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Use of Produced Water in Recirculating Cooling Systems at Power Generating Facilities

Deliverable Number 1
Produced Water Assessment

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Disclaimer

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Abstract

The purpose of this study is to evaluate produced water as a supplemental source of water for the San Juan Generating Station (SJGS). This study incorporates elements that identify produced water volume and quality, infrastructure to deliver it to SJGS, treatment requirements to use it at the plant, delivery and treatment economics, etc.

SJGS, which is operated by Public Service of New Mexico (PNM) is located about 15 miles northwest of Farmington, New Mexico. It has four units with a total generating capacity of about 1,800 MW. The plant uses 22,400 acre-feet of water per year from the San Juan River with most of its demand resulting from cooling tower make-up. The plant is a zero liquid discharge facility and, as such, is well practiced in efficient water use and reuse.

For the past few years, New Mexico has been suffering from a severe drought. Climate researchers are predicting the return of very dry weather over the next 30 to 40 years. Concern over the drought has spurred interest in evaluating the use of otherwise unusable saline waters.

Deliverable 1 presents a general assessment of produced water generation in the San Juan Basin in Four Corners Area of New Mexico. Oil and gas production, produced water handling and disposal, and produced water quantities and chemistry are discussed. Legislative efforts to enable the use of this water at SJGS are also described.

Table of Contents

Executive Summary

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There are over 18,400 oil and gas wells in the San Juan Basin in New Mexico and they generate approximately 62,000 BPD (averaged daily production). The Study Area, which encompasses produced water proximate to SJGS, generated 43,000 BPD of produced water in 2002,.

The Study Area overlays infrastructure that could be used to convey the water, e.g. underutilized or abandoned gas transmission pipelines. Major gas transmission lines generally bisect the Study Area and run parallel to state Highway 64. Some lines branch off in Kirtland area and head in a northwest direction just past SJGS.

All producers are planning more well installations. Accelerated installation of new wells, as a result of denser infill drilling permitted by the Bureau of Land Management (BLM), will increase near-term produced water generation. On the other hand, stepped up withdrawal will more quickly deplete water in the producing zones. Many oil field operators do not see a decline in produced water generation in the next 10 to 20 years.

Available information shows variations in produced water chemistry from north-to-south and east-to-west within the Study Area. In the east, where coal bed methane (CBM) extraction predominates, produced water TDS ranges from 8,400 to 13,800 mg/l. Within this area, TDS falls as production nears the state border to the north. The highest TDS is south of Highway 64 – approaching 60,000 mg/l.

At the McGrath SWD (one of the largest salt water disposal facilities in the Study Area), TDS varies from 6,400 mg/l to 22,600 mg/l. Low TDS water is likely from CBM production to the north and high TDS water from conventional gas production to the west. There is a significant amount of CBM produced water that is close-in to SJGS. Noteworthy of this production is that TDS varies dramatically – from 5,440 to 26,100 mg/l.

Lastly, the bill designating produced water reuse as an alternate method of disposal was signed into law March 2004. This will enable PNM to use produced water at SJGS without bringing into play jurisdictional disputes among state regulating agencies.

1.1 Introduction

The purpose of this study is to evaluate produced water as a supplemental source of water for the San Juan Generating Station (SJGS). This study will incorporate elements that identify produced water volume and quality, infrastructure to deliver it to SJGS, treatment requirements to use it at the plant, delivery and treatment economics, etc. Produced water points of generation, quantity and quality are assessed in this deliverable.

SJGS, which is operated by Public Service of New Mexico (PNM) is located about 15 miles northwest of Farmington, New Mexico. It has four units with a total generating capacity of about 1,800 MW. The plant uses 22,400 acre-feet of water per year from the San Juan River with most of its demand resulting from cooling tower make-up. The plant is a zero liquid discharge facility and, as such, is well practiced in efficient water use and reuse.

For the past few years, New Mexico has been suffering from a severe drought. Tree ring studies conducted by the University of Arizona[1] have shown that the last thirty years in New Mexico have been relatively "wet" as compared to the norm. Historically, wet-dry-wet cycles have occurred every 60 to 80 years. The current wet period in New Mexico is coincident with economic development – expansion of agriculture, extensive oil and gas production and the construction and operation of two large coal-fired power plants in the Four Corners area. Researchers are predicting the return of very dry weather over the next 30 to 40 years. Concern over the drought has spurred interest in evaluating the use of otherwise unusable saline waters.

1.2 San Juan Basin

The San Juan Basin (the Basin) is designated as Geologic Province 22 by US Geological Survey (USGS) and is rich in oil, gas and coal reserves as well as minerals. New Mexico ranks 4th in natural gas and 7th in crude oil production in the nation. The Basin is located in the northwest corner of New Mexico with a small portion in southwest Colorado. Refer to Figure 1.1. At its greatest dimensions, the Basin is 130 miles by 160 miles and is comprised of a number of producing geologic units. The Fruitland Petroleum System (the Fruitland) generates the produced water assessed in this study. SJGS is situated on the western edge of the Fruitland, which is the coal source for the plant.

As oil or gas is produced, the fluid brought to the surface typically contains oil and water, gas and water or all three components. In oil production for example, it is not unusual to get nine barrels of water for every barrel of oil. Produced water salinity is quite variable and is dependent upon the hydrologic conditions of the producing zone, e.g. saline native waters from an ancient seabed or a hydrologic connection to a freshwater aquifer. In the San Juan Basin, produced water salinity measured as total dissolved solids (TDS) can vary from 100 mg/l to 60,000 mg/l.

