DANIEL B. STEPHENS & ASSOCIATES, INC.
ENVIRONMENTAL SCIENTISTS AND ENGINEERS

SANTA FE COUNTY
WATER RESOURCE INVENTORY

VOLUME 1: TEXT AND PLATES

Prepared for
Santa Fe County Land Use and Planning Department
Santa Fe, New Mexico

July 13, 1994

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DANIEL B. STEPHENS & ASSOCIATES, INC.
ENVIRONMENTAL SCIENTISTS AND ENGINEERS

July 13, 1994

0764-3300-94

Mary Helen Follingstad
Principal Planner
Santa Fe County
P.O. Box 276
Santa Fe, New Mexico 87504-0276

Dear Ms. Follingstad:

Enclosed for your review are three copies of the Santa Fe County Water Resource Inventory report. The report summarizes our knowledge of the water resources of Santa Fe County based on our review over the last 7 months of existing reports and data. We believe that this report will provide a solid foundation for formulating and discussing potential policy changes in the Santa Fe County Land Development Code.

We appreciate the opportunity to work with you and your staff.

Sincerely,

DANIEL B. STEPHENS & ASSOCIATES, INC.

Amy Lewis
Project Manager

AL/jt

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GLOSSARY[1]

Aquifer	Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.
Aquifer, confined	An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.
Aquifer, unconfined	An aquifer in which there are no confining beds between the zone of saturation and the surface. Water table aquifer is a synonym.
Areal recharge	Recharge that occurs when precipitation falls directly onto the aquifer in the valley area and a fraction of it seeps down through the soil to the aquifer before it evaporates, is transpired by plants, or discharges to perched aquifer springs or streams.
Barrier boundary	An aquifer system boundary represented by a rock mass that is not a source of water.
Baseflow	That part of stream discharge derived from ground water seeping into the stream.
Confining bed	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. It may lie above or below the aquifer.
Contaminant	Any solute that enters the hydrologic cycle through human action.
Discharge area	An area in which there are upward components of hydraulic head in the aquifer. Ground water is flowing toward the surface in a discharge area and may escape as a spring, seep, or baseflow, or by evaporation and transpiration.
Drainage basin	The land area from which surface runoff drains into a stream system.
Drawdown	A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells.
Dynamic equilibrium	A condition in which the amount of recharge to an aquifer equals the amount of natural discharge.
Evaporation	The process by which water passes from the liquid to the vapor state.
Evapotranspiration	The sum of evaporation and transpiration.

[1] Many of the definitions listed here were derived from Fetter, 1980.

GLOSSARY[1] (Continued)

Ground water	The water contained in interconnected pores located below the water table in an unconfined aquifer or in a confined aquifer.
Ground-water mining	The practice of withdrawing ground water at rates in excess of the natural recharge.
Hardness	A measure of the amount of calcium, magnesium, and iron dissolved in the water.
Heterogeneous	Pertaining to a substance having different characteristics in different locations. A synonym is nonuniform.
Homogeneous	Pertaining to a substance having identical characteristics everywhere. A synonym is uniform.
Hydraulic conductivity	A coefficient of proportionality describing the rate at which water can move through a permeable medium.
Hydraulic gradient	The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.
Hydrograph	A graph that shows some property of ground water or surface water as a function of time.
Mountain-front recharge	Recharge that occurs when precipitation falling on the mountainous regions does not evaporate or leave the recharge area in surface streams, but rather seeps through fractures to the water table, moves downgradient, and ultimately reaches the valley aquifer.
Nonappealable water right	A term used in the Santa Fe County Land Use Code which refers to non-domestic water rights.
Porosity	The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.
Potentiometric surface	A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.
Pumping test	A test made by pumping a well for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the well and the hydraulic characteristics of the aquifer. Also called aquifer test.

[1] Many of the definitions listed here were derived from Fetter, 1980.

GLOSSARY[1] (Continued)

Recharge area	An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.
Safe yield	The amount of naturally occurring ground water that can be economically and legally withdrawn from an aquifer on a sustained basis without impairing the native ground-water quality or creating an undesirable effect such as environmental damage.
Specific yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur. Specific yield is always less than porosity.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storativity is equivalent to the specific yield. Also called storage coefficient.
Stream-channel recharge	Recharge that occurs when runoff in the mountains flow downstream and seeps into the ground to the water table.
Stream, gaining	A stream or reach of a stream, the flow of which is being increased by inflow of ground water. Also known as an effluent stream.
Stream, losing	A stream or reach of a stream that is losing water by seepage into the ground. Also known as an influent stream.
Transmissivity	The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.
Transpiration	The process by which plants give off water vapor through their leaves.
Water budget	An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.
Water table	The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric.
Well interference	The result of two or more pumping wells, the drawdown cones of which intercept. At a given location, the total well interference is the sum of the drawdowns due to each individual well.

[1] Many of the definitions listed here were derived from Fetter, 1980.

GLOSSARY[1] (Continued)

Well, partially penetrating	A well constructed in such a way that it draws water directly from a fractional part of the total thickness of the aquifer. The fractional part may be located at the top or the bottom or anywhere in between the aquifer.
72-12-1 well	A domestic or stock well permitted by the SEO (under NMSA §72-12-1, 1978)

[1] Many of the definitions listed here were derived from Fetter, 1980.

PREFACE

Mercedes Ortega and Nancy Cunningham from the State Engineer Office were helpful in identifying water rights in the county. Neva Van Peski with the Metropolitan Water Board was very generous in providing her databases in the Santa Fe area and in discussing issues and problems with previous reports. Dennis McQuillan, Marcy Leavitt, and Doug Jones with the New Mexico Environment Department helped identify existing ground-water contamination sites throughout the county.

EXECUTIVE SUMMARY

In December 1993 Santa Fe County contracted the services of Daniel B. Stephens & Associates, Inc. (DBS&A) to perform an inventory of technical and managerial information pertaining to the water resources of Santa Fe County. The purpose of this inventory is to assess the general state of water resources in the County and to determine if the existing Land Use Development Code is performing adequately to meet its intended goals.

The scope of the water resource inventory and the review of management reports was limited to existing reports and available digital data that pertain to the entire county. The scope of the project is of a general nature, addressing the management strategy in a broad sense. This project evaluated information at a regional scale; consequently, this report should not be used as a substitute for a water supply study of a particular site within the County.

In order to conduct the County-wide inventory and to perform the necessary analysis, DBS&A divided the work into four major tasks:

- Task 1 involved the review of the existing Santa Fe County Water Plan, the County Land Development Code, and other water resource management reports to define the goals of those efforts and determine whether there were any potential conflicts between the various management strategies. The recommendations provided in each of the reports were synthesized into a discussion of various issues that have resulted in discrepancies among the various reports. The discussion in this report centers on the existing County Code and presents potential problems with the current management procedure.

- Task 2 involved the compilation of all available digital data and the review of existing technical reports pertaining to water resources in the County.

- Task 3 involved the assimilation of information compiled during Task 2 to develop conceptual aquifer systems for Santa Fe County. This work included several components and outcomes, as follows:

- DBS&A divided the water resources of Santa Fe County into three aquifer systems: (1) the North Santa Fe County (NSFC) aquifer system, (2) the Mid-Santa Fe County (MSFC) hydrologic system, and (3) the Estancia Valley (EV) aquifer system.

- Maps showing the lithology, potentiometric surface, rates of water level decline, electrical conductivity, Stiff diagrams of ground-water quality, ground-water contamination sites, aquifer parameters, and aquifer thickness of the County were developed.

- The quantity of water in storage was estimated for the NSFC and EV aquifer systems.

- The quantity of recharge and discharge from each aquifer system was assessed from estimates provided in existing technical reports.

- The aquifer performance was assessed based on two conflicting goals in the County Code: (1) protect existing wells and (2) mine the aquifer in 40 or 100 years. In order to address the first goal, a map was developed showing the locations of wells (identified from the USGS database) that are projected to go dry in 20 or 50 years. The second goal was addressed by assessing areas of each aquifer that may not exceed the lifetimes of 40 or 100 years.

- The effectiveness of the Code was evaluated by comparing projected water level declines from developments proposed after 1980 to actual declines.

• Task 4 entailed summarizing information gathered in the first three tasks and providing conclusions and recommendations for future water resource management. These conclusions and recommendations are summarized in the remainder of this executive summary.

Conclusions

Results of the analysis of available data led to the conclusions presented in the following subsections for each aquifer system. Additionally general conclusions regarding the effectiveness of the Code are provided.

North Santa Fe County Aquifer System

The water resources of the NSFC aquifer system vary from limited to extensive. In the areas where the resource is extensive, the water may not be available due in part to water right constraints. The NSFC aquifer system consists of the Santa Fe Group sedimentary rocks in the valley terrain, the Precambrian rocks in the eastern mountains, and basalts in the southeast. Based on DBS&A's review and analysis, we have concluded the following:

- The water quality in the NSFC aquifer system is generally very good. However, in the vicinity of Santa Fe and Pojoaque, known locations where ground water is contaminated include 14 locations contaminated by gasoline and 29 contaminated by sewage effluent.

- The total quantity of water in storage in the NSFC aquifer system is estimated to be 56,000,000 acre-feet, although it is not necessarily available due to physical and administrative constraints.

- Total ground-water pumping in the NSFC aquifer system to be estimated to be about 16,000 afy, of which about 1,000 afy is used for irrigation.

- Based on available data, the total quantity of ground water pumped from wells and discharged to springs appears to be roughly balanced with the quantity of recharge entering the NSFC aquifer system on the whole.

- Locally, ground-water mining is occurring. The greatest water level declines are observed in the vicinity of the City of Santa Fe (123 feet in 40 years) and Buckman (560 feet in 10 years) well fields. The decline rate at both of these well fields varies with depth.

- If the aquifer is mined, the water table would eventually decline to great depths; thus ground water would be expensive to produce due to increased pumping costs and possible water quality treatment requirements. In addition, land surface subsidence could occur due to compaction of underlying sediments, potentially resulting in damage to structures.

- To satisfy water right protestants, appropriation of additional water rights within the NSFC aquifer system must offset impacts on the Rio Grande, La Cienega springs, Tesuque Creek, the Rio Nambe, and the Rio Pojoaque. In short, it appears that present natural discharges to surface water within the NSFC cannot be depleted further. Approval of additional appropriations by the SEO within the NSFC are highly unlikely, and even a transfer within the NSFC will face many administrative hurdles. The only new diversions that are likely to occur within the NSFC are from individual domestic wells because they are legally mandated for approval by the SEO. Thus, in order to limit future depletions within the NSFC aquifer system, the County would have to limit future development that is dependent upon individual domestic wells.

Mid-Santa Fe County Hydrologic System

Little data are available to assess the aquifer properties of the few productive geologic formations in the MSFC hydrologic system. Water quality is generally poor, and productive aquifers appear to be of limited extent. The MSFC hydrologic system includes Permian through Tertiary sediments, volcanics, and Precambrian rocks in the Galisteo and Pecos River drainage basins. Based on our review and analysis of existing information, DBS&A's conclusions pertaining to the MSFC hydrologic system are as follows:

- Water quality is generally poor, with total dissolved solids concentrations of up to 5,000 ppm, and ground-water contamination from mining activities in the Ortiz Mountains, sewage effluent, and underground storage tanks has locally impacted water quality.

- Less than 300 afy of ground-water pumping is estimated to occur in the MSFC hydrologic system, although identified water rights exceed 1,200 afy.

- Diversions in the Galisteo area appear to exceed the quantity of recharge as evidenced by the rate of water level decline in this area.

Estancia Valley Aquifer System

The EV aquifer system is in an official state of ground-water mining, as administered by the SEO, and is a limited resource. The EV aquifer system consists of Pennsylvanian to Triassic sediments and the Tertiary valley fill in the Estancia Basin. DBS&A's conclusions pertaining to the EV aquifer system are as follows:

- Water quality varies from good to poor, with a total dissolved solids of about 300 ppm in the valley fill to nearly 3,000 ppm in the Glorieta Sandstone. Ground-water contamination from gasoline in the White Lakes and Edgewood areas are the only identified ground-water contamination problems in the EV aquifer system.

- The quantity of water in storage in the valley fill is estimated to be about 1,000,000 acre-feet.

- The quantity of water pumped from the EV aquifer system is estimated to be about 16,000 afy, the majority of which (12,500 afy) is used for agriculture. Pumping far exceeds the quantity of recharge entering the aquifer system, and thus the resources are dwindling at a fairly uniform rate. If pumping continues at the current rate, the productivity of the valley fill aquifer could greatly diminish in about 110 years in the thickest part of the aquifer, and in much less time at the edge of the aquifer.

- The extent of the water resource in the rocks surrounding the valley fill is poorly understood, but it is thought to be limited and marginally productive, with the exception of the Madera Limestone near Edgewood and the Glorieta Sandstone in the south-central part of the EV aquifer system.

Effectiveness of the Santa Fe County Land Development Code

The existing County Code has conflicting goals of sustained yield (protecting existing wells) and specifying a lifetime of the resource. Neither of these goals may be achieved entirely:

- Many existing shallow wells will likely go dry in less than 20 years if current trends in water level decline continue. Most of these wells are located in the Santa Fe, Galisteo, and Edgewood areas.

- At the margins of the aquifers and in recharge areas of fractured Precambrian rocks, the aquifers may not provide a supply for 100 years. Areas where the ground-water resource is limited are also areas where the population of the County is expanding.

In addition, the SEO administers the Estancia Basin on a 40-year lifetime, which conflicts with the Santa Fe County administrative criterion of a 100-year lifetime. Therefore, although a development may appear to have sufficient water in storage to satisfy the 100-year requirement, the SEO may have granted or may in the future grant water rights in neighboring areas that will deplete water beneath the development in a much shorter time frame.

The Code has some potential problems in ensuring a long-term supply:

- The supply at the boundaries of the productive parts of any aquifer may be depleted at a greater rate than predicted by the methods used in the Code.

- The Code's methods for estimating water availability do not incorporate existing depletions from adjacent land owners and thus may overestimate available water supplies.

- Water availability based solely on recharge (such as in the Mountain Zone) may result in insufficient supply during periods of drought.

- Methods for determining the saturated thickness of the aquifer are not reliable, since many of the reports calculate the saturated aquifer thickness as simply the depth of the well minus the depth to water. For example, aquifer thickness may be overestimated if calculated from a well with several hundred feet of saturated but non-productive clay.

- Based on storage coefficients obtained in aquifer tests, the storage coefficient of 0.15 in the Santa Fe Group appears to be too high, and use of such a value would overestimate water availability.

- The Code allows developments to reduce the projected ground-water use from 1 afy to 0.25 afy per household, but does not require metering or other verification.

- Allowing future development to use recharge in the Mountain Zone will ultimately result in interception of water that previously supplied downgradient water users.

Very few water rights are available in Santa Fe County for purchase; consequently, the growth in the County may be limited to water that could be provided by domestic wells (wells allowed under article 72-12-1 of the New Mexico Statutes, 1978) unless new sources of water (e.g., imported) are provided. From a hydrologic point of view, where aquifer characteristics, water quality, and depth to ground water are favorable, individual wells for each lot are a more effective way to develop an aquifer and prolong its lifetime than are community wells. However, if the resource is depleted and imported water will eventually be required, then a community system is more desirable because some of the requisite water distribution system will already be in place.

In summary, DBS&A's review of management and planning documents revealed potential problems regarding water availability and possible impacts related to continued development of the limited water resource. The review also indicated a general lack of communication of ground-water fundamentals which are the basis for any land-use management that is founded in part on water resource considerations. This lack of communication may have contributed to the absence of a clear articulation of a comprehensive policy toward the utilization of water resources. Apparently, this problem is fairly common because as Ingram and others (1984) note, ". . . institutional problems in water resource development and management are more prominent, persistent, and perplexing than technical, physical, or even economic problems . . . ."

It appears that the areas in the County most in need of additional policy direction are those areas having limited water resources that are currently being developed. These areas include areas where aquifer yield and/or storage are low, the edges of the NSFC and the EV aquifers, and the recharge area for the NSFC aquifer system. Areas with limited water resources will likely be the first to experience water shortages, especially if regulations tc restrict ground-water development in the rest of the aquifer system are insufficient.

In the NSFC aquifer system, which has a large volume of ground water in storage in areas remote from the aquifer margins, the policy issue is the amount of aquifer depletion that should be allowed. Should development be limited so that withdrawals would be approximately equal to recharge (as is approximately the current state of withdrawal), thus minimizing impacts, or should withdrawals by domestic wells be allowed to deplete the aquifer in as little as 40 years as is now the case for the current Code? If the latter case is allowed, then the issue of policy toward water-depleted areas—that is, abandonment or importation of water—is raised.

Recommendations

In this report DBS&A has provided recommendations to improve the method of assessing the quantity of water available beneath a proposed subdivision. We have also provided recommendations for possible hydrogeologic studies that may aid the County in making management decisions. Finally, we have suggested possible strategies that the County may wish to consider that we believe may improve the management of water resources in the County. Before any of these recommendations can be implemented, the County needs to clarify and formulate criteria that are consistent with the overall goals for water resource management.

1. INTRODUCTION

In December 1993 Santa Fe County contracted the services of Daniel B. Stephens & Associates, Inc. (DBS&A) to perform an inventory of technical and managerial information pertaining to the water resources of Santa Fe County (Figure 1). The purpose of this inventory is to assess the general state of water resources in the County and to determine if the existing Land Use Development County Code (County Code) is performing adequately to meet its intended goals.

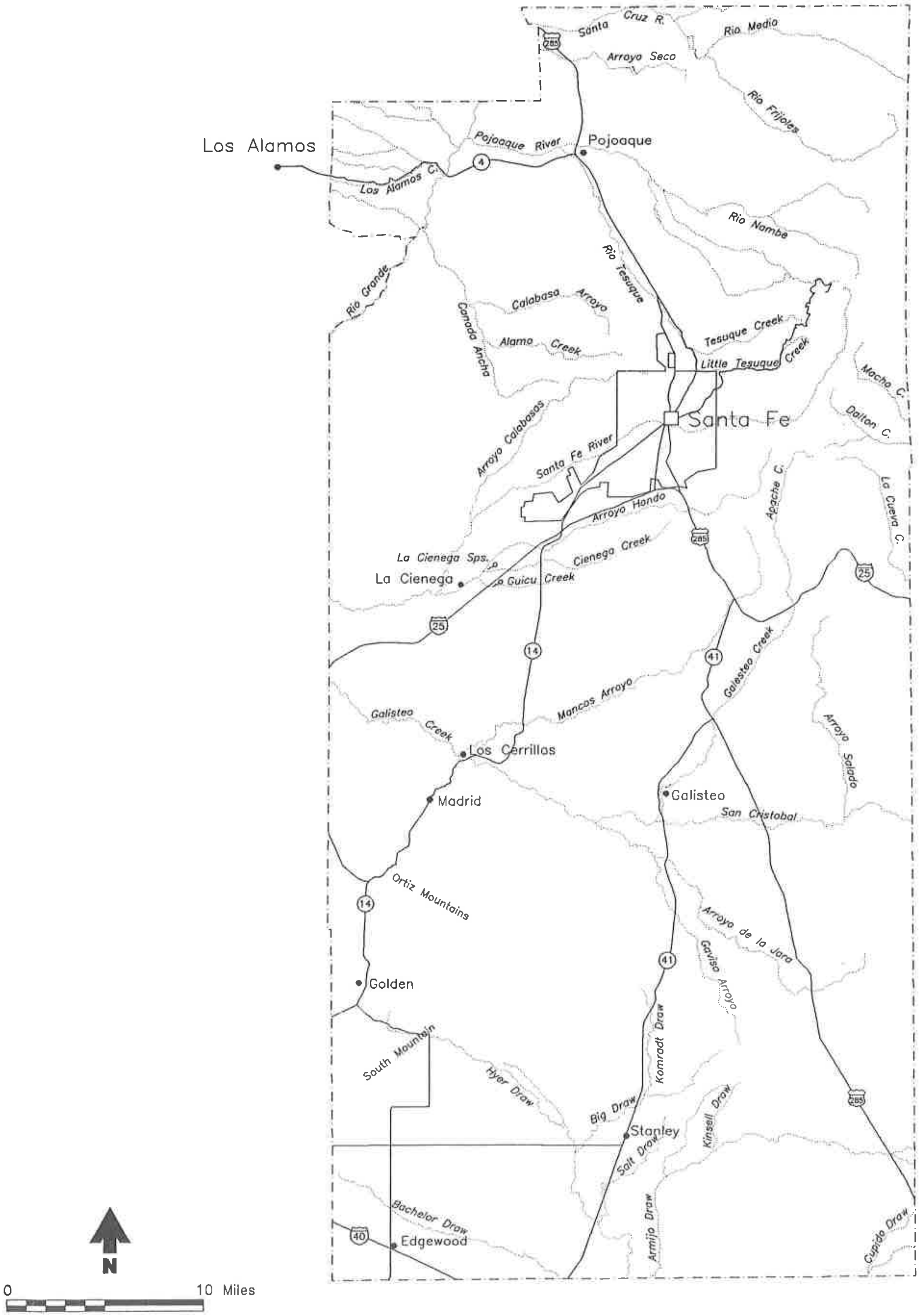
The scope of the water resource inventory and the review of management reports was limited to existing reports and available digital data that pertain to the entire county. The scope of the project is of a general nature, addressing the management strategy in a broad sense. This project evaluated information at a regional scale; consequently, this report should not be used as a substitute for a water supply study of a particular site within the County.

1.1 Scope of Work

In order to conduct the County-wide inventory and to perform the necessary analysis, DBS&A divided the work into four major tasks:

- Task 1 - Review the existing County plan, the County Code, and other water resource management reports to define the goals of those efforts, and then determine whether there were any potential conflicts between the various management strategies. This review and analysis is summarized in Section 3 of this report.

- Task 2 - Compile all available digital data into a series of databases, and review existing technical reports pertaining to the County. The primary source of data presented in plates, figures, and tables was purchased from the U.S. Geological Survey (USGS) and is part of the Ground Water Sites Inventory (GWSI) and the National Well Inventory System (NWIS). These data were supplemented with information presented in consulting reports submitted to the county, well logs on file at the New Mexico Oil Conservation Division, New Mexico State Engineer Office library and database, and the New Mexico Environment Department library and database.



SANTA FE COUNTY

Base Map

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Figure 1

- Task 3 - Assimilate the technical information gathered during Task 2 and delineate the aquifer systems in the County for management purposes. This task included four components:
  - Develop conceptual models of the various hydrologic systems.
  - Describe the water quality, aquifer parameters, and water budget component estimates for each of the systems.
  - Develop aquifer performance criteria for each of the aquifer systems.
  - Evaluate the efficacy of the existing County Code

- Task 4 - Summarize information and analysis gathered in the first three tasks and provide recommendations for future water resource management.

1.2 Well Numbering System

The system of numbering wells in this report is based on the common subdivision of land into townships, ranges, and sections in the Federal land-survey system. In land grants, well numbers are based on projection of the townships, ranges, and sections.

The well numbers based on townships, ranges, and sections consist of four parts separated by periods (Figure 2). The first part is the township number, the second part is the range number, and the third part is the section number. Since all the township blocks within the study area are north of the baseline and east of the principal meridian, the letters N and E, indicating direction, are omitted, as are the letters T for township and R for range. For example, the identifier 18.7.1 is assigned to any well located in T. 18 N., R. 7 E., Sec. 1.

The fourth part of the well number consists of three digits that denote within the section the particular 10-acre tract in which the well is located. The method of numbering the tracts within the section (Figure 2) is based on consecutive subdivision of the section into quarters, as follows:

- The section is first divided into four quarters, numbered 1 through 4 for the northwest, northeast, southwest, and southeast quarters, respectively, each of which is a tract of 160

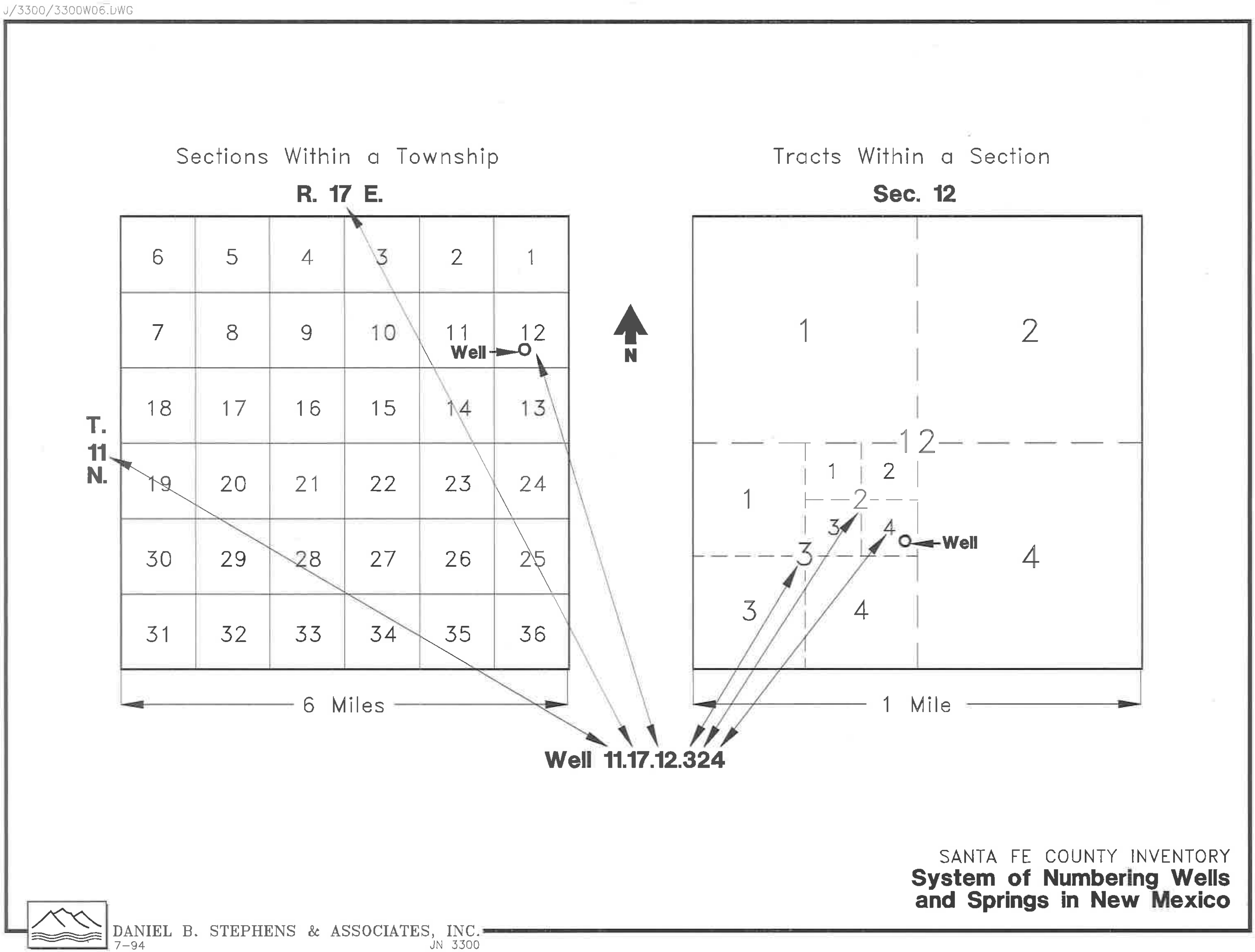
J/3300/3300W06.DWG
Sections Within a Township
R. 17 E.
T. 11 N.
6 5 4 3 2 1
7 8 9 10 11 12
18 17 16 15 14 13
19 20 21 22 23 24
30 29 28 27 26 25
31 32 33 34 35 36
Well
6 Miles
N
Tracts Within a Section
Sec. 12
1
2
12
1
2
1
2
3
4
Well
3
3
4
4
1 Mile
Well 11.17.12.324
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Figure 2

acres. This 160-acre quarter section provides the first digit of the fourth part of the well number

- Each quarter section is then subdivided in the same manner into 40-acre tracts. This 40-acre sixteenth of a section provides the second digit of the fourth part of the well number.

- Finally, the 40-acre tract is divided into four 10-acre tracts; the third digit of the fourth part of the well number denotes one 10-acre tract (1/64 of a section)

Thus, well 18.7.1.224 is in the SE¼ of the NE¼ of the NE¼ of Section 1, T. 18 N., R. 7 E. (Figure 2).

2. AQUIFER DELINEATION AND DESCRIPTION

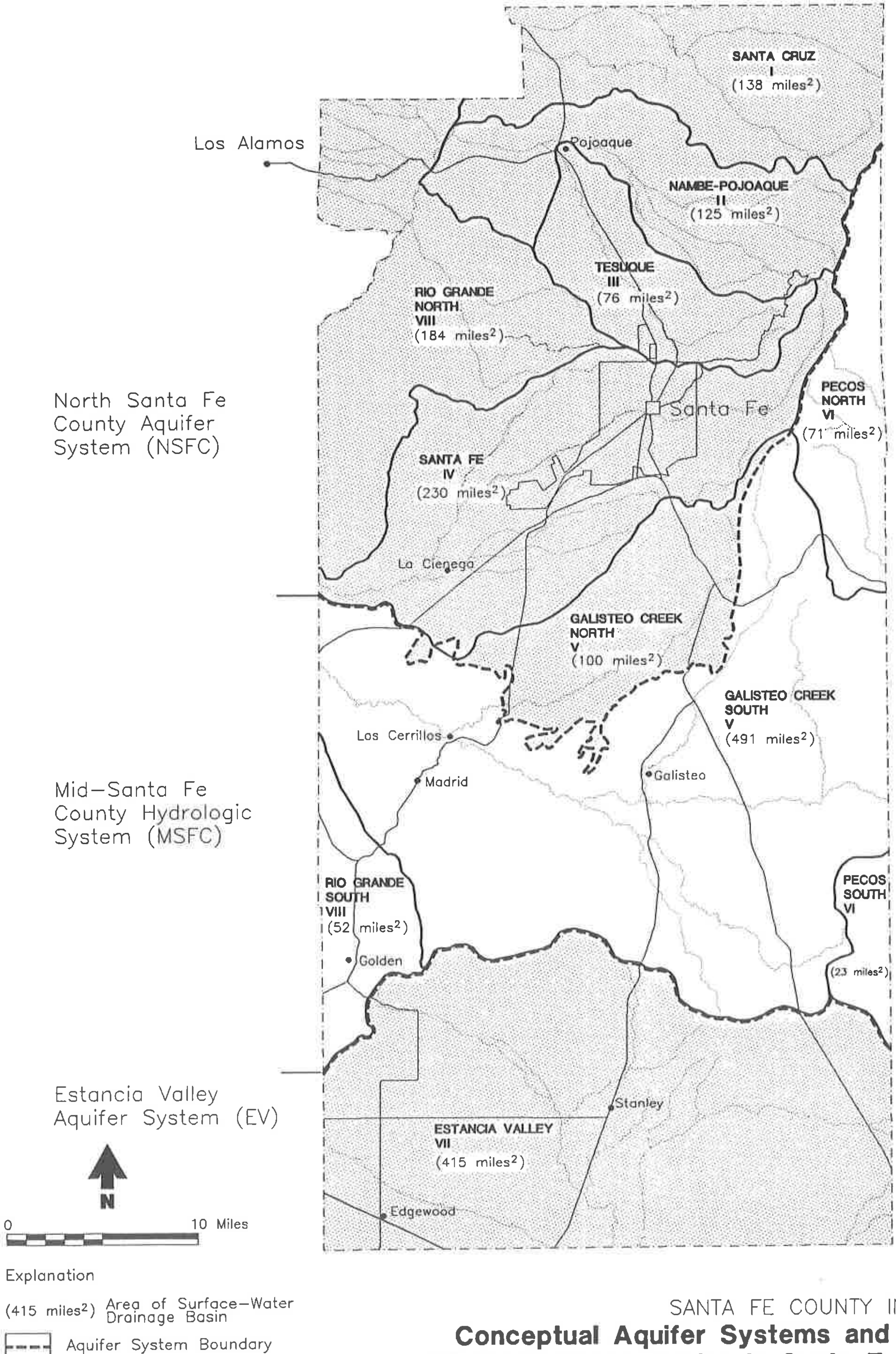
This section outlines the present understanding of the aquifer systems in Santa Fe County and presents hydrologic data and interpretations using available data from the USGS database and published sources. Technical terms and concepts are used that may be confusing for a reader who is unfamiliar with hydrogeologic definitions. Appendix A provides a brief primer on hydrogeology, and a glossary is provided at the beginning of this report for those unacquainted with certain terms.

Section 2.1 describes the conceptual models of the aquifer systems in the county. Section 2.2 presents a discussion of water levels, water quality, aquifer parameters, and the quantity of water in storage. Finally, Section 2.3 addresses the information available for the water budget components (recharge and pumping) for each aquifer system.

2.1 Conceptual Models of Santa Fe County Aquifer and Hydrologic Systems

For regional planning purposes, DBS&A has divided Santa Fe County into three major conceptual aquifers or hydrologic systems as shown in Figure 3. The North Santa Fe County aquifer system (NSFC), the Mid-Santa Fe County hydrologic system (MSFC) and the Estancia Valley aquifer system (EV) were defined, in part, based upon the hydrogeologic conditions discussed in Sections 2.1.1 through 2.1.3. The conceptual models of the aquifer systems were developed from an understanding of the hydrologic processes occurring in the system and the elements that affect these processes. The geologic formations constitute the plumbing system for a conceptual model, and in a natural system, recharge provides the driving force that causes ground water to flow through the aquifer system to areas of discharge. It is expected that these new conceptual hydrologic models of the county will provide insight necessary for eventually updating the county plan. These conceptual models are not drastically different than those used in the current County code, but are divided into regions that may be more useful for a management decision process.

The discussions of the aquifer systems in Sections 2.1.1 through 2.1.3 are intended for regional planning purposes only: the scale of interest is on the order of tens of miles. For consideration of a particular development, it may be necessary to collect site-specific information in order to



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Conceptual Aquifer Systems and Surface Water Drainage Basins in Santa Fe County

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Figure 3

develop a local conceptual model. For a more detailed description of the geologic formations, the reader is referred to reports by Spiegel and Baldwin (1963), Galusha and Blick (1971), Consulting Professionals, Inc. (1974), and Wilson (1975).

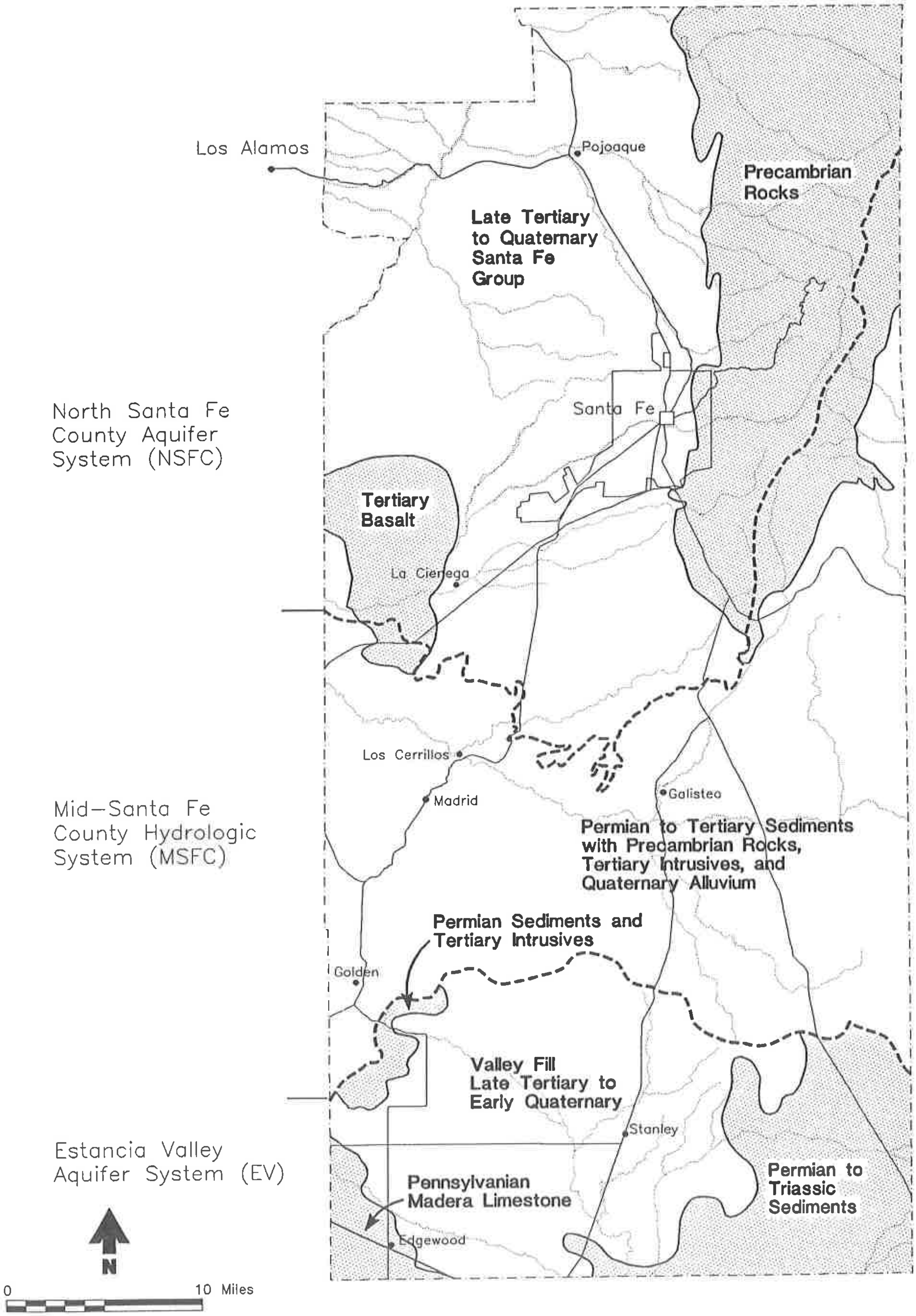
The conceptual model for each hydrogeologic system is described in Sections 2.1.1 through 2.1.3. The geohydrologic framework of the system is discussed first and is followed by a discussion of the recharge mechanisms. Plate 1 shows the lithologic units within each aquifer system, and Figure 4 is a generalized geologic map of the aquifer systems.

2.1.1 North Santa Fe County Aquifer System

2.1.1.1 Geohydrologic Framework. Of the three aquifer systems in Santa Fe County, the geohydrology in northern Santa Fe County is probably best understood. Even so, much remains to be learned about the detailed hydrologic nature of this system. The NSFC aquifer system is defined here as the Late Tertiary Santa Fe Group (the principal aquifer) and hydraulically associated rocks (Precambrian rocks and Tertiary basalts) in the area from the northern Santa Fe County line south to where the Santa Fe Group is truncated by erosion associated with the creation of the Galisteo drainage. The NSFC aquifer system encompasses the northern Basin and Basin Fringe Zones and part of the Mountain and Homestead Zones defined by the existing County Code (discussed in Section 3.2).

The principal aquifer in the NSFC aquifer system occurs within the Tertiary to Quaternary Santa Fe Group described by Spiegel and Baldwin (1963), as expanded by Manley (1979). The Santa Fe Group is comprised of the Tesuque Formation and overlying Ancha and Puye Formations. Figures 5 and 6 are schematic diagrams from west to east and from north to south, respectively, of the NSFC aquifer system. The nature of the rocks beneath the Santa Fe Group is generally unknown since few wells have penetrated the entire saturated thickness of the Santa Fe Group. However, based on the interpretation of gravity data by Cordell (1977), it is very likely that older sediments are present.

