FINAL PRELIMINARY ENGINEERING REPORT - WATER SYSTEM IMPROVEMENTS

CHUPADERO WATER - SEWAGE CORPORATION
SANTA FE COUNTY, NEW MEXICO

Martin/Martin, Inc. Project No.: 17.1400

April 2018

MARTIN/MARTIN
CONSULTING ENGINEERS

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WATER SYSTEM IMPROVEMENTS

Chupadero Water - Sewage Corporation
Santa Fe County, New Mexico

April 2018

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This Preliminary Engineering Report (PER) was prepared by Martin/Martin, Inc. as per the U.S. Department of Agriculture Rural Utilities Service Bulletin 1780-2: *Preliminary Engineering Reports for the Water and Wastewater Disposal Program* (April 4, 2013).

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EXECUTIVE SUMMARY

The Chupadero Water and Sewage Corporation (Chupadero) is located approximately 11 miles north of the City of Santa Fe in Santa Fe County, New Mexico, along State Highway 592 and County Road 78.

Chupadero currently owns and operates a public water system, constructed in 1976, which generally consists of a 20,000-gallon water storage tank, three groundwater supply wells, 3-inch PVC water main, 2-inch PVC laterals, a single pressure reducing valve, isolation valves, and new radio read water meters.

Due to the aging members of the Chupadero Board, and their operator, and the lack of interest in the community for younger members to take over these roles, Chupadero requested that Santa Fe County take over their water system. On July 23, 2012, the Chupadero Board approved incorporating their service area into the County Utility's water service area. On September 25, 2012, Santa Fe County approved a resolution to incorporate the Chupadero service area into the County's as well as committing to execute the proper legal instrument for transfer of water assets and infrastructure to the County. The final transfer is planned to take place upon completion of the needed water system improvements identified in this report.

The purpose of this preliminary engineering report (PER) is to evaluate feasible and cost-effective water system improvement alternatives for the existing Chupadero system. Multiple alternatives were evaluated for this PER. They may generally be categorized as supply, treatment, and transmission/distribution.

The recommended project, based on the life cycle cost analysis and evaluation of non-monetary factors, is a combination of four alternatives for improvements to water supply, disinfection and possibly treatment, storage and transmission/distribution. The estimated capital cost of the recommended project is $2,108,373 and the present worth 20 year life cycle cost is $2,780,609. In order for Chupadero to remain a viable water system, its highest priority is to drill a new well to ensure a sustainable supply of water for its customers. Without a sustainable supply of water, the other improvement alternatives could pose less value.

For this water system improvements project, Chupadero will pursue funding for design and construction. To receive project funding, Chupadero will need to submit this PER to funding agencies as part of the project funding process. Future engineering design of the project must comply with the New Mexico Environment Department Construction Programs Bureau (NMED CPB) 2006 Recommended Standards for Water Facilities. Since Santa Fe County will eventually be taking over ownership of the water system, design must also comply with the 2012 Santa Fe County Water Utility Customer Service Policies and the forthcoming Santa Fe County Utility Standards (currently in draft stage).

This PER was prepared under the responsible charge of a registered New Mexico professional engineer per the guidelines and format published in U.S. Department of Agriculture (USDA) RUS (Rural Utility Services) Bulletin 1780-2: Preliminary Engineering Reports for the Water and Wastewater Disposal Program (April 4, 2013). The planning period for this PER is 20 years.

A public meeting was held at the Rio Medio Community Center on April 9, 2018 to present and discuss the final draft PER. Pertinent comments from this meeting, NMED CPB and Santa Fe County were recorded, evaluated and are included in this PER.

1.0 PROJECT PLANNING

1.1 PROJECT LOCATION

The proposed water system improvements included in this report are located within the Chupadero Water and Sewage Corporation (Chupadero) public water system; NMED Water System No. 3566026. Chupadero is located approximately 11 miles north of the City of Santa Fe in Santa Fe County, New Mexico, along State Highway 592 and County Road 78. A site vicinity map, using a USGS topographic map of the area, is provided as Figure 1 in Appendix A.

The Chupadero water system service area includes residences located along both State and County intersecting roadways as well as several side roads that connect to County Road 78. A map of the service area is provided as Figure 2 in Appendix A. The elevation across the system ranges approximately from 6,990 ft. above mean sea level (AMSL) at the storage tank site to 6,700 ft. AMSL at the lowest service connection. The ephemeral Rio Chupadero passes through the southern portion of the service area. Outcrops of the Tesuque Formation are located just north of the service area.

1.2 ENVIRONMENTAL RESOURCES PRESENT

1.2.1 HYDROLOGY

Since the area of the Rio Chupadero has the lowest elevations, surface water from precipitation migrates towards the Rio Chupadero.

Groundwater in the area, from which Chupadero obtains its potable water, was documented in a technical memo prepared by Daniel B. Stephens & Associates, Inc. (DBS) in July 2016; Hydrogeologic Survey of Chupadero Area. The numerous faults located to the north of Rio Chupadero can act as barriers to lateral groundwater flow. This can limit the long-term production capability of groundwater supply wells located within the faults area. Historically, Chupadero has had four groundwater supply wells (see Section 2.0 – Existing Facilities). Historically, fluoride and uranium concentrations have been detected in two of the wells (Well #1 and Well #3) which has prevented use of these wells in the past. Many of the residences in Chupadero still have private groundwater supply wells. They are used for individual potable supply or for irrigation. Shallow wells in the area produce 5 to 80 gpm and depth to water varies from 10 to hundreds of feet (DBS). The thickness of the coarse-grained materials in the aquifer can also affect well productivity. This thickness in the shallow wells varies from 50 to 300 ft. (DBS). Groundwater flow is predominately to the southwest.

Chupadero's water supply wells are located in the Nambe-Pojaque, which has been closed by the Office of the State Engineer as part of the regional March 2016 Aamodt Settlement with area tribes. During a drought in 2012, Chupadero's shallow Well #2 went dry and their deeper Well #4 only produced an average of 3,000 gallons per day (gpd).

1.2.2 GEOLOGY

The upper 8 ft. of surface geology can be identified by a Soil Resource Report obtained from USDA Natural Resource Conservation Service (NRCS). This report is provided in Appendix B. The NRCS report indicates that the area of the existing water system is comprised primarily of loams, which can include very fine sandy loam and very cobbly sandy loam. At depths greater than 7 ft., the loams can change to sands.

The surface geology of the area has been documented in a study conducted in 2003 by Claudia I. Borchert et al, Geologic Map of the Tesuque Quadrangle, Santa Fe County, New Mexico, published by the New Mexico Bureau of Geology and Mineral Resources for open file digital Geologic Map 47. The geologic map and a blowup of Geologic Map 47, that more clearly shows the Chupadero area, is provided in Appendix B. Soils in the immediate area of the Rio Chupadero are identified as Quaternary Alluvium (Qal) consisting of poorly sorted sands and silts. To the north of the Rio Chupadero, the soils change to Tertiary Tesuque formations consisting of Lithosome A (Ttan, Nambe member of the Tesuque formation Santa Fe Group) and Basalt (Ttnb) in the lower Nambe member. Numerous fault lines have been identified in this formation. To the south of Rio Chupadero exists the same Tertiary Tesuque formations consisting of Lithosome A (Ttan) and smaller areas of Quaternary Gravel of ancestral Rio Chupadero (Qgc) Pleistocene era and also of the assumed Upper Pleistocene era (Qgc2).

1.2.3 WETLANDS

A wetlands inventory map was obtained (provided in Appendix B) from the U.S. Fish & Wildlife Service National Wetlands Inventory. There were no wetlands identified within the area occupied by the current Chupadero water system.

1.2.4 FLOODPLAINS

A FEMA Flood Insurance Rate Map (FIRM) of the Chupadero area was obtained and is provided in Appendix B. The map indicates that the area of the Rio Chupadero is prone to flooding by 100-year storms. Any future improvements and construction work that occurs in the area identified on the FIRM will need to consider the potential for flooding.

1.2.5 BIOLOGICAL CONSIDERATIONS

A list of endangered and threatened species for Santa Fe County, New Mexico was downloaded from the U.S. Fish & Wildlife Service (provided in Appendix B). Potential endangered species in the area includes the New Mexico Jumping Mouse and the Southwest Willow Flycatcher. Potential threatened species includes the Mexican Spotted Owl and the Yellow Billed Cuckoo. Potential critical habitats were not identified in the list. Migratory birds are protected under several historical acts and treaties. The majority of the identified migratory birds breed from March to September. Construction work occurring during this period of time would need to be cognizant of the potential for nesting migratory birds identified in the list.

1.2.6 CULTURAL CONSIDERATIONS

Some homes in Chupadero date back over 150 years. The list of historic sites was reviewed at the New Mexico Preservation Division Cultural Resources website. There were no historic sites identified in Chupadero.

1.3 POPULATION TRENDS

Demographic data for the Chupadero area was obtained from the U.S. Census Bureau and the University of New Mexico Bureau of Business and Economic Research. In 2000, Chupadero became a census designated place (CDP) for the U.S. Census Bureau. Therefore, specific area demographic information is available since that time. The demographic data for Chupadero from 2000 to 2016 is provided in the following Table 1 and a graph of the demographic data with a projected population in 2038 is provided as Table 2.

The U.S. Census Factfinder 2016 population estimate was 315. This indicates a loss in population since 2010. This estimate does not appear to be correct as Chupadero has indicated there has not been a loss in population in the community. Therefore, the 2016 Chupadero estimated population is based on the U.S. Census estimated population change for Santa Fe County (3.1%) for 2000 to 2016. This same value of change was projected for the 20-year planning period to estimate the future population of 414 in 2038. Since Chupadero is located within a closed water basin and Chupadero stopped accepting new members in 2012 (due to lack of sustainable water sources), population growth is not anticipated to be at a higher rate.

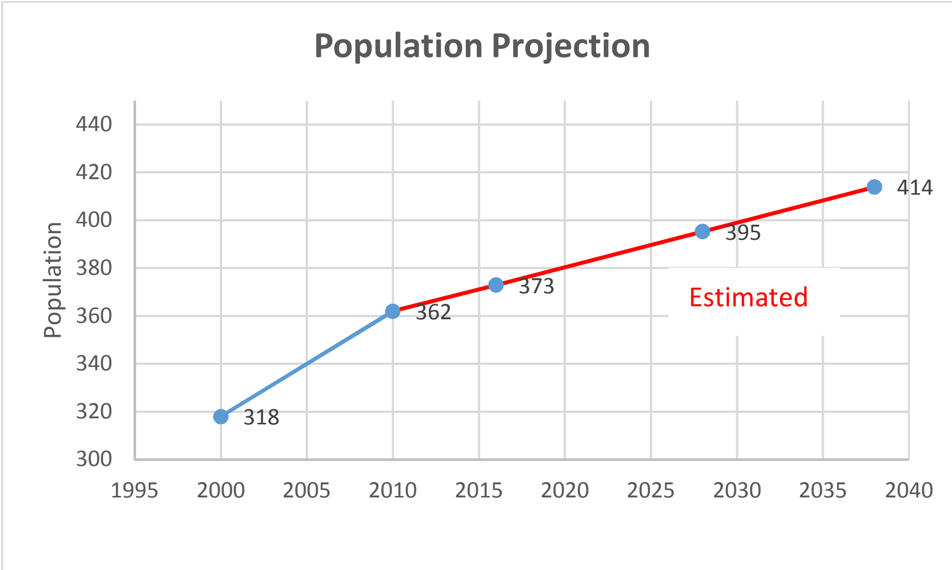
Table 1: Demographic Information

Year	Population	No. of Households	Capita/Household
2000	318	125	2.54
2010	362	149	2.43
2016(1)	373[(1)]	150	2.5
2028(2)	395[(2)]	158	2.5
2038(2)	414[(2)]	166	2.5

[1] Based on *U.S. Census growth estimate rate for Santa Fe County,*

[2]*Estimated using same Santa Fe County increase for 2010 – 2016*

Table 2: Population Projection



1.4 COMMUNITY ENGAGEMENT

The Final Draft PER was presented to the Chupadero community on April 9, 2018. Questions and comments were responded to at this meeting and incorporated, as needed, into the Final PER.

2.0 EXISTING FACILITIES

Chupadero currently owns and operates a public water system (NMED System No. NM3566026), constructed in 1976, which consists of a 20,000-gallon water storage tank, three groundwater supply wells with two underground well vaults and one master meter/electrical vault, one well house, 3-inch PVC water main, 2-inch PVC laterals, a single pressure reducing valve, isolation valves and new radio read water meters. Four new meters have not been installed yet as the service lines have yet to be found. There are currently 54 active connections with 56 active customers (some meters currently shared). The Board believes there may be as many as 10 additional illegal connections. A map of the service area and a map of the existing and historical water system is provided as Figures 2 and 3, respectively, in Appendix A.

2.1 HISTORY

The Chupadero Board was formed in 1974 and the water system was first constructed in 1976. It consisted of the storage tank, piping and most of the 54 service connections noted above. Well #1 was constructed in 1977. Well #1 developed a reportable concentration of fluoride and production reportedly dropped off.

In 1986, the New Mexico State Health Department requested in writing that Well #1 be shut down even though the concentration of fluoride was apparently just above the State standard (4.22 mg/L vs. 4.0 mg/L). In 1987, Chupadero drilled a shallow (65 ft.) replacement well (current Well #2) under a private permit at the property of David Roybal, a historical and current Chupadero Board member. In 2001, Mr. Roybal tried to transfer the well to Chupadero, but it has not been approved by the Office of the State Engineer (OSE) to date.

In May 2002, a PER for Chupadero was prepared by DBS. In the PER DBS indicated that Well #2 had decreased in production in recent years and that in 2002 the water level dropped below the pump intake and the pump burned out. The 2002 PER recommended the following alternatives:

- Drill new well.
- Provide chlorination for disinfection.
- Add a second water storage tank.
- Move water main outside of paved roadway.
- Use C900 PVC for new water main.
- Replace water meters.

Public concerns identified in the 2002 PER included:

- Water quality and quantity.
- Firefighting capability.
- Water rate increases.
- Loss of members and decreased revenues.

A proposed project from the 2002 PER was a new well that was eventually funded and constructed in 2003. Non-funded proposed tasks in the 2002 PER were new water storage tank, improvements to storage tank access road, replacement of distribution piping and appurtenances, installation of a disinfection system and installation of new system-wide metering.

In May 2002, DBS prepared preliminary design plans for a new supply well and improvements to the existing water storage tank site. A new well (Well #3), with well house, was subsequently constructed in 2003 (under emergency status) to a depth of 530 ft. Well #3 was used for approximately 3 months when uranium was detected, and production dropped dramatically. Well #3 was taken offline and shallow private Well #2 again became the sole source of supply for Chupadero. A new well (Well #4) was subsequently drilled beside Well #2 to a depth of 300 ft. Wells #2 and #4 currently provide water for the system.

In May 2002, Chupadero filed an application to the OSE to discontinue use of 39.7 acre-ft. per year (AFY) from 21 private domestic wells and transfer those rights to Chupadero. In 2007 OSE partially approved the application by granting 12.59 AFY for Wells #2 and #3. Chupadero subsequently filed a grievance letter and in 2008 dispute mediation was stayed.

Chupadero's water supply wells are located in the Nambe-Pojoaque Basin, which was closed by the OSE as part of the regional March 2016 Aamodt Settlement with area tribes. During a drought in 2012, Chupadero's shallow well went dry and their deeper well was only producing 3,000 gpd. At this time, Chupadero stopped accepting new members.

Due to the aging of members of the Chupadero Board and their operator, and the lack of interest in the community for younger members to take over these roles, Chupadero requested that Santa Fe County take over their water system. On July 23, 2012, the Chupadero Board approved incorporating their service area into the County utility's water service area. On September 25, 2012, Santa Fe County approved a resolution to incorporate the Chupadero service area into the County's as well as committing to execute the proper legal instrument for transfer of water assets and infrastructure to the County. The final transfer is planned to take place upon completion of the needed water system improvements identified in this report.

In July 2013, a Chupadero Water System Analysis and Water Right Evaluation was prepared for Santa Fe County by Southwest Water Consultants, Inc. to analyze the system and to estimate the monetary value of Chupadero's water rights.

In 2013, Chupadero negotiated a water rights settlement of 20.096 AFY (equivalent to an average of 17,939 gpd) with the OSE. An extension of time must be filed every three years with OSE until that volume is pumped in one calendar year. That volume has not been able to be pumped by the system since that time due to low production from Wells #2 and #4.

In 2014, the water supply situation in Wells #2 and #4 improved and members have been on a voluntary water use reduction program since that time. New members are still not allowed to date.

2.2 CONDITION OF EXISTING FACILITIES

Martin/Martin, Inc. met on-site with Chupadero and Santa Fe County on December 27, 2017 to discuss and observe the existing facilities.

Groundwater Supply Wells

Groundwater supply Wells #2 and #4 are currently being used. Both these wells were originally private wells that were provided to Chupadero for community use. An Agreement is in place that once Santa Fe County takes over the Chupadero system these two wells will be returned to the original owners along with 0.5 ac. ft./yr. water rights. Well #1 is no longer owned by Chupadero and Well #3 is not in use because of low production and the presence of uranium. The two wells in current use appear to be susceptible to recharge from precipitation as the operator indicated that precipitation and drought can quickly affect each well's production. Each well is housed and located within a secured underground concrete vault. Both wells are tied into another underground vault that houses electrical panels and the master meter for both wells. Photographs No. 1 and No. 2 show the wells and master meter. Water pumped from the wells is piped up Abs Road where it connects to the water main. There is not a dedicated fill pipe to the storage tank. The pumped water is not disinfected before entering the water main. A new submersible pump was installed in Well #2 in 2013 and a new submersible pump was installed in Well #4 in 2012.

Photograph 1: Wells #2 and #4

Photograph 2: Wells #2 and #4 Master Meter

Well Production/Water Demand

Wells #2 and #4 have a 1 HP and 1.5 HP pumps. Based on this horsepower and the head to the storage tank, it is estimated that the production rate of the wells is 5 to 7 gpm.

Chupadero provided well diversion readings that have been submitted to OSE. The monthly reported readings were used to calculate an average day demand for the system for 2014 through 2017. The highest average day demand in that time period was 10,666 gpd in October 2017. The lowest average day demand in that time period was 3,154 gpd in March 2017. Please note an average daily demand of 16,658 was calculated for September 2015 but this value is suspect and was not used as it differs considerably from all the other well diversion data. The above reported demands appear similar to other calculated average day system demands and is typical of water systems, with lowest demand in the winter months and highest demand in the summer months.

Water Storage Tank

The existing 20,000-gallon water storage tank is located near the top of a hill to the east and above State Highway 592. The access road to the tank is steep and limits the access of large vehicles. The original tank and pipeline easement date back to 1977. The tank was not built in the location provided in the easement; it was constructed further to the west. In 2014, the current owners of the property applied to Santa Fe County to vacate the current easement and create a new easement that incorporates the existing location of the tank and pipeline. The application was approved by the County in 2014. It is understood that the new tank and pipeline easement prepared in 2014 has not yet been finalized and recorded with the County.

The exterior of the tank appears in good condition. The tank does not have adequate fall protection, does not have a locking ladder access hatch, does not have markings for its external level reader, and the security fence is only partially constructed and does not completely encircle the tank. The tank is equipped with a float level sensor that communicates via radio with groundwater supply pumps to fill the tank. Photographs of the existing tank are provided below:

Photograph 3: Water Storage Tank

Photograph 4: Tank Access Road

Chupadero provided a video of an internal tank inspection conducted by Inland Potable Services, Colorado. Chupadero thinks the inspection was over 10 years old. The tank inspection video viewed by Martin/Martin, Inc. indicates that the paint on the inside of the tank is peeling off in multiple places, there is some corrosion and rust spots on the floors and walls and paint "blisters" were visible on the tank floor. Select photographs of the video are provided below.

Photograph 5: Old Tank Inspection Fill Pipe

Photograph 6: Old Tank Inspection Interior Paint

Since the previous tank inspection videos indicated there are items of concern within the tank, a new tank inspection was conducted as part of this PER. CW Divers Farmington, New Mexico, were contracted to perform an inspection of the existing 20,000-gallon tank. The new inspection was performed on February 1, 2018. The results of the new inspection indicate:

- Tank interior requires sandblasting and repainting with NSF 61 approved paint.
- Corrosion is uniform and measurable corrosion not identified therefore interior welding repairs not anticipated.
- Interior ladder has some corrosion that can be repaired by repainting.
- Exterior ladder requires safety cage and improved fall arrest.
- Vegetation around tank foundation should be removed.

Select photographs of the new tank inspection are provided below:

Photograph 7: New Tank Inspection Interior Ceiling

Photograph 8: New Tank Inspection Interior Wall at Floor

Chupadero purchased a used 20,000-gallon storage tank in 2009. The tank is located at D&R Tank in Albuquerque. D&R provided a quote of $24,000 in 2009 to rehabilitate the tank and move it to a new location. Martin/Martin, Inc. contacted D&R Tank to confirm the tank is still stored at their yard and to obtain a revised quote for rehabilitation, transport and erection. The revised quote information is included in the alternatives section of this report.

Distribution System

The distribution system consists of 3-inch PVC pipe that starts at the existing storage tank, travels approximately 320 ft. down a hill to the east side of State Highway 592, travels approximately 270 ft. north on the east side of State Highway 592, crosses the State Highway to the west at the intersection of County Road 78 and then travels west within the north side of County Road 78 to Los Jimenez Road (see Figure 3, Appendix A). This total route is estimated to be approximately 7,300 ft. long. There are three 2-inch PVC laterals that branch off the water main to the west at Abs Road (Wells #2 and #4 connection to main), Florencio Road and Camino de Pastores. The estimated length of the 2-inch laterals is 2,600 ft. There is a pressure reducing valve (PRV) located in the middle of County Road 78 just east of the intersection of Florencio Road. An isolation valve is located on the east side of the PRV. Main and lateral isolation valves are also located at the intersections of County Road 78 and Abs Road and Camino de Pastores. There are three 2-inch flush hydrants located within the system (see Figure 3, Appendix A). One flush hydrant is located beside Tesuque Fire Department Station No. 2. The other two flush hydrants are located within the water system, not at the ends of the water main or laterals as would normally be the case in order to flush entire pipe segments. There is also a lateral that connects at the Tesuque Fire Department building and travels south approximately 930 ft. to service two homes. It is assumed this lateral is 2 inches in diameter and is PVC as is the rest of the piping system.

Photographs of the water main appurtenances are provided below:

Photograph 9: Pressure Reducing Valve Station

Photograph 10: Water Main/Lateral Isolation Valves

Photograph 11: Flush Valve at Tesuque Fire Station No. 2

County Road 78 pavement ends just west of the intersection with Camino de Pastores. At that point the County Road ends and it becomes a private gated dirt road. The beginning of Abs Road, Florencio Road and Camino de Pastores are paved approximately 50 ft. or less and then the roads become dirt/gravel.

Chupadero has reported a number of leaks occurring in their water main and at some of their isolation valves. An assumed leak (wetted surface extending approximately 20 ft.) was observed by Martin/Martin, Inc. on Camino de Pastores Road during the field reconnaissance conducted on December 27, 2017. Chupadero has also reported that there may be as many as 10 illegal connections and laterals on their water main.

A photograph of the suspected leak is provided below:

Photograph 12: Observed Apparent Leak on Camino de Pastores

Chupadero does not have utility easement permits with either NMDOT or Santa Fe County for the water main. A 20-foot-wide pipeline easement was granted to Chupadero in 1977 by landowners for two roads located within the community. According to the named landowners in the easement these roads are assumed to be Camino de Pastores and Florencio Road.

Santa Fe County hired a surveyor, Morris Surveying Engineering, Santa Fe, New Mexico, in an effort to document private properties and easements in Chupadero with respect to the water main and laterals. The results of the survey indicate that properties are not consistent for utility or roadway easements. It appears portions of roads are at times are located within private properties and at other times portions of roads are not included within any property and may have no legal owner.

Service Meters

Chupadero recently replaced old water meters with new radio read meters. There are still four service meters that require installation as the service lines have not yet been found. Chupadero has been using a set monthly rate for customer billing and in 2018 will implement a new service rate schedule based on metered flows. A photograph of one of the new water meters is provided below.

Photograph 13: New Water Service Meter

2.3 FINANCIAL STATUS OF ANY EXISTING FACILITIES

The 2017-year end financial statement for Chupadero was provided by their accountant and is provided in Appendix D. As indicated in the statement:

- The income from water bills was $23,944.75.
- New meter replacements expenditure was $45,753.41.
- Operations and maintenance cost was $6,320.30
- Electricity cost was $1,830.61
- The net income for 2017 was a negative $41,630.31 (due to recent installation of new water service meters).

The 2018 budget projects:

- Revenues - $75,088
- Expenditures - $74,160
- Ending balance - $20,366
- Reserves - $20,000
- Ending cash balance - $366

Chupadero does not have any debt reserve or required reserve accounts. The 2018 reserve budget is for operations, emergency and capital improvements. The current monthly service billing flat rate is $42/month (including NMGRT). In 2018 Chupadero will be changing their rate schedule to be based on metered flows.

2.4 WATER/ENERGY/WASTER AUDITS

There has not been any water, energy and/or waste audits performed by Chupadero. Water audits have been conducted in the area by the OSE in determining water rights and beneficial use as part of the Aamodt Settlement with area tribes and the closure of the Nambe-Pojoaque water basin to new water right appropriations.

3.0 PROJECT PURPOSE AND NEED

3.1 HEALTH, SANITATION, AND SECURITY

Health and sanitation needs for the project includes:

- A sustainable supply of potable water for the community.
- A disinfection system to ensure a compliant and safe potable water supply for distribution.
- Large enough water storage, water main and fire hydrants for fire flow.

Water supply Well No. 3 was installed in 2003 with the intent of providing a sustainable water supply for Chupadero. After several months of operation, the well production dropped dramatically and a concentration of uranium above state standards was detected in the well water. The well has not been used since that time.

Addition of a disinfection system will ensure sustainable safe drinking water for the community. Chupadero does not currently disinfect their potable water supply and although still in regulatory compliance, one non-compliant water sample could instigate the requirement for a disinfection system.

Tesuque Fire Department Station No. 2 is located along State Hwy 592 just below the Chupadero water storage tank site. A 2-inch flush hydrant is located on the water transmission pipe beside the fire station. Having fire storage, pipe fire flow capability and a fire hydrant located beside the fire station will greatly benefit Chupadero, as well as the surrounding communities that are served by the fire station.

Security needs that will be provided by the project includes:

- Securing existing supply wells with locking access hatches.
- Completely fencing the storage tank site with a security fence.
- Adding locking mechanism to the water storage tank ladder to prevent unwanted access.

The Chupadero water system is inspected annually by the NMED Drinking Water Bureau (DWB). The latest NMED DWB Sanitary Survey Report, dated December 2016, indicated three significant deficiencies and one recommendation for a minor deficiency. The identified significant deficiencies were:

- Lack of an Emergency Response Plan.
- Erosion near the water storage tank and lack of an overfill splash pad.
- Storage facility inadequate site security.

The minor deficiency recommendation was for the removal of vegetation growing around the foundation of the storage tank. A copy of the referenced 2016 NMED DWB Sanitary Survey Report is provided in Appendix C.

Establishing documented and recorded legal easements and acquiring utility permits from NMDOT, and potentially Santa Fe County, for the water main and laterals is necessary for Chupadero to have legal access to property and public right-of-way for future water system improvements construction and operation and maintenance.

3.2 AGING INFRASTRUCTURE

The Chupadero water system is over 40 years old. In recent years there have been multiple water leaks and the water system has trouble keeping up with the current needs and demand. Water main isolation valves are leaking and/or inoperable. Based on review of the 10-year-old storage tank video, the storage tank will require interior re-painting and repair of the tank level indicator. Inoperable water service meters were recently replaced as part of a total water service meter replacement project, in collaboration with Santa Fe County. Continual aging of the existing infrastructure over the 20-year PER planning period will most likely increase the level of operation and maintenance required as well as pose greater health and sanitation risks to the community.

3.3 REASONABLE GROWTH

Recent growth in the Chupadero community has been hindered by the OSE closure of the Nambe-Pojoaque water basin as well as Chupadero's need to prohibit new memberships in 2012 due to drought and unsustainable water supply. As indicated in Section 1.C – Population Trends of this report, population growth in Chupadero and Santa Fe County is anticipated to be fairly flat over the next 20 years, when compared to historical population growth for the past 40 years. Future population growth in Chupadero will be limited by the available water supply. Chupadero has indicated that as many as five additional residences have shown interest in becoming members of the water system and as many as 10 illegal connections to the water system may exist. It is very likely that some other existing residences, and potentially 10 to 20 new residences, will apply for new memberships once Chupadero is able to accept new customers. Ten additional members added after completion of an improvements project would increase the total number of customers by 18% and would help support future system financial requirements.

4.0 ALTERNATIVES ASSESSMENT

There are multiple alternatives to consider for improving the Chupadero water system. Alternatives evaluated include:

- Improving the groundwater supply.
- Improving disinfection and treatment.
- Improving water storage.
- Improving transmission and distribution.

4.1 ALTERNATIVE NO. 1 – GROUNDWATER SUPPLY WELLS

4.1.1 DESCRIPTION

Chupadero is in need of a sustainable supply of groundwater for distribution to its members. Well #1 use was discontinued in the past due to a concentration of fluoride above State standards. Well #3 use was discontinued due to poor production and a concentration of uranium above State standards. Both wells have not been used for more than 14 years. It should be considered to perform pump tests and collect drinking water standard analytical samples in order to determine the current viability of these wells. There are treatment processes available for the removal of fluoride and uranium that are currently operating in New Mexico. Current in use Wells #2 and #4 were originally private wells that have been used by Chupadero for a number of years. The original well owners have an Agreement in place to return the wells and 0.5 ac. ft./yr. of water rights to them once Santa Fe County takes over the Chupadero system.

A new well location at the far west end of the water system was proposed by DBS in a Technical Memo in 2016. As part of this PER, the DBS Technical Memo was reviewed by John Shomaker & Associates, Inc. (JSAI). JSAI's hydrogeologic evaluation is provided in Appendix E. JSAI's review comments and recommendations include:

- The DBS memo lacked supplemental information that was available for review.
- The DBS memo did not indicate review of water quality data.
- Groundwater with elevated uranium concentrations has been documented in multiple wells in the surrounding area.
- Documentation suggests that wells completed deeper into the Tesuque Formation may have a higher than average concentration of uranium.
- A design pumping rate of 20 gpm and a specific capacity of 0.10 gpm/ft. (Well #3 criteria) could have a drawdown in excess of 200 ft.
- Water levels in area wells have declined approximately 0.5 ft./yr. for the past 50 years.
- A new well should be placed to take advantage of the greatest thickness of the Tesuque Formation.
- According to OSE records, Well #1 has a steel casing and only 10 ft. of screen. A 2013 Southwest Water Consultants evaluation indicated water quantity concerns.

- Only potential well sites located west of 108 Chupadero Road (west of Camino de Pastores) should be considered due to the thickness of the Tesuque Formation.
- A new well should be drilled as near as possible to surface drainages in order to take advantage of local recharge.
- The DBS proposed new well location at the west end of Chupadero on the Jimenez property, and located near a surface drainage channel, is within an area deemed the best potential for a new well due to the depth of saturated thickness and in an area anticipated to having the best water quality.
- A water quality sample should be collected from a well close to the Jimenez property prior to starting a new well on the Jimenez property in order to obtain nearby water quality data.
- Drill a 500 ft. exploratory boring on the Jimenez property and run geophysical logs to document lithology and for final well design.
- Construct the new well with PVC due to water quality concerns.

Well #1 use was discontinued over 14 years ago due to a concentration of fluoride, apparently just above State standards. According to JSAI, OSE records and historical knowledge indicate steel was used to construct the well and the length of the screen was only 10 ft. Neither are conducive for a sustainable design as the short well screen is very likely rusted and incapable of providing the necessary production. This well will no longer be considered for re-development and use.

Well #3 use was discontinued shortly after its installation in 2003 due to poor production and a concentration of uranium above State standards. JSAI confirmed in their hydrogeologic evaluation that Well #3 is not in the best location as it is located near a fault. Well #3 also will not be considered further for use as a new well.

As recommended by JSAI, Wells #2 and #4 located on the Roybal property should be videoed and pump tested before starting a new well at the Jimenez property in order to confirm or deny their capability to perform and meet the future needs of Chupadero as supplemental wells. Even if testing confirms the wells are capable of long term performance for use as supplemental wells, the installation of a new well at the Jimenez property should move forward.

The Roybals have verbally indicated that they would consider future supplemental use of these wells by Chupadero. As the current agreement for returning 0.5 AFY of water rights to the Roybals equates to an average of 446 gpd, it is anticipated that the wells could provide an additional 10,000 gpd, as indicated in the well diversion information addressed above in Comment #3. If video and testing of Wells #2 and #4 indicates they are not capable of providing sustainable supplemental flow, other private wells would be considered for use as supplemental wells.

4.1.2 DESIGN CRITERIA

Design criteria for this alternative includes OSE data and standards and NMED DWB regulations and standards.

4.1.3 MAP

A map indicating the location of all existing and proposed wells is provided as Figure 4, Appendix A.

4.1.4 ENVIRONMENTAL IMPACTS

Environmental impacts for this alternative are not anticipated due to the fact that existing and proposed wells are located within previously developed residential properties.

4.1.5 LAND REQUIREMENTS

Approximately 1,000 SF of land would be required for a new well and well house/vault. This land could be granted an access easement or could be bought by Chupadero. Access easements would be required for the continued future use of Wells #2 and #4, located on the Roybal property, as supplemental wells.

4.1.6 POTENTIAL CONSTRUCTION PROBLEMS

Potential construction problems are not anticipated for this alternative as numerous wells have been installed in the area without known construction problems.

4.1.7 SUSTAINABILITY CONSIDERATIONS

Daily water use for 65 customers with an average of 2.5 persons per household and use of 80 gallons/per capita/day for a rural community equals 13,000 gpd. Providing this daily demand in a 12-hour period equals a demand of 18 gpm. With the addition of additional customers and storage capacity (see Storage Alternative No. 3) A 25 gpm submersible pump would be required. This would be considered the minimum flow required from a well to provide a sustainable supply, 60,000 gal. of storage and service for 75 connections.

4.1.7.a WATER EFFICIENCY

Efficient and properly sized water pumps can provide the highest water efficiency available.