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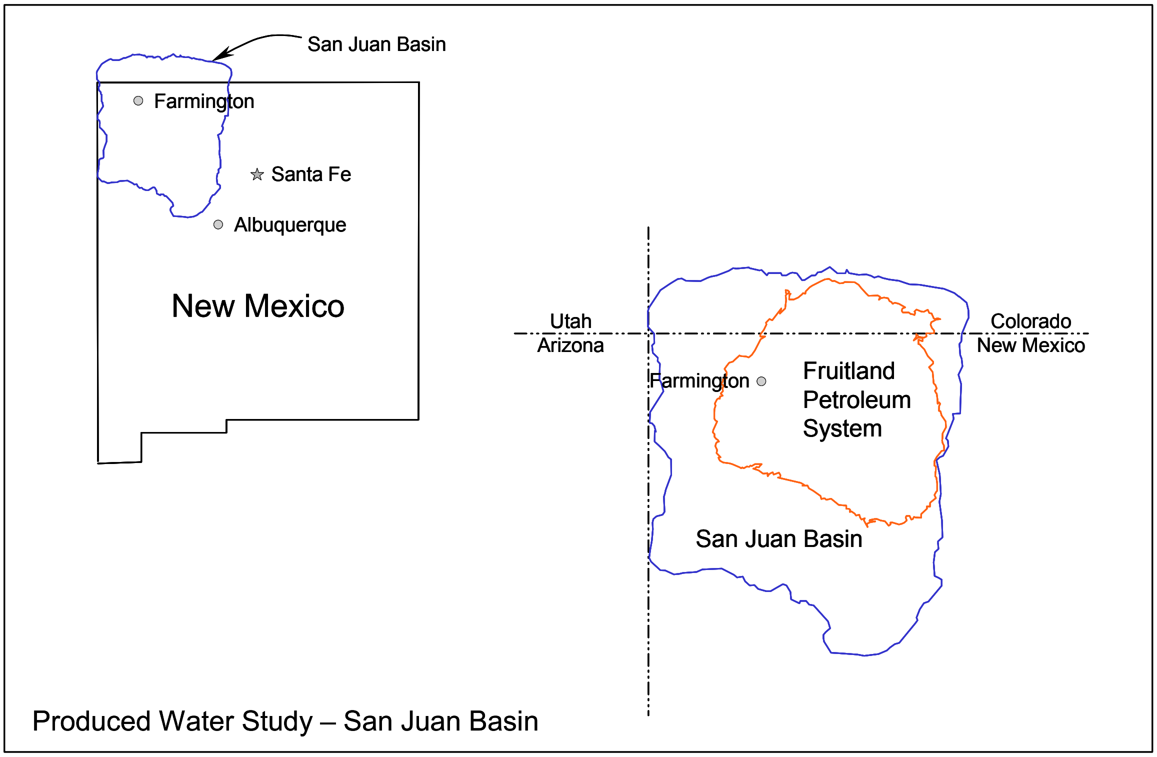
[1] F. Ni, T. Cavazos, M. K. Hughes, A. C. Comrie, and G Funkhouser, "Cool-Season Precipitation in the Southwestern USA Since AD 1000: Comparison of Linear and Nonlinear Techniques for Reconstruction, *International Journal of Climatology,* Volume 22, Issue 13, pp. 1645 - 1662, November 15, 2002.

Figure 1.1



There are two types of oil and gas reserves in the Basin:

- Conventional/continuous oil and gas
- Coal bed methane (CBM)

In conventional and continuous production, a well is drilled into a formation and oil and/or gas are extracted. Conventional formations are well defined from a geologic perspective with clear-cut reserve boundaries. Continuous formations, in contrast, have poorly delineated boundaries and generally defined reserves. In CBM production, methane gas is extracted directly from coal seams. Conventional and continuous wells can range from 3,500 to 8,000 feet in depth in the Fruitland. CBM wells are usually shallow – 1,000 to 3,000 feet – and typically produce a significant amount of water.

1.3 Regulatory Framework

The Oil Conservation Division (OCD) regulates all oil and gas production in the state. In New Mexico (as in many other states), produced water is designated a waste byproduct of oil and gas production. Shortly after produced water is brought to the surface, it is de-oiled, filtered and disposed of via injection wells. There are several underlying formations in the Basin that are routinely used for produced water injection, e.g. the Mesa Verde, Dakota and Entrada. Injection wells are usually 5,000 to 8,000 feet deep and operate at fairly high injection pressures – from 1,000 to 2,500 psi. Production and injection zones are described as “tight” formations in the San Juan Basin and require fracturing to break or crack formation rock to provide flow paths for production fluids.

There have been several attempts to make use of produced water rather than dispose of it via injection (e.g. for dust suppression or road construction). In New Mexico this action is defined as a beneficial use of the state waters and is regulated by the Office of the State Engineer (OSE). Under this designation, a right to use the water must be obtained and its use must comply with all applicable environmental regulations. Also, it must be demonstrated that the produced water being considered has no hydrologic connection to other waters of the state, i.e. rightful water assigned to others has not been appropriated. The regulatory and environmental protection afforded by the OCD (designating the water as a byproduct of oil and gas production) would be lost with beneficial use. It is for this reason that producers would prefer to inject the water rather than use it for another purpose.

1.4 Legislative Remedies

PNM endeavored to address this regulatory issue involving produced water reuse by supporting a bill in the New Mexico legislature in January of 2004 that would specifically allow the "disposal" of produced water at electric generating facilities. This would designate produced water reuse as an alternate method of disposal. As a result, a beneficial use would not be created and the regulatory jurisdiction of the OSE would not be invoked. The bill attempted to accomplish two goals:

- Allow producers to dispose of produced water at SJGS. The plant would treat and utilize the water for cooling tower make-up, scrubber make-up, ash wetting, etc. Most of the water would be consumed as evaporative losses or waters of moisture in scrubber sludge or ash. Any residual produced water (wastes from treatment) would be disposed of in the permitted and regulated evaporation ponds at SJGS.
- PNM would receive a tax credit to compensate for the cost of conveying and treating the water that would otherwise be too costly to consider as economically viable. The amount of the proposed tax credit was $1,000 per acre-foot of produced water delivered to SJGS not to exceed $3 million annually. Also, there would be a maximum payable life-of-the-project cap equal to 50 percent of the capital cost of the project.

