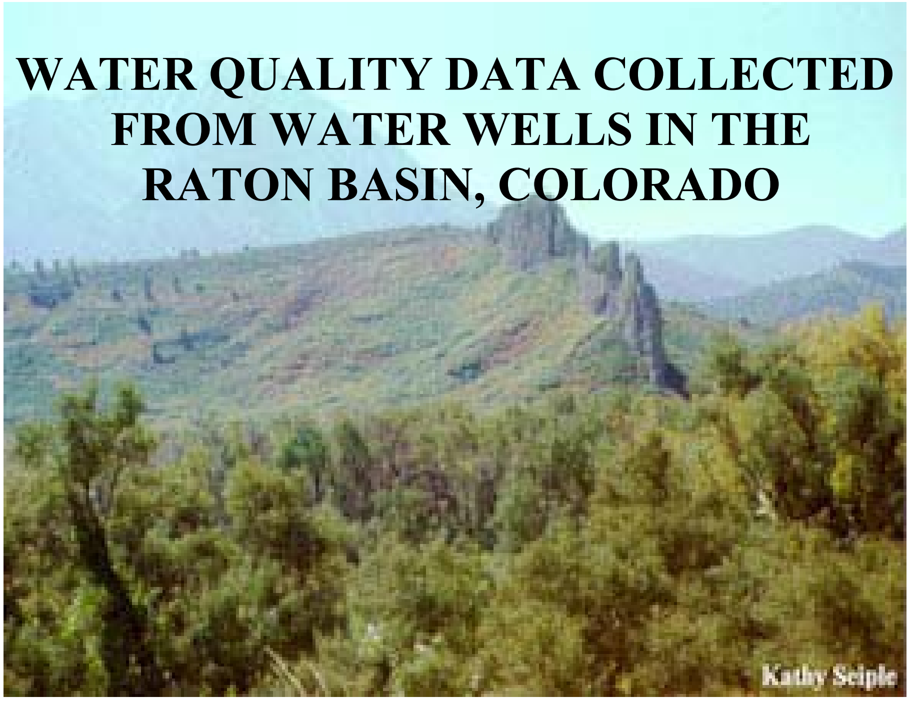
WATER QUALITY DATA COLLECTED FROM WATER WELLS IN THE RATON BASIN, COLORADO



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1. INTRODUCTION

The Raton Basin has an area of approximately 1300 square miles. It is underlain by the Raton and Vermejo coal bearing formations. The coals within these formations have been mined for over 100 years. Currently, the coal formations are being drilled to produce methane. The development of the coal-bed methane (CBM) resource has led to concern from local government and the public regarding potential impacts to groundwater resources.

To address possible concerns, a field survey was conducted in the region from January 9-17, 2002. During this survey, 100 private water sources were tested for a suite of inorganic and organic parameters. The majority of the drinking water in the rural areas of the region are derived from shallow to deep groundwater wells. The overall objective was to develop data which could be used to determine any potential impacts from the CBM development of the area. This report summarizes the findings of the surveys.

2. MATERIALS AND METHODS

2.1. Field Sampling

Water samples were collected from wellheads or spigots inside houses. Appendix 1 provides field data sheets for each of the sampled locations. Locations were confirmed with a handheld differential GPS unit. Stations were corrected to provide accuracy of 1 m or less. Location data are provided in Appendix 2.

At each sampling location, casing was purged before collecting samples. In some cases, residents asked that purging be kept to a minimum so as not to deplete wells. Water samples were collected in a plastic container and temperature, pH, dissolved oxygen and conductivity were measured.

Dissolved oxygen and pH meters were calibrated at least twice daily. DO meters were air calibrated using manufacturer's instructions. The pH meter was calibrated with pH 4 and 10 standards.

Samples for inorganic analyses were collected in 250-ml plastic bottles. Inorganic samples were shipped to ESN Rocky Mountain Labs in Golden, Colorado for analysis of cations (Ca, Na, Mg, K, Fe), anions (Cl, SO_4, CO_3, HCO_3, NO_3), total dissolved solids (TDS), pH, and total metals (eight RCRA metals).