4.1.7.b ENERGY EFFICIENCY

Energy efficiency can be provided by using 3 phase power, however 3 phase power is not currently available in Chupadero. Use of energy efficient pumps results in lower power consumption, therefore it might not be financially effective for the power company to run 3 phase power just for small submersible well pumps. Filling the storage tank during nighttime hours is recommended as the cost of power is typically cheaper during this time of lower power demand.

4.1.7.c OTHER

The primary sustainable consideration for a new well alternative is to provide a constant water supply for many years in the future and one that will not be substantially affected by drought.

4.1.8 COST ESTIMATES

The engineer's life cycle cost estimate of non-construction, construction and operation and maintenance (O&M) cost for two existing well pumps testing and analysis and a new well over the 20-year planning period is provided in Table 3. The cost summary for this alternative is:

- Construction Cost - $281,525
- Non-Constuction Cost - $30,264
- Present Value 20 Year O&M Cost - $153,086
- Total Life Cycle Cost - $464,874

Table 3: Groundwater Supply Wells Cost Estimate

Planning Period = 20 yr.		**Federal Discount Interest Rate=**			2.50%
Construction Cost					
Item	**Description**	**Unit**	**Qty**	**Unit Cost**	**Total Cost**
1	Well #2 Video and Testing	LS	1	$12,000	$20,000
2	Well #4 Video and Testing	LS	1	$12,000	$12,000
3	New Well #5, Pilot Boring, Install Test & Samp	LF	500	$ 300	$ 150,000
4	Master Meter	LS	1	$ 2,000	$2,000
5	Well #5 Vaults	EA	2	$ 7,500	$ 15,000
6	Well #5 Electrical	LS	1	$ 20,000	$ 20,000
				Subtotal	$ 219,000
			Contingency	20%	$ 43,800
		NMGRT		7.125%	$ 18,725
				Construction Cost Total	**$ 281,525**
Non-Construction Cost					
	Engineering Design, Bid & Construction Services			10%	$ 28,152
		NMGRT		7.50%	$ 2,111
				Non-Construction Cost Total	**$ 30,264**
				Total Capital Cost	**$ 311,788**
O&M Cost					
	Pump Replacement, Power, Sampling				$ -
				Total Annual O&M cost	$ 9,820
	20 Yr. Present Value of O&M Cost				$ 153,086
				Total Life Cycle Cost	**$ 464,874**

4.1.9 ADVANTAGES/DISADVANTAGES

Advantages:

- Creates a sustainable supply for the community.
- Would allow new members to join the water system.

Disadvantages:

- There are initial cost and treatment risks for any new well; in case the well does not have enough capacity or requires treatment beyond disinfection.

4.2 ALTERNATIVE NO. 2 – DISINFECTION AND TREATMENT

Disinfection of a water supply prior to storage is required when a periodic required analytical test result indicates the presence of coliforms in the water supply. Most water systems do not wait for a failed coliform test to disinfect the water supply. It is recommended to add disinfection, using sodium hypochlorite, to the water system.

Treatment alternatives for uranium should be considered should new Well #5 be installed and found to contain a concentration of uranium above the State standard (30 ug/l).

4.2.1 DESCRIPTION

Disinfection of the stored water supply using sodium hypochlorite can be accomplished with a packaged system that includes a small storage tank and peristaltic pump system. The disinfection system would need to be installed after the wells and before the storage tanks. Therefore, due to the locations of the multiple existing and future wells, it would be prudent to install the disinfection system at the storage tank site. Installing the disinfection system in an underground vault is expected to be more cost effective than a small heated building. As the existing tank level control radio system obtains electrical power from the Tesuque Fire Department building, it is assumed the low power requirement for a pump and light for the disinfection system can also be obtained from the fire department building; otherwise solar power may be utilized. A flow switch can be installed in the well supply piping at the storage tank site such that the disinfection system only operates when new water is pumped to the storage tanks.

In the event new Well #5 is installed, treatment to reduce the uranium concentration should be considered. Well #1 or Well #3 proves to be a viable well for future use a treatment system for either uranium or fluoride is anticipated. The most cost-effective treatment system for uranium for small scale flows (as previously evaluated by Martin/Martin, Inc. in 2012 for the Upper Arroyo Hondo MDWCA PER) are media adsorption systems, using ion exchange technology. There are six of these systems currently operating in New Mexico. The media adsorption systems do not produce a waste stream and thus are more efficient when considering the loss of water that can occur for treatment processes. The major drawback of the media systems is that the media has to be replenished in a 5 to 7-year timeframe, depending on the amount of flow through the media and the concentration of uranium being removed. The media system does not require a higher level of operator classification than Level 2 as it only requires monitoring and sampling for its operation.

A 20 gpm media absorption /ion exchange uranium treatment system has a small footprint. The 20 gpm uranium treatment system Martin/Martin, Inc. designed for Tierra Monte WUA was housed in a 10 ft. x 18 ft. building. With adequate land and space, a 16 ft. x 20 ft. building can house the treatment equipment and may also be used to house new Well #5 and its power and control panels. Disinfection with sodium hypochlorite must occur after treatment, therefore the planned disinfection to occur at the storage tank site would comply with this requirement.

4.2.2 DESIGN CRITERIA

The design criteria for this alternative includes NMED DWB and Santa Fe County regulations and standards.

4.2.3 MAP

A map of this alternative is provided as Figure 5 in Appendix A.

4.2.4 ENVIRONMENTAL IMPACTS

Environmental impacts are not anticipated for this alternative since construction would take place in previously disturbed locations that has regular foot and vehicle traffic.

4.2.5 POTENTIAL CONSTRUCTION PROBLEMS

There are no apparent potential construction problems with this alternative.

4.2.6 LAND REQUIREMENTS

Additional land should not be required for this alternative as land would be obtained for new Well #5.

4.2.7 SUSTAINABILITY CONSIDERATIONS

4.2.7.a WATER EFFICIENCY

This alternative does not provide additional water efficiency unless a uranium media treatment system is utilized. These treatment systems do promote water use efficiency as they do not require a backwash and do not have a waste stream.

4.2.7.b ENERGY EFFICIENCY

The disinfection and treatment systems described in this alternative use very little power to operate, thus providing energy efficiency for their use.

4.2.8 COST ESTIMATES

The engineer's cost estimate for this alternative is provided in the following table. A summary of this cost alternative, including both a disinfection and uranium treatment system, is provided below.

Construction Cost: $280,239
Non-Construction Cost: $80,689
Present Value 20 Year O&M Cost: $131,826
Total Life Cycle Cost: $492,754

Table 4: Disinfection/Treatment Alternative Cost Estimate

Planning Period = 20 yr.		Federal Discount Interest Rate=			2.50%
Construction Cost					
Item	**Description**	**Unit**	**Qty**	**Unit Cost**	**Total Cost**
1	Mobilization/Demobilization	LS	1	$ 15,000	$ 20,000
2	Testing Allowance	Allow	1	$ 5,000	$ 5,000
3	Chlorination Pump,Tank,Vault, Electrical	LS	1	$ 20,000	$ 20,000
4	20 GPM Uranium Treatment System	LS	1	$ 70,000	$ 70,000
5	PVC Piping	LS	1	$ 3,000	$ 3,000
6	Treatment Building	SF	400	$ 200	$ 80,000
7	Building Electrical	LS	1	$ 20,000	$ 20,000
				Subtotal	$ 218,000
			Contingency	20%	$ 43,600
			NMGRT	7.125%	$ 18,639
				Construction Cost Total	**$ 280,239**
Non-Construction Cost					
	Engineering Design, Bid & Construction Services			25%	$ 70,060
	Geotechnical Study				$ 5,000
			NMGRT	7.500%	$ 5,629
				Non-Construction Cost Total	**$ 80,689**
				Total Capital Cost	**$ 360,928**
Annual O&M Cost					
Sodium Hypochlorite					$ 200
Annual Reserve for Media Replacement					$ 9,000
Utilites - Electrical					$ 500
				Total Annual O&M cost	$ 9,700
	20 Yr. Present Value of O&M Cost				$ 131,826
				Total Life Cycle Cost	**$ 492,754**

4.2.9 ADVANTAGES/DISADVANTAGES

Advantages:

- Disinfection allows Chupadero to ensure a safe supply of potable water for its customers.
- If Chupadero decides not to disinfect their potable water at this time this alternative, if implemented, would still allow Chupadero to start the disinfection system whenever they desired.

Disadvantages:

- Customers may object to the taste of disinfected water if the chlorine residual concentration is maintained at too high a level.
- Additional operator time will be required to monitor and maintain disinfection and treatment systems.
- Treatment system requires long term O&M costs which typically results in increased customer rates.
- Media replacement for a uranium treatment system is a substantial short term 5 to 7-year O&M cost that requires creation of an annual reserve fund to pay for its expense.

4.3 ALTERNATIVE NO. 3 – WATER STORAGE

Chupadero has planned to add additional water storage for over 9 years. They purchased a matching storage tank in 2009 and received a quote at that time from D&R Tank to refurbish the tank and move it to their site. A new budget quote from D&R Tank was obtained for this PER. In order to provide service for 75 connections at 200 gpd per connection, store 2 days of demand and 30,000 gal. for fire flow, a total of 60,000 gal. of storage is required. Chupadero would require a third additional matching 20,000 gal. tank. Chupadero may be able to purchase another used tank for refurbishing but at this time it is assumed a new 20,000 storage will be required.

4.3.1 Description

The easement for the existing storage tank site and access road needs to be finalized and executed for this alternative. The existing 20,000 gal. storage tank will be rehabilitated by sandblasting and re-painting the interior and by adding a safety cage with improved fall protection apparatus to the exterior ladder. The offsite matching 20,000 gal. storage tank would be refurbished, transported and erected on the site beside the existing tank. A new 20,000 gal. matching tank will be purchased and erected at the tank site. Two new ring foundations, set at the same elevation as the existing tank foundation, will be required for the two new tanks. A geotechnical study will be required for the new tank foundations. The tank site and access road will be regraded to remove vegetation and to control stormwater and erosion. A rip rap stormwater swale will be constructed on the north side of the access road from the tank site to State Highway 592 where it would discharge to an existing drainage channel. After re-grading the tank site will be provided with a geotextile fabric overlain with a gravel surface to control vegetation on the site. The new tank will be piped to the existing tank such that each fill and empty in unison. Both tank overflows and drains will be valved and piped to the new stormwater swale. The existing security fence will be completed. The existing radio-controlled tank level sensor will remain. The water level in both tanks will be maintained such that 30,000 gal. of fire flow is available at all times. The second tank will be refurbished, erected onsite and placed in operation prior to improvements to the existing tank taking place.

4.3.2 Design Criteria

Design criteria for this alternative includes American Water Works Association (AWWA), NMED DWB and Santa Fe County regulations, standards and recommendations.

4.3.3 Map

A map of this alternative is provided as Figure 6, Appendix A.

4.3.4 Environmental Impacts

Environmental impacts are not anticipated for this alternative as construction would take place on previously disturbed areas.

4.3.5 Land Requirements

There are no additional land requirements for this alternative.

4.3.6 Potential Construction Problems

Transporting the second tank up the steep dirt access road for erection on the existing tank site may require that the second tank be brought in pieces and re-welded onsite during erection.

4.3.7 Sustainability Considerations

4.3.7.a Water Efficiency

Utilizing a second matching tank to double the available storage volume and provide fire flow storage for Chupadero provides for a more efficient and sustainable water system.

4.3.7.b Energy Efficiency

Filling tanks in the nighttime hours can be planned as the cost of power is less during these hours,

4.3.7.c Other

The storage tank system will be more efficient with the use of two matching tanks.

4.3.8 Cost Estimates

The engineer's cost estimate of this alternative is provided in the table below and is summarized as follows:

Construction Cost: $239,400
Non-Construction Cost: $59,850
Present Value 20 Year O&M Cost: $20,385
Total Life Cycle Cost: $319,365

Table 5: Storage Tanks Alternative Cost Estimate

Planning Period = 20 yr.		**Federal Discount Interest Rate=**			2.50%
Construction Cost					
Item	**Description**	**Unit**	**Qty**	**Unit Cost**	**Total Cost**
1	Mob/Demob	LS	1	$ -	$ 18,000
2	Testing	LS	1	$ 3,000	$ 3,000
3	Rehab Onsite Tank	LS	1	$ 25,000	$ 25,000
4	Rehab Offiste Tank, Install Onsite	LS	1	$ 40,000	$ 40,000
5	New 20K gal. Storage Tank	LS	1	$ 55,000	$ 55,000
6	New Tank Foundation	LS	2	$ 15,000	$ 30,000
7	Tank Interconnection Piping	LF	200	$ 50	$ 10,000
8	Regrade Site & Road	LS	1	$ 7,500	$ 7,500
9	Geotextile Fabric/Gravel Surface Tank Site	LS	1	$ 1,000	$ 1,000
10	Rip Rap Swale	LF	350	$ 20	$ 7,000
11	Security Fence	LF	100	$ 30	$ 3,000
				Subtotal	$ 199,500
			Contingency	20%	$ 39,900
			NMGRT	0.000%	$ -
				Construction Cost Total	**$ 239,400**
Non-Construction Cost					
	Engineering Design, Bid & Construction Services			25%	$ 59,850
			NMGRT	0.00%	$ -
				Non-Construction Cost Total	**$ 59,850**
				Total Capital Cost	**$ 299,250**
Annual O&M Cost					
Maintenance					$ 1,500
				Total Annual O&M cost	$ 1,500
	20 Yr. Present Value of O&M Cost				$ 20,385
				Total Life Cycle Cost	**$ 319,635**

4.3.9 Advantages/Disadvantages

Advantages:

- Increased volume of available potable water.
- Provides fire flow storage capacity which should lower homeowner fire insurance rates.
- Matching tanks aids in O&M.

Disadvantages:

- The water system must maintain 30,000 gal. fire flow capacity at all times.
- In order to provide two days of demand and fire flow storage, only 75 connections can be served (at a demand of 200 gpd/connection) with a 60,000 gal. storage system.

4.4 ALTERNATIVE NO. 4 – TRANSMISSION AND DISTRIBUTION

The existing single water transmission/distribution pipe will be replaced with a dedicated fill pipe and a separate transmission distribution main to improve its capabilities as well as to improve its operation and longevity

4.4.1 Description

The existing single 3-inch water main/transmission pipe will be replaced with a 3 inch Sch. 80 PVC dedicated fill pipe from wells to storage tanks and a new 8 inch C900 PVC water main will be provided for water transmission and distribution. Both pipes will be provided with new isolation valves so segments of the pipe can be isolated for O&M purposes. The existing PRV will be replaced and will include two PRVs, one 8 inch. for large flows and one 4 inch for smaller flows. New piping will be placed under the northern edge of County Road 78. The Santa Fe County Public Works Dept. has indicated that 4 ft. of the northernmost edge of County Road 78 may be used for placement of the new piping. The new piping is unable to be installed outside of the pavement due to both the lack of individual property easements and physical constraints located along the roadway. New piping installed by drilling beneath State Highway 592 will need to be encased in a steel sleeve and a NMDOT District 5right-of-way utility permit will be required prior to construction. It is also anticipated that a utility easement will also be required from Santa Fe County for County Road 78. Easements from property owners along County Road 78 may also be required in the case of historical prescriptive easements that extend into the limits of County Road 78. Existing County Road 78 pavement will be demolished and replaced as part of the construction process. Piping laterals installed on side roads will include replacement of gravel disturbed during construction activities. The use of directional drilling along County Road 78 is not anticipated to provide a cost savings over pavement demolition and replacement due to the number of short curves in the roadway, the lack of physical space to setup drilling equipment and the short length of the project. New fire hydrants will be spaced at 1,000 ft. maximum intervals throughout the distribution main on County Road 78 and will also be located at the Tesuque Fire Dept. building. Flush hydrants will be installed at piping lateral ends. Existing customer water service connections will be connected to the new water main and laterals. A geotechnical study will be conducted along County Road 78 for the PRV vault foundation and to aid in identification of potential subsurface anomalies that could affect construction, such as caliche, boulders and bedrock. Traffic control and control plans will be required for State Highway 592 and County Road 78.

4.4.2 Design Criteria

Design criteria for this alternative includes NMED DWB and Santa Fe County regulations, standards and guidelines. Permits required will include Santa Fe County and NMDOT traffic control plans and a stormwater pollution prevention plan (SWPPP) due to the disturbance of more than one acre of land.

4.4.3 Map

A map of this alternative is provided as Figure 7 Appendix A.

4.4.4 Environmental Impacts

Environmental impacts are not anticipated for this alternative as construction will take place in active highways and roads.

4.4.5 Land Requirements

This is no additional land requirement expected for this alternative other than the easements that will need to be obtained prior to construction.

4.4.6 Potential Construction Problems

Potential construction problems for this alternative include subsurface conditions that could hinder construction progress. A geotechnical study conducted for the new piping routes would assist in the determination of potential problems.

4.4.7 Sustainability Considerations

4.4.7.a Water Efficiency

A new 6-inch water main will hold a volume four times greater than the existing 3-inch pipe that is currently in use. It will also hold a volume equal to approximately 80% of the estimated daily use of the system. This alternative will provide a more efficient means of storing and using water.

4.4.7.b Energy Efficiency

Using a dedicated fill pipe is anticipated to provide a more efficient means of filling storage tanks and should also prove to be more energy efficient.

4.4.8 Cost Estimates

The engineer's cost estimate for this alternative is provided in the following table. A summary of this estimate is provided as follows:

Construction Cost: $883,781
Non-Construction Cost: $252,625
Present Value 20 Year O&M Cost: $366,939
Total Life Cycle Cost: $1,503,345

Table 6: Transmission/Distribution Alternative Cost Estimate

Planning Period = 20 yr.		**Federal Discount Interest Rate=**			2.50%
Construction Cost					
Item	**Description**	**Unit**	**Qty**	**Unit Cost**	**Total Cost**
1	Mob/Demob	LS	1	$ 60,000	$ 63,000
2	Testing	Allow	1	$ 10,000	$ 10,000
3	Traffic Control/SWPPP	LS	1	$ 30,000	$ 30,000
4	3 in. Sch 80 PVC Laterals & Dedicated Fill	LF	3,600	$ 20	$ 72,000
5	8 in. C900 PVC Water Main	LF	7,300	$ 35	$ 255,500
6	3 in. Gate Valve	EA	6	$ 2,500	$ 15,000
7	8 in Gate Valve	EA	4	$ 4,000	$ 16,000
8	1 in. Air Valve	EA	4	$ 5,000	$ 20,000
9	6 in. Fire Hydrant	EA	4	$ 5,000	$ 20,000
10	2 in. Flush Hydrant	EA	4	$ 4,500	$ 18,000
11	8 in. PRV Station	LS	1	$ 33,000	$ 33,000
12	Asphalt Pavement Demo and Replace	SY	2,500	$ 50	$ 125,000
13	Gravel Road Repair	SY	1,000	$ 10	$ 10,000
				Subtotal	$ 687,500
			Contingency	20%	$ 137,500
			NMGRT	7.125%	$ 58,781
				Construction Cost Total	**$ 883,781**
Non-Construction Cost					
	Engineering Design, Bid & Construction Services			20%	$ 165,000
	Survey				$ 50,000
	Easements				$ 20,000
			NMGRT	7.500%	$ 17,625
				Non-Construction Cost Total	**$ 252,625**
				Total Capital Cost	**$ 1,136,406**
Annual O&M Cost					
Misc. annual repair reserve					$ 2,000
Operator					$ 25,000
				Total Annual O&M cost	$ 27,000
	20 Yr. Present Value of O&M Cost				$ 366,939
				Total Life Cycle Cost	**$ 1,503,345**

4.4.9 Advantages/Disadvantages

Advantages:

- Dedicated fill pipe allows better control over entire water system.
- Providing fire flow and fire hydrants will help reduce community fire insurance rates as well as provide fire flow volume to the Tesuque Fire Department.
- New engineered piping should greatly minimize the number of leaks experienced by the water system.

Disadvantages:

- Traffic will be impacted along the community roadways during construction activities.
- Issues may arise within the community if and when illegal system taps are discovered during construction.
- Increases in user rates to help support the capital and future O&M costs of a new water system may not bode well with customers.

5.0 SELECTION OF AN ALTERNATIVE

Each of the four alternatives evaluated is a much needed individual component of the overall Chupadero water system. As such, each of these four components is selected for alternative implementation at Chupadero.

5.1 LIFE CYCLE COST ANALYSIS

Most of the new items installed in the four alternatives are not expected to have an appreciable salvage value at the end of a 20 year life cycle as they have a life expectancy greater than 20 years and are required for use by the water system and could not be sold for salvage value. The federal "real discount" interest rate from Appendix C of OMB Circular A-94 used for calculations is 2.50%.

The 20 year life cycle cost analysis estimate for all four alternatives is a total of $2,573,256. Capital cost of alternatives implementation is estimated to be $1,907,815 and the estimated 20 year present cost of O&M is $665,441. Considering a 20 year plan, this equates to $33,272 per year, in present worth 2018 dollars, for O&M costs.

5.2 NON-MONETARY FACTORS

5.2.1 ENVIRONMENTAL ASPECTS

As previously identified for the improvements project alternatives, each alternative is considered to be sustainable as well as pose little potential threat to the environment during its construction and implementation.

5.2.2 PERMITS

Additional permits required for the implementation of the alternatives includes an OSE permit for a new well and a NMED Radiation Control Bureau General Permit should a uranium treatment system be require. Additional operator training and certification for operation of a media ion exchange/absorption system is minimal.

5.2.3 OPERATION REQUIREMENTS

Additional operator training and certification for operation of a uranium media ion exchange/absorption system is minimal. Annual operation requirements should overall be less with the implementation of new or fully refurbished equipment and materials designated for the alternatives.

6.0 PROPOSED PROJECT (RECOMMENDED ALTERNATIVE)

6.1 PRELIMINARY PROJECT DESIGN

A new water supply well will be installed for the community. The identified first choice location for a new well is on the Jimenez property, located in the far western end of the service area. An easement will be required for the new well site. The required minimum capacity of this new well is 20 gpm. An above or underground well house will be provided to house and protect the well and for the installation of electrical controls and a master meter to read the well flow that must be reported to the OSE. New electrical service will be required for the well and well house.

A new disinfection system is required for the water system. As wells in multiple locations may be used, it is most cost effective to install one sodium hypochlorite disinfection system at the storage tank site. It can be housed in an underground vault to avoid the cost of a building and heating system.

As there are documented concentrations of uranium in wells in Chupadero and the surrounding area, it is possible the new installed well will require uranium treatment. An ion exchange media absorption treatment system is included in the recommended project. The system, if required, can be housed in a small building located at the well site. The system does not require electrical power. The only electrical power required will be for lighting, convenience outlets and heating for the building.

The current 56 connections used by the 2016 estimated 150 households indicates 37% of the households are served by the water system. Using this same ratio for the projected 166 households in 2028 results in an estimated 62 connections in 2028. Assuming another 10 connections from existing households results in a total of 72 connections. The recommended 60,000 gal. of storage can serve 75 connections, based on a 200 gpd demand per household, 2 days of storage and 2 hrs. of 250 gpm (30,000 gal.)fire storage.

Storage tank improvements will include refurbishing the existing tank by sandblasting and painting the interior, adding a ladder safety cage and locking cage door. The matching 20,000 gallon offsite tank will be rehabilitated at the D&R Tank yard, transported and installed beside the existing tank. A new 20,000 gal. tank will also be installed at the tank site. Both new tanks will require a new foundation as well as interconnecting piping with the existing tank such that the tanks can operate in tandem. The tank site and dirt access road will be regraded for stormwater control and a new riprap swale will be installed to collect and transport stormwater to a natural drainage channel located at State Hwy. 592. The overflow and drain pipe from the tanks will be routed to the stormwater swale. Maintaining a minimum of 30,000 gal. in the two storage tanks should allow Chupadero to provide ISO Category 8 fire flow (250 gpm for 2 hours). The existing partially complete security fence at the tank site will be completed.

A new 3 inch diameter PVC or HDPE dedicated fill pipe from wells will be placed on the north side of County Road 78 in a 4 ft. wide maximum trench, be bored and cross under State Hwy. 592 within a steel pipe sleeve and then travel up the tank access road to the storage tanks. A new 8 inch diameter PVC pipe for stored water transmission and distribution will be installed in the same trench as the dedicated fill pipe. Distribution laterals from the new 8 inch water main will be 3 inch diameter PVC pipes. A new 8 inch PRV station with 4 inch PRV bypass will replace the existing 3 inch PRV station. Fire hydrants will be placed along the 8 inch water main and at the Tesuque Fire Department building. Flush hydrants will be placed at the end of the distribution main and/or laterals. The demolished asphalt pavement along County Road 78 for placement of the new pipes will be replaced. The existing 3 inch water pipe will be abandoned in place where located outside of the new pipe trench.

A map of the recommended project is provided as Figure 8 in Appendix A.

Due to the estimated total capital cost of the four alternatives recommended for the improvements project, it is anticipated that the project will be constructed in phases as funding becomes available. The recommended order of phasing is:

1. Existing Well Testing and New Well.
2. Disinfection/Treatment.
3. Storage Tank Improvements.
4. Transmission/Distribution Improvements.

6.2 PROJECT SCHEDULE

The estimated design, permitting and construction schedule for each of the alternatives is as follows:

- Existing Well Testing and New Well – 6 months.
- Disinfection/Treatment – 7 months.
- Storage Tank Improvements – 4 months
- Transmission/Distribution Improvements – one year.

6.3 PERMIT REQUIREMENTS

The anticipated permits required for each phase of the project includes:

- Existing Well Testing and New Well – OSE, NMED DWB, Santa Fe County Building Permit
- Disinfection/Treatment – NMED DWB, Santa Fe County Building Permit
- Storage Tank Improvements – NMED DWB
- Transmission/Distribution Improvements – NMED DWB, EPA SWPPP, Santa County ROW Utility and Traffic Control Permits and NMDOT ROW Utility and Traffic Control Permits.

6.4 SUSTAINABILITY CONSIDERATIONS

6.4.1 WATER EFFICIENCY

Water efficiency components for the recommended project include:

- Efficient and properly sized water pumps can provide the highest water efficiency available.
- Using an ion exchange media absorption system which produces no backwash waste stream provides a high level of water use efficiency.
- Utilizing a second matching tank to double the available storage volume and provide fire flow storage for Chupadero provides for a more efficient and sustainable water system.
- A new 6-inch water main will hold a volume four times greater than the existing 3-inch pipe volume, is equal to approximately 80% of the estimated daily use of the system and is a more efficient means of storing and using water.

6.4.2 ENERGY EFFICIENCY

Energy efficiency components for the recommended project include:

- Use of energy efficient pumps and motors.
- Filling the storage tank during nighttime hours when electrical cost is cheapest.
- Planned disinfection and uranium treatment systems use very little or no electrical power.
- Use of a dedicated tank fill pipe should prove to be more energy efficient for well pump operation.

6.5 TOTAL PROJECT COST ESTIMATE

The estimated cost of the recommended phased project is the summation of each of the four alternatives cost estimates. The cost contingency used for both construction and non-construction costs is 20%. The total estimated recommended project cost estimate is summarized as follows:

Total Capital Cost: $2,400,373 (construction and non-construction)

Total 20 Year Life Cycle Present Worth Cost: $2,780,609

- Construction Cost: $1,684,945
- Non-Construction Cost: $423,428
- 20 Year Life Cycle Present Worth O&M Cost: $672,236

6.6 ANNUAL OPERATING BUDGET

The following annual operating budget is from the end of year 2017 accountant’s financial statement (provided in Appendix D).

6.6.1 INCOME

The total 2017 income, from water bills, was $23,944.75 for unmetered flow. Chupadero is in the process of revising there billing rates for the new metered flow. Moving forward with the recommended project will require additional income for funding matches, increased annual O&M cost and a reserve fund for future equipment O&M requirements. The following table shows the recommended project broken down into four phases with the associated cost scenarios for a variety of loan and grant ratios.

As can be seen in the following table, with the limited number of connections and the estimated expense of the Recommended Project, Chupadero could likely at best financially support a 90% grant/10% loan funded project.

Table 7: Recommended Project Income for Various Funding Scenarios

Connections	56	Interest	2.50%	Term	20	yrs.	
		Residential	Commercial				
Current Monthly Base Rates:		$42.00	na				
Phase/ Est. Cost	Loan %	Loan Monthly Payment	Connection Monthly Rate Increase				
Supply	100%	$1,652	$29.50				
Wells	75%	$1,239		$22.13			
$311,788	50%	$826			$14.75		
	25%	$413				$7.38	
	10%	$165					$2.95
Disinfection/	100%	$1,913	$34.16				
Treatment	75%	$1,434		$25.61			
$360,928	50%	$956			$17.07		
	25%	$478				$8.54	
	10%	$191					$3.41
Storage	100%	$1,586	$28.32				
Tanks	75%	$1,189		$21.23			
$299,250	50%	$793			$14.16		
	25%	$396				$7.07	
	10%	$159					$2.84
Transmission/	100%	$6,022	$108				
Distribution	75%	$4,516		$80.64			
$1,136,406	50%	$3,011			$53.77		
	25%	$1,505				$26.88	
	10%	$602					$10.75
	Estimated Project Rate Increase Totals		**$200**	**$150**	**$100**	**$50**	**$20**
Required Monthly Rate		Loan %	100%	75%	50%	25%	10%
		Residential	$242	$192	$142	$92	$62
		Commercial	***	***	***	***	***
	Estimated 2018 MHI:	**$57,400**					
		Annual future residential base rate as % of MHI:	5.05%	4.01%	2.96%	1.92%	1.30%

6.6.2 ANNUAL O&M COSTS

The 2017 cost for O&M and electricity was $8,150.91. The anticipated annual O&M budget for the recommended project is approximately $33,612 (in 2018 dollars). The bulk of the annual O&M cost is for an operator since it is anticipated that Chupadero in the future will no longer receive low cost volunteer operator services from their community. In order for Chupadero to cover the anticipated improvements project annual O&M costs the monthly billing rate for the current 56 customers would need to be an additional $8/month.

6.6.3 DEBT REPAYMENTS

Chupadero does not currently have any debt repayments. Future debt repayments may be required for the funding agency(s) used for the project.

6.6.4 RESERVES

Chupadero does not currently have any loan debt reserves. Future debt reserves (as much as 10% of the loan value) may be required for the funding agency(s) used for the project.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Chupadero is in need of a number of water system improvements to provide a safe, reliable and sustainable water system for its customers. The cost of the recommended improvements is beyond Chupadero's financial capability and funding assistance will be necessary. The estimated cost for each of the wells, disinfection/treatment and storage tanks improvements should be able to be funded by a number of funding agencies, however, it is anticipated that these improvements will occur over a several year period due to the amount of funding required. The Transmission/distribution improvements project will likely require funding from agencies that specialize in higher cost projects, such as the NM Water Trust Board or USDA Rural Development. This alternative could also be broken down into smaller phases in order to be more amenable to a variety of funding agencies, however, additional cost could be incurred from multiple construction bids and the cost escalation that occurs over time.

In order for Chupadero to remain a viable water system, its highest priority is to drill a new well to ensure a sustainable supply of water for its customers. Without a sustainable supply of water, the other improvement alternatives could pose less value.

Funding constraints and availability may require the proposed project to be broken down into smaller phases. Recommended project phases and tasks in order of importance and required phasing are:

1) Drill new well.
2) Treatment system for new well as required.
3) Secure all necessary easements.
4) Topographic survey of project area.
5) Relocate main PRV for most opportune location and such that all wells can connect upstream of the PRV in the existing single 3 inch water pipe used for tank filling and distribution
6) Connect new well to system.
7) Rehab and install new storage tanks.
8) Install new transmission/distribution and dedicated fill pipes from storage tank site to east end of County Road 78, crossing under St. Hwy. 592.
9) Install remainder of transmission/distribution and dedicated fill pipes on County Road 78.
10) Install new 3 inch distribution laterals.

APPENDIX A

Figures

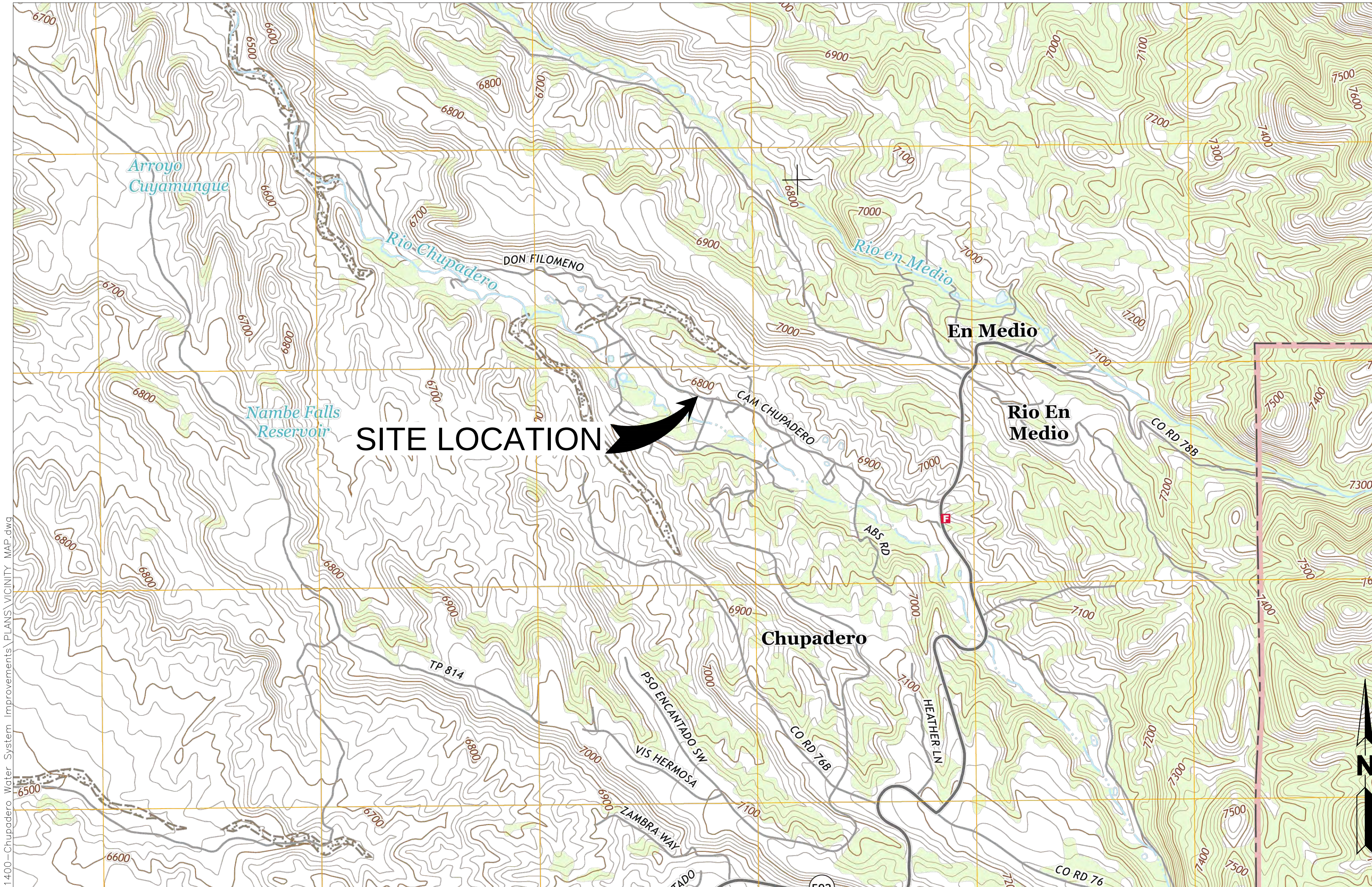


FIGURE 1 – SITE VICINITY MAP

CHUPADERO WATER AND SEWER CORP

0 1000 2000

SCALE: 1"=2000'
ALL DIMENSIONS ARE
U.S. SURVEY FEET

SOURCE:
USGS 7.5' TOPOGRAPHIC MAP. TESUQUE, NEW MEXICO,
DATED: 2017.

