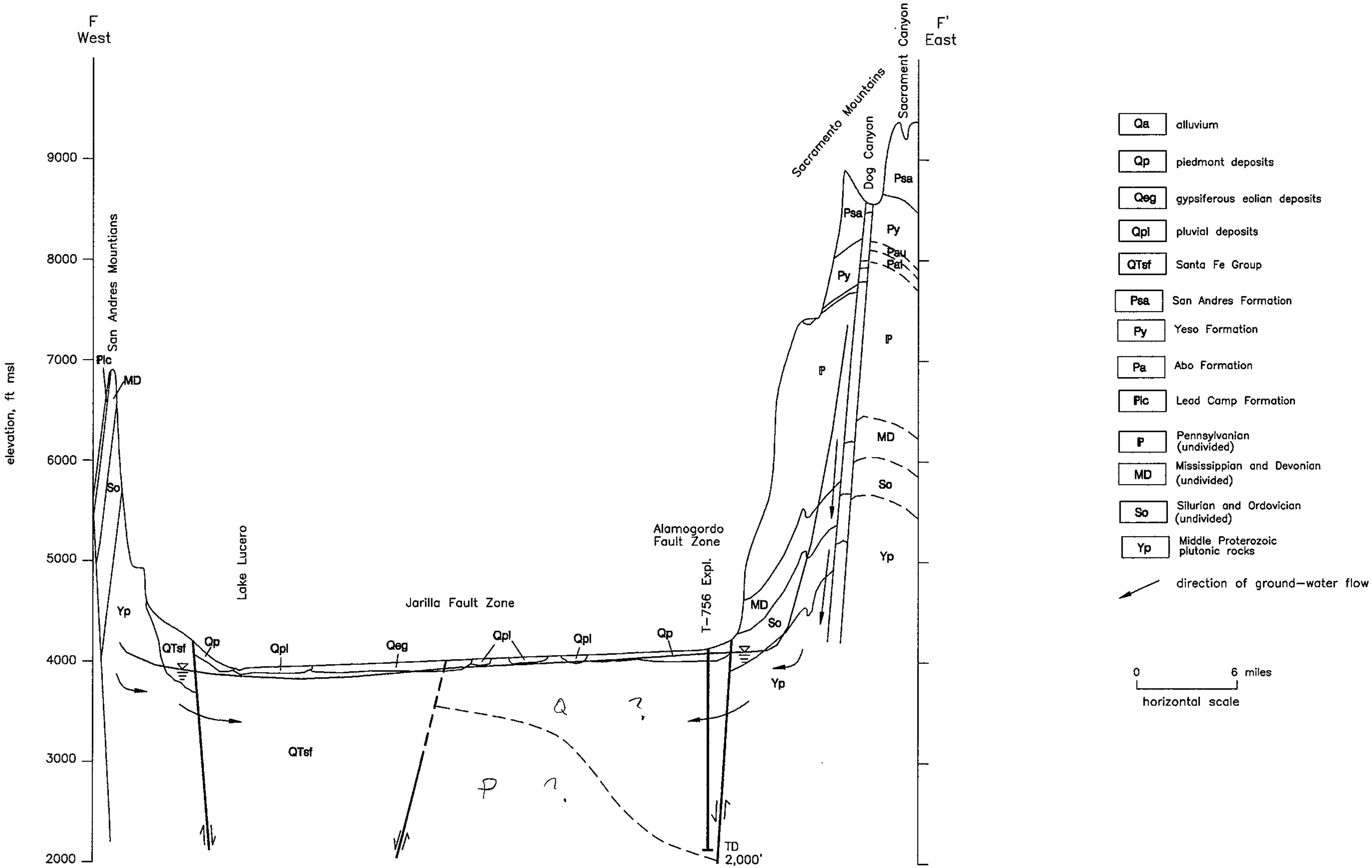


Figure 6.12. Hydrogeologic cross-section, F–F', Tularosa basin. See Figure 6.6 for line of section.

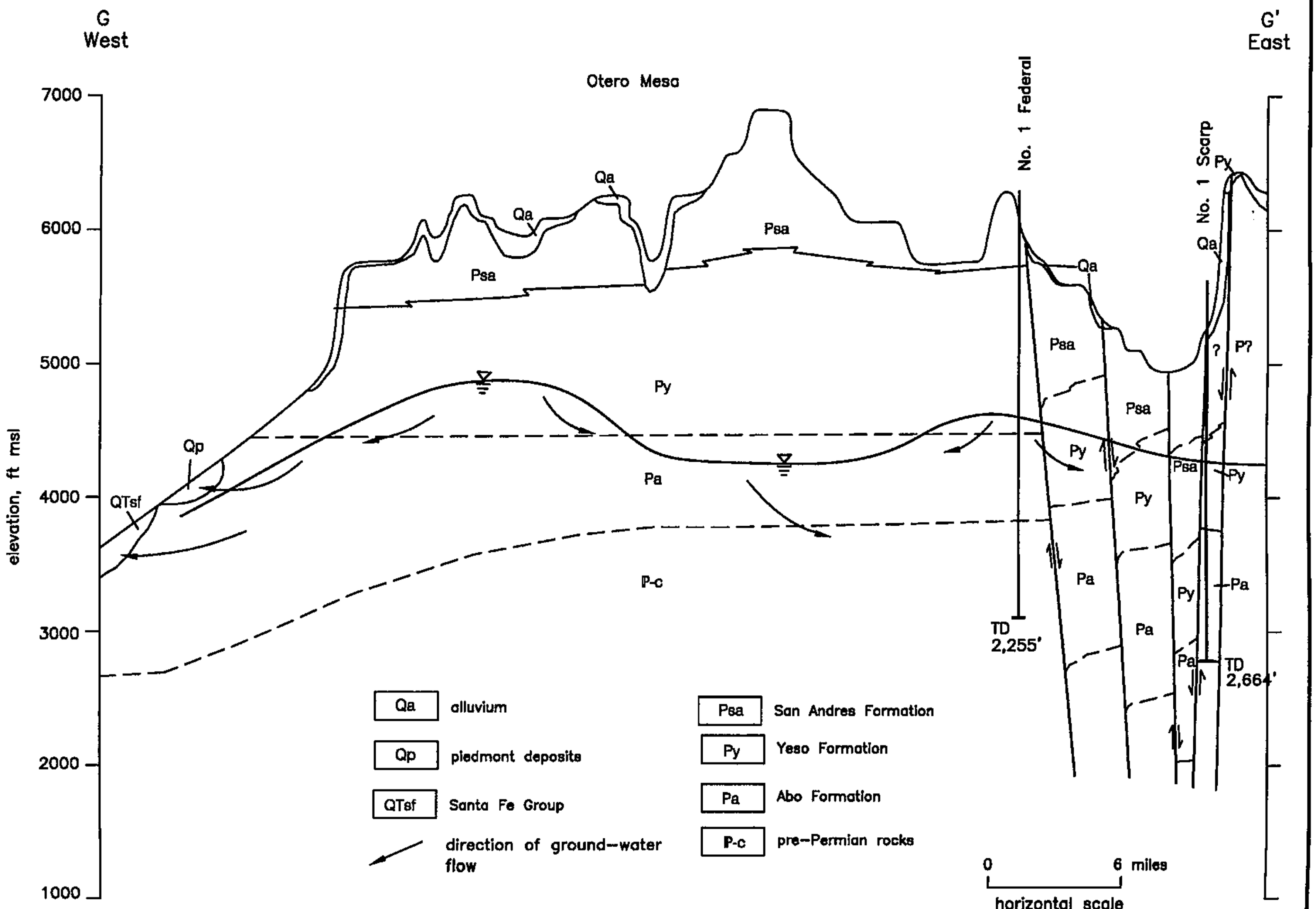


Figure 6.13. Hydrogeologic cross-section, G–G', Salt Basin. See Figure 6.6 for line of section.

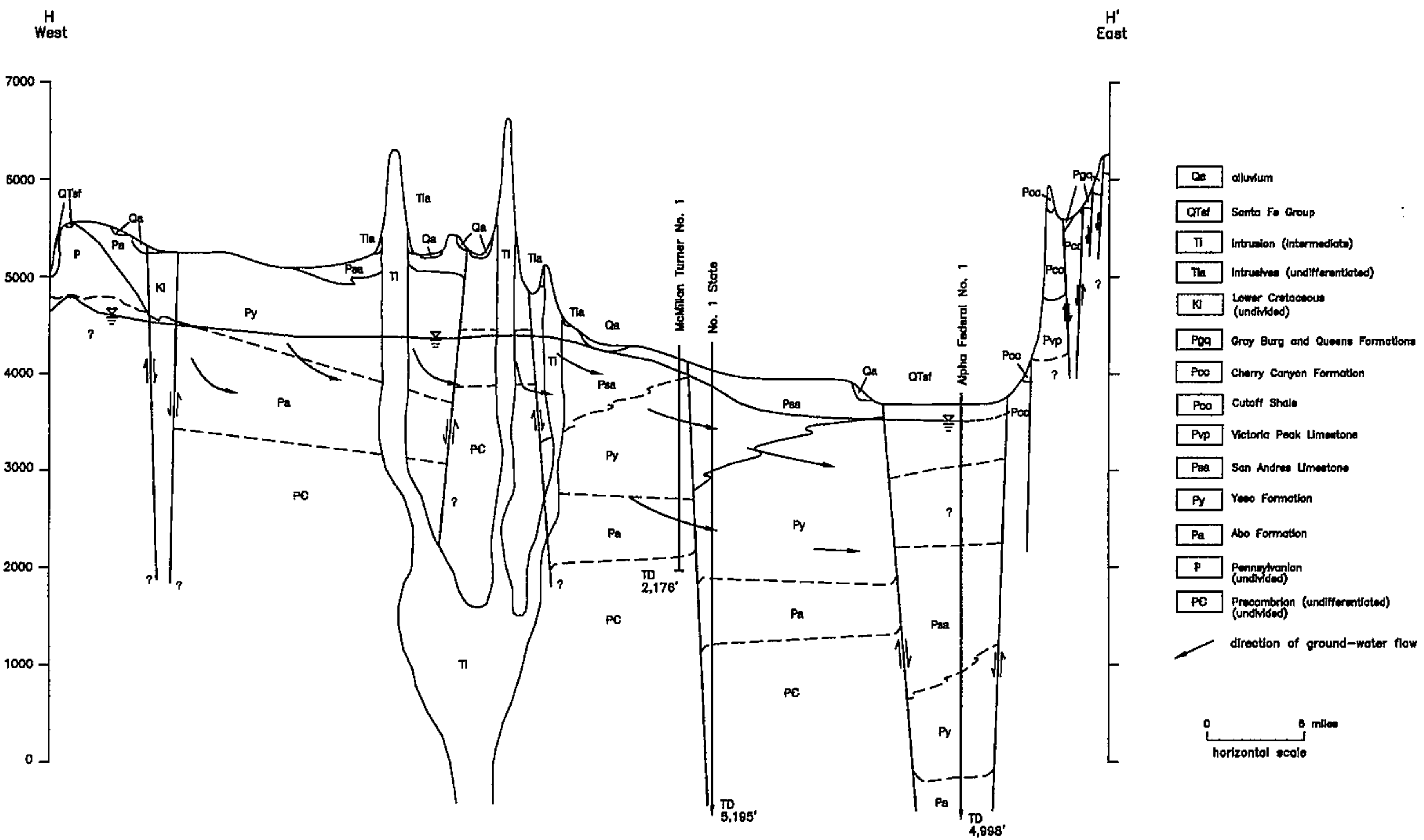


Figure 6.14. Hydrogeologic cross-section, H–H', Salt basin. See Figure 6.6 for line of section.

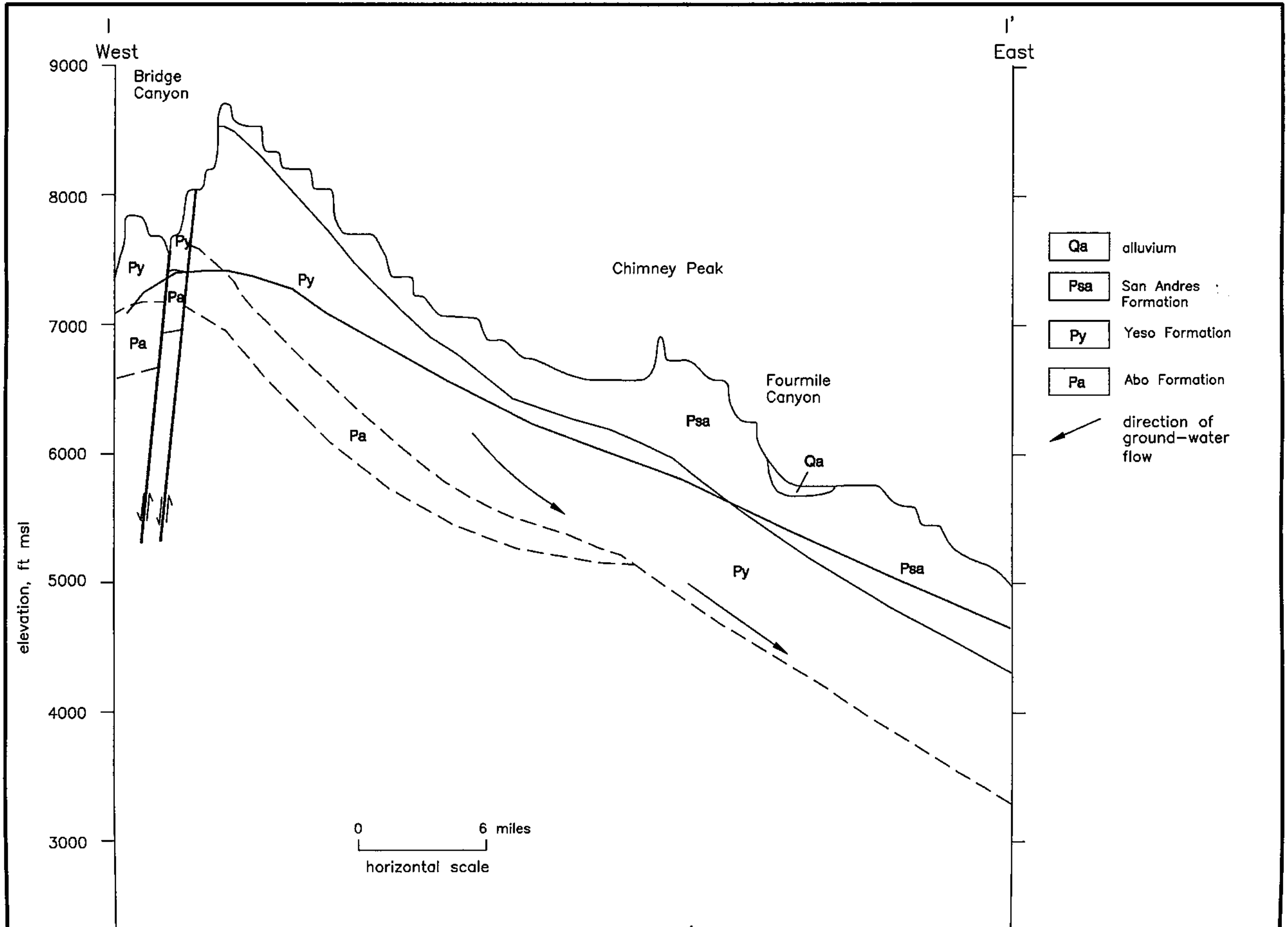


Figure 6.15. Hydrogeologic cross-section, I-I', Tularosa basin.
See Figure 6.6 for line of section.