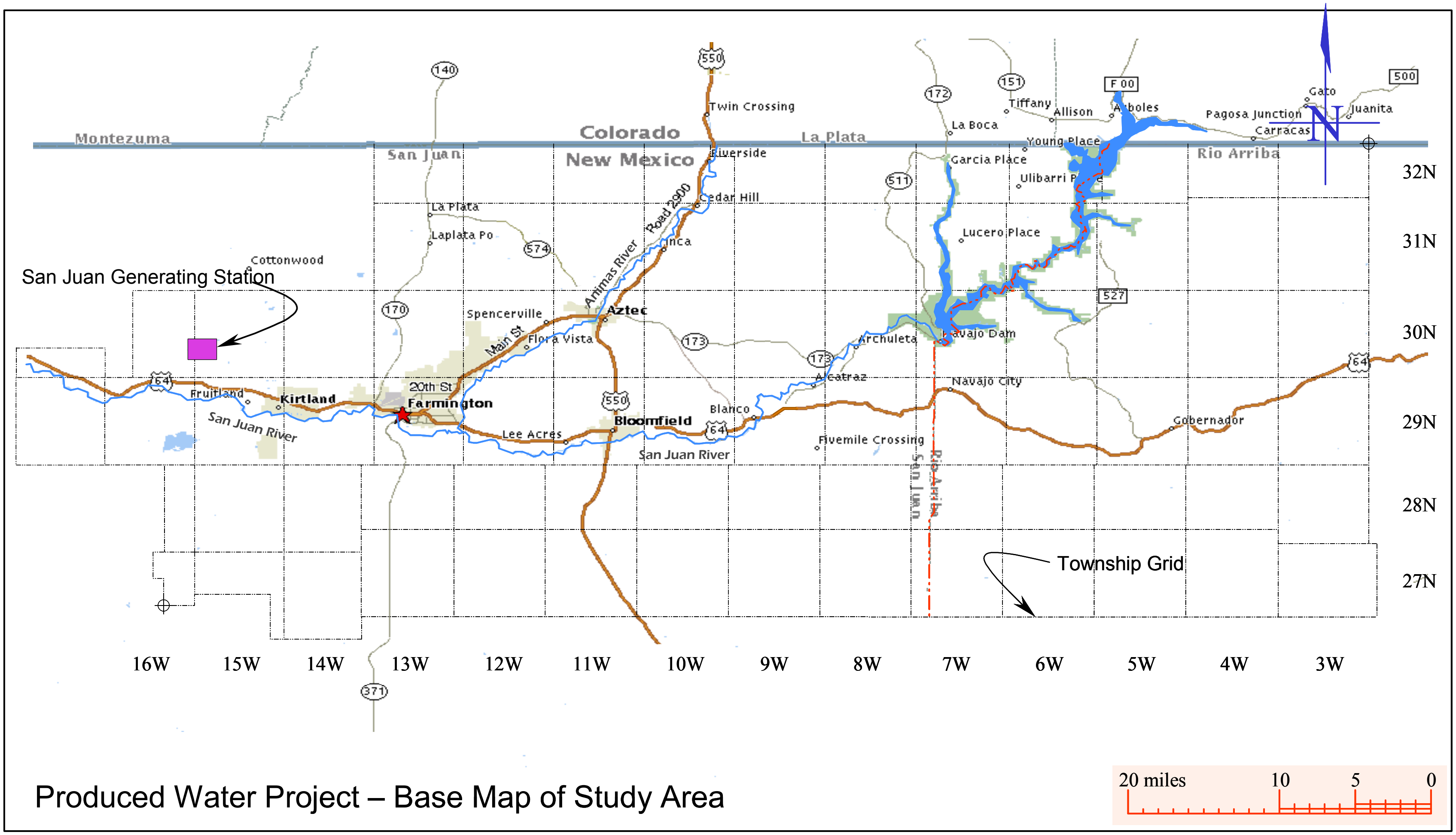
The bill was introduced into the January-February 2004 state legislative session and the provision allowing produced water disposal at electric generation facilities such as SJGS was signed into law March 2004. The tax credit was not included in the bill, and if it is to be achieved, it will have to be reintroduced in an upcoming legislative session.

1.5 Produced Water Quantity

There are over 18,400 oil and gas wells (categorized as active wells by OCD in 2002) in the San Juan Basin and they generate approximately 62,000 BPD (barrels per day) of produced water in an area covering about 3,200 square miles. Refer to Figure 1.2 for a map of the "Study Area". The Study Area was selected based on its proximity to:

- High-volume areas of produced water generation in the Basin
- Existing east-west gas transmission lines and their associated rights of way.

Figure 1.2



Produced Water Project – Base Map of Study Area

The gas transmission lines generally bisect the Study Area and run parallel to state Highway 64. In Kirtland, the lines branch off in different directions westward – some head in a northwest direction just past SJGS.

Refer to Figure 1.3 for a map of the extent of oil and gas production. The township grids are included in Study Area map because they delineate the areas of production activity that OCD uses to locate oil, gas, CBM and injection wells.

The wells are generally located in low-density patterns, i.e. one well every 160 to 320 acres, with little interconnecting piping and infrastructure to gather produced water. Well density will increase in New Mexico with the recent approval from OCD allowing for production infilling, i.e. one well every 80 acres. While some producers have installed water gathering lines, most wells are not connected to any type of collection system.

