City of Alamogordo

40-Year Water Development Plan 2010-2050

(Final Draft)

August 2013

Prepared by

Livingston Associates, P.C.

Consulting Engineers

Alamogordo, NM

in association with

John Shomaker and Associates, Inc.

Albuquerque, NM

City of Alamogordo

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2015-2055 (??)

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Appendix not included in Final Draft

1) No comparison of supply v. demand in ES.

2) ES suggests we stell need to convince SE Snake Tank is best alternative. I suggest we simply state this was recommended in 2000-2040 Plan and adopted by SE. Describe everything done since then to pursue ST.

   1) SE permit
   2) upheld on appeal
   3) BLM row
   4) Funding in progress.

3) Issues:

   1) 2055 demand?
   2) Supply based on City "firm yield" or settlement "reliable supply"?
   3) Any difference between #1 & #2 that would allow City to pursue additional water supplies?

Pursuant to Permit No. T-3825 et al.)

beginning five years after the final approval of the permit.

2015-2055 ?

Executive Summary

~~As required by a settlement agreement with the New Mexico Office of the State Engineer (NMOSE)~~, the City of Alamogordo is required to ~~update~~ their 40-year water development plan every five years. This updated water plan reflects the 2010 to 2050 planning period.

+5

check

Submit progress reports on

The City of Alamogordo has been active in water resource planning and development for more than twenty-five years. The City's water planning efforts have been in response to a number of factors, including:

1) Historically, the majority of the City's water supply has been obtained from surface water originating from spring flows in the Sacramento Mountains and Bonito Lake.
2) A significant reduction in surface water supply due to drought conditions has placed critical limitations on the long-term reliance on surface water.
3) There are significant hydrological, geological and NMOSE administrative limits on local ground water supplies which inhibit further development of the resource.
4) The quality of most of the City's ground water supply does not meet the total dissolved solids (TDS) guidelines adopted by the City (800 mg/L) and would require treatment or blending with better quality water.
5) The City has determined that desalination of brackish ground water, under the Alamogordo Regional Water Supply Project (ARWSP), represents a viable and economic source of supply that will be used to reduce the City's dependence on drought-sensitive surface waters.

Note - the city could submit a 2015-2055 plan.

6) The ARWSP water supply will be used conjunctively with their existing water supplies to optimize the use of the City's water resources and to minimize hydrologic impacts on other water right holders and water resources.
7) No other alternative water supplies have been identified that compare with the ARWSP in expected reliability and ability to deliver the City's total additional water needs through 2050.

This City of Alamogordo 40-Year Water Development Plan, 2010-2050, is the second update to the original Plan for 2000 to 2040, prepared in March 2003 (Livingston Associates, John Shomaker & Associates, Inc.). This Plan demonstrates that the City has urgent need to develop its water supplies, management flexibility, and for the conjunctive management of separate sources of surface and ground water made possible by the ARWSP.

The original Plan contained numerous water development recommendations for the City of Alamogordo. The Plan identified the ARWSP as the most desirable alternative to meet the City's long-term water supply needs. The City has been aggressively pursuing state and federal approvals for the ARWSP. However, those approvals have not come as quickly as the City had hoped. In the interim, the City has had to pursue short-term, stop-gap measures to supply water under these present drought conditions. To provide an incremental increase in ground water supply, the City began a well replacement program. To-date, the following wells have been replaced:

1) La Luz Well Nos. 3 and 5 in the La Luz Well Field;
2) Well Nos. 1 and 2 in the Prather Well Field (T-33 and T-33-S);
3) Golf Course Well (T-814); and
4) Mountain View Well (T-3489).

This program has successfully provided an additional firm yield ground water supply of about 2,000 acre-feet per year (AFY) from these four sources combined.

To further the ARWSP, the City has pursued the following:

1) Completed the Desalination Feasibility Study and Pilot Project;
2) Completed the water rights hearing process and was granted 4,000 AFY of brackish ground water for the ARWSP (~~or 20,000 AF for any 5-year period~~);
3) ~~Prepared the draft~~ Environmental Impact Statement (~~DEIS~~) ~~and is finalizing~~ the National Environmental Policy Act (NEPA) ~~process~~ for the ARWSP;
4) Began developing the Desalination (Snake Tank) Well Field for the ARWSP, which included the drilling and testing of five test wells, with two of the wells (Nos. 4 and 5) considered production-scale wells. Results of the testing verify that the well field will be suitable for the desalination facility;
5) ~~Began developing documents for the~~ right-of-way permitting;
6) Completed construction of Phase I of the Snake Tank Well Transmission Line as part of the ARWSP piping; ~~and~~
7) Developed construction documents for Phase II and Phase III of the Snake Tank Well Transmission Line piping;
8) Began planning for the design and construction of monitoring wells.

While the City is in process of implementing the ARWSP, it continues to examine other methods for conserving water and increasing the water supply. Since the original Plan, the City has:

1) Evaluated the feasibility of developing additional supplemental (back-up) water supply wells or replacement of old wells within the City limits;
2) Evaluated the potential for using reclaimed water for non-potable applications (car washes, industry, etc.) and trading farmers some of the City's reclaimed water for their potable irrigation water;
3) Performed a preliminary evaluation of the potential for utilizing re-purified water for aquifer recharge and/or surface water blending in indirect potable reuse (IPR) applications;
4) Completed covering and lining of the 180 million-gallon water storage reservoirs to reduce losses by approximately 788,500 gallons per day (GPD);
5) Covered and lined the reclaimed water storage reservoirs to reduce evaporation losses and preserve the quality of this valuable non-potable water resource;

6) Continued the waterline repair program, and other water and wastewater projects under the City's Infrastructure Capital Improvement Plan, to reduce water losses from leakage; and

7) Continued to review proposals from the private industry for bulk water supply and potential City purchase.

Permit No. T-3825 et al.

The City of Alamogordo's water rights portfolio has been modified as a result of the settlement agreement with the NMOSE and ~~approved applications by the NMOSE.~~ The firm ground water yield is now close to the water right quantity. A summary of the City of Alamogordo's surface water sources, water rights and firm yield are shown below in **Table ES.1**.

Table ES.1 City of Alamogordo Surface Water Sources, Water Rights and Firm Yield

Surface Water	Water Right, AFY	Firm Yield, AFY
Bonito Lake	1,449	271
La Luz- Fresnal	891 AFY + 16 CFS*	1,653
Alamo Canyon	3,078	601
Total surface water	**5,418 AFY + 16 CFS***	**2,525**

* - 16 CFS (cubic feet per second) is time-of-day limited

Consider a footnote that settlement agmt w/ SE says "reliable sw supply" is 3513 afy - that is "for purposes of settlement" and City planning must be done on firm yield

3000 ?

A summary of the City of Alamogordo ground water sources, water rights and firm supply are shown below in **Table ES.2**.

Table ES.2 City of Alamogordo Ground Water Sources, Water Rights and Firm Supply

settlement

Ground Water	Water Right AFY	Firm Supply AFY
La Luz Wells (T-32-S-2 through T-32-S-9)	3,000	2,979[a]
Prather Wells (T-33 and T-33-S)	500	500
Golf Course Well (T-814)	269.9	270
Mountain View Well (T-3489-repl)	161	160
Snake Tank Well Field (T-3825 et al.)	4,000[c]	3,360[b]
Total ground water	**7,930.9**	**7,269**

3931

3200

[a] based on increase in firm supply associated with replacing Wells 3 (T-32-S-4) and 5 (T-32-S-6), and planned replacement of additional wells under T-32 et al. to maintain optimum well efficiency

[b] based on 4000 AFY diversion and an approximate overall 84 percent treatment recovery

[c] permit conditions allow diversion up to 4,000 AFY, but can be increased up to 5,000 AFY, provided that the sum of annual diversions for any consecutive 5-yr period does not exceed 20,000 AFY

settlement has 7131 afy

should we use 7,269 ?

Settlement "relable supply"

surface water	3,513 afy
GW	3,931 afy
La La2 (3,000 afy)	
Prather (500 afy)	
Golf Course (270 afy)	
Mt View (161 afy)	
	7131
Snake Tank	3,200 afy
	10,644.

City "firm yield"

SW	2,525 afy
GW	3,910 afy
La La2 (2,979 afy)	
Prather (500 afy)	
Golf Course (270 afy)	
Mt View (161 afy)	
	7220
Snake Tank	3,360 afy
	9,795 afy

13,349

Based on previous tables

The total combined water rights for the City of Alamogordo (surface water and ground water) are 14,349 AFY (plus 16 cubic feet per second) with a total combined firm water supply of 10,184 AFY. The firm water supply includes the ARWSP.

9794 (see also p. 49)

Historically, more than seventy percent of the City of Alamogordo's water supply has been derived from surface water that is affected by drought. While there can be a hydraulic connection between surface water and ground water, typically ground water is considered a separate water supply source that is more drought-resistant than surface water. Further expansion of the City's La Luz Well Field is not possible due to hydrogeologic and NMOSE administrative constraints. Additionally, the quality of the ground water does not meet City criteria for a maximum total dissolved solids (TDS) level of 800 mg/L, and would require either blending with surface water or additional treatment.

The majority of fresh water (TDS less than 1,000 mg/L) in the region is the surface water that originates in the Sacramento Mountains and from a small pocket of ground water south of Alamogordo. An adequate amount of additional surface water is not available to satisfy the City of Alamogordo's future water demands. The pumping of fresh ground water in this area is limited by NMOSE special administrative rules, available quantity, and land ownership (more than half of the fresh ground water south of Alamogordo lies beneath military lands). Holloman Air Force Base (HAFB) wells pump from this resource. The City cannot obtain additional water rights for this limited supply of fresh ground water.

Add section on losing Bonita Lake supply due to fire. Receiving less than "firm yield"

Alamogordo urgently needs to develop its existing water rights.

The City has implemented conservation measures and utilized reclaimed water to reduce potable water demands since 2005. Besides landscape watering restrictions, green-space irrigation with reclaimed water and other acceptable water conservation measures, an aggressive water rate structure has been imposed to force reduced consumption. These measures have resulted in the City of Alamogordo having one of

we should compare our firm yield v. settlement reliable supply and explain why we are moving away from settlement numbers. SE likely to disagree unless we can justify lower SW.

the lowest per capita water use figures in the Southwest (*Overview*, 2005). During previous severe drought conditions, the City operated beyond the maximum water use restrictions acceptable to the public. This was a short-term, stop-gap measure to provide the limited water supply during the drought.

Additional development of existing water rights is needed to provide the public with an acceptable level of supply for typical water use needs.

Activities that were recently completed or are currently in progress to improve Alamogordo's water supply include the following:

1. Improvements to the Bonito Pipeline;
2. Replacing some of the La Luz Wells to increase efficiency and redundancy;
3. Replaced the Prather wells to increase efficiency and provide redundancy; and
4. Permitting the Golf Course well as supplemental to the La Luz Well Field, which will allow pumping the Golf Course well at full capacity.

Since 2005, the City has evaluated several other potential water-supply alternatives for meeting future water demands. All of these were determined to be not feasible. These alternatives included:

1) Purchasing water rights and associated irrigation wells (T-3327 and T-3327-S) located west of Alamogordo;
2) Pursuing non-potable (saline) ground water deeper than 2,500 ft. in depth, that may be located in a separate aquifer (72-12-25 applications);
3) Increasing the surface water supply by diverting surface water from the bottom of the La Luz Watershed and abandoning the current diversions; and
4) Using water supply wells and water rights associated with Mesa Verde Ranch.

The Snake Tank Well Field (ARWSP) provides a new, separate ground water supply that is the most reliable source for meeting future water needs. The ARWSP is still

the only alternative evaluated that will provide the City of Alamogordo with the total quantity of new water required for the next 40 years. Desalination of brackish water is the solution to meeting the City of Alamogordo's future water demands, reducing the reliance on drought-sensitive surface water and for developing a long-term, redundant supply. Because the City uses both surface and ground water, the City should develop the ARWSP ground water supply to provide their total future water requirements as a drought contingency and supply redundancy.

The development of the ARWSP, as the water supply solution, is detailed as follows:

1) To meet future water demands, immediately implement the Alamogordo Regional Water Supply Project (ARWSP) desalination facility and infrastructure. This project consists of developing the Snake Tank Well Field, brackish water desalination facility and concentrate disposal system, treated water storage and pumping, and piping infrastructure to the City of Alamogordo.

2) Develop the ARWSP project and the Snake Tank Well Field for worst-case drought (ground water only scenario) as shown in the following **Table ES.3**:

Table ES.3 ARWSP and Snake Tank Well Field Development Schedule for the City of Alamogordo, 2010 to 2050

Year	Total Demand	ARWSP AFY	ARWSP MGD	ARWSP 6 - month Usage MGD[a]	Snake Tank AFY	Snake Tank MGD	Snake Tank 6 - month Usage MGD[a]
2010	6,769	1,137	1.0	2.0	1,354	1.2	2.4
2015	7,185	1,447	1.3	2.6	1,723	1.5	3.0
2020	7,626	1,776	1.6	3.2	2,114	1.9	3.8
2025	8,008	2,060	1.8	3.6	2,452	2.2	4.4
2030	8,409	2,360	2.1	4.2	2,810	2.5	5.0
2035	8,788	2,646	2.4	4.8	3,145	2.8	5.6
2040	9,138	2,903	2.6	5.2	3,456	3.1	6.2
2045	9,458	3,141	2.8	5.6	3,739	3.3	6.6
2050	9,733	3,346	3.0	6.0	3,983	3.6	7.2

a – peaking flow rate utilized over a 6-month period

This updated *City of Alamogordo 40-Year Water Development Plan 2010–2050* is submitted pursuant to NMSA Section 72-1-9 (B) (1985).

In addition to drought, fire in a watershed can eliminate a water supply as it did in the case of Bonito Lake. The City must plan its municipal water supply based upon these possibilities.

1.0 Introduction

Background

The City of Alamogordo differs from most municipalities in the State of New Mexico in that the majority of its historical water supply (approximately 70%) has come from surface water. These surface water sources in the Sacramento Mountains north and east of the City, as well as Bonito Lake, are highly variable and very susceptible to drought conditions that reduce supply. During drought conditions, available water supply from these sources may be less than half of average supply.

The problem facing the City at this time is lack of water, even though the City owns an abundance of water rights. For example, the City has surface water rights of 5,418 AFY plus 16 CFS, however, between 2000 and 2010 an average of only 4,275 acre-feet of surface water was available for diversion and use.

low in any one year?

The City faces a similar problem with ~~their~~ its ground water rights in that the City has ground water rights exceeding 3,900 AFY (excluding the yet-to-be-developed Snake Tank Well Field) in wells that only produced about 1,860 AFY in 2006, when the surface water supply was the lowest in the period of record 1967 to 2010.

how much?

The City has been proactive in its efforts to supply water. Water salvage through the use of reclaimed water is the prime example. After more than 10 years and millions of dollars, the reclaimed water system can supply over 3 million gallons per day (3,000 AFY) of reclaimed water for green-space irrigation.

Conservation through the lining and covering of the raw water storage reservoirs and reclaimed water storage reservoirs, saves almost one million gallons per day previously lost to seepage and evaporation during the summer months. The increasing block water-rate structure, along with efforts identified in the water conservation plan, have been very successful in reducing residential consumption of water.

However, water conservation alone cannot supply the future water needs of the City. Therefore, it is critical for Alamogordo to further develop water resources under their existing water rights to meet current shortfalls, establish a drought resilience and to provide for planned future growth and development.

A concept of "firm supply" from the various sources is used to calculate a minimum guaranteed water supply for the City. The "firm supply" is based on the worst years in the period of record for water supply, and includes hydrologic and system limitations, and ultimately reflects the reliability of the water supply. The short-fall between the firm water supply and the current and future water demand reflects the additional amount of water resources that the City needs to develop under this Plan.

This 40-year Water Development Plan update was prepared for the City of Alamogordo by Livingston Associates, P.C. (consulting engineer), and John Shomaker & Associates, Inc. (JSAI). The contents of the Plan include analysis of available water resources, existing water supplies, current and future water demands, and water supply development alternatives.

Purpose

The purpose of the Plan is to: 1) quantify current water supplies; 2) quantify current water needs; 3) identify future water needs; 4) identify further water conservation; 5) identify future sources of water supply; 6) plan for the next 40 years by developing all of the City's water rights to meet future water needs; and 7) provide drought resilience within the water supply.

Water-Planning Region

The water-planning Region for the City of Alamogordo (sub-Region 3 on **Figure 1.1**) primarily encompasses the eastern part of the Tularosa Underground Water Basin. The water-planning Region will be referred to as "the Region", "the water-planning Region" or the "planning Region", throughout this report. Between 2006 and 2010, the City of Alamogordo has derived about 80 percent of its water supply from surface water that originates from the Sacramento Mountains and Bonito Lake, and the remaining 20 percent from the La Luz and Prather Well Fields, and the Golf Course well, completed in the basin-fill aquifer. The Tularosa Underground Water Basin was declared by an order of the NMOSE on July 7, 1982, and includes about 6,000 square miles and the major part of the planning Region. Availability of fresh ground water in the Tularosa Basin is limited by State Engineer administrative controls, geology, and supply. In addition, all of the surface water has been fully or over-appropriated.

The water-planning Region's eastern boundary is along the crest of the Sacramento Mountains from Three Rivers to the Oro Grande area approximately 40 miles south of Alamogordo. Military boundaries make up the water-planning Region's western boundary. The water-planning Region is approximately 80 miles long and 20 miles wide and is located only within Otero County. The Region primarily encompasses the NMOSE Alamogordo-Tularosa Administrative Area (refer to **Figure 1.3**).

Temperature and precipitation vary within the Region because of the differences in land surface altitude. The lower elevation portion of the Region reflects an arid climate and the Sacramento Mountain portion along the eastern boundary of the Region reflects a semi-arid climate. Most of the precipitation falls during mid-summer as intense thunderstorms and as winter precipitation (rain on the basin floor and snow at higher elevations). Summer precipitation occurs during July through September. The average annual precipitation ranges from 9 inches at the lower elevations of the Region near White Sands National Monument, to 12 inches near Alamogordo, to about 28 inches at the highest elevations of the Region near

Cloudcroft . **Figure 1.2** is a graph showing the relationship between precipitation and surplus precipitation (precipitation in excess of evaporation) with elevation. Surplus precipitation is defined as the remaining precipitation after evapotranspiration losses. The major recharge to the Region is through snow pack in the higher elevations. Highly variable and lower-than-average snowfall and higher-than-average winter temperatures since the late 1990s in the watersheds feeding the spring systems has caused drought conditions (see Appendix for snowfall and temperature information, and reduction in La Luz-Fresnal spring flows).