JOHN SHOMAKER & ASSOCIATES, INC.

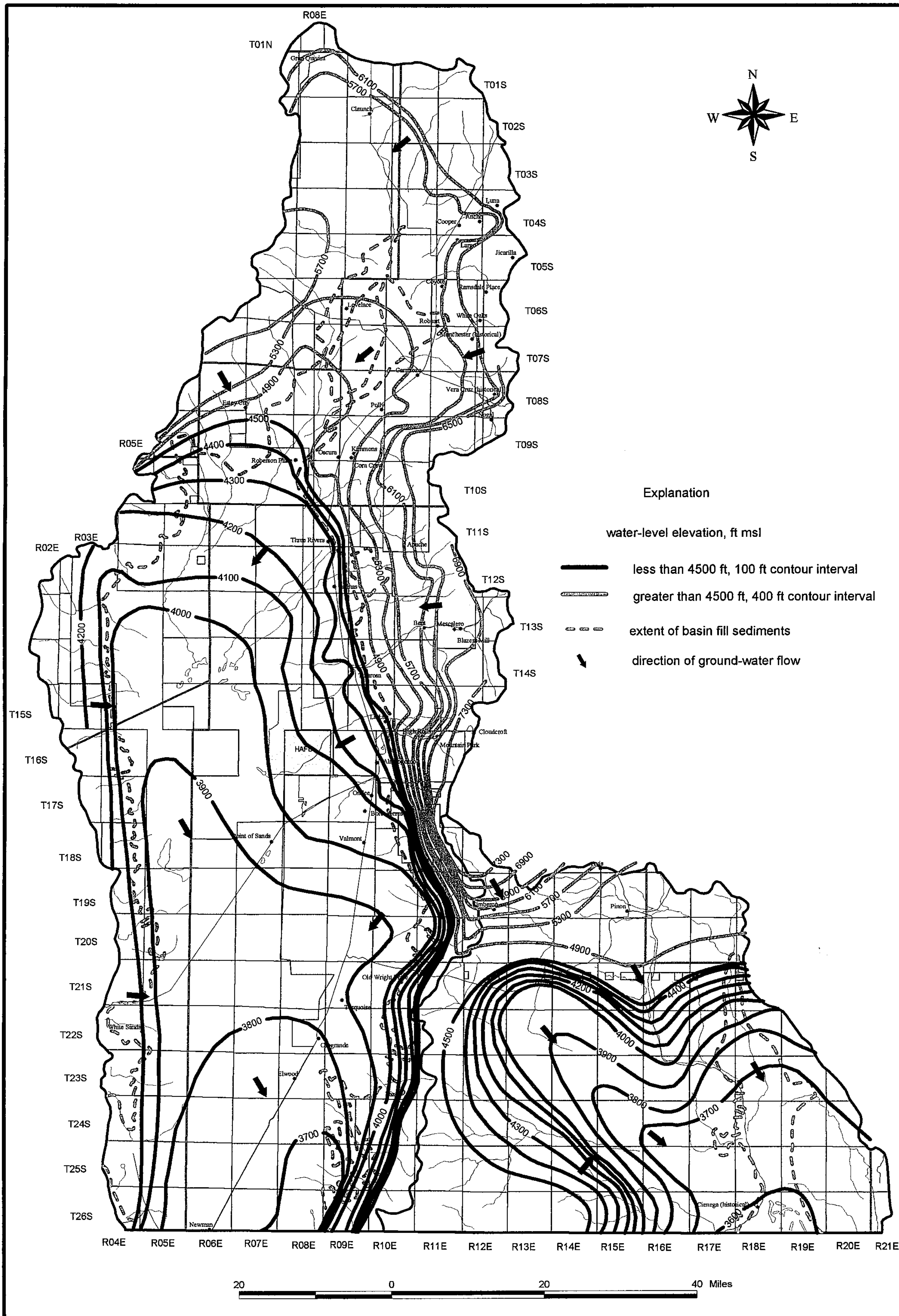


Figure 6.16. Map of the Tularosa and Salt Basins showing water-level elevation contours.

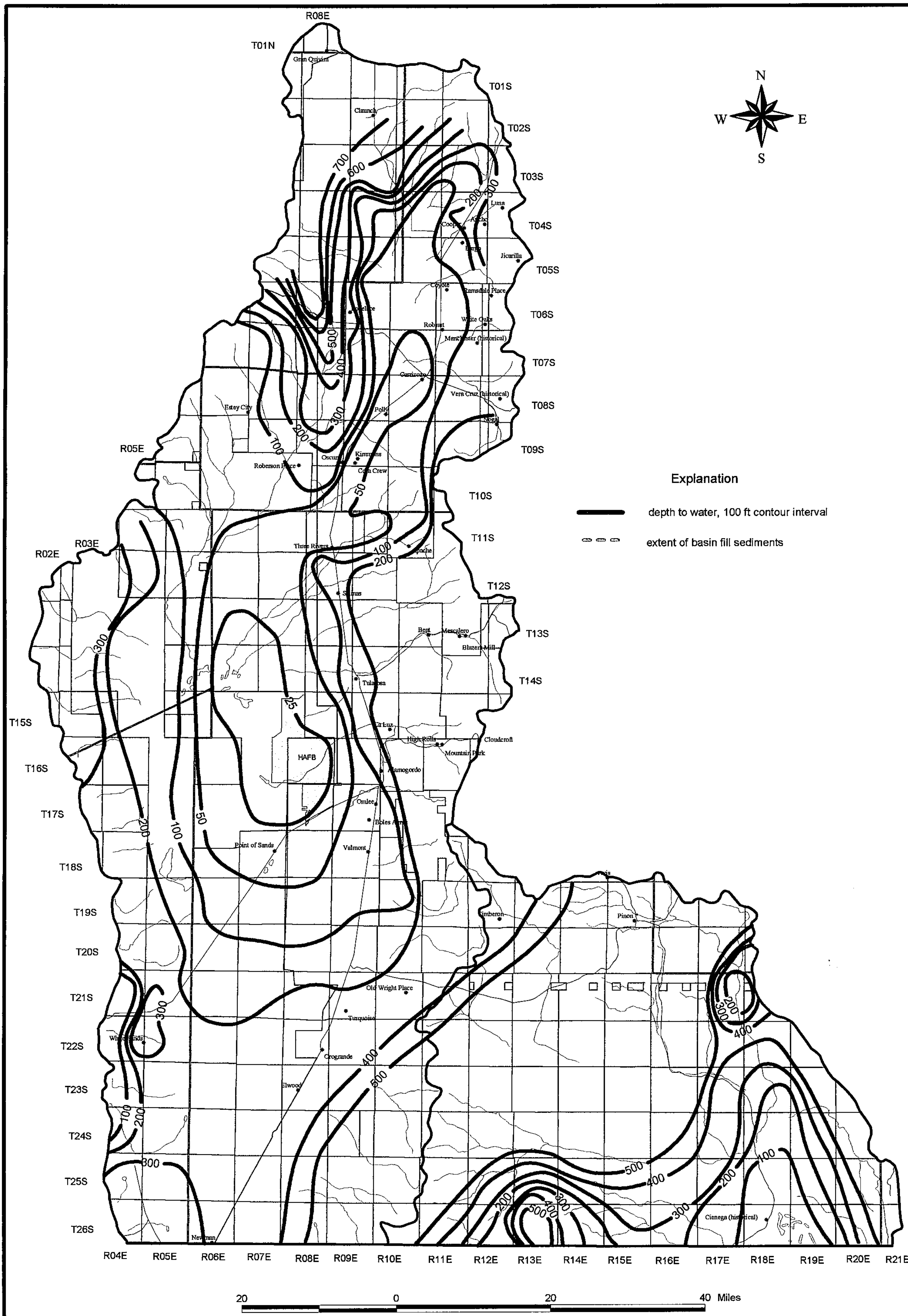


Figure 6.17. Map of the Tularosa and Salt Basins showing approximate depth to water contours.

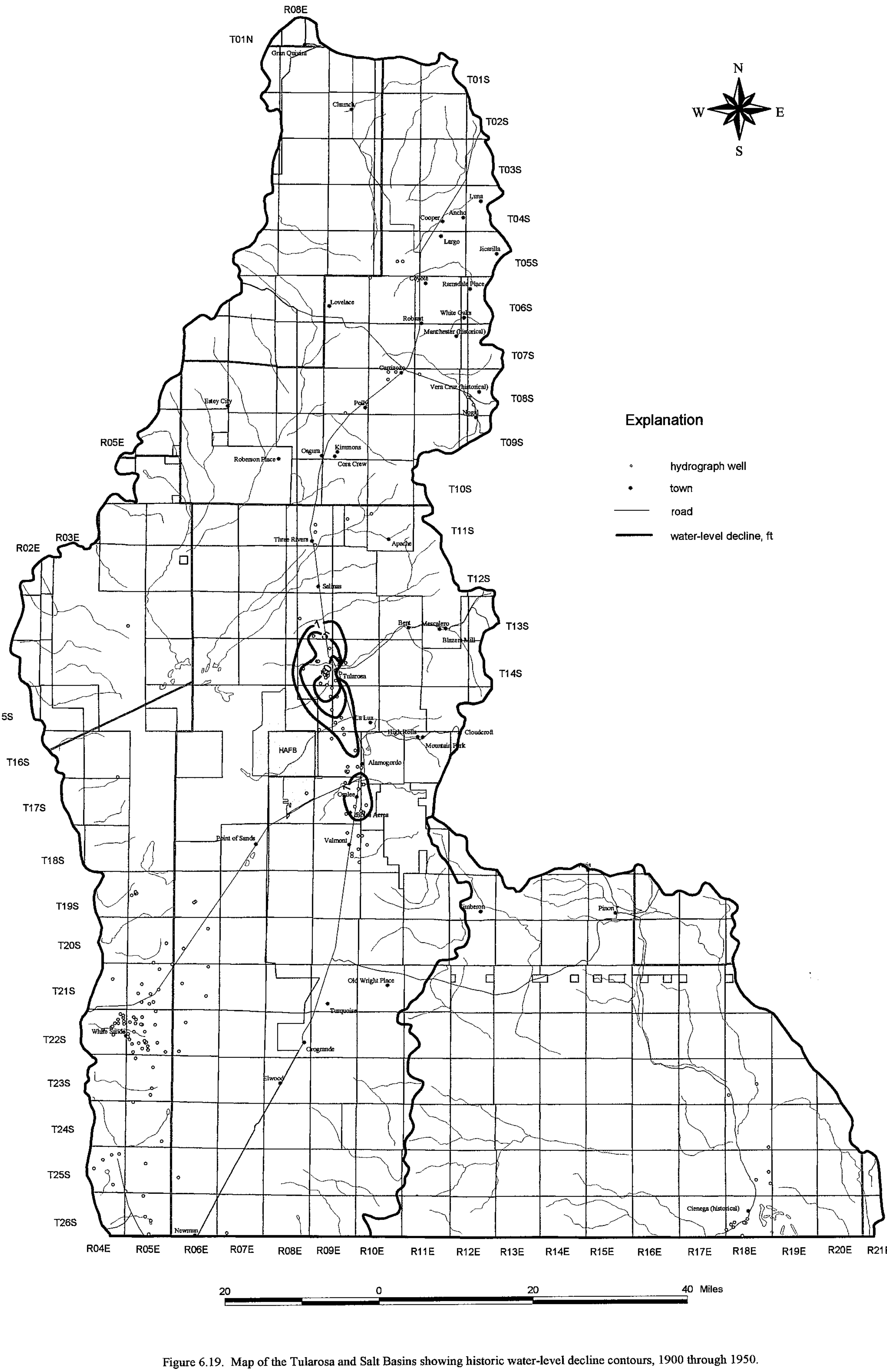
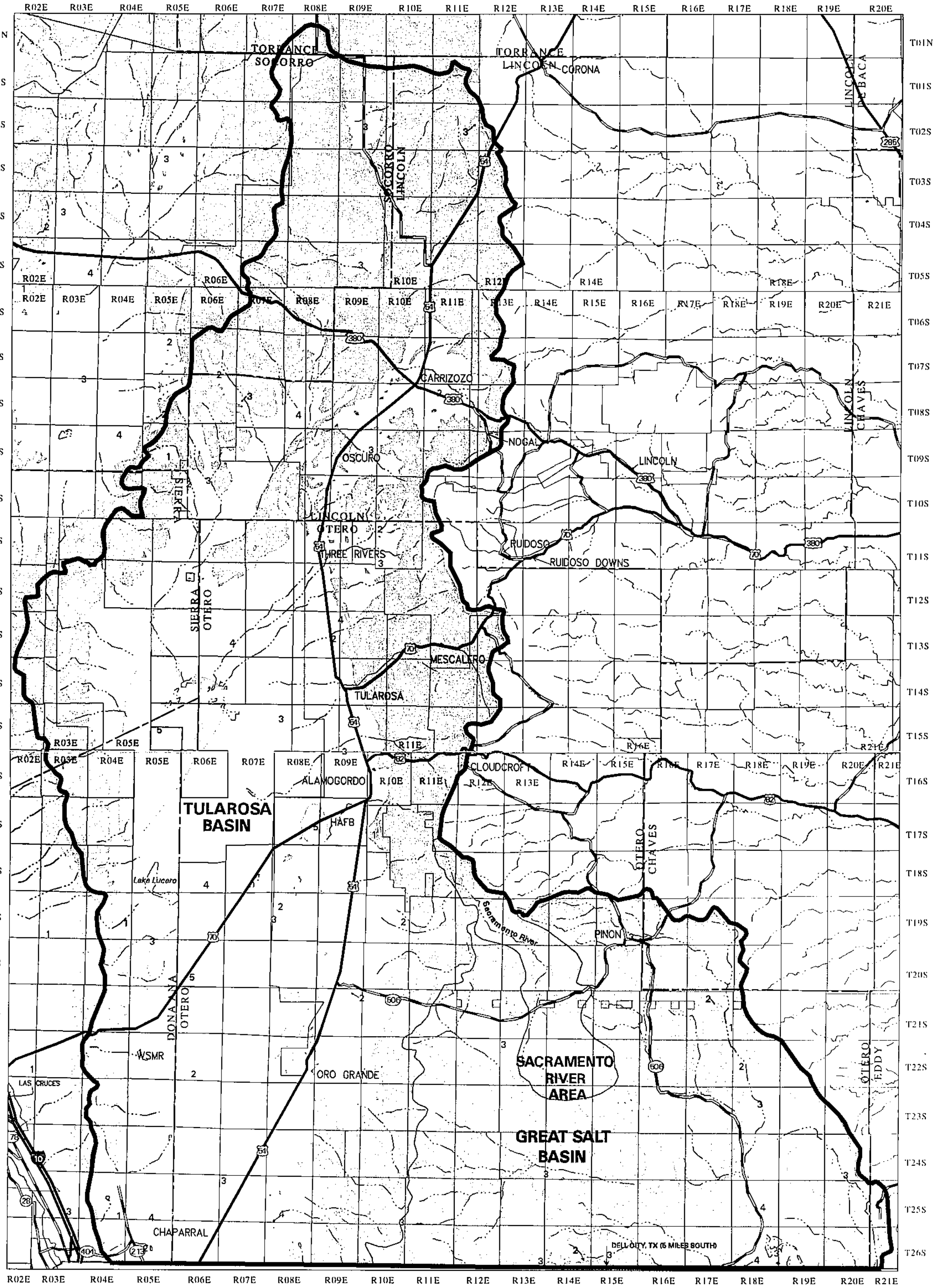
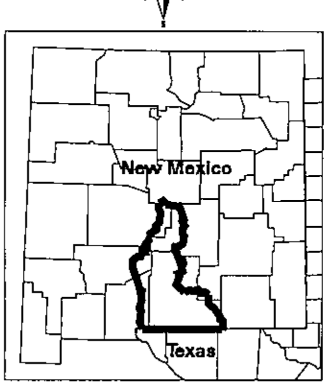