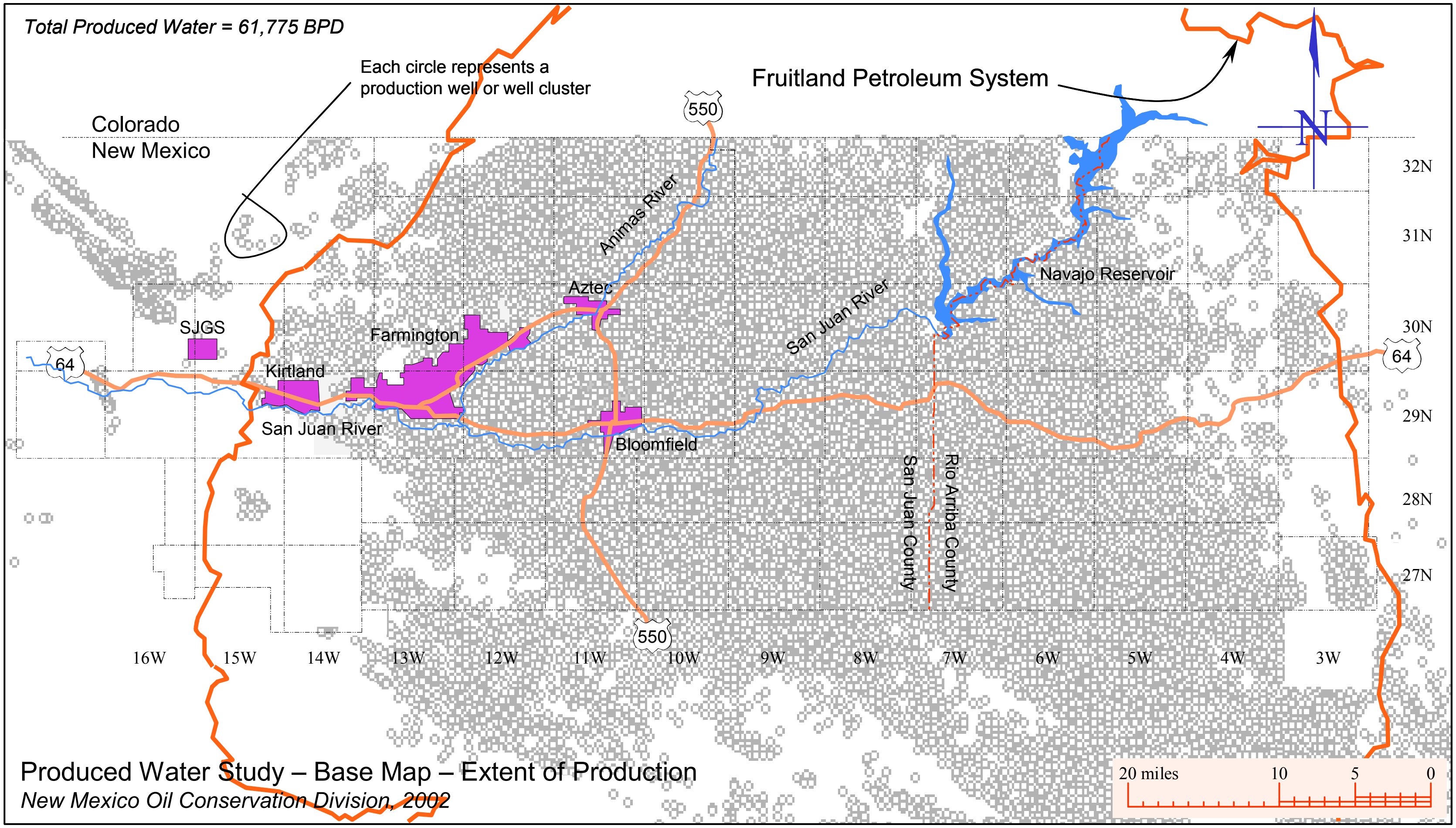
The Study Area was established to identify produced water that is proximate to SJGS as well as existing infrastructure that could be used to convey the water, e.g. underutilized or abandoned pipelines. The Study Area generated 43,000 BPD (average daily) of produced water in 2002 – about 70 percent of all the water produced in the San Juan Basin in New Mexico.

Produced water gathering strategies will be discussed in detail in Section 2, Transfer Requirements and Infrastructure Availability (Deliverable 2). Produced water generation patterns for the Study Area are summarized below:

- 37,800 BPD or 88 percent of the produced water in the Study Area is generated north of or at Highway 64 (township fairways 29N through 32N). Refer to Table 1.1.
- Townships that generate more than 500 BPD of produced water in the Study Area are highlighted in blue. These townships generate approximately 34,700 BPD or 81 percent of the produced water generated in the Study Area. With the exception of two townships, all are located at or north of Highway 64.
- Refer to Table 1.2 for a sensitivity analysis of produced water generation in the Study Area versus township volume. Of the 84 townships in the Study Area, 61 percent do not generate more than 300 BPD (nine had no produced water generation in 2002). As the production-per-township target is increased, the number of townships starts to drop dramatically, as well as total production.
- The two largest clusters in the Study Area generate 29,800 BPD (largest highlighted areas).
- Two of the townships on the western edge of the Fruitland (CBM production) – 29N14W and 30N14W – generate the most produced water of any of the townships in the Study Area.

Three of the high-volume townships are split by the San Juan River and two townships are south of it. Townships south of the river would likely not be utilized for produced water collection (refer to Figure 1.1). Access to produced water south of Highway 64 is complicated by the fact that the San Juan River flows parallel to the highway in the Study Area, which would necessitate a river crossing. Also, produced water south of Highway 64 comprises a small fraction of available water in the Study Area and is generally more saline (discussed later).

Figure 1.3


Total Produced Water = 61,775 BPD
Each circle represents a production well or well cluster
Fruitland Petroleum System
Colorado
New Mexico
550
Animas River
Aztec
SJGS
Farmington
Kirtland
64
San Juan River
Bloomfield
San Juan River
Navajo Reservoir
San Juan County
Rio Arriba County
32N
31N
30N
29N
28N
27N
16W
15W
14W
13W
12W
11W
10W
9W
8W
7W
6W
5W
4W
3W
N
20 miles
10
5
0
Produced Water Study – Base Map – Extent of Production
New Mexico Oil Conservation Division, 2002

Lastly, refer to Figure 1.4 for a summary of produced water generation by township in the Study Area. Raw data was provided by OCD and can be accessed at their website, emnrd.state.nm.us/OCD/. Producers must report oil and gas production as well as produced water generation and disposal to OCD.

Table 1.1
Produced Water Generation by Township Fairway

Township (Range 3W-16W)	Produced Water BPD	Produced Water Pct of Total	Produced Water Cum Pct
32N	7,768	18.1%	18.1%
31N	11,021	25.7%	43.8%
30N	11,835	27.6%	71.4%
29N	7,117	16.6%	88.0%
28N	2,529	5.9%	93.9%
27N	2,647	6.1%	100.0%