The Tularosa Basin is a hydrologic closed basin composed of basin-fill deposits in the center portion and bedrock in the surrounding mountain watersheds. Almost all of the water for the Region is surface water originating from the watersheds along the west side of the Sacramento Mountains, and ground water from basin-fill deposits. Some domestic water supplies are obtained from the bedrock aquifer in the Sacramento Mountains. Ground water flow in the Region is from east to west, originating in the recharge areas along the crest of the Sacramento Mountains, and discharging to the playa lakes in the basin center (see **Figure 3.2**).

The higher-elevation and forested Sacramento Mountain escarpment receives more precipitation and gives rise to several small streams that discharge into the desert. Most of the streams are perennial in their upper reaches and derive their base flow from runoff, primarily as snowmelt, on the western slopes of the Sacramento Mountains. All streams carry flood-flow from infrequent high-magnitude thunderstorms. Only the large drainage areas on the western slope of the Sacramento Mountains contain streams with any appreciable base flow, which is derived largely from snowmelt. These streams include Three Rivers, Rio Tularosa, La Luz Creek, and Alamo Canyon. Part of the total runoff recharges the basin-fill aquifer. Most of the available surface water in the planning Region has been appropriated for use with the exception of surface water in Rinconada Canyon (Temporal Creek). 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 water-planning Region is located entirely within the Tularosa Underground Water Basin. In May of 1997, the NMOSE published criteria for water rights administration of the Alamogordo-Tularosa Administrative Area, a sub-area within the Basin centered on Tularosa and Alamogordo. The location of the Alamogordo-Tularosa Administrative Area is shown on **Figure 1.3**. (Each administrative block is 0.5-square mile. The yellow blocks shown on **Figure 1.3** are deemed critical, orange blocks are near critical and gray blocks represent the Sacramento Mountains in which the administrative criteria do not apply). ~~The NMOSE is currently revising the Criteria for the administration of the Tularosa Basin.~~

New appropriations for fresh ground water are limited or nil under the current administrative criteria (where model cells are critical or near critical). This places a legal constraint on any further fresh ground water development within the Region.

The majority of the Region is rural, and agriculture and military-related enterprises are dominant. As of 2005, the total area irrigated in the Tularosa Basin in Otero County was 5,813 acres, concentrated in the vicinity of Alamogordo, La Luz, Tularosa, and Boles Acres.

U.S. Census 2010 indicates a population of 63,797 for Otero County, with 40,933 in the Alamogordo county subdivision, which includes City of Alamogordo, La Luz, Boles Acres, and Holloman Air Force Base, 13,108 in the Southeast Otero County subdivision, which includes Cloudcroft and Timberon, 6,143 in the Tularosa subdivision, which includes Tularosa and Three Rivers, and 3,613 in the Mescalero subdivision. U.S. Census 2010 indicates a population of 30,403 for City of Alamogordo, and the City is currently ~~investigating~~ the validity of this number.

Water Supply System

The majority of the City of Alamogordo's water supply is derived from spring flows originating from the La Luz-Fresnal Canyon system, which flow via collection

structures and pipelines to the La Luz Water Treatment Plant (WTP), located at the north end of Alamogordo. Bonito Lake water also flows via a 90- mile pipeline to the La Luz WTP. Additional spring flows from the Alamo Canyon and Caballero Canyon systems flow via pipeline to the Alamo Canyon Water Treatment Plant, located at the southeastern end of Alamogordo.

Ground water is used primarily during the summer months to augment the surface water supply. It is derived from seven wells within the La Luz Well Field (T-32-S-3 through –S-9) located at the northern end of the City, two wells in the Prather Well Field (T-33 and T-33-S) located south of the City, and the Golf Course Well (T-814), located on the south side of the City. The Golf Course Well was permitted as supplemental to the La Luz Wells in 2008. The Mountain View Well (T-3489-repl) is not yet operational. It has been necessary to rely on ground water more due to the drought causing reduced surface water supplies.

Three raw water storage reservoirs, totaling 180 million gallons in capacity, are used to store water at the La Luz WTP prior to treatment. All three of the reservoirs have been covered and lined to eliminate evaporation loss and leakage.

At the Alamogordo Water Reclamation Plant, more than 3 MGD of effluent is reclaimed and used for turf and green-space irrigation as well as construction and other needs of the City.

2.0 Surface Water Resources

Regional Setting

The spring flows from the Sacramento Mountains vary seasonally, and are generally greater during the months of March through May. Spring (and stream) flows generally occur after all of the demands for water in the watershed are satisfied (i.e.; vegetation use, evaporation, upstream diversions, domestic wells, etc.). In wet years, rainfall and snowmelt runoff can be a substantial contributor to the amount of stream flow available for diversion. Storm water runoff from summer thunderstorms occurs rapidly and is difficult to capture and clean to potable water standards.

The U. S. Geological Survey (USGS) has limited daily base flow and peak flow measurements for Tularosa Creek at Bent and near Tularosa, and for Alamo Creek, La Luz Creek and the Sacramento River. Only peak flow for Three Rivers was measured by the USGS from 1955 to 1977. A summary of available surface water data is presented as **Table 2.1**, and shows the period of record and annual mean stream flow in acre-feet per year.

Table 2.1 Summary of Available Surface Water Data in the Region

Station Name	Period of Record	Annual Mean Stream Flow, AFY
Tularosa Creek near Bent, NM	1949-2010	9,797
Rio Tularosa near Tularosa, NM	1939-46	11,091
Rio La Luz near La Luz, NM	1911-12	8,536
Rio Fresnal near Mountain Park, NM	1911-12	1,050
Rio La Luz at La Luz, NM	1910-13; 1982-89	8,694
Alamo Creek near Alamogordo, NM	1933-50	1,283
Sacramento River near Sunspot, NM	1984-89	2,173

Listed in **Table 2.2** is a comparison of estimated watershed yield and estimated base stream flow for watersheds in the Region along the Sacramento Mountains. The watershed yield decreases to the south as a result of decrease in mean elevation and total area of the watersheds. Total watershed yield for the Region is estimated at 77,619 AFY, and total stream flow is estimated at 47,099 AFY. The difference between watershed yield and stream flow may be considered as losses to storage in soil (vadose zone) and recharge to the bedrock aquifer in the watershed area above the mountain front. This indicates that approximately 65 percent of the watershed yield in the Eastern Tularosa Basin area becomes stream flow and 35 percent is lost to soil storage or becomes recharge to the mountain bedrock.

Table 2.2 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	Elevation, feet	Watershed Area, mi^2	Estimated Mean Annual Stream Flow AFY	Estimated Watershed Yield AFY
Eastern Basin						
Three Rivers at Three R.[1]	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[1]	19	21.2	6,840	97.5	9,194	10,897
Tularosa Canyon at Tularosa[1]	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[1]	23	21.1	7,464	65.2	5,285	10,906
Dry Canyon[1]	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[1]	27	17.1	6,237	3.5	72	232
Alamo Canyon[1]	28	21.0	7,146	24.9	1,433	3,462
Mule Canyon[1]	29	16.2	6,207	6.7	159	984
San Andres Canyon[1]	30	21.7	7,467	14.8	746	2,532
Dog Canyon[1]	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

Table 2.2 Continued

Watershed Name	Map ID [2]	Mean Annual Precip, in/yr	Elevation, feet	Watershed Area, mi2	Estimated Mean Annual Stream Flow AFY	Estimated Watershed Yield AFY
Escondido Canyon[1]	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 [1]	35	19.5	6,730	12.3	492	1,190
Grapevine Canyon [1]	36	19.4	6,415	33.5	1,875	2,293
Pipeline Canyon [1]		14.3	5,353	6.1	116	0
Culp Canyon [1]	37	14.3	5,765	23.2	687	707
Eastern Basin total					**47,099**	**77,619**

[1] Waltemeyer, S.D., 2001, Estimates of mountain-front streamflow available for potential recharge to the Tularosa Basin, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 01-4013, 8 p.
[2] watershed map ID on Figure 1.1

Surface Water Budget

The estimated watershed yield provides some estimate of runoff plus storage in the soil horizon and ground water recharge to mountain block for a particular watershed. Not all of the watershed yield can be captured. Furthermore, not all of the stream flow can be captured; particularly storm flow events. Of particular importance are the water budgets for La Luz Canyon and Alamo Canyon watersheds and the availability of surface water. **Table 2.3** summarizes the surface water components of each of these watersheds. The water rights in La Luz Canyon are greater than the estimate yield, and can only be fully exercised in times of above-average precipitation and streamflow. Upon reviewing **Table 2.3**, it is apparent that the availability of streamflow is limited, and surface water is over-appropriated.

Table 2.3 Surface Water Components of Alamo Canyon and La Luz Canyon

Component	Alamo Canyon	La Luz Canyon
Watershed yield (AFY)	3,460	10,900
Mean annual flow (AFY)	1,280	8,600
Percent of streamflow resulting from storm flow events	10 to 20[a]	
Total surface water rights	3,078	6,700 +
Estimated range in annual streamflow (AFY)	700 to 2,000[b]	4,800 to 13,300[b]

[a] based on analysis of daily streamflow for Rio Tularosa, Tularosa Creek, and La Luz Creek

[b] based on analysis of annual streamflow for Rio Tularosa, Tularosa Creek, and La Luz Creek

City's Surface Water Supplies

Historically, more than seventy percent of the City of Alamogordo's water supply has been derived from surface water that is affected by drought. **Figure 2.1** presents total surface-water diversions between 2006 and 2010. **Figures 2.2**, **2.3** and **2.4** present historical surface-water diversions from La Luz-Fresnal Canyon, Alamo Canyon, and Bonito Lake, respectively, from 1967 to 2010. Historical meter records document water diversions from La Luz-Fresnal Canyon, Alamo Canyon, and Bonito Lake to the City of Alamogordo. Meter records from a Parshall flume, referred to as the La Luz-Fresnal Flume, document diversions from springs in La Luz-Fresnal Canyons. Meter records for Alamo Canyon document diversions from the springs in Alamo Canyon. Meter records for the Bonito Lake Receival document diversions from Bonito Lake when they reach the La Luz WTP, where water is apportioned between Alamogordo and Holloman Air Force Base.

Table 2.4 summarizes the annual surface water diversions, shows the average diversion for the period of record, and shows the annual diversion rate that statistically will occur 95 percent of the time (the fifth percentile of the historical data-set).

Definition of Firm Yield

A water-supply definition for *firm yield* can be found in Linsley et al. (1982), and is "*Firm yield is the minimum yield during the life of the reservoir* [supply]." Therefore, the firm yield is based on the worst years in the record for water supply, which includes hydrologic and system limitations, and ultimately reflects reliability of supply. A case study in Linsley et al. (1982) demonstrates that simply using the average or median tends to overestimate supply. To base the availability of water supply on the assumption of stationarity of streamflows in semi-arid and arid regions is described by Evans (1985) as unrealistic, and other statistical analyses, such as the use of confidence intervals, provides a more realistic approach to determining firm yield (supply).

Firm Yield Method for Surface Water Sources

The firm yield analysis is based on diversion records, and it is assumed that the amount of water diverted is the maximum amount that could be diverted.

This assumption is based upon knowledge of the City's operations and communications with City staff. Any amount of water that was not diverted, for any reason, is not measured and therefore cannot be counted upon. Because the datasets are not normally distributed, non-parametric statistical analysis of the fifth percentile of the historical surface water diversion dataset, and the tolerance interval associated with the fifth percentile, was determined to be the most sound and appropriate method for determining the firm yield of Alamogordo's surface water supplies. These methods rely on historical surface-flow data as opposed to assumptions about future flows (Helsel and Hirsch, 1992). Calculating a percentile of the historical dataset is essentially using observations from the past to make inferences about what can be expected for the future. The fifth percentile was chosen as a conservative flow value that is available upon demand, since 95 percent of historical flows exceeded the fifth percentile.

The tolerance interval is essentially a confidence interval centered around a percentile, and is "the most commonly reported statistic for analyses of low flows (Helsel and Hirsch, 1992)." A confidence level of 90 to 99 percent is commonly used for hydrologic applications (Yevjevich, 1982). A confidence limit of 95 percent was used in calculating the tolerance interval for the fifth percentile. Because the annual surface-water diversion datasets for La Luz-Fresnal Canyon, Alamo Canyon, and Bonito Lake do not have normal distributions, non-parametric methods were used to determine the fifth percentiles and the tolerance intervals presented in **Table 2.4**.

Alamo Canyon

Alamo Canyon, which has a drainage area of 25 square miles, drains 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. Stream flow measurements from Alamo Creek from 1933 to 1950 indicated an average of 1,283 AFY (**Table 2.1**), and the USGS has estimated stream flow in Alamo Creek to average 1,433 AFY (**Table 2.2**). The chemical quality of the water is generally good; it commonly contains

about 500 mg/L total dissolved solids and about 130 mg/L sulfate. The water rights of Alamo Creek (3,078 AFY) are owned by the City of Alamogordo. The City has extended its pipeline upstream to utilize springs in Alamo Canyon and its tributaries. A graph showing the diversions from Alamo Canyon is provided as **Figure 2.2.** Diversions from Alamo Canyon have averaged 1,257 AFY over the last 44 years (see **Table 2.4**). The minimum diversion of 579 AFY occurred in 2006.

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 65 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. The City of Alamogordo owns approximately 12,500 AFY of water rights associated with La Luz Creek. The USGS gauged daily base flow in La Luz Creek from 1982 to 1989, which showed an average daily base flow of 12 CFS or 8,694 AFY (**Table 2.1**). The La Luz Irrigation District has rights to the first 400 GPM diverted from the La Luz-Fresnal system, which can significantly limit the City's diversion during drought conditions.

The total dissolved solids content of La Luz Creek water varies from 672 mg/L at a spring in Fresnal Canyon to 1,700 mg/L near the La Luz railway station.

A graph showing the diversions from La Luz Creek is provided as **Figure 2.3.** Diversions from La Luz Creek have averaged 3,318 AFY over the last 44 years (see **Table 2.4**), but a significant decline in water diverted from La Luz Creek has occurred ~~for~~ over the last decade (**Figure 2.3**). In the last decade, since the diversion system has been modified for optimum capture, the minimum diversion of 1,489 AFY occurred in 2006.

Table 2.4 Historical Diversions Measured at La Luz-Fresnal Flume, Alamo Canyon, and Bonito Lake Receival

Year	La Luz-Fresnal Diversion, AF	Alamo Canyon Diversion, AF	Bonito Lake* Diversion, AF
1967	1,961	784	1,608
1968	2,028	838	2,431
1969	2,046	1,034	2,204
1970	2,229	1,169	2,019
1971	2,412	(b)	524
1972	2,070	(b)	2,050
1973	2,232	(b)	2,196
1974	3,466	(b)	1,146
1975	3,891	(b)	2,196
1976	4,279	(b)	1,759
1977	4,209	(b)	2,027
1978	3,670	1,046	1,818
1979	1,951	1,823	1,383
1980	2,437	1,570	2,129
1981	2,189	1,390	1,290
1982	1,610	1,495	2,279
1983	3,299	1,475	1,853
1984	4,255	1,467	1,791
1985	(a)	(a)	(a)
1986	3,047	1,872	1,757
1987	4,326	1,920	(a)
1988	5,137	1,340	1,715
1989	4,237	1,471	(a)
1990	5,032	1,414	1,359
1991	3,869	1,491	1,637
1992	5,782	2,081	786
1993	5,099	1,760	748
1994	5,529	1,490	(a)
1995	5,330	1,368	(a)
1996	5,382	1,260	(a)
1997	5,739	1,111	1,236
1998	4,425	1,106	1,282
1999	3,542	1,108	788
2000	3,334	1,121	542
2001	2,765	888	1,484
2002	2,523	684	766
2003	2,232	683	1,200
2004	2,309	634	1,468
2005	2,080	605	2,535
2006	1,489	579	1,014
2007	1,866	1,131	1,817
2008	2,674	1,260	1,506
2009	2,784	1,522	864
2010	1,826	1,143	1,277
average diversion, AF	**3,318**	**1,257**	**1,539**
diversion exceeded 95% of the time, AF[c]	**1,653**	**601**	**542**
95% tolerance interval	**1,489 to 1,961**	**579 to 784**	**524 to 788**

* total diversions for City of Alamogordo and Holloman Air Force Base

10 yr ave.?

(a) no data available; (b) diversion system under repair during this period and surface-flow diversion data-set incomplete; [c] based on the 5th percentile of the historical dataset

move to same page as table

The recent decline in diversions from La Luz Creek is largely due to drought conditions, but domestic water demands (from more than 480 wells) in the La Luz Creek watershed have increased over the last 15 years. These wells contribute to reducing stream flow by diverting (pumping) ground water before it reaches the stream and becomes surface flow.

- Need to add a ft on the line

Bonito Lake

Bonito Lake is located approximately 15 miles northwest of the Village of Ruidoso, within the Lower Pecos River 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 Holloman AFB. The City of Alamogordo and Holloman each own 1,449 AFY of water rights (2,898 AFY combined). Annual amounts of water diverted from Bonito Lake, which have been less than the combined right, are divided evenly between Alamogordo and Holloman. Other entities owning Bonito Lake water rights, which total approximately 190 AFY, are Carrizozo and Nogal.

what about Ft. Stanton?

Water from Bonito Lake, superior in chemical quality at 300 mg/L TDS, is mixed with the spring and ground water at the La Luz WTP to increase the overall supply and improve the quality.

Bonito 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 (33 square miles).