Fifty water and gas samples were shipped to Isotech Labs in Illinois and analyzed for dissolved inorganic carbon (DIC) and two stable isotopes (carbon and deuterium of methane). Water samples were collected in 125-ml plastic bottles directly from the well or spigot. These samples were collected using a stainless steel Millipore filtering device modified to collect the gas (Figure 1). Water from each well was pumped through an inlet on the top of the stainless steel chamber. Water flowed out of the device through a valve at the bottom. Inlet and outlet flows were adjusted to allow creation of a headspace within the chamber. Water was allowed to flow for several minutes before collection to allow methane in water to outgas into the headspace atmosphere. Using a Millipore handpump, headspace gas was pumped from the collection chamber into 0.5-liter Tedlar bags. These bags were then sent to Isotech Labs for analysis.

Figure 1. Sampling apparatus to collect methane gas in water samples in the Raton Basin.

Additionally, 100 water samples were collected in 40-ml VOA viles for measurements of methane in water. These samples were chilled until being returned to a temporary field lab for analysis. Chain of custody forms for samples for chemical analyses are provided in Appendix 3.

2.2. Analysis for Methane in Water

Upon return to the lab, methane in water samples were allowed to return to ambient room temperature. A sample was then collected by upending the vial and inserting a 20-ml syringe through the rubber septum. A second 18-gauge needle was also inserted. Water escaped through this needle when 20 ml of air was injected into the vial creating a headspace. Each vial was then shaken and allowed to stabilize for approximately 20 minutes.

Samples of the gas in the headspace were then collected and injected directly into a Century OVA 128 GC equipped with a 24 in., Porapak-N, 80/100 gas chromatograph column and equipped with a flame ionization detector (FID). Hydrogen was used as the carrier gas. Temperature and atmospheric pressure were recorded at the time of analyses.

The OVA was calibrated using a 91 ppm methane in air standard. Calibration curves were made from measurements using various volumes of the methane standard injected into the OVA. Regression coefficients were calculated based on the standards curve. The standards curves had an r^2 value that averaged 0.923. The detection limit with the procedures used was 3.2 μg/l. Procedures for calculating methane concentrations in the water sample are provided in Appendix 4.

3. RESULTS

3.1. Field Parameters

Table 1 summarizes data for dissolved oxygen, pH, and conductivity collected during the field surveys. Each of these parameters was characterized by extremes that ranged from very low to high/very high. Figures 2 to 4 show the distribution of these parameters across the region. Overall, no clear pattern emerges for any of the three parameters.

3.2. Cations/Anions

Cation/anion data are provided in Tables 2 and 3. The cation/anion composition tended to be comprised primarily of sodium and bicarbonate (Figure 5). Table 4 shows the high variability measured in these samples. Total dissolved solids (TDS) ranged from low to high (86 - 2582 mg/l) with a mean value of 565 mg/l. The recommended maximum TDS level in drinking water is 500 mg/l. Most of the high levels were due to bicarbonate. Recommended drinking water levels for sulfate (250 mg/l) were exceeded for some samples. There is no indication of any kind of a distribution pattern (Figure 6).

Table 1. Dissolved oxygen, pH and conductivity data collected in the field at water sampling locations.

