Water Resources Planning Study
Rio Rancho Estates Area
Sandoval County, New Mexico

July, 2013

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July, 2013

Submitted to:
County of Sandoval
Planning and Zoning
1500 Idalia Road, Building D
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I. EXECUTIVE SUMMARY

This Water Resources Planning Study was prepared for Sandoval County to summarize groundwater resources in the Rio Rancho Estates area and evaluate potential options for development of a water supply for the Rio Rancho Estates area. Rio Rancho Estates is situated west of and adjacent to the City of Rio Rancho and comprises 41,323 acres with approximately 41,000 platted lots. It is generally bounded by Rainbow Road on the east and the Rio Grande Valley escarpment to the west, the Sandoval County line to the south and Perlman Road to the north.

Rio Rancho Estates is underlain by Quaternary (young) surficial stream and air-lain sediments. Thin surficial sediments are underlain by Tertiary-aged Santa Fe Group alluvium. The Santa Fe Group alluvium is in excess of 4,000 feet thick in the Rio Rancho Estates area, and is comprised of interbedded sand, silt, clay and gravel. The area is cut by a north-northeast trending low-permeability fault zone. Depth to water beneath Rio Rancho Estates varies from approximately 650 feet on the eastern margin to greater than 1,000 feet on the western margin.

Projected water use for the Rio Rancho Estates area was estimated by comparison with surrounding areas, particularly the City of Rio Rancho. Projected future water use for the City of Rio Rancho is 135 gallons per capita per day. Census data for the area predicts a household size of 2.72 persons per lot. Water use is therefore projected at 134,028 gallons per year per residence, which is equivalent to 0.41 acre-feet per year (ac-ft/yr) per lot. For industrial areas within Rio Rancho Estates area, the estimate of water use is 1,200 ac-ft/yr total for the four industrial areas. Total projected water use for Rio Rancho Estates is therefore calculated to be 18,010 ac-ft/yr (5.9 billion gallons per year).

SMA and its subcontractor, John Shomaker & Associates, evaluated potential effects on the aquifer underlying Rio Rancho Estates caused by pumping for water supply for Rio Rancho Estates supply using the New Mexico Office of the State Engineer (NMOSE) numerical model of groundwater flow in the Middle Rio Grande Basin (NMOSE, 2001). The model is a computerized representation of the aquifer underlying the Middle Rio Grande Basin that can be used to predict drawdown (water level decline). The model takes into account hydrogeologic conditions (water levels, aquifer properties, surface water recharge) as well as existing and future well pumping that has been approved by the NMOSE.

Several development scenarios were evaluated. The initial scenario evaluated was full build-out of approximately 41,000 lots, with water supplied through individual domestic supply wells (one well per lot), or through several large municipal supply wells. Assuming a water use of 18,010 acre-feet per year, the predicted drawdown caused by individual wells or municipal wells was in excess of 2.5 feet per year, which is the maximum allowable drawdown as defined by the NMOSE Middle Rio Grande Administrative Area Guidelines (NMOSE, 2000). Drawdown in excess of this amount has the potential to impair other water rights and cause land subsidence. In order to not exceed the maximum allowed drawdown, it was determined that a maximum of approximately 8,600 acre-feet per year could be pumped from the Rio Rancho Estates Area in order to not cause drawdown in excess of 2.5 feet per year. This equates to approximately 18,077 lots.

Several water development scenarios were evaluated at the lower pumping rate of 8,600 acre-feet per year. These included water supply from individual wells, and also from large municipal supply wells. Full build-out (worst case drawdown) was evaluated for each option, as well as phased build-out through the year 2040. Results indicate that the only scenario that does not exceed the NMOSE maximum drawdown limit is water supply from municipal supply wells with phased buildout. Pumping from individual supply wells consistently causes excessive drawdown, caused primarily from the fact that domestic supply wells will tap only the upper portion of the aquifer, while municipal supply wells draw water from deeper in the aquifer.

A potential source of water for Rio Rancho Estates is deep, brackish water located outside the Middle Rio Grande Basin. Brackish water is highly mineralized, and requires desalination before it can be consumed. Brackish water with total dissolved solids (TDS) in excess of 1,000 milligrams per liter (mg/l, ppm) located in aquifers at a depth of greater than 2,500 feet is regulated differently by the NMOSE than shallow, fresh water. Potential for appeal of pumping is limited, and appropriated amounts are not regulated by the NMOSE. Brackish water requires treatment, with treatment costs estimated at $4.00 to $8.00 per 1000 gallons, which is relatively expensive. Several entities have filed Notices of Intent with the NMOSE to produce brackish water, including Recorp/Aperion, L-Bar Resources, Commonwealth Utilities, Atrisco Oil and Gas LLC, and others. To date several deep brackish wells have been drilled and tested, but no entity has moved past the pilot testing stage, generally due to lack of funding. Development of deep brackish water resources hold good potential for the future, but appear to be several years off at best.

Conceptual engineering and cost estimates for several water supply scenarios (individual domestic wells, shared domestic wells, and utility scale municipal water distribution systems) have been prepared. Additionally, conceptual engineering and cost estimates for several wastewater disposal and collection/treatment scenarios (individual septic tank/leachfield, utility scale wastewater collection and treatment) have been prepared.

II. INTRODUCTION

This water resources planning study was completed by Souder, Miller & Associates (SMA) in order to support Sandoval County in preparation of the Rio Rancho Estates Area Plan (RREAP). It was designed to determine the amount of water that could be developed (pumped) from the Rio Rancho Estates area without causing excessive drawdown of the groundwater aquifer. Excessive drawdown has the potential to cause land subsidence, impair water rights of others, and be detrimental to the public welfare of the State of New Mexico, in violation of requirements of the State Engineer.

The report also summarizes other potential sources of water for the area, and conceptual design and cost estimates for water supply and wastewater treatment options for the area.

III. PROJECT STUDY AREA

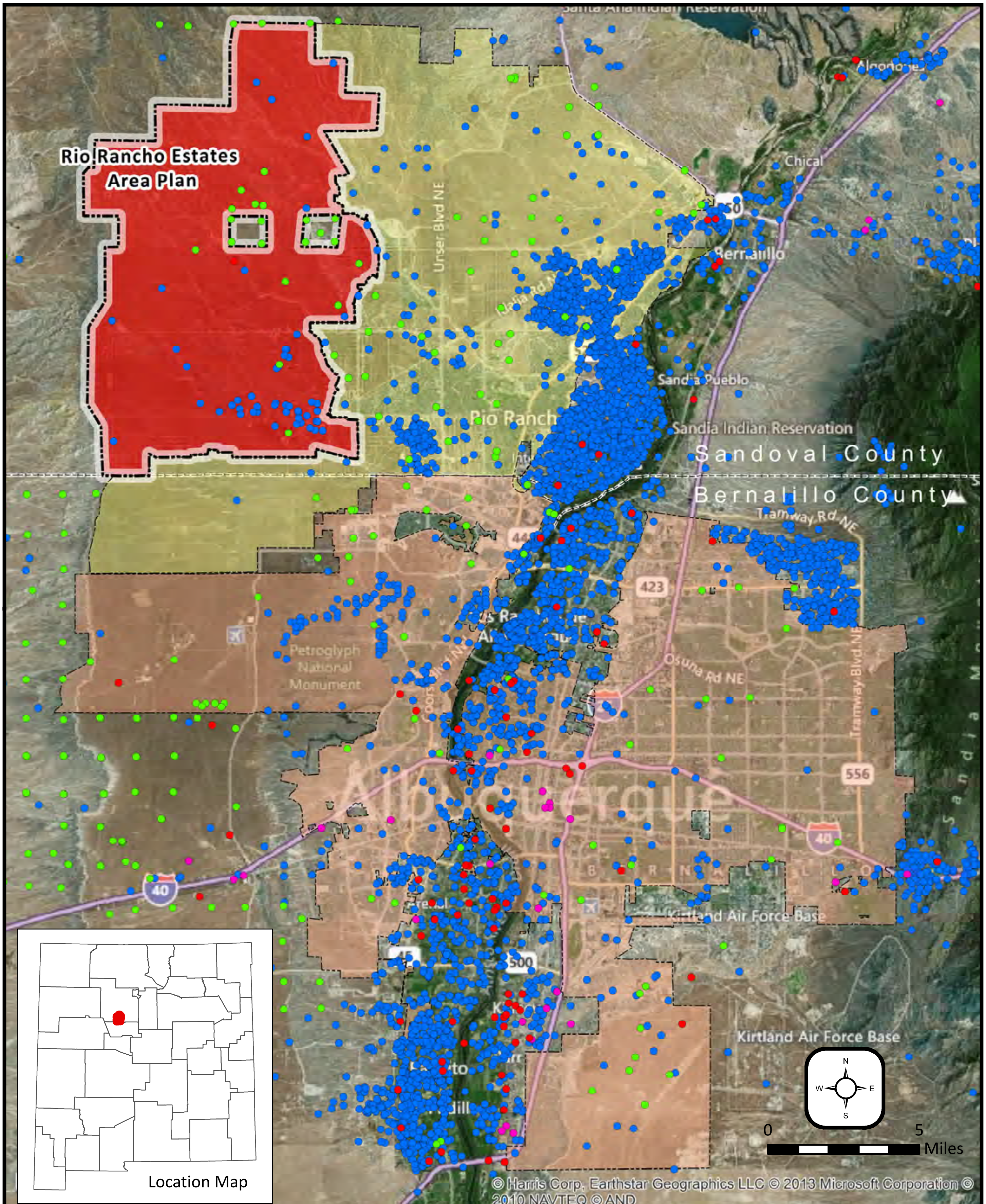
A. Location

Rio Rancho Estates is an area of south central Sandoval County and is made up of a portion of the Town of Alameda Land Grant and a portion of the historical King Ranch. Rio Rancho Estates is situated west of and adjacent to the City of Rio Rancho and comprises approximately 41,323 acres with approximately 41,000 platted lots. It is generally bounded by Rainbow Road on the east and the Rio Grande Valley escarpment to the west, the Sandoval County line to the south and Perlman Road to the north. See Figure 1 for location.

The area is located within the Albuquerque Basin at elevations ranging from 5,500 to 6,500 feet above mean sea level (AMSL). The topography of the area is generally flat and sloping downward to the east toward the Rio Grande. The area is incised with shallow arroyos draining to the southeast. Vegetation in the area is dominated by native grasses and shrubs, with scattered native woodland trees at higher elevations.

B. Existing Development

Rio Rancho Estates contains approximately 41,000 lots platted during the period of 1960 to 1975 (Figure 2). The area also includes two truncated sections of land (approximately 1,100 acres) within the study area. State land parcels are also located to the east, north and south of the study area. Approximately one-third of the lots are owned by American Realty and Petroleum Corporation (AMREP), with the remainder held by private owners. In 2000, Sandoval County's Planning & Zoning Division tallied 395 dwellings in the area. In 2010, Sandoval County estimated that 688 dwellings exist in the area. Current estimates by Sandoval County of the number of developed lots in the study are is 440.



Legend
NM Office of the State Engineer Well Use

COM	IRR
DOM	MUN

Data as of 07/2011

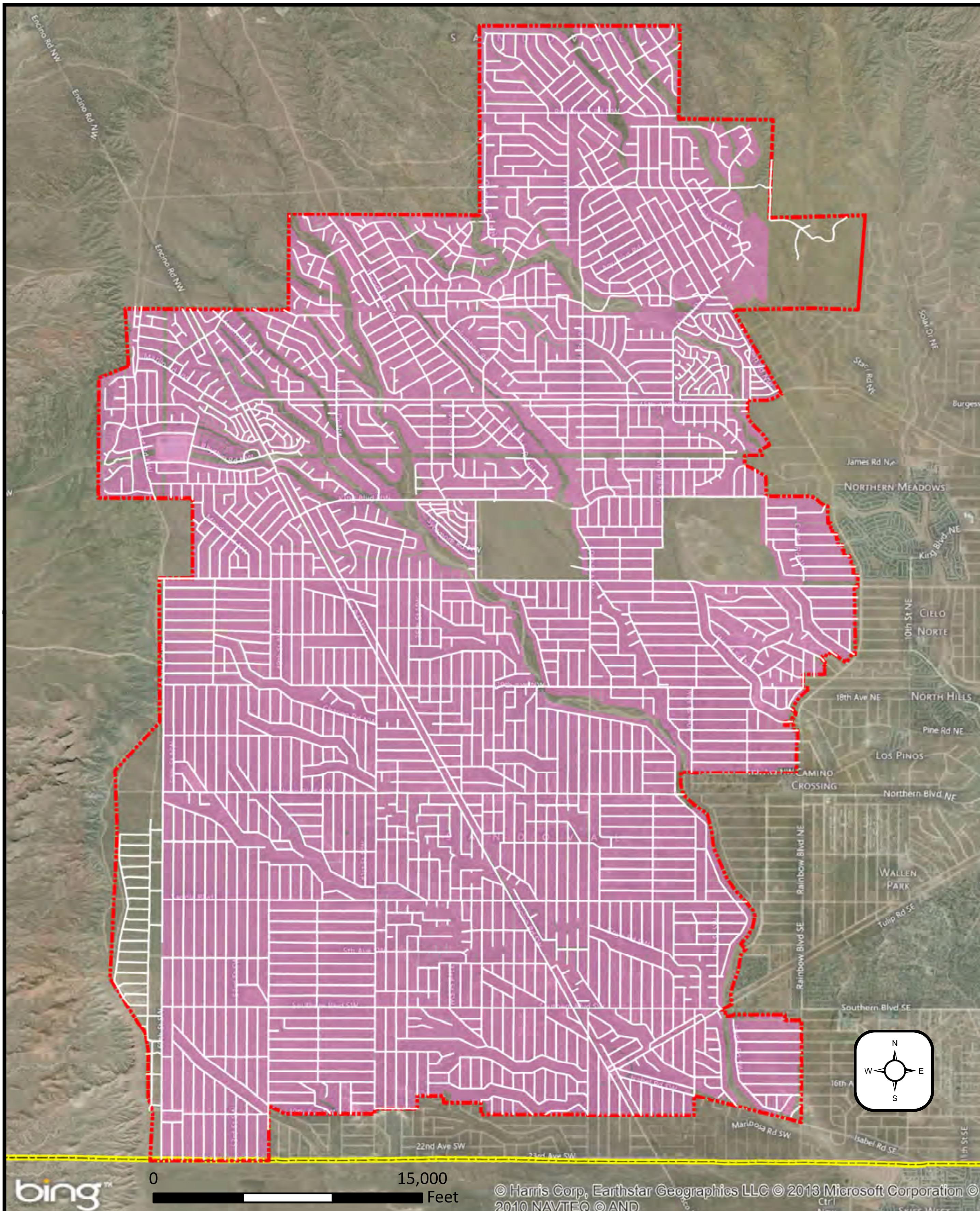
SOUDER, MILLER & ASSOCIATES
SMA
Civil/Environmental Scientists & Engineers
1201 PARKWAY DRIVE
SANTA FE, NM 87507-7258

Rio Rancho Estates Water Planning Study

Sandoval County, NM

Figure 1

3/5/13



Legend

Rio Rancho Estates — Road

County Line — Parcel

Parcel data as of 2012

SOUDER, MILLER & ASSOCIATES

SMA

Civil/Environmental Scientists & Engineers

1201 PARKWAY DRIVE
SANTA FE, NM 87507-7258

Rio Rancho Estates Water Planning Study

Sandoval County, NM

Figure 2

3/5/13

IV. GEOLOGY AND HYDROLOGY

A. Regional Geologic Structure

The Rio Rancho Estates area is located in the western extents of the Rio Grande Rift. The Rio Grande Rift is an area of east-to-west crustal extension that was active during the Oligocene and Miocene epochs, generally over the last 35 million years (Thorn et al., 1993). In the study area, the Rio Grande Rift is characterized by a series of down-dropped fault blocks bounded to the east by the Sandia Mountains. The study area is generally bounded on the west by the Rio Puerco escarpment, consisting of Mesozoic and Tertiary sedimentary units that have been tectonically faulted and folded (Tedford and Barghoorn, 1999). Crustal extension has created an extensive basin that has accreted over 10,000 feet of sediment in the central portions of the rift valley (Connell, 2006).

B. Local Geology

The Rio Rancho Estates area is located on young Quaternary alluvial deposits overlying Tertiary Santa Fe Group sediments. Quaternary deposits include fluvial deposits (stream sediments) and eolian (air-lain) deposits. These deposits are relatively thin in the study area (few 10s to 100 feet). These deposits are underlain by sediments of the Santa Fe Group. Santa Fe Group sediments are associated with the ancestral Rio Grande, and are made up of fluvial sediments and minor volcanic material. These sediments have a thickness in excess of 4,000 feet in the study area, and include the following formations (Connel, 2006):

- Ceja Formation: Pliocene- to Pleistocene-aged, with a thickness of up to 600 feet. This unit is dominated by sands, gravels, and mudstones, and unconformably overlies the Arroyo Ojito Formation.

- Arroyo Ojito Formation: Miocene-aged unit with a thickness of up to 1,400 feet. The unit consists of fluvial deposits of conglomerates, sandstones, and mudstones derived from sources to the north and west of the Albuquerque Basin.

- Cerro Conejo Formation: Miocene-aged unit with a thickness of up to 1,000 feet. The unit consists of pink to pale-brown cross-stratified sandstones with interbedded mudstones.

- Zia Formation: Lower-Miocene unit with a thickness of 1,300 feet dominated by cross-stratified sandstones and mudstone.

The Santa Fe Group sediments are underlain at depth by Mesozoic sedimentary units, including the Mesaverde Group Sandstones, the Mancos Shale, and Dakota Formation. These units are much older than the Santa Fe Group sediments, and are typically more consolidated. They were deposited in marine and shoreline environments when the area was covered by oceans approximately 70 million years ago. Figure 3 is a geologic map of the study area, Figure 4 includes unit descriptions, and Figure 5 is a cross-section depicting subsurface geology.

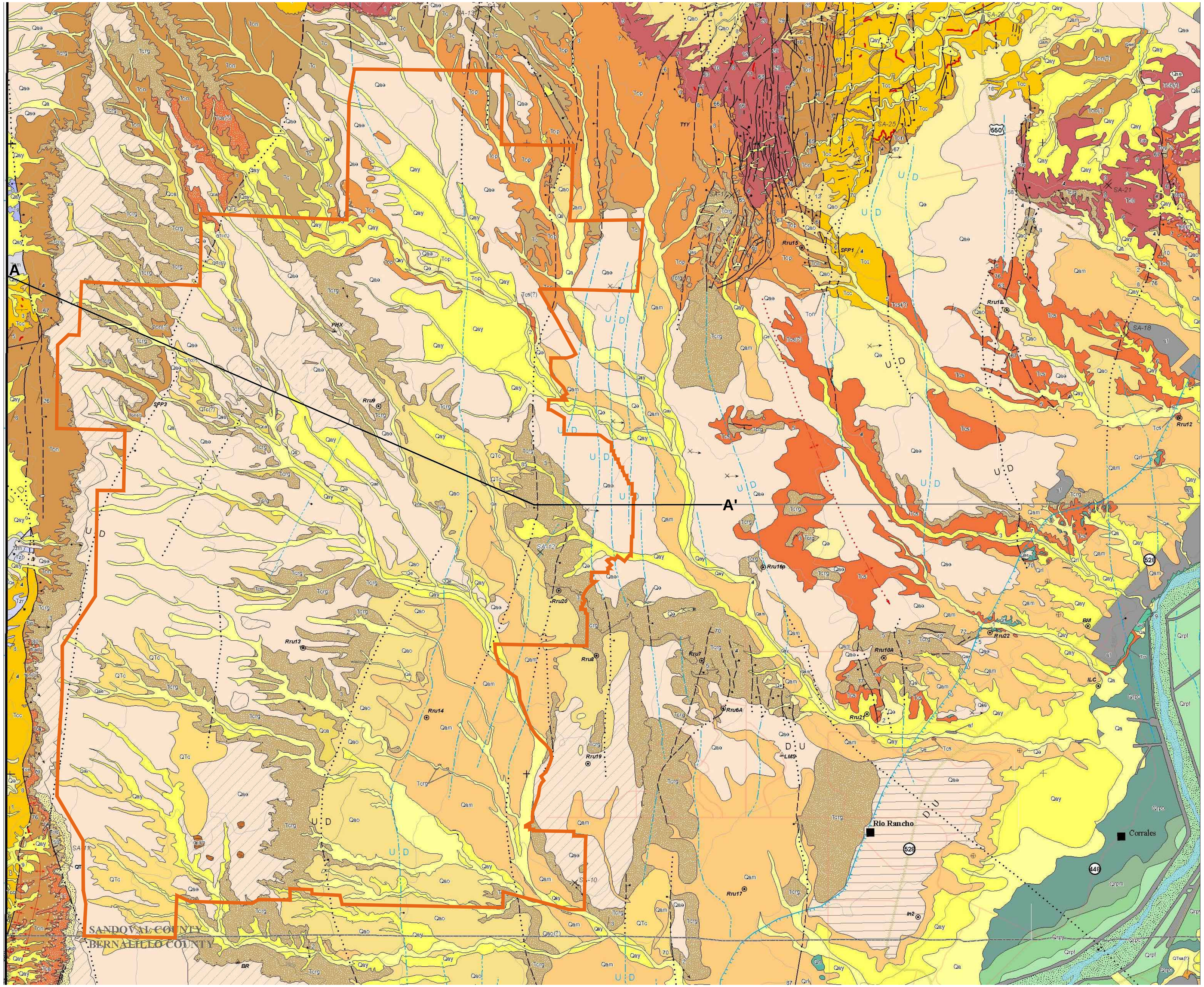
C. Groundwater Hydrology

The Rio Rancho Estates area is located within the Middle Rio Grande Basin, a management district overseen by the New Mexico Office of the State Engineer (NMOSE). The hydrology of the Middle-Rio Grande basin is well studied, and the aquifer has been extensively characterized by several studies, including Thorn et al (1993), McAda (1996), and Bartolino and Cole (2002).

In the Middle Rio Grande Basin, groundwater is located almost exclusively within the Tertiary-aged Santa Fe Group sediments discussed above. The aquifer units are located predominantly within fluvial sediments, with highest production coming from paleostream channels of the ancestral Rio Grande. Upper portions of the Santa Fe Group aquifer have hydraulic conductivities ranging from 4 to 150 feet per day, but conductivity decreases significantly in lower portions of the sediments to values ranging from 4 to 11 feet per day (McAda and Barroll, 2002).

As shown on Figure 1, several municipal supply wells and domestic supply wells have been completed in the Rio Rancho Estates area. As shown on the same figure, the number of domestic supply wells increases greatly toward the Rio Grande, due to the shallower water table proximal to the river. Information obtained from the NMOSE Water Rights Reporting System (WRRS) database indicates that the average depth to groundwater in the study area is approximately 650 feet on the eastern margin, deepening with increased ground surface elevation to in excess of 1,000 feet on the western margin. Domestic supply wells are generally completed within the top hundred feet of the shallowest groundwater intersected. Well logs from several of the municipal supply wells located near the study area indicate total well depths on the order of 2,000 to 3,000 feet. These wells demonstrate production in excess of 1,200 gallons per minute (gpm), with average yearly diversions ranging from 490 to 1,730 acre-feet per year.

Water quality in domestic wells in the Rio Rancho Estates area is generally good, and doesn't generally require treatment for use. This is due to the fact that these wells tap the upper portions of the aquifer, which generally are good quality. Deeper municipal wells in the area demonstrate more variable water quality, indicating that water deeper in the aquifer may contain naturally occurring contaminants (Jim Riesterer, Glorieta Geoscience, pers. comm. 2013). Known water quality issues in the area include the presence of arsenic, a naturally occurring constituent that can cause adverse health effects. Several City of Rio Rancho municipal supply wells require treatment prior to use. Additionally, several City of Rio Rancho supply wells contain elevated Total Dissolved Solids (TDS) concentrations. Water with elevated TDS is "hard," and can cause excessive scaling in water fixtures. Elevated TDS can also cause poor water taste and odor. In situations where TDS is elevated, water may require treatment prior to use.



N

0 3750 7500 15000

SCALE: 1"=7500 FT.

EXPLANATION

STUDY AREA BOUNDARY

A — A' CROSS SECTION LOCATION (FIGURE 3)

(UNIT DESCRIPTIONS INCLUDED AS FIGURE 2a)

Geologic Map from Preliminary Geologic Map of the Albuquerque–Rio Rancho Metropolitan Area and Vicinity, Bernalillo and Sandoval Counties, New Mexico by S. Connell (2006)

FIGURE 3

GEOLOGIC MAP
RIO RANCHO ESTATES
SANDOVAL COUNTY, NEW MEXICO

3451 CANDELARIA ROAD NE, SUITE D
ALBUQUERQUE, NEW MEXICO, 87107
505-299-0942, FAX 505-293-3430
SERVING THE SOUTHWEST AND ROCKY MOUNTAINS

SMA Engineering Environmental Surveying

DRAWN MAE
CHECKED SAM
APPROVED SAM

REVISIONS
BY ____ DATE ____ DESCR. ____
BY ____ DATE ____ DESCR. ____

6421284
3/6/2013

Explanation of Map Units

Primero Alto terrace surface (upper Pleistocene) — depositional top of Arenal Formation (**Qra**); exhibits weakly developed calcic soils with stage I-II carbonate morphology developed on gravel; originally defined by Lambert (1968) for his Edith Formation on west side of Rio Grande; 15-21 m above Rio Grande flooplain.

Segundo Alto terrace surface (middle Pleistocene) — depositional top of Los Duranes Formation (**Qrd**) and intermediate stream-valley alluvium (**Qam**); exhibits weakly developed calcic soils with stage I-II carbonate morphology; defined by Lambert (1968); 42-48 m above Rio Grande floodplain.

Sunport and Las Huertas geomorphic surfaces complexes (lower Pleistocene) — local depositional top of Sierra Ladrones Formation (**QTsp**); exhibits strongly developed petrocalcic soils with stage III+ carbonate morphology; Sunport surface defined by Lambert (1968); Las Huertas surface defined by Connell and Wells (1999) north and northwest of Sandia Mountains; 92-122 m above Rio Grande floodplain.

Llano de Albuquerque geomorphic surface complex (upper Pliocene-lower Pleistocene(?) — depositional top of Ceja Formation (**Tc, Tcrg**); exhibits strongly developed petrocalcic soils with stage III+ to locally weak stage IV carbonate morphology; dashed hachures denote inferred relict surfaces; modified after Machette (1985); 215-110 m above Rio Grande floodplain.

Lomos Altos geomorphic surface (upper Pliocene) — depositional top of gravel of Lomos Altos (**QTta**), exhibits strongly developed petrocalcic soils with stage IV carbonate morphology; defined by Connell and Wells (1999); 21-92 m above local base level.

Pediment surface (upper Pliocene(?)-Pleistocene) — erosion surface, mostly cut on Sandia granite (**Ys**); common along southwestern flank of Sandia Mountains, Tijeras Canyon, and northern Manzanita Mountains.

af — **Disturbed land and artificial fill (af, modern-historic)** — excavations and areas of artificially deposited fill and debris; delineated where areally extensive; includes deposits associated with floor of Jemez Reservoir.

Qpl — **Playa-lake deposits (Qpl, Holocene-upper Pleistocene)** — silt, mud, and sand in local depressions on low-relief surfaces; less than 2 m thick.

Qe — **Eolian sand, undivided (Qe, Holocene-upper Pleistocene)** — pink to light yellowish-brown, well-sorted sand recognized as laterally extensive, active and inactive sand sheets and discontinuous low-relief dunes; soil development is weak (stage I to II+ carbonate morphology) to nonexistent; north to northeast dune-crest orientations; 1-3 m thick.

Qed — **Eolian sand dune (Qed, Holocene-upper Pleistocene)** — pink to light yellowish-brown, well sorted sand primarily recognized as moderate-relief narrow dunes; weakly developed soils with stage I to II carbonate morphology; 1-33 m thick.

Qls / Tls — **Landslide debris (Qls, Pleistocene) and landslide megablock (Tls, Miocene(?) or Pliocene)** — massive to chaotically bedded sand, gravel, and mud derived from steep hill slopes; includes large Toreva blocks along margin of Santa Ana Mesa; older **landslide megablocks (Tls)** are large allocthonous blocks of Madera Group limestone resting on sheared Sandia granite (**Ys**) along the southwestern base of Sandia Mountains; 6-30 m estimated thickness.

Qca — **Colluvium and alluvium, undivided (Qca, Holocene-Pleistocene)** — sand and gravel from nearby hill slopes and along margins of mesa-capping lavas; weakly to strongly developed calcic soils (stage I to III+ carbonate morphology); up to 5 m estimated thickness.

Qae — **Eolian sand and alluvium, undivided (Qae, Holocene-upper Pleistocene)** — pale-brown to light reddish-brown, moderately sorted, sand and silt with scattered pebbles; weakly to moderately developed soils with stage I to II carbonate morphology and clay films; 1-3 m thick.

QTc — **Calabacillas Formation (QTc, upper Pliocene(?)-Pleistocene)** — pale-brown to yellowish-brown sand with interbedded pebbly sand, mud, and multiple buried calcic paleosols (stage I to III+ carbonate morphology); associated with hanging walls of intrabasinal faults (e.g., San Ysidro fault); generally poorly exposed; defined by Connell (*in preparation*); 0-30 m thick.

Qpy — **Younger piedmont-slope alluvium (Qpy, Holocene-upper Pleistocene)** — light-brown sand, muddy sand, and pebble to cobble gravel; boulders locally present along front of the Sandia Mountains; weakly developed soils (up to stage I carbonate morphology); up to 12 m thick.

Qpm (Qpm2, Qpm1) — **Intermediate piedmont-slope alluvium (Qpm, middle Pleistocene)** — pale- to strong-brown silty sand, clayey sand and gravel; contains weakly to moderately developed soils (stage II, III+ carbonate morphology); divided into **older (Qpm1)** and **younger (Qpm2)** subunits; 9 m thick.

QTp — **Older eastern-slope alluvium, undivided (QTp, upper Pliocene(?)-lower Pleistocene)** — cobble and boulder gravel along eastern dip-slope of Sandia Mountains; dominated by rounded limestone clasts; surface is commonly partly stippled and locally exhibits stage III+ carbonate morphology; may be partly correlative to the Tuerto Formation; up to 10 m thick.

Qrp (Qrpc, Qrpf, Qrpy, Qrpyc, Qrpm, Qrpmc, Qrpo, Qrpoc) — **Las Padillas Formation (Qrp, historic-upper Holocene)** — fluvial deposits of the Rio Grande; pinkish-gray to grayish-brown sand and pebbly sand with lenses of reddish-brown silt and clay; contains paleochannel, point-bar, and overbank levee deposits; underlies modern (inner) valley of the Rio Grande; very weak to no soil development; base not exposed; 15-34 m thick in wells; proposed by Connell and Love (2001); divided into 8 units based largely on surface morphology (Kelson et al., 1999):
Modern channel deposits (Qrpc, historic) — active channel and floodplain of Rio Grande since 1951.
Modern floodplain deposits (Qrpf, historic) — channel and floodplain of Rio Grande prior to 1930s.
Younger channel and floodplain deposits (Qrpy) and younger channel (Qrpyc) deposits (historic-upper Holocene) — sand, silt, and clay with gravelly interbeds.
Intermediate channel and floodplain (Qrpm) and intermediate channel (Qrpmc) deposits (upper Holocene) — sand, silt, and clay with gravelly interbeds.
(Older channel and floodplain (Qrpo) and older channel (Qrpoc) deposits (upper Holocene) — sand, silt, and clay with gravelly interbeds.

Qra — **Arenal Formation of (Qra, upper Pleistocene)** — pale- to yellowish-brown pebbly to cobbly sand; weakly developed soil (stage I to II+ carbonate morphology on gravel) on *Primero Alto terrace surface* ; inset against Los Duranes Formation (**Qrd**); proposed by Connell and Love (2001); 3-6 m thick.

Qrd — **Los Duranes Formation (Qrd, middle Pleistocene)** — pale-brown to light reddish-brown sand, sandy gravel and sandy clay; weakly developed soil (Stage I carbonate moprhology on sand) on *Segundo Alto terrace surface* , inset against Lomatas Negras Formation (**Qrl**); locally subdivided into the Menaul Member (**Qrm**); defined by Lambert (1968); 40-52 m thick.

Qrm — **Los Duranes Formation, Menaul Member (Qrm, middle Pleistocene)** — yellowish-brown pebble gravel and pebbly sand; probably a coarse-grained lens of Los Duranes Formation; overlies intermediate stream-valley deposits (**Qam1**) and Edith Formation (**Qre**); typically overlain by intermediate stream-valley deposits of unit **Qam2**; originally defined as Menaul formation by Lambert (1968); 26-36 m above Rio Grande floodplain; less than 3 m thick.

Qre — **Edith Formation (Qre, middle Pleistocene)** — pale-brown to yellowish-brown pebble and cobble gravel, sand and sandy clay typically exhibiting a single upward-fining succession; locally contains white diatomite bed; disconformably overlain by intermediate stream-valley alluvium (**Qam, Qam2, Qam1, Qamt2**) and Menaul Member of the Los Duranes Formation (**Qrm**) deposits; 12-24 m above Rio Grande floodplain; defined by Lambert (1968); 2-12 m thick.

Qrl — **Lomatas Negras Formation (Qrl, middle Pleistocene)** — pale-brown to pink sandy pebble to cobble gravel that unconformably overlies a low-relief strath cut on the Ceja Formation (**Tc, Tcs**); disconformably overlain by older stream-valley alluvium; oldest inset terrace deposits of the ancestral Rio Grande; 65-75 m above Rio Grande floodplain; proposed by Connell and Love (2001); commonly 3-12 m thick, but locally reaches 18 m in thickness near the mouth of Arroyo de las Calabacillas.

Qru — **Undivided ancestral Rio Grande deposits (Qru, upper-middle Pleistocene)** — undivided fluvial deposits associated with the ancestral Rio Grande in the San Felipe Pueblo quadrangle; probably correlative to Los Duranes and Edith Formations (**Qrd, Qre**).

Qa — **Active stream-valley alluvium (Qa, historic-Holocene)** — light grayish- to yellowish-brown sand, silty to clayey sand, and gravel; boulders are common along the western flank of the Sandia Mountains; associated with modern incised stream valleys; very weakly developed (stage I carbonate morphology) to nonexistent soils; 1-12 m thick.

Qay — **Younger stream-valley alluvium (Qay, upper Pleistocene-Holocene)** — pale- to light-brown sand, muddy sand, and pebble to cobble gravel; boulders locally present along front of the Sandia Mountains; weakly developed soils (Stage I and II carbonate morphology); locally contains active stream-valley alluvium (**Qa**); radiocarbon dates on detrital charcoal yielded radiocarbon ages of 1790±90 and 4550±140 radiocarbon years (*SC-1* and *SC-2*, Table 1); up to 24 m thick.

Qam (Qam2, Qam1) — **Intermediate stream-valley alluvium (Qam, Qam1, Qam2, upper-middle Pleistocene)** — yellowish-brown to reddish-yellow sand, silty clay, and gravel; granite and limestone clasts dominant east of Rio Grande; variable lithology, dominated by chert and volcanic clasts west of the Rio Grande; surface is commonly mantled by eolian sand; variable soil development; divided into two subunits: **Younger subunit (Qam2)** contains moderately developed soils (stage II and III carbonate morphology); **Older subunit (Qam1)** contains weakly developed soils (stage II carbonate morphology); 5-43 m thick.

Qamt (Qamt3, Qamt2, Qamt1) — **Intermediate stream-valley alluvium of Tijeras Canyon (Qamt, Qamt1, Qamt2, Qamt3, middle Pleistocene)** — sand and gravel associated with former drainage courses of Tijeras Canyon; gravel composition more diverse than in intermediate stream-valley alluvium (**Qam**) and contains greenstone and sandstone; interfingers with intermediate stream-valley alluvium; divided into three subunits:
Younger subunit (Qamt3), Intermediate subunit (Qamt2), and **Older subunit (Qamt1)**; 5-43 m thick.

Qao (Qao4, Qao3, Qao2, Qao1) — **Older stream-valley alluvium (Qao, Qao1, Qao2, Qao3, Qao4, middle Pleistocene)** — light reddish-brown sand and gravel; soil development is variable and exhibits stage I to III carbonate morphology with few or no clay films; divided into four subunits based on surface morphology, soil development, and inset relationships (from youngest to oldest):
subunit 4 (Qao4), subunit 3 (Qao3), subunit 2 (Qao2), and subunit 1 (Qao1); 2-14 m thick.

Qaot2, Qaot1 — **Older stream-valley alluvium of Tijeras Canyon (Qaot2, Qaot1, middle Pleistocene)** — sand and gravel derived from former drainage courses of Tijeras Canyon; divided into two subunits: **younger subunit (Qaot2)** and **older subunit (Qaot1)**; 0-15 m thick.

QTt / QTta — **Tuerto Formation (QTt, QTta, upper Pliocene-lower Pleistocene)** — pale-brown pebbly to cobbly sandstone; unconformably overlies units **QTsp** and **Tsp**; locally capped by petrocalcic soils with stage III+ to IV+ pedogenic carbonate morphology; clasts are predominantly limestone; Tuerto gravels of Stearns (1953); includes the **gravel of Lomos Altos of Connell and Wells (1999) (QTta)** west of the San Francisco fault, where the basal contact is 80-100 m above local base level; 4-18 m thick.

QTsa — **Sierra Ladrones Formation, axial-fluvial member (QTsa, Miocene(?), Pliocene-lower Pleistocene)** — light-gray to yellowish-brown sand, pebbly to cobbly sand, and sparse interbedded mud; clasts dominated by rounded othoquartzite and volcanic rocks; deposits associated with the ancestral Rio Grande; interfingers with piedmont member (**QTsp**); contains early Irvingtonian mammalian fossils (*SB-1*, Table 1); base not exposed, estimated thickness more than 300-800 m.

Tc (Tcrg, Tcau, Tca, Tcs) — **Ceja Formation (Tc, Tcrg, Tcau, Tca, Tcs, Pliocene-lowest Pleistocene(?))** — sand, gravel, and mud derived from western and northwestern Albuquerque basin; disconformably overlies Arroyo Ojito Formation (**Ton** and **Top**) and generally coarsens upsection; defined by Kelley (1977); contains Blancan mammalian fossils (*SB-2*, Table 1); 20-700(?) m thick; divided into three members and one subunit:
Upper sand and gravel member (Tcrg), Pliocene-lower Pleistocene(?)) — pale-brown to yellowish-brown cobbly sand and gravel with scattered boulders; top is defined by *Llano de Albuquerque surface*; 20-260(?) m thick; generally less than 100 m thick west of Rio Grande Vallley.
Atrisco Member (Tca, Pliocene) — pink to yellowish-brown sandstone, pebbly sandstone, and mudstone; interpreted to interfinger with Sierra Ladrones Formation (**QTsa**) to east; rests on Arroyo Ojito Formation (**Ton, Top**) and *Rincones paleosurface*; locally subdivided into **upper sandy subunit (Tcau)**; defined by Connell et al (1998a); 20-600(?) m thick.
Santa Ana Mesa Member (Tcs, Pliocene) — reddish-brown to yellowish-red sandstone, conglomerate, and mudstone; modified from Soister (1952) for exposures beneath Santa Ana Mesa; interfingers with axial-fluvial memeber of Sierra Ladrones Formation (**QTsa**); contains thin bed of fallout ash yielding a single-crystal $^{40}Ar/^{39}Ar$ date on hornblende of 3.81±0.29 Ma (*SA-15*, Table 1); 100-600(?) m thick.

QTct — **Cochiti Formation (QTct, upper Miocene-lower Pleistocene)** — light-brown sandstone and pebbly and cobbly sandstone; clasts are predominantly mafic and intermediate volcanic rocks; recognized below and above basaltic lavas of the San Felipe volcanic field; interfingers with axial-fluvial member of the Sierra Ladonres Formation (**QTsa**); usage after Smith and Kuhle (1998); base not observed, but more than 50 m thick.

Tpc — **Cochiti Formation and Peralta Tuff Member of the Bearhead Rhyolite (Tpc, upper Miocene)** — pale-brown, tuffaceous conglomerate and sandstone; contains pumice-bearing intervals, Apache tears obsidian, and lapilli and ash of the Peralta Tuff; single-crystal $^{40}Ar/^{39}Ar$ date on sanidine of 7.05±0.06 Ma (*SA-24*, Table 1); 0-200 m thick.

To (Top, Tob, Ton) — **Arroyo Ojito Formation (1999) (To, Ton, Tob, Top, upper Miocene)** — gravel-bearing fluvial deposits derived from north and northwest of the Albuquerque basin; defined by Connell et al. (1999) and modified by Connell (*in preparation*); 437-456 m thick at type section in Arroyo Ojito; divided into three conformable members:
Picuda Peak Member (Top) — pinkish-gray to reddish-yellow cobbly sandstone and conglomerate; contains abundant red granite clasts; locally capped by petrocalcic soil with stage III+ and V pedogenic carbonate morphology (*Rincones paleosurface*); 10-50 m thick;
Loma Barbon Member (Tob) — pink to reddish-yellow sandstone, mudstone, and pebble to cobble conglomerate; contains scattered sandstone boulders and abundant granite clasts; contains fallout of Peralta Tuff (single-crystal $^{40}Ar/^{39}Ar$ dates on sanidine range from 6.85-7.14 Ma, *SA-20* through *SA-23*, Table 1); 200 m thick;
Navajo Draw Member (Ton) — yellowish-brown to pale-brown pebbly sandstone and yellow to reddish-yellow mudstone; contains abundant rounded chert and intermediate volcanic tuff clasts; contains Oligocene tuff cobbles (Connell et al., 1999); 230 m thick.

Tcc — **Cerro Conejo Formation (Tcc, middle-upper Miocene)** — pink to very pale-brown tabular and cross-stratified sandstone with thin to medium bedded mudstone; contains sandstone concretions and volcanic fallout ashes (11.3-10.8, *SA-25* through *SA28*, Table 1), and late Barstovian mammalian fossils (*SB-3*, *SB-4*, Table 1); base is probably disconformable with the Zia Formation; top may be disconformable with Arroyo Ojito Formation to west, but interfingers with Navajo Draw Member to east; originally defined as Cerro Conejo Member (Zia Formation) by Connell et al. (1999), but elevated to formation rank based on mappability; 245-316 m thick.

Tz (Tzr, Tzm, Tzp) — **Zia Formation (Tz, lower-middle Miocene)** — cross-stratified sandstone and mudstone; unconformably overlies Galisteo and Menefee Formations (**Tg, Kvm**) and unit of Isleta well #2 (**Tis**, in subsurface, see Plate 2); defined by Galusha (1966) and Gawne (1981) and contains late Arikareean through Hemmingfordian mammalian fossils (*SB-5*, Table 1; Galusha, 1966) and divided into three members.
Cañada Pilares Member (Tzr, middle Miocene) — red mudstone and sandstone; discontinuously exposed; defined by Gawne (1981); 8-75 m thick.
Chamisa Mesa Member (Tzm, middle Miocene) — pale-brown to light reddish-brown cross-stratified fluvial and eolian sandstone and mudstone; 30-200 m thick.
Piedra Parada Member (Tzp, lower-middle Miocene) — whitish-gray to pinkish-gray cross-stratified sandstone, eolian in origin; 70-122 m thick.

Tsp — **Eastern basin-margin piedmont deposits, undivided (Tsp, upper Oligocene(?)-Miocene)** — pale-brown to reddish-brown conglomerate and sandstone with minor mudstone; contains abundant clasts of limestone and sandstone in northern Sandia Mountains; dark-gray hornfels and hypabyssal intrusive clasts from the Ortiz Mountains increase in abundance to the north; contact with overlying Sierra Ladrones Formation piedmont member deposits (**QTsp**) is indistinct and approximate; 150-800 m thick.

Tg — **Galisteo Formation (Tg, Eocene)** — variegated red, green, purple and gray mudstone with intercalated thin beds of yellowish-brown, cross-bedded, arkosic sandstone and conglomerate; defined by Stearns (1943); unconformably overlies Menefee Formation; upper contact gradational with Espinaso Formation exposed northeast of map area; contains Duchesnean (Eocene) fossils; exposed thickness is 133 m; regional thickness ranges from 22 to 979 m.

Td — **Diamond Tail Formation (Td, Paleocene(?)-Eocene)** — dark-red and gray variegated sandstone and mudstone with scattered pebbly sandstone; defined by Lucas et al. (1997); unconformably overlain by Galisteo Formation; contains Wasatchian (late Paleocene-early Eocene) fossils; exposed thickness is 133 m; regional thickness ranges from 100 to 442 m.

Kvp — **Mesaverde Group, Point Lookout Sandstone (Kvp, Upper Cretaceous)** — grayish-tan to light-yellow, very fine- to fine-grained, massive, quartzose sandstone with limonitic sandstone lenses and interbedded thin gray shale; 73 m thick.

Kvm — **Mesaverde Group, Menefee Formation (Kvm, Upper Cretaceous)** — white to light-yellow fine- to medium-grained, well sorted, lenticular, cross-stratified, quartzose sandstone with interbeds of dark-gray to black siltstone and carbonaceous shale and coal; 205-365 m thick.

Kms — **Mancos Shale, Semilla Sandstone (Kms, Upper Cretaceous)** — dark-gray shale and tan to yellow, planar laminated siltstone overlain by well sorted, well rounded, fine-grained and horizontally bedded sandstone; in lower part of Mancos Shale; 20 m thick.

Kmh — **Mancos Shale, Hosta-Dalton Sandstone (Kmh, Upper Cretaceous)** — yellowish-gray to yellowish-tan, very fine- to medium-grained, weakly cemented, fossiliferous sandstone with olive-brown sandstone lenses; 84-112 m thick.

Km — **Mancos Shale, undivided (Km, Upper Cretaceous)** — medium- to dark-gray to olive-gray, shale, silty shale and calcareous shale; divided into lower and upper shale by Hosta-Dalton Sandstone (**Kmh**); upper shale includes thin, regionally recognizable marker beds such as the Greenhorn Limestone and Juana Lopez Member; upper shale is correlative to the Graneros-Niobrara interval of the southern High Plains and San Juan Basin; total thickness ranges between 330-675 m.

Kd — **Dakota Fm (Kd, Upper Cretaceous)** — light- to yellowish-gray and brown, silica-cemented quartzose sandstone; overlain by and interbedded with dark-gray to olive-gray shale of the Mancos Shale; 8-40 m thick.

Ju — **Jurassic sedimentary rocks, undivided (Ju, Middle-Upper Jurassic)** — light-brown to pale-orange cross-stratified sandstone, dark-gray, thinly laminated limestone, gray gypsum, brown silty sandstone, pale-orage to grayish-red, variegated feldspathic cross-stratified sandstone, conglomerate and mudstone; includes deposits of the *San Rafael Group (Entrada, Todilto, and Summerville Formations)* and *Morrison Formation*; 310 m thick.

TRu — **Triassic sedimentary rocks, undivided (TRu, Middle-Upper Triassic)** — red mudstone, trough cross-bedded sandstone, and conglomerate with petrified wood overlain by pale-orange, mica-bearing fluvial sandstone; includes deposits of the *Chinle Group* and *Moenkopi Formation*: 400-500 m thick.

Psg — **San Andres and Glorieta Formations, undivided (Psg, Upper Permian)** — light-gray to tan, locally karstic limestone and grayish-white cross-stratified quartzose sandstone; 15-77 m thick.

Pay — **Abo and Yeso Formations, undivided (Pay, Lower Permian)** — pale-red and grayish-red mudstone and grayish-white to light-orange lenticular, cross-stratified arkosic sandstone, siltstone, claystone and beds of gypsum and gypsiferous sandstone; 500 m thick.

IPm — **Madera Group, undivided (IPm, Pennsylvanian)** — gray, ledge-forming, cherty limestone with interbedded argillaceous limestone of the *Gray Mesa Formation*; overlain by fossiliferous limestone with interbedded sandstone and mudstone of the *Atrasado Formation*; uppermost part of unit includes mixed marine carbonate and nonmarine clastic sediments; 385-402 m thick.

IPs — **Sandia Formation and Arroyo Peñasco Group, undivided (IPs, Pennsylvanian-Mississippian)** — quartz-pebble conglomerate, sandstone, and dolostone (Arroyo Peñasco Group) and interbedded brown claystone and gray limestone (Sandia Formation); 37-81 m thick.

Qb (Qb5, Qb4, Qb3, Qb2, Qb1) — **Basaltic lavas of the Albuquerque volcanoes (Qb, middle Pleistocene)** — vesicular olivine tholeiite lava flows locally divided into five flows (**Qb1-Qb5**) based on surface morphology and stratigraphic position (modified from Kelley and Kudo, 1978; and Thompson et al., *in preparation*); whole-rock $^{238}U/^{230}Th$ date of 0.156±0.02 Ma (Peate et al., 1996); generally less than 15 m thick.

Vents of the Albuquerque volcanoes (Qbv, middle Pleistocene) — larger cinder and spatter cones of Albuquerque volcanoes volcanic field; smaller vents denoted by asterisk (*).

Tb / Tbv — **Basaltic lavas of Santa Ana Mesa (San Felipe volcanic field) (Tb, upper Pliocene)** — tholeiitic flood basalts and vents (**Tbv**) forming Santa Ana Mesa; whole-rock $^{40}Ar/^{39}Ar$ dates of 1.78±0.21 and 2.60±0.11 Ma (*SA-7* and *SA-8*, Table 1); ; 6-30 m thick.

Tvc / Tvcb — **Tuff of Canjilon Hill (Tvc, upper Pliocene)** — oval-shaped tuff-breccia diatreme that intrudes Santa Ana Mesa Member (**Tcs**, Ceja Formation) south of Santa Ana Mesa; includes basaltic lavas, dikes, and brecciated lava flows (**Tvcb**); whole-rock $^{40}Ar/^{39}Ar$ date on basaltic dike of 2.54±0.43 Ma (*SA-9*, Table 1).