Figure 6.19. Map of the Tularosa and Salt Basins showing historic water-level decline contours, 1900 through 1950.

Tularosa , Sacramento River Area and Great Salt Basin Regional Water Plan

Salinity Map





Produced by New Mexico Water Resources Research Institute, June 2000

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. Dominant chemical type groundwater map digitized from Water-Resources Investigation Report 83-4118-C (Thompson et al., 1984). Boundary of the Tularosa, Sacramento, and Great Salt Basin Water Planning Region is based on surface drainage divides.

Horizontal accuracy: At the scale of 1:900,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 762 ground meters, of their true location.

Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.

Thompson, T.H., Chappell, R.W., and Hart, D.L., 1984, Maps showing distribution of dissolved solids and dominant chemical type in ground water, Basin and Range province, New Mexico: U.S. Survey Water-Resources Investigations 83-4118-C, scale 1:500,000, 2 sheets, 5 p.

SCALE 1: 900 000

25 0 25 50 MILES

25 0 25 50 KILOMETERS

Explanation

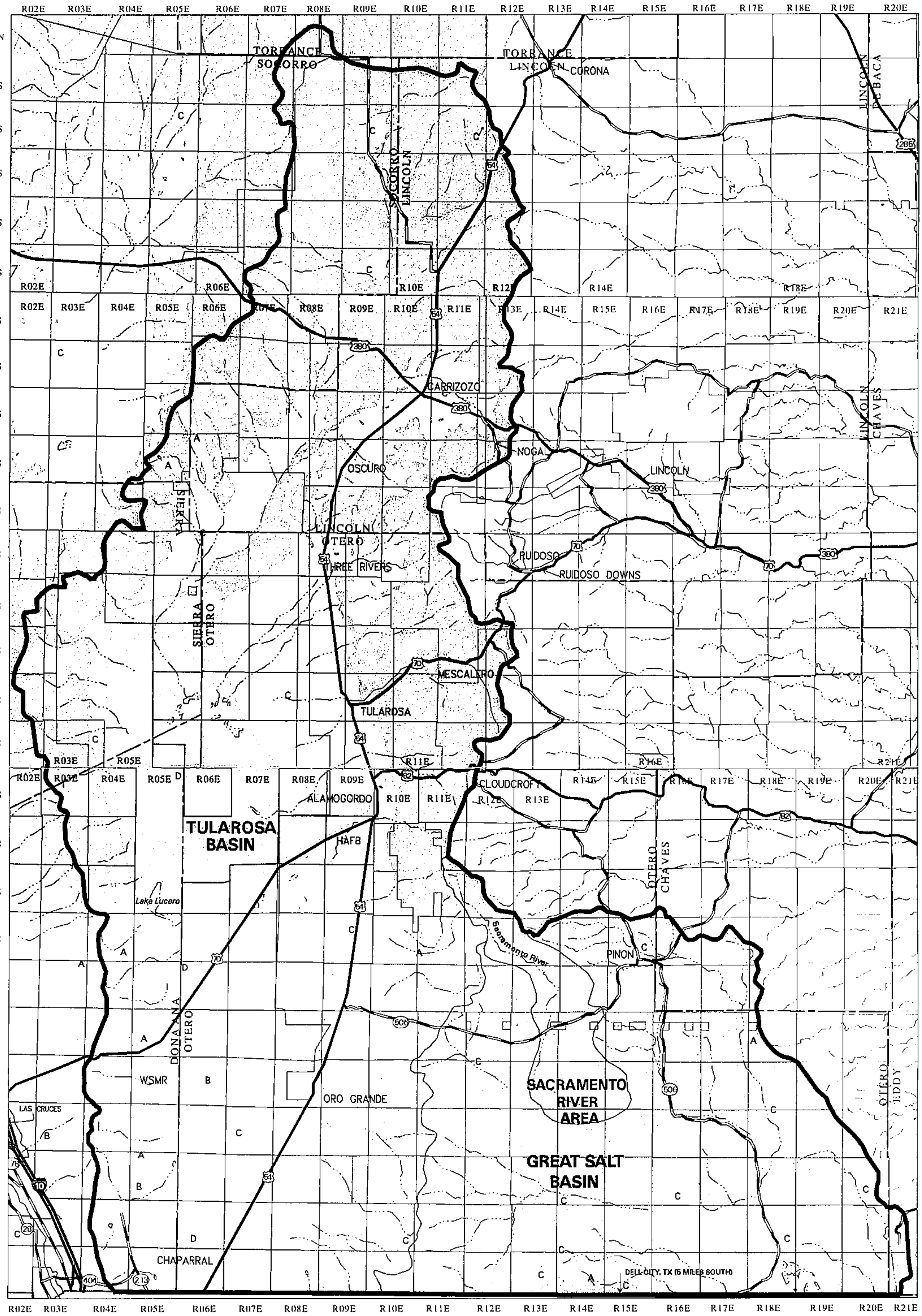
- State Line
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State Highway
- Township/Ramge
- Planning Region
- Sub-region

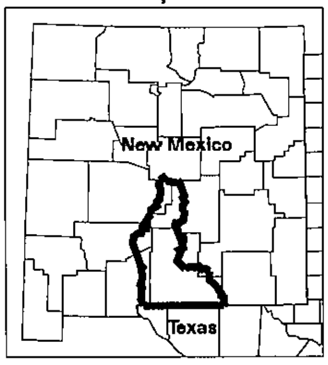
- 1 -0 to 500 mg/L TDS
- 2 -501 to 1,000 mg/L TDS
- 3 -1,001 to 3,000 mg/L TDS
- 4 -3,001 to 10,000 mg/L TDS
- 5 -Greater than 10,000 mg/L TDS
- Consolidated Bedrock
- No Data

Figure 6.21 – Salinity Map

Tularosa , Sacramento River Area and Great Salt Basin Regional Water Plan

Map Showing Dominant Chemical Type Water





Produced by New Mexico Water Resources Research Institute, June 2000

Base map prepared by the U.S. Geological Survey

Compiled from digital data provided by the New Mexico Resource Geographic Information System Program (RGIS). Original base maps digitized from 1:500,000 mylar sheets and 100,000 paper maps for New Mexico. These data meets National Mapping Accuracy Standards for 1:500,000 and 1:100,000 scale maps. Dominant chemical type groundwater map digitized from Water-Resources Investigation Report 83-4118-C (Thompson et al., 1984). Boundary of the Tularosa, Sacramento, and Great Salt Basin Water Planning Region is based on surface drainage divides.

Horizontal accuracy: At the scale of 1:900,000 at least 90 percent of the points tested are within 1/30th inch (0.0333 inch), or within 762 ground meters, of their true location.

Projection: Universal Transverse Mercator, Zone 13, Units meters, NAD83.

Thompson, T.H., Chappell, R.W., and Hart, D.L., 1984, Maps showing distribution of dissolved solids and dominant chemical type in ground water, Basin and Range province, New Mexico: U.S. Survey Water-Resources Investigations 83-4118-C, scale 1:500,000, 2 sheets, 5 p.

Explanation

- State Line
- County Line
- Perennial Stream/River
- Intermittent Stream
- Interstate
- U.S. Highway
- State Highway
- Township/Ramge
- Planning Region
- Sub–region
- A –calcium magnesium bicarbonate type w
- B –sodium bicarbonate type water
- C –sulfate type water
- D –chloride type water
- Consolidated Bedrock
- No Data