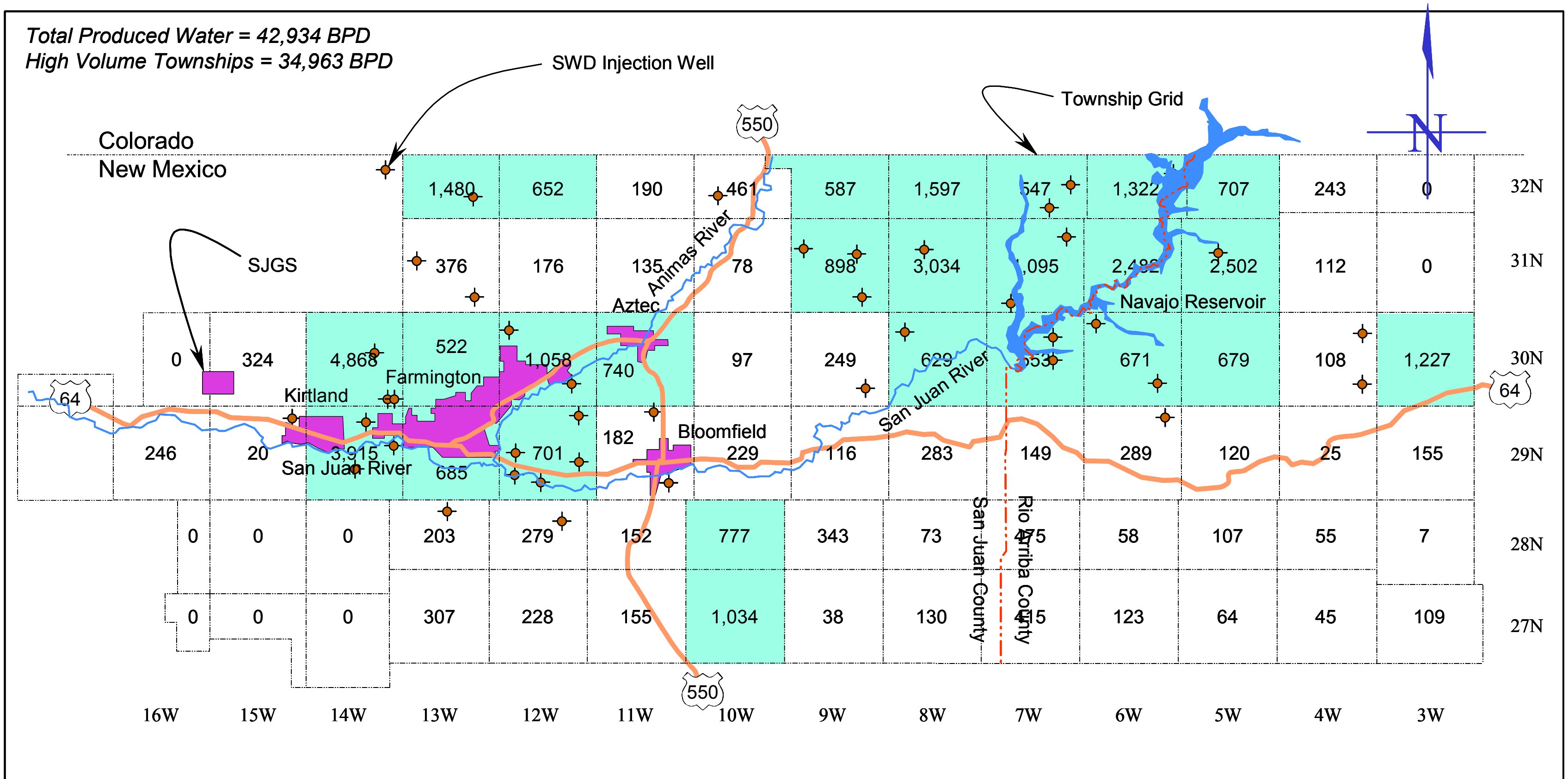
Table 1.2
Produced Water Generation versus Township Volume

Townships with Volume Greater Than	Number of Townships	Total Produced Water Generation
300 BPD	33	37,481 BPD
400 BPD	29	36,054 BPD
500 BPD	26	34,684 BPD
600 BPD	22	32,566 BPD
700 BPD	17	28,779 BPD
800 BPD	14	26,338 BPD
1,000 BPD	12	24,838 BPD
2,000 BPD	5	15,671 BPD

1.6 Salt Water Disposal Facilities

Produced water is separated from oil and/or gas and stored in a covered atmospheric tank at the well head. The water is then transported via tanker truck to a salt water disposal facility (SWD) where it is treated before final disposal by way of deep-well injection. There are 61 SWDs listed as active injection wells (by OCD in 2002) in the Basin in New Mexico. They are operated by 30 entities – large and small oil companies, one refinery and several private treatment and disposal operations. Of these, 43 are in the Study Area and are operated by 20 entities. Also included in Figure 1.4 are the locations of active SWDs in the Study Area.

Figure 1.4



Produced Water Daily Volume (BPD) – All Producers

High Volume Townships (highlighted blue)

New Mexico Oil Conservation Division, 2002

Water delivered to a SWD is first passed through an API[2] oil separator to remove solid material (e.g. sand and gravel), oily sludge and floatable oil. After oil removal, the water is filtered to remove fine particulate matter (cartridge-type filtration). A non-oxidizing biocide is usually added to the filtered water to prevent downhole biological fouling just prior to injection into the formation.

SWDs are clustered in areas of high produced water generation to minimize transportation costs of hauling produced water from the well head to the disposal well. Hauling frequency depends on the amount of water a well produces (new wells generally produce more water initially – this is especially true for CBM production). Hauling is the largest cost component of produced water disposal. Depending on distance, hauling costs from range $1.00 to $2.00 per barrel and up. Disposal costs vary from $0.25 to $1.00 per barrel.

1.7 Produced Water Generated in Colorado

The focus of this deliverable applies only to produced water generated in the Basin in New Mexico. A significant amount of CBM water is produced in Colorado along the northern edge of the Fruitland. Compacts established between Colorado and New Mexico bar interstate transfers of water without the approval of their respective OSEs. Therefore, this water is considered outside of the scope of this project.

1.8 Future Produced Water Quantities

When a conventional oil or gas well is developed, initial volumes of produced water can be high with a gradual decline over time. Some wells, depending on the formation, generate produced water without a drop-off in volume. CBM wells typically generate high initial volumes of produced water that decline at a greater pace than conventional wells. No effort has been made by any of the producers to predict the decline of produced water generation in any parts of the Study Area. A large producer in the Basin) felt that their water volume might fall by an annual factor of $e^{-0.05}\ to\ \ e^{-0.1}$ (equivalent to 4.9% to 9.5%) at current levels of production, i.e. rates of extraction remain the same with no new well installations. Several CBM producers on the western edge of the Fruitland have not seen any falloff in their wells and do not expect to see any in the near future.