Although all three geologic members of the Santa Fe Group are in hydraulic communication, the Tesuque Formation forms the main aquifer in the NSFC aquifer system. An understanding of the



Explanation

Aquifer System Boundary

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Generalized Geologic Map of the Aquifer Systems in Santa Fe County

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Figure 4

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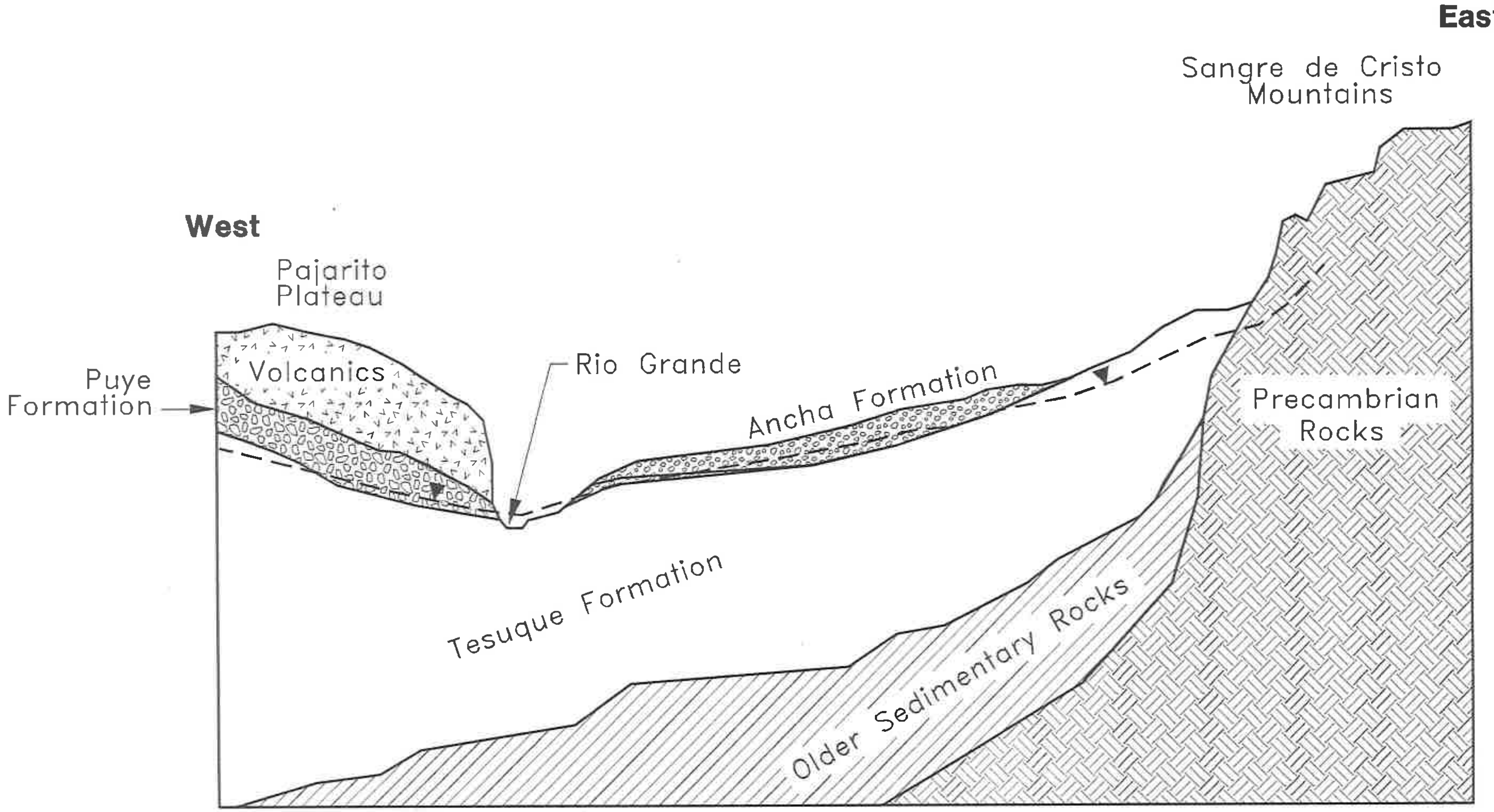

Not to Scale

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Schematic East-West Cross Section of the North Santa Fe County Aquifer System

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Figure 5

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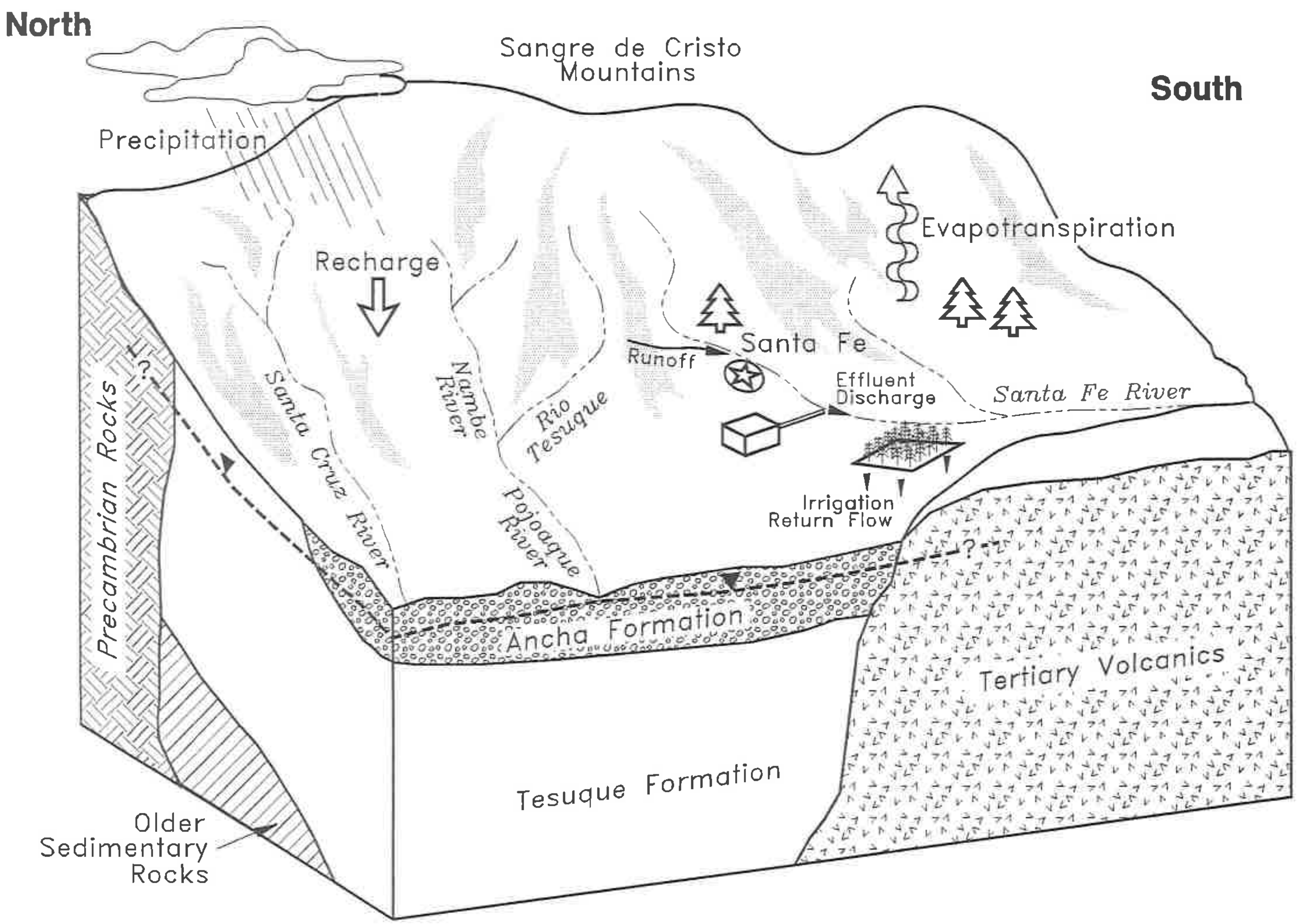

Not to Scale

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SANTA FE COUNTY INVENTORY
Schematic Block Diagram of the North Santa Fe County Aquifer System

Figure 6

depositional environment of the formation materials sheds light on the hydrogeology of the Tesuque Formation, which is comprised of sand, gravel, silt, and clay. The Tesuque Formation was deposited mainly as coalescing alluvial-fan deposits along the developing Rio Grande depression known as the Española Basin (McAda and Wasiolek, 1988). The fan material was derived from the emerging Sangre de Cristo mountains to the east of the depression. Most of the beds within the old alluvial fans have a general westward dip of about 8 degrees (Hearne, 1980a), but locally the dip can be as much as 25 degrees. The depositional environment has resulted in a discontinuity of the deposits of the Tesuque Formation, causing it to be very heterogeneous on a local scale.

Two areas of rock east and west of the Santa Fe Group appear to be hydraulically connected to the Santa Fe Group. Bounding the Santa Fe Group to the east are Precambrian rocks that comprise the primary recharge area to the Santa Fe Group. The hydrology of the western portion of the NSFC aquifer system is poorly understood where basalts crop out, because of insufficient subsurface data to determine the distribution of basalts within the Santa Fe Group. However, these volcanic rocks are included in the NSFC aquifer system because previous investigators, such as Spiegel and Baldwin (1963) and McAda and Wasiolek (1988), interpreted these geologic units to be hydraulically connected to the Santa Fe Group.

Faulting in the basin has further disrupted any original continuity of the aquifer. The Tesuque Formation has been subjected to faulting during at least two periods of tectonic activity (Baltz, 1978). Kelly (1978) mapped numerous faults in the Española Basin but included only the major faults on the published map for ease of readability (Kelly, 1977).

Faulting has affected the hydraulic properties of the Tesuque Formation by reducing the horizontal permeability in three ways. First, lateral continuity tends to be reduced at the fault by positioning higher-permeability beds next to lower-permeability beds. Second, faults that are initially vertical conduits for ground-water flow, tend to become sealed by chemical deposition through time. This sealing process also reduces horizontal flow between fault blocks. Third, movement along faults can smear clay along the fault surface, thereby causing the fault to inhibit water migration across it.

The relatively random nature of the Tesuque Formation depositional environment, coupled with the discontinuities created by faulting, has resulted in an aquifer with considerable heterogeneity. In most areas, the level of heterogeneity is so high locally that when the Tesuque Formation is viewed on a regional scale, it appears to be essentially homogeneous. This is the conceptual model scale used by McAda and Wasiolek (1988) to construct the regional-scale computer model of the Tesuque aquifer system. In other areas, the local discontinuities in permeable strata are of a sufficient scale that they are detectable on water level contour maps. We note, for example, the flattening of the water table contours in the graben (structural valley) proposed by Hagerman and VeneKlasen (CPI, undated) in the area of the Santa Fe well field. Local-scale heterogeneity exists throughout the aquifer system, and ultimately, the average permeability of these local features determines the permeability on a regional scale. Therefore, for local-scale assessments of new wells, site-specific conceptual models embedded in the framework of the regional model are required.

The Ancha Formation, which overlies the Tesuque Formation east of the Rio Grande, is more homogeneous in composition and has fewer low-permeability layers than the underlying Tesuque Formation. Conceptually, the problem of scale dependence is less significant for the Ancha Formation than for the Tesuque Formation. In most areas the Ancha Formation sediments lie above the water table, but where it is saturated, the Ancha Formation is generally in hydraulic communication with the Tesuque Formation. However, the rate of flow of ground water between formations is limited, because the Tesuque Formation is approximately ten times less permeable than the Ancha Formation (Fleming, 1993); therefore, where both formations are water-bearing, ground water will flow preferentiall / through the more permeable Ancha Formation. Pumping in the Tesuque Formation, however, can impact water levels in the Ancha and vice versa.

The Puye Formation overlies the Tesuque Formation west of the Rio Grande. The Puye Formation is substantially coarser than the Tesuque or Ancha Formations as it primarily consists of sand and pebbles. The Puye Formation is predominately above the water table; however, near the Rio Grande the lower portion of the Puye Formation is saturated and provides water to the Los Alamos well field.

The three formations of the Santa Fe Group are also in hydraulic communication with the geologic formations that exist along the basin edge and underneath the Santa Fe Group. The bounding rocks are generally of lower permeability than the Santa Fe Group, although zones that are of higher permeability, primarily as a result of fracturing, occur in localized areas.

The Precambrian crystalline rocks of the Sangre de Cristo mountains provide recharge to the Santa Fe Group along much of the eastern boundary of the Española Basin. Two types of contacts between units exist along this boundary. Along the northeastern part of the eastern boundary the contact between the Santa Fe Group and the underlying crystalline rock coincides with a fault (Baltz, 1978). Along the southeastern part of the eastern boundary the contact is depositional; that is, the Santa Fe Group was deposited directly onto the underlying rocks (Galusha and Blick, 1971), often feathering out against the underlying (mostly unfractured) crystalline rock.

The nature of the contact between the Santa Fe Group and the crystalline rocks has important hydrologic implications. Better hydraulic communication likely exists between two units where the contact consists of a fault face than between two where the contact is depositional. The reason for this is that where faulting has occurred, the basement rock has been fractured and thus is probably more permeable. For instance, the east-southeastern basin boundary is in an area where the Santa Fe Group was deposited along the margins of the Española Basin where little faulting occurred. In this region the Santa Fe Group thins to the east over a suite of various underlying formations that are generally of low permeability. The contact east of Santa Fe is a fault face. The fractured Precambrian rocks are relatively productive and are the primary recharge area (discussed in Section 2.1.1.2) for the Santa Fe Group.

In areas where the crystalline rocks are fractured, water may be found in sufficient quantities for domestic water supply. Fractures in the crystalline rocks have been created by the faulting and tectonic stresses associated with mountain building. Spiegel and Baldwin (1963) reported that the distribution of fractures was not uniform, and that the greatest density of fractures appeared to occur along, and strongly controlled the development of, surface drainage channels. Thus, the least fractured rock is generally associated with topographically high areas on a local scale. The major faults and the associated fracturing generally trend northwest to southeast along the front of the Sangre de Cristo Mountains.

Little information exists concerning the rocks that underlie the NSFC aquifer system described above. Along the southern boundary of the Santa Fe Group, where the Santa Fe Group has been removed by erosion associated with the development of the Galisteo Creek drainage, the underlying rocks include the Espinosa Volcanics, the Galisteo Formation, and undifferentiated Cretaceous-age rocks (Disbrow and Stoll, 1957). At the southwestern boundary of the Santa Fe Group, which is along the southwestern margin of the Española Basin in the Cerrillos to Cieneguilla area, the underlying rocks again include the Tertiary Espinosa Volcanics, the Tertiary Galisteo Formation, and undifferentiated Cretaceous-age rocks.

The Santa Fe Group extends beyond the northern and northwestern county line into Rio Arriba and Los Alamos Counties. Conveniently, however, these administrative boundaries are reasonably appropriate hydrologic boundaries. Ground water flows roughly parallel to the northern county line and discharges to the Rio Grande at the northwestern county line, with the exception of the area west of the Rio Grande.

2.1.1.2 Recharge and Discharge Mechanisms. Recharge to the NSFC aquifer system occurs through three primary mechanisms (Figure 7): mountain-front, areal, and stream-channel recharge. Mountain-front recharge occurs when precipitation falling on the mountainous regions does not evaporate or leave the recharge area in surface streams, but rather seeps through fractures to the water table, moves downgradient, and ultimately reaches the Santa Fe Group aquifer. Areal recharge occurs when precipitation falls directly onto the aquifer in the valley area and a fraction of it seeps down through the soil to the aquifer before it evaporates, is transpired by plants, or discharges to perched aquifer springs or streams. Stream-channel recharge occurs when runoff in the mountains flows downstream and seeps into the ground to the water table in the valley. On streams such as the perennial Santa Cruz River, stream-channel recharge occurs throughout the year; on the other hand, on ephemeral streams this recharge mechanism usually only occurs during periods of snowmelt or intense thunderstorms.

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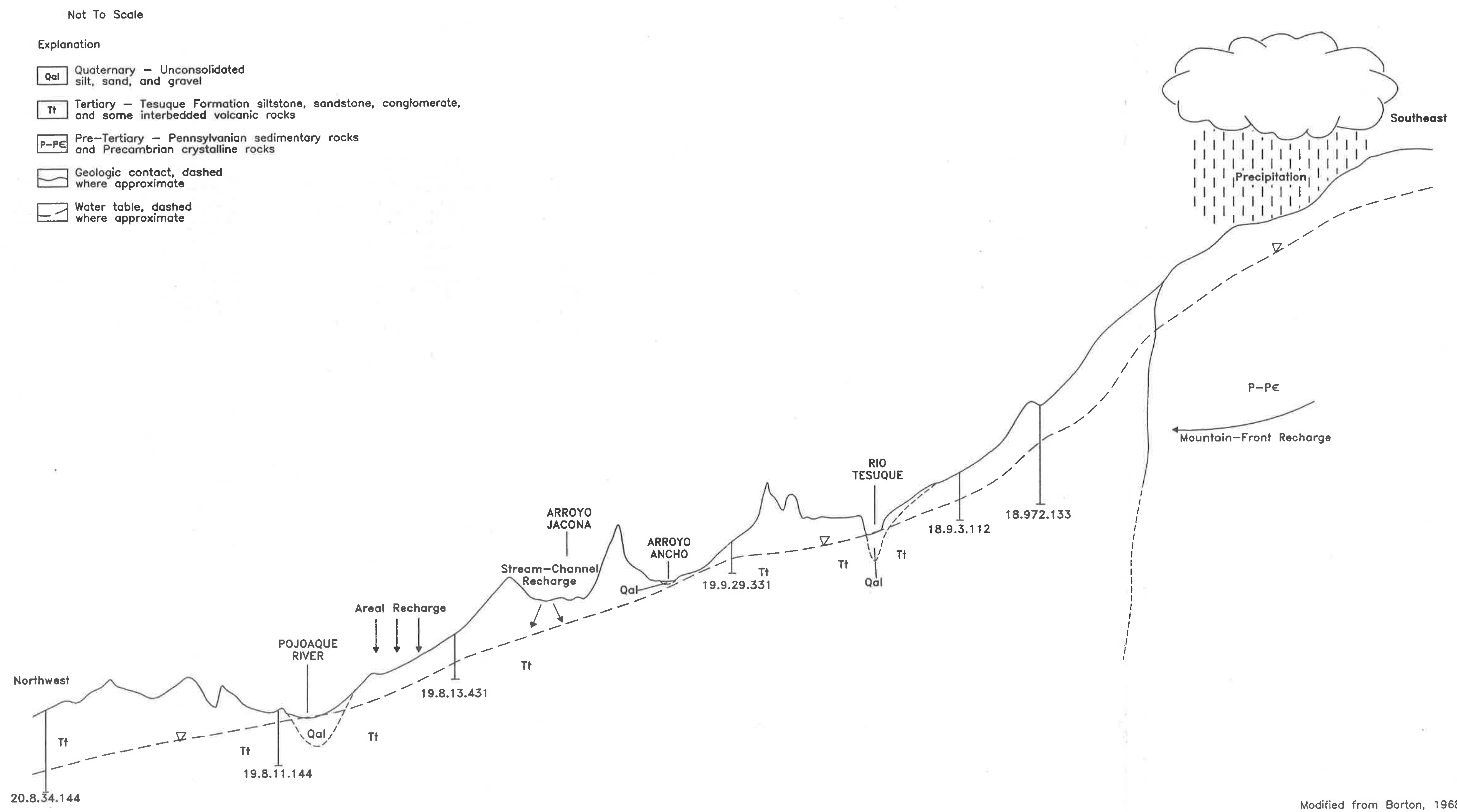

Modified from Borton, 1968

SANTA FE COUNTY INVENTORY

The Relation of Water Table to Land Surface in the NSFC Aquifer System Showing Recharge Mechanisms

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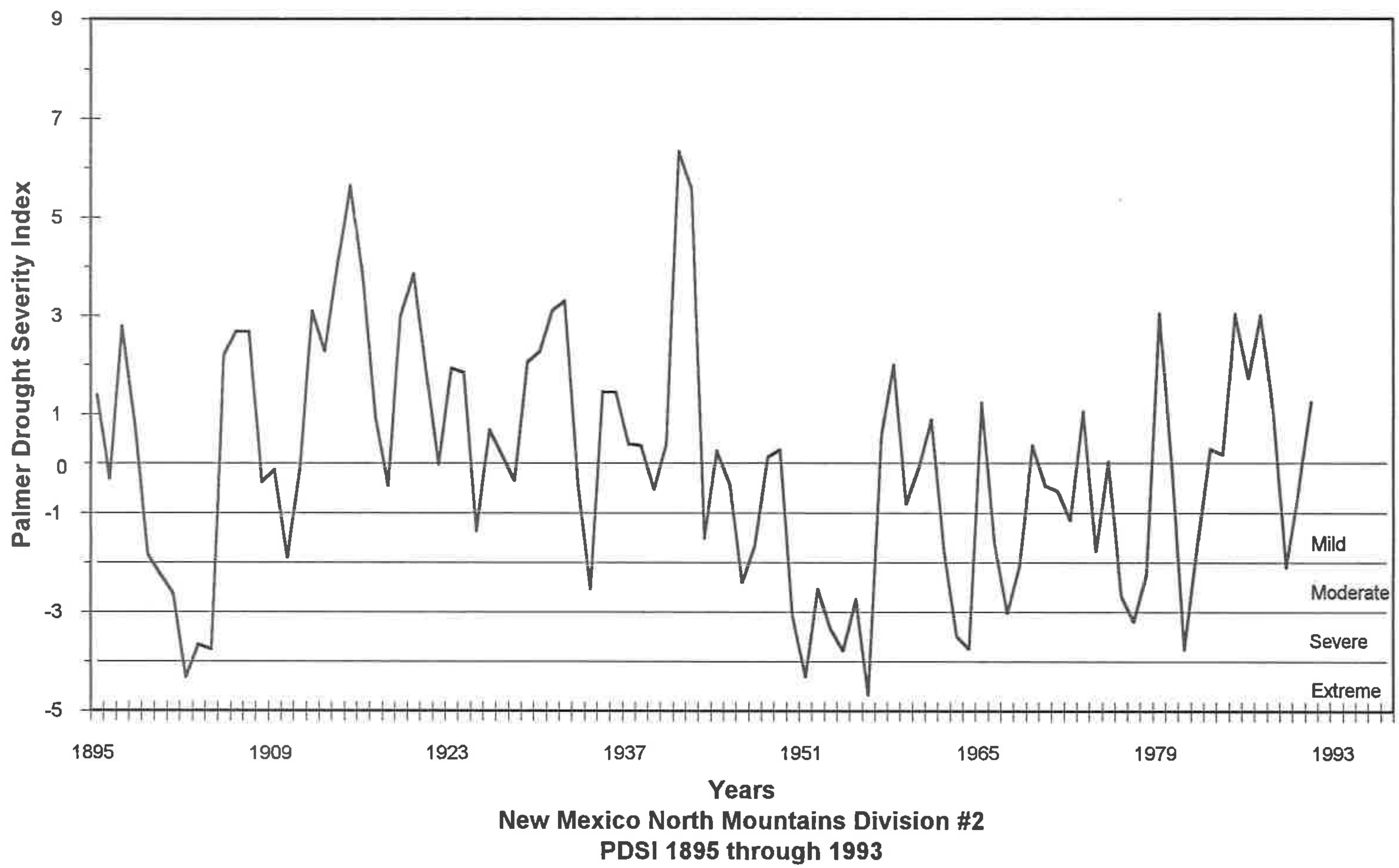
Figure 7

Recharge is more likely to occur at higher elevations, where precipitation is greater and temperatures are cooler, than at lower elevations, where less rainfall occurs, temperatures are higher, and thus the potential for evaporation is greater. Geologic formations also impact the rate of recharge. In the mountains, recharge is enhanced due to exposed permeable, fractured rocks with limited vegetative cover. Conversely, in the valley much of the incident precipitation is taken up by vegetation, and additionally, clay and caliche in soils above the water table can impede the downward migration of potential recharge. A recent study by Anderholm (1990) using a chloride mass balance technique suggests that recharge from areal precipitation is insignificant in the vicinity of Arroyo Hondo, the Santa Fe River, and Tesuque Creek.

From this brief description of recharge mechanisms, it is clear that the infiltration in areas of crystalline rocks that are covered with snow fields in the higher elevations (some over 12,000 feet above mean sea level) are the primary source of mountain-front recharge for the Santa Fe Group. While little water is likely in storage within the crystalline rocks, the fractures probably are good local conduits to transmit the infiltrated water from the high elevations to the Santa Fe Group. The crystalline rocks are thus important to the overall operation of the NSFC aquifer system in spite of the fact that these rocks regionally tend to be poor aquifers due to their low average permeability and low storage capacity.

Once recharge enters the rocks at higher elevations, the ground water flows from higher to lower elevations, east to west. Coincidentally, the flow is also generally in the direction of dip of the geologic layers. Because the permeability in the direction parallel to the geologic layers is greater than the permeability in the vertical (upward) direction, the ground water eventually becomes partially confined (under pressure beneath tight clay-rich layers) as it moves into the valley. Wells that penetrate a confined portion of the aquifer might flow at the surface, in which case they are called flowing artesian wells. The deeper a well is, the greater the likelihood that water under pressure will be encountered. The old flowing railroad well at Buckman is an example of this phenomenon.

Recharge is a highly variable quantity in Santa Fe County due to the seasonal and annual variability of precipitation. The Palmer Drought Severity Index (Figure 8) can be used as an indication of the annual variability of recharge. Another indicator of the variability of annual



Source: Army Corps of Engineers, 1991

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Palmer Drought Severity Index for the Northern Mountains, New Mexico

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Figure 8

recharge is the cumulative departure from mean annual precipitation, such as that illustrated in Figure 9 for precipitation stations throughout Santa Fe County (Appendix B shows graphs for individual stations). These data indicate that the dry period in the late 1940s and early 1950s likely contributed to substantially reduced recharge. Additionally, it appears that during the 1980s the amount of recharge may have returned to nearly the long-term average.

Precipitation data from the Santa Fe gauge must be interpreted cautiously in assessing recharge potential because the gauge location has changed two times; the first two locations were within the city limits, and its current location is near the municipal airport. The lower elevation and dramatically different vegetation at the present gauge location suggest that the climate is much dryer than at previous gauge locations.

Natural points of discharge from the NSFC aquifer system include the Rio Grande, La Cienega springs, and Tesuque, Nambe and Pojoaque Creeks in northern Santa Fe County. Pumping of ground water has resulted in the interception of some of the water that would have otherwise discharged to these streams and springs, thus reducing the magnitude of these discharges.

2.1.2 Mid-Santa Fe County Hydrologic System

2.1.2.1 Geohydrologic Framework. The MSFC hydrologic system is dramatically different from the NSFC and EV aquifer systems, both in geologic structure and lithology. The extent of the MSFC hydrologic system generally coincides with that of the Galisteo Basin, excluding the area of Santa Fe Group in the northern part of the Galisteo Basin (Figure 3). The MSFC system also extends into the Pecos Basin. The MSFC hydrologic system includes part of the Mountain and Homestead Zones as defined by the County Code.

The MSFC hydrologic system is comprised predominantly of sedimentary rocks of Tertiary, Cretaceous, Jurassic, Triassic, and Permian age including sandstone, mudstone, conglomerate, shale, limestone, dolomite, siltstone, and evaporite rocks. Precambrian crystalline rocks, intrusive rocks, and recent alluvial deposits are also present within the area. The MSFC hydrologic system is structurally complex and most of the rock formations are generally not considered aquifers. Figure 10 is a schematic cross section from east to west of the MSFC hydrologic system.

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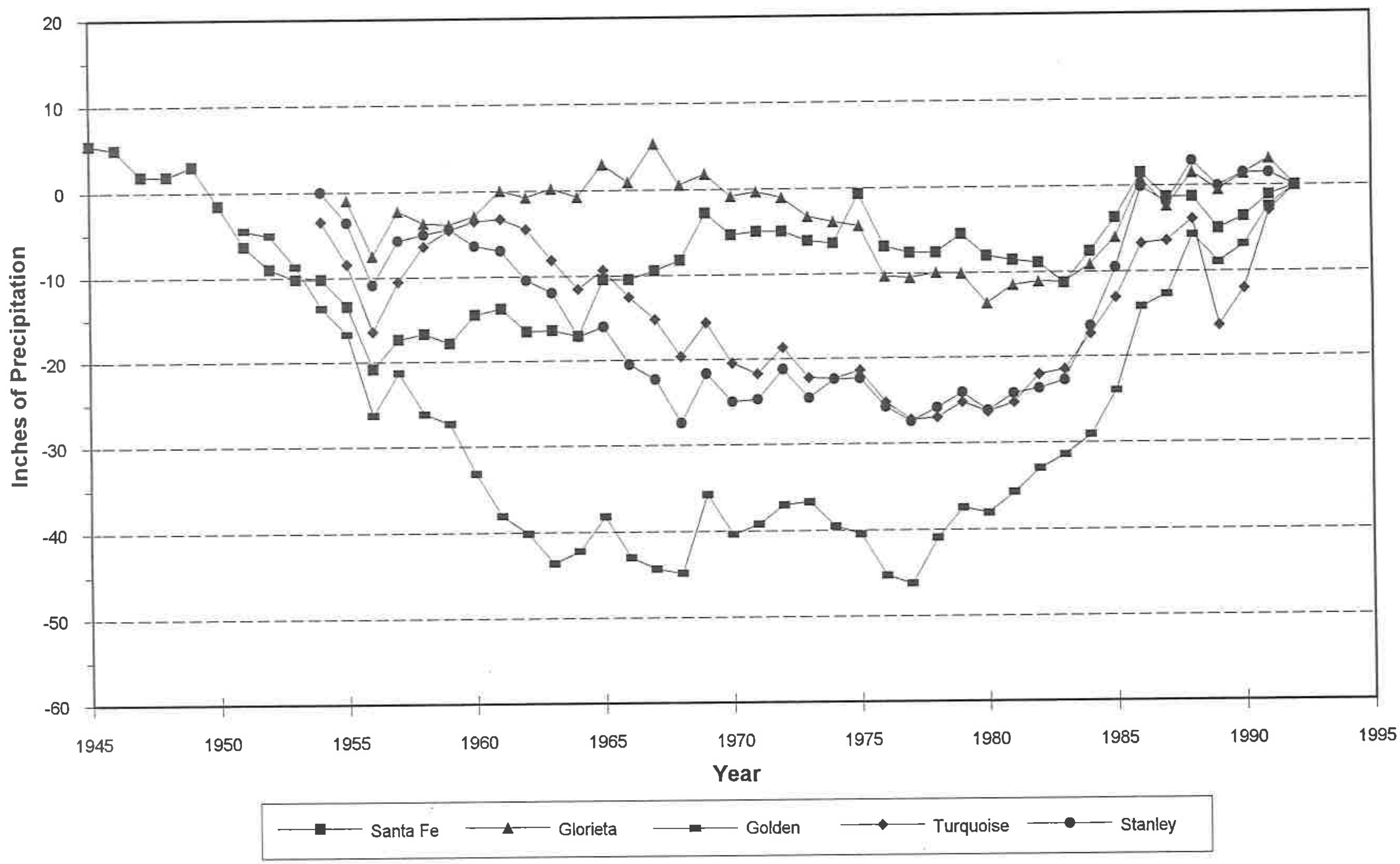

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Cumulative Departure from Mean Annual Precipitation

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Figure 9

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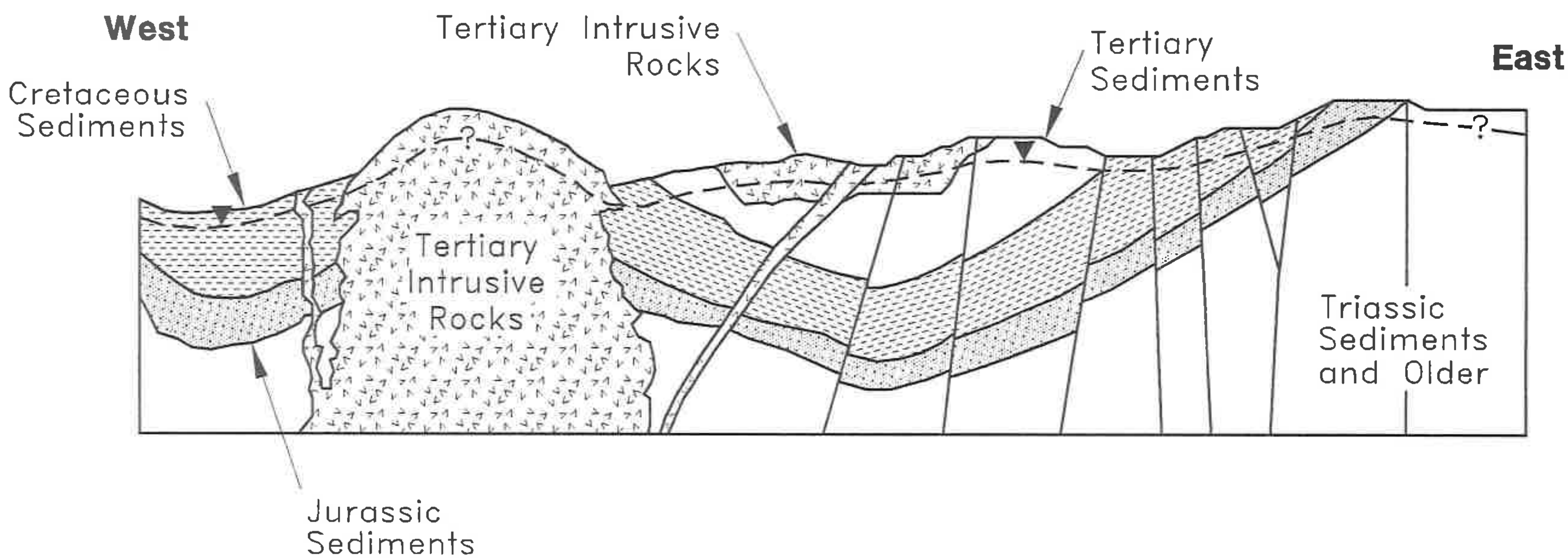

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SANTA FE COUNTY INVENTORY
Schematic East-West Cross Section of the Mid-Santa Fe County Hydrologic System

Figure 10

The MSFC hydrologic system contains, or is part of, several structural features which include, from east to west, the Glorieta Slope (Baltz, 1978), the Galisteo Basin (Kelly, 1979), the Cerrillos Uplift (Disbrow and Stoll, 1957), and the Santo Domingo Basin (Baltz, 1978). The area has been described as an accommodation zone (Cather, 1992) because it is the area where the northern section of the Rio Grande depression becomes offset eastward relative to the southern part of the Rio Grande depression. Although numerous local structural features exist, the general dip of the rocks is toward the west (Read and Andrews, 1944; Stearns, 1953; Disbrow and Stoll, 1957; Budding, 1972).

It is not appropriate to describe the MSFC hydrologic system as an aquifer system because most of the rocks are not considered to be aquifers due to their low permeability and storage capacity. Some of the geologic units do form aquifers, but generally they are thin, entirely bounded laterally by low-permeability rocks that receive little recharge; thus, on a regional scale, they are not considered to be significant water-bearing units.

2.1.2.2 Recharge and Discharge Mechanisms. The recharge mechanisms in the MSFC hydrologic system are primarily the same as for the NSFC aquifer system, but source regions and pathways of recharge are more complex and less well understood. Several areas appear to provide mountain-front recharge to the MSFC hydrologic system, and areal recharge may occur in outcrop areas. Additionally, infiltration of surface water runoff in streams and arroyos recharges bedrock areas of alluvial fill or bedrock aquifers where stream channels pass directly over formation outcrops.

The mountain-front recharge areas for the MSFC hydrologic system are principally the Sangre de Cristo Mountains, Rowe Mesa, and the Ortiz and San Pedro Mountains. In general, both surface- and ground-water flow is westward along the regional dip of the rocks. A small portion of the MSFC surface water flows to the Pecos River, but even in these areas the rocks dip west; thus the regional ground water, especially in the deeper units, may flow mostly toward the west.

Discharge from the aquifers within the MSFC hydrologic system is toward Galisteo Creek and ultimately the Rio Grande.

2.1.3 Estancia Valley Aquifer System

2.1.3.1 Geohydrologic Framework. The EV aquifer system is probably the simplest system in the county to conceptualize in that it may be thought of as a bathtub filled with sand, where the tub itself is capable of collecting recharge and transmitting it to the sand filling the tub. Figure 11 shows a schematic block diagram of the EV aquifer system in Santa Fe County. The structure of the rocks underlying the valley fill is poorly understood and more complex than depicted in Figure 11. The EV is defined as the Estancia Valley surface drainage basin within Santa Fe County, which includes the Southern Basin and Basin Fringe Zones and part of the Homestead Zone defined by the County Code.

The EV aquifer system occurs within a structural trough (Smith, 1957) that lies between the Sandia Uplift (Titus, 1980) to the west and the Glorieta Slope (Baltz, 1978) to the east. The axis of the structural trough is aligned north-south and is probably associated with the same regional deformation that created the Galisteo and Española Basins to the north. Beds of sand, gravel, silt, and clay were deposited in the trough in thicknesses up to 350 feet in the middle of the valley. The formations that either underlie the valley fill or crop out along the margins of the basin include, from oldest to youngest, the Pennsylvanian Madera Limestone, the Permian Abo Formation, Yeso Formation, Glorieta Sandstone, and San Andres Formation, and the Triassic Dockum Group (Figure 11).

The western side of the EV aquifer system, where the Madera Limestone is exposed, is a dip slope off the Sandia Mountains (to the west of the EV). In this area the formations stratigraphically above the Madera Limestone have been stripped away by erosion. As one proceeds eastward through the EV, the east-dipping Madera Limestone becomes covered by an increasing thickness of valley fill. In the vicinity of Moriarity the Glorieta Sandstone crops out or immediately underlies the valley fill. As one proceeds farther eastward, the Abo Formation and then Yeso Formation underlie the valley fill and are exposed as a slightly west-dipping slope off the Glorieta Slope.

The valley fill is generally an excellent aquifer, and where the saturated thickness is sufficient, it will supply water to wells in quantities required for irrigation. The Madera Limestone is inherently

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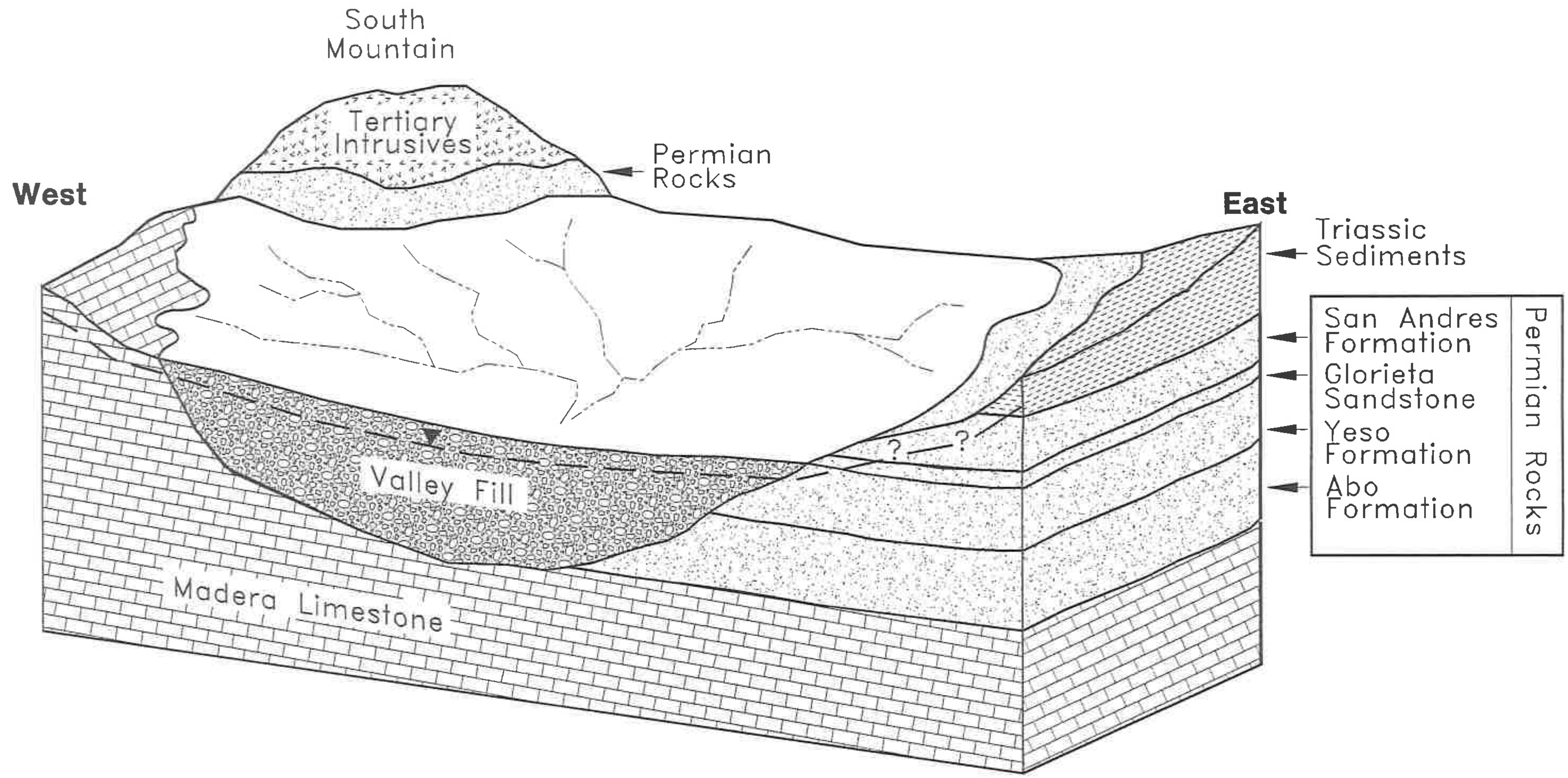

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SANTA FE COUNTY INVENTORY

Schematic Block Diagram of the Estancia Valley Aquifer System

Figure 11

of low permeability at the local scale, except where it has been fractured and subsequently subjected to the formation of solution channels. In some areas where the Madera Limestone crops out, the fracture permeability is sufficiently high that surface water drainage across it essentially disappears (Titus, 1980).

In the area east of Moriarity, the Glorieta Sandstone supplies water to irrigation wells, but a little farther east the aquifer is less fractured and is only capable of producing enough water for domestic or stock wells. This wide range in well production capacities from essentially dry holes (Titus, 1980) to irrigation wells (1,000 to 2,000 gallons per minute) is characteristic of both the Madera Limestone and the Glorieta Sandstone.

The Abo and Yeso Formations are generally of low permeability and do not supply large quantities of water either to wells or to recharging the valley fill. However, in the northwestern portion of the EV near South Mountain, many shallow wells tap the Abo Formation, and typical well yields range from 1 to 20 gpm (Jenkins, 1980a).

2.1.3.2 Recharge Mechanisms. The predominant recharge mechanisms in the Estancia Valley are mountain-front and areal recharge. Mountain-front recharge to the EV occurs from the west and northwest, where rain falls on the South Mountain area. Areal recharge occurs primarily on outcrops of the Madera Limestone in the west and to a lesser extent in central and eastern portions of the EV. Since the valley fill aquifer is in hydraulic communication with underlying and adjacent formations, the water that recharges these formations in outcrop areas also replenishes the valley fill.