Buried igneous rocks inferred from aeromagnetic anomalies (Miocene-Pliocene) — probable buried intrusive or volcanic rocks recognized by areas of higher relative value (>180 nT) on high-resolution aeromagnetic anomaly maps (Kucks et al., 2001) and locally encountered in drillholes; buried features may extend beyond lateral limit of unit.

Mafic dike (Paleogene) — dark-gray, steeply dipping dike of mafic to intermediate composition; whole-rock $^{40}Ar/^{39}Ar$ date of 31.1±0.5 Ma (*SA-29*, Table 1) for dike on Placitas quadrangle; up to 8 m thick.

Ys / Yss — **Sandia granite (Ys, Mesoproterozoic)** — pink megacrystic biotite monzogranite and granodiorite; includes zones of sheared megacrystic biotite monzogranite and granodiorite of the Seven Springs shear zone (**Yss**) just north of trace of Tijeras fault zone; U-Pb dates on zircon indicate age of crystallization between 1455±12 Ma and 1446±26 Ma.

Felsic dike (Mesoproterozoic) — pegmatite and aplite dikes, pods and lenses; coeval with emplacement of Sandia granite (**Ys**); thickness ranges from 30 cm to over 15 m; up to 1600 m in length.

Xg — **Older granite, undivided (Xg, Paleoproterozoic)** — isolated screens and xenoliths of banded biotite-rich granitic gneiss intruded by the Sandia granite; also contains leucocratic and aplitic granite and biotite-poor granite; includes Manzanita granite and Cibola granite (gneiss) with U-Pb dates on zircon indicate age of crystallization of 1645±16 Ma and 1653±21 Ma, respectively (Karlstrom et al., 2004).

Xv — **Metavolcanic rocks, undivided (Xv, Paleoproterozoic)** — Metarhyolite, felsic metavolcanic, mafic metavolcanic, and metamorphosed dacitic tuff; intruded by older granite (**Xg**); not dated in map area, but U-Pb date on zircon from the nearby Monte Largo Hills metarhyolite indicate an age of crystallization of 1700±20 Ma (Karlstrom et al., 2004).

Xs — **Schist, undivided (Xs, Paleoproterozoic)** — pelitic, locally quartz-bearing, schist and phyllite; commonly crenulated with zones of quartz-muscovite and andalusite- to sillimanite and biotite-bearing schist; includes Juan Tabo series; intruded by Sandia granite with contact aureole on Rincon Ridge; whole-rock Rb-Sr age of metamorphism is 1640±40 Ma (Brookins and Majumdar, 1983, cited in Kirby et al., 1995).

Xq — **Metasedimentary rocks, undivided (Xq, Paleoproterozoic)** — gray to white, thick-bedded to massive, cross-stratified quartzite with pelitic partings and interbeds; includes Isleta metasediments, and Cerro Pelon, Coyote, and Cibola quartzite, U-Pb age on zircon of metamorphism is 1423±2 Ma.

Geologic Map from Preliminary Geologic Map of the Albuquerque–Rio Rancho Metropolitan Area and Vicinity, Bernalillo and Sandoval Counties, New Mexico by S. Connell (2006)

FIGURE 4

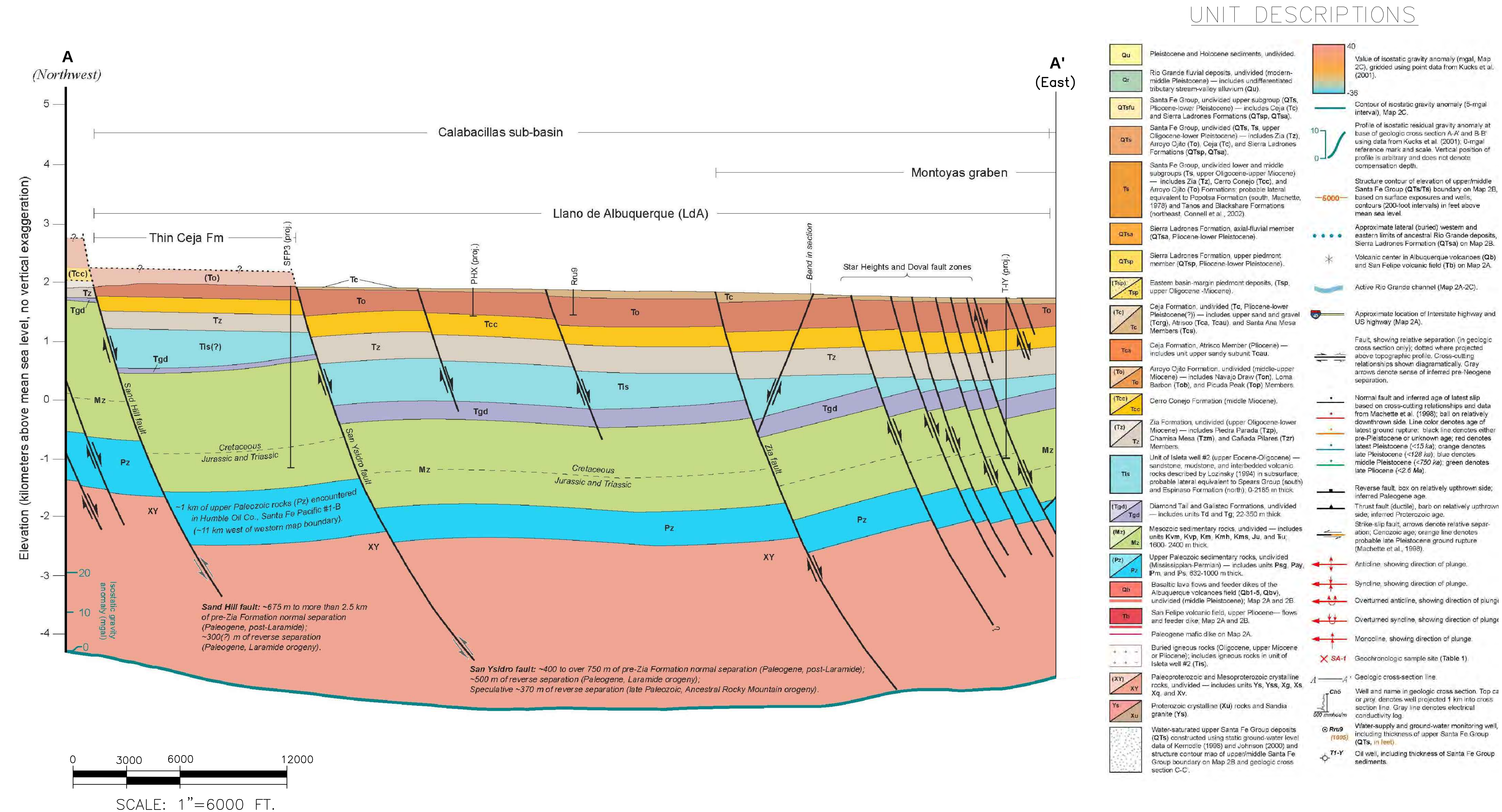
GEOLOGIC UNIT DESCRIPTIONS
RIO RANCHO ESTATES
SANDOVAL COUNTY, NEW MEXICO

SMA Engineering Environmental Surveying
3451 CANDELARIA ROAD NE, SUITE D
ALBUQUERQUE, NEW MEXICO, 87107
505-299-0942, FAX 505-293-3430
SERVING THE SOUTHWEST AND ROCKY MOUNTAINS

DRAWN MAE
CHECKED SAM
APPROVED SAM

REVISIONS
BY ____ DATE ____ DESCR. ____
BY ____ DATE ____ DESCR. ____

4219863
3/6/2013



Cross Section from Plate 2 of Preliminary Geologic Map of the Albuquerque–Rio Rancho Metropolitan Area and Vicinity, Bernalillo and Sandoval Counties, New Mexico by S. Connell (2006)

FIGURE 5

GEOLOGIC CROSS SECTION
RIO RANCHO ESTATES
SANDOVAL COUNTY, NEW MEXICO

3451 CANDELARIA ROAD NE, SUITE D
ALBUQUERQUE, NEW MEXICO, 87107
505-299-0942, FAX 505-293-3430
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CHECKED SAM
APPROVED SAM

REVISIONS
BY ___ DATE ___ DESCR. ___
BY ___ DATE ___ DESCR. ___

4219863
3/6/2013

Aquifer recharge in the Middle Rio Grande Basin is from infiltration of water from the Rio Grande and associated irrigation structures and Cochiti Reservoir (Bartolino, 2002), and also from recharge on mountain fronts on the margins of the basin (Bartolino and Constantz, 2002).

V. WATER USE AND REGULATION

A. Regional Water Use

Water depletions in the Middle Rio Grande are shown on the figure below (Middle Rio Grande Water Assembly, 1999). As can be seen, urban consumption makes up approximately 13% of total depletions. Other depletions are related to irrigated agriculture, evaporation and transpiration (plant uptake), and aquifer recharge.

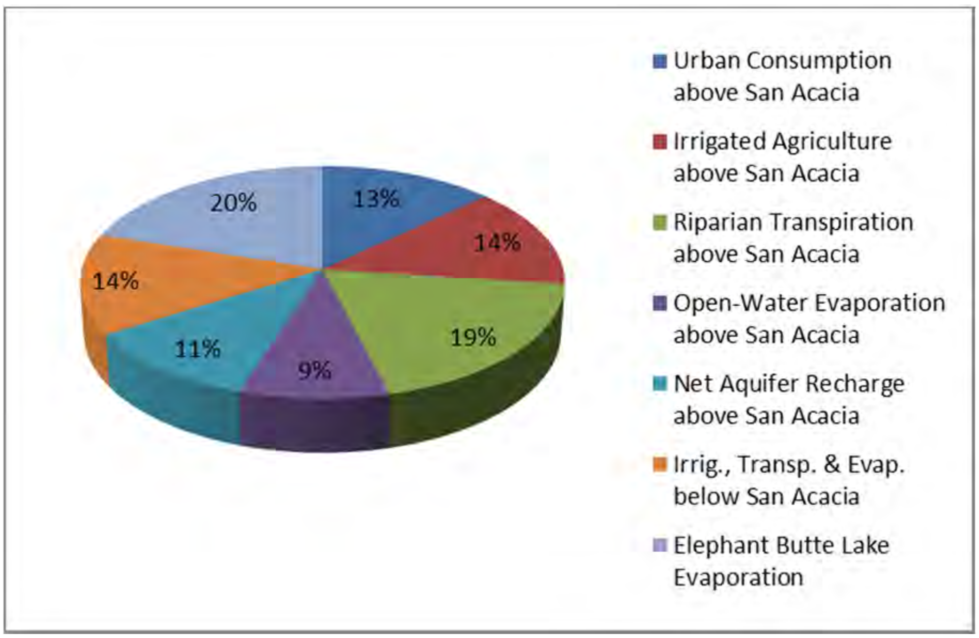

Figure 6 - Water Consumption in the Middle Rio Grande Basin

The principal water producers in the area are the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) and the City of Rio Rancho. ABCWUA produced 106,191 acre-ft for 2011 (ABCWUA, 2013), while the City of Rio Rancho produced 13,617 acre-ft in 2011 (Marian Wrage, City of Rio Rancho, personal communication 2013). The NMOSE has records of in excess of 95,000 domestic wells within the Middle Rio Grande valley, which likely produce in the neighborhood of 40,000 acre-ft/yr (assuming a use of 0.41 acre/ft-yr per well, discussed below), in addition to the production delineated above.

Until the recent development of surface water resources as a water supply for the ABCWUA, the Santa Fe Group aquifers were the sole source of drinking water for the

Albuquerque Metropolitan area. The City of Albuquerque (now ABCWUA) was withdrawing 127,000 acre-feet per year from the aquifer in 1989, before conservation efforts led to a reduction in use (McAda and Barroll, 2002). The high diversion from the aquifer has led to substantial declines in groundwater elevation over the past few decades (McAda and Barroll, 2002). The extensive decline in groundwater within the area has led the NMOSE to develop the Middle Rio Grande Administrative Area Guidelines for Review of Water Right Applications (NMOSE, 2000) which includes requirements limiting water level drawdown. These guidelines are discussed in further detail below.

The water rights controlled by the City of Rio Rancho describe the well field for production of water as being located within the Town of Alameda Grant, and the service area of the Rio Rancho municipal water system. At least 7 existing or planned City of Rio Rancho wells are located within Rio Rancho Estates, which implies that the service area for the City of Rio Rancho includes at least part of Rio Rancho Estates. Although this is the case, the City of Rio Rancho is not required to provide water service to any portion of Rio Rancho Estates, though they may elect to. Additionally, there is no restriction on another municipality, county, utility, or member-owned community water system providing water to the area. It is relatively common in New Mexico for service areas of these types of entities to overlap.

B. Water Use Regulation

Efficient water regulation in New Mexico began when the Territorial Legislature passed the 1907 New Mexico Water Code, which provided broad authority to the New Mexico Territorial Engineer, later to become the New Mexico State Engineer. Additionally, the 1907 Code also greatly increased the scope of the adjudication process in the courts. The 1907 Water Code was enacted in order to promote the value of water rights, address quarrels that arose when water was unregulated, and attract development to New Mexico.

In 1931, the regulation of groundwater was included in the State Engineer's duties. Given that surface water and groundwater are interconnected, the State Engineer began to manage these resources conjunctively in the 1960s. The understanding that use of groundwater affects the surface water flows and the availability of surface water was the driving factor. This meant that someone applying to appropriate groundwater under the groundwater code would be held responsible for the effects of the appropriation on surface water users.

All surface waters of the Rio Grande have been considered fully appropriated (owned) since the Rio Grande Compact was consummated in 1938. The Rio Grande Compact is the agreement between New Mexico, Colorado and Texas which equitably apportions the waters of the Rio Grande Basin. Accordingly, the State Engineer does not allow new Rio Grande surface water appropriations, and conjunctively manages water resources within the Rio Grande Basin to protect existing water rights and to ensure compliance with the Rio Grande Compact. In order to use water (with the exception of individual domestic supply wells, 72-12-1 NMSA), any water used must be purchased from a current water right holder.

In 2000, the State Engineer adopted the *Middle Rio Grande Administrative Area Guidelines for Review of Water Rights Applications* (NMOSE 2000). The Middle Rio Grande Administrative Area (MRGAA) is defined as the area between Cochiti Dam to the north and San Acacia Dam to the south, including the Rio Grande main stem, all tributaries to and aquifers underlying, irrigation canals and laterals within, and drains and wasteways within, that stretch of the Rio Grande.

The Guidelines embody the State Engineer's current practice for evaluating pending and future applications for permits for groundwater use in the MRGAA to ensure compliance with the Rio Grande Compact, to prevent impairment to existing rights, to limit the rate of decline of groundwater levels so that the life of the aquifer is extended, and to minimize land subsidence due to groundwater removal.

The Guidelines do not apply to individual domestic wells. These wells do not have a water right associated with them, but instead have a permitted diversion. Domestic wells are generally limited to use of 1 acre-ft/yr. This amount can be limited further by county or municipal ordinance. The Guidelines require that new domestic wells be metered if they are within a Critical Management Area (discussed below).

Since the declaration of the Rio Grande Underground Water Basin, which includes the MRGAA, groundwater permittees have been required to obtain (purchase) valid water rights in an amount sufficient to offset the effects of their diversions on the surface flows of the Rio Grande stream system. This requirement protects surface flows of the Rio Grande from being depleted or reduced by groundwater diversions. This is done by the new permittee finding a seller of valid surface water rights and obtaining a permit from the State Engineer to transfer the surface water rights. This transfer within the Rio Grande stream system is a complicated and often lengthy process due to the complex interrelationship between the surface and ground waters, the numerous existing appropriations to be protected, and the diversity of the numerous interests having standing to participate in the administrative process for an application for permit. Because transfer application decisions can be appealed to the District Court, the Court of Appeals and the state Supreme Court, the final decision on approval of a water rights transfer may be rendered long after the time the application was filed.

The State Engineer, in order to fulfill his duty to the public welfare, may limit actual groundwater diversions within the MRGAA to the amount of valid surface water rights purchased and transferred or otherwise held by the permittee, plus the amount of water the permittee returns directly to the river or the aquifer. The MRGAA Guidelines define a methodology to ensure compliance with these limits, as summarized below.

Ability to Acquire and Hold Water Rights

Municipalities, counties, state universities, member-owned community water systems, and water utilities supplying municipalities or counties may acquire and hold unused water rights based on reasonably projected future needs within a 40-year planning period. This is consistent with requirements across the state.

Permit Limit on Actual Water Diversion

A permit to divert ground water shall limit the actual groundwater diversion to the valid consumptive use surface water rights held and designated for offset purposes, plus any flow returned to the Rio Grande, indirect return flow, or return flow to the aquifer, as approved by the State Engineer.

Valid Surface Rights

Valid surface rights include surface water rights transferred to groundwater, and other valid water rights, including contracts for San Juan Project water, as approved by the State Engineer.

Offset Requirements

Valid consumptive use surface water rights as described above shall be obtained and designated by the permittee to offset the greater of either:

- Total well diversions less any flow returned directly to the Rio Grande or
- The net surface water depletion associated with past and present use including consideration of residual effects of past diversions, on a time schedule approved by the State Engineer

Lease of Water Rights

Valid water rights held by the permittee for the purposes of offsetting future depletions may be leased for other purposes for the period of time until needed to offset the surface water depletions caused by the permitted groundwater diversion. The amount of water available for lease is determined using the MRGAA model (discussed below).

MRGAA Restrictions

Applications for well permits are evaluated to determine the predicted amount of water level drawdown using the MRGAA model (discussed below). The State Engineer does not allow drawdown in non-critical areas (defined below) in excess of 2.75 feet per year. If this condition is met, the state engineer may approve the application as long as

- granting the right will not impair existing water rights, be contrary to water conservation within the state, or be detrimental to the public welfare of the state; or

- the proposed appropriation combined with the exercise of existing water rights will not cause total water level declines in any Critical Management Area to exceed 250 feet from pre-development conditions to the year 2040.

If predicted drawdown is greater than this amount, the State Engineer will not approve the permit.

Critical Management Areas

A Critical Management Area (CMA) is defined as any area with excessive water level declines, as predicted by the MRGAA model or measured in the field, which are caused by exercise of existing permits. Excessive water level declines are defined as those greater than 2.5 feet per year through the year 2040. These areas are closed to additional appropriations. As of the date of implementation of the Guidelines, a CMA existed beneath the City of Albuquerque, largely due to ABCWUA pumping.

Critical Management Area Restrictions

The State Engineer will accept no applications in a CMA for appropriation of additional water. Existing permit holders may apply to replace, repair, deepen or supplement an original well. The amount of water previously placed to beneficial use under an existing permit will be the limit for replaced, repaired, deepened or supplemental wells. Owners of declared water rights within a CMA will be limited similarly to the amount of water previously placed to beneficial use.

Calculation of Water Level Decline Rates

The MRGAA model is used to calculate water level decline based on the full production of proposed wells from the time of application through 2040. If a pumping schedule is proposed, the pumping schedule will be modeled, instead of full production. The model takes into account all approved permits in the MRGAA, and permits approved after development of the model are included in the model for future evaluations.

Land Subsidence

The MRGAA Guidelines prohibition of greater than 2.5 feet per year of drawdown is based on the need to minimize the potential for subsidence caused by groundwater pumping (Jess Ward, NMOSE, personal communication 2013). The goal of the Guidelines is to not allow greater than 250 feet of drawdown over 100 years (thus 2.5 feet/year). Studies indicate that drawdown of the water table in excess of 250 feet is likely to cause land subsidence.

Land subsidence occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock falls in on itself. Land subsidence is not readily obvious because it occurs over large areas rather than in a small spot, like a sinkhole. That doesn't mean that subsidence is not a big event -- states like California, Texas, and Florida have suffered damage to the tune of hundreds of millions of dollars over the years (Waller, 1982). Additional information is provided by the the United States Geological Survey at the website http://water.usgs.gov/ogw/subsidence.html .

VI. EVALUATION OF DEVELOPMENT OPTIONS

The MRGAA model was used to evaluate groundwater decline caused by a range of development scenarios, and related water pumping rates and locations, for the Rio Rancho Estates area. This work was conducted by John Shomaker & Associates, and is contained in Appendix A. The model was used because it is an accepted tool that takes into account all existing permitted water uses within the area, as well as realistic regional use of domestic supply wells. While not currently used to evaluate water level declines from individual domestic supply wells, the model is capable of being used in this manner. A summary of the model is included below.

A. MRGAA Model

Future groundwater-level drawdown and surface-water changes associated with potential Rio Rancho Estates development were evaluated using an updated version of the MRG Administrative Model (NMOSE, personal communication, August 2012). The model represents historical and permitted future groundwater pumping under all existing groundwater rights in the Basin (e.g., City of Rio Rancho and Albuquerque-Bernalillo County Water Utility Authority pumping). Potential Rio Rancho Estates pumping was added to the total pumping for the model simulations in this report.

The groundwater system in the MRG Basin is simulated using the U.S. Geological Survey (USGS) MODFLOW computer program (Harbaugh and McDonald, 1996), which is commonly used for groundwater-flow modeling. The model represents the basin as a finite-difference grid of rectangular cells with 113 rows and 60 columns, covering an area of about 3,468 square miles (Figure 7). The grid cells are relatively large (0.3 to 0.4 square mile) near Rio Rancho Estates. The three-dimensional grid also has 6 layers, representing a total aquifer thickness of about 1,600 ft.

Municipal and industrial wells are typically simulated as pumping from layers 4 through 6 in the model, and domestic wells are typically simulated as pumping from shallower layers 1 through 3. The lower 3 layers are defined as constant transmissivity, confined aquifer units. The upper 3 model layers (upper 200 ft) are defined as variable transmissivity aquifer units that may change between confined and unconfined conditions. Cells in the upper 3 model layers can become dry if the simulated water level drops below the cell bottom. The MRG model assumes that wells will be deepened as necessary; if the model cell to which a pumping well has been assigned becomes dry during a simulation, the pumping is automatically shifted to the next layer below.

Transmissivity within each model layer varies spatially. Figure 7 shows the model grid along with simulated hydraulic conductivity (transmissivity per unit aquifer thickness) for layer 3, indicating a low-conductivity fault zone trending north-northeast through Rio Rancho Estates. The simulated location and hydraulic properties of the fault zone are based on geologic mapping and model calibration results (Tiedeman et al., 1998; NMOSE, 2001). Although the fault zone as represented in the model is at least one cell (0.6 mile) wide, in reality it is probably much narrower. In practice, wells can likely be drilled off of the fault zone without moving such a large distance. Moving wells off the fault zone is simulated in the model by moving the pumping locations to an adjacent cell. This has been an accepted practice (NMOSE, 2001) with the Middle Rio Grande Administrative Model for evaluating pumping in and adjacent to the fault zone, and it is used for the “Individual Wells, modified” pumping scenarios presented below. Generally speaking, hydraulic conductivity is greater to the east of the fault zone, which allows water to flow more readily to wells, causing less drawdown.

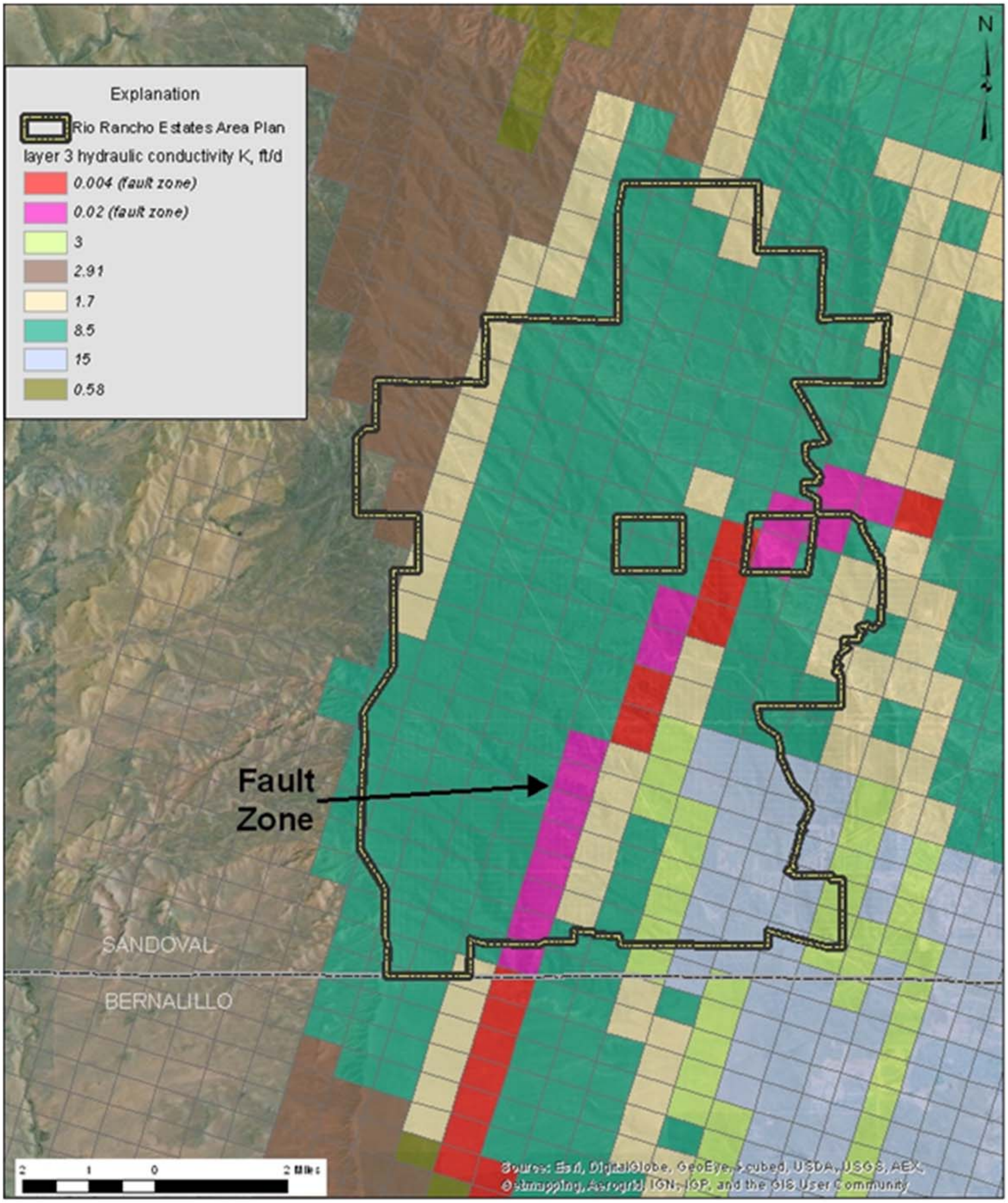

Figure 7 - Model grid and layer 3 hydraulic conductivity

B. Water Usage Calculation

In order to characterize the future water resource needs of Rio Rancho Estates, SMA estimated the water use assuming a full build-out of the development. To approximate the water use from Rio Rancho Estates, SMA utilized current water use within the City of Rio Rancho and applied it to the anticipated population of the development. The City of Rio Rancho is currently using 141.8 gallons of water per capita per day (gpcd) (Marian Wrage, City of Rio Rancho, pers. comm. 2012). The City of Rio Rancho has a water conservation goal of reducing this use to 135 gpcd by 2017. As the water use in Rio Rancho was 150 gpcd in 2007, SMA believes that Rio Rancho will be able to reach its conservation goals of 135 gpcd, and this number was utilized in future water use estimates.

The water use per capita was used in conjunction with the median household size for Rio Rancho as determined in the 2010 census (2.72 persons per household) to provide a water use per lot of 0.41 acre-feet per year. Assuming a full build-out of Rio Rancho Estates (41,000 lots), this equates to a daily water need of 15 million gallons, or 16,810 acre-feet per year. Assuming an additional 1,200 acre-feet per year of water use from industrial sources, Rio Rancho Estates would require approximately 18,000 acre-feet per year of water resources at full build-out.

C. Model Representation of Pumping

The estimated water use for each Rio Rancho Estates development scenario was added to the model as simulated future pumping. The most recent model version (NMOSE, pers. comm. 2012) already includes future pumping from all existing groundwater rights in the Basin (e.g., City of Rio Rancho and ABCWUA pumping). The projected 2014-2039 drawdown due to all permitted pumping (not including Rio Rancho Estates) is depicted on Figure 8, which shows an area with projected drawdown greater than 2.5 feet/year, or 65 feet over the 26 model-life years, east of the Rio Grande within the City of Albuquerque. By definition, this area is a Critical Management Area (CMA) as defined by the MRGAA Guidelines. The Guidelines prohibit the creation of new CMA.

For the municipal wells scenarios, pumping was simulated from nine potential supply wells (Figure 9) located in areas with moderately high transmissivity in the model west of the low-permeability fault zone (Figure 7), some distance from existing and permitted City of Rio Rancho supply well locations (Figure 9). Pumping was taken in equal portions from the bottom three model layers (layers 4-6), representing the deep completions and long screen intervals typical of large municipal wells. The number of municipal wells (nine) projected was based on the minimum number of wells necessary to produce the required water at expected flow rates for municipal wells. The expected average flow rate for a municipal well is approximately 1,250 gallons per minute (gpm).

Pumping for the individual domestic wells scenarios was taken initially from model layer 1, reflecting typical domestic well completion and screening through the upper part of the

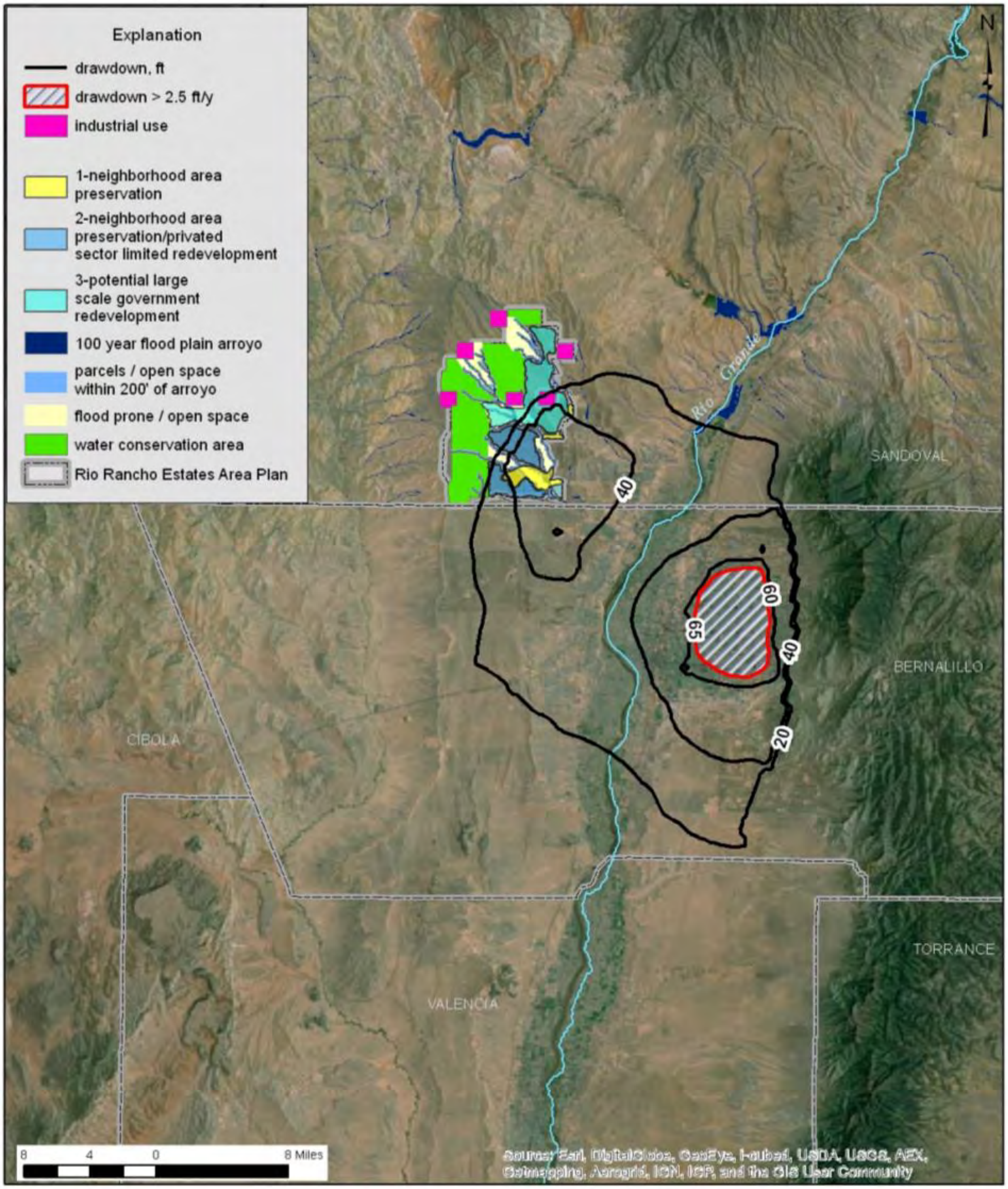

Figure 8 - Projected drawdown, 2014-2039, without Rio Rancho Estates development

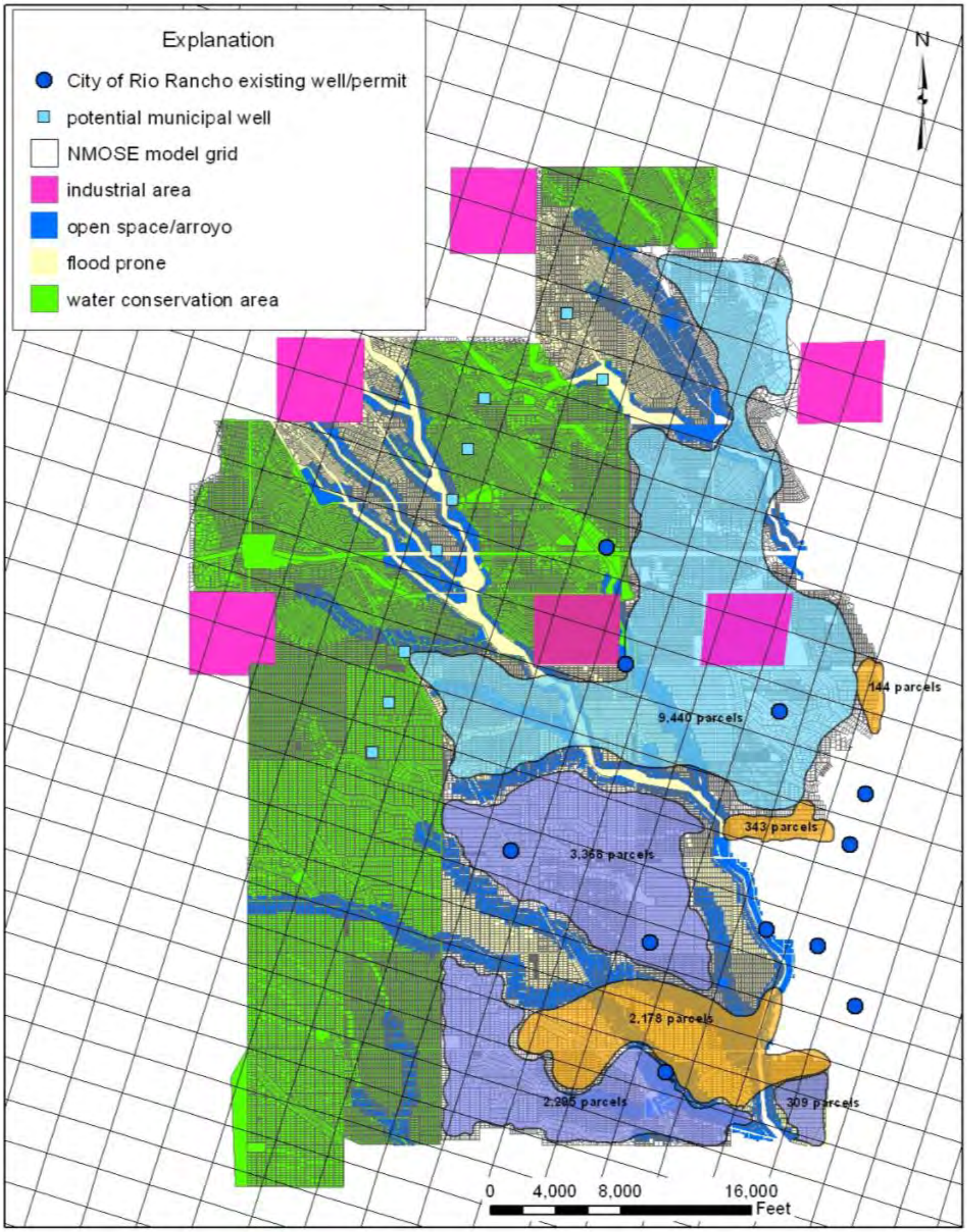

Figure 9 - Rio Rancho Estates showing existing and potential municipal well locations

water table. The model assumes that wells will be deepened as necessary, so that if a model cell becomes dry, simulated pumping is automatically shifted to the next layer below.

D. Initial Model Scenarios – Maximum Pumping Rate

The initial model scenarios completed evaluated pumping for the original development plan (41,000 lots) and four industrial areas from individual domestic wells, or from a system of municipal wells. Total water production in this scenario is 18,010 acre-ft/yr.

For the individual domestic well scenario, pumping was simulated from each model cell location (Figure 7) according to the number of lots within each cell. Pumping for 41,000 individual lots was assumed to begin with full build-out in 2014 (worst-case scenario). Results indicate excessive drawdown and doubtful supply. Figure 10 shows the CMA (drawdown in excess of 2.5 feet/year) that would be formed due to full pumping from individual supply wells.

For the municipal well scenario, pumping was simulated from nine potential municipal wells (Figure 9). Pumping to supply 41,000 lots was assumed to begin with full build-out in 2014 (worst case scenario). Results predict drawdown from 2013 to 2040 in excess of NMOSE guidelines. Figure 11 shows the CMA that would be formed due to full pumping from municipal wells.

Based on these results, model runs were completed to determine the maximum pumping rate that could be implemented without causing a CMA to be formed. The pumping rate was determined to be between 8,000 and 9,000 acre-ft/yr.

E. Model Scenarios at Lower Pumping Rate

Modeling of water necessary to develop 18,077 lots and four industrial areas (total of 8,612 ac-ft/yr) was completed for supply from both individual domestic wells and municipal wells. Individual domestic well and municipal well scenarios were modeled with pumping implemented two ways: 1) full build-out starting in 2014 (worst-case scenario); and 2) build-out phased over a period of years. Results of scenarios are summarized below.

Individual Wells, 18,077-Lot Full Build-Out: Pumping was apportioned to cells by number of lots and/or size of industrial area, beginning with full build-out in 2014. Results indicate excessive drawdown and doubtful supply along the low-permeability fault zone that bisects the development area, as shown by Figure 12.

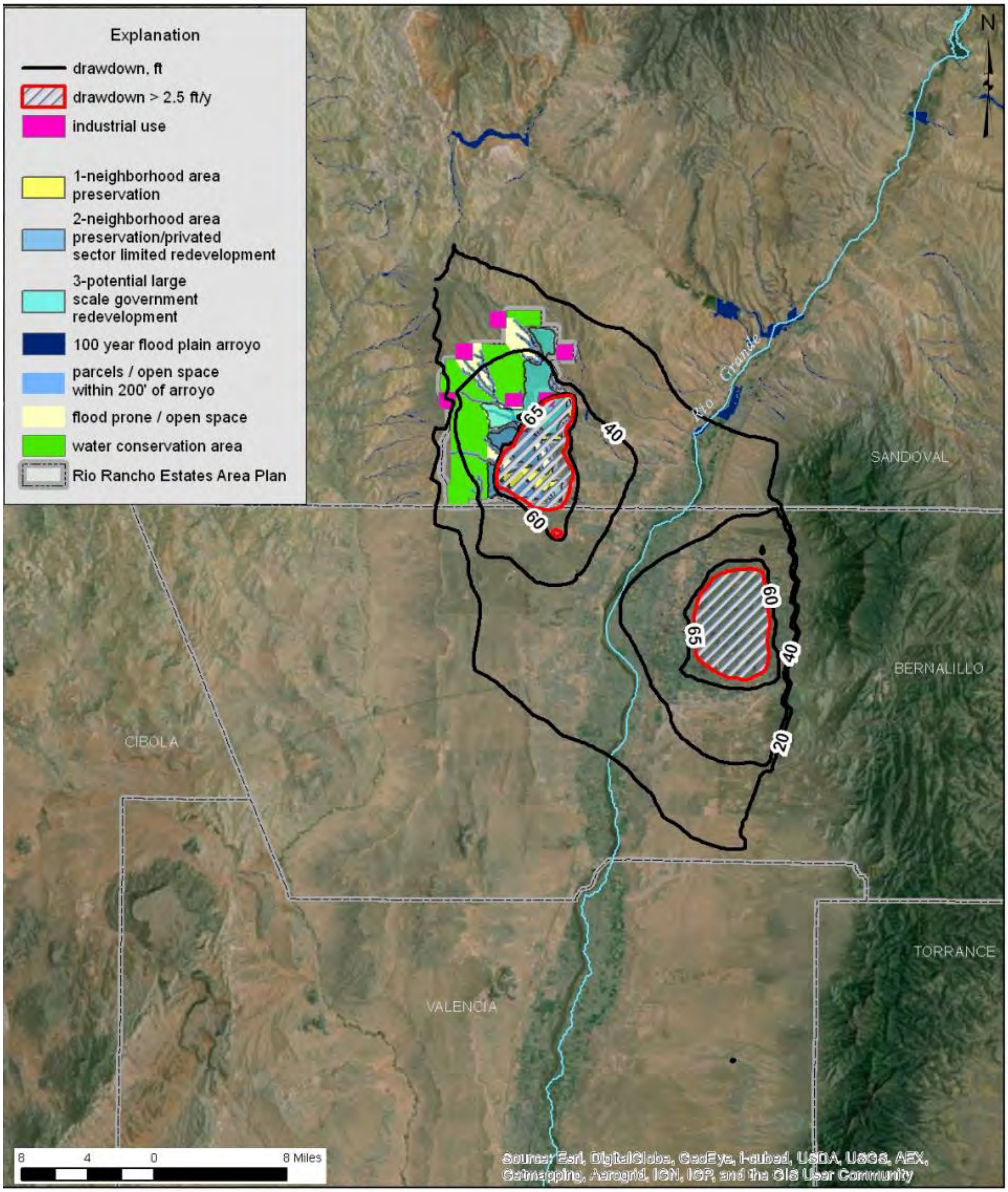

Figure 10 - Projected drawdown, 2014-2039, individual wells, 41,000-lot full build-out scenario

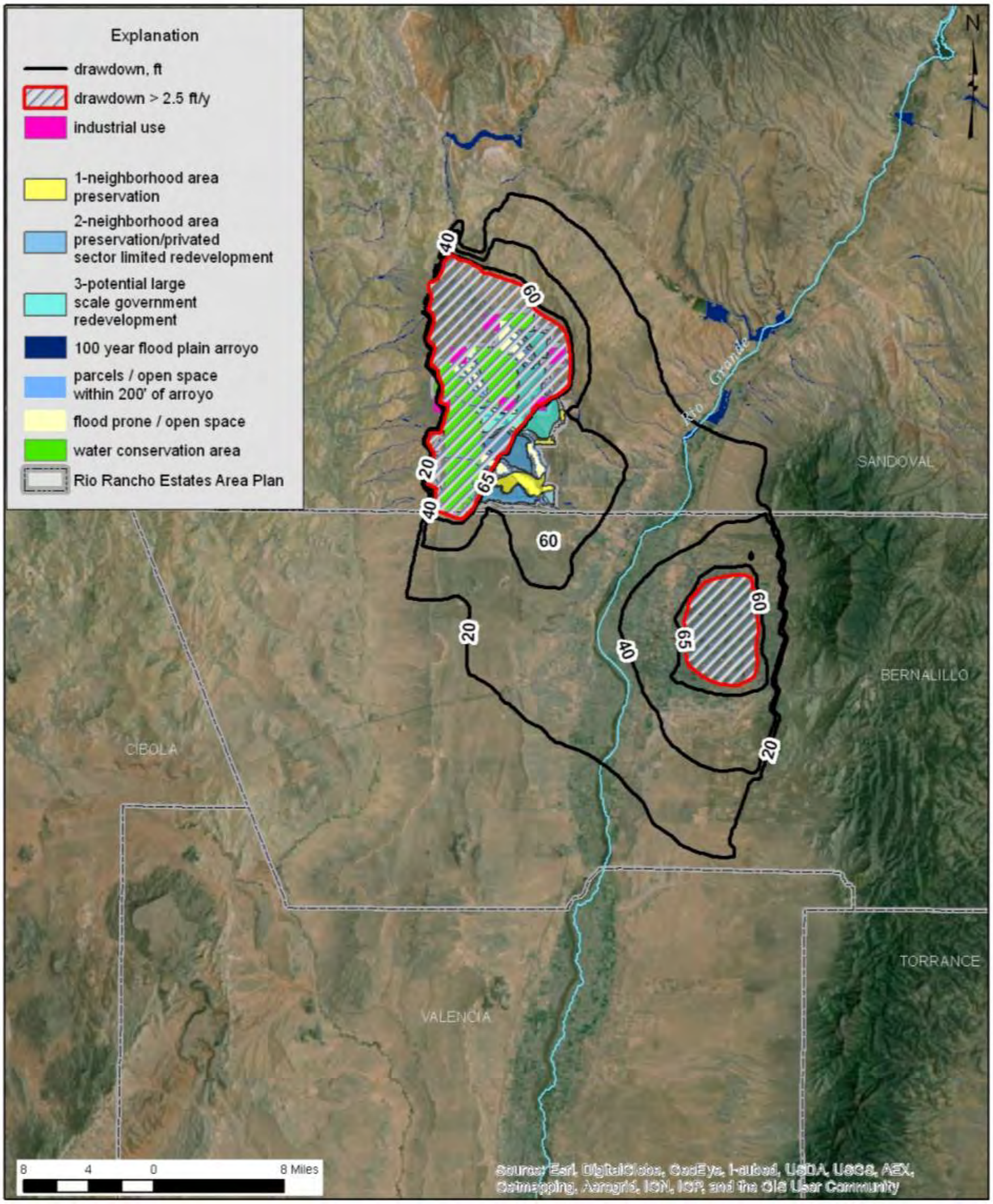

Figure 11 - Projected drawdown, 2014-2039, municipal wells, 41,000-lot full build-out scenario

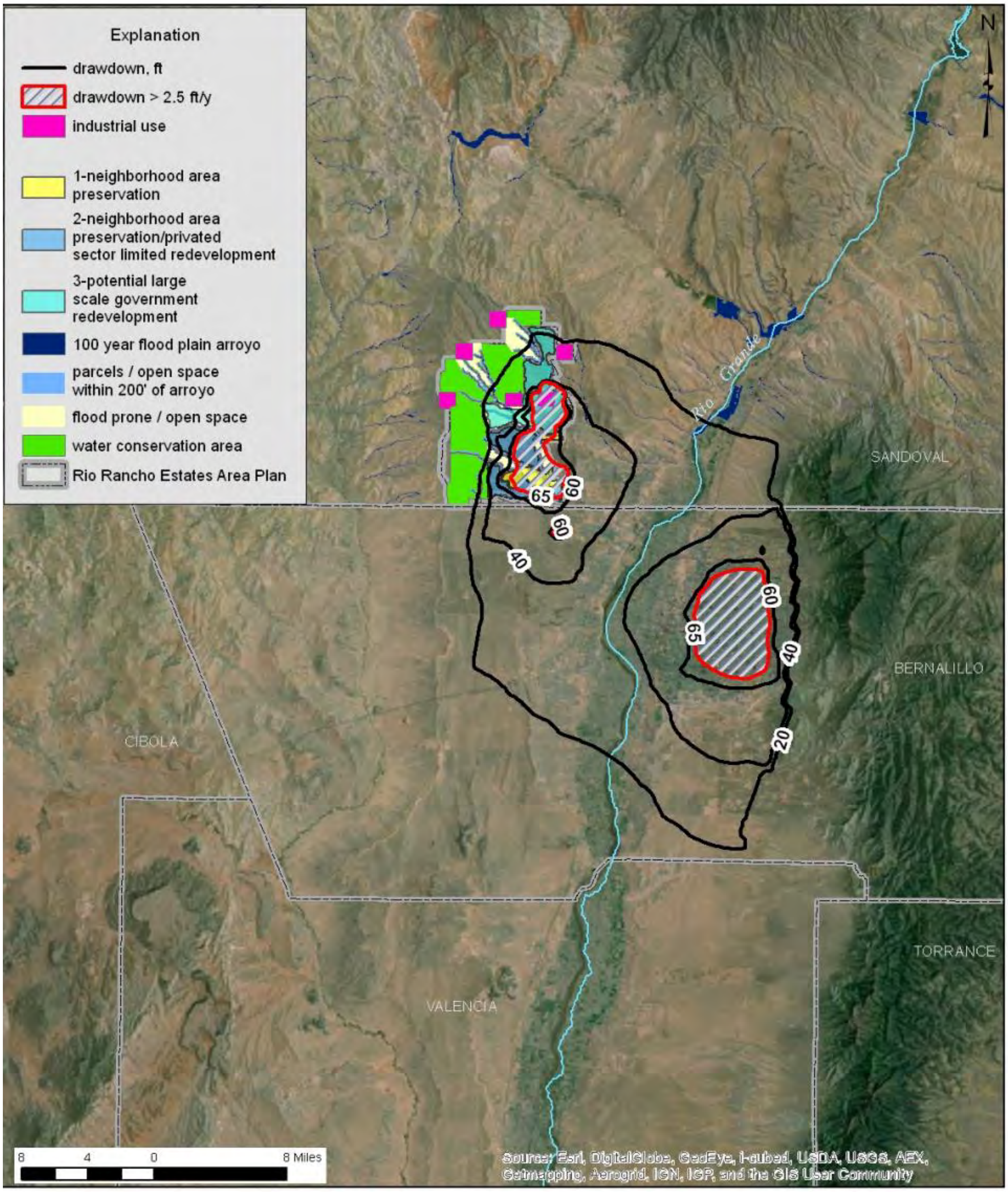

Figure 12 - Projected drawdown, 2014-2039, individual wells, 18,077-lot full build-out scenario

Individual Wells, Modified, 18,077-Lot Full Build-Out: Pumping was moved from the low-permeability fault zone cells to adjacent cells. Pumping for 18,077 lots was assumed to begin with full build-out in 2014. Results indicate excessive drawdown and doubtful supply in a limited area east of the low-permeability fault zone, as shown in Figure 13.