WELL_NAME	ID_NUM	pH	DISSOLVED OXYGEN (mg/l)	CONDUCTIVITY (umho/cm)
CORS1	1000	7.30	7.36	579
TOK1	1001	6.12	6.72	565
SHA1	1002	7.25	1.72	413
PED1	1003	7.88	1.16	442
PED2	1004	7.89	1.21	338
BROW1	1005	5.58	6.12	428
PHIL1	1006	6.74	1.97	535
PORT1	1007	7.88	1.34	718
NICK1	1008	7.55	14.37	348
RAY1	1009	6.63	4.80	501
DAND1	1010	7.10	7.93	212
BOW1	1011	8.22	5.18	1145
RRID1	1012	9.01	1.40	394
ANSI1	1013	7.40	5.43	552
ANS2	1014	7.38	3.94	640
BRE1	1015	6.99	4.34	291
POND1	1016	7.26	5.35	228
BRE2	1017	6.98	5.17	1471
NAND1	1018	6.86	5.14	1462
NAND2	1019	6.34	1.18	681
NUNN1	1020	6.01	5.35	435
YOU1	1021	5.86	4.99	417
HEAL2	1022	6.40	4.60	440
HEAL1	1023	6.10	4.87	571
CHEAL1	1024	7.01		359
LEU1	1025	6.34	1.90	463
MEST1	1026	6.43	7.29	455
MEST2	1027	5.46	2.90	336
JBR1	1028	5.78	2.57	548
JBR2	1029	5.52	2.59	584
GONZ1	1030	6.47	6.46	433
BUT1	1031	6.67	3.35	409
KEI1	1032	6.69	6.19	192
CAR1	1033	6.45	6.90	248
PAR1	1034	5.50	9.07	189
INC1	1035	5.11	8.94	266
SAK1	1036	5.34	9.07	323
GAR1	1037	5.84	2.60	386
ASH1	1038	5.19	8.54	326
CHAV1	1039	5.68	5.08	261
STIL1	1040	7.35	4.23	859
PAT1	1041	6.86	6.90	256
NEE1	1042	4.91	8.34	323
HAY1	1043	7.95	0.92	533
WW1	1044	5.66	6.50	955

WELL_NAME	ID_NUM	pH	DISSOLVED OXYGEN (mg/l)	CONDUCTIVITY (umho/cm)
FRA1	1045	5.80	1.80	912
GARC1	1046	8.20	8.09	799
TAM1	1047	5.51	4.71	722
CGAR1	1048	5.78	4.35	532
LIZ1	1049	5.92	2.53	666
CTAM1	1050	5.62	7.30	518
UNK1	1051	6.16	6.36	713
MIL1	1052	5.62	7.06	1150
KIMB1	1053	7.32	1.62	1335
COLT1	1054	7.81	3.32	3008
BESS1	1055	8.01	3.60	2015
TAYL1	1056	7.04	2.41	1402
ROBIN1	1057	7.47	4.85	835
LUJA1	1058	7.92	1.87	1672
ANDRJ1	1059	7.20	6.32	196
ANDRD1	1060	7.34	6.33	882
FODO1	1061	7.03	5.88	292
KLEIN1	1062	8.67	1.56	427
KLEIN2	1063	8.30	1.12	717
KLEIN3	1064	7.96	1.95	1129
MENEL1	1065	7.76	1.91	531
MENEL2	1066	7.04	2.59	1587
ZUBA1	1067	7.44	6.08	1406
ZUBA2	1068	7.34	2.69	1454
GOLD1	1069	7.37	6.32	649
PETE1	1070	8.54	2.20	635
OGRAD1	1071	9.04	1.31	485
OGRAD2	1072	7.70	1.47	326
OGRAD2	1073	7.65	6.27	
THEIG1	1074	8.02	1.62	696
WEB1	1075	8.29	2.85	810
OGRAD3	1076	5.89	6.39	324
TROM1	1077	6.95	7.31	495
SWIL1	1078	6.58	5.44	536
SWIL2	1079	6.87	7.33	571
SWIL3	1080	7.08	3.77	461
VAN1	1081	7.48	5.83	578
PAIN1	1082	6.30	2.22	577
ROB1	1083	7.18	2.77	418
ROB2	1084	6.10	6.44	432
ROB3	1085	6.17	1.26	445
THO1	1086	6.23	1.20	674
ROB4	1087	8.10	0.81	387
BAY1	1088	7.61	2.30	911
CURT1	1089	8.09	1.98	1559
FREN1	1090	8.40	1.26	2568
WOOD1	1091	8.13	0.65	1195
HARR1	1092	8.57	0.81	1720
SHAN1	1093	7.65	2.48	1780
SHANJ1	1094	8.30	7.65	599

WELL_NAME	ID_NUM	pH	DISSOLVED OXYGEN (mg/l)	CONDUCTIVITY (umho/cm)
LASS1	1095	7.35	1.92	517
MASO1	1096	7.07	4.40	675
KOSOJ1	1097	7.24	3.02	7
KOSOT2	1098	7.10	1.07	2254
KOSOT1	1099	7.31		1032
AVERAGE		**6.97**	**4.30**	**706**
STANDARD DEVIATION		**0.97**	**2.60**	**514**