The Estancia Basin is a closed ground-water basin, meaning that ground water does not flow out to adjacent areas in significant quantities. If recharge were increased, the water levels would continue to rise (if no pumping was occurring), eventually forming a lake. Therefore, the only discharge of water in storage in the basin is through pumping. Pumping south of the EV aquifer system in the Estancia Basin could deplete the reserves within the EV.

2.2 Hydrologic Characteristics of the Aquifer Systems

This section presents data and information concerning the hydrologic characteristics of each of the aquifer or hydrologic systems. The data used for this evaluation, obtained primarily from the USGS GWSI and the NWIS, were compiled into the databases documented in Appendix C. Where data voids existed, DBS&A supplemented the database with information from various technical reports. All aquifer test data were obtained from technical reports, as the USGS GWSI contained no hydraulic properties data such as transmissivities or storage coefficients.

2.2.1 Potentiometric Surface and Water Level Fluctuations

Plate 2 is a potentiometric surface map of primarily unconfined shallow water throughout Santa Fe County as measured from 1980 to 1989. This map is very similar to Mourant's (1980) map of the county, which was prepared using all available data through 1977. Water level measurements were obtained primarily from the USGS GWSI. Where possible, the latest January measurement in the 1980s was selected as an observation point for the potentiometric contour map. January is selected because water levels are representative of static conditions, since there is no irrigation pumping occurring at this time. However, static conditions near municipal well fields do not necessarily occur during winter months. Where multiple wells were located close to one another, the observation from the shallowest well was selected for contouring.

The USGS data were supplemented with water level observations obtained from hydrogeologic consultant reports submitted to the county. Data from the 1970s were also used to obtain the general shape of the water level contours in areas where few 1980s data were available (e.g., in T13N.R8&9). Appendix D provides a table of the well locations, depths, aquifer codes and water level measurements, dates of measurement, and sources of information used to prepare Plate 2.

Hydrographs for 45 wells throughout Santa Fe County are presented in Appendix E. Data for the hydrographs were obtained from the USGS GWSI. The wells in Appendix E were selected based on the availability of data and their location within the County. A description of the water level fluctuations shown on these hydrographs, and on hydrographs published by Fleming and Finch

(1992), is presented in Subsections 2.2.1.1 through 2.2.1.3 for each of three aquifer/hydrologic systems.

2.2.1.1 Potentiometric Surface in the North Santa Fe County Aquifer System. The potentiometric surface of the NSFC aquifer system is fairly uniform and generally slopes from east to west (Plate 2). The recharge area is evident on the potentiometric map as the region of highest water levels. Precipitation falling on the higher elevations (in the east) recharges the ground water and provides the driving force for ground-water flow throughout the basin. Ground water flows in a westwardly direction and, if not intercepted by wells, ultimately discharges at the Rio Grande, at perennial tributaries to the Rio Grande, or at La Cienega or other springs. A minor component of ground-water flow may discharge to the southwest into the MSFC hydrologic system; however, water level data are insufficient to determine the exact nature of this boundary.

Several features of the potentiometric surface are notable. A flattening of the water table gradient west of Santa Fe in Township 16 North Range 8E, also evident on potentiometric maps of Spiegel and Baldwin (1963) and Mourant (1980), is probably due to several factors. First of all, recharge from the Santa Fe River and associated irrigation ditches, as well as seepage from Arroyo Hondo and from Santa Fe treated municipal sewage water, may increase the saturated thickness of the aquifer in this area, thus causing flattening of the water table surface. This hypothesis is supported by hydrographs for this area, which show a steady rise in water levels since at least 1955. Second, the highly permeable Ancha Formation is saturated in this area. Highly permeable units are characterized by gently sloping water tables. Finally, a structural trough may also contribute to the formation of this feature if the west side of the trough is relatively impermeable.

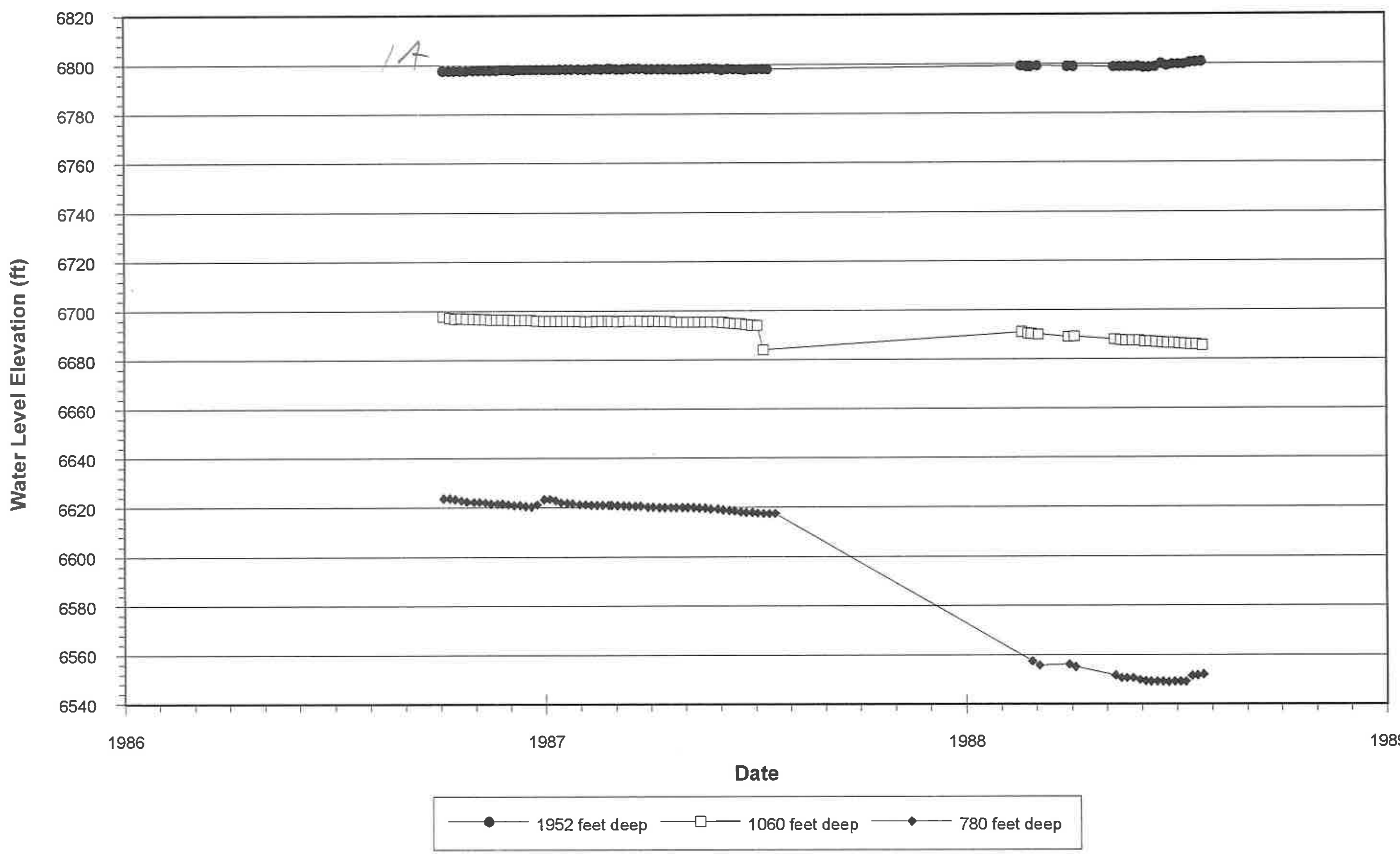
The complex shape of the water table contours in the general vicinity of Santa Fe is probably due to several factors. First of all, more data are available in this area than in other areas of the county, and therefore the water table surface can be delineated in greater detail. Secondly, pumping occurs in this region throughout the year and, therefore, even January measurements probably include the effects of pumping. A third explanation is that the water levels reflect recharge from the Santa Fe River and Arroyo Hondo, which are losing streams in this area.

Perched water in the vicinity of Santa Fe and the Santa Fe River appears to be a local phenomenon. The depth to water in several wells near the river is less than 25 feet, whereas most wells in the Santa Fe area encounter water at depths greater than 200 feet.

Hydrographs for the NSFC aquifer system (Appendix E) show the general variability and trend of water level fluctuations. No large-scale general trends are evident for the NSFC aquifer system from the hydrographs, except that the water level fluctuations appear to be very site-specific. Many of the hydrographs show no decline in water levels from the mid-1950s to 1993, and several show an increase in water levels. Wells that show long-term water level declines are often located near wells that show little or no decline. For instance, water level declines southwest of Santa Fe (T17N.R09E.S27&28) range from 0 feet per year up to 2.6 feet per year. It appears that many wells exhibiting significant water level declines are completed in zones of the aquifer that are being stressed by nearby production wells.

Two well nests, each consisting of three observation wells, in Santa Fe County demonstrate the variability of water level declines with depth. One nest of wells located in T17N.R09E.S35.131 (at depths of 780, 1,060, and 1,952 feet) shows a large difference with depth in water level fluctuations over a 2-year period (1986 to 1988) (see Figure 12). The shallowest well experienced a 75-foot water level decline over the 2-year period, whereas the 1,060-foot-deep well declined only about 15 feet, and the deepest well shows not only no water level decline at all, but perhaps a slight increase. This phenomenon is probably due to the fact that the Santa Fe City wells pump from depths of 600 to 800 feet in the vicinity of this well nest. The presence of clay lenses and the natural stratification of the sediments, coupled with the fact that pumping stresses tend to migrate horizontally even in an isotropic homogeneous medium (Helms, 1987), have limited the effects of pumping in the vertical direction.

The apparent linear rate of water level decline observed in wells that are completed at the same depth interval that the city wells are producing from (Figure 13) can be explained in two ways. One explanation is that the local aquifer system is bounded. It has been suggested that a fault-bounded structural trough (called a graben) exists on the southwest side of Santa Fe (CPI, undated). It is likely that faults around the graben have been sealed somewhat by clay or by mineral precipitates left by circulating ground water. If so, these faults could limit hydrologic



SANTA FE COUNTY INVENTORY
Hydrographs for Well Nest Located in T17N.R09E.S35.131

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Figure 12

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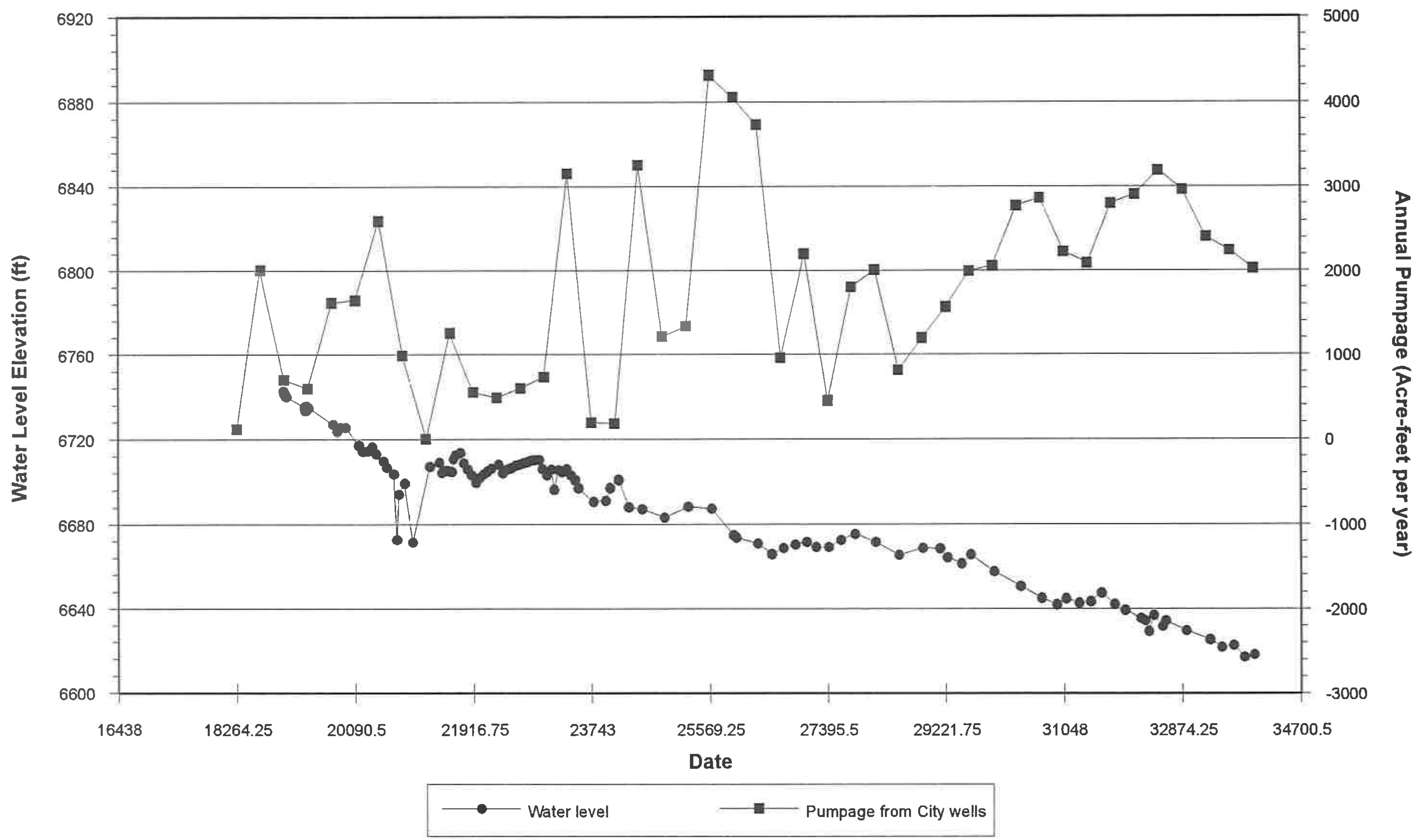

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Annual Pumping from City Wells and Water Level Decline in Well Located in T17N.R09E.S27.441

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Figure 13

communication with adjacent areas and form isolated production zones, thus resulting in linear water level declines with time. A second explanation for the water level decline is increased pumping in the area by new and existing wells. Pumping from the city wells has varied greatly through the past 40 years as shown on Figure 13. Figure 14, a plot through 1993 of cumulative historical pumping from city wells, shows that approximately 50 percent of the total quantity pumped to date has been withdrawn since 1975 (over a period of about 18 years). The previous 50 percent was diverted over a 25-year period. This comparison indicates that the overall pumping rate increased about 30 percent over the previous 18-year period.

The effects on water levels of a bounded aquifer and increased pumping would be additive, so it is not possible assess the amount due to a particular cause. The important point is that water levels may decline at a faster rate in the Santa Fe area than in surrounding areas because of more intensive withdrawals.

The second nest of wells is located in T19N.R07E.S36.3113, in the Buckman well field. The depths of the wells are 346, 824, and 1,863 feet. Water levels for these wells were also measured by the USGS over a 2-year period (1986-88) (see Figure 15). In this case the shallowest well exhibited the least decline (60 feet) and the deepest well showed the greatest decline (130 feet). The Buckman wells, which pump up to 5,000 acre-feet per year (afy) in this area, are approximately 1,200 feet deep, with the screened interval between 700 and 1,200 feet. Contrary to the response observed in the nest of wells near Santa Fe, water level observations from this nest of wells indicate more hydrologic communication in the vertical direction.

Several hydrographs (Appendix E) have shown a rise in water level since the 1950s and 1960s. For example, the hydrograph for well 16N.08E.12.13114 shows a steady rise in water level that is probably due to its proximity to the return flow from the Santa Fe sewage treatment plant and nearby irrigated areas. Water level changes in well 16N.09E.01.31121 show a steady decline of almost 40 feet from 1958 to 1974, and then a rise from 1975 to 1989 of about 70 feet. This rise could be attributed to a possible decrease in pumping or to an increase in recharge. Although the latter is possibly due to an increase in the cumulative departure from mean annual precipitation over the same period (Figure 9), the same substantial increase is not observed in other wells, as would be expected if an increase in recharge were the explanation. A well located

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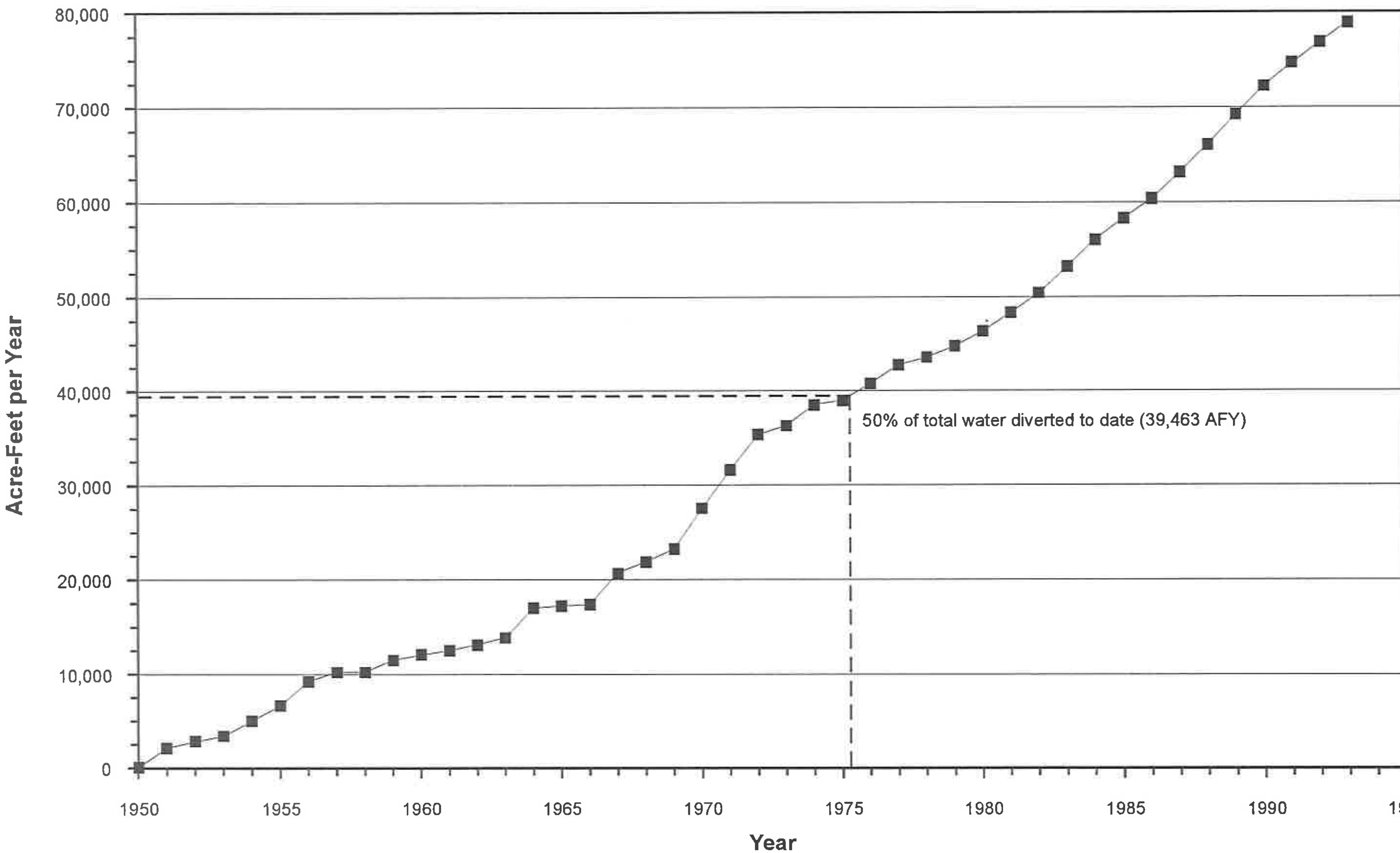

SANTA FE COUNTY INVENTORY

Cumulative Historical Ground Water Withdrawals from the City of Santa Fe Wells

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Figure 14

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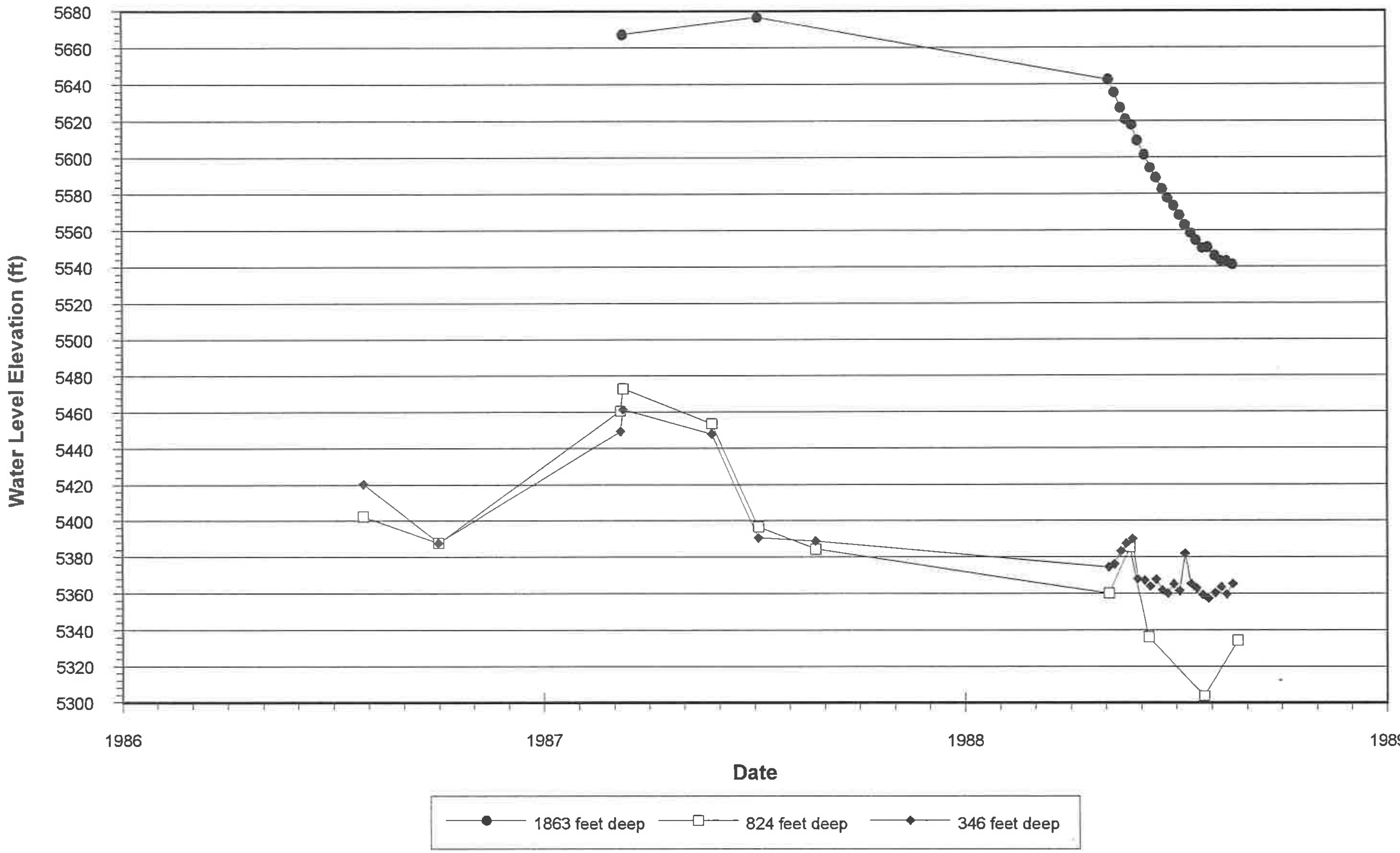

Note: Vertical scale is increased to 160 feet

SANTA FE COUNTY INVENTORY

Hydrographs for Well Nest Located in T19N.R07E.S36.3113

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7-94 JN 3300

Figure 15

in the recharge area (16N.10E.17.42234) in Precambrian granite also shows a rise in water levels from 1975 to 1989, but conceptually, this well should show a more dramatic increase than a well in the Santa Fe Group given its proximity to the recharge area and its completion in an aquifer with a much lower storage coefficient.

Water level declines, as mentioned previously, vary greatly throughout the aquifer system. Plate 3 shows the rate of decline as determined from the hydrographs provided in Appendix E and the hydrographs presented by Fleming and Finch (1992). These declines are discussed in more detail in Section 2.4.

2.2.1.2 Potentiometric Surface of the Mid-Santa Fe County Hydrologic System. The potentiometric surface of the MSFC hydrologic system appears to follow, in general, the topographic slope of the land surface. Ground water appears to flow primarily toward the drainage of Galisteo Creek from all directions within the MSFC hydrologic system. Recharge, as interpreted from the potentiometric map (Plate 2), appears to be attributable to infiltration of precipitation in (1) the Ortiz and other mountains in the southwest portion of the hydrologic system and (2) the eastern portion of the county.

Four hydrographs for the MSFC hydrologic system (Appendix E) were prepared from the best available data in the USGS GWSI. The period of record begins in the 1970s and continues to 1993. Two of the hydrographs show a decline, although in only one does there appear to be a steady decline, with a total decline of about 20 feet from 1972 to 1993. This well is located in T14N.R10E.S34.42241, 5 miles east of Galisteo. The other hydrographs show very little fluctuation over the same period.

2.2.1.3 Potentiometric Surface of the Estancia Valley Aquifer System. As with the MSFC hydrologic system, the potentiometric surface in the EV aquifer system also appears to follow the topographic surface. The water table is sloping to the south and east from South Mountain and also appears to be sloping to the west from the eastern portion of the basin. In the area of valley fill the water table is essentially flat. The potentiometric surface in the Madera Limestone on the west side of the basin near Edgewood is also relatively flat (due to high transmissivity) and is several hundred feet higher than the water table in the valley fill to the east.

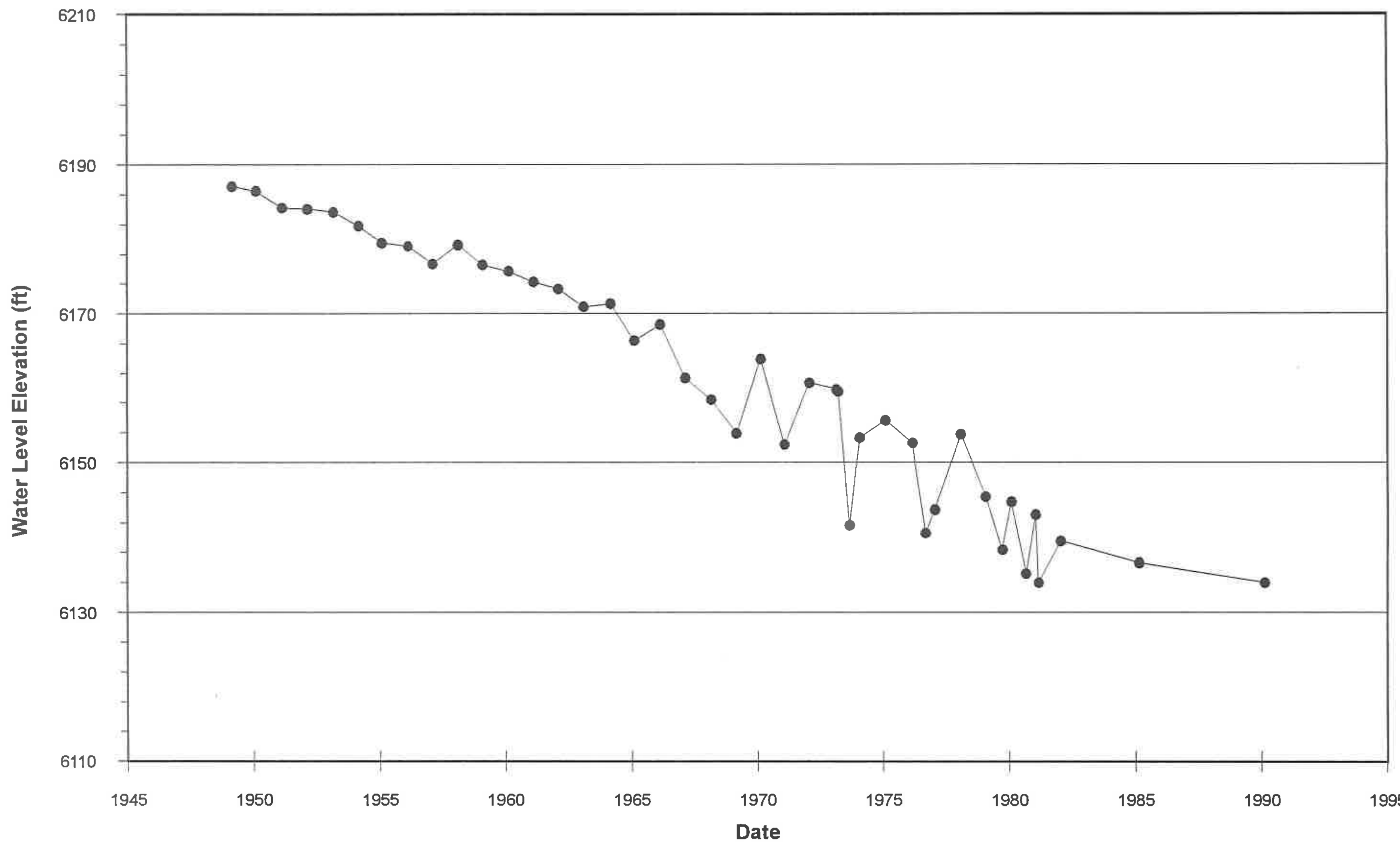
Hydrographs for wells in the valley fill show a linear, steady rate of decline, an indication that ground-water mining is occurring in the Estancia Valley. Figure 16 is an example of one of the hydrographs; others are in Appendix E. Since 1950 water levels in the EV aquifer system have been declining at a relatively uniform rate of about 1.4 feet per year, attributable primarily to agricultural irrigation.

In the Madera Limestone to the west of the valley fill, interpretation of the water level fluctuations is more difficult. A hydrograph from a well in this area (10N.07E.23.21243, Appendix E) shows water levels dropping at a fairly uniform rate of 1 foot per year from 1948 to 1968. However, from 1968 until 1983 (the last year in the record) the water level fluctuates by about 10 feet, but overall no trend is observed. One explanation for the fluctuations observed in this hydrograph could be changes in recharge due to precipitation. The cumulative departure from mean annual precipitation for the Stanley Station (Figure 9; Appendix B) correlates well with this hydrograph. On the other hand, Fleming and Finch (1992) present a hydrograph in the Edgewood area, in the same section (T10N.R07E.S23) as the well 10N.07E.23.21243 hydrograph, that appears to be declining at a uniform rate of about 0.9 feet per year (ft/yr) from 1948 to 1993. However, only three water level measurements are available from 1963 to 1993, so it is difficult to determine the accuracy of the observed trend from this hydrograph.

Hydrographs of wells to the north and east of the valley fill show no decline in water levels from the early 1970s to 1993, and one shows a rise.

2.2.2 Water Quality

An evaluation of water quality throughout the county is important for land use planning and overall management of the water resource. The water quality of aquifers is influenced both by natural hydrogeologic conditions and by human activities. DBS&A has assessed the general water quality of the aquifer systems using data available in the USGS NWIS. Areas of existing and potential ground-water contamination have also been addressed by DBS&A. The 25 water samples collected by Fleming and Finch (1992) throughout the county provided additional water quality information. The water quality of each of the aquifer/hydrologic systems in Santa Fe County is discussed in Sections 2.2.1.1 through 2.2.1.3.



SANTA FE COUNTY INVENTORY

Hydrographs for Well Located in T10N.R09E.S05.1113

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Figure 16

Plate 4 is a map of electrical conductivity measurements of ground water obtained from the USGS NWIS for the period from 1948 to 1986. The electrical conductivity of water is an indication of the total amount of dissolved solids (salinity) in the water. Electrical conductivity (EC) measurements are inexpensive to obtain, and therefore the distribution and number of measurements conducted tend to be greater than those made for a specific chemical analysis such as total dissolved solids (TDS).

Plate 5 shows the general chemical quality of water in the county using Stiff diagrams. A list of the wells and the chemical concentrations used for preparing this plate is presented in Appendix F. The shapes of the Stiff diagrams are used as a visual representation of the chemical constituents of ground water.

2.2.2.1 Water Quality of the North Santa Fe County Aquifer System. Overall, ground water in the NSFC aquifer system is of high quality and suitable for domestic purposes virtually everywhere. Locally, the water quality can be variable, due to geologic conditions and minor ground-water contamination.

As shown on Plate 4, the EC of the water in the NSFC aquifer system is relatively low, ranging from 150 to 800 micromhos per centimeter (µmhos/cm). These values correspond to TDS values of 90 to 500 parts per million (ppm), which is well below the New Mexico Water Quality Control Commission Regulations' numerical standard for TDS of 1,000 ppm.

Figure 17 is a graph of electrical conductivity versus TDS for ground water in the Santa Fe Group aquifers. A curve fit to this data yields a linear relationship of TDS = 0.62 x EC + 12 ppm. Water quality in the Precambrian rocks in the eastern part of the NSFC aquifer system is very similar to that in the Santa Fe Group, with electrical conductivity varying from about 200 to 900 µmhos/cm. Figure 18 shows the relationship between TDS and EC for ground water in the Precambrian rocks. This relationship for the Precambrian rocks can be expressed as TDS = 0.71 x EC − 55 ppm.

With few exceptions, the predominant chemical species in the eastern portion of NSFC are calcium and bicarbonate, which result in water that is very hard. However, in the western portion

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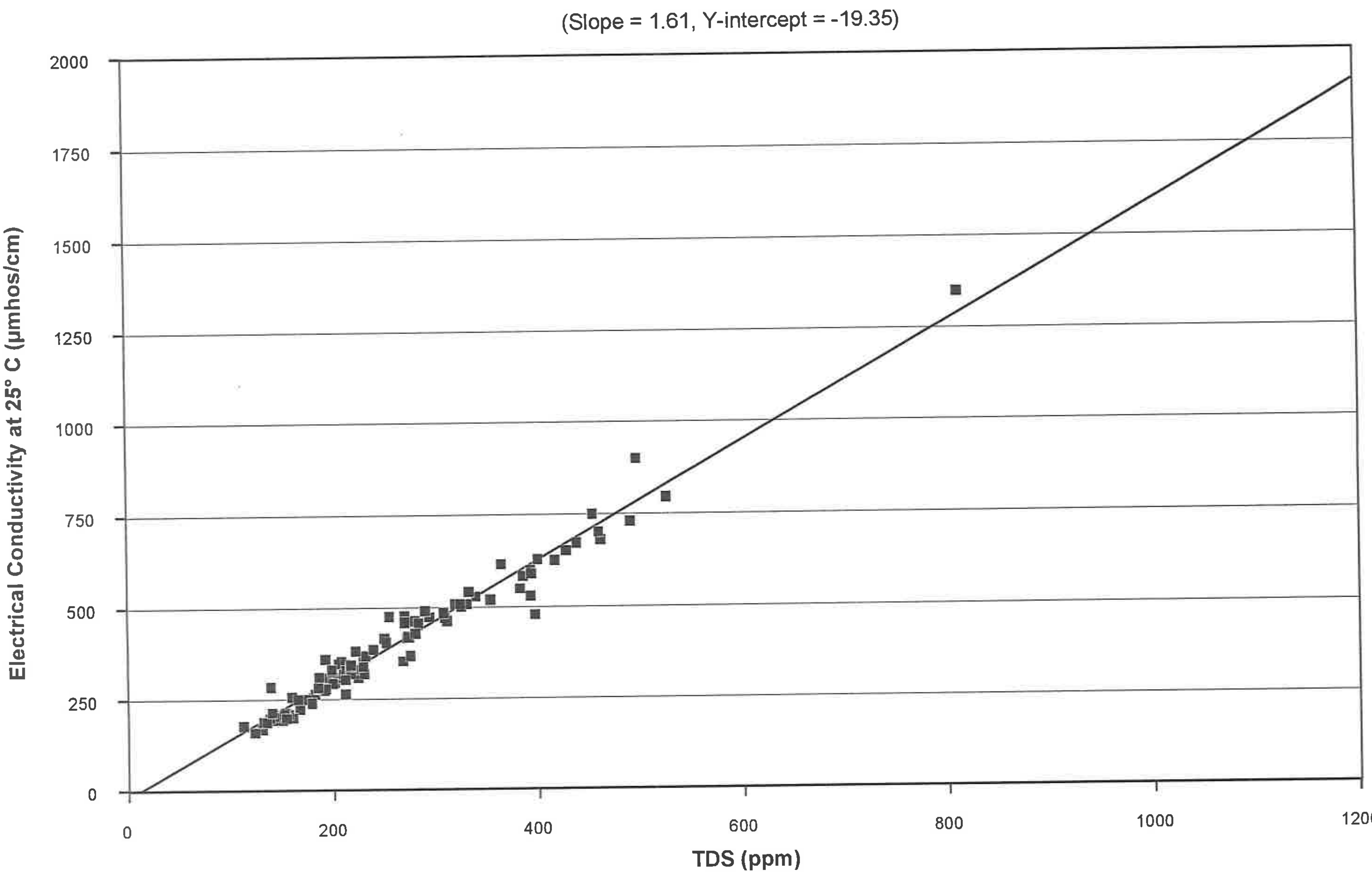

SANTA FE COUNTY INVENTORY

Electrical Conductivity versus TDS in Ground Water from the Santa Fe Group

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7-94
JN 3300

Figure 17

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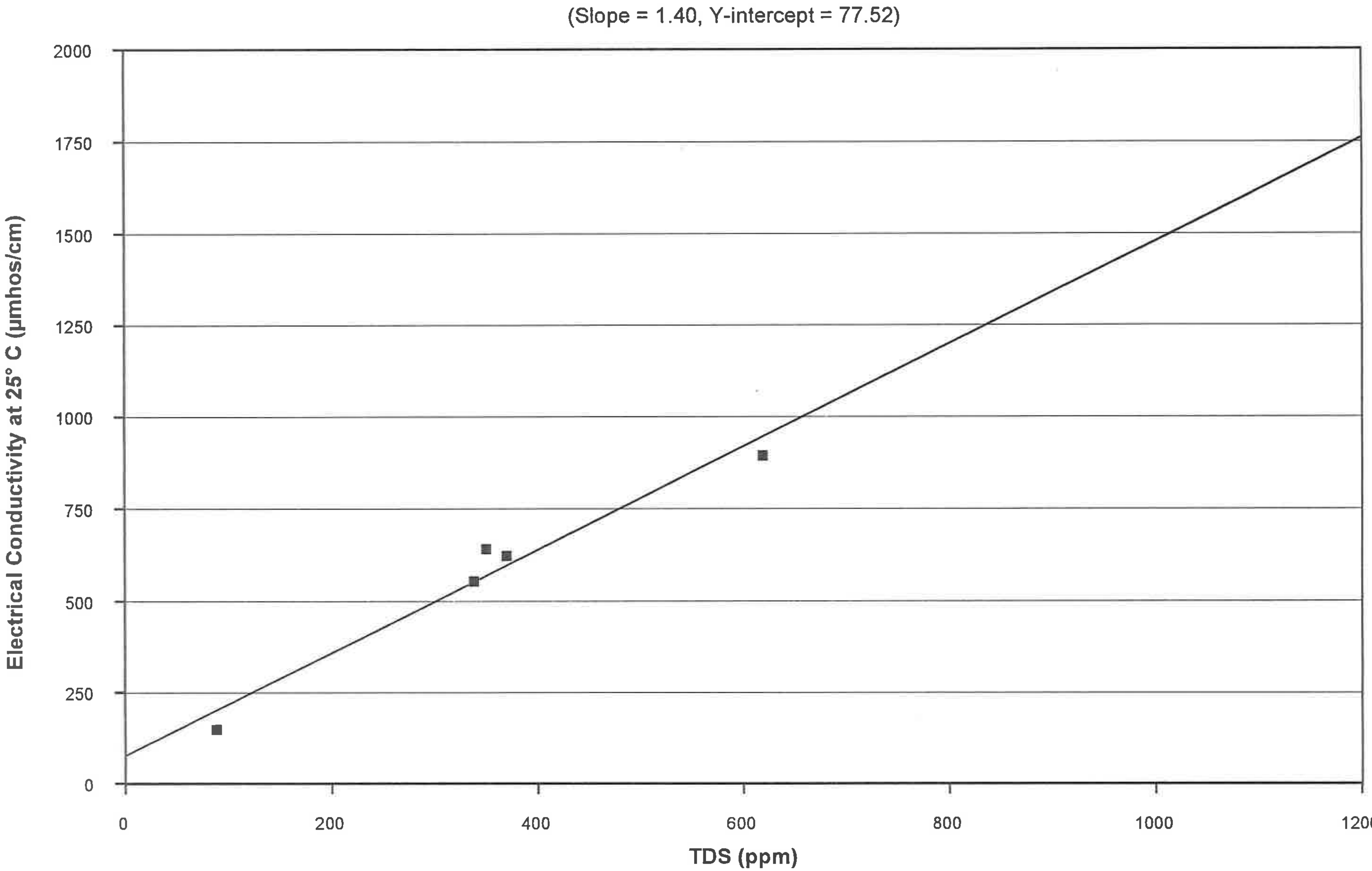

SANTA FE COUNTY INVENTORY

Electrical Conductivity versus TDS in Ground Water from the Precambrian Rocks

DANIEL B. STEPHENS & ASSOCIATES, INC.

7-94 JN 3300

Figure 18

of the NSFC aquifer system, near the Buckman wells, the water is much softer as a result of sodium replacing calcium as the predominant cation. Several wells have significant concentrations of iron, probably due to corrosion of the well casing or reducing conditions in the ground water.