Municipal Wells, 18,077-Lot Full Build-Out: Pumping was simulated from nine potential municipal wells. Pumping to supply 18,077 lots was assumed to begin with full build-out in 2014. Results predict drawdown from 2013 to 2040 in excess of NMOSE guidelines, as shown in Figure 14.

Individual Wells, Modified, 18,077-Lot Phased Build-Out: Pumping was phased in, beginning with 20 percent of full pumping in 2014, increasing by 20 percent in 2019, 2024, and 2029, reaching full build-out in 2034. Results indicate excessive drawdown and doubtful supply in a relatively small area at the east edge of the low-permeability fault zone, as shown in Figure 15. This area is adjacent to a 537-acre area noted as public use.

The model was re-run to determine what reduced pumping amount would not cause excessive drawdown on the east edge of the low-permeability fault zone. This area corresponds to four model cells on the southeastern part of the Zone 3 development area and three model cells on the southeastern part of the Zone 2 development area. It was determined that decreasing pumping in the four Zone 3 model cells by 390 acre-ft/yr and decreasing the pumping in the four Zone 2 model cells by 230 ac-ft/yr would allow the scenario to not cause excessive drawdown. This pumping is equivalent to a decrease in 1,510 lots.

Municipal Wells, 18,077-Lot Phased Build-Out: Pumping was simulated from nine potential municipal wells, beginning with 20 percent of full pumping in 2014, increasing by 20 percent in 2019, 2024 and 2029, reaching full build-out for 18,077 lots in 2034. Results predict drawdown approaching but not exceeding NMOSE guidelines, as shown by Figure 16

Summary of Findings

Initial model runs indicate that inadequate groundwater exists to supply the full 41,000 lots currently platted in Rio Rancho Estates. Modeling indicates that water is available to supply approximately 18,100 lots. Modeling of pumping at this rate indicates that excessive drawdown (greater than 2.5 feet/year) would be caused if individual domestic wells are utilized for water supply. Use of municipal wells phased in over a period of years does not cause excessive drawdown.

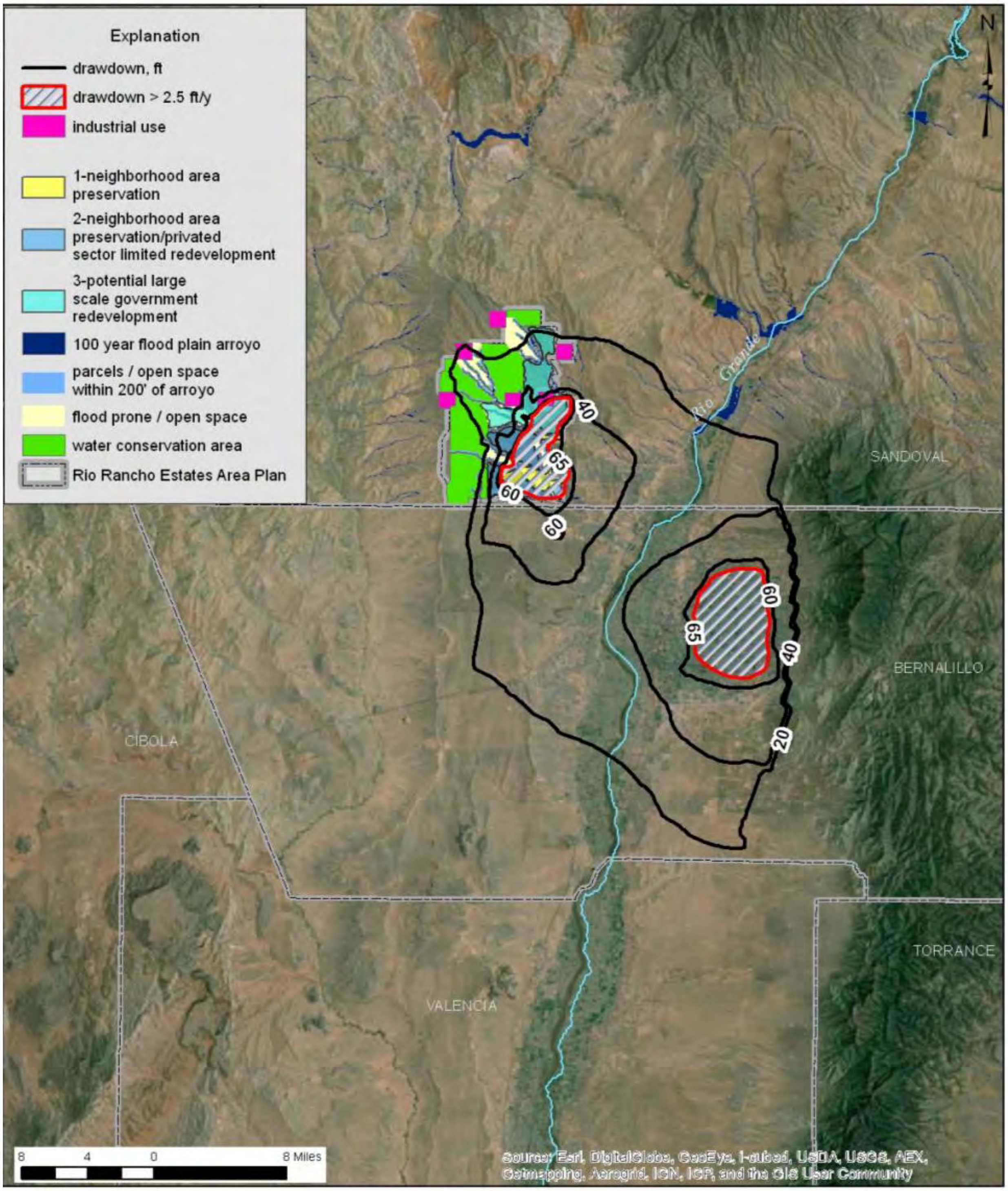

Figure 13 - Projected drawdown, 2014-2039, individual wells, modified, 18,077-lot full build-out scenario

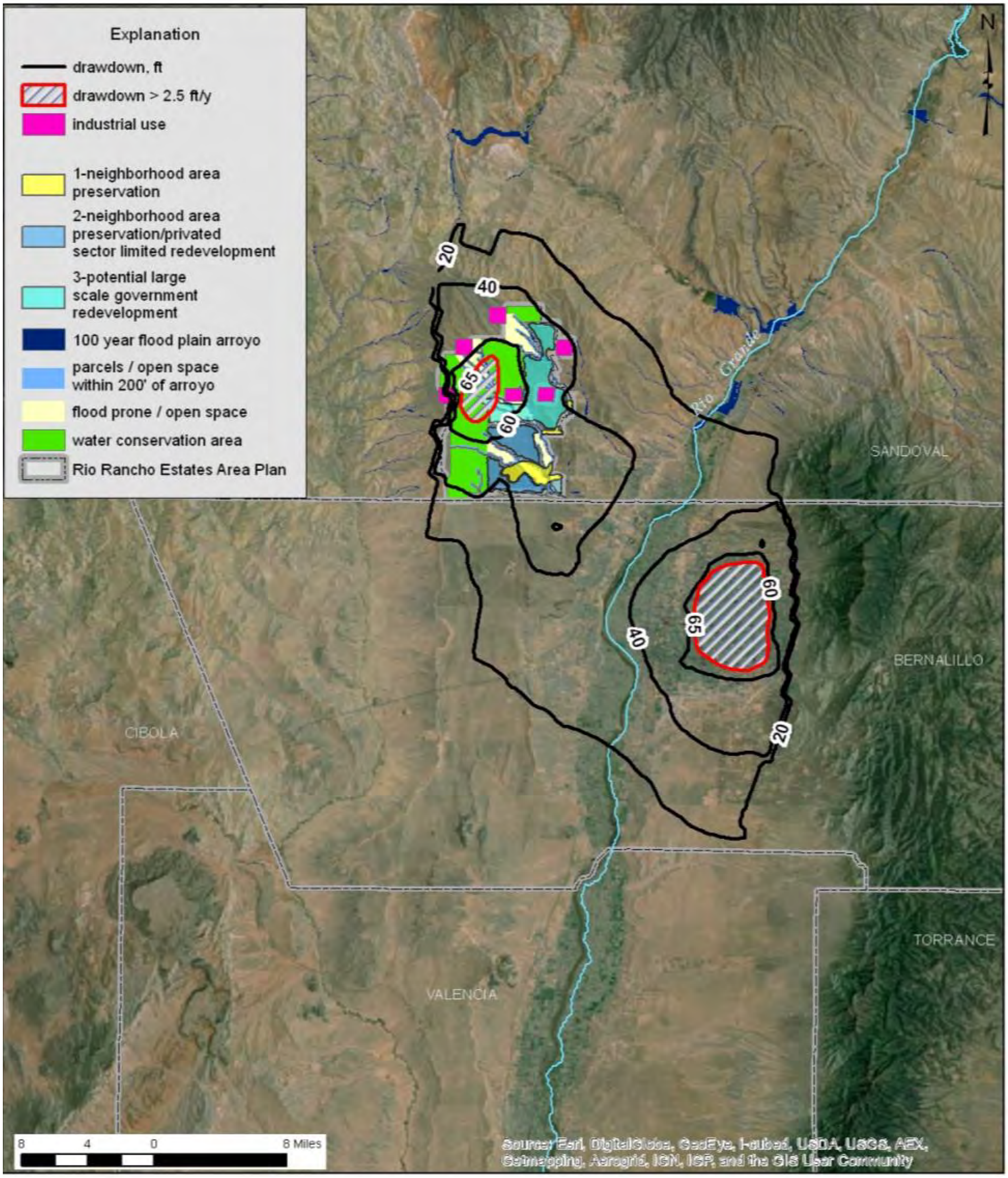

Figure 14 - Projected drawdown, 2014-2039, municipal wells, 18,077-lot full build-out scenario

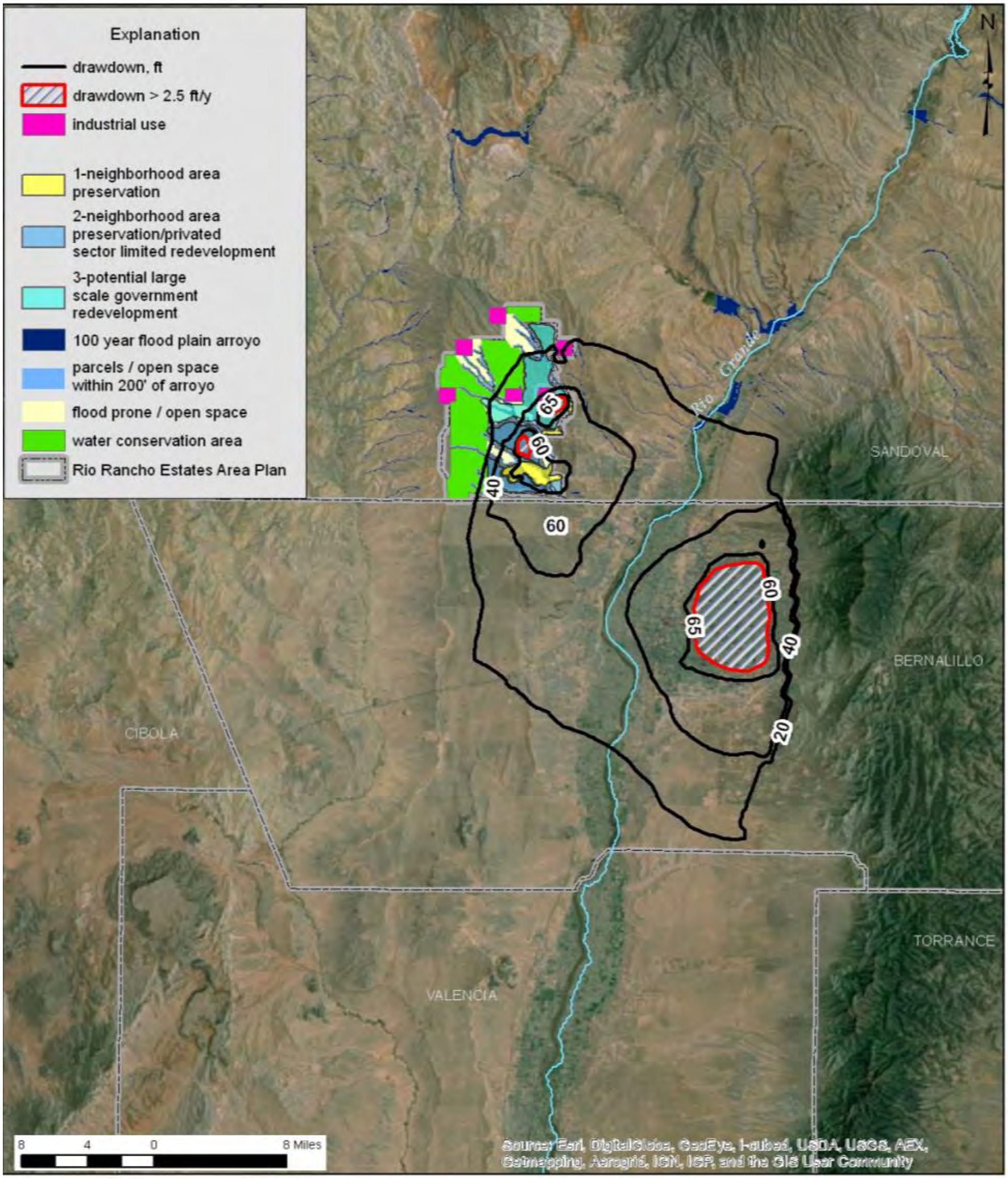

Figure 15 - projected drawdown, 2014-2039, individual wells, modified, 18,077-lot phased build-out scenario

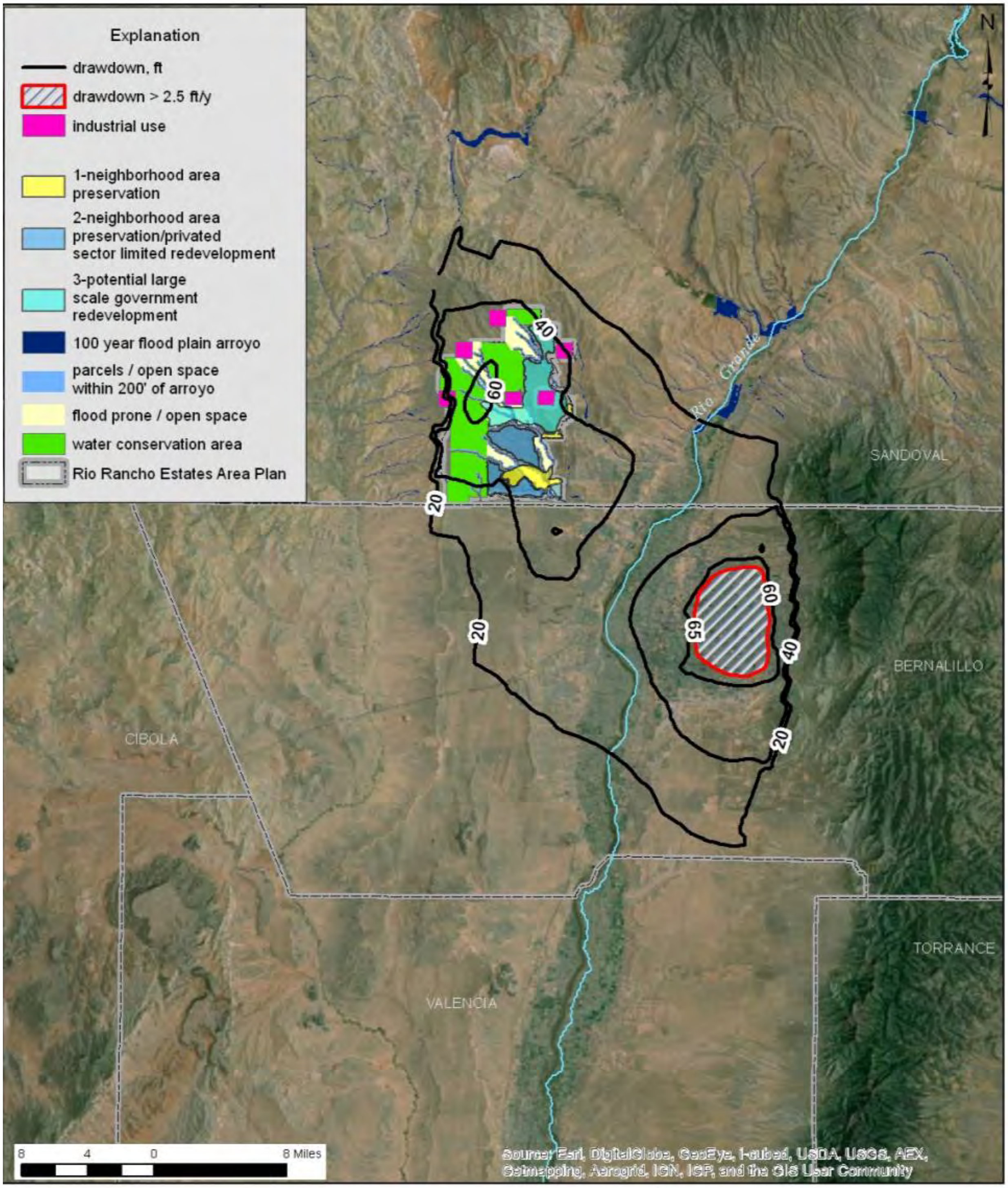

Figure 16 - Projected drawdown, 2014-2039, municipal wells, 18,077-lot phased build-out scenario

F. 100-Year Impact Model Scenarios at Lower Pumping Rate

Modeling of 100-year impact was conducted to determine associated drawdown. Sandoval County requires subdivisions to demonstrate a 100-year water supply (Sandoval County Subdivision Ordinance, Appendix A.4A). Projected cumulative groundwater-level drawdown to year 2113 is presented for each scenario.

Figures 17 through 23 show model-simulated 2013-2113 cumulative drawdown for each model scenario, considering the existing permitted groundwater pumping in addition to the development of Rio Rancho Estates. Areas with drawdown greater than 2.5 ft/year, if any, are indicated on each figure.

Areas with greater than 2.5 ft/year of model-projected 100-year drawdown are shown for all of the individual wells scenarios (Figs. 18, 21, 22 and 23), with only a small area for the individual wells, modified, 18,077-lot phased build-out scenario (Fig. 23).

The municipal wells scenarios (Figs. 17 through 20) project maximum drawdown on the order of 150 ft (1.5 ft/year). Areas with model-simulated drawdown greater than 250 ft (2.50 ft/yr x 100-year period) are indicated when applicable.

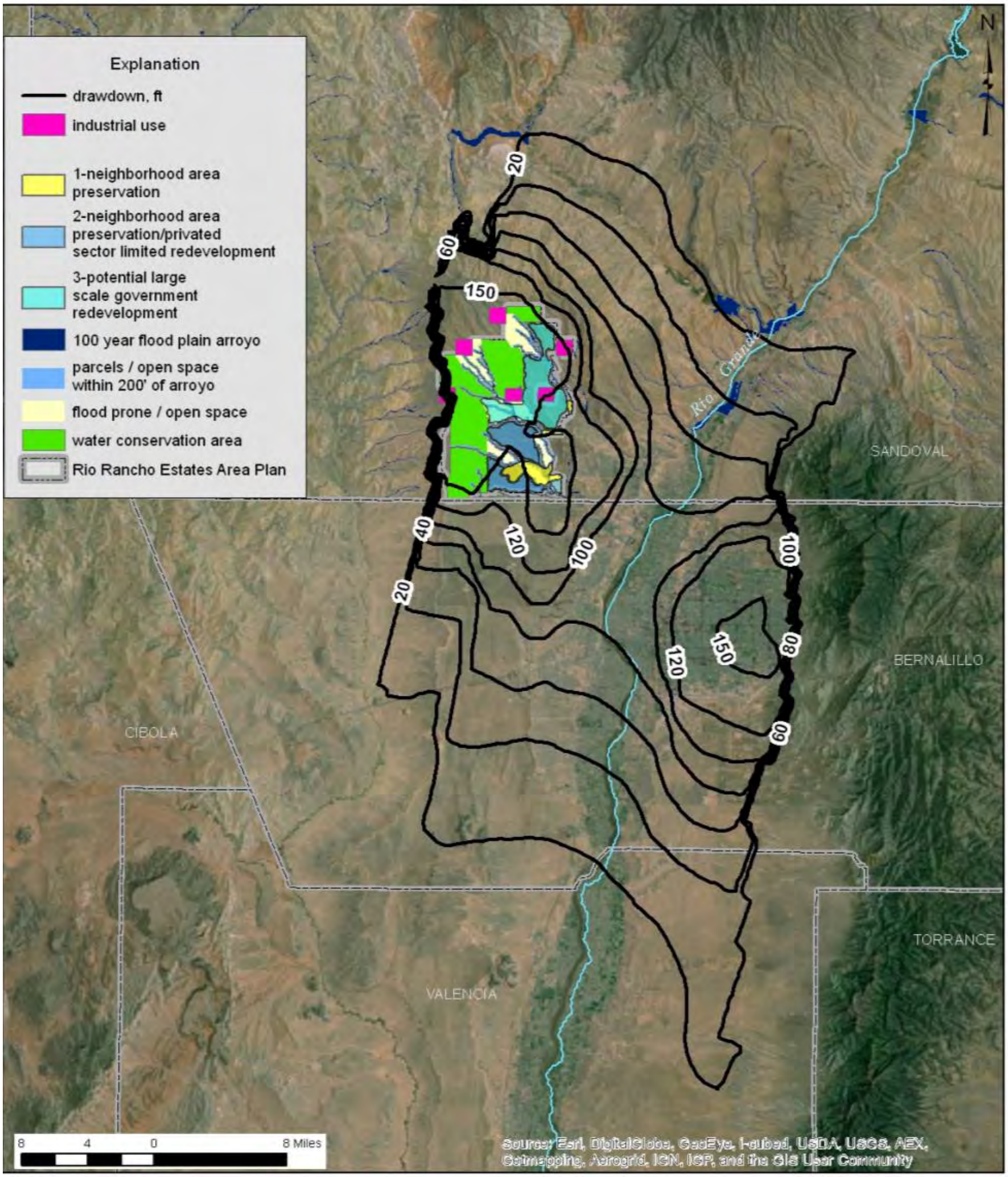

Figure 17 - Projected drawdown, 2014-2113, municipal wells, 41,000-lot full build-out scenario.

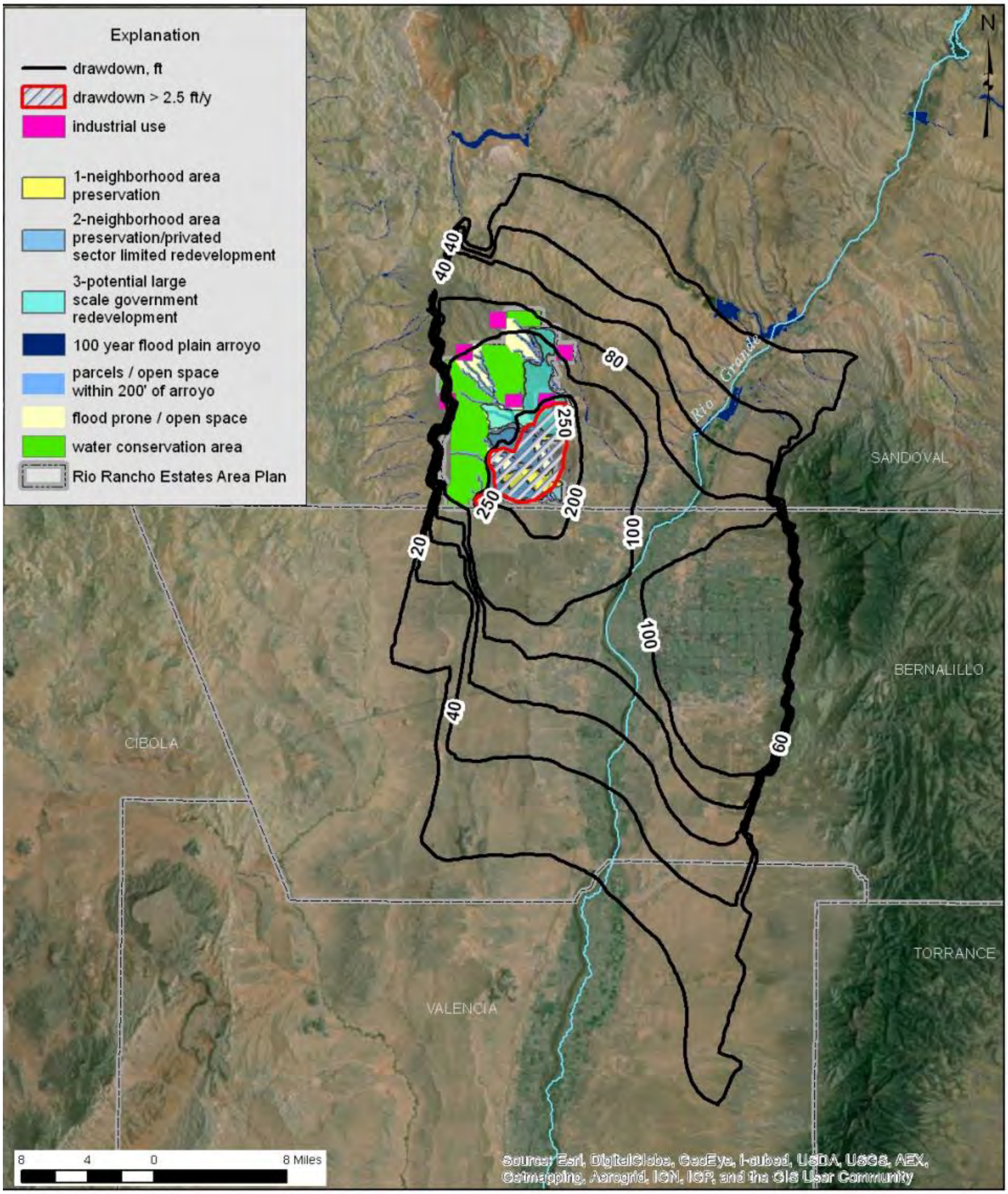

Figure 18 - Projected drawdown, 2014-2113, individual wells, 41,000-lot full build-out scenario.

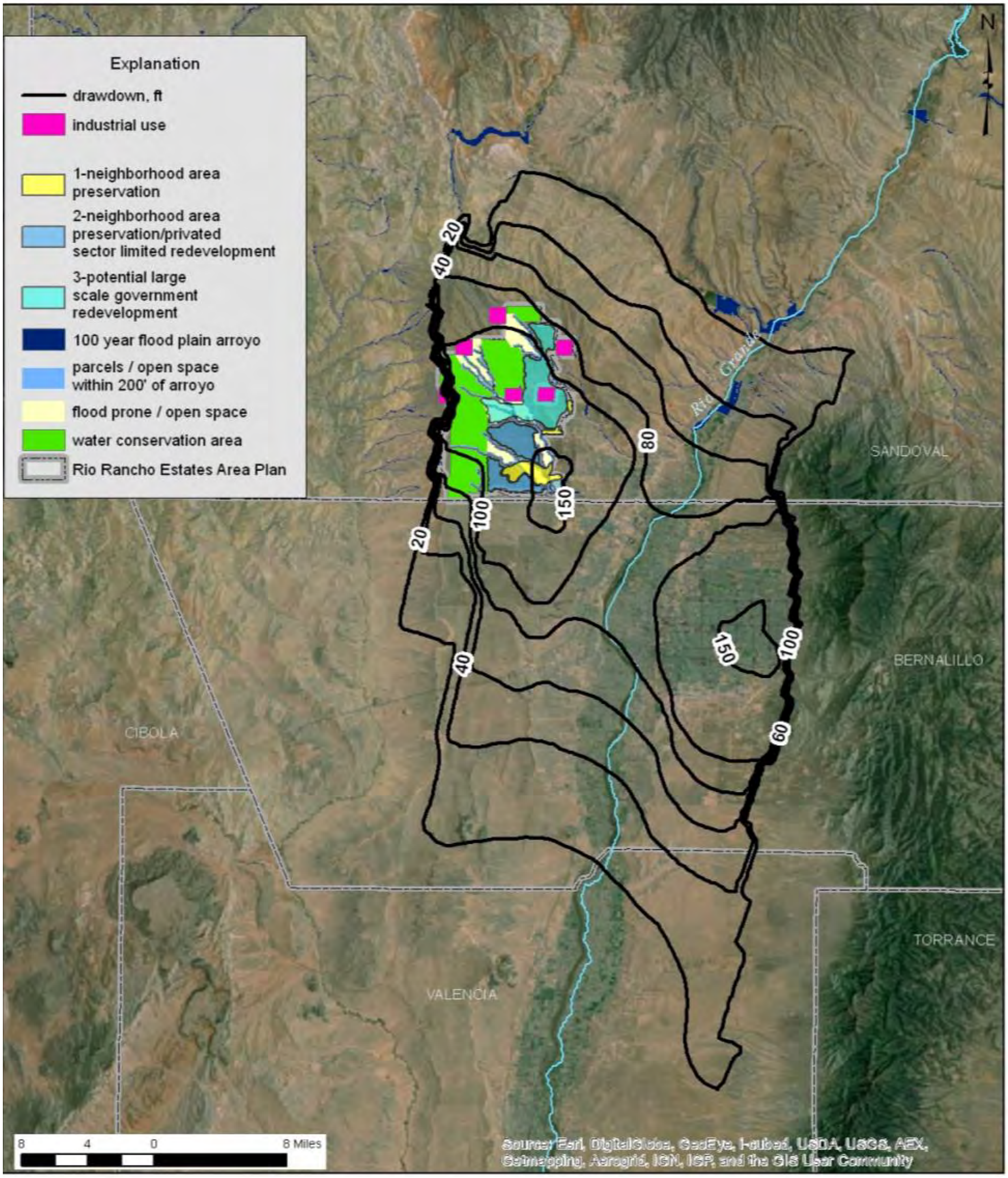

Figure 19 - Projected drawdown, 2014-2113, municipal wells, 18,077-lot full build-out scenario.

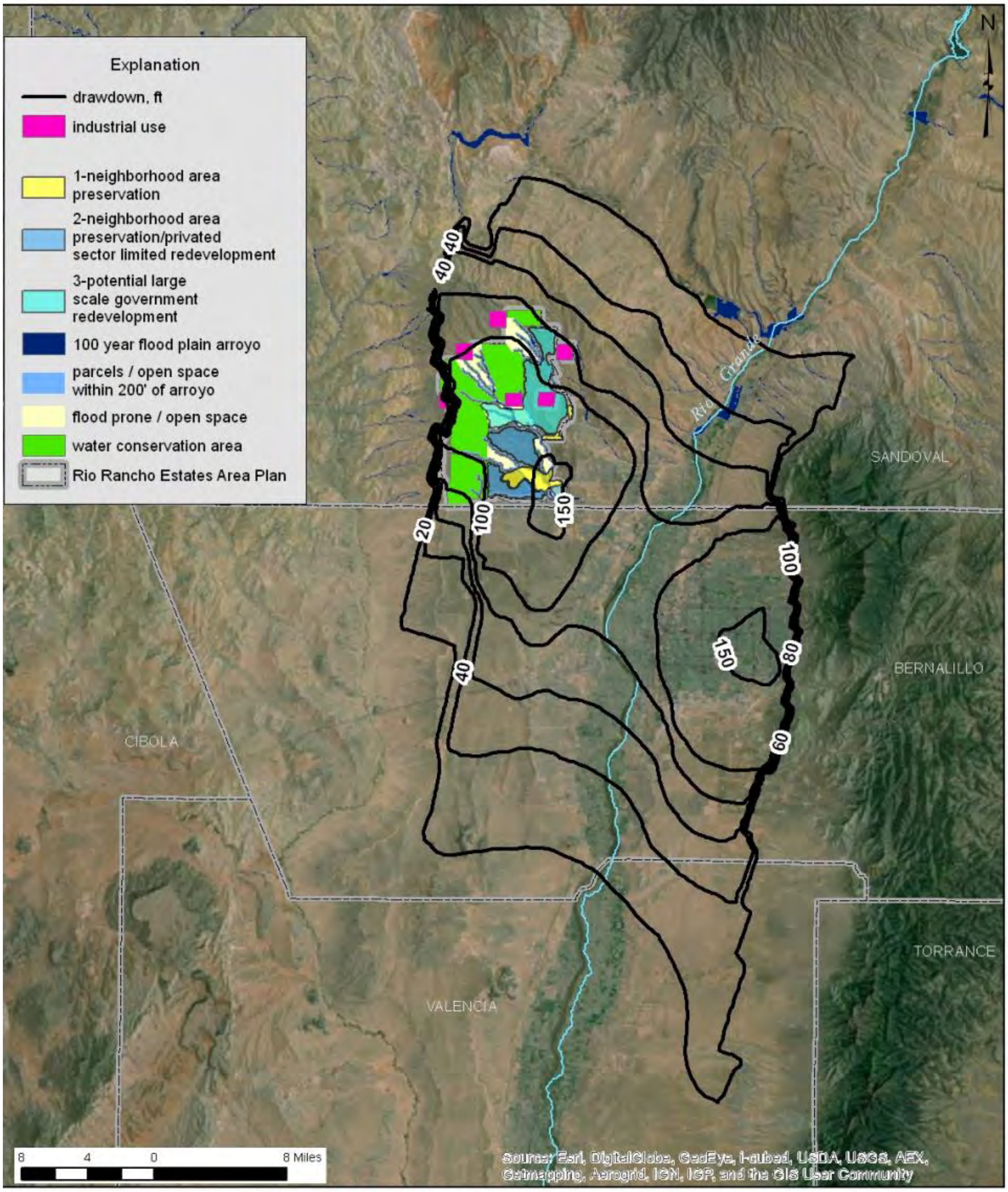

Figure 20 - Projected drawdown, 2014-2113, municipal wells, 18,077-lot phased build-out scenario.

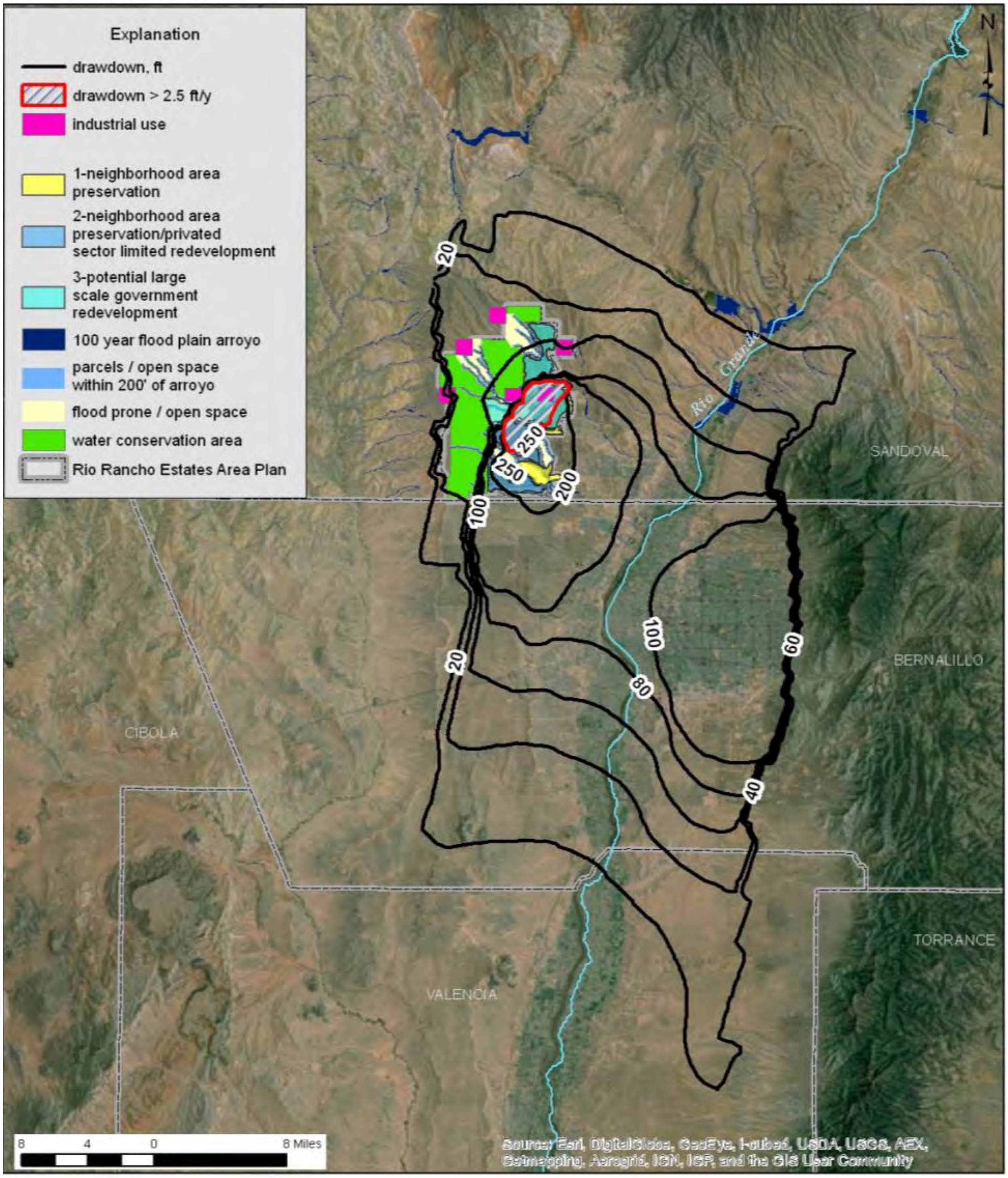

Figure 21 - Projected drawdown, 2014-2113, individual wells, 18,077-lot full build-out scenario.

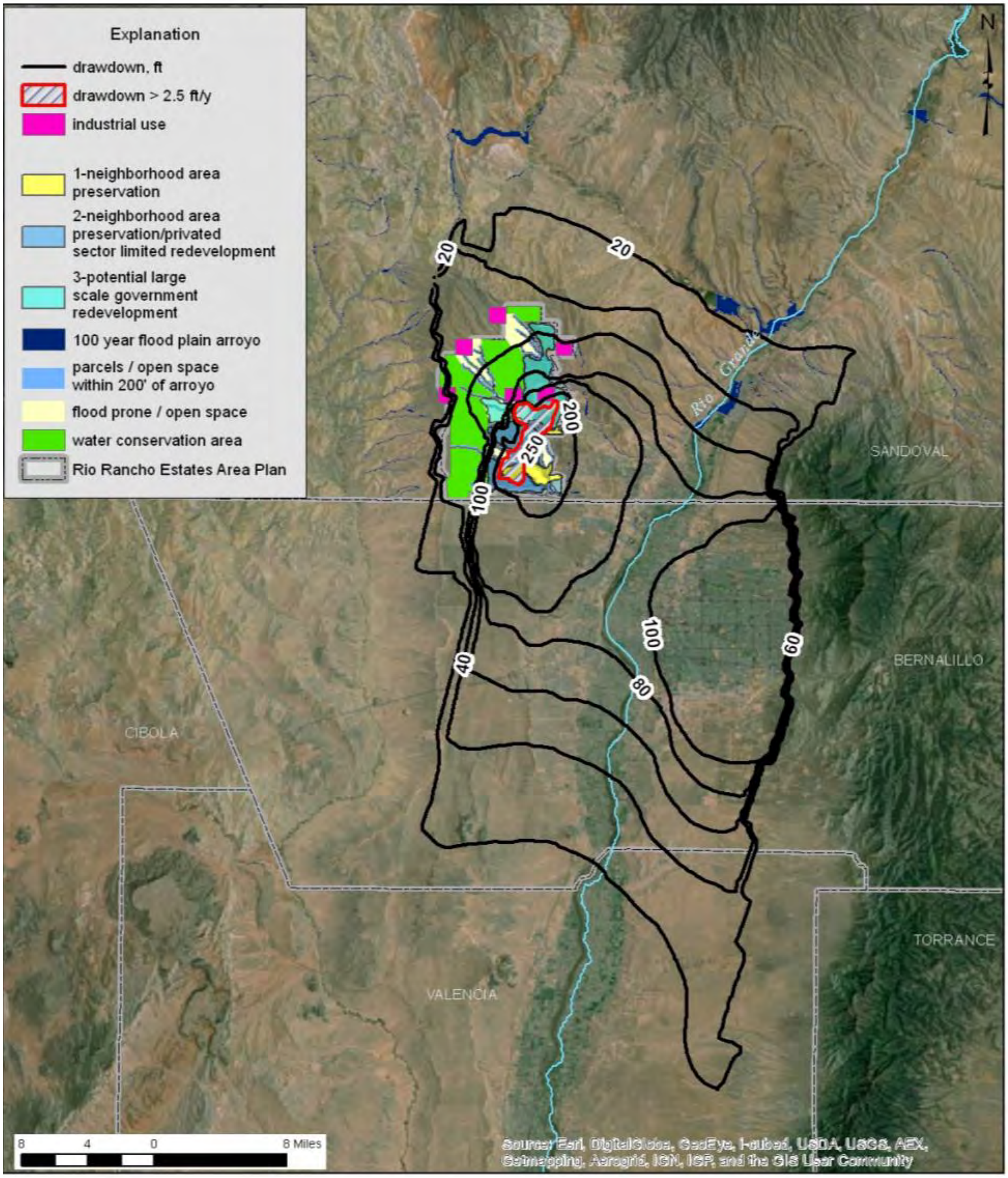

Figure 22 - Projected drawdown, 2014-2113, individual wells, modified, 18,077-lot full build-out scenario.

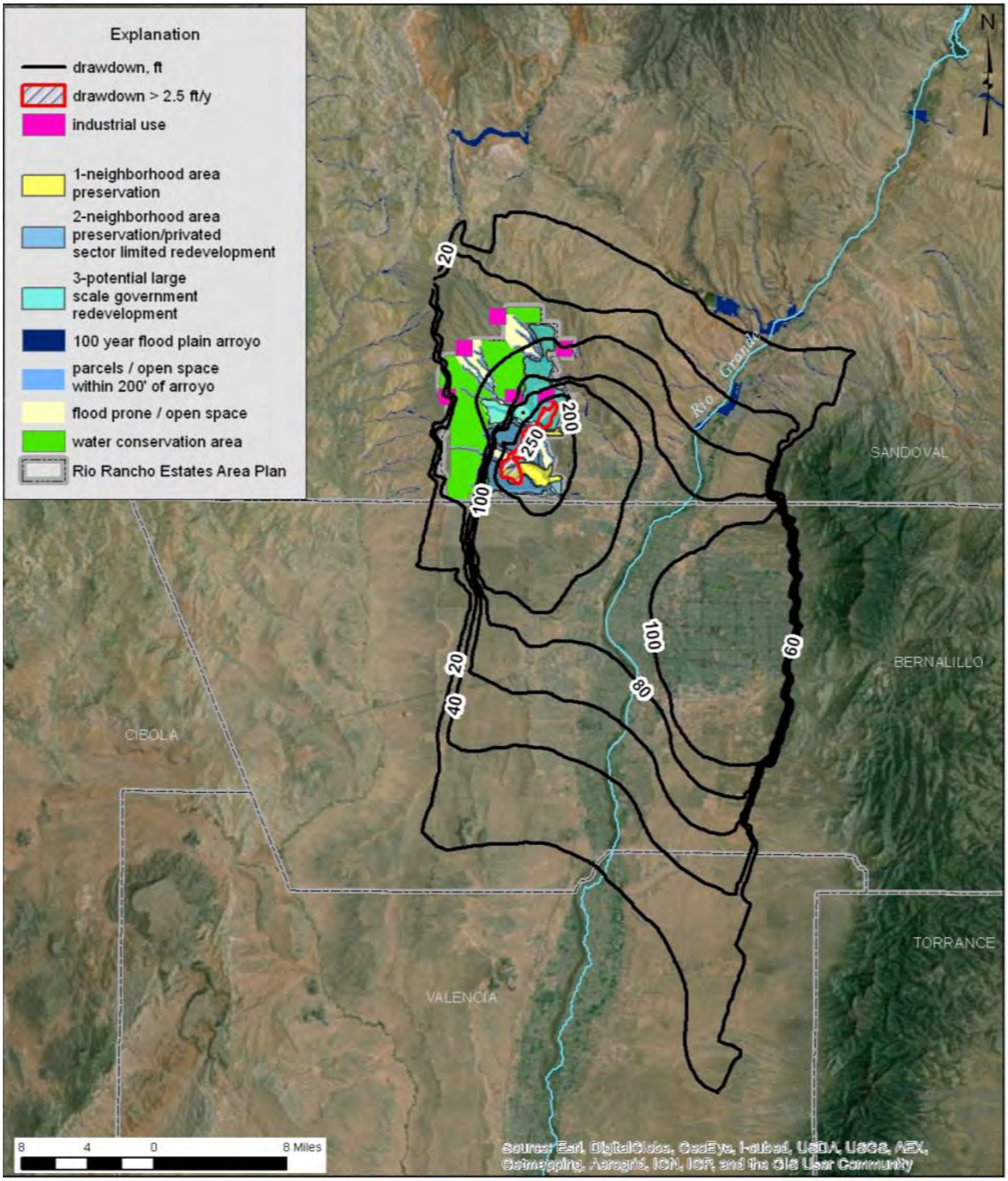

Figure 23 - Projected drawdown, 2014-2113, individual wells, modified, 18,077-lot phased build-out scenario.

VII. ALTERNATE WATER SUPPLY

SMA contacted both ABCWUA and the City of Rio Rancho to determine if either entity planned to or would consider extending water service to Rio Rancho Estates. In order for ABCWUA to extend service into Sandoval County, a legislative amendment to their charter would be required. ABCWUA has no current plans to amend their charter or to extend service into Sandoval County (Alan Porter, ABCWUA, pers. comm. 2012). In addition to the charter amendment, ABCWUA would be required to purchase additional water rights to provide service to Rio Rancho Estates, which is not planned.

Similarly, the City of Rio Rancho has no plans to extend water service into Rio Rancho Estates beyond what is currently existing (Larry Webb, City of Rio Rancho, pers. comm. 2013). The City of Rio Rancho is required by their NMOSE water rights permit to purchase water rights on an annual schedule. Providing service to Rio Rancho Estates would require purchase of additional water rights, which is not planned.

Another potential source of water for Rio Rancho Estates is deep, brackish water located outside the Middle Rio Grande Basin. Brackish water is highly mineralized, and requires desalination before it can be consumed. Brackish water with total dissolved solids (TDS) in excess of 1,000 milligrams per liter (mg/l, ppm) located in aquifers at a depth of greater than 2,500 feet is regulated differently by the NMOSE than shallow, fresh water. Potential for appeal of pumping is limited, and appropriated amounts are not regulated by the NMOSE. Brackish water requires treatment, with treatment costs estimated at $4.00 to $8.00 per 1000 gallons, which is relatively expensive. Several entities have filed Notices of Intent with the NMOSE to produce brackish water, including Recorp/Aperion, L-Bar Resources, Commonwealth Utilities, Atrisco Oil and Gas LLC, and others. To date several deep brackish wells have been drilled and tested, but no entity has moved past the pilot testing stage, generally due to lack of funding. Development of deep brackish water resources hold good potential for the future, but appear to be several years off at best.

VIII. CONCEPTUAL DESIGN AND COST ESTIMATE FOR WATER AND WASTEWATER SYSTEMS

Prior to pumping of groundwater from municipal-scale water wells, it is required that water rights be purchased and transferred to the point of use. Water rights can be purchased from existing water rights owners. Cost is dependent on numerous factors, and varies through time from market influences. Historical water rights cost was relatively consistent until around 2004 (Brown, 2008), with cost at less than $5,000 per acre foot of consumptive use per annum. Water rights cost spiked in approximately 2008, with costs approaching $20,000 per acre-ft. Costs have decreased to the current estimate of $8,000 to $10,000 per acre-ft (Taylor, 2013).

Conceptual engineering and cost estimates for several water supply scenarios (individual domestic wells, shared domestic wells, and utility scale municipal water distribution systems) have been prepared. Additionally, conceptual engineering and cost estimates for several wastewater disposal and collection/treatment scenarios (individual septic tank/leachfield, utility scale wastewater collection and treatment) have been prepared.

A. Water Supply – Individual Domestic Supply Wells

An analysis of the costs of constructing individual wells for each of the 41,000 lots in the Rio Rancho Estates planning area was performed by SMA as part of the overall report.

The depth of private wells in the area ranges between 1,200 and 500 feet, with the average depth being about 850 feet. Each well would consist of the well casing, screen, plug, sand pack, submersible pump and water supply line. Each pump would be capable of providing a minimum of 5 gallons per minute at 20 psi. It is assumed that electrical service for each well will be provided as part of the individual services to the homes. It is important to consider the amount of power that would need to be supplied to the area to support the operation of the pumps for each of the 41,000 wells. Assuming that each well is equipped with a 5 horse power pump. The total power consumption during average daily demand would be about 152 megawatts. For comparison purposes the Four Corners Power Plant operated by PNM generates 2,040 megawatts.