SCALE 1: 900 000

25 0 25 50 MILES

25 0 25 50 KILOMETERS

Figure 6.2[illegible] – Dominant Chemical Type Water Map

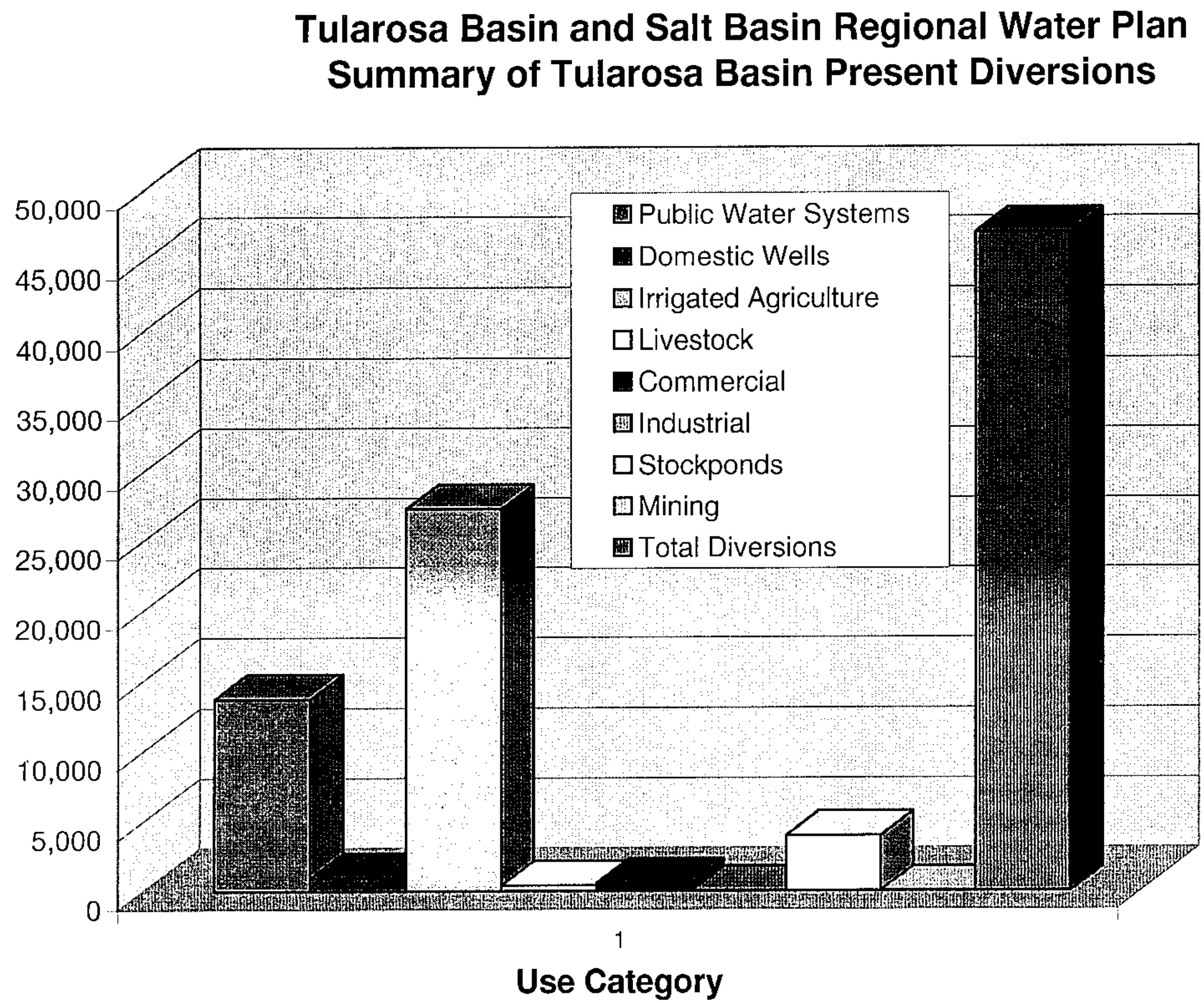


Fig. 7.1 - Present Tularosa Basin Diversions

Livingston Associates, P.C.
Consulting Engineers

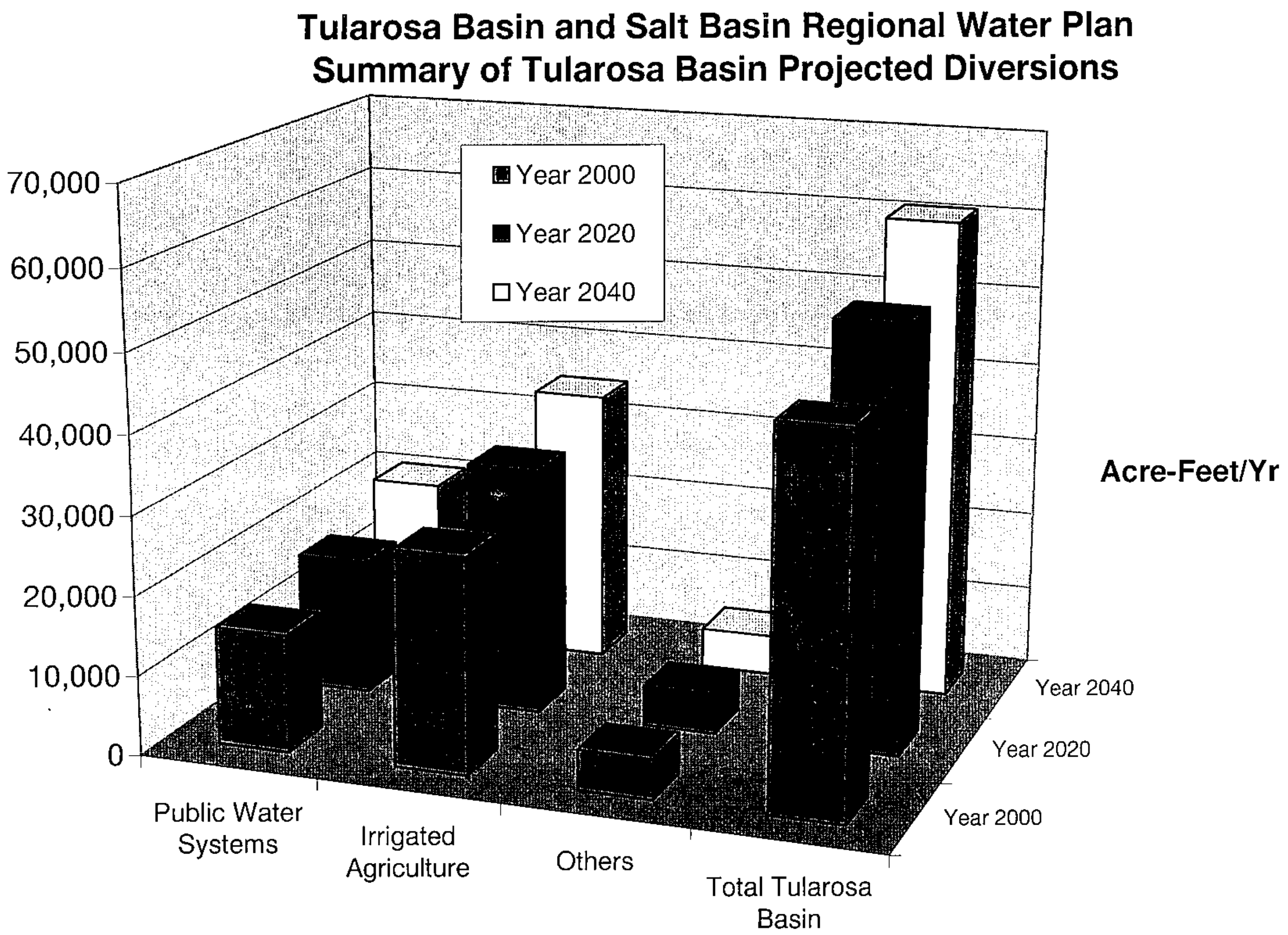


Fig. 7.2 - Future Tularosa Basin Diversions

Livingston Associates, P.C.
Consulting Engineers

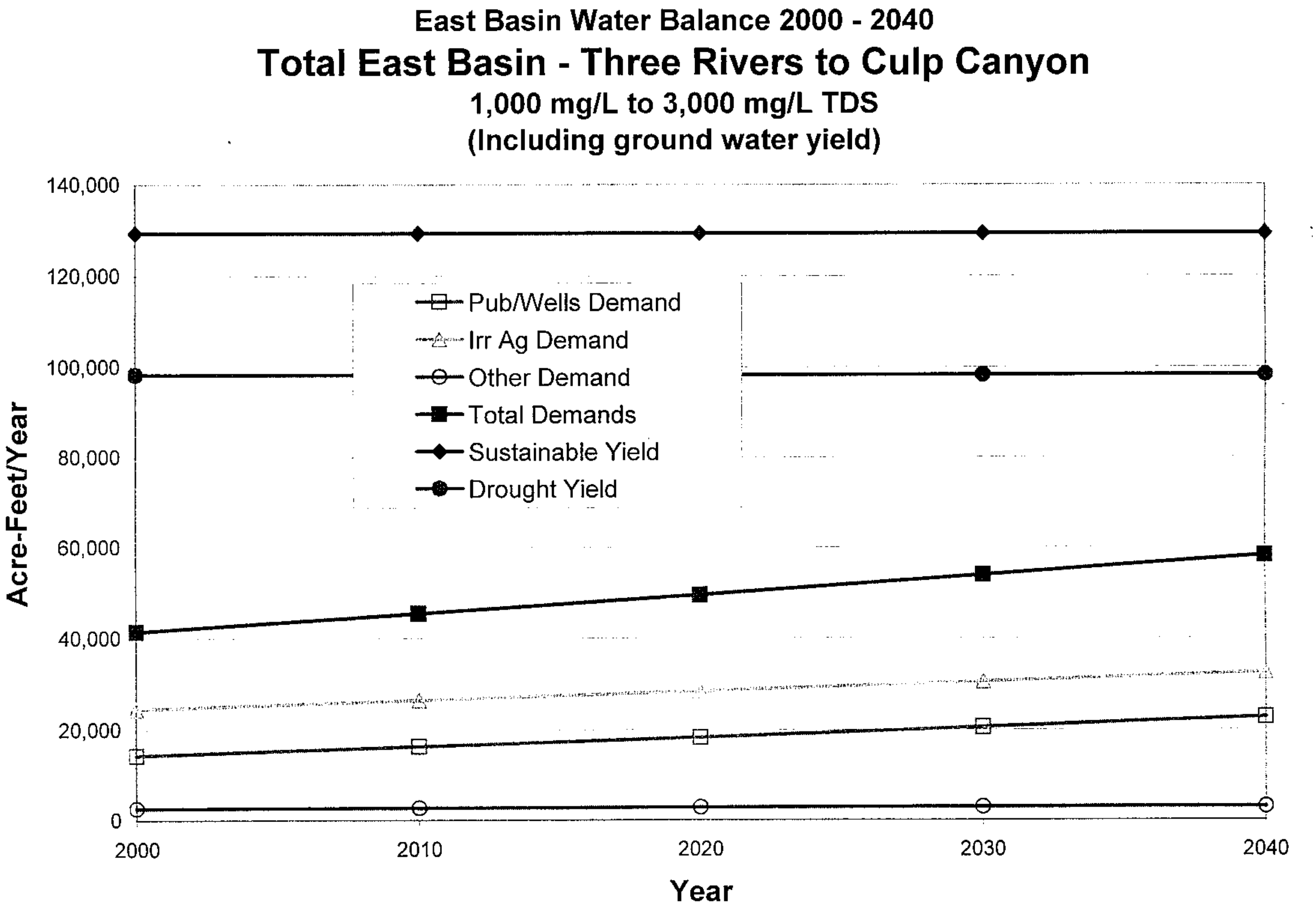


Figure 8.1 - Total East Basin Water Balance

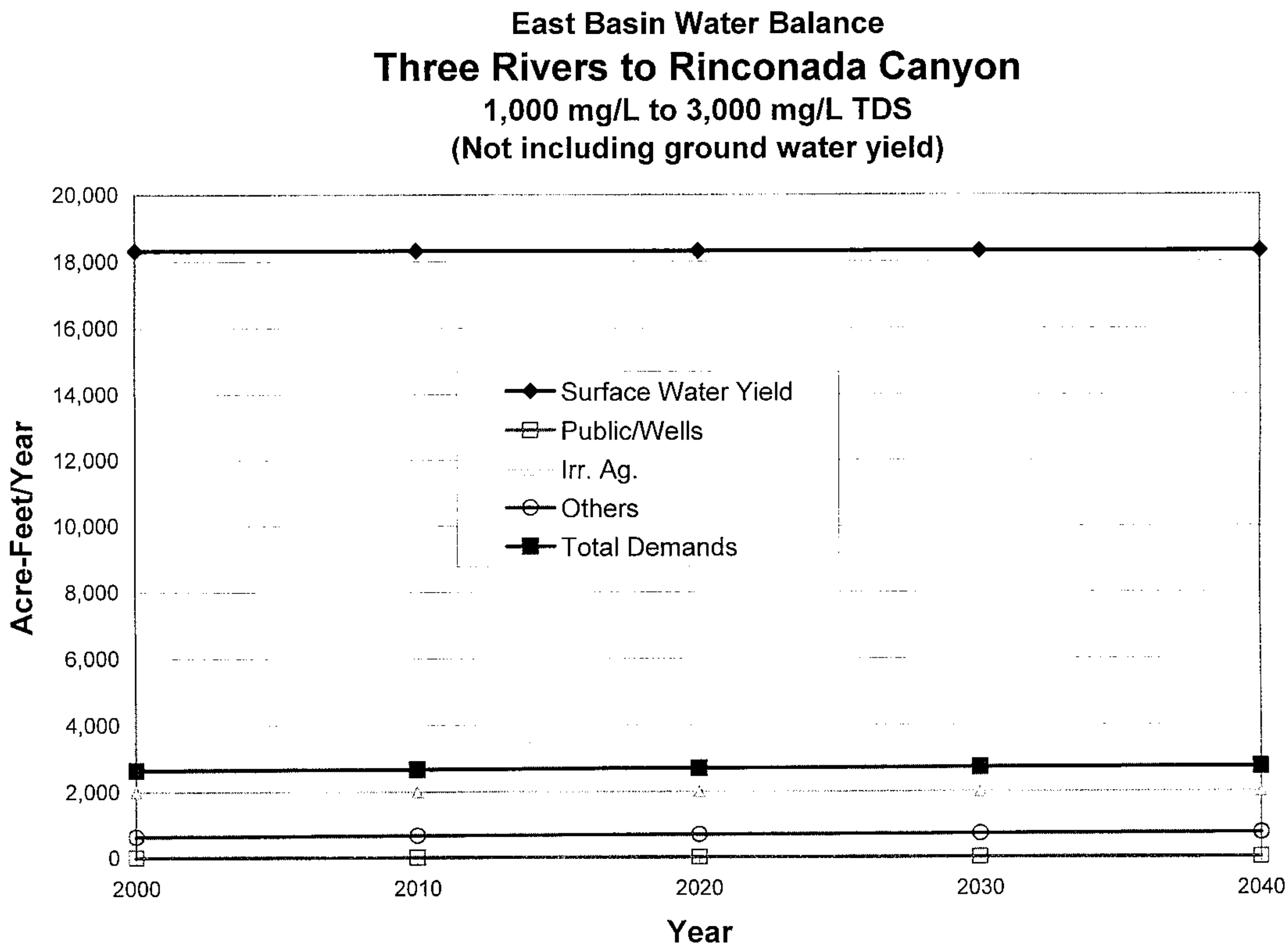


Figure 8.2 - Three Rivers to Rinconada Canyon Water Balance

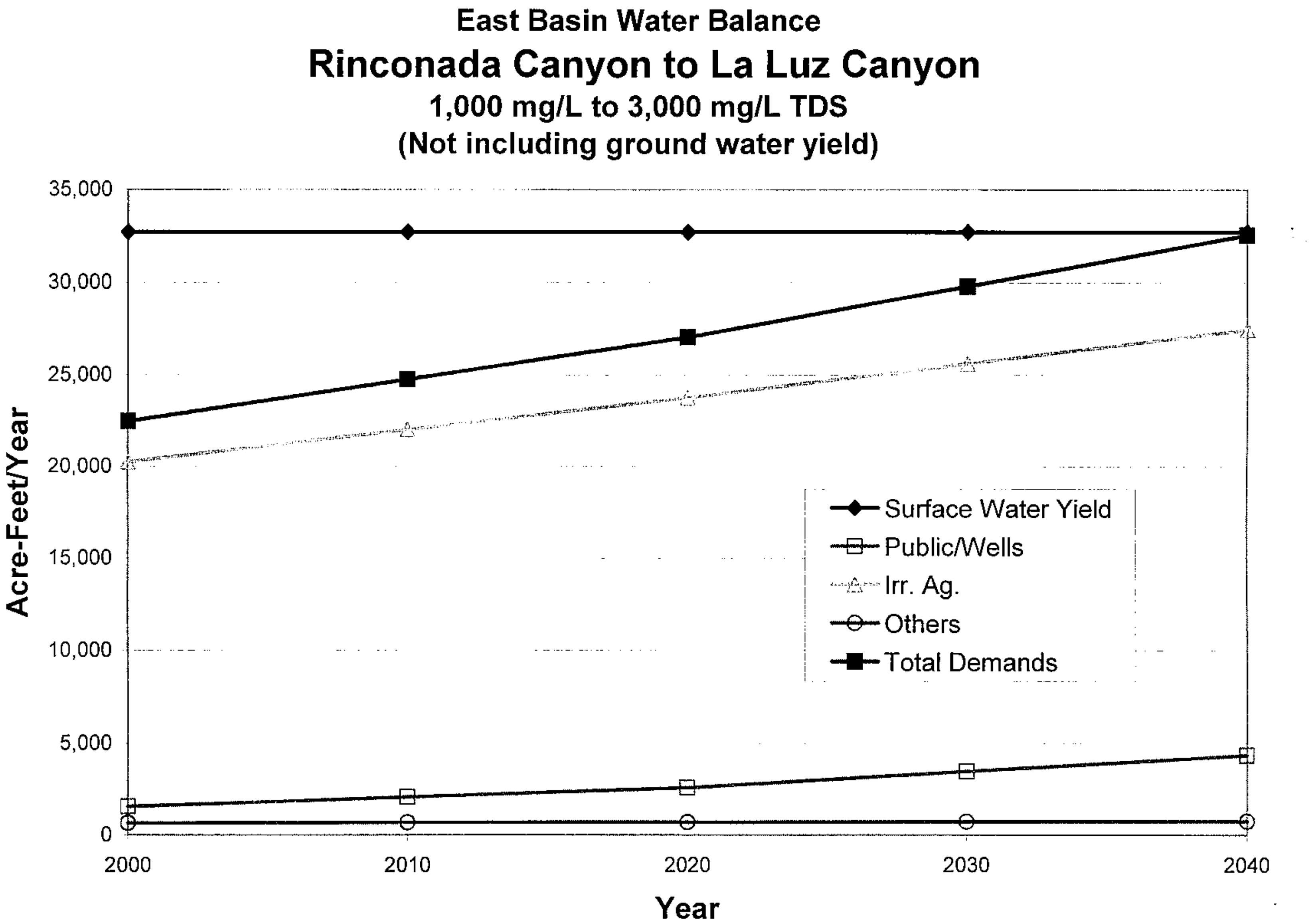


Figure 8.3 - Rinconada Canyon to La Luz Canyon

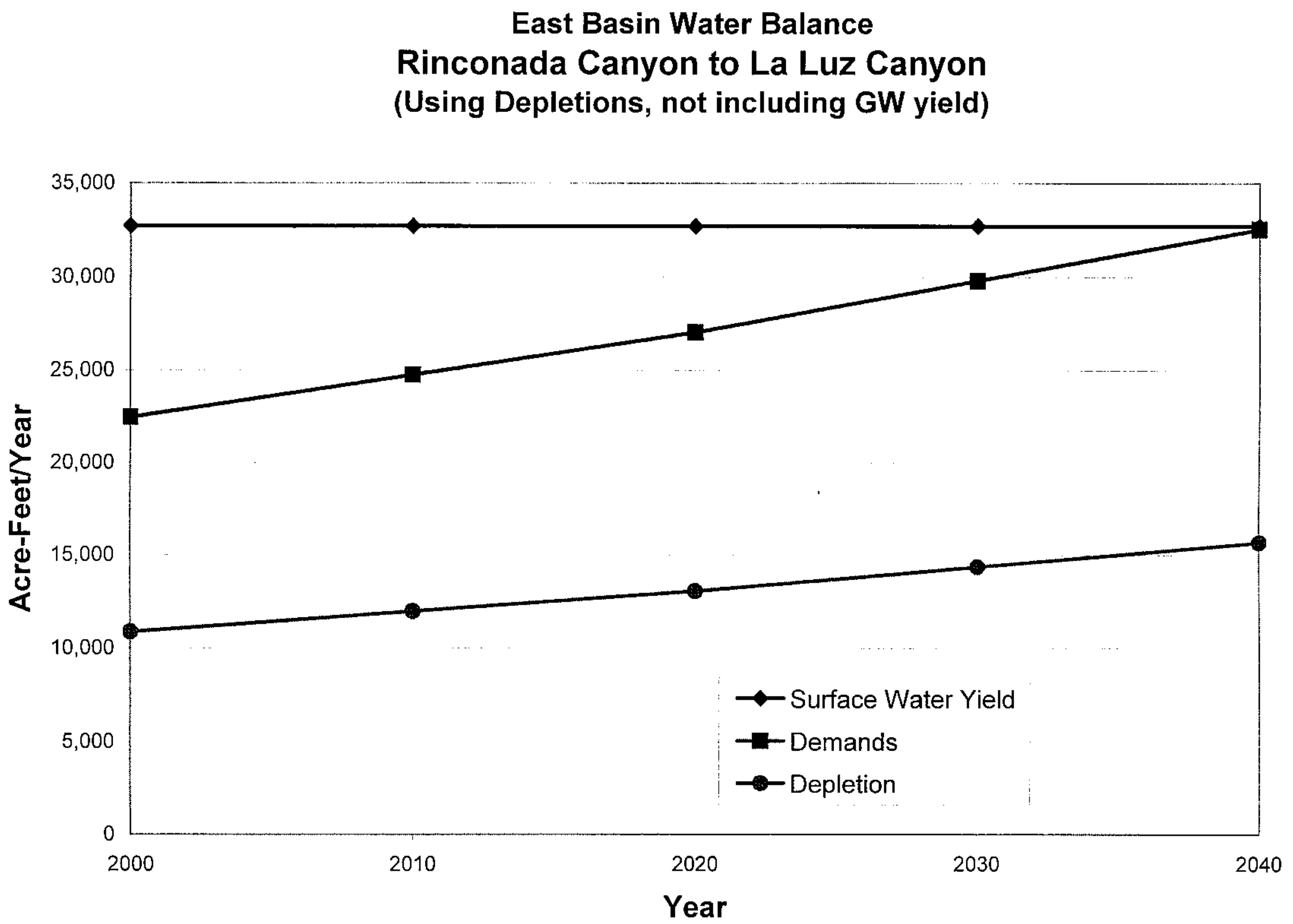


Figure 8.4 - Rinconada Canyon to La Luz Canyon using Depletions

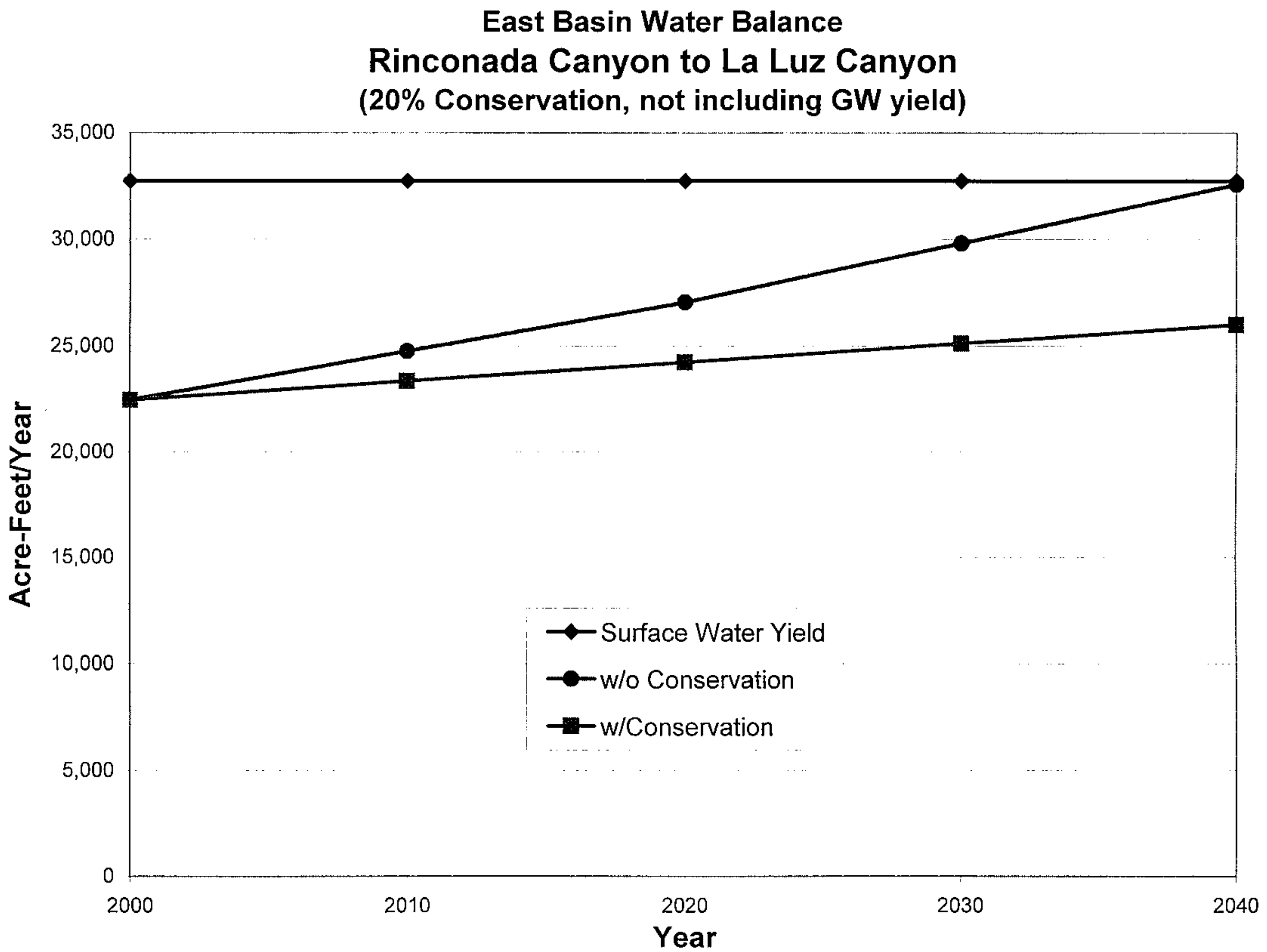


Figure 8.5 - Rinconada Canyon to La Luz Canyon with Conservation

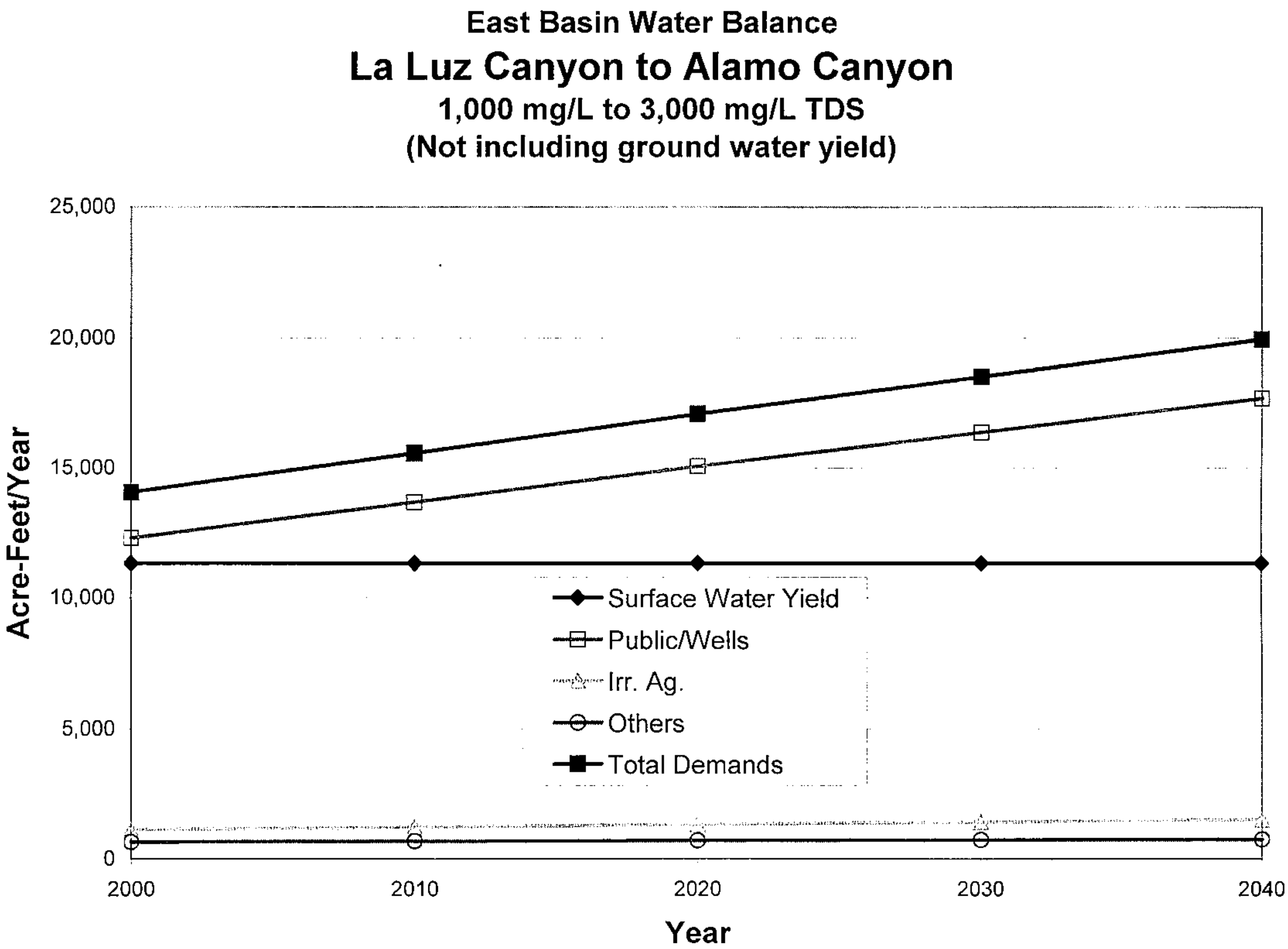


Figure 8.6 - La Luz Canyon to Alamo Canyon Water Balance

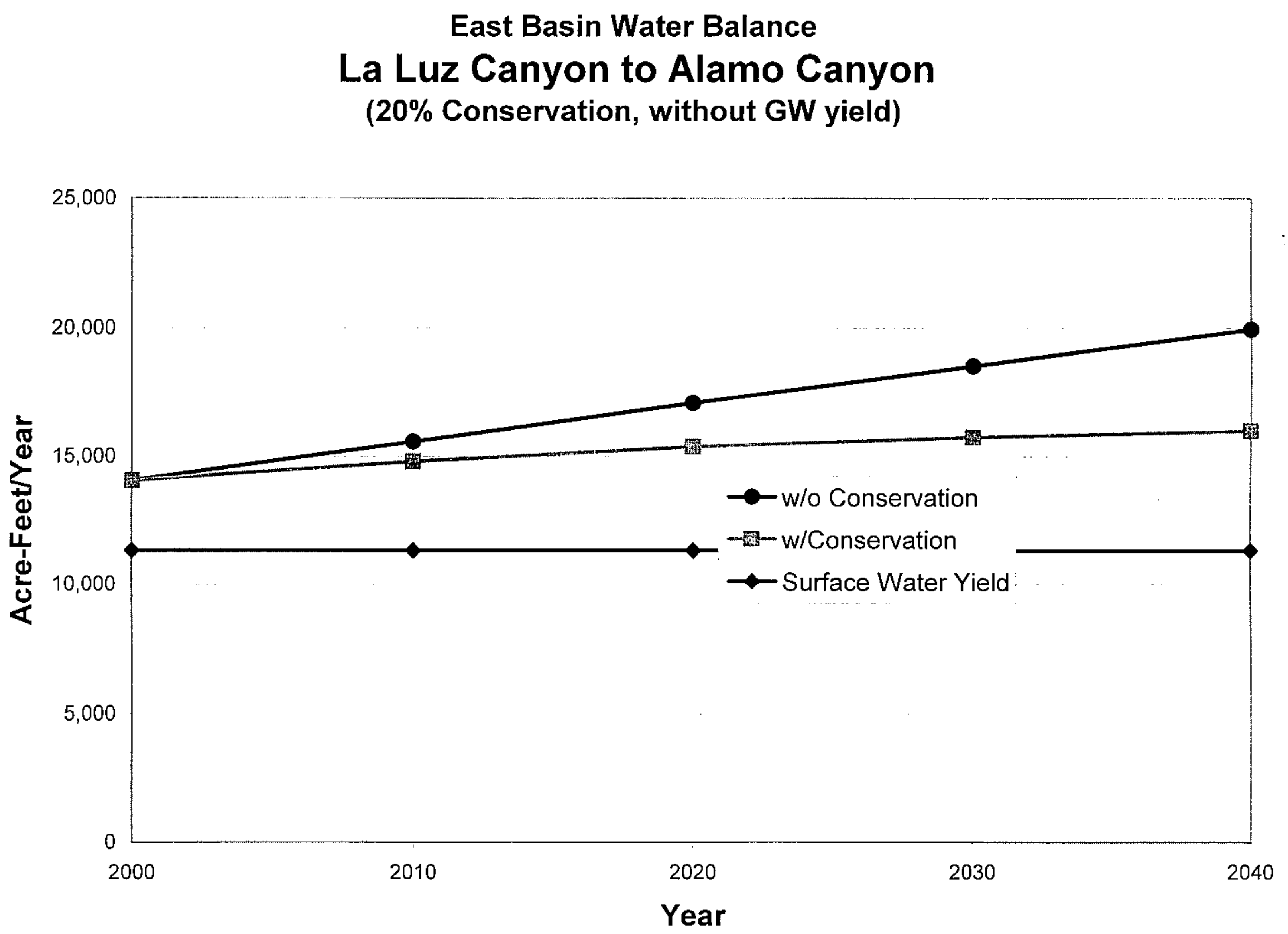


Figure 8.7 - La Luz Canyon to Alamo Canyon with Conservation

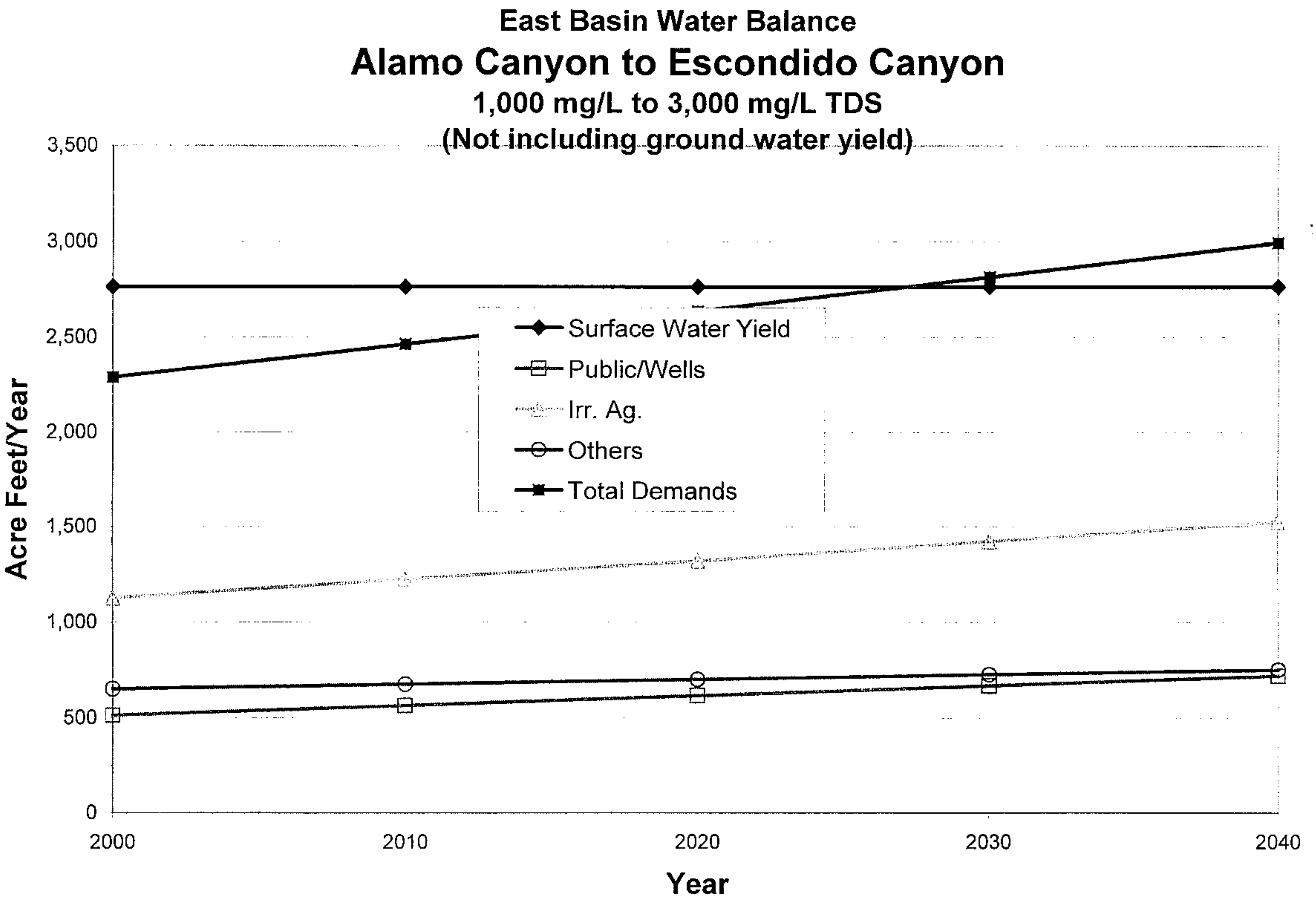


Figure 8.8 - Alamo Canyon to Escondido Canyon Water Balance

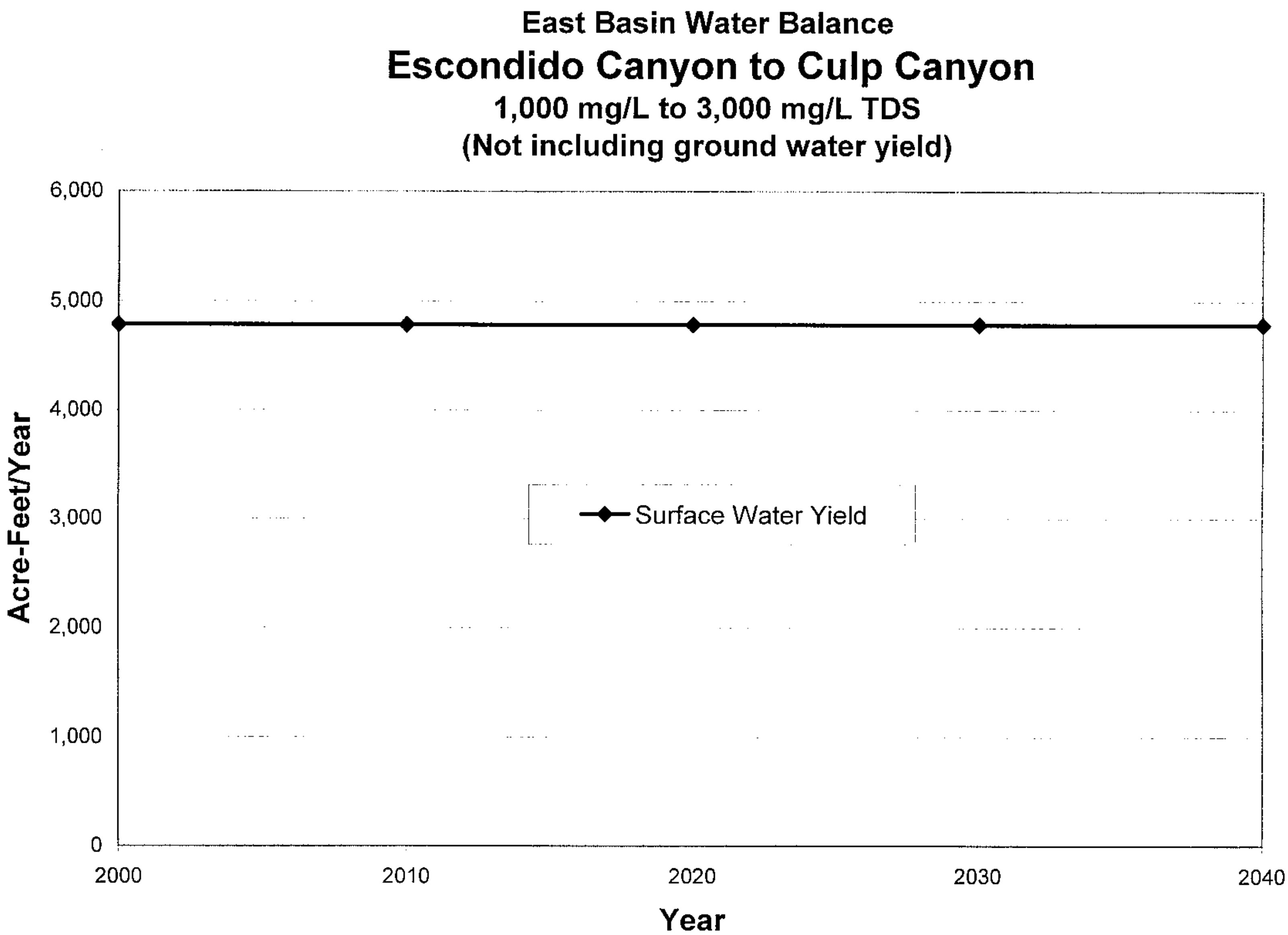


Figure 8.9 - Escondido Canyon to Culp Canyon Water Balance

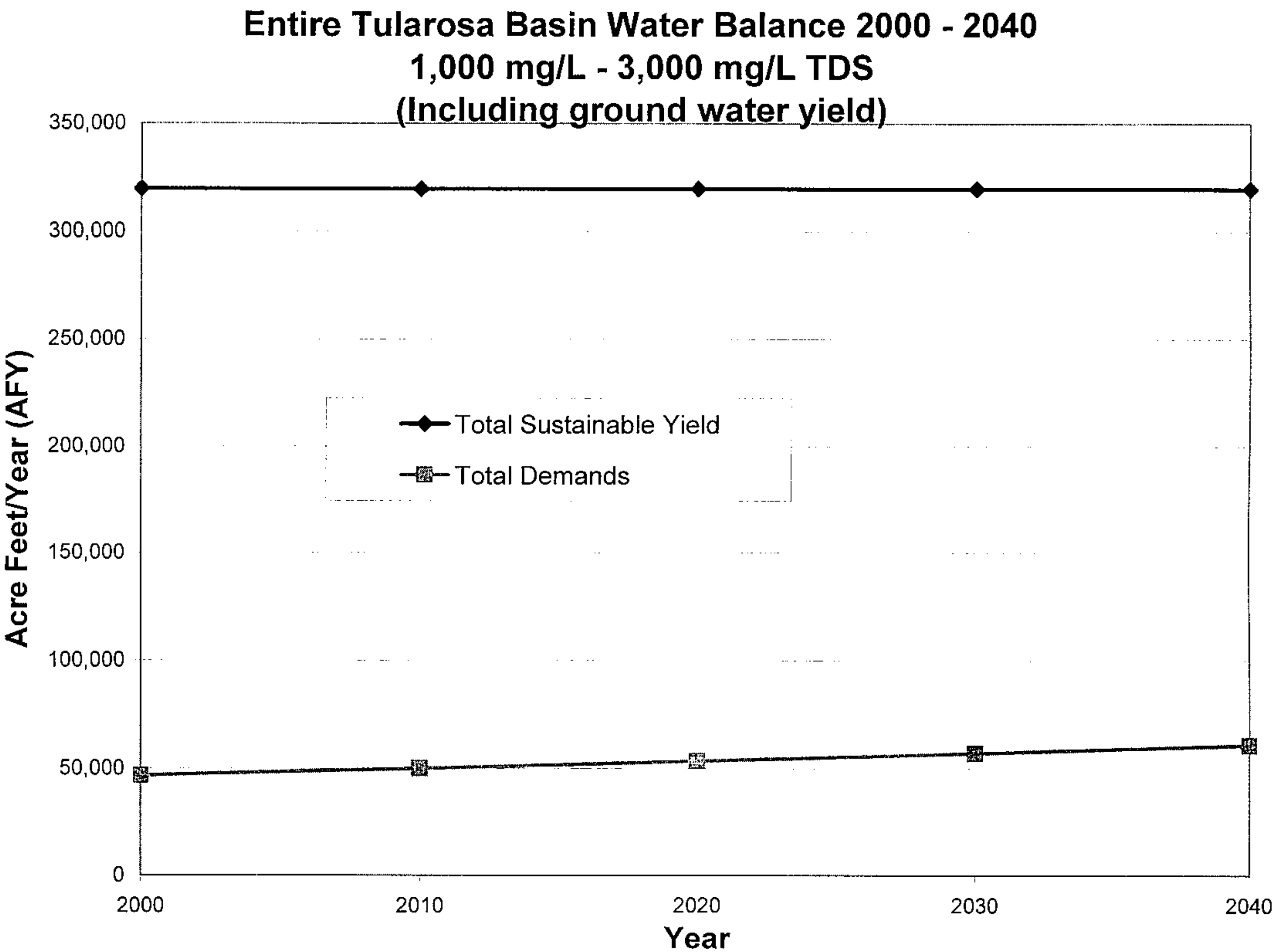


Figure 8.10 - Entire Tularosa Basin Water Balance

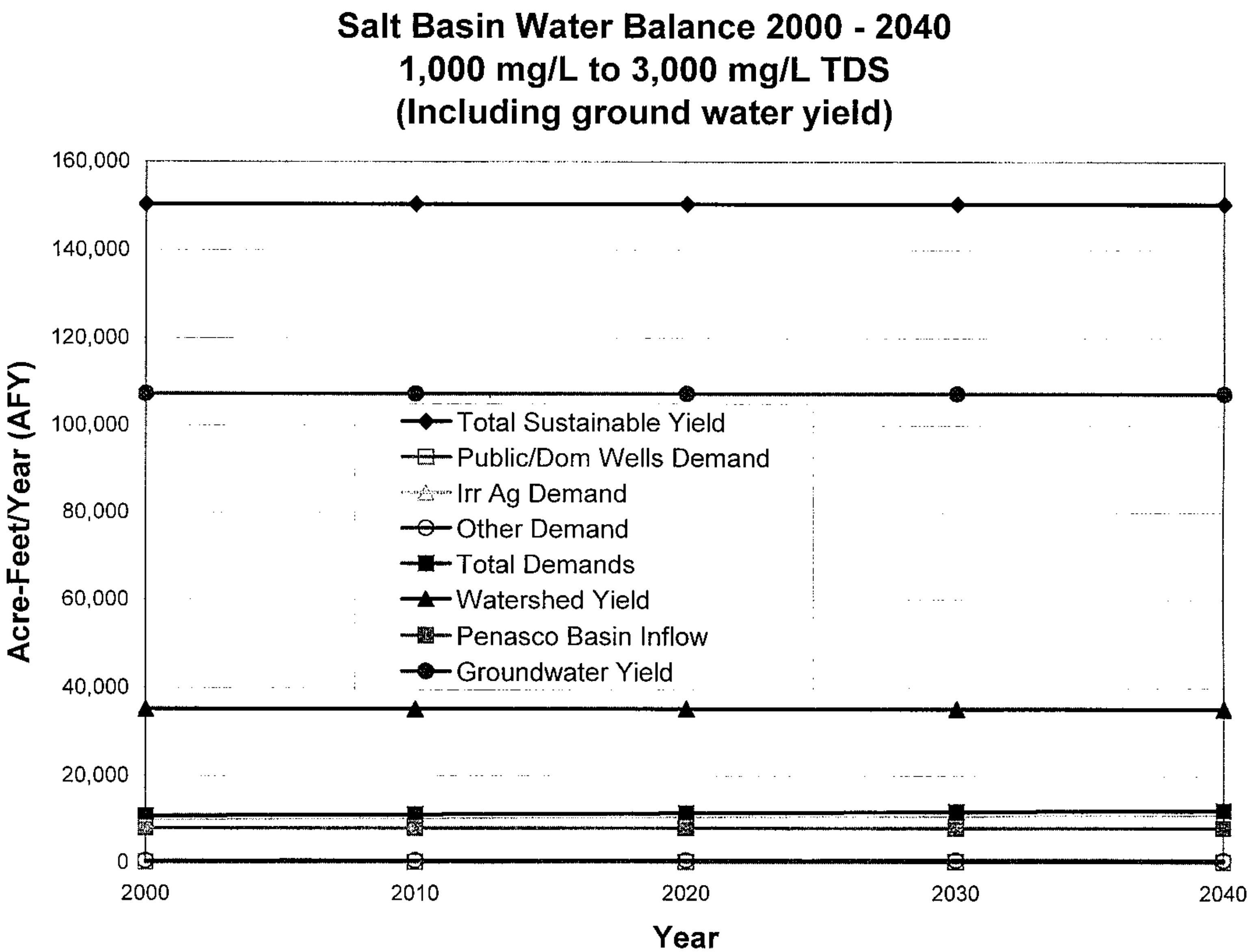


Figure 8.11 - Salt Basin Water Balance

BIBLIOGRAPHY

BIBLIOGRAPHY

State Engineers Office

1. County Profile Lincoln County, New Mexico Water Resources Assessment for Planning Purposes, the New Mexico Interstate Stream Commission and the New Mexico State Engineer Office, Santa Fe, New Mexico, 1974.

2. County Profile, Otero County, New Mexico Water Resources Assessment for Planning Purposes, the New Mexico Interstate Stream Commission and the New Mexico State Engineer Office, Santa Fe, New Mexico 1975.

3. *Fleming, W. M.. 1986. Analysis of Alamogordo's 40-Year Water supply and Demand. NMSEO Hydrology Report 86 - 2.

4. *Garza, S. and J. S. McLean. 1977. Fresh-Water Resources in the Southeastern Part of the Tularosa Basin. NMSEO Tech. Report 40.

5. Hydrographic Survey/The Water Rights Adjudication Process, Hydrographic Survey Section, New Mexico State Engineer Office, August, 1986.

6. Morrison, T.D. 1989. A Regional Model of the Basin Fill Aquifer Near Tularosa and Alamogordo, New Mexico. SEO Hydrology Report 89-3.

7. Nixon, J. 1982. SEO memorandum regarding the depletion of irrigation water for agricultural use in the Tularosa Basin.

8. Water Use in New Mexico in 1985, Wilson, Brian, New Mexico State Engineer Office, Technical Report 46, November 1986.

9. *Tolisano, J. 1986. Analysis of Alamogordo's Surface Water Supply. NMSEO Hydrology Report 86- 3.

10. *Bjorklund, L.J., 1957. Reconnaissance of groundwater conditions in the Crow Flats area, Ortero County. Technical Report 8.

11. Sorenson, E.F., 1982. Water use by categories in New Mexico counties and river basins, and irrigated acreage in 1980. Tech. Report 44.

