Public Comment to County Commissioners about County Oil/Gas/Water ordinance -- Concern about Ordinance Review Process

David Craig <dtc.bayern@gmail.com>

Fri 9/7/2018 2:56 PM

To: Public Comment <PublicComment@sandovalcountynm.gov>;

Cc: Aparcio C. Hererra <ahererra@sandovalcountynm.gov>; Peter J. Adang <padang@sandovalcountynm.gov>; James G. Maduena <JMaduena@sandovalcountynm.gov>; Keith Brown <kbrown@sandovalcountynm.gov>; Daniel J. Stoddard <DStoddard@sandovalcountynm.gov>; Geoffrey Stamp <gstamp@sandovalcountynm.gov>; Dennis R.. Trujillo <DTrujillo@sandovalcountynm.gov>; Dave Heil <dheil@sandovalcountynm.gov>; James Holden-Rhodes <jholden-rhodes@sandovalcountynm.gov>; Jay Block <jblock@sandovalcountynm.gov>; Don Chapman <dchapman@sandovalcountynm.gov>; Kenneth Eichwald <keichwald@sandovalcountynm.gov>; Michael Springfield <MSpringfield@sandovalcountynm.gov>; Makita Hill <mhill@sandovalcountynm.gov>; Robin S. Hammer <rhammer@sandovalcountynm.gov>; Dianne Maes <dmaes@sandovalcountynm.gov>;

1 attachments (295 KB)

CWG Charter -- Approved County Commission 15 Mar 2018.pdf;

September 7, 2018

Hello County Planning & Zoning Commissioners and County Commissioners,

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I fully support *responsible* oil and gas development in Sandoval County and fully expect my county representatives to seriously consider the health, welfare and safety of the people they represent. Water protection and preservation is critical for people's health and welfare.

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This document is the foundation document for the Citizens Working Group and contains the mandate as specified by the County Commission for this group's activities. This document *should* serve as the guiding direction for how the county commissions review the various draft ordinances. Instead, this mandate has been completely ignored by most of the Planning & Zoning Commission. This mandate must not be ignored by the County Commission.

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Oil & Gas Drilling - Sandoval County NM - 21 Aug 2018 - Aztec NM "Toxic Tour of Hell"
https://www.youtube.com/watch?v=0le8gpjOe3s

Thank you for your time.

- David Craig
- Sandoval County resident
- Member of CWG (secretary)

March 11, 2018

Approved by County Commission March 15, 2018

SANDOVAL COUNTY

AQUIFER WATER PROTECTION &
OIL AND GAS CITIZENS WORKING GROUP

Objective

Preservation and protection of drinking water aquifers, groundwater, and surface water and development of a county oil and gas ordinance

Participants

Independent Leader (non-voting):
Donald T. Phillips (Pending)
Writer/Author
Geologist (BS, MS); Oil and Gas Exploration (Mobil Oil, Tenneco Inc., CNG Producing Co.)
Former 3-term mayor, Fairview, Texas

Members (Voting):

Algodones: John Arango
Former Chairman, Sandoval County, Planning & Zoning Commission
20 years' experience in Sandoval County Ordinance process

Bernalillo: Phoebe Suina
Environmental Engineering & Management (BA, MA, Dartmouth)
Environmental Management (MA; Dartmouth)
Owner, High Water Mark (Environmental Consulting Company)

Cochiti Lake: David Craig
Computer Science (BS), 34 years professional programming experience
Chairman, Cochiti Lake Zoning Board

Corrales: Mary Feldblum
PhD in Sociology and Economics
Former Chair Corrales Planning and Zoning Commission
Has worked in policy issues for over 3 decades at state and local levels, including expertise in oil and gas issues. Consultant for the Oil and Gas Accountability Project (OGAP)

Cuba: Aparcio C. Hererra, Jr.
BS in Business (UNM)
Chairman, Sandoval County Planning & Zoning Commission
Owner, The Copper Mug, Cuba, NM; former O&G field pumper

La Madera: Bill Deaton
Chemical Engineer (MS)
Math and Economics (BA)
Executive MBA (Stanford)

Placitas: Bill Brown
Geologist (BS, MS, UNM)
Professional hydrologist (investigation and cleanup of soil/groundwater hydrocarbons)
Owner, Brown Environmental, Inc.

March 11, 2018

Pueblo: Myron Armijo
Former Governor, Santa Ana Pueblo; Chairman, Southern Sandoval Investments, Ltd.
Tribal Liaison, NM Office of the State Engineer, Interstate Stream Commission

Pueblo: Derrick Lente
Attorney
New Mexico State Representative, District 65
Represents Pueblos (Cochiti, Jemez, Sandia, San Felipe, Santa Ana, Santo Domingo, Zia) Navajo Tri-Chapter and Jicarilla Apache

Navajo Tri-Chapter Rep: To be named [Pending]

Rio Rancho: Edward Paulsgrove
Geologist (BS)
U.S. Army Corps of Engineers (Geotechnical and Environmental Divisions)
U.S. Army Paratrooper (509 Airborne combat infantry)

County Support Liaisons (non-voting):
•Peter Adang (Planning and Zoning Commissioner)
•Keith Brown (Planning and Zoning Commissioner)

Participation

- Maximum citizen participation
- Each member is encouraged to contact interested citizens and solicit input from their area
- A call for papers from interested Sandoval County citizens
- Pueblo and Navajo members are citizen representatives only and do not in any way reflect individual tribal government decisions or formal communications with the Sandoval County government

Technical/Scientific Reviews

- Sandoval County commissioned New Mexico Tech Study
- Albuquerque Bernalillo County Water Advisory Board commissioned aquifer study
- Other pertinent studies
- Experts invited to present (O&G, Environmental, Water, Legal, Health, etc.)

Consultation and Coordination with Other Governments

All local governments in:

- Sandoval County
- Bernalillo County
- Valencia County
- All Pueblo Nations
- Navajo, Jicarilla Apache

See change at bottom

End Product

- Present a joint recommendation for action directly to the Sandoval County Commissioners
- Produce a comprehensive oil and gas ordinance directly to the Sandoval County Commissioners that includes aquifer source water, groundwater, and surface water protection.

Recommended Timeline

- Four months

Operating Guidelines

- Meeting times, frequency, other details, etc. to be set by CWG members (Provided to SCC)
- Full meeting agendas posted 72 hours in advance
- Public invited to attend with structured open comment
- Progress updates to SCC prior to every regularly scheduled county commission meeting

Commission voted to have End Product first go directly to County Planning & Zoning Commission

Re: Public Comment to County Commissioners about County Oil/Gas/Water ordinance -- Concern about Ordinance Review Process

donna dowell <dowelldirect@gmail.com>

Sat 9/8/2018 7:20 AM

To:David Craig <dtc.bayern@gmail.com>;

Cc:Public Comment <PublicComment@sandovalcountynm.gov>; Aparcio C. Hererra <ahererra@sandovalcountynm.gov>; Peter J. Adang <padang@sandovalcountynm.gov>; James G. Maduena <JMaduena@sandovalcountynm.gov>; Keith Brown <kbrown@sandovalcountynm.gov>; Daniel J. Stoddard <DStoddard@sandovalcountynm.gov>; Geoffrey Stamp <gstamp@sandovalcountynm.gov>; Dennis R.. Trujillo <DTrujillo@sandovalcountynm.gov>; Dave Heil <dheil@sandovalcountynm.gov>; James Holden-Rhodes <jholden-rhodes@sandovalcountynm.gov>; Jay Block <jblock@sandovalcountynm.gov>; Don Chapman <dchapman@sandovalcountynm.gov>; Kenneth Eichwald <keichwald@sandovalcountynm.gov>; Michael Springfield <MSpringfield@sandovalcountynm.gov>; Makita Hill <mhill@sandovalcountynm.gov>; Robin S. Hammer <rhammer@sandovalcountynm.gov>; Dianne Maes <dmaes@sandovalcountynm.gov>;

Wow David you blow me away! What a great comment, well put, comprehensive, yours is an important voice to be heard and your piece serves to educate the public! Thank you for taking the time. I will pass on! Yours, Donna

Sent from my iPhone

On Sep 7, 2018, at 22:54, David Craig <dtc.bayern@gmail.com> wrote:

September 7, 2018

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- David Craig
- Sandoval County resident
- Member of CWG (secretary)

<CWG Charter -- Approved County Commission 15 Mar 2018.pdf>

Re: Public Comment to County Commissioners about County Oil/Gas/Water ordinance -- Concern about Ordinance Review Process

Alan Friedman <alfreedo@comcast.net>

Sat 9/8/2018 4:32 PM

To:David Craig <dtc.bayern@gmail.com>;

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Good David. You always call it as you see it.

Alan

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Thank you for your time.

- David Craig
- Sandoval County resident
- Member of CWG (secretary)

Review of Draft ordinances for Oil & Gas Drilling

Jeff Silesky <jeff@silesky.net>

Sat 9/8/2018 1:27 PM

To: Public Comment <PublicComment@sandovalcountynm.gov>;

Dear county commissioners,

I am a resident of Rio Rancho, a real estate developer and own several businesses in both Rio Rancho & Albuquerque.
I have also been a member of the Citizens Working Group (CWG) as part of the oil & gas county review process.

Over the last several months it has been a pleasure to work with such a committed group of volunteers with various backgrounds, all dedicated to creating an ordinance draft that BOTH supports responsible oil & gas development in Sandoval Co AND protects our natural resources (especially water) as well as the health, welfare & safety of our citizens. Since last spring, the CWG has collectively spent several thousand VOLUNTEER hours and also engaged additional outside expertise in our efforts to fulfill the mandate approved by the county commissioners dated March 15th 2018 and entitled "Sandoval Co. Aquifer Water Protection Oil & Gas Citizen's Working Group."

Unfortunately it appears the desire of the Planning & Zoning Commission is to submit to the county commissioners for their consideration BOTH the "Block ordinance" as well as our citizens ordinance draft. Any reasonable review of the Block Ordinance document clearly reveals that it FAILS to provide any meaningful water protection or protect of the health, welfare or safety of county citizens. Most importantly, this document IS NOT BASED UPON CITIZEN INPUT. This failure, was the original impetus behind the county commission decision last March to create the CWG. Neither the lack of expertise or resources within the county is an excuse to consider an inferior ordinance that lacks important safeguards. Our CWG document is carefully designed to require the operator/licensee to bear all costs for the provision of this expertise.

I urge all commissioners to keep us on their original intended path toward a responsible Oil & Gas ordinance that will enhance the future for ALL county citizens.

Sincerely,

Jeff Silesky
jeff@silesky.net
Cell: (425) 830-7037

Proposal to forward three O&G ordinances to the County Commission

Steve Palmer <sepalmer@gmail.com>

Mon 9/10/2018 11:19 AM

To: Public Comment <PublicComment@sandovalcountynm.gov>;

Dear Commissioners,

I am writing to provide input on the P&Z Commission's current proposal to forward three ordinances governing oil and gas (O&G) extraction to the County Commission: the Baseline (Block) Ordinance, the CWG (Science) Ordinance, and the CWG (Ordinance) Ordinance.

Last December the County Commission charged the P&Z Commission to consider an O&G ordinance from a Citizens Working Group (CWG) that meets two primary requirements:

(1) to protect the County from damage due to O&G extraction operations, **specifically including the protection of our precious water supply and aquifers**, and

(2) to include significant input from representatives of all Sandoval County residents, **specifically including Native American communities.**

The current proposal is to rush ahead by forwarding **three ordinances** to the County Commission rather than just the requested single ordinance. I strongly urge the P&Z Commission to **slow down** and forward a **single ordinance** that meets both primary requirements requested by the County Commission.

First, I recommend that you discard the Block ordinance. It is a slightly rehabilitated version of the Stoddard Ordinance that was roundly (and rightly) rejected in a 4-to-1 vote last December. In particular, the Block ordinance does not adequately address either of the two requirements of the County Commission: it does not adequately protect the County's precious water supply and it does not include Native American input. Commissioner Adang eloquently and forcefully made both points at the last P&Z meeting, but his clear-headed analysis was not fully appreciated. He is correct: the Baseline (Block) Ordinance should not be forwarded to the County Commission; it would be an embarrassment to P&Z.

Why? Most importantly, the Block Ordinance is hopelessly vague in its language aimed at protecting aquifers. It says only that the extraction operator will "take reasonable measures necessary" to comply with NM requirements to avoid water pollution. But it does not do any of the following:

(1) define what constitute "reasonable necessary" measures to avoid water pollution,

(2) regulate how hazardous wastes will be safely managed,

(3) specify how dangerous spills will be remedied, or

(4) provide consequences for violations beyond a pitiful $300 fine.

What kind of protection against aquifer pollution is that? Totally inadequate, in my opinion, and I believe the County Commission would agree. So ... don't forward that one.

My second recommendation is that you slow down the process and give the two halves of the CWG time to merge their comprehensive and complementary ordinances. Both groups agree that a single merged version can be created with dispatch that would meet the requirements of the County Commission. I believe that the two CWG groups will jointly endorse this merging process at tonight's P&Z meeting (9/10/2018). Both ordinances are well-crafted, comprehensive, and largely compatible approaches that will only be made stronger by the merging process. I further believe that this single ordinance could well serve as a template for O&G ordinances in other NM counties facing similar issues arising from O&G extraction operations. I predict that it will be that good!

Sincerely,

Stephen E. Palmer
Resident of Placitas NM
Professor Emeritus, University of California, Berkeley

~ ~ *Life isn't about waiting for the storm to pass... It's about learning to dance in the rain*
(Vivian Greene)

Oil & Gas Ordinance Review

dgreatmassage@aol.com

Mon 9/10/2018 1:01 PM

To: Public Comment <PublicComment@sandovalcountynm.gov>;

Dear County and P&Z Commissioners,

I am a resident of RioRancho and have been closely following the ordinances on this matter. I feel that the P&Z Director, Mike Springfield, has done a disservice to the County Residents by trying to push forward a prior rejected and recycled Block ordinance that favors the oil and gas industry. As he said in a previous Commission meeting; he and his staff are not qualified to make decisions regarding oil and gas drilling. It appears that he is also trying to deceive the residents by changing meeting times without a 72 hour notice as he did 9/10/18. The P&Z were given 2 researched ordinances from the CWG and have failed to ask for any input from them regarding any of the facts therein. The CWG ordinances are well researched, studied and consider the protection of what a responsible oil and gas ordinance would mean for the citizens, water, tribes and lands, etc.; as was charged to them.

I am asking that you rethink recommending sending the Baseline Ordinance to the County Commission and consider the combining CWG ordinances and research.

Sincerely,
Denise Flores

Re: Public Comment to County Commissioners about County Oil/Gas/Water ordinance -- Concern about Ordinance Review Process

Randy Erickson <torandyerickson@gmail.com>

Mon 9/10/2018 2:51 PM

To:David Craig <dtc.bayern@gmail.com>;

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Well done David! Thanks for submitting this!
Randy

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September 7, 2018

Hello County Planning & Zoning Commissioners and County Commissioners,

Concerning the county's current review of draft ordinances relating to oil and gas extraction within Sandoval County, I would like to express my concern as a county resident and a member of the Citizens Working Group with the county's oil and gas ordinance review process.

I fully support *responsible* oil and gas development in Sandoval County and fully expect my county representatives to seriously consider the health, welfare and safety of the people they represent. Water protection and preservation is critical for people's health and welfare.

Please also post the attached file "CWG Charter 11 Mar 2018 (approved County Commission 15 Mar 2018).pdf" as part of my public comment. I think it is important that county residents with an interest in the county's oil and gas regulation efforts are aware of this county's mandate for the development of the county's oil and gas ordinance. This charter does not appear to be on the county web site.

The county Planning & Zoning commission's ordinance review process does not follow the mandate that the county commission approved in March 2018 when the commission established the Citizens Working Group. Any ordinance which does not follow this mandate should be rejected by the county. Instead, the county Planning & Zoning commission, which is supposed to be run by the commission members is instead being run by their staff headed by Michael Springfield (mspringfield@sandovalcountynm.gov, 505-867-7628), has decided that a pro-oil & gas industry ordinance (now called the "Block" ordinance, previously called the "Stoddard" ordinance) is best for the county residents and Tribes.

This citizens group, which is composed of unpaid volunteers from different areas of the county, was established because the commission's attempt in 2017 to create an oil & gas ordinance was found extremely lacking by county residents. These residents very vocally expressed their extreme displeasure at the county commissioners failure to produce an oil and gas ordinance that protects county residents and tribes water sources, residents and Tribes health, safety and welfare. These residents and Tribes were presented by the commissioners, who are supposed to work for their constituents and not against them, with an oil and gas ordinance that instead protected the profit oriented interests of the oil and gas industry.

Several videos of the people's distaste of the county's 2017 ordinance direction may be found on YouTube in the following videos:

Residents rally against oil and gas ordinance
https://www.youtube.com/watch?v=76Nir5OtdOc

Press Conference: Sandoval County Oil and Gas Ordinance
https://www.youtube.com/watch?v=eyv9q2sq39s

In an effort to deflect resident and Tribal public displeasure from the commission, the commissioners created this citizens group whose mandate is to preserve and protect the county's drinking water aquifers, groundwater, and surface water and develop a county oil and gas ordinance. This citizens group mandate also requires "maximum citizen participation" in the development of an oil and gas ordinance.

The current focus of the majority of the county Planning & Zoning commissioners is to use the "Block" ordinance as the base ordinance for county ordinance modifications. County Commissioner Jay Block (jblock@sandovalcountynm.gov, 505-252-6218) presented this ordinance to the county Planning & Zoning commission to review. It seems the Planning & Zoning commission never actually approved the submission of this ordinance to them for review -- seems Springfield instead accepted this ordinance for this commission since he runs this commission anyway so why should he bother asking the commissioners for their permission. To clarify the Planning & Zoning commission's governance, it seems this commission should really just be called the "Springfield Commission".

This "Block" proposed ordinance does not provide any meaningful water protection, protect people's health, safety and welfare, and was not based on resident input throughout the county. Block's ordinance relies on the State of New Mexico to regulate oil and gas drilling, which unfortunately favors the oil and gas companies over protection for resident health, welfare and safety.

Planning & Zoning commissioner Peter Adang, who is part of the citizens working group, has several times in commission meetings expressed very eloquently his displeasure with the proposed Block ordinance. Adang has correctly stated that the Planning & Zoning commission (oops, the Springfield commission) failed to even consider the water protection provisions of the various ordinances the commission reviewed and water protection was not even listed in the commission's original list of ordinance topics for review. Springfield, as Planning & Zoning department director, even claimed in a recent commission meeting that the county commission never told him water protection should be part of the county's oil and gas ordinance.

This citizens group mandate is stated in a document which the county commission approved on March 15, 2018 titled "Sandoval County Aquifer Water Protection & Oil and Gas Citizens Working Group".

This document is the foundation document for the Citizens Working Group and contains the mandate as specified by the County Commission for this group's activities. This document *should* serve as the guiding direction for how the county commissions review the various draft ordinances. Instead, this mandate has been completely ignored by most of the Planning & Zoning Commission. This mandate must not be ignored by the County Commission.

For a very personal account of the negative effects of oil and gas development which occur when people's health and safety are ignored, it is suggested that the commissioners and others who read this comment view a recent video taken in Aztec New Mexico (near Farmington). A long-time local residents describes the oil and gas drilling efforts in Aztec.

Oil & Gas Drilling - Sandoval County NM - 21 Aug 2018 - Aztec NM "Toxic Tour of Hell"
https://www.youtube.com/watch?v=0le8gpjOe3s

Thank you for your time.

- David Craig

- Sandoval County resident
- Member of CWG (secretary)

<CWG Charter -- Approved County Commission 15 Mar 2018.pdf>

Brine can be for Fracking Water source

*Note: Two email attachments were identical (the map). Therefore the County only included one map copy.

Elaine Cimino <ecimino10@gmail.com>

Mon 9/10/2018 3:47 PM

To: Public Comment <PublicComment@sandovalcountynm.gov>;

3 attachments (7 MB)

Figure ! Rio Puerco Deep weel impacts to RG and RSJ.pdf; Figure 1 Rio Puerco Deep well impacts to RG and RSJ.png; DeepAquifer-JSAI_FINAL DRAFT FIGS 063010.pdf;

Any Brine pumped or withdrawal of Water will Impact the Rio Grande and the Compact. It will also impact Shallow Subbasin that is used for Drinking water. Any fracking in the Rio Puerco of the Rio Rancho Rio Rancho Estate. This report was Covered up by the Partnership of Recorp Carinos, Butera and IMH of which Sandoval County is a partner and stands to sell 4000 afy. for industrial use.
It is part of a settlement agreement. The Settlement agreement gave away the RIO Grande Water to Out-state hedge funds for moving profits out of state, estimated $1B in Water alone.
Mike Springfield and George King celebrated, the then SE John D Antonio, testifying to the Legislature that there would be no impacts and convinced them based on lies to agree to preempting beneficial use of brine in NM. The State legislature was lobbied by Sandoval County to support these impacts knowing full well that this report was covered up.

Any fracking and brine use in this region must take this report into consideration these impacts. See attachments

Elaine Cimino
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505 604-9772

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Nothing is more perishable than our relationship with the Earth."

"In a time where every living system is declining and the rate of decline is accelerating, we must figure out what it means to be a human on Earth and remain humane in the process."-Elaine Cimino

"Our lives begin to end the day we become silent about things that matter."

-Martin Luther King Jr.

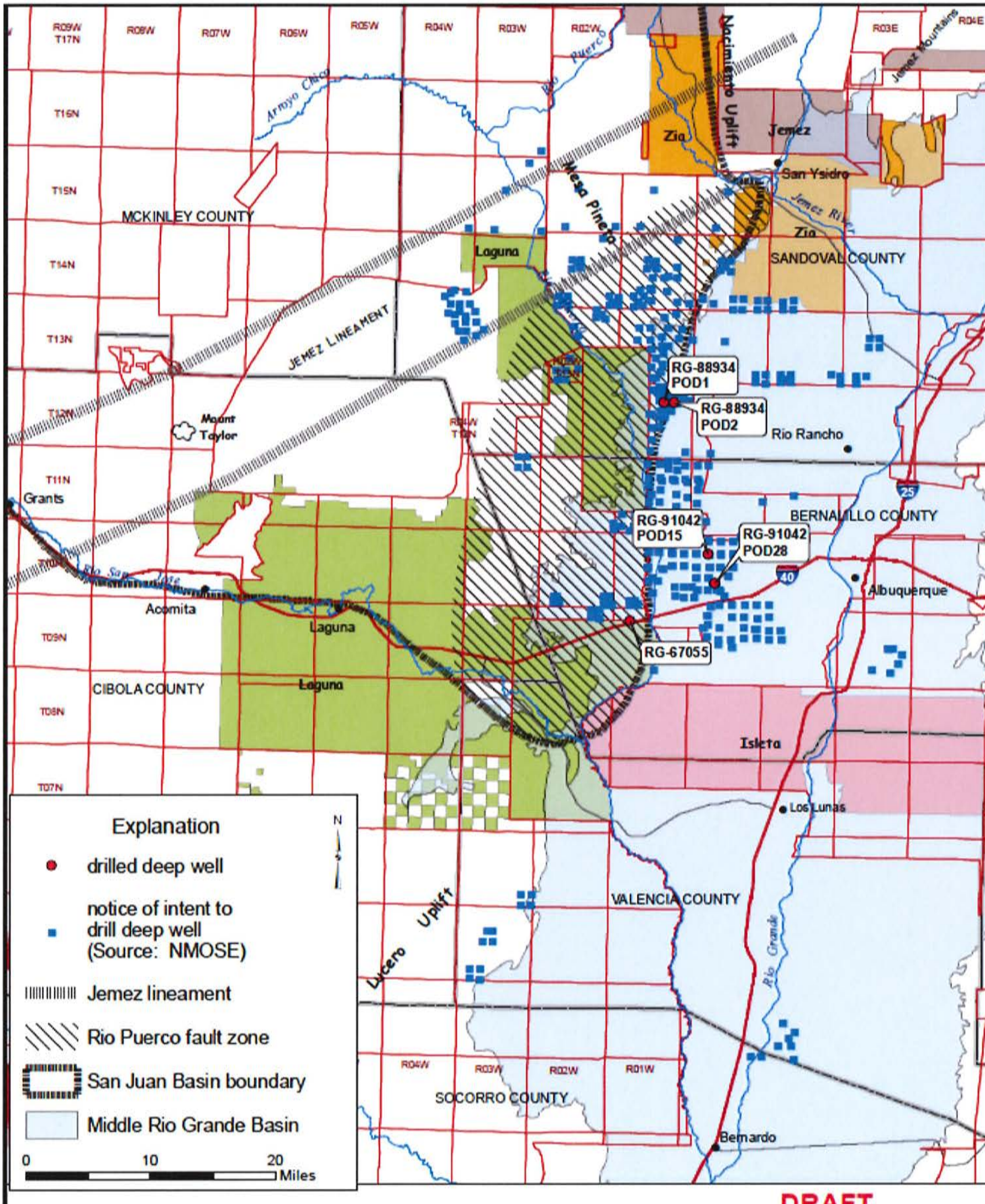
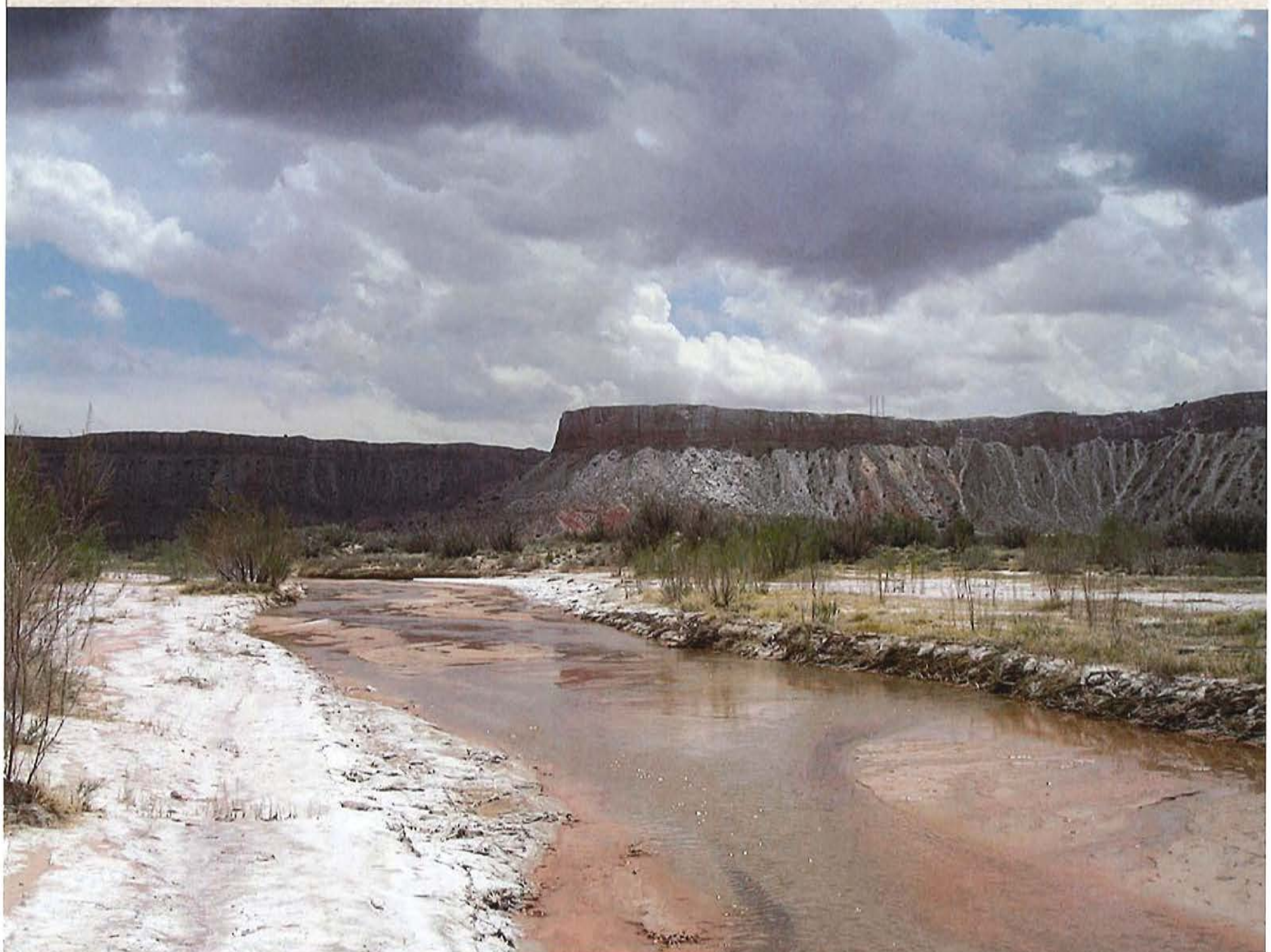


Figure 1. Regional map showing study area, geographic features, and notices of intent to drill a deep well, part of the Middle Rio Grande Basin and the southeastern San Juan Basin.