The power required for operation of the individual wells in the Rio Rancho Estates would require upgrades to the power generation and transmission infrastructure in the area.

When paired with septic tank/leachfield wastewater disposal systems, individual domestic wells have the potential to act as conduits for water contaminants to move to the aquifer. State law requires a minimum separation of 100 feet between septic tank/leachfield systems and domestic supply wells in order to attempt to minimize the potential for contamination of groundwater. Given the relatively small width of some Rio Rancho Estates lots (widths as small as 80 feet), this minimum setback requirement will be difficult to comply with.

Full Buildout

The estimated cost of construction of the 41,000 individual wells is $2.02 billion. This includes engineering and construction contingency fees. A breakdown of the estimated cost is included in Appendix B.

Zoned Option

The estimated cost of constructing individual wells on each of the 18,077 lots in Zones 1, 2 and 3 is $890 million. The power required for these 18,077 wells would be 67 megawatts. A breakdown of the estimated cost is included in Appendix B.

B. Water Supply – Shared Domestic Wells

In addition to the individual wells, SMA performed a cost analysis for shared domestic wells which are similar to the individual wells in design and cost with some minor differences. Shared domestic wells are very similar to individual wells, but include a storage tank and booster pump and can be used to supply water to multiple lots. One shared domestic well would be capable of supplying water for up to 4 lots and each well would include a 5,000 gallon tank with a booster pump and float switch for controlling the well pump.

Full Buildout

Assuming that each shared domestic well would supply potable water for 4 lots results in an estimated 10,250 wells being required for full buildout. The cost for the construction of all 10,250 wells is estimated at $890 million and would require 51 megawatts of electricity. A breakdown of the estimated cost is included in Appendix B.

Zoned Option

With the reductionin total lots from 41,000 to 18,077 the number of shared wells would decrease to 4,519 resulting in an estimated cost of $390 million and a power demand of about 17 megawatts. A breakdown of the estimated cost is included in Appendix B.

C. Water Supply – Municipal System

SMA analyzed the potential cost of constructing a complete water system including waterlines, valves, hydrants, and other appurtenances, storage tanks, wells, treatment systems, pumps and metered service connections for the entire Rio Rancho Estates area. The system layout was based on the currently platted configuration with waterlines being installed within existing road rights-of-way (ROW). The overall system would consist of an estimated 3.6 million feet of pipe, 5,000 gate valves, 2,500 fire hydrants and 19 million gallons of storage. Appendix B includes detailed design and cost information.

The system would be supplied by nine municipal scale wells with high production capacity and a series of water storage tanks into which the wells pump and from which water flows by gravity into a water distribution system. Due to the significant relief in the topography it is not expected that additional booster pumps for pressurizing the system will be needed; storage tanks would provide adequate gravity flows into the system and boosting to storage tanks would maintain these at full operational levels.

In general municipal wells in the area have been installed to a depth of 2,000 feet, and this analysis assumes that new municipal wells would be placed at similar depths. This analysis assumed that the minimum pipe size for the system would be 8 inches with transmission lines being 10 and 12 inch diameter pipes. It was assumed that all pipes would be PVC with a thickness rating of DR-18. The number of valves and fire hydrants was estimated by laying out valves in a one mile square section and then estimating the number of valves per acre. This ratio was then applied as an average across the entire system to estimate the total number of valves.

The number of pressure reducing valves (PRVs) was estimated using the existing topography (elevations) and applying an optimal system pressure rage of 50 to 80 psi. This assumption results in an overly conservative number of PRVs, so the estimated number was reduced by 10% to better represent the actual number of PRVs while still remaining conservative.

Tank storage volume was based on the New Mexico Environment Department's recommendation that communities store enough water to meet average demand for a 24 hour period. Fire flow storage consisting of 1,000 gpm for 2 hours was added to this number to represent the total storage requirement. Determination of the exact locations of the proposed water tanks is outside of the scope of this feasibility-level study.

Based on the above assumptions, it is estimated that total build-out of the water system for the Rio Rancho Estates area will cost $640 million. Table 1 shows the breakdown of the cost estimate.

TABLE 1 - RIO RANCHO ESTATES				
Preliminary Opinion of Probable Cost				
Entire Area (Full Build Out)				
Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
8 Inch, C900 PVC DR 18, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	3,070,288	$ 40	$ 122,811,520
10 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	216,788	$ 50	$ 12,500,000
12 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	379,714	$ 60	$ 12,393,000
Gate Valves	EA	5,000	$ 3,000	$ 15,000,000
Fire Hydrants	EA	2,500	$ 5,000	$ 12,500,000
Presure Reducing Valves	EA	413	$ 30,000	$ 12,393,000
Connections to Existing Water Lines	EA	14	$ 3,000	$ 42,000
Connect waterline to well head	EA	25	$ 6,000	$ 150,000
5/8" Water Meter	EA	41,000	$ 2,500	$ 102,500,000
1" Service Line	LF	820,000	$ 20	$ 16,400,000
Wells	EA	9	$ 1,000,000	$ 9,000,000
Site Prep and Grading for Booster Station	EA	4	$ 10,000	$ 40,000
Booster Stations	EA	4	$ 125,000	$ 500,000
Booster Station Buildings	EA	4	$ 150,000	$ 600,000
Water Storage Tanks	GALLONS	18,705,923	$ 2	$ 37,411,846
Subtotal				$ 354,241,366
Mobilization (5%)	LS	1	$ 17,712,068	$ 17,712,068
Temporary Traffic Control	LS	1	$ 13,750,463	$ 13,750,463
Material Testing Allowance	LS	1	$ 8,856,034	$ 8,856,034
SUBTOTAL FOR CONSTRUCTION				**$ 394,559,931**
Non-Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
Professional Services (Project management, drafting and design, engineering design review and inspection, construction administration and observation, legal, archeological, geotechnical, surveying)	EA	1	$ 138,095,976	$ 138,095,976
SUBTOTAL FOR NON-CONSTRUCTION				**$ 138,095,976**
Contingency (includes inflation, taxes, bid and construction contingencies, material cost fluctuations)		20%		$ 106,531,181
TOTAL PROJECT COST (Round Numbers)				**$ 640,000,000**

D. Water Supply – Municipal System for Reduced Number of Lots

Sandoval County developed a Land Use Concept for Rio Rancho Estates based on a number of factors including the maximum amount of water production that could be sustained without causing excessive groundwater drawdown. The concept includes a division of the Rio Rancho Estates area into four main zones. Within each of those zones, lots located in areas near arroyos were removed due to the potential for flooding, and to preserve sensitive environments. Removing these lots also focuses development in areas where costs for infrastructure would be less. A map of the four zones is included in Appendix B.

The four zones include two neighborhood area preservation zones (Zone 1 and Zone 2), a potential large scale government redevelopment area (Zone 3) and a water conservation area.

Zones 1 and 2 have the most potential for large scale, diversified development and were looked at in their currently platted state (minus arroyos and floodplains) to determine the cost of developing water infrastructure in each zone.

Zone 3 is planned to be used as large scale government redevelopment. Since the amount of water use and required infrastructure can vary substantially depending on the nature of the uses proposed, the cost for development was based on the existing number of lots (9,440) as current layout. Once a more detailed plan for the development in the area is completed, the demand for each area can be converted to equivalent residential units (ERUs) and used to relate storage requirements and uses with this report.

Zone 1 includes 2,665 lots, Zone 2 includes 5,972 lots and Zone 3 includes 9,440 lots resulting in a total of 18,077 lots.

A municipal water system would consist of similar piping, wells, storage and pumps as the full build out system, but would be reduced in size to match the reduction in demand. This analysis assumes that the current platting would remain the same for determining waterline layout.

The assumptions used for this analysis are the same as those for the full municipal supply system. In determining the cost for each zone, it was assumed that the ratio of infrastructure (pipes, valves, PRVs, fire hydrants, etc.) to the number of lots would remain relatively constant throughout each zone. This ratio was then used to determine the quantity of infrastructure in each zone.

Based on the above assumptions, it is estimated that the water system for Zone 1 will cost $25.2 million, Zone 2 will cost $64.4 million and Zone 3 will cost $97.0 million. A detailed breakdown of the cost for construction in each zone is shown in Table 2.

TABLE 2 - RIO RANCHO ESTATES				
Preliminary Opinion of Probable Cost				
Zone 1, 2 and 3				
Construction Cost				
Area	**1676**	**Parcells**	**2665**	
Description	Unit	Qty	Unit Price	Total Price
8 Inch, C900 PVC DR 18, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	987,741	$ 42.00	$ 41,485,109.12
10 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	69,743	$ 42.00	$ 4,138,778.05
12 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	122,158	$ 45.00	$ 4,070,783.84
Gate Valves	EA	1,971	$ 2,800.00	$ 5,518,370.73
Fire Hydrants	EA	985	$ 4,200.00	$ 4,138,778.05
Presure Reducing Valves	EA	163	$ 25,000.00	$ 4,070,783.84
Connections to Existing Water Lines	EA	21	$ 2,000.00	$ 42,000.00
Connect waterline to well head	EA	75	$ 6,000.00	$ 450,000.00
5/8" Water Meter	EA	18,077	$ 1,800.00	$ 32,538,600.00
1" Service Line	LF	361,540	$ 16.00	$ 5,784,640.00
Site Prep and Grading for Booster Station	EA	4	$ 5,000.00	$ 20,000.00
Booster Stations	EA	4	$ 60,000.00	$ 240,000.00
Booster Station Buildings	EA	4	$ 120,000.00	$ 480,000.00
Water Storage Tanks	GALLONS	7,074,658	$ 2.50	$ 17,686,644.00
Subtotal				$ 120,664,487.62
Mobilization (not to exceed 5% of the bid)	LS	1	$ 6,033,224.38	$ 6,033,224.38
Temporary Traffic Control	LS	1	$ 1,895,869.49	$ 1,895,869.49
Material Testing Allowance	LS	1	$ 1,037,127.73	$ 1,037,127.73
SUBTOTAL FOR CONSTRUCTION				**$ 129,630,709.21**
Non-Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
Professional Services (Project management, drafting and design, engineering design review and inspection, construction administration and observation, legal, archeological, geotechnical, surveying)	EA	1	$ 25,926,141.84	$ 25,926,141.84
SUBTOTAL FOR NON-CONSTRUCTION				**$ 25,926,141.84**
Contingency (includes inflation, taxes, bid and construction contingencies)		20%		$ 31,111,370.21
TOTAL PROJECT COST				**$ 186,668,221.26**

Summary of Water Costs
The table below shows a breakdown of the cost of each option discussed above for the water systems in Rio Rancho Estates and includes an estimated cost per lot for each of the alternatives.

Table 3
Cost Summary and Estimated Cost Per Lot

Option Evaluated	Total Cost	Number of Lots	Cost Per Lot
Full Buildout (Individual Wells)	$ 2,020,000,000	41,000	$ 49,268.29
Zoned Option (Individual Wells)	$ 890,000,000	18,077	$ 49,233.83
Full Buildout (Shared Domestic Wells)	$ 890,000,000	41,000	$ 21,707.32
Zoned Option (Shared Domestic Wells)	$ 390,000,000	18,077	$ 21,574.38
Full Buildout (Municipal Wells)	$ 640,000,000	41,000	$ 15,609.76
Zoned Option (Municipal Wells)	$ 186,668,221	18,077	$ 10,326.28

E. Wastewater Disposal – Individual Septic Tank/Leachfield Systems

This alternative assumes that each lot would receive an individual or decentralized wastewater system in conjunction with lot development and according to the design flows specific to each. This could include individual septic tank and leachfield or advanced onsite treatment units. While it has been widely accepted that local governments typically provide sewer and water services for new developments, developments that have outstripped capacities and technological improvements in small onsite advanced treatment systems have fueled the decentralized approach to addressing wastewater needs.

Conventional septic tank/leachfield systems are allowed on lots platted prior to 1990 that are one-half acre or greater when the depth to groundwater is in excess of 600 feet (New Mexico Liquid Waste Disposal Regulations, 20.7.3.301.F.5 NMAC). When the depth to groundwater is less than 600 feet, the minimum lot size for use of septic tanks is three-quarters of an acre. For lots smaller than three-quarters of an acre and depth to water less than 600 feet, regulations require the use of Advanced Treatment Systems (ATSs). The majority of Rio Rancho Estates lots are generally one-half acre or greater and the depth to groundwater exceeds 600 feet, therefore individual septic tank/leachfield systems are permitted for use on those lots. A portion of the lots may require installation of ATSs. Selection of the appropriate system and acquisition of the appropriate permit would be the responsibility of the land owner.

The existing lot layout was assumed to remain unchanged and it is assumed that all lots are of sufficient size to accommodate individual systems, decentralized systems or some combination. It is also assumed that the soil types present throughout the area are conducive to subsurface discharge and that no lots are within the 100 year flood plain and all lots meet required setbacks from arroyos, ditches, wells (domestic and public) and property lines/easements. These assumptions are indicative of important zoning and development considerations that should be implemented if the above conditions are not the case.

The costs associated with this option would be the responsibility of the individual property owners/developers and would vary depending on location, wastewater quality, environmental factors, and whether some advanced treatment is required to ensure protection of ground/surface water. Excluding advanced treatment, a reasonable cost estimate per lot for a septic tank and leachfield would be in the range of $6,000 to $8,000 per lot or $287 million for the entire area (41,000 lots x $7,000 = $287 million)

F. Wastewater Disposal – Individual Septic Tank/Leachfield Systems for Reduced Number of Lots

The cost to construct individual septic systems for the reduced number of lots (18,077) as described above was calculated by scaling of the cost for the full build-out. This assumption leads to an estimated cost of $126.5 million for the reduced number of lots.

G. Wastewater Disposal – Municipal Conventional Sanitary Sewer

SMA analyzed the potential cost of constructing a complete conventional sanitary sewer system and centralized wastewater treatment plant. This option evaluated cumulative flows based on the current layout of lots and determined gravity sewer line sizes based on an assumed 350 gpd for each lot. The collection system was laid out in a progressive manner by identifying sections within the development (refer to Appendix C, Conceptual Municipal Sanitary Sewer Design and Cost Estimate).

The area topography generally slopes down towards the southeast. This bottommost zone (just north of 19th Street) is labeled "1" and each subdivision block in this zone is labeled "a" through "f". Within each subdivision block, gravity sewers are laid out to capture flows from each lot. Each block label displays the number of lots (e.g. 1e-994 indicates 994 lots are present in that block) and the linear footage of gravity sewer present within that block (e.g. 1e has 107,641 linear feet of 8" residential collector sewer present within the block). It is assumed that all blocks in zone 1 gravity collect and flow into the trunk line "1" which runs along the 19th Street corridor. There are 10 total trunk lines (labeled 1 through 10). These trunk lines then tie into two major sewer lines, or interceptors, labeled B & C, which extend generally from north to south. Trunk lines 1 through 10 connect to main lines B and C at their intersecting points.

We assumed a minimum pipe size of 8" (per New Mexico Standards for Public Works Construction and other industry standard guidelines) for all residential collector sewer lines within the development blocks. For all trunk lines (1 through 10) and the interceptor lines (B&C), cumulative flows were calculated and alignment profiles were generated in order to calculate projected velocities and determine minimum pipe sizes. Allowable velocities in these feasibility-level design calculations were 2 to 10 feet per second (fps). Sewer sizing, flows, and velocity calculations are included in Appendix C. A manhole interval of 300 ft was also assumed to calculate the number of manholes for a given sewer line size. It is apparent on the profile for interceptor line "C" that a lift station will be required at the low point where trunk line 5 intersects.

For this option, it was assumed that all of the 41,000 existing lots would be developed. We assumed a 350 gpd flow for the domestic waste stream from each lot. The existing lot layout currently has a significant number of lots located in arroyos or floodplains, on extreme slopes or in other areas that would be difficult to develop. It was assumed that all of these lots would be developed as currently platted in order to determine the feasibility of providing wastewater service for full build out of the area.

Based on the above assumptions, it is estimated that total build-out of the conventional sanitary sewer system for the Rio Rancho Estates area will cost approximately $444 million. Table 4 shows the breakdown of the cost estimate.

H. Wastewater Disposal – Municipal Conventional Sanitary Sewer for Reduced Number of Lots

The cost to construct municipal conventional sanitary sewer for the reduced number of lots (18,077) as described above was calculated by scaling of the cost for the full build-out conventional sanitary sewer. This assumption leads to an estimated cost of $189 million for the reduced number of lots.

Summary of Wastewater Costs

The table below shows a breakdown of the cost of each option discussed above for the wastewater systems in Rio Rancho Estates and includes an estimated cost per lot for each of the alternatives.

Table 4
Cost Summary and Estimated Cost Per Lot

Option Evaluated	Total Cost	Number of Lots	Cost Per Lot
Full Buildout (Individual Septic Systems)	$287,000,000	41,000	$7,000.00
Zoned Option (Individual Septic Systems)	$126,500,000	18,077	$7,000.00
Full Buildout (Municipal Sanitary Sewer)	$435,600,000	41,000	$10,624.39
Zoned Option (Municipal Sanitary Sewer)	$188,800,000	18,077	$10,444.21

In addition to costs summarized above, wastewater that is collected in a municipal system and treated in a municipal wastewater treatment plant can be used as a return flow credit for water rights accounting purposes. Water that is returned to the Rio Grande or re-injected to the aquifer can act as an offset in accounting for water diverted for use, when an appropriate return flow credit plan or aquifer storage and recovery plan has been approved by the NMOSE. Thus, return flow decreases the amount of water rights required to be obtained. Given the range of water required for either the reduced number of lots or full build-out scenario of 8,600 to 18,100 acre-ft/year and a likely return of water to a municipal wastewater treatment plant of 60%, the available return flow credit from wastewater collection and treatment in a municipal system is 5,160 to 10,860 acre-ft/yr. Assuming a value of $12,000 per acre-ft of water, this equates to $62 to $130 million in opportunity costs if wastewater is not collected.

IX. IMPACT, CONNECTION AND USAGE RATES

A. Overview

Municipalities typically utilize impact fees to recover the cost of constructing large capital improvement projects that benefit specific communities or areas of a community. Connection fees are typically utilized to recover the direct costs of constructing individual connections to the water system and sometimes include costs for acquisition of the additional water rights necessary to serve the new connection. Water and Wastewater usage fees are then charged based on the amount of water used and wastewater produced by a customer. Included in the usage fee is the cost of pumping, treating and storing the water and wastewater. In addition the usage fee is intended to cover the cost of infrastructure repairs, administration of the system, billing and minor capital improvements to the system. Municipalities will often strive to maintain additional money in the accounts for water and wastewater to cover unforeseen problems and costs that arise.

A breakdown of the estimated impact and connection fees for the full system build out and the water conservation area option is included later in this section. In order to recommend a usage fee for water or wastewater, a detailed analysis of the operating and maintenance costs for the system would be required. Since detailed information regarding the system construction, operation and administration are not currently available; it would be difficult to make an accurate estimate of the water rates needed to cover all of the costs of producing and treating the water and wastewater for the system.

The City of Rio Rancho currently operates a system that is similar in a number of ways to the proposed system for Rio Rancho Estates. The City's system pumps from the same aquifer as the wells proposed for Rio Rancho Estates and has similar densities and occupancy rates as the Rio Ranch Estates system. Based on these similarities it is fair to assume that the costs for water and wastewater production and treatment would be similar for both communities.

The City of Rio Rancho currently has a four tiered rate schedule for water usage for residential customers and a flat rate structure for wastewater.

B. Full Buildout

1. Water system Impact and Connection Fees

The overall cost of construction for the complete water system is estimated at $660 million with $133 million of that being items that are typically included in water connection fees which reduces the impact fee associated costs to $527 million. Based on the total number of lots in the system (41,000) this results in an estimated impact fee of $12,250 per lot. It is assumed that the system would be built in stages as growth and demand for service increase to prevent the need for taking out large loans to complete the water and wastewater systems.

Connection fees (which are not included in impact fees) for the water system would cover the cost of the installation of the water meter, service line, taping saddle and backflow check valves and would be estimated at approximately $3000.

2. Wastewater system Impact and Connection Fees

The overall cost for construction of the complete wastewater system is estimated at $444 million, with $70 million of that being items that are included in the wastewater connection fee. The remaining $374 million in impact fee associated costs results in an estimated impact fee of $9,125 per lot. Connection fees for the wastewater system would include the construction of the piping and connections to the existing system and are estimated at $1,500 per lot.

C. Water Conservation Area Option

1. Water system Impact and Connection Fees

The overall costs of construction for the water conservation area option are significantly less than the complete water system. With a cost of $176 million for impact fee related construction, the 18,077 lots in Zones 1, 2 and 3, would result in an estimated impact fee of $9,750 per lot. The connection fee would remain the same at $3,000 per lot

2. Wastewater System Impact and Connection Fees

Although not as significant, the wastewater system for the water conservation area option would also be less than the cost of full build out. The total cost of $146 million for providing sewer service to the estimated 18,077 lots would result in an estimated impact fee of $8,000 per lot. The connection fees for the wastewater system would remain the same at an estimated $1,500 per lot.

X. CONCLUSIONS AND RECOMMENDATIONS

1. Available Water Resources and Drawdown

Groundwater resources in the Rio Rancho Estates area are limited due to the general scarcity of water as well as constraints imposed by the NMOSE *Middle Rio Grande Administrative Area Guidelines for Review of Water Rights Applications*, which constrain the amount of predicted and actual drawdown in the Middle Rio Grande Administrative Area. Modeling indicates that water could be supplied through groundwater pumping for a smaller number of lots than are currently platted. This number is projected at approximately 18,100 lots, assuming that development is phased through time.

The policies of the NMOSE currently dictate that no program to withdraw water from the underlying aquifer will be approved that creates a Critical Management Area (CMA). In general terms, if modeling projects that groundwater pumping would cause a decline in static level of greater than 250 feet in 100 years (from a pre-development condition), or a decline of greater than 65 feet over the modeled period of the present to 2040, the proposed pumping would not be allowed.

In practical terms, appropriate selection of types of wells (shallower low production domestic wells and deeper high production municipal supply wells) and appropriate well locations can mitigate drawdown and limit the potential of causing excessive drawdown and formation of a CMA. As there is known to be a significant fault structure underlying the Estates area, the impacts of drilling wells and withdrawing water will be different based on what side of the fault the well is on, plus the variations in the depths of the wells and the formations into which they are completed can impact the results.

Recommendation: Land use plans for the Estates area should be developed which acknowledge the limits of water projected to be available in the area. Policies on water use and conservation measures should be crafted in view of known limits. As a function of the above, it may become necessary to evaluate or re-evaluate the plan to accommodate new knowledge gained in the future as the impacts of wells, their locations, and the timing of others' actions (City of Rio Rancho, and potential development of land south of the Estates) become manifest.

2. Potential Competition for Water Resources

Among the findings of the study is the fact that the City of Rio Rancho holds water rights and permits from the NMOSE granting the City current and future wells and withdrawals in the Rio Rancho Estates area and in the western parts of the City itself. Several of these wells exist and produce water now. Other wells approved in the permit have not yet been constructed, but their projected pumping has been approved by the OSE and is part of the total demand built into the OSE's water model (used for this analysis). While these wells are or will be completed at depths greater than domestic wells are normally drilled to, there exists a potential that pumping from these wells may impact (dry up) domestic wells in the vicinity.

Domestic wells in the State of New Mexico, including the Rio Rancho Estates area, are not granted "water rights" per se. Domestic well owners are granted a point of diversion for an amount of water not to exceed 1 acre foot per year (previously 3 acre feet per year). As currently implemented, domestic well applicants are generally issued a permit (by the OSE) to drill upon completion of the application and payment of the applicable fee with no restrictions. The NMOSE has the ability to reject domestic well applications in areas where restrictions on the use of water have been imposed by a court, and to limit pumping in areas that have been declared a domestic well management area. To date, the NMOSE has not implemented these actions. This regulatory system has the potential to place the rights of the City of Rio Rancho in opposition to the rights of private land owners for use of the limited water resources in the Rio Rancho Estates area. Given that the City of Rio Rancho does not plan to add the Rio Rancho Estates area to its service area, the selection of one of the discussed options becomes necessary.

Recommendation: The County, on behalf of, and including, the generic community of property owners in the Rio Rancho Estates area, should begin discussions with the City of Rio Rancho on how future water use in the Rio Rancho Estates area will be managed. It is important to begin this discussion well in advance of land development and water usage that may cause confrontation between the parties.

XI. REFERENCES

(ABCWUA) Albuquerque Bernalillo County Water Utility Authority, 2013, personal communication: in-person conversation between ABCWUA and Scott McKitrick, SMA regarding ABCWUA 2011 water use, February 4, 2013.

(ABCWUA) Albuquerque Bernalillo County Water Utility Authority, 2012, personal communication: in-person conversation between Alan Porter, ABCWUA and Scott McKitrick, SMA regarding ABCWUA service area and future plans, October 8, 2012.

Bartolino, J.R., 2002, How ground-water/surface-water interaction of the Rio Grande has been studied, in Bartolino, J.R., and Cole, J.C., Ground-water resources of the Middle Rio Grande Basin, New Mexico: U.S. Geological Survey Circular 1222, p. 78-79.

Bartolino, J.R., and Cole, J.C., 2002. Groundwater resources of the Middle Rio Grande Basin, New Mexico: U.S. Geological Survey Circular 1222, p. 74-75.

Bartolino, J.R., and Constantz, Jim, 2002, How mountain-front recharge is studied, in Bartolino, J.R., and Cole, J.C., 2002. Groundwater resources of the Middle Rio Grande Basin, New Mexico: U.S. Geological Survey Circular 1222, p. 74-75.

Brown, F. Lee., 2008, The evolution of markets for water rights and bulk water, in 53rd Annual Water Conference Proceedings, WRRI Report No. 337.

City of Rio Rancho, 2012, personal telephone communication between Marian Wrage, City of Rio Rancho Environmental Program Manager and Matthew Earthman, SMA regarding per capita water use and conservation goals, September 25, 2012.

City of Rio Rancho, 2013, personal communication: telephone conversation between Marian Wrage, City of Rio Rancho Environmental Program Manager and Matthew Earthman, SMA regarding annual water system production, March 6, 2013.

City of Rio Rancho, 2013, personal communication: in-person conversation between Larry Webb, City of Rio Rancho and Scott McKitrick, SMA regarding Rio Rancho Estates Water System, February 8, 2013.

Connel, S, 2006, Preliminary geologic map of the Albuquerque-Rio Rancho Metropolitan Area and vicinity, Bernalillo and Sandoval Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources Open-File Report 496.

Glorietta Geoscience, Inc., 2013, personal communication: telephone conversation between Jim Riesterer, Glorieta Geoscience and Scott McKitrick, SMA regarding deep Santa Fe Group aquifer water quality, February 4, 2013.

Harbaugh, A.W., and McDonald, M.G., 1996, User's documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model: U.S. Geological Survey Open-File Report 96-485, 56 p.

McAda, D.P., 1996, Plan of study to quantify the hydrologic relations between the Rio Gradne and the Santa Fe Group Aquifer System near Albuqerque, central New Mexico, U.S. Geology Survey Water Resources Investigations Report 94-4006, 58p.

McAda, D.P., and Barroll, P., 2002, Simulation of groundwater flow in the Middle Rio Grande Basin between Cochiti and San Acacia, New Mexico, United States Geological Survey Water-Resources Investigations Report 02-4200.

(NMOSE) New Mexico Office of the State Engineer, 2013, personal communication: in-person conversation between Jess Ward, NMOSE and Scott McKitrick, SMA regarding Middle Rio Grande aquifer draw-down, February 12, 2013.

(NMOSE) New Mexico Office of the State Engineer, August 2012, personal communication: email from Ghassan Musharrafieh of NMOSE to Annie McCoy of John Shomaker & Associates, Inc. regarding current version of Middle Rio Grande Administrative Groundwater Model and regional pumping file, August 2, 2012.

(NMOSE) New Mexico Office of the State Engineer, 2001, Documentation of the Administrative Groundwater Model for the Middle Rio Grande Basin: New Mexico Office of the State Engineer Hydrology Bureau Report 99-3, prepared by P. Barroll.

(NMOSE) New Mexico Office of the State Engineer, 2000, Middle Rio Grande Administrative area guidelines for review of water right applications: administrative guidelines prepared by New Mexico Office of the State Engineer, September 13, 2000, 9 p. plus figures.

Taylor, Elizabeth Newlin, 2013, personal communication: electronic mail between Elizabeth Newlin Taylor, Taylor & McCaleb, P.A. and Scott McKitrick, SMA regarding cost of water rights, May 13, 2013

Tedford, R.H., and Baarghorn, S., 1999, Santa Fe Group (Neogene), Ceja del Rio Puerco, northwestern Albuqerque Basin, Sandoval County, New Mexico, Geological Society Guidebook, 50th Field Conference, Albuquerque Geology

Tiedeman, C.R., Kernodle, J.M., and McAda, D.P., 1998, Application of nonlinear-regression methods to a ground-water flow model of the Albuquerque Basin, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 98-4172, 90 p.

Thorn, C.R., McAda, D.P., Kernodle, J.M., 1993, Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico, U.S. Geological Survey Water-Resources Investigations Report 93-4149.

Waller, Roger M., 1982, Ground Water and the Rural Homeowner, Pamphlet, U.S. Geological Survey

Middle Rio Grande Water Assembly, Action Committee, 199, Middle Rio Grand Water Budget - Where water comes from, & goes, & how much

APPENDIX A

EVALUATION OF WATER SUPPLY FOR DEVELOPMENT OF RIO RANCHO ESTATES SANDOVAL COUNTY, NEW MEXICO

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EVALUATION OF WATER SUPPLY FOR DEVELOPMENT OF RIO RANCHO ESTATES, SANDOVAL COUNTY, NEW MEXICO

1.0 INTRODUCTION

Water-supply options for potential development of Rio Rancho Estates (Fig. 1.0) were evaluated using the New Mexico Office of the State Engineer (NMOSE) numerical model of groundwater flow in the Middle Rio Grande (MRG) Basin (MRG Administrative Model; NMOSE, 2001).

Section 1 of this report describes the suite of development scenarios evaluated, the water requirement for each, and the model representation of the projected groundwater pumping. Scenarios represent different levels of development, use of potential municipal or individual domestic wells, and immediate full build-out or phased build-out development.

In Section 2, the NMOSE Administrative Guidelines (NMOSE, 2000) for administration of water rights in the MRG are considered. These put a limit on model-projected cumulative groundwater-level drawdown, resulting from all permitted water rights in the basin, of 2.5 ft/year, over a planning period ending in 2040. Model-projected drawdown to 2040 is presented for each scenario.

In Section 3, the Sandoval County requirement of a 100-year water supply (Sandoval County Subdivision Ordinance, Appendix A.4A) is considered. Projected cumulative groundwater-level drawdown to year 2113 is presented for each scenario.

In Section 4, the effects of development are considered. The incremental drawdown resulting from development of Rio Rancho Estates, without including the effects of other pumping in the basin, is presented for each scenario.

In Section 5, the consumptive use of basin water rights is presented for each scenario, to quantify the amount of pumping that comes from surface flows or reduced groundwater discharge at the surface. The projected schedule of surface-water depletion, used by NMOSE to compute requirements for purchase of offsetting water rights, is presented for each scenario.

Section 6 briefly discusses the potential effects of wastewater disposal through septic tanks, both to potential return flow to the aquifer and to potential water-quality effects. A summary and conclusions are presented in Section 7.

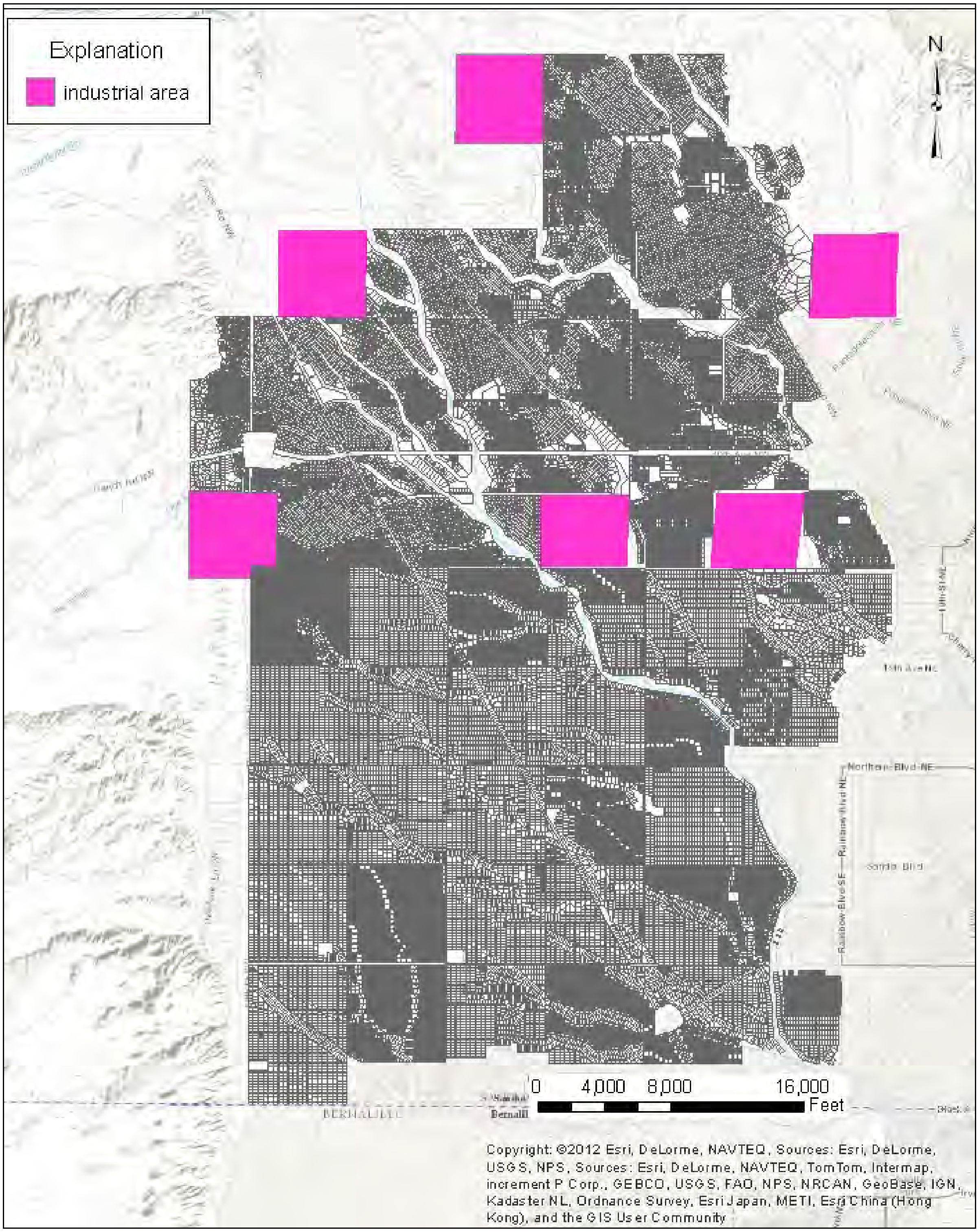

Figure 1.0. Rio Rancho Estates plat representing 41,000-lot development scenario.

1.1 Middle Rio Grande Administrative Model

Future groundwater-level drawdown and surface-water changes associated with potential Rio Rancho Estates development were evaluated using an updated version of the MRG Administrative Model (NMOSE, personal communication, August 2012).

The model represents historical and permitted future groundwater pumping under all existing groundwater rights in the Basin (e.g., City of Rio Rancho and Albuquerque-Bernalillo County Water Utility Authority pumping). Potential Rio Rancho Estates pumping was added to the total pumping for the model simulations in this report.

The groundwater system in the MRG Basin is simulated using the U.S. Geological Survey (USGS) MODFLOW computer program (Harbaugh and McDonald, 1996) commonly used for groundwater-flow modeling. The model represents the basin as a finite-difference grid of rectangular cells with 113 rows and 60 columns, covering an area of about 3,468 square miles (Fig. 1.1). The grid cells are relatively large (0.3 to 0.4 square mile) near Rio Rancho Estates.

The three-dimensional grid also has 6 layers, representing a total aquifer thickness of about 1,600 ft. Municipal and industrial wells are typically simulated as pumping from layers 4 through 6 in the model, and domestic wells are typically simulated as pumping from shallower layers 1 through 3.

The lower 3 layers are defined as constant transmissivity, confined aquifer units. The upper 3 model layers (upper 200 ft) are defined as variable transmissivity aquifer units that may change between confined and unconfined conditions. Cells in the upper 3 model layers can become dry if the simulated water level drops below the cell bottom.

The MRG model assumes that wells will be deepened as necessary; if the model cell to which a pumping well has been assigned becomes dry during a simulation, the pumping is automatically shifted to the next layer below.

Transmissivity within each model layer varies spatially. Figure 1.1 shows the model grid along with simulated hydraulic conductivity (transmissivity per unit aquifer thickness) for layer 3, indicating a low-conductivity fault zone trending north-northeast through Rio Rancho Estates. The simulated location and hydraulic properties of the fault zone are based on geologic mapping and model calibration results (Tiedeman et al., 1998; NMOSE, 2001).

Although the fault zone as represented in the model is at least one cell (0.6 mile) wide, in reality it is probably much narrower. In practice, wells can likely be drilled off of the fault zone without moving such a large distance. Moving wells off the fault zone is simulated in the model by moving the pumping locations to an adjacent cell. This has been an accepted practice (NMOSE, 2001) with the Middle Rio Grande Administrative Model for evaluating pumping in and adjacent to the fault zone, and it is used for the "Individual Wells, modified" pumping scenarios presented below.

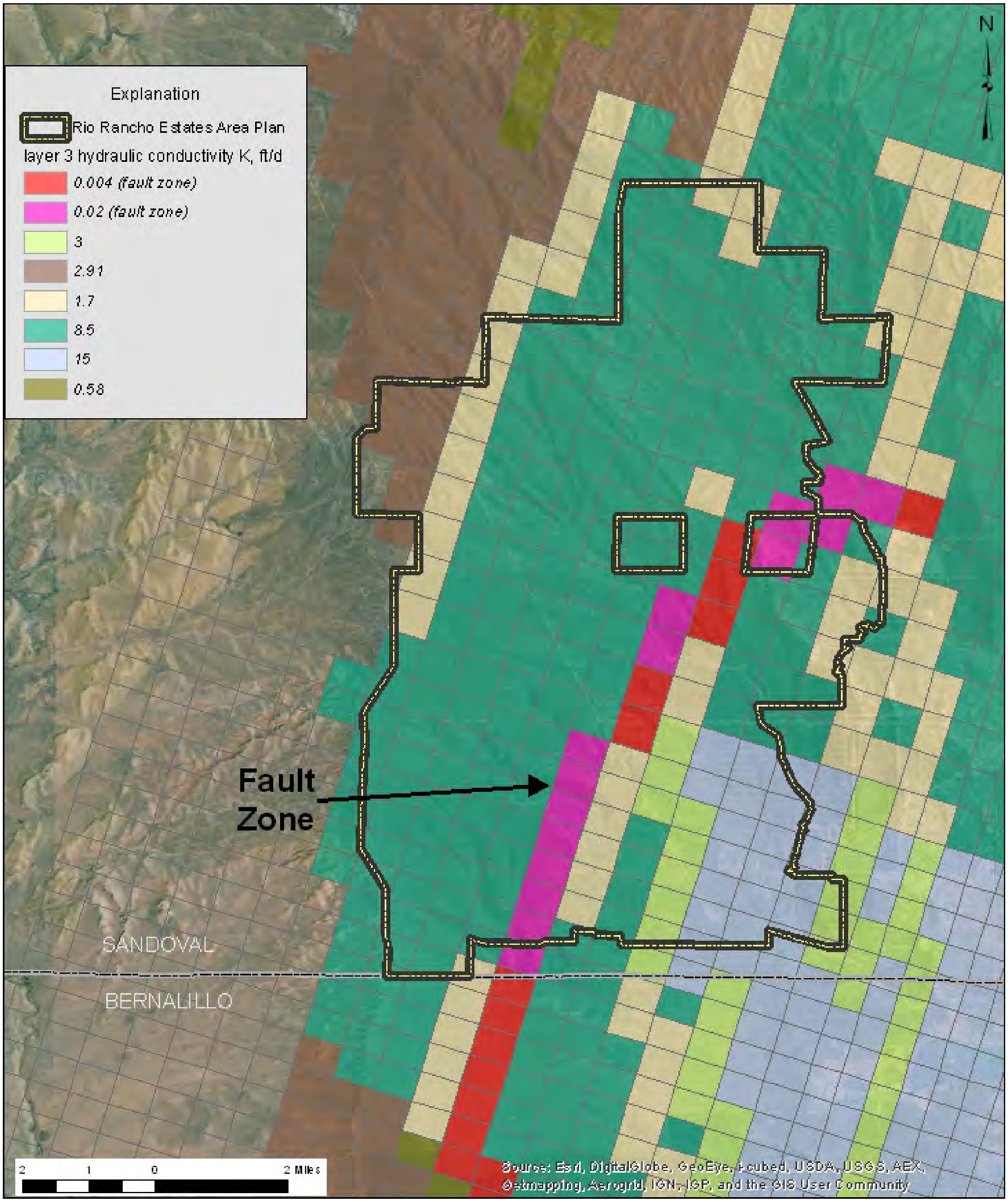

Figure 1.1. Model grid and layer 3 hydraulic conductivity, near Rio Rancho Estates.

1.2 Model Scenarios

The original development plan (SMA, personal communication, October 2012), shown on Figure 1.0, included approximately 41,000 lots. A modified plan (Sandoval County, personal communication, November 2012) including 18,077 lots is shown on Figure 1.2.

The original development plan was a result of land platting in the 1960s and early 1970s, prior to the adoption of the State's first Subdivision Act for counties, and prior to establishment of county zoning (Sandoval County, 2012). Issues with the original development plan include a lack of planned infrastructure improvements, inadequate street layouts, and a lack of conformance to the area's natural features such as 100-year arroyo flood areas. The 18,077-lot scenario was developed in light of these issues, using current information on land planning, infrastructure development, and water resources in the area (Sandoval County, 2012).

Seven scenarios were simulated:

1) **Municipal Wells, 41,000-Lot Full Build-Out:** Pumping was simulated from nine potential municipal wells (Fig. 1.2). Pumping to supply 41,000 lots was assumed to begin with full build-out in 2014. Results predict drawdown from 2013 to 2040 in excess of NMOSE guidelines.

2) **Individual Wells, Modified, 41,000-Lot Full Build-Out:** Pumping was simulated from each model cell location (Fig. 1.1) according to the number of lots within each cell. Pumping for 41,000 individual lots was assumed to begin with full build-out in 2014. Results indicate excessive drawdown and doubtful supply.

3) **Municipal Wells, 18,077-Lot Full Build-Out:** Pumping was simulated from nine potential municipal wells. Pumping to supply 18,077 lots was assumed to begin with full build-out in 2014. Results predict drawdown from 2013 to 2040 in excess of NMOSE guidelines.

4) **Municipal Wells, 18,077-Lot Phased Build-Out:** Pumping was simulated from nine potential municipal wells, beginning with 20 percent of full pumping in 2014, increasing by 20 percent in 2019, 2024 and 2029, reaching full build-out for 18,077 lots in 2034.

5) **Individual Wells, 18,077-Lot Full Build-Out:** Pumping was apportioned to cells by number of lots and/or size of industrial area, beginning with full build-out in 2014. Results indicate excessive drawdown and doubtful supply along the low-permeability fault zone that bisects the development area.

6) **Individual Wells, Modified, 18,077-Lot Full Build-Out:** Pumping was moved from the low-permeability fault zone cells to adjacent cells. Pumping for 18,077 lots was assumed to begin with full build-out in 2014. Results indicate excessive drawdown and doubtful supply in a limited area east of the low-permeability fault zone.

7) **Individual Wells, Modified, 18,077-Lot Phased Build-Out:** Pumping was phased in, beginning with 20 percent of full pumping in 2014, increasing by 20 percent in 2019, 2024, and 2029, reaching full build-out in 2034. Results indicate excessive drawdown and doubtful supply in a minimal area at the east edge of the low-permeability fault zone.

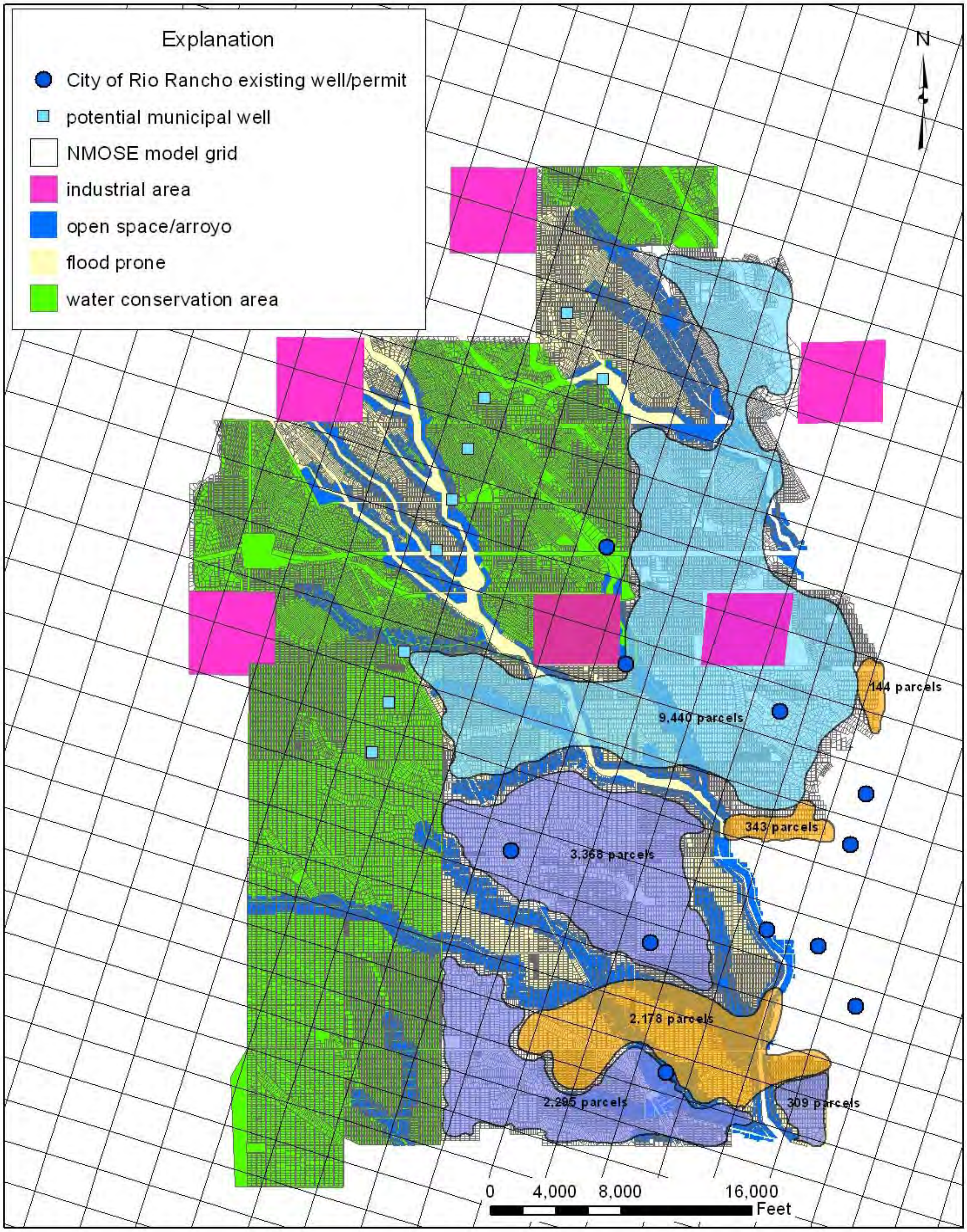

Figure 1.2. Rio Rancho Estates 18,077-lot development scenario and potential municipal well locations.

1.3 Water Demand

Each Rio Rancho Estates development scenario assumes a water demand of 0.41 acre-feet per year (ac-ft/yr) per lot, based on an individual use of 135 gallons per capita per day and a household size of 2.72 persons per lot (SMA, personal communication, October 2012).

In addition, a demand of 1,200 ac-ft/yr was assumed for four of the six industrial areas shown on Figure 1.2. The total demand simulated is therefore (41,000 x 0.41 + 1,200) 18,010 ac-ft/yr for the 41,000-lot scenarios, and (18,077 x 0.41) + 1,200) 8,612 ac-ft/yr for the 18,077-lot scenarios.

1.4 Model Representation of Pumping

The estimated water use for each Rio Rancho Estates development scenario was added to the model as simulated future pumping. The most recent model version (NMOSE, personal communication, August 2012) already includes future pumping from all existing groundwater rights in the Basin (e.g., City of Rio Rancho and Albuquerque-Bernalillo County Water Utility Authority pumping).

Pumping for the municipal wells scenarios was simulated from nine potential supply wells (Fig. 1.2) located in areas with moderately high transmissivity in the model west of the low-permeability fault zone (Fig. 1.1), some distance from existing and permitted City of Rio Rancho supply well locations (Fig. 1.2). Pumping was taken in equal portions from the bottom three model layers (layers 4-6), representing the deep completions and long screen intervals typical of large municipal wells.

Pumping for the individual domestic wells scenarios was taken initially from model layer 1, reflecting typical domestic well completion and screening through the upper part of the water table. The model assumes that wells will be deepened as necessary, so that if a model cell becomes dry, simulated pumping is automatically shifted to the next layer below.