A graph showing the diversions from Bonito Lake is provided as **Figure 2.4**. The average annual diversion from Bonito Lake to the City of Alamogordo is only about

760 AFY. The total firm supply of Bonito Lake is calculated as 542 AFY. The City of Alamogordo's portion is one half of the firm supply based on the total diversion shared with Holloman AFB (**Table 2.4**). It should be noted that the diversions from Bonito Lake over the period of record account for only about 5 to 19 percent of the overall water supply to Alamogordo.

The Bonito Lake supply has been highly unreliable due to low storage during periods of drought, pipeline conditions, periods of poor water quality due to fall and spring turn over, and minimum lake-level requirements for fish, wildlife, and recreation. In addition, the reservoir is over 75 years old and has lost significant storage capacity due to sedimentation. The Bonito Pipeline has been replaced, but it is unlikely that the full annual diversion of Bonito Lake water will be realized on a consistent basis. For future planning purposes, it is assumed that the City of Alamogordo's portion of the Bonito Lake supply is approximately 271 AFY (half of firm yield).

Firm Yield Analysis

Based on the available period of record (1967-2010), the diversions that are met or exceeded 95 percent of the time, calculated for La Luz-Fresnal (1,653 AFY), Alamo Canyon (601 AFY), and Bonito Lake (271 AFY) water delivered to the City of Alamogordo, is an estimate of the firm yield from each of these sources. Including data from the 1980s and early 1990s leads to a higher estimate of firm yield, because above-normal precipitation during this period caused an increase in stream flow during this time. **Table 2.5** summarizes the City of Alamogordo's Surface Water Sources, Water Rights and Firm Yield

Table 2.5 City of Alamogordo's Surface Water Sources, Water Rights and Firm Yield

Surface Water	Water Right, AFY	Firm Yield, AFY
Bonito Lake	1,449	271
La Luz- Fresnal	891 AFY + 16 CFS*	1,653
Alamo Canyon	3,078	601
Total surface water	**5,418 AFY + 16 CFS***	**2,525**

* - 16 CFS (cubic feet per second) is time-of-day limited

Therefore, the firm yield of Alamogordo's surface water sources indicates a potential minimum available supply of about 2,525 AFY, based on recorded diversion data from the previous 44 years. *However, it is possible that the City may experience extended severe drought conditions or other circumstances in the future where there is little to no surface water supply, and water demands must be offset entirely by ground water resources.*

For planning purposes, the City of Alamogordo should rely on a future firm surface water supply of only 2,525 AFY. During extreme drought conditions, the City should not rely on any surface water supply.

Discuss 3 options:

1) 3,513 afy (settlement amt)
2) 2,525 afy (firm yield)
3) ~~0~~ under conjunctive management

3.0 Ground Water Resources

Regional Supply

Ground water in the Region can be divided into two generalized geologic settings: 1) the basin fill aquifer, and 2) the bedrock aquifer. The extent and total dissolved solids content of water in the basin fill aquifer is shown on **Figure 3.1**. 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 and municipal supply. 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 100 GPM (Shomaker and Finch, 2006).

Recharge to the Eastern Tularosa Basin area was previously estimated at 14,500 AFY by the NMOSE (Morrison, 1989). Morrison's estimate was based on the stream flow remaining after diversion, which infiltrated at the mountain front. This is a conservative estimate because it does not account for underflow from the bedrock aquifer to the basin fill or for smaller streams that contribute recharge to the basin fill. For this 40-Year Water Development Plan, the recharge was estimated using the ground water flow model developed by JSAI (2006). Estimated recharge and components of recharge to the entire Region can be referenced from **Table 3.1**. Since development of surface water sources began in the late 1890s, a reduction in recharge to the basin fill aquifer has occurred as a result of stream flow diversions in the planning Region, particularly during the 1950s drought. The reduction in recharge to the basin fill aquifer is concentrated in both La Luz Canyon and Alamo Canyon, which has limited recharge and development of ground water resources.

Table 3.1 Summary of Estimated Ground Water Recharge Rates and Recharge Components for Region (JSAI, 2006)

Component	Estimated Rate, AFY
Prior to Development	
Recharge to basin fill from stream flow	22,887
Recharge to bedrock aquifer from precipitation	6,662
Total recharge to Region	29,920
1950s Drought	
Recharge to basin fill from stream flow	17,002
Recharge to bedrock aquifer from precipitation	6,662
Total recharge to Region	23,664

JSAI, 2006, Predicted drawdown effects and evaluation of potential saline encroachment due to pumping under City of Alamogordo application nos. T-3825 through T-3825-S-9, approximately 10 miles north of Tularosa, Otero County, New Mexico: consultant's report prepared John Shomaker & Associates, Inc. for City of Alamogordo, 55 p. plus figures and appendices.

Estimates of ground water in storage for different ranges in salinity are provided in **Table 3.2** and the distribution of salinity is shown on **Figure 3.1**. Fresh water storage (<1,000 mg/L TDS) within the Eastern Tularosa Basin area is mainly limited to alluvial fan (basin fill) deposits along the Sacramento Mountain front. The Region is estimated to have approximately 1.9 million acre-feet of recoverable fresh water from the basin fill aquifer. The estimated 3.8 million acre-feet of recoverable fresh water in the bedrock aquifer is located in the mountain watershed areas, and will yield low flows to small diameter wells, but large amounts of fresh water cannot be obtained. These estimates do not account for ground water removed from storage since ground water development began. Practically all of the fresh water in the Region is south of Alamogordo in the NMOSE administrative area and within Fort Bliss military lands (**Figure 3.1**). The NMOSE administrative criteria in this area limit ground water development to approximately existing diversion amounts. The fresh water underlying military land is unavailable for City (or any other) development due to access security concerns.

Table 3.2 Estimated Total and Recoverable Volume of Ground Water Stored in the Eastern Tularosa Basin Area

TDS Range mg/ L	Basin Fill Total Volume in Storage AF	Basin Fill Recoverable Volume in Storage AF	Bedrock Total Volume in Storage AF	Bedrock Recoverable Volume in Storage AF
>10,000	2,764,800	691,200	0	0
5,000-10,000	46,786,560	11,696,640	0	0
4,000-5,000	22,256,640	5,564,160	0	0
3,000-4,000	27,095,040	6,773,760	599,040	299,520
2,000-3,000	6,819,840	1,704,960	1,739,520	869,760
1,000-2,000	44,928,000	11,232,000	11,669,760	5,834,880
<1,000	7,879,680	1,969,920	7,637,760	3,818,880
total	158,530,560	39,632,640	21,646,080	10,823,040

Notes:

- Total volume of water stored in basin fill is based on 1,000 feet average saturated thickness and porosity of 0.2
- Total volume of water stored in bedrock is based on 1,000 feet average saturated thickness and porosity of 0.05
- Total volume of fresh water stored in basin fill is based on 500 feet average saturated thickness and porosity of 0.2 (area south of Alamogordo)
- 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

The estimate 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 equal be to dewatering the upper 250 feet of the aquifer. This would be equal to a ground water yield of approximately 37,250 AFY for 100 years. The NMOSE Administrative criteria for the Alamogordo-Tularosa Administrative Area may allow drawdowns of up to 2.5 feet per year.

Fresh water in the basin fill aquifer south of Alamogordo is typically less than 500 feet in thickness, and in some areas dewatering 250 feet would remove one half of the thickness or potentially all of the fresh ground water. Besides the hydrologic limitations in this area, the NMOSE Administrative Criteria also limits the

appropriation of ground water. A preliminary administrative model run was attempted for this area and determined that additional appropriations would be difficult (Tularosa Basin and Salt Basin Regional Water Plan 2000-2040, May 2002).

Many of the irrigation wells in the Region that have high yields (>100 GPM) are located along the base of the mountain front where sediments are coarse-grained. This zone of high well yield is 5 to 10 miles in width and 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. Well yield decreases significantly with distance west of the Sacramento Mountain front, potentially from 1,000 GPM down to 100 GPM (McLean, 1970).

Over the last twenty years domestic well drilling in the 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 are highly dependent on local geologic conditions. Well yields in the bedrock aquifer can be reduced dramatically by a slight lowering of the water table because of the decrease in permeability that occurs with depth.

City Ground Water Supply

The City has ground water supply wells associated with the La Luz Well Field (T-32-S through T-32-S9), the Prather Well Field (T-33 and T-33-S), the Golf Course Well (T-814) and the Mountain View Well (T-3489-repl). Historical meter records document water diversions from the La Luz and Prather Well Fields, and the Golf Course Well. The Mountain View Well is not yet in production.

La Luz Well Field (T-32-S through T-32-S-9)

Some of the most productive wells in the Region are completed in basin fill as well as bedrock. 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 250 GPM to

900 GPM. Alamogordo's La Luz Well Field is located a few miles north of Alamogordo. La Luz Well Field data are summarized in **Table 3.3**.

Table 3.3 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 repl.	Well No. 4	Well No. 5 repl.	Well No. 6 repl.	Well No. 7	Well No. 8
Date drilled	1956	2008	1964	2008	1992	1971	1999
Total depth, feet	703	880	780	935.7	844	750	991
Water level, feet bgl	362	400	440	438	359	336	408
Water column, feet	341	480	340	497.7	485	414	583
Pumping level, feet bgl	560	590	516	615	500	481	625
Instantaneous production rate, GPM	320	500	320	600	900	850	250

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

The La Luz Well Field consists of seven wells, and is used to meet summer water demands when surface-water diversions are low. Historically, the well field is pumped approximately six months out of the year from April to September. Annual diversions from the La Luz Well Field have ranged from 147 AFY to 2,750 AFY, with an average of 524 AFY over the last 5 years. The fluctuation in diversions from the well field has varied as a result of changes in surrounding demand from other ground water users, encroachment of junior water rights, variable recharge and aquifer storage capacity, and ability to use surface water and reclaimed water to meet part of the City's total water demand (see **Figure 3.4**).

Water level declines that have accumulated in the La Luz Well Field area over the last 50 years are shown on **Figure 3.3**. The average water level decline is approximately 0.5 feet per year, but varies from well to well (see hydrographs in **Appendix**). The observed water level declines in the La Luz Well Field area are a

result of local and regional ground water pumping, reduced recharge from captured stream flow, and numerous domestic wells. Additionally, the water quality diminishes throughout the pumping season. During the last decade, water level declines have accelerated (up to 5 feet per year), although production has decreased (see **Figure 3.4**). The most plausible explanation is increased demand on the aquifer from surrounding users and decreased recharge from La Luz Canyon; both conditions resulting from the recent drought.

Reliable supply from the La Luz Well Field is difficult to estimate because it would depend on successful NMOSE applications to replace wells, and management decisions such as acceptable levels of long-term drawdown and pumping rates of individual wells, as well as recharge and aquifer management.

An analysis of the potential yield from the La Luz Well Field was performed using the JSAI ground water flow model (JSAI, 2006). The long-term predicted yield from the La Luz Well Field, assuming a successful well replacement program and optimum well efficiency, is 2,979 AFY as shown in the following **Table 3.4**.

Table 3.4. Summary of Predicted Yield from the La Luz Well Field Assuming Optimum Well Efficiency and the Ability to Replace Wells to Maintain Efficiency

Well	Predicted yield, AF
2	314
3 repl.	538[a]
4	340
5 repl.	646[b]
6 repl.	387
7	580
8	174
total	2,979

settlement - 3000 afy

[a] based on operation at 500 gpm, 8 months out of each year (JSAI, 2009, Well report: City of Alamogordo La Luz Well No. 3-R, T-32-S-4: consultant's report prepared by John Shomaker & Associates, Inc., for City of Alamogordo, 13 p. plus figures and appendices)

[b] based on operation at 600 gpm, 8 months out of each year (JSAI, 2009, Well report: City of Alamogordo La Luz Well No. 5-R, T-32-S-6: consultant's report prepared by John Shomaker & Associates, Inc., for City of Alamogordo, 13 p. plus figures and appendices)

Another factor limiting yield from the La Luz wells is water quality. The average TDS concentration is approximately 1,500 mg/L to 1,800 mg/L in water produced from the well field. Without blending with surface water, the water produced from the wells would need to be treated to meet the desired water quality requirement of 800 mg/L TDS. Therefore, the production from the La Luz wells is limited by the available surface water for blending or would be reduced to reflect losses due to treatment.

Prather Well Field (T-33 and T-33-S)

Prather Wells No. 1 (T-33 repl.) and No. 2 (T-33-S repl.) were replaced in January 2010. Currently, based on evaluation of pumping test data, the two Prather wells can produce a combined 500 AFY, and the permitted water right for the Prather Well Field is now 500 AFY.

settlement = 500 afy

Golf Course Well (T-814)

The Golf Course Well (T-814) was in poor condition and replaced in 2005. The replacement well was drilled deeper and produced better quality water than the old well. The replacement well is capable of producing 423 AFY, which is 153 AFY more than the permitted right of 269.9 AFY. An application to make a portion of the Golf Course Well diversions supplemental to T-32-S-2 through T-32-S-9 (La Luz wells) for 160 AFY was approved by the NMOSE in 2008. Under the approved permit, a total of 429.9 AFY can be diverted from the Golf Course Well.

Only in years when the diversion from the Golf Course Well exceeds 269.9 AFY will the additional water be counted toward beneficial use of the water right under T-32 et al.

settlement = 170 afy

Mountain View Well (T-3489-repl)

The Mountain View Well was replaced during the summer of 2006. The City filed an application to replace T-3489 (True Value Well) at a location 500 feet to the west and in the same administrative block. The application was published and

protested, although the NMOSE granted the City emergency authorization to replace T-3489. The Mountain View Well was completed to 500 feet and is capable of producing the allocated water right of 160 AFY. Water produced from the Mountain View Well is slightly saline and will require treatment prior to use in the potable water supply.

Snake Tank Well Field (T-3825 et al.)

The City has begun to develop the Snake Tank Well Field for the ARWSP, including the drilling and testing of five test wells, with two of the wells considered production-scale wells. Results of the testing verify that the well field will be suitable for the desalination facility. The City completed the water rights hearing process and was granted 4,000 AFY of brackish water under T-3825 et al. for the ARWSP in 2007. The permit conditions allow diversions up to 4,000 AFY, which can be increased up to 5,000 AFY, provided that the sum of annual diversions for any consecutive five-year period does not exceed 20,000 AFY. However, for firm yield calculations, an average diversion of 4,000 AFY has been assumed.

Firm Ground Water Supply

As a way to quantify the City's current and future water needs, and to be consistent with the approach used for surface water, it is necessary to estimate firm ground water supply of existing ground water rights using the potential long-term yield of existing wells in their current (2010) condition.

Since the development of the previous 40-Year Water Development Plan for the City (Livingston Associates, and JSAI, 2006), La Luz Wells 3 and 5, the Prather Wells, and the Golf Course Well have been replaced and brought into production, and the Mountain View Well has been replaced but is not yet in production. **Table 3.5** presents an estimate of the firm ground water supply currently available to the City of Alamogordo.

Table 3.5. Summary of City of Alamogordo Ground Water Rights and Firm Supply Settlement

Supply Name	NMOSE File Number	Water Right, AFY	Firm Supply AFY
La Luz Wells	T-32-S-2 to T-32-S-9	3,000	2,979[a]
Prather Wells	T-32, T-32-S	500	500
Golf Course	T-814	269.9	270
Mountain View	T-3456	161	160
Snake Tank Well Field	T-3825 et al.	4,000[c]	3,360[b]
Total		**7,930.9**	**7,269**

3000
500
270
160
3200
7131

[a] based on increase in firm supply associated with replacing Wells 3 (T-32-S-4) and 5 (T-32-S-6), and planned replacement of additional wells under T-32 et al. to maintain optimum well efficiency
[b] based on 4,000 AFY and an 84 percent treatment recovery
[c] permit conditions allow diversion up to 4,000 AFY, but can be increased up to 5,000 AFY, provided that the sum of annual diversions for any consecutive 5-yr period does not exceed 20,000 AFY

For planning purposes, the City of Alamogordo should rely on a minimum potential firm ground water supply of 7,269 AFY, which includes the ARWSP project. This should be considered the sole water supply for severe drought condition planning.

4.0 Water Demand

Present Water Demand

The City of Alamogordo's average annual water diversions were about 1.5 billion gallons per year (4,502 AFY) between 2006 and 2010. Average metered water deliveries totaled 3,982 AFY between 2006 and 2010. Of these metered deliveries, residential use is approximately 80%; and commercial use is around 20%. **Table 4.1** presents a summary of water diversions and deliveries between 2006 and 2010.

Table 4.1 Summary of Water Diversions and Deliveries Between 2006 and 2010

Year	Surface Water Diversions, AF	Ground Water Diversions, AF	Total Diversions, AF	Billed/Metered Deliveries, AF
2006	2,382	1,859	4,241	3,889
2007	3,765	631	4,396	3,930
2008	4,160	451	4,611	3,970
2009	5,050	504	5,050	4,097
2010	4,213	448	4,213	4,022
average	3,723	779	4,502	3,982

Average daily diversions totaled about 4.0 MGD between 2006 and 2010. Average diversions for the month of June, typically the month with highest water use, totaled about 5.1 MGD between 2006 and 2010 (refer to the **Appendix** for water production graphs).

Water losses, as a percentage of total diversions, averaged about 11 percent between 2006 and 2010 (which is typical for a municipality). **Table 4.2** presents a summary of total diversions, authorized consumption, and water losses.

Table 4.2 Summary of Total Diversions, Authorized Consumption, and Water Losses

Year	Total Diversions, AF	Authorized Consumption		Water Losses, AF	Water Losses as Percentage of Total Diversions
		Billed/Metered Deliveries, AF	Unbilled/Metered Deliveries, AF		
2006	4,241	3,889	6	346	8
2007	4,396	3,930	10	455	10
2008	4,611	3,970	4	637	14
2009	5,050	4,097	14	940[a]	19
2010	4,213	4,022	15	176	4
average	4,502	3,982	10	511	11

a - includes waterline flushing for multiple waterline replacement contracts

Projected Populations

The City developed a Comprehensive Plan (2000), which projected population growth to the year 2020. For the Plan, the University of New Mexico Bureau of Business and Economic Research (BBER) developed population projections for low, medium and high growth scenarios. BBER also developed medium-growth projections for 2020 through 2040. After public comment, the medium-growth scenario was adopted for planning purposes. For this Plan, annual growth rates of 1.2 percent in 2010, declining to 0.6 percent in 2050 were assumed. These rates are substantially consistent with the recent wastewater treatment plant expansion Preliminary Engineering Report estimated growth rates (June 2010).