JOHN SHOMAKER & ASSOCIATES, INC.

PRELIMINARY HYDROGEOLOGIC EVALUATION OF THE COLORADO PLATEAU - MIDDLE RIO GRANDE BASIN TRANSITION NEW MEXICO BASIC DATA COMPILATION



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prepared for

New Mexico
Interstate Stream Commission
Santa Fe

June 30, 2010

PRELIMINARY HYDROGEOLOGIC EVALUATION OF THE COLORADO PLATEAU-MIDDLE RIO GRANDE BASIN TRANSITION, NEW MEXICO BASIC DATA COMPILATION

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PRELIMINARY HYDROGEOLOGIC EVALUATION OF THE COLORADO PLATEAU-MIDDLE RIO GRANDE BASIN TRANSITION, NEW MEXICO BASIC DATA COMPILATION

EXECUTIVE SUMMARY

The purpose of this hydrogeologic evaluation of the Colorado Plateau-Middle Rio Grande Basin transition is to provide basic data to help quantify the natural discharge from the saline bedrock aquifers along the transition to the Middle Rio Grande Basin. An improved understanding of the discharge from the saline bedrock aquifers along the transition will allow the flow in the various bedrock aquifers to be better estimated, will allow important and perhaps distinct recharge zones to be identified, and allow any nearby shallow wells to be identified as important to monitor eventual future saline groundwater withdrawals that would take away a portion of saline subsurface recharge from the Colorado Plateau to the Middle Rio Grande Basin (e.g., Hogan et al., 2007).

In the southwestern U.S., reliable bedrock aquifers are commonly found in Mesozoic-age sandstones or Paleozoic-age limestones (e.g., Dettinger et al., 1995). Saline groundwater makes up seven percent of the alluvial water along the Rio Puerco (Plummer et al., 2004aa). In this study, using a small part of the Plummer et al. (2004a) dataset groundwater collected from Rio Puerco alluvial wells has a higher specific conductance downstream from the confluence with the Rio San Jose possibly due to a large component of saline subsurface recharge that enters the Middle Rio Grande Basin (MRGB) from the northern Lucero Uplift. Field-determined spring flow rates combined with historical data suggest that the northern Lucero Uplift and Rio San Jose area saline springs discharge from bedrock aquifers is 1,780 ac-ft/yr. This is only a fraction of the subsurface recharge entering the MRGB.

CONTENTS

page

TABLES

ILLUSTRATIONS

(follow text)

ILLUSTRATIONS

(follow text)

APPENDICES

(follow illustrations)

Appendix A. Complete list of springs along the Western Boundary of the Middle Rio Grande Basin (MRGB) sorted by UTM number from north to south, and data sorted by geographic area.

Appendix B. Geochemistry of selected wells and springs along the Western Boundary of the Middle Rio Grande Basin (MRGB).

Appendix C. Graphs of streamflow data and gains/losses for the period of record, and for individual years, with stream data files of the Rio Puerco and its tributaries in the study area provided on CD.

ABBREVIATIONS

ac-ft	acre-feet
ac-ft/yr	acre-feet per year
amsl	above mean sea level
bgl	below ground level
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
°C	degrees Celsius
EPA	Environmental Protection Agency
cfs	cubic feet per second
Fig(s).	Figure(s)
ft	foot/feet
gal	gallon(s)
gpm	gallons per minute
hr(s)	hour(s)
in.	inch(es)
in./yr	inches per year
JSAI	John Shomaker & Associates, Inc.
MCL	maximum contaminant level
mg/L	milligrams per liter
min	minute(s)
ml	milliliters
MRGB	Middle Rio Grande Basin
NMBGMR	New Mexico Bureau of Geology and Mineral Resources
NMBMMR	New Mexico Bureau of Mines and Mineral Resources
NMISC	New Mexico Interstate Stream Commission
NMOSE	New Mexico Office of the State Engineer
NMSLO	New Mexico State Land Office
ppm	parts per million
RP	Rio Puerco
RPfz	Rio Puerco fault zone
RSJ	Rio San Jose
SCS	Soil Conservation Service of the U.S. Department of Agriculture
TDS	total dissolved solids
µS/cm	microSiemens per centimeter
USGS	U.S. Geological Survey

PRELIMINARY HYDROGEOLOGIC EVALUATION OF THE COLORADO PLATEAU-MIDDLE RIO GRANDE BASIN TRANSITION, NEW MEXICO

1.0 INTRODUCTION

John Shomaker & Associates, Inc. (JSAI) was contracted by the New Mexico Interstate Stream Commission (NMISC) to perform a hydrogeologic evaluation of the natural discharge from bedrock aquifers along the Colorado Plateau-Middle Rio Grande Basin transition, including the Rio Puerco fault zone (RPfz), Lucero Uplift, and Nacimiento Uplift / Pajarito fault areas in the southeastern San Juan Basin and part of the Middle Rio Grande Basin (Fig. 1). This stage of the evaluation, intended to result in this basic-data report, included the following three tasks:

1. field surveys of spring discharge and quality
    - Nacimiento Uplift / Pajarito fault area springs west of San Ysidro and near Rio Salado
    - springs near Rio San Jose (still pending Pueblo of Laguna approval for access)
2. groundwater-level and groundwater-quality measurements in the Rio Puerco valley
3. streamflow analysis
    - Rio Puerco from available U.S. Geological Survey (USGS) gaging station records
    - seepage runs along Rio Salado between Ojo del Espiritu Santo Grant boundary and the NM-550 bridge in San Ysidro
    - seepage runs along Rio San Jose from Correo to confluence with the Rio Puerco (still pending Pueblo of Laguna approval for access)

1.1 Purpose of Study

The purpose of the study is to summarize basic data and to advance the hydrogeologic evaluation of the Colorado Plateau-Middle Rio Grande Basin transition, in order to quantify the natural discharge from saline bedrock aquifers to the Middle Rio Grande Basin and provide a database of springs, surface water, and wells to assist in the study of possible changes in the groundwater over time. The lack of large, viable shallow alluvial aquifers in the area, and the fact that the Rio Grande is fully appropriated, have led to the exploration of the bedrock aquifer along the fault zone as a potential groundwater resource for future development in the area. Several deep test wells have been completed in the area, and saline groundwater demand of 43,200 acre-feet per year (ac-ft/yr; INTERA, 2008) has been estimated for the Rio West master-planned community in southwestern Sandoval County, immediately east of the study area. Notices of intent to drill a "deep well" under the provisions of Sec. 72-12-25 of the New Mexico statutes have been filed for many other locations in the area (Fig. 1).

1.2 Geographic Setting

The Rio Puerco fault zone (RPfz) comprises a large part of the study area, which extends to the Nacimiento Uplift / Pajarito fault area to the north, and the Lucero Uplift, to the south (Fig. 1). The RPfz is a vast and poorly-accessible area along the middle reach of the Rio Puerco and lying about 25 miles west and northwest of Albuquerque. For the purposes of this study, the RPfz is loosely defined as starting south of Mesa Prieta (south of the Jemez lineament/Puerco Necks area of Hallett et al., 1997) east of the Ignacio monocline of Kelley and Clinton (1960) or the westernmost of RPfz faults, north of the Rio San Jose, and west of the Sand Hill fault zone to San Ysidro in Sandoval County (Fig. 1).

The primary surface drainage of the study area is the Rio Puerco, a large north-to-south tributary to the Rio Grande, with a total watershed area of about 7,000 square miles. Large tributary drainages to the Rio Puerco, from north to south, include Arroyo Chico (1,390 square miles watershed area), Rio San Jose (3,660 square miles watershed area), and several smaller, ephemeral arroyos (http://waterdata.usgs.gov/nm/nwis/sw).

1.3 Land Ownership and Access

Land ownership in the RPfz includes the Pueblo of Laguna, the Tohajiilee community (formerly the Cañoncito Band of the Navajo Nation), Zia Pueblo, Jemez Pueblo, the Bureau of Land Management, the New Mexico State Land Office (NMSLO), King Ranch, and various other ranches. In the western Lucero Uplift, ownership includes the Pueblo of Laguna, Isleta Pueblo, and McKinley Ranch.

Best access to the northern part of the study area (Cabezon area: 70 miles driving distance) is via NM-550 and State Road 279. Access to the western part of the study area is via State Road 279 from NM-124 through Pueblo of Laguna and the turn off to Ceboyeta (La Gotera area: 79 miles driving distance). Alternatively, a slower, but more direct road cuts through the Cañoncito Navajo Reservation to the western part of the study area (La Gotera area: 48 miles driving distance). The southern part of the study area is best reached via a dirt road that parallels the Rio Puerco and starts at the gas station on the northern frontage road alongside I-40 at exit 140. This route ends at the Bernabe M. Montano Grant boundary (Pueblo of Laguna). The eastern part of the study area can be reached via Southern Boulevard SW in Rio Rancho, Encino Road NW, Frost Road NW, and Ranch Road NW to Alamo and Sandoval Ranch (about 32 miles driving distance). Additional access to this area is provided by taking Cabezon Road (BLM-administered Ojito Wilderness turnoff) from NM-550 just south of San Ysidro. Access to the Lucero Uplift is via Bernardo and Socorro County Road 12. This route was only open to the southern boundaries of the Comanche Ranch, owned by the Isleta Pueblo. Access to the northern part of the Lucero Uplift was gained through the Waste Management-operated Valencia County Regional Landfill, just south of NM-6 at Rio Puerco, and across the McKinley Ranch owned by Weldon and Margaret McKinley (phone 505-864-4055 before accessing and obtain written permission to enter at the landfill). Springs at the northern end of the Lucero Uplift can be accessed via NM-6 and the small communities of Correo, Suwannee, and South Garcia. Land in the northern Lucero Uplift is within the Pueblo of Laguna and at this time the Pueblo has not granted permission to access the Rio San Jose, or sample the saline springs on their land. According to the Bureau of Indian Affairs (BIA), one of the liaisons contacted during this study, the request for permission is being studied by the Pueblo.

2.0 HYDROGEOLOGIC SETTING

2.1 Regional Geology

The region that includes the Rio Puerco fault zone has exposed at the surface mostly Jurassic-age, and Cretaceous-age rocks typical of the San Juan Basin (Table 1; Fig. 2). Only in the north near the terminus of the southern Nacimiento Uplift, and in the south near the Lucero Uplift, are deeper, thick shale units of the Triassic-age Chinle Group exposed (Table 1; Fig. 2). Triassic and Paleozoic units are present at depth. The RPfz shares a similar early-Tertiary tectonic history with the uplifts along the western Middle Rio Grande Basin (MRGB).

These uplifts include the Lucero Uplift, the Nacimiento Uplift, and the Mt. Taylor area, where Pliocene-Pleistocene-age basalts cover Mesozoic-age sedimentary rocks. At its southeastern margin, the RPfz is deeply buried by Tertiary-age units associated with Laramide tectonism, Basin and Range faulting, and rifting of the MRGB (e.g., Tedford and Barghoorn, 1999). Presently, the RPfz is tectonically active, characterized by shallow earthquakes, rapid uplift rates, rapid erosion and high sediment yields in stream channels (http://esp.cr.usgs.gov/rio_puerco/).

The RPfz contains predominantly northeast-oriented normal faults with an overall southeast-side-down sense of displacement (Slack, 1975). The RPfz links opposite-polarity uplifts, the Nacimiento Uplift in the north, with a west-side-down geometry, and the Lucero Uplift to the south, with an east-side-down geometry. At its northwest end, the RPfz mostly contains small displacement faults of, at most, several hundred feet (Slack and Campbell, 1975). Faults alternate from steeply northwest-dipping to steeply southeast dipping, repeating a horst-and-graben morphology. Only at its southeastern end do larger displacement, southeast-side-down faults dominate. The Moquino fault, cut by Sandoval County-Recorp deep exploration Well 5 (RG-88934POD1; see Fig. 1), has 2,600 ft of displacement (Sengebush, 2008). Northeast-oriented faults are cut by, and trend into, north-oriented structures that possibly indicate Rio Grande-style rifting superimposed on the earlier-formed RPfz.

Table 1. Geologic units exposed at the surface in the Rio Puerco fault zone

Rio Puerco fault zone			
age (million years ago)		**units**	**map symbol**
0- 23	Neogene	Santa Fe Group sediments of the Middle Rio Grande Basin	QTs
66-101	Upper Cretaceous	Mesaverde Group to Point Lookout Sandstone	Kmv - Kpl
		Lower Mancos Shale	Kmm - Kmd
101 -132	Upper/Lower Cretaceous	Dakota Sandstone	Kd
132-145	Upper Jurassic	Morrison Formation	Jm
		Todilto Limestone	Jt
		Entrada Sandstone	Je
145-160	Upper Triassic	Chinle Group	Trc

2.2 Hydrogeologic Conditions

The average pan evaporation rate of 60 in./yr for the San Ysidro area (SCS, 1972), used for spring flow rate calculations in this study, is comparable with the average gross lake-surface evaporation rates of 50 in./yr for the uplands in the study area, and 65 in./yr along the Rio Puerco (http://www.nm.nrcs.usda.gov). Recharge in the study area occurs primarily as subsurface recharge from the San Juan Basin (Table 2; JSAI, 2009). Potentiometric-surface maps for bedrock aquifers in the study area suggest that the bedrock receives mountain-front recharge from the Zuni Mountains and the Mt. Taylor area (Frenzel, 1992; Baldwin and Anderholm, 1992).

Regional groundwater flow in the study area is eastward, away from the Colorado Plateau, with a head gradient in the San Andres-Glorieta aquifer of 0.008 ft /ft (Rio San Jose area; Frenzel, 1992). The gradient is less steep in the Acoma Sag.

Table 2. Various model estimates of groundwater flow (subsurface recharge) from the San Juan Basin bedrock aquifers to other parts of the basin and the MRGB

area represented in model	affected flow area and direction	estimated flow	reference
San Juan Basin	flow into the MRGB	1,200 ac-ft/yr west to east flow	Frenzel and Lyford, 1983
Acoma Embayment – Eastern Zuni Uplift	flow to the Rio Grande basin	2,949 ac-ft/yr west to east flow	Frenzel, 1992
MRGB	flow into the MRGB	13,598 ac-ft/yr west to east flow	Kernodle et al., 1995
MRGB	flow into the MRGB	13,500 ac-ft/yr west to east flow[1]	Tiedeman et al., 1998
Conceptual model of the MRGB	flow into the MRGB	2,000 ac-ft/yr west to east flow	Sanford et al., 2001
MRGB	flow from the Colorado Plateau into the MRGB	1,568 ac-ft/yr east to west flow	McAda and Barroll, 2002
San Juan Basin	flow to the MRGB	2,000 ac-ft/yr west to east flow	Petronis et al., 2005
MRGB	combined (Western Boundary and SJB) flow into the MRGB	8,442 ac-ft/yr east to west flow	Sanford et al., 2004

[1] includes Rio Puerco flow from model boundary to Rio San Jose confluence and Rio San Jose inflow
MRGB - Middle Rio Grande Basin
ac-ft/yr - acre-feet per year

2.3 Springs

A database of spring within the larger RPfz area was constructed to aid in the field assessment. Sources included Renick (1931), Wright (1946), Titus (1963), Summers (1976), Trainer (1978), Risser and Lyford (1983), Craigg (1984), White and Kues (1992), Newell et al. (2005) and USGS topographic maps of the study area (1:24,000 and 1:100,000 scale). The final database contains 199 springs organized according to geographic area (Fig. 3; Appendix A). Based on historical flow-rate information spanning the time period 1926 to 2000, and excluding the large Horace and Ojo del Gallo Springs near Grants, which are technically outside the study area, these springs typically produced 2,672 ac-ft/yr of saline groundwater with an average total dissolved solids (TDS) concentration of 10,887 milligrams/liter (mg/L) (Appendix A).

The six geographic areas used to organize the spring database include: southern Nacimiento Uplift/Pajarito fault area, Rio Puerco fault zone, Puerco Necks, Mt. Taylor/Acoma Sag, northern Lucero Uplift/Rio San Jose, and Lucero Uplift (Fig. 4 through 9). In the Lucero Uplift area, south of Pueblo of Laguna, springs were analyzed in detail, due to their easy access, and since it is the best exposed Permian-age and Pennsylvanian-age section. The Puerco Necks and the Mt. Taylor springs were not technically within the study area, and these springs were included in the database for completeness only. They will not be further mentioned. Each of the other areas is discussed in detail in the following sections.

2.3.1 Rio Puerco Fault Zone (RPfz)

The RPfz itself contains relatively few springs; the database includes just eight historic springs, of which only one, Sandoval Spring, was found to be flowing (Figs. 8 and 11). This water has a specific conductance of 1,170 microSiemens per centimeter (μS/cm). A calculation based on surface area and evaporation rate suggests that this spring flows at a rate of 36 gallons per minute (gpm). The field chemistry suggests that this spring contains relatively fresh groundwater, in comparison to deeper, saline groundwater with higher specific conductance. Five other visited springs in the RPfz are dry at the surface, though four are accompanied by abundant phreatophytes and salt encrustation that is consistent with evaporation of shallow groundwater and precipitation of dissolved salts.

Ojito Spring (RL-66) and an unnamed spring (topo 49), on Pueblo of Laguna and Zia Pueblo lands respectively, were not visited (Fig. 8). 'La Gotera spring' (informal name; topo 10) and three nearby springs at the intersection of the Ignacio monocline and the Jemez lineament/Puerco Necks (topo 7, topo 8, and topo 9), characterized by numerous Quaternary-age volcanic dikes, plugs, necks, and flows, were not visited.

2.3.2 Nacimiento Uplift/Pajarito Fault Area

At least 34 springs exist in this geographic area, mostly on Zia Pueblo and Jemez Pueblo lands (Fig. 6). Springs near Holy Ghost Spring emanate from a broad dome, referred to as the Holy Ghost – Warm Spring dome within the broader Jemez lineament of Neogene- to Quaternary age volcanism (Woodward and Martinez, 1974). All springs are near the Pajarito fault, marking the edge of the San Juan Basin and the Nacimiento Uplift. Based on historic records, these springs contribute 49.5 gpm to the Rio Salado, which drains east to the Jemez River and the Rio Grande (Appendix A). The travertine mounds in this area are some of the most spectacular of all travertine deposits along the western MRGB, and the most extensive of the travertine deposits exists in the Peñasco – Cuchillo area, where a dozen springs occur (Appendix A; Craigg, 1984). Likewise, within the south-plunging Tierra Amarilla anticline (e.g., Newell et al., 2005), several springs issue forth from extensive travertine deposits.

Many of the travertine mounds associated with the springs, and some associated with dormant springs, appear on the geologic map of the San Ysidro quadrangle (Woodward and Ruetschilling, 1972). To quantify spring flow from the 31 mapped travertine deposits north of NM-550, and the three mapped travertine deposits south of NM-550, a planimeter was used to measure the areas of the travertine deposits. Travertine deposits in the Holy Ghost Spring quadrangle and other travertine deposits in the San Ysidro quadrangle, but within the Jemez River drainage were not measured. The total area of travertine bordering the reach of the Rio Salado along which the seepage run was conducted (between Ojo del Espiritu Santo Grant boundary and the NM-550 bridge in San Ysidro), is about 335 acres. If only the estimated 10 percent of the mapped area of travertine contributes groundwater to the surface, and using pan evaporation of 60 inches per year (in./yr) for the San Ysidro area (SCS, 1972), the travertine deposits contribute about 104 gpm to the surface flow of the Rio Salado in the area. The historically documented spring flow is 49.5 gpm (Summers, 1976; Trainer, 1978; Craigg, 1984).

The average specific conductance of water from all the springs in this area is 10,442 µS/cm, and the average TDS concentration is 7,983 mg/L. Four springs west of the Ojo del Espiritu Santo Grant/Zia Pueblo and along NM-550 were visited (Fig. 6; Table 3). These springs typically consist of a conical travertine spring mound encrusted with salt, with a surface area of 400 to 1,000 ft^2. The center of the mound is filled with water that supports marsh grass, floating on it. On June 4, 2010, discharge from three of the four springs had an average temperature of 23.1°C, a pH of 6.27, and a specific conductance of 10,350 µS/cm, near the average of historic measurements in the area. The fourth spring had water only within the highway ditch about 100 ft downstream of its mound, which was dry. It is excluded from the averages.

Table 3. Summary of water quality at four selected springs, Tierra Amarilla anticline, west of San Ysidro, Sandoval County, New Mexico

appendix-listed spring no.[1]	pH	temperature, °C	specific conductance, µS/cm
sampling event on June 3, 2010			
nac 0	6.26	23.4	9,840
nac 1	6.32	25.3	9,640
field 2	6.22	20.6	11,570
field 5	7.25	30.4	12,330

°C - degrees Celsius µS/cm - microSiemens per centimeter
[1] – Appendix A

2.3.3 Northern Lucero Uplift-Rio San Jose

Forty-six springs are in this geographic area, mostly on the Pueblo of Laguna lands (Fig 3). The most prolific historic springs are along the Rio San Jose where Kelley and Wood (1946) mapped more than a dozen faults cutting Mesozoic-age bedrock. Eight springs are located along the Rio San Jose. The highest flow rate, at 400 gpm, is documented at Dipping Vat Spring (White and Kues, 1992). From historic records (see Appendix A), springs along this reach of the Rio San Jose contributed 520 gpm (839 ac-ft/yr; 1.2 cfs); whereas Risser and Lyford (1983) report a baseflow gain of 3 cfs (1,300 gpm, or 2,200 ac-ft/yr) in this reach, which doubtless represents some groundwater discharge that does not appear in the springs. Along the eastern margin of the Lucero Uplift in this area (Townships 7 and 8 North), travertine mounds are commonplace (e.g., Wright, 1946). They can best be seen by train, and on April 16, 2010 during an afternoon trip from Albuquerque to Grants, several of the drainages below these springs had surface water.

The average specific conductance of all the springs in this area is 19,883 µS/cm, and the average TDS concentration is 20,047 mg/L. In this area, two springs were visited: Lucero Spring and an unnamed spring on private land just west of Mesa Redondo and south of Suwannee. Lucero Spring (Figs. 9, 10 and 13) consists of a salt-encrusted area surrounding a travertine spring mound rising about 10 ft above the surrounding landscape. An orthophotograph of the area (Fig. 10) shows about 24 acres of saline spring deposits surrounding phreatophytes. Assuming the pan evaporation rate of 60 in./yr. (SCS, 1972), the area of 24 acres, and an estimated 10 percent of flow from the total area Lucero Spring is estimated to have a flow rate of 8.5 gpm, whereas the unnamed spring with a bubbling surface pond of about 1,080 ft^2 was estimated to have a flow rate of 5 gpm. Lucero Spring had a water temperature of 17.9°C, pH of 7.05, and specific conductance of 4,760 µS/cm, whereas the unnamed spring had a water temperature of 22.4°C, pH of 6.55, and specific conductance of 16,660 µS/cm.

One of the inaccessible springs, Lower Water Spring, has a large travertine deposit of almost 445 acres, which was visited, but not sampled. The spring is inaccessible, but from the road leading past it, several visible wet areas were noted and therefore its flow rate was evaluated using a possible evaporation of 10 percent of its surface. Using a pan evaporation rate of 60 in./yr. (SCS, 1972), this results in about 150 gpm of flow. Another spring that is currently inaccessible, Suwannee Spring, was visited for a hydrogeologic investigation in 2000, when its flow was estimated at 100 gpm (JSAI, 2000). The eight springs with measurable flow, plus Lower Water and Suwannee Springs, contribute a total of 353 gpm, or about 570 ac-ft/year to the MRGB. Adding the historic flow rates from springs not visited resulted in 656 gpm, or 1,059 ac-ft/yr, of total spring flow for the southern Lucero Uplift area. This compares well with the historic estimate of 599 gpm, or 966 ac-ft/yr using only referenced flow rates (White and Kues, 1992).