Fleming and Finch (1992) report gross alpha and gross beta radioactivity in a Nambe well that were eight and two times, respectively, the Federal standards. They also report elevated barium concentrations in the Torreon and Wood wells within the city limits of Santa Fe.

It is likely that the water at greater depths than existing wells will be of relatively poor quality, limiting or preventing its use for human consumption without treatment. Hart (1989) reported increasing salinity with depth at the Buckman well field. In addition, deep-penetrating electrical studies indicated areas of low electrical resistivity at depth (Biehler et al., 1991). Low resistivity may be due to several factors, but in an area of known volcanic and geothermal activity, one of the more likely explanations is hot geothermal waters. Geothermal waters are often high in total dissolved solids and sometimes high in arsenic and fluoride. The use of certain wells in the Los Alamos well field located west of the Rio Grande in Santa Fe County has been curtailed because of high arsenic levels (Purtyman, 1980).

Existing ground-water contamination sites identified by the New Mexico Environment Department (NMED) are shown on Plate 6. Table 1 is a list of the site locations, sources, and types of contamination. As shown on Plate 6, the predominant contamination problems in the NSFC are nitrate contamination from seepage and hydrocarbon contamination from underground gasoline storage tanks. Not surprisingly, areas with the largest population densities, that is, those around Pojoaque and Santa Fe, appear to have the greatest number of ground-water contamination problems. Several areas have poor water quality due to reducing conditions in the aquifer (labeled as ANOX on Plate 6), where insufficient oxygen is present. This may or may not be from natural conditions, but generally, reducing conditions occur where the depth to water is very shallow (less than 30 feet) and are exacerbated by the use of septic tanks and leach fields for sewage disposal.

The potential for ground-water contamination is highest primarily in the populated areas. From this viewpoint, it is fortunate that the NSFC aquifer system has relatively few industrial facilities

Table 1. Santa Fe County Ground-Water Contamination Inventory
Page 1 of 2

DBS&A Case No.	Case Name	Town	Location (T.R.S)	Contaminant(s)[1]	Source Type[2]
1	Arroyo Hondo	Santa Fe	16N.10E.07.3	Gasoline, Mn, Fe	AGST
2	Arroyo Hondo Fina	Santa Fe	16N.10E.07	Solvents	Plant
3	Bobcat Bite	Santa Fe	16N.10E.29	NO_3	STP
4	Capitol 66	Santa Fe	17N.09E.24	Gasoline	LUST
5	Exxon W Alameda	Santa Fe	17N.09E.24	Gasoline	LUST
6	Galisteo & Water Manhole	Santa Fe	17N.09E.24	Gasoline	LUST
7	Gold Fields Mining Corp	Rural	13N.08E.19	CN, Co, NO_3	MNG Mill AU
8	Nambe Well	Nambe	19N.09E.03	Radionuclides, F, Mn	UNK
9	Nifty Cafe	Santa Fe	16N.10E.07	NO_3	STP
10	NMSHTD Pojoaque Weigh Stn	Pojoaque	19N.09E.17	NO_3	STP
11	Oppenheimer Well	Santa Fe	17N.09E.24	NO_3	NP ST
12	Pkg Building	Santa Fe	17N.09E.24	Gasoline	LUST
13	PNM Santa Fe Station	Santa Fe	17N.09E.26	Solvents	Plant PWR
14	Rodriquez Well	Santa Fe	17N.09E.24	Ba	NP ST
15	Rubin Well	Santa Fe	17N.10E.30	Solvents, BTEX	Plant
16	San Pedro Mine	Golden	12N.07E.27	Cd, Fe, Pb, Mn, TDS	MNG Mine AU
17	Santa Fe STP	Santa Fe	16N.08E.17	NO_3	POTW
18	Santana Well	Santa Fe	16N.09E.03	Zn	UNK
19	Santa Fe Well	Santa Fe	17N.09E.26.133	Gasoline	Plant
20	Torreon Well	Santa Fe	17N.09E.22.442	NO_3, Ba	NP ST
21	Speedy's	Santa Fe	17N.09E.26	Gasoline	LUST
22	Cerrillos & Guadalupe	Santa Fe	17N.09E.24	Gasoline	Plant
23	Pegasus Mine	Rural	13N.08E.19	SO_4, pH	MNG Mill AU
24	Santa Fe West MHP	Santa Fe	17N.09E.32.442	NO_3	UNK
25	Frank Ortiz Park Landfill	Santa Fe	17N.09E.22	Metals	Landfill
26	Alto Well (SDC)	Santa Fe	17N.09E.23	EDB	UNK
27	Above Agua Fria	Santa Fe	17N.09E.32	NO_3	NP ST
28	Agua Fria	Agua Fria	17N.09E.32	NO_3	NP ST
29	Agua Fria Area 6/17/91	Agua Fria	17N.09E.32	NO_3	NP ST
30	Canoncito MDWCA Atrazine	Canoncito	15N.10E.12	Pesticides	NP Pest
31	Cuyamungue	Cuyamungue	19N.09E.20	ANOX	NP ST

Source: New Mexico Environment Department

[1] Mn = Manganese
Fe = Iron
CN = Cyanide
Co = Cobalt
NO_3 = Nitrate
F = Fluoride
Cd = Cadmium
Pb = Lead
Ba = Barium
BTEX = Benzene, toluene, ethylbenzene, and xylene
ANOX = Reducing conditions
EDB = Ethylene dibromide

[2] AGST = Aboveground storage tank
LUST = Leaking underground storage tank
MNG Mill AU = Gold mining mill
MNG Mine AU = Gold mine
NP Pest = Nonpoint-source pesticides
NP ST = Nonpoint-source septic tank
Plant = Chemical, processing, etc. plant
Plant PWR = Power plant
POTW = Publicly owned treatment works
STP = Point-source septic tank
UNK = Source unknown

Table 1. Santa Fe County Ground-Water Contamination Inventory
Page 2 of 2

DBS&A Case No.	Case Name	Town	Location (T.R.S)	Contaminant(s)[1]	Source Type[2]
32	Cuyamungue	Cuyamungue	19N.09E.21	HC	UNK
33	El Rancho	El Rancho	19N.08E.09	ANOX	NP ST
34	El Rancho	El Rancho	19N.08E.09	NO_3	NP ST
35	Girls Ranch Atrazine	Glorietta	16N.11E.28	Pesticides	NP Pest
36	Glorieta MDWCA	Glorietta	16N.11E.22	NO_3	NP ST
37	Glorieta MDWCA Atrazine	Glorietta	16N.11E.27	Pesticides	NP Pest
38	Golden Area I	Golden	12N.07E.17	NO_3, TDS, SO_4	NP ST
39	Golden Area II	Golden	12N.07E.17	Fe, Al, NO_3, TDS, SO_4	NP ST
40	Jacona	Jacona	19N.08E.12	ANOX	NP ST
41	Lamy Junction NO_3	Lamy	14N.10E.05	NO_3, Gasoline, EDC	NP ST/LUST
42	Lamy MDWCA Atrazine	Lamy	15N.10E.34	Pesticides	NP Pest
43	Le Fevre well Atrazine	Lamy	15N.10E.34	Pesticides	NP Pest
44	Nambe Area	Nambe	19N.09E.09	NO_3	NP ST
45	Pojoaque	Pojoaque	19N.09E.08	ANOX	NP ST
46	Pojoaque WF	Pojoaque	19N.09E.08	ANOX	NP ST
47	Quartales	Quartales	20N.09E.05	ANOX	NP ST
48	Quartales	Quartales	20N.09E.05	NO_3	NP ST
49	Rancheros de Santa Fe	Santa Fe	15N.10E.10	NO_3	NP ST
50	Richardson Well	Agua Fria	17N.09E.32	NO_3	NP ST
51	Roadrunner Cafe	Pojoaque	19N.09E.07	Gasoline	LUST
52	Tesuque Area	Tesuque	18N.09E.25	NO_3	NP ST
53	Vista Redonda	Santa Fe	17N.09E.13	NO_3	NP ST
54	NMSHTD Cuyamungue	Cuyamungue	19N.09E.20	Gasoline	LUST
55	Sam's Texaco	Pojoaque	19N.09E.08	Gasoline	LUST
56	Wood Well	Santa Fe	17N.09E.24	NO_3, TDS	NP ST
57	White Lakes	White Lakes	11N.11E.09	Gasoline, NO_3	LUST
58	Santa Fe WWTP	Santa Fe	16N.08E.10	NO_3	POTW
59	Downs at Santa Fe	Santa Fe	16N.08E.27	NO_3	POTW
60	Riverside Mob. Home Pk.	Tesuque	18N.09E.25	NO_3	POTW
61	Edgewood Wells	Edgewood	10N.07E.16.444	MTBE	UNK

Source: New Mexico Environment Department

[1] Mn = Manganese
Fe = Iron
CN = Cyanide
Co = Cobalt
NO_3 = Nitrate
F = Fluoride
Cd = Cadmium
Pb = Lead
Ba = Barium
BTEX = Benzene, toluene, ethylbenzene, and xylene
ANOX = Reducing conditions
EDB = Ethylene dibromide

[2] AGST = Aboveground storage tank
LUST = Leaking underground storage tank
MNG Mill AU = Gold mining mill
MNG Mine AU = Gold mine
NP Pest = Nonpoint-source pesticides
NP ST = Nonpoint-source septic tank
Plant = Chemical, processing, etc. plant
Plant PWR = Power plant
POTW = Publicly owned treatment works
STP = Point-source septic tank
UNK = Source unknown

that may have generated toxic wastes such as solvents. Where the soil between the land surface and the ground water is very permeable or fractured and the depth to water is shallow, the potential for contaminants migrating to ground water is enhanced.

Ross (1992) attempted to map the potential for ground-water contamination in Santa Fe County using a system called DRASTIC (Aller et al., 1987). DRASTIC uses the depth to water, recharge, aquifer media, soil media, topography, vadose zone media, and the hydraulic conductivity of the aquifer to evaluate the potential for ground water to be contaminated. DBS&A considered presenting the DRASTIC map of Santa Fe County as developed by Ross (1992); however, we found the results of the DRASTIC interpretation to be contrary to common sense. For instance, the DRASTIC map showed the recharge area for the NSFC aquifer system in the Precambrian fractured rocks to have a lower potential for ground-water contamination than the western area where the water table is over 1,000 feet deep.

Because all ground water has the potential to become contaminated given an adequate source of pollution, no areas are immune. A major concern for county land-use planning is the potential contamination from developments that rely on septic tanks and individual domestic wells. All proposed subdivisions need to be evaluated on an individual basis as to the potential for attenuation and biodegradation of septic tank waste to occur. A major problem from septic tanks is nitrate contamination which occurs in oxidizing conditions (generally where depth to water is greater than 30 feet) (McQuillan, 1994). Nitrate is a concern because in high concentrations it can be toxic to infants. Nitrate contamination has been detected in the Española area in northern Santa Fe County (McQuillan, 1994) in an area where the depth to water is greater than 200 feet. Where reducing conditions occur, iron, manganese, and other metals concentrations are often elevated in ground water.

2.2.2.2 Water Quality of the Mid-Santa Fe County Hydrologic System. The water quality detected in wells in the MSFC hydrologic system is highly variable but generally poor, as can be expected from the types of aquifer material present. Measurements of EC vary from 900 to 5,500 μmhos/cm (Plate 4). These EC measurements correspond to a TDS ranging from 700 to 4,000 ppm (using the average relationship of TDS and EC for the entire County). Much of the ground water exceeds the state standard for TDS of 1000 ppm.

The plots of the Stiff diagrams on Plate 4 shows that the water chemistry in the eastern portion of the basin is similar to the chemistry observed in NSFC aquifer system; that is, the chemical nature of the water is predominantly calcium bicarbonate. However, in the western portion of the MSFC hydrologic system, sulfate replaces bicarbonate as the predominant anion. Sulfide mineralization in the Ortiz Mountains and Cerrillos Hills, sulfides in the Mancos Shale, and coal deposits found near Madrid are likely causes of the elevated concentrations of sulfate in this area. High concentrations of iron have also been detected in wells in the western area of the MSFC; these high concentrations may be natural or may be due to corrosion of well casings from reducing conditions in the aquifer.

Existing ground-water contamination sites in the MSFC hydrologic system are shown on Plate 6. Nitrate contamination from sewage effluent has occurred in the vicinity of Glorieta and Lamy. Contamination from gasoline underground storage tanks has also occurred near Lamy. Contamination from mining in the county has occurred at the Ortiz mine southeast of Cerrillos and the San Pedro Mine near Golden. Cyanide, cobalt, and sulfate have been detected in observation wells downgradient from the cyanide leaching operation, and acid drainage is occurring from the mine overburden stockpile.

2.2.2.3 Water Quality of the Estancia Valley Aquifer System. Water quality is marginal for domestic use in much of the EV aquifer system, based on the EC measurements illustrated on Plate 4. The EC in the EV varies from about 500 μmhos/cm in the northwestern portion (recharge area) to 3,800 μmhos/cm in the central area where wells are completed in the Glorieta Sandstone. Based on water samples from wells completed in the Madera Limestone, Glorieta Sandstone, and alluvium (Figures 19, 20, and 21, respectively), the relationship between TDS and EC in the EV aquifer system is expressed by the following equation: $TDS = 0.75\ EC - 100$ ppm. Therefore, TDS varies from about 300 ppm to 2750 ppm in the EV.

The chemical quality of the ground water in the EV, as elsewhere in the county, appears to be controlled predominantly by lithology. The water quality as illustrated by the Stiff diagrams on Plate 4 varies from calcium carbonate in the west, where wells are completed in the Madera Limestone and valley fill, to calcium sulfate in the central area where wells are completed in the Glorieta Sandstone. Sodium is a predominant cation in the eastern portion of the basin.

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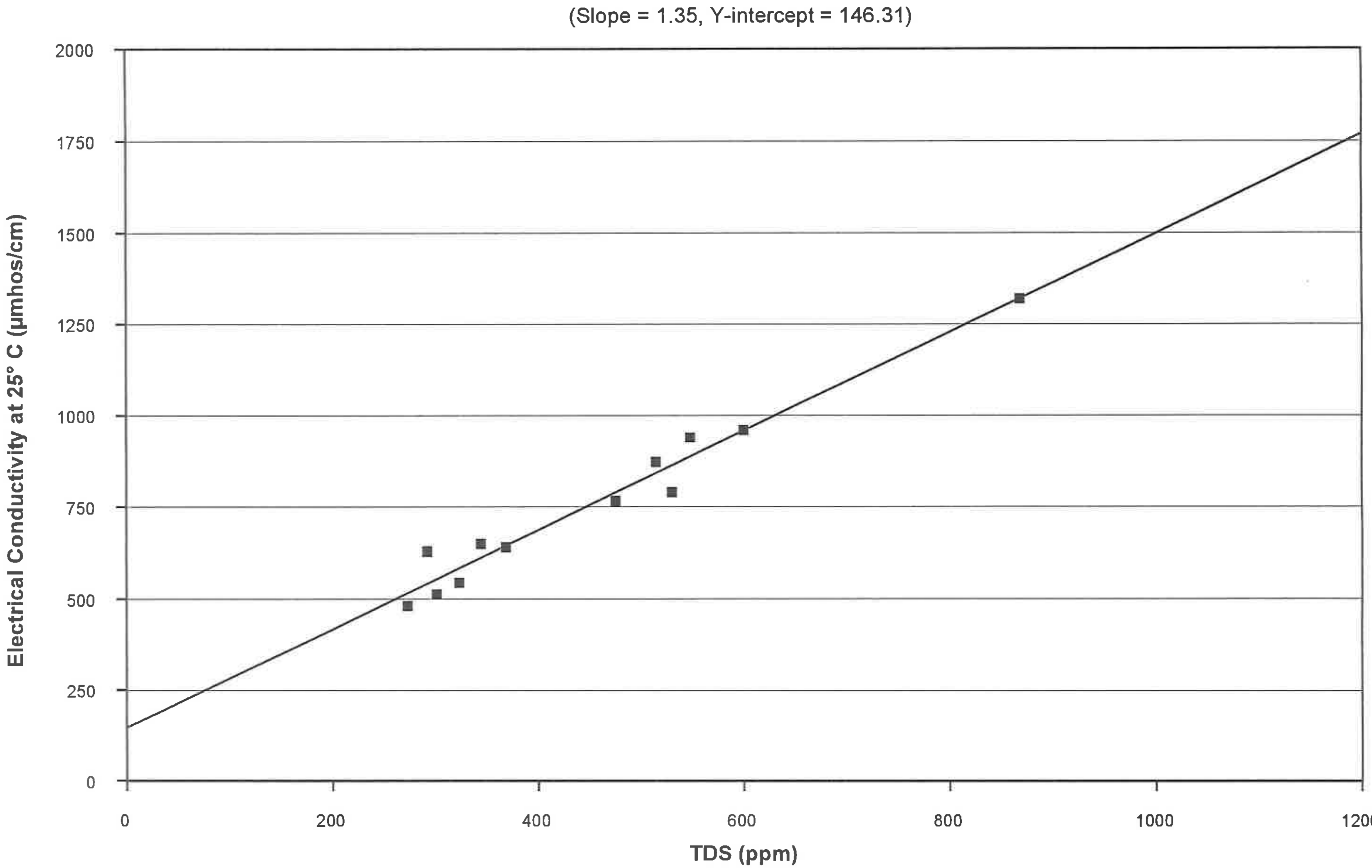

SANTA FE COUNTY INVENTORY

Electrical Conductivity versus TDS in Ground Water from the Madera Limestone

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7-94 JN 3300

Figure 19

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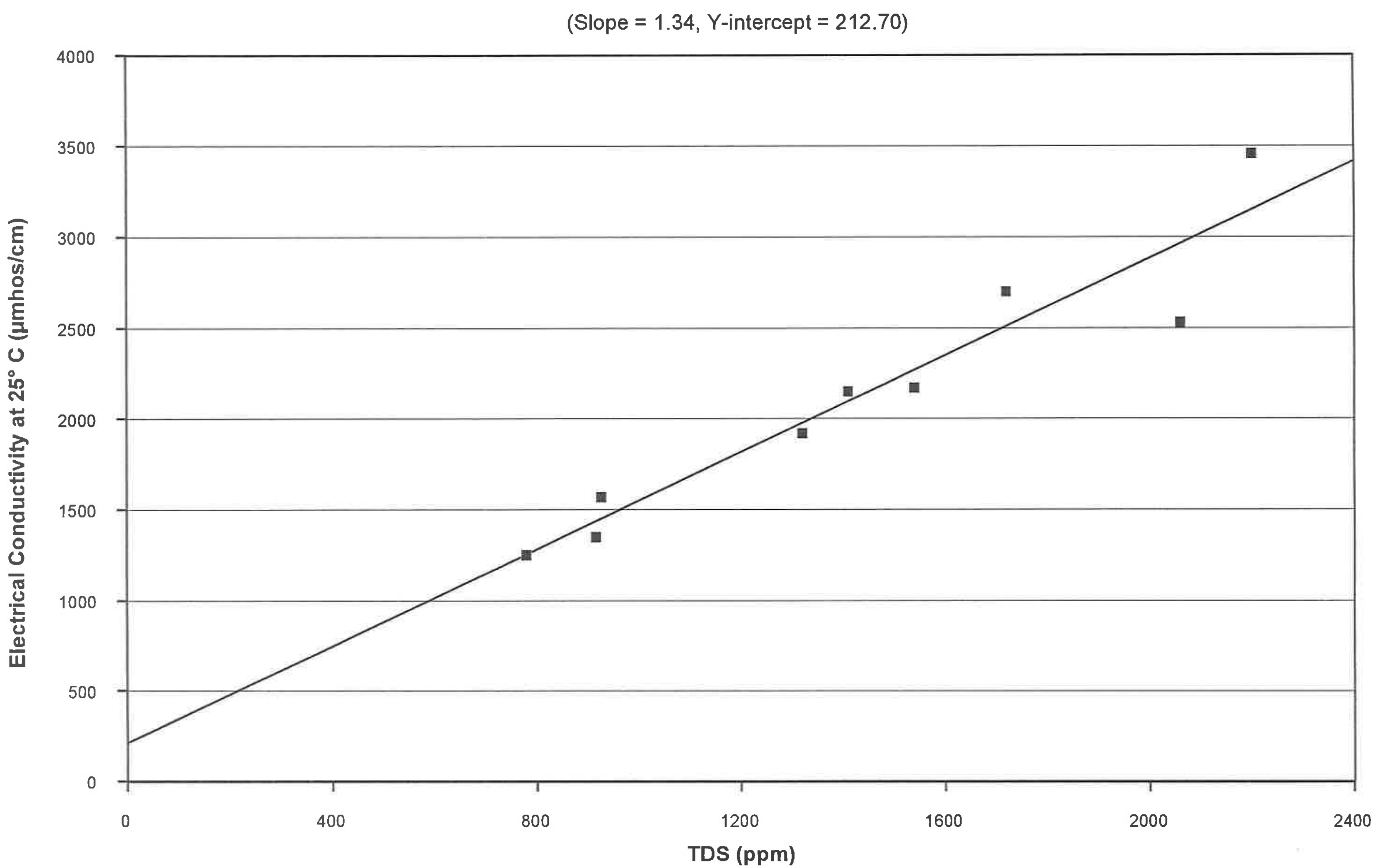

Note: Both X scale and Y scale are doubled

SANTA FE COUNTY INVENTORY

Electrical Conductivity versus TDS in Ground Water from the Glorieta Sandstone

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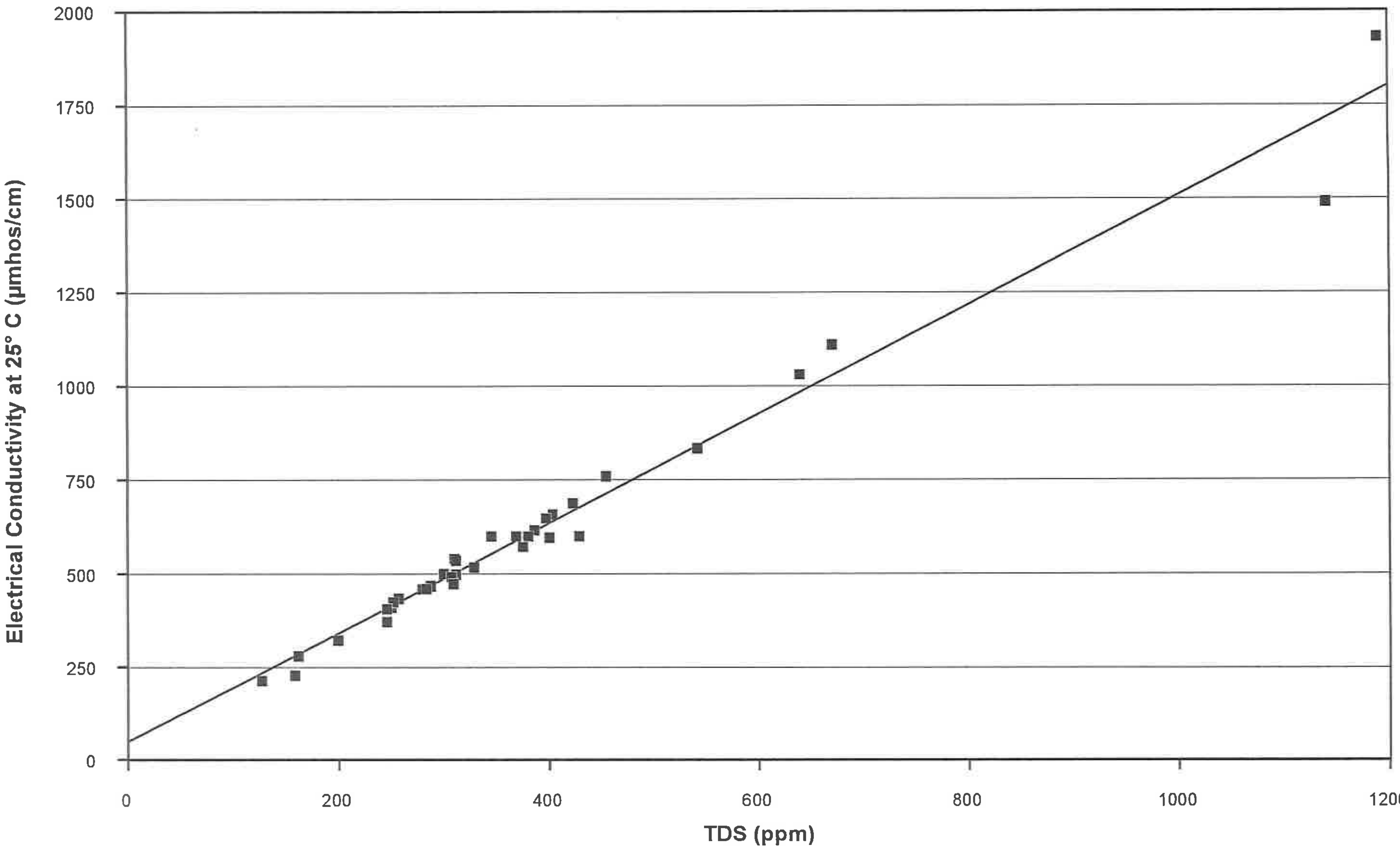
7-94 JN 3300

Figure 20

J/3300/3300W17...

(Slope = 1.46, Y-intercept = 48.54)



SANTA FE COUNTY INVENTORY

Electrical Conductivity versus TDS in Ground Water from the Alluvium

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Figure 21

Few ground-water contamination sites have been detected in the EV (Plate 6). The only sites identified in the NMED inventory are a gasoline contamination site near White Lakes and wells impacted by methyl tertiary-butyl ether (MTBE, an additive to gasoline) in the Edgewood area. Tom Leck of the NMED Underground Storage Tank Bureau detected MTBE in about 12 wells north and northeast of Edgewood. Concentrations are well below the 100-ppm standard and vary between 2 and 7 parts per billion (ppb) (Leck, 1994). Given that irrigation has been the primary economic activity in the EV aquifer system, the potential for ground-water contamination from pesticides and nitrate fertilizers also exists. DBS&A does not know if ground water in the area has been tested for the presence of nitrate and pesticides.

2.2.3 Aquifer Parameters

The transmissivity (T) and storage coefficient (S) are aquifer parameters used to predict the response of aquifers to stresses such as pumping. Transmissivity embodies both the permeability and thickness of the aquifer; it is directly proportional to aquifer thickness. In general, if the transmissivity is high, the impact of pumping will cause smaller drawdown directly within the cone of depression in comparison to an aquifer with a low transmissivity (see Appendix A). The storage coefficient is a parameter which indicates the volume of water that can be obtained from a given volume of the aquifer as the water level is lowered. A low storage coefficient will result in a more rapid propagation of the cone of depression throughout the aquifer than would a higher value. When evaluating the potential impact of pumping that a new well may have on neighboring wells, knowledge of these aquifer parameters is essential.

DBS&A reviewed existing water availability studies submitted to the county by consultants and summarized the available aquifer parameter data. Plate 7 illustrates the data obtained from these reports; a summary of the reported aquifer parameters is provided in Appendix G. DBS&A made no attempt to verify the accuracy of the reported aquifer parameters, nor to normalize the transmissivity to the full saturated thickness at a given location. For example, If an aquifer test was conducted on a shallow (partially penetrating) well for a short time frame, the calculated transmissivity may underestimate the transmissivity of the entire aquifer thickness.

Another valuable source of aquifer parameter data was obtained from reports describing numerical models constructed for the Santa Fe area. The aquifer parameter data are discussed in Sections 2.2.3.1 through 2.2.3.3.

2.2.3.1 Aquifer Parameter Data for the NSFC Aquifer System. Aquifer transmissivity of the Santa Fe Group as found from aquifer tests varies from 0.4 to 82,000 gallons per day per foot (gpd/ft). A similar range is observed for Precambrian rocks in the NSFC aquifer system, which have reported transmissivity estimates ranging from 15 to 53,000 gpd/ft, although most transmissivity values are less than about 500 gpd/ft. The high value of 53,000 gpd/ft was estimated from a well adjacent to Arroyo Hondo, which is in a highly fractured zone.

Transmissivity values for the Santa Fe Group used by McAda and Wasiolek (1988) in a 4-layer computer model of the aquifer range from 1,200 to 18,000 gpd/ft and average 6,600 gpd/ft for the upper 800 feet of the aquifer. Transmissivity values for the deeper sections of the aquifer ranged from 270 to 5,000 gpd/ft. The average transmissivity for the 15-layer model used by Hearne (1980a) for the upper 1,100 feet of the Tesuque Formation is about 17,000 gpd/ft.

Few storage coefficient values from aquifer tests have been reported for the Santa Fe Group. Of those reported, the values range from 0.000085 to 0.17, but most are less than 0.05. Storage coefficient values reported for Precambrian rocks in the NSFC aquifer system range from 0.00044 to 0.1, and most are less than 0.02.

McAda and Wasiolek (1988) used a storage value of 0.05 for the Santa Fe Group in the vicinity of the Los Alamos well field, west of the Rio Grande, but used 0.15 throughout the remainder of the model domain in the upper layer. A storage coefficient value of 0.001 was assigned to the lower 3 layers.

2.2.3.2 Aquifer Parameters in the Mid-Santa Fe County Hydrologic System. Very few transmissivity estimates are available for the MSFC hydrologic system. Of the five reported values, the transmissivity estimates range from 3 to 12,500 gpd/ft. Because the hydrogeology is so variable, no regional values can be assumed and site-specific data would be necessary for reasonable predictions of water level changes.

Only two estimates of storage coefficients are reported in the entire MSFC: 0.015 and 0.02. If these values are reliable and the aquifer is under water table conditions, they suggest that much of the ground water occurs in fractured bedrock. As with transmissivity, site-specific storage estimates would be required for any predictive analysis.

2.2.3.2 Aquifer Parameters for the Estancia Valley Aquifer System. Available transmissivity estimates for the EV aquifer system are all based on tests conducted in the western portion of the basin, where the tested wells are probably completed in the Madera Limestone. The transmissivity estimates range from 120 to nearly 640,000 gpd/ft. The very high transmissivity values are most likely from wells that tap a large cavern or solution cavity within the limestone. A transmissivity of 30,000 gpd/ft was used by the State Engineer Office (SEO) to develop the administrative criteria for mining the valley fill aquifer.

Storage coefficients submitted in consultant reports to the county vary from 0.00038 to 0.05 for the western portion of the EV aquifer system in the Madera Limestone. A value of 0.125 was used by the SEO to develop administrative criteria for mining the valley fill.

2.2.4 Quantity of Water in Storage

The quantity of water in storage in the principal aquifers is presented in this section for the NSFC and EV aquifer system. This quantity is not necessarily useful for management planning purposes, in that the water may not be administratively accessible, as explained in Section 3.3. Estimates of the quantity of water in storage in the MSFC are not provided due to the highly variable nature of the hydrologic system and the lack of available data. Localized studies will be required to assess the amount of water in storage for a given aquifer in the MSFC.

Previous investigators have devoted considerable effort to assessing the ground-water resources available to Santa Fe County, particularly those resources in the Santa Fe River Basin (CPI, 1974b; Hagerman, 1974; Koopman, 1975; Wilson, 1978; WCC, 1980; McAda and Wasiolek, 1988; Harza et al., 1988; Browne, Bortz, and Coddington, Inc. et al., 1992). Estimates of the amount of ground water in storage made by these investigators cover a range of two orders of magnitude.

To some extent, the range of estimates is a result of the basic technical approach of each of the investigators and the assumptions used.

For instance, one investigator clearly stated the intent to evaluate reserves conservatively (i.e., on the low end of reasonable estimates) and in the process incorrectly multiplied the saturated thickness, area, and porosity by the specific yield to produce an unrealistically low estimate of water storage. To account for uncertainty in the volume of water held in storage and to be conservatively low in estimating this volume, Wilson (1978) multiplied the calculated volume by a reliability factor. Other investigators used parameters they considered to be reasonable based on their professional judgment so as to make a "best" estimate (Spiegel and Baldwin, 1963; Koopman, 1975; WCC, 1980). In the Santa Fe River basin, the most conservative estimate of water in storage was 350,000 acre-feet (CPI, 1974b), whereas the "best" estimate was 30,000,000 acre-feet (WCC, 1980). In the Pojoaque-Nambe-Tesuque area the conservative estimate for water in storage was 148,090 acre-feet (CPI, 1974b), whereas the "best" estimate was 55,013,000 acre-feet (Koopman, 1975).

DBS&A made its own estimates of the quantity of water in storage in the NSFC and EV aquifer systems by multiplying the volume of the saturated sediments by an assumed storage coefficient. The volume of saturated sediments was determined by assessing the aquifer thickness of each system and multiplying the determined value by the areal extent of the aquifer. An appropriate storage coefficient was determined through review and assessment of estimates made by previous investigators. The particular estimates used for each of the two aquifer systems and the results of the calculations are discussed in detail in Sections 2.2.4.1 and 2.2.4.2.

2.2.4.1 Quantity of Water in Storage in the North Santa Fe County Aquifer System. In determining the quantity of water in storage in the NSFC aquifer system, DBS&A restricted the estimate to the ground-water resources of the Santa Fe Group. The volume of water contained in the bounding rocks is probably either small in comparison to that contained in the Santa Fe Group or is too deep to be a viable consideration for current water resource evaluations.

In general, most water wells have not penetrated the full thickness of the Santa Fe Group, so they can only be used to obtain minimum thicknesses. To gain insight as to the probable thickness of the Santa Fe Group, several additional sources of information were used, in particular, the results of geophysical studies and deep exploration boreholes.

Cordell (1977) inverted maps of the gravity field in the area to obtain a map of the configuration of the underlying, relatively high-density Precambrian basement rock. This map was used as a guide for the probable configuration of the bottom of the Santa Fe Group. However, over much of the area it is likely that a substantial thickness of older sedimentary rocks lies between the Santa Fe Group and the underlying Precambrian basement rock. This intervening layer of sedimentary rock is suggested by seismic profiles conducted in two studies (Black, 1984; Biehler et al., 1991). The overall thickness of the sedimentary sequence, the Santa Fe Group plus older underlying rocks, is supported by the interpretation of the probable distribution of the density of sediments above the Precambrian rocks. Some additional confirmation is suggested by deep-penetrating electrical studies (Biehler et al., 1991). Insight as to the extent of the northwest-trending Cerrillos Uplift (Disbrow and Stoll, 1957) was gained by interpreting the aeromagnetic map of Cordell (1977) using the method suggested by Gay (1972). Studies based on field observations of the stratigraphy suggested a total maximum thickness of the Santa Fe Group of 4,500 feet (Galusha and Blick, 1971).

The logs of 106 deep test holes by Nuclear Dynamics provided particularly useful data (on file at OCD) regarding the thickness of the Santa Fe Group. Additionally, the 4,755-foot-deep oil test well 17N.8E.S24, the deepest well in the NSFC, provided the best information on the thickness of the Santa Fe Group. This well penetrated 3,100 feet of Santa Fe Group sediments and was completed in the Espinosa Volcanics.

DBS&A's estimate of the saturated thickness of the Santa Fe Group resulted in thicknesses ranging from 0 to at least 3,500 feet as shown on Plate 8. DBS&A considers the thickness estimates to be conservative and only useful on a regional scale. The thickness in the fringe area (0 to 500 feet) is highly uncertain, and site-specific data are therefore essential for estimating the thickness in this area.

Using the estimated volume of saturated sediments and a conservative value of 0.10 for the specific yield, DBS&A calculated the volume of water potentially drainable from saturated sediments in the NSFC aquifer system to be 56,300,000 acre-feet. As discussed in Section 3.2.4, the value of S is a function of the stress on the system. Even though a value of 0.10 has not been observed in any substantial aquifer test in the Santa Fe Group, it is likely that if the formation were eventually dewatered, the value would be this high. Table 2 summarizes the data used to obtain this estimate.

Table 3 summarizes the parameters used by previous investigators to determine the amount of water in storage. For comparison, because each investigator examined different size areas, we have provided a column which shows the average quantity of water in storage per square mile. The estimate by DBS&A falls within the range reported by previous investigators. As shown in Tables 2 and 3, the estimates of the volume of water in the Santa Fe Group based on standard values used in the Code is about 20 times less than our estimate.

2.2.4.2 Quantity of Water in Storage in the Estancia Valley. After the Estancia Basin was declared in 1950, the SEO reviewed numerous well logs and other geologic data to determine the quantity of water in storage in the valley fill. This information was necessary to develop a block system of administering water rights in the basin based on a 40-year lifetime. The SEO reserved 40 feet of saturated aquifer to provide adequate well capacities for irrigation purposes at the end of the 40-year period (except in areas where wells are completed in the Glorieta Sandstone, in which case, total depletion of the valley fill above the Glorieta Sandstone was allowed for calculation of water rights administration). In 1965, the SEO examined additional information from new well logs and revised the storage estimate to 1,200,000 acre-feet for the area in Santa Fe County (Akin, 1975). DBS&A inquired with the SEO as to any present estimates of the quantity of water in storage and whether any unappropriated rights remained in Santa Fe County, but such information is not available (Thompson, 1994).

The volume of water recoverable by drainage of the EV aquifer system was estimated by DBS&A in the following manner. Using a map of saturated thickness of alluvium based on February 1965 data obtained from SEO files, the area between the contours was calculated using AutoCAD. The minimum thickness within each contoured zone was multiplied by the area and a specific yield of 0.125 to obtain a total amount of water in storage in 1965. The calculated volume of 1,400,000 acre-feet is somewhat higher than SEO's 1965 estimate.

Table 2. Summary of Data Used to Estimate the Quantity of Water in Storage in the Santa Fe Group of the North Santa Fe County Aquifer System

Contour Interval (feet)	Thickness (feet)	Area (acres)	Sy	Quantity of Water in Storage (acre-feet)	Volume in Storage Using Standard Values in Code	
					Thickness (feet)	Quantity (acre-feet)
0-500	250	92,165	0.1	2,304,125	50	182,487
500-1,000	750	61,202	0.1	4,590,150	250	605,900
1,000-1,500	1,250	39,174	0.1	4,896,750	250	387,823
1,500-2,000	1,750	58,764	0.1	10,283,700	250	581,764
2,000-2,500	2,250	21,282	0.1	4,788,450	250	210,692
2,500-3,000	2,750	19,023	0.1	5,231,325	250	188,328
3,000-3,500	3,250	53,045	0.1	17,239,625	250	525,146
3,500+	3,500	19,823	0.1	6,938,050	250	196,248
TOTAL		364,478	NA	56,272,175	NA	2,878,385

Note: The standard values for the Santa Fe Group are Sy = 0.15, RL = 0.33, RC = 0.8

NA = Not applicable

Table 3. Estimates of Recoverable Water in Storage in the Santa Fe Group

Source of Estimate	Area (mi^2)	Thickness (ft)	Specific Yield	Reliability Factor	Storage (acre-ft)	Storage (acre-ft/mi^2)
Lee Wilson (1984)	234	500	0.01	---	750,000	3,200
Spiegel and Baldwin (1963)	234	1,000	0.2	---	30,000,000	128,000
Woodward-Clyde (1980)	140	2,640	0.05	---	12,000,000	84,500
DBS&A (1994) (see Table 2)	570	250-3,500	0.10	---	56,300,000	99,000
County Code (see Table 2)	570	50-250	0.15	0.33	2,880,000	5,050
CPI (1974b) (Santa Fe Area)	108	250	0.15	0.12	311,040	2,400
Koopman (1975) (Pojoaque Area)	122	3,500	0.2	---	55,000,000	448,000

--- = Not used

Water levels have declined since 1965, so we must correct for the depletion. If we assume that the water level has dropped at a constant rate of 1.4 ft/yr throughout the valley fill (Plate 3), the water level would have lowered roughly 40 feet since 1965. The total area of the valley fill within Santa Fe County is about 69,000 acres. Assuming a specific yield of 0.125, a total volume of roughly 345,000 acre-feet has been removed since 1965. Thus, a present total of approximately 1,055,000 acre-feet of recoverable water remain in storage. The volume of water recoverable from storage estimated here is conservative because the volume of water in the rocks surrounding the alluvial fill (e.g., Glorieta Sandstone) is not included. Also, water levels in some areas of valley fill have declined at a rate of less than 1.4 feet per year.

In order to check the reasonableness of the above method for estimating storage, we can compare the volume depleted based on water level decline rate with the amount depleted based on diversion estimates (discussed in Section 2.3.2). A total amount of water depleted from the basin since 1965 is estimated to be about 386,000 acre-feet, based on a depletion rate of 13,300 afy. Because recharge to the aquifer has occurred during this time, the net depletion calculated from water level declines is much less than the quantity of water withdrawn by pumping. Therefore, the storage estimate appears to be reasonable.

2.3 Water Budget Components

Water resource management strategists are often interested in how much water can be pumped from a given area. Depending on the administrative policy (lifetime of the resource), quantification of the water budget components (i.e., recharge and discharge) may be useful for planning purposes.

DBS&A has attempted to define the water budget components using available data and literature. None of the components are known with a high degree of confidence, and the numbers presented herein should be considered gross estimates with a large degree of uncertainty. We present them here to show what has been and can be done with existing data to define these terms. Recharge estimates for each aquifer system or drainage basin within an aquifer system are discussed in Section 2.3.1. The total quantity of diversions from pumping are also estimated for each aquifer system and discussed in Section 2.3.2.