All producers are planning more well installations. Accelerated installation of new wells, as a result of denser infill drilling permitted by OCD, will increase near-term produced water generation. On the other hand, stepped up withdrawal will more quickly deplete water in the producing zones. However, many oil field operators do not see a decline in produced water generation in the next 10 to 20 years.

Lastly, if and when produced water volumes start to fall, there is a potential to back-flow retired SWD injection wells in order to extract water previously injected. Several producing companies have offered this idea as another means of generating produced water. One large producer felt they could generate at least 10,000 BPD by back flowing

[2] The API seperator was developed over 70 years ago in a joint effort by the American Petroleum Institute (API) and the Rex Chain Belt Company (currently known as US Filter Envirex Products). The first API separator was commissioned in 1933.

several of their SWD injection wells. Also, back-flowing could easily be incorporated into a project where produced water is being gathered and conveyed to SJGS.

1.9 Produced Water Chemistry

A sampling and analysis program was conducted to identify the geochemical characteristics of produced water at the McGrath SWD, which is central to conventional oil and gas and CBM production in the Study Area (Figure 1.4). McGrath SWD is owned and operated by Burlington Resources – the largest producer in the Basin in New Mexico. Thirty samples were taken over a 30-day period – one per day at random times. The water quality analysis includes:

- General mineral chemistry – Na^{+1}, Ca^{+2}, Mg^{+2}, alkalinity, Cl^{-1}, etc.
- Heavy metals
- TDS, electrical conductivity and pH
- Ammonia, sulfide and boron
- Total Suspended Solids (TSS) and Total Petroleum Hydrocarbons (TPH)

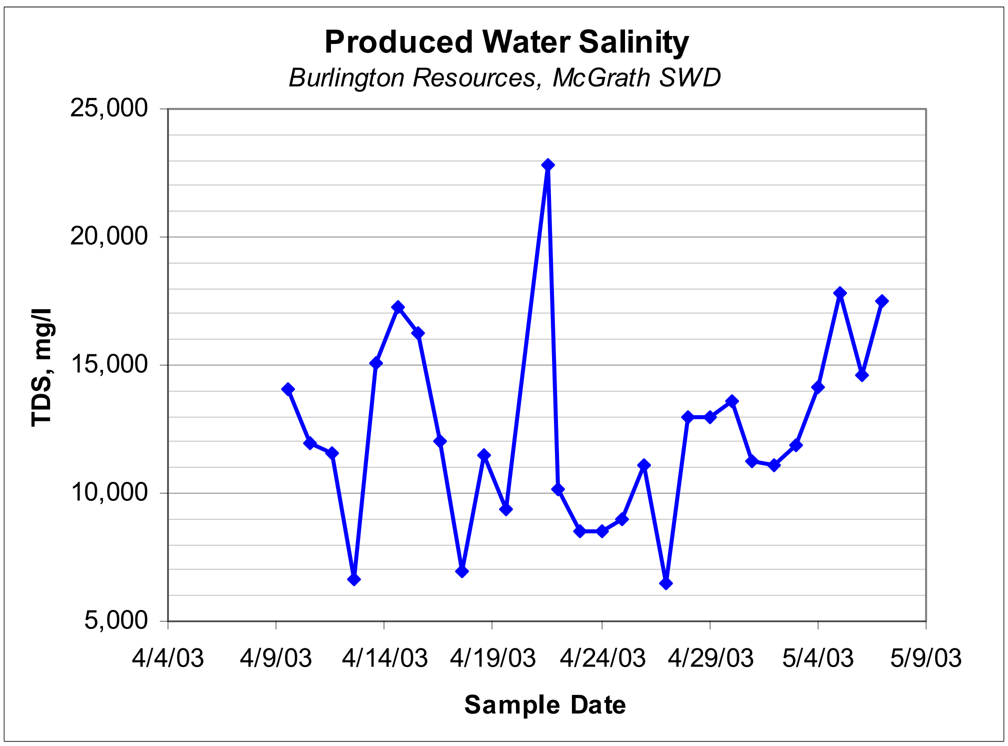
Refer to Figure 1.5 for a summary of TDS results and Table 1.4 for a summary of produced water chemistry. At the McGrath SWD, TDS varied from 6,400 mg/l to 22,600 mg/l. Low TDS water likely was from CBM production to the north and high TDS water from conventional gas production to the west. Other chemistry of interest includes:

- Sodium, chloride and bicarbonate alkalinity predominate the chemistry. This is typical of produced water.
- Relative to total ion content, calcium and magnesium hardness are low.
- Barium and strontium levels averaged 3.1 mg/l and 19 mg/l, respectively.
- Sulfate levels ranged from 168 to 884 mg/l.
- Total and dissolved iron levels were high. Most of the iron comes from aboveground carbon steel pipe used to convey produced water.
- Copper, chrome and lead ranged from non-detectable levels to less than 0.050 mg/l. Selenium ranged from non-detectable levels to 0.080 mg/l. Arsenic and mercury were not detected.
- Silica levels were relatively low for produced water – from 12.2 to 27.6 mg/l.
- Ammonia levels ranged from 7.0 to 23.0 mg/l.
- Boron levels were typical of many oil field operations – from 1.00 to 3.00 mg/l.
- Sulfide levels were very low – almost always non-detectable. This is characteristic of the Fruitland.
- Total petroleum hydrocarbons (TPH) ranged from 23 to 520 mg/l. High levels of TPH are assumed to be from conventional oil and gas wells. CBM produced water typically has very low levels of TPH – usually <10 mg/l.

There is a significant amount of CBM produced water that is close-in to SJGS in townships 29N14W and 30N14W (Figure 1.4). Refer to Table 1.5 for a summary of chemistry for four SWDs. Noteworthy of these chemical analyses is the fact that TDS varies dramatically – from 5,440 to 26,100 mg/l. This is due in part to local geology, i.e. the proximity of the wells to the edge of the Fruitland Petroleum System. Many of the chemistry observations cited above hold for this water as well.