2.3.4 Lucero Uplift

A total of 61 springs are documented in the general Lucero Uplift area (Fig. 4). Of these, 39 historic springs are on the Pueblo of Laguna lands and have been separated into a north Lucero Uplift-Rio San Jose springs section of the database (Appendix A), as described in the preceding section. The remaining, accessible 22 springs in the Lucero Uplift area were targeted for survey during the spring of 2010 while we awaited access approval from the Pueblo of Laguna.

The 22 saline springs surveyed are distributed along the eastern boundary of the Lucero Uplift over a distance of about 20 miles (Figs. 4, 11, 12, and 13), and information was compiled from the literature (White and Kues, 1992; Titus, 1963; Wright, 1946; Newell et al., 2005). The list was cross-referenced with springs shown on USGS topographic maps (at 1:100,000, published by the BLM, 2009, and USGS published 1:24,000 scale). In the database, springs identified on topographic maps have a prefix "topo" and springs from the literature have a county "code" prefix referencing their database number in White and Kues (1992). In the Lucero Uplift, one seep was identified in the field and is noted (field) in the database (Appendix A).

Of the 22 springs in the database, 13 were visited, seven were inaccessible and two were duplicate records in the database likely describing the same spring or an area where a spring had historically emanated but is currently not flowing at the surface. The inaccessible springs are south of Mesa Aparejo and on Comanche Ranch (Fig. 4), a property owned by Isleta Pueblo and presently inaccessible. Of the 13 visited sites, five spring sites were dry. Three dry sites had evidence of older and inactive, often dissected, spring mounds or travertine deposits, and had springs within a 2-mile radius and within the same drainage. Two dry spring sites had evidence of surface drainage modification and are currently being used as surface impoundments for ranching.

Eight remaining saline springs had flows ranging from 0.5 to 36 gpm (Fig. 13). Flow was measured using a stopwatch and beaker or bucket, or a portable Parshall flume installed downstream of the spring. Springs that had spring mounds, travertine deposits, or surface salt encrustation also had additional flow calculated by multiplying the area of salt deposition (estimated from GoogleEarth aerial photographs) by the pan evaporation rate (SCS, 1972). This spring evaporation component was added to the flow measured by flume or bucket. The springs had a bimodal flow distribution, two seeps average 1.5 gpm, and six other springs averaged 16 gpm. In addition, six of the inaccessible springs not surveyed contribute from 0.1 to 30 gpm (White and Kues, 1992).

2.3.5 Spring Discharge, and Contribution to the MRGB

Estimates of the rate of discharge from the springs are most useful in understanding of the head and flow characteristics of the deep aquifers. Some spring discharge does contribute to the MRGB groundwater system, but much of the discharge is lost to evaporation before it becomes available for recharge. Many of the spring-flow estimates described above are based, at least in part on discharge area and evaporation rate, and to the extent that the discharge is evaporated at the spring, it cannot reach the MRGB.

The spring discharge along the southern Lucero Uplift occurs over a distance of about 20 miles. This amounts to about 53 ac-ft of saline groundwater per mile along the southern Lucero Uplift. An additional 446 gpm, or 721 ac-ft/yr, of saline groundwater is added in the northern Lucero area (Appendix A). This results in about 1,780 ac-ft/yr of total saline groundwater discharge over 30 to 40 miles along the Lucero Uplift, or an average of 45 to 57 ac-ft/yr per mile. This is similar to the subsurface recharge of 1,534 ac-ft/yr in the McAda and Barroll (2002) model, based on calibration to geochemical data (Sanford et al., 2004; table 2; Western Boundary). This in turn is about half of the Acoma Sag subsurface recharge estimate of 2,949 ac-ft/yr (Frenzel, 1992).

Springs add an additional 85 to 165 ac-ft/yr in the RPfz and the Rio Salado areas (Appendix A). The McAda and Barroll model (2002) represented an inflow to the MRGB of 1,185 ac-ft/yr in this area. A revised total subsurface recharge for the entire western MRGB was recently estimated to be about 8,442 ac-ft/yr (or 106 ac-ft/yr per mile of MRGB boundary; Sanford et al., 2004). This is about four times the spring-flow total estimated in this study. Perhaps three times as much saline groundwater is entering the MRGB in the subsurface, as at the surface. The sum of these would be equivalent to the combined flow through the deep aquifers.

The present companion study performed by the New Mexico Bureau of Geology and Mineral Resources, to investigate fault-zone juxtaposition of individual bedrock aquifers, could help identify additional components of subsurface recharge. Due to the unknown aquifer thickness and unknown fault and fracture characteristics at depth, an increased understanding of the third dimension might lead to revised rates for saline groundwater recharge across the boundary of the MRGB.

2.3.6 Existing Water-Well Data in the Rio Puerco Area

Water well data obtained from Plummer et al. (2004a), combined with wells encountered, checked in the field and cross-referenced with the Plummer et al. (2004a) database are presented in Appendix B. In the field, it was found that stock wells often had their casings welded shut, and about three quarters of the stock wells were found to be inoperable with damaged wellheads, preventing the collection of groundwater data. Seventy-four wells (Appendix B) were included in the water well/geochemistry database largely based on Plummer et al., (2004); whose hydrochemical zones are presented in Figure 15. Wells within Zone 5 (Rio Puerco) of Plummer et al. (2004a), mostly alluvial water wells along the Rio Puerco, had completion depths ranging from 50 to 720 feet below ground level (ft bgl) with a median of 200 ft bgl. Depth to water in these wells ranges from 14 to more than 599 ft bgl with a median of 165 ft bgl.

Three pairs of Rio Puerco valley wells, in close proximity and at similar elevations, were used to look at water level changes over time (Table 4). At least three well-casings were found at the location of stock Well No. 2 (S094/DB387) and the Benavidez Well (RG 24176; see Fig. 14). In the 30 years between measurements water levels in this area appear to have risen by about 47 ft. To the south, at the location of Wells DB175 (USGS 350158106563801) and S185 (Domestic No.31), in 39 years water levels may have risen about 6 ft, but the lack of an elevation for one of the wells renders this questionable. Farther south, at the location of Wells DB026 (USGS 342707106532201) and S032 (Windmill No. 17), on the inaccessible Comanche Ranch, in 43 years water levels may have risen about 0.6 ft, but again, the elevation for one of the wells of the pair is not known.

It would be useful to field-check additional USGS wells from the Plummer et al. (2004a) database, and to build a time series water-level dataset for the area. It could also be beneficial to create a separate database for the large number of domestic wells completed in the Correo-Suwanee area that are not included in the Plummer et al. (2004a) database. Perhaps some of the domestic wells have the potential to be monitoring wells.

Table 4. Wells completed in the Rio Puerco alluvium and historical water-level data from this study and Plummer et al. (2004a)

name/NMOSE File No.	use	distance of separation, ft	surface elevation, ft amsl	well depth ft	water level date	non-pumping water level ft	aquifer
Stock Well No. 02 (S094/DB387)	stk	250	5,700	120	6/20/1980	107.17	Qal
Benavidez Well (RG 24176)	stk	250	5,718	90	6/9/2010	77.5[1]	Qal
350158106563801 (DB175)	stk	1,390	nd	unk	1956	81.21	Qal
Domestic No.31 (S185)	dom	1,390	5,280	150	10/30/1995	75.25	Qal
342707106532201 (DB026)	dom stk	250	nd	70	11/21/1949	34.97	Qal
Windmill No. 17 (S032)	stk	250	4,771	61	2/2/1993	34.4	Qal

[1] - pumping water level
ft amsl - feet above mean sea level
NMOSE - New Mexico Office of the State Engineer
unk – unknown
Qal - Neogene- to Quaternary-age alluvium
stk - stock
dom - domestic

2.4 Groundwater Quality Along the Rio Puerco

The best groundwater quality along the Rio Puerco was found in the Benavidez Well (RG-24176) and Well DB235, within the southern RPfz. During a June 9, 2010 field visit, the Benavidez Well produced 4 gpm from the shallow alluvium east of the Rio Puerco, with a specific conductance of 884 μS/cm. In contrast, Windmill No. 1 (Table 5; Fig. 14), just west of the Rio Puerco and east of the Lucero Uplift (30 miles south of the Benavidez Well) had a specific conductance of 4,040 μS/cm. It appears that the aquifer at the Benavidez Well is recharged by fresher groundwater possibly from the east along the short west-draining streams that cut the western edge of the Llano de Albuquerque. This is also possibly the case for Sandoval Spring, which according to Plummer et al. (2004a) has dilute Rio Puerco and Western Boundary groundwater, or Lucero-sourced groundwater, as part of its make-up. Western Boundary groundwater of Plummer et al. (2004a) is characterized as NaCl-type water with indicative of long residence times in a limestone-evaporite aquifer (Fig. 16).

Wells north of the Rio San Jose confluence have variable specific conductance, ranging from 460 to 6,900 μS/cm and averaging about 3,000 μS/cm. This average value can be compared to the average value of Plummer et al. (2004a) Zone 5 (Rio Puerco), 2,731 μS/cm. There are also large variations in specific conductance downstream along the Rio Puerco (Table 5). The highest specific conductance along the Rio Puerco (DB114; Table 5) occurs just below the confluence of the Rio Puerco and the Rio San Jose, an area thought to be close to a major hydraulic boundary, because the predevelopment potentiometric surface is hypothesized to have had a steep gradient (Plummer et al., 2004a; p.22). This suggests inflow of brine water (NaCl-type) from the Rio San Jose and the Lucero Uplift area. Increases in specific conductance in alluvial wells along the Rio Puerco could also suggest however that a bedrock aquifer source may be discharging locally. Alternatively, differences in groundwater sampling procedures, or well completion in a bedrock unit, and not the alluvial aquifer, could have resulted in specific conductance increases. It would be highly beneficial to start a long-term baseline survey of Rio Puerco alluvial wells and understand in greater detail the contribution of bedrock aquifer-sourced groundwater to the MRGB.

2.5 Chemical Analyses of Saline and Mixed Groundwater

Plummer et al. (2004a) suggest that 7 percent of the groundwater within Zone 5 (Rio Puerco) has its origin at the Western Boundary zone (Table 6) and from a Colorado Plateau bedrock aquifer. Plummer et al. (2004a) also suggest that source rock variation can be detected from the average geochemical make-up of their samples, and not just their geographical location. However, this hypothesis is difficult to confirm due to the variation of bedrock sources, including Pennsylvanian-age and Permian-age rocks south of the Rio San Jose, Jurassic-age and Cretaceous-age rocks north of the Rio San Jose, and Triassic-age rocks in the Rio Salado area. Nonetheless, four geographic groupings of geochemistry data are presented in Table 6. Each of the groupings shows a distinct geochemical identity,

Table 5. Published specific conductance data for wells completed in the Rio Puerco alluvium from north to south (Plummer et al., 2004a, and this study)

name	date	specific conductance, µS/cm
north of Rio San Jose confluence		
Benavidez Well (RG 24176)	6/09/2010	884
350501106571201 (DB235)	6/06/1967	951
350158106563801 (DB175)	6/05/1975	4,360
Domestic No. 31 (S185)	6/16/1997	2,378
345632107003701 (DB132)	4/29/1957	4,910
Windmill No. 07 (S198)	8/21/1996	5,420
345230106591501 (DB114)	4/26/1956	8,540
south of Rio San Jose confluence		
343606106534201 (DB055)	1/09/1950	3,270
343459106535401 (DB051)	6/04/1980	5,100
Windmill No. 31 (S238)	6/24/1997	3,457
Windmill No. 1 (JSAI No. 3)	5/26/2010	4,040
Windmill No. 17 (S032)	6/24/1997	3,804
342707106532201 (DB026)	no date	3,520

Plummer et al., 2004a, appendix A2 µS/cm - microSiemens per centimeter

Table 6. Median values of selected water-quality parameters by hydrochemical zone, western MRGB (after Plummer et al., 2004a, table 8, with data added from Trainer, 1978; Craigg, 1984; Risser and Lyford, 1983; and this study)

constituent	Western Boundary (Lucero of this study)	Rio Puerco	Nacimiento Uplift	Rio San Jose
hydrochemical zone of Plummer et al. (2004a)	5	4	nac	RSJ
specific conductance (µS/cm)	4,572	2,731	11,133	16,144
field pH	7.70	7.50	7.35	7.87
water temperature (°C)	22.0	20.0	23.2	20.0
dissolved oxygen (mg/L)	4.1	3.7	-	-
calcium (mg/L)	135	135	242	307
magnesium (mg/L)	56.4	42.7	50.5	132
sodium (mg/L)	589	290	2,250	4,030
potassium (mg/L)	15.2	10.4	71.8	111
alkalinity (mg/L as HCO_3)	300	190	1,060	1,180
sulfate (mg/L)[2]	**793**	**1,080**	**2,400**	**4,070**
chloride (mg/L)[2]	**820**	185	**1,940**	**4,410**
fluoride (mg/L)[1]	1.64	0.63	**2.70**	0.80
bromide (mg/L)	0.38	0.64	5.3	-
silica (mg/L)	22.5	21.8	18.7	22.5
nitrate (mg/L as N)	0.86	0.88	0.25	-
aluminum (µg/L)[2]	5.00	5.00	**839**	6.00
arsenic (µg/L)[1]	1.8	1.0	**36.5**	**10**

mg/L - milligrams per liter µg/L – micrograms per liter
µS/cm - microSiemens per centimeter °C - degree Celsius
bold – exceeds the EPA-established MCL for public drinking water standards
[1] – subject to the national primary drinking water regulations
[2] – subject to the national secondary drinking water regulations

As mentioned previously, the best groundwater quality is found in the Rio Puerco area (Zone 5 of Plummer et al., 2004a), where recharge from arroyos and from better-quality surface water infiltrates the alluvium. Average groundwater quality in the Rio Puerco area most likely exceeds the EPA maximum contaminant level (MCL) aesthetic standard for TDS, sulfate, and chloride, but is likely below the EPA MCL standards for arsenic and fluoride. Groundwater in the bedrock of the Western Boundary (Lucero Uplift), Rio San Jose, and Nacimiento Uplift/Pajarito fault areas is all quite similar, having sodium, sulfate, and chloride concentrations that are nearly equal, and which make up the majority of the major ions. This suggests that these brines have long residence times, like the water from RG-88934POD1 (JSAI, 2009; see Fig. 1).

Plummer et al. (2004a) indicate that the Rio Salado and Jemez River-sourced groundwater have specific conductance ranging from 530 to more than 11,000 μS/cm, with a median SO_4/Cl concentration ratio of 0.56 and a median Ca/Na ratio of 0.28 for alluvial and Chinle Group groundwater sources. Additionally, Plummer et al. (2004a) indicate that the Triassic-age, Jurassic-age, and Cretaceous-age bedrock aquifers of the RPfz have specific conductance ranging from 1,650 to 41,500 μS/cm, a median SO_4/Cl ratio of 1.2 (and a maximum of 110), and a median Ca/Na ratio of 0.09 for Triassic-age, Jurassic-age, and Cretaceous-age bedrock aquifers within the RPfz. Permian-age and Pennsylvanian-age bedrock aquifers along the Western Boundary (Lucero Uplift) have specific conductance ranging from 3,000 to 45,000 μS/cm, a median SO_4/Cl ratio of 0.58 and a median Ca/Na ratio of 0.13. The similarity of the SO_4/Cl ratio in the saline groundwater geochemistry from the Rio Salado and the Western Boundary is striking. Plummer et al., (2004, p. 67) state that saline groundwater from bedrock aquifers along the Western Boundary with the MRGB is old, on the order of 10,000 years in age, with no tritium, chlorofluorocarbons, or "any other environmental tracer of anthropogenic origin" (Plummer et al., 2004a). It is here suggested that perhaps groundwater from the Western Boundary is oldest, water from the Nacimiento Uplift a bit younger, and groundwater in the Rio Puerco area is mixed (e.g., Plummer et al., 2004a), and possibly youngest. Groundwater in the Nacimiento Uplift could also be affected by volcanic/meteoric water associated with the Jemez lineament, based on the elevated concentrations of fluoride and arsenic in these waters.

2.6 Rio Puerco

According to Stone et al., (1983), the Rio Puerco downstream of its confluence with Arroyo Chico had a mean surface discharge of about 35 cubic feet per second (cfs), or 25,350 ac-ft/yr, based on data for the period of record 1951 to 1977 at the Rio Puerco above Arroyo Chico gage, and the period of record 1943 to 1977 at the Arroyo Chico near Guadalupe gage. Some of this surface water possibly recharges along the RPfz (Stone et al., 1983). To more directly address the nature of Rio Puerco surface flow, and whether there are any gains or losses to the stream across the RPfz, a more detailed year-by-year analysis was performed. This is described in the next section. The Rio Puerco has two major tributaries; Arroyo Chico, north of the RPfz, and Rio San Jose, which crosses the RPfz just north of the Lucero Uplift. Both of the tributaries also have gages (Fig. 17). Two stream gages are additionally present on the main stem of the Rio Puerco in the reach of interest, above the Arroyo Chico confluence, and below the Rio San Jose confluence. The Rio San Jose is documented to have a gain across the RPfz of about 3 cfs (1,300 gpm, or 2,200 ac-ft/yr) between Correo and its confluence with the Rio Puerco (Risser and Lyford, 1983, p. 40). Stone et al. (1983) suggests that vertical groundwater flow between the bedrock aquifers is limited by the many shale layers, except perhaps where faulted, which implies that the reported gain represented upward flow along faults and fractures.

2.6.1 Analysis of Rio Puerco Streamflow From Above Arroyo Chico to Rio Puerco, New Mexico

Rio Puerco streamflow data from the USGS stream gages were analyzed to determine gains or losses across the RPfz. Daily mean discharge at the Rio Puerco gage above Arroyo Chico near Guadalupe, and the gage at Rio Puerco, were compared for the period of overlapping record. Locations of the USGS stream gages used in this analysis are presented in Figure 9 and are about 40 miles apart. In order to directly compare Rio Puerco daily mean discharge upstream and downstream of the fault zone, Arroyo Chico inflow (Arroyo Chico near Guadalupe gage) was added to flow at the upstream gage (Rio Puerco above Arroyo Chico near Guadalupe gage), and Rio San Jose inflow (Rio San Jose at Correo gage) was subtracted from the flow at the downstream gage (Rio Puerco at Rio Puerco).

2.6.1.1 Rio Puerco Streamflow Data

Rio Puerco streamflow datasets used in the analysis are summarized in Table 7. Wherever possible, the USGS-computed daily mean discharge datasets were used in the analysis because these datasets provide a value for each day within the period of record and thus provide greater opportunity for direct comparison of daily mean discharge data. A computed continuous record of flow at a gage is made by the USGS using records of stage and the discharge rating for the gage following the methods of Carter and Davidian (1968). The overlapping period of record for which the corrected Rio Puerco discharge data were compared is February 1948 through December 1976.

Table 7. Summary of datasets used in Rio Puerco streamflow analysis

gaging station	period of record	daily mean discharge dataset
Rio Puerco above Arroyo Chico near Guadalupe, NM	2/28/1948 to 9/30/1951	USGS-measured [a]
Rio Puerco above Arroyo Chico near Guadalupe, NM	10/1/1951 to 6/8/2010	USGS-computed [b]
Arroyo Chico near Guadalupe, NM	10/1/1943 to 6/8/2010	USGS-computed [b]
Rio Puerco at Rio Puerco, NM	3/1/1934 to 12/31/1976	USGS-computed [b]
Rio San Jose at Correo, NM	4/1/1943 to 10/21/1994	USGS-computed [c]

[a] obtained from USGS water quality data for the Nation website
[b] obtained from Philip Bowman, Hydrologist, USGS New Mexico Water Science Center, 6/9/2010 email
[c] obtained from USGS surface-water data for the Nation website
USGS – U.S. Geological Survey

2.6.1.2 Rio Puerco Streamflow Analysis

Graphs of corrected streamflow data and gains/losses for the period of record as well as for individual years are presented in Appendix C. Gains and losses center around zero and fluctuate greatly. The Rio Puerco is an ephemeral reach from above Arroyo Chico south to Rio Puerco, NM, with many days of zero discharge in each year and instantaneous flow rates during monsoon-season storm runoff events peaking in the thousands of cubic feet per second (Stone et al., 1983).

Years with above-average water-year (October of previous year through September of current year) precipitation typically have a period of spring runoff in April and May during which flows greater than 10 cfs are maintained for a week or more. This period of spring runoff is typically absent or negligible in years with below-average water-year precipitation. Table 8 presents annual spring runoff statistics, water-year precipitation at the Albuquerque WSFO airport weather station (chosen for its long record, and only for the purpose of indicating which years were relatively wet or dry) , and average streamflow loss during spring runoff, for the overlapping period of record for which the corrected Rio Puerco discharge data were compared.

Both gains and losses can be observed in the Rio Puerco stream channel across the RPfz during storm runoff events, but during spring runoff seasons, estimated losses average about 27.8 cfs (Table 8). Although there is not a clear trend of increasing losses with increasing daily mean discharge during spring runoff, there appears to be a maximum loss associated with a given rate of discharge, and this maximum increases with increasing discharge (Appendix C, Fig. C31).

Another approach to the question of streamflow gain or loss across the Rio Puerco fault zone was to plot cumulative discharge at the upstream (Rio Puerco near Guadalupe, plus Arroyo Chico near Guadalupe) and downstream (Rio Puerco at Rio Puerco minus Rio San Jose at Correo) gages for the common periods of record between October 1951 and December 1976. That plot (Appendix C, Fig. C32) suggests a tendency for a gain of around 25,000 ac-ft to appear occasionally, then decay. This would be consistent with an occasional storm inflow from an ungaged tributary, but not with a consistent baseflow gain that might be attributed to upward flow from bedrock aquifers. That condition would lead to a greater slope for the cumulative-discharge plot representing the downstream gage.

The decay of the apparent occasional gains is attributable to recharge to shallow groundwater in the alluvium and Santa Fe Formation in the Puerco valley.

Table 8. Annual spring runoff statistics and water-year precipitation

water year	water-year precipitation at Albuquerque, inches	Rio Puerco above Arroyo Chico, spring runoff period (> 10 cfs)	Rio Puerco above Arroyo Chico, no. of days of spring runoff	Rio Puerco at Rio Puerco, spring runoff period (> 10 cfs)	Rio Puerco at Rio Puerco, no. of days of spring runoff	average loss during spring runoff period [b]
1948	7.20	nd	nd	4/21 to 5/13	23	nd
1949	8.51	nd	nd	nd	nd	nd
1950	4.82	nd	nd	nd	nd	nd
1951	4.60	nd	nd	nd	nd	nd
1952	8.15	4/27 to 5/21	25	5/6 to 5/13	8	40.3
1953	4.15	nr	nr	nr	nr	nr
1954	5.56	nr	nr	nr	nr	nr
1955	6.84	nr	nr	nr	nr	nr
1956	3.97	nr	nr	nr	nr	nr
1957	6.83	nr	nr	nr	nr	nr
1958	10.83	4/8 to 6/11	65	4/12 to 6/3	53	40.3
1959	9.96	nr	nr	nr	nr	nr
1960	8.40	4/7 to 5/22	46	4/12 to 4/30	19	25.7
1961	10.61	4/18 to 5/30	43	4/22 to 5/9 [a]	18	24.1
1962	5.12	4/3 to 5/22	50	4/17 to 5/17	31	30.1
1963	8.29	4/8 to 4/24	17	4/13 to 4/19	7	16.4
1964	7.75	nr	nr	nr	nr	nr
1965	7.41	4/22 to 6/7	47	5/5 to 5/29	25	13.4
1966	8.81	nr	nr	nr	nr	nr
1967	7.79	nr	nr	nr	nr	nr
1968	10.03	5/4 to 6/20	48	5/22 to 6/1	11	26.8
1969	8.99	4/2 to 6/1	61	5/5 to 5/28	24	13.7
1970	8.82	4/28 to 6/2	36	5/13 to 5/21	9	28.7
1971	5.39	nr	nr	nr	nr	nr
1972	9.20	nr	nr	nr	nr	nr
1973	14.55	2/24 to 6/29	126	4/25 to 6/20	57	54.6
1974	7.44	nr	nr	nr	nr	nr
1975	10.30	4/12 to 6/20	70	5/13 to 5/26	14	19.1
1976	5.28	nr	nr	nr	nr	nr
average	7.78	-	-	-	-	27.8

[a] two consecutive days with 8 cfs within spring runoff period
[b] average loss during spring runoff period at Rio Puerco above Arroyo Chico
nd - insufficient data
nr - negligible spring runoff
cfs - cubic feet per second

2.7 Rio Salado Seepage Runs

Five stations were chosen to measure streamflow along a 4.3-mile reach of the Rio Salado between the Ojo del Espiritu Santo Grant east boundary and the NM-550 highway bridge at San Ysidro (Fig. 18). Streamflow was measured using a portable Parshall flume as described by Kilpatrick and Schneider (p. 13; 1983). The flume was installed per USGS guidelines, as level as possible with dikes around the flume to prevent flow from passing by along the sides. Additionally, the flume was installed as near as parallel to the flow direction as possible. Given the braided nature of the Rio Salado in the study area, this often posed a challenge. With the exception of Station 5, the flume was installed away from the river banks. The coarseness of the stream bed material made underflow impossible to prevent, and considerable additional flow is likely at all the stations. Kilpatrick and Schneider (1983) warn of considerable overestimation of the streamflow at low heads, with errors of about 7 percent (p. 13; 1983). The Station 5 streamflow rate including the error, for example, would thus be 25.6 ± 1.8 gpm.

Streamflow on the Rio Salado was measured twice, on May 14 and June 3, 2010 (Table 9). Station 1 streamflow was remarkably consistent on both days at 93.4 and 97.9 gpm, respectively. Station 2 streamflow, measured northeast and downstream of the Tierra Amarilla anticline, was also consistent on both days at 107 and 121 gpm, respectively. The May 14, 2010 measurement at Station 2 is likely a minimum, due to considerable underflow and erosion necessitating repeated reconstruction. Station 3 streamflow differed considerably on the two days of measurement. On May 14, 2010, flow at Station 3 was 116 gpm, whereas on June 3, 2010, there was no surface flow at that location. However, on June 3, 2010, groundwater existed just beneath the surface at Station 3, and flow measured about 1,000 ft upstream from Station 3 was 28.3 gpm. Flow was measured only on June 3, 2010, at Stations 4 and 5 due to thunderstorms on May 13, 2010. Station 4 did not have any surface flow on June 3, 2010 and Station 5 had less than 25.6 gpm.