U.S. Census 2010 indicated a population of 30,403 for City of Alamogordo. The U.S. Census 2010 estimate would indicate a 14.6 percent decrease in the City population since 2000 (U.S. Census 2000 estimate was 35,582). The City submitted a challenge to U.S. Census Bureau in June 2013, demonstrating the actual population in 2010 was likely somewhere between 36,000 and 37,000.

The following **Table 4.3** shows the projected populations for the City of Alamogordo for the period year 2010 to 2050:

LA City pop. projections are more accurate because ..... and are therefore used in this report.

Compare to Table 4.1 (p. 31) in 2005 report

Table 4.3 Projected Populations for City of Alamogordo for 2010 to 2050

Year	Future Projected Population	Difference from Yr 2010 Population	Average Annual Growth Rate
2010	36,622	-	1.2 %
2015	38,874	2,252	1.2 %
2020	41,263	4,641	1.2 %
2025	43,326	6,704	1.0 %
2030	45,500	8,878	1.0 %
2035	47,548	10,926	0.9 %
2040	49,442	12,820	0.8 %
2045	51,172	14,550	0.7 %
2050	52,660	16,038	0.6%

Per Capita Water Use

As the result of a highly successful conservation program, the City of Alamogordo has reduced its total gallons per capita day (gpcd) water consumption from over 260 gpcd in 1992 to an average of 132 gpcd between 2006 and 2010. Total City-wide per-capita water use is defined as the total water diversions divided by the population served. The City Commission adopted a total City-wide per-capita goal of 165 gpcd as the City standard for water use, based on: 1) the average total gpcd between 1999 and 2001, 2) the existing water supply, 3) water conservation programs, and 4) reasonable standard of living in the arid climate of southern New Mexico. Reclaimed water use is not considered a part of the 165 gpcd City-wide water use goal.

Beginning in 2002, water supplies available to the City, and particularly surface water supplies, decreased dramatically. In response, the City passed ordinances that provided for strict water restrictions and surcharges. The restrictions were necessary to ensure that the City had an adequate water supply to meet essential services. While the City's average annual per capita use has been below 165 gpcd since 2002, these figures are supply-driven and the result of water use restrictions and surcharges.

Average total per-capita use of 165 gpcd is reasonable and was previously adopted for current and future water use planning purposes by the City (Plan, 2003). Additionally, the NMOSE accepted the City's proposed 165 gpcd water use figure

165 - In a settlement w/ SE, adopted by Dist. Ct, & upheld on appeal, & in Permit T-3825 et al.

and utilized it in forecasting future water requirements for the City of Alamogordo during the 2003 water rights hearing. The use of reclaimed water was not considered a part of the 165 gpcd future water use planning figure accepted by the NMOSE.

An estimate of acceptable residential per capita water use was made using NMOSE criteria as outlined in the *Water Conservation Guidelines for Public Water Supply Systems* (Wilson, 1999). The estimate includes both indoor and outdoor (landscaping) water uses, and assumes acceptable levels of water conservation. The estimated single-family residential gpcd use is computed to be around 125 gpcd, of which 76 gpcd is associated with indoor use and 49 gpcd is associated with outdoor uses. To develop a total gpcd estimate, all revenue and non-revenue uses and water losses (treatment and system losses, etc.) also have to be included. Non-residential water use is estimated at 25 gpcd, bringing the sub-total water use to 150 gpcd. Water losses are estimated at 15 gpcd, which reflects a level of approximately 10 percent. Therefore, the average overall per-capita water demand budget figure of 165 gpcd is considered reasonable.

Future Demand for Water

Future water demands for the City of Alamogordo are computed using the adopted City-wide total water use goal of 165 gpcd (refer to previous section). This assumes that the current proportion of single-family and multi-family residential, commercial, industrial and other water uses remain relatively constant for the planning period. This assumption also provides for the continued commercial and industrial economic development within the City (at approximately 20 percent of total water use). ~~As noted above, the use of reclaimed water is not considered a part of the 165 gpcd future~~ water use planning ~~figure used in completing this Plan.~~

The following **Table 4.4** summarizes the projected future water demands for the City of Alamogordo to 2050, in Acre-Feet per Year (AFY), Million Gallons per Year (MGY), Average Daily use in Million Gallons per Day (MGD) and Peak Daily use in MGD, based on 165 gpcd and future population shown in **Table 4.3**:

Table 4.4 Projected Water Demands for the City of Alamogordo, 2010 to 2050

Year	Projected Future Water Demand in AFY, MGY, Average MGD and Peak MGD			
	AFY	MGY	MGD	Peak MGD
2010	6,769	2,205	6.0	14.1
2015	7,185	2,341	6.4	15.0
2020	7,626	2,485	6.8	15.7
2025	8,008	2,609	7.1	16.5
2030	8,409	2,740	7.5	17.2
2035	8,788	2,863	7.8	17.9
2040	9,138	2,977	8.1	18.6
2045	9,458	3,081	8.7	19.1
2050	9,733	3,171	7.6	16.6

Note: Peak Day use estimated at 2.2 times Average Day use.

2055 ≈ 10,000

As shown in **Table 4.4**, future demand for water by the City of Alamogordo will reach approximately 9,733 AFY by 2050. Projections of future water demand are extrapolated using the estimated projected population of 52,660.

This projected future water use is demand-driven, where there is an adequate water supply for the public's consumption and beneficial use.

(or) Need 2300 afy w/ gw only - conj. use

Need = 0 under settlement

Need = 200 under City firm yield

Worst case → what is demand @ 2010 Census pop. x 139 gpcd ?

John Longworth criticized the current conservation plan for not setting future plans to produce additional restrictions.

5.0 Water Conservation Overview

The City of Alamogordo has an aggressive water conservation program. The City's Water Conservation Ordinance is provided in the **Appendix**. A report prepared by the City of Alamogordo in November 2006 entitled *City of Alamogordo Water Conservation Overview* describes the water conservation program in detail. Refer to the City website for the Overview (http://ci.alamogordo.nm.us), under the 'Water Conservation' tab. Water conservation measures implemented by the City are summarized below:

- Water Conservation Ordinance No. 948 (1995 and updates) established days and times when outdoor watering is permitted; requires covers on swimming pools when not in use; prohibits outdoor decorative fountains; and places restrictions on vehicle washing; new construction landscaping; and other activities.
- Water Rationing Ordinance No. 1008 (1997, amended 2003) mandates reduction in water usage during diminished water supplies; established automatic water rate surcharges; and set trigger points for a 3-stage rationing plan.
- Water Rate Ordinance No. 1106 (2000, amended 2002) established increasing block water rates system; provided for surcharges in addition to block rates.
- Established a low-flow toilet rebate program (2001) and will be considering other potential rebate programs (evaporative coolers, etc.).
- Mandated use of reclaimed water for irrigation of City green spaces and for use in construction activities by contractors and City departments,

which saves up to 3 million gallons of potable water each day. The City's reclaimed water system includes 16.2 miles of pipeline, two booster stations, and a 1,000,000-gallon storage tank completed in 2006.

- Established a per capita residential-only water use goal of 124.73 gpcd.
- Replacing all of the water meters in the City with "water smart" meters.
- On-going water and wastewater distribution system repairs and upgrades under the City's Infrastructure Capital Improvement Plan, to minimize loss through leakage.
- Lining and covering of three raw water storage reservoirs and two reclaimed water reservoirs to reduce evaporation and leakage losses by approximately 600 AFY.
- Replacement of water meters over 12 years old.
- Public education programs through the *City Profile* publication and xeriscaping workshops through the Keep Alamogordo Beautiful program.
- Department of Public Safety / Fire Services implemented innovative water conserving methods to conduct required equipment testing, resulting in a savings of tens of thousands of gallons per year (2004).

The results of the various water conservation measures taken by the City over the last few years have been to reduce overall per capita water demand from about 261 gpcd in 1992 to the current 137 gpcd. Previously achieved further reductions were supply driven, and not a result of conservation practices. In February 2006, the City was awarded the U.S. Conference of Mayors Municipal Water Conservation Achievement Award.

what time period ?

Sep. p. 3C

The *Overview* concludes with:

> The City of Alamogordo will continue to emphasize and encourage water conservation. This is our duty as a responsible community in the arid Southwest, and it will continue to be necessary due to characteristic long periods of drought. However, Alamogordo has done much already to achieve

significant results in responsible water conservation and may in fact be reaching a plateau, where further water restrictions are no longer possible while maintaining a reasonable quality of life. Currently, we are the only municipality in the State that has covered and lined our reservoirs and have instituted 100% use of reclaimed water during the bulk of the year.

6.0 Water Budget

Supply and Demand

Municipalities have a special obligation to guarantee an adequate water supply at all times for their residents. In the City of Alamogordo's case, more than 40,000 people (including Holloman Air Force Base), rely on the City to provide water for their health, safety, and welfare. Because of this significant responsibility to provide water at all times and under all circumstances, each municipality must analyze its specific circumstances to assess current and future water needs.

Alamogordo's need for completing the development of its existing water rights is urgent. There are a number of physical and legal constraints limiting development of new ground water supplies. Some of these constraints are summarized below.

Constraints on Existing Water Supply

1. Lack of supply due to drought

A municipality's first priority is to guarantee a water supply for the public. The American Water Works Association (AWWA) *Manual of Water Supply Practice* (AWWA, M50) states:

> A primary function of water resources planning is to provide water for periods of drought. Most municipal water supply plans consider the drought of record when estimating the firm or safe yield of a water source.... Therefore, according to the plan, *there should be adequate water supply and system capacity to meet increased demand under drought conditions*. (p.87, emphasis added).

The Manual of Water Supply Practice also discusses how firm yield (or safe yield) must be considered in determining a municipality's need for additional water supplies:

> To establish the need for additional sources of supply, reliable diversion rates must be established from water supply sources (safe yield) contributing to the water supply system. Most simply, safe yield [firm yield] is defined as the reliable withdrawal rate of acceptable quality water that can be supplied by available flows and/or storage releases from reservoirs and/or ground water reserves throughout a critical drought period.....The yield [firm yield] of a water system combined with demand forecasts identifying a reasonable range of future needs provides the basis for evaluating actions that will need to be considered over the planning period. (p.121).

There has been recognition at a national level that the decade-long drought in the West is causing surface water supplies to dry up and forcing municipalities to consider new sources. The abundant supply of brackish ground water is allowing some cities in the Southwest to consider desalination as their new supply, as reported in the publication *New Scientist*:

> Desalination is also being considered for landlocked states such as New Mexico, Nevada and Utah, where a decade of drought has caused surface water to run dry, while saltwater lies untouched in underground reserves. (New Scientist Tech, June 30, 2006).

As discussed earlier in this Plan, the City of Alamogordo relies to a great extent on surface water, which is susceptible to drought. This has been a significant factor in the City's lack of an adequate water supply since 2002.

2. Lack of supply due to infrastructure (supply) limitations

The La Luz well field has limited ground water supply availability due to hydrologic conditions in the aquifer, NMOSE administrative limitations, local domestic wells affecting recharge, and well conditions. The wells have been cleaned numerous times, but continued growth of iron-bacteria on the well casing and screen causes encrustation and plugging of the screen openings, severely restricting flow into the well pump and causing pump cavitation. This *infrastructure-limitation* contributes to overall supply delivery and availability. Over time, the bacterial growth causes complete well failure due to aquifer plugging. Replacement well drilling permits may be applied for, but are subject to protest and possible denial, and are time consuming. Even if replacement wells are authorized, there is a limit to total water production from the well field due to aquifer (and other) limitations.

3. Lack of supply due to NMOSE administrative (legal) limitations

NMOSE administrative rules limit the amount of water withdrawn in certain areas, and are beyond the control of the City. This water is *administratively-limited*, and effectively constrains the City as to where it can (and more importantly, cannot) look for new water. This *administratively-imposed* constraint forces the City to look beyond its municipal boundaries for additional water supply, and the areas adjacent to the City are not feasible for additional ground water development because: 1) The adjacent mountain areas to the east are now also administered by the NMOSE; 2) the area south of the City is not a feasible option because of military land ownership; 3) the area west of Alamogordo is not a feasible option because of military land ownership, hydrologic and water quality issues (too high a TDS to be treated economically and low well yields). Therefore, these administrative restrictions imposed on the City by the NMOSE *forced the City to go north of Tularosa* for ground water development for the ARWSP. This location is far away, costly, and requires desalination treatment.

Farther yet are the Salt Basin and Hueco-Bolson south of the City. These two areas have water rights issues. Further, developing these areas as water supply sources would be costly and require treatment and up-hill pumping of the water. The areas

have not been substantially studied to make long-term decisions on feasibility, environmental concerns, or political (public) acceptability. The Regional Water Plan for the Lower Rio Grande water users includes both basins as a potential future water supply so there may be competition among regions of the State for these resources.

Additionally, there are no more available surface water sources. The surface water rights the City does hold are limited by maxi ıum flow rates, so the City cannot divert the occasional large amount of storm generated stream flows. Additionally, the La Luz Irrigation District has the "first call" on the water in the La Luz-Fresnal diversion, which often leaves the City with minimal remaining water supply. Also, due to the adjudication of the surface waters, there are water rights holders along the stream with priority dates senior to the City's. This means that the City cannot divert its flows with the later priority dates until the others' earlier priority rights have been satisfied. This effectively stops any further development of surface water in the area.

4. Lack of supply due to water-quality constraints

According to the *Desalination and Water Purification Technology Roadmap* (USBOR, SNL, 2004):

> Water availability includes issues of both water quantity and quality. After all, just as drought conditions can reduce the *amount* of water available, reductions in water quality can diminish the *available* water supply for its intended use (emphasis added).

The City's water quality goal is established at 800 mg/L total-dissolved-solids (TDS). The limit recommended by the New Mexico Environment Department (for aesthetic purposes) is 500 mg/L. The actual quality of the blended water supply varies from about 800 mg/L to over 1,000 mg/L when the existing City wells are used extensively. Other cities in New Mexico provide a water supply with a quality better than the recommended 500 mg/L TDS, i.e., with lower TDS. Other communities,

such as the White Cliffs Mutual Domestic Water Users Association, use reverse osmosis to treat their water supply. If the City adopted the 500 mg/L TDS goal, the actual available supply would be even less because the surface water would require treatment. Additionally, the United States Environmental Protection Agency (USEPA) has considered adding sulfates to the list of contaminants for required removal, which would add further burden to necessary water treatment for the City.

Many residents of Alamogordo use water softeners to reduce hardness and minimize its corrosive effect on appliances (dish washer, washing machine, evaporative coolers, etc.), and many use reverse osmosis systems to create better tasting water for drinking and cooking. The cost of treating down to 500 mg/L TDS would be enormous. The ARWSP allows the City flexibility in supplying less than 800 mg/L TDS water through blending, when other supplies allow. This is an operational decision for the City of Alamogordo, and would be more costly, but should have the flexibility to serve better water to the citizens if so desired. Quality also plays an important part in general O&M issues in the distribution system. Typically, higher TDS waters cost cities more in repair/replacement of pumping components, valves, etc. Also, the costs to the public in increased maintenance for evaporative coolers, washing machines, dishwashers, etc., must be considered.

5. Vulnerability to contamination by accidental (fire, flood), emergency (spill) or deliberate (terrorist) causes

Watersheds are vulnerable to forest fires, mudslides, and other "acts of nature" that may impair the water quality to the point that it cannot be treated. In some cases in the past, the City has had to decline to divert stream flows that are highly turbid (muddy) because the treatment plant could not treat the water. Ash created by forest fires can plug treatment works. Forest fires also leave the affected watershed areas void of ground cover vegetation, which allows topsoil runoff (containing high levels of organic material) that is highly turbid and creates treatment challenges. Floods can have the same effect, and as demonstrated in the Village of Cloudcroft this summer, 2013?

floods there rendered the surface water pond unavailable. In addition, watersheds can become unsuitable as sources of surface water because of high levels of pathogens from livestock or native wildlife. These can create a human health hazard (such as occurred in the Milwaukee outbreak in 1993, where many got sick). Redundant supplies are needed for this reason.

Add ft wl Bonito fire as an example

Accidental contamination from environmental spills (fuel, fertilizer, etc.) are a concern along transportation routes, and can render an entire surface water supply unusable for extended periods of time, if not forever. Deliberate contamination from human activity is also possible as an act of terrorism. Surface water supplies are most vulnerable. Precautions against this threat are important at this time. Because water supplies are vulnerable to contamination, redundant supplies are necessary.

6. The need to guarantee a water supply for the public health, safety and welfare

An essential responsibility of a city is to guarantee the water supply for the public. Water supply has to be there 100 percent of the time, in all conditions, all climates. The only way to ensure guaranteed water supply availability is to rely only on the "firm yield" of existing supplies and develop additional water supplies.

The *AWWA Manual of Water Supply Practice (M50)* states:

> Safe yield [firm yield] is the *maximum* quantity of water that can be guaranteed to be available …during a critical dry period [drought]. (p.163, emphasis and wording supplied).

Certainly amounts of storage are important for maintaining daily, weekly or monthly peaking delivery capacity, but annual (or multiple year) storage is not practical nor generally practiced. Therefore, the City's actual water supplies must be able to meet all of the public's water needs each and every day and year, even (and especially) during times of limited availability. Unfortunately, no one can predict when a drought

will be over or when one will recur, so a city is faced with making sure that its water facilities (both supply and distribution) are capable of providing all of the water needed, 100 percent of the time, under "worst case" conditions of drought. This fundamental level of water supply planning, as well as emergency supply planning, is necessary to provide a safe and reliable water supply to the public, and protect public health and welfare.

Need entire section on this

7. Availability and Reliability

The City is developing increasingly expensive water supplies. Surface water is the least expensive alternative, followed by the La Luz wells, the Golf Course and Prather wells (once shut down due to expensive pumping), and then the ARWSP. If there were other less-costly, readily available water supplies, the City would pursue them first. Conjunctive management of separate sources of water is also defined as a "need" because it allows the City to most efficiently and economically manage its water supplies for maintaining quality and providing redundancy.