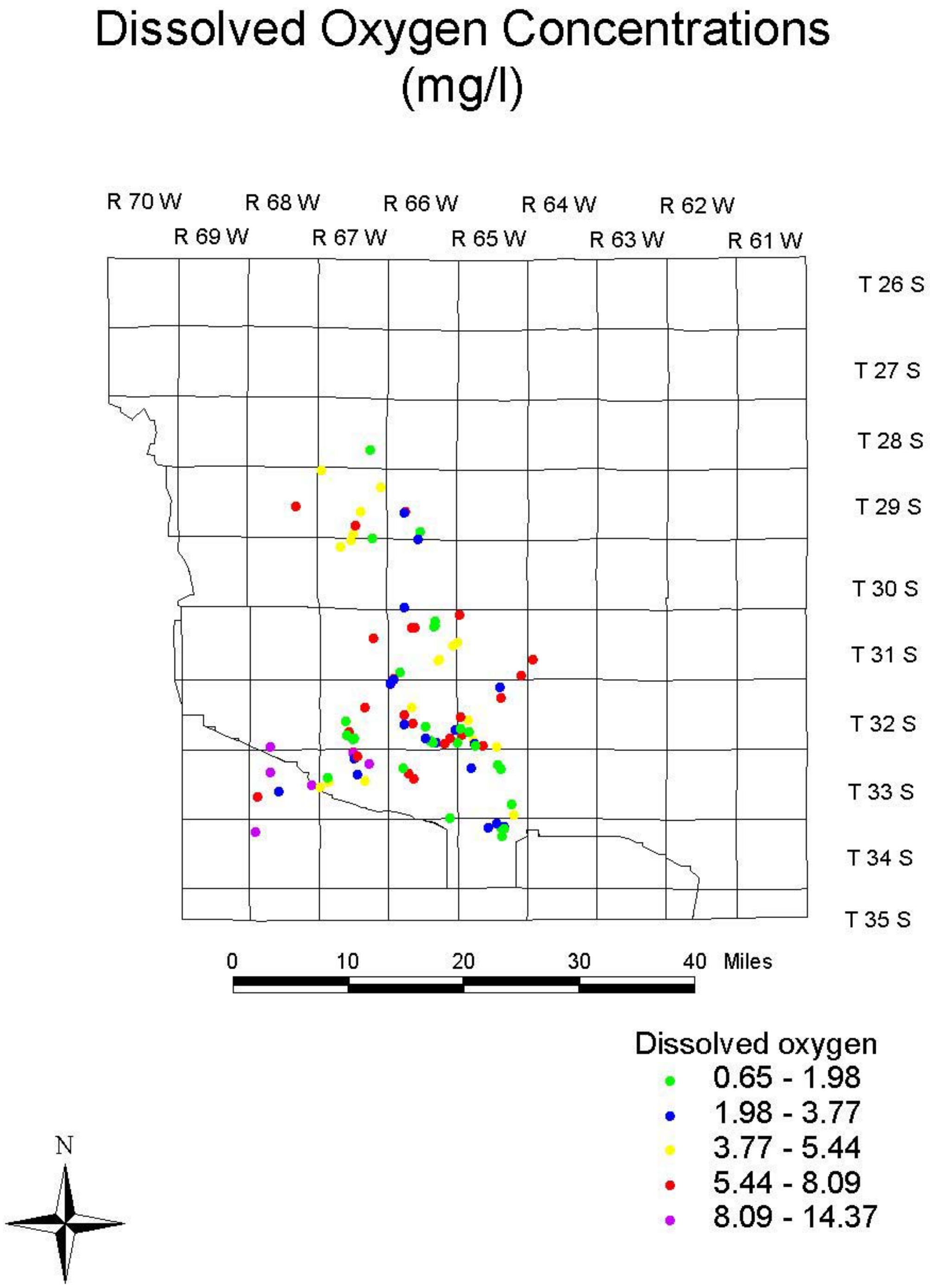


Figure 2. Dissolved oxygen concentrations (mg/l) in water samples collected in the Raton Basin.