The Petroleum Recovery Research Center[3] is currently developing a database of produced water chemistry for the San Juan Basin (as well as other producing units). Current information shows variations in produced water chemistry from north-to-south and east-to-west within the Study Area. Refer to Figure 1.6. In the east, where CBM extraction predominates, produced water TDS ranges from 8,400 to 13,800 mg/l. Within this area, note how TDS falls as production nears the state border to the north. The highest TDS is south of Highway 64 – approaching 60,000 mg/l. A cluster of data north of Farmington is representative of both conventional and CBM production. Lastly, TDS of produced water to the west (in Farmington) is higher than that of produced water directly to the east.

Figure 1.5



[3] PRRC is a division of New Mexico Institute of Mining and Technology.

Table 1.4

McGrath SWD Chemistry

30-Day Random Sampling Program

		Average	Min	80th Percentile	90th Percentile	Max
Na	mg/l	4,149	1,980	5,044	6,046	8,060
K	mg/l	177	55	282	368	434
Calc'd NH_4	mg/l	16	9	20	24	29
Ca	mg/l	143	60	178	200	311
Mg	mg/l	34	12	43	48	88
Ba	mg/l	3.1	0.72	4.7	5.5	8.0
Sr	mg/l	19	7.2	24	31	55
Iron, Total	mg/l	41	5.2	70	85	187
Iron, Dissolved	mg/l	33	1.1	42	80	187
Cu	mg/l	ND	ND	0.016	0.017	0.019
Zn	mg/l	0.23	ND	0.356	0.425	0.564
As	mg/l	ND	ND	ND	ND	ND
Cr	mg/l	ND	ND	0.034	0.034	0.035
Pb	mg/l	ND	ND	0.028	0.029	0.031
Se	mg/l	ND	ND	0.057	0.069	0.080
Hg	mg/l	ND	ND	ND	ND	ND
HCO_3	mg/l	764	319	973	1,075	1,298
Calc'd CO_3	mg/l	0.64	0.10	1.24	1.68	17.3
Cl	mg/l	6,298	2,590	7,760	9,062	12,500
Br	mg/l	14.5	7.1	18	19	21.8
F	mg/l	ND	ND	ND	ND	ND
NO_3	mg/l	ND	ND	4.4	4.8	5.7
NO_2	mg/l	ND	ND	ND	ND	ND
SO_4	mg/l	544	168	758	810	884
Calc'd CO_2	mg/l	62	6.7	82	102	247
Calc'd NH_3	mg/l	0.098	0.015	0.16	0.17	1.33
SiO_2	mg/l	18.5	12.2	20.3	24.0	27.6
Total Hardness	mg/l_{CaCO3}	498	200	612	725	1,001
Total Alkalinity	mg/l_{CaCO3}	697	320	868	931	1,100
Total NH_3	mg/l_N	12.8	7.0	16	19	23.0
B	mg/l_B	2.05	1.00	2.39	2.64	3.00
O-PO_4	mg/l_P	ND	ND	2.33	2.51	2.70
Total Sulfides	mg/l_S	ND	ND	ND	ND	1.60
pH		7.05	6.41	7.25	7.30	8.23
EC	µS/cm	19,883	10,300	23,740	26,690	35,900
TDS (Calc'd)	mg/l	12,714	6,363	14,529	17,308	22,629
TSS	mg/l	108	26	160	211	240
TPH	mg/l	163	23	258	310	520