2.3.1 Recharge Components

As discussed in Section 2.1.1, recharge to aquifers occurs from several mechanisms: (1) mountain-front recharge, (2) stream-channel recharge, and (3) areal recharge. Methods for quantifying recharge can be aimed at defining the quantity occurring from a specific mechanism or at quantifying the total recharge. A discussion of the recharge components that have been estimated for Santa Fe County is presented in Sections 2.3.1.1 through 2.3.1.3. In addition, we have included estimates of recharge from irrigation and municipal return flow.

2.3.1.1 Recharge Components for the NSFC Aquifer System. A summary of the recharge estimates for each drainage basin within the Santa Fe County are provided in Table 4. Recharge estimates for surface water drainage basins in the NSFC aquifer system are published by Lee Wilson (1978) and McAda and Wasiolek (1988). Lazarus (1985) also estimated recharge based on water level changes over a 6-month period (June to January 1985) for the Santa Fe area. DBS&A has included artificial recharge estimates of return flow from the Santa Fe municipal sewage treatment plant and irrigation from surface and ground water. Return flow from individual septic tanks, although possibly significant, is not included in the recharge estimates because of the lack of available estimates of the quantity of return flow as well as the time required to reach the water table.

Lee Wilson (1978) published what he considered conservative estimates of recharge within surface water drainage basins in the county by evaluating streamflow records of gaining streams. He assumed the stream gains during low-flow periods resulted from recharge to the contributing aquifer at higher elevations. He obtained recharge rates for various rock types and then multiplied the rates by the total area of outcrop in each drainage to get a total recharge estimate. He used the following estimates for various rock types: Precambrian rocks = 0.56 inches per year (in/yr), Santa Fe Group = 0.28 in/yr, and all other units = 0.19 in/yr. The data used to obtain these rates are not provided with the estimates in his report; therefore, it is difficult to determine the recharge mechanism he was attempting to quantity. This method probably addressed only a portion of the mountain-front and areal recharge components and did not include recharge from losing streams, thus resulting in very conservative estimates.

Table 4. Water Budget Component Estimates in 1990 for Various Surface Water Drainage Basins in Santa Fe County

Sources	Water Budget Component (afy)									
	NSFC						MSFC			EV
	Santa Cruz	Nambe-Pojoaque	Tesuque	Santa Fe	Galisteo-N	Rio Grande N	Rio Grande S	Galisteo-S	Pecos N&S	Estancia
Sources of Recharge										
Recharge (McAda-Wasiolek)[1]	4,200	5,502	4,995	8,145	1,158	NA	NA	NA	NA	NA
Recharge (Wilson)[2]	3,400	2,700	1,500	3,500	1,000	1,900	NA	5,000	1,800	5,500
Recharge (Lazarus)[3]	NA	NA	NA	3,083	NA	NA	NA	NA	NA	NA
Sewage effluent[4]	NA	NA	NA	3,432	NA	NA	NA	NA	NA	NA
Irrigation return flow from ground-water diversion[5]	19	148	0	161	0	0	NA	0	0	2,653
Irrigation return flow from surface-water diversion[5]	4,680	3,968	0	1417	0	0	NA	0	0	0
Total Recharge Range	*3,400-8,900*	*2,700-9,600*	*1,500-4,995*	*6,900-13,155*	*1,000-1,150*	*1,900*	*NA*	*5,000*	*1,800*	*5,500-8,150*
Sources of Discharge										
Domestic use based on population[6]	851	617	333	1,879	713	96	NA	226	58	389
Municipal (not accounted in domestic use estimate)[7]	NA	NA	NA	2,320	NA	2,128	NA	NA	NA	NA
Other (not accounted in domestic use estimate)[8]	205	NA	NA	1,033	NA	4,500	NA	NA	NA	3,040
Irrigation-depletion[5]	(86)	(239)	0	(360)	0	0	0	0	0	(9,830)
Irrigation-withdrawals[5]	105	387	0	521	0	0	0	0	0	12,483
Springs (or discharge to river)[9]	Unknown	4,315	883	4,706	NA	Unknown	NA	NA	NA	NA
Total Discharge	*1,161*	*5,319*	*1,216*	*10,459*	*713*	*Unknown*	*NA*	*226*	*58*	*15,912*

[1] McAda-Wasiolek, 1988 (mountain-front and stream-channel recharge only)
[2] Wilson, L., 1978
[3] Lazarus, 1985
[4] Return flow from septic tanks is not included in the recharge estimates
[5] Wilson, B., 1992 (reported 6,000 afy for entire Galisteo)
[6] Population estimates made by Prior (1994)
[7] Frank Bailey, Sangre de Cristo Water Co.
[8] SEO meter readings of DOE and state penitentiary; Wilson, B. (1992) for Estancia and Santa Cruz Basins
[9] McAda-Wasiolek, 1988

afy = Acre-feet per year
NA = Not available

Through the calibration of a computer model of the Tesuque Formation, McAda and Wasiolek (1988) estimated mountain-front recharge, stream-channel recharge, and areal recharge from precipitation. Only the mountain-front and stream-channel recharge components reported for the transient runs in the computer model simulation are reported herein. Because studies by Fleming and Finch (1992) and Anderholm (1990) question the magnitude of areal recharge used in the model, areal recharge to the Santa Fe Group is not included in this evaluation in order to be conservative.

For initial estimates of the mountain-front recharge component in the model development, McAda and Wasiolek (1988) used the following method. The quantity of precipitation was first estimated for various elevation ranges in the Sangre de Cristo Mountains. Recharge was then estimated by calculating the total precipitation for each drainage basin and subtracting estimates of evapotranspiration and runoff. This was a gross method for identifying the upper limit of mountain-front recharge in each drainage basin (Wasiolek, 1994). The simulated mountain-front recharge estimates obtained from model calibration are approximately half the calculated precipitation estimates.

As shown on Table 4, McAda and Wasiolek's (1988) estimates are up to four times the quantity estimated by Lee Wilson (1978). Wilson considered his estimates to be very conservative, which could account for at least a portion of the disagreement between the two estimates.

Lazarus (1985) measured water levels in the Precambrian rocks in the Santa Fe River Basin from January to June of 1985. He estimated the volume of water (using storage coefficients ranging from 0.0004 to 0.2) that contributed to the observed rise in water level over the 6-month period. Based on that volume, he estimated a total recharge of 3,200 acre-feet for the 6-month period.

Recharge from the Santa Fe municipal sewage treatment plant was estimated by McAda and Wasiolek (1988) to be 3,432 afy. Brian Wilson (1992) estimated return flow from septic tanks in Santa Fe County to be 1,285 afy. Return flow from irrigation amounts to about 200 afy from ground-water diversions in the Santa Fe, Santa Cruz and Pojoaque areas, and return flow from surface water diversions is about 10,000 afy, with 80 percent of the surface diversions located in the Pojoaque and Santa Cruz areas.

2.3.1.2 Recharge Components for the Mid-Santa Fe County Hydrologic System. Lee Wilson (1978) provides the only published estimates of recharge for the MSFC hydrologic system (Table 4). Using a recharge rate of 0.19 in/yr for the rock types in the Galisteo Basin (part of which is in the NSFC aquifer system), he calculated a total recharge of 6,000 afy. Using the same rate of 0.19 in/yr for the entire MSFC hydrologic system, a recharge rate would be 7,500 afy.

2.3.1.3 Recharge Components for the Estancia Valley Aquifer System. Lee Wilson (1978) also provides the only published recharge estimate for the EV aquifer system in Santa Fe County. He used a recharge rate of 0.28 in/yr to obtain a volumetric recharge rate of 5,500 afy. Return flow from irrigation in the EV aquifer system is estimated by Brian Wilson (1992) to be about 22 percent of diversions, or about 2,800 afy for 1990.

The recharge estimate of 5,500 afy by Lee Wilson (1978) appears to be reasonable. Assuming a volume of water in storage of 1,060,000 afy (Section 2.2.4), an average recharge rate of 5,500 afy, and a depletion rate of 13,300 afy (Section 2.3.2), the aquifer would have a lifetime of about 136 years. If this estimate is compared to the lifetime based on the total saturated thickness in 1994 and the rates of water level decline, it appears that at the present withdrawal rates, the aquifer has a lifetime of 150 years. This indicates that recharge, return flow, or storage may be slightly greater. In order to sustain the aquifer for 150 years at the present depletion rate of 13,300 afy, recharge would have to be about 6,200 afy. This recharge estimate includes the ground water from Torrance County entering the EV aquifer system from the south.

2.3.2 Discharge Components

The quantity of water presently discharged from the aquifer systems either by natural discharge to springs and streams or by pumping is summarized in Table 4. Quantities of water subsequently diverted from the streams or springs are not considered here.

The volume of water pumped from an aquifer system is very difficult to quantify because it is not routinely measured. Efforts to define the water rights using SEO reports from their database were unsuccessful due to numerous problems, such as multiple listings of what appears to be the same right. A database developed by Neva Van Peski of the Santa Fe Metropolitan Water Board was helpful in identifying some rights, but was not complete (rights for Sunlit Hills and Eldorado were missing, for example). The SEO Hydrographic Survey Section is in the process of identifying water rights in the Galisteo Basin, but their work will not be completed for many months.

An inherent problem in estimating pumping from the water right records is that the records represent the quantity that is authorized for diversion, but that quantity is not necessarily the actual amount diverted. For instance, the Sangre de Cristo Water Company Buckman wells have total rights of 10,000 afy, but presently they only have the physical capacity to pump about 5,000 afy. The following is a general discussion of how DBS&A estimated the quantity of water diverted in Santa Fe County.

The estimates of discharge to springs and streams in the NSFC aquifer system were obtained from predictions made by the McAda and Wasiolek (1988) computer model. Our discharge estimates are derived from the steady-state simulation, which represents predevelopment conditions in the aquifer. The steady-state discharge to springs and streams may be less than that during pumping periods; consequently, our method may overestimate actual discharge. For example, Fleming (1993) reports that the flow at La Cienega Springs has diminished 41 percent from 1966 to 1993.

Use within the Santa Fe city limits was based on water diversions from city wells, the St. Michaels well and the Buckman wells provided by Frank Bailey of the Sangre de Cristo Water Company. Domestic use outside the Santa Fe city limits was estimated based on population estimates in a recent study conducted for the county by John Prior and Associates (Prior, 1994). Table 5 summarizes the population estimates for each drainage basin and the number of approved building sites that may affect future diversions. The diversion from domestic use outside the city limits was based on an average per capita use of 0.12 afy, or 0.312 afy per household with 2.6 people per household (Prior, 1994), reported by Brian Wilson (1992) for municipal systems in Santa Fe County. Diversions that fall outside of the above categories, such as the Los Alamos well field and the New Mexico State Penitentiary, were obtained from the SEO meter readings for 1993 provided by Nancy Cunningham. Diversions from the Española well field were based on Brian Wilson's study (1992).

Table 5. Santa Fe County Population Estimates and Approved Building Sites for 1992 by Drainage Basin

Drainage Basin	Population	Approved Building Sites
North Santa Fe County Aquifer System		
Santa Cruz	7,091	437
Nambe-Pojoaque	5,145	201
Tesuque	2,774	200
Rio Grande (north)	802	1,809
Santa Fe (excluding city)	15,661	3,146
City of Santa Fe	55,859	8,167
Galisteo (north)	5,945	1,842
Mid-Santa Fe County Hydrologic System		
Galisteo (south)	1,887	362
Pecos	486	298
Rio Grande (south)	NA	NA
Estancia Valley Aquifer System		
Estancia Basin	3,240	2,227
TOTAL	98,890	18,689

Source: Prior, 1994
NA = Not available

Irrigation depletion (pumping plus recharge from return flow) and withdrawal (pumping) rates were obtained from an SEO report of water use in New Mexico that included irrigation use (B. Wilson, 1992). The irrigation depletion rate is calculated as a function of the number of acres irrigated, the consumptive irrigation requirement, and incidental depletions, such as conveyance losses. The total irrigation withdrawals are calculated as a function of the acres irrigated and the consumptive irrigation requirement divided by the irrigation efficiency. These numbers were subtracted to obtain the return flow estimates provided in the discussion of recharge.

The actual depletion rates from irrigation may vary from year to year depending on weather and economics; the values in Table 4 (B. Wilson, 1992) are based on the diversions in 1990. Table 6 shows the variability of the reported depletion of ground water for irrigation (Sorensen, 1977; Sorensen, 1982; B. Wilson, 1986; B. Wilson, 1992) in all of Santa Fe County.

Table 6. Depletion of Ground Water by Irrigated Agriculture in Santa Fe County

Year	Amount	Information Source
1975	11,590 acre-feet	Sorensen, 1977
1980	15,930 acre-feet	Sorensen, 1982
1985	11,426 acre-feet	Wilson, 1986
1990	10,515 acre-feet	Wilson, 1992

All but about 700 acre-feet of this depletion is in the Estancia Valley (Wilson, 1992).

The total quantity of ground-water diversions from wells estimated for the County is 36,700 afy. This estimate is higher than the 25,371 afy estimated to be pumped from the ground water by Wilson (1992). Part of the discrepancy may be due to estimates of municipal usage. It appears that Wilson (1992) did not include diversions within Santa Fe County for the Los Alamos well field.

Three terms are used in the following discussion that can be confusing. They are diversion, depletion, and discharge. Diversion refers to a quantity pumped whereas depletion refers to the amount pumped minus the quantity returned (or recharged) to the aquifer. Discharge includes diversions through pumping and natural discharges from the aquifer to streams and springs.

2.3.2.1 Discharge Components from the North Santa Fe County Aquifer System. Our total estimated discharge from the NSFC aquifer system is about 25,592 afy. Of this amount, 9,900 afy is discharged from the aquifer to springs and streams as estimated by McAda and Wasiolek (1988) through model calibration. However, this model estimate does not include the quantity of ground water that directly recharges the Rio Grande, because it is not known what portion simulated in the model originates from the east or west side of the river. As stated in Section 2.3.2, since these estimates were determined for predevelopment conditions, our estimates of discharge to springs and streams may be much less today. Our total estimated discharge also includes an estimated 15,700 afy of ground-water diversions from pumping for the NSFC aquifer system. This estimate is substantially higher than the 6,700 afy estimated for 1975 conditions by Lee Wilson (1978); this discrepancy may be due in part to the growing population in the county.

Figure 22 shows the historical water use for the City of Santa Fe. The Buckman wells are located in T19N.R07E, adjacent to the Rio Grande. This location was selected based upon the theory that most of the water diverted from the wells would come directly from the Rio Grande and/or intercept water that would otherwise discharge to the Rio Grande and thus would not significantly deplete the aquifer. However, the fact that water levels at the Buckman wells have declined over 500 feet in the past 10 years suggests that leakage from the Rio Grande and recharge to the area is not sufficient to supply the entire withdrawal from the well field. The city wells are located throughout the City of Santa Fe; the St. Michaels well is singled out on Figure 22 because the water right for this well is associated with the surface diversion right from the Santa Fe River.

2.3.2.2 Diversion Components from the Mid-Santa Fe County Hydrologic System. The total diversions from the MSFC hydrologic system include the diversions in (1) the North and South Pecos River drainages in the county, (2) part of the Galisteo basin, and (3) the southern Rio Grande drainage basin. A total estimate of 471 afy was calculated for the MSFC based on the population (Prior, 1994). Lee Wilson (1978) estimated about 300 afy of ground-water diversions from this area and indicated that the primary water use is from domestic wells, although mining operations divert water when operational. Brian Wilson (1992) estimated only 25 afy of diversions for mining purposes for the entire county. DBS&A was able to identify at least 1,200 afy of water rights for the MSFC hydrologic system, indicating that the potential exists for much greater diversions to occur in the future.

2.2.3.3 Diversions from the Estancia Valley. The total diversions from the ground water in the EV aquifer system are estimated to be 15,912 afy. Most of this amount is for irrigation, which totals 12,483 afy of ground-water diversions. About 3,040 afy of water rights are designated municipal and serve areas outside Santa Fe County, in the Cedar Crest area of Bernalillo County

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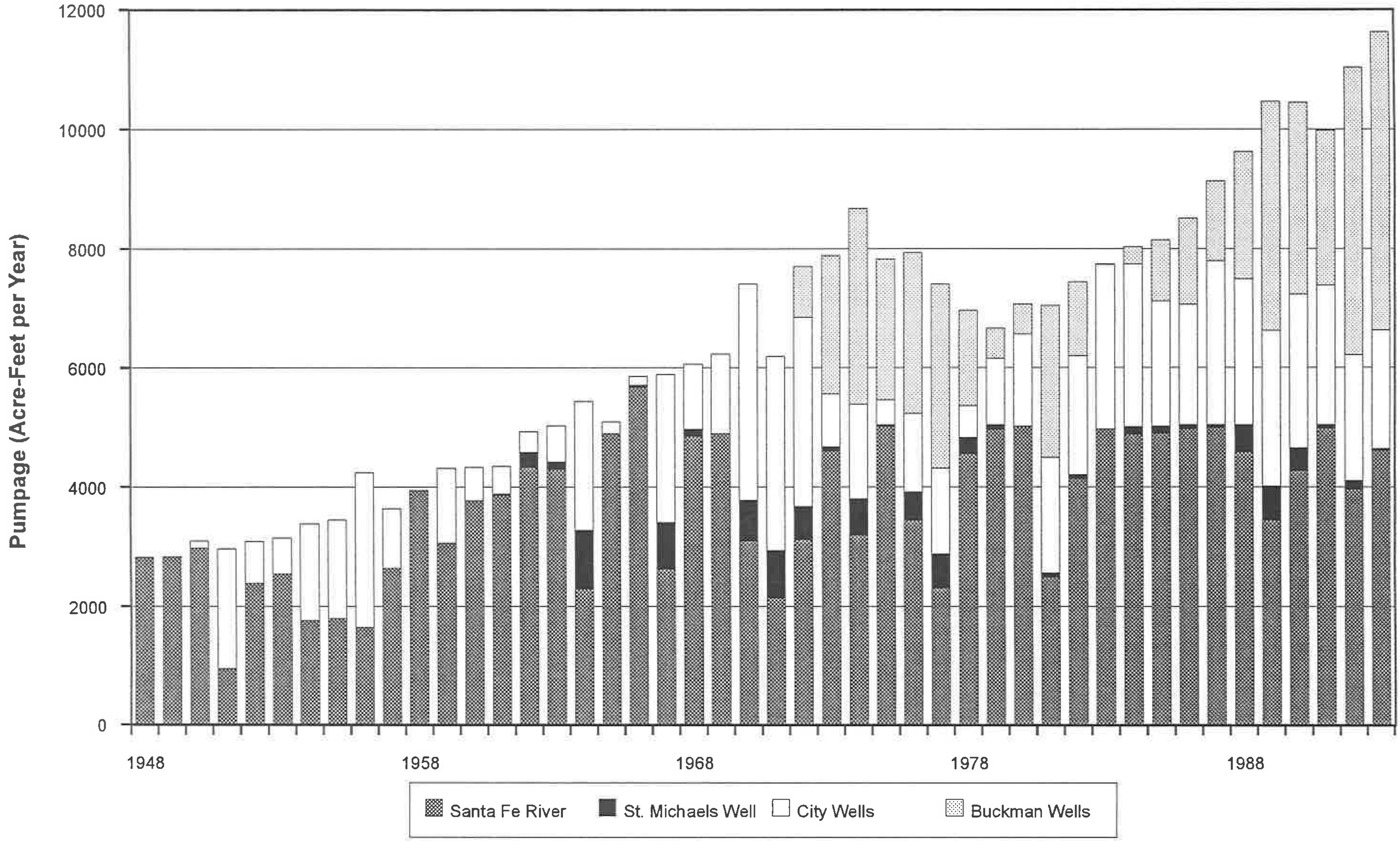

SANTA FE COUNTY INVENTORY

City of Santa Fe Water Supply History

DANIEL B. STEPHENS & ASSOCIATES, INC.
7-94 JN 3300

Figure 22

(this quantity is based on the water right as opposed to the actual diversion). The remainder (389 afy) was estimated based on population estimates for 1990 (Prior, 1994).

Although diversion estimates vary from year to year, Brian Wilson's (1992) 1990 estimates of irrigation depletion rate were used to formulate the total diversion in the EV aquifer system of 13,300 afy. This annual volume includes 9,830 afy depleted (pumped return flow) in the Estancia Valley part of Santa Fe County, about 400 afy from domestic wells (based on population), and 3,100 afy that is exported from the county for municipal purposes.

2.3.3 Water Balance

The overall balance between the recharge and discharge estimates for each aquifer system is discussed in Sections 2.3.3.1 through 2.3.3.3, along with the rates of water level decline. Because the County may be considering updating the County Code and revising its policy, a discussion of the aquifer performance in a general sense is also provided. Identifying recharge and discharge processes, and quantifying them, are integral parts of water resource management programs that recognize a state of dynamic equilibrium. Although this approach may be useful on a regional scale, it may not be adequate or practical on a local scale, depending on hydrogeologic conditions. Local water balance effects are not considered in detail in this report.

2.3.3.1 Water Balance for the North Santa Fe County Aquifer System. Ranges of recharge and discharge estimates, as well as water level changes, from 1950 to 1993 are discussed here for each drainage basin in the NSFC aquifer system. The NSFC aquifer system includes the Santa Cruz, Nambe-Pojoaque, Tesuque, Santa Fe, north Galisteo, and north Rio Grande surface water basins. The assessment of individual surface water drainage basins is a convenient method of looking at subregional areas, but these areas are not necessarily isolated from each other. For instance, pumping in the Santa Fe River Basin can influence water levels in the North Galisteo River Basin or the Tesuque Basin.

Santa Cruz Basin. Combined stream-channel and mountain-front recharge estimates to the Santa Cruz Basin in Santa Fe County range from 3,400 to 4,200 afy, as shown in Table 4, and return flow from surface water is estimated to be 4,680 afy[1]. Ground-water discharges in the Santa Cruz Basin within the County are estimated to be 1,161 afy. Ground water will ultimately discharge at the Rio Grande to the west of the County line. The basin here appears to be in equilibrium based on storage. Two hydrographs from the basin support the recharge and discharge estimates. One hydrograph shows only a slight decline in water level over time (0.1 ft/yr from 1973 to 1993), and the other shows no decline (Plate 3). The Santa Cruz River recharges (loses water to) the aquifer (McAda and Wasiolek, 1988). Therefore, it is expected that increased pumping in this area would result in a lowering of the water table without substantially decreasing flow from the river. Based on the availability of vacant lots (Prior, 1994), the potential for ground-water diversions from domestic wells may increase to 3,853 afy in the Santa Cruz Basin.

Nambe-Pojoaque Basin. Combined stream-channel and mountain-front recharge estimates for the Nambe-Pojoaque Basin range from 2,700 to 5,500 afy (Table 4). The total discharges from ground water are estimated to be 5,319 afy, which is close to the highest recharge estimate. The near equilibrium condition is supported by water level declines, which range from 0 ft/yr southeast of the Village of Pojoaque to 0.1 ft/yr near Pojoaque to 0.35 ft/yr on the western edge of the basin near the Buckman well field (Plate 3). The Pojoaque River and Rio Nambe are gaining rivers (the aquifer is discharging about 4,300 afy to the streams); thus, increased pumping would eventually deplete the streamflow, which is used by surface water users. Additional depletions from ground water in the area are likely to be protested by the Pueblos or perhaps prevented by the final conditions set out in the Ammodt suit (adjudication suit in the Nambe-Pojoaque Basin).

Tesuque Basin. Combined stream-channel and mountain-front recharge estimates for the Tesuque Basin range from 1,500 to 5,000 afy, and the discharge estimate is approximately 1,216 afy (this figure does not include the quantity that flows out to the Rio Grande Basin and eventually to the Rio Grande). Hydrographs for the area show water level declines ranging from 0 ft/yr in T19N.R9E.S21 to 0.1, 0.6, and 1.4 ft/yr in the area between the Santa Fe Opera Theater and the

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[1] Return flow from irrigation using surface water may replenish the Santa Cruz River rather than recharge ground water. A field investigation would be required to determine the ultimate fate of this potential source of recharge. The McAda and Wasiolek (1988) model did not include this level of detail; therefore, it would be prudent to exclude this component from the analysis.

Village of Tesuque (Plate 3). The water level declines, in spite of the apparent surplus recharge, may be due to several factors. First, ground-water discharge by underflow to the Rio Grande is not taken into account. Second, the impact of pumping in the Santa Fe area may be spreading north and causing water level declines in this area. Finally, the local aquifer transmissivity or storage coefficient may be low, causing water levels to drop more rapidly than in other areas. Any recharge entering the Tesuque drainage that is not diverted by wells will ultimately recharge the Rio Grande Basin or the Nambe-Pojoaque Basin to the west.

North Rio Grande Basin. No estimates of recharge for the north Rio Grande Basin alone; however, Lee Wilson (1978) estimated areal recharge to the north and south Rio Grande Basins as 1,900 afy. The NSFC aquifer system includes the north Rio Grande Basin, and the MSFC hydrologic system includes the south Rio Grande Basin. Additional recharge undoubtedly enters this area from the Rio Grande and inflow from the east. The total diversion by pumping in the north Rio Grande Basin is estimated to be about 8,500 afy. It is probable that the total diversion exceeds recharge, as evidenced by the water level declines at the Buckman wells in T19N.R07E.S36. Water levels are declining at rates varying from 36 ft/yr in shallow wells to 86 ft/yr in deep wells, suggesting that this area is not being replenished by the Rio Grande and other sources at a fast enough rate to prevent mining. Although these declines were observed over a 2-year period (1986-88), Robert Jorgensen with Sangre de Cristo Water Company has recorded 536 feet of water level decline in Buckman wells from July 1983 to January 1993, a decline rate of 56.4 ft/yr (Jorgensen, 1994). Recharge and discharge to the north Rio Grande Basin from and to the aquifers could not be gleaned from the McAda and Wasiolek (1988) model since water entering or exiting river cells would come from, or to, both the east and west sides of the river.

Santa Fe Basin. Combined stream-channel and mountain-front recharge estimates for the Santa Fe Basin range from 3,100 to 8,200 afy, return flow from irrigation is estimated at 1,600 afy, and recharge from municipal sewage is estimated to be 3,400 afy, giving a total range of recharge estimates of 8,110 afy to 13,200 afy. Total diversions are estimated to be about 11,000 afy, close to the highest recharge estimate. Water level changes in the basin (Plate 3) vary from a rise (−0.5 ft/yr) in the recharge area to a 2.7-ft/yr decline southwest of Santa Fe. Most declines in the Santa Fe River Basin range from 0.3 to 1.1 ft/yr (Plate 3). Overall, it appears that ground water is being mining in the vicinity of Santa Fe, and areas downstream are receiving greater amounts of recharge as a result of the municipal return flow.

North Galisteo Basin. The portion of the Galisteo basin that falls within the NSFC aquifer system is denoted here as the north Galisteo Basin. No specific estimates of recharge to the north Galisteo Basin in the NSFC aquifer system are available. However, the McAda and Wasiolek (1988) model, which included most of the north Galisteo Basin, simulated 1,158 afy of stream-channel and mountain-front recharge entering this portion of the aquifer. Since the model domain covers most of the recharge area, this figure may be a reasonable estimate. Lee Wilson (1978) estimated a total recharge of 6,000 afy for the entire Galisteo Basin. Based on the area of the north Galisteo Basin (2.8 x 10^9 square feet) and using Wilsons' recharge rate of 0.19 in/yr, recharge would be about 1,000 afy to the north Galisteo Basin.

Discharge estimates for the north Galisteo Basin, based solely on the population (Prior, 1994), amount to about 700 afy. DBS&A was able to identify at least 1,424 afy of water rights in this area, so water diversions could likely be greater than the 700 afy. In addition, if existing vacant lots are developed, the total diversion based on population (at 2.6 people per household) could increase to about 1,300 afy.

As shown on Plate 3, water level declines vary throughout the north Galisteo Basin from no decline (observed in 6 hydrographs in Appendix E) to 3.1 ft/yr near the boundary of the Santa Fe Group aquifer. Water levels south of Arroyo Hondo in the Santa Fe Group are dropping at about 0.5 to 1 ft/yr, and near Eldorado three available estimates of 0, 0.08, and 0.2 ft/yr are available. Two hydrographs for areas located east of Highway 14 show stable water levels until 1985, and then declining water levels at the rates of 1.25 and 3.1 ft/yr. Two other wells in this area show no decline over the same period, suggesting that the declines observed to date are very localized.

Overall, it appears that the north Galisteo Basin could be approaching a state of substantial ground-water mining, where diversions are exceeding recharge in some areas. Because residential development has increased dramatically in recent years in this area (Prior, 1994), pumping has also increased. When stress on an aquifer is increased, ground water generally declines at a higher rate initially until a new equilibrium is approached; therefore, the recent rate of water level decline may eventually decrease.

2.3.3.2 Water Balance for the Mid-Santa Fe County Hydrologic System. The MSFC hydrologic system includes the north and south Pecos River Basins, the south Rio Grande Basin, and the south Galisteo Basin. Because the hydrogeology of the area is so complex and aquifers within the area are local and tend to be isolated from one another, it may not be useful for management of local water supply to analyze the total recharge versus discharge (even if reliable estimates were available) for the entire MSFC. From DBS&A's compilation of water budget components, it appears that estimated recharge (6,800 afy) is much greater than estimated discharge (284 afy) from domestic wells. The following discussion of the aquifer performance of the MSFC hydrologic system focuses on site-specific water level declines.

Hydrographs in the Galisteo area indicate water level declines varying from 0 (over the period from 1972 to 1982) to 27 ft/yr during the 1990s. Hydrographs presented by Fleming and Finch (1992) show higher rates of decline (4 to 27 ft/yr) from 1990 to 1992 than the hydrographs presented in Appendix E due to the short period of record available. It is possible that the wells that showed no water level decline from 1972 to 1982 may have exhibited a decline since then. Very little water level data before 1990 were used in the development of the hydrographs presented by Fleming and Finch (1992) for this area, and the true trend is therefore difficult to determine. However, east of Galisteo the water level in a well located in T14N.R10E.S34 has dropped at a steady rate of 1 ft/yr from 1972 to 1993, and another well showed a drop of 0.25 ft/yr from 1972 to 1982. No water level data for the Cerrillos, Madrid, or Golden areas were available in the USGS database for plotting hydrographs, and Fleming and Finch (1992) do not include this area in their study of the county.

2.3.3.3 Water Balance of the Estancia Valley Aquifer System in Santa Fe County. Discharge from pumping (about 13,300 afy) in the EV aquifer system exceeds the quantity of recharge (estimated as 5,500 afy by Lee Wilson [1978]) as evidenced by the steady decline in water levels observed in the center of the EV aquifer system and in the Madera Limestone near Edgewood on the western side of the EV. At the northern fringe of the EV aquifer system, in the recharge area, water levels have apparently not declined, and they have even risen in some areas. The decline in the south-central portion of the EV aquifer system, where wells are completed in the Glorieta Sandstone, averages about 1.4 ft/yr from the 1950s to 1993. To the west the decline is less, about 0.6 to 0.9 ft/yr.

The EV aquifer system is clearly in a state of ground-water mining, which is consistent with the philosophical administration of this basin by the SEO. A 40-year lifetime, beginning in 1956, has been set by the SEO for administration of the basin. Since not all available water was appropriated or diverted (18 percent of irrigated land is fallow), the aquifer lifetime will extend beyond the original 40-year period. Based on storage estimates and the quantity of water presently diverted, DBS&A estimates that the aquifer has a remaining life of at least 80 years.

Because the Edgewood area is the fastest growing area in the County (Prior, 1994) pumping will likely increase unless existing water rights are transferred from irrigation use to domestic use. Additional pumping in the EV aquifer system will increase the rate at which the aquifer is mined in the central portion of the basin, even in the recharge area where water levels are not dropping (pumping will divert recharge that presently replenishes the basin).

3. WATER RESOURCE MANAGEMENT ISSUES

This section describes water resource management issues identified by DBS&A through the review of existing management reports. Section 3.1 is a historical overview pertaining to water resource management in Santa Fe County. Section 3.2 is a summary of the County Code, which contains the administrative criteria currently used by the County for land-use administration. Aquifer performance criteria are addressed in Section 3.3, and the effectiveness of the County Code is evaluated in Section 3.4. Finally, Section 3.5 provides a discussion and analysis of documents reviewed by DBS&A. The reader is encouraged to review Appendix A, which describes hydrologic concepts that relate to the management issues. The reader is also encouraged to examine Appendix H, which provides an overview of each report used in this analysis with excerpts specific to Santa Fe County water resource management.

3.1 Historical Overview of Water Resource Management in Santa Fe County

The use of land and water have been regulated at least since, if not before, the formal establishment of Santa Fe in 1610. One study indicated that such control existed even with the Pueblo Indians who occupied the area before the Spanish settlers (Wittfogel, 1957). Don Pedro de Peralta (the governor in 1610) gave specific instructions that "officials were to mark out for each resident two lots for a house and garden as well as two suertes for a vegetable garden, two for a vineyard and olive grove . . . and for the irrigation thereof necessary water" (Clark, 1987). Clark (1987), in his history of water resource administration in New Mexico, states that "although there were two primary acequias, one on each side of the Santa Fe River, the uncertainty of the water supply was to create a perennial problem as the population increased. Domestic and agricultural requirements could be wholly satisfied only in years of exceptional rainfall, a condition commonly noted by contemporary observers."

By the time Santa Fe became the territorial capital, around 1846, water shortages were a perennial concern (Clark, 1987). The area was caught up in the exciting prospect of adding substantially to its limited supply of surface water by developing ground water. Lieutenant John Pope drilled one of his deep exploratory wells in the 1850s on the Galisteo River south of Santa Fe, but without success (Clark, 1987). In 1853 the Santa Fe Artesian Well Company was incorporated in what also proved to be a vain attempt to tap the new source of water (Clark, 1987). After these failed attempts to exploit the ground-water reserves, efforts to expand the surface water supply were attempted. A dam on the Santa Fe River was approved and built in 1866, but it proved to be inadequate, and in the mid-1890s, a second dam was constructed below the first dam (Clark, 1987).

Actions by the state and Federal government influenced the administration of water supplies in Santa Fe County. On January 11, 1893, President Harrison created the Pecos River Reserve, the avowed purpose of which was to protect the headwaters of the Pecos and Santa Fe rivers so they would serve as unpolluted sources of water (Clark, 1987). The New Mexico Water Code of 1907 set out the procedures and limits on the appropriation and use of surface water (N.M. Laws, 1907). In 1931 a similar statute was passed to control and regulate the development of ground water by providing for the declaration of ground-water basins by the State Engineer (N.M. Laws, 1931). This legislation was the first enacted by any state to regulate ground water.

Commitments made in 1938 to deliver water to Texas via the Rio Grande would eventually limit the appropriation of ground water in the Santa Fe area, although not until 1956, when the Rio Grande Underground Water Basin was declared. In the mid-1950s the Santa Fe area experienced substantial population growth; unfortunately, a protracted severe drought occurred about the same time (Spiegel and Baldwin, 1963). To meet the increased demand for water, a number of wells were drilled in the Santa Fe area and in the rest of the Rio Grande Basin.

Due to the efforts of C.V. Theis (who is known as the father of modern ground-water hydrology) of the U.S. Geological Survey District Office in Albuquerque, it became generally recognized that the pumping of ground water that was occurring in the Rio Grande Basin would ultimately affect the flow of the Rio Grande (Theis, 1941). In response to the delivery obligation in the Rio Grande Compact, the Rio Grande Underground Water Basin, part of which is in Santa Fe County, was declared by the State Engineer in 1956. After this declaration, wells could be drilled in the basin only by permit from the State Engineer. However, wells drilled before the basin's declaration could proceed with development according to plans and the capacity of the well.

In 1962 special administrative criteria were adopted by the State Engineer for the Santa Fe area upstream from La Cienega, because it was recognized that additional withdrawals of ground water upstream from the springs would further reduce the flow of the springs (West, 1961). However, as provided by NMSA §72-12-1 (1978), the State Engineer was still required to grant applications for domestic and stock wells.

Legislation regarding subdivision development was first passed in 1963. The 1963 Subdivision Act, passed in response to complaints of consumer fraud (such as developments with quarter-acre lots requiring wells and septic tanks), gave local government control primarily over misrepresentation. One 1972 article pointed out that unregulated growth of subdivisions correlates to the depletion of New Mexico's water resources and that subdivision growth in New Mexico must be regulated and planned with water resources in mind (Noya and Stribling, 1972). Further legislation was passed in 1973 in response to concerns regarding the impact of subdivision development on water resources. The resulting legislation, the Land Subdivision Act, gave counties the authority to control subdivisions by adopting regulatory requirements for various items such as the quality and quantity of water for subdivision use (New Mexico Laws, 1973).

During the legislative session in which the 1973 Land Subdivision Act was passed, fear of the consequences of drilling numerous domestic wells (because these wells are granted automatically upon request by New Mexico Law [NMSA §72-12-1, 1978]) was widespread. This fear prompted the New Mexico House of Representatives to pass a memorial that would urge the counties to write into their regulations that subdivisions would not be permitted to use individual domestic wells as a water supply system (Clark, 1987). The Land Subdivision Act also directed the State Engineer to provide assistance to the counties in drafting their regulations. In 1973 the State Engineer submitted to the counties guidelines requiring subdivisions containing 25 or more lots averaging 10 acres or less in size to have a central water supply (N.M. SEO, 1973).

In October 1980 the Board of County Commissioners adopted the Santa Fe County General Plan (Plan) and its implementing document, the Santa Fe County Land Development Code (County Code). The Plan sets forth a vision for the county's future based on community consensus. One aspect of this Plan involves the management of land-use development as it pertains to water resource availability in the county.

The Code has been amended 14 times since 1980, and the county has received recent requests for additional amendments; however, none of the amendments pertained to water resources. Before proceeding with an update of the Code, the county thought it wise to review existing recommendations in water resource management reports for Santa Fe County. Section 3.5 of this report provides such a review and analysis to aid the county in future planning.

3.2 Summary of Santa Fe County Administrative Criteria

The administrative criteria for managing the water resources in Santa Fe County are set forth in the 1992 County Code. The water policy as stated in the Code is that "future population growth in the County should be supported by adequate long-term water availability and concentrate population growth in Urban and Metropolitan Areas and traditional Communities." The Code uses the concept of density zoning to manage the water resources, such that the total number of houses or lots is limited in any proposed subdivision. The intent of this approach is to ensure that each development balances its water use to be consistent with its water supply.

An application to the County for a permit for a proposed development may be based on one of two approaches:

- Non-appealable water rights (except rights permitted under article 72-12-1 of the New Mexico Statutes [1978], which primarily apply to domestic and stock wells) recognized by the Director of the Water Rights Division of the State of New Mexico Natural Resources Department

- A demonstration that sufficient water is available to supply individual domestic wells for a specified lifetime (the required specified lifetime depends on the location of the development)

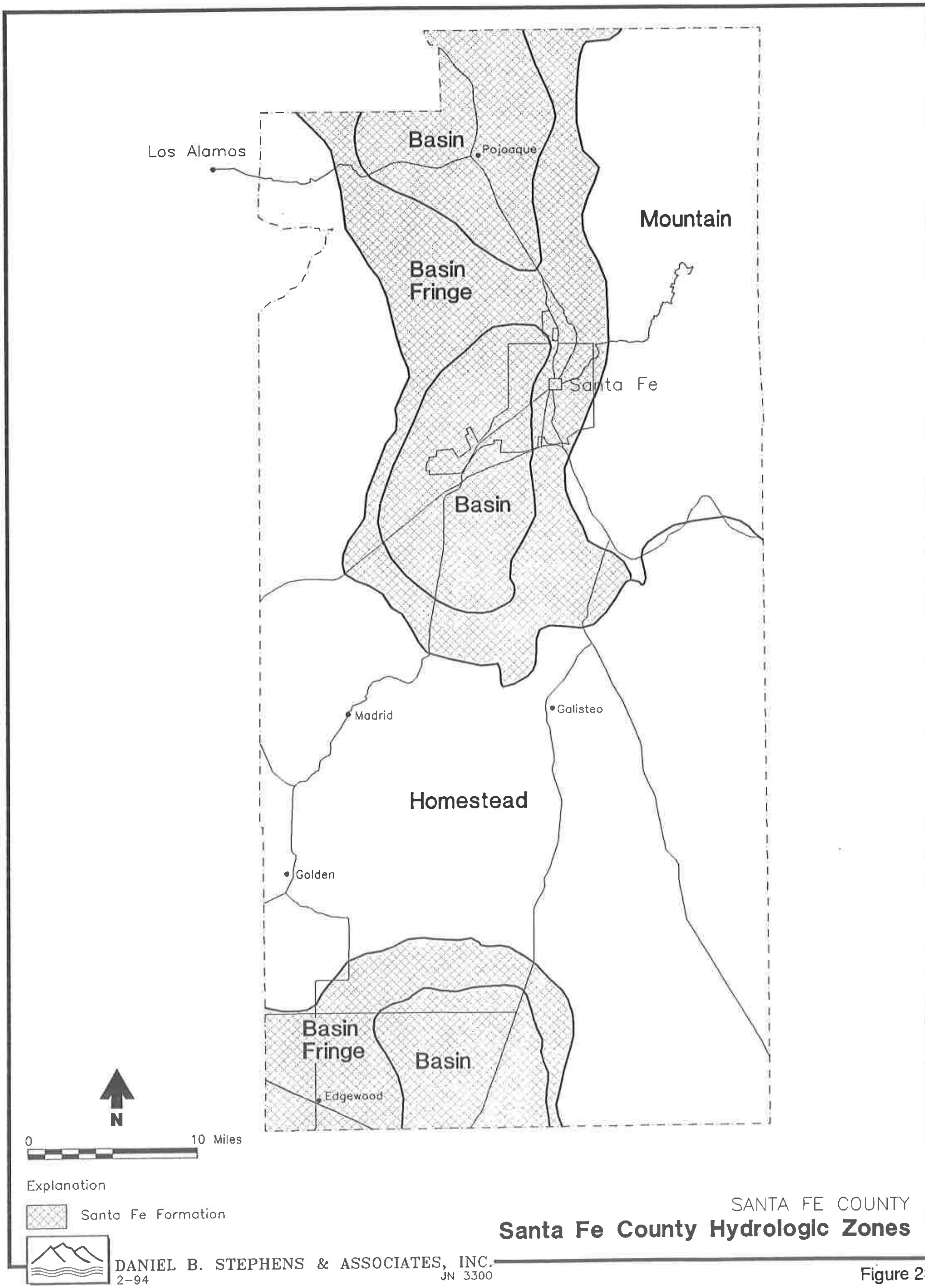
Each of these approaches places limits on the minimum lot size. Sections 3.2.1 through 3.2.3 briefly outline the method for determining the minimum lot size.