1.5 Sets of Results

For each scenario, the following results are presented:

- Projected 26-year (2014-2039) total drawdown (due to Middle Rio Grande regional pumping plus Rio Rancho Estates pumping) is presented for each scenario in Section 2.0.
- Projected 100-year (2014-2113) total drawdown (due to Middle Rio Grande regional pumping plus Rio Rancho Estates pumping) is presented for each scenario in Section 3.0.
- Projected 100-year incremental drawdown (caused by Rio Rancho Estates pumping) is presented for each scenario in Section 4.0.
- Projected 100-year surface-water depletion (change of flow and discharge in the Middle Rio Grande) schedule is presented for each scenario in Section 5.0.

2.0 MIDDLE RIO GRANDE GUIDELINES: 2014-2039 DRAWDOWN

The projected 2014-2039 drawdown without Rio Rancho Estates development is presented on Figure 2.1, showing an area with projected drawdown greater than 2.5 ft/year, or 65 ft over 26 years, east of the Rio Grande. Such areas are termed Critical Management Areas (CMA) in the Middle Rio Grande Guidelines (NMOSE, 2000), which prohibit the creation of new CMA.

Although the Middle Rio Grande Guidelines do not strictly apply to the individual wells scenarios (because individual wells are granted automatic state permits for domestic use), the Guidelines provide a consistent framework for evaluation, and the 2.5 ft/year drawdown criterion is a reasonable general indicator of questionable supply and/or impairment of other water rights.

Figures 2.2 through 2.8 show model-simulated 2013-2039 cumulative drawdown for each model scenario, considering the existing permitted groundwater pumping in addition to the development of Rio Rancho Estates. Model-simulated areas with drawdown greater than 2.5 ft/year are indicated on each figure.

Figures 2.2 through 2.8 show model-simulated creation of CMA in the Rio Rancho Estates area in all scenarios except the municipal wells, 18,077-lot phased build-out scenario (Fig. 2.5). The CMA in the individual wells, modified, 18,077-lot phased build-out scenario (Fig. 2.8) includes only a small area.

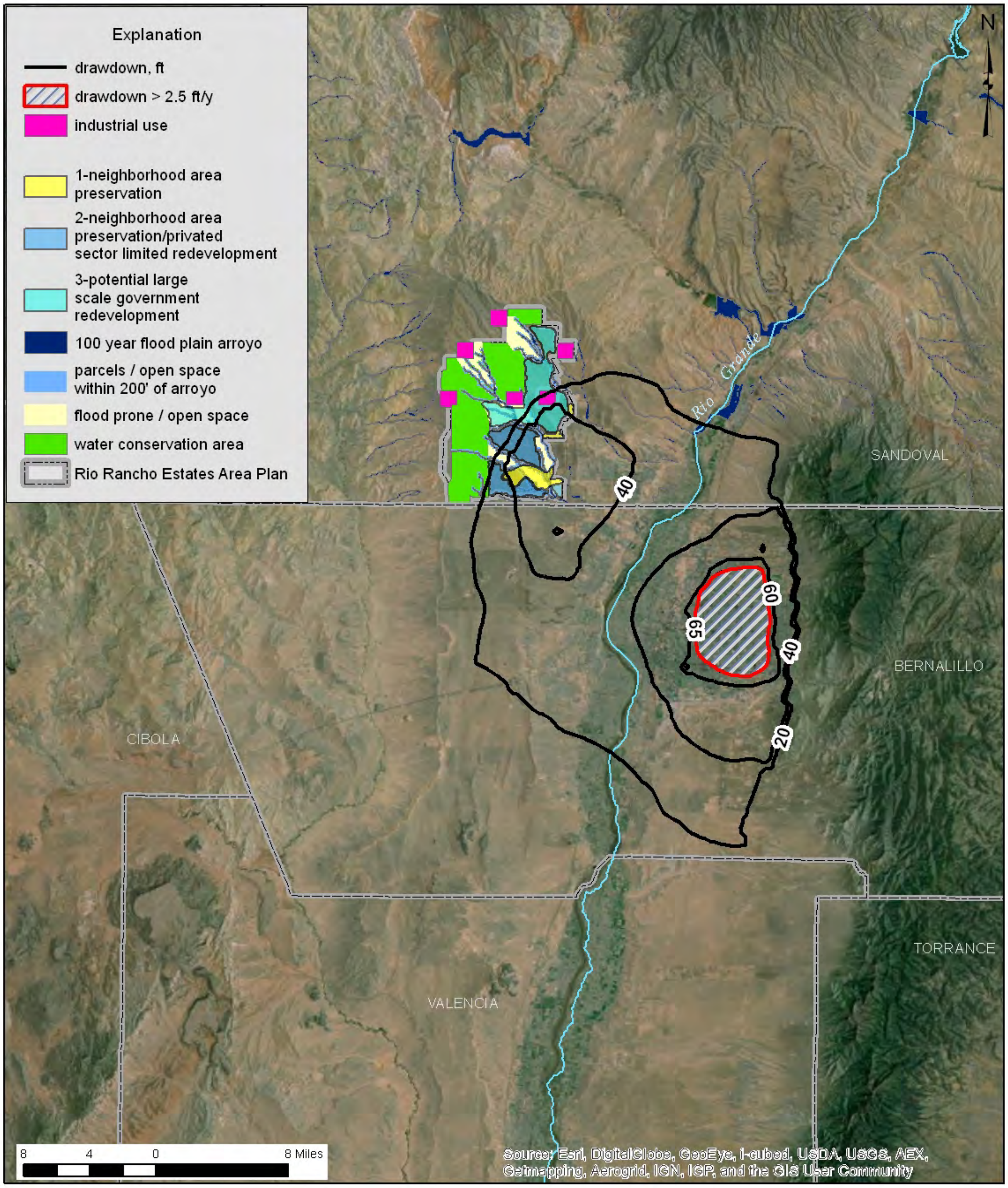

Figure 2.1. Projected drawdown, 2014-2039, without Rio Rancho Estates development.

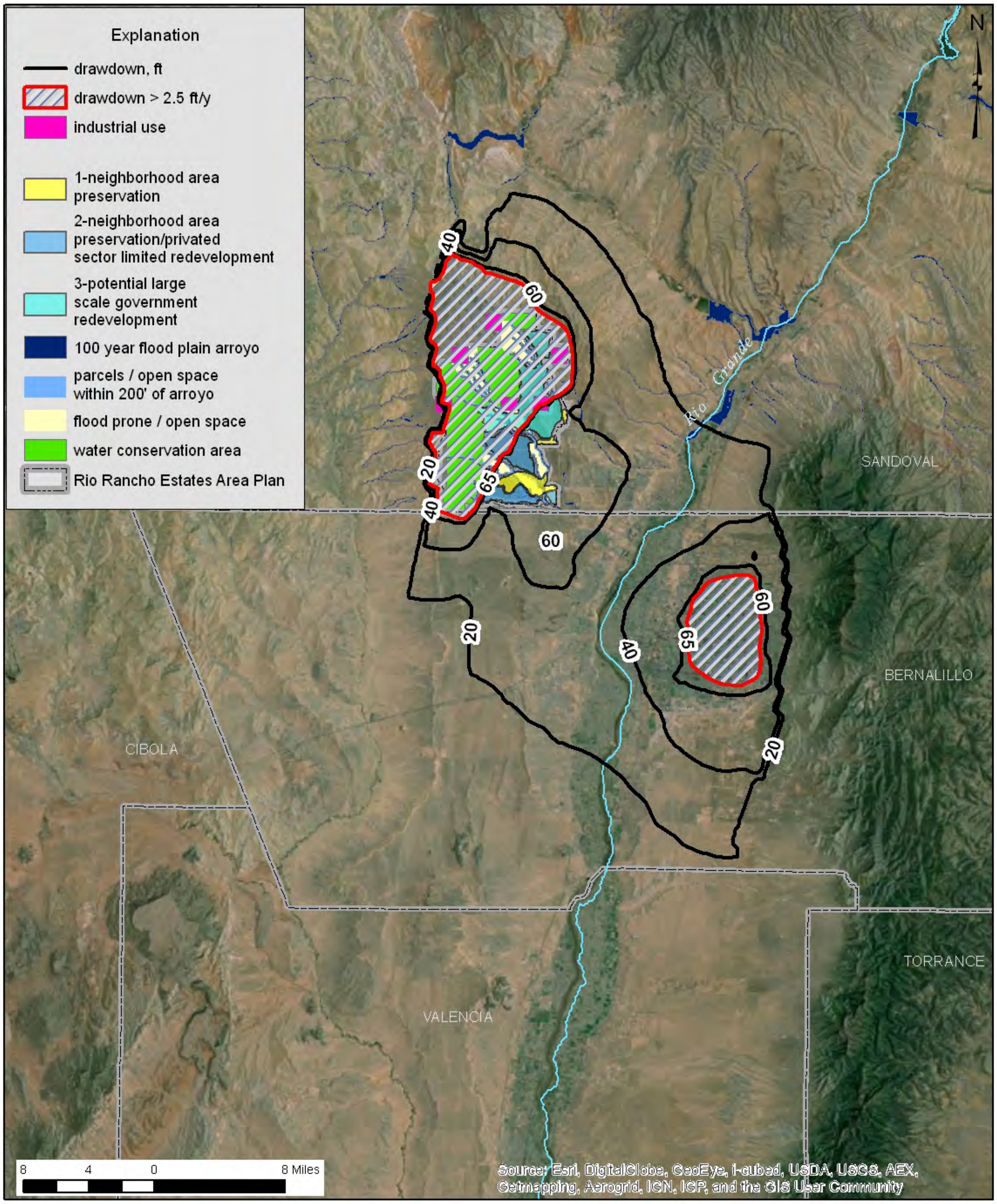

Figure 2.2. Projected drawdown, 2014-2039, municipal wells, 41,000-lot full build-out scenario.

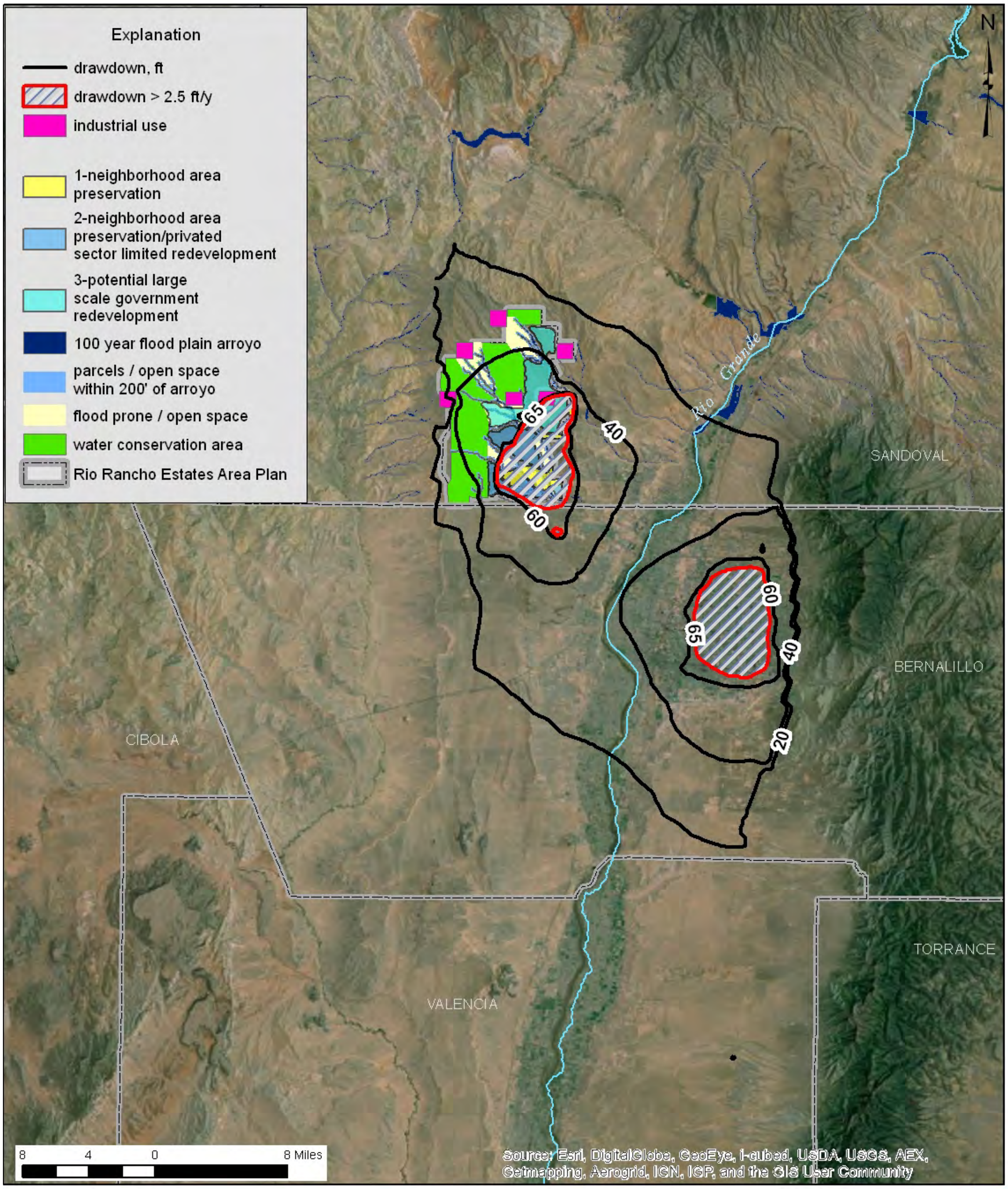

Figure 2.3. Projected drawdown, 2014-2039, individual wells, modified 41,000-lot full build-out scenario.

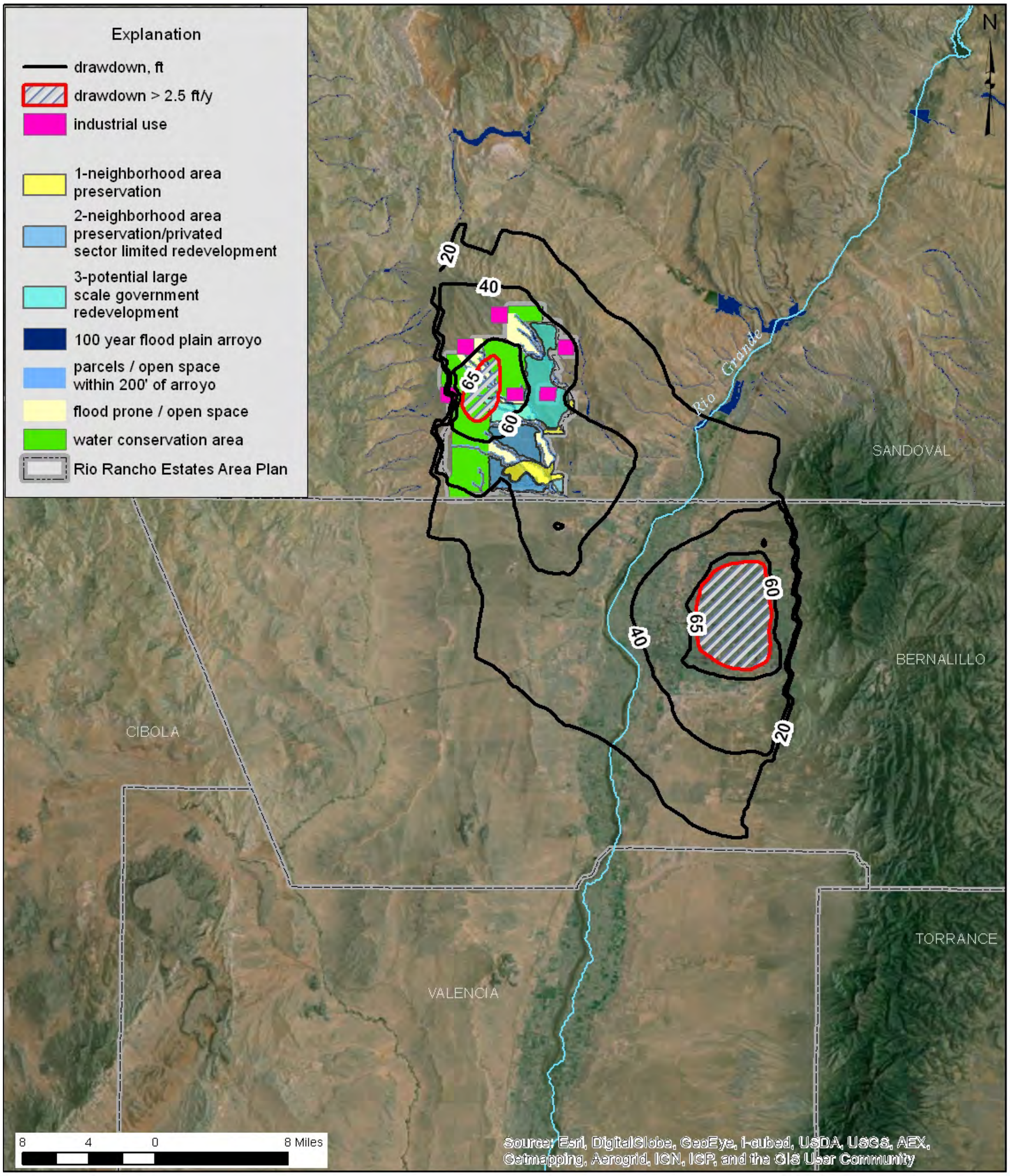

Figure 2.4. Projected drawdown, 2014-2039, municipal wells, 18,077-lot full build-out scenario.

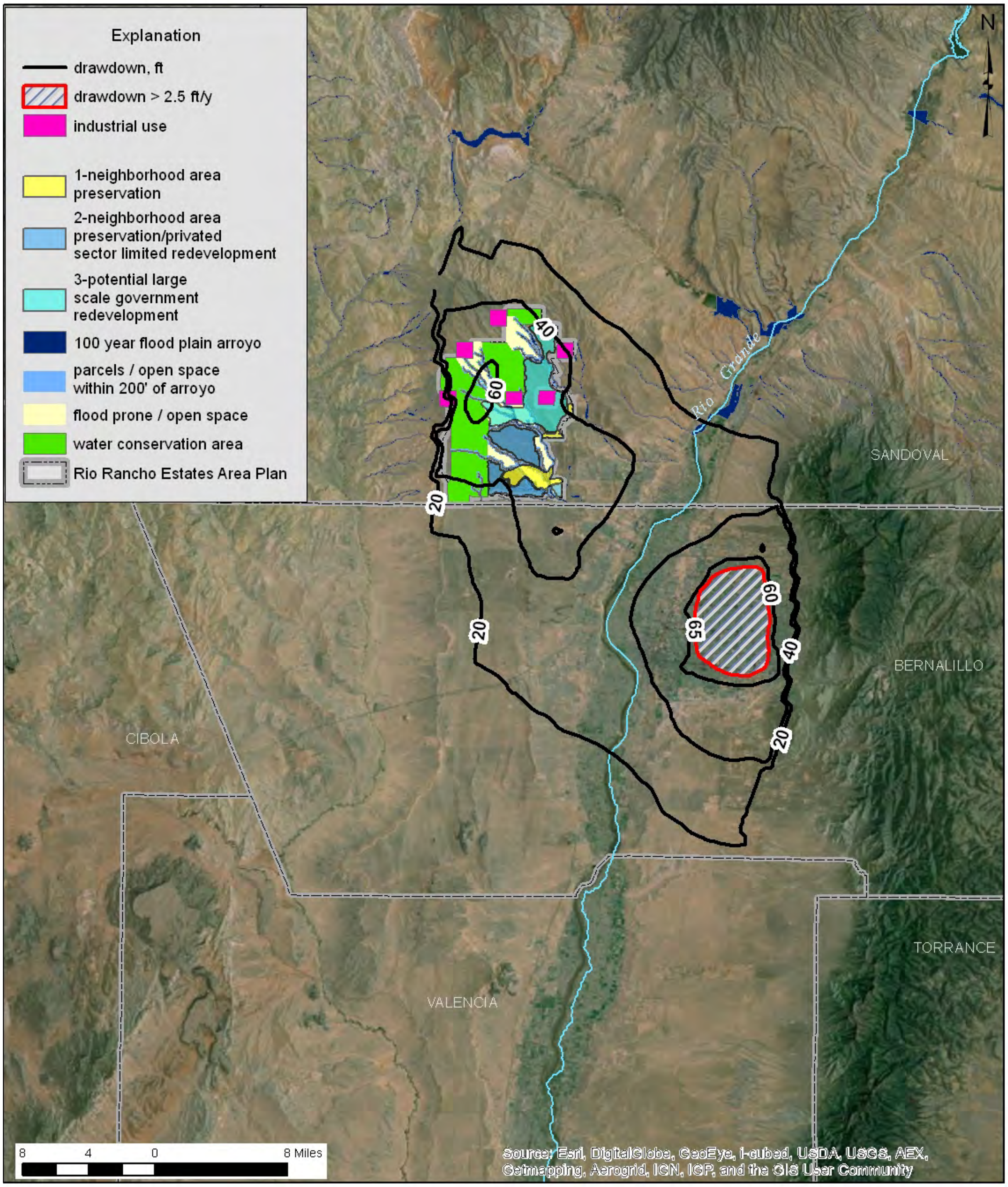

Figure 2.5. Projected drawdown, 2014-2039, municipal wells, 18,077-lot phased build-out scenario.

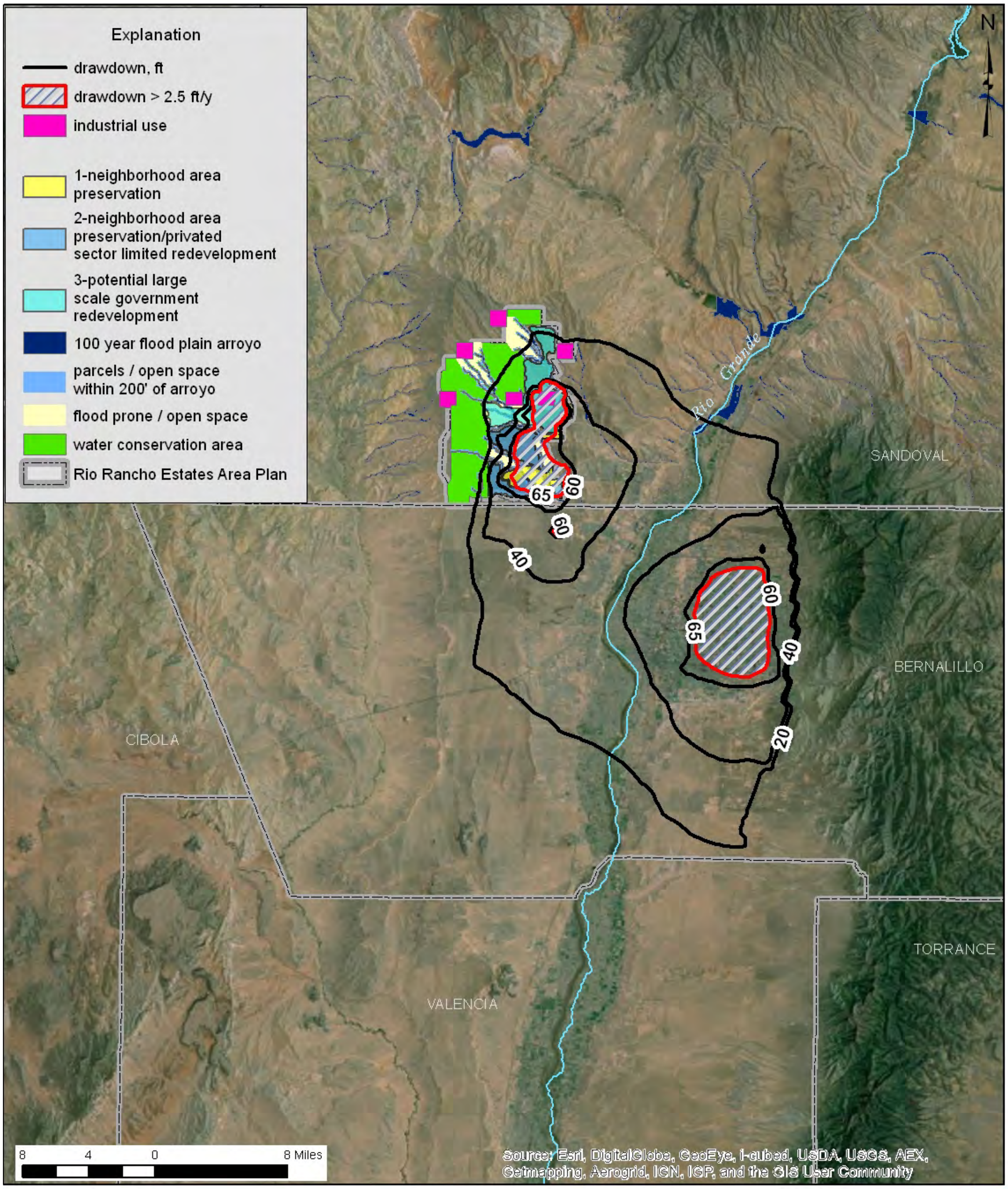

Figure 2.6. Projected drawdown, 2014-2039, individual wells, 18,077-lot full build-out scenario.

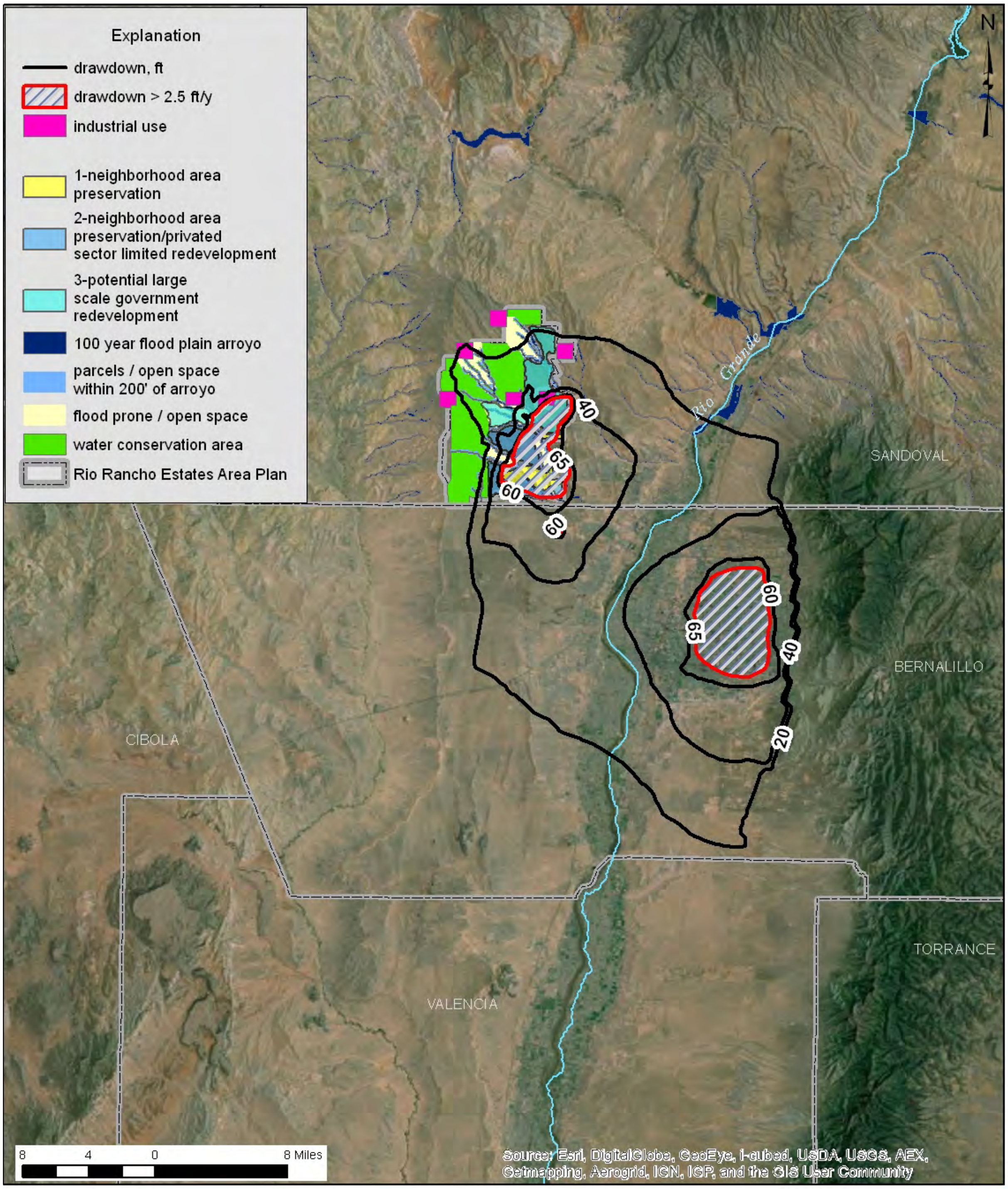

Figure 2.7. Projected drawdown, 2014-2039, individual wells, modified, 18,077-lot full build-out scenario.

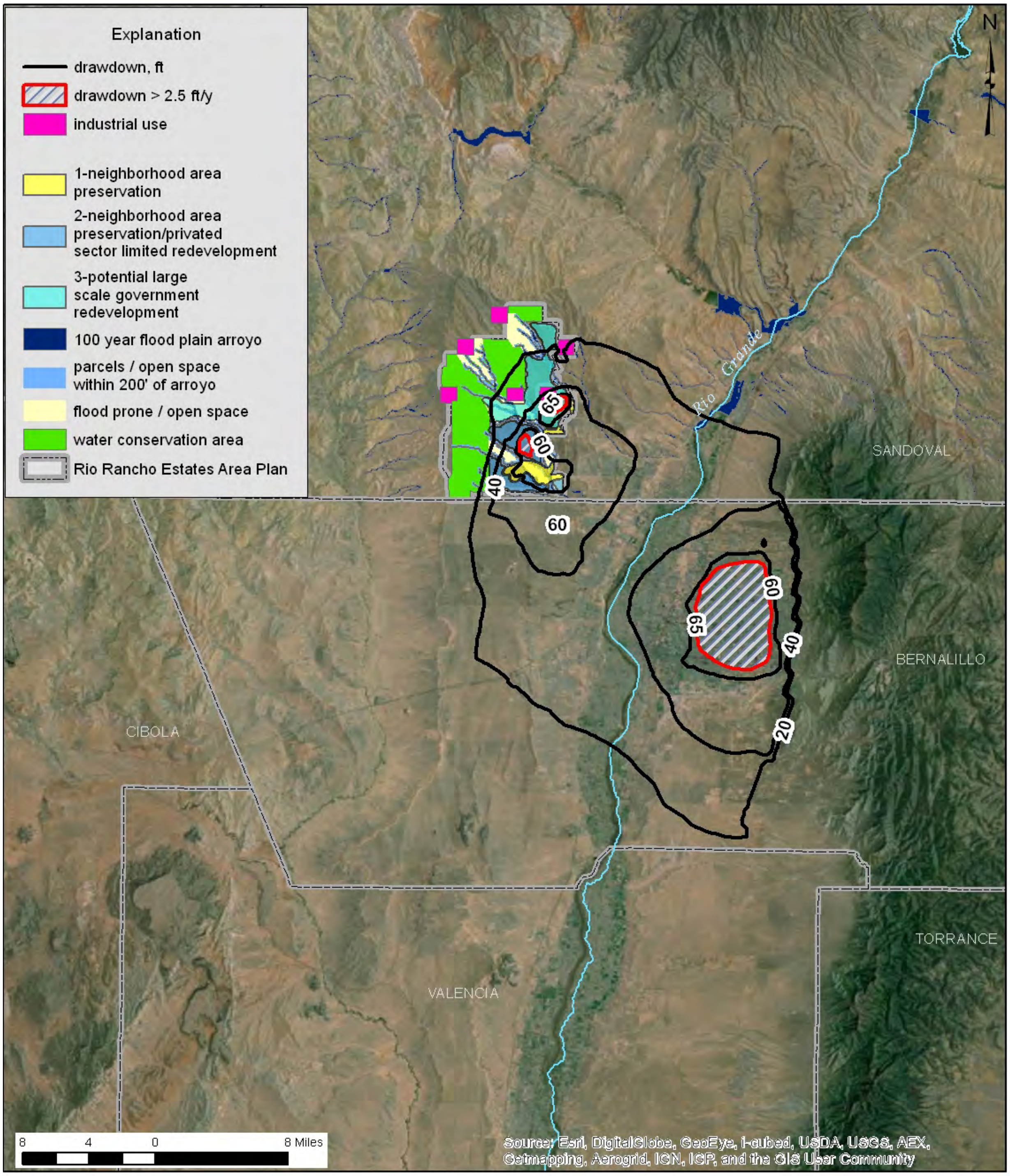

Figure 2.8. Projected drawdown, 2014-2039, individual wells, modified, 18,077-lot phased build-out scenario.

3.0 ONE-HUNDRED YEAR SUPPLY: 2014-2113 DRAWDOWN

Figures 3.1 through 3.7 show model-simulated 2013-2113 cumulative drawdown for each model scenario, considering the existing permitted groundwater pumping in addition to the development of Rio Rancho Estates. Areas with drawdown greater than 2.5 ft/year, if any, are indicated on each figure.

Areas with greater than 2.5 ft/year of model-projected 100-year drawdown are shown for all of the individual wells scenarios (Figs. 3.2, 3.5, 3.6, and 3.7), with only a small area for the individual wells, modified, 18,077-lot phased build-out scenario (Fig. 3.7).

The municipal wells scenarios (Figs. 3.1 through 3.4) project maximum drawdown on the order of 150 ft (1.5 ft/year). Areas with model-simulated drawdown greater than 250 ft (2.50 ft/yr x 100-year period) are indicated when applicable.

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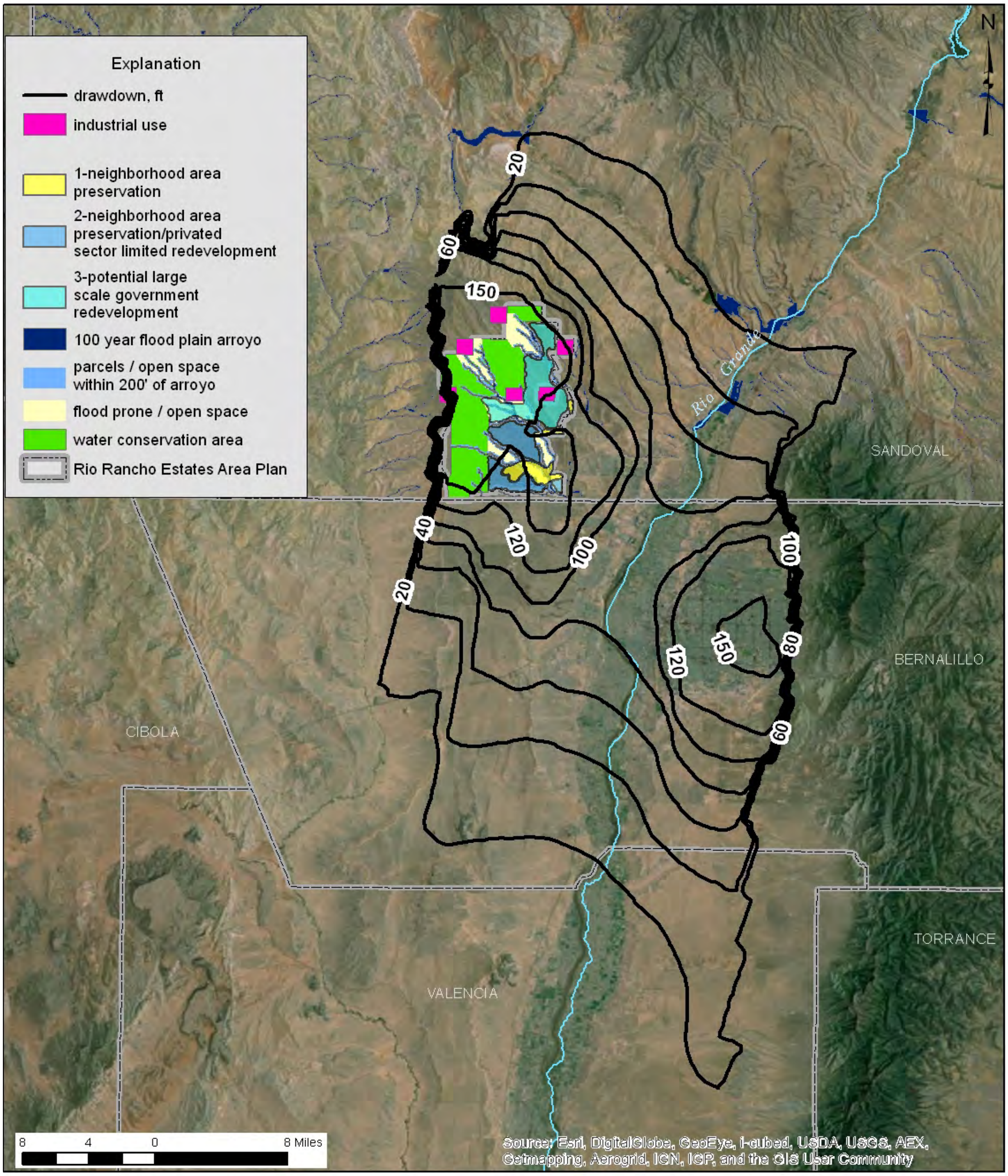

Figure 3.1. Projected drawdown, 2014-2113, municipal wells,
41,000-lot full build-out scenario.

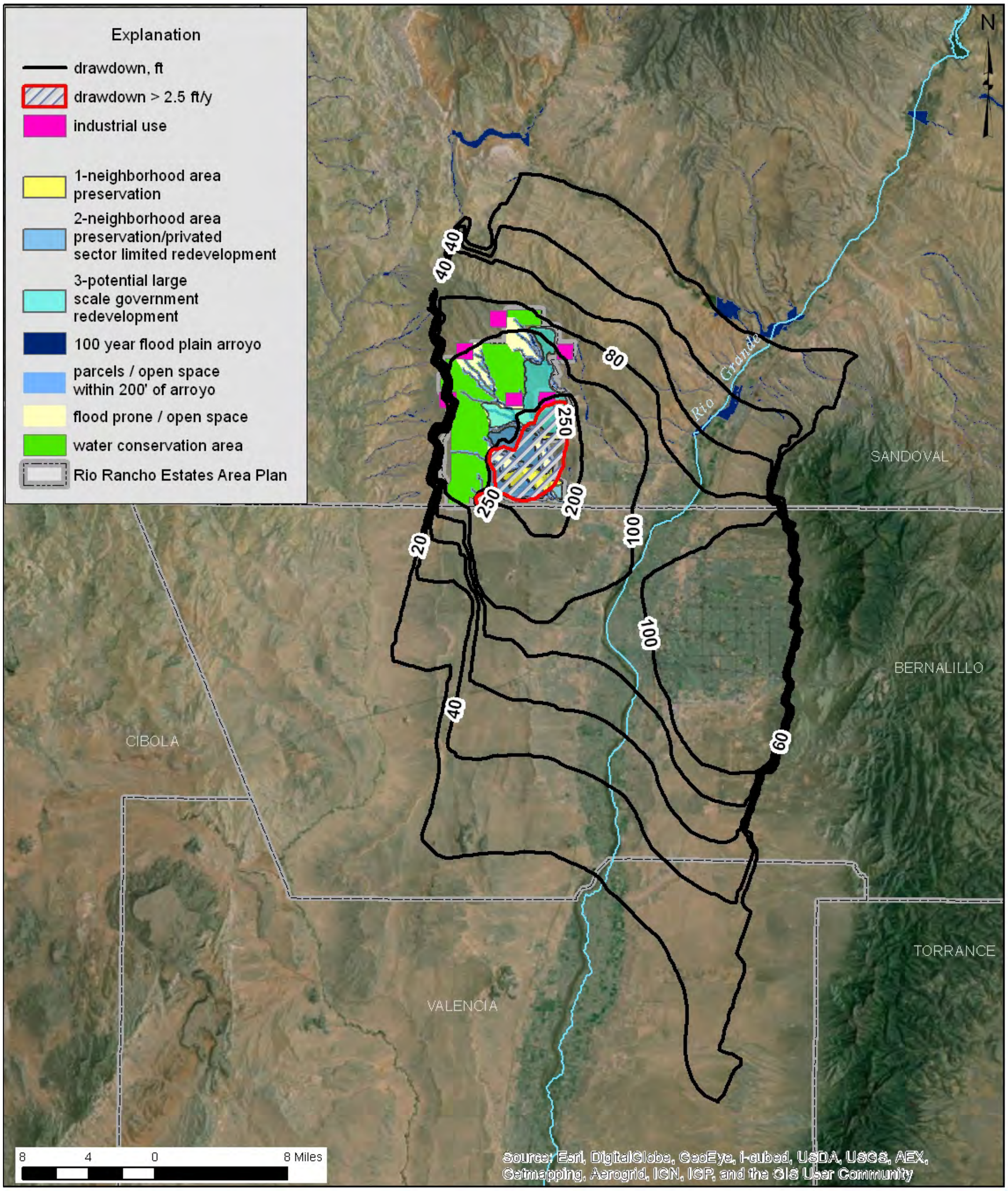

Figure 3.2. Projected drawdown, 2014-2113, individual wells, 41,000-lot full build-out scenario.

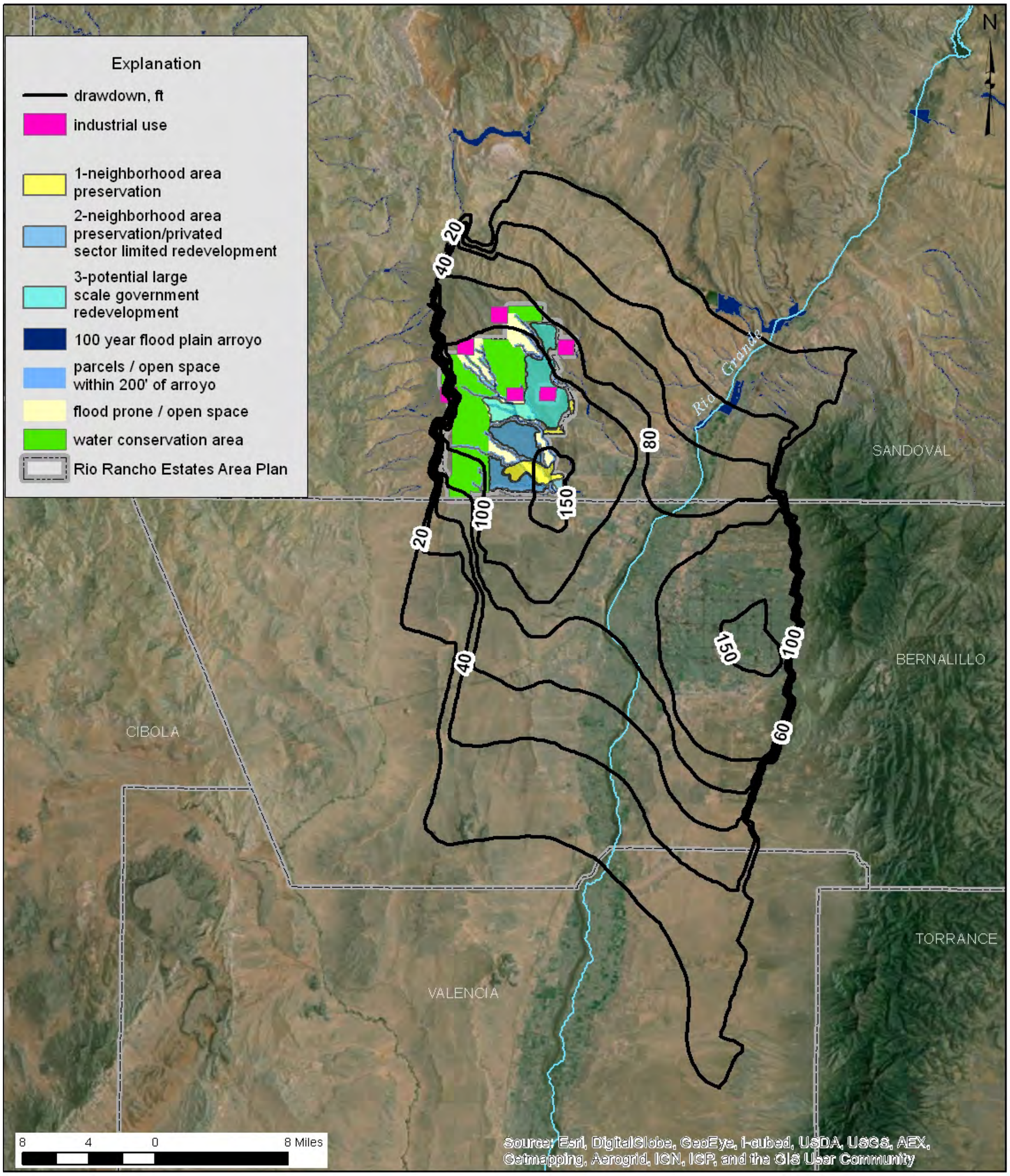

Figure 3.3. Projected drawdown, 2014-2113, municipal wells,
18,077-lot full build-out scenario.

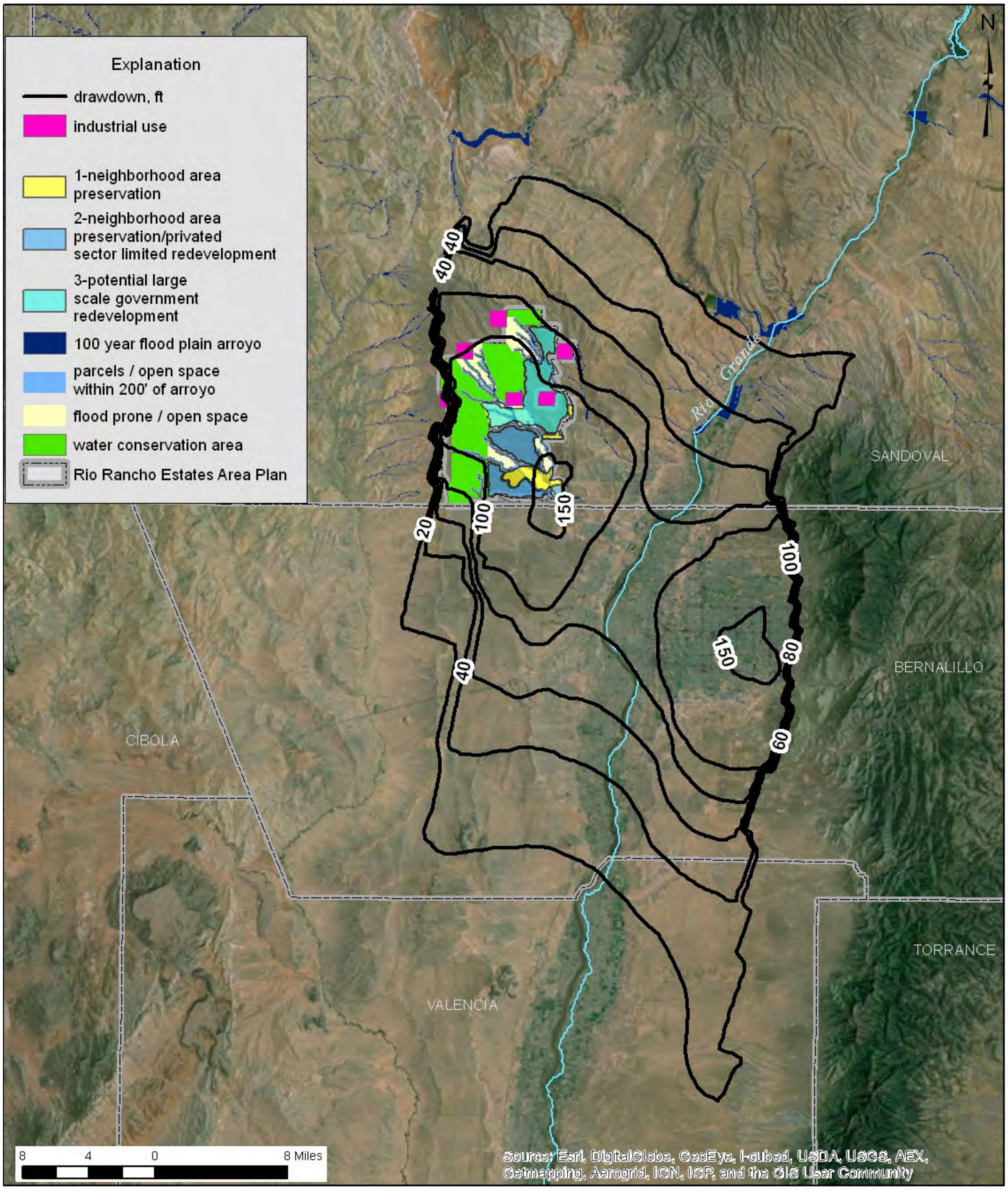

Figure 3.4. Projected drawdown, 2014-2113, municipal wells, 18,077-lot phased build-out scenario.