12. Hudson, J.D., and R.L. Borton, 1983. Groundwater levels in New Mexico, 1978 - 80. NMSEO Basic Data Report.

13. Fresnal (Creek) Hydrographic Survey, 1912

14. *Draft Amended Lower Pecos River Basin Study (Sacramento River Area of Otero County), 1992

15. *Nixon, J. December 6, 1982. SEO Memorandum regarding the surface water supplies for the City of Alamogordo.

16. *Morrison, T. 1986. Hydrologic Impacts of Alamogordo's Proposed Well Field. Exhibit 10

USGS

1. McDonald, M.G. and A. W. Harbaugh, 1983. A Modular Three-Dimensional Finite-Difference Groundwater Flow Model. Book 6: Modeling Techniques, US Geological Survey.

2. Meinzer, O. E. And R. F. Hare. 1915. Geology and Water Resources of the Tularosa Basin, New Mexico. USGS Water Supply Paper 343.

3. *Orr, B.R. and R.G. Myers. 1986. Water Resources in Basin Fill Deposits in the Tularosa Basin, New Mexico. USGS Report 85-4219

4. Herrick and L. Davis. 1965. Availability of Ground Water in Tularosa Basin and Adjoining Areas, New Mexico and Texas, USGS Hydrologic Investigations Atlas HA-191

US Bureau of Reclamation

1. Bureau of Reclamation, High Plains States Groundwater Demonstration Program, Phase 1 Report, 1987.

2. *Bureau of Reclamation. 1986. Working Document For Alamogordo Municipal and Industrial Water Supply Study, New Mexico. Southwest Region, Amarillo.

3. *Bureau of Reclamation, Tularosa Basin Water and Energy Study, New Mexico, Southwest Region Amarillo, Texas. 1984

4. *DOI, Office of Saline Water. Saline Ground-Water Resources of the Tularosa Basin, New Mexico. Research and Development Report No. 561

5. *Situation Assessment Report, New Mexico State Water Plan, 1972

City of Alamogordo

1. Herkenhoff and Associates. 1982. Water Master Plan Update: City of Alamogordo. Consulting report to Alamogordo.

2. Leedshill - Herkenhoff, "40 Year Water Study for City of Alamogordo, Village of Tularosa, Otero and Lincoln County", 1987.

3. Molzin - Corbin & Assoc. 1990. Effluent Disposal Study for Alamogordo.

4. *Boyle Eng. Corp., 1995 Planning Level Water Treatment Study

5. *US Bureau of Reclamation, 1989. Study of the Bonito Watershed Area

Otero County

1. Otero County Water Resources Assessment for Planning Purposes.
2. *Leedshill-Herkenhoff, 1993. Otero County 40 - Year Water Plan, 1990 - 2030

Lincoln County

1. *Lincoln County Water Resources Assessment for Planning Purposes, 1974.

New Mexico State University

1. Cotter, D. J. and D. B. Croft, 1974. Water Application Practices and Landscape Attributes Associated With Residential Water Consumption, NM Water Resource Research Inst. Rpt 49.

2. *Lansford, et. al., 1993 Sources of Irrigation Water and Irrigated and Dry Cropland Aceages in New Mexico, by County and Hydrologic Unit, 1991-1993, Technical Report 21, Agricultural Experiment Station, New Mexico State University

3. *Lansford, et. al., 1995 Sources of Irrigation water and Cropland Acreages in New Mexico, 1992-1994, Technical Report 22, Agricultural Experiment Station, New Mexico State University