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CONSULTING ENGINEERS
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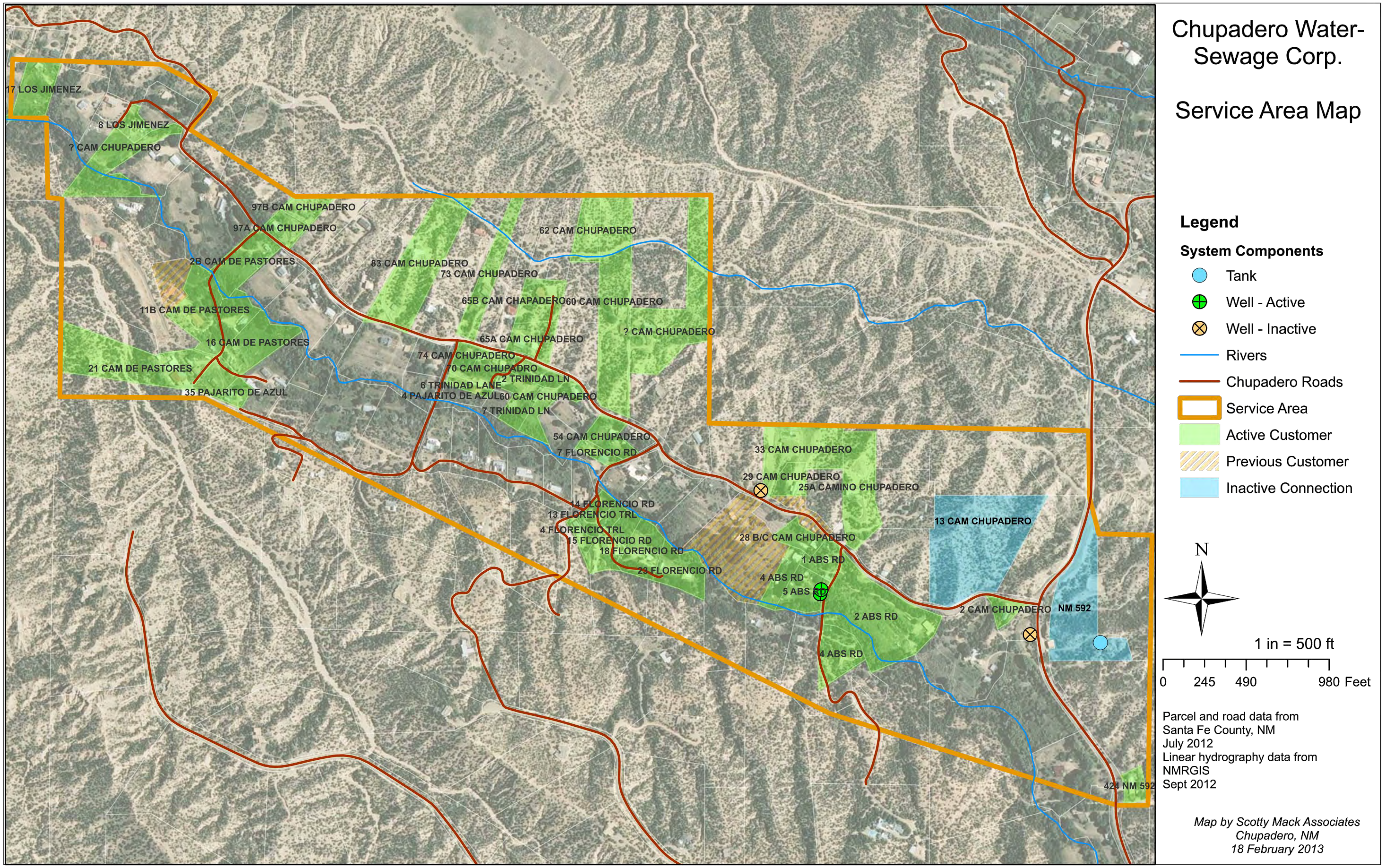

FIGURE 2 – SERVICE AREA MAP
CHUPADERO WATER AND SEWER CORP

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DRAWING LOCATION: G:\MAY\17.1400-Chupadero Water System Improvements\PLANS\SERVICE AREA MAP.dwg

N

0 250 500

SCALE: 1"=500'
ALL DIMENSIONS ARE
U.S. SURVEY FEET

FIGURE 3 – EXISTING WATER SYSTEM
CHUPADERO WATER AND SEWER CORP

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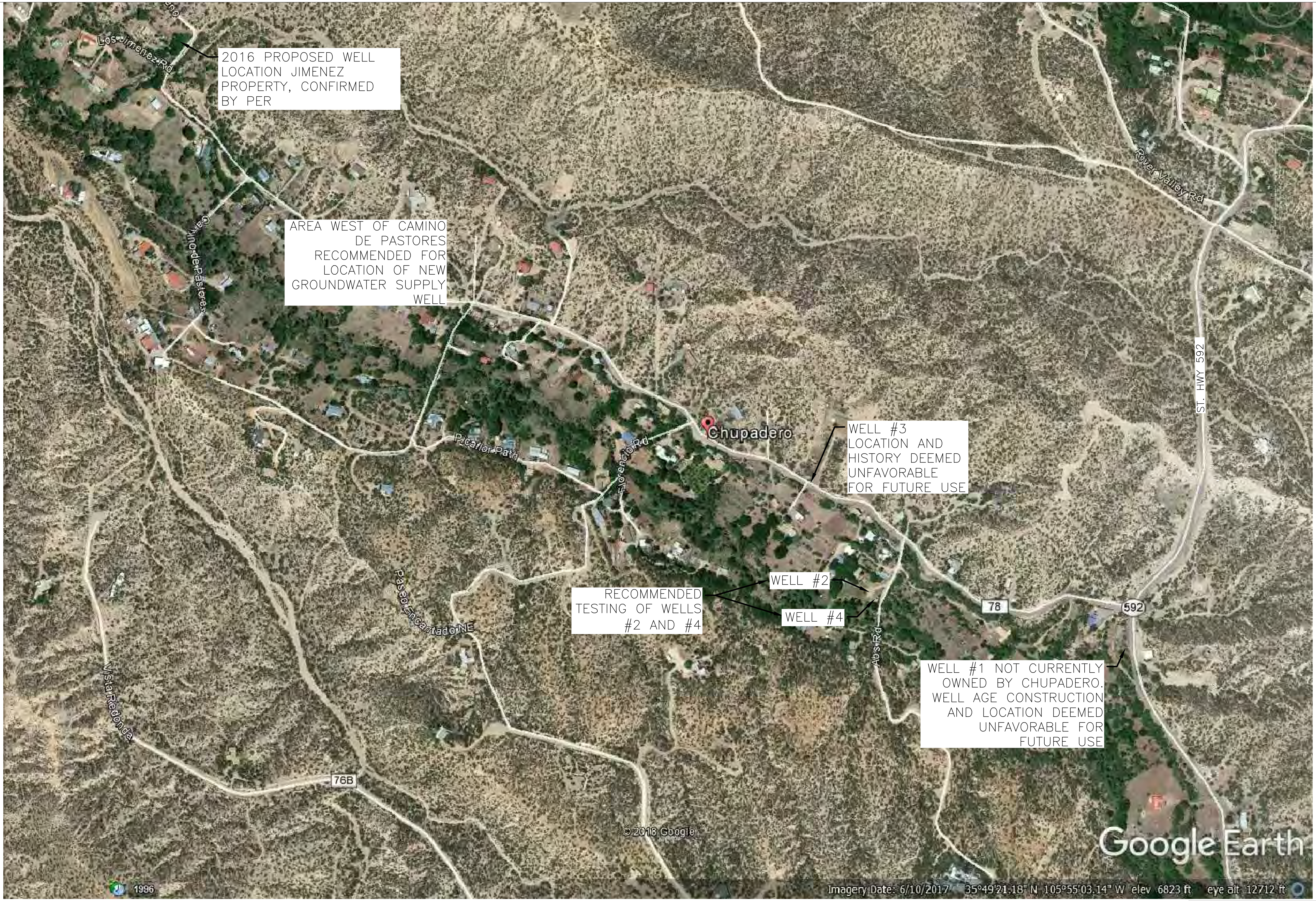

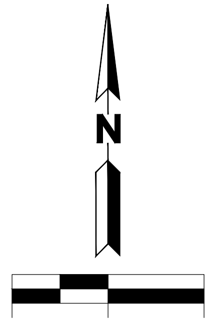

SCALE: 1"=500'
ALL DIMENSIONS ARE U.S. SURVEY FEET

FIGURE 4 – GROUNDWATER SUPPLY WELLS ALTERNATIVE
CHUPADERO WATER AND SEWER CORP

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DRAWING LOCATION: G:\MAY\17.1400–Chupadero Water System Improvements\PLANS\GROUNDWATER SUPPLY.dwg

FIGURE 5 – DISINFECTION–TREATMENT ALTERNATIVE
CHUPADERO WATER AND SEWER CORP

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DRAWING LOCATION: G:\MAY\17.1400–Chupadero Water System Improvements\PLANS\DIFINFECTION TREATMENT.dwg

N

0 25 50

SCALE: 1"=50'
ALL DIMENSIONS ARE U.S. SURVEY FEET

FIGURE 6 – WATER STORAGE TANK IMPROVEMENTS ALTERNATIVE
CHUPADERO WATER AND SEWER CORP

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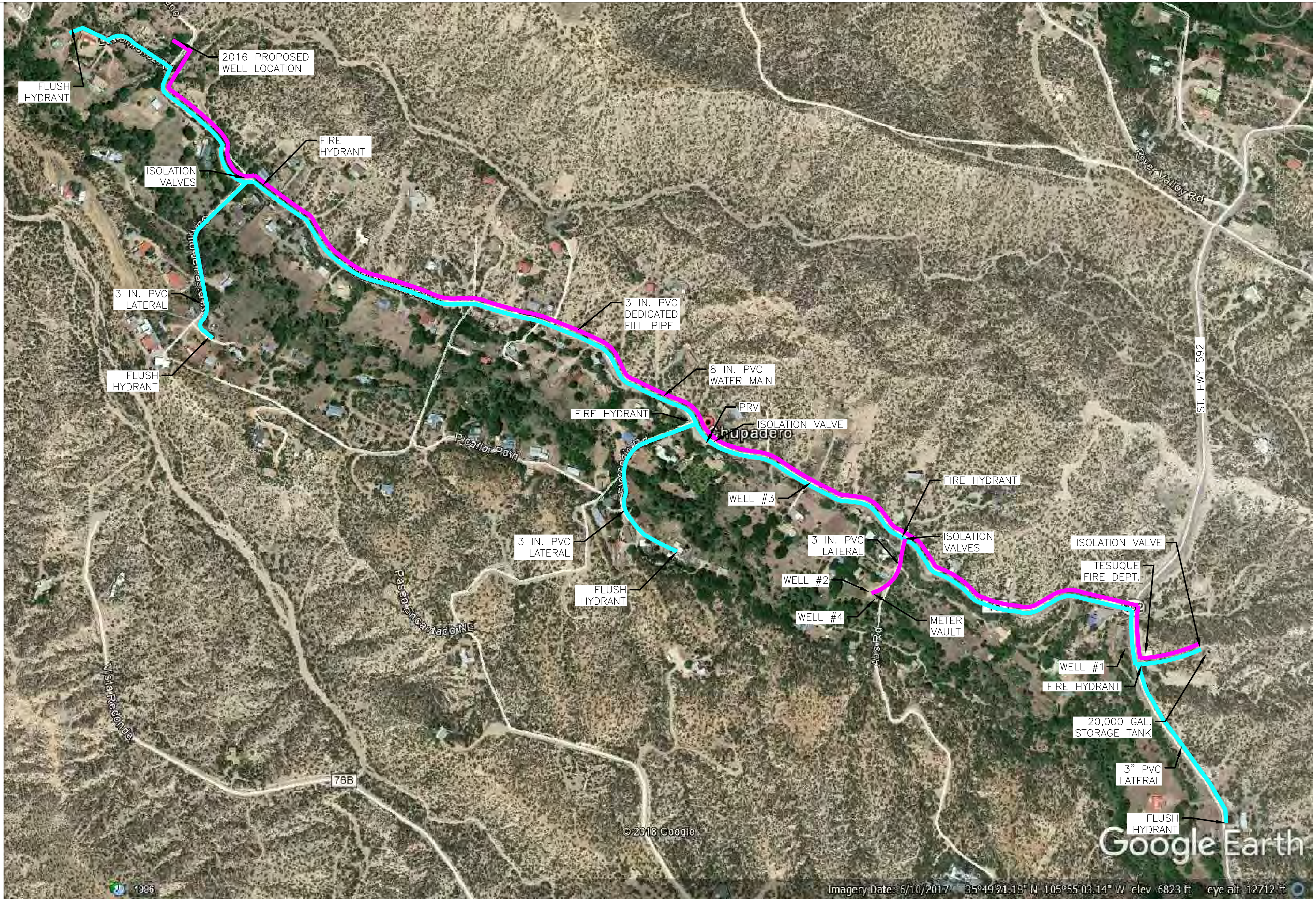
DRAWING LOCATION: G:\MAY\17.1400-Chupadero Water System Improvements\PLANS\WATER STORAGE TANK.dwg



N

0 250 500

SCALE: 1"=500'
ALL DIMENSIONS ARE U.S. SURVEY FEET

FIGURE 7 – WATER TRANSMISSION–DISTRIBUTION
SYSTEM IMPROVEMENTS ALTERNATIVES
CHUPADERO WATER AND SEWER CORP

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DRAWING LOCATION: G:\MAY\17.1400–Chupadero Water System Improvements\PLANS\WATER TRANSMISSION.dwg

FIGURE 8 – RECOMMENDED PROJECT
CHUPADERO WATER AND SEWER CORP

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DRAWING LOCATION: G:\MAY\17.1400-Chupadero Water System Improvements\PLANS\RECOMMENDED PROJECT.dwg

APPENDIX B

Environmental Resource Documentation

United States Department of Agriculture

NRCS

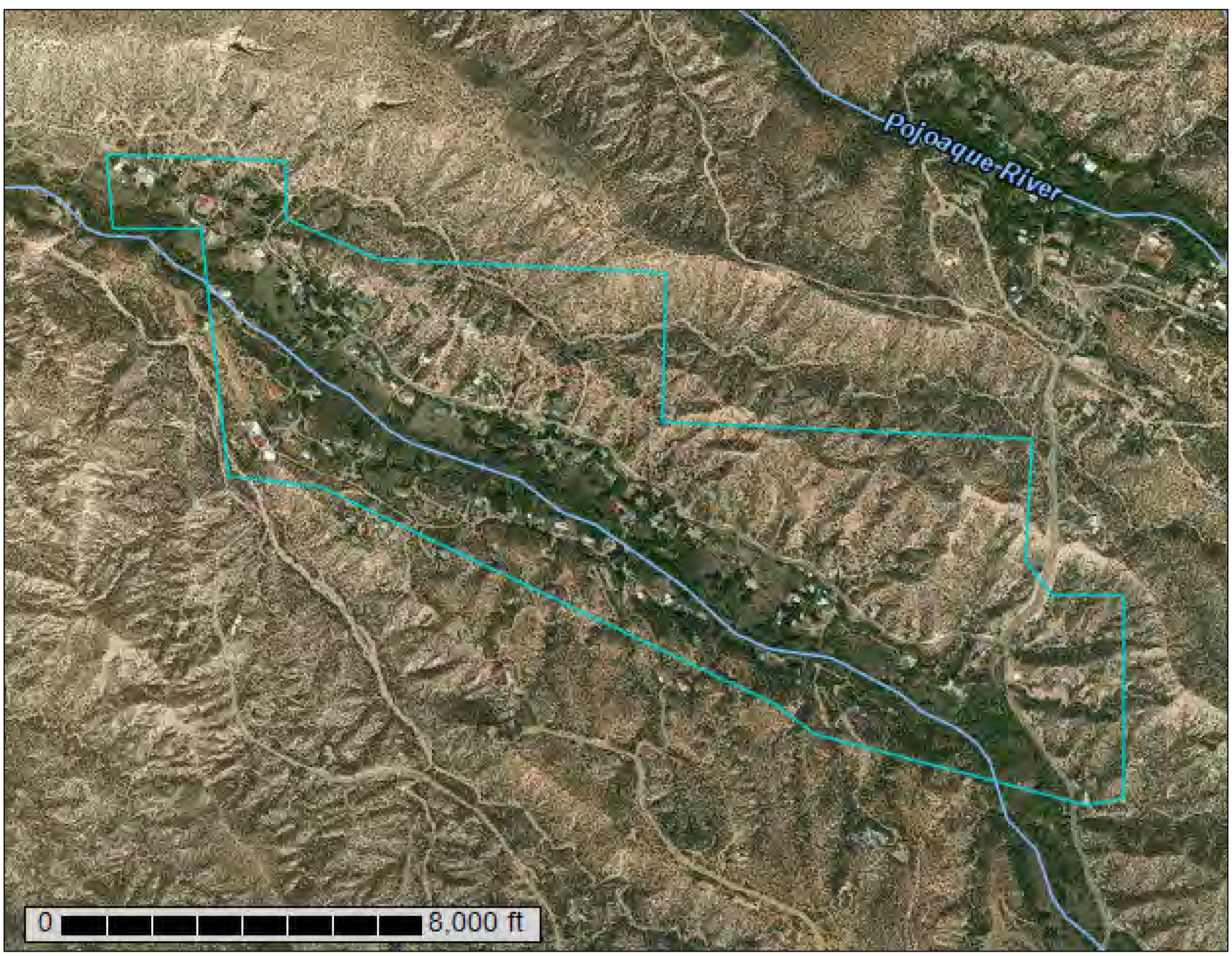
Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Santa Fe County Area, New Mexico

Chupadero Water Improvements Project



January 8, 2018

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

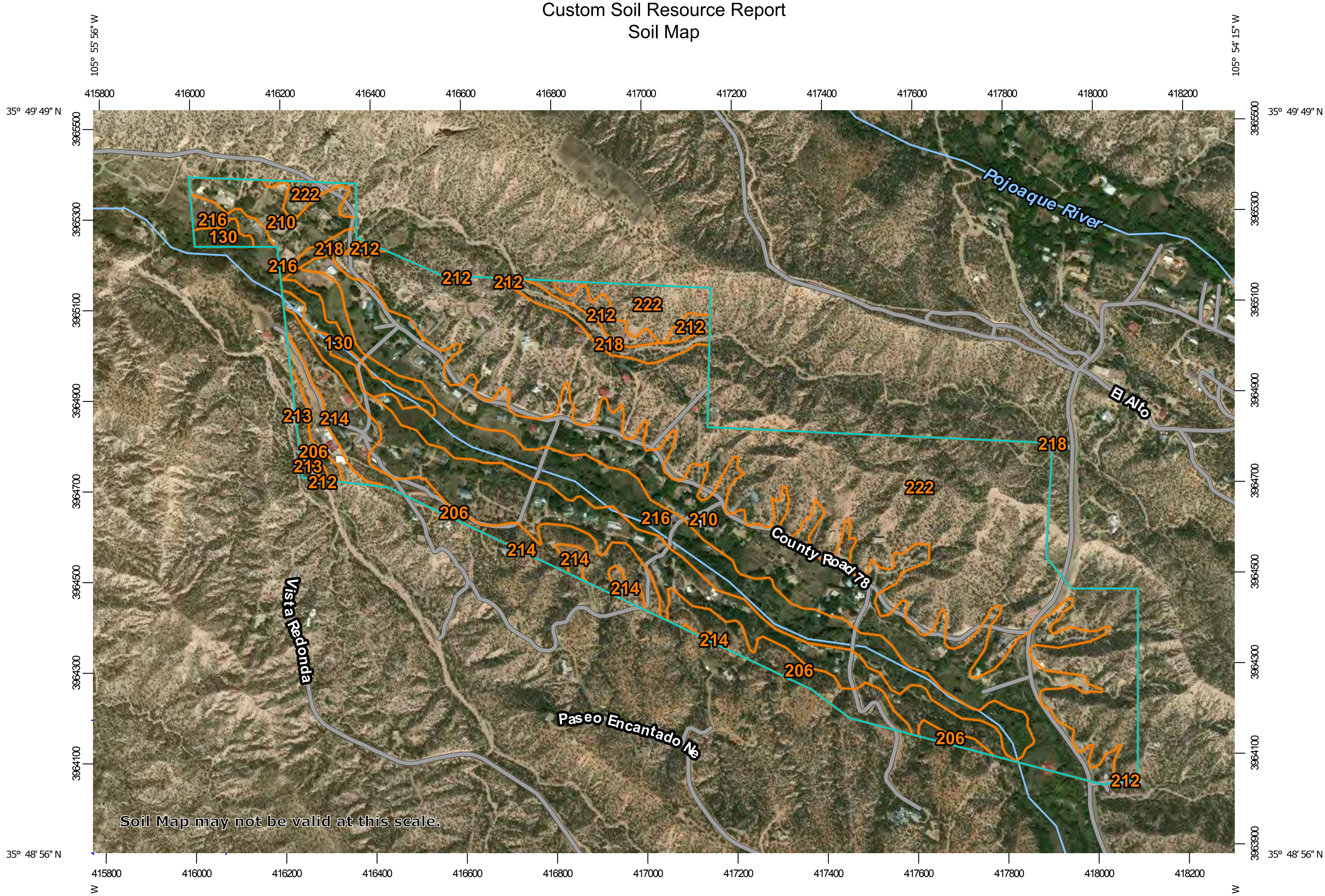
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:11,600 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 150, 300, 600, 900

Feet: 0, 500, 1000, 2000, 3000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Santa Fe County Area, New Mexico
Survey Area Data: Version 9, Sep 6, 2017

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jan 18, 2014—Oct 20, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
130	Jaralosa very fine sandy loam, 0 to 2 percent slopes, flooded	4.8	1.7%
206	Encantado very cobbly sandy loam, 25 to 45 percent slopes	24.6	8.5%
210	Urban land-Buckhorse-Altazano complex, 2 to 8 percent slopes	92.9	32.1%
212	Junebee gravelly sandy loam, 5 to 15 percent slopes	4.0	1.4%
213	Levante-Riverwash complex, 1 to 3 percent slopes, flooded	0.4	0.1%
214	Nazario-Urban land complex, 2 to 8 percent slopes	4.8	1.6%
216	Dondiego loam, 1 to 3 percent slopes	31.6	10.9%
218	Pedregal very gravelly loam, 2 to 15 percent slopes	5.0	1.7%
222	Sipapu-Yuzarra-Kachina complex, 5 to 65 percent slopes	121.1	41.9%
Totals for Area of Interest		**289.3**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Santa Fe County Area, New Mexico

130—Jaralosa very fine sandy loam, 0 to 2 percent slopes, flooded

Map Unit Setting

National map unit symbol: drbg
Elevation: 5,400 to 6,900 feet
Mean annual precipitation: 9 to 14 inches
Mean annual air temperature: 47 to 52 degrees F
Frost-free period: 140 to 170 days
Farmland classification: Not prime farmland

Map Unit Composition

Jaralosa and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Jaralosa

Setting

Landform: Flood-plain steps on valley floors
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from micaceous sandstone and siltstone over alluvium derived from granite, gneiss, or schist

Typical profile

A - 0 to 1 inches: very fine sandy loam
AC1 - 1 to 6 inches: loamy very fine sand
AC2 - 6 to 10 inches: very fine sandy loam
ACnz - 10 to 16 inches: very fine sandy loam
Cnz1 - 16 to 22 inches: loamy very fine sand
Cnz2 - 22 to 35 inches: stratified very fine sandy loam to loamy very fine sand
2C1 - 35 to 42 inches: gravelly sand, gravelly coarse sand
2C2 - 42 to 53 inches: stratified very gravelly coarse sand to very gravelly coarse sand
2C3 - 53 to 84 inches: very gravelly coarse sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 20 to 39 inches to strongly contrasting textural stratification
Natural drainage class: Moderately well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Low (about 4.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: A
Ecological site: Riverine Riparian (F036XA005NM)
Hydric soil rating: No

Minor Components

Bosquecito

Percent of map unit: 6 percent
Hydric soil rating: No

Innacutt

Percent of map unit: 4 percent
Hydric soil rating: No

Cuyamungue

Percent of map unit: 3 percent
Hydric soil rating: No

Urban land

Percent of map unit: 2 percent
Hydric soil rating: No

206—Encantado very cobbly sandy loam, 25 to 45 percent slopes

Map Unit Setting

National map unit symbol: f3gx
Elevation: 5,700 to 7,600 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Encantado and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Encantado

Setting

Landform: Eroded fan remnants
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Colluvium derived from granite, gneiss, and schist over residuum weathered from granitic fanglomerate and sandstone

Typical profile

ABk - 0 to 2 inches: very cobbly sandy loam
Bk1 - 2 to 8 inches: gravelly sandy loam
Bk2 - 8 to 12 inches: gravelly coarse sandy loam
Bk3 - 12 to 24 inches: very gravelly coarse sandy loam
BCk - 24 to 31 inches: gravelly loamy sand
BCk1 - 31 to 56 inches: very gravelly loamy coarse sand
BCk2 - 56 to 67 inches: gravelly loamy sand
C - 67 to 82 inches: gravelly loamy coarse sand

Properties and qualities

Slope: 25 to 45 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 30 percent
Salinity, maximum in profile: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Nazario

Percent of map unit: 4 percent
Hydric soil rating: No

Encantado

Percent of map unit: 3 percent
Hydric soil rating: No

Urban land

Percent of map unit: 2 percent
Hydric soil rating: No

Rock outcrop

Percent of map unit: 1 percent
Hydric soil rating: No

210—Urban land-Buckhorse-Altazano complex, 2 to 8 percent slopes

Map Unit Setting

National map unit symbol: f5r5
Elevation: 5,700 to 7,500 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Urban land: 60 percent
Buckhorse and similar soils: 20 percent
Altazano and similar soils: 10 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Urban Land

Setting

Landform: Eroded fan remnants
Down-slope shape: Linear
Across-slope shape: Linear

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s
Hydric soil rating: No

Description of Buckhorse

Setting

Landform: Eroded fan remnants
Landform position (two-dimensional): Toeslope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Slope alluvium derived from granite, gneiss, schist, granitic sandstone, fanglomerate, and mudstone

Typical profile

A - 0 to 4 inches: coarse sandy loam
Bt - 4 to 11 inches: coarse sandy loam
Btk1 - 11 to 22 inches: loam
Btk2 - 22 to 37 inches: loam
Bk - 37 to 49 inches: fine sandy loam
BCk - 49 to 61 inches: sandy loam
C - 61 to 83 inches: gravelly coarse sand

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Moderate (about 6.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: B
Ecological site: Loamy (R035XA112NM)
Hydric soil rating: No

Description of Altazano

Setting

Landform: Inset fans on eroded fan remnants
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Slope alluvium derived from granite, gneiss, schist, granitic sandstone, fanglomerate, and mudstone

Typical profile

AC - 0 to 2 inches: gravelly sandy loam
C1 - 2 to 8 inches: gravelly coarse sandy loam
C2 - 8 to 19 inches: very gravelly loamy coarse sand
C3 - 19 to 29 inches: gravelly sandy loam
Btkb1 - 29 to 46 inches: loam
Btkb2 - 46 to 65 inches: loam
BCkb - 65 to 74 inches: gravelly coarse sandy loam
Ckb - 74 to 90 inches: gravelly loamy coarse sand

Properties and qualities

Slope: 2 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Calcium carbonate, maximum in profile: 20 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Low (about 5.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4w
Hydrologic Soil Group: B
Ecological site: Gravelly (R035XG114NM)
Hydric soil rating: No

Minor Components

Levante

Percent of map unit: 7 percent
Hydric soil rating: No

Riverwash

Percent of map unit: 3 percent
Hydric soil rating: No

212—Junebee gravelly sandy loam, 5 to 15 percent slopes

Map Unit Setting

National map unit symbol: f5rb
Elevation: 6,100 to 7,800 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Junebee and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Junebee

Setting

Landform: Eroded fan remnants
Landform position (two-dimensional): Toeslope
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Slope alluvium derived from granitic sandstone, fanglomerate, and mudstone

Typical profile

A - 0 to 3 inches: gravelly sandy loam
Btk1 - 3 to 14 inches: sandy loam
Btk2 - 14 to 29 inches: sandy loam
Btk3 - 29 to 38 inches: sandy loam
Btk4 - 38 to 48 inches: gravelly coarse sandy loam

Btk5 - 48 to 58 inches: gravelly coarse sandy loam
Bk1 - 58 to 72 inches: gravelly coarse sandy loam
Bk2 - 72 to 88 inches: gravelly coarse sandy loam
BCk - 88 to 112 inches: gravelly loamy coarse sand
C - 112 to 122 inches: gravelly loamy coarse sand

Properties and qualities

Slope: 5 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat excessively drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Salinity, maximum in profile: Nonsaline (0.0 to 1.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 1.0
Available water storage in profile: Low (about 4.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: A
Ecological site: Deep Sand (R035XA115NM)
Hydric soil rating: No

Minor Components

Altazano

Percent of map unit: 6 percent
Hydric soil rating: No

Levante

Percent of map unit: 5 percent
Hydric soil rating: No

Riverwash

Percent of map unit: 4 percent
Hydric soil rating: No

213—Levante-Riverwash complex, 1 to 3 percent slopes, flooded

Map Unit Setting

National map unit symbol: f5rc
Elevation: 5,600 to 7,700 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Levante and similar soils: 55 percent
Riverwash: 35 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Levante

Setting

Landform: Flood plains on valley floors
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from granite, gneiss, schist, and granitic sandstone

Typical profile

AC - 0 to 4 inches: loamy sand
C1 - 4 to 17 inches: coarse sand
C2 - 17 to 32 inches: gravelly coarse sand
C3 - 32 to 45 inches: stratified gravelly loamy coarse sand to gravelly coarse sand
C4 - 45 to 58 inches: gravelly loamy coarse sand
C5 - 58 to 86 inches: very gravelly coarse sand
C6 - 86 to 122 inches: very gravelly coarse sand

Properties and qualities

Slope: 1 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Salinity, maximum in profile: Nonsaline (0.0 to 1.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 1.0
Available water storage in profile: Very low (about 2.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: A
Ecological site: Sandy (R035XA113NM)
Hydric soil rating: No

Description of Riverwash

Setting

Landform: Channels on flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from mixed

Typical profile

C1 - 0 to 10 inches: gravelly coarse sand

C2 - 10 to 50 inches: very gravelly coarse sand
C3 - 50 to 65 inches: gravelly sandy clay loam
C4 - 65 to 85 inches: gravelly coarse sand

Properties and qualities
Slope: 0 to 1 percent
Natural drainage class: Excessively drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Frequency of flooding: Frequent
Calcium carbonate, maximum in profile: 3 percent
Gypsum, maximum in profile: 3 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Very low (about 3.0 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydric soil rating: No

Minor Components

Altazano
Percent of map unit: 5 percent
Hydric soil rating: No

Dondiego
Percent of map unit: 3 percent
Hydric soil rating: No

Urban land
Percent of map unit: 2 percent
Hydric soil rating: No

214—Nazario-Urban land complex, 2 to 8 percent slopes

Map Unit Setting
National map unit symbol: f5rf
Elevation: 6,200 to 7,400 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition
Nazario and similar soils: 55 percent
Urban land: 30 percent

Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Nazario

Setting

Landform: Eroded fan remnants
Landform position (two-dimensional): Summit
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Alluvium derived from granite, gneiss, schist, and loess over residuum weathered from granitic fanglomerate and sandstone

Typical profile

ABk - 0 to 2 inches: gravelly loam
Bk1 - 2 to 7 inches: gravelly loam
Bk2 - 7 to 15 inches: gravelly loam
Bk3 - 15 to 24 inches: gravelly loam
2BCk1 - 24 to 43 inches: very gravelly loamy coarse sand
2BCk2 - 43 to 52 inches: gravelly loamy coarse sand
2C1 - 52 to 67 inches: coarse sand
2C2 - 67 to 94 inches: gravelly coarse sand

Properties and qualities

Slope: 2 to 8 percent
Depth to restrictive feature: 20 to 28 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 30 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Very low (about 2.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: B
Hydric soil rating: No

Description of Urban Land

Setting

Landform: Eroded fan remnants
Down-slope shape: Linear
Across-slope shape: Linear

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydric soil rating: No

Minor Components

Alire

Percent of map unit: 8 percent
Hydric soil rating: No

Encantado

Percent of map unit: 4 percent
Hydric soil rating: No

Tanoan

Percent of map unit: 3 percent
Hydric soil rating: No

216—Dondiego loam, 1 to 3 percent slopes

Map Unit Setting

National map unit symbol: f5rk
Elevation: 6,100 to 7,400 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Dondiego and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Dondiego

Setting

Landform: Stream terraces on valley floors
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from granite, gneiss, schist, and loess

Typical profile

A - 0 to 2 inches: loam
Bt1 - 2 to 9 inches: loam
Bt2 - 9 to 22 inches: loam
Btk - 22 to 28 inches: loam
BCk - 28 to 36 inches: sandy loam
Btb1 - 36 to 48 inches: loam
Btb2 - 48 to 59 inches: loam
BCb - 59 to 69 inches: gravelly sandy loam
Cb1 - 69 to 85 inches: gravelly loamy coarse sand
Cb2 - 85 to 102 inches: stratified gravelly loamy coarse sand to sandy loam