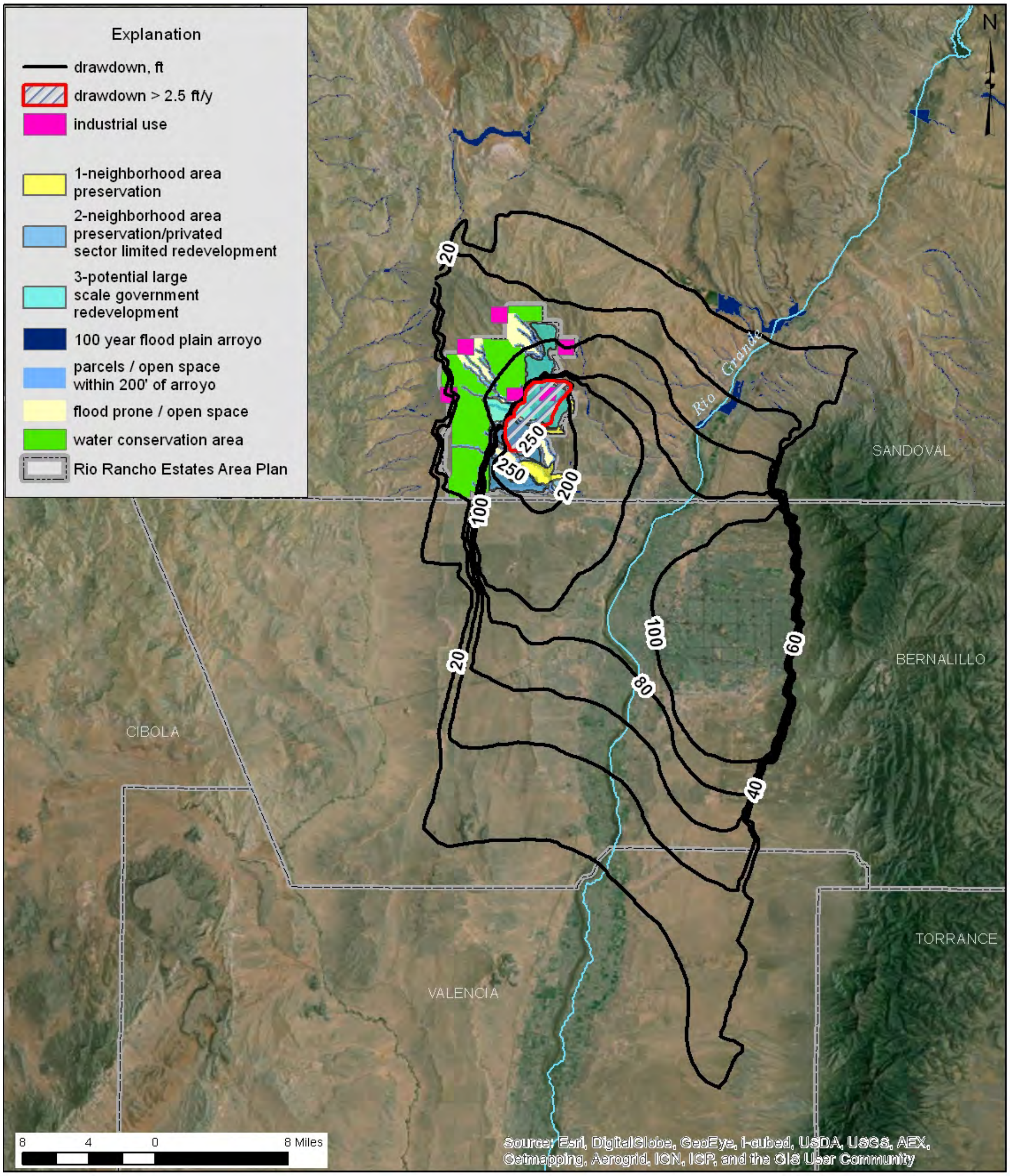

Figure 3.5. Projected drawdown, 2014-2113, individual wells, 18,077-lot full build-out scenario.

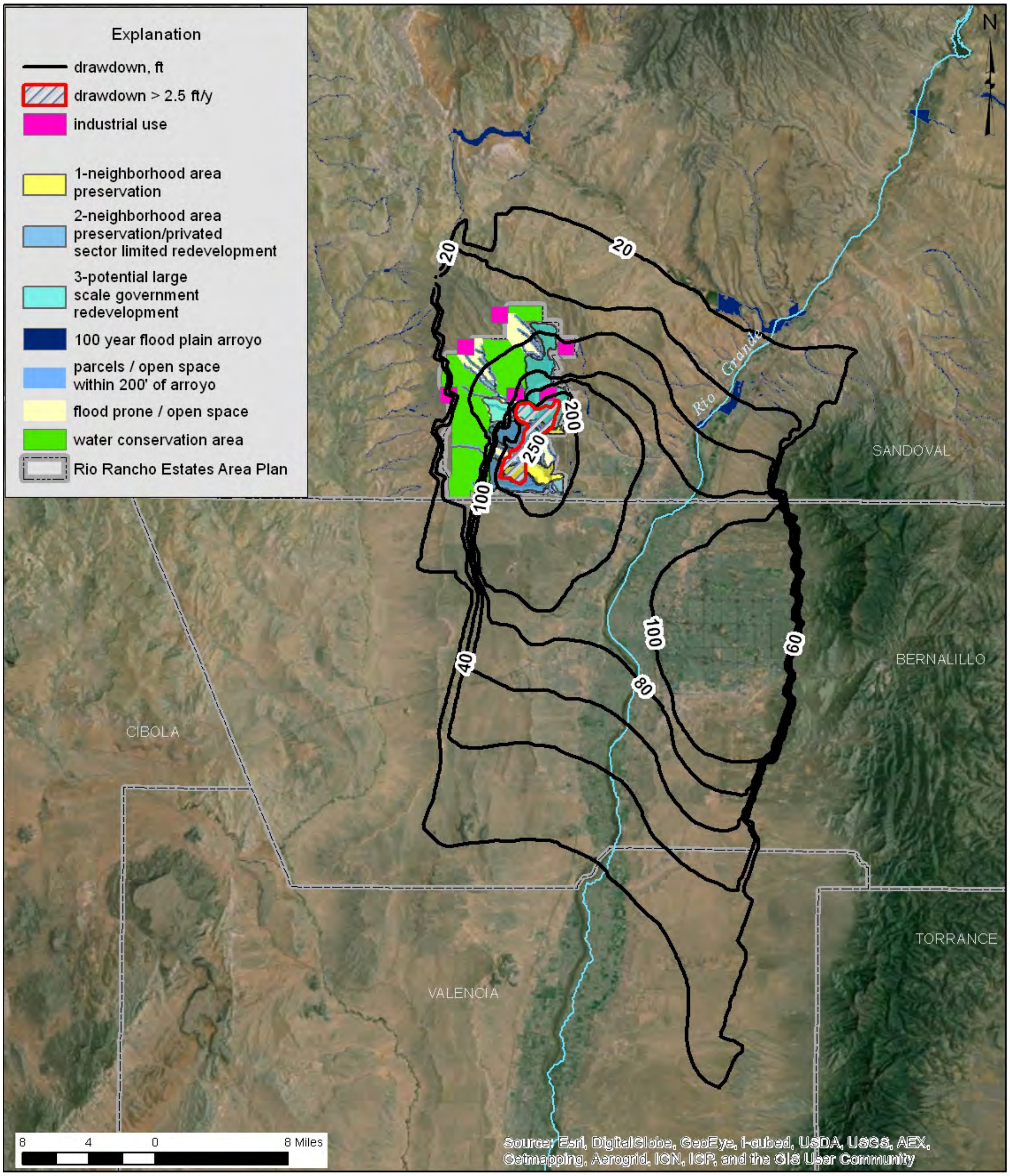

Figure 3.6. Projected drawdown, 2014-2113, individual wells, modified, 18,077-lot full build-out scenario.

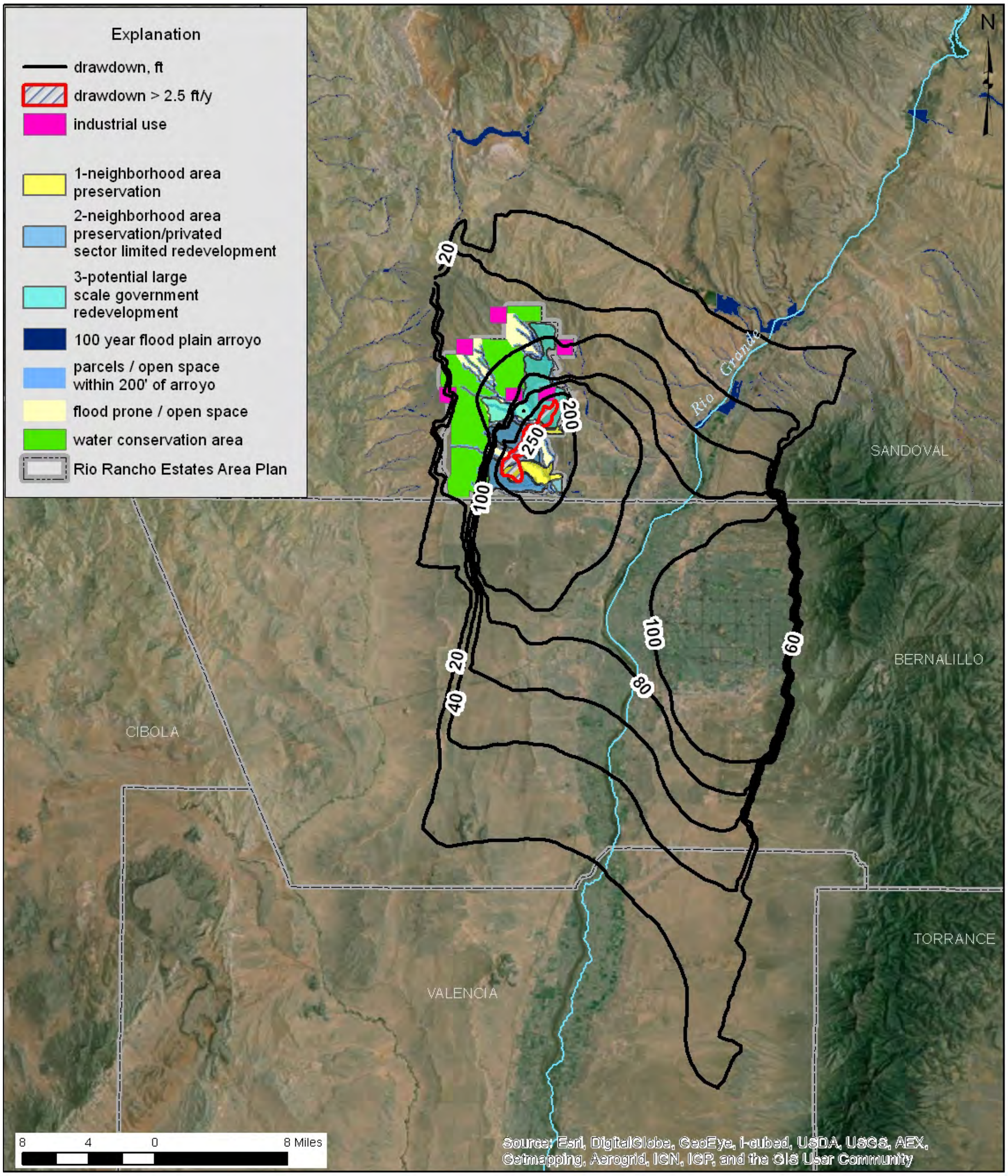

Figure 3.7. Projected drawdown, 2014-2113, individual wells, modified, 18,077-lot phased build-out scenario.

4.0 INCREMENTAL EFFECTS: 2014-2113 INCREMENTAL DRAWDOWN

The projected 2014-2113 incremental drawdown due to Rio Rancho Estates development, characterizing the drawdown effects of the development over a 100-year period, is presented for each scenario in Figures 4.1 through 4.7.

The municipal wells scenarios show 100-year incremental drawdown reaching 100 ft for the 41,000-lot scenario (Fig. 4.1) and 80 ft for the 18,077-lot scenarios (Figs. 4.3-4.4).

The individual wells, modified, 41,000-lot full build-out scenario (Fig. 4.2) shows incremental drawdown over the entire Rio Rancho Estates area, reaching a maximum of around 200 ft along the low-permeability fault zone, which inhibits recharging flow from the west.

The individual wells 18,077-lot full build-out scenario (Fig. 4.5) shows less drawdown overall when compared to the 41,000-lot scenario, but also shows an area with more drawdown, reaching 250 ft along the fault zone. This is due to the concentration of pumping east of the fault zone in the 18,077-lot individual wells scenarios (Figs. 4.5-4.7).

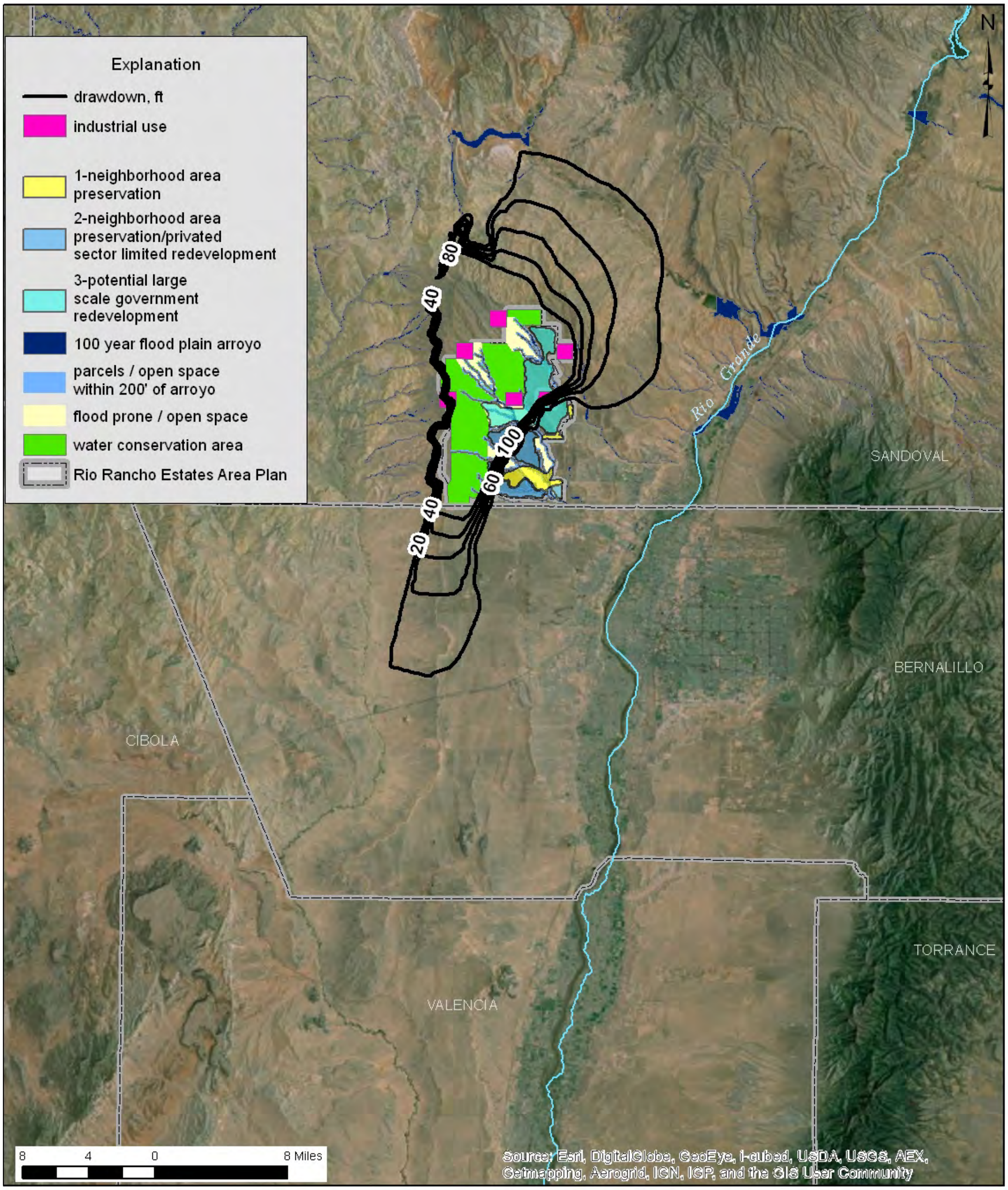

Figure 4.1. Projected incremental drawdown, 2014-2113, municipal wells, 41,000-lot full build-out scenario.

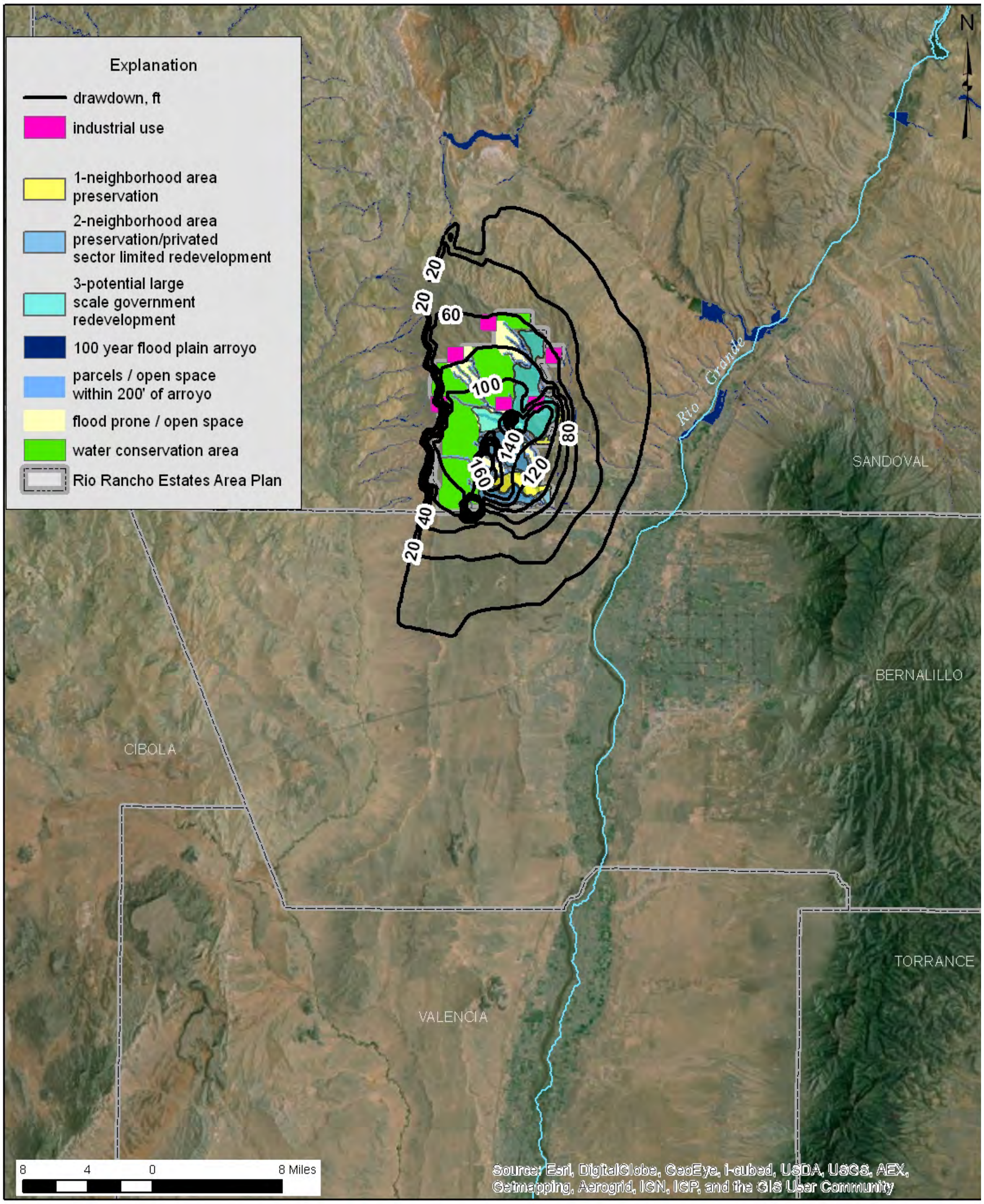

Figure 4.2. Projected incremental drawdown, 2014-2113, individual wells, 41,000-lot full build-out scenario.

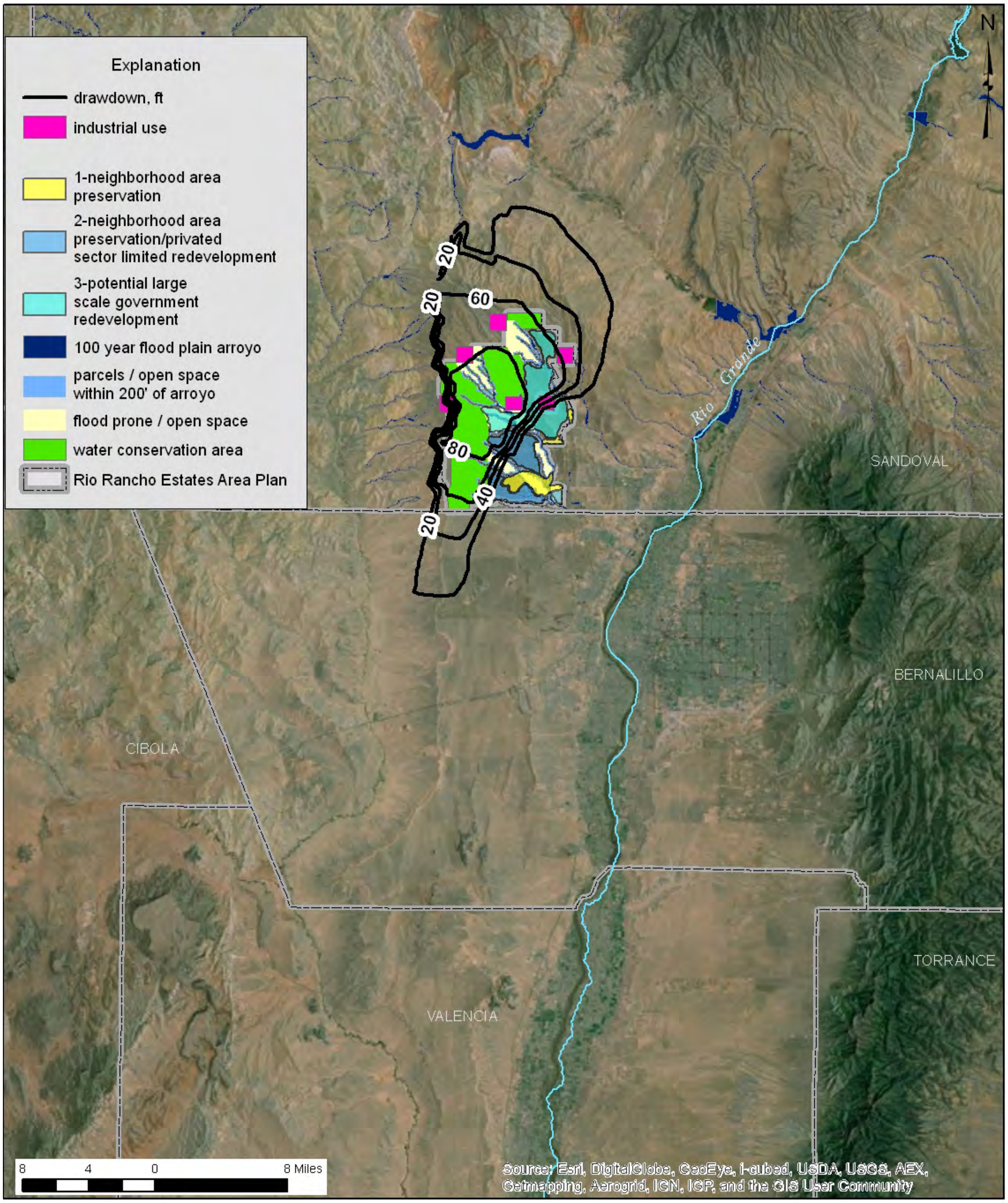

Figure 4.3. Projected incremental drawdown, 2014-2113, municipal wells, 18,077-lot full build-out scenario.

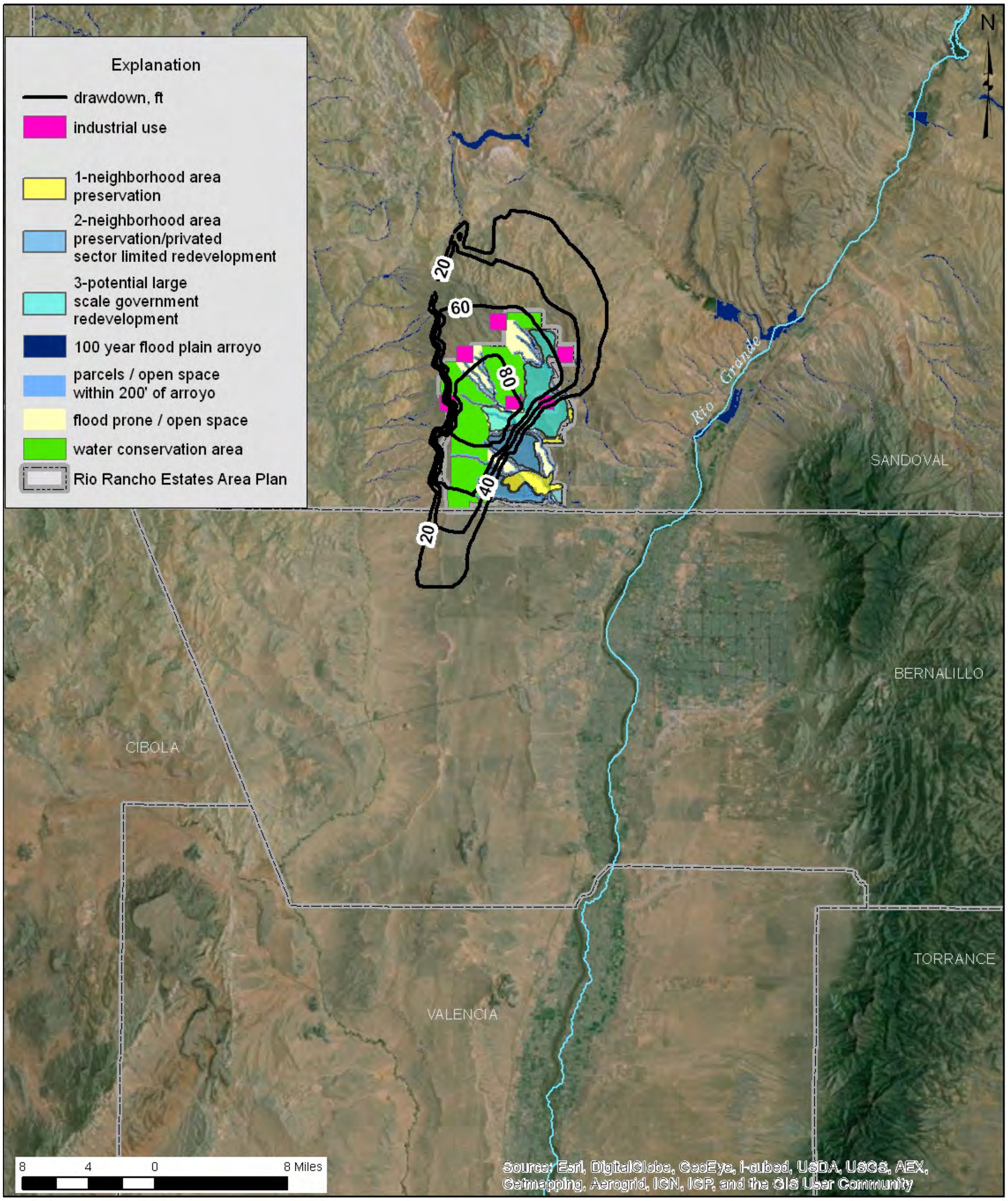

Figure 4.4. Projected incremental drawdown, 2014-2113, municipal wells, 18,077-lot phased build-out scenario.

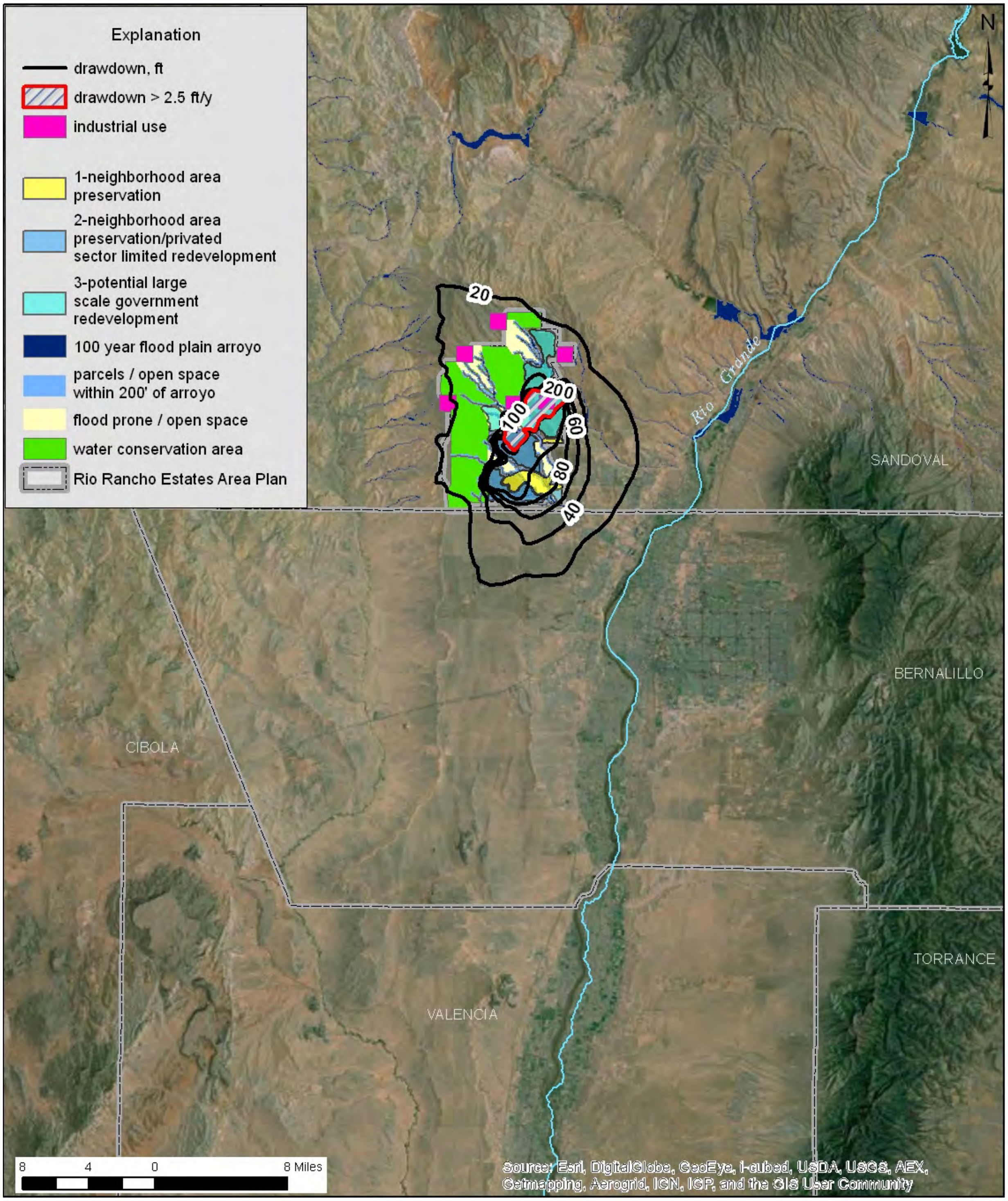

Figure 4.5. Projected incremental drawdown, 2014-2113, individual wells, 18,077-lot full build-out scenario.

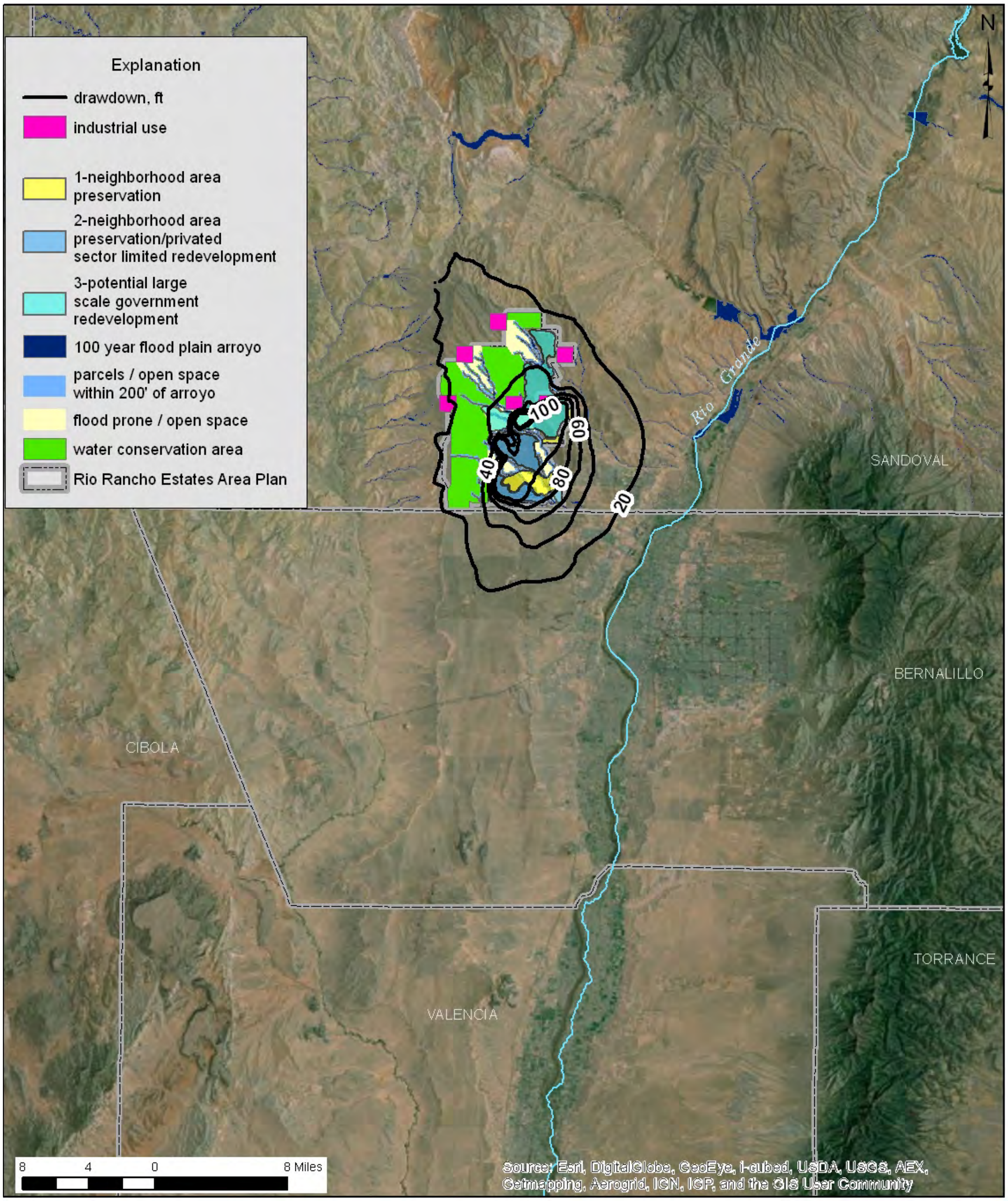

Figure 4.6. Projected incremental drawdown, 2014-2113, individual wells, modified, 18,077-lot full build-out scenario.

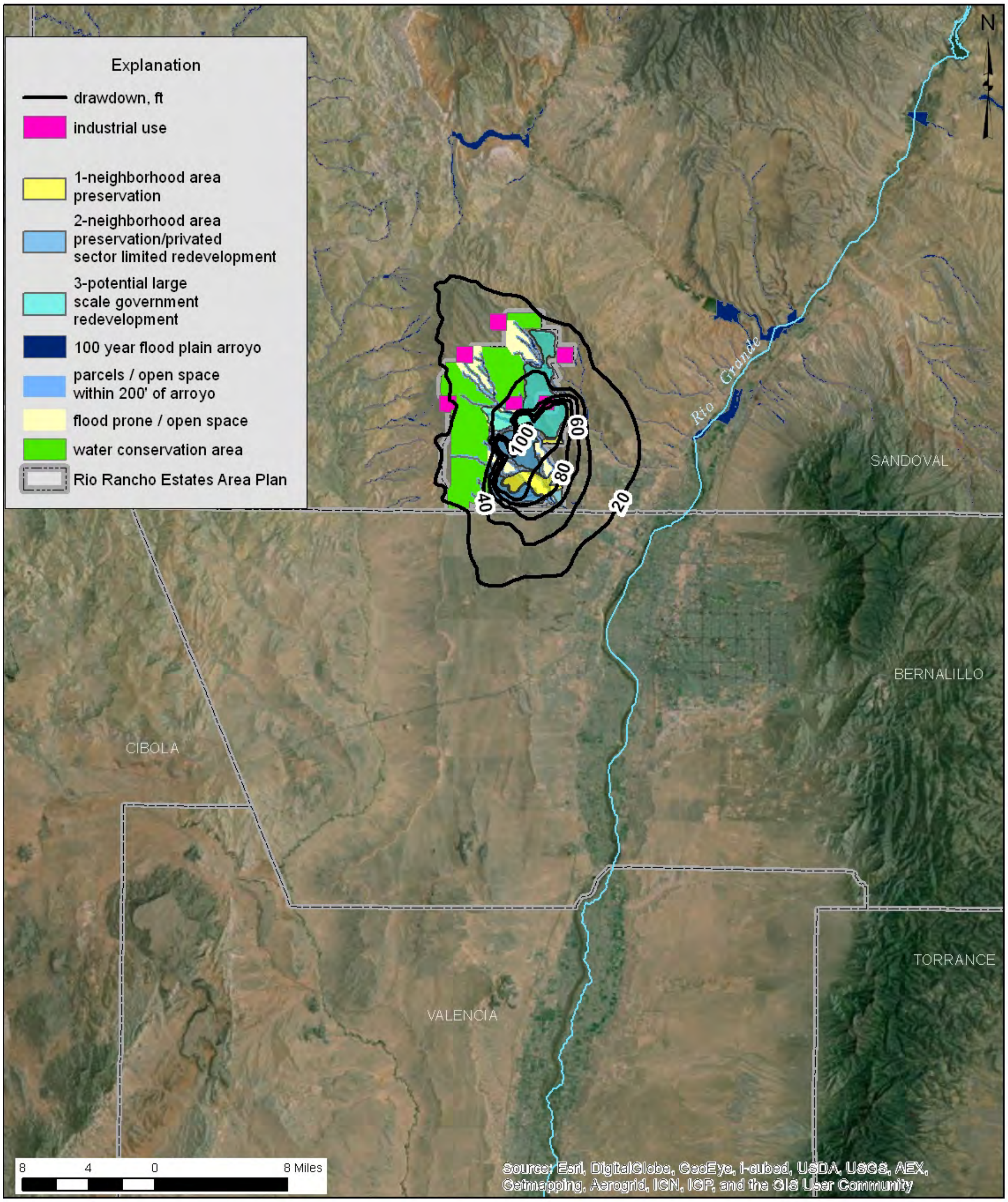

Figure 4.7. Projected incremental drawdown, 2014-2113, individual wells, modified, 18,077-lot phased build-out scenario.

5.0 CONSUMPTIVE WATER-RIGHTS USE: 2014-2113 SURFACE-WATER DEPLETION

The projected surface-water depletions over a 100-year period due to Rio Rancho Estates development are presented for each scenario in Figures 5.1 through 5.7, which show pumping for each scenario and the components of pumping coming from (1) aquifer storage and from (2) depletion of surface flow and reduction of groundwater discharge at the surface.

Model-simulated surface-water depletion would be used to compute a schedule for obtaining surface-water rights to offset net surface-water depletion. Wells would initially pump entirely from groundwater storage; then, the portion of pumping from storage steadily declines and surface depletions increase. Eventually, all pumping would come from surface depletion.

For the municipal wells scenarios (Figs. 5.1 and 5.3-5.4), depletion reaches only 24 to 27 percent of pumping after 100 years, due to the municipal well locations west of the low-permeability fault zone, which impedes the transmission of effects eastward to the river.

For the 18,077-lot individual wells scenarios (Figs. 5.5-5.7), depletion reaches 50 to 56 percent of pumping after 100 years, due to the location of individual wells east of the fault zone. For the individual wells, modified, 41,000-lot full build-out scenario (Fig. 5.2), much of the pumping is west of the fault zone, and depletion only reaches 42 percent of pumping.

Surface-water depletion effects are higher in the individual wells scenarios because of pumping east of the fault zone, at shallower depth. Depletion for the individual wells scenarios accelerates after 60 to 70 years as the basin groundwater flow system adjusts to the new stresses.

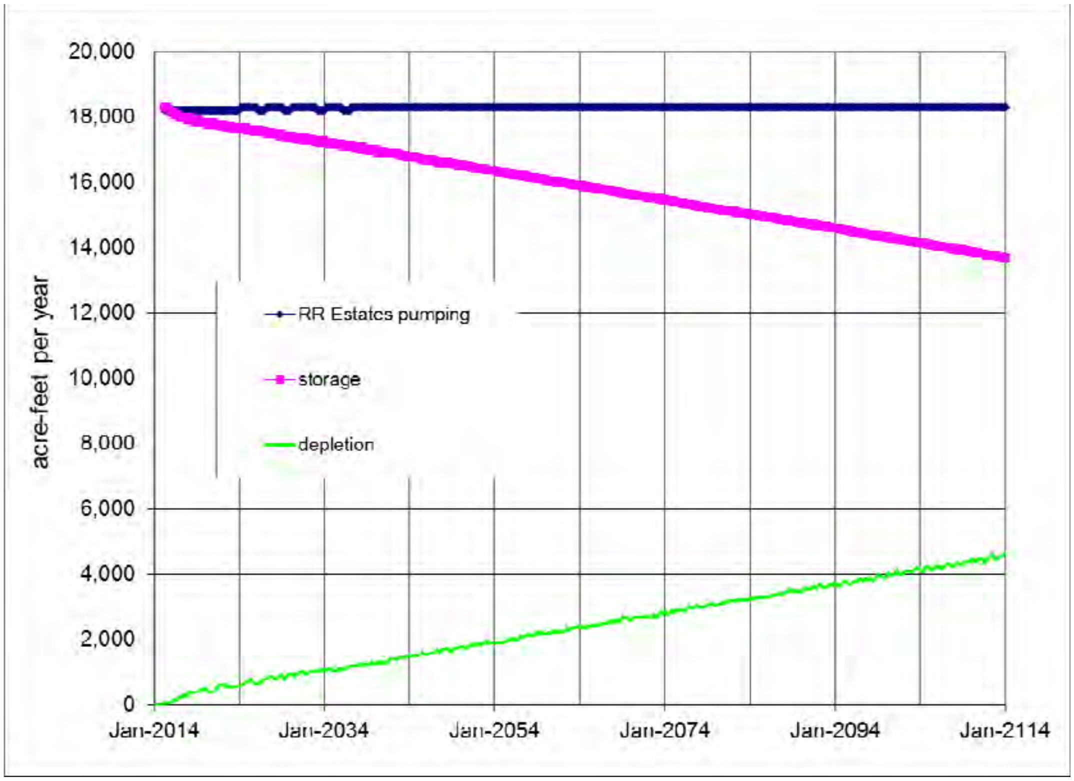

Figure 5.1. Projected flow depletion, 2014-2113, municipal wells, 41,000-lot full build-out scenario.

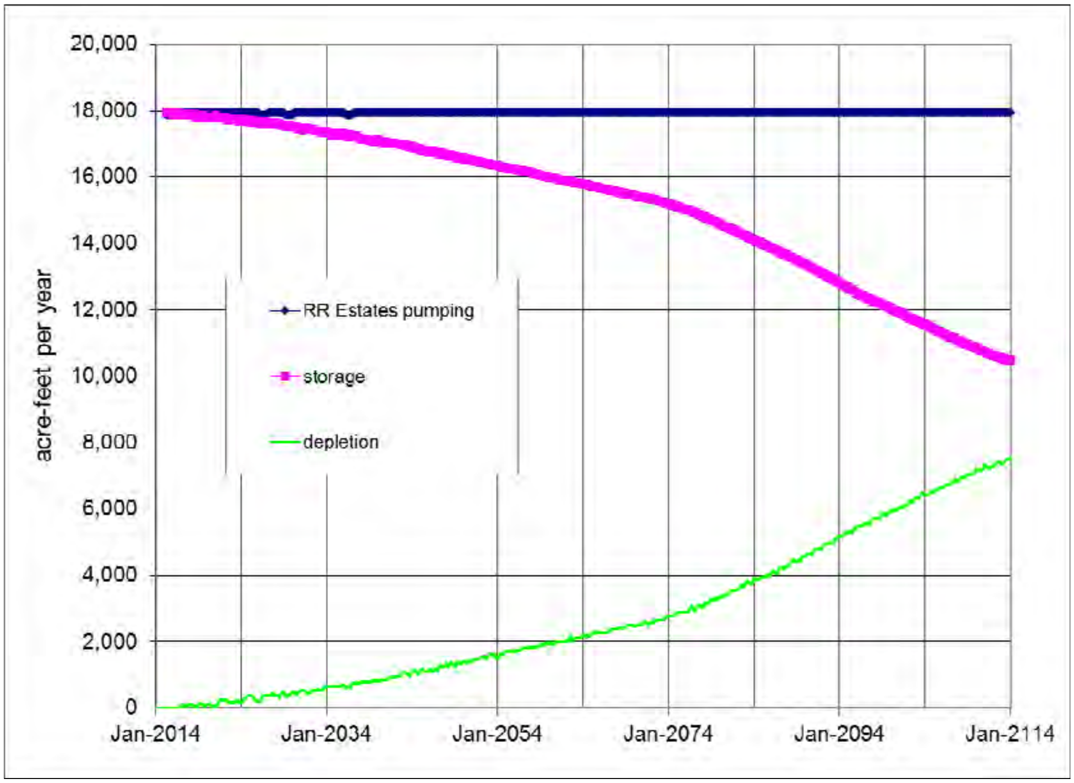

Figure 5.2. Projected flow depletion, 2014-2113, individual wells, 41,000-lot full build-out scenario.

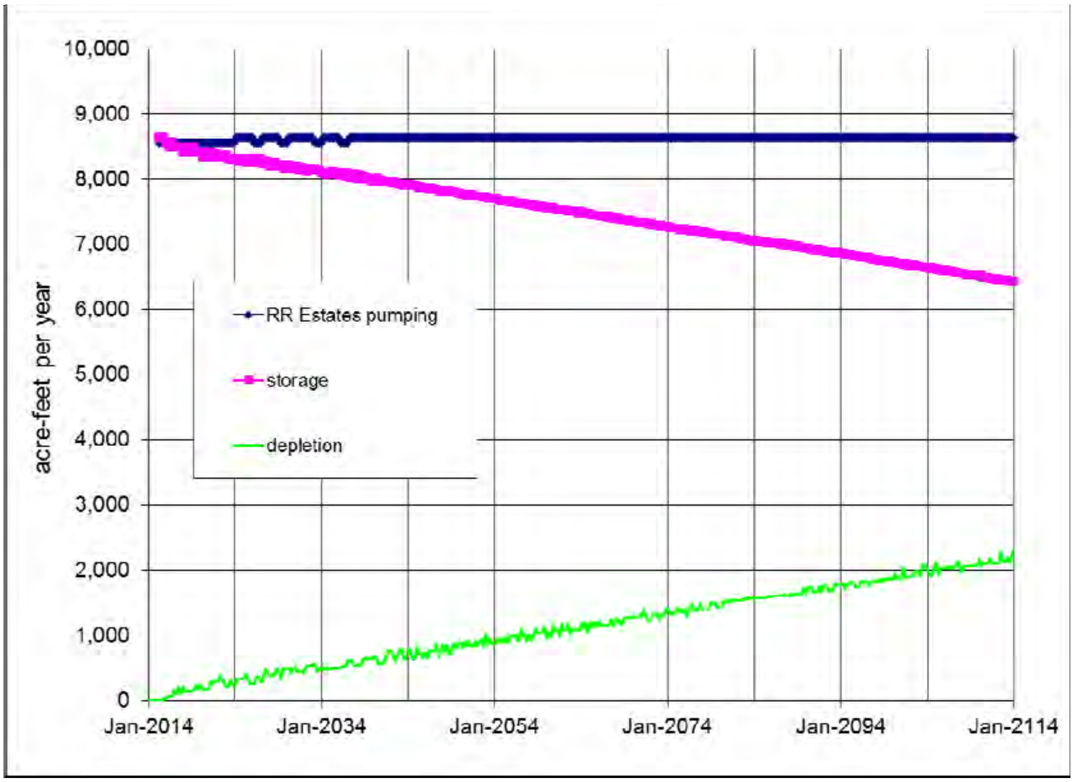

Figure 5.3. Projected flow depletion, 2014-2113, municipal wells, 18,077-lot full build-out scenario.