4. *Gregory, et. al., 1995 Twenty-Five Years of Climatological Data, 1969-1993, Agricultural Science Center, Farmington, New Mexico, Research Report 693, Agricultural Experiment Station, New Mexico State University

University of New Mexico

1. *Historical and Projected Population Trends for Water Planning Districts in New Mexico: 1960 - 2060, Bureau of Business and Economic Research, July 1995.

USDA/NRCS/SCS

1. Sources of Irrigation Water and Irrigated and Dry Cropland Acreage in New Mexico, by County, 1986 - 1988.

2. Water Use By Categories in NM Counties and River Basins and Irrigated Acreage in 1980.

3. *Irrigation Water Management Study 1991, Hidalgo and Luna Counties

4. *Tularosa Pipeline Project, Alamogordo, New Mexico

5. *Tularosa Basin ???

6. *Conservation Needs Inventory, New Mexico, 1970

Tularosa

1. *Water Study of Tularosa Creek, Village of Tularosa, New Mexico, Burke/Collins/Assoc., and Karl Soards

Misc.

1. *Newcomer, R. and Shomaker, J. 1991. Water Resources of the Ruidoso-Carrizozo-Tularosa Areas, Lincoln and Otero Counties, New Mexico. New Mexico Geological Society Handbook.

2. Arizona Dept. Of Water Resources. 1988. Draft Management Plan for the Prescott Management Area.

3. Grisham, A. and W. M. Fleming. 1989. Long-Term Options for Municipal Water Conservation.JOURNAL AWWA, Vol 81, No. 3, pp. 34-42.

4. Hillen, D. 1983. Advances in Irrigation, v. 1: D. Hillen, ed., Academic Press.

5. Jacoby, B. 1990. Xeriscape Ordinances for New Development. Proc. Conserve 90 Conference, Phoenix, pp. 225 - 229.

6. Jensen, M. E. 1981. Summary and Challenges: Irrigation Scheduling for Water Conservation. Am. Soc. Of Ag. Engr., pp. 275 - 278.

7. Larsen, K. R. 1990. The Phoenix Water Resources Plan for 1990: a Holistic Approach, Proc. Conserve 90 Conference, Phoenix, pp. 391 - 398.

8. Maddaus, W. O. 1987. Water Conservation. AWWA, Denver.

9. Martin, W. E. et al. 1984. Saving Water in a Desert City. Res. For the Future Monograph.

10. Metcalf and Eddy. 1979. Wastewater Engineering: Treatment, Disposal and Reuse. McGraw-Hill.

11. Residential Water Demand, Alternative Choices for Management, Grima, Angelo P., University of Toronto Press, Toronto, 1972, 211 p.

12. City of Albuquerque Water Conservation plan

G L O S S A R Y

GLOSSARY

ACRE-FOOT: Volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot, equivalent to 325,851 gallons.

ALLUVIUM: General term for deposits of clay, silt, sand, gravel, or other particulate material deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain.

AQUACULTURE: Art and science of farming organisms that live in water, such as fish, shellfish, and algae.

AQUIFER: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

ARTESIAN WATER: Ground water under sufficient pressure to rise above the level at which the water-bearing bed is reached in a well. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is an artesian aquifer.

ARTIFICIAL RECHARGE: The addition of water to the ground water reservoir by man's activities, such as irrigation or induced infiltration from streams or wells.