Water quality varied considerably from station to station, as shown in Table 1. From Station 1 through Station 4 specific conductances increases steadily whereas pH varies significantly only at Stations 4 and 5. Station 5 has a significantly lower specific conductance than the other stations. One well, a disconnected windmill with an open casing, well 1

(Fig. 18), surveyed in Section 2 of Township 15 North, Range 1 East, had a depth to water of 11.55 ft bgl on May 14, 2010, and a depth to water of 13.10 ft bgl on June 3, 2010, indicating a groundwater-level drop of 1.55 ft between the two surveying days. The groundwater elevation in this well, situated about 720 ft north of the Rio Salado at a place where the surface water elevation is about 5,482 feet above mean sea level (ft amsl) (when there is surface flow), is 5,474.45 ft amsl, indicating that the water table is 5.55 ft deeper to the north of the Rio Salado, with a hydraulic gradient (0.008 ft/ft). This suggests that the reach downstream of Station 3 is a losing section. This is supported by the lack of surface water at Station 3 and Station 4 on June 3, 2010, as well as the increase in specific conductance between Stations 3 and 4 from 17,920 µS to 30,800 µS. There appears to be evaporation from shallow groundwater beneath the channel, and infiltration of surface water into the streambed, and sediments of the MRGB, east of the San Ysidro fault. The total Rio Salado surface flow of about 107 to 121 gpm (average of 114 gpm – 184 ac-ft/yr) likely infiltrates into the coarse stream sand and recharges the northwestern part of the MRGB within Plummer et al., (2004) zone 3. The total historical spring discharge could also be evaluated with the total Rio Salado flow at Station 1. These two estimated flows differ by a factor of two. However the Rio Salado discharge roughly equals a spring flow calculation based on evaporation rates (Section 2.3.2).

Table 9. Summary of field measurements, Rio Salado del Norte, west of San Ysidro, Sandoval County, New Mexico

station	date	flow, cfs	pH	temperature, °C	specific conductance, µS/cm
UPSTREAM					
1	5/14/2010	0.208	8.30	19.5	13,840
1	6/3/2010	0.218	8.36	20.7	14,440
2	5/14/2010	0.238	8.43	19.4	14,530
2	6/3/2010	0.269	8.35	23.6	15,210
3a	5/14/2010	0.259	8.38	21.4	16,280
3b	6/3/2010	0.063	8.32	26.7	17,920
4	6/3/2010	0	7.71	22.2	30,800
5	6/3/2010	0.057	7.98	29.2	3,150
DOWNSTREAM					

cfs - cubic feet per second
°C - degrees Celsius
µS/cm - microSiemens per centimeter

3.0 CONCLUSIONS

3.1 Saline Springs and Groundwater Recharge

- Based on spring surveying and historical discharge records of saline springs at the edge of the MRGB, at least 1,865 ac-ft/yr discharges from the deep aquifers (Fig. 19).
- Springs most commonly emanate from bedding planes, near basin-bounding faults, along Laramide-age faults or monoclines and along fractures
- The RPfz consists mostly of dry springs, but depending on subsurface geology and juxtaposition of productive aquifers across faults, the PRfz may contribute additional saline groundwater to the MRGB.

3.2 Groundwater Quality

- Brines, as evidence of long residence times within bedrock aquifers, generally originate in the San Juan Basin, and possibly show a regional similarity.
- Locally, better-quality groundwater (fresh-water) is found in the alluvium near areas that likely receive recharge from storm-water runoff, such as Sandoval Canyon and Benavidez Canyon, with storm-water runoff flowing off the Llano de Albuquerque.
- Plummer et al. (2004a) suggest that 7 percent of the water in the Rio Puerco area (Zone 5) is sourced from a deep, saline groundwater source. Well data suggest however that Rio Puerco water quality varies considerably. This could suggest local areas of upwelling where deeper groundwater discharges to the Rio Puerco alluvium. Large variations in groundwater quality could locally exist and wells in this zone might have significantly worse groundwater quality depending on their proximity to discharge sites for bedrock-sourced (saline) groundwater.

3.3 Surface Water

- The Rio Puerco loses surface water during spring run-off periods at an average rate of 27.8 cfs across the RPfz. This equals an annual loss across the RPfz that averaged 1,454 ac-ft/yr and ranged from 0 to 6,937 ac-ft/yr between 1952 and 1976 during spring runoff periods. On the other hand, cumulative discharge comparison for gages upstream and downstream from the RPfz do not suggest a consistent gain or loss.
- Rio Salado average surface water loss across the RPfz, and thus inflow to the MRGB, on two days in the late spring of 2010 was 184 ac-ft/yr. It is unknown how much this varies with season and from year to year. This compares well with an estimated spring contribution to the Rio Salado of between 85 and 165 ac-ft/yr (see Section 2.3.2).

4.0 RECOMMENDATIONS

4.1 Water Balance for the Mt. Taylor Area

A new effort could be made to calculate the water balance for the Mt. Taylor recharge area, since approximate spring discharge rates along the MRGB boundary have now been determined. This would involve calculation of precipitation and recharge for the entire Mt. Taylor and Mesa Chivato area, and comparison of calculated recharge with previous estimates for Mt. Taylor and nearby comparable highlands, including the Zuni Uplift (cf. Frenzel, 1992).

4.2 Continuation of Spring and Well Survey on Pueblo of Laguna Lands, if access permitted

- Several large springs have not been surveyed in detail in the area of the Rio San Jose.
- Characterize and sample the numerous travertine seeps and saline springs along the western Lucero Uplift between Rio Puerco and Suwannee.
- Make a reconnaissance survey of the springs in the Puerco Necks area, since no record of these springs currently exists (they were identified on a topographic map).
- Identify wells with largest saline groundwater components and propose long-term water-level and water-quality monitoring.

4.3 Model Update

- Modify the HFB (the barrier-to-horizontal-flow package) in the current JSAI model to allow for more detailed fault leakance and sealing in areas that act hydrogeologically as such.
- Calibrate the model to spring flow.

5.0 REFERENCES

Baldwin, J.A., and Anderholm, S.K., 1992, Hydrogeology and groundwater chemistry of the San Andres-Glorieta Aquifer in the Acoma Embayment and Eastern Zuni Uplift, West-Central New Mexico: U.S. Geological Survey Water-Resources Investigations Report 91-4033, 304 p. and 2 plates.

Bureau of Land Management, 2009, Surface Management Status 30 x 60 minute series (topographic) map of Acoma Pueblo, New Mexico: U.S. Department of the Interior, Bureau of Land Management, scale 1:100,000

Carter, R.W., and Davidian, J., 1968, General procedure for gaging streams: Techniques of Water-Resources Investigations of the U.S. Geological Survey, Chapter A6, Book 3 (TWI 3-A6) Applications of Hydraulics, 13 p.

Craigg, S.D., 1984, Hydrologic Data on the Pueblos of Jemez, Zia, and Santa Ana, Sandoval County, New Mexico: U.S. Geological Survey Open-File Report 84-460, 37p., and two plates.

Dettinger, M.D., Harrill, J.R., Schmidt D.L., and Hess, J.W., 1995, Distribution of carbonate rock aquifers and the potential for their development, southern Nevada and parts of Arizona, California and Utah: U.S. Geological Survey Water-Resources Investigations Report 91-4146, 100 pp.

Frenzel, P.F., 1992, Simulation of groundwater flow in the San Andres-Glorieta Aquifer in the Acoma Embayment and Eastern Zuni Uplift, West-Central New Mexico: U.S. Geological Survey Water-Resources Investigations Report 91-4099, 381 p.

Hallett, R.B., Kyle, P.R., and McIntosh, W.C., 1997, Paleomagnetic and 40Ar/39Ar age constraints on the chronologic evolution of the Rio Puerco volcanic necks and Mesa Prieta, west-central New Mexico: Implications for transition zone magmatism: Geological Society of America Bulletin, v. 109, n. 1, pp. 95-106.

Hogan, J.F., Phillips, F.M., Mills, S.K., Hendrickx, J.M.H., Ruiz, J., Chesley, J.T., and Asmerom, Y., 2009, Geologic origins of salinization in a semi-arid river: The role of sedimentary basins brines: Geology, V. 35, No. 12, pp. 1063-1066.

Hood, J.W., and Kister, L.R., 1962, Saline-Water Resources of New Mexico: U.S. Geological Survey Water-Supply Paper 1601, 70 p.

INTERA, 2008, Draft Sandoval County Rio Puerco basin water development project, aquifer test and analysis report: consultant's report to Sandoval County, 46 p.

[JSAI] John Shomaker & Associates, Inc., 2000, Hydrogeologic evaluation and results of groundwater flow model for the proposed gravel pit at the Day Ranch site near I-40 and Highway 6, Valencia County, New Mexico: Consultants Report, 8 p.

[JSAI] John Shomaker & Associates, Inc., 2009, Interim Report of Regional Groundwater-Flow Model to evaluate the effects of deep bedrock groundwater withdrawals on the Middle Rio Grande Basin Aquifer System: Consultants Report, 56 p and appendices.

Kelley, V.C., and Clinton, N.J., 1960, Fracture systems and tectonic elements of the Colorado Plateau: University of New Mexico Publications in Geology Number 6, 104 p.

Kelley, V.C., and Wood, G.H., 1946, Lucero Uplift, Valencia, Socorro, and Bernalillo Counties, New Mexico: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 47, 1 sheet.

Kelly, T.E., 1974, Reconnaissance Investigation of Ground Water in the Rio Grande Drainage Basin – with special emphasis on saline ground-water resources: U.S. Geological Survey Hydrologic Investigations Atlas HA-510, scale 1:250,000

Kernodle, J. M., McAda, D. P., and Thorn, C. R., 1995, Simulation of ground-water flow in the Albuquerque Basin, central New Mexico, 1901-1994, with projections to 2020: U.S. Geological Survey Water-Resources Investigations Report 94-4251, 114 p.

Kilpatrick, F.A., and Schneider, V.R., 1983, Use of flumes in measuring discharge: Techniques of Water-Resources Investigations of the United States Geological Survey, Chapter A14, Book 3 (TWI 3-A14), 46 p.

McAda, D.P., and Barroll, P., 2002, Simulation of groundwater flow in the Middle Rio Grande Basin between Cochiti and San Acacia, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 02-4200, 81 p.

Newell, D.L., Crossey, L.J., Karlstrom, K.E., Fischer, T.P., and Hilton, D.R., 2005, Continental-scale links between the mantle and groundwater systems of the western United States: Evidence from travertine springs and regional He isotope data: GSA Today, V. 15, No. 12, pp. 4-10.

Newell, D.L., 2007, Hydrochemistry of CO_2-rich mineral springs: Implications for tectonics and microbiology: University of New Mexico Department of Earth and Planetary Sciences, Ph.D. dissertation, 156 p. and maps.

Petronis, L.H., Finch, S.T., Freiherr Von Schwerin, C., Shomaker, J.W., and Coward R., 2005, Hydrogeologic study of the Jicarilla Apache Nation and development of a regional groundwater-flow model: consultant's report for the Jicarilla Apache Nation, 96 p., plus figures and appendices.

Phillips, F.M., Hogan, J., Mills, S., and Hendrickx, J.M.H., 2003, Environmental tracers applied to quantifying causes of salinity in arid-region rivers: Preliminary results from the Rio Grande, Southwestern USA: *in* Alsharlan, A.S., and Wood, W.W., editors, Water Resources Perspectives: Evaluation, Management, and Policy: Developments in Water Science, V. 50: Amsterdam, Elsevier Science, pp. 327-334.

Plummer, L.N., Bexfield, L.M., Anderholm, S.K., Sanford, W.E., and Busenberg, E., 2004a, Geochemical characteristics of groundwater flow in the Santa Fe Group aquifer system, Middle Rio Grande Basin, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 03-4131, 395 p. with tables and CD-ROM.

Plummer, L.N., Sanford, W.E., Bexfield, L.M., Anderholm, S.K., and Busenberg, E., 2004b, Using geochemical data and aquifer simulation to characterize recharge and groundwater flow in the Middle Rio Grande Basin, New Mexico: *in* Groundwater recharge in a desert environment: The Southwestern United States, Hogan, J.F., Phillips, F.M., Scanlon, B.R., eds., AGU Monograph Series, Water Science and Application 9, pp. 185-216.

Renick, B. C., 1931, Geology and groundwater resources of western Sandoval County, New Mexico: U.S. Geological Survey Water-Supply Paper 620, 117 p.

Risser, D.W., and Lyford, F.P., 1983, Water resources on the Pueblo of Laguna, West-Central New Mexico: U.S. Geological Survey Water-Resources Investigations Report 83-4038, 308 p. and several plates.

Sanford, W.E., Plummer, N.L., McAda, D.P., Bexfield, L.M., and Anderholm, S.K., 2001, Estimation of hydrologic parameters for the groundwater model of the Middle Rio Grande Basin using Carbon-14 and water-level data: *in* Cole, J.C., Editor, U.S. Geological Survey Middle Rio Grande Basin Study-Proceedings of the Fourth Annual Workshop, Albuquerque, New Mexico, February 16-16, 2000: U.S. Geological Survey Open-File Report 00-488, pp. 4-6.

Sanford, W.E., Plummer, N.L., McAda, D.P., Bexfield, L.M., and Anderholm, S.K., 2004, Hydrochemical tracers in the middle Rio Grande Basin, U.S.A.: 2. Calibration of a groundwater-flow model: Hydrogeology Journal, v. 12, n. 4, pp. 389-407.

SCS, 1972, Gross annual lake evaporation New Mexico: U.S. Department of Agriculture, Soil Conservation Service, 1 map sheet no. 4-R-33582.

Sengebush, R.M., 2008, Structural and stratigraphic controls of deep brackish water exploration, Rio Puerco Basin, New Mexico: Proceedings Volume of the 2008 Spring Meeting of the New Mexico Geological Society, Socorro, New Mexico, 47 p.

Slack, P.B., 1975, Tectonic development of the northeast part of the Rio Puerco fault zone, New Mexico: Geology, v. 3, n. 11, pp. 425-434.

Slack, P.B., and Campbell, J.A., 1976, Structural Geology of the Rio Puerco fault zone and its relationship to central New Mexico tectonics: New Mexico Geological Society Special Publication 6, pp. 46-52.

Spiegel, Z., 1955, Geology and Ground-water resources of Northeastern Socorro County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Ground-Water Report 4, 99 p. and several plates.

Stone, W.J., Lyford, F.P., Frenzel, P.F., Mizell, N.H., and Padgett, E.T., 1983, Hydrogeology and water resources of the San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 6, 70 p. and several plates.

Summers, W.K., 1976, Catalog of thermal waters in New Mexico: New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 4, 80 p. and microfiche appendix.

Tedford, R.H., and Barghoorn, S., 1999, Santa Fe Group (Neogene), Ceja del Rio Puerco, northwestern New Mexico: *in* Guidebook of Albuquerque Geology: New Mexico Geological Society, 50th field conference, pp. 327-235.

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

Titus, F. B., Jr., 1963, Geology and groundwater conditions in eastern Valencia County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Groundwater Report 7, 113 p., plus plates.

Trainer, F.W., 1978, Geohydrologic data from the Jemez Mountains and vicinity, north-central New Mexico: U.S. Geological Survey Water-Resources Investigations 77-131, 146 pp.

White, W. D., and Kues, G. E., 1992, Inventory of springs in the State of New Mexico: U.S. Geological Survey Open-File Report 92-118, 253 p.

Williams, P.L., and Cole, J.C., 2007, Geologic Map of the Albuquerque 30' x 60' quadrangle, north-central New Mexico: U.S. Geological Survey Scientific Investigations Map 2946, 31 pp and plate.

Wright, H.E., 1946, Tertiary and Quaternary geology of the Lower Rio Puerco area, New Mexico: Bulletin of the Geological Society of America, V. 57, pp. 383-456, 10 pls., 12 figs.

Woodward, L. A., and Martinez, R., 1974, Geologic Map and Sections of Holy ghost Spring Quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources Geologic Map 33, scale 1:24,000.

Woodward, L. A., and Ruetschilling, R.L., 1972, Geology of San Ysidro Quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources Geologic Map 37, scale 1:24,000.

ILLUSTRATIONS

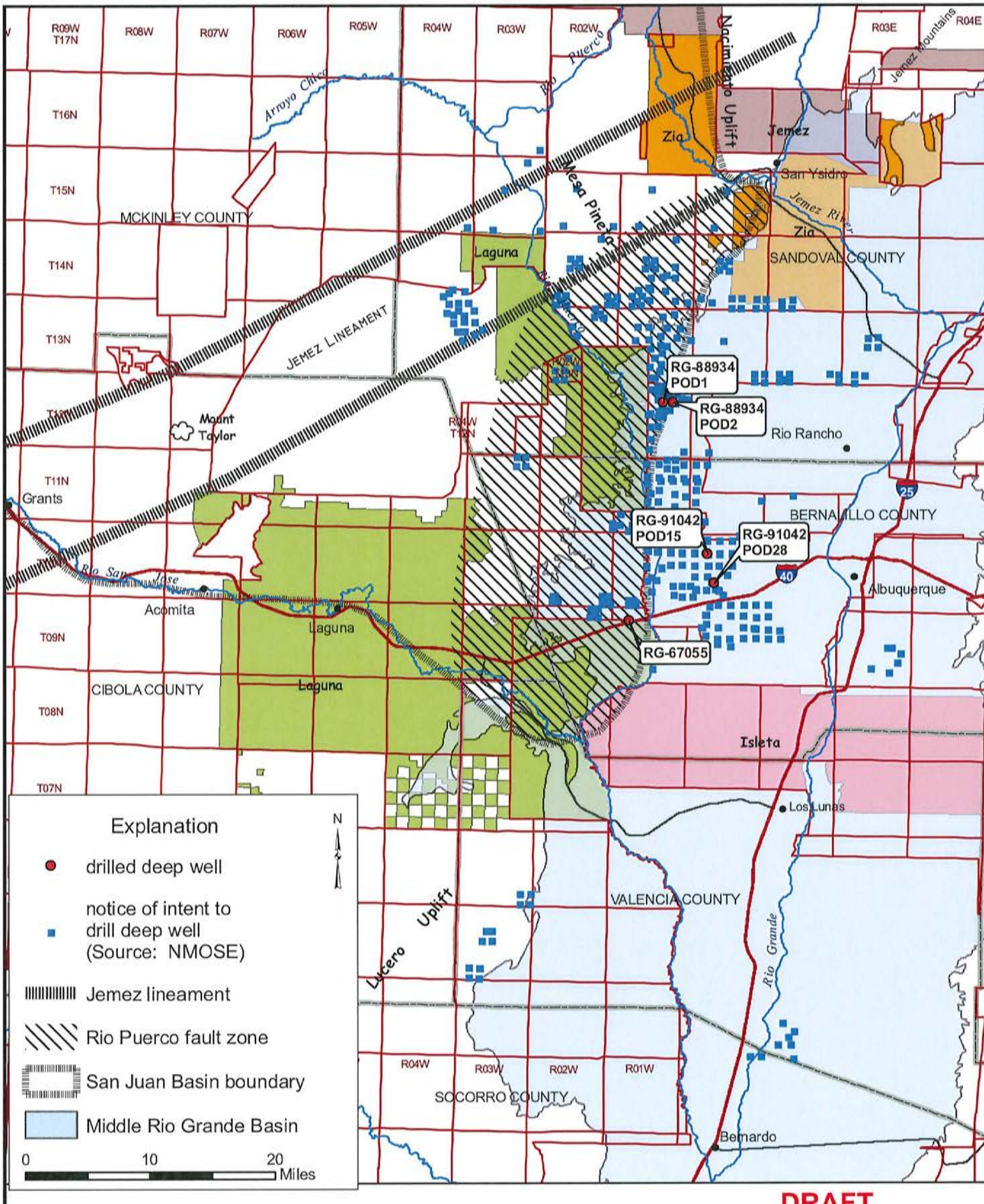

Figure 1. Regional map showing study area, geographic features, and notices of intent to drill a deep well, part of the Middle Rio Grande Basin and the southeastern San Juan Basin.

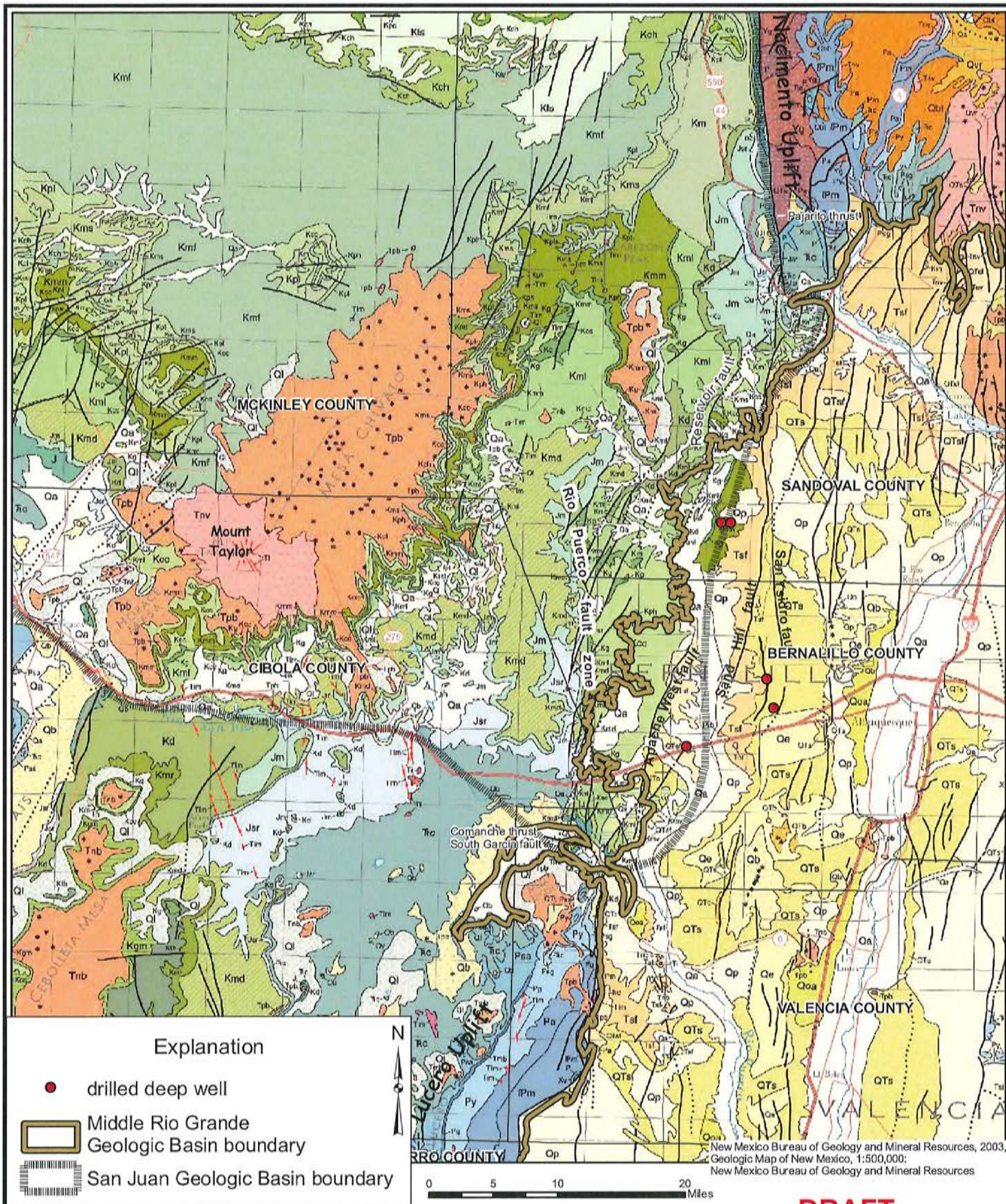

Figure 2. Geologic map of the study area, part of the Middle Rio Grande Basin and the southeastern San Juan Basin.

QTt	Quaternary-age travertine
Ql	Quaternary-age landslide deposits
Qb	Quaternary-age basalts
Qp	Quaternary-age piedmont
Qa	Quaternary-age alluvium
Qe	Quaternary-age Eolian deposits
Qoa	Quaternary-age older alluvium
QTs	Tertiary-age Upper Santa Fe Group
QTsf	Quaternary- & Tertiary-age Santa Fe Group (undiv.)
Tpb	Tertiary-age andesite - basalt flow
Tsf	Tertiary-age Lower & Middle Santa Fe Group
Ti	Tertiary-age intrusive rocks
Kmf	Cretaceous-age Menefee Formation
Kmv	Cretaceous-age Mesaverde Formation
Kmu	Cretaceous-age Upper Mancos Shale
Km	Cretaceous-age Mancos Shale (undivided)
Kms	Cretaceous-age Satan member of the Mancos Shale
Kph	Cretaceous-age Hosta member of the Point Lookout Sandstone
Kpl	Cretaceous-age Point Lookout Sandstone
Kcc	Cretaceous-age Crevasse Canyon Formation
Kmm	Cretaceous-age Mulatto member of the Mancos Shale
Kml	Cretaceous-age Lower Mancos Shale
Kg	Cretaceous-age Gallup Sandstone
Kmd	Cretaceous-age Dakota - Mancos interbedded sequence
Kd	Cretaceous-age Dakota Formation
Jm	Jurassic-age Morrison Formation
Jsr	Jurassic-age San Rafael Group (includes (Jt) Todilto Limestone and (Je) Entrada Sandstone)
TRc	Triassic-age Chinle Group (includes (TRaz) Agua Zarca Formation)
Psa	Permian-age San Andres Formation
Py	Permian-age Yeso Formation
Pa	Permian-age Abo Formation
IPu	Pennsylvanian-age Madera Formation
P€	Lower Proterozoic-age granites
	fault

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Figure 2a. Simplified explanation of units found on Figure 2 (from NM Bureau of Geology and Mineral Resources, 2003).