Reliability defines the level of a "guaranteed supply". Reliability in meeting long-term water demands is a recommended criterion for water development alternative evaluation. Again, *AWWA Manual M50* states:

> Reliability to meet long-term demands. In this case, goals should be set to balance supply and demand during below-normal [drought] water supply years. (p. 279, wording supplied).

8. City of Alamogordo 40-Year Water Supply Need

For planning future water needs for the City of Alamogordo, the available firm water supply must satisfy the projected demands. **Table 6.1** below summarizes the water rights, firm combined supply and average diversion from 2006 to 2010 for each current source.

Table 6.1 Water Supply Source, Water Right, Firm Supply and Average Production 2006 to 2010 for City of Alamogordo

Water Supply Source	Water Rights AFY	Firm Supply AFY	Avg. Production 2006 to 2010 AFY
Total surface water	5,418 AFY + 16 CFS	2,525	3,723
Total ground water	8,930.9 AFY	7,269	779
Totals	**14,349 AFY + 16 CFS**	**9,794**	**4,502**

As indicated in **Table 6.1** above, the current water rights (14,349 AFY + 16 CFS) remain somewhat greater than the available combined firm supply (9,794 AFY). As previously stated, the firm supply is based on the worst years in the record, which includes drought, hydrologic and system limitations, and ultimately reflects the actual reliability of the water supply source. This table also emphasizes the significant differences in water rights (on paper) and actual firm (available, wet) water supply.

Discuss

For planning purposes, the City of Alamogordo will rely on a minimum combined firm surface and ground water supply of 9,794 AFY. In planning for severe drought conditions, the City will rely on only the firm ground water supply of 7,269 AFY.

what does this mean?

How will the City proceed?

4.4

Need for Developing the City's Existing Water Rights

Projected future water demands for the City of Alamogordo are indicated in **Table 4.2**, and increase from 6,769 AFY in 2010 to 9,733 AFY by 2050. The City will use primarily its surface water supply, to the extent that it is available, and develop and maintain a firm ground water supply of 7,269 AFY (including the Snake Tank Well Field), under its existing water rights. Both of these firm water sources are needed to meet City of Alamogordo future demands for water through year 2050.

Table 6.2 below summarizes the projected water demands, firm water supply and conjunctive use of water for the City of Alamogordo, for the period 2010 to 2050. This is shown graphically on **Figure 6.1**. As soon as possible, the ARWSP must be

included to complete the firm ground water supply. Ground water will account for up to 74% of the total water supply by 2050, with 99% of the water rights utilized. Surface water will only be 26% of the water supply by 2050.

objective ?

Table 6.2 Projected Water Demands, Firm Water Supply, AWSRP Supply and Percent Water Right for the City of Alamogordo, 2010 to 2050

Year	Total Demand	GW Supply	ARWSP Supply	GW % Demand	% GW Right[a]	Firm SW Supply	SW % Demand
2010	6,769	3,909	335	63%	54%	2525	37%
2015	7,185	3,909	751	65%	61%	2525	35%
2020	7,626	3,909	1,192	67%	67%	2525	33%
2025	8,008	3,909	1,574	68%	73%	2525	32%
2030	8,409	3,909	1,975	70%	79%	2525	30%
2035	8,788	3,909	2,354	71%	85%	2525	29%
2040	9,138	3,909	2,704	72%	90%	2525	28%
2045	9,458	3,909	3,024	73%	95%	2525	27%
2050	9,733	3,909	3,299	74%	99%	2525	26%

a - Includes Snake Tank Wells and 84% recovery for ARWSP

Table 6.3 indicates severe drought conditions, when only firm ground water supply is used. During such extreme conditions, a mandated 25% reduction in gpcd water use (down to 123 gpcd) is assumed. The firm ground water supply is completely utilized, and the ARWSP is required immediately in this scenario (refer to **Figure 6.2**).

objective ?

Table 6.3 Projected Severe Drought Demands, Firm Ground Water Supply, AWSRP Supply for the City of Alamogordo, 2010 to 2050

Year	Total Demand	Drought Demand	GW Supply	ARWSP Supply	Snake Tank Diversion[a]	% GW Right	SW % Demand
2010	6,769	5,046	3,909	1,137	1,354	66%	0
2015	7,185	5,356	3,909	1,447	1,723	71%	0
2020	7,626	5,685	3,909	1,776	2,114	76%	0
2025	8,008	5,969	3,909	2,060	2,452	80%	0
2030	8,409	6,269	3,909	2,360	2,810	85%	0
2035	8,788	6,551	3,909	2,646	3,145	89%	0
2040	9,138	6,812	3,909	2,903	3,456	93%	0
2045	9,458	7,050	3,909	3,141	3,739	96%	0
2050	9,733	7,255	3,909	3,346	3,983	100%	0

a – Assumes 84% recovery for ARWSP

7.0 Water Supply Development

Required Minimum Water Supply Development

As discussed in **Section 6.0** and indicated in **Table 6.2**, the City has an urgent need to develop ~~their~~ its existing water rights in order to meet future demands and allow true conjunctive management of separate water supplies and flexibility in system operations and optimization.

This Plan recommends full development of the City's ground water supplies to 7,269 AFY under its existing water rights, for supply redundancy, severe drought, emergencies, and future needs.

Ongoing Water Supply Development Projects

Of the water supply development projects considered over the past decade, development of the Snake Tank Well Field for the ARWSP is currently the only technically (and administratively) feasible, cost effective project that meets the City's requirements in terms of water quality, quantity and needed time frame.

Alamogordo Regional Water Supply Project (ARWSP)

Desalination of brackish ground water as a municipal supply in the Tularosa Basin has been studied since the 1950s (1958, Armor Foundation; 1970, OSW; 1986, BOR; 2002, Regional Water Plan; 2003, COA Desalination Study; others). The Alamogordo Regional Water Supply Project (ARWSP) is the result of the City of Alamogordo's effort towards the development of a desalination water supply alternative. The ARWSP will assist in producing the water supply needed to meet current and future demands. The

desalinated water will meet the City's water quality goal of 800 mg/L TDS. A feasibility study for desalination of brackish ground water south of Three Rivers (Snake Tank Well Field) was conducted in 2003 (Livingston, 2003, Shomaker, 2006). The City completed the water rights hearing process, and was granted ~~5,000 AFY of brackish water under permit~~ T-3825 et al. ~~for the ARWSP in 2007. The permit conditions allow~~ diversion ~~up to~~ of 4,000 AFY, which can be increased up to 5,000 AFY provided that the sum of annual diversions for any consecutive five-year period does not exceed 20,000 AFY. The City has begun to develop the Snake Tank Well Field for the ARWSP, including the drilling and testing of five test wells, with two of the wells considered production-size wells. Results of the testing verify that the well field will be suitable for the ARWSP desalination facility.

When approved by the applicable state and federal agencies (the approval process is ongoing), implementation of the ARWSP will result in the production of up to 5,000 AFY of new water supply for the City of Alamogordo. Expansion of the Snake Tank Well Field may be possible in the future, or other additional sources of brackish ground water (if located) could be used for future expansion of the ARWSP, should revised projections show the need for additional ground water supply in the future. The permit conditions under T-3825 et al. require updates to the 40-Year Water Development Plan every 5 years, and these updates will continue to include revised projections based on the most up-to-date and highest-quality data. The NMOSE has determined if other entities, such as the Village of Tularosa, rural water suppliers or Holloman Air Force Base, desire to participate in the project in the future, they will be required to use their own water rights in doing so. Not totally.

The Alamogordo Regional Water Supply Project (Desalination Project) will provide the future ground water supply needed by the City of Alamogordo to at least 2050. This project should be implemented immediately upon approvals, including the development of existing ground water rights at the Snake Tank Well Field.

2.

Supplemental Wells and Replacement Wells

The City will continue its well replacement program in the La Luz Well Field to maintain firm ground-water supply. After an extensive analysis of the NMOSE administrative criteria, evaluating the validity of existing water rights and impacts to wells of other ownership, a location west of Highway 54 between the Golf Course and the Airport was identified for a potential supplemental well to the La Luz Well Field. The City has withdrawn their application associated with this potential supplemental well, and is not currently pursuing this option.

Is this source at long-term risk?

3.

Water Conservation

As previously discussed, the City adopted an aggressive water conservation program, described in the Water Conservation Ordinance. This program will be continued. Educational programs, rebates for replacing existing plumbing fixtures, landscaping restrictions, change in water rate structure and other strategies will assist in maintaining the City's per capita water use goals. However, this program will not create future water supply needed by the City of Alamogordo. In addition, because it is associated with the use of existing supplies, it does not provide any additional drought protection.

Water Supply Development Alternatives

5.

Re-Purified Water Use

The reclaimed water system is a valuable resource. This reclaimed water is used for turf irrigation at City parks, golf courses and recreational fields, construction, and other City needs. Utilizing reclaimed water for these uses offsets the demand for potable water. As part of the reclaimed water system, the City has spent over $4 million constructing 16.2 miles of pipeline and two booster stations. Construction was completed in 2006 on a 1-million gallon storage tank. Currently the City uses up to 3 MGD reclaimed water during the spring through fall months, and has plans to expand the system to use up to 4 MGD in the future (Boyle, 2002). However, during the winter months, approximately 1,000 acre-feet of reclaimed water is not needed for

irrigation and is diverted to the center pivots located near the Water Reclamation Plant or to land disposal (within Township 16 South, Range 10 East, Section 16).

Planned indirect potable reuse is the addition of highly-treated wastewater (re-purified water) into the potable water system through aquifer recharge or surface water augmentation. Many communities throughout the United States are practicing indirect potable reuse, including the cities of El Paso (for more than 25 years) and Dallas, Texas. Communities in New Mexico are also considering indirect potable reuse projects, including Cloudcroft, Ruidoso, Gallup and Rio Rancho. For Alamogordo, some of the reclaimed water produced during the winter months could be re-purified and used for aquifer recharge at the Prather wells or La Luz wells, or for surface water blending at the La Luz reservoirs. New Mexico Environment Department permitting and feasibility studies would need to take place prior to the City's final decision for implementation. However, this alternative cannot provide the additional future water supply needed by the City of Alamogordo. Indirect potable reuse would provide the additional benefit of reducing the City-wide gpcd, because the use of re-purified water is not considered a water right diversion.

6/1

Agricultural Water Exchange

A new concept called Multiple Use Water Conservation (MUWC) uses agricultural water for municipal water supply first, then for farm irrigation using municipal reclaimed water. The agricultural water right is utilized, and a portion of the municipality's water is used to keep the diverted water amount and irrigation water amounts equal. A study was conducted in partnership with the City (Livingston, 2006) on the MUWC concept, and a water supply project was evaluated for Alamogordo. Considering desalination of the agricultural ground water, the City would realize about 850 acre-feet of additional (new) water supply from a contribution of only 365 acre-feet of City water, for a total 1,215 acre-foot water supply. The project would require about 300 acres of farm land for irrigation and 1,000 AFY of leased agricultural water rights. Additionally, the new Mountain View well could be used to provide all or a portion of the City's water contribution.

A meeting with the NMOSE (March, 2006) indicated that this concept could likely be permitted. New Mexico Environment Department permitting would be needed prior to implementation. This alternative, however, cannot provide the additional future water supply needed by the City of Alamogordo.

6/7

Outside Bulk Water Purchases

As the market for water expands in the Region, some outside bulk-water purchase scenarios may be feasible. Any new water purchases to be considered should meet the City's adopted water quality goal of 800 mg/L TDS or less. Additionally, the facilities to convey the water into the City's distribution system should be provided. The cost of purchased water should be equal to or less than the cost to produce the same quality and quantity of water under the ARWSP (or other) water-supply alternative. Water that may be used for blending in the ARWSP should also be considered. This alternative may also become more attractive for longer-term (beyond 2050) water needs, such as the Salt Basin water.

4.

Aquifer Storage and Recovery (ASR)

Aquifer Storage and Recovery (ASR) may allow the City to store unused surface water in the La Luz Well Field aquifer during the winter months, for pumping out during the peak summer months. A draft study (Livingston Associates and JSAI, 1997) showed that an average of 2,000 AFY might be stored and re-pumped (if the extra surface water is available). All diverted and stored winter flows would be retained under the City's current water rights. This alternative is affected by drought conditions, as there may not be excess surface water during the winter available to divert, treat and store. However, as an option, re-purified water may be considered for supplying an aquifer recharge project when excess surface water is not available.

Secondly, an ASR program provides more flexible conjunctive use water resource management. In this case, more ARWSP water is produced to meet demands, and the available surface water is stored within the aquifer. A hybrid injection (recharge) and recovery well was drilled in the La Luz Well Field for the purpose of ASR (2001),

to maximize existing water rights & water supplies.

but the project has not been permitted due to the lack of excess surface water flows. This alternative will not provide the additional future water supply needed by the City of Alamogordo, but should be used ~~for what it could provide~~.

Alternatives Not Recommended ~~for Period 2010 - 2050~~ at this time

There exist other potential water resources within the Region which are not recommended alternatives at this time. Economic or other considerations may necessitate re-evaluation of these alternatives in the future, however.

Salt Basin Water Supply

Although a substantial quantity of good-quality ground water is in storage in the Salt Basin aquifer, the capital and operational costs associated with the City independently developing a system to convey this water to Alamogordo are greater than the desalination alternative (Regional Water Plan, 2002). Also, this water would require treatment to meet the City's goal of 800 mg/L for TDS. There may be potential for a regional water supply system which, if economical for the City to participate in, should be considered in the future. ~~Additionally, other entities have already filed for water rights from the Salt Basin, and it is not likely that the City of Alamogordo could obtain separate water rights there.~~ However, a regional water supply from the Salt Basin could be considered for longer-term City needs.

Bonito Lake Watershed Enhancement

Add fire discussion

Currently, the Bonito Lake system does not deliver the full water right for the City of Alamogordo. Drought conditions have substantially reduced the amount of snow pack, and hence, watershed yield to the Bonito Lake. Historically, Bonito Lake has contributed only 5 percent to 15 percent of the water supply. Additionally, the storage capacity of the reservoir is diminished due to sedimentation. A watershed restoration program could be implemented, which may increase the yield from the watershed. However, this alternative is a long-term management program and would take years to realize any additional water yield in the Lake. Additionally, the Bonito Lake watershed is primarily US Forest Service wilderness area, which may prohibit

extensive restoration efforts. This alternative cannot provide the additional water supply needed by the City of Alamogordo (Regional Water Plan, 2002).

or discouraging?

Agricultural Water Purchased and Converted to Municipal Use

There may be available agricultural water rights that could be purchased and transferred to municipal use. However, the water right would first need to be converted from agricultural use to municipal use. Because only the consumptive portion of the water right is convertible for municipal use, about forty-percent of the water right is lost (non-convertible). ~~In addition~~, also the City has a policy prohibiting the purchase and conversion of agricultural water rights, because of the potential loss of production and economy from the agricultural community. In point, to supply the entire additional water requirements of the City, most of the farmland from Tularosa to Alamogordo would need to be removed from production and their water rights purchased and converted. Also, because of the distances between farms and the need for water treatment, this alternative is considered not feasible (Information derived from Regional Water Plan, 2002).

Flood Control Aquifer Recharge

The US Army Corps of Engineers flood control project has potential to store flood waters and recharge the shallow, aquifer. However, because flood quantity is unreliable and drought-sensitive, this is not considered a reliable supply for planning purposes.

Sacramento River Pipeline

The Sacramento River flows are drought-sensitive and unreliable. The cost of facilities to convey water to Alamogordo (via the Alamo Canyon Water Treatment Plant) are not justified by the potential resource (BOR, 1986).

In addition, because of Basin Criteria, exceed dd if move or to existing wells, meaning piping water from present pod.

General Notes -

1) No discussion of climate change.

2) No present app for SE to act on. Plan submitted simply to satisfy a COA a no action to be taken by SE. (Quote 72-1-9)

3) No mention of Maxwell Springs.

---

w/ no app, what is objective?

- this could hurt future applications

Consider new theme -

1) City demand = X
   (downplay 2010 census - wrong #s)

2) T-3825 resolved some issues re supply
   - 165 + pop
   - gw
   - sw

3) Post-T-3825, City has need to consider
   a) Declining sw
      < 3500
      < 2500
      maybe need to consider

Conjunctive Management

8.0 Water Development Plan

Water Development Recommendations

Historically, the La Luz Well Field, Bonito Lake, and surface water from La Luz Canyon were alternative sources developed in the 1950s to supplement Alamogordo's primary water supply from Alamo Canyon during the 1950s drought. Over fifty years and more than 30,000 people later, the City of Alamogordo is developing additional ground water supply by implementing the Alamogordo Regional Water Supply Project (ARWSP) and the Snake Tank Well Field located south of Three Rivers.

good, but develop more

The solutions for developing the existing water rights to realize the additional water supply required by the City of Alamogordo, for the 40-year period (2010 to 2050) include the following:

1) Complete implementation of the Alamogordo Regional Water Supply Project (ARWSP) desalination facility and infrastructure. This project consists of developing the Snake Tank Well Field under the existing T-3825 et al. permit, brackish water desalination facility and concentrate disposal system, treated water storage, pumping and distribution, and raw water piping infrastructure to the City of Alamogordo. Currently, Phase I and Phase II of the Snake Tank Well transmission pipeline has been constructed. Phase III is currently under construction.

2) Complete the Snake Tank Well Field and develop existing water rights under permit T-3825 et al. The overall ground water diversion requirements for desalination are greater than the delivered potable water supply amounts due

b) Declining gw
- LL well Field unreliable.
< 3000
< 2970
consider going to ∅

c) STWF was meant to be backup, but could become primary because of declining sw & gw from existing rights

City well continue to use existing sw & gw to best of its ability. Will evaluate "firm yield" or "reliable supply" in context of next application.

to the recovery rate of the desalination process (projected at 84%). Develop the Snake Tank Well Field capacity and water rights up to 4,000 AFY with the capability to divert 5,000 AFY. Analyze the well field pumping data annually and evaluate the potential for increasing the well field capacity and water rights.