Properties and qualities

Slope: 1 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Very rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 3 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 1.0
Available water storage in profile: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: B
Ecological site: Loamy (R035XA112NM)
Hydric soil rating: No

Minor Components

Ohke

Percent of map unit: 7 percent
Hydric soil rating: No

Altazano

Percent of map unit: 4 percent
Hydric soil rating: No

Urban land

Percent of map unit: 4 percent
Hydric soil rating: No

218—Pedregal very gravelly loam, 2 to 15 percent slopes

Map Unit Setting

National map unit symbol: f5rq
Elevation: 5,900 to 7,600 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Pedregal and similar soils: 90 percent
Minor components: 10 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pedregal

Setting

Landform: Eroded fan remnants
Landform position (two-dimensional): Shoulder, summit
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Alluvium derived from granite, gneiss, and schist over residuum weathered from granitic sandstone, siltstone, and fanglomerate

Typical profile

A - 0 to 2 inches: very gravelly loam
Bt1 - 2 to 5 inches: very gravelly clay loam
Bt2 - 5 to 8 inches: very gravelly clay loam
Btk - 8 to 12 inches: very gravelly sandy clay loam
Bk1 - 12 to 22 inches: very gravelly sandy loam
Bk2 - 22 to 45 inches: extremely gravelly coarse sandy loam
BCk - 45 to 62 inches: extremely gravelly coarse sand
C1 - 62 to 81 inches: gravelly loamy sand
2C2 - 81 to 92 inches: silt loam
2C3 - 92 to 104 inches: silt loam

Properties and qualities

Slope: 2 to 15 percent
Depth to restrictive feature: 2 to 4 inches to abrupt textural change
Natural drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 45 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Very low (about 0.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4s
Hydrologic Soil Group: C
Ecological site: Steep Gravelly - Woodland (F035XG135NM)
Hydric soil rating: No

Minor Components

Predawn

Percent of map unit: 4 percent
Hydric soil rating: No

Alire

Percent of map unit: 2 percent
Hydric soil rating: No

Urban land

Percent of map unit: 2 percent
Hydric soil rating: No

Encantado

Percent of map unit: 1 percent
Hydric soil rating: No

Nazario

Percent of map unit: 1 percent
Hydric soil rating: No

222—Sipapu-Yuzarra-Kachina complex, 5 to 65 percent slopes

Map Unit Setting

National map unit symbol: f5rx
Elevation: 5,600 to 7,800 feet
Mean annual precipitation: 12 to 14 inches
Mean annual air temperature: 48 to 50 degrees F
Frost-free period: 140 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Sipapu and similar soils: 45 percent
Yuzarra and similar soils: 30 percent
Kachina and similar soils: 15 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Sipapu

Setting

Landform: Hills, ridges
Landform position (two-dimensional): Backslope
Down-slope shape: Convex
Across-slope shape: Convex, linear
Parent material: Colluvium derived from granite and gneiss over residuum weathered from granitic sandstone, siltstone, and mudstone

Typical profile

A - 0 to 1 inches: gravelly sandy loam
Bk - 1 to 3 inches: sandy loam
2BCk - 3 to 8 inches: very paragravelly fine sandy loam
2Cr - 8 to 18 inches: cemented bedrock

Properties and qualities

Slope: 20 to 65 percent
Depth to restrictive feature: 6 to 10 inches to paralithic bedrock
Natural drainage class: Somewhat excessively drained
Runoff class: High

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Salinity, maximum in profile: Nonsaline (0.0 to 1.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 1.0
Available water storage in profile: Very low (about 1.0 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: D
Ecological site: Steep Gravelly - Woodland (F035XG135NM)
Hydric soil rating: No

Description of Yuzarra

Setting
Landform: Ridges, hills
Landform position (two-dimensional): Summit
Down-slope shape: Convex
Across-slope shape: Convex, linear
Parent material: Alluvium derived from granite, gneiss, and schist over residuum weathered from granitic sandstone and fanglomerate

Typical profile
ABk - 0 to 3 inches: very gravelly sandy loam
Bk1 - 3 to 10 inches: gravelly sandy loam
2Bk2 - 10 to 22 inches: very gravelly coarse sand
2Bk3 - 22 to 26 inches: gravelly sand
2Bk4 - 26 to 34 inches: very gravelly coarse sand
2Cr - 34 to 44 inches: cemented bedrock

Properties and qualities
Slope: 5 to 15 percent
Depth to restrictive feature: 20 to 39 inches to paralithic bedrock
Natural drainage class: Somewhat excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 35 percent
Salinity, maximum in profile: Nonsaline (0.0 to 1.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 1.0
Available water storage in profile: Very low (about 1.6 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4s
Hydrologic Soil Group: B
Ecological site: Steep Gravelly - Woodland (F035XG135NM)
Hydric soil rating: No

Description of Kachina

Setting

Landform: Ridges, hills
Landform position (two-dimensional): Toeslope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Slope alluvium derived from micaceous sandstone, siltstone, mudstone, and fanglomerate

Typical profile

A - 0 to 3 inches: fine sandy loam
Bk1 - 3 to 13 inches: fine sandy loam
Bk2 - 13 to 24 inches: sandy clay loam
Bk3 - 24 to 44 inches: loam
BCk1 - 44 to 53 inches: sandy loam
BCk2 - 53 to 73 inches: gravelly sandy loam
BCk3 - 73 to 81 inches: gravelly sandy clay loam
2BCk4 - 81 to 93 inches: very paragravelly silty clay loam
2Cr - 93 to 103 inches: cemented bedrock

Properties and qualities

Slope: 5 to 15 percent
Depth to restrictive feature: 79 to 98 inches to paralithic bedrock
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Salinity, maximum in profile: Very slightly saline to slightly saline (2.0 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: High (about 9.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: B
Ecological site: Steep Gravelly - Woodland (F035XG135NM)
Hydric soil rating: No

Minor Components

Junebee

Percent of map unit: 3 percent
Hydric soil rating: No

Badland

Percent of map unit: 2 percent
Hydric soil rating: No

Dondiego

Percent of map unit: 2 percent
Hydric soil rating: No

Levante

Percent of map unit: 1 percent
Hydric soil rating: No

Rock outcrop

Percent of map unit: 1 percent
Hydric soil rating: No

Urban land

Percent of map unit: 1 percent
Hydric soil rating: No

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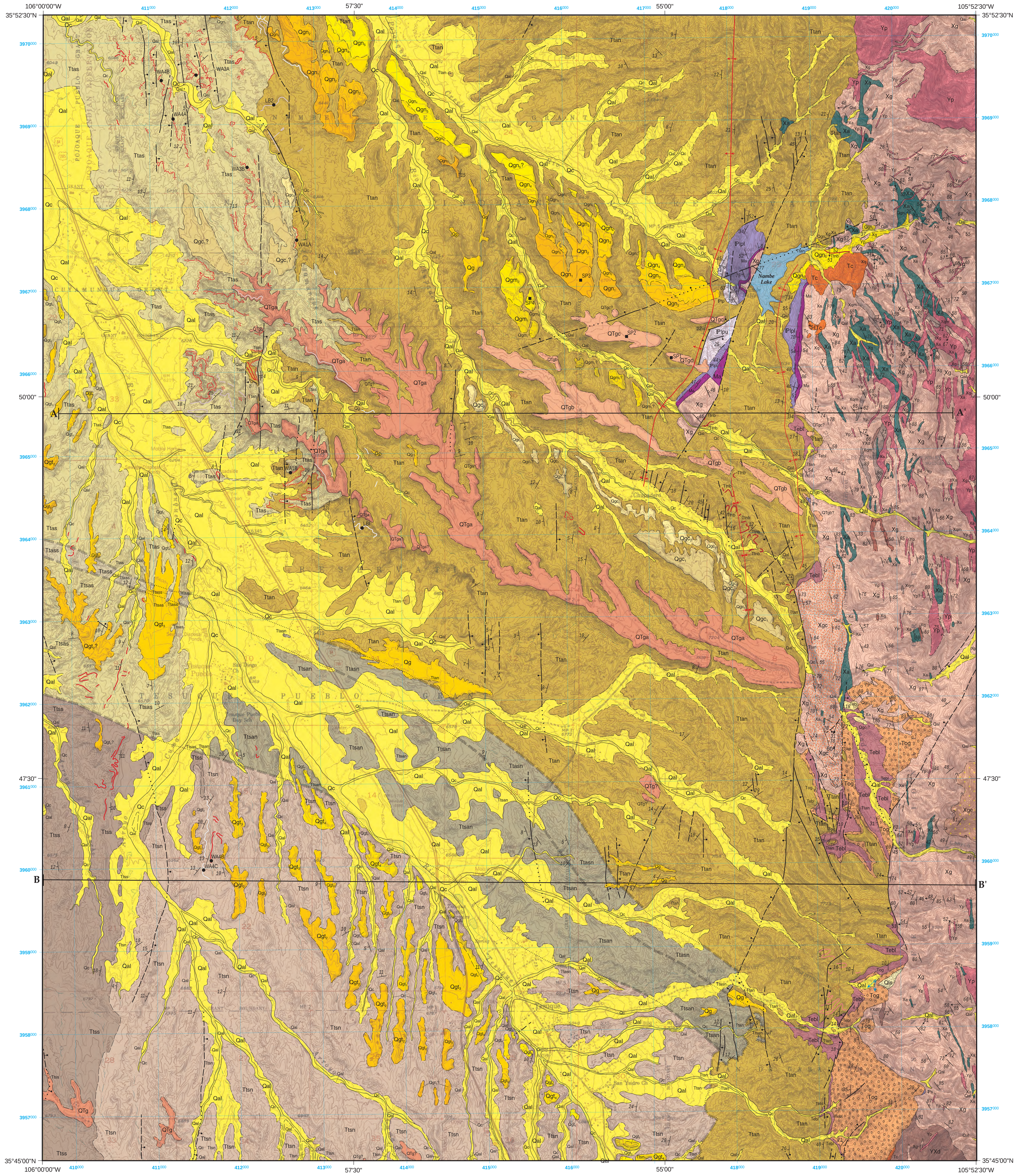
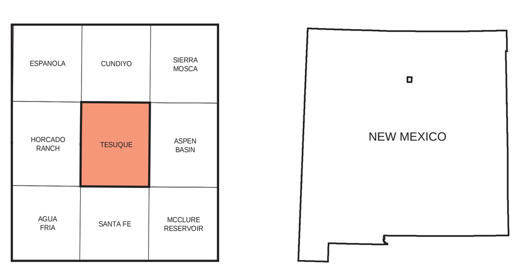
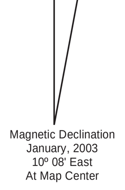


Base map from U.S. Geological Survey 1953, photorevised 1993.
1927 North American datum, Universal Transverse Mercator projectionn.
1000-meter grid, UTM zone 13, shown in blue.



QUADRANGLE LOCATION



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CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

New Mexico Bureau of Geology and Mineral Resources
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This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:

http://geoinfo.nmt.edu

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 47

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Geologic map of the Tesuque quadrangle, Santa Fe County, New Mexico

February 2003

by

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MAP SYMBOLS

- Location of geologic cross section. (A—A')
- Geologic contact. Solid where exposed or known, dashed where approximately known, dotted where concealed.
- Gradational geologic contact, location approximately known.
- Normal fault. Solid where well exposed, dashed where poorly exposed or approximated, dotted where covered. Bar-ball on downthrown side. Tic shows dip of the fault plane; arrow shows trend and plunge of slickensides.
- Trace of syncline axial plane.
- Trace of synclinal bend of monocline showing direction of plunge.
- Basalt flow in the lower Nambé Member.
- Tephra beds:
  - Guaje pumice bed, Otowi Member, Bandelier Tuff.
  - Tephra beds of the Skull Ridge Member lithosome A:
    - White fine tephra, undifferentiated.
    - No. 1 white ash
    - Lower light blue ash
    - No. 2 white ash
    - Nos. 2A, 2B, 2C ashes
    - No. 3 white ash
    - No. 4 white ash.
  - Tephra beds of the Nambé Member lithosome A:
    - "Upper" Nambé white ash
    - Nambé white ash (grayish white color on map)
    - Chupadero ash
    - Gabaldon tephra, coarse white ash.
- Strike and dip of bedding.
- Inclined S2 foliation in metamorphic rocks, showing dip. Arrow shows trend and plunge of lineation.
- Breccia.
- Paleocurrent vector measured from clast imbrication; tail of arrow is located at measurement.
- WA4A Tephra sample location and number, collected for geochemical correlation.
- SP3 Exploratory soil pit location and number.

COMMENTS TO MAP USERS

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map are based on reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. Revision of the map is likely because of the on-going nature of work in the region. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Mines and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government. Cross-sections are constructed based upon the interpretations of the authors made from geologic mapping, and available geophysical (regional gravity and aeromagnetic surveys), and subsurface (drillhole) data.

Cross-sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

MAP UNITS

(Partial description of units; complete descriptions are found in the accompanying report.)

CENOZOIC

Quaternary

Qc — **Modern channels (streams and arroyos) and associated active floodplain alluvium (Holocene)** — Tan, poorly-sorted, gravelly sand and silt. Most deposits occur within 2 m elevation of the present channel. Floodplain may contain vegetation. Only channels >3 m in width are identified on map. Thickness unknown.

Qal — **Alluvium, undifferentiated (Pleistocene? - Holocene)** — Tan, poorly-sorted sand and silt, with minor amounts of subrounded gravel (mostly granite and granitic gneiss); surface soils may have been inflated by addition of eolian material. Grades to 2-10 m above modem channel (base level) of current main¬stem stream (Rio Tesuque or Rio Nambé). Unit includes at least four undifferentiated terraces, such as the inhabited and cultivated terraces along the Rio Tesuque, Rio en Medio, and Rio Chupadero. Alluvial deposits, estimated <2 m thick, are not included within this map unit. Likely equivalent to *Qal* of the Santa Fe quadrangle geologic map by Kottlowski and Baldwin (1963). Thickness is unknown, but estimated to be less than 25 m on the basis of regional well logs.

Qls — **Landslide deposits (Pleistocene)** — Unconsolidated, disturbed sediment consisting of angular to subangular granitic clasts and sand.

Qg — **Gravel, undifferentiated (Pleistocene)** — Dominantly subrounded gravel and tan sand with lesser silt. Gravel clasts are dominantly pinkish granite and granitic gneiss (70%), with some quartz and quartzite and sparse limestone, amphibolite, and quartz-mica schist. Clasts are as much as 0.4 m in diameter and generally smaller than the *QTg* gravel deposits. A 1-2 m thick silt deposit, which has largely been pedogenically altered, overlies the gravels and is attributed to eolian dust influx. Deposits are set into existing valleys (most commonly the south and west side) and unconformably overlie the gently dipping beds of the Tesuque Formation. Unit is sufficiently isolated to make correlation to other gravel deposits or to ancestral stream difficult. *Qg* deposits are not correlative to one another. Deposits typically 2-10 m thick.

Gravel of the ancestral Rio Nambé (Pleistocene) — Gravel deposits inset into the southwestern flanks Rio Nambé drainage basin:

- **Qgn5** — **Lowermost terrace of the ancestral Rio Nambé (middle to upper(?) Pleistocene)** — Terrace tread is approximately 30-45 m above modem channel. 4-10 m thick.
- **Qgn4** — **Lower terrace of the ancestral Rio Nambé (middle to upper(?) Pleistocene)** — Terrace tread is approximately 45-56 m above modem channel. 2-10 m thick.
- **Qgn3** — **Middle terrace of the ancestral Rio Nambé (middle Pleistocene)** — Terrace tread is approximately 60-73 m above modem channel. Deposit may correlate to Qt2 Rio del Oso terrace of Dethier and Demsey (1984) with an estimated age of 160 ka. 2-3 m thick.
- **Qgn2** — **Upper terrace of the ancestral Rio Nambé (middle Pleistocene)** — Terrace tread is approximately 75-83 m above modem channel. 2-5 m thick.
- **Qgn1** — **Uppermost terrace of the ancestral Rio Nambé (lower Pleistocene)** — Terrace tread is approximately 85-92 m above modem channel. Includes a well-developed soil with a 0.5 m-thick Bt horizon and a 1 m thick Stage II calcium carbonate horizon (Borchert and Wisniewski, unpublished). Soil age is estimated to be >330 ka using the method outlined in Machette (1982, using a constant dust influx rate of 0.25 g cm^{-1} ka^{-1}). Actual age may be significantly older, since observations of soil profile horizon suggest at least two soil-stripping events. 2-10 m thick.

Gravel of the ancestral Rio en Medio (Pleistocene) — Gravel deposits inset into the southwestern flanks Rio en Medio drainage basin:

- **Qgm2** — **Lower terrace of the ancestral Rio en Medio (upper(?) Pleistocene)** — Terrace tread is approximately 24-31 m above modem channel. Includes a well-developed soil with a 0.52 m thick Bt horizon and a 0.5 m thick Stage II calcium carbonate horizon (Borchert and Wisniewski, unpublished). Soil age is estimated to be >120 ka using the method outlined in Machette (1982, using a constant dust influx rate of 0.25 g cm^{-1} ka^{-1}). Actual age may be significantly older, since observations of soil profile horizon suggest at least two soil-stripping events. This deposit may correlate to *Qt2* Rio del Oso terrace of Dethier and Demsey (1984) with an estimated age of 160 ka. 2-6 m thick.
- **Qgm1** — **Upper terrace of the ancestral Rio en Medio (middle to upper Pleistocene)** — Terrace tread is approximately 43-61 m above modem channel. 2-8 m thick.

Gravel of the ancestral Rio Chupadero (Pleistocene) — Gravel deposits inset into the southwestern flanks Rio Chupadero drainage basin:

- **Qgc2** — **Lower terrace of the ancestral Rio Chupadero (late(?) Pleistocene)** — Terrace tread is approximately 22-28 m above modem channel. This deposit may correlate to the *Qt3* Rio del Oso terrace of Dethier and Demsey (1984), whose age is estimated to be 51 ka. 1-5 m thick.
- **Qgc1** — **Upper terrace of the ancestral Rio Chupadero (middle to late Pleistocene)** — Terrace tread is approximately 36-49 m above modem channel. 2-5 m thick.

Gravel of the ancestral Rio Tesuque (Pleistocene) — Gravel deposits inset into the southwestern flanks Rio Tesuque drainage basin:

- **Qgt5** — **Lowermost terrace of the ancestral Rio Tesuque (upper(?) Pleistocene)** — Terrace tread is approximately 20-28 m above modem channel. 1-4 m thick.
- **Qgt4** — **Lower terrace of the ancestral Rio Tesuque (middle to upper Pleistocene)** — Terrace tread is approximately 30-35 m above modem channel. This deposit may correlate to the *Qt3* Rio del Oso terrace of Dethier and Demsey (1984), whose age is estimated to be 51 ka. 1-5 m thick.
- **Qgt3** — **Middle terrace of the ancestral Rio Tesuque (middle to upper Pleistocene)** — Terrace tread is approximately 45-55 m above modem channel. 2-5 m thick.
- **Qgt2** — **Upper terrace of the ancestral Rio Tesuque (middle Pleistocene)** — Terrace tread is approximately 60-65 m above modem channel. 2-6 m thick.
- **Qgt1** — **Uppermost terrace of the ancestral Rio Tesuque (middle Pleistocene)** — Terrace tread is approximately 75-85 m above modem channel. 2-8 m thick.

Qbo — **Guaje pumice bed of the Otowi Member, Bandelier Tuff (lower Pleistocene; *ca.* 1.61 ± 0.01 Ma (Izett and Obradovich, 1994)** — White pumice clasts generally less than 1 cm long with rare clasts as much as 7 cm long derived from the Valles caldera. Pumice includes quartz and sanidine phenocrysts. Lies within upper 3 m of a 4-12 m fill terrace, *QTga*, and is visible from Hwy 285/84 in the cliffs east of Camel Rock Casino (T18N, R9E, Sec. 2; Plate 1). Constrains age of *QTga* as late Pliocene to early Pleistocene. 1-1.5 m thick.

Late Pliocene to early Pleistocene

Stream gravel (late Pliocene to early Pleistocene) — Nearly flat-lying, bedded, sub-rounded to subangular gravel and sand (with some silt) unconformably overlying the gently dipping Tesuque Formation. Basal unit is commonly rusty yellow, subrounded gravel with tan sand and silt. Clasts are dominantly pinkish granitic gneiss (40-60%) and granite (10-20%), with some quartzite (10-30%), limestone (5-15%), amphibolite <10%), and schist <10%). Limestone clasts are present in greater number and larger size at high elevations close to the mountain front. The gravel varies from 2 mm to 80 cm in diameter and is commonly imbricated to the east. These coarse-grained, fluvial deposits are overlain by 1+ m of silt and fine sand, which we attribute to eolian deposition. Deposits are divided into *QTga-c* based on their interfluve position and not by clast composition:

- **QTg** — Gravel units of small aerial extent in interfluve positions. Deposits range from 2-18 m thick.
- **QTga** — Fill terrace. Caps the interfluve south of Rio Chupadero. Includes the 1.61 Ma Guaje Pumice bed of the Otowi Member of the Bandelier Tuff (Qbo, age from Izett and Obradovich, 1994) within the upper 3 m of the fill terrace. Well exposed behind the Camel Rock Casino (T18N R9E, Sec. 3) and along County Road 592, where it underlies the Vista Redondo subdivision. As much as 18 m thick.
- **QTgb** — Fill terrace. Caps the interfluve south of Rio en Medio. As much as 20 m thick.
- **QTgc** — Fill terrace. Caps the interfluve south of Rio Nambé. As much as 15 m thick.

Tertiary

Tesuque Formation

Proposed by Baldwin (1963), the Tesuque Formation consists of relatively arkosic sandstone and silty sandstone intercalated with variable gravelly channel-fills and subordinate mudstone and siltstone. Strong cementation is not common and its characteristic colors are tan to pink, with minor reddish brown. Galusha and Blick (1971) subdivided the Tesuque Formation in the eastern Española Basin into three stacked members (listed in ascending order, but note the Pojoaque Member is not present on this quadrangle): the Nambé, Skull Ridge, and Pojoaque Members. Later, Cavazza (1986) subdivided the Tesuque Formation into two lithosomes (lithosomes A and B) based on composition, paleocurrents, and provenance considerations; note that lithosome B is not exposed on this quadrangle. Following up on this approach, Koning et al. (2004) recognized another lithosome, called lithosome S, in the Santa Fe area. The map units on the Tesuque quadrangle reflect a combination of the nomenclature of both Cavazza (1986) and Galusha and Blick (1971), with primary emphasis on the former.

Lithosome A interfingers and grades laterally southward into lithosome S (described below). Smith (2000b) and Kuhle and Smith (2001) have interpreted correlative sediment to the north as alluvial slope deposits. Lithosome A is subdivided into the Skull Ridge and Nambé Members, following Galusha and Blick (1971). [description modified from Koning and Read, 2010].

Lithosome A, Tesuque Formation, Santa Fe Group (upper Oligocene to middle Miocene) — Pink-tan alluvial slope deposits composed of sandstone, silty-clayey very fine- to medium-grained sandstone, and subordinate mudstone; these are intercalated with minor, coarse-grained channel-fills. Colors of the sandy sediment range from very pale brown, light yellowish brown, pink, to light brown (most common to least common). Sandstone outside of the coarse channel-fills is generally very fine- to medium-grained, mostly moderately to well consolidated, weakly cemented, and in very thin to thick (mostly medium to thick), tabular beds. Coarse channel-fills consist of medium- to very coarse-grained sandstone, pebbly sandstone, and sandy conglomerate. The coarse channel-fills are clast-supported, weakly to strongly cemented by calcium carbonate, and ribbon- to lenticular-shaped. The proportion of coarse channel-fills increases near (within 5 km) the modern mountain front, where gravelly sediment dominates. Conglomerate includes pebbles with minor cobbles. Clasts are poorly to moderately sorted, subrounded to angular (larger clasts are rounded to subrounded), and composed of granite with trace to 5% quartzite, 1-5% amphibolite, and minor intraformational clasts of cemented sandstone. Sand is subangular to subrounded, moderately to well sorted, and arkosic.

Ttas — **Lithosome A, Skull Ridge Member of the Tesuque Formation, Santa Fe Group (middle Miocene)** — Pinkish, interbedded sandstone and siltstone, with lenses of conglomerate and mudstone. Sedimentary structures include cross bedding, ripple lamination, channel scour-and-fill, and bioturbation (burrows). Distinguished from other members by its numerous tephra layers. Approximately 200-230 m (650-750 ft) thick (Galusha and Blick, 1971).

Tephras of the Skull Ridge Member in lithosome A

The Skull Ridge Member contains as many as 37 ash beds whose color, texture and thickness may vary laterally. Tephra beds are thicker than original ash fall as a consequence of fluvial reworking of the ash. Some pure fallout ash may locally remain at the base. Four prominent, white tephra horizons, labeled as the No. 1, 2, 3, and 4 white ashes by Galusha and Blick (1971), are specified on the map where identified. The "lower light blue", a useful horizon marker between the No. 1 and No. 2 white ashes, is also identified. All other white tephra are marked as "undifferentiated white tephra."

Ashes were identified in the field generally by stratigraphic context (especially in relation to other non-white ashes) rather than internal characteristics (e.g. mineralogy). Galusha and Blick (1971) use the No. 1 white ash to mark the contact between the Skull Ridge and the Nambé Members. In absence of the No. 1 white ash, the contact between the Skull Ridge and Nambé Members is not stratigraphically identifiable; hence where the No. 1 white ash is covered or not present in the Tesuque quadrangle (approximately 90% of the quadrangle), the basal contact has been approximated (dashed on the map) using local bedding orientation. Magnetostratigraphy (Barghoorn; 1981), biostratigraphy (Tedford and Barghoorn; 1993), and $^{40}Ar/^{39}Ar$ geochronology (McIntosh and Quade, 1995; McIntosh, unpub. in Kuhle, 1997, Izett and Obradovich, 2001) establish the age of the Skull Ridge between 14.5 and 16 Ma (middle Miocene).

White tephra, undifferentiated – White to very light-gray, vitric tephra. May include quartz, sanidine, biotite, hornblende, and/or pyroxene. Variably indurated and weathered. 0.3-3.3 m thick.

No. 1 white ash, 15.86 ± 0.03 Ma (Perkins, *personal communication*, by tephra-stratigraphic correlation, in Kuhle, 1997) – Blocky white, fine-grained, vitric, stuctureless tephra. Includes sparse quartz and lithic fragments. Base weathers to bentonite locally. Constitutes the contact between the Skull Ridge and Nambé Members. Visible from U.S. Hwy. 285/84 north of Camel Rock Casino (T19N, R9E, Sec. 34). 1-2 m thick.

Lower light blue ash – White, fine-grained tephra. Typically capped by a 0.2-0.5 m-thick, cemented sandstone ledge. Visible from U.S. Hwy. 285/84 north of Camel Rock Casino (T19N, R9E, Sec. 34). 0.2-0.5 m thick.

No. 2 white ash, 15.5 ± 0.07 Ma (Izett and Obradovich, 2001) and 15.59 ± 0.07 Ma (MacIntosh, *personal communication*, in Kuhle, 1997) – White, fine-grained, vitric tephra. Contains quartz, sanidine, plagioclase, and little biotite. Occurs 41 m (stratigraphic distance) above the No. 1 white ash. Encircles the base of a hill east of U.S. Hwy. 285/84, 1.5 km northwest of Camel Rock Casino (T19N, R9E, Sec. 34). 0.2-0.8 m thick.

Ashes slightly above the No. 2 white ash (Nos. 2A, 2B, or 2C of Galusha and Blick, 1971) – Thin ashes that lie within 7-10 m above the No. 2 white ash. Not described.

No. 3 white ash, 15.4 ± 0.08 Ma (Izett and Obradovich, 2001) – White, fine-grained, vitric, structureless tephra. Locally found stratigraphically below a highly bioturbated bed. Occurs 58 m (stratigraphic distance) above the No.1 white ash. Crops out east of Cuyamungue (T19N, R9E, Sec. 34). 0.4-1.0 m thick.

No. 4 white ash, 15.3 ± 0.05 Ma (Izett and Obradovich, 2001) and 15.42 ± 0.06 Ma (MacIntosh and Quade, 1995) – White, fine-grained, vitric, structureless tephra. Contains quartz, sanidine, plagioclase, and sparse biotite. Occurs 157 m (stratigraphic distance) above the No. 1 white ash. Crops out approximately 5 m below a distinct blue ash (T19N, R9E, Sec. 21).

Ttan — **Lithosome A, Nambé Member of the Tesuque Formation, Santa Fe Group (upper Oligocene to lower Miocene)** — Light gray, tan and pinkish, coarse-grained sandstone interbedded with conglomerate, siltstone, and sparse claystone layers. The upper section is tan and pink silty sandstone with more mudstone than in the lower and middle sections. Galusha and Blick (1971) named the upper 120 m the "fossiliferous part" of the member. The section is well exposed in an arroyo with a road east of Rio Tesuque (T18N, R9E, section 12).

The reddish brown, coarse-grained, lower-middle 305-345 m (1000-1100 ft) section (called the 'lower conglomeratic portion' by Galusha and Blick, 1971, depicted in cross section B-B' as *Ttanc*) varies in grain size, sorting, and rock fragment composition. Outcrops exhibit 80-90% poorly-sorted, sub-angular, arkosic sandstone and conglomerate in beds as much as 40 cm thick; clasts are commonly 2-10 cm (and as much as 35 cm) in diameter and composed of granite and granitic gneiss. A distinctive interval in the lower-middle section commonly overlies outcrops of the Bishop's Lodge Member (now of the Espinaso Formation). It consists of angular to sub-rounded, moderately sorted, medium to coarse-grained, quartz-rich (60-75%) gravelly sandstone and sandy conglomerate; this interval is commonly cemented by a white, calcium-carbonate-rich matrix and bedded on the cm to dm scale. This cemented interval crops out discontinuously in many places in the Tesuque quadrangle and is reminiscent of quartz grus visible on modern transport-limited granite or granite gneiss hill slopes. 400-450 m thick (Galusha and Blick, 1971); 500-550 m thick from the cross sections.

Tephras of the Nambé Member in lithosome A

Multiple white and gray tephra exist within the Nambé Member. As many as three white tephras have been identified. The upper tephra was called the Nambé Ash by Galusha and Blick (1971). The lower tephra is herein named the Chupadero Ash, because of its locality within the Chupadero valley (T18N, R9E, Sec. 1); it may possibly correlate with an ash dated by Izett and Obradovich (2001) at 16.4 ± 0.13 Ma.

White ash, undifferentiated – White tephra that was not described in detail. Variably indurated and weathered. 0.3-1 m thick.

"Upper" Nambé white ash – A white, fine ash bed located 10-13 m stratigraphically above the Nambé white ash and lithologically similar to it. Located near the northern quadrangle boundary (T19 N, R9E, Sec. 15 and 22).

Nambé white ash – White, fine-grained, vitric, structureless tephra. Contains quartz, sanidine, plagioclase, and sparse biotite. 0.6-1.2 m thick. Located approximately 35 m (stratigraphic distance) below the contact between the Nambé and Skull Ridge Members.

Chupadero ash – A white, fine ash located in the Chupadero valley (T18N, R9E, Sec. 1).

Gabaldon tephra – A 0.2-100 cm-thick, white tephra bed consisting of fluvially reworked coarse ash and fine lapilli; the latter consists of felsic (latite?) clasts. Tephra is mixed with subordinate arkose sand. Located approximately 18 m (stratigraphic distance) above the basal contact (below which lies the Bishops Lodge Member of the Espinaso Formation). $^{40}Ar/^{39}Ar$ analyses on sanidine crystals returned an age of 25.52 ± 0.07 Ma (Koning *et al.*, 2013).

Lithosome S of the Tesuque Formation, Skull Ridge Member (upper Oligocene(?) to middle Miocene) — Pebbly sandstone channel-fill deposits and fine sandstone and mudstone floodplain deposits associated with a large drainage exiting the Sangre de Cristo Mountains near the modern Santa Fe River. Lithosome S is recognized by its clast composition (35-65% granite, 3-40% Paleozoic clasts, 5-30% quartzite, including a distinctive black quartzite, and 1-8% chert), reddish color (particularly compared to the browner, distal alluvial slope facies of lithosome A), and high-energy-flow deposits in very broad, thick channel complexes that possess very thin to medium, planar to lenticular internal bedding. Channel-fill conglomerate is commonly clast-supported, poorly to moderately sorted, and mostly subrounded (but granitic clasts may be subangular). The sand fraction is arkosic and is composed of quartz, 10-30% potassium feldspar, trace to 7% yellowish Paleozoic siltstone, sandstone, or limestone grains, and trace to 5% chert and dark quartzite grains. Channel-fill sand is commonly light brown (7.5YR 6/3), fine- to very coarse-grained, poorly to well sorted, and subrounded to subangular. Cementation of channel-fills is variable. Finer-grained strata of lithosome S are in very thin to medium, tabular beds with horizontal-planar to wavy laminations; locally, this sediment is structureless. Overbank sediment consists of light brown to reddish yellow and pink to very pale brown siltstone, very fine- to coarse-grained (generally fine-grained) sandstone, and silty to clayey sandstone. Within the fine sediment are local very thin to medium, lenticular channel-fills. There are also variable amounts of reddish brown to yellowish red to light reddish brown mudstone and sandy mudstone. Lithosome S interfingers and grades northwards into lithosome A. Lithosome S is subdivided into the Skull Ridge and Nambé Members, following Galusha and Blick (1971). [description modified from Koning and Read, 2010].

Ttss — **Lithosome S, Skull Ridge Member of the Tesuque Formation, Santa Fe Group (lower to middle Miocene)** — Sediment as described above. Unit overlies the inferred, approximate projection of White Ash No. 1. Approximately 200-230 m (650-750 ft) thick (Galusha and Blick, 1971).

Ttsn — **Lithosome S, Nambé Member of the Tesuque Formation, Santa Fe Group (late Oligocene to early Miocene)** — Sediment as described above. This unit gradationally overlies a 350(?) m-thick tongue of lower lithosome A sediment. Approximately 380-400 m thick.

Ttsas — **Gradational zone between lithosomes S and A of the Skull Ridge Member, slightly more lithologically similar to lithosome S (upper to middle Miocene)** — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome S than lithosome A; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 200-230 m (650-750 ft) thick, similar to the thickness of the Skull Ridge Member to the north.

Ttsan — **Gradational zone between lithosomes S and A of the Nambé Member, slightly more lithologically similar to lithosome S (upper Oligocene to lower Miocene)** — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome S than lithosome A; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 380-400 m thick.