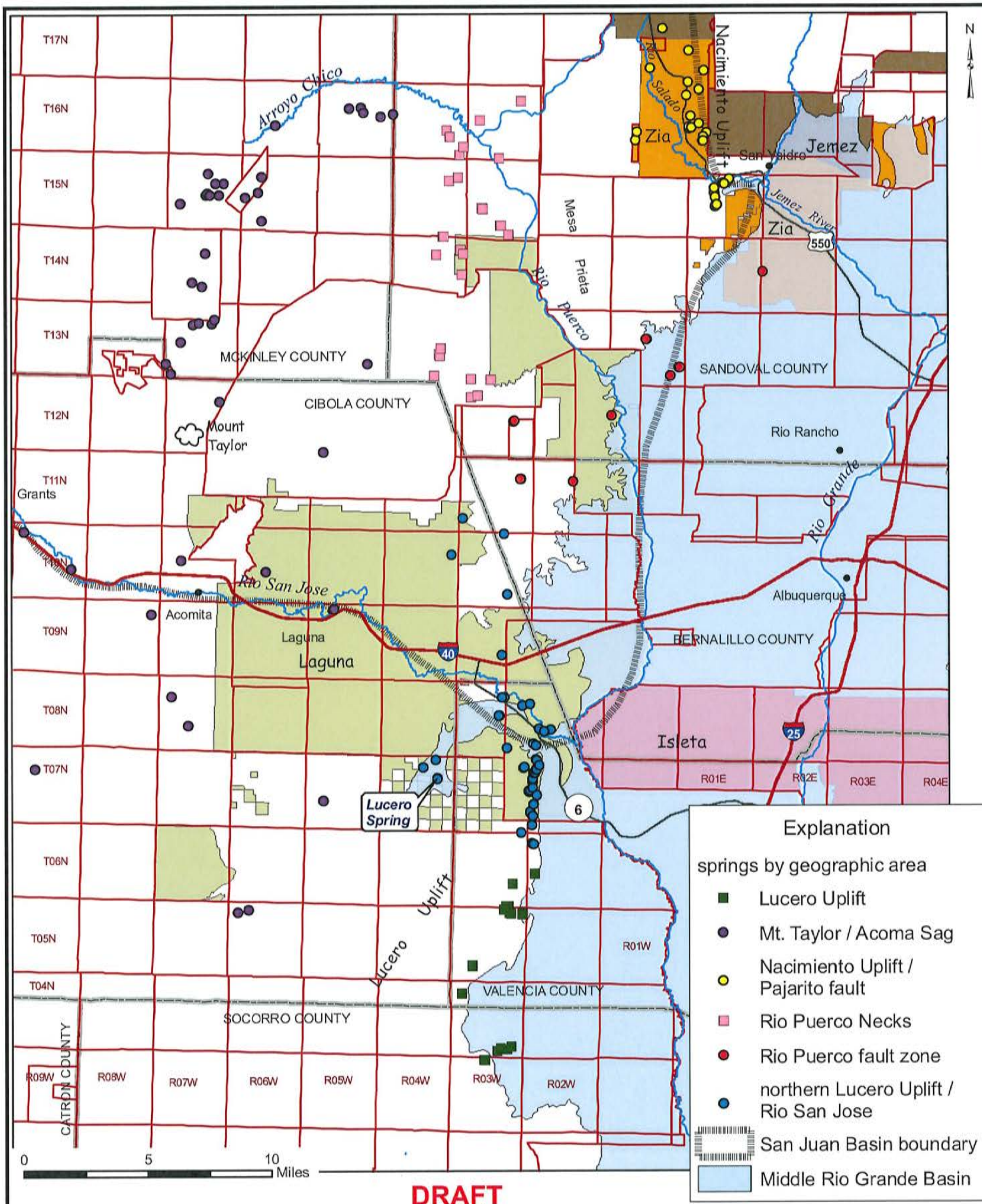

Figure 3. Map showing all springs on record in and around the study area organized according to geographic area, part of the Middle Rio Grande Basin and southeastern San Juan Basin.

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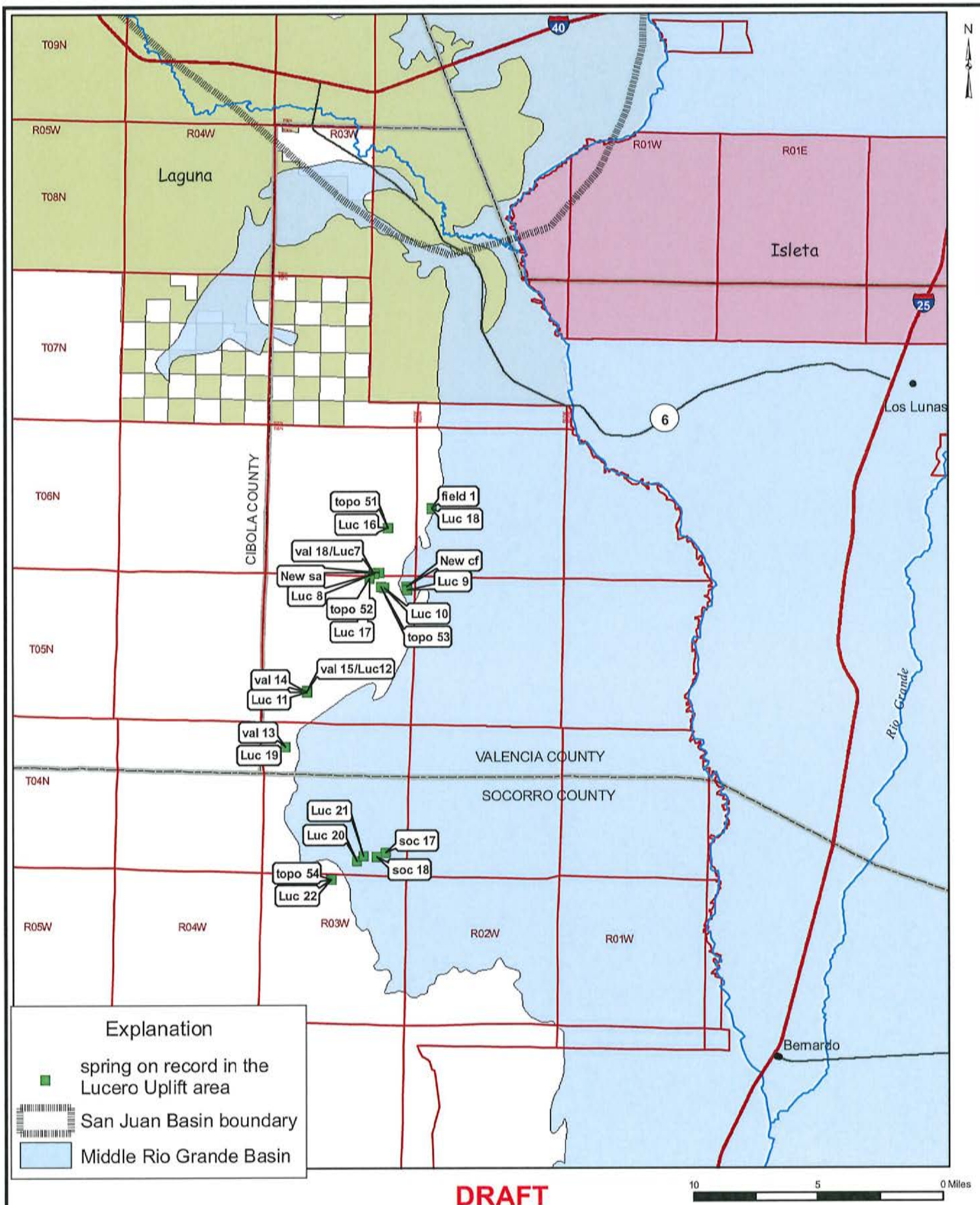

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Figure 4. Map showing springs on record in the Lucero Uplift area.

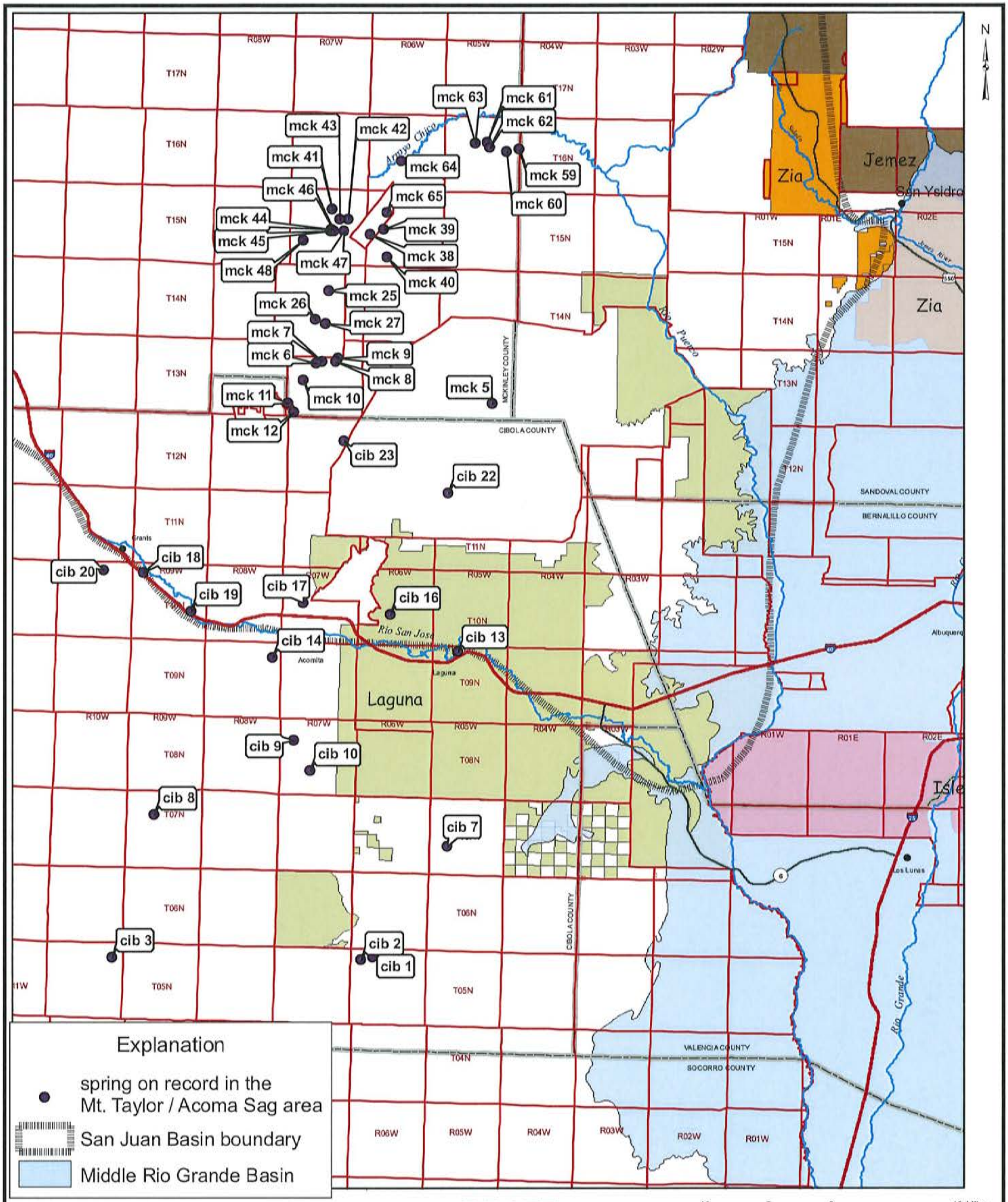

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Figure 5. Map showing springs on record in the Mt. Taylor - Acoma Sag area.

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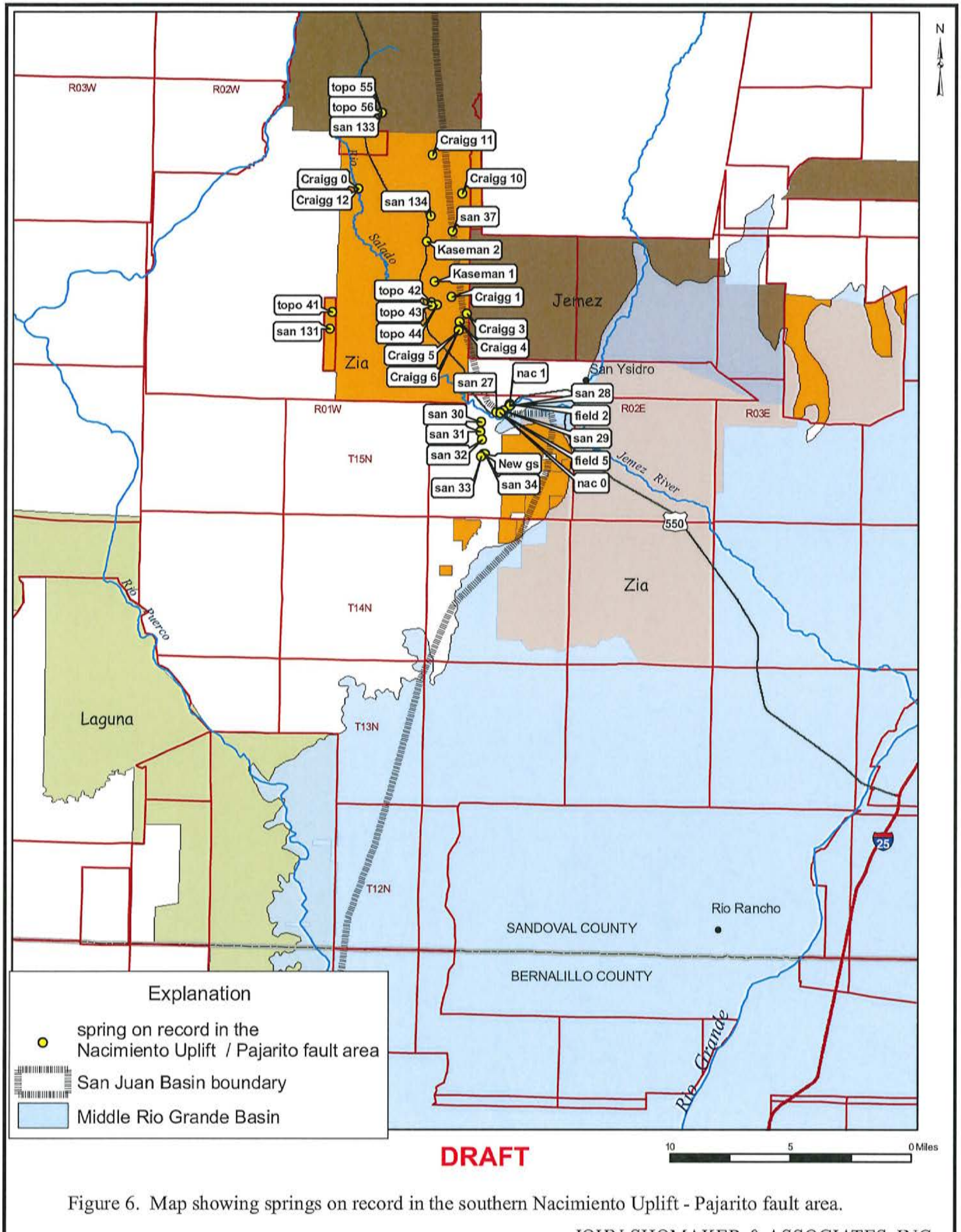

Figure 6. Map showing springs on record in the southern Nacimiento Uplift - Pajarito fault area.

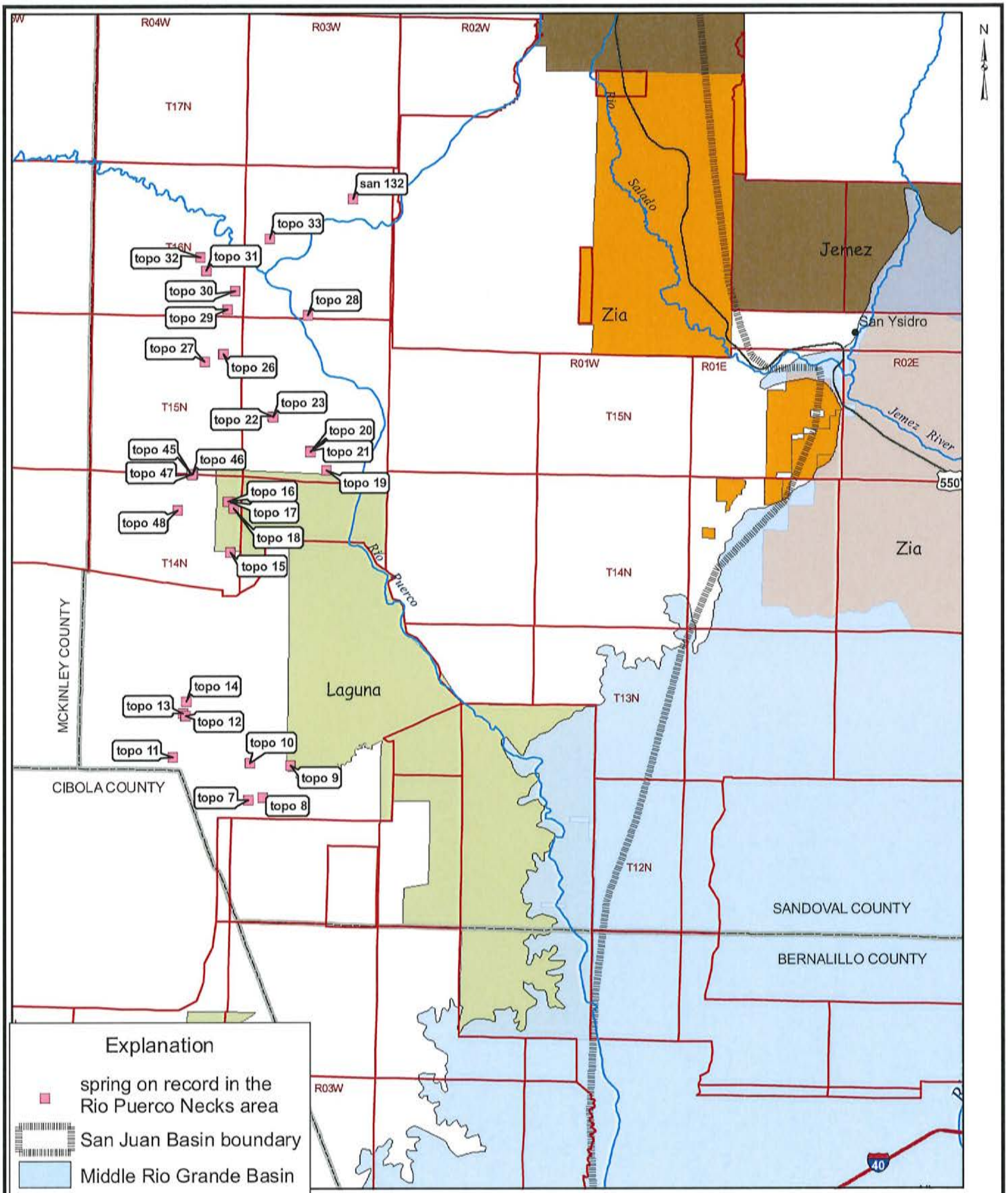

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Figure 7. Map showing springs on record in the Rio Puerco Necks area.

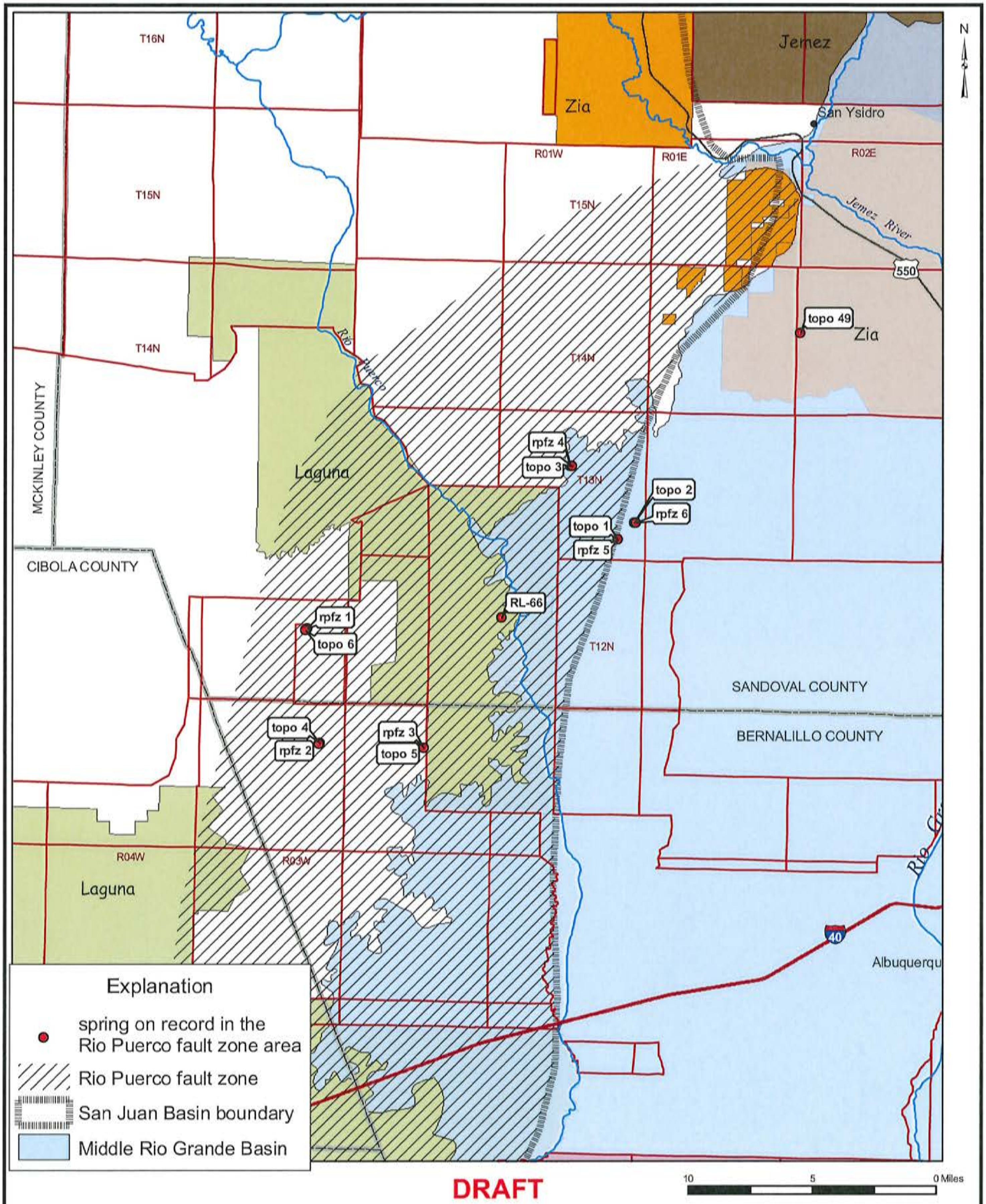

Figure 8. Map showing springs on record in the Rio Puerco fault zone.

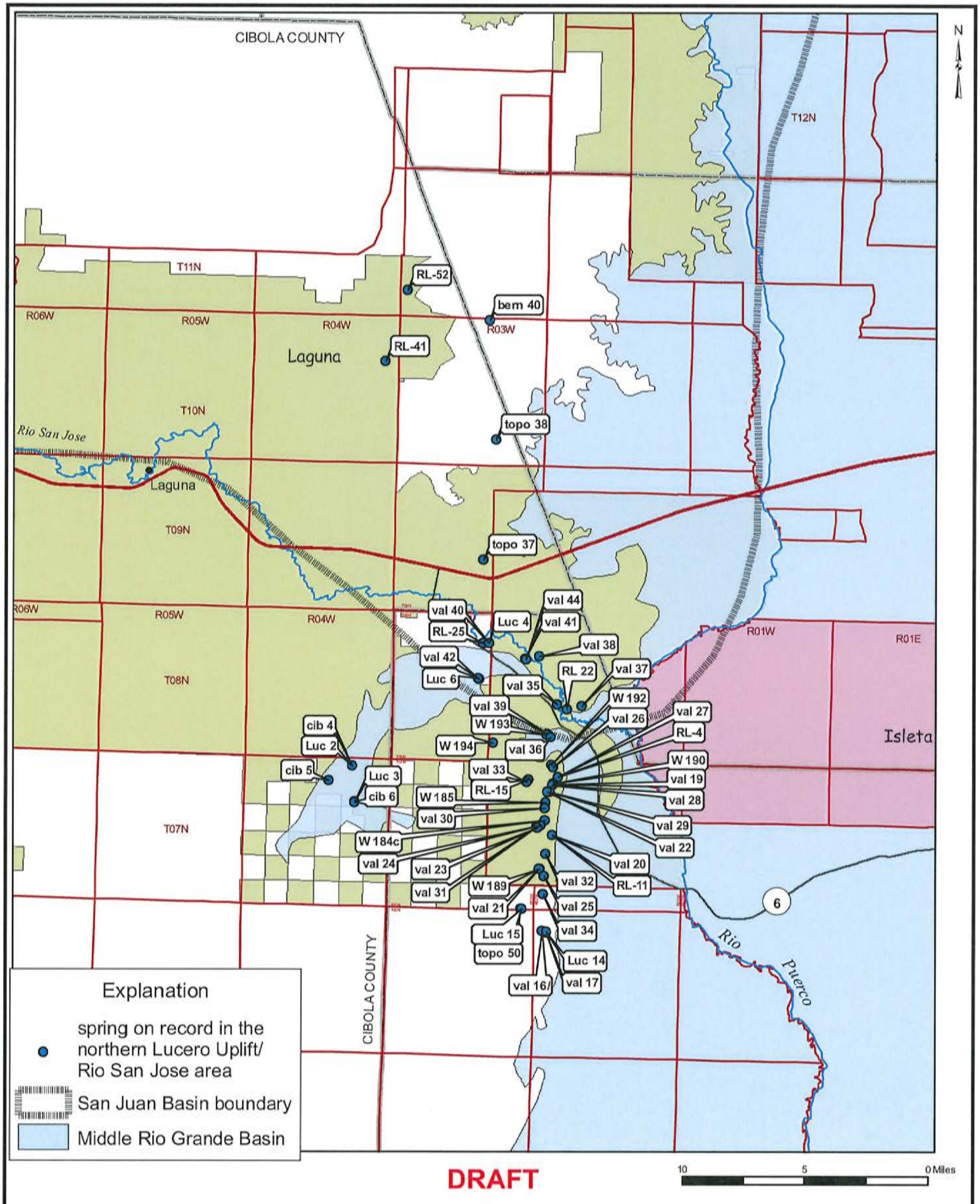

Figure 9. Map showing springs on record in the northern Lucero Uplift - Rio San Jose area.