3) Develop the ARWSP project and the Snake Tank Well Field for worst-case drought (ground water only scenario) as shown in the following **Table 8.1**, assuming that ARWSP water will typically be used over a 6-month period for peaking purposes:

Table 8.1 ARWSP and Snake Tank Well Field Development Schedule for the City of Alamogordo, 2010 to 2050

Year	Total Demand	ARWSP AFY	ARWSP MGD	ARWSP 6 month Usage MGD[a]	Snake Tank AFY	Snake Tank MGD	Snake Tank 6 month Usage MGD[a]
2010	6,769	1,137	1.0	2.0	1,354	1.2	2.4
2015	7,185	1,447	1.3	2.6	1,723	1.5	3.0
2020	7,626	1,776	1.6	3.2	2,114	1.9	3.8
2025	8,008	2,060	1.8	3.6	2,452	2.2	4.4
2030	8,409	2,360	2.1	4.2	2,810	2.5	5.0
2035	8,788	2,646	2.4	4.8	3,145	2.8	5.6
2040	9,138	2,903	2.6	5.2	3,456	3.1	6.2
2045	9,458	3,141	2.8	5.6	3,739	3.3	6.6
2050	9,733	3,346	3.0	6.0	3,983	3.6	7.2

a – peaking flow rate utilized over a 6-month period

4) Continue exploration for brackish ground water sources, to be used in the potential expansion of the ARWSP ~~beyond 2050.~~

5) Continue the process of evaluating water supply needs and water development alternatives for the longer-term (~~beyond 2050~~).

6) Continue to evaluate proposals for outside bulk water purchases, provided they meet the City's water quality criteria, delivery requirements, blending potentials and the costs are comparable with the ARWSP.

7) Continue the well replacement program within the La Luz Well Field, in order to maintain the firm ground-water supply shown in this Plan.

8) Develop an integrated water resource management plan (IWRMP) that will optimize the conjunctive operation of the various water supply sources, including the phased augmentation of the ARWSP.

9) Maintain the water conservation program to continue to meet the single-family residential gpcd use goal of 125 gpcd and the total City-wide gpcd use goal of 165 gpcd.

10) Expand the reclaimed water system as described in the master plan to provide a water supply for future non-potable uses (development of additional green spaces, etc.); evaluate the opportunity for winter water storage and reuse; and evaluate the potential for industrial and/or commercial uses.

11) Evaluate opportunities for up to 1,000 AFY of indirect potable reuse of re-purified water to augment the potable water supply through aquifer storage at the Prather wells, and surface water blending at the La Luz Water Treatment Plant raw water storage reservoirs.

12) Evaluate opportunities for trading up to 1,000 AFY of the City's reclaimed water to local farmers for irrigation, in exchange for leasing their irrigation water, which would be treated and used in the City water supply under the Multiple Use Water Conservation scenario previously outlined.

move up

13) Develop the aquifer storage and recovery (ASR) program. Extend the pilot and demonstration program at Well No. 9; complete the Well No. 9 ASR permitting; implement ASR by conjunctive use of ARWSP water and surface water.

14) Continue to maintain the special use permits from the US Forest Service, for spring diversions along the La Luz-Fresnal water supply system.

15) Continue replacement and upgrade of water system infrastructure to reduce leakage and water losses.

16) Continue participation with the Brackish Ground Water Desalination Research Facility (BGWDRF) in research activities that support the ARWSP project, and others as may benefit the residents of Alamogordo and the furtherance of desalination technologies.

FIGURES

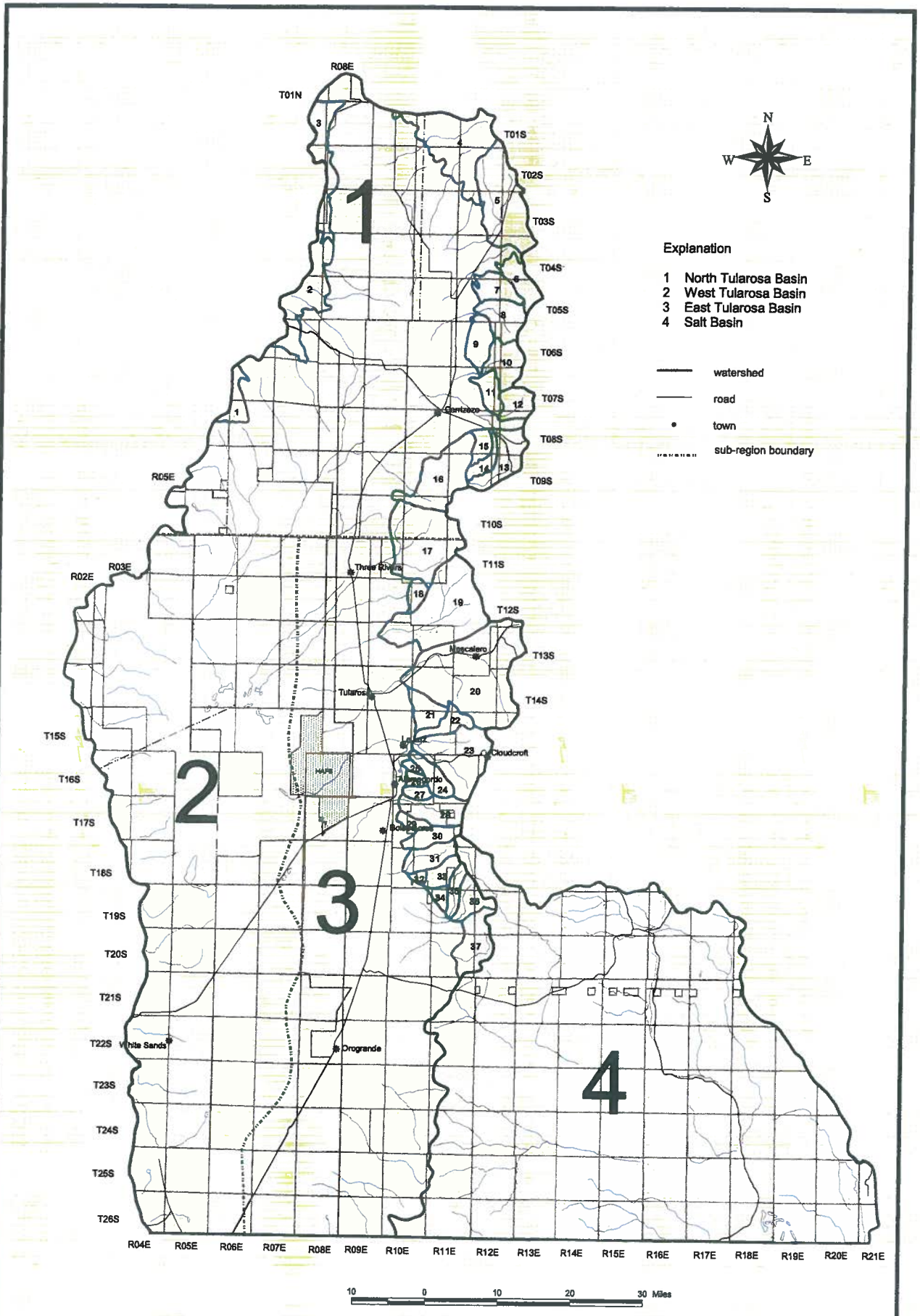

Figure 1.1. Map of the Tularosa and Salt Basins showing sub-regions, major watersheds, and geographic details.

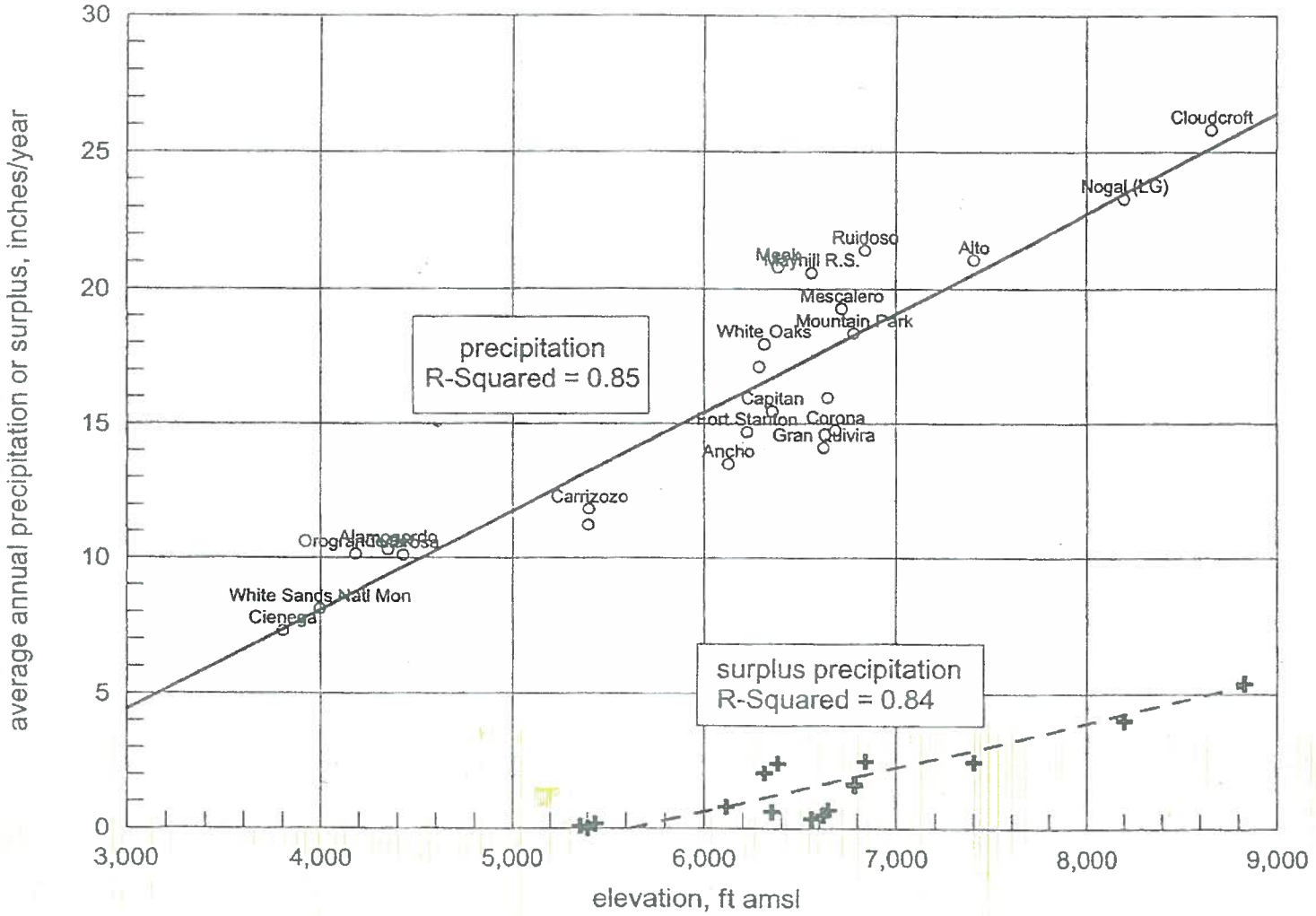

Figure 1.2 Graph of precipitation and surplus versus elevation for the planning region.

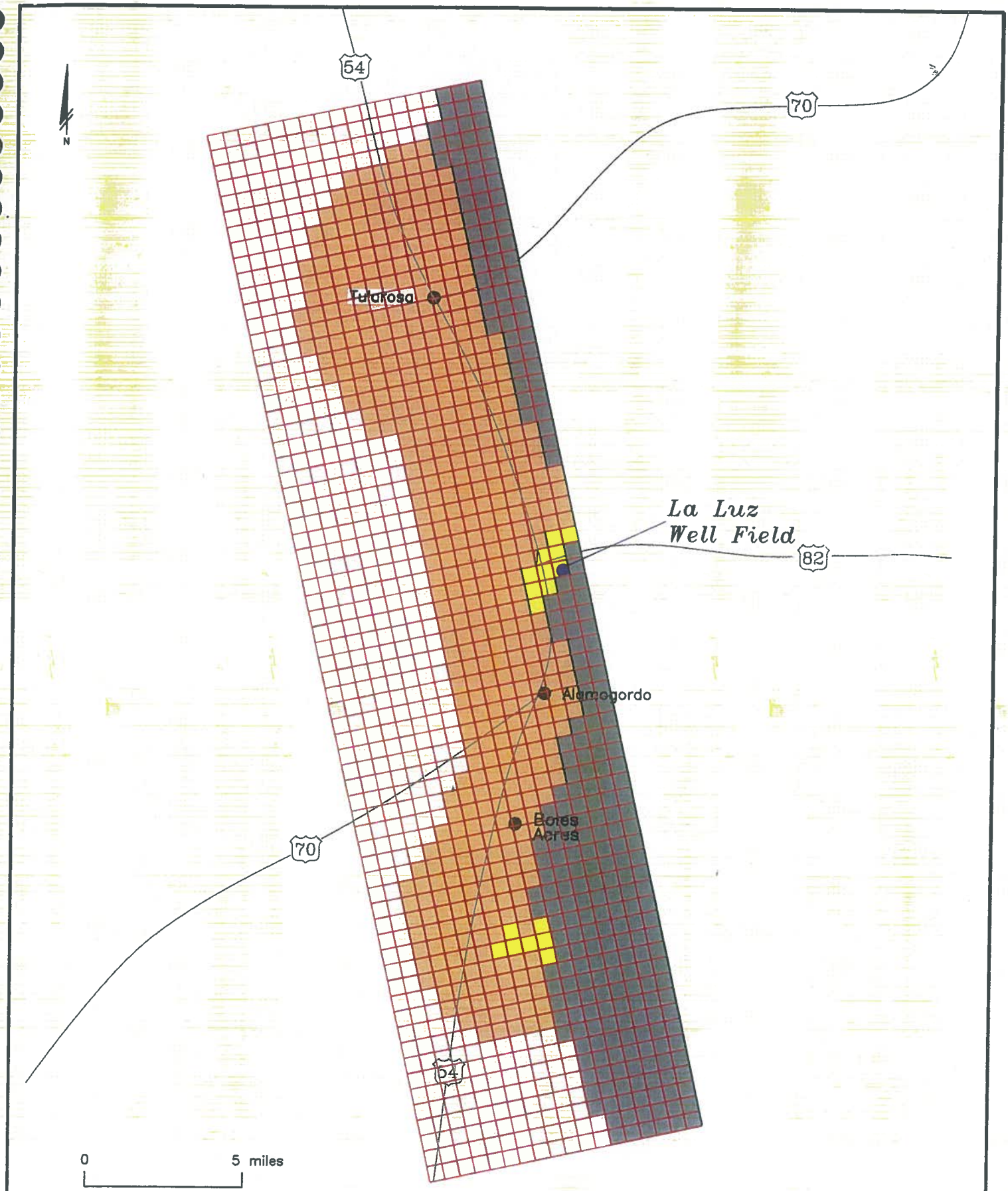

Figure 1.3 Map showing Alamogordo and Tularosa Administrative Area.

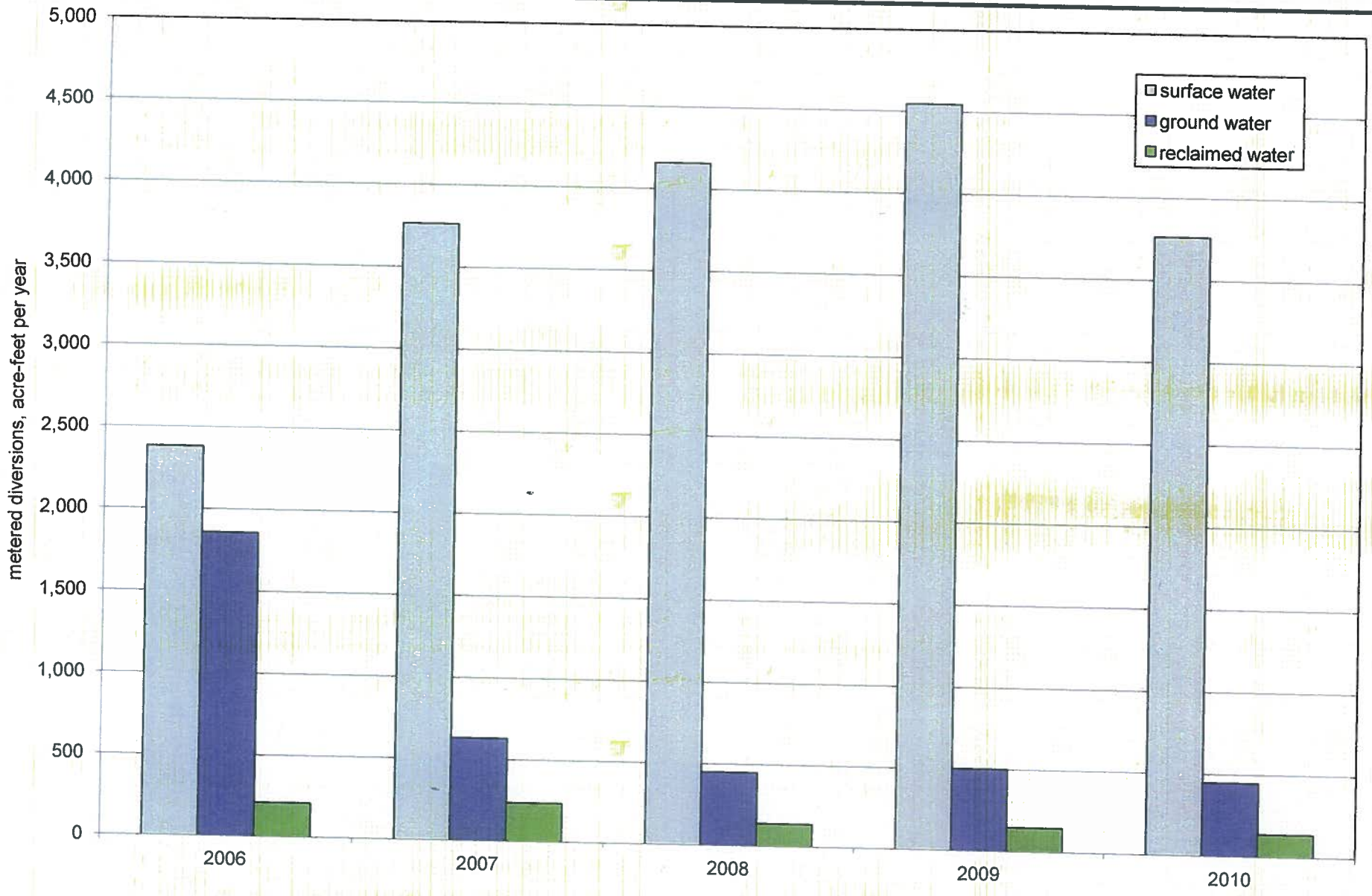

Figure 2.1. Graph showing metered surface- and ground-water diversions, and reclaimed water use, from 2006 to 2010, for the City of Alamogordo.