For water resource management purposes, the Code divides Santa Fe County into four zone types as shown on Figure 23. In principle, these zone types are based primarily on the availability of water. In general, less water is available in the Mountain and Homestead zone types as compared to the Basin and Basin Fringe zone types. Within the four zone types are further refinements based on land use, that is, agricultural, urban and metropolitan areas, and traditional communities. The rational for designation of the northwest side of the Santa Fe area as Basin Fringe is not clear since a substantial thickness of saturated sediment underlies this area. It may be that other issues (besides the quantity of water in storage) were considered in developing the zones, such as the impact of pumping on the Rio Grande.

For each proposed development project, the applicant must submit a hydrogeology report to the County regarding the water supply for the development. A checklist of the requirements for the hydrogeology report to be submitted to the County is provided in Appendix I. The primary thrust of the Code is the procedure for calculating water availability, as this is the method by which lot sizes and the total diversion are determined. No clear standards for evaluating or incorporating the other information is set out in the Code.

3.2.1 Water Policies Governing Lot Sizes Where the Development Will Use Permitted Water Rights

The minimum lot size for developments relying on non-appealable, transferable water rights is 2.5 acres per lot unless the development is located in an urban or metropolitan area or traditional community. Adjustments to the lot size in the urban and metropolitan areas or in a traditional community can be pursued, but the allowable adjustments to the lot size are reportedly explained in Sections 10.5.2 and 10.5.3 of the Code, which are absent from the Code. Furthermore, the term non-appealable is not appropriate since all SEO actions are appealable. Perhaps the only truly non-appealable water right would be from the Supreme Court.



SANTA FE COUNTY

Santa Fe County Hydrologic Zones

DANIEL B. STEPHENS & ASSOCIATES, INC.
2-94
JN 3300

Figure 23

3.2.2 Water Policies Governing Lot Sizes Where Developments Will Not Use Permitted Water Rights

The procedures for determining the minimum lot size based on water availability are documented by Wilson (1980) and summarized here. The equation for calculating the minimum lot size is as follows:

$$MLS = U/A \qquad \textbf{Eq. 1}$$

Where	MLS	=	Minimum lot size (acres per lot)
	U	=	Water use (acre-feet per lot per year)
	A	=	Water availability (acre-feet per acre per year)

The value of U is assumed to be 1 acre-foot per year unless the applicant can demonstrate that conservation measures will result in less usage. In any event, U may not be less than 0.25 acre-feet per lot per year.

The value of A is defined as either (1) the quantity of water in storage per acre divided by the lifetime of the resource or (2) the annual quantity of water available from recharge per acre (option 2 may only be used in the Homestead or Mountain Zones). The value of A can be based on either of the two approaches listed above by using either (1) standard values for each zone or (2) estimates of the quantity of water available, which must be accompanied by a geohydrology report. The standard values of A are given in Tables 7a and 7b. Sections 3.2.2.1 and 3.2.2.2 discuss the two approaches for estimating A; the first approach is based on storage (Table 7a), and the second approach is based on recharge (Table 7b).

3.2.2.1 Determination of A from Quantity of Water in Storage. In all zones, estimates for water availability (A) may be based on the quantity of water in storage. The units of A are acre-feet per acre per year, which is the quantity of water (acre-feet) for each acre per year. Since this concept of available water is based on withdrawal from a finite source (ground-water storage), the lifetime of the resource is limited. The Code allows for depletion of the water in storage over a

Table 7a. Standard Values of Calculation of Water Availability Storage Based

Zone	Sy	ST (feet)	RL	RC	S[1]	A[2]
Homestead	0.02	100	0.2	0.8	0.32	0.0003
Mountain	0.02	50	0.25	0.8	.2	0.002
Basin Fringe	0.15	50	0.33	0.8	1.98	0.02
Basin	0.15	250	0.33	0.8	9.90	0.1

[1] S = Sy x ST x RL x RC
[2] A is per acre of land in subdivision. A x AC = the total water in the subdivision. A = S/100 and is expressed in acre-feet per acre per year.

Sy = Specific yield
ST = Saturated thickness
RL = Reliability factor
RC = Recovery factor
S = Storage
A = Water availability
AC = Area

Table 7b. Standard Values of Calculation of Water Availability Recharge Based

Zone	R[1]	RL	RC	A[2]
Homestead	0.03125[3]	0.2	1.0	0.00625
Mountain	0.05	0.25	1.0	0.0125
Basin Fringe	0.04	0.33	1.0	0.013
Basin	0.04	0.33	1.0	0.013

[1] R = Recharge (acre-feet per acre per year)
[2] A is per acre of land in subdivision. A x AC = the total water in the subdivision. A = R x RL x RC and is expressed in acre-feet per acre per year.
[3] In the original studies, Homestead recharge was estimated at a lower rate; the value cited here reflects the need to round off the minimum lot size to a relatively convenient number.

RL = Reliability factor
RC = Recovery factor
A = Water availability
AC = Area

Source: Wilson, 1980, Exhibit 3

100-year lifetime except in metropolitan areas, where a 40-year period of depletion is allowed. Thus, the value of A is ultimately obtained from the following formula:

$$A = \frac{S/AC}{Lifetime\ (years)} \quad \textbf{Eq. 2}$$

Where S = Storage (acre-feet)
AC = Area (acres)

The quantity of water in storage is estimated as follows:

$$S = AC \times SY \times ST \times RL \times RC \quad \textbf{Eq. 3}$$

Where SY = Specific yield (volume/volume)
ST = Saturated thickness (feet)
RL = Reliability factor (0 < RF < 1)
RC = Recovery factor (0 < RC < 1)

The storage (S) is the water beneath and available to the entire area (AC) of the tract. The specific yield (SY), the storage coefficient for an unconfined or water table aquifer, is the ratio of the volume of water that will drain from a unit volume of the aquifer. The saturated thickness (ST) is the thickness of the aquifer having the given specific yield. Values provided in the hydrogeology report that are different from the standard values in Table 7a must be supported by detailed hydrologic data.

The reliability factor (RL) is "used to reduce estimates of storage to reflect: (1) aquifer variability and (2) inadequate data which leads to uncertainties about aquifer performance" (Wilson, 1980). The following values of RL are defined in the Code:

- If RL = 1, a detailed geohydrologic report (as defined in Section 6.7 of the Code) must be submitted to support estimates of SY and ST.

- If RL = 0.7, a reconnaissance geohydrology report must be submitted to support estimates of SY and ST.

- If RL = the standard values listed in Table 7b for each zone, no site-specific data are required.

The recovery factor (RC) is the portion of water in storage that can be recovered economically. An RC value of 0.8 is assumed unless it can be demonstrated with computer modeling that the aquifer can yield a greater portion of its total storage.

3.2.2.2 Determination of A from the Water Available from Recharge. The second approach to determine A is based upon recharge analysis and may only be applied in the Homestead and Mountain Zones using the following formula:

$$A = R \times RL \times RC \quad [1] \qquad \textbf{Eq. 4}$$

Where	A	=	Water availability (acre-feet per acre per year)
	R	=	Recharge (acre-feet per acre per year)
	RL	=	Reliability factor
	RC	=	Recovery factor

The recharge (R) estimates must be based on two different methods, and RC is assumed to be 1 "since depletion of the reservoir is not so large that well failures will result." Values for RL are as described in Section 3.2.2.1. This method seems to assume that in the Homestead and Mountain Zones some rejected recharge (i.e., streamflow) will be captured or salvaged by pumping, thereby avoiding aquifer depletion as explained in Appendix A.

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[1] Wilson (1980) defines A as equal to AC x R x RL x RC, a formula that yields the incorrect units; however, an equation in Exhibit 3 of the same document yields the correct units. It is unclear why standard values of A based on recharge for the Basin and Basin Fringe Zones are presented in Wilson's Exhibit 3 (same as Tables 7a/7b) when estimates based on recharge are not allowed in those zones.

3.2.3 Estimates for the Minimum Lot Size

Using Eq. 1 and substituting the highest standard values of A for each zone in Table 7 results in the following minimum lot sizes:

- Basin Zone 10 acres
- Basin Fringe Zone 50 acres
- Mountain Zone 80 acres
- Homestead Zone 160 acres

Adjustments to U based on conservation efforts, or to SY, ST, RL, RC, or R based on geohydrology reports, may reduce the minimum lot size.

3.3 Aquifer Performance Criteria

County planners are interested in some means of identifying areas where the underlying aquifer may be incapable of performing adequately to meet future needs. These aquifer performance criteria should be based on goals specified in the County Code. The County Plan and its implementation document (the County Code) state that one objective is to protect existing wells. At the same time, the code also specifies a lifetime of ground-water supplies of 40 and 100 years (Section 3.2.2.1). Because these goals are not always consistent with each other, defining the performance criteria is very difficult. As an illustration, a pumping rate in one well that is sufficient to deplete the aquifer over 100 years may be a rate which causes excess drawdown in adjacent existing wells to the extent that the adjacent wells cannot produce for 100 years.

To evaluate areas of the aquifer that may or may not meet the goal of protecting existing wells, a map (Plate 9) was prepared which shows the number of wells that are projected to go dry at their present drilled depth in the next 20 and 50 years, assuming the present local rate of water level decline continues. This map was developed using data available in the USGS database, which does not include most of the domestic wells in the county. A database developed by Neva Van Peski lists over 7,000 domestic wells, but contains no completion information such as well depth.

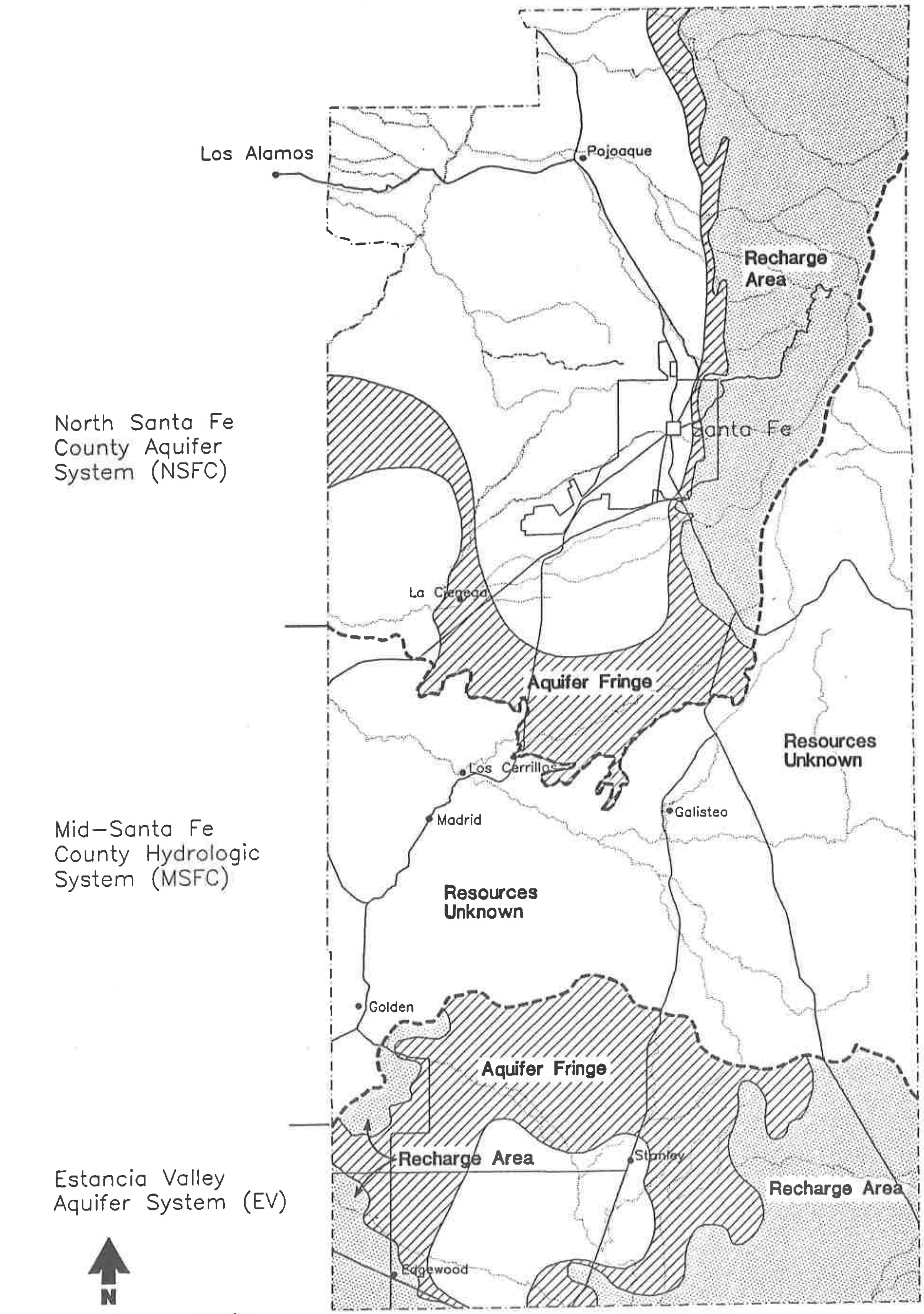
In the Homestead, Mountain, Basin and Basin Fringe Zones, the County Code requires that proposed developments demonstrate water availability for 100 years. The areas where the water supply is uncertain or questionable are outlined on Figure 24 and discussed in Sections 3.3.1 through 3.3.3. DBS&A has not identified any areas that are certain to go dry within 100 years. However, areas near the edge of the aquifer, areas where the aquifer is thin, and areas that rely on recharge for the supply (e.g., fractured bedrock) have the greatest potential for insufficient aquifer performance. The 40-year criterion is applied in the Santa Fe area, where the aquifer is sufficiently thick.

3.3.1 North Santa Fe County Aquifer System

Plate 9 illustrates the saturated thickness in existing wells in the 1980s, the rate of water level decline obtained from hydrographs, and the location of wells that would go dry in less than 20 years and in less than 50 years. As shown in Plate 9, with the exception of the two shallowest observation wells at the Buckman well field, which could go dry within 20 years, most of the threatened wells in the NSFC aquifer system are located around the City of Santa Fe.

The County Code specifies that residential subdivision or other developments that fall within the metropolitan area must demonstrate water availability for 40 years. Although the water levels are declining in the vicinity of Santa Fe from 1.1 to 2.7 ft/yr, the Santa Fe Group is at least 1,500 feet thick, and some of the wells that go dry could be drilled deeper. The lifetime of the aquifer with the present stresses, therefore, is at least 40 years.

The fringe areas of the aquifers described here are very similar to the Basin Fringe defined in the County Code. The areas at the fringe of the Santa Fe Group, particularly the southern portion of the NSFC aquifer system, are vulnerable to aquifer mining. The actual aquifer thickness at the fringe is unknown and may be as little as 80 feet in the Eldorado area (Browne, Bortz & Coddington, Inc. et al., 1992). The present rate of water level decline (0.13 ft/yr) is not alarming, but the situation could change with increased stress on the aquifer. Projections of impacts by proposed developments near the aquifer boundary should consider the effects of existing pumping as well as future pumping on water level declines and the ultimate lifetime of the resource.



Explanation

Aquifer System Boundary

SANTA FE COUNTY INVENTORY

Areas In Santa Fe County Where the Aquifer Performance May Be Insufficient to Meet Future Demands

Development outside of the Santa Fe Group, particularly in the Precambrian rocks to the east, will obtain most water from intercepting recharge rather than from water in storage. In these locations the performance of the aquifer during periods of drought is uncertain.

3.3.2 Mid-Santa Fe County Hydrologic System

The water supply throughout the MSFC hydrologic system is uncertain and appears to be of limited extent; therefore, we cannot determine the water balance through the scope of this project. Detailed hydrologic data and site-specific modeling would be required to determine future aquifer performance.

Several existing wells near Galisteo are projected to go dry within the next 20 years based on long-term hydrographs and information on existing wells in the USGS database (Plate 3). It is likely that many more shallow domestic wells exist that are not included in the USGS database.

3.3.3 Estancia Valley Aquifer System

Several existing wells northeast of Edgewood and south of Stanley are projected to go dry within 20 years and 50 years, respectively, as shown on Plate 9. It is likely that many more shallow domestic wells exist that are not included in the USGS database.

The County Code requires that proposed developments in the EV area demonstrate that a water supply will last 100 years beneath the property. Given the current rate of water level decline (1.4 ft/yr) in the thickest part of the aquifer (260 ft), and assuming that the allowable drawdown is 60 percent of the saturated thickness (Heath, 1983), the productivity of the EV aquifer will diminish greatly in about 110 years. Developments along the edge of the valley fill in the EV aquifer system may not have sufficient water to last 100 years. Recharge entering the valley fill occurs at the fringe, thus tending to reduce the rate of decline in the fringe areas. However, the aquifer is being mined, and where the aquifer thins, drawdown will undoubtedly occur as well. Development outside of the valley fill in recharge areas would intercept water that replenishes the valley fill and would thereby shorten the lifetime of the resource. Recharge areas may also be prone to insufficient supply during periods of drought.

3.4 Effectiveness of Existing Code

The water policy as stated in the Code is that "future population growth in the County should be supported by adequate long-term water availability and concentrate population growth in Urban and Metropolitan Areas and traditional communities." This policy suggests that population centers could eventually be supplied with imported water, while the remainder of the county has a long-term supply. It appears from a recent population study (Prior, 1994), that the Code is not effective in concentrating population in the metropolitan areas. Prior (1994) states that "The areas outside the City of Santa Fe, especially in the central part of the County, are absorbing larger shares of the County-wide population growth. Between 1930 and 1960, 82% of the County's increase occurred within the City of Santa Fe. Since 1970, 68% of the increase of population has occurred outside the City of Santa Fe." DBS&A has evaluated the effectiveness of the Code in ensuring a long-term water supply for the areas where this urban sprawl is occurring and has identified several inherent problems that could render it ineffective. These problems are explained in detail in Section 3.5.

Despite the limitations and potential problems, the Code appears to be functioning properly thus far, although it is too soon to formulate a conclusion. DBS&A selected four developments that were proposed in the early 1980s to determine how well the water supplies are performing in comparison to the predictions. The Code was adopted in 1980; therefore, only developments proposed after that date would have used the new criteria. Although 14 years have passed and over 150 geohydrology reports have been submitted to demonstrate water availability under the Code, the proposed development may have taken years to consummate. Therefore, the full stress on the aquifer may have only recently begun for most of the developments, and thus one cannot draw firm conclusions as to the effectiveness of the Code. Also, water level decline rates from nearby wells were used to calculate the lifetime of the resource at the proposed development, which may not accurately reflect the conditions beneath the property. Furthermore, precipitation has been above average since 1985; therefore, pumping may have been less and recharge greater than average. However, based on the following analysis of four subdivisions, water availability appears to be adequate to support the developments for at least 100 years.

Four proposed and approved subdivisions were selected for evaluation based on the date of the proposal (the closer to 1980, the better), the proximity to available hydrograph data, and the scale of the project with favor given to larger developments (the majority of the hydrogeology reports are for small-scale developments, such as lot splits or adding a guest house). The following subdivisions were evaluated to determine if the Code was effective in ensuring an adequate water supply (which should last 40 years within metropolitan areas and 100 years outside metropolitan areas):

- Arroyo Hondo West (T16N.R09E.S15)
- Thorpe Condominiums (T17N.R10E.S06)
- Vista Chamiso Subdivision (T16N.R09E.S01)
- Colimo Subdivision (Old Pecos Trail Estates) (T16N.R10E.S20&29)

The proposals for all four of these developments based water availability on the volume of water in storage. The evaluation of the sustainability of the water supply is therefore very simple as it is based on observed water level declines only. In order to perform a rigorous evaluation of the future impacts due to existing diversions and boundary effects, numerical modeling or complex analytical solutions would be required.

The hydrogeology report for Arroyo Hondo West Subdivision, located south of Santa Fe, was prepared by VeneKlasen & Associates in February 1986 (1986a). The proposal was to subdivide an 80-acre tract into 24 lots, with a total diversion of 21.4 acre-feet per year (796 gallons per day [gpd] per lot). The report showed that the saturated thickness of the Tesuque Formation in the supply well is 369 feet. The water level decline in a nearby well (less than 1 mile to the north, T16N.R09E.S10.42114) was determined by DBS&A to be about 1.1 feet per year (from 1958 to 1993). The rate of decline has been relatively steady, such that the decline rate in the late 1980s is about the same as the rate prior to that period. If it is assumed that the yield of the well will not be significantly impacted until the water level has dropped 60 percent of the saturated thickness (Heath, 1983), then the maximum allowable drawdown would be about 220 feet, which would take about 200 years at the present rate of water level decline. Additionally, the aquifer is probably much thicker than 369 feet in this area, and the well could be deepened to extend the supply.

The hydrogeology report for Thorpe Condominiums, located north of Santa Fe, was prepared by David N. Jenkins and submitted in November 1982 (1982b). The proposal was to build ten dwelling units on 12 acres, with a total diversion of 2.5 acre-feet per year (223 gpd/unit). The hydrogeology report shows that the thickness of the Tesuque Formation is 300 feet and the thickness of the underlying Magdalena Group is 130 feet at the supply well. The maximum allowable drawdown in the Tesuque Formation would be 180 feet (60 percent of the saturated thickness) without significantly impairing the yield of the well (Heath, 1983). Water level declines about 2 miles to the northwest (in T18N.R09E.S25.13111) are about 1.54 feet per year from 1962 to 1993. The decline rate has been relatively uniform over this period and does not appear to increase since the early 1980s. If this decline is also occurring in the vicinity of Thorpe Condominiums, the maximum allowable drawdown could occur in about 115 years. Because this development is near the hydrologic boundary of the Santa Fe Group, drawdown may occur at a faster rate in the future.

The hydrogeology report prepared for the Vista Chamiso Subdivision, located in the southern part of the city of Santa Fe, was prepared by Jay Lazarus in August 1983. Since this development is within the metropolitan area, the proposal had to demonstrate water availability over a 40-year period. The proposal was to split 10 acres into 9 tracts and produce a total of 2.25 acre-feet per year from the existing well (223 gpd/lot). The saturated thickness of the aquifer at the supply well was estimated to be 180 feet. Water levels in a USGS monitor well (16N.09E.01.31121) located less than 1 mile from the supply well shows a rise in water levels since the 1950s. Therefore, it appears that the supply in this area should last at least the requisite 40 years.

The hydrogeology report for the Colimo Subdivision (now known as Old Pecos Trail Estates), located southwest of Santa Fe, was submitted by VeneKlasen & Associates, Inc. in October 1981. The proposal was to subdivide 135 acres into 37 lots and produce a total of 10.8 acre-feet per year (261 gpd/lot). The final development included only 24 lots, but the same total quantity of water was allowed for diversion (402 gpd/lot) (although a storage value of 0.02 instead of 0.05 should have been used for the calculations). VeneKlasen & Associates showed that the saturated thickness in the production wells was 200 feet. Water levels in this area (less than 1 mile away) have risen about 12 feet since 1974 (in T16N.R10E.S17.42234), and therefore it appears that the water supply may last indefinitely. However, because this well is located in low storage igneous rocks in the recharge area, water levels could drop rapidly during periods of drought.

3.5 Review and Analysis of Existing Reports

Of the approximately 50 documents reviewed, only 3 major reports are specific to the management of the ground-water resources for the whole of Santa Fe County. These are:

- Consulting Professionals, Inc. (CPI), 1974b. *Santa Fe County Current Water Use and Availability.*
- Wilson, Lee, 1978. *Santa Fe County Water Plan.*
- Santa Fe County Board of Commissioners, 1980. *Santa Fe County Land Development Code* (recompiled in 1992 and summarized in Section 3.2).

Wilson (1978) incorporated part of CPI's (1974b) work, and the Code essentially implements the recommendations presented in Wilson's report. These two studies and the Code define hydrologic zones and specify minimum lot sizes for developments county-wide based on the quantity of water in storage or available from recharge.

Other planning studies and recommendations addressed a more comprehensive picture for water resource administration for the Santa Fe area only. Studies such as *Long-Range Water Planning Study for the Santa Fe Area* (Harza et al., 1988), *Water Supplies for the Santa Fe Area* (Wilson, 1984), the planning study for Public Service Company by Woodward-Clyde Consultants (1980), and the Santa Fe Basin Water Users' Association report to the City Council (1988) addressed balancing the three sources of water for the Santa Fe area. These sources are (1) the Santa Fe River, (2) ground water, and (3) imported water from the Rio Grande. Table 8 summarizes the scopes of the reports reviewed.

Table 8. Summary of Reports Relating to the Management of Santa Fe County Water Resources
Page 1 of 5

Year	Author	Title	Agency Directing Study/Report	Scope of Report	Recommendations (if any)
1958	Reynolds, S. E.	Rio Grande Underground Water Basin	State Engineer Office	Overview of water resource administration for the Rio Grande Underground Water Basin	
1961	American Society of Civil Engineers	Ground Water Basin Management, Manual of Engineering Practice	Professional Organization	Manual describes commonly used terms and concepts that relate to ground-water management. Not specific to Santa Fe County or New Mexico.	
Undated	Consulting Professionals, Inc. (CPI)	Santa Fe Well Field	Unknown	Discusses the fate of Santa Fe's city well field	Expansion of water supply must be outside of Santa Fe area.
1974	Consulting Professionals, Inc. (CPI)	Santa Fe County Current Water Use and Availability-Phase III - Santa Fe County Water Study	Santa Fe County	Describes water resources, water use, population for Santa Fe County	Future water supplies must come from retirement of irrigated lands.
1974	Hagerman, Charles de B.	Geologic Units and Hydrologic Conditions, Santa Fe County, New Mexico	Santa Fe County	Describes the water availability in Santa Fe County and provides recommendations for development densities	Recommended development densities ranging from 2.5 acres/lot to no development by lots. Suggested that the Rio Grande is only source of new water.
1975	Koopman, F.C.	Estimated Ground-Water Flow, Volume in Storage, and Potential Yield of Wells in the Pojoaque River Drainage Basin	United States Geological Survey	Investigated aquifer characteristics and water availability	
1975	Consulting Professionals, Inc. (CPI)	Water Use and Availability	Santa Fe County	Describes current use and availability of water in Santa Fe County	

Table 8. Summary of Reports Relating to the Management of Santa Fe County Water Resources

Year	Author	Title	Agency Directing Study/Report	Scope of Report	Recommendations (if any)
1975	Santa Fe County Staff	Land Use Policies Related to Water Availability	Santa Fe County	Describes the importance of water availability and water rights in determination of any land use policy	• Rural growth should be restrained. • Rural lot sizes should be based on sustained yield in Homestead Zone. • Ground-water resource in the Basin Zone should be based on 100-year lifetime or imported water. • Lots on agricultural lands should be sized to deter transfer of water rights.
1975	Wilson, Lee	Water Availability and Land-Use Policy in Santa Fe County	Santa Fe County	A precursor to the 1978 study by the same author	Recommended zoning districts and lot sizes ranging from 10 to 160 acres.
1977	Spiegel, Zane	Water Resources Aspects of Santa Fe County	Voluntary	A review of the Santa Fe County General Plan	The plan should be revised to incorporate concise and correct definitions and descriptions of hydrologic terms such as steady-state, equilibrium, natural discharge, etc. Recommended that the 100-year lifetime for mining the aquifer be revised since communities in Santa Fe County have been occupied for more than 370 years.
1978	Wilson, Lee	Santa Fe County Water Plan	Santa Fe County	An extensive overview of all aspects of water resources in Santa Fe County	• Limit individual domestic wells. • SEO investigate the cause of declining runoff and develop means to predict future effects of climatic change and watershed management practices. • SFMWB investigate the potential for an artificial recharge project using Santa Fe River water.
1980	Hearne, G.A.	Mathematical model of the Tesuque aquifer system underlying Pojoaque River Basin and vicinity, New Mexico	U.S. Geological Society	Describes a mathematical model of the Tesuque aquifer system, which is relevant to stream-aquifer interaction on Indian lands	

Table 8. Summary of Reports Relating to the Management of Santa Fe County Water Resources
Page 3 of 5

Year	Author	Title	Agency Directing Study/Report	Scope of Report	Recommendations (if any)
1980	Wilson, Lee	Procedures for determination of Water Availability (A) Pursuant to Section 6.4.1d, Article VII of the Santa Fe County Land Development Code	Santa Fe County	Describes procedures for determination of water availability	
1980	Woodward-Clyde Consultants (WCC)	Planning Study - Santa Fe Water Resources for Public Service Company	Public Service Company of NM	Describes the possibilities for meeting the long-term water supply requirements for Santa Fe	Recommends diverting water directly from the Rio Grande since expansion of ground-water rights is not possible, even though aquifer could sustain demands in Santa Fe for hundreds of years.
1983	Reynolds, S.E.	Letter to C.T. Dumars, Chairman, N.M. Legislative Water Law Study Committee, State Engineer Office	State Engineer Office	Describes the process for offsetting rights on the Rio Grande	
1984	Wilson, Lee	Water Supplies for the Santa Fe Area, New Mexico, A Status Report. A Hydrologic Support Document prepared for the Santa Fe Metropolitan Water Board	Santa Fe Metropolitan Water Board	Summarizes the best available information about three sources that provide water to the Santa Fe municipal system	
1984	Santa Fe Metropolitan Water Board	Santa Fe Regional Water Supply System	Santa Fe Metropolitan Water Board	Describes the Santa Fe regional water supply system	• Decrease dependence on ground water and increase use of San Juan/Chama Project water. • Rely on surface water, using ground water on an as-needed basis. • Reduce number of wells in marginal aquifers or in areas of heavy pumping. • Prohibit/restrict well-supplied central water systems. • Develop a policy concerning 72-12-1 wells.

Table 8. Summary of Reports Relating to the Management of Santa Fe County Water Resources

Year	Author	Title	Agency Directing Study/Report	Scope of Report	Recommendations (if any)
1985	Lazarus, Jay	Preliminary Estimates of Recharge from the Sangre de Cristo Mountains to the Santa Fe Basin		Estimates mountain-front recharge	
1988	McAda, D.P. and M. Wasiolek	Simulation of the Regional Geohydrology of the Tesuque Aquifer System near Santa Fe	U.S. Geological Survey	Develops a numerical model and ground-water budget for the Tesuque aquifer system	
1988	Santa Fe Basin Water Users Association	Report to the City Council and Staff County Commission and Staff Area Planners	Citizens Group	Provides comments to City and County planners regarding the management of water resources in Santa Fe County	• All developments with greater densities than stipulated in the present County Code should use imported water. • No transfers of water rights that create a new point of diversion in the extraterritorial area; distinguish between new supply of water for new developments and a replacement supply for existing users. • Protect recharge zones from further overuse • Expansion of ground-water utilization should be discouraged until an adequate database is available on which to base decisions.
1988	Harza Engineering Co.; Browne, Bortz and Coddington Inc.; and J. Shomaker, Inc.	Long Range Water Planning Study for the Santa Fe Area - Phase I	Santa Fe Metropolitan Water Board	Comprehensive report on possible management strategies for the Santa Fe metropolitan area	• Rely on ground-water pumping even though water levels are declining because it may be cheaper than importing water. • Reach a consensus on water resource management policy.

Table 8. Summary of Reports Relating to the Management of Santa Fe County Water Resources

Year	Author	Title	Agency Directing Study/Report	Scope of Report	Recommendations (if any)
1989	Harza Engineering Co.; Brown, Bortz and Coddington Inc.; and J. Shomaker, Inc.	Long Range Water Planning Study for the Santa Fe Area Phase II Report	Santa Fe Metropolitan Water Board	Comprehensive report on possible management strategies for the Santa Fe metropolitan area	• Recommends regional water and sewer system for the Santa Fe area. • Recommended that planning processes move forward through a forum and that water concerns be separated from ancillary issues.
1991	Fleming, W.M.	Evaluation of the Hydrogeologic Basis for the South-Boundary Area of the USGS Santa Fe Ground Water Model	Santa Fe Metropolitan Water Board	Review of hydrologic parameters used in an USGS model	
1992	Browne, Bortz and Coddington Inc. et al.	South Santa Fe County Water Resource Assessment		Compilation of data for south Santa Fe Area	
1992	Finch, S.T. and W.T. Fleming	Recalibration of the USGS-SEO Santa Fe Model Using Revised Recharge Estimates	Santa Fe Metropolitan Water Board	Recalibration of USGS model using revised recharge estimates	
1992	Santa Fe County	Santa Fe County Ordinance 1992-1, Land Development Code	Santa Fe County	Amended version of the original code established in 1980	

The three Santa Fe County water management reports listed above and the other planning studies were written by or for various entities, each of which has a different interest in the ground-water resources of Santa Fe County. These differing interests result in goals or objectives that are not entirely coincident, and some elements of those reports apparently reflect the interests of the party that commissioned the reports. The primary parties and their particular interests are outlined below:

- Santa Fe County's interests began with their responsibility under the Subdivision Act to assure that there was "enough water for subdivision purposes" (CPI, 1974b; Wilson, 1978).

- The Sangre de Cristo Water Company was interested in the resource from the standpoint of a utility company (WCC, 1980).

- The Santa Fe Basin Water Users Association (1988) was concerned about the effect on their wells of increased pumping by new developments.

- The State Engineer was involved in administering state water laws and complying with interstate water compacts for the Rio Grande (Reynolds, 1958).

Although the intent of the reports differ, all of the reports considering the management of the water resources of Santa Fe County had in one respect or another a common denominator: the use of a limited resource.

Table 8 is a summary of the reviewed water resource management reports describing the scope of the studies and summarizing any recommendations provided in the reports. The contents of the reports and their recommendations are discussed in more detail in Appendix H. Because the scope of each report is different, it is difficult to compare them directly. In order to synthesize the contents of the reports, we have organized the following discussion by the important issues where discrepancies appear. The focus of the discussion is centered on the existing County Code.

The main issue of agreement or disagreement revolves around the policy decision of whether to base development on local, sustainable resources or to deplete the resource and import water.

Most of the reports agree that if cost is not a factor, Santa Fe County has (or has access to) adequate water resources to sustain development for the indefinite future.

The disparities in some of the recommendations presented in the reports and discussed below appear to stem from a misunderstanding or misuse of hydrologic terms and/or dissimilar (or a lack of clear) objectives in managing the water resources. For example, there appear to be conflicting objectives between protecting individual well owners and encouraging community water systems, and between obtaining a sustained yield in the basin and specifying a lifetime for the resource. Legal constraints in obtaining available water have also caused problems for water management strategists. Sections 3.5.1 through 3.5.8 discuss some of the key issues that have resulted in a disparity in recommendations or potential problems.

3.5.1 Concepts and Terms

The limited nature of the ground-water resource gave rise to the concept of a "lifetime" for the use of the resource (Santa Fe County Staff, 1975). It was indicated that there are two options available at the end of a lifetime: cease the demand or develop a new source of supply (CPI, 1974b).

Several euphemisms were developed, probably in part to allay fears of the over-utilization of the aquifer, including terms such as "safe-yield" (Wilson, 1984; Santa Fe MWB, 1984; Harza et al., 1988), "sustained-yield" (Santa Fe County Staff, 1975), "optimum-yield" (WCC, 1980), and "steady-state" (Wilson, 1978; Wilson, 1984). These terms are commonly used in the water resource field; unfortunately, there is little consistency in use of the terms. Furthermore, several of the terms are vague and ambiguous from a hydrologic or management standpoint, as described below.

- The term "steady-state" appeared to be used at times to suggest a concurrent hydrologic balance in the aquifer between volumes of ground-water recharge and ground-water withdrawals. On a basin-wide scale, such a balance may occur only after decades or centuries when no appreciable change in water levels is observed. In this sense the terminology is similar to the concept of a dynamic equilibrium as explained in Appendix A.

At the local scale, however, a steady state condition does not necessarily occur where the pumping rate equals the recharge rate, because the pumping and the recharge are likely taking place in different locations in the basin; hence, water-level declines from pumping may still occur near the pumped wells as water is taken from storage in the aquifer.

- As generally used, the term "safe-yield" does not have anything to do with safety, and each usage seems to have its own definition of safe. Generally, safe yield is the rate of withdrawal from the aquifer that will not cause undesirable effects. The key issue is in defining undesirable effects. Obviously, different interests may have different definitions of safe-yield. Moreover, there is no generally-agreed-upon method to quantify the safe-yield. For these reasons, the term is now commonly avoided.

- In that the administrative land-use zones have associated lifetimes (of 40 to 100 years), the term "sustained-yield" is confusing because a specific time frame and subsequent end is set out. Presumably, the sustained yield of a well also could be such that the lifetime exceeds 100 years or lasts indefinitely.

- Woodward-Clyde Consultants (1980) recommend "optimizing" the yield of the aquifer, but they do not define this term. Optimization of yield could mean, for example, to produce as much water as possible in the shortest time with the fewest wells, to pump the wells at locations and rates to meet demand for a specific period of time, or to pump at locations and rates so that drawdowns do not exceed a specified depth.

The often-used term of "ground-water mining" generally describes the condition of over-pumping an aquifer with respect to its rate of replenishment. This condition results in a lowering of the water table, because the pumped water is derived from aquifer storage. Unfortunately, almost every report has used the term in a different sense or with different criteria for the onset of "mining." Some of the various distinctions are outlined below.

- In the earliest of the reviewed reports (ASCE, 1961), the term ground-water mining was used to mean the volume of extractable, but non-renewable water in a ground-water reservoir. In a ground-water basin where pumping does not induce spring or streamflow depletion or cause reductions in discharge such as evapotranspiration, the source of the pumped water will always be from storage. The term mining was quite appropriately applied to the Estancia Basin (southern Santa Fe County) where the withdrawals of water are substantially greater than the recharge.

- Reynolds (1958) adapted the term to stream-connected aquifers by defining mining as the period of time between the start of pumping and the time when all of the water is being derived from a source such as the Rio Grande. Thus, in this context a ground-water mine exists for only a period of time. When pumping begins, all of the water is derived from aquifer storage and is therefore "mined." As the cone of depression (the mine) strikes sources of water other than storage, water is derived from the source and the amount of water being taken from storage (mined) decreases until all of the water being withdrawn is derived from the source (such as a river). In the context of Theis' (1941) analysis, Reynolds' definition of mining occurs prior to reaching a new dynamic equilibrium in the aquifer when the source of the pumped water is the aquifer discharge that would have flowed to the river in the absence of pumping.

3.5.2 Relying on Recharge from Precipitation

The Plan (Wilson, 1978) suggests and the 1992 Code provides for land use and development based on recharge by the only "new" source of water available to the County: precipitation. Procedures outlined (Wilson, 1980) for the calculation of recharge generally rely on the average precipitation over a long period of time. This supply has been characterized as a steady-state source of water (Wilson, 1980), and as a result, the land-use administration has at times been characterized as being based on steady-state conditions. The use of long-term averages of precipitation as a basis for development can be misleading to lot owners, because a full supply of ground water would not be available in years of drought and low recharge.

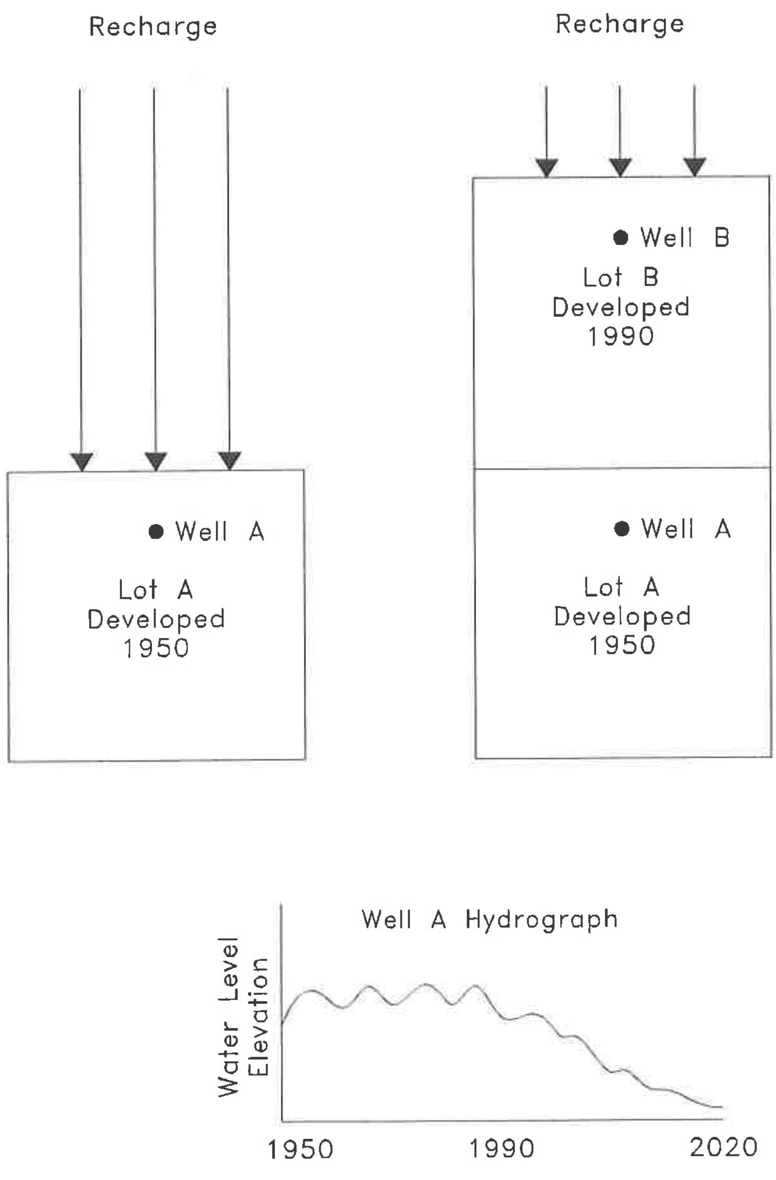
The potential variability of recharge with time is illustrated in Figure 8, which is a graph of the Palmer Drought Severity Index for the northern mountains of New Mexico (Army Corps of Engineers, 1991). This index may be a better proxy indicator of recharge than just precipitation because it includes temperature. One can see from the graph that the potential for recharge is quite variable over long periods of time. It can be argued that recharge occurs effectively only during the most favorable periods, when precipitation is above average. In the past, such as the drought of the 1950s, numerous wells have been reported to go dry. Studies of paleoclimate using techniques such as tree ring analysis indicate periods of severe drought on the order of 40 years in length (Orcutt, 1991).