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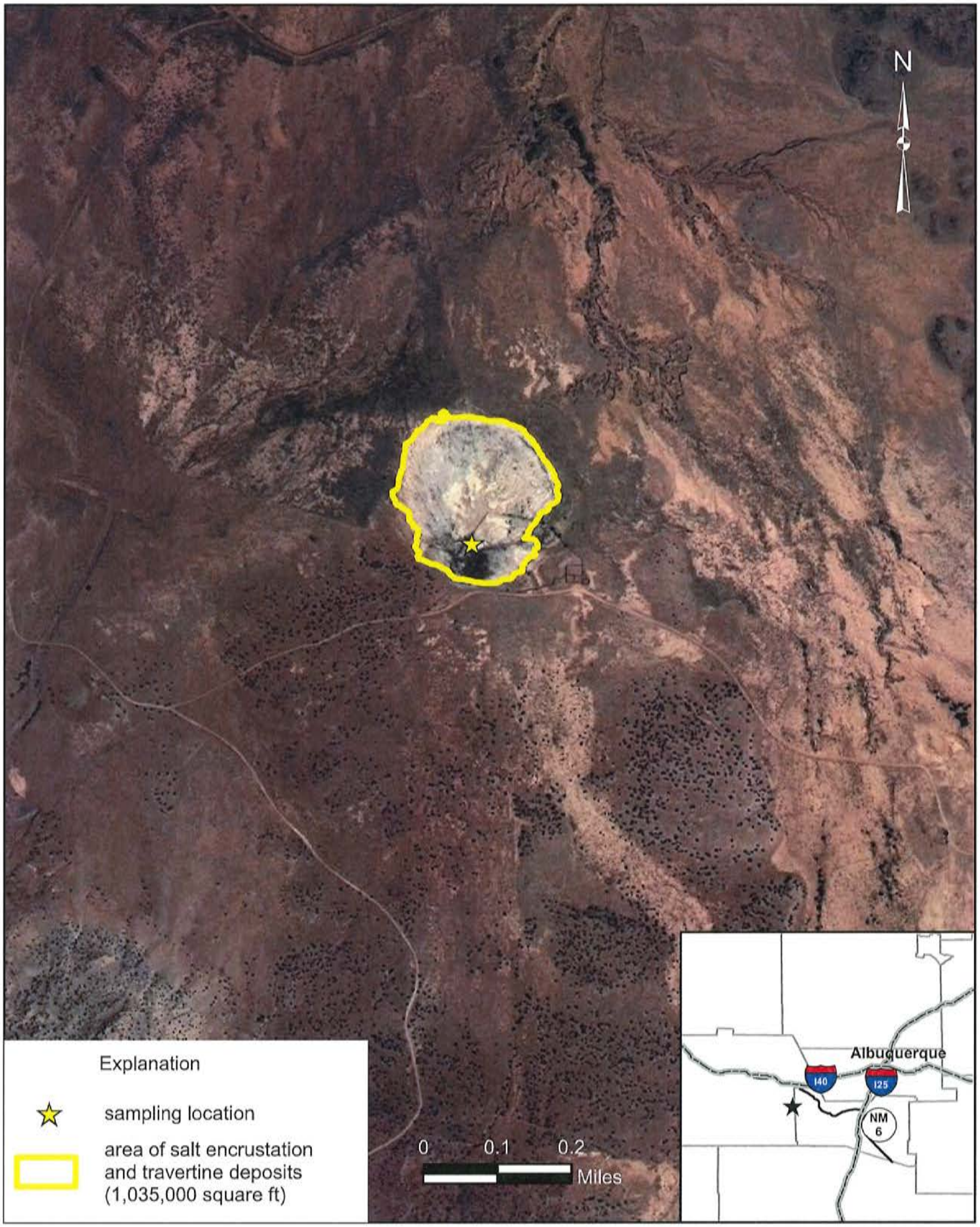

Figure 10. Orthophotograph showing Lucero Springs, New Mexico, and sampling location. Area of salt encrustation and travertine deposits was used to estimate a flow rate based on gross-annual lake-surface evaporation rates (SCS, 1972).

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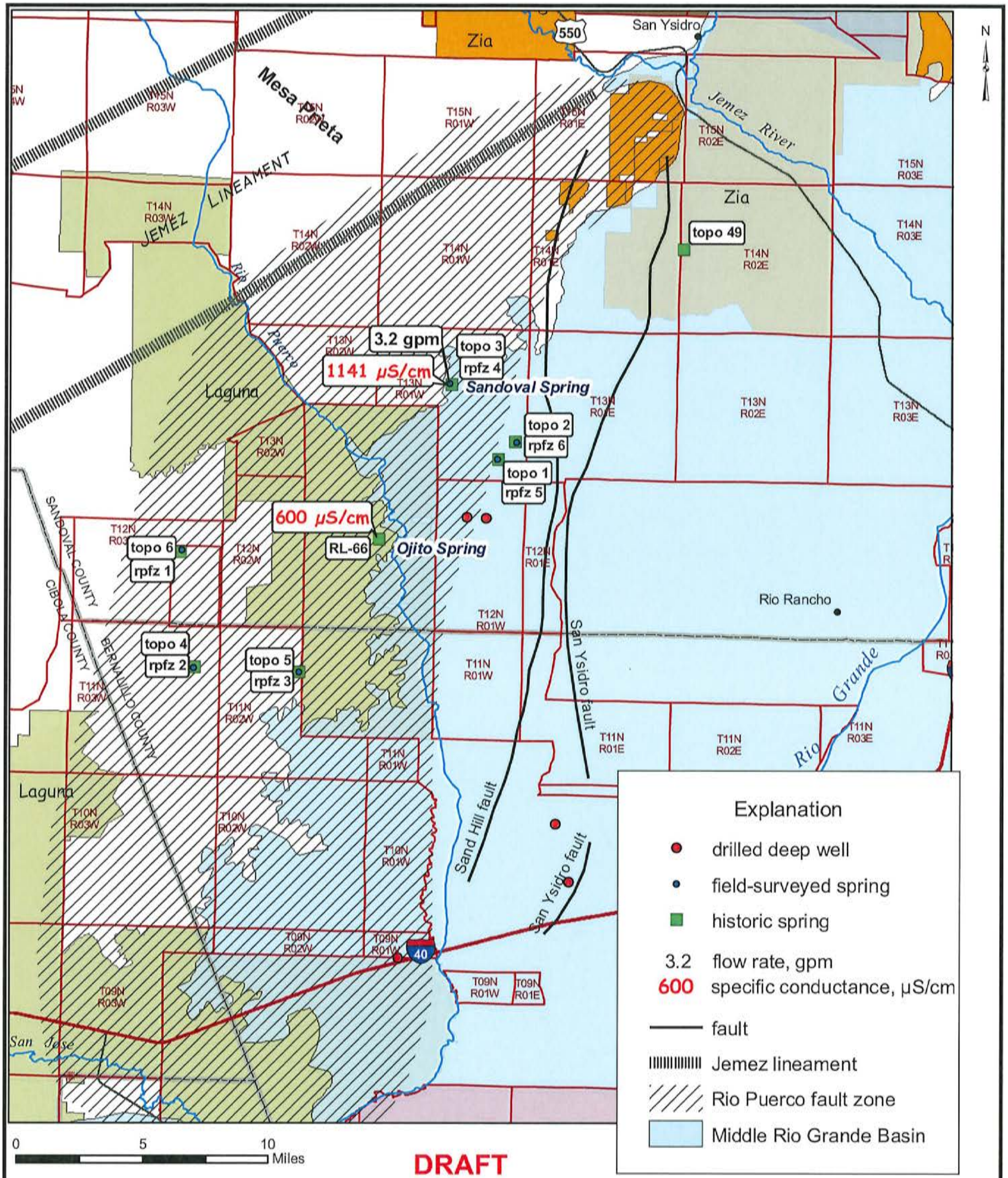

Figure 11. Map of historic and field-surveyed springs with specific conductance data and flow rate within the Rio Puerco fault zone.

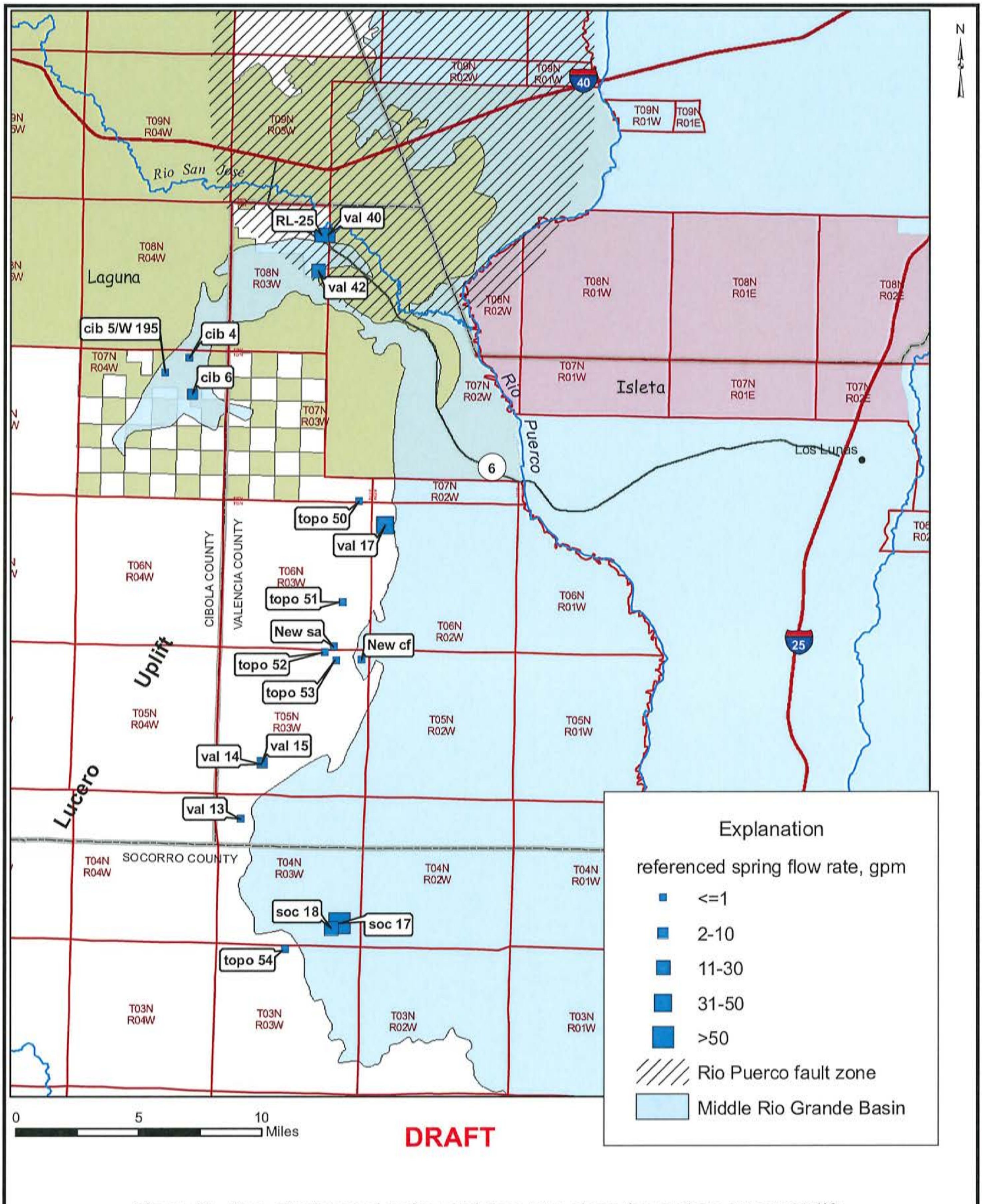

Figure 12. Map of referenced springs and flow rates along the southern Lucero Uplift.

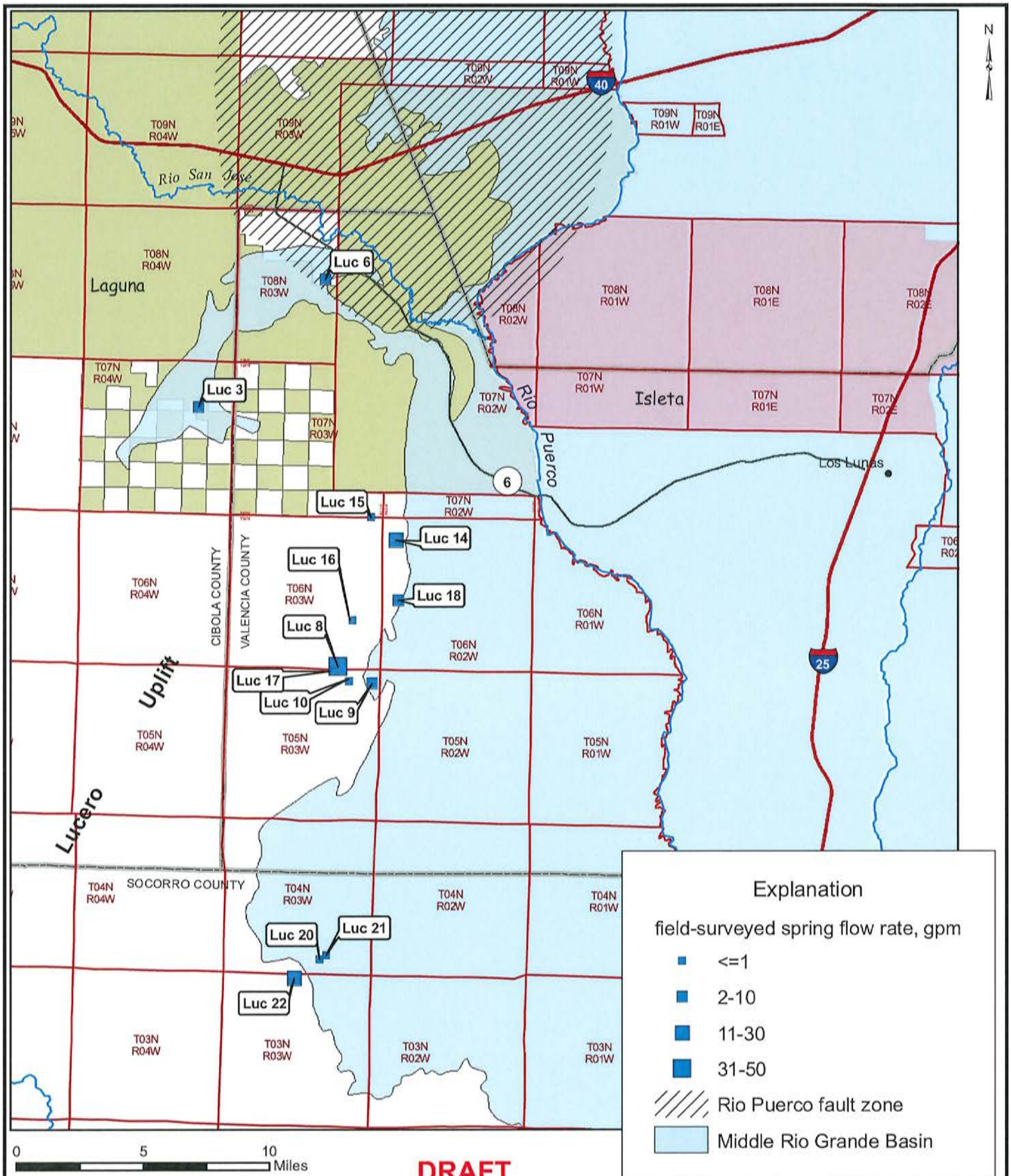

Figure 13. Map of field-surveyed springs and flow rates along the southern Lucero Uplift.

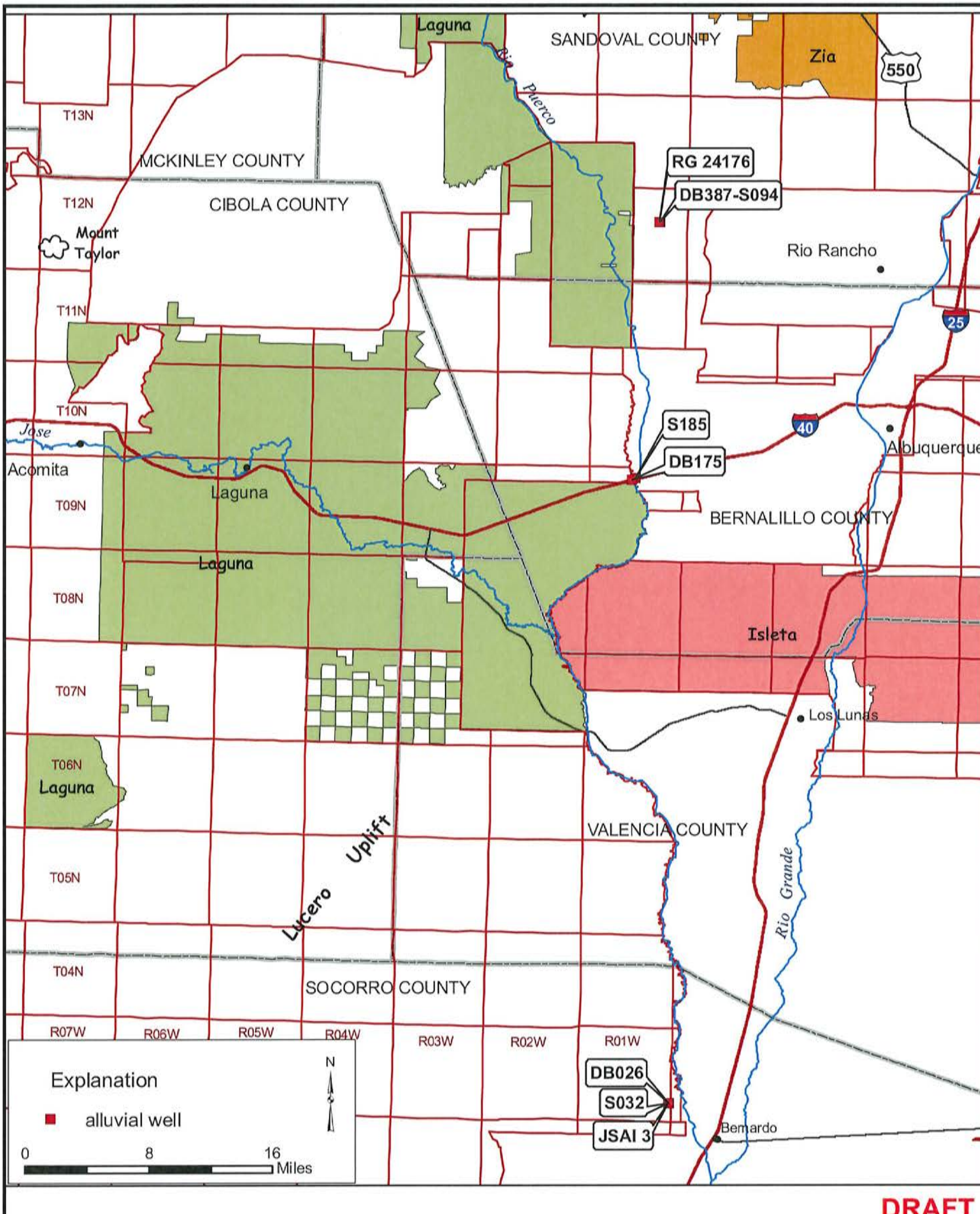

Figure 14. Location map of selected alluvial wells (Table 4) along the Rio Puerco.

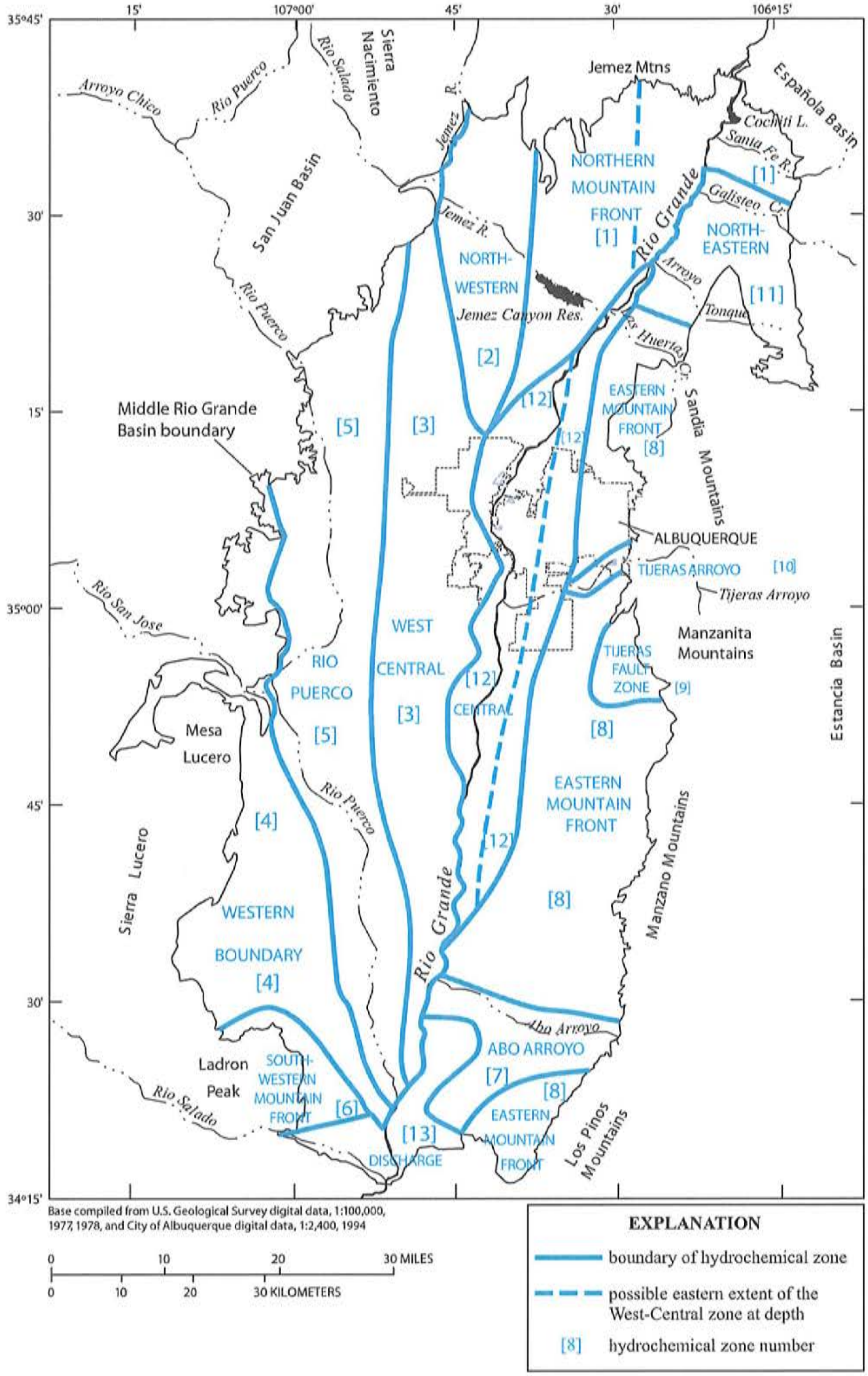

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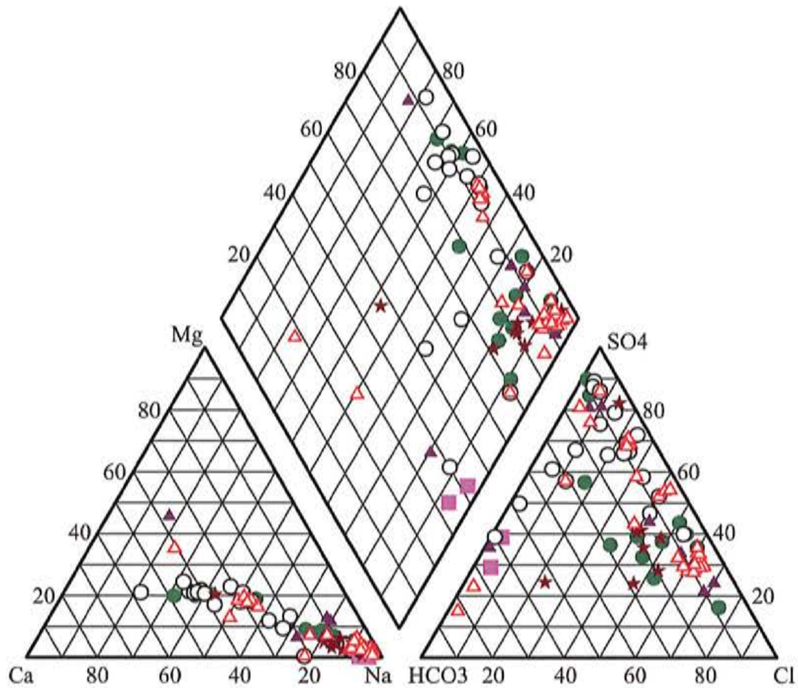
Figure 15. Hydrochemical zones (after Plummer et al., 2004a) for shallow groundwater within the Middle Rio Grande Basin.



Sources: Data from Newell et al. (2005), Plummer et al. (2004a), Risser and Lyford (1983), Trainer (1978), Craigg (1984), and this study.

EXPLANATION

- ■ Zone 3 of Plummer et al. (2004a)
- ● Zone 4 (Western Boundary) of Plummer et al. (2004a)
- ○ Zone 5 of Plummer et al. (2004a)
- ▲ Exotic Water of Plummer et al. (2004a)
- ★ Rio Nacimiento/Rio Salado spring data of Trainer (2004) and this study
- △ Rio San Jose data of Risser and Lyford (1983)

Figure 16. Piper diagram showing variations in the major chemistry of saline and shallow Rio Puerco groundwater in the study area, central New Mexico.