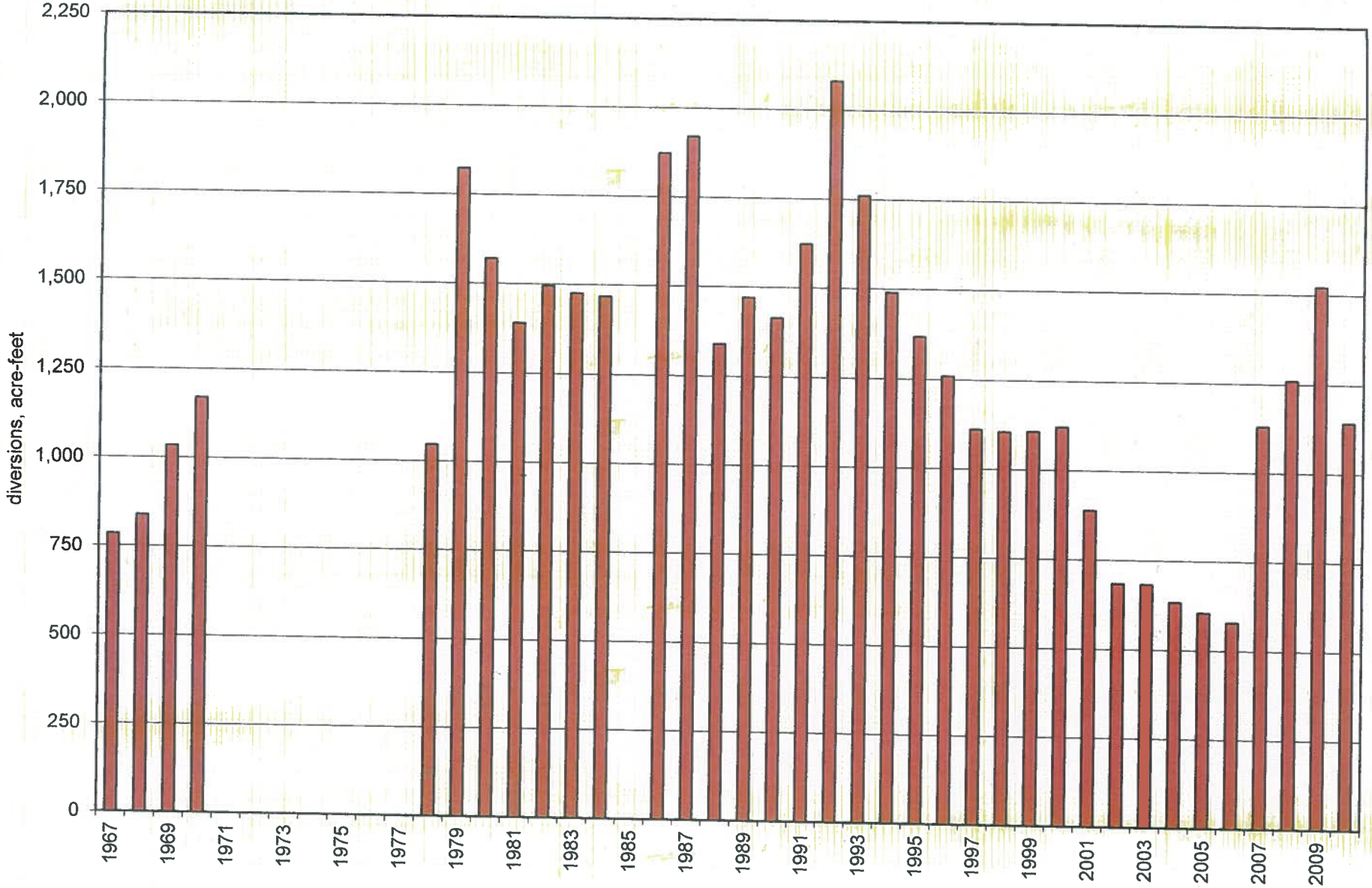

Figure 2.2. Graph showing surface-water diversions from Alamo Canyon, from 1967 to 2010, for the City of Alamogordo.

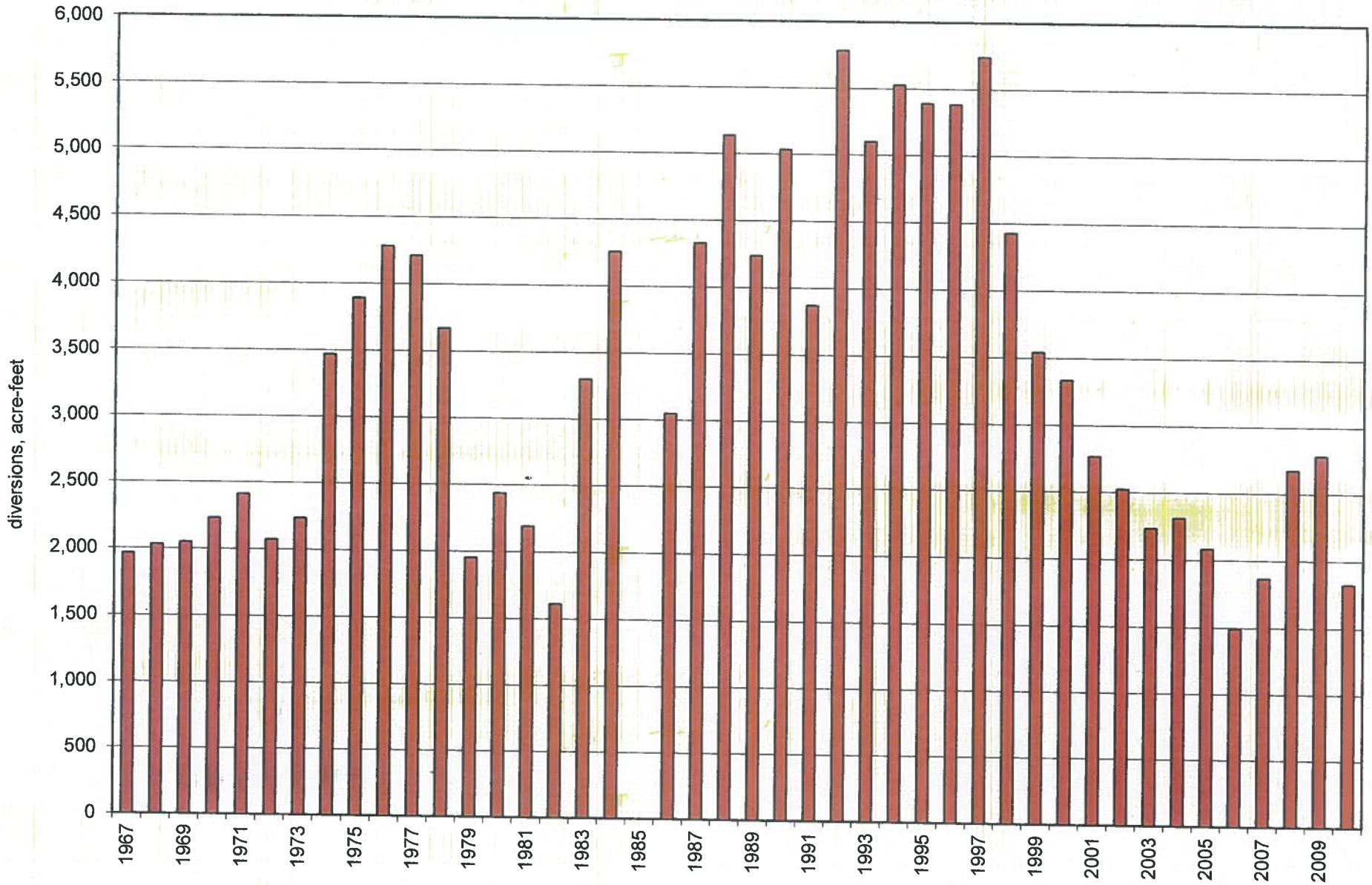

Figure 2.3. Graph showing surface-water diversions from the La Luz-Fresnal Canyon, from 1967 to 2010, for the City of Alamogordo.

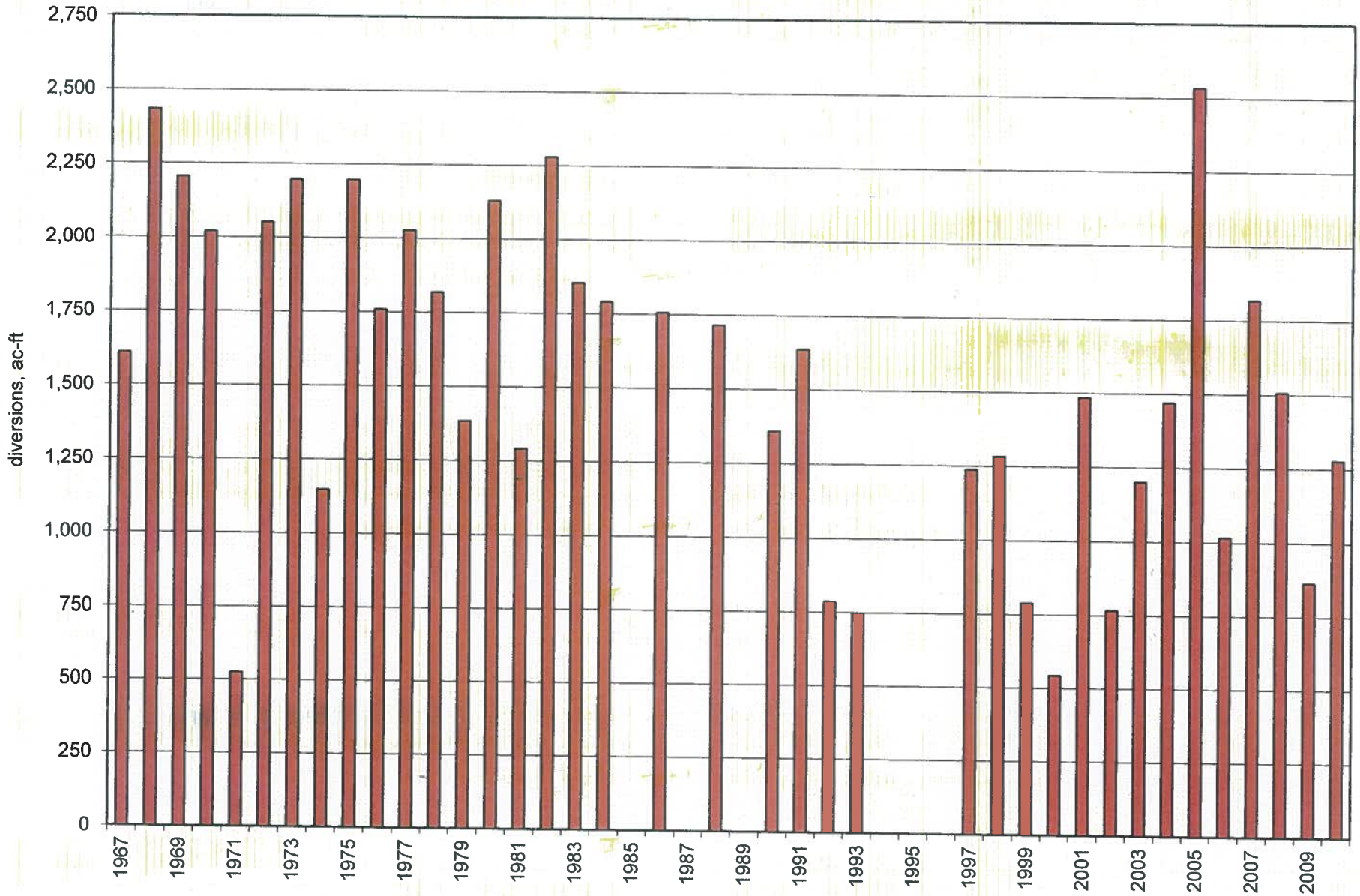

Figure 2.4. Graph showing surface-water diversions from Bonito Lake, from 1967 to 2010, for City of Alamogordo and Holloman Air Force Base.

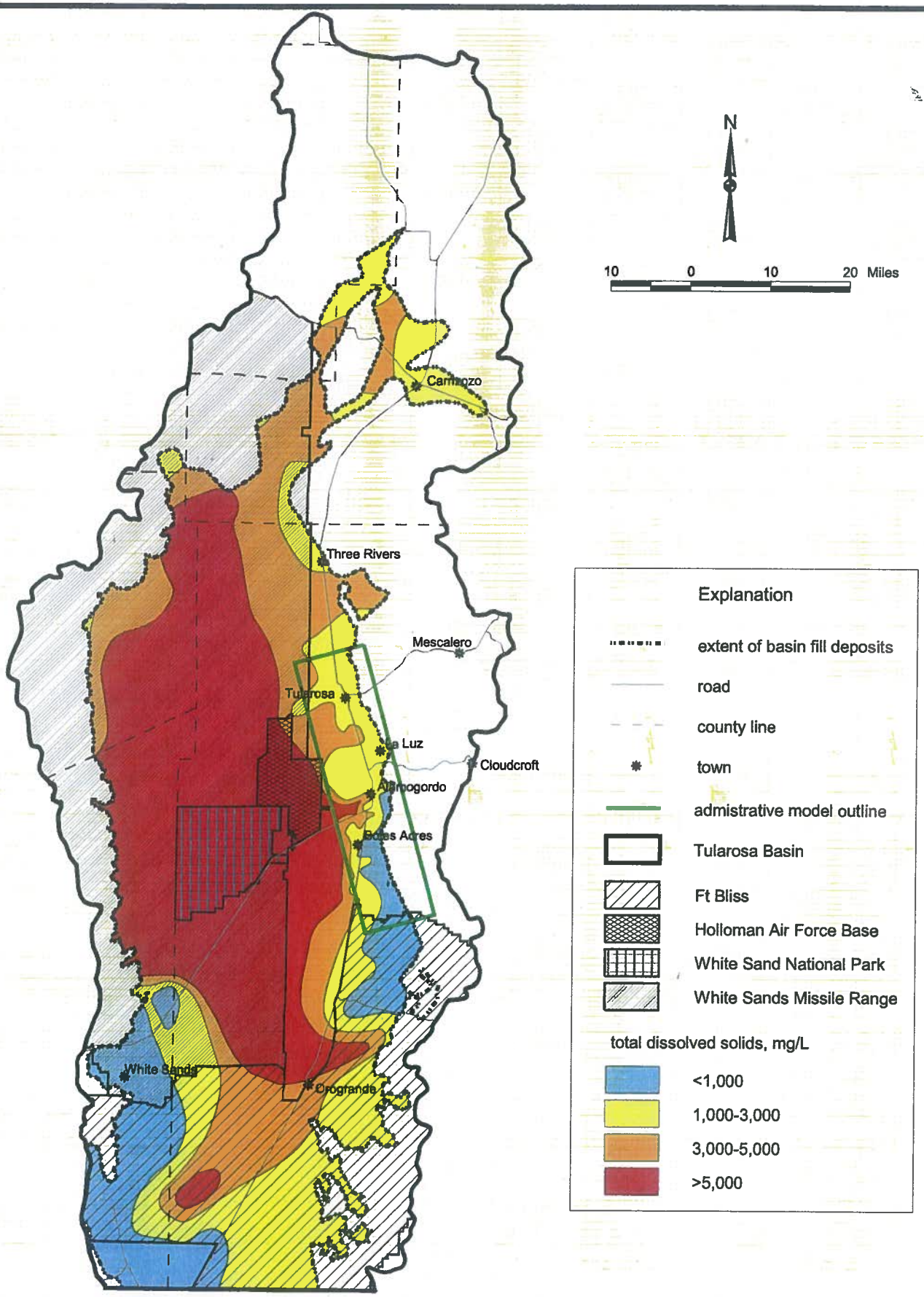

Figure 3.1. Map of Tularosa Basin showing distribution of total dissolved solids in basin-fill aquifer and location of Alamogordo-Tularosa Administrative area and other geographic features.