AVERAGE ANNUAL YIELD (WATER): The average annual supply of water produced by a given stream or water development over a period of 12 months.

BANK STORAGE: Water absorbed and stored in the banks of a stream, lake, or reservoir when the stage rises above the water table in the bank formations and stays there for an appreciable length of time. Bank storage may be returned in whole or in part as seepage back to the water body when the level of the surface water returns to a lower stage.

BEDLOAD: That part of the sediment load in which the particles of material move on or near the stream bed.

BEDROCK: General term for consolidated (solid) rock that underlies soils or other unconsolidated material.

BENEFICIAL USE OF WATER: The use of water by man for any purpose which benefits are derived, such as domestic, municipal, irrigation, livestock, industrial, power development, and recreation. Under the New Mexico constitution beneficial use is the basis, the measure and the limit of the right to use water; therefore, beneficial use of public water diverted or impounded by manmade works is an essential element in the development of a water right.

BIOCHEMICAL OXYGEN DEMAND (BOD): The quantity of oxygen utilized primarily in the biochemical oxidation of organic matter in a specified time and at a specified temperature.

BOLSON: An alluvium-floored basin, depression, or wide valley, mostly surrounded by mountains and drained by a system that has no surface outlet. Bolson fill is the alluvial detritus that fills a bolson—also commonly called bolson deposits.

CENTER-PIVOT IRRIGATION: See Irrigation.

CHEMIGATION: Application of pesticides or fertilizers to farmlands through irrigation systems.

CLOSED BASIN: A basin is considered closed with respect to surface flow if its topography prevents the occurrence of visible outflow. It is closed hydrologically if neither surface nor underground outflow can occur.

CONFINING BED: A rock formation that will not readily transmit water and which retards or stops the free movement of water underground. Confining beds have also been called aquicludes, aquitards, or semiconfining beds.

CONJUNCTIVE WATER USE: Combined use of ground water and surface water.

CONSUMPTIVE IRRIGATION REQUIREMENT (CIR): The quantity of irrigation water, exclusive of precipitation, stored soil moisture, or ground water that is required consumptively for crop production.

CONSUMPTIVE USE (EVAPOTRANSPIRATION): The quantity of water used in a given area in transpiration, building of plant tissue, and evaporated from adjacent soil, water surface, snow or intercepted precipitation in a specific period of time.

CONVEYANCE LOSS: Water that is lost in transit from a canal, conduit, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, can percolate to a groundwater source and be available for further use.

CUBIC FOOT PER SECOND: The rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second. It is equivalent to 7.48 gallons per second, or 448.8 gallons per minute.