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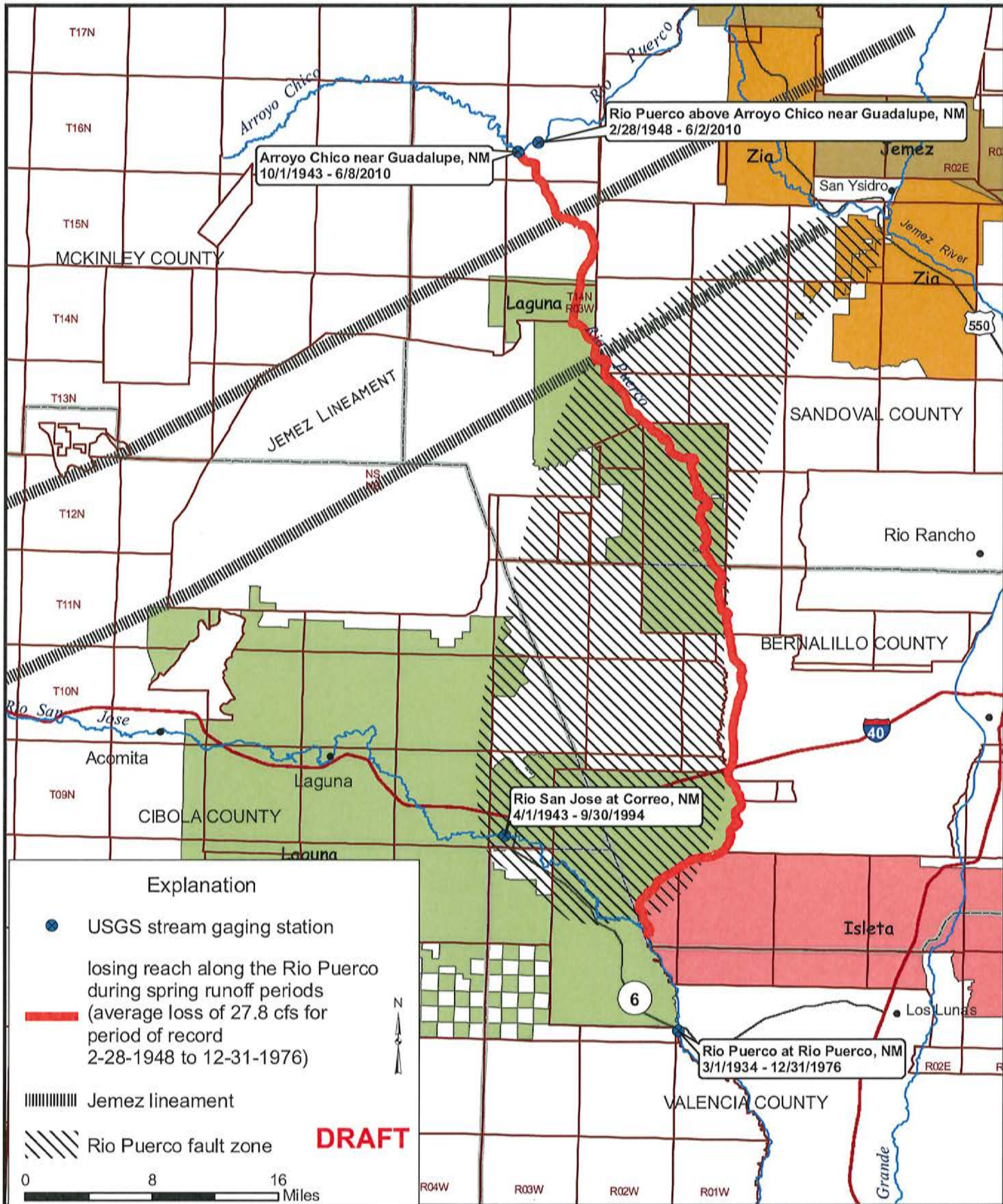

Figure 17. Map showing locations of USGS stream gaging stations and periods of record used in the analysis of Rio Puerco streamflow across the Rio Puerco fault zone.

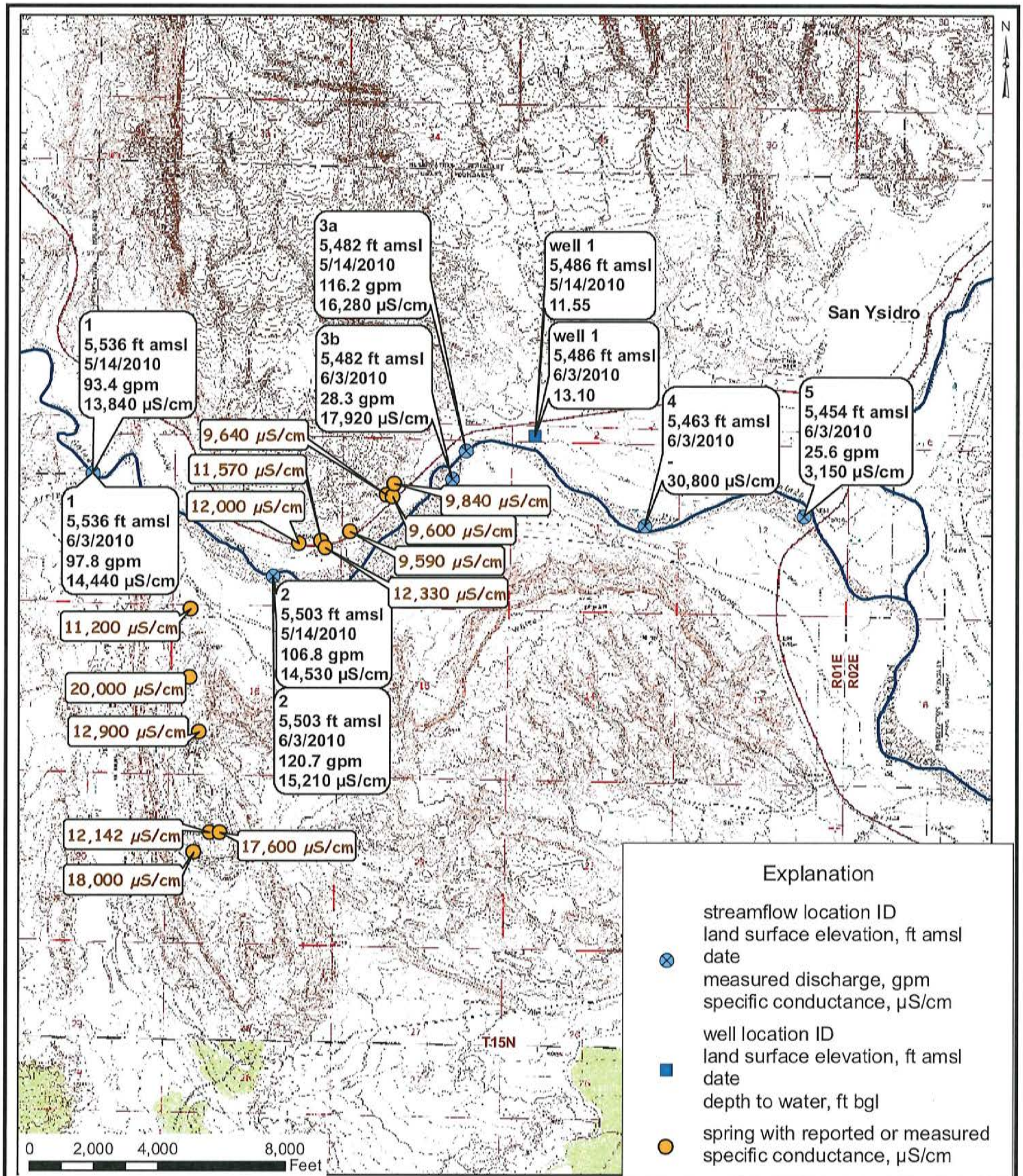

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Figure 18. Map showing 2010 streamflow and specific conductance data for the lower Rio Salado, 2010 groundwater-level data, and historic spring specific conductance data, Nacimiento Uplift - Pajarito fault area.

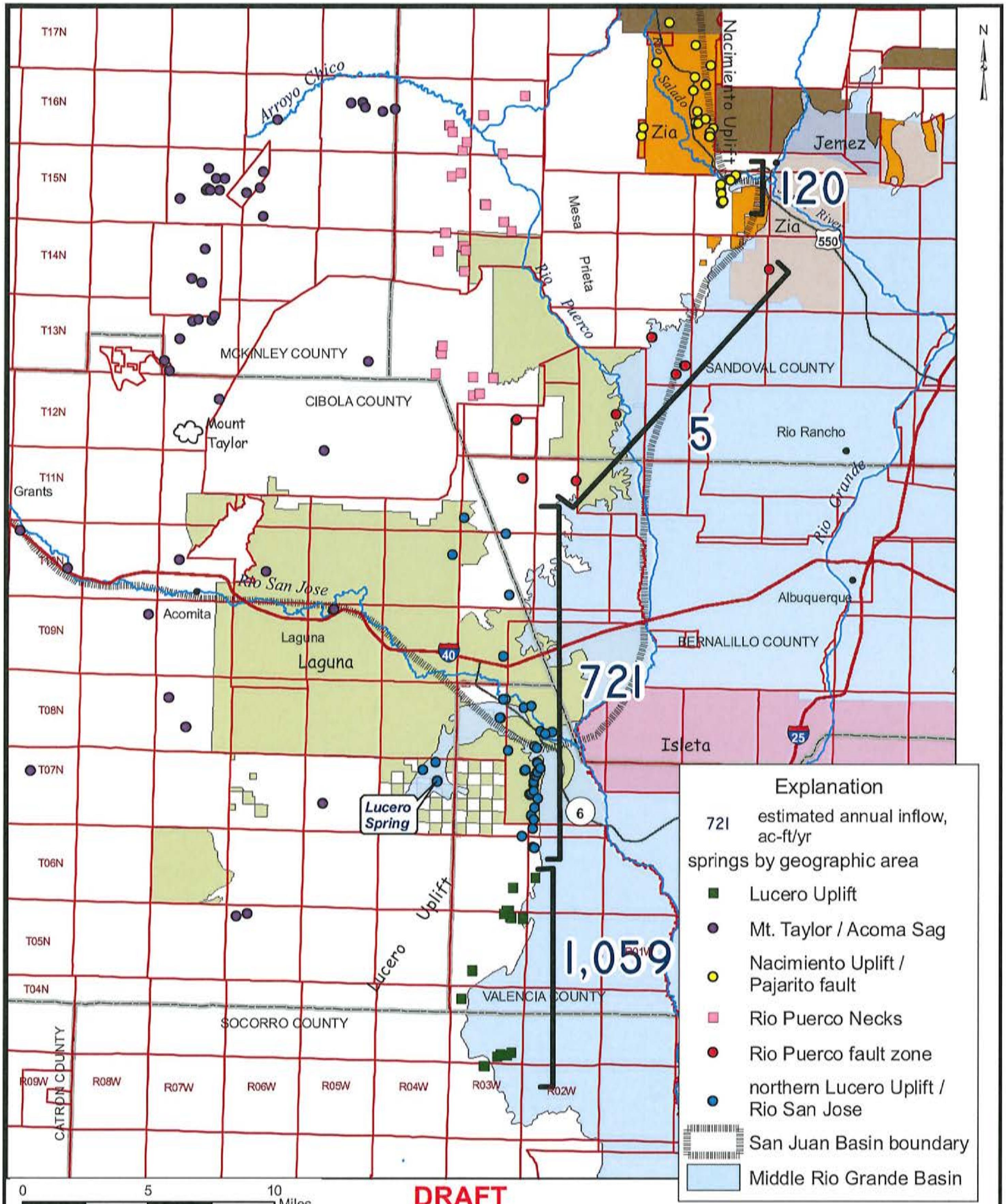

Figure 19. Regional map showing springs in the study area and estimated annual inflow in acre-feet per year at selected study sites along the Western Boundary of the Middle Rio Grande Basin.

JOHN SHOMAKER & ASSOCIATES, INC.

APPENDICES

Appendix A.

Complete list of springs along the Western Boundary of the Middle Rio Grande Basin (MRGB) sorted by UTM number from north to south, and data sorted by geographic area

Table A1. Comprehensive inventory of springs along the western margin of the Middle Rio Grande Basin (MRGB)

gpm=gallons per minute; geological source Qal=Quaternary alluvium, Qb=Quaternary basalt, Qc=Quaternary colluvium, Qt=Quaternary travertine, Te=Tertiary extrusives, Tb=Tertiary basalt, Tcc=Tertiary Cerro Conejo, Kd=Cretaceous Dakota Sandstone, Kg=Cretaceous Gallup Sandstone, Km=Cretaceous Mancos Shale, Kmf=Cretaceous Menefee Formation, Kmv=Cretaceous Mesaverde Group, Kpl=Cretaceous Point Lookout Sandstone, Kplh=Cretaceous Hosta Tongue of Point Lookout, Jm=Jurassic Morrison Formation, Jw=Jurassic Westwater Canyon Member of Morrison, Js=Jurassic Summerville Formation, Jt=Jurassic Todilto Limestone, Trc=Triassic Chinle Formation, Trs=Triassic Santa Rosa Sandstone, Pc=Permian Cutler Formation, Pg=Permian Glorieta Sandstone, Psa=Permian San Andres Limestone, Py=Permian Yeso Formation, Pm=Pennsylvanian Madera Formation, Ps=Pennsylvanian Sandia Formation, PC=Precambrian rocks; ft amsl=feet above mean sea level; spec. cond=specific conductance; µS/cm=microSiemens per centimeter; TDS=total dissolved solids; mg/L=milligrams per liter; 3rd/2nd/1st drain= minor to major drainages; BLM=Bureau of Land Management; RPfz=Rio Puerco fault zone; RP=Rio Puerco; RSJ=Rio San Jose

reference no.	category	spring name/ informal name	owner	county	fault zone	esti-mated yield (gpm)	geo-logical source	altitude (ft amsl)	Township	Range	Section.4q.16q.64q	date	sample type	easting, X (UTM NAD83, m)	northing, Y (UTM NAD83, m)	approx. area (sq ft)	temp (°C)	pH	spec cond (µS/cm)	TDS (mg/L)	data source	USGS topo-graphic quad. map	geographic area	3rd drain	2nd	1st	notes
san 133	historic	Holy Ghost Spring	Jemez Pueblo	Sandoval		9.5	Km	6,395	17N	1W	10.241	12/6/1983	spring	325,902	3,954,865		13.5		720	576	White & Kues, 1992; Trainer, 1978	Holy Ghost Spring	Nacimiento Uplift / Pajarito fault		Rio Salado		
topo 55	topo	Soda Spring	Jemez Pueblo	Sandoval			Km	6,398						325,902	3,954,865						USGS topo, surveyed JSAI June 2010	Holy Ghost Spring	Nacimiento Uplift / Pajarito fault		Rio Salado		
topo 56	topo	unnamed spring	Jemez Pueblo	Sandoval			Km	6,398						325,902	3,954,865						USGS topo, surveyed JSAI June 2010		Nacimiento Uplift / Pajarito fault		Rio Salado		
Craigg 11	historic	"Upper Cuchana Arroyo Spring"	Zia Pueblo	Sandoval		-	Jm	6,700	17N	1W	13.322	-	spring	329,266	3,952,033						Craigg, 1984		Nacimiento Uplift / Pajarito fault		Rio Salado		
Craigg 12	historic	Chamisa Vega Spring	Jemez Pueblo	Sandoval		1	Km	6,100	17N	1W	28.243	8/1/1983	spring	324,341	3,949,765				2,450	1,960	USGS topo, surveyed JSAI June 2010	Holy Ghost Spring	Nacimiento Uplift / Pajarito fault		Rio Salado		
Craigg 0	historic	Swimming Pool Spring	Jemez Pueblo	Sandoval		20	Pm	6,060	16N	1E	20.412	5/8/1984	spring	324,341	3,949,765		19.5		10,500		Craigg, 1984		Nacimiento Uplift / Pajarito fault		Rio Salado		
Craigg 10	historic	"Upper Cuchana Spring"	Zia Pueblo	Sandoval		-	PC	7,075	17N	1E	29.312	-	seep	331,225	3,949,467						Craigg, 1984		Nacimiento Uplift / Pajarito fault		Rio Salado		
san 134	historic	Cachana Spring/ Trainer C5	Zia Pueblo	Sandoval		-	Qc	6,140	15N	1E		7/1/1946	spring	329,145	3,947,945		-		1,130	904	White & Kues, 1992; Trainer, 1978	Holy Ghost Spring	Nacimiento Uplift / Pajarito fault				
san 37	historic	unnamed spring/ Trainer C1	Zia Pueblo	Sandoval		-	Trc	6,320	16N	1E	6.221	10/2/1973	spring	330,585	3,946,931		26.0		960	768	White & Kues, 1992; Trainer, 1978; Craigg, 1984	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
Kaseman 2	historic	"Warm Spring" Kaseman test well No. 2/ Trainer C3	Zia Pueblo	Sandoval			Pm	6,025	16N	1W	1.41			328,895	3,946,248						Renick, 1931	Holy Ghost Spring	Nacimiento Uplift / Pajarito fault		Rio Salado		
san 132	historic	unnamed spring	Aparcio Gurule	Sandoval		-	Km	6,080	16N	3W	11	5/26/1967	spring	307,457	3,945,551		-		9,940	7,952	White & Kues, 1992	Arroyo Empedrado	Puerco Necks			Rio Puerco (N bank)	
mck 61	historic	unnamed spring	J. Montoya	McKinley		2	Kmf	6,330	16N	5W	15.122	9/19/1962	spring	286,722	3,944,759		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 63	historic	unnamed spring	Sandoval	McKinley		2	Kmf	6,330	16N	5W	16.124	9/19/1962	spring	285,208	3,944,641		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 62	historic	Ojo Azabache	J. Montoya	McKinley		1	Kmf	6,330	16N	5W	15.233	9/19/1962	spring	287,033	3,944,074		20.5		1,150	920	White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 59	historic	unnamed spring	E. Montoya	McKinley		0.1	Kmf	6,325	16N	5W	13.422	9/19/1962	spring	290,881	3,943,890		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
Kaseman 1	historic	Kaseman test well No. 1/ Trainer C2	Zia Pueblo	Sandoval			Trc	5,900	16N	1W	1.421			329,425	3,943,557						Renick, 1931	Ojito Spring	Nacimiento Uplift / Pajarito fault		Rio Salado		
mck 60	historic	unnamed spring	J. Montoya	McKinley		1	Kmf	6,360	16N	5W	14.442	9/19/1962	spring	289,210	3,943,529		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 33	topo	unnamed spring	Federal, state, or private lands	Sandoval					16 N	3 W	17		spring	302,150	3,943,049						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	Canada de la Lena		N off Rio Puerco	

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gpm=gallons per minute; geological source Qal=Quaternary alluvium, Qb=Quaternary basalt, Qc=Quaternary colluvium, Qt=Quaternary travertine, Te=Tertiary extrusives, Tb=Tertiary basalt, Tcc=Tertiary Cerro Conejo, Kd=Cretaceous Dakota Sandstone, Kg=Cretaceous Gallup Sandstone, Km=Cretaceous Mancos Shale, Kmf=Cretaceous Menefee Formation, Kmv=Cretaceous Mesaverde Group, Kpl=Cretaceous Point Lookout Sandstone, Kplh=Cretaceous Hosta Tongue of Point Lookout, Jm=Jurassic Morrison Formation, Jw=Jurassic Westwater Canyon Member of Morrison, Js=Jurassic Summerville Formation, Jt=Jurassic Todilto Limestone, Trc=Triassic Chinle Formation, Trs=Triassic Santa Rosa Sandstone, Pc=Permian Cutler Formation, Pg=Permian Glorieta Sandstone, Psa=Permian San Andres Limestone, Py=Permian Yeso Formation, Pm=Pennsylvanian Madera Formation, Ps=Pennsylvanian Sandia Formation, PC=Precambrian rocks; ft amsl=feet above mean sea level; spec. cond=specific conductance; µS/cm=microSiemens per centimeter; TDS=total dissolved solids; mg/L=milligrams per liter; 3rd/2nd/1st drain= minor to major drainages; BLM=Bureau of Land Management; RPfz=Rio Puerco fault zone; RP=Rio Puerco; RSJ=Rio San Jose

reference no.	category	spring name/ informal name	owner	county	fault zone	esti-mated yield (gpm)	geo-logical source	altitude (ft amsl)	Township	Range	Section.4q.16q.64q	date	sample type	easting, X (UTM NAD83, m)	northing, Y (UTM NAD83, m)	approx. area (sq ft)	temp (°C)	pH	spec cond (µS/cm)	TDS (mg/L)	data source	USGS topo-graphic quad. map	geographic area	3rd drain	2nd	1st	notes
Craigg 1	historic	"6092 Spring"	Zia Pueblo	Sandoval		-	Qt	6,092	16N	1E	18.441	-	seep	330,543	3,942,552						Craigg, 1984		Nacimiento Uplift / Pajarito fault		Rio Salado		
mck 64	historic	unnamed spring	Fernandez Ranch	McKinley		5	Kpl	6,370	16N	5W	21.432	10/3/1962	spring	275,736	3,942,408		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 42	historic	Cuchillo "1"/ Craigg 8	Zia Pueblo	Sandoval	Pajarito fault	-	Trc	5,808	16N	1W	24.441		spring	329,230	3,942,154						USGS topo, surveyed JSAI December 2010	Ojito Spring	Nacimiento Uplift / Pajarito fault	Cuchilla Arroyo	NE off Rio Salado (N)		
topo 44	topo	Cuchillo "3"/ Craigg 2	Zia Pueblo	Sandoval	Pajarito fault			5,790	16N	1E	19.114		spring	329,590	3,941,979						USGS topo, surveyed JSAI December 2010	Ojito Spring	Nacimiento Uplift / Pajarito fault	Cuchilla Arroyo	NE off Rio Salado (N)		
topo 43	historic	Cuchillo "2"/ Craigg 9	Zia Pueblo	Sandoval	Pajarito fault	-	Trc	5,795	16N	1W	24.441		spring	329,225	3,941,959						USGS topo, surveyed JSAI December 2010	Ojito Spring	Nacimiento Uplift / Pajarito fault	Cuchilla Arroyo	NE off Rio Salado (N)		
topo 32	topo	unnamed spring	Federal, state, or private lands	Sandoval					16 N	4 W	23		spring	297,765	3,941,849						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	Canada de las Lomitas	SW off Arroyo Chico	W off Rio Puerco	
topo 41	topo	"Upper Ojito spring"/Trainer A6	Zia Pueblo	Sandoval		-		5,780	16N	1W	20.421		spring	322,560	3,941,534						USGS topo, surveyed JSAI April 2010	Ojito Spring	Nacimiento Uplift / Pajarito fault	Arroyo Ojito	NW off Rio Salado (N)		
Craigg 3	historic	Penasco "1"	Zia Pueblo	Sandoval	Pajarito fault	-	Pm	6,000	16N	1E	20.322	-		331,557	3,941,418						Craigg, 1984	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
topo 31	topo	Ojo Frio	Federal, state, or private lands	Sandoval					16 N	4 W	26		spring	298,165	3,940,984						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	Canada de las Lomitas	SW off Arroyo Chico	W off Rio Puerco	
Craigg 4	historic	Penasco "2"	Zia Pueblo	Sandoval	Pajarito fault	5	Pm	5,960	16N	1E	20.322	5/8/1984	spring	331,107	3,940,890		22.5		15,000		Craigg, 1984	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
san 131	historic	Ojito Spring/ Trainer C4	Zia Pueblo	Sandoval		2	Km	5,770	16N	1W	29.232	6/5/1973	spring	322,377	3,940,370		21.0		10,100	8,080	White & Kues, 1992; Trainer, 1978	Ojito Spring	Nacimiento Uplift / Pajarito fault	Arroyo Ojito	NW off Rio Salado (N)		
Craigg 6	historic	Penasco "4"	Zia Pueblo	Sandoval	Pajarito fault	-	Pm	5,830	16N	1E	29.114	-	seep	331,055	3,940,337						Craigg, 1984	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
Craigg 5	historic	Penasco "3"	Zia Pueblo	Sandoval	Pajarito fault	10	Pm	5,830	16N	1E	29.113	5/8/1984	spring	331,011	3,940,306		27		12,000		Craigg, 1984	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
topo 30	topo	Ojo Atascoso	Federal, state, or private lands	Sandoval					16 N	4 W	36		spring	299,950	3,939,694						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	unnamed western channel		W off Rio Puerco	
topo 29	topo	Ojo de las Yeguas	Federal, state, or private lands	Sandoval					16 N	4 W	36		spring	299,475	3,938,544						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	unnamed western channel		W off Rio Puerco	
topo 28	topo	Ojo de los Jaramillos	Federal, state, or private lands	Sandoval					16 N	3 W	33		spring	304,575	3,938,149						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks			Rio Puerco (E bank)	
mck 41	historic	Pena Spring	F. Lee (?)	McKinley		1	Kmf	6,535	15N	7W	10.411	10/16/1962	spring	266,961	3,936,250		12.0		780	624	White & Kues, 1992		Mt. Taylor / Acoma Sag				

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mck 65	historic	unnamed spring	Fernandez Ranch	McKinley		17	Kplh	6,410	16N	5W	29.231	10/3/1962	spring	273,907	3,935,825		13.0		1,350	1,080	White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 26	topo	Cerro Chamisa Losa spring'	Federal, state, or private lands	Sandoval					15 N	4 W	12		spring	299,225	3,935,679						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	Canon Chamisa Losa		W off Rio Puerco	
field 2	field id	Tierra Amarilla springs	BLM	Sandoval	Pajarito fault		Trc					6/4/2010	seep	334,461	3,935,363		23.4	6.26	9,840	7,872	JSAI field checked June 2010	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
nac 1												6/4/2010	seep	334,389	3,935,252		25.2	6.32	9,640	7,712			Nacimiento Uplift / Pajarito fault		Rio Salado		
san 28	historic	Tierra Amarilla springs	BLM	Sandoval	Pajarito fault	-	Trc	5,500	15N	1E	10.141	5/22/1975	spring	334,443	3,935,237		16.0		9,600	7,680	White & Kues, 1992	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
topo 27	topo	Chamisa Losa Spring	Federal, state, or private lands	Sandoval					15 N	4 W	11		spring	298,015	3,935,224						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	Canon Chamisa Losa		W off Rio Puerco	
mck 42	historic	Coal Mine Spring	Fernandez Ranch	McKinley		-	Kmf	6,550	15N	7W	14.131	10/15/1962	spring	268,995	3,934,964		13.5		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 43	historic	Burro Springs	Fernandez Ranch	McKinley		2	Kmf	6,555	15N	7W	15.243	10/115/1962	spring	267,886	3,934,962		13.0		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
san 29	historic	Tierra Amarilla anticline spring(s)/ Trainer A2	BLM	Sandoval	Pajarito fault	<1	Trc	5,500	15N	1E	10.311	1/25/1974	spring	334,034	3,934,906		14.5		9,590	7,672	White & Kues, 1992; Trainer, 1978	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
nac 0												6/4/2010	seep	333,764	3,934,819		20.6	6.22	11,570	9,256			Nacimiento Uplift / Pajarito fault		Rio Salado		
san 27	historic	Tierra Amarilla anticline spring/ Trainer A1	BLM	Sandoval	Pajarito fault	2	Trc	5,520	15N	1E	9.414	5/22/1975	spring	333,553	3,934,792		15.0		12,000	9,600	White & Kues, 1992; Trainer, 1978	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
field 5	field id	Tierra Amarilla springs	BLM	Sandoval	Pajarito fault		Trc					6/4/2010	seep	333,800	3,934,750		30.4	7.25	12,330	9,864	JSAI field checked June 2010	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
san 30	historic	Tierra Amarilla anticline spring/ Trainer A3	BLM	Sandoval	Pajarito fault	-		5,530	15N	1E	16.111	12/20/1974	spring	332,509	3,934,164		25.0		11,200	8,960	White & Kues, 1992; Trainer, 1978	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
mck 39	historic	unnamed spring	A. Michael	McKinley		0.25	-	6,600	15N	6W	20.121	10/3/1962	spring	273,425	3,933,740		16.5		451	361	White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 44	historic	unnamed spring "600"		McKinley		-	Kmf	6,569	15N	7W	22.114	10/11/1956	spring	266,819	3,933,694		13.5		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
san 31	historic	Tierra Amarilla anticline spring/ Trainer A4	BLM	Sandoval	Pajarito fault	-	Trc	5,740	15N	1E	16.233	10/18/1974	spring	332,497	3,933,517		18.0		20,000	16,000	White & Kues, 1992; Trainer, 1978	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
mck 45	historic	Ojo Redondo	Fernandez Ranch	McKinley		2	Kmf	6,569	15N	7W	22.131	3/31/1961	spring	266,662	3,933,483		14.8		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 47	historic	Doctor Spring	Fernandez Ranch	McKinley		15	Kmf	6,588	15N	7W	23.132	10/3/1962	spring	268,376	3,933,469		14.0		350	280	White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 46	historic	Montano Spring	Fernandez Ranch	McKinley		-	Kmf	6,586	15N	7W	22.141	10/31/1961	spring	267,114	3,933,440		20.0		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				