Ttass — **Gradational zone between lithosomes S and A of the Skull Ridge Member, slightly more lithologically similar to lithosome A (upper to middle Miocene)** — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome A than lithosome S; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 200-230 m (650-750 ft) thick, similar to the thickness of the Skull Ridge Member to the north.

Ttasn — **Gradational zone between lithosomes S and A of the Nambé Member, slightly more lithologically similar to lithosome A (upper Oligocene to lower Miocene)** — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome A than lithosome S; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 380-400 m thick.

Ttnb — **Basalt in the lower Nambé Member (upper Oligocene to lower Miocene(?))** — Dark-green to dark gray, weathered, olivine basalt with a coarse-crystalline texture. Vesicles and calcite amygdules are concentrated near the top of the flows. Outcrops tend to weather spheroidally. Five separate basalt flows have been identified in a relatively unaltered outcrop in an arroyo north of the Chupadero fire station. Basalt is overlain by a 1-2 m greenish siltstone within the lower Nambé Member. Basalt crops out near faults in several locations northeast of the Rio Chupadero, close to the mountain front. May be correlative to a basalt dated at 24.9 ± 0.6 Ma (K-Ar age-determination by Baldridge et al., 1980; sample UAKA-77-80) located 5 km east-northeast of Nambé Pueblo. 1-3 m thick.

Tcb+Tte — **Cieneguilla basanite flows interbedded with lithosome E, Tesuque Formation (Oligocene)** — Cieneguilla basanite flows interbedded with sandstone and pebbly sandstone of lithosome E of the Tesuque Formation (Koning and Read, 2010; Koning and Johnson, 2006). The flows correlate in part with the basalt in the lower Nambé Member (unit *Ttnb*). They consist of gray, porphyritic, mafic volcanic rocks -- probably basanite but may also include nephelinite and basalt. Cuttings from correlative strata in the Yates No. 2 La Mesa well, located 8.1 km southwest of the southwestern corner of this quadrangle, indicates that these flows contain a dark groundmass composed of fine-grained pyroxene and plagioclase; phenocrysts include clinopyroxene, iddingsite-replaced olivine, and plagioclase (Myer and Smith, 2006, unit 2). These cuttings also indicate that the sand is grayish in color and composed of altered basalt, variable percentages of latite, and 1-5% greenish, granular grains of unknown composition. Very fine to fine sand has minor quartz and lesser (about 3%) potassium feldspar and granitic grains. Sand grains are very fine- to very coarse, poorly sorted, and angular to subrounded. Note that some of the sand grains are likely slough from strata higher in the well. Locally there are minor (10-15%) very fine pebbles of basalt. At least one tuff interval. Description of volcaniclastic sediment is from observations of the Yates No. 2 La Mesa well cuttings (Daniel Koning and David Sawyer, unpublished data). Cross section B-B' only.

Espinaso Formation

Tebl — **Bishop's Lodge Member of the Espinaso Formation (upper Oligocene to lower Miocene(?))** — Light gray to white, tuffaceous (?) siltstone and sandstone with gray pumiceous, porphyritic (plagioclase and pyroxene), and andesitic to latitic clasts. Pumice clasts reached 45 cm, whereas latite rock clasts are as much as 18 cm in diameter. At the type-section near The Bishop's Lodge within the Santa Fe quadrangle, Smith (2000) has distinguished at least two volcaniclastic intervals that are each 10-60 m thick: an older, coarser-grained interval that includes latitic and pumaceous clasts and a finer-grained upper interval.

The member differs from the Nambé Member by the presence of volcanic clasts and its characteristically whitish-gray, fine-grained sandy silt. The contact with the pinker, more granitic Nambé Member is interfingered and locally both sharp and gradational, likely because the sediment of a volcanic apron was shed intermittently and mixed with sediment derived from the mountains to the east. Fine-grained material (tuffaceous sand and silt) that contains few volcanic pebbles, but may include volcanic granules or small pumice lapilli, have been included in the Bishop's Lodge Member, as well as fine-grained siltstones exhibiting the characteristic light-gray Bishop's Lodge Member color. The Bishop's Lodge Member crops out discontinuously, close to the mountain front (e.g. west and south of Pacheco Canyon road and along the National Forest Boundary in Secs. 17 and 22, T10N, R8E) and commonly fills valley floors. Smith (2000) reported a 30.45 ± 0.16 Ma tephra age ($^{40}Ar/^{39}Ar$ date on biotite,) from within the member. Although this member was named by Baldwin (1963), who included it within the Tesuque Formation, Galusha and Blick (1971) call the member the Picuris Formation. Ingersoll, et al. (1990) consider it contemporaneous with deposition of the upper Abiquiu and middle Picuris Formations, which are late Oligocene to early Miocene age. Typically 2-25 m thick.

Tc — **Colluvium (Oligocene? to lower Miocene?)** — Buff and yellowish poorly-exposed, limestone boulder-rich deposit overlying basal Nambé Member adjacent to the contact between the basement rock and basin fill. Probably >10 m thick.

Tog — **Older gravels (Eocene to lower Oligocene)** — Limestone- and granite-bearing pebbly sandstone and conglomerate that underlies the Bishops Lodge Member (Espinaso Formation) at and north of Santa Fe. At the mouth of Pacheco Canyon, 10-30 m of limestone-rich gravel overlies the Bishops Lodge Member and is assigned to this unit. Beds are commonly medium thicknesses and tabular to lenticular. Clasts are subangular to subrounded, commonly clast-supported, moderately to poorly sorted, and consist of pebbles with varying amounts of cobbles (but cobbles are generally subordinate). Clasts are composed of granite, granitic gneiss, and yellowish Paleozoic limestone and siltstone. Sand is light yellowish brown to light gray, mostly medium- to very coarse-grained, subrounded to subangular, poorly to moderately sorted, and arkosic in its upper part. Strong cementation is common. [modified from Koning and Read, 2010].

This unit correlates to a >400-m section of limestone-rich strata below the Bishop's Lodge Member that Smith (2000) included in the Nambé Member. Following Koning and Read (2010), we have elected to informally call this interval as an "older gravel unit (*Tog*)," in part because the lower part of this unit may be correlative with the Laramide-age Galisteo Formation. At least three distinct intervals, whose heterogeneity are perhaps influenced by local basin characteristics (such as drainage basin size, location within drainage basin, and proximity to faults) are present in the *Tog* unit near its basal contact with the basement rock. One is a 25+ m exposure of a quartz-rich interval visible in the footwall along a near-vertical fault surface (State Plane coordinates: x=605000, y=1732000). The fault juxtaposes the quartz-rich strata in the footwall against pink, arkosic, gravelly, sub-angular sand and silt beds in the hanging wall; the hanging wall arkosic beds interfinger with the light gray, tuffaceous, volcaniclastic Bishop's Lodge Member. The second interval comprises a very light tan sandstone and/or siltstone, which does not contain volcanic clasts but may represent a mixing of volcanic ash with granitic source material. The strata are rich in limestone (25-40% limestone cobbles) and more visible in the Tesuque quadrangle as lag deposit than in outcrop. The third interval is a pink to dark reddish brown, coarse, angular sand and gravel much like the 'lower-middle' unit of the Nambé Member described previously. >400 m thick (Smith, 2000).

PALEOZOIC

Pennsylvanian

IPlpu — **La Pasada Formation – upper part (Desmoinesian)** — Gray, fossiliferous limestone (weathering buff to tan) with some gray shale and red to maroon, subrounded, sandstone and conglomerate. This unit is well exposed in an unnamed drainage 0.5 km south the Nambé Lake Dam (northwest comer of T19N, R10E, Sec. 32). Sutherland and Harlow, 1973 (pp. 109-114) mapped a thrust fault at the base of this unit that explains the missing Atokan part of the La Posada Formation. However, this contact is interpreted here as a disconformity because there is no clear evidence for a fault contact. Approximately 30-50 m thick.

IPlpl — **La Pasada Formation – lower part (Morrowan)** — Gray, highly fossiliferous limestone (weathering buff to tan) with some green to black mudstone, gray, green and buff shale, and green, red, maroon and brown, poorly sorted sandstone and conglomerate. Overlies the Arroyo Peñasco Group (Mississippian) along western boundary of Nambé Lake (T19N, R10E, Sec. 29). Outcrops may include Arroyo Peñasco Group locally at base. Approximately 60 m thick.

Mississippian

Ma — **Arroyo Peñasco Group** — Predominantly gray, crinkly-laminated dolomitic limestone (~0.5 m-thick beds) interbedded with lesser amounts of platy mudstone, blocky limestone, and reddish sandstone. Basal unit is a greenish, very fine to fine-grained, silty sandstone. Unconformably overlies the Proterozoic rocks west of Nambé Lake Dam. Approximately 12 m thick.

PROTEROZOIC

YXu — **Proterozoic undifferentiated** — Strongly foliated granitic gneiss with lesser amounts of amphibolite, quartzite, and quartz-muscovite schist (likely Paleoproterozoic). Cross sections only.

Yp — **Pegmatite (Middle (?) Proterozoic)** — Very coarse-grained, anhedral to subhedral pink, locally perthitic K-feldspar, light gray to clear-gray quartz, and locally variable amounts of either muscovite or biotite. Muscovite is much more common. Crystals range up to 6 or more cm across. Some bodies contain abundant anhedral to euhedral bipyramidal magnetite crystals. Red garnet is rare. Some exposures reveal K-feldspar and quartz intergrown in graphic textures several tens of cm across. These rocks form thin veins less than a meter wide to thick dikes and irregularly shaped bodies. The pegmatites tend to erode into coarse debris that commonly mantles slopes and creates the illusion of a much thicker body. Hence in many areas contacts are difficult to identify and dashed contacts on the map should be regarded as best guesses.

YXd — **Diorite (Middle (?) Proterozoic)** — Medium-grained, equigranular, non-foliated intrusive rocks containing roughly equal parts amphibole, biotite, and plagioclase, with subordinate quartz. Exposures are poor and rock weathers into sandy grus-covered slopes in the extreme southeastern corner of the Tesuque 7.5' quadrangle. Weathers dark green.

Xg — **Fine- to medium-grained granite—"Embudo Granite" (Early Proterozoic)** — Locally heterogeneous, predominantly fine-to medium-grained granite. This equigranular rock contains pink K-feldspar, light gray plagioclase, clear-gray quartz, and minor biotite (1-3%). Many exposures are light tan to pink and contain coarser-grained muscovite crystals and a preponderance of K-feldspar over plagioclase. The coarse muscovite is probably not primary, but was likely created during metamorphism by the reaction between K-feldspar and quartz. The excess(?) K-feldspar suggests that some of these rocks may have undergone addition of potassium during an episode of potassium metasomatism. The axial plane of rare isoclinal folds are sub-parallel to S2. The dominant foliation, S2, and stretching lineation, L2 (indicated on the map), may represent a secondary tectonic fabric, overprinting an earlier tectonic stress history (with an associated Sl and Ll). The Embudo granite has been dated by Register and Brookins (1979) in the Nambé Falls area at 1,412 and 1,372 Ma and in Pacheco Canyon at 1,534 and 1,492 Ma.

Miller, *et al.* (1963) described a separate gneissic variety as well as a coarse-grained variety and a quartz-dioritic phase. Mapping has shown that the gneissic variety grades into rock where foliation is weak to nonexistent and is clearly recognizable as fine-grained granite. Hence, the gniessic and fine-grained rocks are probably the same granite. Exposed very locally south of Rio Nambe is a medium-gray, strongly foliated, fine- to medium-grained rock containing very little recognizable K-feldspar and abundant (~10%) biotite. This rock, though not mapped separately, is adjacent to a large band of quartz-muscovite schist/quartzite. The rock may be equivalent to the quartz diorite variety described by Miller, *et al.* (1963). However, they interpret the variety as having originated from the partial assimilation of amphibolite, but here the rock is not immediately in contact with any amhibolite.

Map unit *Xg* may be equivalent to 'tonalite' mapped in the northeast part of the Chimayo 7.5' quadrangle (Koning, 2003). This unit contains some areas that are coarse-grained.

Xgc — **Coarse-grained granite – "Embudo Granite" (Early Proterozoic)** — Coarse-grained granite containing obvious pink K-feldspar phenocrysts up to about 1.5 cm across. Biotite is abundant (5-10%) and is characteristically fresh, anhedral, and relatively large (1-3 mm) compared to biotite crystals in the fine-grained granite (map unit *Xg*). This unit, as mapped, is everywhere foliated. Miller, *et al.* (1963) describe a coarse-grained variety of the Embudo granite. However, at the time of their study, few accurate age-dates were available and the significance of the later pulse of ~1.4 Ga plutonism was not fully recognized. Hence, it is possible that this coarse-grained granite may either be part of the early Proterozoic Embudo pluton or it may be a younger ~1.4 Ga intrusion. Comparison of these exposures with granites to the east may help to resolve this problem.

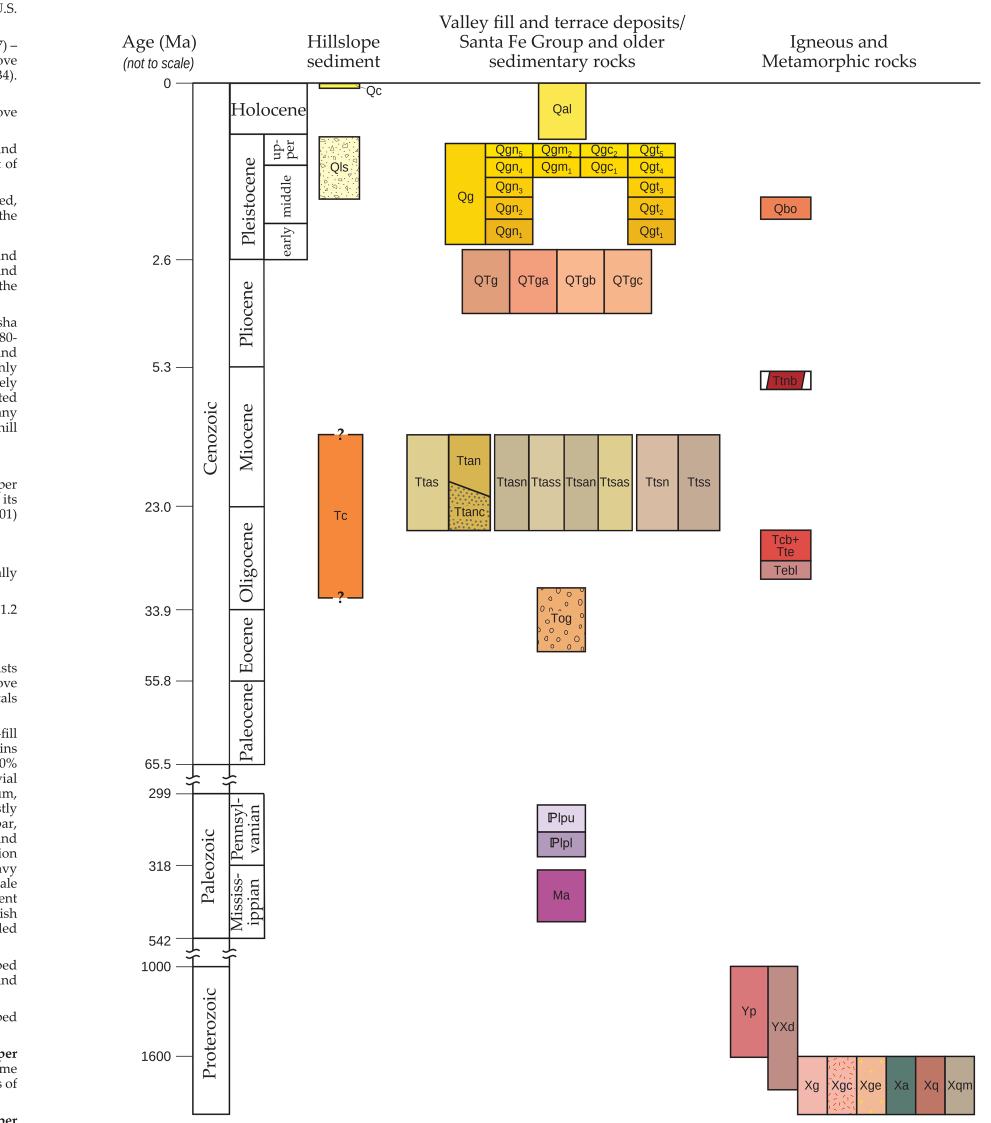
Xge — **Medium- to coarse-grained, equigranular granite – "Embudo Granite" (Early Proterozoic)** — This unit is tentatively separated from map unit *Xg* on the basis of homogeneous and apparently widespread (at least locally) exposures on the high, steep face on the north side of Pacheco Canyon, in the southern part of the Tesuque 7.5' quadrangle. Here it approaches coarse-grained, is equigranular, and forms very bold cliffs with subangular to rounded, bouldery outcrops.

Xa — **Amphibolite (Early Proterozoic)** — Amphibole-rich gniess, biotite schists, and all gradations in between. Outcrops are rather heterogeneous and contain highly variable amounts of amphibole, feldspar (mostly plagioclase), biotite, and quartz. Biotite schists commonly contain abundant light gray feldspar and quartz, and are approximately granodioritic in composition. The biotite schists generally appear slightly lighter gray than the dark greenish gray amphibolites. Amphibolites range from fine-grained to relatively coarse-grained and contain tabular subhedral amphibole phenocrysts locally up to 1 cm long, that appear as though they formed both during and after metamorphism. The percentage of feldspar is highly variable. Some rocks contain only amphibole and quartz. The amphibolites and biotite schists together may have originally been either intermediate to mafic igneous rocks or intermediate-composition pelitic rocks, or both.

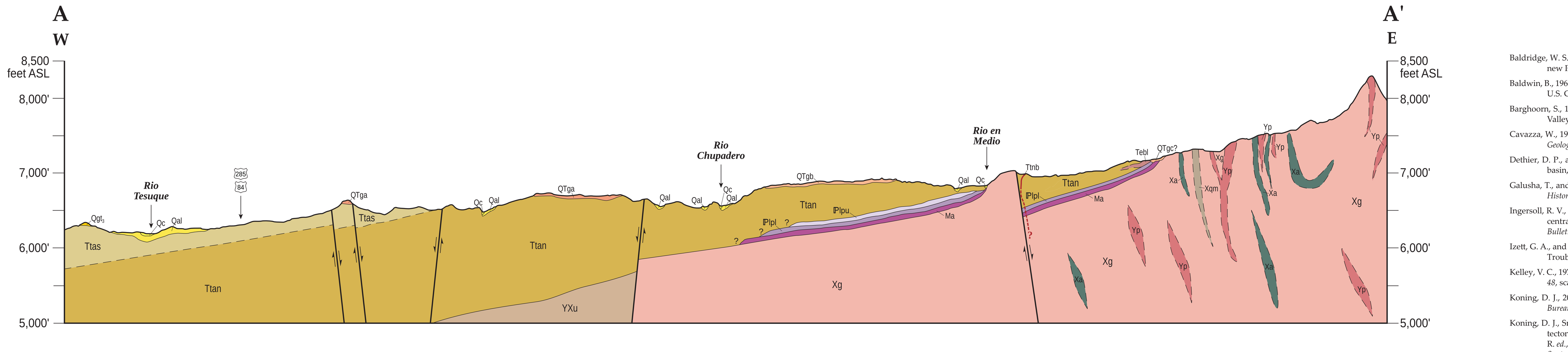
Xq — **Quartzite (Early Proterozoic)** — These discontinuous, lens-shaped bluish gray exposures are composed of quartz and thin laminae of darker iron oxides. No bedding is obvious. Exposures are foliated.

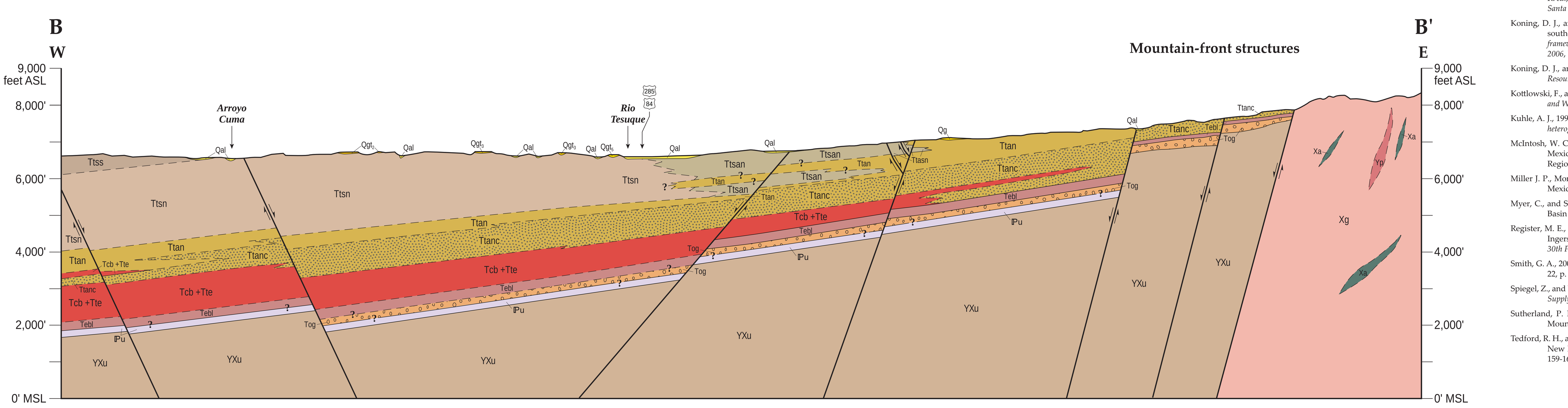
Xqm — **Quartz-Muscovite Schist (Early Proterozoic)** — Composed of quartz and medium- to coarse grained muscovite. Commonly strongly foliated. This unit was likely a sedimentary protolith that contained abundant quartz and finer material that included some clay.

CORRELATION OF MAP UNITS



GEOLOGIC CROSS SECTIONS





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Geologic Map of the Tesuque Quadrangle, Santa Fe County, New Mexico

By

Claudia I. Borchert, Steven J. Skotnicki, Adam S. Read, Daniel J. Koning, and David J. McCraw

February, 2003

New Mexico Bureau of Geology and Mineral Resources
Open-file Digital Geologic Map OF-GM 72

Scale 1:24,000

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EXPLANATION TO THE GEOLOGIC MAP OF THE TESUQUE QUADRANGLE, SANTA FE COUNTY, NEW MEXICO

Claudia I. Borchert, Steven J. Skotnicki, Adam S. Read, Daniel J. Koning, and David J. McCraw

Field mapping was conducted by Claudia Borchert (formerly of the University of New Mexico, now with the City of Santa Fe) as part of her Master thesis. The effort was supervised by Dr. Gary Smith (University of New Mexico) and assisted by Susan Hoffman, Aaron Cavosie, and Mike Gaud. Proterozoic mapping was done by Dr. Steven Skotnicki (private consultant) and Adam Read (New Mexico Bureau of Geology and Mineral Resources); Adam also mapped Paleozoic rocks around Nambé Dam. Terrace-related soil studies were performed by C. Borchert and Paul Wisniewski. Daniel Koning updated the Tertiary basin deposits in 2009-2010 (Koning and Read, 2010). David McCraw synthesized the disparate contributions that have occurred since 2003 into the final map product.

Description of Map Units

CENOZOIC

QUATERNARY

Qc **Modern channels (streams and arroyos) and associated active floodplain alluvium (Holocene)** — Tan, poorly-sorted, gravelly sand and silt. Most deposits occur within 2 m elevation of the present channel. Floodplain may contain vegetation. Only channels >3 m in width are identified on map. Thickness unknown.

Qal **Alluvium, undifferentiated (Pleistocene (?) - Holocene)** — Tan, poorly-sorted sand and silt, with minor amounts of subrounded gravel (mostly granite and granitic gneiss); surface soils may have been inflated by addition of eolian material. Grades to 2-10 m above modem channel (base level) of current mainstem stream (Rio Tesuque or Rio Nambé). Unit includes at least four undifferentiated terraces, such as the inhabited and cultivated terraces along the Rio Tesuque, Rio en Medio, and Rio Chupadero. Alluvial deposits, estimated <2 m thick, are not included within this map unit. Likely equivalent to *Qal* of the Santa Fe quadrangle geologic map by Kottlowski and Baldwin (1963). Thickness is unknown, but estimated to be less than 25 m on the basis of regional well logs.

Qls **Landslide deposits (Pleistocene)** — Unconsolidated, disturbed sediment consisting of angular to subangular granitic clasts and sand.

Quaternary terrace gravels

Dominantly subrounded gravel and tan sand with lesser silt. Gravel clasts are dominantly pinkish granite and granitic gneiss (70%), with some quartz and quartzite and sparser limestone, amphibolite, and quartz-mica schist. Clasts are as much as 0.4 m in diameter and generally smaller than the *QTg* gravel deposits. A 1-2 m silt deposit, which has largely been pedogenically altered, overlies the gravels and is attributed to eolian dust influx. Deposits are set into existing valleys (most commonly the south and west side) and unconformably overlie the gently dipping beds of the Tesuque Formation. Deposits are typically between 2-10 m thick.

Terrace deposits are correlated by field observation and tread and strath positions and not by clast composition or soil profiles. Map units bear the letter of the drainage system they are within (*Qgn* for Rio Nambé-Pojoaque River, *Qgm* for Rio en Medio, Qgc for Rio Chupadero, and *Qgt* for Rio Tesuque) and are labeled from oldest and highest elevation (Qgn_1, Qgm_1, Qgc_1, and Qgt_l) to youngest and lowest in elevation (Qgn_5, Qgm_2, Qgc_2, and Qgt_5), but described below from youngest to oldest. Since the number of terraces per stream system varies (from two within the Rio Chupadero valley to five within the Rio Nambé), the units which bear the same numeral subscript are not necessarily correlative. Where stream-gravel boundaries are covered by a colluvial apron shed from an older, higher terrace (e.g., Qgn_3, Qgt_4, and Qgn_5 in T19N, R10E, Sec. 30), the boundary between deposits has been placed midpoint between the two terrace treads. Where no field outcrops were found, the assumption was made that each tread represents a distinct terrace-forming deposit. The alternative, in which several strath terrace treads have been carved into a larger cut-and-fill stream deposit, is also plausible. Ages for deposits are approximate.

Qg **Gravel, undifferentiated (Pleistocene)** — Gravel unit that is sufficiently isolated to make correlation to other gravel deposits or to ancestral stream difficult. *Qg* exposures are not correlative to one another.

Qgn **Gravel of ancestral Rio Nambé (Pleistocene)** — Gravel deposits inset into the southwestern flanks Rio Nambé drainage basin:

Qgn_5 **(middle to upper(?) Pleistocene)** — Terrace tread is approximately 30-45 m above modem channel. 4-10 m thick.

Qgn_4 (**middle to upper (?) Pleistocene)** — Terrace tread is approximately 45-56 m above modem channel. 2-10 m thick.

Qgn_3 **(middle Pleistocene)** — Terrace tread is approximately 60-73 m above modem channel. Deposit may correlate to *Qt_2* Rio del Oso terrace of Dethier and Demsey (1984) with an estimated age of 160 ka. 2-3 m thick.

Qgn_2 **(middle Pleistocene)** — Terrace tread is approximately 75-83 m above modem channel. 2-5 m thick.

Qgn_1 **(lower Pleistocene)** — Terrace tread is approximately 85-92 m above modem channel. Includes a well-developed soil with a 0.5 m-thick Bt horizon and a 1 m thick Stage II calcium carbonate horizon (Borchert and Wisniewski, unpublished). Soil age is estimated to be >330 ka using the method outlined in Machette (1982, using a constant dust influx rate of 0.25 g cm^{-1} ka^{-1}). Actual age may be significantly older, since observations of soil profile horizon suggest at least two soil-stripping events. 2-10 m thick.

Qgm **Gravel of ancestral Rio en Medio (Pleistocene)** — Gravel deposits inset into the southwestern flanks of the Rio en Medio drainage basin:

Qgm_2 **(upper (?) Pleistocene)** — Terrace tread is approximately 24-31 m above modem channel. Includes a well-developed soil with a 0.52 m thick Bt horizon and a 0.5 m thick Stage II calcium carbonate horizon (Borchert and Wisniewski, unpublished). Soil age is estimated to be >120 ka using the method outlined in Machette (1982, using a constant dust influx rate of 0.25 g cm^{-1} ka^{-1}). Actual age may be significantly older, since observations of soil profile horizon suggest at least two soil-stripping events. This deposit may correlate to *Qt2* Rio del Oso terrace of Dethier and Demsey (1984) with an estimated age of 160 ka. 2-6 m thick.

Qgm_1 **(middle to upper Pleistocene)** — Terrace tread is approximately 43-61 m above modem channel. 2-8 m thick.

Qgc **Gravel of ancestral Rio Chupadero (Pleistocene)** — Gravel deposits inset into the southwestern flanks of the Rio Chupadero drainage basin:

Qgc_2 **(upper (?) Pleistocene)** — Terrace tread is approximately 22-28 m above modem channel. This deposit may correlate to the *Qt3* Rio del Oso terrace of Dethier and Demsey (1984), whose age is estimated to be 51 ka. 1-5 m thick.

Qgc_1 **(middle to upper Pleistocene)** — Terrace tread is approximately 36-49 m above modem channel. 2-5 m thick.

Qgt **Gravel of ancestral Rio Tesuque (Pleistocene)** — Gravel deposits inset into the southwestern flanks of the Rio Tesuque drainage basin:

Qgt_5 **(upper (?) Pleistocene)** — Terrace tread is approximately 20-28 m above modem channel. 1-4 m thick.

Qgt_4 **(middle to upper Pleistocene)** — Terrace tread is approximately 30-35 m above modem channel. This deposit may correlate to the *Qt3* Rio del Oso terrace of Dethier and Demsey (1984), whose age is estimated to be 51 ka. 1-5 m thick.

Qgt_3 **(middle to upper Pleistocene)** — Terrace tread is approximately 45-55 m above modem channel. 2-5 m thick.

Qgt_2 **(middle Pleistocene)** — Terrace tread is approximately 60-65 m above modem channel. 2-6 m thick.

Qgt_1 **(middle Pleistocene)** — Terrace tread is approximately 75-85 m above modem channel. 2-8 m thick.

Qbo **Guaje pumice bed of the Otowi Member, Bandelier Tuff (lower Pleistocene; *ca.* 1.61 ± 0.01 Ma (Izett and Obradovich, 1994)** — White pumice clasts generally less than 1 cm long with rare clasts as much as 7 cm long derived from the Valles caldera. Pumice includes quartz and sanidine phenocrysts. Lies within upper 3 m of a 4-12 m fill terrace, *QTga,* and is visible from Hwy 285/84 in the cliffs east of Camel Rock Casino (T18N, R9E, Sec. 2; Plate 1). Constrains age of *QTga* as late Pliocene to early Pleistocene. 1-1.5 m thick.

Upper Pliocene to lower Pleistocene

QTg **Stream gravel (upper Pliocene to lower Pleistocene)** — Nearly flat-lying, bedded, subrounded to subangular gravel and sand (with some silt) unconformably overlying the gently dipping Tesuque Formation. Basal unit is commonly rusty yellow, subrounded gravel with tan sand and silt. Clasts are dominantly pinkish granitic gneiss (40-60%) and granite (10-20%), with some quartzite (10-30%), limestone (5-15%), amphibolite <10%), and schist <10%). Limestone clasts are present in greater number and larger size at high elevations close to the mountain front. The gravel varies from 2 mm to 80 cm in diameter and is commonly imbricated to the east, conforming to the east to west transport direction near the eastern margin of the basin. These coarse-grained, fluvial deposits are overlain by 1+ m of silt and fine sand, which we attribute to eolian deposition. Deposits are divided into *QTga-c* based on their interfluve position and not by clast composition. Age approximations for stream gravel are rough at best. Some of the gravel highest in the landscape has been previously named Ancha Formation by Speigel and Baldwin (1963) and piedmont gravels by Kelley (1978). Deposits range from 2-18 m thick.

QTg — Gravel units of small aerial extent in interfluve positions.

QTga — Fill terrace. Caps the interfluve south of Rio Chupadero. Includes the 1.61 Ma Guaje Pumice bed of the Otowi Member of the Bandelier Tuff (*Qbo*, age from Izett and Obradovich, 1994) within the upper 3 m of the fill terrace. Well exposed behind the Camel Rock Casino (T18N R9E, Sec. 3) and along County Road 592, where it underlies the Vista Redondo subdivision. As much as 18 m thick.

QTgb — Fill terrace. Caps the interfluve south of Rio en Medio. As much as 20 m thick.

QTgc — Fill terrace. Caps the interfluve south of Rio Nambé. As much as 15 m thick.

TERTIARY

Tesuque Formation

Proposed by Baldwin (1963), the Tesuque Formation consists of relatively arkosic sandstone and silty sandstone intercalated with variable gravelly channel-fills and subordinate mudstone and siltstone. Strong cementation is not common and its characteristic colors are tan to pink, with minor reddish brown. Galusha and Blick (1971) subdivided the Tesuque Formation in the eastern Española Basin into three stacked members (listed in ascending order, but note the Pojoaque Member is not present on this quadrangle): the Nambé, Skull Ridge, and Pojoaque Members. Later, Cavazza (1986) subdivided the Tesuque Formation into two lithosomes (lithosomes A and B) based on composition, paleocurrents, and provenance considerations; note that lithosome B is not exposed on this quadrangle. Following up on this approach, Koning et al. (2004) recognized another lithosome, called lithosome S, in the Santa Fe area. The map units on the Tesuque quadrangle reflect a combination of the nomenclature of both Cavazza (1986) and Galusha and Blick (1971), with primary emphasis on the former.

Lithosome A interfingers and grades laterally southward into lithosome S (described below). Smith (2000b) and Kuhle and Smith (2001) have interpreted correlative sediment to the north as alluvial slope deposits. Lithosome A is subdivided into the Skull Ridge and Nambé Members, following Galusha and Blick (1971). [description modified from Koning and Read, 2010].