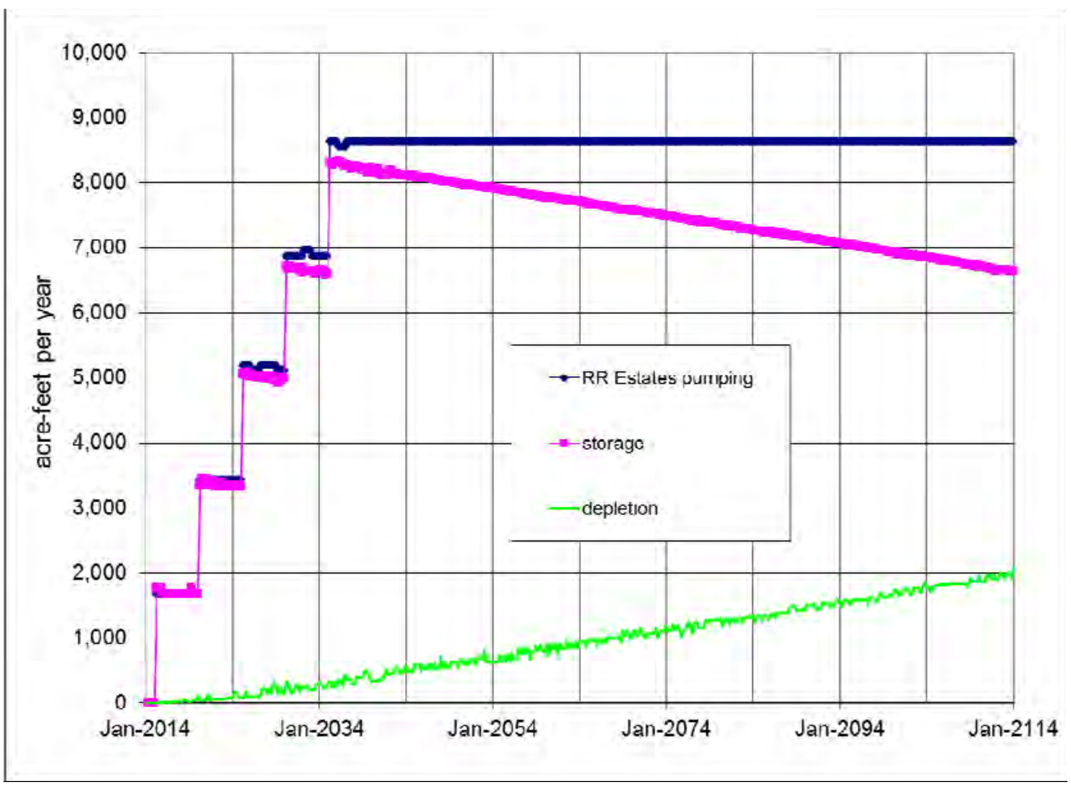

Figure 5.4. Projected flow depletion, 2014-2113, municipal wells, 18,077-lot phased build-out scenario.

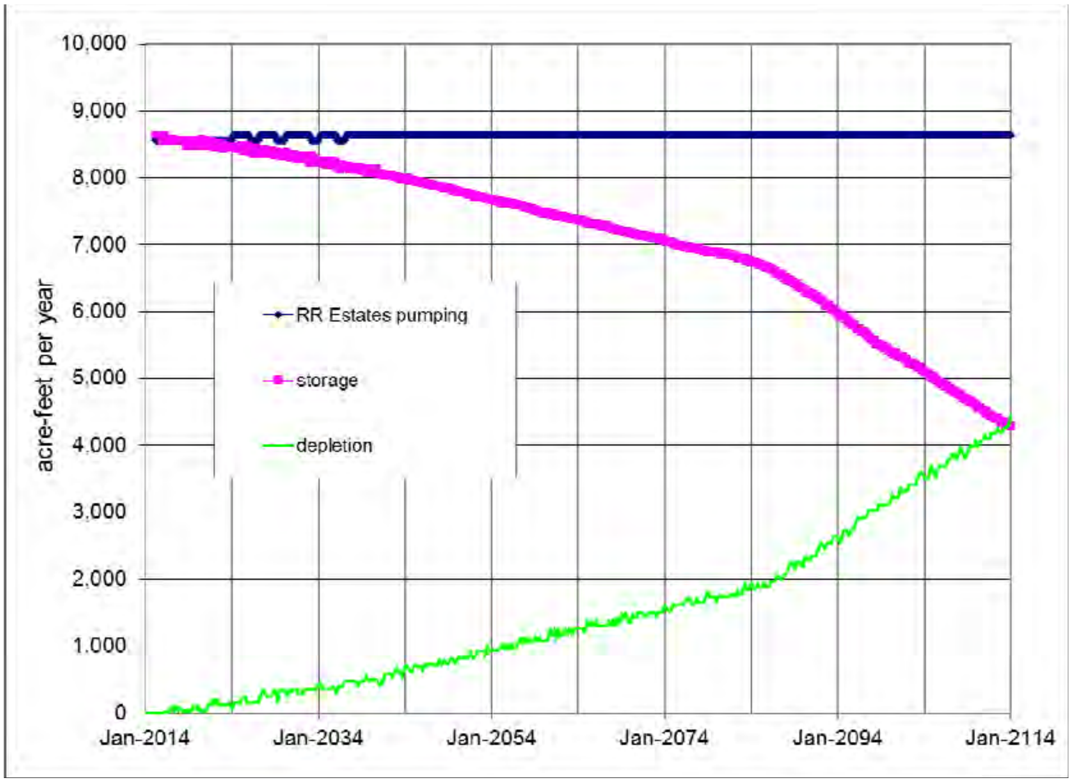

Figure 5.5. Projected flow depletion, 2014-2113, individual wells, 18,077-lot full build-out scenario.

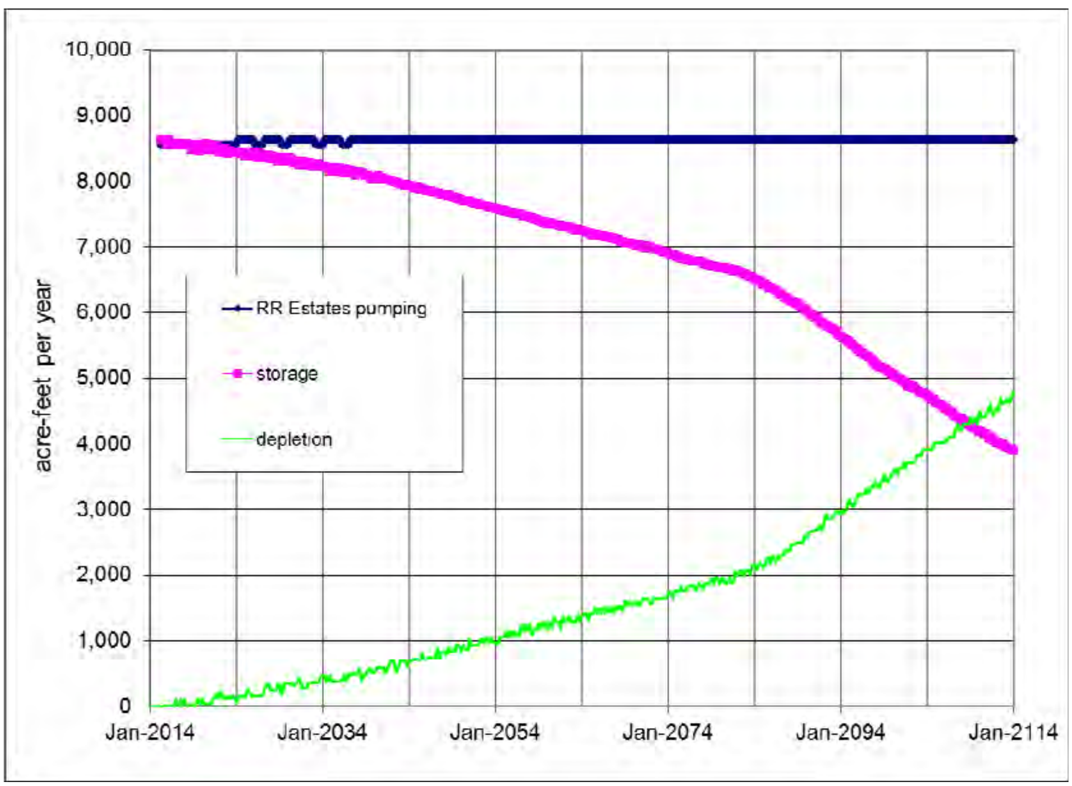

Figure 5.6. Projected flow depletion, 2014 -2113, individual wells, modified, 18,077-lot full build-out scenario.

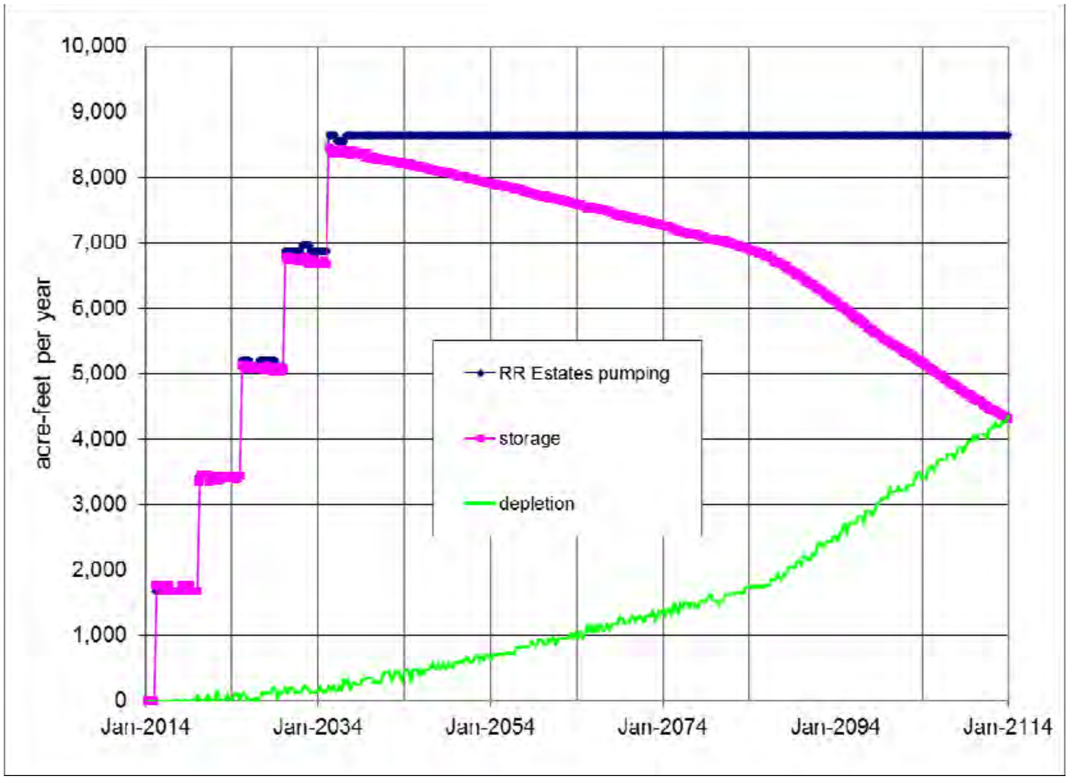

Figure 5.7. Projected flow depletion, 2014-2113, individual wells, modified, 18,077-lot phased build-out scenario.

6.0 SEPTIC TANK RETURN FLOW AND GROUNDWATER QUALITY EFFECTS

Because of relatively deep groundwater levels (800 to 1,000 ft) throughout most of the Rio Rancho Estates area, return flow from septic systems is not expected to recharge the water table. The presence of clay and caliche layers, along with general stratification of sedimentary beds, will tend to promote lateral flow of infiltration.

Rather than infiltrate hundreds of feet to the water table, the effluent will flow laterally and discharge along the local arroyo channels through plant transpiration. Neither return flow to the aquifer nor effects to groundwater quality are expected to occur.

7.0 SUMMARY AND CONCLUSIONS

Municipal wells scenarios with full build-out in 2014 indicate excessive drawdown by 2040, and individual domestic wells scenarios indicate excessive drawdown and doubtful supply along the low-permeability fault zone. The municipal wells, 18,077-lot phased build-out scenario complies with the Middle Rio Grande Guidelines in terms of average drawdown through the end of 2039, and does not indicate excessive drawdown or doubtful supply.

In general, the municipal wells scenarios appear more favorable than the individual domestic well scenarios because the nine potential supply wells were located west of the low-permeability fault zone, farther from existing development, with pumping spread over a larger vertical interval.

Of the individual domestic well scenarios, the individual wells, modified, 18,077-lot phased build-out scenario showed the most potential in terms of adequate long-term water supply. This scenario shows excessive drawdown in a narrow northeast-trending zone located just east of the low-permeability fault zone. The number of lots to be developed in this area could be further reduced to control long-term drawdown.

8.0 REFERENCES

Harbaugh, A.W., and McDonald, M.G., 1996, User's documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model: U.S. Geological Survey Open-File Report 96-485, 56 p.

[NMOSE] New Mexico Office of the State Engineer, 2001, Documentation of the Administrative Groundwater Model for the Middle Rio Grande Basin: New Mexico Office of the State Engineer Hydrology Bureau Report 99-3, prepared by P. Barroll.

[NMOSE] New Mexico Office of the State Engineer, 2000, Middle Rio Grande Administrative area guidelines for review of water right applications: administrative guidelines prepared by New Mexico Office of the State Engineer, September 13, 2000, 9 p. plus figures.

[NMOSE] New Mexico Office of the State Engineer, August 2012, personal communication: email from Ghassan Musharrafieh of NMOSE to Annie McCoy of John Shomaker & Associates, Inc. regarding current version of Middle Rio Grande Administrative Groundwater Model and regional pumping file, August 2, 2012.

Sandoval County, 2012, Rio Rancho Estates area plan report: draft report prepared by Sandoval County, September 2012, 39 p.

Sandoval County, November 2012, personal communication: email from Guy Bralley with Sandoval County to Scott McKitrick and Michael Jones regarding updated map of Rio Rancho Estates Area Plan, November 8, 2012.

[SMA] Souder, Miller & Associates, October 2012, personal communication: email from Scott McKitrick of SMA to Michael Jones of John Shomaker & Associates, Inc. regarding water usage and household size for Rio Rancho Estates, and Sandoval County map files, October 2, 2012.

Tiedeman, C.R., Kernodle, J.M., and McAda, D.P., 1998, Application of nonlinear-regression methods to a ground-water flow model of the Albuquerque Basin, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 98-4172, 90 p.

APPENDIX B

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TECHNICAL MEMORANDUM

To: Scott McKitrick, PG, Senior Scientist scott.mckitrick@soudermiller.com
Souder, Miller & Associates

From: Annie McCoy, Senior Hydrogeologist
Michael Jones, Principal Hydrologist

Date: May 22, 2013

Subject: Rio Rancho Estates development scenario "Individual Wells, 16,848-Lot Phased Build-Out"

As requested and as follow-up to the report *Evaluation of water supply for development of Rio Rancho Estates, Sandoval County, New Mexico*, prepared by John Shomaker & Associates, Inc. for Souder, Miller & Associates in February 2013 (JSAI, 2013[1]), JSAI has modified the Rio Rancho Estates development scenario "Individual Wells, Modified, 18,077-Lot Phased Build-Out," to reduce groundwater drawdown along a fault zone (JSAI, 2013, fig. 1.1). The resulting scenario includes development of 16,848 lots in a phased build-out.

The Rio Rancho Estates development scenario Individual Wells, Modified, 18,077-Lot Phased Build-Out (subject scenario) is described in the February 2013 report, and future drawdown under this scenario was modeled using the New Mexico Office of the State Engineer (NMOSE) numerical model of groundwater flow in the Middle Rio Grande Basin (MRG Administrative Model, NMOSE, 2001[2]).

In the subject scenario, Rio Rancho Estates pumping was phased in, beginning with 20 percent of full pumping in 2014, increasing by 20 percent in 2019, 2024, and 2029, reaching full build-out (8,108 acre-feet per year) in 2034. The subject scenario includes up to 6,908 ac-ft/yr of pumping for individual domestic wells, and up to 1,200 ac-ft/yr of pumping for industrial wells distributed across four areas identified for industrial or public use.

[1] [JSAI] John Shomaker & Associates, Inc., 2013, Evaluation of water supply for development of Rio Rancho Estates, Sandoval County, New Mexico: consultant's report prepared by John Shomaker & Associates, Inc. for Souder, Miller & Associates, February 2013, 39 p.

[2] [NMOSE] New Mexico Office of the State Engineer, 2001, Documentation of the Administrative Groundwater Model for the Middle Rio Grande Basin: New Mexico Office of the State Engineer Hydrology Bureau Report 99-3, prepared by P. Barroll.

Results for the subject scenario indicated excessive drawdown and doubtful supply in a minimal area at the east edge of the low-permeability fault zone, based on 2014-2039 model-projected drawdown exceeding 65 ft (JSAI, 2013, fig. 2.8). The excessive model-predicted drawdown was occurring in four model cells that coincide with the southeastern part of the "Zone 3" development area and three model cells that coincide with the southeastern part of the "Zone 2" development area, as shown on the November 5, 2012 Rio Rancho Estates Area Plan (rev4).

Model-projected 2014-2039 drawdown can be reduced to less than 65 ft by reducing the full build-out by 625 lots (256 ac-ft/yr of water use) in Zone 3 and 604 lots (248 ac-ft/yr) in Zone 2. Model-simulated results for the 16,848-lot, phased build-out scenario are shown on Figures 1 through 4.

AMM:MAJ

Enc: Figures 1 though 4

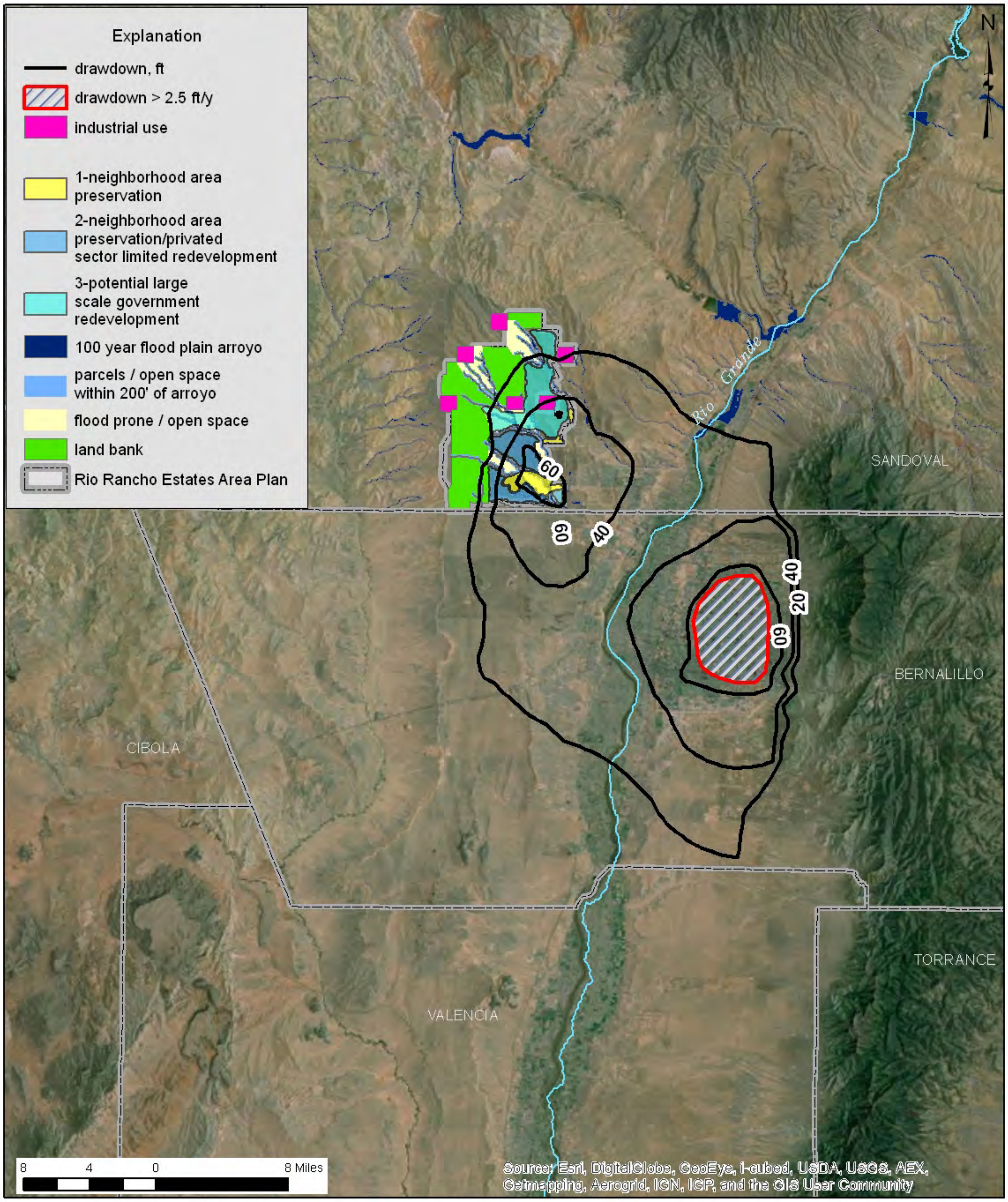


Figure 1. Projected drawdown, 2014-2039, individual wells,
16,848-lot phased build-out scenario.

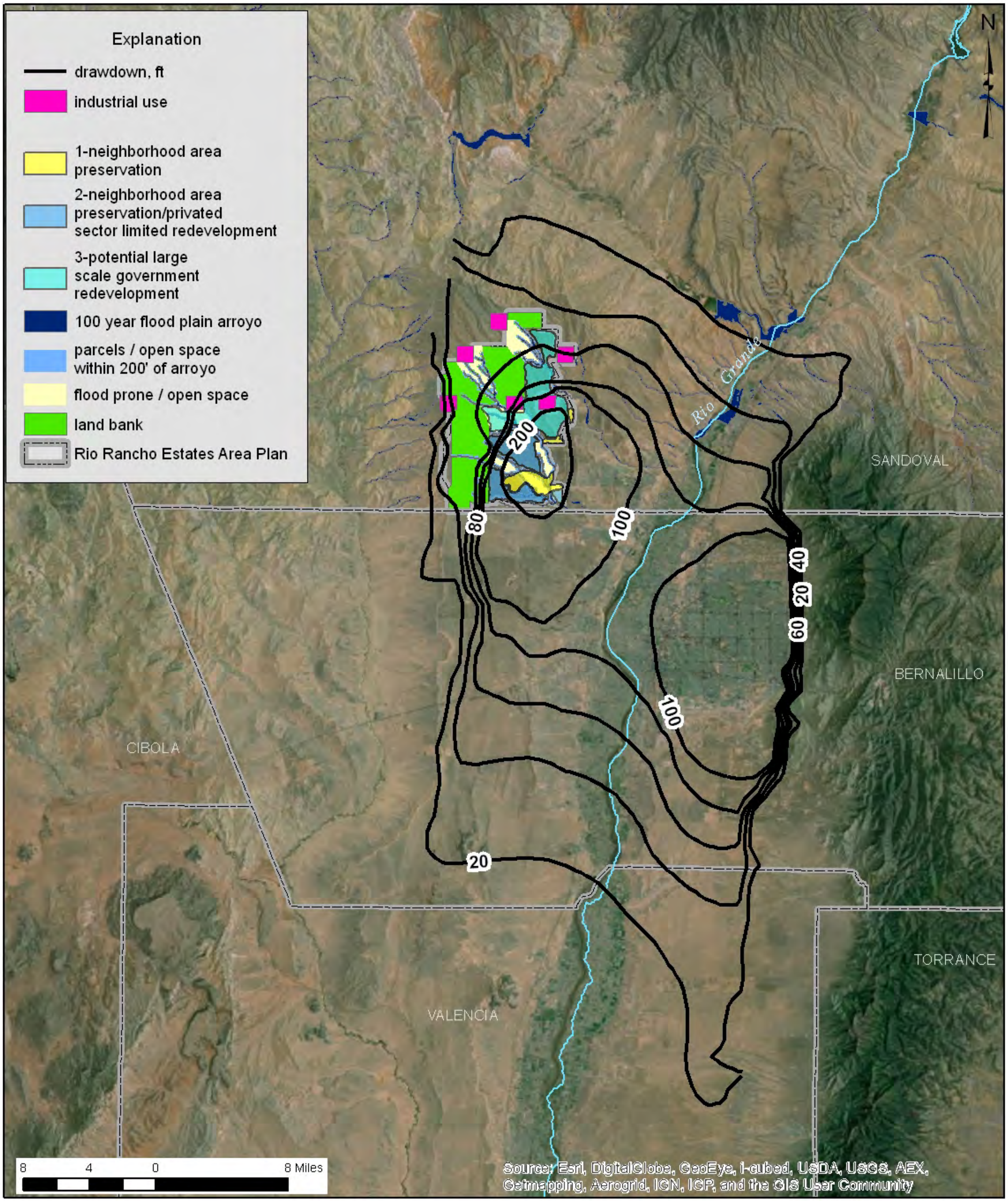


Figure 2. Projected drawdown, 2014-2113, individual wells, 16,848-lot phased build-out scenario.

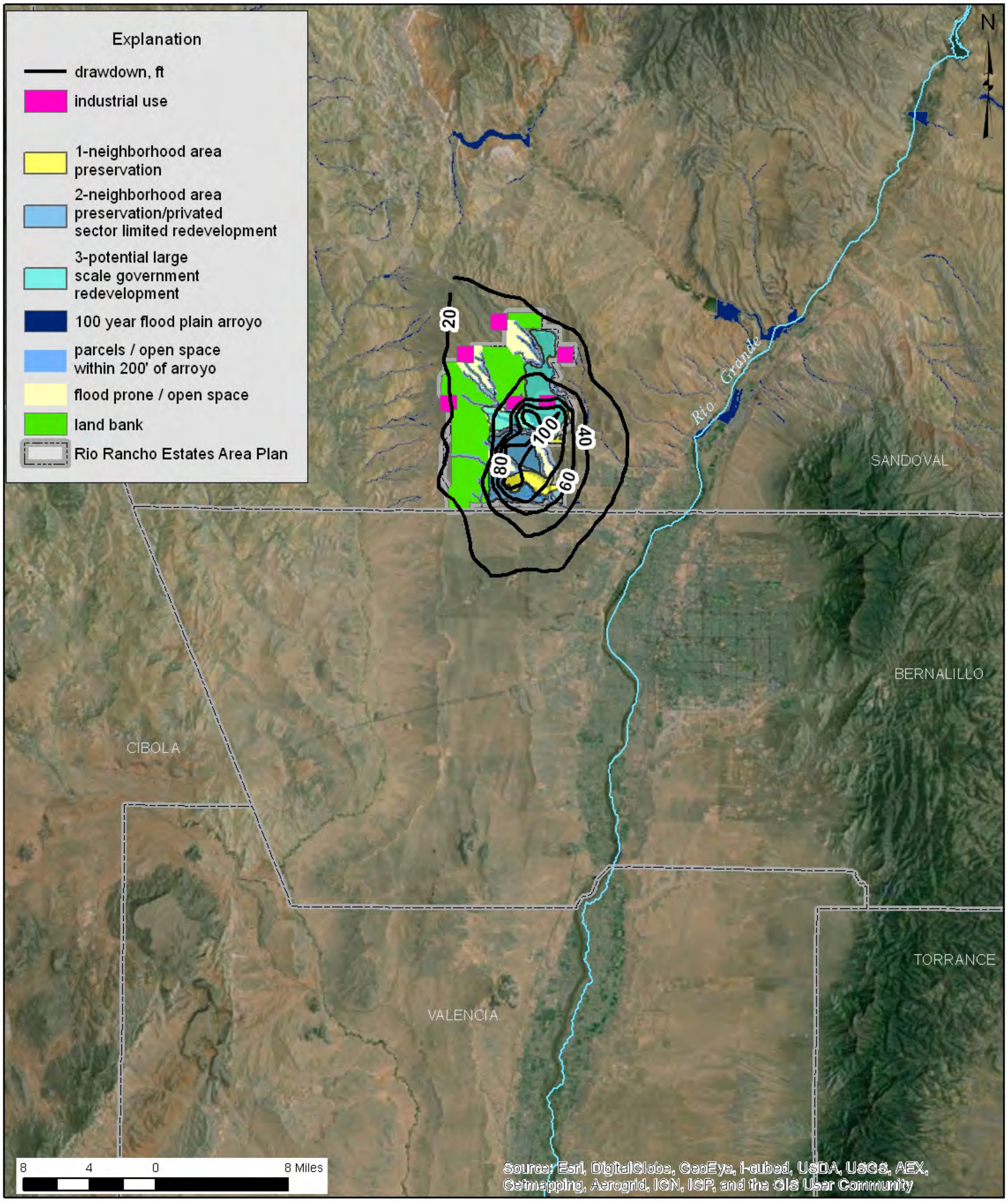


Figure 3. Projected incremental drawdown, 2014-2113, individual wells, 16,848-lot phased build-out scenario.

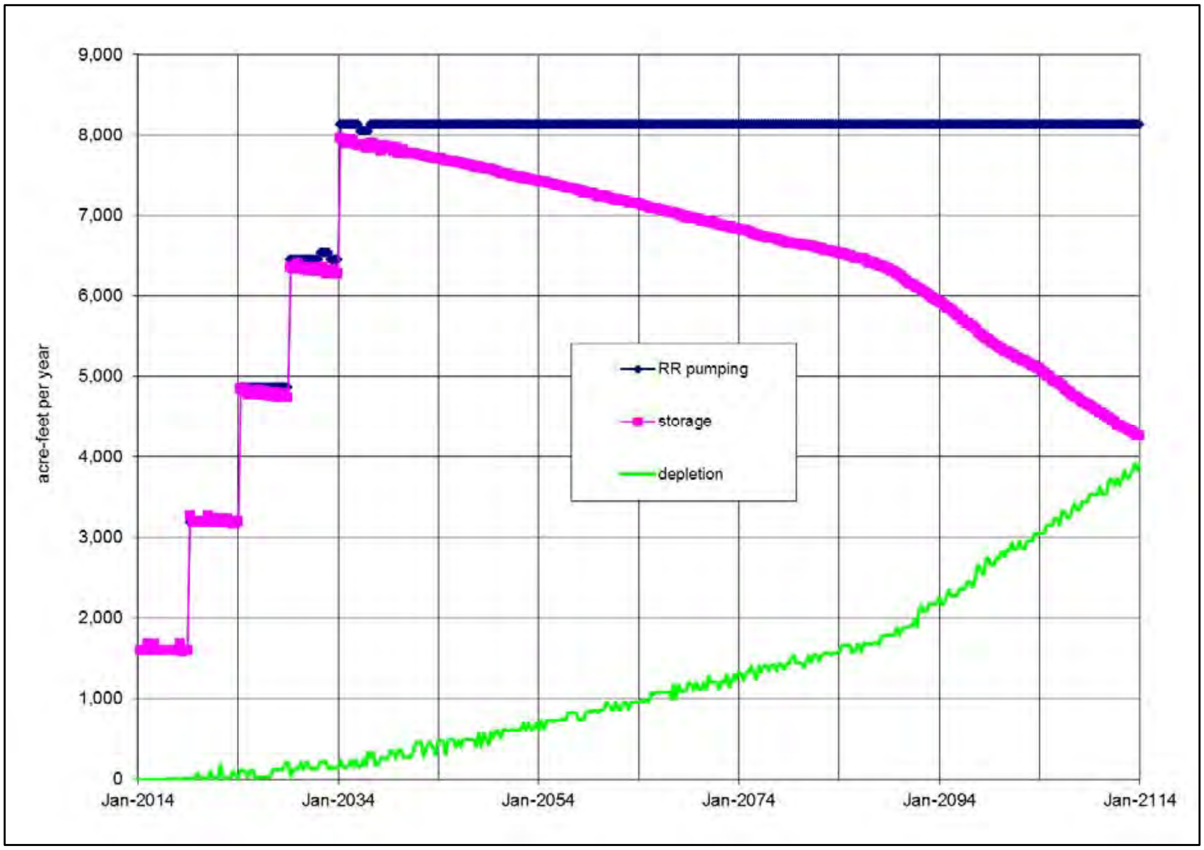


Figure 4. Projected flow depletion, 2014-2113, individual wells, 16,848-lot phased build-out scenario.

APPENDIX C

Water Resources Planning Study

Rio Rancho Estates

Sandoval County, New Mexico

July, 2013

Souder, Miller & Associates
1201 Parkway Drive
Santa Fe, NM 87507

TABLE OF CONTENTS

I – Introduction

Souder, Miller & Associates analyzed the feasibility and costs of various options for supplying water to the Rio Rancho Estates area. The area is situated west of the City of Rio Rancho and comprises 41,323 acres with 45,861 lots. This portion of the study looked at the feasibly of number alternatives and sub-alternatives for delivering water for domestic, municipal and industrial uses. The alternatives evaluated were:

1. Individual Domestic Supply Wells (Full System Build out)
2. Individual Domestic Supply Wells (Zones 1, 2 and 3)
3. Shared Domestic Supply Wells (Full System Build out)
4. Shared Domestic Supply Wells (Zones 1, 2 and 3)
5. Municipal Wells (Full System Build out)
6. Municipal Wells (Zones 1,2 and 3)

Each of the options was reviewed on a feasibility level to determine the potential cost and the effect of each project on the aquifer. The Water Resources Planning Study report details the effects of each option on the aquifer. This portion of the report will focus on the cost and feasibility of each option.

II. - Overview of Alternatives Considered

The following assumptions and values were used in determining the cost of each of the alternatives.

The City of Rio Rancho estimates the current water use for residential customers at 106 gallons per capita (person) per day (gpcpd) with overall community demand (including industrial and commercial uses) at 141 gpcd. Water conservation programs are currently being implemented that will likely lower the per capita use in the future. Since the overall plan includes areas for residential, commercial and industrial uses it was assumed that water usage for Rio Rancho Estates would match the current usage in the area. Based on this information, a rate of 141 gpcd was used in estimating pipe sizes and water storage tank volumes.

The state of New Mexico has adopted a fire flow requirement of 1,000 gallons per minute (gpm) for residential and 1,500 gpm for commercial and industrial areas. A fire storage requirement of two hours at 1,500 gpm was used in estimating water storage tank sizes.

III. – Alternatives Considered

A. – Individual Wells/ Shared Domestic Wells

Description of Alternative

This alternative considers water supply and distribution sourced from individual or shared domestic wells for both the 41,000 full build out and reduced 18,044 lot options. Each well would include pumps and appurtenances and distribution assemblies to deliver water to each individual residence. The shared domestic wells would supply water to up to four homes and would significantly reduce the number of wells.

This alternative would likely result in the use of individual septic systems since development in the area would be sporadic with individual lots developing at various times interspersed with larger-scale developments. Although the ground water level is deep enough to allow for septic tank/ leach field systems, the individual wells can potentially act as a conduit for water contaminants to enter the aquifer. State law requires a minimum separation of 100 feet between septic tank/leachfield systems and domestic supply wells in order to minimize the potential for contamination of groundwater. Given the relatively small width of some Rio Rancho Estates lots (widths between 80 and 160 feet), the 100 foot minimum setback requirement will be difficult to comply with. At least 1/3 of the lots in the planning area are under the minimum 1/2 acre requirement for permitting on septic systems and would require some other form of collection and treatment.

In order to protect the groundwater supply and allow all of the lots in the area to be developed, it is recommended that a sewer collection and treatment system be constructed as part of any concentrated development.

Assumptions

The existing lot layout was assumed to remain unchanged. It was assumed that the water use rate would be the same for individual wells as for a municipal supply system. This alternative assumes that homes and businesses would be placed on individual or shared domestic wells that would serve four lots each. The individual or communal wells would be small diameter wells that would generally be installed to a depth of 600 to 1,200 feet. Communal wells would include a 5,000 gallon storage tank and booster pump. The shared domestic wells would significantly reduce the total number of wells in the overall area and the impact on the aquifer.

Each well would consist of the well casing, screen, plug, sand pack, submersible pump and water supply line. Each pump would be capable of providing a minimum of 5 gallons per minute at 20 psi. It is assumed that electrical service for each well will be provided as part of the individual services to the homes. It is important to consider the amount of power that would need to be supplied to the area to support the operation of the pumps for each of the 41,000 wells. Assuming that each well is equipped with a 5 horse power pump, the total power consumption during average daily demand would be about 152 mega watts. For comparison purposes the Four Corners Power Plant operated by PNM generates 2,040 megawatts.

The power required for operation of the individual wells in the Rio Rancho Estates would require upgrades to the power generation and transmission infrastructure in the area.

Cost Estimate

Individual Wells - Full Build out

The estimated cost of construction of the 41,000 individual wells is $2.02 billion. This includes engineering and construction contingency fees. A breakdown of the estimated cost is included in Appendix B.

Individual Wells - Zoned Option

The estimated cost of constructing individual wells on each of the 18,077 lots in Zones 1, 2 and 3 is $890 million. The power required for these 18,077 wells would be 67 megawatts. A breakdown of the estimated cost is included in Appendix B.

Shared Domestic - Full Build out

Assuming that each shared domestic well would supply potable water for 4 lots, it is estimated that 10,250 wells would be required for full build out. The cost for the construction of all 10,250 wells is estimated at $890 million and would require 51 megawatts of electricity. A breakdown of the estimated cost is included in Appendix B.

Shared Domestic - Zoned Option

With the reduction in total lots from 41,000 to 18,077 the number of shared wells would decrease to 4,519 resulting in an estimated cost of $390 million and a power demand of about 17 megawatts. A breakdown of the estimated cost is included in Appendix B.

Advantages

- Little to no additional cost to the county
- Places responsibility for water quality and quantity monitoring and reporting on individual users
- Utilizes all of the available lots in the area

Disadvantages

- Insufficient water availability to supply water for the full build out option
- Zoned option causes excessive drawdown on aquifer
- Harder to regulate water use and water quality
- No fire storage or protection
- Potential for aquifer contamination

Summary of Findings

This alternative is not recommended due to the lack of available water supply to provide for the full build out demand. Both the individual wells and the shared domestic wells for the zoned option cause excessive drawdown of the aquifer. Additionally, this option is discouraged due to the increased potential for ground water contamination due to the number of aquifer penetrations and inability for some lots to be permitted for septic tanks. If individual wells and community wells are allowed, a municipal sewer system is encouraged for collection and centralized treatment to reduce the risk of groundwater contamination. Finally, the alternative of individual and community wells will result in responsibility for water quality and quantity monitoring and reporting being placed on individual homeowners and communities who may not have the capacity to adhere to state and federal regulations.

B. – Municipal Wells

Description of alternative

SMA analyzed the potential cost of constructing a complete water system including waterlines, valves, hydrants, and other appurtenances, storage tanks, wells, pumps and metered service connections for the entire Rio Rancho Estates area. The system layout was based on the currently platted configuration with waterlines being installed within existing road rights-of-way (ROW). The overall system would consist of an estimated 3.6 million feet of pipe, 5,000 gate valves, 2,500 fire hydrants and 19 million gallons of storage.

The system would be supplied by nine municipal scale wells with high production and a series of water storage tanks into which the wells pumps and from which water gravity flows into the water distribution system. Due to the significant relief in the topography it is not expected that additional booster pumps for pressurizing the system will be needed; storage tanks would provide adequate gravity flows into the system and boosting to storage tanks would maintain these at full operational levels.

In general municipal wells in the area have been installed to a depth of 2,000 feet, and this analysis assumes that new municipal wells would be placed at similar depths. This analysis assumed that the minimum pipe size for the system would be 8 inches with transmission lines being 10 and 12 inch diameter pipes.

ASSUMPTIONS

For this option, SMA assumed that all of the 41,000 current lots would eventually be developed. Based on information from water use in the City of Rio Rancho, it was estimated that water use in the area will be approximately 141 gallons per capita per day (gpcd). It is important to note that although all of the lots were used in reviewing this option, there are a significant number of these 41,000 lots that are located in arroyos, on slopes, in flood zones or on other areas that would be difficult to develop. It was assumed that all of these lots would be developed.

This alternative assumes water supply is sourced from at least 9 large diameter wells with pumps capable of supplying 500 plus gallons per minute (gpm), and assumes that water is pumped up into water storage tanks placed strategically throughout the system. In general municipal wells in the area have been installed to a depth of 2,000 feet, and this analysis assumes that new municipal wells would be placed at similar depths.

This analysis assumed that the minimum pipe size for the system would be 8 inches with transmission lines being 10 and 12 inch diameter pipes. It was assumed that all pipes would be PVC with a thickness rating of DR-18. The number of valves and fire hydrants was estimated by laying out valves in a one mile square section and then estimating the number of valves and hydrants per acre. This ratio was then applied as an average across the entire system to estimate the total number of valves.

The number of pressure reducing valves (PRVs) was estimated using the existing topography (elevations) and applying an optimal system pressure rage of 50 to 80 psi. This assumption results in an overly conservative number of PRVs, so the estimated number was reduced by 10% to better represent the actual number of PRVs while still remaining conservative.

Tank storage volume was based on the New Mexico Environment Department's recommendation that communities store enough water to meet average demand for a 24 hour period. Fire flow storage consisting of 1,000 gpm for 2 hours was added to this number to represent the total storage requirement. Determination of the exact locations of the proposed water tanks is outside of the scope of this feasibility-level study.

COST ESTIMATE

Based on the above assumptions, it is estimated that total build-out of the water system for the Rio Rancho Estates area will cost $640 million. Table 1 below shows the breakdown of the cost estimate.

TABLE 1 - FULL BUILD OUT COSTS

RIO RANCHO ESTATES				
Preliminary Opinion of Probable Cost				
Entire Area (Full Build Out)				
Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
8 Inch, C900 PVC DR 18, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	3,070,288	$ 40	$ 122,811,520
10 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	216,788	$ 50	$ 12,500,000
12 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	379,714	$ 60	$ 11,704,500
Gate Valves	EA	5,000	$ 3,000	$ 15,000,000
Fire Hydrants	EA	2,500	$ 5,000	$ 12,500,000
Presure Reducing Valves	EA	390	$ 30,000	$ 11,704,500
Connections to Existing Water Lines	EA	14	$ 3,000	$ 42,000
Connect waterline to well head	EA	25	$ 6,000	$ 150,000
5/8" Water Meter	EA	45,861	$ 2,500	$ 114,652,500
1" Service Line	LF	917,220	$ 20	$ 18,344,400
Wells	EA	25	$ 250,000	$ 6,250,000
Site Prep and Grading for Booster Station	EA	4	$ 10,000	$ 40,000
Booster Stations	EA	4	$ 125,000	$ 500,000
Booster Station Buildings	EA	4	$ 150,000	$ 600,000
Water Storage Tanks	GALLONS	18,705,923	$ 2	$ 37,411,846
Subtotal				$ 364,211,266
Mobilization (5%)	LS	1	$ 18,210,563	$ 18,210,563
Temporary Traffic Control	LS	1	$ 13,750,463	$ 13,750,463
Material Testing Allowance	LS	1	$ 9,105,282	$ 9,105,282
SUBTOTAL FOR CONSTRUCTION				**$ 405,277,573**
Non-Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
Professional Services (Project management, drafting and design, engineering design review and inspection, construction administration and observation, legal, archeological, geotechnical, surveying)	EA	1	$ 141,847,151	$ 141,847,151
SUBTOTAL FOR NON-CONSTRUCTION				**$ 141,847,151**
Contingency (includes inflation, taxes, bid and construction contingencies, material cost fluctuations)		20%		$ 109,424,945
TOTAL PROJECT COST (Round Numbers)				**$ 660,000,000**

ADVANTAGES

- The full build-out option utilized all of the available area for development providing significant room for long term expansion.
- An area wide water system helps control water rights, monitoring and reporting and adherence to the Safe Drinking Water Act regulations
- The system could be built out in phases if development is controlled and orderly
- System users would finance operation and maintenance of the system through monthly user fees
- Impact fees from new development could help capitalize the construction of the infrastructure

DISADVANTAGES

- Most expensive of the options
- Insufficient water to supply water for the full build out option
- Water would need to be brought in from outside of the area to provide sufficient flow
- Monitoring and reporting, water rights and state and federal regulation adherence would be the responsibility of the County or a newly established Utility Authority
- Certified operations would be required as well as administrators to handle a billing system

Areas with greater slopes are more expensive to build due to increased construction costs and require additional PRVs to keep pressures within acceptable ranges. The ground on the west and north side of the area slopes significantly more than areas on the west and south and will be more expensive to construct.

SUMMARY OF FINDINGS

The full build-out option would require $640 million to build and would result in drawdown of more than the allowable 2 feet per year with in the aquifer. The further to the west and north development spreads, the more costly water infrastructure installation will be. Unless additional sources of water can be developed, it would be impossible to develop the entire area.

C. –Municipal System for Reduced Number of Lots

Description of alternative

Sandoval County developed a Land Use Concept for Rio Rancho Estates based on a number of factors including the maximum amount of water production that could be sustained without causing excessive groundwater drawdown. The concept includes a division of the Rio Rancho Estates area into four main zones. Within each of those zones, lots located in areas near arroyos were removed due to the potential for flooding, and to preserve sensitive environments. Removing these lots also focuses development in areas where costs for infrastructure would be less. A map of the four zones is included in Exhibit 1.

The four zones include two neighborhood area preservation zones (Zone 1 and Zone 2), a potential large scale government redevelopment area (Zone 3) and a water conservation area.

Zones 1 and 2 have the most potential for large scale, diversified development and were looked at in their currently platted state (minus arroyos and floodplains) to determine the cost of developing water infrastructure in each zone.

Zone 3 is planned to be used as large scale government redevelopment. Since the amount of water use and required infrastructure can vary substantially depending on the nature of the uses proposed, the cost for development was based on the existing number of lots (9,440) as current layout. Once a more detailed plan for the development in the area is completed, the demand for each area can be converted to equivalent residential units (ERUs) and used to relate storage requirements and uses with this report.

Zone 1 contains 2,665 lots, Zone 2 includes 5,972 lots and Zone 3 includes 9,440 lots resulting in a total of 18,077 lots.

The system would consist of similar piping, wells, storage and pumps as the full build out system, but would be reduced in size to match the reduction in demand. This analysis assumes that the current platting would remain the same for determining waterline layout.

Assumptions

The assumptions used for this analysis are the same as those for the full municipal supply system. In determining the cost for each zone, it was assumed that the ratio of infrastructure (pipes, valves, PRVs, fire hydrants, etc.) to the number of lots would remain relatively constant throughout each zone. This ratio was then used to determine the quantity of infrastructure in each zone.

Cost Estimate

Based on the above assumptions, it is estimated that the water system for Zone 1 will cost $25.2 million, Zone 2 will cost $64.4 million and Zone 3 will cost $97.0 million. A detailed breakdown of the cost for construction in each zone is included in Table 2 below.

RIO RANCHO ESTATES				
Preliminary Opinion of Probable Cost				
Zone 1, 2 and 3				
Construction Cost				
Area	**1676**	**Parcells**	**2665**	
Description	Unit	Qty	Unit Price	Total Price
8 Inch, C900 PVC DR 18, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	987,741	$ 42.00	$ 41,485,109.12
10 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	69,743	$ 42.00	$ 4,138,778.05
12 Inch PVC, including all material, labor, joint restraints, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	122,158	$ 45.00	$ 4,070,783.84
Gate Valves	EA	1,971	$ 2,800.00	$ 5,518,370.73
Fire Hydrants	EA	985	$ 4,200.00	$ 4,138,778.05
Presure Reducing Valves	EA	163	$ 25,000.00	$ 4,070,783.84
Connections to Existing Water Lines	EA	21	$ 2,000.00	$ 42,000.00
Connect waterline to well head	EA	75	$ 6,000.00	$ 450,000.00
5/8" Water Meter	EA	18,077	$ 1,800.00	$ 32,538,600.00
1" Service Line	LF	361,540	$ 16.00	$ 5,784,640.00
Site Prep and Grading for Booster Station	EA	4	$ 5,000.00	$ 20,000.00
Booster Stations	EA	4	$ 60,000.00	$ 240,000.00
Booster Station Buildings	EA	4	$ 120,000.00	$ 480,000.00
Water Storage Tanks	GALLONS	7,074,658	$ 2.50	$ 17,686,644.00
Subtotal				$ 120,664,487.62
Mobilization (not to exceed 5% of the bid)	LS	1	$ 6,033,224.38	$ 6,033,224.38
Temporary Traffic Control	LS	1	$ 1,895,869.49	$ 1,895,869.49
Material Testing Allowance	LS	1	$ 1,037,127.73	$ 1,037,127.73
SUBTOTAL FOR CONSTRUCTION				**$ 129,630,709.21**
Non-Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
Professional Services (Project management, drafting and design, engineering design review and inspection, construction administration and observation, legal, archeological, geotechnical, surveying)	EA	1	$ 25,926,141.84	$ 25,926,141.84
SUBTOTAL FOR NON-CONSTRUCTION				**$ 25,926,141.84**
Contingency (includes inflation, taxes, bid and construction contingencies)		20%		$ 31,111,370.21
TOTAL PROJECT COST				**$ 186,668,221.26**

Advantages

The advantages to the zoned approach to build out are:

- Reduces the overall cost of the infrastructure
- Infrastructure can be phased to match development
- Water demands can be feasibly met with available supply
- Reduces impacts on existing infrastructure and roads
- Maintains the existing lot layout in Zones 1 and 2
- Reduces effects of development on environmentally sensitive areas
- Allows for future growth as new water sources are identified and developed

Disadvantages

Disadvantages to the zoned approach to build out are:

- Defers developments of some areas into the future
- Infrastructure costs are still significant
- Operation and administration of the system still required

IV. - Summary of Findings

The table below shows a breakdown of the cost of each option discussed above for the water systems in Rio Rancho Estates and includes an estimated cost per lot for each of the alternatives.

Table 2
Cost Summary and Estimated Cost Per Lot

Option Evaluated	Total Cost	Number of Lots	Cost Per Lot
Full Buildout (Individual Wells)	$ 2,020,000,000	41000	$ 49,268.29
Zoned Option (Individual Wells)	$ 890,000,000	18077	$ 49,233.83
Full Buildout (Shared Domestic Wells)	$ 890,000,000	41000	$ 21,707.32
Zoned Option (Shared Domestic Wells)	$ 390,000,000	18077	$ 21,574.38
Full Buildout (Municipal Wells)	$ 640,000,000	41000	$ 15,609.76
Zoned Option (Municipal Wells)	$ 186,668,221	18077	$ 10,326.28

The zoned option would provide a reasonable approach to supplying water to areas where development is more likely to occur. This approach reduces the cost of providing roads and other utilities by placing new homes closer to existing utilities near the City of Rio Rancho.

By reducing the number of lots to the 18,077 for zones 1,2 and 3 the cost for infrastructure is significantly reduced from $660 million for full build out to $28.8 million for Zone 1, $72 million for Zone 2 and $109.3 million for Zone 3 ($210.1 million total).