Table 1.5

CBM SWD Chemistry - Close-In Fruitland

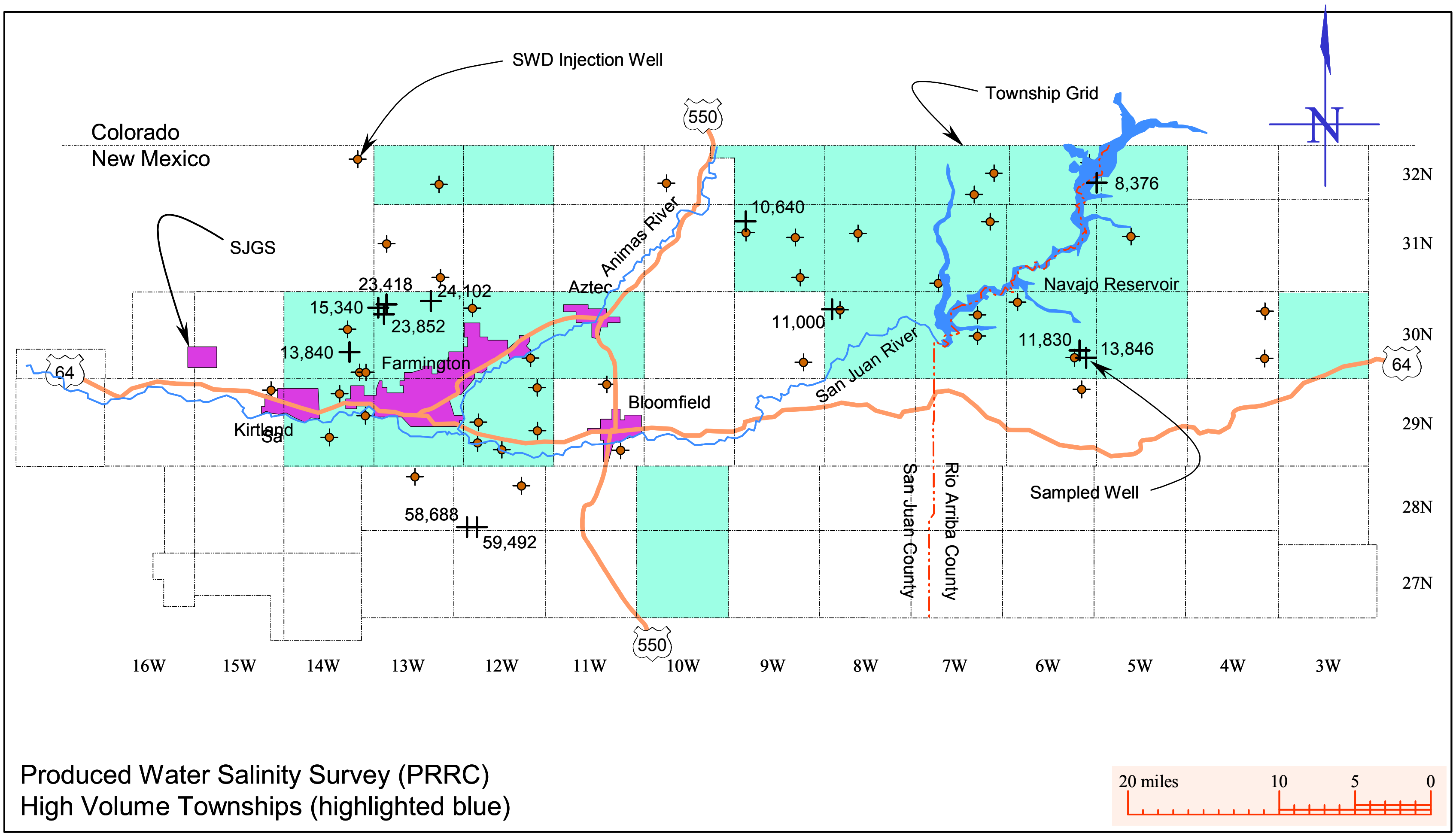
Townships 29N14W and 30N14W

		Salty Dog 2 Injection Well Richardson	Salty Dog 3 Injection Well Richardson	Turk's Toast Injection Well Dugan	Locke Taber Injection Well Dugan
Na (3)	mg/l	9,558	9,801	2,175	6,920
K	mg/l	149	55.60	6.45	17
Ca	mg/l	128	105.00	6.27	23.3
Mg	mg/l	87.4	95.30	4.34	32.7
Ba	mg/l	20.8	23.90	1.86	12.8
Sr	mg/l	20.6	34.50	1.73	16.8
Iron, Total	mg/l	0.782	N/A	4.05	N/A
Iron, Dissolved	mg/l	0.843	ND	ND	ND
Cu	mg/l	ND	ND	ND	ND
Zn	mg/l	0.298	ND	ND	ND
As	mg/l	ND	ND	ND	ND
Cr	mg/l	ND	ND	0.005	ND
Pb	mg/l	0.0364	ND	ND	0.1
Se	mg/l	0.0171	ND	ND	ND
Hg	mg/l	ND	ND	ND	ND
Ag	mg/l	NA	0.20	ND	0.18
U	mg/l	NA	ND	ND	ND
TC	mg/l_{CaCO3}	21,715	22,089	4,772	15,287
HCO_3	mg/l	1,440	967	1,952	872
CO_3	mg/l	ND	NA	185	NA
Cl (3)	mg/l	14,526	15,104	2,004	10,335
Br	mg/l	15.6	NA	2.74	NA
F	mg/l	ND	NA	2.3	NA
NO_3	mg/l	2.5	NA	ND	NA
NO_2	mg/l	ND	NA	ND	NA
SO_4	mg/l	24.9	ND	37.4	ND
TA	mg/l_{CaCO3}	21,697	22,089	4,772	15,287
SiO_2	mg/l	9.7	(Note 4)	12.2	(Note 4)
Total Alkalinity	mg/l_{CaCO3}	1,180	NA	1,910	NA
Total NH_3	mg/l_N	10.6	11.5	1.9	8.8
B	mg/l_B	2.87	(Note 4)	1.6	(Note 4)
O-PO_4	mg/l_P	ND	ND	ND	ND
Total Sulfide	mg/l_S	ND	NA	17	NA
pH		8.23	7.26	8.82	7.47
Specific Conductance	µS/cm	40,300	NA	9,160	NA
TDS (Residue)	mg/l	26,100	23,600	5,440	16,600
TDS (Calculated)	mg/l	25,300	NA	5,370	NA
TSS	mg/l	42	NA	16	NA
TPH	mg/l	ND	NA	17	NA
Phenolics	mg/l	NA	NA	ND	NA

Notes…..

1. ND = not detectable
2. NA = not analyzed
3. Na and Cl adjusted to maintain ionic balance.
4. Not included - questionable data.

Figure 1.6


SWD Injection Well
Township Grid
550
Colorado
New Mexico
SJGS
8,376
10,640
Animas River
23,418
24,102
Aztec
Navajo Reservoir
15,340
23,852
11,000
13,840
Farmington
11,830
13,846
San Juan River
64
Bloomfield
Kirtland
San Juan County
Rio Arriba County
Sampled Well
58,688
59,492
550
32N
31N
30N
29N
28N
27N
16W
15W
14W
13W
12W
11W
10W
9W
8W
7W
6W
5W
4W
3W
N
Produced Water Salinity Survey (PRRC)
High Volume Townships (highlighted blue)
20 miles
10
5
0

1.10 Summary

There are over 18,400 oil and gas wells (categorized as active wells by OCD in 2002) in the San Juan Basin in New Mexico and they generate approximately 62,000 BPD (averaged daily production). The Study Area, which encompasses produced water proximate to SJGS, generated 43,000 BPD of produced water in 2002,.

The Study Area overlays infrastructure that could be used to convey the water, e.g. underutilized or abandoned gas transmission pipelines. Major gas transmission lines generally bisect the Study Area and run parallel to state Highway 64. Some lines branch off in Kirtland area and head in a northwest direction just past SJGS.

All producers are planning more well installations. Accelerated installation of new wells, as a result of denser infill drilling permitted by OCD, will increase near-term produced water generation. On the other hand, stepped up withdrawal will more quickly deplete water in the producing zones. Many oil field operators do not see a decline in produced water generation in the next 10 to 20 years.

Current information developed by PRRC shows variations in produced water chemistry from north-to-south and east-to-west within the Study Area. In the east, where CBM extraction predominates, produced water TDS ranges from 8,400 to 13,800 mg/l. Within this area, TDS falls as production nears the state border to the north. The highest TDS is south of Highway 64 – approaching 60,000 mg/l.

At the McGrath SWD, TDS varied from 6,400 mg/l to 22,600 mg/l. Low TDS water likely was from CBM production to the north and high TDS water from conventional gas production to the west. There is a significant amount of CBM produced water that is close-in to SJGS. Noteworthy of this production is that TDS varies dramatically – from 5,440 to 26,100 mg/l.

Lastly, the bill designating produced water reuse as an alternate method of disposal was signed into law March 2004. As a result, a beneficial use would not be created and the regulatory jurisdiction of the OSE would not be invoked.