Tta **Lithosome A, Tesuque Formation, Santa Fe Group (upper Oligocene to middle Miocene)** — Pink-tan alluvial slope deposits composed of sandstone, silty-clayey very fine- to medium-grained sandstone, and subordinate mudstone; these are intercalated with minor, coarse-grained channel-fills. Colors of the sandy sediment range from very pale brown, light yellowish brown, pink, to light brown (most common to least common). Sandstone outside of the coarse channel-fills is generally very fine- to medium-grained, mostly moderately to well consolidated, weakly cemented, and in very thin to thick (mostly medium to thick), tabular beds. Coarse channel-fills consist of medium- to very coarse-grained sandstone, pebbly sandstone, and sandy conglomerate. The coarse channel-fills are clast-supported, weakly to strongly cemented by calcium carbonate, and ribbon- to lenticular-shaped. The proportion of coarse channel-fills increases near (within 5 km) the modern mountain front, where gravelly sediment dominates. Conglomerate includes pebbles with minor cobbles. Clasts are poorly to moderately sorted, subrounded to angular (larger clasts are rounded to subrounded), and composed of granite with trace to 5% quartzite, 1-5% amphibolite, and minor intraformational clasts of cemented sandstone. Sand is subangular to subrounded, moderately to well sorted, and an arkose.

Ttas **Lithosome A, Skull Ridge Member of the Tesuque Formation, Santa Fe Group (middle Miocene)** — Pinkish, interbedded sandstone and siltstone, with lenses of conglomerate and mudstone. Sedimentary structures include cross bedding, ripple lamination, channel scour-and-fill, and bioturbation (burrows). Distinguished from other members by its numerous tephra layers. Approximately 200-230 m (650-750 ft) thick (Galusha and Blick, 1971).

Tephras of the Skull Ridge Member in lithosome A

The Skull Ridge Member contains as many as 37 ash beds whose color, texture and thickness may vary laterally. Tephra beds are thicker than original ash fall as a consequence of fluvial reworking of the ash. Some pure fallout ash may locally remain at the base. Four prominent, white tephra horizons, labeled as the No. 1, 2, 3, and 4 white ashes by Galusha and Blick (1971), are specified on the map where identified. The "lower light blue", a useful horizon marker between the No. 1 and No. 2 white ashes, is also identified. All other white tephra are marked as "undifferentiated white tephra."

Ashes were identified in the field generally by stratigraphic context (especially in relation to other non-white ashes) rather than internal characteristics (e.g. mineralogy). Galusha and Blick (1971) use the No. 1 white ash to mark the contact between the Skull Ridge and the Nambé Members. In absence of the No. 1 white ash, the contact between the Skull Ridge and Nambé Members is not stratigraphically identifiable; hence where the No. 1 white ash is covered or not present in the Tesuque quadrangle (approximately 90% of the quadrangle), the basal contact has been approximated (dashed on the map) using local bedding orientation. Magnetostratigraphy (Barghoorn; 1981), biostratigraphy (Tedford and Barghoorn; 1993), and $^{40}Ar/^{39}Ar$ geochronology (McIntosh and Quade, 1995; McIntosh, unpub. *in* Kuhle, 1997, Izett and Obradovich, 2001) establish the age of the Skull Ridge between 14.5 and 16 Ma (middle Miocene).

White tephra, undifferentiated – White to very light-gray, vitric tephra. May include quartz, sanidine, biotite, hornblende, and/or pyroxene. Variably indurated and weathered. 0.3-3.3 m thick.

No. 1 white ash – 15.86 ± 0.03 Ma (Perkins, *personal communication*, by tephra-stratigraphic correlation, in Kuhle, 1997). Blocky white, fine-grained, vitric, stuctureless tephra. Includes sparse quartz and lithic fragments. Base weathers to bentonite locally. Constitutes the contact between the Skull Ridge and Nambé Members. Visible from U.S. Hwy. 285/84 north of Camel Rock Casino (T19N, R9E, Sec. 34). 1-2 m thick.

Lower light blue ash – White, fine-grained tephra. Typically capped by a 0.2-0.5 m-thick, cemented sandstone ledge. Visible from U.S. Hwy. 285/84 north of Camel Rock Casino (T19N, R9E, Sec. 34). 0.2-0.5 m thick.

No. 2 white ash – 15.5 ± 0.07 Ma (Izett and Obradovich, 2001) and 15.59 ± 0.07 Ma (MacIntosh, *personal communication*, in Kuhle, 1997) – White, fine-grained, vitric tephra. Contains quartz, sanidine, plagioclase, and little biotite. Occurs 41 m (stratigraphic distance) above the No. 1 white ash. Encircles the base of a hill east of U.S. Hwy. 285/84, 1.5 km northwest of Camel Rock Casino (T19N, R9E, Sec. 34). 0.2-0.8 m thick.

Ashes slightly above the No. 2 white ash (Nos. 2A, 2B, or 2C of Galusha and Blick, 1971) – Thin ashes that lie within 7-10 m above the No. 2 white ash. Not described.

No. 3 white ash – 15.4 ± 0.08 Ma (Izett and Obradovich, 2001) – White, fine-grained, vitric, structureless tephra. Locally found stratigraphically below a highly bioturbated bed. Occurs 58 m (stratigraphic distance) above the No.1 white ash. Crops out east of Cuyamungue (T19N, R9E, Sec. 34). 0.4-1.0 m thick.

No. 4 white ash – 15.3 ± 0.05 Ma (Izett and Obradovich, 2001) and 15.42 ± 0.06 Ma (MacIntosh and Quade, 1995) – White, fine-grained, vitric, structureless tephra. Contains quartz, sanidine, plagioclase, and sparse biotite. Occurs 157 m (stratigraphic distance) above the No. 1 white ash. Crops out approximately 5 m below a distinct blue ash (T19N, R9E, Sec. 21).

Ttan Lithosome A, Nambé Member of the Tesuque Formation, Santa Fe Group (upper Oligocene to lower Miocene) — Light gray, tan and pinkish, coarse-grained sandstone interbedded with conglomerate, siltstone, and sparse mudstone layers. The upper section is tan and pink silty sandstone with more mudstone in than the lower and middle sections. Galusha and Blick (1971) named the upper 120 m the "fossiliferous part" of the member. The section is well exposed in an arroyo with a road east of Rio Tesuque (T18N, R9E, section 12).

The reddish brown, coarse-grained, lower-middle 305-345 m (1000-1100 ft) section (called the 'lower conglomeratic portion' by Galusha and Blick, 1971, depicted in cross section B-B′ as *Ttanc*) varies in grain size, sorting, and rock fragment composition. Outcrops exhibit 80-90% poorly-sorted, sub-angular, arkosic sandstone and conglomerate in beds as much as 40 cm thick; clasts are commonly between 2-10 cm (and as much as 35 cm) in diameter and compsed of granite and granitic gneiss. A distinctive interval in the lower-middle section commonly overlies outcrops of the Bishop's Lodge Member (now of the Espinaso Formation). It consists of angular to sub-rounded, moderately sorted, medium to coarse-grained, quartz-rich (60-75%) gravelly sandstone and conglomerate; this interval is commonly cemented by a white, calcium-carbonate-rich matrix and bedded on the cm to dm scale. This cemented interval crops out discontinuously in many places in the Tesuque quadrangle and is reminiscent of quartz grus visible on modern transport-limited granite or granite gneiss hill slopes. 400-450 m thick (Galusha and Blick, 1971); 500-550 m thick from the cross sections.

Tephras of the Nambé Member in lithosome A

Multiple white and gray tephra exist within the Nambé Member. As many as three white tephras have been identified. The upper tephra was called the Nambé Ash by Galusha and Blick (1971). The lower tephra is herein named the Chupadero Ash, because of its locality within the Chupadero valley (T18N, R9E, Sec. 1); it may possibly correlate with an ash dated by Izett and Obradovich (2001) at 16.4 ± 0.13 Ma.

White ash, undifferentiated – White tephra that was not described in detail. Variably indurated and weathered. 0.3-1 m thick.

"Upper" Nambé white ash – A white, fine ash bed located 10-13 m stratigraphically above the Nambé white ash and lithologically similar to it. Located near the northern quadrangle boundary (T19 N, R9E, Sec. 15 and 22).

Nambé white ash – White, fine-grained, vitric, structureless tephra. Contains quartz, sanidine, plagioclase, and sparse biotite. 0.6-1.2 m thick. Located approximately 35 m (stratigraphic distance) below the contact between the Nambé and Skull Ridge Members.

Chupadero ash – A white, fine ash located in the Chupadero valley (T18N, R9E, Sec. 1).

Gabaldon tephra – A 0.2-100 cm-thick, white tephra bed consisting of fluvially reworked coarse ash and fine lapilli; the latter consists of felsic (latite?) clasts. Tephra is mixed with subordinate arkose sand. Located approximately 18 m (stratigraphic distance) above the basal contact (below which lies the Bishops Lodge Member of the Espinaso Formation). $^{40}Ar/^{39}Ar$ analyses on sanidine crystals returned an age of 25.52 ± 0.07 Ma (Koning *et al*., 2013).

Tts **Lithosome S of the Tesuque Formation, Skull Ridge Member (upper Oligocene(?) to middle Miocene)** — Pebbly sand channel-fill deposits and fine sandstone, siltstone, and mudstone floodplain deposits associated with a large drainage exiting the Sangre de Cristo Mountains near the modern Santa Fe River. Lithosome S is recognized by its clast composition (35-65% granite, 3-40% Paleozoic clasts, 5-30% quartzite, including a distinctive black quartzite, and 1-8% chert), reddish color (particularly compared to the browner, distal alluvial slope facies of lithosome A), and high-energy-flow deposits in very broad, thick channel complexes that possess very thin to medium, planar to lenticular internal bedding. Channel-fill conglomerate is commonly clast-supported, poorly to moderately sorted, and mostly subrounded (but granitic clasts may be subangular). The sand fraction is arkosic and is composed of quartz, 10-30% potassium feldspar, trace to 7% yellowish Paleozoic siltstone, sandstone, or limestone grains, and trace to 5% chert and dark quartzite grains. Channel-fill sand is commonly light brown (7.5YR 6/3), fine- to very coarse-grained, poorly to well sorted, and subrounded to subangular. Cementation of channel-fills is variable. Finer-grained strata of lithosome S are in very thin to medium, tabular beds with horizontal-planar to wavy laminations; locally, this sediment is structureless. Overbank sediment consists of light brown to reddish yellow and pink to very pale brown siltstone, very fine- to coarse-grained (generally fine-grained) sandstone, and silty to clayey sandstone. Within the fine sediment are local very thin to medium, lenticular channel-fills. There are also variable amounts of reddish brown to yellowish red to light reddish brown mudstone and sandy mudstone. Lithosome S interfingers and grades northwards into lithosome A. Lithosome S is subdivided into the Skull Ridge and Nambé Members, following Galusha and Blick (1971) [description modified from Koning and Read, 2010].

Ttss Lithosome S, Skull Ridge Member of the Tesuque Formation, Santa Fe Group (lower to middle Miocene) — Sediment as described above. Unit overlies the inferred, approximate projection of White Ash No. 1. Approximately 200-230 m (650-750 ft) thick (Galusha and Blick, 1971).

Ttsn Lithosome S, Nambé Member of the Tesuque Formation, Santa Fe Group (upper Oligocene to lower Miocene) — Sediment as described above. This unit gradationally overlies a 350(?) m-thick tongue of lower lithosome A sediment. 380-400 m thick.

Ttsas Gradational zone between lithosomes S and A of the Skull Ridge Member, slightly more lithologically similar to lithosome S (upper to middle Miocene) — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome S than lithosome A; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 200-230 m (650-750 ft) thick, similar to the thickness of the Skull Ridge Member to the north.

Ttsan Gradational zone between lithosomes S and A of the Nambé Member, slightly more lithologically similar to lithosome S (upper Oligocene to lower Miocene) — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome S than lithosome A; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 380-400 m thick.

Ttass Gradational zone between lithosomes S and A of the Skull Ridge Member, slightly more lithologically similar to lithosome A (lower to middle Miocene) — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome A than lithosome S; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 200-230 m (650-750 ft) thick, similar to the thickness of the Skull Ridge Member to the north.

Ttasn Gradational zone between lithosomes S and A of the Nambé Member, slightly more lithologically similar to lithosome A (upper Oligocene to lower Miocene) — Fine-grained lateral gradation between lithosomes A and S; unit is laterally closer to lithosome A than lithosome S; predominantly fine sandstone, silty sandstone, and mudstone. Approximately 390-400 m thick.

Ttnb Basalt in the lower Nambé Member (upper Oligocene to lower Miocene(?)) — Dark-green to dark gray, weathered, olivine basalt with a coarse-crystalline texture. Vesicles and calcite amygdules are concentrated near the top of the flows. Outcrops tend to weather spheroidally. Five separate basalt flows have been identified in a relatively unaltered outcrop in an arroyo north of the Chupadero fire station. Basalt is overlain by a 1-2 m greenish siltstone within the lower Nambé Member. Basalt crops out near faults in several locations northeast of the Rio Chupadero, close to the mountain front. May be correlative to a basalt dated at 24.9 ± 0.6 Ma (K-Ar age-determination by Baldridge *et al*., 1980; sample UAKA-77-80) located 5 km east-northeast of Nambé Pueblo. 1-3 m thick.

Tcb+

Tte Cieneguilla basanite flows interbedded with lithosome E, Tesuque Formation (Oligocene) — Cieneguilla basanite flows interbedded with sandstone and pebbly sandstone of lithosome E of the Tesuque Formation (Koning and Read, 2010; Koning and Johnson, 2006). The flows correlate in part with the basalt in the lower Nambé Member (unit *Ttnb*). They consist of gray, porphyritic, mafic volcanic rocks -- probably basanite but may also include nephelinite and basalt. Cuttings from correlative strata in the Yates No. 2 La Mesa well, located 8.1 km southwest of the southwestern corner of this quadrangle, indicates that these flows contain a dark groundmass composed of fine-grained pyroxene and plagioclase; phenocrysts include clinopyroxene, iddingsite-replaced olivine, and plagioclase (Myer and Smith, 2006, unit 2). These cuttings also indicate that the sand is grayish in color and composed of altered basalt, variable percentages of latite, and 1-5% greenish, granular grains of unknown composition. Very fine to fine sand has minor quartz and lesser (about 3%) potassium feldspar and granitic grains. Sand grains are very fine- to very coarse, poorly sorted, and angular to subrounded. Note that some of the sand grains are likely slough from strata higher in the well. Locally there are minor (10-15%) very fine pebbles of basalt. At least one tuff interval. Description of volcaniclastic sediment is from observations of the Yates No. 2 La Mesa well cuttings (Daniel Koning and David Sawyer, unpublished data). Cross section B-B′ only.

Tebl Bishop's Lodge Member of the Espinaso Formation (late Oligocene to early Miocene(?)) — Light gray to white, tuffaceous (?) siltstone and sandstone with gray pumiceous, porphyritic (plagioclase and pyroxene), and andesitic to latitic clasts. Pumice clasts reached 45 cm, whereas latite rock clasts are as much as 18 cm in diameter. At the type-section near The Bishop's Lodge within the Santa Fe quadrangle, Smith (2000) has distinguished at least two volcaniclastic intervals that are each 10-60 m thick: an older, coarser-grained interval that includes latitic and pumaceous clasts and a finer-grained upper interval.

The member is differentiated from the Nambé Member by the presence of volcanic clasts and its characteristically whitish-gray, fine-grained sandy silt. Contact with the pinker, more granitic Nambé Member is interfingered and both erosional and gradational, likely because the sediment of a volcanic apron was shed intermittently and mixed with sediment derived from the mountains to the east. Any mappable thicknesses of fine-grained material (tuffaceous sand and silt) that may have very little in the way of volcanic pebbles, but may include volcanic granules or small pumice lapilli, have been included in the Bishop's Lodge Member, as well as fine-grained silts exhibiting the characteristic light-gray Bishop's Lodge Member color. The Bishop's Lodge Member crops out discontinuously, close to the mountain front (e.g. west and south of Pacheco Canyon road and along the National Forest Boundary in Secs. 17 and 22, T10N, R8E) and commonly fills valley floors. Smith (2000) reports a 30.45 ± 0.16 Ma tephra ($^{40}Ar/^{39}Ar$ date on biotite,) from within the member. Although this member was named by Baldwin (1963), who included it within the Tesuque Formation, Galusha and Blick (1971) call the member the Picuris Formation. Ingersoll, *et al.* (1990) consider it contemporaneous with deposition of the upper Abiquiu and middle Picuris Formations, which are late Oligocene to early Miocene age. Typically 2-25 m thick.

Tc Colluvium (Oligocene? to early Miocene?) — Buff and yellowish poorly-exposed, limestone boulder-rich deposit overlying basal Nambé Member adjacent to the contact between the basement rock and basin fill. Probably >10 m thick.

Tog Older gravels (Eocene to lower Oligocene) — Limestone- and granite-bearing pebbly sandstone and conglomerate that underlies the Bishops Lodge Member (Espinaso Formation) at and north of Santa Fe. At the mouth of Pacheco Canyon, 10-30 m of limestone-rich gravel overlies the Bishops Lodge Member and is assigned to this unit. Beds are commonly medium and tabular to lenticular. Gravel clasts are subangular to subrounded, commonly clast-supported, moderately to poorly sorted, and consist of pebbles with varying amounts of cobbles (but cobbles are generally subordinate). Clasts are composed of granite, granitic gneiss, and yellowish Paleozoic limestone and siltstone. Sand is light yellowish brown to light gray, mostly medium- to very coarse-grained, subrounded to subangular, poorly to moderately sorted, and an arkose in its upper part. Strong cementation is common. [modified from Koning and Read, 2010].

This unit correlates to a >400-m section of limestone-rich strata below the Bishop's Lodge Member that Smith (2000) included in the Nambé Member. Following Koning and Read (2010), we have elected to informally call this interval as an "older gravel unit (*Tog*)," in part because the lower part of this unit may be correlative with the Laramide-age Galisteo Formation. At least three distinct intervals, whose heterogeneity are perhaps influenced by local basin characteristics (such as drainage basin size, location within drainage basin, and proximity to faults) are present in the *Tog* unit near its basal contact with the basement rock. One is a 25+ m exposure of a quartz-rich interval visible in the footwall along a near-vertical fault surface (State Plane coordinates: x=605000, y=1732000). The fault juxtaposes the quartz-rich strata in the footwall against pink, arkosic, gravelly, sub-angular sand and silt beds in the hanging wall; the hanging wall arkosic beds interfinger with the light gray, tuffaceous, volcaniclastic Bishop's Lodge Member. The second interval comprises a very light tan sand and/or silt, which does not contain volcanic clasts but may represent a mixing of volcanic ash with granitic source material. The strata are rich in limestone (25-40% limestone cobbles) and more visible in the Tesuque quadrangle as lag deposit than in outcrop. The third interval is a pink to dark reddish brown, coarse, angular sand and gravel much like the 'lower-middle' unit of the Nambé Member described previously. >400 m thick (Smith, 2000).

PALEOZOIC

Pennsylvanian

IPlp La Pasada Formation (Desmoinesian) — Gray, fossiliferous limestone (weathering buff to tan) with some gray shale and red to maroon, subrounded, sandstone and conglomerate. Exposed in an unnamed drainage 0.5 km south the Nambé Lake Dam (northwest comer of T19N, R10E, Sec. 32). Approximately 30-50 m thick.

IPs Sandia Formation (Morrowan) — Gray, highly fossiliferous limestone (weathering buff to tan) with some green to black mudstone, gray, green and buff shale, and green, red, maroon and brown, poorly sorted sandstone and conglomerate. Overlies the Arroyo Peñasco Group (Mississippian) along western boundary of Nambé Lake (T19N, R10E, Sec. 29). Outcrops may include Arroyo Peñasco Group locally at base. Approximately 60 m thick.

Mississippian

Ma Arroyo Peñasco Group — Predominantly gray, crinkly-laminated dolomitic limestone (~0.5 m-thick beds) interbedded with lesser amounts of platy mudstone, blocky limestone, and reddish sandstone. Basal unit is a greenish, very fine to fine-grained, silty sandstone. Unconformably overlies the Proterozoic rocks west of Nambé Lake Dam. Approximately 12 m thick.

PROTEROZOIC

YXu Proterozoic undifferentiated — Strongly foliated granitic gneiss with lesser amounts of amphibolite, quartzite, and quartz-muscovite schist (likely Paleoproterozoic). Cross sections only.

Yp Pegmatite (Middle Proterozoic?) — Very coarse-grained, anhedral to subhedral pink, locally perthitic K-feldspar, light gray to clear-gray quartz, and locally variable amounts of either muscovite or biotite. Muscovite is much more common. Crystals range up to 6 or more cm across. Some bodies contain abundant anhedral to euhedral bi-pyramidally shaped magnetite crystals. Red garnet is rare. Some exposures reveal K-feldspar and quartz intergrown in graphic textures several tens of cm across. These rocks form thin veins less than a meter wide to thick dikes and irregularly shaped bodies. The pegmatites tend to erode into coarse debris that commonly mantles slopes and creates the illusion of a much thicker body. Hence in many areas contacts are very difficult to identify and dashed contacts on the map should be regarded as best guesses.

YXd Diorite (Middle Proterozoic?) — Medium-grained, equigranular, non-foliated intrusive rocks containing roughly equal parts amphibole, biotite, and plagioclase, with subordinate quartz. Exposures are poor and rock weathers into sandy grus-covered slopes in the extreme southeastern corner of the Tesuque 7.5′ quadrangle. Weathers dark green.

Xg **Fine- to medium-grained granite—"Embudo Granite" (Early Proterozoic)** — Locally heterogeneous, predominantly fine-to medium-grained granite. This equigranular rock contains pink K-feldspar, light gray plagioclase, clear-gray quartz, and very minor biotite (1-3%). Many exposures are light tan to pink and contain coarser-grained muscovite crystals and a preponderance of K-feldspar over plagioclase. The coarse muscovite is probably not primary, but was likely created during metamorphism by the reaction between K-feldspar and quartz. The excess(?) K-feldspar suggests that some of these rocks may have undergone addition of potassium during an episode of potassium metasomatism. The axial plane of rare isoclinal folds are sub-parallel to S_2. The dominant foliation, S_2, and stretching lineation, L_2 (indicated on the map), may represent a secondary tectonic fabric, overprinting an earlier tectonic stress history (with an associated S_1 and L_1). The Embudo granite has been dated by Register and Brookins (1979) in the Nambé Falls area at 1412 and 1372 Ma and in Pacheco Canyon at 1534 and 1492 Ma.

Miller and others (1963) described a separate gneissic variety as well as a coarse-grained variety and a quartz-dioritic phase. Mapping has shown that the gneissic variety grades into rock where foliation is weak to nonexistent and is clearly recognizable as fine-grained granite. Hence, the gniessic and fine-grained rocks are probably the same granite. Exposed very locally south of Rio Nambe is a medium-gray, strongly foliated, fine- to medium-grained rock containing very little recognizable K-feldspar and abundant (~10%) biotite. This rock, though not mapped separately, is adjacent to a large band of quartz-muscovite schist/ quartzite. The rock may be equivalent to the quartz diorite variety described by Miller and others (1963). However, they interpret the variety as having originated from the partial assimilation of amphibolite, but here the rock is not immediately in contact with any amphibolite.

Map unit *Xg* may be equivalent to 'tonalite' mapped in the northeast part of the Chimayo 7.5′ quadrangle (Koning, 2003). This unit contains some areas that are coarse-grained.

Xgc **Coarse-grained granite - "Embudo Granite" (Early Proterozoic)** — Coarse-grained granite containing obvious pink K-feldspar phenocrysts up to about 1.5 cm across. Biotite is abundant (5-10%) and is characteristically fresh, anhedral, and relatively large (1-3 mm) compared to biotite crystals in the fine-grained granite (map unit *Xg*). This unit, as mapped, is everywhere foliated. Miller and others (1963) describe a coarse-grained variety of the Embudo granite. However, at the time of their study, few accurate age-dates were available and the significance of the later pulse of ~1.4 Ga plutonism was not fully recognized. Hence, it is possible that this coarse-grained granite may either be part of the early Proterozoic Embudo pluton or it may be a younger ~1.4 Ga intrusion. Comparison of these exposures with coarse-grained granites presumably to the east may help to resolve this problem.

Xge **Medium- to coarse-grained, equigranular granite - "Embudo Granite" (Early Proterozoic)** — This unit is tentatively separated from map unit Xg on the basis of homogeneous and apparently widespread (at least locally) exposures of this granite variety exposed in the high, steep face on the north side of Pacheco Canyon, in the southern part of the Tesuque 7.5′ quadrangle. Here it approaches coarse-grained, is equigranular, and forms very bold cliffs with subangular to rounded, bouldery outcrops.

Xa **Amphibolite (Early Proterozoic)** — Amphibole-rich gniess, biotite schists, and all gradations in between. Outcrops are rather heterogeneous and contain highly variable amounts of amphibole, feldspar (mostly plagioclase), biotite, and quartz. Biotite schists commonly contain abundant light gray feldspar and quartz, and are approximately granodioritic in composition. The biotite schists generally appear slightly lighter gray than the dark greenish gray amphibolites. Amphibolites range from fine-grained to relatively coarse-grained and contain tabular subhedral amphibole phenocrysts locally up to 1 cm long, that appear as though they formed both during and after metamorphism. The percentage of feldspar is highly variable. Some rocks contain only amphibole and quartz. The amphibolites and biotite schists together may have originally been either intermediate to mafic igneous rocks or intermediate-composition pelitic rocks, or both.

Xq **Quartzite (Early Proterozoic)** — These discontinuous, lens-shaped bluish gray exposures are composed of quartz and thin laminae of darker iron oxides. No bedding is obvious. Exposures are foliated.

Xqm **Quartz-Muscovite Schist (Early Proterozoic)** — Composed of quartz and medium- to coarse grained muscovite. Commonly strongly foliated. This unit was likely a sedimentary protolith that contained abundant quartz and finer material that included some clay.

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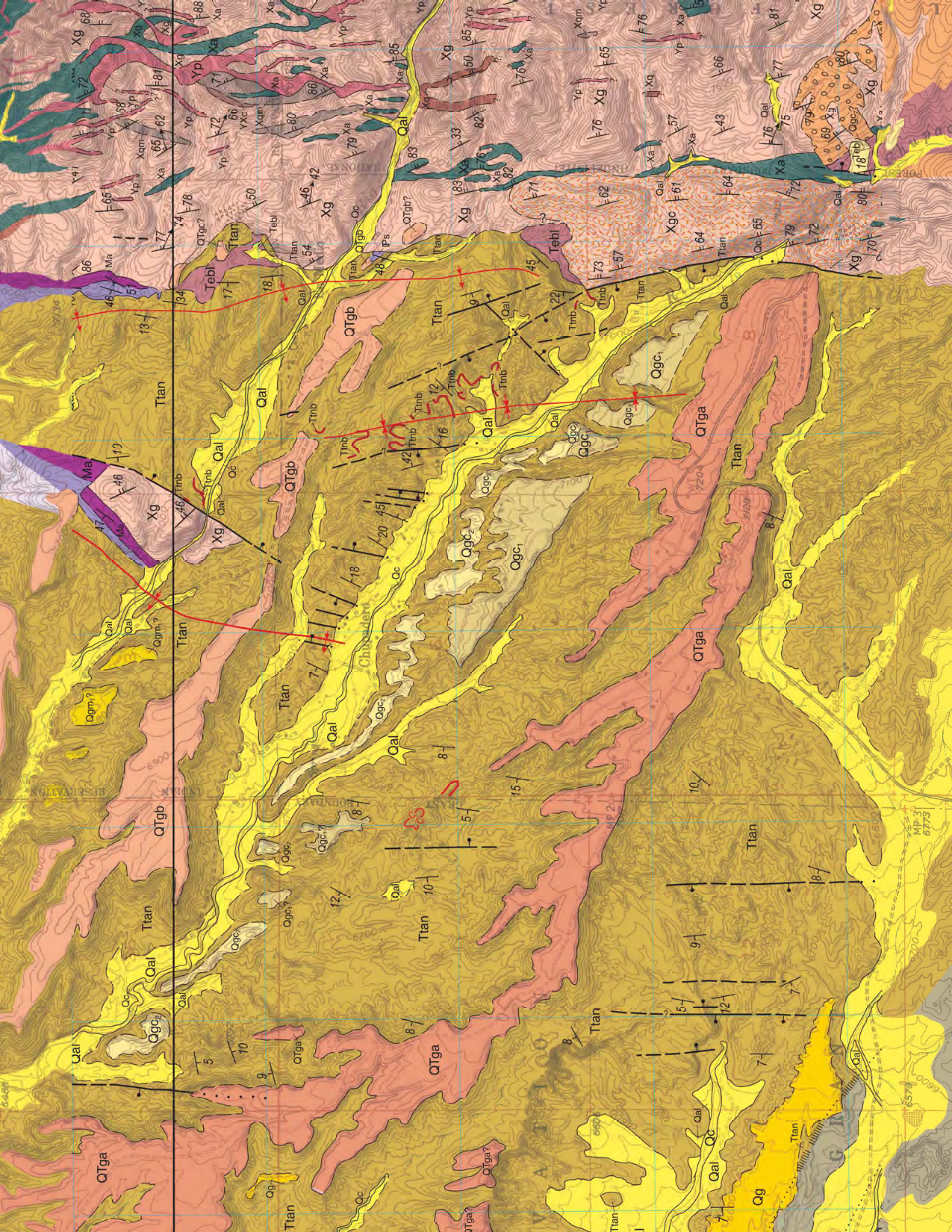

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6773

U.S. Fish and Wildlife Service
National Wetlands Inventory

Chupadero Water Improvements

January 8, 2018

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction, and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures in this jurisdiction.

The **projection** used in the preparation of this map was New Mexico State Plane, Central Zone (FIPS 3002). The **horizontal datum** was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey, SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit their website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was provided in digital format by City of Santa Fe, 2009 and 2010; and Santa Fe County, 2006. Additional information was taken directly from the previous Countywide FIRM dated June 17, 2008. Other information was photogrammetrically compiled at a scale of 1:12,000 from U.S. Department of Agriculture aerial photography dated 2009.

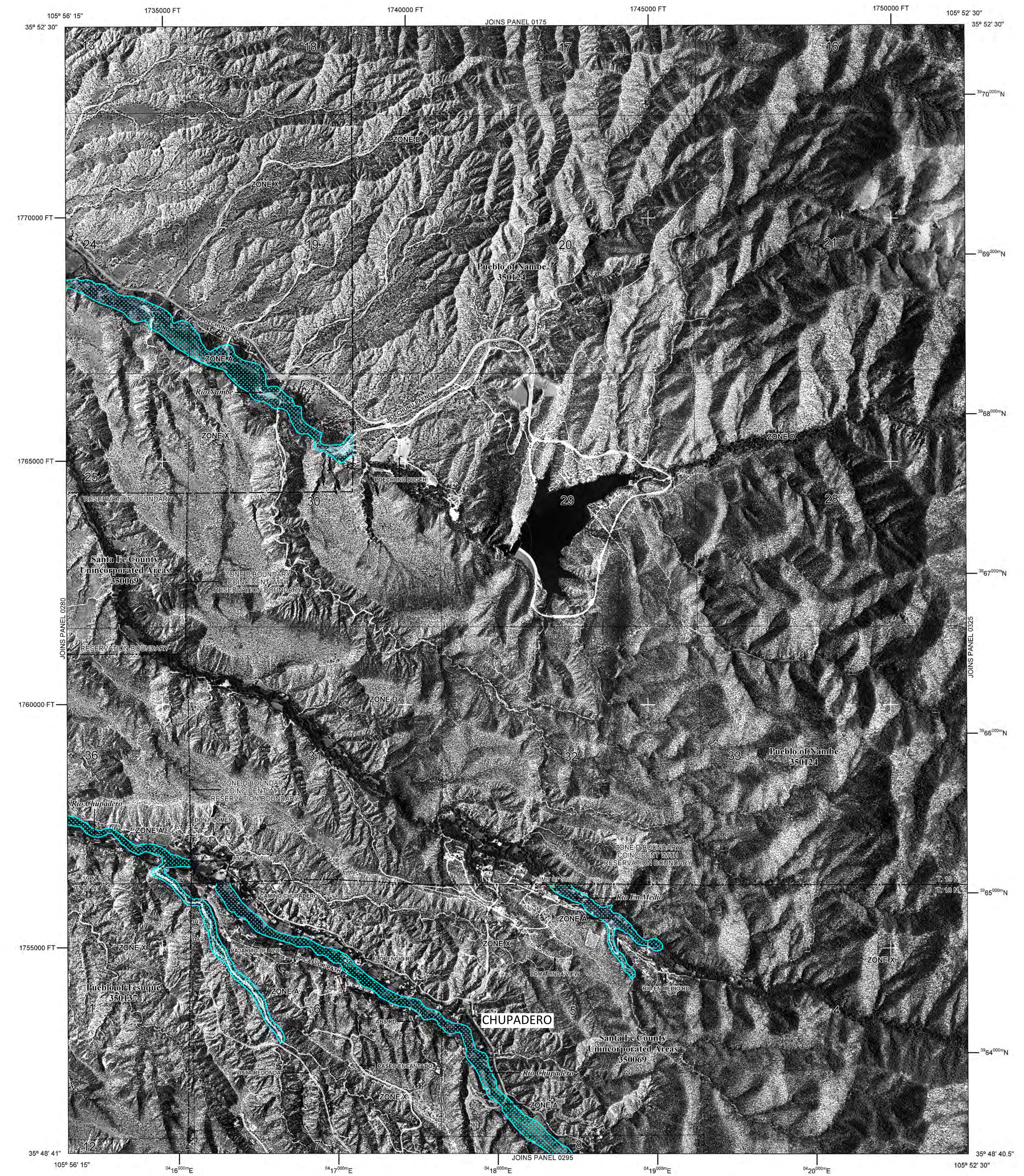
Based on updated topographic information, this map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map**, how to order products or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange (FMIX) at **1-877-FEMA-MAP (1-877-336-2627)** or visit the FEMA website at http://www.fema.gov/business/nfip.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% annual chance floodplain boundary
0.2% annual chance floodplain boundary
Floodway boundary
Zone D Boundary
CBRS and OPA Boundary
Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 - - - - - 23	Transect line
97° 07' 30", 32° 22' 30"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
$^{42}76^{000m}$E	1000-meter Universal Transverse Mercator grid values, zone 13
600000 FT	5000-foot grid ticks: New Mexico State Plane coordinate system, Central zone (FIPSZONE 3002), Transverse Mercator
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index.