The analysis of the aquifer drawdown by John Shomaker & Associates shows that providing water to the entire 41,000 lot Rio Rancho estates area would cause extreme impacts to the aquifer and trigger drastic conservation measures to prevent over pumping. By reducing the number of lots to 18,077, water can be supplied to all of the lots via municipal wells without causing significant drawdown or problems, especially when a phased build out approach is considered.

V. References

(ABCWUA) Albuquerque Bernalillo County Water Utility Authority, 2013, personal communication: in-person conversation between ABCWUA and Scott McKitrick, SMA regarding ABCWUA 2011 water use, February 4, 2013.

(ABCWUA) Albuquerque Bernalillo County Water Utility Authority, 2012, personal communication: in-person conversation between Alan Porter, ABCWUA and Scott McKitrick, SMA regarding ABCWUA service area and future plans, October 8, 2012.

City of Rio Rancho, 2012, personal telephone communication between Marian Wrage, City of Rio Rancho Environmental Program Manager and Matthew Earthman, SMA regarding per capita water use and conservation goals, September 25, 2012.

City of Rio Rancho, 2013, personal communication: telephone conversation between Marian Wrage, City of Rio Rancho Environmental Program Manager and Matthew Earthman, SMA regarding annual water system production, March 6, 2013.

City of Rio Rancho, 2013, personal communication: in-person conversation between Larry Webb, City of Rio Rancho and Scott McKitrick, SMA regarding Rio Rancho Estates Water System, February 8, 2013.

APPENDIX

RIO RANCHO ESTATES AREA PLAN
LAND USE CONCEPT
NOVEMBER, 2012
Approximate Acreage Totals
Arroyo Open Space -3,841 Acres / Parcels 4,927
Land Bank- 20,378 Acres / 21,843 Lots
Rio Rancho Estates-43,460 Acres
Path:K:\E911\E911\Projects\backup_projectsHD\MakitaRREAP2012MAYBACH
SANDOVAL COUNTY
STATE OF NEW MEXICO
N
Rio Rancho Estates
Area Plan Legend
Lots Improvements
Privately Owned Industrial Area- 905 Acres
State / Industrial -2,345 Acres
1 - Neighborhood Area Preservation- 1,676 Acres
2 - Neighborhood Area Preservation/Private Sector Limited Redevelopment- 4,631 Acres
3 - Potential Large Scale Government Redevelopment- 7,307 Acres
Sandoval County
100 Year Flood Plain Arroyo
Parcels / Open Space within 200' of Arroyo-2,288 Acres/2,400 Parcels
Flood Prone / Open Space-3,841 Acres/4,927 Lots
Land Bank-20,378 Acres/21,843 Lots
Rio Rancho Estates Area Plan-48,460 Acres
User must assume responsibility to determine the appropriate use for the data. Sandoval County does not make any warranties, express or implied concerning the accuracy, completeness, reliability or suitability for any particular purpose of the information contained in or furnished in connection with this data. Sandoval County undertakes no obligation to users of the information presented and will not be held liable for any invalidity, discrepancies or errors in this data.
Arroyo Open Space
1,438 Acres
2,094 Parcels
Montoyas Arroyo
Industrial Use
640 Acres
Undetermined
640 Acres
City of Rio Rancho
RAINBOW
Arroyo Open Space
1,525 Acres
1,753 Parcels
Panta De Leon Arroyo
KING
3
Industrial Use
528 Acres
Public Use
537 Acres
134 Acres
144 Parcels
Planned Paseo Del Volcan Rd.
1
6,770 Acres
9,440 Parcels
ENCINO
21,903 Acres
23,596 Parcels
2,858 Acres
3,368 Parcels
1
233 Acres
343 Parcels
NORTHERN
2
905 Acres
Arroyo Open Space
1,438 Acres
2,094 Parcels
Calabacillas Arroyo
IDALIA
Industrial Area
1
1,309 Acres
2,178 Parcels
SOUTHERN
2
217 Acres
309 Parcels
1,773 Acres
2,295 Parcels
2
City of Rio Rancho

APPENDIX D

Waste Water System Feasibility Study Report

Rio Rancho Estates

Sandoval County, New Mexico

July, 2013

Souder, Miller & Associates
1201 Parkway Drive
Santa Fe, NM 87507

TABLE OF CONTENTS

I. – INTRODUCTION

Souder, Miller & Associates analyzed the feasibility of various options for providing wastewater collection, treatment and disposal to the Rio Rancho Estates area. The area is situated west of the City of Rio Rancho and comprises 41,323 acres with 41,000 lots. This portion of the study looked at the feasibly of four alternatives for wastewater management. The four alternatives evaluated were:

1. Individual Septic Tank Leach Field – Full Build Out
2. Individual Septic Tank Leach Field – Zoned Option
3. Conventional Sanitary Sewer – Full Build Out
4. Conventional Sanitary Sewer – Zoned Option

Each of the four options was reviewed on a feasibility level to determine the potential cost, regulatory agency requirements and the potential impact of each to ground water.

II. – OVERVIEW OF ALTERNATIVES CONSIDERED

The New Mexico Environmental Department Liquid Waste Program (NMED-LWP) prescriptive flow rates for a single residential unit is 75 gallons per day per person (gpcd) with two people per bedroom for the first two bedrooms and one for each additional bedroom thereafter. For a typical three bedroom home that would equate to 375 gallons per day (gpd) per residence. In working with numerous other communities/municipalities in New Mexico, our experience is that even 350 gpd per house is conservatively high therefore, for the purposes of conservatively estimating sewer infrastructure sizing, we assumed 350 gpd per lot.

Conventional septic tank/leachfield systems are allowed on lots that are one-half acre or greater when the depth to groundwater is in excess of 600 feet (New Mexico Liquid Waste Disposal Regulations, 20.7.3.301.F.5 NMAC). The majority of Rio Rancho Estates lots are generally one-half acre or greater and the depth to groundwater exceeds 600 feet, therefore individual septic tank/leachfield systems are permitted for use on those lots.

The New Mexico Environmental Department Ground Water Quality Bureau (NMED-GWQB) is the permitting agency for discharges in excess of 2,000 gpd. Any proposed centralized or decentralized Wastewater Treatment Plant discharging in excess of 2,000 gpd will be required to comply with Subparts III and V of the Water Quality Control Commission (WQCC) regulations

(20.6.2 NMAC) requirements for discharge limits, operations, sampling and reporting. Discharge permits are issued for 5 years after which time a permit renewal will be required.

III. – INDIVIDUAL SEPTIC TANK LEACH FIELD FULL BUILD OUT

A. DESCRIPTION OF ALTERNATIVE

This alternative assumes that each lot would receive an individual or Decentralized Wastewater System in conjunction with lot development and according to the design flows specific to each. This could include individual septic tank leach fields or Advanced Onsite Treatment Units. While it has been widely accepted that local governments typically provide sewer and water services for new developments; developments that have outstripped capacities and technological improvements in small onsite advanced treatment systems have fueled the decentralized approach to addressing wastewater needs.

Unlike a centralized system that requires a significant initial capital investment for collection and treatment infrastructure, a decentralized approach can be built on an as-needed basis wherever and whenever needed. This circumvents the typical "build-to-Capacity" approach with expectations for projected future growth to compensate for the cost of improvements. Additionally, as much as 60% of the cost for a centralized system can go into the collection alone (large sewer lines, manholes and lift stations) where a decentralized approach requires very little investment in collection as all infrastructure for conveyance, treatment and disposal remain relatively close to the source. Since in this option, treatment takes place relatively close to the source, the potential for re-use is greatly increased for applications such as subsurface drip irrigation.

B. ASSUMPTIONS

For the purposes of estimating the total cost for full build out, the existing lot layout was assumed to remain unchanged and it is assumed that all lots are of sufficient size to accommodate individual systems, decentralized systems or some combination. It is also assumed that the soil types present throughout the area are conducive to subsurface discharge and that no lots are within the 100 year flood plain and all lots meet required setbacks from arroyos, ditches, wells (domestic and public) and property lines/easements. These assumptions are indicative of important zoning and development considerations that should be implemented if the above conditions are not the case.

C. COST ESTIMATE

The costs associated with this option would be the responsibility of the individual property owners/developers and would vary depending on location, wastewater quality, environmental factors, and whether some advanced treatment is required to ensure protection of ground/surface water. Excluding advanced treatment, a reasonable cost estimate per lot for a septic tank and leach field would be in the range of $6,000 to $8,000 per lot or $287 million for the entire area (41,000 lots x $7,000 = $287 million)

D. ADVANTAGES

- Little to no additional cost to the county
- Places operation and maintenance responsibilities on individual users (lot owners)
- Utilizes all of the available lots in the area
- No inter-basin transport of water
- No “point-discharge”
- Allows system to be built as needed when needed
- Conducive to re-use for irrigation and other purposes

E. DISADVANTAGES

- Places the burden of operations and maintenance on the individual lot owners (some lot owners may not be capable of advanced treatment unit operation and maintenance if this type of installation is necessitated by conditions)
- Requires permitting and regulation of each individual system
- Least protective of ground water (relies primarily on soils for nutrient removal)
- Loss of water for recharge credits to County
- Generation of vast non-point source pollution
- Some lots may not have the assumed conditions conducive to subsurface discharge
- Some lots may be in the flood plain, may be undersized or may not have the proper setbacks to wells, arroyos or property lines/easements

F. SUMMARY OF FINDINGS

Individual septic tank leach fields are a viable option for a large portion of the project but some smaller lots (less than 1/2 of an acre) may require alternatives such as advanced onsite treatment which could include clusters of homes on a single decentralized collection treatment and disposal system or individual systems or some combination. Without some sort of tertiary treatment (advanced treatment) this option would rely entirely on the active soil layer for nutrient removal.

IV. – CONVENTIONAL SANITARY SEWER FULL BUILD OUT

A. DESCRIPTION OF ALTERNATIVE

SMA analyzed the potential cost of constructing a complete conventional sanitary sewer system and centralized wastewater treatment plant. This option evaluated cumulative flows based on the current layout of lots and determined gravity sewer line sizes based on an assumed 350 gpd for each lot. The collection system was laid out in a progressive manner by identifying sections within the development (refer to Exhibit A "Wastewater Planning Plan and Profile").

The area topography generally slopes down towards the southeast corner. This bottommost zone (just north of 19th Street) is labeled "1" and each subdivision block in this zone is labeled "a" through "f". Within each subdivision block, gravity sewers are laid out to capture flows from each lot. Each block label displays the number of lots (e.g. 1e-994 indicates 994 lots are present in that block) and the linear footage of gravity sewer present within that block (e.g. 1e has 107,641 linear feet of 8" residential collector sewer present within the block). It is assumed that all blocks in zone 1 gravity collect and flow into the trunk line "1" which runs along the 19th Street corridor. There are 10 total trunk lines (labeled 1 through 10). These trunk lines then tie into two major sewer lines, or interceptors, labeled B & C, which extend generally from north to south. Trunk lines 1 through 10 connect to main lines B and C at their intersecting points.

It was assumed a minimum pipe size of 8" (per New Mexico Standards for Public Works Construction and other industry standard guidelines) would be used for all residential collector sewer lines within the development blocks. For all trunk lines (1 through 10) and the interceptor lines (B&C), cumulative flows were calculated and alignment profiles were generated in order to calculate projected velocities and determine minimum pipe sizes. Allowable velocities in these feasibility-level design calculations were 2 to 10 feet per second (fps). Sewer sizing, flows, and velocity calculations are included in Appendix A A manhole interval of 300 ft was also assumed to calculate the number of manholes for a given sewer line size. It is apparent on the profile for interceptor line "C" that a lift station will be required at the low point where trunk line 5 intersects.

B. ASSUMPTIONS

For this option, it was assumed that all of the 41,000 existing lots would be developed. It was also assumed that the domestic waste stream from each lot would be about 350 gpd. The existing lot layout currently has a significant number of lots located in arroyos or floodplains, on extreme slopes or in other areas that would be difficult to develop. It was assumed that all of these lots would be developed as currently platted in order to determine the feasibility of providing wastewater service for full build out of the area.

C. COST ESTIMATE

Based on the above assumptions, it is estimated that total build-out of the waste water system for the Rio Rancho Estates area will cost $435 million. Table 1 below shows the breakdown of the cost estimate.

Table 1 – Preliminary Opinion of Probably Cost - Full Build Out

RIO RANCHO ESTATES				
Preliminary Opinion of Probable Cost				
Full Build Out				
Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
8 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	3,212,960	$35	$112,453,600
10 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	145,326	$45	$6,539,670
12 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	26,394	$60	$1,583,640
14 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	391,935	$65	$25,475,775
16 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	7,207	$70	$504,490
18 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	14,000	$80	$1,120,000
21 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	32,786	$90	$2,950,740
4' Diameter Standard Manhole to 6' Deep, (incl. materials, trenching, backfill and site restoration), CIP	EA	11,310	$5,000	$56,551,517
6' Diameter Standard Manhole to 6' Deep, (incl. materials, trenching, backfill and site restoration), CIP	EA	1,489	$10,000	$14,891,296
Service Connections Complete In place (with stub to lot line).	EA	41,000	$1,500	$61,500,000
Waste Water Treatment Plant	Per Gallon	16,402,400	$9	$147,621,600
6.7 MGD Lift Station	Per HP	152	$28,846	$4,384,592
Subtotal				**$435,576,920**

D. ADVANTAGES

- The full build-out option utilizes all of the available area for development providing significant room for long term expansion
- A single wastewater treatment plant simplifies operations and maintenance and removes compliance responsibility from individual homeowners
- Most protective of ground water (does not rely on in situ soil for nutrient removal)
- Impact fees for scheduled developments can help allay the costs of infrastructure
- Depending upon treated effluent disposal methods, reuse options can be implemented or recharge credits claimed

E. DISADVANTAGES

- Most expensive of the options
- Insufficient waste stream to maintain minimum scour velocities until area is fully developed
- Large investment in collection system that does not provide any treatment
- Operation and maintenance expenses must be handled by a Utility Authority of some kind and wastewater treatment plant will require Certified Operators
- Point discharge and associated NPDES permit required
- Requires growth to pay for construction and rate structures /monthly fees to pay for improvements, replacement reserves and operation/maintenance
- Potential for inter-basin transport of water
- Reuse options would require extensive distribution infrastructure, including pumping uphill

F. SUMMARY OF FINDINGS

Unlike a decentralized approach, the full build out of a collection and centralized treatment system would require a significant upfront investment in the collection system just to get the sewage to the wastewater treatment plant. The wastewater treatment plant could potentially be constructed to handle initial flows with the allowance for phased expansion but there would still be an initial large investment there as well. Some of the investment could potentially be recouped with impact fees but this is entirely contingent on the incidence of growth. Additionally, until such time as the growth approaches anticipated design assumptions, the actual flows may be insufficient to maintain minimum scour velocities requiring frequent cleaning of lines. The additional cost to sewer the entire area as opposed to onsite systems is roughly $149 million ($435,600,000 – $287,000,000) if it is assumed that all lots can accommodate an onsite system within the given regulatory requirements. Any potential for reuse would most likely require significant additional infrastructure for a distribution system and increased cost.

V. –CONVENTIONAL SANITARY SEWER ZONED OPTION

A. DESCRIPTION OF ALTERNATIVE

This alternative evaluated a conventional gravity sewer system broken down into a phased construction project. This includes a division of Rio Rancho Estates area into four main zones. Within each of those zones, lots located in areas near arroyos were removed due to the potential for flooding, and to preserve sensitive environments. Removing these lots also focuses development in areas where costs for infrastructure would be less. A map of the four zones is included in Exhibit A. The four zones include two neighborhood area preservation zones (Zone 1 and Zone 2), a potential large scale government redevelopment area (Zone 3) and a water conservation area. Zone 1 contains 2,665 lots, Zone 2 includes 5,972 lots and Zone 3 includes 9,440 lots resulting in a total of 18,077 lots.

B. ASSUMPTIONS

The assumptions for this analysis are the same as those for IV “Conventional Sanitary Sewer Full Build-out”.

The cost to construct municipal conventional sanitary sewer for the reduced number of lots (18,077) as described above was calculated by scaling of the cost for full build-out. This assumption leads to an estimated cost of $10,444.21 per lot for each of the zones.

C. COST ESTIMATE

Based on the above assumptions, it is estimated that the waste water system for Zone 1 will cost $27.8 million, Zone 2 will cost $62.4 million and Zone 3 will cost $98.6 million for a total cost of $188.8 million. A detailed breakdown of the cost for construction for the three zones is included in Table 2 below.

Table 2 - Preliminary Opinion of Probable Cost - Full Build Out

RIO RANCHO ESTATES				
Preliminary Opinion of Probable Cost				
Full Build Out				
Construction Cost				
Description	Unit	Qty	Unit Price	Total Price
8 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	1,416,602	$35	$49,581,067
10 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	172,805	$45	$7,776,229
12 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	64,075	$60	$3,844,475
14 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	11,637	$65	$756,417
16 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	9,350	$70	$654,515
18 Inch, Sewer Line, including all material, labor, fittings, warning tape, tracer wire, trenching, bedding, backfilling and site restoration	LF	14,455	$80	$1,156,434
4' Diameter Standard Manhole to 6' Deep, (incl. materials, trenching, backfill and site restoration), CIP	EA	4,987	$5,000	$24,933,702
6' Diameter Standard Manhole to 6' Deep, (incl. materials, trenching, backfill and site restoration), CIP	EA	657	$10,000	$6,565,609
Service Connections Complete In place (with stub to lot line).	EA	18,077	$1,500	$27,115,500
Waste Water Treatment Plant	Per Gallon	7,231,858	$9	$65,086,723
2 MGD Lift Station	Per HP	45	$28,846	$1,308,833
Subtotal				**$188,779,505**

Table 3 below shows the cost summary and estimated cost per lot for all of the proposed alternatives.

Table 3 - Wastewater Estimated Cost Per Lot

Cost Summary and Estimated Cost Per Lot			
Option Evaluated	**Total Cost**	**Number of Lots**	**Cost Per Lot**
Full Buildout (Individual Septic Systems)	$ 287,000,000	41000	$ 7,000.00
Zoned Option (Individual Septic Systems)	$ 126,500,000	18077	$ 7,000.00
Full Buildout (Municipal Sanitary Sewer)	$ 435,600,000	41000	$ 10,624.39
Zoned Option (Municipal Sanitary Sewer)	$ 188,800,000	18077	$ 10,444.21

D. ADVANTAGES

The advantages to the Phased System Build-out are:

- Reduces the overall initial cost of the infrastructure
- Protective of ground water
- Cost Per Lot is reduced compared to full build-out
- Depending upon treated effluent disposal methods, reuse options can be implemented or recharge credits claimed
-

E. DISADVANTAGES

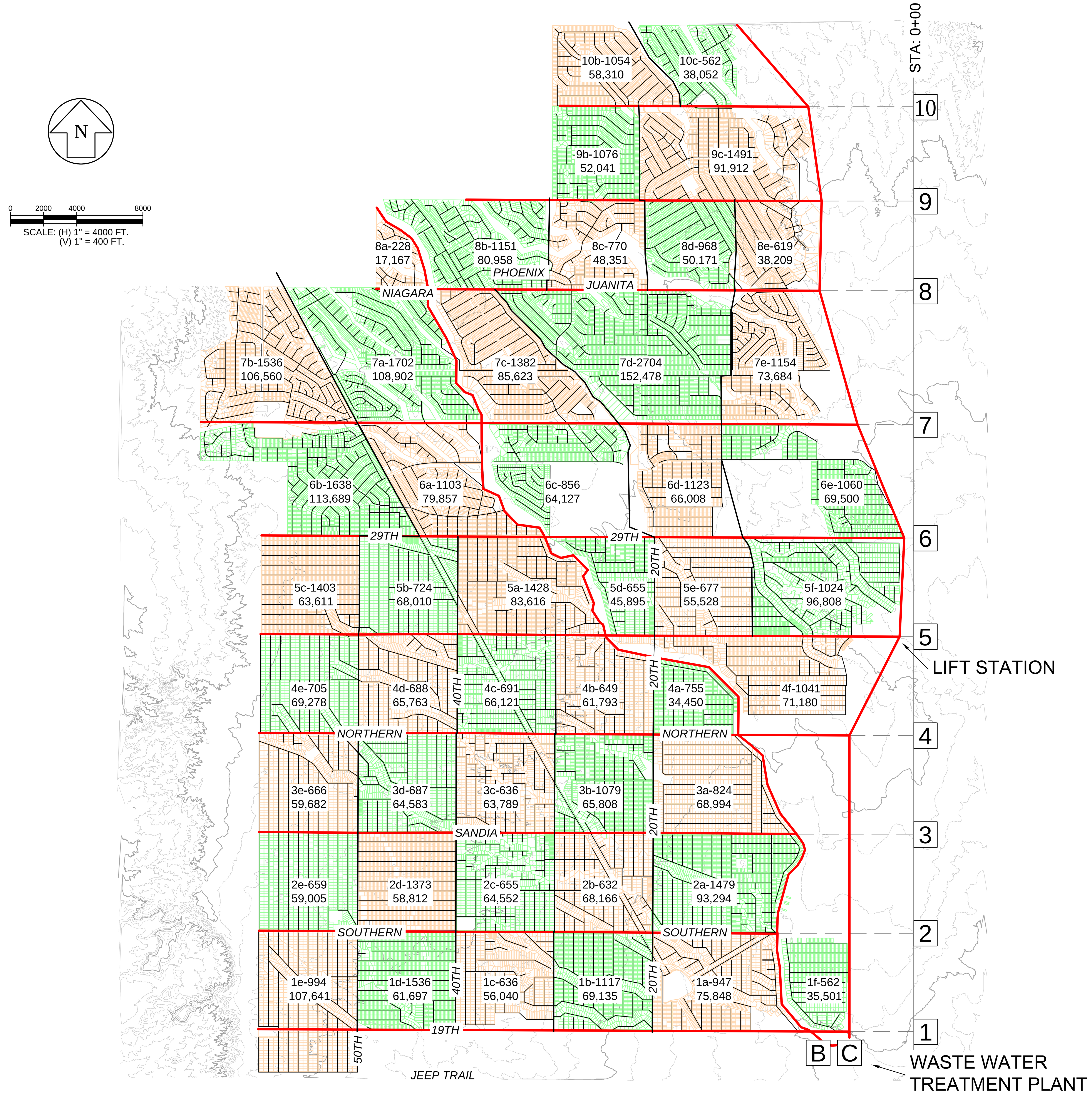
- Restricts growth/development to phased approach

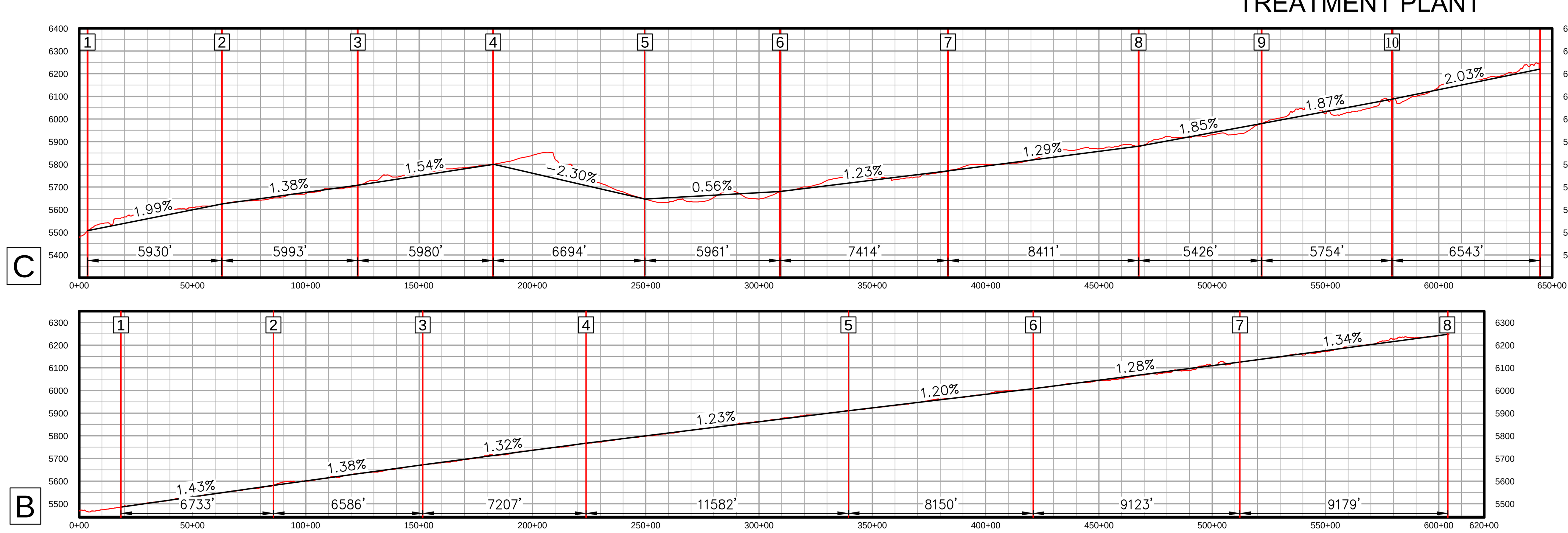
F. SUMMARY OF FINDINGS

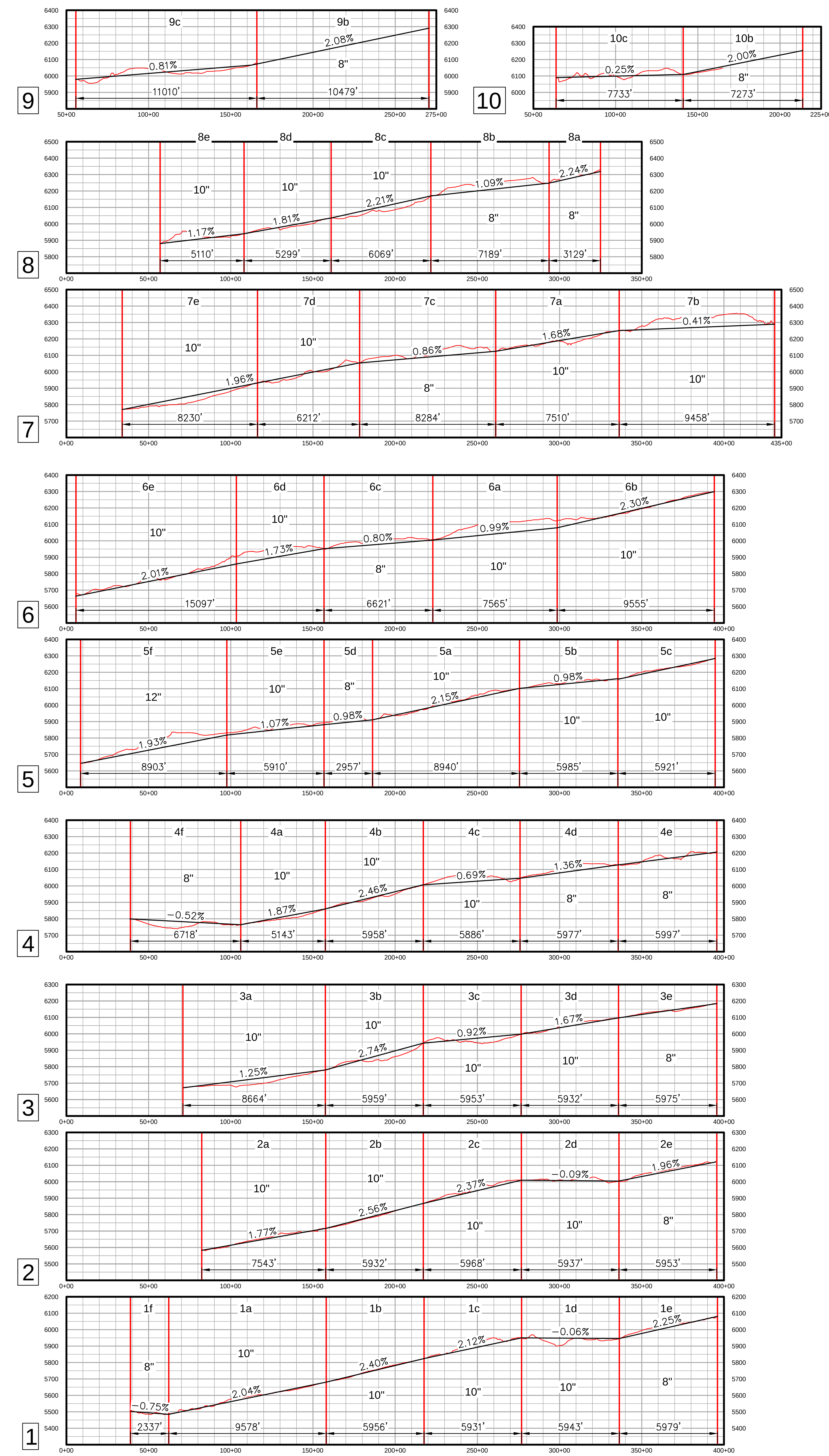
While this alternative is more expensive than individual septic systems, it will be able to provide waste water collection and treatment for all of the lots specified. The feasibility of the individual septic systems comes into play due to the inability of a large number of the lots to meet the New Mexico Liquid Waste Disposal Regulations, 20.7.3.301.F.5 NMAC. Not only are some of the lots smaller than the one-half acre minimum specified for permitting, they are also within the 100 year flood plain or fail to meet the required setbacks for arroyos.

Compared to the full system build-out, this phased approach not only reduces the initial upfront investment, it also significantly reduces the overall cost by 56%. This alternative also provides the opportunity for a return flow credit from waste water collection and treatment of approximately 5,160 acre-ft/yr or $62 million per year assuming a value of $12,000 per acre-ft of water.

EXHIBIT A







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Sandoval County

RIO RANCHO ESTATES WASTEWATER SYSTEM PLANNING PLAN & PROFILE

THIS DRAWING IS INCOMPLETE AND NOT TO BE USED FOR CONSTRUCTION UNLESS IT IS STAMPED, SIGNED AND DATED

Designed	Drawn	Checked
ECY	BE	KJE

Date: 2/15/2013

Scale: Horiz: 1" = 4000'
Vert: 1" = 400'

Project No: 6421284

Sheet: 1

P:\6-Sandoval County Rio Rancho Estates (6421284)\CAD\dwg\Construction Drawings\RRE-P&P.dwg, 2/15/2013 3:31:07 PM jwe

APPENDIX A

Selected n value

0.013

Line B, Zones B1-B9

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	B1 (south of Line #1)	5,792	27,732	9,706,200	15.01743264	37.10	0.0143	21	7.90	19.00	0.79	0.75	0.98	7.74	15.75
2	B2 (between Line 1&2)	4,798	21,940	7,679,000	11.8809488	33.00	0.0143	21	7.90	19.00	0.63	0.64	0.91	7.19	13.44
3	B3 (between line 2&3)	3,892	17,142	5,999,700	9.28273584	29.17	0.0138	18	7.00	12.37	0.75	0.71	0.96	6.72	12.78
4	B4 (between line 3&4)	3,488	13,250	4,637,500	7.17514	25.65	0.0132	16	6.33	8.84	0.81	0.75	0.98	6.20	12.00
5	B5 (between line 4&5)	3,555	9,762	3,416,700	5.28631824	22.01	0.0123	14	5.59	5.98	0.88	0.79	1.05	5.87	11.06
6	B6 (between line 5&6)	2,741	6,207	2,172,450	3.36121464	17.55	0.012	12	4.98	3.91	0.86	0.78	1.00	4.98	9.36
7	B7 (Between line 6&7)	3,238	3,466	1,213,100	1.87690832	13.12	0.0128	10	4.56	2.49	0.76	0.71	0.96	4.37	7.10
8	B8 (between line 7&8)	228	228	79,800	0.12346656	3.36	0.0134	8	4.02	1.40	0.09	0.23	0.53	2.13	1.84
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line B **9,706,200** **15.01743264**

Selected n value

0.013

Line #10, Zones b-c																
Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)					
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	10c Line #10	562	1,616	565,600	0.87509632	8.96	0.0025	10	2.01	1.10	0.80	0.75	0.98	1.97	7.50
2	10b Line #10	1054	1,054	368,900	0.57076208	7.23	0.0163	8	4.43	1.55	0.37	0.49	0.78	3.46	3.92
3		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #10 **565,600** **0.87509632**

Selected n value

0.013

Line #9, Zones b-c

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	9c Line #9	1491	2,567	898,450	1.39008184	11.29	0.01	10	4.03	2.20	0.63	0.64	0.92	3.71	6.40
2	9b Line #9	1076	1,076	376,600	0.58267552	7.31	0.0063	8	2.76	0.96	0.61	0.62	0.91	2.51	4.96
3		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #9 **898,450** **1.39008184**

Selected n value

0.013

Line #8 (Juanita St.), Zones a

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	8a (Juanita St.)	228	228	79,800	0.12346656	3.36	0.0194	8	4.83	1.69	0.07	0.69	0.94	4.54	5.52
2		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
3		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Line #8 (Juanita St.), Zones b-e

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	8e (Juanita St.)	619	3,508	1,227,800	1.89965216	13.20	0.0117	10	4.36	2.38	0.80	0.75	0.98	4.27	7.50
2	8d (Juanita St)	968	2,889	1,011,150	1.56445128	11.98	0.0181	10	5.42	2.96	0.53	0.59	0.86	4.66	5.90
3	8c (Juanita St.)	770	1,921	672,350	1.04025992	9.77	0.0221	10	5.99	3.27	0.32	0.43	0.74	4.43	4.30
4	8b (Juanita St.)	1151	1,151	402,850	0.62328952	7.56	0.0115	8	3.72	1.30	0.48	0.55	0.84	3.13	4.40
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #8 **1,307,600** **2.02311872**

Selected
n value
0.013

Line #7, Zones a-b

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	7a Line #7	1702	3,238	1,133,300	1.75344176	12.68	0.0168	10	5.22	2.85	0.62	0.59	0.86	4.49	5.90
2	7b Line #7	1536	1,536	537,600	0.83177472	8.73	0.0041	10	2.58	1.41	0.59	0.61	0.90	2.32	6.10
3		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Line #7, Zones c-e

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	7e Line #7	1154	5,240	1,834,000	2.8375648	16.13	0.0196	10	5.64	3.08	0.92	0.82	1.30	7.33	8.20
2	7d Line #7	2704	4,086	1,430,100	2.21265072	14.24	0.0196	10	5.64	3.08	0.72	0.70	0.95	5.36	7.00
3	7c Line #7	1382	1,382	483,700	0.74838064	8.28	0.0086	8	3.22	1.12	0.67	0.76	0.99	3.19	6.08
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #7 **2,967,300** **4.59100656**

Selected n value

0.013

Line #6 (29th Street), Zones a-b

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	6a (29th St.)	1103	2,741	959,350	1.48430632	11.66	0.0153	10	4.98	2.72	0.55	0.56	0.85	4.23	5.60
2	6b (29th St.)	1638	1,638	573,300	0.88700976	9.02	0.0102	10	4.07	2.22	0.40	0.44	0.95	3.86	4.40
3		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Line #6 (29th Street), Zones c-e

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	6e (29th St.)	1060	3,039	1,063,650	1.64567928	12.28	0.18	10	17.09	9.32	0.18	0.34	0.64	10.94	3.40
2	6d (29th St.)	1123	1,979	692,650	1.07166808	9.91	0.18	10	17.09	9.32	0.11	0.25	0.55	9.40	2.50
3	6c (29th St.)	856	856	299,600	0.46354112	6.52	0.0084	8	3.18	1.11	0.42	0.51	0.81	2.58	4.04
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #6 **2,023,000** **3.1299856**

Selected n value

0.013

Line #5, Zones a-c

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	5a Line #5	1428	3,555	1,244,250	1.9251036	13.28	0.0216	10	5.92	3.23	0.60	0.62	0.90	5.33	6.20
2	5b Line #5	724	2,127	744,450	1.15181304	10.28	0.0098	10	3.99	2.17	0.53	0.59	0.87	3.47	5.90
3	5c Line #5	1403	1,403	491,050	0.75975256	8.35	0.0214	10	5.89	3.21	0.24	0.39	0.68	4.01	3.90
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.59	0.87	4.27	4.72
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.41	0.72	3.53	3.28
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Line #5, Zones d-f

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	5f fLine #5	1024	2,356	824,600	1.27582112	10.81	0.0166	12	5.86	4.60	0.28	0.41	0.72	4.22	4.92
2	5e Line #5	677	1,332	466,200	0.72130464	8.13	0.0063	10	3.20	1.74	0.41	0.51	0.81	2.57	5.05
3	5d Line #5	655	655	229,250	0.3546956	5.70	0.0063	8	2.76	0.96	0.37	0.49	0.77	2.12	3.92
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #5 **2,068,850** **3.20092472**

Selected n value

0.013

Line #4 (Northern St.) Zones a-e

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	4a (Northern St.)	755	3,488	1,220,800	1.88882176	13.16	0.0187	10	5.51	3.00	0.63	0.65	0.92	5.07	6.50
2	4b (Northern St.)	649	2,733	956,550	1.47997416	11.65	0.0246	10	6.32	3.45	0.43	0.51	0.82	5.18	5.10
3	4c (Northern St.)	691	2,084	729,400	1.12852768	10.17	0.0069	10	3.35	1.82	0.62	0.63	0.91	3.04	6.30
4	4d (Northern St.)	688	1,393	487,550	0.75433736	8.32	0.0136	8	4.05	1.41	0.53	0.59	0.87	3.52	4.72
5	4e (Northern St.)	705	705	246,750	0.3817716	5.92	0.013	8	3.96	1.38	0.28	0.41	0.72	2.85	3.28
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Line #4 (Northern St.) Zones F

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	4f (Northern St.)	1041	1,041	364,350	0.56372232	7.19	0.0052	8	2.50	0.87	0.65	0.66	0.93	2.33	5.28
2		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.52	0.82	4.03	4.16
3		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.58	0.86	4.22	4.64
4		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.40	0.70	3.44	3.20
5		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.39	0.68	3.34	3.12
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #4 **1,585,150** **2.45254408**

Selected n value

0.013

Line #3 (Sandia St.) Zones a-e																
Estimated Number Of Connections			**Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)**				**Actual Velocity Given Pipe Slope and Diameter (flowing full)**				**Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)**					
Zone	**Zone Description**	**No. of Lot's**	**Cumulative No. of Lot's**	**Zone Flow (gpd)**	**Zone Flow (Cu.Ft./Sec)**	**Min Pipe Size (in)**	**Pipe Slope (ft./Foot)**	**Pipe Size Used (in)**	**Velocity (Ft./Sec)**	**Actual Capacity (Cu.Ft./Sec)**	**Q/Q(full)**	**Hydraulic Element Figure Appendix 19.C (d/D)**	**Hydraulic Element Figure Appendix 19.C (v/V)**	**Actual Velocity At pipe "d" full**	**Depth of water at design value**	
1	3a (Sandis St.)	824	3,892	1,362,200	2.10759584	13.90	0.0125	10	4.50	2.46	0.86	0.78	1.00	4.50	7.80	
2	3b (Sandia St.)	1079	3,068	1,073,800	1.66138336	12.34	0.0274	10	6.67	3.64	0.46	0.52	0.82	5.47	5.20	
3	3c (Sandia St.)	636	1,989	696,150	1.07708328	9.94	0.0092	10	3.86	2.11	0.51	0.58	0.86	3.32	5.80	
4	3d (Sandia St.)	687	1,353	473,550	0.73267656	8.20	0.0167	10	5.21	2.84	0.26	0.40	0.70	3.64	4.00	
5	3e (Sandia St.)	666	666	233,100	0.36065232	5.75	0.0146	8	4.19	1.46	0.25	0.39	0.68	2.85	3.12	
6		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
7		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
8		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
9		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
10		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
11		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
12		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
13		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
14		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
15		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
16		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
17		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
18		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
19		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	
20		0	0	0	0	0.00	0.02	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00	

Total Flow For Line #3 **1,362,200** **2.10759584**

Selected
n value
0.013

Line #2 (Southern St.) Zones a-e																
Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity & Capacity Given selected Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)					
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	2a (Southern St.)	1479	4,798	1,679,300	2.59821296	15.43	0.0177	10	5.36	2.92	0.89	0.82	1.20	6.43	8.15
2	2b (Southern St.)	632	3,319	1,161,650	1.79730488	12.84	0.0256	10	6.44	3.52	0.51	0.56	0.86	5.54	5.60
3	2c (Southern St.)	655	2,687	940,450	1.45506424	11.55	0.0237	10	6.20	3.38	0.43	0.46	0.76	4.71	4.60
4	2d (Southern St.)	1373	2,032	711,200	1.10036864	10.04	0.0009	10	1.21	0.66	1.67	0.00	0.00	0.00	0.00
5	2e (Southern St.)	659	659	230,650	0.35686168	5.72	0.0196	8	4.86	1.70	0.21	0.35	0.64	3.11	2.80
6		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Total Flow For Line #2 **1,679,300** **2.59821296**

Selected
n value
0.013

Line #1 (19th Street) Zones a-e

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity & Capacity Given selected Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C (d/D)	Hydraulic Element Figure Appendix 19.C (v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	1a (19th street)	947	5,230	1,830,500	2.83	16.11	0.0204	10	5.75	3.14	0.90	0.82	1.20	6.90	8.15
2	1b (19th street)	1117	4,283	1,499,050	2.32	14.58	0.0240	10	6.24	3.40	0.68	0.68	0.94	5.87	6.80
3	1c (19th street)	636	3,166	1,108,100	1.71	12.54	0.0212	10	5.86	3.20	0.54	6.00	0.88	5.16	60.00
4	1d (19th street)	1536	2,530	885,500	1.37	11.21	0.0006	10	0.99	0.54	2.55	0.00	0.00	0.00	0.00
5	1e (19th street)	994	994	347,900	0.54	7.02	0.0231	8	5.28	1.84	0.29	0.43	0.72	3.80	3.44
6		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
7		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
8		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
9		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
10		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
11		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
12		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
13		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
14		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
15		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
16		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
17		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
18		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
19		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00
20		0	0	0	0.00	0.00	0.0200	8	4.91	1.71	0.00	0.00	0.00	0.00	0.00

Line #1 (19th Street) Zones f

Estimated Number Of Connections			Min. Pipe Size At 2ft/sec for Cumulative Flow (flowing full)				Actual Velocity & Capacity Given Pipe Slope and Diameter (flowing full)				Actual Velocity at Design flow Given Pipe Diameter and Slope (not flowing full)				
Zone	Zone Description	No. of Lot's	Cumulative No. of Lot's	Zone Flow (gpd)	Zone Flow (Cu.Ft./Sec)	Min Pipe Size (in)	Pipe Slope (ft./Foot)	Pipe Size Used (in)	Velocity (Ft./Sec)	Actual Capacity (Cu.Ft./Sec)	Q/Q(full)	Hydraulic Element Figure Appendix 19.C(d/D)	Hydraulic Element Figure Appendix 19.C(v/V)	Actual Velocity At pipe "d" full	Depth of water at design value
1	1f (19th street)	562	562	196,700	0.30433424	5.28	0.0012	8	1.202440083	0.419731752	0.7250684	0.7	1.1	1.322684092	5.6
2		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0.65	3.190811705	0
3		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
4		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
5		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
6		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
7		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
8		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
9		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
10		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
11		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
12		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
13		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
14		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
15		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
16		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
17		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
18		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
19		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0
20		0	0	0	0	0.00	0.02	8	4.908941084	1.713547701	0	0	0	0	0

Total Flow For Line #1 **2,027,200** **3.13648384**

SUBJECT GRAVITY SEWER PROJECT PAGE

CLIENT RIO RANCHO ESTATES DATE 12/20/12 BY E

CHECKED BY

1) Design Flow

\# of Lots (350 gpd)

$5230\ (350\ \text{gpd}) = 1{,}830{,}500\ \text{gpd} = 2.8321$ F

2) Min Pipe size for Design flow @ 2 FT/se

$Q\ \text{full} = V\ \text{full} \therefore Q = V\left(\frac{\pi D^2}{4}\right) \therefore D =$

$$D = \sqrt{\frac{4\ (2.8321)}{2\ (\pi)}} = 1.3428\ \text{FT} = 16.11\ \text{in}$$

3) actual Velocity / capacity given Dia & slope

$$V = \frac{1.49}{n}\left(\frac{D}{4}\right)^{2/3}(S)^{1/2}$$

$$V = \frac{1.49}{0.013}\left(\frac{10/12}{4}\right)^{2/3}(0.0204)^{1/2} = 5.75\ \text{Ft}$$

$$Q = V\left(\frac{\pi D^2}{4}\right) = 5.75\left(\frac{\pi (10/12)^2}{4}\right) = 3.1$$

4) actual Velocity @ Design flow Given Pipe Ø

$$\frac{Q\ (\text{Design})}{Q\ (\text{full})} = \frac{2.8321}{3.1378} = 0.9026$$

From Hydraulic Figure $\frac{v}{V} = 1.20$

$$\frac{d}{D} = 0.82$$

$\therefore\ v = 1.20\ (5.75) = 6.9\ \text{FT/sec}$

$\therefore\ d = 0.82\ (10) = 8.2\ \text{FT}$

C4

T^3/sec.

$\sqrt{\frac{4Q}{V\pi}}$

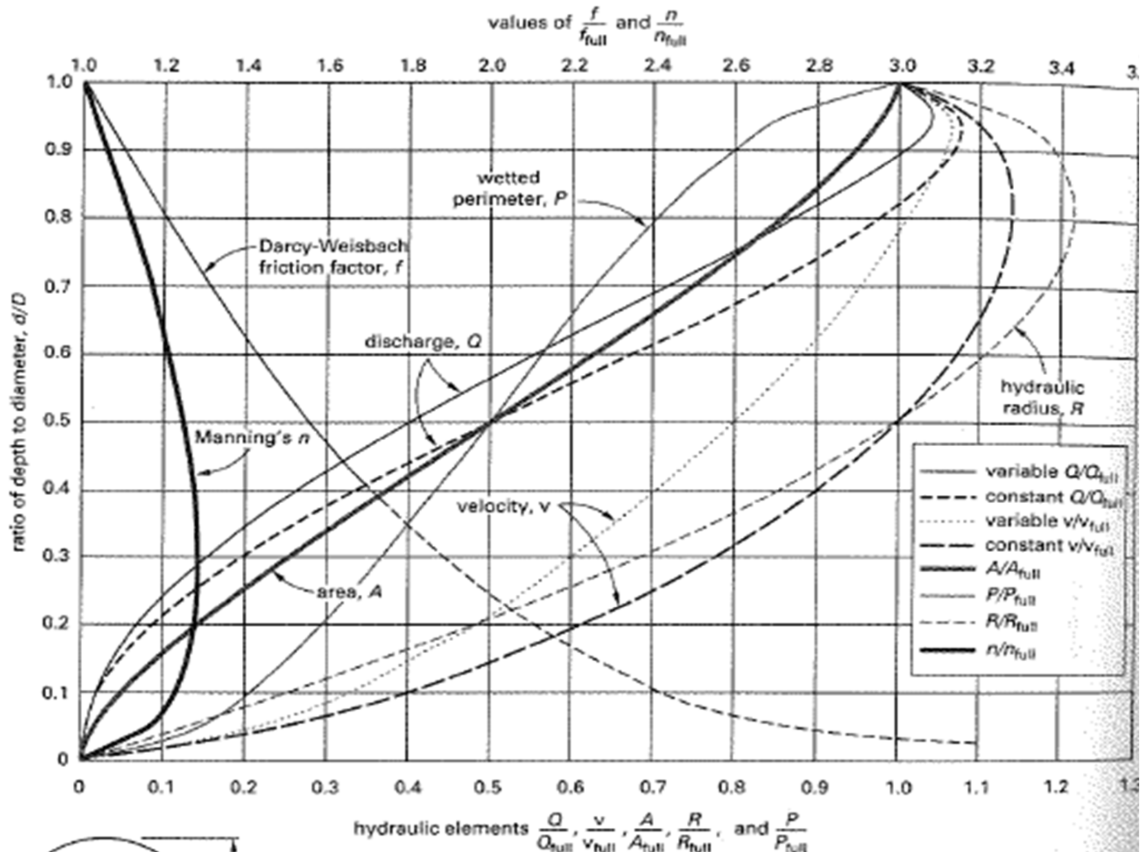
/sec

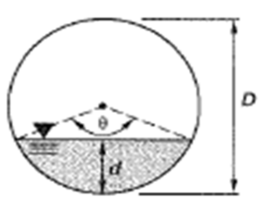
3.78 FT^3/sec

& slope.

APPENDIX 19.C
Circular Channel Ratios[a,b]

Experiments have shown that n varies slightly with depth. This figure gives velocity and flow rate ratios for va
n (solid line) and constant n (broken line) assumptions.





Governing equations

$$\theta_{deg} = 2 \arccos\left(\frac{\frac{D}{2} - d}{\frac{D}{2}}\right)$$

$$A = \left(\frac{D}{2}\right)^2 \frac{\theta_{rad} - \sin\theta_{deg}}{2}$$

$$P = \frac{D\theta_{rad}}{2}$$

$$R = \frac{A}{P}$$

$$v = \left(\frac{1.486}{n}\right) R^{\frac{2}{3}} \sqrt{S}$$

$$Q = Av$$

Slope is constant.

$n = 0.013$

$$\frac{n}{n_{full}} = 1 + \left(\frac{d}{D}\right)^{0.540} - \left(\frac{d}{D}\right)^{1.200}$$

[a]Adapted from *Design and Construction of Sanitary and Storm Sewers*, p. 87, ASCE, 1969, as originally presented in "Design of Se
to Facilitate Flow," Camp, T. R., *Sewage Works Journal*, 18, 3 (1946).
[b]For $n = 0.013$