It is therefore possible that some of the development that is based on recharge may experience dry wells at times of lower than average precipitation. The Plan (Wilson, 1978) indicates that during such periods of poor water supply it may be necessary for some users relying on recharge to import water. The Code does not make this aspect entirely clear, and therefore the concern has been raised as to whether purchasers of such lots have been fully informed by not only the developer but also by the County.

Development based on the availability of water in storage has an associated factor of safety (recovery factor) that development based on recharge does not have (especially in areas where storage is limited). The use of a safety factor for recharge-based developments would seem to be appropriate and is perhaps a required rationale for consistent land-use administration.

3.5.3 Interception of Recharge

Allowing future developments to base their water availability on recharge could result in the depletion of water that is counted on by existing water right users. The Plan (Wilson, 1978) states that "water rights are generally used to offset use of runoff or recharge water, not water from storage." The intent of the plan for water resource management was that those exercising their water rights would derive the pumped water from recharge (or by reducing natural discharge), and the basin would be operating under a sustained yield at steady-state. However, the policy of allowing recharge-based water availability (to individual domestic wells, less than 3 acre-feet per year) in the Homestead and particularly in the Mountain Zones conflicts with the Plan and the accounting of recharge to the basin as a whole. This problem has been noted by the Santa Fe Basin Water Users Association (1988) who recommended that "the zones of basin recharge should be protected from further over use." This issue is explained in more detail below and illustrated in Figure 25.



Lots A and B are developed based on upgradient recharge in 1950 and 1990, respectively. Water levels on Lot A decline after pumping on Lot B intercepts the recharge.

SANTA FE COUNTY INVENTORY

Diagram Illustrating Effects of Intercepting Recharge

DANIEL B. STEPHENS & ASSOCIATES, INC.

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Figure 25

If the ground-water basin strategy is to limit total annual pumping of all wells so that it does not exceed the amount of annual replenishment, then pumping would eventually lead to a state of dynamic equilibrium. To maintain a balance in the basin after pumping disturbs the dynamic equilibrium, the water must be derived from increased recharge or decreased discharge as discussed in Appendix A. Whether pumping increases recharge or decreases natural discharge depends upon the aquifer characteristics and the location of the wells. If we pump at a rate equal to the predevelopment recharge along a mountain front and no new recharge such as increased stream infiltration occurs, then there will be a reduction in aquifer storage (water level declines) and a reduction in discharge elsewhere (e.g., to the Rio Grande). This new state of dynamic equilibrium may impair existing rights.

Nevertheless, recharge has been adapted, in part, as a basis for the administration of land use (Section 3.2). Under this procedure mountain-front recharge is already allocated to future development in the Mountain and Homestead Zones. Consequently, incorporation of the historical quantity of recharge to the basin for planning purposes may not be appropriate because future recharge-based development in mountain areas may intercept the mountain-front recharge. When considering what "yield" the basin (Santa Fe MWB, 1984) or a well field (WCC, 1980) may have, the inclusion of mountain-front recharge in the computation of potential impacts downgradient of the recharge area would in effect be double accounting, since that mountain-front recharge is already allocated to the Mountain and Homestead Zones. (No report was found that indicated any model simulations were performed to assess the effects of the cessation of mountain-front recharge as a result of the future development.)

3.5.4 Inconsistencies in Administrative Lifetimes

Part of Santa Fe County lies within the Estancia Basin, for which the SEO has established special administrative criteria based on a 40-year lifetime beginning in 1956. In parts of the Estancia Basin, the Code provides for development based on the demonstration of the availability of water for a period of 100 years. This time frame is inconsistent with that adopted by the SEO.

The administration of the Estancia Basin area is based on the "mining" of ground water. For the part of the Estancia Basin that occurs in Santa Fe County, applications have not yet been filed with the SEO for all of the water estimated to be available for appropriation under the SEO administrative criteria. Therefore, it is possible for a developer to show that a 100-year supply of water is still available under the land based on the proposed use. If the SEO receives no other applications for this water, then sufficient water may be available for the developer. However, the administrative policy of the SEO may preclude a 100-year life of the water supply for the development, as explained below.

The administration of the Estancia Basin was developed on the basis that the principal use of water would be for agricultural purposes, which require a 40-year life to amortize land development and operational costs and to provide a retirement for the farmers. This context is rapidly changing to a residential use of water. Typically, the SEO assumes that it will be uneconomical for farmers to completely dewater the aquifer, because of declining rates of water production from wells, and have reserved the lower 40 feet of the aquifer. Thus, the remaining "uneconomic" water could support a rural population, by pumping relatively small quantities of ground water from a number of low-productivity wells. This approach may offset some of the potential problems with the different administrative lifetimes for the Estancia Basin since 40 feet of aquifer thickness would theoretically remain at the end of the 40-year period.

The end of the 40-year administrative life of the Estancia Basin is approaching. This may present an opportunity for the County to bring to the SEO's attention the conflict in the Estancia Basin between the policies of the County and the State Engineer for a possible solution under the provisions of the 1985 law regarding public welfare (NMSA, 1985). This statute is an amendment to the water code that recognizes the importance of public welfare in administering its public waters and allows those who assert "legitimate" public welfare concerns to protest applications for appropriation of water rights (Bokum, Gabin and Morgan, 1992). Expression of these concerns at the end of the existing policy period may serve to alter that policy to recognize the intervening changes in the nature of the water use over the years and the attendant public welfare issues. This may be an efficient route for impacting an area of the administration of water resources that supersedes the authority of the County to control land use and subdivisions.

3.5.5 Individual Wells and Community Wells

Theis (1940) pointed out and Woodward-Clyde Consultants (1980) also mention that from a hydrologic standpoint the most efficient way to use an aquifer is to draw from a large number of small-capacity wells. This method will allow the water level to decline relatively uniformly over the entire aquifer. Although small-capacity wells are preferable from a hydrological standpoint, some reports speak out against them, because individuals can obtain permits from the SEO for "domestic" wells (under NMSA §72-12-1, 1978) without any water resource management consideration (Wilson, 1978; Santa Fe MWB, 1984; Santa Fe County Board of Commissioners, 1992). This criticism occurred in spite of the fact that a proposed development served by individual domestic wells would still be required to obtain approval under the County Code by demonstrating the availability of water for a specified period. However, such a demonstration of water availability is not required by the Code for wells based on water rights.

Critics of individual domestic wells claim that the use of water from these wells is greater than it would be if the user was supplied by a central system. Few hard data exist on the actual usage from domestic wells. Although domestic wells can under the conditions of the SEO permit withdraw up to 3 acre-feet annually, it appears that generally the wells withdraw only about 0.25 to 0.50 acre-feet annually (Wilson, 1978). This use rate generally appears consistent with average water use in homes on a community water system.

One key problem occurs when there is a mix of water users (e.g., shallow individual wells for farms, shallow domestic wells, deep community wells, and deep large-capacity irrigation wells). The drawdowns from wells of large water users increase drawdowns in wells of the smaller water users with shallow wells. Large-capacity wells not only impact shallow well owners by causing those shallow wells to dry prematurely, but they shorten the lifetime of the aquifer at least locally. The deeper cone of depression created by a single large-capacity well serving a community system will locally dewater the aquifer faster than if the same volume were pumped from multiple, widely spaced wells. In either system, the available water resource is limited, and eventually, alternative sources such as imported water will need to be developed. Other factors, such as the economics of production, may make community wells more desirable than individual domestic wells when the depth to water is great.

The assumption in the early reports used in the development of the Plan and the Code was, in fact, that the local source will not last forever and that the main source of water supply of Santa Fe County must ultimately be imported water (Santa Fe County Staff, 1975; Wilson, 1975; WCC, 1980; Santa Fe MWB, 1984; Santa Fe Basin Water Users Association, 1988; Harza et al., 1988). By requiring community water systems and thus permitting the depletion of the ground water, it appears that the commitment has been made, at least implicitly, by Santa Fe County to supply community systems with imported water at some point in the future. The ultimate cost of a system for importing water will be reduced by having a local distribution infrastructure built at the time of development. It remains now to develop a plan for importation by pipeline or to reduce pumping. If this is not done, then some of the County residents will have the options that Wilson (1978) listed: capture rainfall or import water by truck.

3.5.6 Relying on Available Water in Storage

The main basis for administration of land use under the Code is the availability of water beneath the development (with the very minor exception of a few developments that have used recharge to demonstrate water availability). The volume of water available is the volume stored in the aquifer beneath the geographical boundaries of the property. This procedure has been used in several other areas of New Mexico where ground-water mining is occurring. It is a straightforward and self-accounting method of water resource management and thus is efficient and economical (for the developer), particularly as compared to alternative procedures which may require more complex analysis. However, from a hydrologic point of view, there are three weaknesses that undermine this approach. These weaknesses are discussed in the following paragraphs. A fourth weakness stems from the implementation of the Code.

The Code requires that each development relying on §72-12-1 permits have a sufficient amount of water in storage under the development to supply the use for a specified period, such as 100 years. However, when the development begins pumping, the cone of depression will spread and water may be obtained from under the surrounding areas beyond the property boundary (Figure 26, Scenario A). At the same time, surrounding developments presumably will also pump from the aquifer and lower the water table (Figure 26, Scenario B). Because it is believed that everyone has enough water under their development to supply their needs at least for the 100

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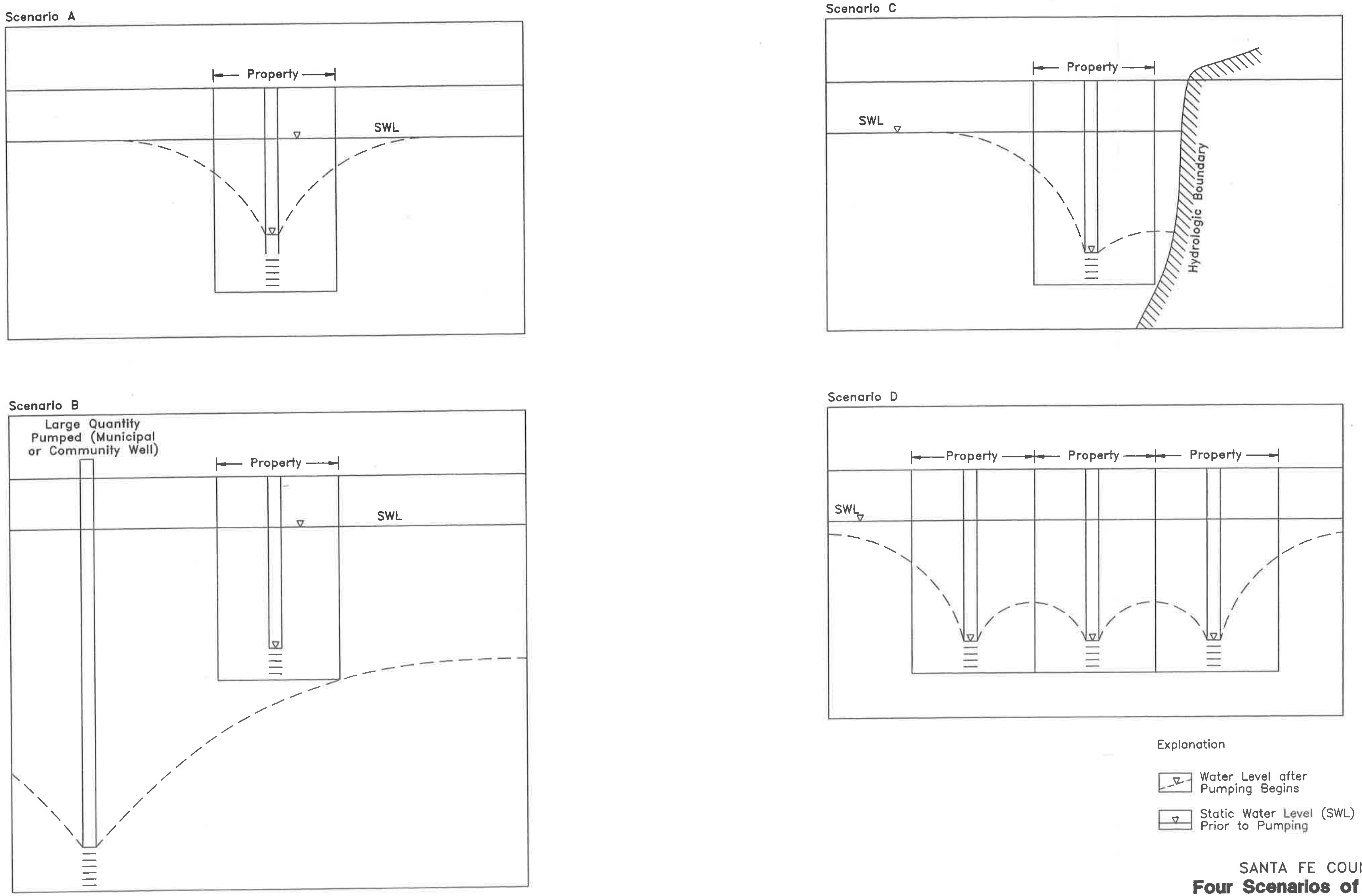

SANTA FE COUNTY INVENTORY

Four Scenarios of Water Level Response to Pumping

year period, the fact that water pumped from one development is derived from the aquifer beneath the adjacent development is not a concern.

A problem with the existing procedure used to predict the volume of ground water available to wells occurs in the vicinity of a barrier boundary (Figure 26, Scenario C), where the aquifer thins or pinches out. In this situation, the rate of water level decline will be greater than it would have been if the barrier boundary were not present. This phenomenon occurs because the cone of depression caused by the pumping well(s) cannot extend beyond the boundary. Consequently, the saturated thickness of the aquifer will decrease more rapidly than might otherwise be expected, and the lifetime of the well will be shorter than predicted. The closer the well is to the boundary, the quicker this phenomenon will occur.

Another difficulty with this system of administration occurs when a large-capacity well is allowed based on the acquisition of non-domestic (e.g., agricultural or municipal) water rights (Figure 26, Scenario ~~D~~ B). A demonstration of the quantity of water available for such rights in Santa Fe County is not required by the Code, because the County has deferred to the SEO for regulation of non-domestic water rights. It is possible that large-capacity non-domestic wells could deplete large areas of an aquifer to the extent that the residential lot may not have sufficient water in storage under it to sustain the pumping rate for domestic use over the lifetime prescribed by the County. Under such a scenario, domestic water users would find rather significant declines in the water table and may need to drill deeper wells.

The Code specifically mentions that the developer should give consideration to protecting water resources for existing County residents who rely on domestic wells. However, when considering an application to transfer water rights to a particular location, or an application for unappropriated water, the SEO may not consider the availability of water for a period as great as 100 years when determining whether impairment will occur. Typically, the SEO will consider the water level declines that are estimated to occur as a result of a proposed withdrawal. However, declines that are acceptable to the SEO are sometimes greater than those the protestant would like to experience. For example, the SEO in the past has considered a water level decline of 100 feet over 40 years in the Mimbres Basin, and 400 feet in the Grants-Bluewater Basin, not to be unreasonable and, therefore, not to be an impairment to existing users. Since impairment is not a determination that the County can make with regard to water right transfers, its hands are tied with respect to these applications unless the County requires that all developments demonstrate the availability of water for a specified period. The County has actually required developers with recognized water rights (e.g., El Dorado) to submit a hydrogeology report, but the basis for this requirement is not clearly established in the Santa Fe County Code.

Another potential problem with the Code that may render it ineffective is the current method of allowing developments to subdivide as long as the average lot size is greater than the minimum lot size. In such a development the minimum lot size may be 5 acres, but the development may actually have 1-acre and 11-acre lots, such that the average lot size in the development is greater than the minimum of 5 acres. It is conceivable that a future proposal could be submitted to subdivide the 11-acre lot, without regard to adjacent lot sizes.

For these hypothetical situations, the potential problem with the Code is that it ignores the existing conditions of adjacent properties. The Code does require information that addresses the above issues, but the information is not necessarily incorporated into determining the minimum lot size. The Santa Fe County Land Use Code Hydrogeology Report Checklist (Appendix I) includes the requirement that the report evaluate the probable length of time that water in the aquifer can meet the demand and the mutual interference of proposed and existing wells. This evaluation is to be based in part on aquifer tests, hydrologic boundaries, and historical water level changes. In practice, the reports rarely incorporate the effects of boundaries or existing diversions and usually only evaluate the impact to water levels from the proposed diversion. The main thrust of the geohydrology reports and the County's evaluation is on the calculations of water availability (Section 3.2).

An additional problem that has resulted from the County's present water management approach is a lack of accuracy in estimating the available water in storage at a given location. A rule of thumb that has been used by the County for determining the saturated thickness is to subtract the depth of the well from the depth to water. Then, using standard values for the specific yield and calculating the available water in storage, a developer could determine how deep a well needs to be in order to achieve the desired lot size (Morgan, 1994). But in reality, each well will have a different yield depending on its location and, most importantly, on the permeability and thickness of the formation at that location. For example, a well may penetrate hundreds of feet of clay that is incapable of providing significant quantities of water. Therefore, the portion of the well depth that corresponds to clay and other low-permeability deposits should not be used in the saturated thickness calculation. As described in Appendix A, well yield is dependent upon a variety of aquifer characteristics, in addition to well construction.

The storage coefficient of 0.15 used as the standard value in the Basin Zone may be too high. The County Code has allowed for the use of a standard value of 0.15 as the storage coefficient, based on experience in similar areas (Wilson, 1978). However, even where extensive aquifer tests have been performed in the Santa Fe area, a storage coefficient of 0.15 has not been observed (Hearne, 1980a). McAda and Wasiolek (1988) found it necessary to use a storage coefficient of 0.05 to be able to model the effects of the Los Alamos well field.

The storage coefficient of 0.15 has been determined in other areas, such as the Deming, New Mexico area, by determining the volume of sediment that appeared to be dewatered in areas of substantial pumping; usually, these have been areas of irrigated farming that use deep wells and large pumps. Subsequent to this estimate of a storage coefficient of 0.15, some of these areas now have experienced land subsidence (Holzer, 1984; Contaldo and Mueller, 1991). The subsidence has been explained by ascribing part of the water being withdrawn as resulting in the compaction of the sediments, rather than water simply draining from the pore space by gravity (Poland, 1984) as is the case for the concept of specific yield. This phenomenon of sediment compaction does not occur until the effective stress in the aquifer exceeds the stress previously experienced by the aquifer (Jorgensen, 1980).

Typically, the pumping rate for individual wells, or even large fields of wells, do not have rates of withdrawal in the short term, and perhaps not even in the long term, to produce the stress levels required before aquifer compaction can occur. On the other hand, large-capacity wells create larger cones of depression which cause the effective stress to increase at a greater rate. Therefore, the aquifer storage coefficient for a development scenario based on individual wells would be less than for one based on large-capacity wells because the effective storage coefficient would not include as much water derived from compaction. The storage coefficient appropriate for development based on individual domestic wells may be more on the order of 0.01 to 0.1

rather than 0.15. However, if water levels are lowered because of prolonged pumping, say for 100 years, then a greater percentage of the water production would come from compaction by a process described by Helm (1982; 1984; 1987).

A field verification of this phenomenon in a similar geologic environment of semiconsolidated sediments is currently underway in the El Paso aquifer, which like the Santa Fe area, is one of valley fill. The initial results indicate that the specific compaction in the El Paso area is as high as 1.0 x 10^{-5} feet per foot squared, a value comparable to those found in the areas of major subsidence in Texas and California (Land and Armstrong, 1985). (This value indicates that 1,000 feet of water level decline in a 3,000-foot-thick aquifer could produce a subsidence of 30 feet).

The pre-consolidation stress level for the Santa Fe Group has not been determined as yet, and therefore the relationship between the amount of water that will be released per foot of water level decline over the lifetime of the aquifer is not known precisely. Lacking this information, it appears that a reasonable estimate of the storage coefficient for a period of 40 years would be 0.1. This estimate is based on the premise that the storage coefficient is stress dependent and varies over time from a value of 0.001 at the initiation of pumping to a value of 0.15 after the effective stress exceeds the pre-consolidation stress in the zone of pumping, with 0.1 being something of a reasonable average value over this time period. This discussion would seem to call into question the use of 0.15 as a standard value for the storage coefficient in the Basin and Basin Fringe Zones.

Another potential problem may result from a development that proposes to limit the total use to 0.25 acre-feet per year. The Code does not require meter readings to be reported; therefore, the actual quantity diverted may be much greater.

3.5.7 Long-Term Management Plans That Rely on Obtaining Physically Available Water from Ground-Water Storage

Despite the extensive efforts to define the quantity of water in storage, portions of that water may actually be administratively inaccessible. Currently the SEO administers stream-connected aquifers, such as the NSFC aquifer system, by requiring the retirement (because of appropriation and commitments to downstream users) of surface-water rights to offset the effects of impacts on the river; in other words, flow in the river is maintained. Water mined from storage in the aquifer is treated as a new appropriation of water. This management approach thus correctly recognizes that part of the pumped ground water is derived from the river or intercepts water that otherwise would discharge to the river.

In response to a hypothetical question, the State Engineer made a rough estimate (Reynolds, 1983) of how much water could be pumped from ground water in the reach of the Rio Grande from the Colorado state line to the Elephant Butte Reservoir if most of the surface-water rights from this reach were retired to offset the effects of mining. This estimate was substantially less than the amount of water estimated to be in storage in river-connected aquifers. The distinction implicit in the State Engineer's interpretation is an important point that is often overlooked in water resource management strategies. Harza et al. (1988) made it clear that the available amount of water in storage is very limited from the standpoint of water supply because of the administrative limitations on the effects of pumping on the Rio Grande.

Water quality may also limit the reserves, or at least increase the cost of production as the City of Albuquerque has recently discovered. Although the aquifer may be greater than 3,500 feet deep, tests from an 1,872-foot-deep well at the Buckman well field show TDS concentrations of 810 ppm, which is approaching the New Mexico Water Quality Control Commission standard of 1,000 ppm.

A portion of the available ground-water reserves has already been lost to pollution or has the potential to be lost. No attempt has been made in any of the reviewed reports to quantify the ground-water reserves that are being lost due to pollution; however, it is known that many wells have been taken out of production as a result of ground-water contamination (Melendez, 1993). The portions of the aquifer that are impacted in effect diminish the volume available for drinking. Often the impact occurs in the upper part of the aquifer and pumping causes the contamination to spread horizontally and vertically, further increasing the contaminated area over time, until a remedial action is taken. However, aquifer restoration can take years or decades.

Replacing these "lost" wells by moving their locations is problematical. Generally speaking, the "lost" wells were drilled when the legal, social, and environmental constraints were not as great as they are today. It may well be that in some cases the cost of obtaining the needed permits (due to legal and hydrological services) to redrill in the vicinity of the old well may be higher than that associated with wells adjacent to the Rio Grande or direct diversions from the Rio Grande, even when costs of conveyance are considered.

Another problem that must be considered by management strategists relying on published storage estimates is the possible inaccessibility of portions of the water associated with non-private lands. A significant portion of the lands in Santa Fe County are non-private. Estimates of the amount of available water in the county include the water in storage beneath these lands. Santa Fe County has the following non-private lands (N.M. SEO, 1974):

Land Owner	Land Area (acres)	Percent of Total Acreage Within Santa Fe County
Indian	79,548	6.5
State	85,857	7.0
Forest Service	250,628	20.5
Bureau of Land Management	83,587	6.8
Other	1,942	0.2
Total Area of County	1,221,760	41.0

The lands in the County that create the most uncertainty from an institutional standpoint of regulation of land use through the availability of water are those of the six Indian pueblos. Pueblo land and water use are not under the jurisdiction of the County. Most of the Indian land lies in the Nambe-Pojoaque drainage and covers a large portion of the ground water in storage.

The water rights of these pueblos are currently being adjudicated in Federal Court (New Mexico rel. Reynolds versus Aamodt and U.S. District Court, N.M District). Although the final outcome of this suit is unknown, the current range of water right acres being discussed is from 1,200 to 12,000 acres (Hearne, 1980b). Most of the water for the proposed expansion of irrigation would come from ground-water storage and would cause water level declines of up to 334 feet in 50 years (Hearne, 1980b). In any event, water in storage under the pueblos may not be available to private developments in the County.

The non-Indian public lands appear to present less of a problem in terms of water use. Substantial quantities of ground water underlie Forest Service lands that are in the vicinity of the Rio Grande. However, the Forest Service will permit the withdrawal of these waters if the proper studies are performed and permits obtained. Similarly, the Bureau of Land Management (BLM) also will permit the use of water from under its lands with the proper studies and permits, as will the New Mexico State Land Office for its trust lands. However, any withdrawal of water from under Forest Service, BLM, or State Trust lands also requires a permit from the SEO.

3.5.8 Recent Changes in Water Laws

Several reports (CPI, 1974b; Santa Fe County Staff, 1975; Wilson, 1975; WCC, 1980; Reynolds, 1983; Harza et al., 1988) have noted that the legal constraints discussed in the Section 3.5.7 may limit the availability of ground-water resources more than the physical properties of the aquifers. Since the referenced reports were published, two changes have been made in the water law (NMSA §72-5-5.1, 1985; NMSA §72-1-9, 1983). These charges are described below.

The State Engineer has always had the implicit responsibility to protect the public's interest, and in 1985 a law was passed to require the State Engineer to consider public welfare before final action on water rights applications (NMSA §72-5-5.1). However, the statute does not define public welfare, so it remains for the State Engineer to determine it on a case by case basis in a manner similar to that used when considering what constitutes impairment. For instance, in a transfer of water rights the applicant will have to show that the transfer is not contrary to public welfare, thus imposing an additional hurdle. Additionally in the 1983 law (NMSA §72-1-9), municipalities, counties, and public utilities are restricted to the acquisition and holding of unused water rights up to the reasonable needs for a period of up to 40 years, whereas previously this restriction did not exist.

These changes will likely only reinforce the observation that constraints other than the physical availability of ground water may determine the source of additional water supplies. Additionally, both of these new laws suggest that the process of developing new supplies of ground water, which was judged to be severe in previous reports, will only be more difficult.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on its review of technical data and reports, DBS&A divided the water resources of Santa Fe County into three aquifer systems: (1) the North Santa Fe County (NSFC) aquifer system, (2) the Mid-Santa Fe County (MSFC) hydrologic system, and (3) the Estancia Valley (EV) aquifer system. Conclusions and recommendations regarding these three systems are provided in Sections 4.1 and 4.2, respectively.

4.1 Conclusions

Results of the analysis of available data led to the conclusions presented in Sections 4.1.1 through 4.1.3 for each aquifer system. Additionally, conclusions regarding the effectiveness of the Santa Fe County Land Development Code (County Code) are presented in Section 4.1.4.

4.1.1 NSFC Aquifer System

The water resources of the NSFC aquifer system vary from limited to extensive. In the areas where the resource is extensive, the water may not be available due in part to water right constraints. The conclusions pertaining to the water resources of the NSFC are as follows:

- The NSFC consists of the Santa Fe Group sedimentary rocks in the valley terrain, the Precambrian rocks in the eastern mountains, and basalts in the southeast.

- The water resources of the NSFC aquifer system vary from limited at the edge of the Santa Fe Group in the east and south to extensive in the northwest where the aquifer thickness exceeds 3,500 feet.

- The extent of the water resource in the fractured Precambrian rocks is highly variable, and the supply is dependent almost entirely on recharge, due to the low storage capacity of the rocks.

- The water in the NSFC aquifer system is generally very hard, but has a relatively low total dissolved solids.

- In the vicinity of Santa Fe and Pojoaque, known locations where ground water is contaminated include 14 locations contaminated by gasoline and 29 contaminated by sewage effluent.

- The total quantity of water in storage in the NSFC aquifer system is estimated to be 56,000,000 acre-feet, although it is not necessarily available due to physical and administrative constraints.

- Total ground-water pumping in the NSFC aquifer system to be about 16,000 afy, of which about 1,000 afy is used for irrigation.

- Based on available data, the total quantity of ground water pumped from wells and discharged to springs appears to be roughly balanced with the quantity of recharge entering the NSFC aquifer system on the whole.

- Locally, ground-water mining is occurring. The greatest water level declines are observed in the vicinity of the City of Santa Fe (123 feet in 40 years) and Buckman (560 feet in 10 years) well fields. The decline rate at both of these well fields varies with depth.

- If the aquifer is mined, the water table would eventually decline to great depths; thus ground water would be expensive to produce due to increased pumping costs and possible water quality treatment requirements. In addition, land surface subsidence could occur due to compaction of underlying sediments, potentially resulting in damage to structures.

- To satisfy water right protestants, appropriation of additional water rights within the NSFC aquifer system must offset impacts on the Rio Grande, La Cienega springs, Tesuque Creek, the Rio Nambe, and the Rio Pojoaque. In short, it appears that present natural discharges to surface water within the NSFC cannot be depleted further. Approval of additional appropriations by the SEO within the NSFC are highly unlikely, and even a transfer within the NSFC will face many administrative hurdles. The only new diversions that are likely to occur within the NSFC are from individual domestic wells because they are legally mandated for approval by the SEO. Thus, in order to limit future depletions within the NSFC aquifer system, the County would have to limit future development that is dependent upon individual domestic wells.

4.1.2 Mid-Santa Fe County Hydrologic System

Little data are available to assess the aquifer properties of the few productive geologic formations in the MSFC hydrologic system. Water quality is generally poor, and productive aquifers appear to be of limited extent. Conclusions pertaining to the MSFC hydrologic system are as follows:

- The MSFC hydrologic system includes Permian through Tertiary sediments, volcanics, and Precambrian rocks in the Galisteo and Pecos River drainage basins.

- Water quality is generally poor, with total dissolved solids concentrations of up to 5,000 ppm.

- Ground-water contamination from mining activities in the Ortiz Mountains, sewage effluent, and underground storage tanks has locally impacted water quality.

- Less than 300 afy of ground-water pumping is estimated to occur in the MSFC hydrologic system, although identified water rights exceed 1,200 afy.

- Diversions in the Galisteo area appear to exceed the quantity of recharge as evidenced by the rate of water level decline in this area.

4.1.3 Estancia Valley Aquifer System

The EV aquifer system is in an official state of ground-water mining, as administered by the SEO, and is a limited resource. Conclusions pertaining to the EV aquifer system are as follows:

- The EV aquifer system consists of Pennsylvanian to Triassic sediments and the Tertiary valley fill in the Estancia Basin.

- Water quality varies from good to poor, with a total dissolved solids of about 300 ppm in the valley fill to nearly 3,000 ppm in the Glorieta Sandstone.

- Ground-water contamination from gasoline in the White Lakes and Edgewood areas are the only identified ground-water contamination problems in the EV aquifer system.

- The quantity of water in storage is estimated to be about 1,000,000 acre-feet.

- The quantity of water pumped from the EV aquifer system is estimated to be about 16,000 afy, the majority of which (12,500 afy) is used for agriculture.

- Pumping far exceeds the quantity of recharge entering the aquifer system, and consequently, the water resources of the valley fill in the EV aquifer system are dwindling at a fairly uniform, steady rate. If pumping continues at the current rate, the productivity of the valley fill aquifer could be greatly reduced in about 110 years in the thickest portions of the aquifer and in much less time at the fringe of the aquifer.

- The extent of the water resource in the rocks surrounding the valley fill is poorly understood, but it is thought to be limited and marginally productive except in areas where the Madera Limestone and Glorieta Sandstone are productive.

4.1.4 Effectiveness of the Santa Fe County Land Development Code

The existing County Code has conflicting goals of sustained yield (protecting existing wells) and specifying a lifetime of the resource. Neither of these goals may be achieved entirely:

- Many existing shallow wells will likely go dry in less than 20 years if current trends in water level decline continue. Most of these wells are located in the Santa Fe, Galisteo, and Edgewood areas.

- At the margins of the aquifers and in recharge areas of fractured Precambrian rocks, the aquifers may not provide a supply for 100 years. Areas where the ground-water resource is limited are also areas where the population of the County is expanding.

In addition, the SEO administers the Estancia Basin on a 40-year lifetime, which conflicts with the Santa Fe County administrative criterion of a 100-year lifetime. Therefore, although a development may appear to have sufficient water in storage to satisfy the 100-year requirement, the SEO may have granted or may in the future grant water rights in neighboring areas that will deplete water beneath the development in a much shorter time frame.

The Code has some potential problems in ensuring a long-term supply:

- The supply at the boundaries of the productive parts of any aquifer may be depleted at a greater rate than predicted by the methods used in the Code.

- The Code's methods for estimating water availability do not incorporate existing depletions from adjacent land owners and thus may overestimate available water supplies.

- Water availability based solely on recharge (such as in the Mountain Zone) may result in insufficient supply during periods of drought.

- Methods for determining the saturated thickness of the aquifer are not reliable, since many of the reports calculate the saturated aquifer thickness as simply the depth of the well minus the depth to water. For example, aquifer thickness may be overestimated if calculated from a well with several hundred feet of saturated but non-productive clay.

- Based on storage coefficients obtained in aquifer tests, the storage coefficient of 0.15 in the Santa Fe Group appears to be too high, and use of such a value would overestimate water availability.

- The Code allows developments to reduce the projected ground-water use from 1 afy to 0.25 afy per household, but does not require metering or other verification.

- Allowing future development to use recharge in the Mountain Zone will ultimately result in interception of water that previously supplied downgradient water users.

Despite its potential problems, the Code appears to be functioning reasonably well since it was adopted in 1980 although it is too soon to support this conclusion. This conclusion is based on the review of actual water level decline rates near proposed developments. The rate of decline (if any) does not appear to be increasing recently. Three factors may contribute to no noticeable increase in the rates of decline of water levels: (1) precipitation since 1985 has been greater than average, (2) some developments have actually taken many years to consummate, such that significant stress on the aquifer may have only recently begun, and (3) the wells used for determining water level declines, which were located up to 2 miles from the property, may not accurately reflect water level changes beneath the property. Based on the rate of decline and the aquifer thickness, the aquifer beneath each of the proposed developments appears to have a lifetime of at least 40 or 100 years.

Very few water rights are available in Santa Fe County for purchase; consequently, the growth in the County may be limited to water that can be provided by domestic wells (wells allowed under article 72-12-1 of the New Mexico Statutes, 1978) unless new sources of water (e.g., imported) are provided. From a hydrologic point of view, where aquifer characteristics, water quality, and depth to ground water are favorable, individual wells for each lot are a more effective way to develop an aquifer and prolong its lifetime than are community wells. However, if the resource is depleted and imported water will eventually be required, then a community system is more desirable because the requisite distribution system will already be in place.

The volume of ground water available for future developments in the county is less than the volume of ground water in storage because:

- Such development would potentially diminish flow in the Rio Grande and affect delivery obligations to Texas, impact streams on Pueblo lands, or impact flow to La Cienega springs.

- The quality of water at depths greater than 2,000 feet may not be suitable for domestic use without treatment.

- A portion of the ground-water in storage is or could become contaminated and, as a result, may be unsuitable for domestic use (drinking water purposes).

- Water in storage beneath non-private land, which comprises 40 percent of the county, may not be available.

4.2 Recommendations

Based on our review of available data, DBS&A offers the following recommendations for revision to the existing code.

- Estimates of saturated thickness (different from the standard values used in the Code) should be based on on-site geological and geophysical well logs. Geologic logs prepared by a professional geologist may improve the quality of logs presently reported in many reports, but geophysical logs (performed prior to setting casing) will better define the true thickness of unproductive (e.g., clay) layers (which should be subtracted from the total saturated thickness).

- The submitted estimates of water availability should include calculations to correct for any hydrogeologic (recharge or discharge) boundary conditions. Calculations by developers should demonstrate water availability based on mathematical techniques that incorporate the effects of existing pumping.

- Proposed developments that are located adjacent to areas with existing non-domestic (non-72-12-1 wells) water rights (i.e., municipal and irrigation wells) should demonstrate water availability based on numerical modeling techniques that incorporate existing or future foreseeable pumping.

- The standard value of specific yield (Sy) should be limited to 0.1 for determining the available amount of water in storage in the Santa Fe Group of the NSFC aquifer system (Basin and Basin Fringe Zones). The current value of 0.15 may not be justified for the aquifer, unless compaction occurs as a result of substantial withdrawals.

- Water availability should not be based on the quantity of recharge entering the property.

- If recharge is not eliminated as a method for demonstrating water availability, then developments relying on recharge for the water supply should take into account the annual variability of recharge. The quantity of recharge based on a 30-year regional precipitation record, which has a 95 percent probability of occurring, would be an appropriate method for determining long-term water availability.

- Estimates of the quantity of water in storage in the MSFC hydrologic system should be provided by a site-specific hydrogeology report. Standard values are not appropriate in the MSFC hydrologic system due to the complex hydrogeology of the area. The development proposal should include a conceptual plan for the end of the 100-year lifetime of the resource, describing potential sources for imported water.

- The standard value of Sy in the EV should be reduced to 0.125 to be consistent with that used by the SEO.

Possible studies that may aid the County in making management decisions include the following:

- Evaluate the actual water available in subdivisions that were approved by the County on the basis of a water availability calculation that did not include the effects of (relatively impermeable) aquifer boundaries. Evaluation should include preparation of a detailed numerical model of the aquifer fringe areas.

- Perform a detailed review of well logs in the aquifer fringe areas, the recharge areas, and the MSFC hydrologic system to better define the aquifer properties in these areas.

- Expand the water level monitoring network presently conducted for the County to include aquifer fringe areas and the MSFC hydrologic system.

- Better define the vertical extent and quality at depth of the Santa Fe Group in the NSFC aquifer system if the plan is to ultimately rely on this water.

- If it is decided that the future supply of the Santa Fe area should be based either in part or totally on the dewatering of the NSFC aquifer system, expend some effort to determine the specific compaction and pre-consolidation values for the NSFC aquifer system. Such studies should also include assessments of probable effects and their likely surface expressions, such as fissures.

In addition, the County may consider taking the following strategies:

- Consider the concept of designating critical ground-water management zones where water levels are currently declining at an unacceptable rate. Defining the unacceptable rate will be the greatest challenge facing the County. Within these critical zones, future pumping could be prohibited or limited to reduce future drawdown within the critical ground-water management zone.

- Instigate discussions between the County and the SEO to consider a limit to granting of any additional permits for the appropriation of ground water in the EV aquifer system. The County could argue that conserving this water for future expanding domestic use is in the public's welfare.

- The County may wish to consider the acquisition of existing water rights in the EV for supplying future domestic uses, as provided for by state law (NMSA §72-1-9).

We also recommend that the County decide whether to change policy from mining the aquifers to achieving a dynamic equilibrium. This would, no doubt, be a controversial decision and may entail significant studies by the County to better define recharge and discharge components throughout each basin.