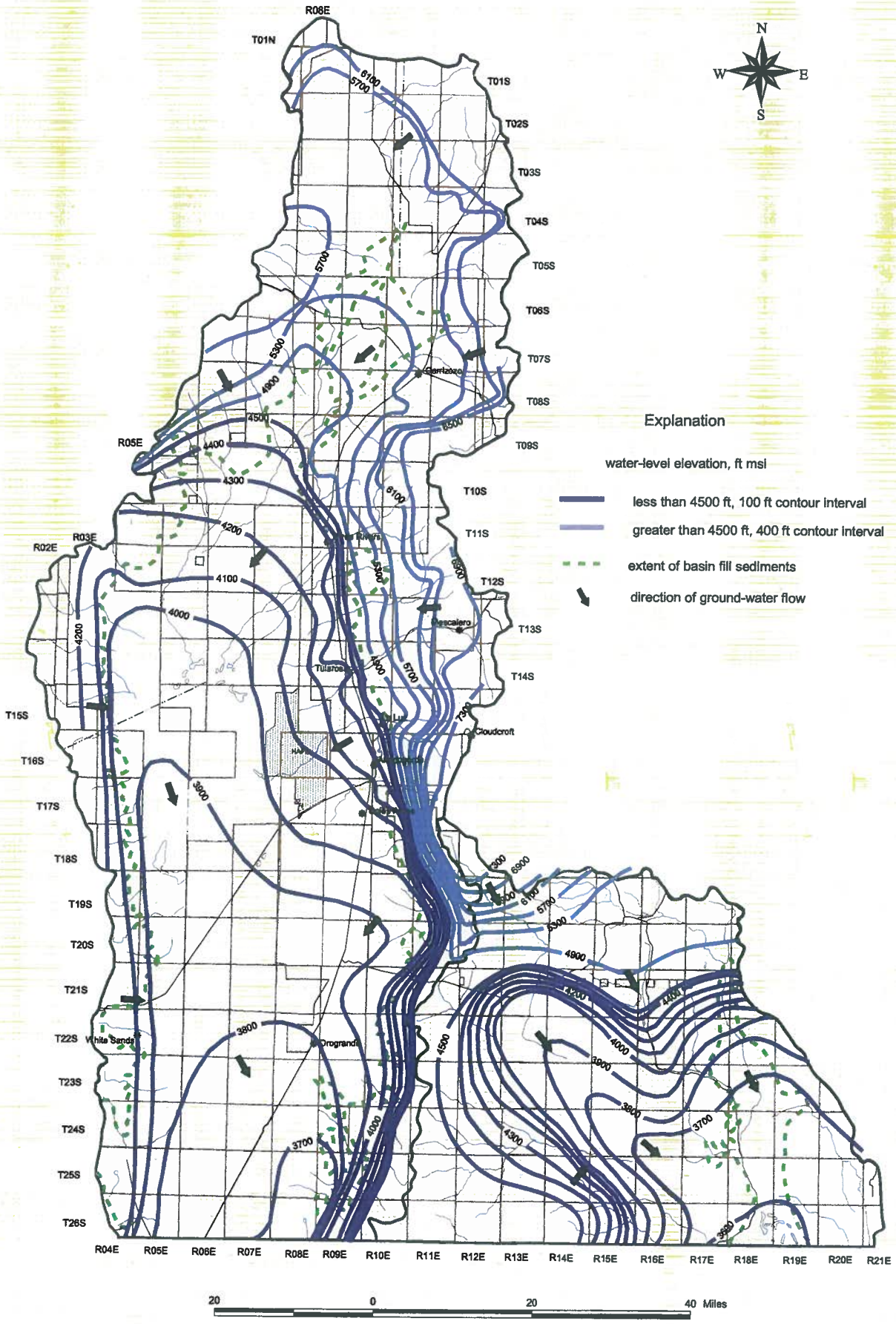

Figure 3.2. Map of the Tularosa and Salt Basins showing water-level elevation contours and ground-water flow direction.

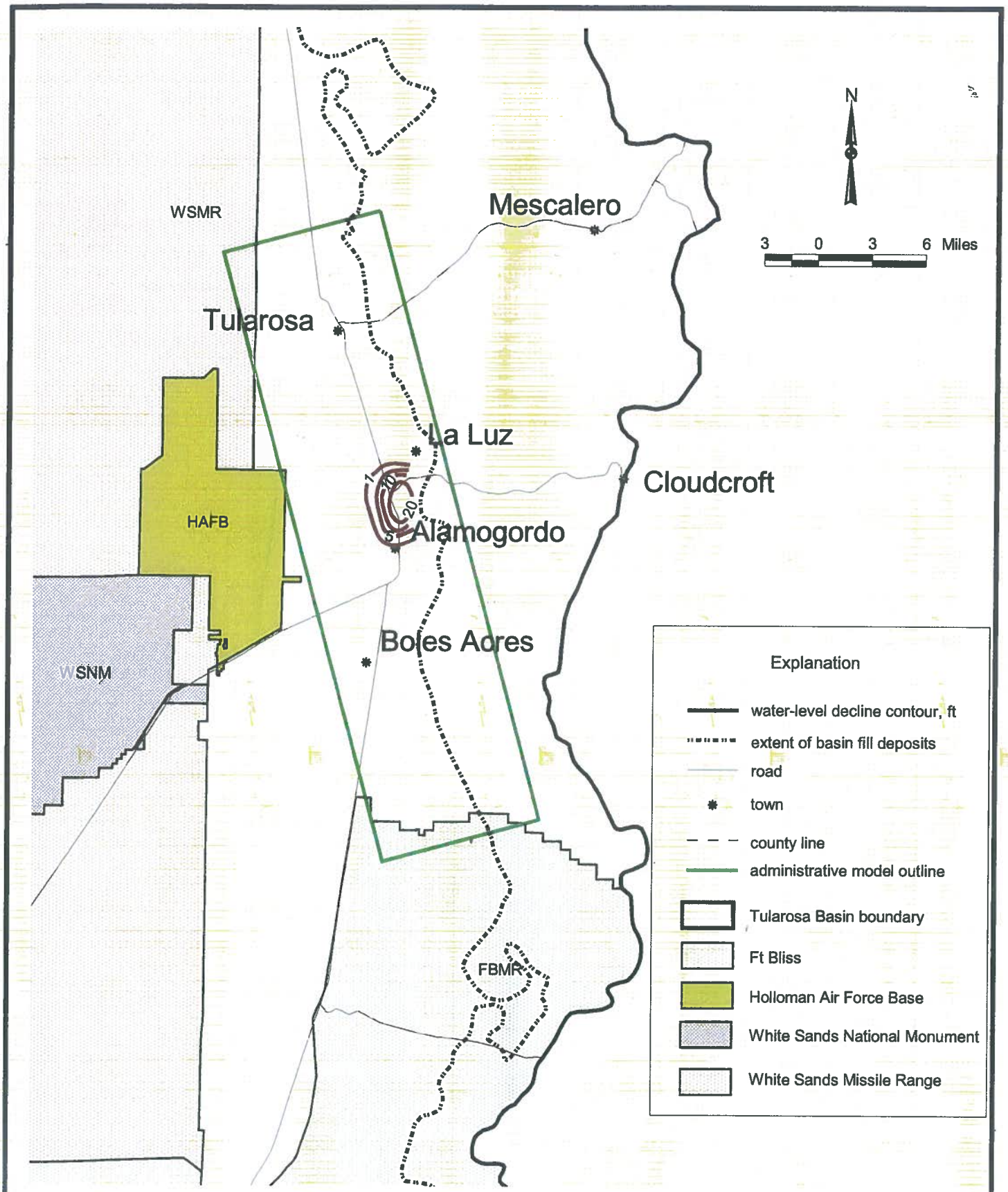

Figure 3.3. Map of the La Luz area within the Tularosa Basin showing historic water-level decline contours, 1900 through 1995.

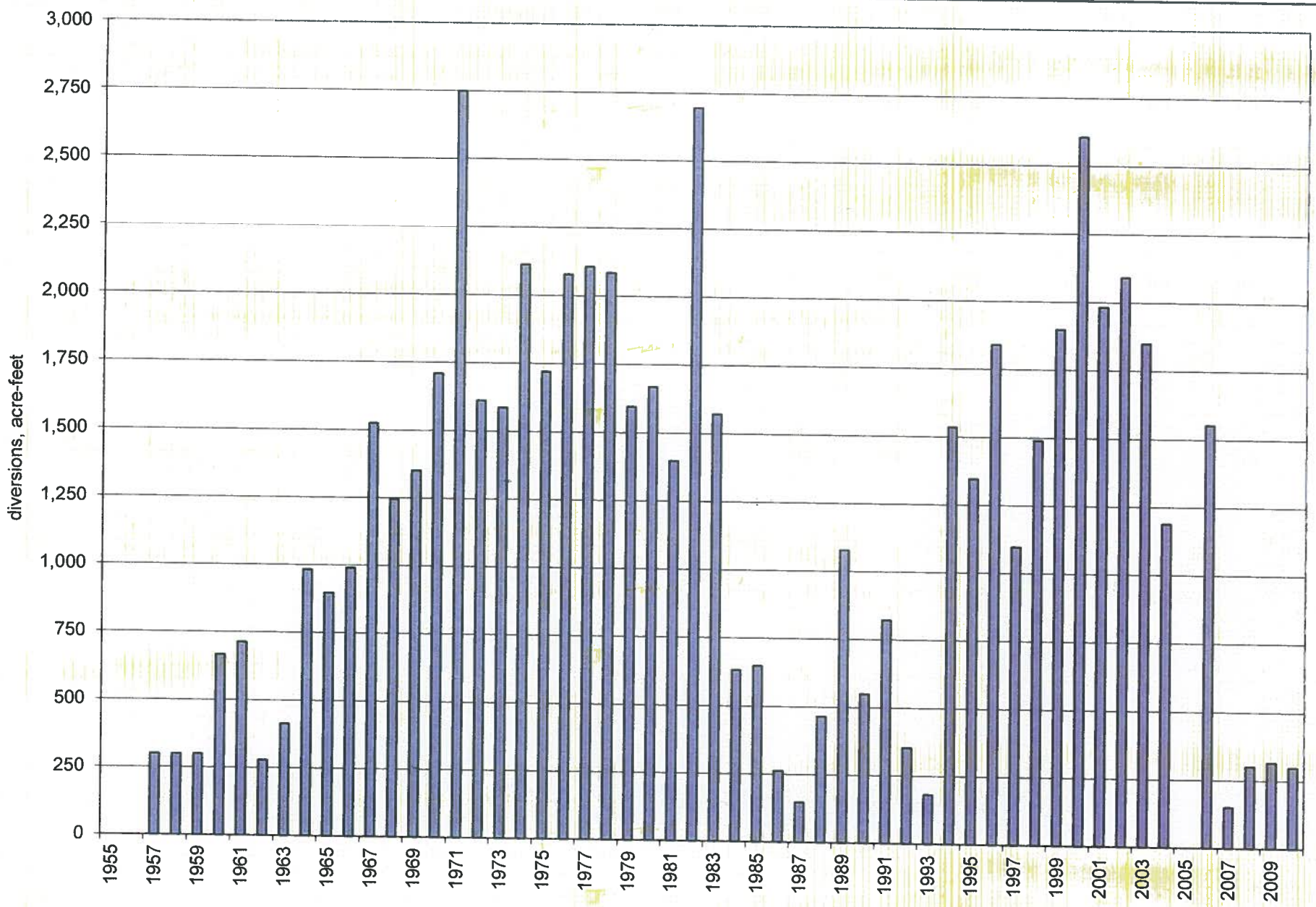

Figure 3.4. Graph showing ground-water diversions from La Luz Well Field, from 1957 to 2010, for the City of Alamogordo.

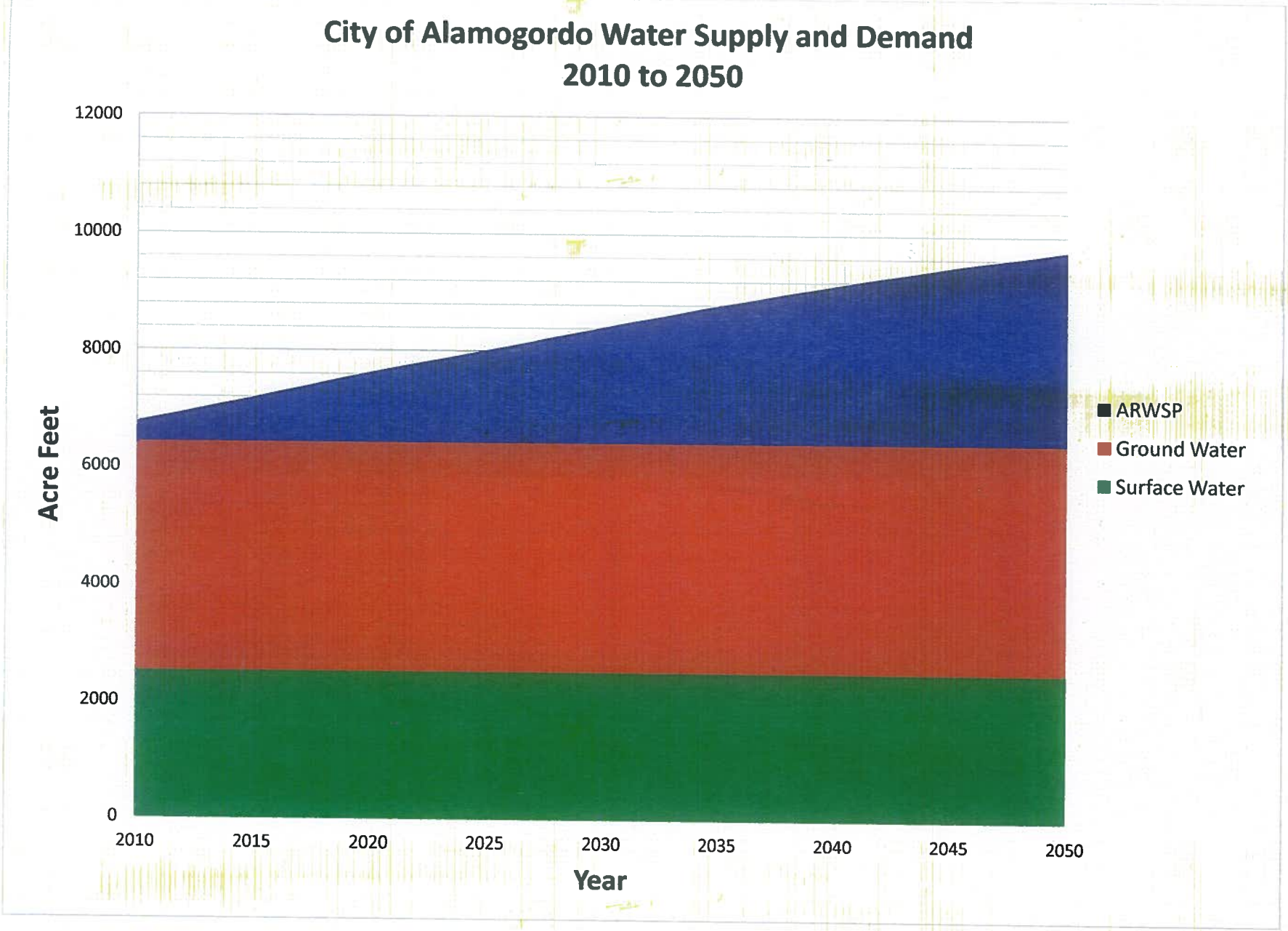
City of Alamogordo Water Supply and Demand
2010 to 2050
12000
10000
8000
6000
4000
2000
0
Acre Feet
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year
ARWSP
Ground Water
Surface Water

Figure 6.1

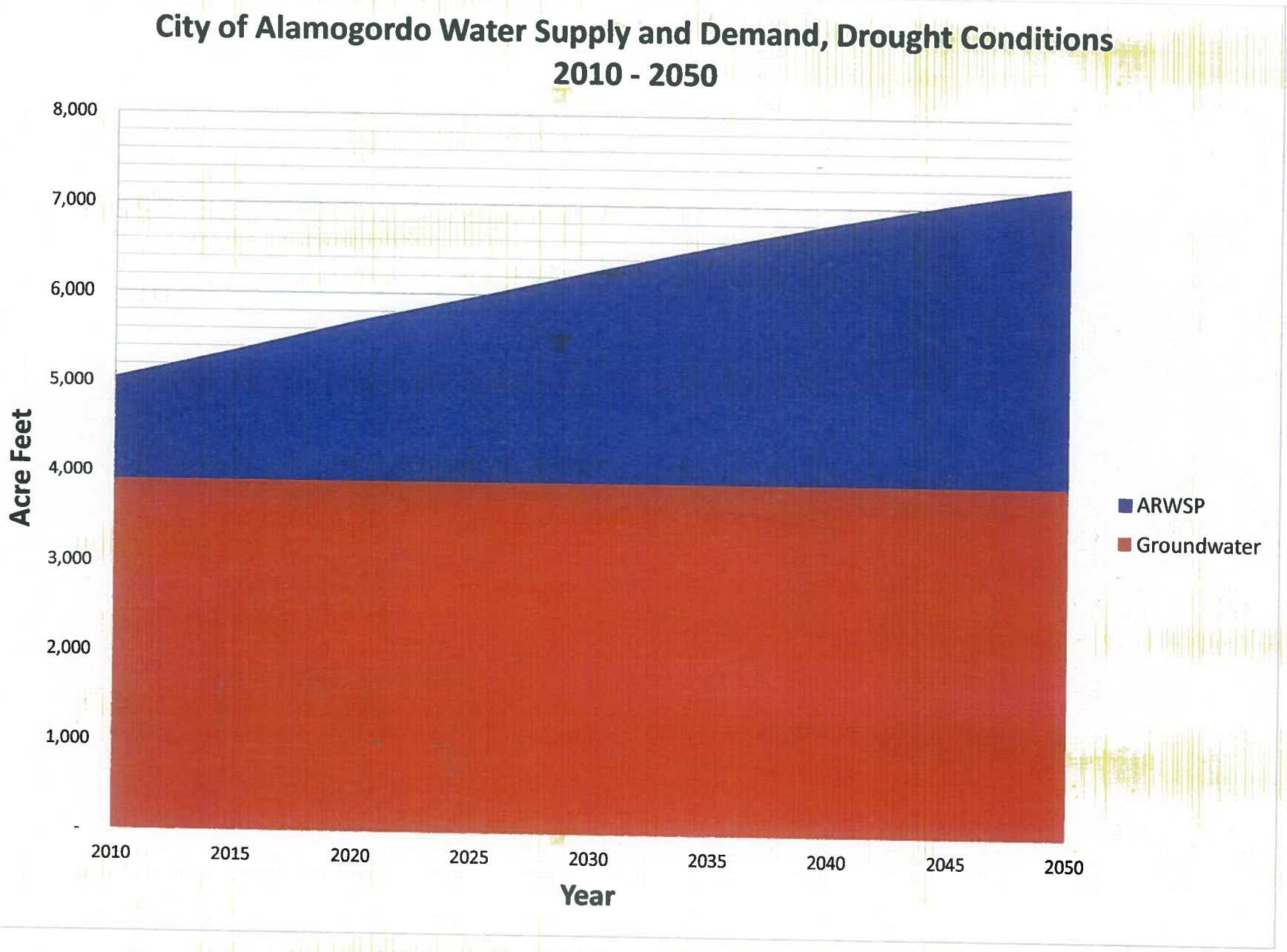
City of Alamogordo Water Supply and Demand, Drought Conditions
2010 - 2050
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
Acre Feet
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year
ARWSP
Groundwater

Figure 6.2