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP PANEL

JUNE 17, 2008

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

DECEMBER 4, 2012 - to update corporate limits, to add Special Flood Hazard Areas, to add Base Flood Elevations, to add or update roads and road names, to incorporate previously issued LOMRs.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0285E

FIRM

FLOOD INSURANCE RATE MAP

SANTA FE COUNTY, NEW MEXICO
AND INCORPORATED AREAS

PANEL 285 OF 1100

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
NAMBE, PUEBLO OF	350124	0285	E
SANTA FE COUNTY, (UNINCORPORATED AREAS)	350069	0285	E
TESUQUE, PUEBLO OF	350137	0285	E

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER 35049C0285E

MAP REVISED DECEMBER 4, 2012

Federal Emergency Management Agency

IPaC **U.S. Fish & Wildlife Service**

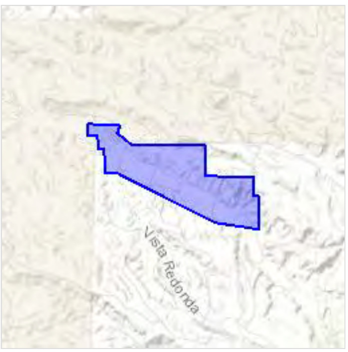
IPaC resource list

This report is an automatically generated list of species and other resources such as critical habitat (collectively referred to as *trust resources*) under the U.S. Fish and Wildlife Service's (USFWS) jurisdiction that are known or expected to be on or near the project area referenced below. The list may also include trust resources that occur outside of the project area, but that could potentially be directly or indirectly affected by activities in the project area. However, determining the likelihood and extent of effects a project may have on trust resources typically requires gathering additional site-specific (e.g., vegetation/species surveys) and project-specific (e.g., magnitude and timing of proposed activities) information.

Below is a summary of the project information you provided and contact information for the USFWS office(s) with jurisdiction in the defined project area. Please read the introduction to each section that follows (Endangered Species, Migratory Birds, USFWS Facilities, and NWI Wetlands) for additional information applicable to the trust resources addressed in that section.

Location

Santa Fe County, New Mexico



Local office

New Mexico Ecological Services Field Office

(505) 346-2525
(505) 346-2542

2105 Osuna Road Ne
Albuquerque, NM 87113-1001

http://www.fws.gov/southwest/es/NewMexico/
http://www.fws.gov/southwest/es/ES_Lists_Main2.html

Endangered species

This resource list is for informational purposes only and does not constitute an analysis of project level impacts.

The primary information used to generate this list is the known or expected range of each species. Additional areas of influence (AOI) for species are also considered. An AOI includes areas outside of the species range if the species could be indirectly affected by activities in that area (e.g., placing a dam upstream of a fish population, even if that fish does not occur at the dam site, may indirectly impact the species by reducing or eliminating water flow downstream). Because species can move, and site conditions can change, the species on this list are not guaranteed to be found on or near the project area. To fully determine any potential effects to species, additional site-specific and project-specific information is often required.

Section 7 of the Endangered Species Act **requires** Federal agencies to "request of the Secretary information whether any species which is listed or proposed to be listed may be present in the area of such proposed action" for any project that is conducted, permitted, funded, or licensed by any Federal agency. A letter from the local office and a species list which fulfills this requirement can **only** be obtained by requesting an official species list from either the Regulatory Review section in IPaC (see directions below) or from the local field office directly.

For project evaluations that require USFWS concurrence/review, please return to the IPaC website and request an official species list by doing the following:

1. Draw the project location and click CONTINUE.
2. Click DEFINE PROJECT.
3. Log in (if directed to do so).
4. Provide a name and description for your project.
5. Click REQUEST SPECIES LIST.

Listed species[1] are managed by the Ecological Services Program of the U.S. Fish and Wildlife Service.

1. Species listed under the Endangered Species Act are threatened or endangered; IPaC also shows species that are candidates, or proposed, for listing. See the listing status page for more information.

The following species are potentially affected by activities in this location:

Mammals

NAME	STATUS
New Mexico Meadow Jumping Mouse *Zapus hudsonius luteus* This species only needs to be considered if the following condition applies: • If project affects dense herbaceous riparian vegetation along waterways (stream, seep, canal/ditch). There is **final** critical habitat for this species. Your location is outside the critical habitat. https://ecos.fws.gov/ecp/species/7965	Endangered

Birds

NAME	STATUS
Mexican Spotted Owl *Strix occidentalis lucida* There is **final** critical habitat for this species. Your location is outside the critical habitat. https://ecos.fws.gov/ecp/species/8196	Threatened
Southwestern Willow Flycatcher *Empidonax traillii extimus* There is **final** critical habitat for this species. Your location is outside the critical habitat. https://ecos.fws.gov/ecp/species/6749	Endangered
Yellow-billed Cuckoo *Coccyzus americanus* There is **proposed** critical habitat for this species. Your location is outside the critical habitat. https://ecos.fws.gov/ecp/species/3911	Threatened

Critical habitats

Potential effects to critical habitat(s) in this location must be analyzed along with the endangered species themselves.

THERE ARE NO CRITICAL HABITATS AT THIS LOCATION.

Migratory birds

Certain birds are protected under the Migratory Bird Treaty Act[1] and the Bald and Golden Eagle Protection Act[2].

Any activity that results in the take (to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct) of migratory birds or eagles is prohibited unless authorized by the U.S. Fish and Wildlife Service[3]. There are no provisions for allowing the take of migratory birds that are unintentionally killed or injured. Any person or organization who plans or conducts activities that may result in the take of migratory birds is responsible for complying with the appropriate regulations and implementing appropriate conservation measures, as described below.

1. The Migratory Birds Treaty Act of 1918.
2. The Bald and Golden Eagle Protection Act of 1940.
3. 50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

Additional information can be found using the following links:

- Birds of Conservation Concern http://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php
- Measures for avoiding and minimizing impacts to birds http://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures.php
- Nationwide conservation measures for birds http://www.fws.gov/migratorybirds/pdf/management/nationwidestandardconservationmeasures.pdf

The birds listed below are birds of particular concern either because they occur on the USFWS Birds of Conservation Concern (BCC) list or are known to have particular vulnerabilities in your project location. To learn more about the levels of concern for birds on your list, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your specific project area. To see maps of where birders and the general public have sighted birds in and around your project area, visit E-bird tools such as the E-bird data mapping tool (search for the scientific name of a bird on your list to see specific locations where that bird has been reported to occur within your project area over a certain time-frame) and the E-bird Explore Data Tool (perform a query to see a list of all birds sighted in your county or region and within a certain time-frame). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list can be found below.

NAME	BREEDING SEASON
Bald Eagle Haliaeetus leucocephalus This is not a Bird of Conservation Concern (BCC), but is of concern in this area either because of the Eagle Act, or for potential susceptibilities in offshore areas from certain types of development or activities. https://ecos.fws.gov/ecp/species/1626	Breeds Mar 20 to Sep 15
Bendire's Thrasher Toxostoma bendirei This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9435	Breeds Mar 15 to Jul 31
Black Swift Cypseloides niger This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/8878	Breeds Jun 15 to Sep 10
Black-chinned Sparrow Spizella atrogularis This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9447	Breeds Apr 15 to Jul 31
Brewer's Sparrow Spizella breweri This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA https://ecos.fws.gov/ecp/species/9291	Breeds May 15 to Aug 10
Brown-capped Rosy-finch Leucosticte australis This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Jun 15 to Sep 15
Burrowing Owl Athene cunicularia This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA https://ecos.fws.gov/ecp/species/9737	Breeds Mar 15 to Aug 31
Chestnut-collared Longspur Calcarius ornatus This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds elsewhere

Golden Eagle Aquila chrysaetos — Breeds Apr 1 to Aug 31
This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA
https://ecos.fws.gov/ecp/species/1680

Gray Vireo Vireo vicinior — Breeds May 10 to Aug 20
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/8680

Lesser Yellowlegs Tringa flavipes — Breeds elsewhere
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/9679

Lewis's Woodpecker Melanerpes lewis — Breeds Apr 20 to Sep 30
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/9408

Long-billed Curlew Numenius americanus — Breeds Apr 1 to Jul 31
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/5511

Long-eared Owl asio otus — Breeds Mar 1 to Jul 15
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/3631

Marbled Godwit Limosa fedoa — Breeds elsewhere
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/9481

Mountain Plover Charadrius montanus — Breeds Apr 15 to Aug 15
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/3638

Olive-sided Flycatcher Contopus cooperi — Breeds May 20 to Aug 31
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/3914

Pinyon Jay Gymnorhinus cyanocephalus — Breeds Feb 15 to Jul 15
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/9420

Rufous Hummingbird selasphorus rufus — Breeds elsewhere
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.
https://ecos.fws.gov/ecp/species/8002

Willet Tringa semipalmata — Breeds elsewhere
This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Willow Flycatcher Empidonax traillii — Breeds May 20 to Aug 31
This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA
https://ecos.fws.gov/ecp/species/3482

Probability of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds.

Probability of Presence (■)

Each green bar represents the bird's relative probability of presence in your project's counties during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

To see a bar's probability of presence score, simply hover your mouse cursor over the bar.

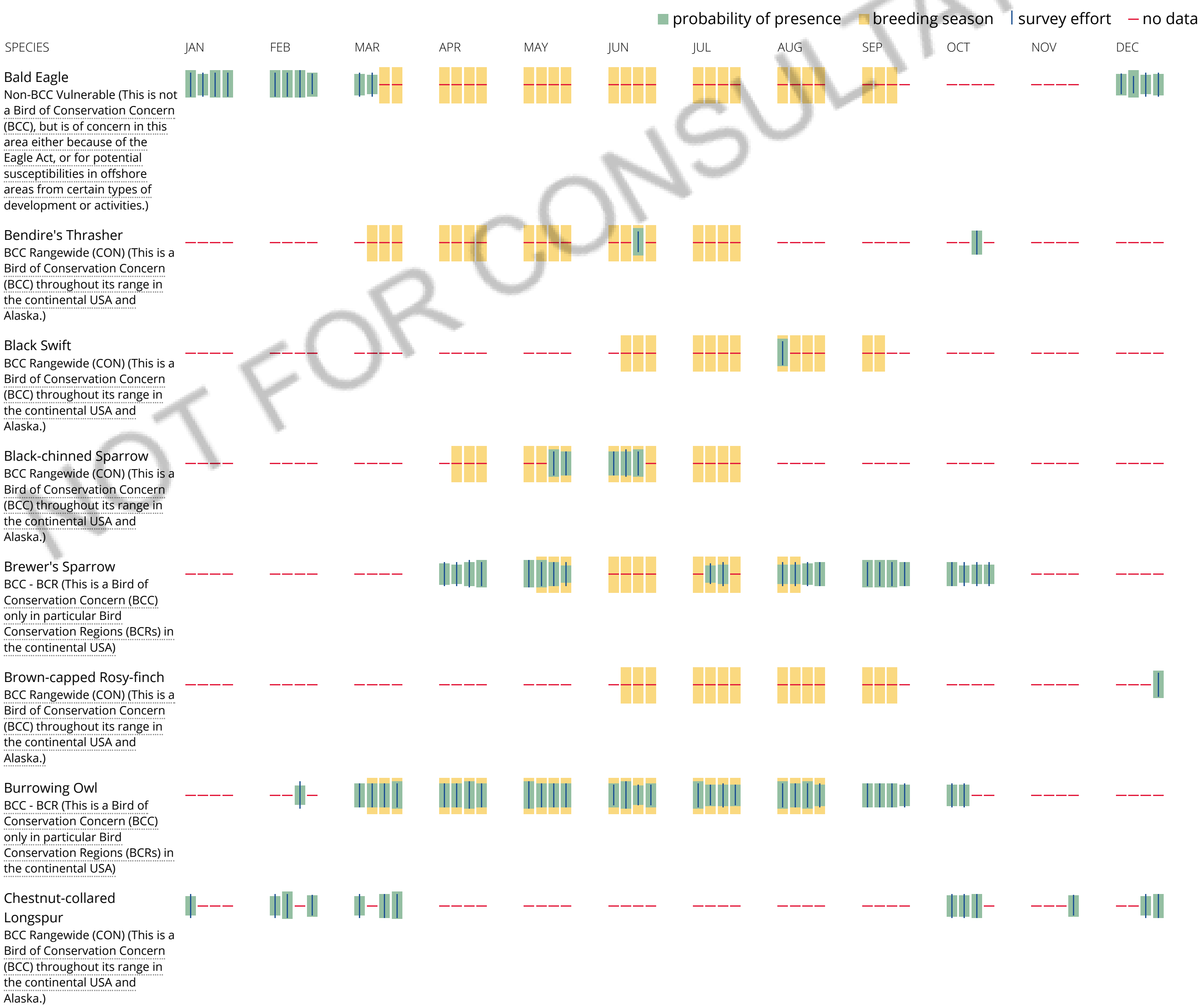
Breeding Season ( )
Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

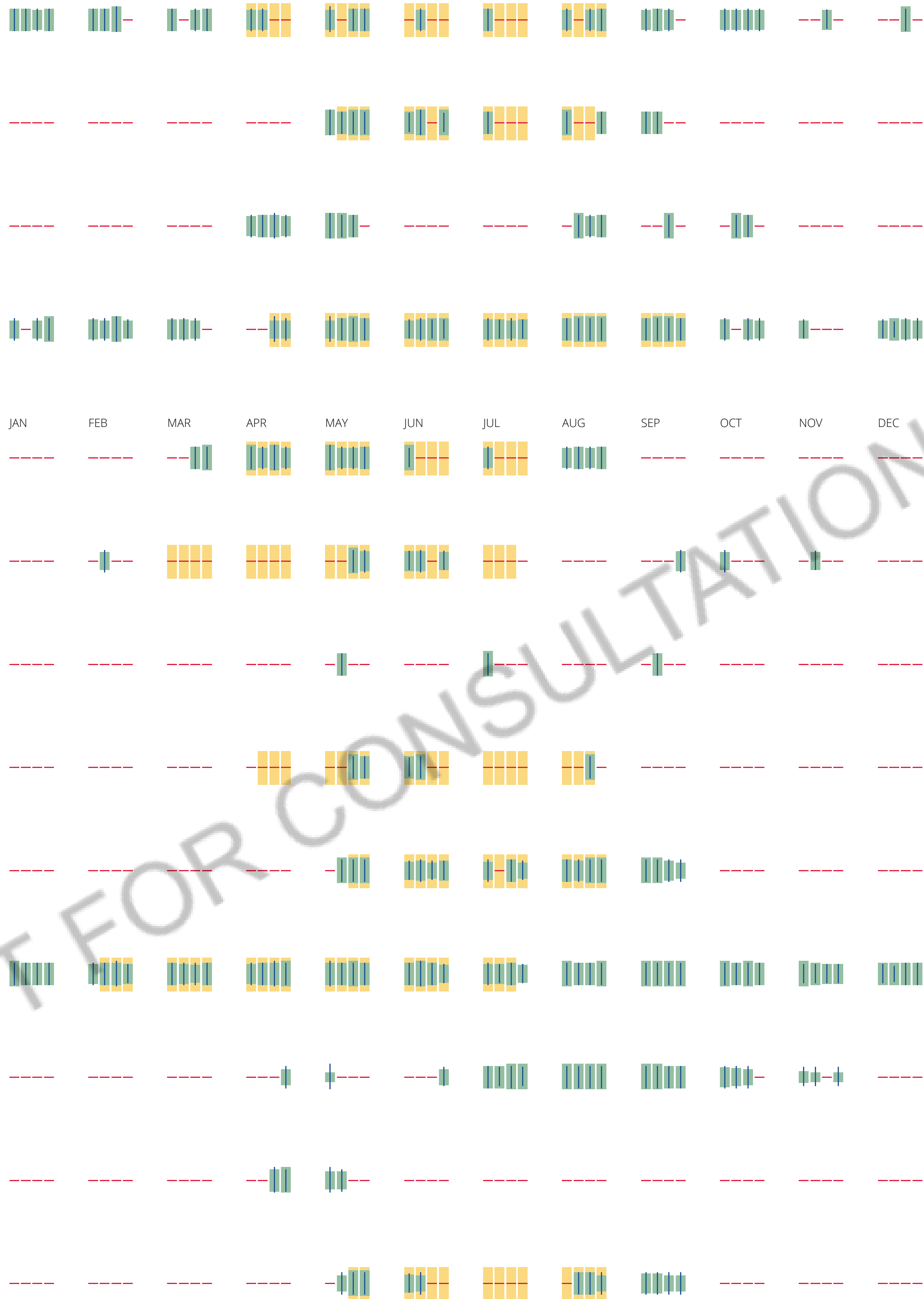
Survey Effort (|)
Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the counties of your project area. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

To see a bar's survey effort range, simply hover your mouse cursor over the bar.

No Data (–)
A week is marked as having no data if there were no survey events for that week.

Survey Timeframe
Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information.





Golden Eagle
BCC - BCR (This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA)

Gray Vireo
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Lesser Yellowlegs
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Lewis's Woodpecker
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Long-billed Curlew
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Long-eared Owl
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Marbled Godwit
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Mountain Plover
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Olive-sided Flycatcher
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Pinyon Jay
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Rufous Hummingbird
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Willet
BCC Rangewide (CON) (This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.)

Willow Flycatcher
BCC - BCR (This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA)

Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Such measures are particularly important when birds are most likely to occur in the project area. To see when birds are most likely to occur in your project area, view the Probability of Presence Summary. Special attention should be made to look for nests and avoid nest destruction during the breeding season. The best information about when birds are breeding can be found in Birds of North America (BNA) Online under the "Breeding Phenology" section of each species profile. Note that accessing this information may require a subscription. Additional measures and/or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the migratory birds potentially occurring in my specified location?

The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) that might be affected by activities in your project location. These birds are of priority concern because it has been determined that without additional conservation actions, they are likely to become candidates for listing under the Endangered Species Act (ESA).

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets. The AKN list represents all birds reported to be occurring at some level throughout the year in the counties in which your project lies. That list is then narrowed to only the Birds of Conservation Concern for your project area.

Again, the Migratory Bird Resource list only includes species of particular priority concern, and is not representative of all birds that may occur in your project area. Although it is important to try to avoid and minimize impacts to all birds, special attention should be made to avoid and minimize impacts to birds of priority concern. To get a list of all birds potentially present in your project area, please visit the E-bird Explore Data Tool.

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?

The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets.

Probability of presence data is continuously being updated as new and better information becomes available.

How do I know if a bird is breeding, wintering, migrating or present year-round in my project area?

To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may refer to the following resources: The The Cornell Lab of Ornithology All About Birds Bird Guide, or (if you are unsuccessful in locating the bird of interest there), the Cornell Lab of Ornithology Neotropical Birds guide. If a bird entry on your migratory bird species list indicates a breeding season, it is probable the bird breeds in your project's counties at some point within the time-frame specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?

Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Avoidance and minimization measures should be implemented to reduce impacts to birds on your list, and all other birds that may occur in your project area. Nationwide Standard Conservation Measures can be applied for any project, regardless of project type or location.

If measures exist that are specific to your activity or to any of the species on your list that are confirmed to exist at your project area, these should also be considered for implementation in addition to the Nationwide Standard Conservation Measures. Implementation of avoidance and minimization measures is particularly important for BCC birds of rangewide concern.

If your project has the potential to disturb or kill eagles, you will need to obtain a permit to avoid violating the BGEPA should such impacts occur.

Details about birds that are potentially affected by offshore projects

For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

Facilities

Wildlife refuges and fish hatcheries

REFUGE AND FISH HATCHERY INFORMATION IS NOT AVAILABLE AT THIS TIME

Wetlands in the National Wetlands Inventory

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

This location overlaps the following wetlands:

FRESHWATER POND

PUB

RIVERINE

R4SBC
R5UBH

A full description for each wetland code can be found at the National Wetlands Inventory website: https://ecos.fws.gov/ipac/wetlands/decoder

Data limitations

The Service's objective of mapping wetlands and deepwater habitats is to produce reconnaissance level information on the location, type and size of these resources. The maps are prepared from the analysis of high altitude imagery. Wetlands are identified based on vegetation, visible hydrology and geography. A margin of error is inherent in the use of imagery; thus, detailed on-the-ground inspection of any particular site may result in revision of the wetland boundaries or classification established through image analysis.

The accuracy of image interpretation depends on the quality of the imagery, the experience of the image analysts, the amount and quality of the collateral data and the amount of ground truth verification work conducted. Metadata should be consulted to determine the date of the source imagery used and any mapping problems.

Wetlands or other mapped features may have changed since the date of the imagery or field work. There may be occasional differences in polygon boundaries or classifications between the information depicted on the map and the actual conditions on site.

Data exclusions

Certain wetland habitats are excluded from the National mapping program because of the limitations of aerial imagery as the primary data source used to detect wetlands. These habitats include seagrasses or submerged aquatic vegetation that are found in the intertidal and subtidal zones of estuaries and nearshore coastal waters. Some deepwater reef communities (coral or tuberficid worm reefs) have also been excluded from the inventory. These habitats, because of their depth, go undetected by aerial imagery.

Data precautions

Federal, state, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, state, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate federal, state, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

Critical Habitat for Threatened & Endangered Species [USFWS]

A specific geographic area(s) that contains features essential for the conservation of a threatened or endangered species and that may require special management and protection.

U.S. Fish and Wildlife Service | Bureau of Land Management, Texas Parks & Wildlife, Esri, HERE, Garmin, INCREMENT P, Intermap, USGS, METI/NASA, EPA, USDA

APPENDIX C

Regulatory Correspondence

State of New Mexico
ENVIRONMENT DEPARTMENT
Drinking Water Bureau
525 Camino de los Marquez, Suite 4
Santa Fe, New Mexico 87505-1816
Telephone (505) 827-7536
Fax (505) 827-7545

BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

DERRITH WATCHMAN-MOORE
DEPUTY SECRETARY

ANNE MARIE ORTIZ
DIRECTOR

February 8, 2005

Chupadero MDWCA
Mr. Jack Miller, Operator
RT 4 P.O. Box 60A (01 AB-S RD SF)
Santa Fe, New Mexico 87506

RE: **Well #3, Violation of the Maximum Contaminant Level (MCL) for Gross Alpha**
Well #3, Advisory for Uranium MCL for Federal Safe Drinking Water Act Regulations or Future State Drinking Water Regulations Uranium MCL (Effective Enforcement Date of January, 2007)
Chupadero MDWCA, WSS #660-26

Dear Mr. Miller:

Pursuant to 20.7.10.100 NMAC of the New Mexico Drinking Water Regulations (NMDWR), which incorporates federal regulation 40 CFR §141.15(b), indicates that the Chupadero MDWCA exceeded the MCL of 15.0 pCi/L for gross alpha particle activity (including Radium 226 but excluding radon and uranium) for Well #3 in their drinking water. This was based on an annual composite baseline water sample consisting of four (4) consecutive quarterly sampling events during 2004. This was for the system's new well put on-line back on January 14, 2005 by the Drinking Water Bureau (DWB) staff's site visit.

The Chupadero MDWCA water system's Well #3 had a final laboratory result of 19.518 pCi/L for gross alpha particle activity calculations pursuant to a final laboratory report completed on January 10, 2005 and received by the DWB oversight staff on February 3, 2005. The final gross alpha particle activity result is due to the natural occurring radioactive decay process that is primarily present from the Uranium element found in underlying basement igneous and metamorphic rocks, formations and volcanic tuff of the immediate Nambe, Pojoaque and Tesuque areas.

The Uranium mass concentrations detected in the drinking water from Well #3 was reported at 53.50 ug/L when compared with the current federal drinking water standard of 30 ug/L. The actual State Drinking Water Regulations for the Uranium MCL of 30 ug/L will be effective in 2007. This will allow State Drinking Water Programs to complete their regulatory compliance requirements for the standardized monitoring framework for radionuclides effectively from January 1, 2004 through December 31, 2006 for all applicable regulated water systems and work with systems on corrective action plans.

Pursuant to 20.7.10.100 NMAC of the New Mexico Drinking Water Regulations (NMDWR), which incorporates federal regulation 40 CFR §141.201, the Chupadero MDWCA water system must now post **Public Notice** for exceeding the MCL running annual average composite result in 2004 for gross alpha particle activity in Well #3 (according to the State's laboratory chain of custody). The public notification also includes information for the elevated Uranium mass concentrations. Enclosed is a Public Notice for your use. Please make the necessary changes to the Public Notice and comply with the notification requirements. The water system is also required to sign the public notice and return a copy to the Department.

The water systems Well #3 will remain on quarterly monitoring by the DWB for radionuclides for as long as the gross alpha MCL exists and due to the elevated Uranium mass concentrations (future State Drinking Water Standard MCL in 2007) for this active well. The water system has received funding to drill and install a new Well #4 by this spring. This well is being installed due to the lack of water production at the Well #3. The water system is also now faced unfortunately with elevated drinking water results for radionuclides. This was based on the recently made available aforementioned laboratory results for an annual "baseline" composite sampling event that occurred in consecutive quarters of 2004.

As required, the State DWB staff is always available toward assisting the water system on a possible corrective action plan for fixing their current water quality issues of radionuclides at Well #3 or other possible options. If you have any further questions, please contact me at our toll free number 1-877-654-8720, or at (505) 827-7536, extension 1026 or email at chris_serazio@nmenv.state. nm.us.

Sincerely,

Chris Serazio

Chris Serazio
Environmental Specialist
District II, System Oversight
NMED Drinking Water Bureau

Enclosure: Public Notice for Gross Alpha Particle Activity and Uranium Information
Radionuclides Rule Fact Sheet Reference Guide

CC: Michael Huber, Manager, DWB-DII
Joe Chavez, Sampling Manger, DWB
Santa Fe Field Office
Central File
System File

NMED
New
Mexico
Environment
Department

SANITARY SURVEY REPORT

For

Chupadero MDWCA
NM3566026

Este informe contiene información importante acerca de su agua potable.
Haga que alguien lo traduzca para usted, o hable con alguien que lo entienda.

Prepared by: Chris Cudia
New Mexico Environment Department
1190 St. Francis
PO Box 5469
Santa Fe, NM 87502-5469
505.476.8636

Date December 1, 2016

State of New Mexico
Environment Department
Water Protection Division
Drinking Water Bureau
1190 St Francis Drive
Santa Fe, NM 87505

RECORD OF INSPECTION

This Sanitary Survey Report fulfills the requirements of New Mexico Administrative Code 20.7.10.100 incorporating 40 Code of Federal Regulations 141.21(d) (ii) (2) and 142.16(o)(2) for completing a State approved survey. The information and data was prepared by Chris Cudia North Region Compliance Supervisor.

NMED APPROVING AUTHORITY: Chris Cudia Date: 12-1-16
Chris Cudia North Region Compliance Supervisor

Introduction

A sanitary survey enables the NMED Drinking Water Bureau Water (DWB) to provide a comprehensive and accurate review of the components of a water system, to assess the operating condition and adequacy of the water system, and to determine if past recommendations have been implemented effectively. The Sanitary Survey encompasses eight specific elements that are evaluated during the survey. Those eight elements are:

- Source (Protection, Physical Components, and Condition);
- Treatment
- Distribution System
- Finished Water Storage
- Pumps/Pump Facilities and Controls
- Monitoring/Reporting/Data Verification
- Water System Management/Operations
- Operator Compliance with State Requirements

Each element may not be specifically mentioned within this report, however, a significant deficiency or recommendation will be noted if any issues are discovered with any of these eight (8) elements.

As part of a sanitary survey the DWB conducted a site inspection of the Chupadero MDWCA water system on June 14, 2016. The site inspection was conducted by Chris Cudia, DWB North Region Compliance Supervisor and accompanied by Jack and Linda Miller, Chupadero MDWCA water system operator and administrative contacts. David Roybal, Major Domo for the local Acequia Association was also consulted during the Survey. In addition to the site inspection, DWB reviewed various operational, managerial, and financial documents submitted by the Chupadero MDWCA water system and conducted a review of DWB compliance files for the water system.

System Description

The Chupadero MDWCA water system has 56 service connections, serves approximately 131 year-round customers[1], and is classified as a Community Water System according to the New Mexico Drinking Water Regulations 20.7.10 NMAC. The water system consists of two wells (Well #2 & Well #4), a 20,000 gallon storage tank (Storage Tank #1) and distribution. Each well is metered individually. The tank floats in distribution and all distribution lines consists of PVC pipe.

Water from Wells 2 and 4 enters a meter pit before being delivered to the floating storage tank. During periods of high demand, water can be delivered to customers before supplying the tank. Pressure is reduced to 60 PSI with a single pressure reducing valve.

Survey Findings

Sanitary surveys serve as a proactive public health measure and can provide important information on a water system's design and operations, can identify minor and significant deficiencies for correction before they become major problems, and can improve overall system compliance. The following significant and minor deficiencies were identified during the sanitary survey.

[1] Pursuant to 20.7.10.9(A) NMAC; U.S. States Census Bureau indicates average persons per household in Santa Fe County (2010-2014) = 2.34. Water System reports 56 connections. (http://www.census.gov/quickfacts/table/HSD310214/35049).

SUSANA MARTINEZ
Governor

JOHN A. SANCHEZ
Lt. Governor

NEW MEXICO ENVIRONMENT DEPARTMENT

P.O. Box 5469
Santa Fe, NM 87502-5469
Tel. 505-476-8648 • Fax 505-222-1234
www.env.nm.gov

BUTCH TONGATE
Acting Cabinet Secretary

J. C. BORREGO
Acting Deputy Secretary

12/1/2016

Linda Miller
Chupadero MDWCA, NM3566026
01 Ab's Road
SANTA FE, NM 87506

RE: 2016 Sanitary Survey Report

Dear Linda Miller:

Enclosed is the Sanitary Survey Report for the Chupadero MDWCA water system, conducted on June 14, 2016 by Chris Cudia of the New Mexico Environment Department Drinking Water Bureau (DWB).

During the survey three (3) significant deficiencies were identified and one (1) recommendation was provided. Chupadero MDWCA water system must consult with the DWB within 30 days of the date of this letter and take corrective action on the three (3) significant deficiencies no later than 120 days after the date of this letter, or be in compliance with a DWB-approved schedule and plan for correcting these deficiencies within the same 120 day period. Failure to correct any significant deficiency will result in a treatment technique violation of NMAC 20.7.10.100 incorporating 40 C.F.R. 141 Subpart S.

If you have any questions or need additional clarification concerning this report please call 505-476-8648 or e-mail chris.cudia@state.nm.us.

Respectfully,

Chris Cudia, North Region Complaince Supervisor
Drinking Water Bureau
Water Protection Division

cc: Area Supervisor (electronic)
Chupadero MDWCA water system Area Office file
Electronic Central File

Significant Deficiencies:

A significant deficiency is defined as any deficiency that is causing or has the potential to cause a threat to public health [New Mexico Administrative Code (NMAC) 20.7.10.100 incorporating 40 Code of Federal Regulations (CFR) §141.403(a)(4)]. Water systems must consult with DWB within 30 days and take corrective action for any significant deficiencies found during the sanitary survey no later than 120 days after receiving written notification of such deficiencies, or be in compliance with a DWB-approved schedule and plan for correcting these deficiencies within the same 120 day period [NMAC 20.7.10.100 incorporating 40 CFR §141.403(a)(4) and §141.403(a)(5)(i)-(ii)]. Failure to remedy any significant deficiency will result in a treatment technique violation of NMAC 20.7.10.100 incorporating 40 CFR Part 141 Subpart S.

A total of three (3) significant deficiencies were identified at the Chupadero MDWCA water system during the survey.

1. ***Deficiency:*** **(004B) Inadequate or lack of Emergency Response Plan (ERP)**

Regulatory Citation: **40 CFR 141.403 (a)(4)**

Concern/Description: **Operation/Management.** Lack of an adequate Emergency Plan could lead to extended delays in supplying safe potable drinking water during minor or major emergencies. Public Water Systems that assess their vulnerabilities and adopt thorough emergency response plans are minimizing the likelihood of major delays in supplying safe and potable drinking water to their customers.

Corrective Action: Submit adequate Emergency Response Plan specific to the Barranco MDWCA water system to DWB Compliance Officer.

2. ***Deficiency:*** **(004K) Inadequate Overflow Splash Pad.**

Regulatory Citation: **40 CFR 141.403(a)(4)**

Concern/Description: **Finished Water Storage.** Erosion of the facility site can result in a collapse of storage facilities which can cause a water outage.

Corrective Action: Implement erosion control measures to mitigate erosion at the storage facility. (See Figures 1 & 2).

Figure 1. Significant Deficiency #2. Erosion near storage tank facility.

Figure 2. Significant Deficiency #2. Erosion near storage facility.

3. Deficiency **(001S) Inadequate Site Security at storage facility**

Regulatory Citation: 20.7.10.400.D NMAC

Concern/Description: Unauthorized access can result in water system being contaminate and key components being compromised which could result in a water Outage.

Corrective Action: Reinstall/repair breaks in the perimeter fence around the storage tank. (See Figure 3)

Figure 3. Significant Deficiency #3. Perimeter fence at storage tank is down.

Minor Deficiencies:

The following are minor deficiencies which DWB recommends be corrected before the next sanitary survey to ensure the deficiencies do not become significant.

1. ***Deficiency:*** Brush Growing Around Foundation of Storage Tank

   Recommendation: Remove vegetation (Siberian Elm) from around the storage tank. Vegetation could compromise the integrety of the tank foundation and the tank. See Figure 4.

Figure 4. Siberian Elm and other woody plants should be cleared from around the tank to maintain the structural integrity of the facility.

Conclusion

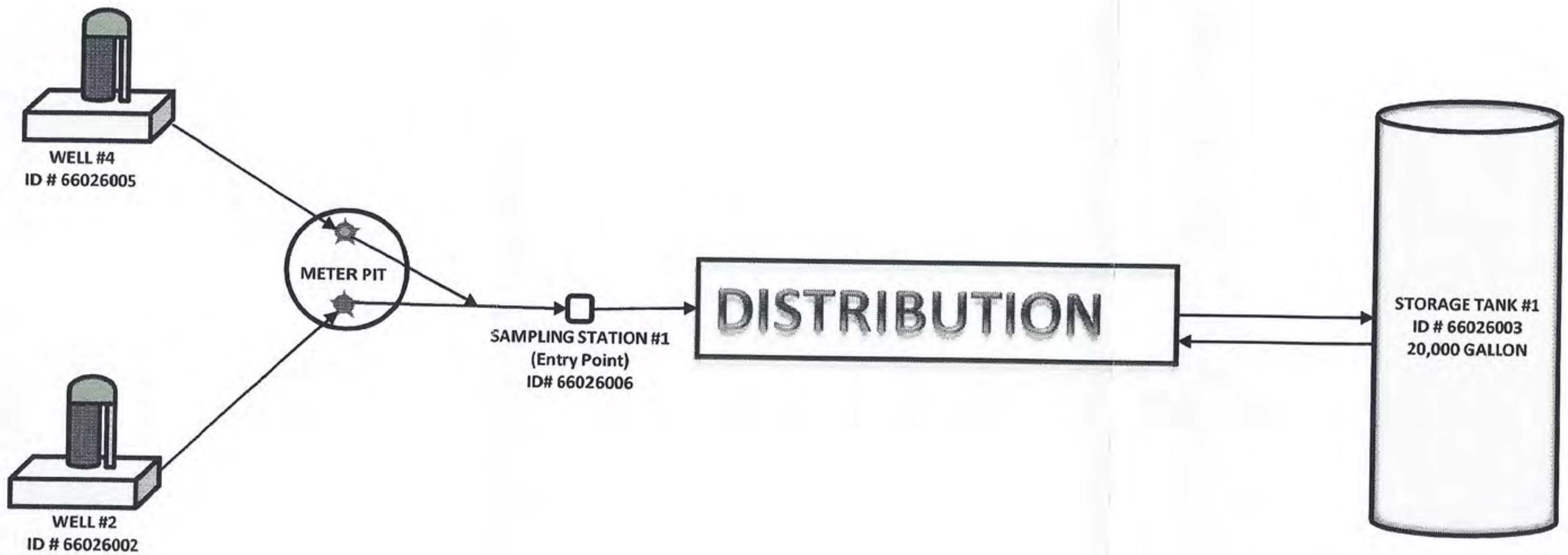
The sanitary survey for the Chupadero MDWCA water system was completed on June 14m, 2016. Based upon the onsite inspection and review of various operational and managerial documents and of DWB compliance files, three (3) significant deficiencies were identified and one (1) minor deficiencies was identified. The Chupadero MDWCA water system must comply with the following in the correction of these deficiencies.