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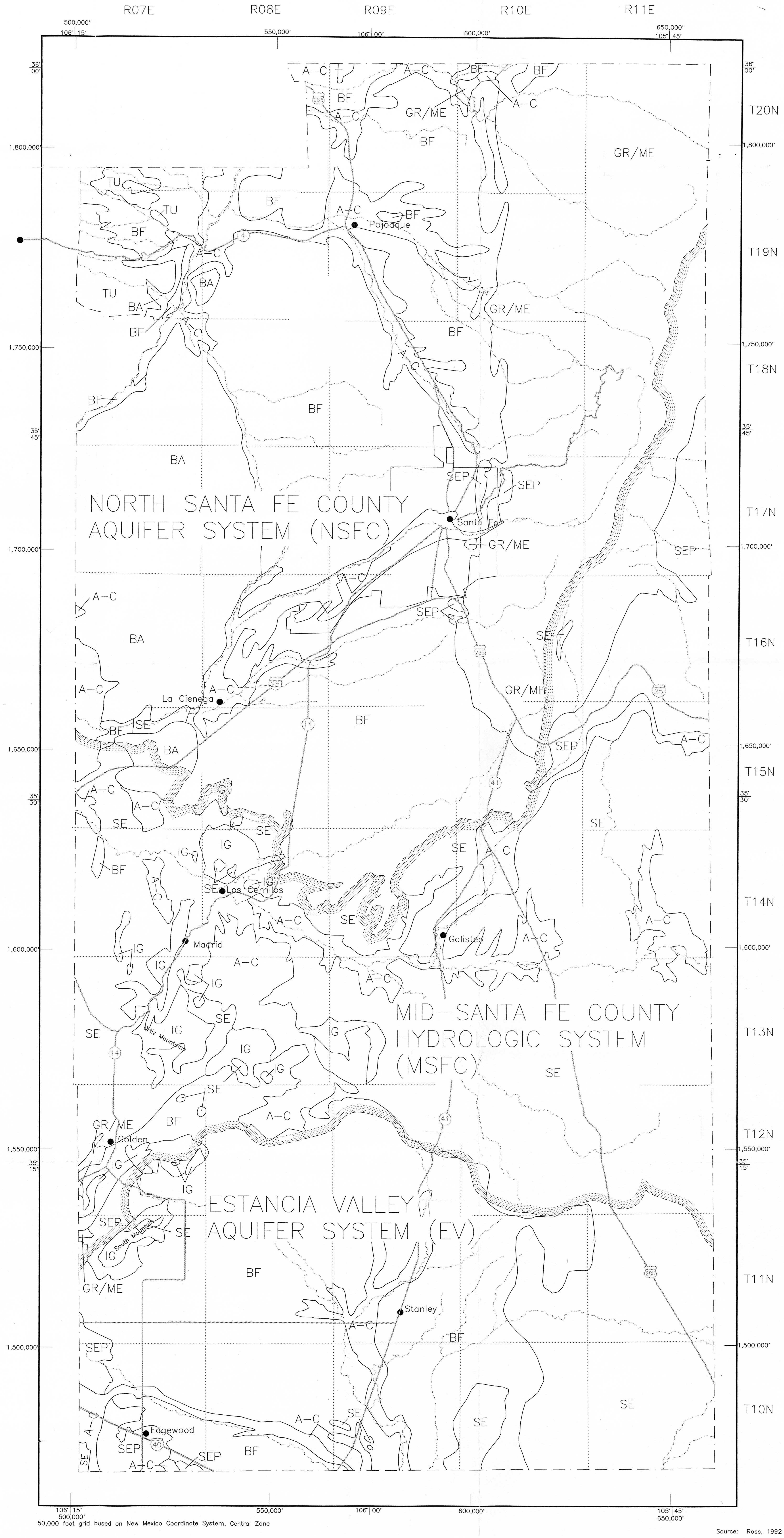
PLATES



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Explanation

Lithographic Map Symbols

Symbol	Explanation
A–C	Alluvium, colluvium, landslide deposits, piedmont alluvial deposits, and/or alluvial fan deposits. Upper and Middle Quaternary age.
BF	Santa Fe Group (includes Ancha, Puye, Alamosa, Cochiti, Tesuque, Chamita, and Abiquiu Fm) and older alluvial deposits, predominantly consisting of unconsolidated sands, gravels, and clays. Late Tertiary to Early Quaternary age.
TU	Bandelier Tuff. Quaternary age.
BA	Basalt and andesite flows. May be interbedded with Santa Fe Group. Late Tertiary age.
IG	Undifferentiated intrusive rocks. Tertiary age.
SE	Undifferentiated sedimentary rocks consisting of sandstones, mudstones, conglomerates, shales, and limestones, with lesser dolomites, siltstones, and evaporites. Tertiary, Cretaceous, Jurassic, Triassic, and Permian age.
GR/ME	Undifferentiated granitic,plutonic, and metamorphic rock. Precambrian age.
SEP	Sedimentary, dark maroon sandstone, shale and gray limestone of Pennsylvanian age.

System Boundary

County Border

Surface Drainage

Source: Ross, 1992

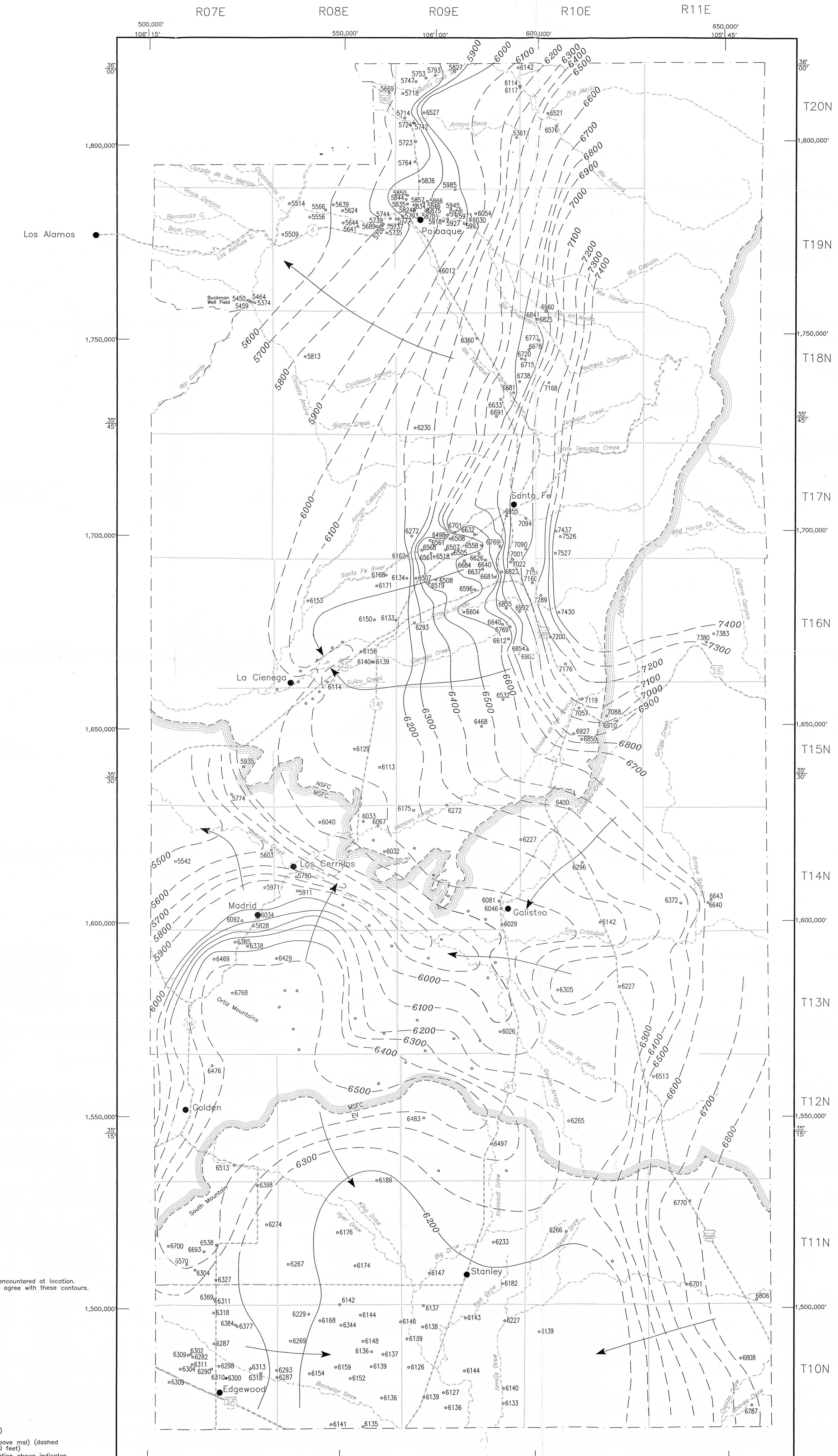
SANTA FE COUNTY INVENTORY

Aquifer Systems and Lithology

3300C01B

DANIEL B. STEPHENS & ASSOCIATES, INC.
7–94 JN 3300

Plate 1



Note: Contours represent shallowest water encountered at location. Water levels in deeper wells may not agree with these contours.

N

0 5 Miles

Explanation

- 6311 Water Level Elevation (feet above msl)
- 6300 Water Level Elevation Contour (feet above msl) (dashed where uncertain) (contour interval 100 feet)
- Monitor Well (without water-level elevation shown indicates data from 1970's used in contouring to obtain greater control)
- Direction of Ground-Water Flow
- Aquifer System Boundary
  - NSFC – North Santa Fe County Aquifer System
  - MSFC – Mid-Santa Fe County Hydrologic System
  - EV – Estancia Valley Aquifer System
- County Border
- Surface Drainage

SANTA FE COUNTY INVENTORY

Well Locations and Water Level Elevations Measured in the 1980's for Santa Fe County

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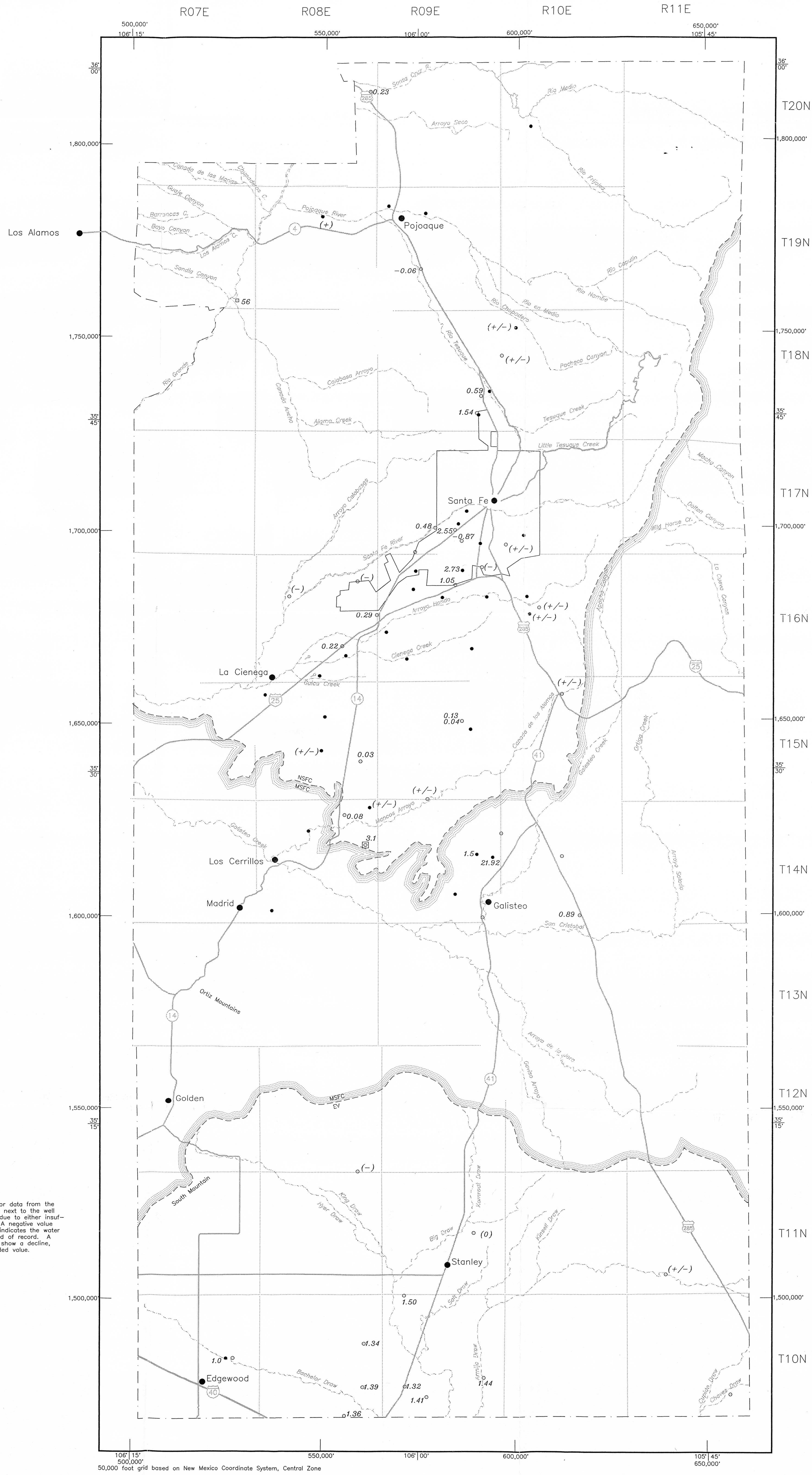
7-94 JN 3300

Plate 2



Note: Water level declines are given in ft/year for data from the 1950's to 1993. Where no value is given next to the well symbol, a trend could not be determined due to either insufficient record or fluctuating water levels. A negative value indicates a rise in water level. A (+/−) indicates the water levels have fluctuated throughout the period of record. A (+) with no value indicates that the data show a decline, a (−) indicates a rise from earliest recorded value.

N

0 5 Miles

Explanation

- Data from USGS Shows Recent Decline
- Data from SGWC
- Data from USGS GWSI
- Data from Fleming & Finch (1992)
- Major Spring Area
- Aquifer System Boundary
  - NSFC – North Santa Fe County Aquifer System
  - MSFC – Mid–Santa Fe County Hydrologic System
  - EV – Estancia Valley Aquifer System
- County Border
- Surface Drainage

3300C01N

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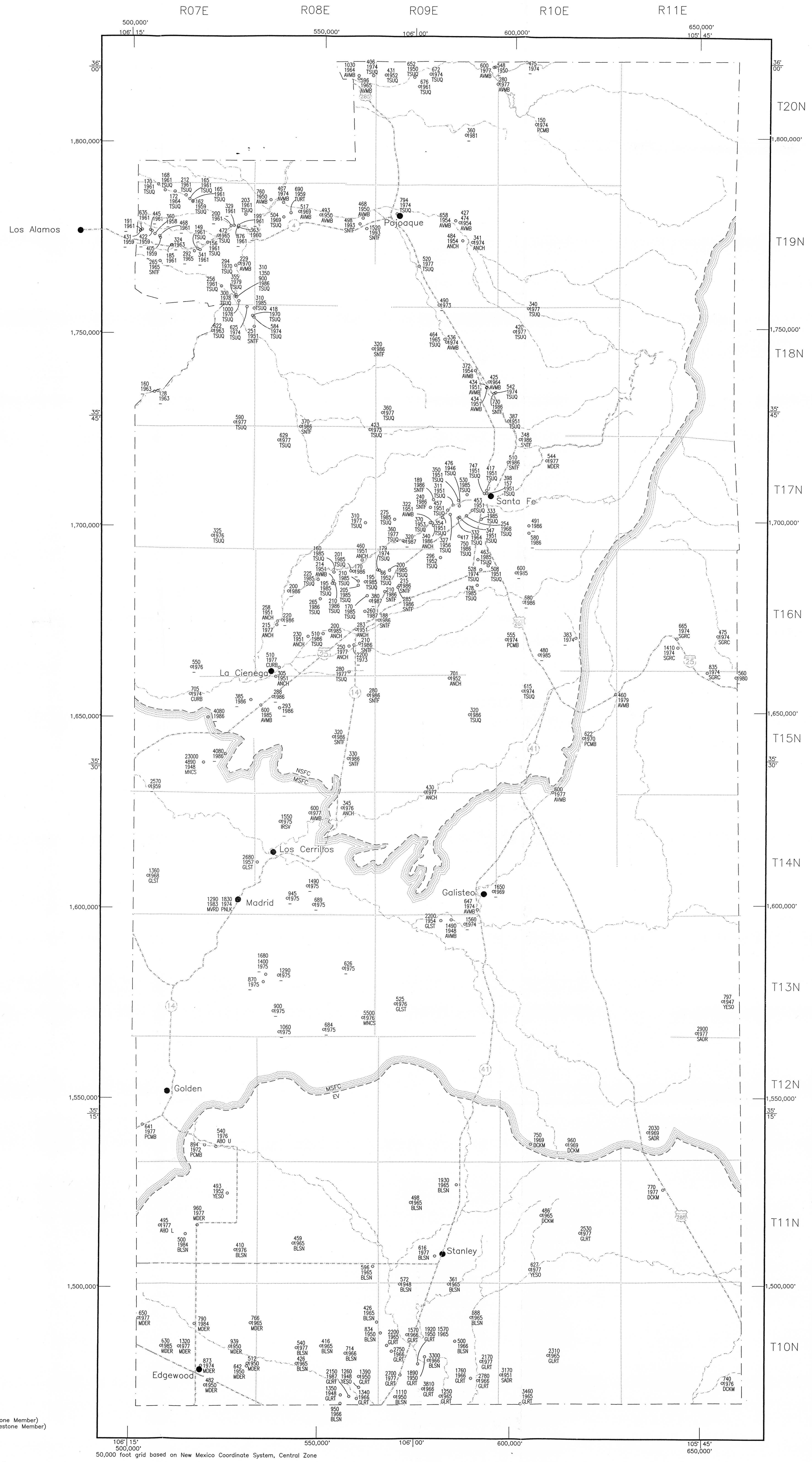
SANTA FE COUNTY INVENTORY

Historical Water-Level Decline

Plate 3



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Explanation

○ Electrical Conductivity (µmhos/cm)
Year Surveyed
Aquifer Code

Aquifer Code

EXRV	Extrusive Rocks
IRSV	Intrusive Rocks
AVMB	Alluvial Fill
BLSN	Bolson Fill
OPTOD	Pediment Deposits
TURT	Tuerto Gravel of Santa Fe Group
ANCH	Ancha Formation
CURB	Cuerbio Basalt
SNTF	Santa Fe Group, Undifferentiated
PUYEF	Puye Conglomerate
TSUQ	Tesuque Formation
GLST	Galisteo Formation
MNC	Mancos Shale
MNCS	Mancos Shale
MVRD	Mesa Verde Group
PNLK	Point Lookout Sandstone
DCKM	Dockum Group
GLRT	Glorieta Sandstone
SGRC	Sangre de Cristo Formation
YESO	Yeso Formation
SADR	San Andres Limestone
ABO L	Abo Sandstone (Lower Tongue)
ABO U	Abo Sandstone (Upper Tongue)
MDER	Madera Limestone
MDERL	Madera Limestone (Lower Gray Limestone Member)
MDERU	Madera Limestone (Upper Arkosic Limestone Member)
PCMB	Precambrian Erathem

- Monitor Well
- Aquifer System Boundary
  - NSFC – North Santa Fe County Aquifer System
  - MSFC – Mid-Santa Fe County Hydrologic System
  - EV – Estancia Valley Aquifer System
- County Border
- Surface Drainage

Source: USGS NWIS

SANTA FE COUNTY INVENTORY

Electrical Conductivity from Selected Wells in Santa Fe County

DANIEL B. STEPHENS & ASSOCIATES, INC.
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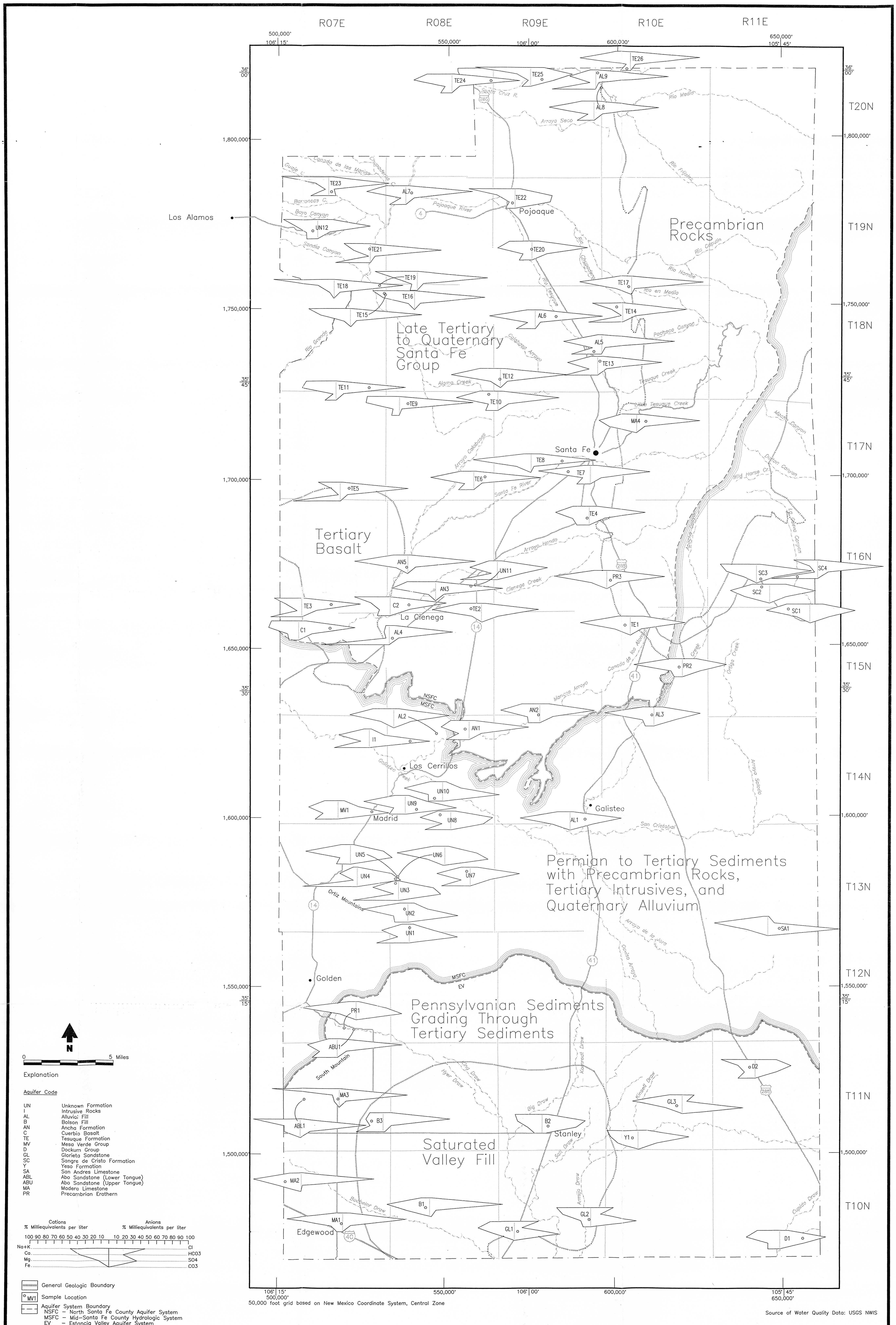
3300C01G

Plate 4



SANTA FE COUNTY INVENTORY

Stiff Diagrams for Selected Wells in Santa Fe County

DANIEL B. STEPHENS & ASSOCIATES, INC.
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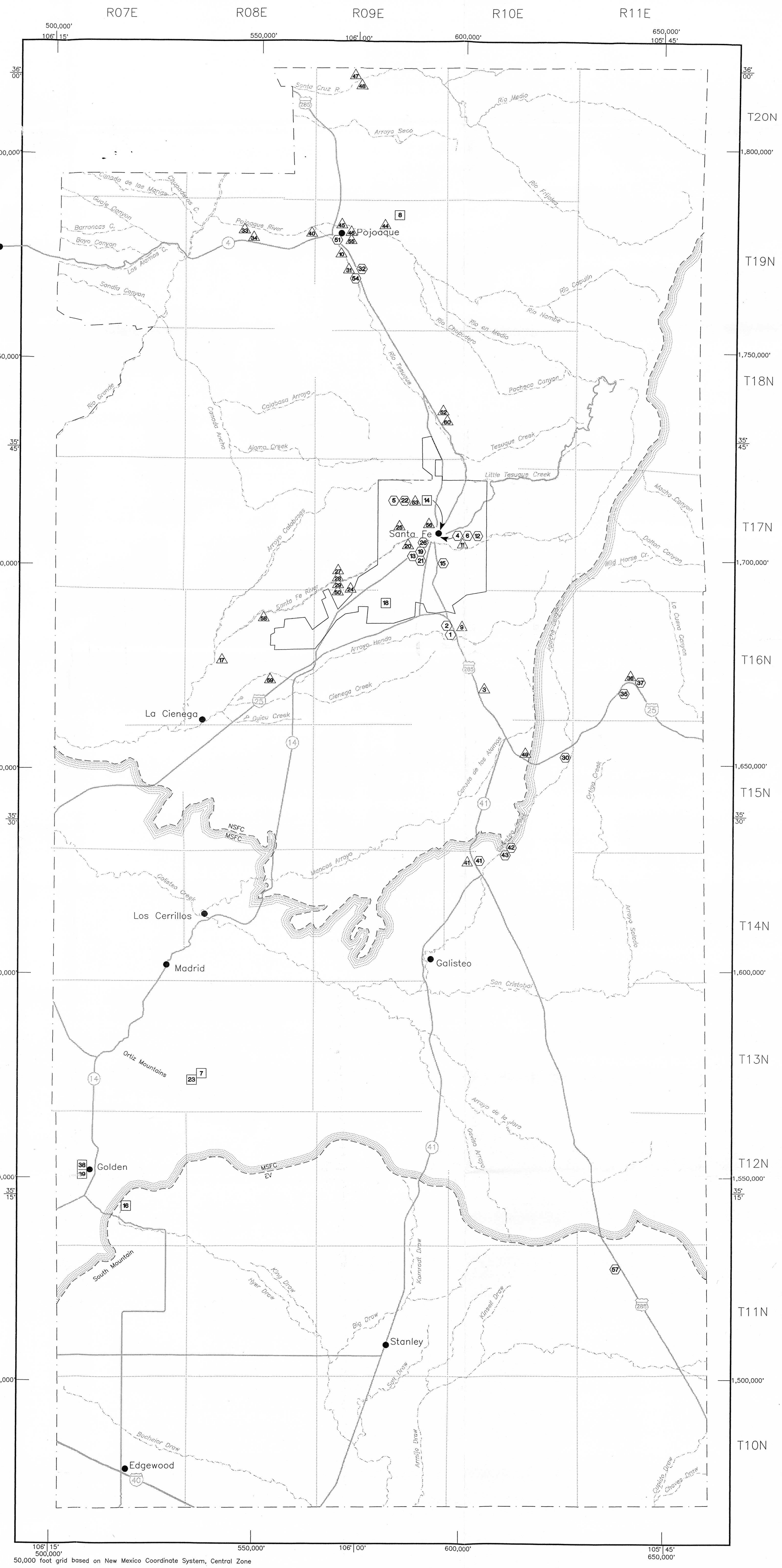
Plate 5



0 5 Miles

Explanation

DBS&A Case No.	Contaminant(s)
1	Gasoline, Mn, Fe
2	Solvents
3	NO3
4	Gasoline
5	Gasoline
6	Gasoline
7	Cn, Co, NO3
8	Radionuclides, F, Mn
9	NO3
10	NO3
11	NO3
12	Gasoline
13	Solvents
14	Ba
15	Solvents, BTEX
16	Cd, Fe, Pb, Mn, TDS
17	NO3
18	Zn
19	Gasoline
20	NO3, Ba
21	Gasoline
22	Gasoline
23	SO4, pH
24	NO3
25	NO3
26	EDB
27	NO3
28	NO3
29	NO3
30	Pesticides
31	ANOX
32	HC
33	ANOX
34	NO3
35	Pesticides
36	NO3
37	Pesticides
38	NO3, TDS, SO4
39	Fe, Al, NO3, TDS, SO4
40	ANOX
41	NO3, Gasoline, EDC
42	Pesticides
43	Pesticides
44	NO3
45	ANOX
46	ANOX
47	ANOX
48	NO3
49	NO3
50	NO3
51	Gasoline
52	NO3
53	NO3
54	Gasoline
55	Gasoline
56	NO3, TDS
57	Gasoline, NO3
58	NO3
59	NO3
60	NO3
61	MTBE

16 DBS&A Case Number
Hydrocarbon Contamination
Sewage Effluent Contamination
Other Contamination (metals, sulfates)
Aquifer System Boundary
NSFC – North Santa Fe County Aquifer System
MSFC – Mid-Santa Fe County Hydrologic System
EV – Estancia Valley Aquifer System
County Border
Surface Drainage

Source: New Mexico Environmental Department Database, Dec. 1993

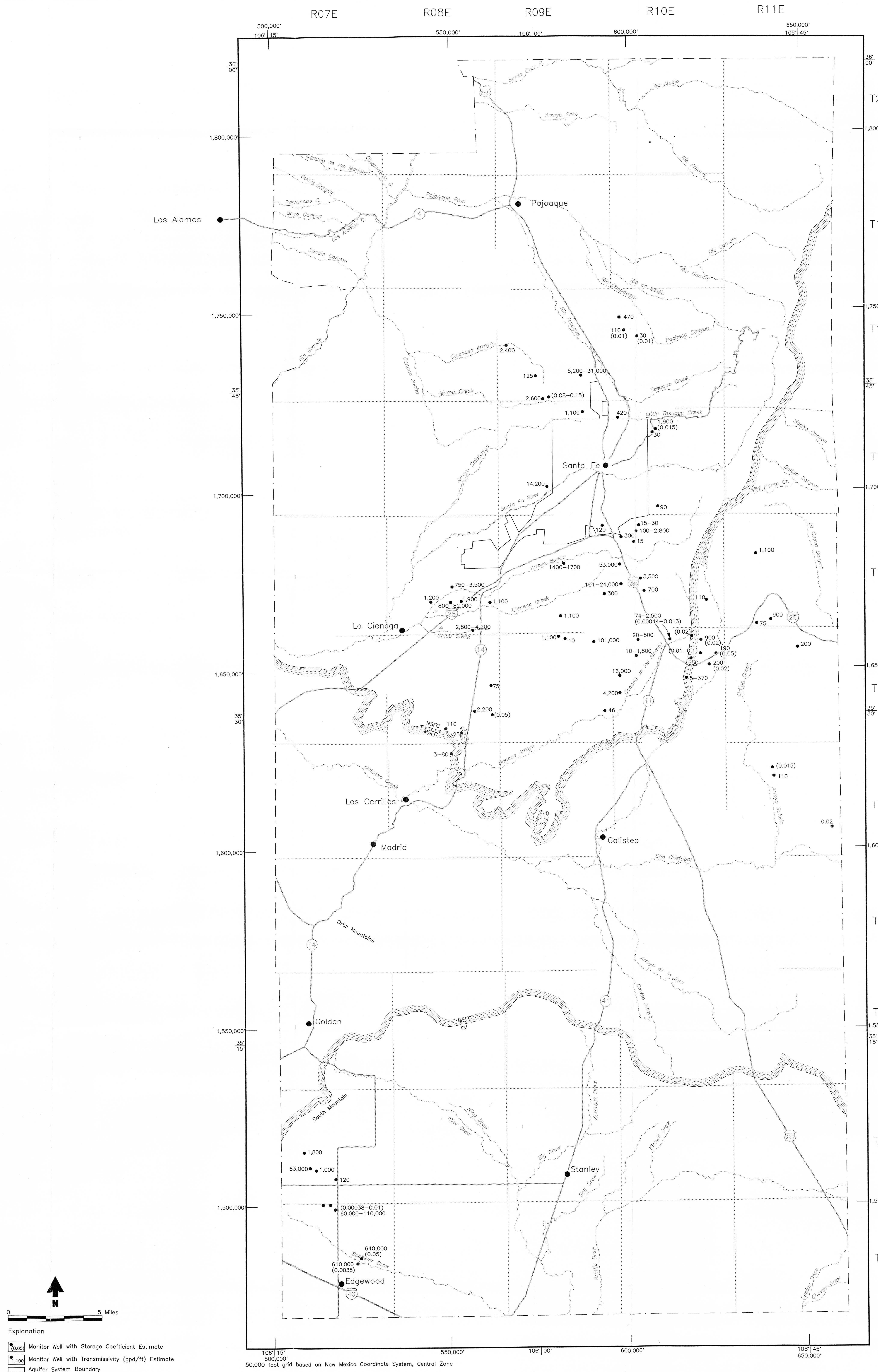
SANTA FE COUNTY INVENTORY

Location of Known Ground Water Contamination Sites

DANIEL B. STEPHENS & ASSOCIATES, INC.
7-94
JN 3300

3300C01M

Plate 6

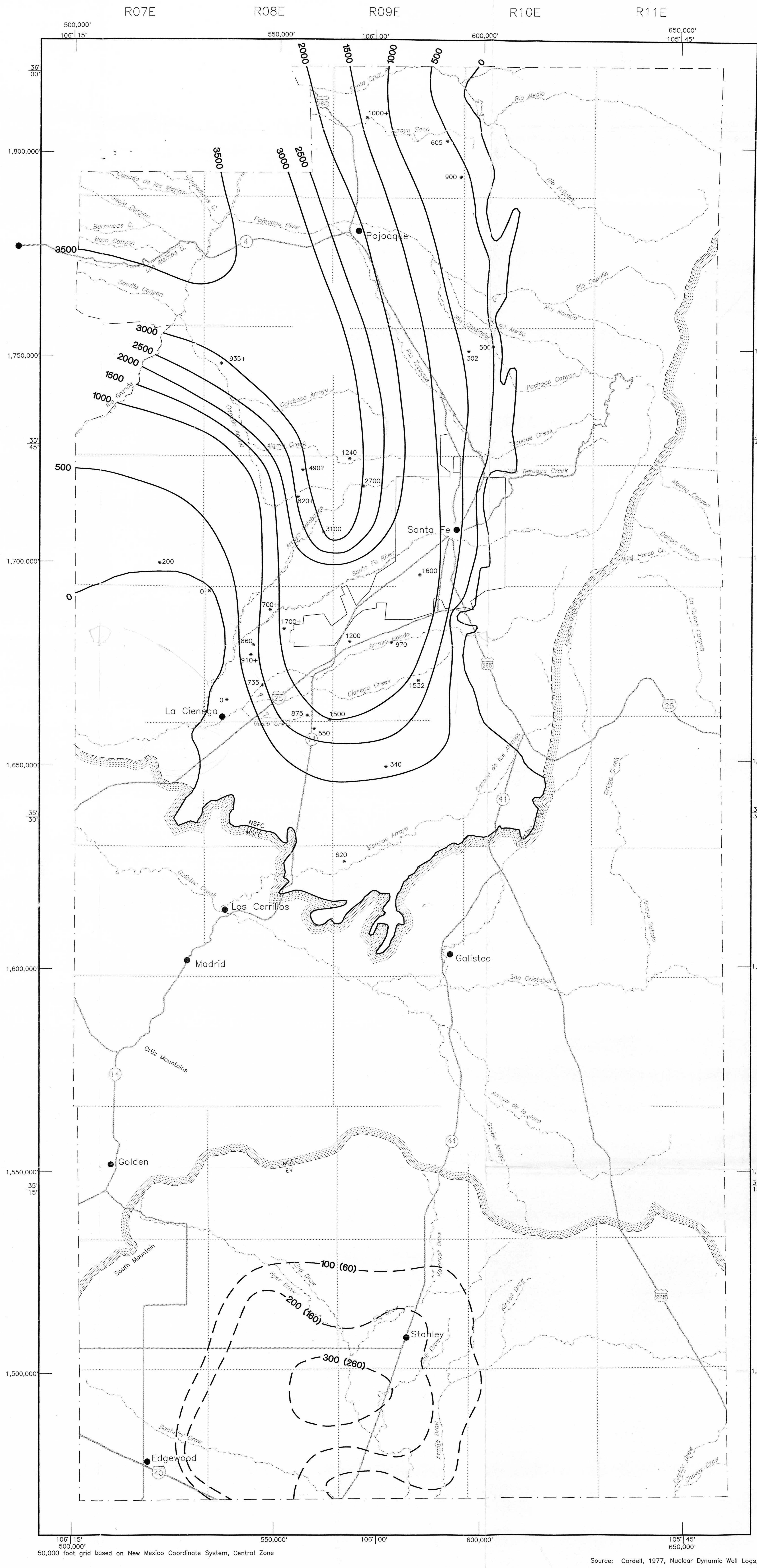


SANTA FE COUNTY INVENTORY

Aquifer Parameter Estimates Reported in Geohydrology Reports Submitted to Santa Fe County

DANIEL B. STEPHENS & ASSOCIATES, INC.
7-94
JN 3300

3300C01L



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0 5 Miles

Explanation

970 Well Showing Saturated Thickness of Santa Fe Group (as determined from Nuclear Dynamics well logs)

500-foot contour interval of saturated thickness of the Santa Fe Group in the NSFC Aquifer System (thickness between 0- and 500-foot contour is highly uncertain) (thickness based on gravity data (Cordell, 1976), USGS, GWSI, and Nuclear Dynamics well logs on file at OCD)

100-foot contour interval of saturated thickness of the valley fill in the EV Aquifer System as determined by the SEO in 1965 (numbers in parentheses represent the minimum thickness of saturated valley fill in 1994 based on rate of water level decline)

Aquifer System Boundary
NSFC – North Santa Fe County Aquifer System
MSFC – Mid-Santa Fe County Hydrologic System
EV – Estancia Valley Aquifer System

County Border

Surface Drainage

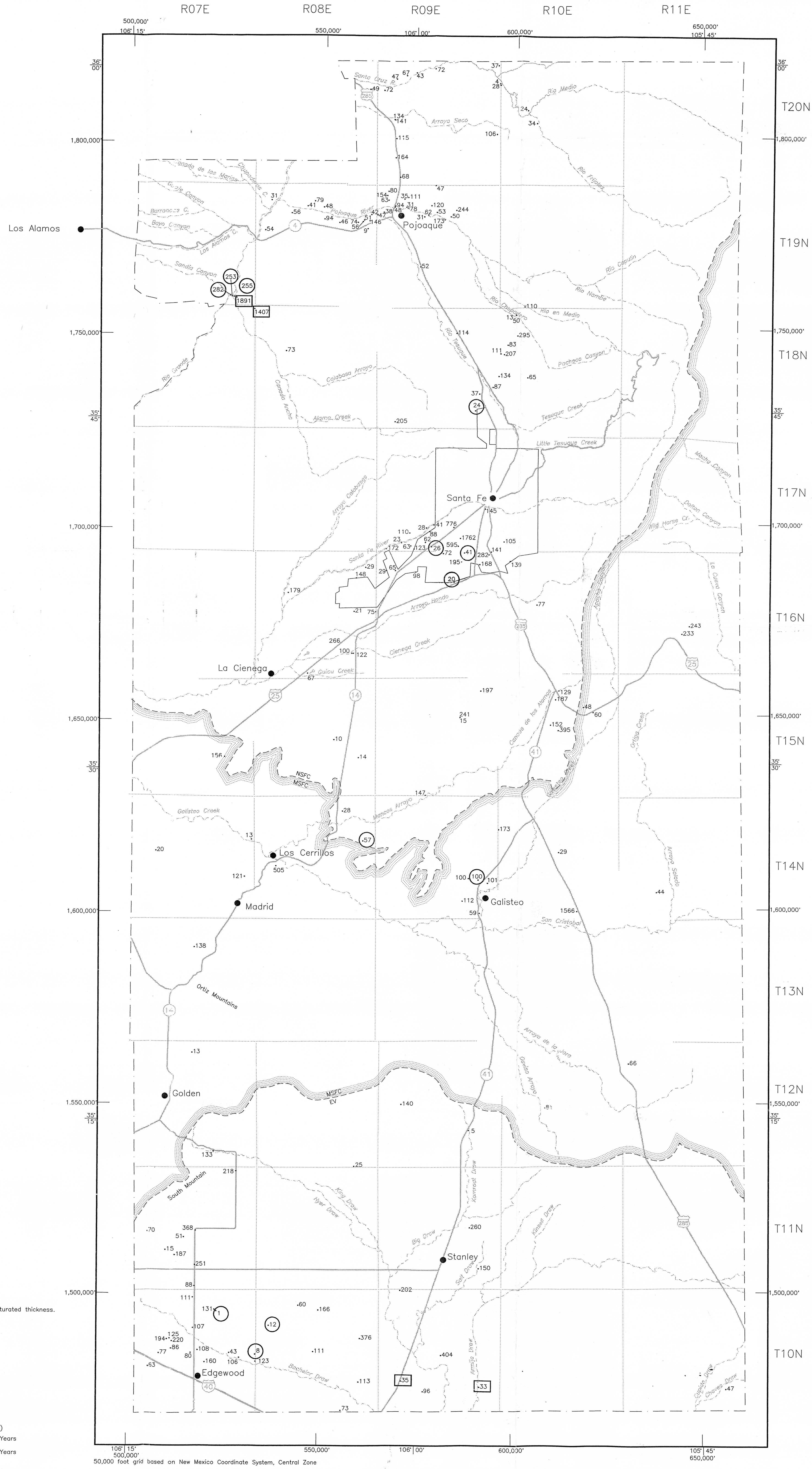
DANIEL B. STEPHENS & ASSOCIATES, INC.
7-94 JN 3300

Source: Cordell, 1977, Nuclear Dynamic Well Logs, USGS GWSI

SANTA FE COUNTY INVENTORY

Saturated Thickness of the Santa Fe Group in the NSFC Aquifer System and the Valley Fill in the EV Aquifer System

Plate 8



Note: The available drawdown is less than the saturated thickness.

N

0 5 Miles

Explanation

- •107 Depth of Well Minus Depth to Water (in feet)
- ○ Indicates Well May Go Dry in Less than 20 Years if Present Trend Continues
- □ Indicates Well May Go Dry in Less than 50 Years if Present Trend Continues
- Aquifer System Boundary
  - NSFC – North Santa Fe County Aquifer System
  - MSFC – Mid-Santa Fe County Hydrologic System
  - EV – Estancia Valley Aquifer System
- County Border
- Surface Drainage

50,000 foot grid based on New Mexico Coordinate System, Central Zone

SANTA FE COUNTY INVENTORY

Saturated Thickness in Existing Wells in the 1980's

DANIEL B. STEPHENS & ASSOCIATES, INC.
7-94 JN 3300

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Plate 9