DECLARED UNDERGROUND WATER BASIN: An area of the state proclaimed by the State Engineer to be underlain by a ground water source having reasonably ascertainable boundaries. By such proclamation the State Engineer assumes jurisdiction over the appropriation and use of ground water from the source.

DEPLETION: That part of a withdrawal that has been evaporated, transpired, incorporated into crops or products, consumed by man or livestock, or otherwise removed.

DEISCHARGE: Rate of flow at a given instant in terms of volume per unit of time; pumping discharge equals pumping rate, usually given in gallons per minute (gal/min); stream discharge, usually given in cubic feet per second (ft^3/s). With respect to water underground, the movement of water out of an aquifer. Discharge may be natural, as from springs, as by seepage, or by evapotranspiration, or it may be artificial as by constructed drains or from wells.

DISSOLVED OXYGEN: The amount of free (not chemically combined) oxygen in water. Usually expressed in milligrams per liter.

DISSOLVED SOLIDS: Chemical compounds in solution.

DIVERSION: A turning aside or alteration of the natural course of a flow of water, normally considered physically to leave the natural channel. In some States, this can be a consumptive use direct from a stream, such as by livestock watering. In other States, a diversion must consist of such actions as taking water through a canal or conduit.

DOMESTIC WATER USE: Water for normal household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns, gardens and livestock supplied from a domestic source. Also called residential water use. The water can be obtained from a public supply or be self-supplied.

DRAINAGE BASIN: A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

DRAWDOWN (GROUND WATER): The depression or decline of the water level or potentiometric surface in a pumped well or in nearby wells caused by pumping. At the well, it is the vertical distance between the static and the pumping level.

DRIP IRRIGATION: See Irrigation.

DRYLAND FARMING: Practice of crop production without irrigation in semiarid regions usually by using moisture-conserving farming techniques.

EPHEMERAL STREAM: A stream or portion of a stream which flows only in direct response to precipitation. Such flow is usually of short duration. Most of the dry washes of a region may be classified as ephemeral streams.

EVAPORATION: Process by which water is changed from the liquid state to the vapor state. See also Evapotranspiration; Transpiration.

EVAPORATION, NET RESERVOIR: The evaporative water loss from a reservoir after making allowance for precipitation on the reservoir. Net reservoir evaporation equals the total evaporation minus the precipitation on the reservoir surface.

EVAPOTRANSPIRATION: The process by which water is returned to the air through direct evaporation or by transpiration of vegetation.

FALLOW: Cropland, either tilled or untilled, allowed to lie idle, during the whole or the greater part of the growing season.

FARM EFFICIENCY: The consumptive crop irrigation requirement divided by the farm delivery.

FECAL COLIFORM BACTERIA: Bacteria that are present in the gut or the feces of warm blooded animals; they are indicators of possible sewage pollution.

FLOOD IRRIGATION: See Irrigation.

FLOOD PLAIN: Land bordering a stream. The land was built up of sediment from overflow of the stream and is still subject to flooding when the stream is at flood stage.

FREE-FLOWING WELL: An artesian well in which the potentiometric surface is above the land surface. See also Potentiometric surface.

FRESHWATER: Water that contains less than 1,000 mg/L (milligrams per liter) of dissolved solids; generally, more than 500 mg/L is considered undesirable for drinking and many industrial uses.

FURROW IRRIGATION: See Irrigation.

GAGING STATION: A particular site on a stream, canal, lake or reservoir where systematic observations of gage height or discharge are made.

GAINING STREAM: A river, or reach of a stream or river, that gains flow from ground water seepage or from springs in, or alongside, the channel—sometimes called an effluent stream.

GRAVITY IRRIGATION: See Irrigation.

GROUD WATER: Generally, all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone (a zone in which all voids, large and small, ideally are filled with water under pressure equal to or greater than atmospheric).

GROUND WATER MINING: The condition that exists when the withdrawal of water from an aquifer exceed the recharge causing a decline in the ground water level.

GROUND WATER RESERVOIR STORAGE: The amount of water in storage within the defined limit of the aquifer.

HYDRAULIC GRADIENT (GROUND WATER): The gradient or slope of the water table or potentiometric surface in a specific direction.

HYDROELECTRIC POWER: Electrical energy generated by means of a power generator coupled to a turbine through which water passes.

HYDROGRAPH: A graph showing the stage, flow, velocity, or other property of water with respect to the passage of time. Hydrographs of wells show the changes in water levels during the period of observation.

IMPERMEABLE: Not capable of transmitting fluids or gases in appreciable qualities. Few rocks are completely impermeable; but some--such as unweathered granite, dense basalt, welded tuff, dense limestone, and well-cemented conglomerate—may be so considered for practical purposes.

INTERBASIN TRANSFER OF WATER: See water exports; Water imports.

INTERMITTENT STREAM: A stream which flows for only a part of the time. Flow generally occurs for several weeks or months in response to seasonal precipitation, due to ground water discharge, in contrast to the ephemeral steam that flows but a few hours or days following a single storm.

IRRIGATED AREA: The gross area upon which water is artificially applied.

IRRIGATION: Generally, the controlled application of water to arable lands to supply water requirements of crops not satisfied by rainfall. (See also Irrigation water use.) Systems used include the following:

Center-pivot: Automated sprinkler irrigation achieved by rotating the sprinkler pipe or boom, supplying water to the sprinkler heads or nozzles, as a radius from the center of the circular field to be irrigated. The pipe is supported above the crop by towers at fixed spacings and propelled by pneumatic, mechanical, hydraulic, or electric power on wheels or skids in fixed circular paths at uniform angular speeds. Water, which is delivered to the center or pivot of the system, is applied at a uniform rate by progressive increase of nozzle size from the pivot point of the system to the end of the line. The depth of water applied is determined by the rate of travel of the system. Single units are ordinarily about 1,250 to 1,300 feet long and irrigate about a 130-acre circular area.

Drip: An irrigation system in which water is applied directly to the root zone of plants by means of applicators (orifices, emitters, porous tubing, perforated pipe, and so forth) operated under low pressure. The applicators can be placed on or below the surface of the ground or can be suspended from supports.

Flood: The application of irrigation water where the entire surface of the soil is covered by ponded water.

Furrow: A partial surface flooding method of irrigation normally used with clean-tilled crops where water is applied in furrows or rows of sufficient capacity to contain the design irrigation stream.

Gravity: Irrigation in which the water is not pumped but flows in ditches or pipes and is distributed by gravity.

Sprinkler: A planned irrigation system in which water is applied by means of perforated pipes or nozzles operated under pressure so as to form a spray pattern.

Subirrigation: A system in which water is applied below the ground surface either by raising the water table within or near the root zone or by using a buried perforated or porous pipe system that discharge directly into the root zone.

Traveling gun: Sprinkler irrigation system consisting of a single large nozzle that rotates and is self-propelled. The name refers to the fact that the base is on wheels and can be moved by the irrigator or affixed to a guide wire.

IRRIGATION CONVEYANCE LOSS: The loss of water in transit from a reservoir, point of diversion, or ground water pump to the point of use, whether in natural channels or in artificial ones, such as canals, ditches, and laterals.

IRRIGATION EFFICIENCY: The percentage of the water diverted from a water source that is consumed. It is the product of the distribution efficiency and the farm efficiency.

IRRIGATION LEACHING REQUIREMENT: The amount of water required to move residual salts out of the root zone and maintain an adequate soil-salt balance for crop production.

IRRIGATION REQUIRMENT: The quantity of water, exclusive of precipitation, that is required for production of a specific crop.

IRRIGATION RETURN FLOW: Part of irrigation water that is not consumed by evapo-transpiration and that drains from the irrigated area to an aquifer or surface-water body.

IRRIGATION WATER USE: Artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth on recreational lands such as parks and golf courses. See also Irrigation.

KARST: A type of topography that is formed on limestone, dolomite, gypsum beds, and other rocks by dissolution and is characterized by closed depressions, sinkholes, caves, and underground drainage.

LOSSES INCIDENTAL TO IRRIGATION: The quantity of water depleted by irrigation in excess of the beneficial irrigation consumptive use.

MILLIGRAMS PER LITER: The weight in milligrams of any substance contained in 1 liter of liquid. (Equivalent to parts per million for values less than about 7,000 mg/L.)

MILLION GALLONS PER DAY: A rate of flow of water of one million gallons per twenty four hour period.

OVERDRAFT: Withdrawals of ground water at rates perceived to be excessive. See also Groundwater mining.

PER CAPITA USE: The average amount of water used per person during a standard time period, generally per day.

PERCHED GROUND WATER: Water in a saturated zone of material underlain by a relatively impervious stratum which acts as barrier to downward flow and which is separated from the main ground water body by a zone of unsaturated material above the main ground water body.

PERENNIAL STREAM: A stream that normally has water in its channel at all times.

PHREATOPHYTE: A plant that habitually obtains its water supply from the zone of saturation, either directly or through the capillary fringe.

PLAYA: Flat-floored bottom of an undrained desert plains basin.

POROSITY: The ratio of the total volume of pore space (voids) in a rock or soil to its total volume, usually stated as a percentage. Effective porosity is the ratio of the volume of interconnected voids to the total volume. Unconnected voids contribute to total porosity but are ineffective in transmitting water though the rock.

POTABLE WATER: Water that is safe and palatable for human consumption.

POTENTIOMETRIC SURFACE: An imaginary surface representing the static head of ground water in tightly cased wells that tap a water-bearing rock unit (aquifer); or in the case of unconfined aquifers, the water table.

PRECIPITATION: Includes atmospheric hail, mist, rain, sleet and snow which descends upon the earth; the quantity of water accumulated from the above events.

RECHARGE: The addition of water to an aquifer by infiltration, either directly into the aquifer or indirectly by way of another rock formation. Recharge may be natural, as when precipitation infiltrates to the water table, or artificial, as when water is injected through wells or spread over permeable surfaces for the purpose of recharging an aquifer.

RECOVERABLE GROUND WATER: The amount of water which may be physically and economically withdrawn from the ground water reservoir.

RECYCLED WATER: Water that is used more than one time before it passes back into the natural hydrologic system.

RETURN FLOW: That part of a diverted flow which is not consumptively used and which returns to a water body.

RIPARIAN VEGETATION: Vegetation growing on the banks of a stream or other body of surface water.

RUNOFF: The part of the precipitation that appears in surface streams.

SALINE WATER: Water that contains more than 1,000 milligrams per liter of dissolved solids. It generally is considered unsuitable for human consumption and less desirable for irrigation because of its high content of dissolved solids. Salinity generally is expressed as milligrams per liter (mg/L) of dissolved solids, with 35,000 mg/L defined as seawater. A general salinity scale is:

SALINITY	DISSOLVED SOLIDS (MG/L)
Slight	1,000-3,000
Moderate	3,000-10,000
Very	10,000-35,000
Brine	more than35,000

SALTWATER INTRUSION: Replacement of freshwater by saline water in an aquifer or body of water.

SALVAGED WATER: The part of a particular stream or other water supply that is saved from loss and made available for use.

SEWAGE: Waste matter carried off by sewers and drains.

SEWAGE TREATMENT: The processing of wastewater for the removal or reduction in the level of dissolved solids or other undesirable constituents.

SEWAGE-TREATMENT RETURN FLOW: Water returned to the hydrologic system by sewage-treatment facilities.

SPECIFIC CAPACITY: In ground water hydrology, the yield of a well in gallons per minute per foot of drawdown after a period of sustained pumping.

SPRINKLER IRRIGATION: See Irrigation.

STOCK POND/TANK: Any manmade or natural catchment used exclusively for livestock watering. Generally, for purposes of determining permitting requirements a stock pond/ tank either within a water course or off-stream that is used exclusively for livestock, of 10 acre-feet or less regardless of height, does not require a permit. However, there are basins in the state that require permitting in any case, so checking with the State Engineer is advised.

STREAM, PERENNIAL: A stream that flows continuously.

STREAMFLOW: The discharge that occurs in a natural channel of the surface stream course.

SUBIRRIGATION: See Irrigation.

SURFACE WATER: An open body of water, such as a stream or lake.

SUSPENDED SEDIMENT: Sediment that is transported in suspension by a stream. Fragmental material, both mineral and organic, that is maintained in suspension in water by the upward components of turbulence and currents and (or) by colloidal suspension.

TAILWATER RECOVERY: Process of collecting irrigation water run-off for reuse.

THERMOELECTRIC POWER: Electrical power generated by using fossil fuel (coat, oil, or natural gas), geothermal, or nuclear energy.

TOTAL DISSOLVED SOLIDS (TDS): An aggregate of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, etc., of calcium, magnesium, manganese, sodium, potassium, and other cations which form salts. High TDS solutions have the capability of changing the chemical nature or water. High TDS concentrations exert varying degrees of osmotic pressures and often become lethal to the biological inhabitants of an aquatic environment. The common and synonymously used term for TDS is "salt".

TOTAL SEDIMENT LOAD: The sum of the bedload and the suspended sediment load.

TRANSMISSIBILITY (GROUND WATER): The rate at which water at the prevailing water temperature is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is generally expressed as gallons per day through a vertical strip of the aquifer 1 foot wide under a hydraulic gradient of 1 foot, or more recently as cubic feet per day under the same conditions. It replaces the term "coefficient of transmissibility".

TRANSPIRATION: Process by which water is absorbed by plants, usually through the roots. The residual water vapor is emitted into the atmosphere from the plant surface.
See also Evaporation; Evapotranspiration.

TRAP EFFICIENCY OF RESERVOIRS: Ratio of sediment retained to sediment inflow expressed as a percentage.

TURBIDITY: The opaqueness or reduced clarity of a fluid due to the presence of suspended matter.

WASTEWATER: Water that contains dissolved or suspended solids as a result of human use.

WATER BUDGET: An accounting of the inflow to, outflow from, and storage changes of water in a hydrologic unit.

WATER EXPORTS: Artificial transfer (pipe, canals) of water to one region or subregion from another.

WATER RIGHT: Legal rights to use a specific quantity of water, on a specific time schedule, at a specific place, and for a specific purpose.

WATER TABLE: The upper surface of zone of saturation. See also Potentiometric Surface.

WETLANDS: Lands that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support and that, under normal circumstances, do support a prevalence of vegetation typically adapted for life in saturated soil conditions.

WITHDRAWAL: Water removed from the ground or diverted from a surface-water source for use.

ZONE OF SATURATION: The zone in which all the connected interstices or voids in permeable rock or soil information are filled with water under pressure equal to, or greater than atmospheric pressure.