- Upon receipt of this report, the Chupadero MDWCA water system must consult with the DWB within 30 days for all significant deficiencies (i.e., provide written documentation to DWB within 30 days of receipt of this report stating how and when each significant deficiency will be addressed).
- Failure to consult with DWB within 30 days on all significant deficiencies will result in a monitoring and reporting violation of NMAC 20.7.10.100 incorporating 40 CFR Par 141 Subpart S.
- The Chupadero MDWCA water system must take corrective action on all significant deficiencies no later than 120 days after receiving written notification of such deficiencies, OR be in compliance with a DWB approved schedule and plan for correcting these deficiencies within 120 days.
- Failure to correct any significant deficiency in accordance with the previous bullet will result in a treatment technique violation of NMAC 20.7.10.100 incorporating 40 CFR Part 141 Subpart S.

- In addition, the Chupadero MDWCA must provide written documentation to the DWB within 30 days of completing corrective action for each significant deficiency. Failure to submit documentation within 30 days will result in a monitoring and reporting violation of NMAC 20.7.10.100 incorporating 40 CFR Part 141 Subpart S.

If you have any questions or need additional clarification concerning this report please call 505-476-8636 or e-mail chris.cudia@state.nm.us.

NMED - Drinking Water Bureau
System Schematic
CHUPADERO MDWCA
NM 3566026



APPENDIX D

Financial Information

Chupadero Water and Sewage Corp
Profit & Loss
January through December 2017

		Jan - Dec 17
Ordinary Income/Expense		
Income		
Water bills		23,944.75
Total Income		23,944.75
Expense		
Advertising		55.09
Bank charges		124.85
Corporate filing fees		30.00
Dues		135.00
Insurances		
Insurance	3,064.00	
Total Insurances		3,064.00
Locates		489.54
Materials		27.68
Meter replacements		
Labor	44,255.37	
Materials & Rentals	1,498.04	
Total Meter replacements		45,753.41
Office expenses		
Bookkeeping	5,392.80	
Office supplies	426.66	
PO Box rental	86.00	
Postage	198.72	
Total Office expenses		6,104.18
Operations $ Maintenance		
CCR report	267.50	
Repairs	660.00	
Water master	5,392.80	
Total Operations $ Maintenance		6,320.30
Professional fees		
Lawyer	1,962.58	
Total Professional fees		1,962.58
Software support		105.44
System Maintenance		80.00
Utilities		
Electricity	1,830.61	
Total Utilities		1,830.61
Total Expense		66,082.68
Net Ordinary Income		-42,137.93
Other Income/Expense		
Other Income		
Interest		7.62
Transfer fee		500.00
Total Other Income		507.62
Net Other Income		507.62
Net Income		-41,630.31

MDWCA Name: Chupadero Water-Sewage Corp
Mailing Address: PO Box 24051 Santa Fe NM 87502
Email Address: afcwa@msn.com
Phone number: 505-490-2128

Calendar Year
2017

	APPROVED BUDGET	1st QR: Jan - Mar	2nd QR: Apr - Jun	3rd QR: Jul - Sept	4th QR: Oct -Dec	Year to Date(YTD) Totals	YTD (over)/under BUDGET	% of Budget
Beginning balances: Cash	11,267							
Savings	51,341							
CDs								
Investments								
Beginning Balance TOTAL	$ 62,608							
REVENUES								
Water Sales (Water Use Fees)	24,833	4,922	6,059	7,876	5,088	23,945	888	96%
Connection/Reconnection Charges	500	500				500	0	100%
Membership and Meter Sales (Utility Service Fees)						0	0	-
Late Fees and Penalties (Other Fines and Forfeits)						0	0	-
Gross Receipts Tax (Other State shared taxes)						0	0	-
Other Operating Revenue (miscellaneous - other)	12	3	3	2	1	8	4	66%
TOTAL	$ 25,345	5,424	6,062	7,878	5,089	24,453	892	96%
EXPENDITURES								
Salaries - Operator, Bookkeeper, etc.						0	0	-
Employee Benefits and Expenses						0	0	-
Electricity	1,800	442	369	522	498	1,831	(31)	102%
Other Utilities - Gas, Water, Sewer, Telephone						0	0	-
System Parts and Supplies	1,200	28		1,168		1,195	5	100%
System Repairs and Maintenance	4,268	904	440	39,116	4,704	45,164	(40,896)	1058%
Vehicle Expenses						0	0	-
Office and Administrative Expenses	1,387	325	87	404		817	571	59%
Professional Services - Accounting, Engineering, Legal	12,600	2,696	2,964	4,156	3,199	13,016	(416)	103%
Insurance	3,255			1,761	1,303	3,064	191	94%
Dues, Fees, Permits and Licenses	155	135	30			165	(10)	106%
Taxes - Gross Receipts Tax, Water Conservation Fee	180					0	180	0%
Training						0	0	-
Miscellaneous	25			591	231	822	(797)	3286%
Loans								
Annual debt service - Loan 1						0	0	-
Annual debt service - Loan 2						0	0	-
TOTAL	$ 24,870	4,531	3,890	47,717	9,935	66,073	(41,203)	266%
Ending Balance	63,083					20,987		
LESS:Operating Reserve	11,000					11,000		
Emergency Reserve	11,000					11,000		
Capital Improvement Reserve	40,000					40,000		
Debt Reserve								
Ending Available Cash Balance	$ 1,083					$ (41,013)		

I HEREBY CERTIFY THE CONTENTS IN THIS REPORT ARE TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND THAT THIS REPORT DEPICTS ALL FUNDS.

Linda Miller
President/Chairperson

1/3/2017
Date

Name: Chupadero Water-Sewage Corp.
Mailing Address: PO Box 24051
Email Address: afcwa@msn.com
Phone number: 505-490-2128

Calendar Year
2018

	APPROVED BUDGET	1st QR: Jan - Mar	2nd QR: Apr - Jun	3rd QR: Jul - Sept	4th QR: Oct -Dec	Year to Date(YTD) Totals	YTD (over)/under BUDGET	% of Budget
Beginning balances: Cash	5,000							
Savings	14,438							
CDs								
Investments								
Beginning Balance TOTAL	$ 19,438							
REVENUES								
Water Sales (Water Use Fees)	24,588					0	24,588	0%
Connection/Reconnection Charges	500					0	500	0%
Membership and Meter Sales (Utility Service Fees)						0	0	-
Late Fees and Penalties (Other Fines and Forfeits)						0	0	-
Gross Receipts Tax (Other State shared taxes)						0	0	-
Other Operating Revenue (miscellaneous - other)	50,000					0	50,000	0%
TOTAL	$ 75,088	-	-	-	-	-	75,088	0%
EXPENDITURES								
Salaries - Operator, Bookkeeper, etc.						0	0	-
Employee Benefits and Expenses						0	0	-
Electricity	1,900					0	1,900	0%
Other Utilities - Gas, Water, Sewer, Telephone						0	0	-
System Parts and Supplies	2,000					0	2,000	0%
System Repairs and Maintenance	3,000					0	3,000	0%
Vehicle Expenses						0	0	-
Office and Administrative Expenses	1,000					0	1,000	0%
Professional Services - Accounting, Engineering, Legal	12,600					0	12,600	0%
Insurance	3,300					0	3,300	0%
Dues, Fees, Permits and Licenses	160					0	160	0%
Taxes - Gross Receipts Tax, Water Conservation Fee	200					0	200	0%
Training						0	0	-
Miscellaneous	50,000					0	50,000	0%
Loans								
Annual debt service - Loan 1						0	0	-
Annual debt service - Loan 2						0	0	-
TOTAL	$ 74,160	-	-	-	-	-	74,160	0%
Ending Balance	20,366					19,438		
LESS:Operating Reserve	5,000							
Emergency Reserve	10,000							
Capital Improvement Reserve	5,000							
Debt Reserve								
Ending Available Cash Balance	$ 366					$ 19,438		

I HEREBY CERTIFY THE CONTENTS IN THIS REPORT ARE TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND THAT THIS REPORT DEPICTS ALL FUNDS.

Renee Roybal
President/Chairperson

11/9/2017
Date

APPENDIX E

JSAI Hydrogeologic Evaluation

February 20, 2018

Jerry A. May, P.E., Principal
Martin/Martin, Inc., Consulting Engineers
5353 Wyoming Blvd. NE, Suite 2A
Albuquerque, New Mexico 87109
jmay@martinmartin.com

Re: Hydrogeologic evaluation for Chupadero Water & Sewage Corporation (CWSC)

Dear Jerry:

John Shomaker & Associates, Inc. (JSAI) has performed a review of "Hydrogeologic Survey of Chupadero Area" by Daniel B. Stephens & Associates, Inc. (DBSA) completed on June 22, 2016 and provided to JSAI in November of 2017. The objective of the DBSA (2016) memo was to give Santa Fe County and the Chupadero Water & Sewage Corporation (CWSC) scientific information to make decisions regarding the location of a future water supply well considering hydrogeologic conditions in the CWSC service area.

Supplemental Information

Supplemental data were provided on January 2, 2018 that changed the conclusions of the above DBSA (2016) report. The supplemental information consisted of the following:

1. "Water System Analysis & Water Rights Valuation" of the CWSC completed in 2013 for Santa Fe County by Southwest Water Consultants.
2. "Supply Well Construction Specification Standard" with a proposed well diagram approved by a NM-licensed Professional Engineer on August 2, 2017.
3. New Mexico Environmental Department (NMED) "Notice of Violation and Public Notice Advisory" dated February 8, 2005 concerning gross alpha and uranium concentration results from CWSC Well 3.
4. Well Records for CWSC Wells 3 and 4, and water well meter readings for these wells for the period 2005-2014.
5. "Well Installation Report" dated February 21, 2014, concerning the borehole completion, well construction, and pumping tests for CWSC Well 3 performed in 2003.
6. Correspondence between Martin/Martin and Santa Fe County detailing a revised recommended well location for CWSC.
7. Three maps detailing the new chosen CWSC well site at the Jiminez property, and a hand-drawn DBSA cross-section sketch centered on this property dated May 25, 2017.
8. CWSC "Service Area Map" dated February 18, 2013.

Review

The DBSA (2016) memo is limited primarily due to the limited scope of study, which includes the lack of water-quality data, and the lack of integration of supplemental information listed above. The memo summarizes data for domestic wells on file with New Mexico Office of the State Engineer (NMOSE) and concludes that the ideal well site for CWSC lies in thicker sequences of the Tesuque Formation to the south and west of the Village of Chupadero. However, significant data gaps exist, and the data available through NMOSE are not extremely reliable and should be interpreted cautiously as the memo states.

The DBSA (2016) memo did not include a comprehensive evaluation of local water-quality results. Additional water-quality data for Chupadero wells, and not contained in the DBSA (2016) memo, are contained in Johnson et al. (2008), the NMED (2018), and contained in Manning (2008). These omissions are problematic, as groundwater with elevated uranium concentrations has been documented in the area, and CWSC Wells 1 and 3 are currently not utilized due to elevated fluoride and uranium. An NMED letter dated February 8, 2005 indicates that the relatively deep completion of CWSC Well 3 sources uranium "found in underlying igneous and metamorphic rock (…) of the Tesuque area."

Elevated uranium concentrations have also been documented for the Vista Redonda Subdivision, located about a quarter-mile south of the Village of Chupadero (NMED, 2018). Elevated uranium concentrations in the Tesuque aquifer have been attributed to the granite bedrock (Johnson et al., 2008), volcanic ash layers in the aquifer (McQuillan and Montes, 1998), and oxidation of sulfide minerals (McQuillan et al., 2010). McQuillan et al. (2010) also suggested that uranium concentrations tend to be higher near the mountain front where deeper groundwater is close to the surface and recharge waters are ephemeral and scarce. There is some documentation suggesting that wells completed deeper in the Tesuque Formation in the area may have higher average uranium concentrations. However, uranium concentrations can vary considerably within individual wells in the area, depending on factors including the age of the well, declining well efficiency, sampling protocol, and how the well is (and has been) operated in terms of pumping rates and durations (JSAI, 2013).

The DBSA (2016) study aimed to select a location for a future water supply well based on the following criteria: "maximize saturated thickness of the aquifer," "maximize the coarsest sediments," and "maximize the distance from the nearest fault(s)." The DBSA (2016) study utilized NMOSE domestic Well Records to gain an understanding of the sediments coarseness and by proxy possible well yields; however, drillers' logs submitted with domestic Well Records should be interpreted cautiously, as they may not provide adequate detail or accuracy to provide reliable information on coarseness of sediments. The DBSA (2016) memo concluded that "well sites located in the western parts of the study area will … penetrate the greatest saturated thickness" (p. 12) and western and southern areas the "greatest thicknesses" of "saturated coarse-grained aquifer materials" (p. 11), where "lesser to no indication of faulting" and "higher reported production capacities" (p. 12) are found. JSAI generally agrees, and in addition, would caution that deeper wells completed near the base of the Tesuque Formation should also be avoided as water quality near the bedrock is problematic. The DBSA (2016) memo favored a hilltop site in close proximity to the Vista Redonda Wells 4 and 7; however, JSAI would not recommend a new CWSC well in this location, as the greater depth to water would add to drilling costs, and fail to consider potential well interference and drawdown effects from nearby Vista Redonda wells. In addition, Vista Redonda might be expected to protest.

Lack of available saturated thickness and potentially low specific capacity are problematic for the three CWSC-proposed sites described in the DBSA (2016) memo. Additionally, the DBSA (2016) memo fails to point out that based on a design pumping rate of about 20 gallons per minute (gpm) and conservative specific capacity of 0.10 gpm/ft (based on CWSC Well 3), drawdown could be in excess of 200 ft. If a 200-ft vertical buffer is to be maintained above bedrock due to water-quality issues, and a 300-ft screen interval is desired for the well (DBSA proposed well diagram dated 8/2/2017; and pumping water levels are to be maintained above the screen interval), a location with Tesuque Formation saturated thickness greater than 700 ft would be needed. The three CWSC proposed sites do not meet this criterion; locally as little as 100 ft saturated thickness may be available due to a geologically complex basin accommodation zone (Koning and Read, 2010). A well completed at any of the three above mentioned CWSC proposed sites would also likely have unacceptable water-quality parameters as these areas intercept very little recharge, and likely have elevated uranium, fluoride, or arsenic concentrations (cf. Manning, 2008). The well would likely also experience the effects of regional groundwater declines, exacerbated by aquifer compartmentalization further reducing well yield and longevity.

Additional Information Considered: Basin Structure and Sediments

In the area of interest, a shallowing Española Basin is filled with sediments abutting the Sangre de Cristo Mountains, consisting mostly of granites. The basin is a half graben, and its eastern side is defined by thin Miocene-age Tesuque Formation consisting of red coarse-cemented sandstone and angular conglomerate with generally poor permeability. The aquifer becomes more fine-grained with depth and correspondingly hydraulic conductivity also decreases (Hearne, 1985; Borchert et al., 2003; Koning and Read, 2010).

Total Tesuque Formation thickness increases rapidly along the Rio Chupadero to the west according to Grauch et al. (2009), from about 400 ft in the northeastern part of the CWSC service area to about 1,000 ft in the southwestern part of the CWSC service area. The eastern two-thirds of the CWSC service area is structurally complex, characterized by an intra-basin bedrock uplift, a dozen closely spaced faults, an accommodation zone, and several folds, as well as total Tesuque Formation thicknesses of less than 700 ft. The western end of the CWSC service area is characterized by a monocline indicative of a rapidly thickening basin (>700 ft thick), and an area Grauch et al. (2009) characterized as "underlain by magnetic sediments," which are explained as likely indicating coarse-grain size, or less likely "magnetic lithic detritus, such as volcanic clasts."

Additional Information Considered: Well Completion Data and Aquifer Properties

Domestic wells completed locally in the Tesuque Formation have depths ranging from 12 to 950 ft based on wells in the NMOSE NMWRRS database (DBSA, 2016; table 1). These wells average 280 ft in depth, although since 2000, the average well depth has increased, possibly as a result of declining water levels, or possibly as a result of newer homes being developed on mesas away from riparian areas. Wells tend to be completed relatively shallow near the riparian areas as depths to water are shallow, ranging from 0 to 103 ft below ground level (bgl), and averaging 41 ft bgl (DBSA, 2016; table 1). Depth to water in all areas range up to 305 ft bgl, and average 110 ft bgl (200 ft bgl over the last 17 years; DBSA, 2016). Groundwater generally flows westward or northwestward in the study area.

Data on aquifer transmissivity for the Tesuque Formation are summarized in the DBSA memo (2016; table 2), but the transmissivity value for CWSC Well 3 is low for the area, 8 ft^2/day, compared with a local median value of 50 ft^2/day (DBSA, 2016). The Well 3 recovery curve of its constant-rate pumping test is characteristic of a fractured rock aquifer. The database compiled by DBSA (2016; table 2) almost exclusively consists of deep wells with depth to water exceeding 229 ft bgl. Shallow wells completed locally within the alluvium have reported transmissivities of 1,600 ft^2/day, whereas Tesuque Formation wells average 160 ft^2/day in the Pojoaque and Tesuque drainages (Koopman, 1975). Specific-capacity values range locally from 0.1 to 1.1 gallons per minute per foot (gpm/ft) of drawdown, with a median value of 0.42 gpm/ft (no shallow wells). CWSC Well 3 had a specific capacity of 0.10 gpm/ft of drawdown after 3 hours of pumping, and as DBSA (2016) points out, its location close to a fault is likely the reason for the excessive drawdown and limited saturated thickness.

Additional Information Considered: Groundwater Quality

Groundwater produced from the Tesuque Formation within the CWSC service area appears to be of poor to moderate quality based on water-quality data contained in NMED (1980). Johnson et al. (1980) and Manning (2008) contain additional water-quality results for the area some of which corroborate the 1980 published data, some of which include a better water quality for wells. Water-quality results for CWSC Well 3 (NMED letter dated February 8, 2005) list a uranium concentration of 0.0535 mg/L, and a gross alpha concentration of 19.52 pCi/L, both exceeding the current primary drinking water standards of the NMED/DWB. CWSC Well 1 water quality results from 1979 list arsenic, cadmium, fluoride, lead, uranium, and gross alpha concentrations that exceed the current NMED/DWB National Primary Drinking Water Regulations (Table 1); whereas, pH exceeds the National Secondary Drinking Water Regulations. The high pH suggests caustic groundwater that is corrosive to the well casing, which may be the reason for elevated metals such as cadmium and lead. See Table 1 for CWSC Well 1 water-quality data. CWSC Well 4 uranium concentrations reviewed online (NMED, 2018) range from 0.013 to 0.021 mg/L (2014-2015), or below the NMED/DWB standard.

Just south of the CWSC, the Vista Redonda MDWCA operates seven wells all of which, completed to depths between 405 and 950 ft bgl (and lying at elevations between 7,160 and 6,920 ft above mean sea level; amsl), have at times exceeded the uranium standards of the NMED/DWB. Uranium concentrations have generally varied from about 0.01 to 0.05 mg/L (JSAI, 2013). Water quality results for the nearby Rio En Medio community wells in NMED (1980) show no exceedance in any water-quality constituents, suggesting that these wells may not have the same problems or are taking in mostly surface water, which is almost certainly lower in pH and hence would ameliorate problems with deeper caustic groundwater, which are common in the Española Basin (e.g., Manning, 2008). Nothing is known about the Rio En Medio well completions, or whether these wells are still in existence.

JSAI also briefly reviewed potential contamination in the CWSC area associated with leaking underground petroleum storage tanks, landfills, and other sites. Based on a review of the NMED, Petroleum Storage Tank Bureau's (NMED, 2018) inventories of active leaking petroleum sites and no further action sites, accessed on January 2, 2018, there are no sites within a 1-mile radius of the CWSC service area.

Table 1. Summary of water-quality data, CWSC Well 1, Santa Fe County, New Mexico

constituent	unit	Chupadero Water & Sewage Corporation (CWSC) Well 1	NMED-DWB MCL standard
color	CU	5	15[a]
odor	TON	0	3[a]
surfactants	mg/L	<0.05	0.5[a]
pH	pH units	**8.65**	6.5 to 8.5[a]
hardness	mg/L	8	no standard
alkalinity	mg/L	216	no standard
bicarbonate	mg/L	248.2	no standard
carbonate	mg/L	7.8	no standard
specific conductance	µmhos/cm	497	no standard
total dissolved solids (TDS)	mg/L	271	500[a]
turbidity	NTU	4.6	5
chloride	mg/L	5.2	250[a]
fluoride	mg/L	**4.22**	2[a] to 4
nitrate	mg/L	0.02	10
nitrite	mg/L		1
sulfate	mg/L	26.7	250[a]
arsenic (total)	mg/L	**0.021**	0.010
barium	mg/L	<0.10	2.0
cadmium	mg/L	**0.015**	0.005
calcium	mg/L	3.2	no standard
chromium	mg/L	<0.005	0.1
iron	mg/L	<0.25	0.3[a]
lead	mg/L	**0.017**	0.015
magnesium	mg/L	0.0	no standard
manganese	mg/L	<0.05	0.05[a]
mercury	mg/L	-	0.002
potassium	mg/L	0.78	no standard
selenium	mg/L	<0.005	0.05
silver	mg/L	<0.005	no standard
sodium	mg/L	108.1	no standard
gross alpha	pCi/L	**40.6±2.7**	15
gross beta	pCi/L	22.4±3.8	50[b]
radium-226	pCi/L	<0.04	5 (combined)
radium-228	pCi/L	<1.0	

[a] - national secondary drinking water standard (non-enforceable guidelines)
[b] - NMED-DWB defined level below which the equivalent radiation is below EPA mandated radiation threshold of 4 mrem/year
[c] - not officially reported by laboratory due to QC problem, result is provisional
NMED-DWB MCL – NMED-Drinking Water Bureau maximum contaminant level

bold indicates exceedance of the MCL
mg/L - milligrams per liter
pCi/L - picoCuries per liter
CU – color unit
µmhos/cm – micromhos per centimeter

Additional Information Considered: Groundwater Availability and Declines

Water levels in U.S. Geological Survey (USGS) monitored wells in the area have declined between the 1960s and present, showing yearly changes of <10 ft, and an average decline of about 0.5 ft/yr over the period of record (see Fig. 1). JSAI (2013) documented average water-level declines of 0.4 to 2.2 ft/yr in the area. Long-term water-level declines are another reason that a future water-supply well for CWSC should be placed to take advantage of the greatest possible thickness of the Tesuque Formation within close proximity to areas of potential surface-water recharge. In contrast, areas of limited saturated thickness, and at higher elevations, distant from areas of recharge would only limit water production. Artesian conditions could locally be present in the Tesuque Formation aquifer.

Additional Information Considered: Assessment of Existing Wells

Some important observations can be made based on the CWSC well completions and the age of the CWSC wells. Available well completion data for CWSC wells are summarized in Table 2, along with average values for domestic wells in the area for comparison.

CWSC Well 1 with NMOSE file number RG-28780 and completion date 1977 has steel well casing that has likely corroded, resulting in the production of poor quality water. According to its NMOSE Well Record, it only has a 10-ft screen from 435 to 445 ft bgl, and according to your email of January 2, 2018, the CWSC has lost ownership of this well. Your email also suggests it's a "good producer," contrary to the SWC (2013) report, which lists "water quantity concerns," which could be caused by its short screen interval.

CWSC Well 2 data were not found, as the NMOSE file number (RG-45650) given in the SWC (2013) report is for another well. The SWC (2013) report gives CWSC Well 2's completion year as 1987, its NMOSE file number as RG-78029-S (amended), and a completion depth of 67 ft bgl. The NMOSE well database (table 1; DBSA, 2016) has only one well completed in 1987 (RG-47074), a well with steel casing, completed to 80 ft bgl with 20 ft of screen from 58 to 78 ft bgl and a depth to water of 28 ft bgl. This well is currently in service.

CWSC Well 3, a well with PVC casing, is completed to 530 ft bgl with 220 ft of screen and according to your email of January 2, 2018, was "not producing very well." The NMOSE Well Record, with file number RG-78029, indicates it was completed in 2003 with an estimated yield of 40 gpm. This well is not currently in service.

CWSC Well 4, with NMOSE file number RG-84262 (subsequently amended by the NMOSE to RG-78029-S2) has PVC casing, and was completed in 2005 to a depth of 300 ft bgl with screen from 220 to 280 ft bgl and a depth to water of 22 ft bgl. According to its NMOSE Well Record, the well produced 20 gpm when built. Currently, CWSC Wells 2 and 4 are the only wells in service to supply the CWSC system. Individual well efficiencies, or decreases in well efficiencies, for CWSC wells are unknown, and it is not known if well video surveys have ever been performed for any of these wells.

Table 2. Summary of available data for CWSC wells, Santa Fe County, New Mexico

well name	NMOSE file number	year completed	total depth (ft)	screen interval (ft bgl)	depth to water (ft bgl)	reported test yield / current yield (gpm)	reported specific capacity (gpm/ft)
CWSC Well 1 [1]	RG-28780	1977	445	435-445	17 (7/1977)	not operational	-
CWSC Well 2 [2,3]	RG-78029-S	1987	67 (?)	-	dry (2012)	- / 5 (?)	-
CWSC Well 3 [1]	RG-78029	2003	530	300-520	140 (4/2003)	40 / 22	0.10 (4/2003)
CWSC Well 4 [1]	RG-84262 (old) RG-78029-S2 (new)	2005	300	220-280	22 (2/2005)	20 / 3	-
average of domestic wells [2]	various	various	282	various	107	2 to 115 (average 22)	0.47 [4]

[1] NMOSE NMWRRS, 2018
[2] NMOSE listed domestic well within 1-mile radius (DBSA, 2016)
[3] SWC, 2013
[4] DBSA, 2016; table 2
CWSC - Chupadero Water & Sewage Corporation

ft/bgl - feet below ground level
gpm - gallons per minute
mg/L - milligrams per liter
gpm/ft - gallons per minute per foot of drawdown
NMOSE - New Mexico Office of the State Engineer

Recommendations

Local water-quality considerations are very important in locating potential well sites for a future water supply well for CWSC. A potential well location near the western end of the service area in the lower Chupadero valley, where depth to water is 50 ft bgl or less, and saturated thicknesses exceed 1,000 ft, has a greater likelihood of achieving acceptable water quality and a production capacity that averages 20 gpm. Regarding the conclusions reached in the revised DBSA (2016) report, JSAI generally agrees with siting the new CWSC well at the southwest corner of the Jiminez property (closest to the arroyo bottom); JSAI has the following (additional) recommendations:

1. As the Jiminez property is the preferred location for CWSC water supply (DBSA cross-section, 2016), JSAI suggests that a water-quality sample is collected from a well close to Jiminez property as an alternative to open-borehole zone water-quality sampling.

2. Drill an exploratory borehole to about 500 ft bgl where a final well design (total well depth and placement of screen interval) are based on the interpretation of lithologic and geophysical logs (and take into account an estimated specific capacity of 0.2 gpm/ft and about 100 ft of drawdown at 20 gpm).

3. Run geophysical logs in the open borehole, including temperature (logged down, first log run), caliper, spontaneous potential, resistivity (8", 16", 32", and 64"), neutron, sonic and gamma-ray logs.

4. Construct the well with PVC well casing and PVC factory-slot screen, rather than HSLA steel casing due to water-quality concerns.

5. Exploratory well drilling, well construction, and pumping tests should be supervised by an experienced Hydrogeologist to interpret drill cuttings and prepare a detailed lithologic log (at 10-ft intervals), determine screen setting (at least 200 ft interval suggested), supervising proper development, and adequate quality data gathering. Geophysical logs would be reviewed by the Hydrogeologist in combination with the lithologic log to determine total depth and placement of screen interval(s) for the well.

6. All well construction materials, including blank casing and screen and annular materials, must be on-site upon completion of drilling the borehole, so that the well may be constructed promptly following geophysical logging and interpretation of logs.

7. Only potential well locations west of 108 Camino Chupadero should be considered, as Tesuque Formation thickness is limited to the east.

8. The well should be located as close to the surface drainages associated with the Rio Chupadero as possible to take advantage of local recharge (and minimize depth to water).

9. Septic set-back regulations should be observed per NMED regulations.

10. Sanitary seals should extend to at least 50 ft bgl.

Additionally, the CWSC should ascertain why the current wells (CWSC Wells 2 and 4) are inadequate for their needs. This ideally should include a step-drawdown pumping test, video survey, water-quality determination, and bacteriological analysis including iron-related, sulfate-reducing, and slime-forming bacteria (BART test kit) to provide an accurate determination of the condition of CWSC wells, what they are capable of producing, and baseline capacity. Note that a well video survey requires that the pump be removed from the well. The results of the video survey and the qualitative bacteriological analysis should be analyzed to determine if rehabilitation should be considered for the CWSC wells. It should be understood that older wells, particularly if they are constructed of mild steel, can be irreparably damaged during rehabilitation. A post-rehabilitation step-drawdown pumping test should also be performed at the same pumping rates as the initial test to determine the effectiveness of rehabilitation efforts.

Please let me know if you have any questions or comments.

Sincerely,

JOHN SHOMAKER & ASSOCIATES, INC.

Erwin A. Melis, PhD, PG (CA 8870)
Senior Hydrogeologist

EAM:em

Enc: References
Figure 1. Hydrographs for USGS-monitored wells 354738105553901 and 354555105564501.

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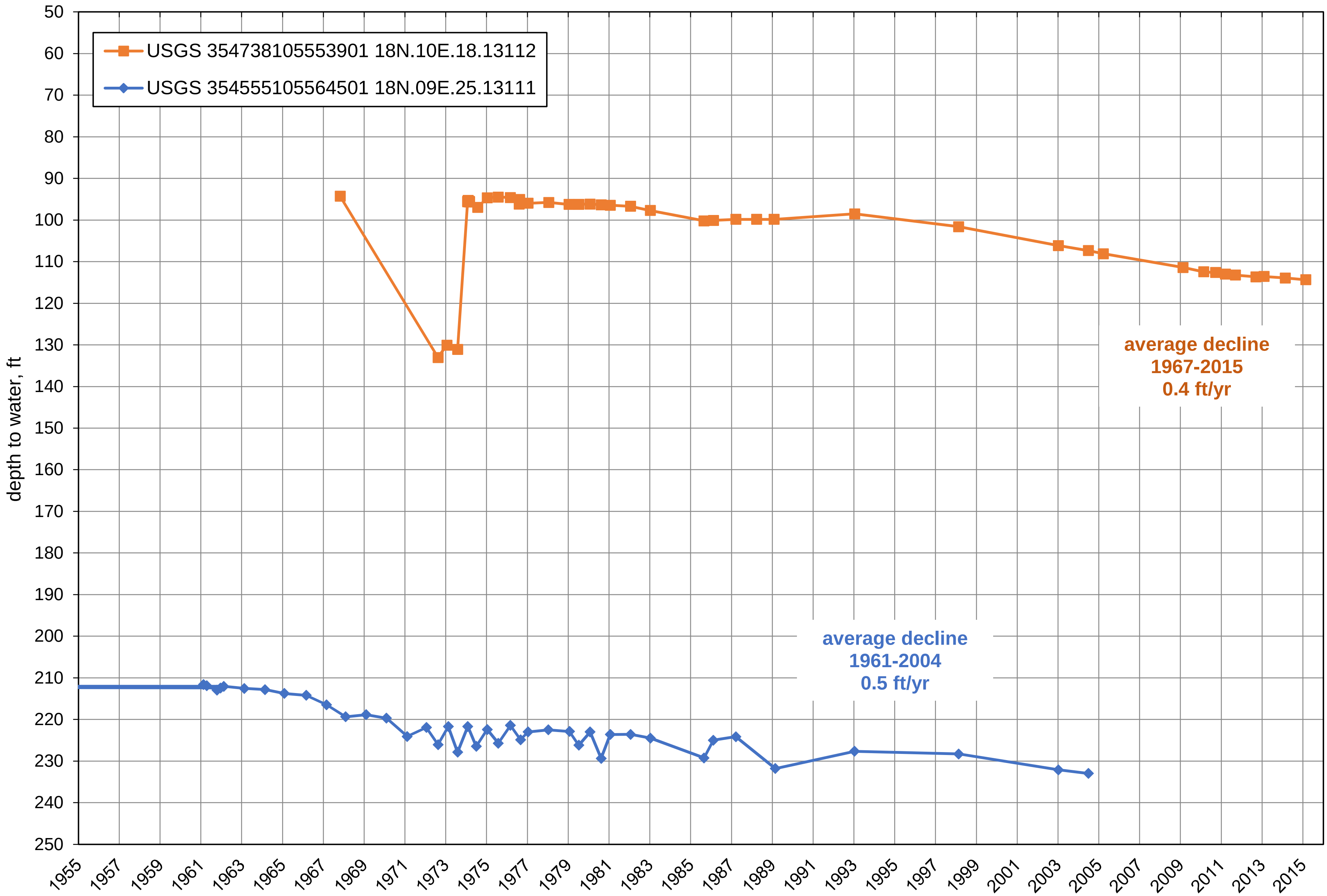

Figure 1. Hydrographs for USGS-monitored wells 354738105553901 and 354555105564501, near Chupadero, Santa Fe County, New Mexico.