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mck 38	historic	El Dado Springs	Fernandez Ranch	McKinley		5	Kmf	6,595	15N	6W	19.321	7/21/1962	spring	271,770	3,933,073		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
san 32	historic	Tierra Amarilla anticline spring/ Trainer A5	BLM	Sandoval	Pajarito fault	-		5,810	15N	1E	16.313	12/20/1974	spring	332,588	3,932,991		11.0		12,900	10,320	White & Kues, 1992; Trainer, 1978	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
mck 48	historic	San Ysidro Spring	Fernandez Ranch	McKinley		1	Kmf	6,655	15N	7W	29.431	3/31/1961	spring	263,253	3,932,339		14.0				White & Kues, 1992		Mt. Taylor / Acoma Sag				
New gs	historic	Grassy Spring			Pajarito fault	seep	Trc - anticl.						seep	332,692	3,932,039		21.4		12,142		Newell et al., 2005	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
san 34	historic	Tierra Amarilla anticline spring	BLM	Sandoval	Pajarito fault	-	Trc	5,820	15N	1E	21.141	5/22/1975	spring	332,796	3,932,032		19.0		17,600	14,080	White & Kues, 1992	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
san 33	historic	Tierra Amarilla anticline spring(s)	BLM	Sandoval	Pajarito fault	-	Trc	5,680	15N	1E	21.141	5/22/1975	spring	332,541	3,931,852		14.0		18,000	14,400	White & Kues, 1992	San Ysidro	Nacimiento Uplift / Pajarito fault		Rio Salado		
topo 22	topo	unnamed spring (w)	Federal, state, or private lands	Sandoval					15 N	3 W	20		spring	302,300	3,931,714						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	Canon Salado		W off Rio	
topo 23	topo	unnamed spring (e)	Federal, state, or private lands	Sandoval					15 N	3 W	20		spring	302,390	3,931,654						USGS topo, surveyed JSAI December 2010	Guadalupe	Puerco Necks	Canon Salado		W off Rio	
mck 40	historic	Ojo de las Yuges	A. Michael	McKinley		2	Kmf	6,725	15N	6W	32.231	10/22/1962	spring	273,863	3,930,121		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 21	topo	Cerro Tinaja spring (n)'	state or private lands	Sandoval					14 N	4 W	28		spring	304,755	3,929,519						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	unnamed western		W off Rio	
topo 20	topo	Cerro Tinaja spring (s)'	state or private lands	Sandoval					14 N	4 W	28		spring	304,720	3,929,469						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	unnamed western		W off Rio	
topo 19	topo	Gonzales Ranch spring'	state or private lands	Sandoval					14 N	4 W	34		spring	305,770	3,928,274						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canoncito		W off Rio	
topo 45	topo	Rancho Viejo Spring (east)	U.S. Forest Service/Cibola Nat'l Forest	Sandoval					15 N	4 W	35		spring	297,160	3,928,064						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canon Tapia		SW off Rio Puerco	
topo 47	topo	Rancho Viejo Spring (west)	U.S. Forest Service/Cibola Nat'l Forest	Sandoval					15 N	4 W	35		spring	297,305	3,928,054						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canon Tapia		SW off Rio Puerco	
topo 46	topo	Rancho Viejo Spring (middle)	U.S. Forest Service/Cibola Nat'l Forest	Sandoval					15 N	4 W	35		spring	297,225	3,928,029						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canon Tapia		SW off Rio Puerco	
topo 17	topo	Sanchez Ranch spring (e)'	state or private lands	Sandoval					14 N	4 W	12		spring	299,590	3,926,324						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canada Ancha		W off Rio	
topo 16	topo	'Sanchez Ranch spring (w)'	state or private lands	Sandoval					14 N	4 W	12		spring	299,465	3,926,309						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canada Ancha		W off Rio	
mck 25	historic	Cerro Spring	Fernandez Ranch	McKinley		10	Kmf	6,822	14N	7W	10.333	10/23/1962	spring	266,515	3,925,901		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 18	topo	unnamed spring	state or private lands	Sandoval					14 N	4 W	12		spring	299,850	3,925,879						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canada Ancha		W off Rio	
topo 48	topo	Ojo Canoa	U.S. Forest Service/Cibola Nat'l Forest	Sandoval					14 N	4 W	10		spring	296,330	3,925,769						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canon Tapia		SW off Rio Puerco	
topo 49	topo	unnamed spring	Zia Pueblo	Sandoval				5,735	14N	2E	18		spring	338,655	3,923,314						USGS topo, surveyed JSAI December 2010	Sky Village NE	Rio Puerco fault zone	Arroyo Ojito		Jemez River	

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gpm=gallons per minute; geological source Qal=Quaternary alluvium, Qb=Quaternary basalt, Qc=Quaternary colluvium, Qt=Quaternary travertine, Te=Tertiary extrusives, Tb=Tertiary basalt, Tcc=Tertiary Cerro Conejo, Kd=Cretaceous Dakota Sandstone, Kg=Cretaceous Gallup Sandstone, Km=Cretaceous Mancos Shale, Kmf=Cretaceous Menefee Formation, Kmv=Cretaceous Mesaverde Group, Kpl=Cretaceous Point Lookout Sandstone, Kplh=Cretaceous Hosta Tongue of Point Lookout, Jm=Jurassic Morrison Formation, Jw=Jurassic Westwater Canyon Member of Morrison, Js=Jurassic Summerville Formation, Jt=Jurassic Todilto Limestone, Trc=Triassic Chinle Formation, Trs=Triassic Santa Rosa Sandstone, Pc=Permian Cutler Formation, Pg=Permian Glorieta Sandstone, Psa=Permian San Andres Limestone, Py=Permian Yeso Formation, Pm=Pennsylvanian Madera Formation, Ps=Pennsylvanian Sandia Formation, PC=Precambrian rocks; ft amsl=feet above mean sea level; spec. cond=specific conductance; µS/cm=microSiemens per centimeter; TDS=total dissolved solids; mg/L=milligrams per liter; 3rd/2nd/1st drain= minor to major drainages; BLM=Bureau of Land Management; RPfz=Rio Puerco fault zone; RP=Rio Puerco; RSJ=Rio San Jose

reference no.	category	spring name/ informal name	owner	county	fault zone	esti-mated yield (gpm)	geo-logical source	altitude (ft amsl)	Township	Range	Section.4q.16q.64q	date	sample type	easting, X (UTM NAD83, m)	northing, Y (UTM NAD83, m)	approx. area (sq ft)	temp (°C)	pH	spec cond (µS/cm)	TDS (mg/L)	data source	USGS topo-graphic quad. map	geographic area	3rd drain	2nd	1st	notes
topo 15	topo	Jara Loso Spring	state or private lands	Sandoval					14 N	4 W	24		spring	299,650	3,923,104						USGS topo, surveyed JSAI December 2010	Cerro Tinaja	Puerco Necks	Canon Jara Loso	Canada Ancha	W off Rio	
mck 26	historic	Sap Hole Spring	Fernandez Ranch	McKinley		0.25	Kmf	6,908	14N	7W	28.134	10/23/1962	spring	264,802	3,922,183		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 27	historic	Ft Miguel Ruins Spring	Fernandez Ranch	McKinley		2	Kmf	6,950	14N	7W	28.424	3/31/1961	spring	266,025	3,921,657		14.0		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 9	historic	C.C.C. Spring	Fernadez Ranch	McKinley		75	Tb	7,950	13N	7W	11.131	12/12/1956	spring	267,656	3,917,329		11.0		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 7	historic	unnamed spring	U.S. Forest Service	McKinley		50	Te, Kmv	7,840	13N	7W	9.423	10/23/1962	spring	265,623	3,916,889		-		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 8	historic	unnamed spring		McKinley		50	Tb	8,130	13N	7W	10.423	10/23/1962	spring	267,313	3,916,814		11.0		-		White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 6	historic	unnamed spring	U.S. Forest Service	McKinley		50	Te, Kmv	7,810	13N	7W	9.323	10/23/1962	spring	264,911	3,916,691		11.0		203	162	White & Kues, 1992		Mt. Taylor / Acoma Sag				
rpfz 4	visited	Sandoval Spring/ S215 of Plummer et al., (2004)			probable	3.20	Km	5,862				6/9/2010	spring	323,706	3,914,720	45,200	23.8	7.84	1,141				Rio Puerco fault zone				
topo 3	topo	Sandoval Spring	state or private lands	Bernalillo	probable	-	Km	5,862	13 N	1 W	16		spring	323,800	3,914,704						USGS topo, surveyed JSAI December 2010	San Felipe Mesa	Rio Puerco fault zone	Arroyo Bernardo		E off Rio Puerco	
mck 10	historic	San Lucas Spring	U.S. Forest Service	McKinley		20	Tb	7,850	13N	7W	20.123	8/29/1962	spring	263,262	3,914,484		12.0		255	204	White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 14	topo	unnamed spring (n)	private (?)	Sandoval									spring	296,875	3,913,599						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	East Canon de Santa Rosa	Salado Canon	W off Rio Puerco	
topo 13	topo	unnamed spring(s)	private (?)	Sandoval									spring	296,615	3,912,824						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	East Canon de	Salado Canon	W off Rio	
topo 12	topo	Ojo de Santa Rosa	private (?)	Sandoval									spring	296,800	3,912,684						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	East Canon de	Salado Canon	W off Rio	
mck 11	historic	San Mateo Springs	Fernandez Ranch	McKinley		-	Tb	7,700	13N	7W	20.334	9/13/1956	spring	261,391	3,911,634		6.8		194	155	White & Kues, 1992		Mt. Taylor / Acoma Sag				
mck 5	historic	Ojo Marquez	Village of Marquez	McKinley		25	Kmv	7,380	13N	5W	26.134	8/27/1962	spring	287,419	3,911,536		17.0		329	263	White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 2	topo	Tortola Spring	state or private lands	Sandoval		0	Tcc	6,020	13 N	1 W	25		spring	327,875	3,911,019						USGS topo, surveyed JSAI December 2010	San Felipe Mesa	Rio Puerco fault zone	Alamo Arroyo		E off Rio Puerco	
rpfz 6	visited	Tortola Spring			Navajo-Moquino	0	Tcc	6,020						327,988	3,911,009								Rio Puerco fault zone				Spring not found at this location (6/9/2010)
mck 12	historic	San Mateo Springs	Fernandez Ranch & San Mateo	McKinley		275	Tb	8,120	13N	7W	31.414	10/24/1962	spring	262,041	3,910,414		13.5		117	94	White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 11	topo	'Evans Ranch spring'	private (?)	Sandoval									spring	296,000	3,910,069						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	Salado Creek	Salado Canon	W off Rio	
topo 1	topo	Alamo Spring (dry)	state or private lands	Sandoval	unknown	0	Km	5,880	13 N	1 W	35		spring	326,800	3,909,904						USGS topo, surveyed JSAI December 2010	San Felipe Mesa	Rio Puerco fault zone	Alamo Arroyo		E off Rio Puerco	
topo 10	topo	La Gotera spring'	private (?)	Sandoval	likely	0.96	Jm	6,120					spring	300,860	3,909,679						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	Salado Creek	Salado Canon	W off Rio	
topo 9	topo	unnamed spring	Laguna Pueblo	Sandoval	likely	0	Jm	6,000					spring	303,430	3,909,514						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	Salado Creek	Salado Canon	W off Rio	
topo 8	topo	Dorcy Mine spring'	private (?)	Sandoval		0	Jm	6,120					spring	301,670	3,907,504						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	Canon del Piojo	Salado Canon	W off Rio	

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gpm=gallons per minute; geological source Qal=Quaternary alluvium, Qb=Quaternary basalt, Qc=Quaternary colluvium, Qt=Quaternary travertine, Te=Tertiary extrusives, Tb=Tertiary basalt, Tcc=Tertiary Cerro Conejo, Kd=Cretaceous Dakota Sandstone, Kg=Cretaceous Gallup Sandstone, Km=Cretaceous Mancos Shale, Kmf=Cretaceous Menefee Formation, Kmv=Cretaceous Mesaverde Group, Kpl=Cretaceous Point Lookout Sandstone, Kplh=Cretaceous Hosta Tongue of Point Lookout, Jm=Jurassic Morrison Formation, Jw=Jurassic Westwater Canyon Member of Morrison, Js=Jurassic Summerville Formation, Jt=Jurassic Todilto Limestone, Trc=Triassic Chinle Formation, Trs=Triassic Santa Rosa Sandstone, Pc=Permian Cutler Formation, Pg=Permian Glorieta Sandstone, Psa=Permian San Andres Limestone, Py=Permian Yeso Formation, Pm=Pennsylvanian Madera Formation, Ps=Pennsylvanian Sandia Formation, PC=Precambrian rocks; ft amsl=feet above mean sea level; spec. cond=specific conductance; µS/cm=microSiemens per centimeter; TDS=total dissolved solids; mg/L=milligrams per liter; 3rd/2nd/1st drain= minor to major drainages; BLM=Bureau of Land Management; RPfz=Rio Puerco fault zone; RP=Rio Puerco; RSJ=Rio San Jose

reference no.	category	spring name/ informal name	owner	county	fault zone	esti-mated yield (gpm)	geo-logical source	altitude (ft amsl)	Township	Range	Section.4q.16q.64q	date	sample type	easting, X (UTM NAD83, m)	northing, Y (UTM NAD83, m)	approx. area (sq ft)	temp (°C)	pH	spec cond (µS/cm)	TDS (mg/L)	data source	USGS topo-graphic quad. map	geographic area	3rd drain	2nd	1st	notes
topo 7	topo	unnamed spring	private (?)	Sandoval		0	Jm	6,160					spring	300,795	3,907,309						USGS topo, surveyed JSAI December 2010	La Gotera	Puerco Necks	Canon del Piojo	Salado Canon	W off Rio	
cib 23	historic	Elkin's Spring	Summer Camp	Cibola		5	-	9,250	12N	7W	11.3	8/29/1962	spring	268,369	3,906,765		7.0		257	206	White & Kues, 1992		Mt. Taylor / Acoma Sag				
RL-66	historic	Ojito Spring	Laguna Pueblo			-	Qal	5,515	12N	1W	18.134	6/17/1974	spring	319,220	3,904,802				600		Risser & Lyford, 1983	San Felipe Mesa	Rio Puerco fault zone				
rpfz 1	visited	Pino Spring				0	Kg	6,210						306,526	3,904,139								Rio Puerco fault zone				Spring not found at this location - rockwall moist (6/3/2010)
topo 6	topo	Pino Spring	private (?)	Sandoval		0	Kg	6,210					spring	306,440	3,904,019						USGS topo, surveyed JSAI December 2010	La Gotera	Rio Puerco fault zone	Canada del Ojo		W off Rio	
cib 22	historic	unnamed spring	MDWSWA of Seboyeta	Cibola		10	Kmv	6,535	12N	5W	32.331	3/9/1965	spring	281,763	3,900,172		-		429	343	White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 4	topo	'Herrera spring'	private (?)	Bernalillo	likely	0	Jm/Kd	5,930	11 N	3 W	11		spring	307,350	3,896,684						USGS topo, surveyed JSAI December 2010	Herrera	Rio Puerco fault zone	Canada del Ojo		W off Rio	
rpfz 2	visited	'Herrera spring'			likely	0	Jm/Kd	5,930						307,289	3,896,614								Rio Puerco fault zone				Spring not found at this location - soil muddy (6/3/2010)
rpfz 3	visited	unnamed spring			N-S fracture	0	Kd	5,770						314,093	3,896,343								Rio Puerco fault zone				Spring not found at this location - phreatophytes (6/3/2010)
topo 5	topo	unnamed spring	private (?)	Sandoval	N-S fracture	0	Kd	5,770	11 N	2 W	10		spring	314,090	3,896,339						USGS topo, surveyed JSAI December 2010	Herrera	Rio Puerco fault zone	unnamed western		W off Rio	
RL-52	historic	Hanging Grape Spring	Laguna Pueblo			0.5	Kd	6,260	11N	3W	30.343	10/15/1973	spring	299,740	3,891,587				560		Risser & Lyford, 1983	Arch Mesa	northern Lucero/ Rio San Jose				
cib 20	historic	Ojo de Gallo		Cibola		3,000	Psa	6,449	10N	10W	3.423	7/12/1946	spring	237,898	3,890,388		16.0		1,070	856	White & Kues, 1992		Mt. Taylor / Acoma Sag				
cib 18	historic	unnamed spring	S. Gottlieb	Cibola		0.5	Qb	6,401	10N	9W	6.442	5/13/1958	spring	242,930	3,889,997		10.5		3,110	2,488	White & Kues, 1992		Mt. Taylor / Acoma Sag				
bern 40	historic	Jose Manuel Spring	Canoncito Navajo	Bernalillo		seep	Jm	-	10N	3W	3.212	1952, 1953	spring	305,139	3,889,620		-		372 - 389	311	White & Kues, 1992	Arch Mesa	northern Lucero/ Rio San Jose				
RL-41	historic	Cheromiah Spring	Joe Cheromiah			1	Jm	6,100	10N	4W	12.342	10/15/1973	spring	298,294	3,886,899				4,000		Risser & Lyford, 1983	Mesa Gigante	northern Lucero/ Rio San Jose				
cib 17	historic	unnamed spring		Cibola		100	-		10N	7W	20.411	2/20/1951	spring	263,305	3,886,205		8.5		571	457	White & Kues, 1992		Mt. Taylor / Acoma Sag				
cib 19	historic	Horace Springs		Cibola		2,000	Qb	6,276	10N	9W	23.423	5/13/1957	spring	249,005	3,885,140		16.0		1,170	936	White & Kues, 1992		Mt. Taylor / Acoma Sag				
cib 16	historic	unnamed spring	Laguna Indian Reservation	Cibola		50	-		10N	6W	21.4	5/12/1957	spring	274,344	3,884,691		11.0		204	163	White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 38	topo	Alamos Spring	Canoncito Navajo	Cibola					10 N	3 W	26		spring	305,585	3,881,779						USGS topo, surveyed JSAI December 2010	Mesa Gigante	northern Lucero/ Rio San Jose	Canada de los Alamos	Canada de las Apaches	W off Rio Puerco	
cib 13	historic	AT & SF RR	AT &SF RR	Cibola			Qb	5,760	9N	5W	4.133	3/19/1965	spring	282,999	3,879,917		-		2,280	1,824	White & Kues, 1992		Mt. Taylor / Acoma Sag				
cib 14	historic	Canipa Spring	Acoma Indian Reservation	Cibola		-	-	6,197	9N	8W	12.123	9/16/1952	spring	259,446	3,879,245		-		1,490	1,192	White & Kues, 1992		Mt. Taylor / Acoma Sag				
topo 37	topo	Coyote Spring	Laguna Nation	Cibola			Trc	5,600	9 N	3 W	22	4/26/1973	spring	304,775	3,873,889				4,400		USGS topo, surveyed JSAI December 2010	Correo	northern Lucero/ Rio San Jose	unnamed northern channel	Rio San Jose	W off Rio Puerco	

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reference no.	category	spring name/ informal name	owner	county	fault zone	estimated yield (gpm)	geological source	altitude (ft amsl)	Township	Range	Section.4q.16q.64q	date	sample type	easting, X (UTM NAD83, m)	northing, Y (UTM NAD83, m)	approx. area (sq ft)	temp (°C)	pH	spec cond (µS/cm)	TDS (mg/L)	data source	USGS topographic quad. map	geographic area	3rd drain	2nd	1st	notes
cib 9	historic	Acoma Springs		Cibola		10	Jm	6,275	8N	7W	8.331	1/28/1966	spring	262,037	3,868,693		-		1,050	840	White & Kues, 1992		Mt. Taylor / Acoma Sag				
RL-25/ Luc 5	historic	unnamed spring	Talavera Corp.	Valencia		30.00	Qb	5,400	8N	3W	10.214	10/4/1973	spring	304,762	3,868,432				3,800		Risser & Lyford, 1983	Correo	northern Lucero/ Rio San Jose		RSJ	RP (south)	1,300 ft west of Suwanee Spring; no access
val 40/ Luc 4	historic	Suwance Spring	Day Ranch/ Laguna Pueblo	Valencia	Suwanee	30.00/ **100.00**	Jt	5,360	8N	3W	10.224	5/16/1958/ **3/10/2000**	spring	305,145	3,868,423		16.7		3,790	3,020	Titus, 1963; **JSAI, 2000**	Correo	northern Lucero/ Rio San Jose		RSJ	RP	Major Cattle and Land Co. contact stated spring is owned by the Pueblo of Laguna
val 38	historic	Miranda Spring	Laguna Pueblo	Valencia		-	Jm	5,240	8N	2W	7.314	4/21/1975	spring	308,424	3,867,541				30,100	24,080	White & Kues, 1992; Risser & Lyford, 1983	South Garcia	northern Lucero/ Rio San Jose	Arroyo de Miranda	Rio San Jose	W off Rio Puerco	
val 41	historic	Dipping Vat Spring	Laguna Nation	Valencia	YES	400	Jm (Qal?)	5,320	8N	3W	12.342	12/7/1957	spring	307,477	3,867,370				4,030	3,224	White & Kues, 1992	South Garcia	northern Lucero/ Rio San Jose		Rio San Jose	W off Rio Puerco	
val 44	historic	unnamed spring	Laguna Pueblo	Valencia			Jm					4/21/1975	spring	307,531	3,867,344						White & Kues, 1992	South Garcia	northern Lucero/ Rio San Jose				
val 42 Luc 6	historic visited	unnamed spring		Valencia	Suwanee	25 5.00	Jw Jw	5,550 5,555	8N 8N	3W 3W	15.413 15.413	4/21/1975 5/7/2010	spring	304,508 304,416	3,866,052 3,866,084	1,080	16.5 22.4	6.55	4,030 16,660	3,224	White & Kues, 1992	Correo	northern Lucero/ Rio San Jose	unnamed arroyo	RSJ		west of Mesa Redondo
cib 10	historic	unnamed spring		Cibola		-	Jz	-	8N	7W	28.124	1/28/1966	spring	264,096	3,864,847		-		474	379	White & Kues, 1992		Mt. Taylor / Acoma Sag				
val 35	historic	El Ojo Escondido	Laguna Pueblo	Valencia		20	Jm	5,203	8N	2W	19.421	9/8/1941	spring	309,580	3,864,372		22.8			239	Titus, 1963; Wright, 1946	South Garcia	northern Lucero/ Rio San Jose				
val 37	historic	Salt Spring	Laguna Pueblo	Valencia		0.5	Jm	5,180	8N	2W	20.423	4/21/1975	spring	311,174	3,864,278		24.0		32,600	26,080	White & Kues, 1992; Risser & Lyford, 1983	South Garcia	northern Lucero/ Rio San Jose				
RL 22	historic	Ojo Escondido	Laguna Pueblo	Valencia			Jm	5,250	8N	2W	20.332		spring	310,220	3,864,058						Risser and Lyford, 1983		northern Lucero/ Rio San Jose				
val 39	historic	DB 117 of Plummer et al., (2004)	Laguna Pueblo	Valencia			Jm					4/21/1975	spring	308,927	3,862,475				41,400	33,120	White & Kues, 1992	South Garcia	northern Lucero/ Rio San Jose				
W 193	historic	unnamed spring	Laguna Pueblo			5	Jm(?), Kd(?)	5,320(?)	8N	2W	30.34	1941	spring	308,881	3,862,419		22.2			20,900	Titus, 1963	South Garcia	northern Lucero/ Rio San Jose				
val 36	historic	DB 116 of Plummer et al., (2004)	Laguna Pueblo	Valencia		5	Jm					9/3/1941	spring	309,150	3,862,250		22.0				White & Kues, 1992	South Garcia	northern Lucero/ Rio San Jose				
W 194	historic	unnamed spring	Laguna Pueblo			1	Trc	5,800(?)	8N	3W	35.1	9/3/1941	spring	305,417	3,861,842		18.3			355	Titus, 1963	Correo	northern Lucero/ Rio San Jose				
W 192	historic	unnamed spring	Laguna Pueblo			0.3	Km	5480(?)	7N	2W	6.21	1941	spring	309,226	3,860,426					32,400	Titus, 1963	South Garcia SE	northern Lucero/ Rio San Jose				
cib 4/ Luc 2	historic	Lower Water Spring	A. Harrington/ Diamond L Ranch	Cibola		0.01/ 150.00	Qal	5,720	7N	4W	2.144	9/4/1941	spring	296,104	3,860,378	19,375,000	18.5		-		White & Kues, 1992	White Ridge	northern Lucero/ Rio San Jose	Arroyo Lucero	RSJ		contact tried but not established