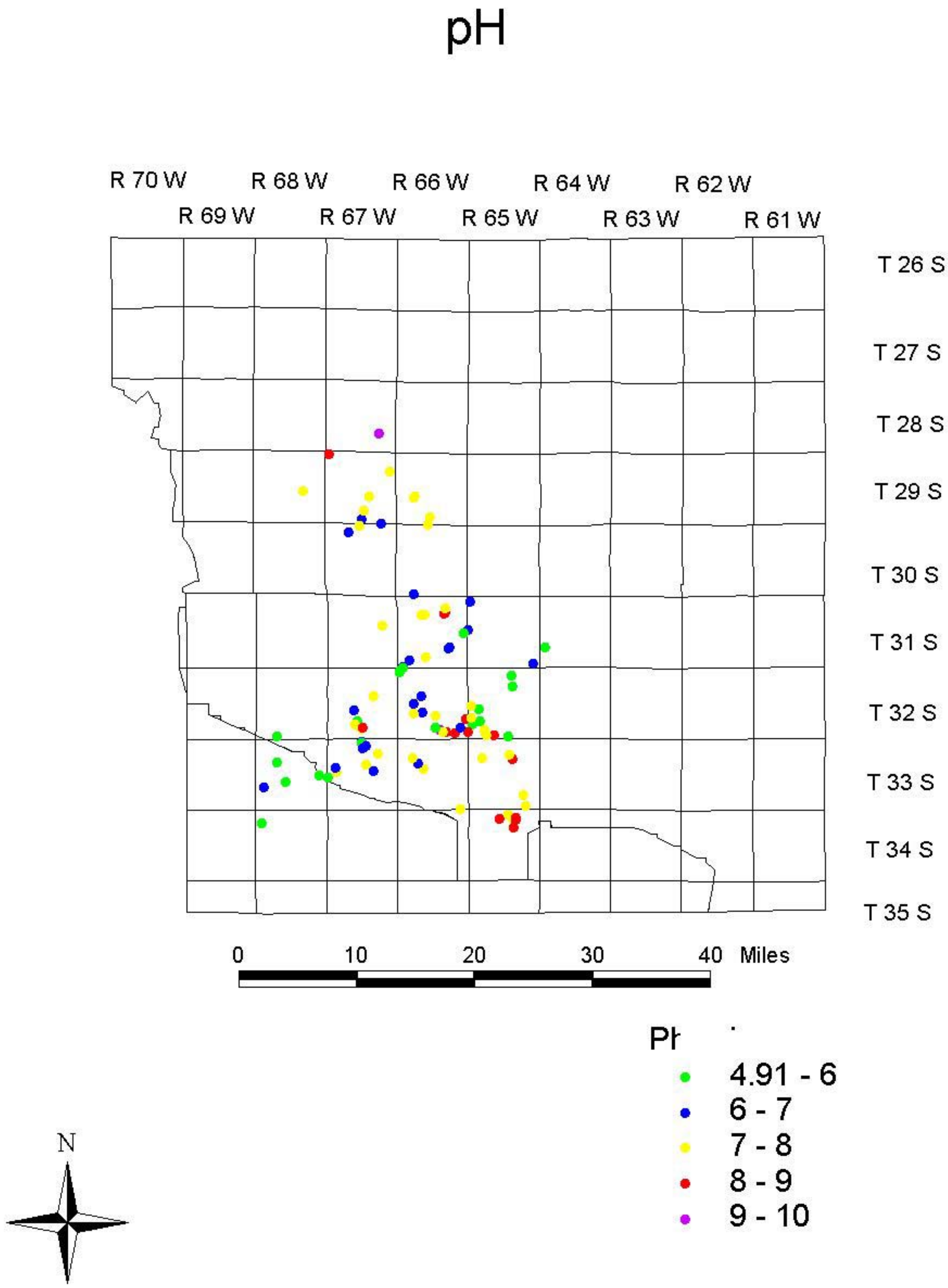


Figure 3. pH in water samples collected in the Raton Basin.

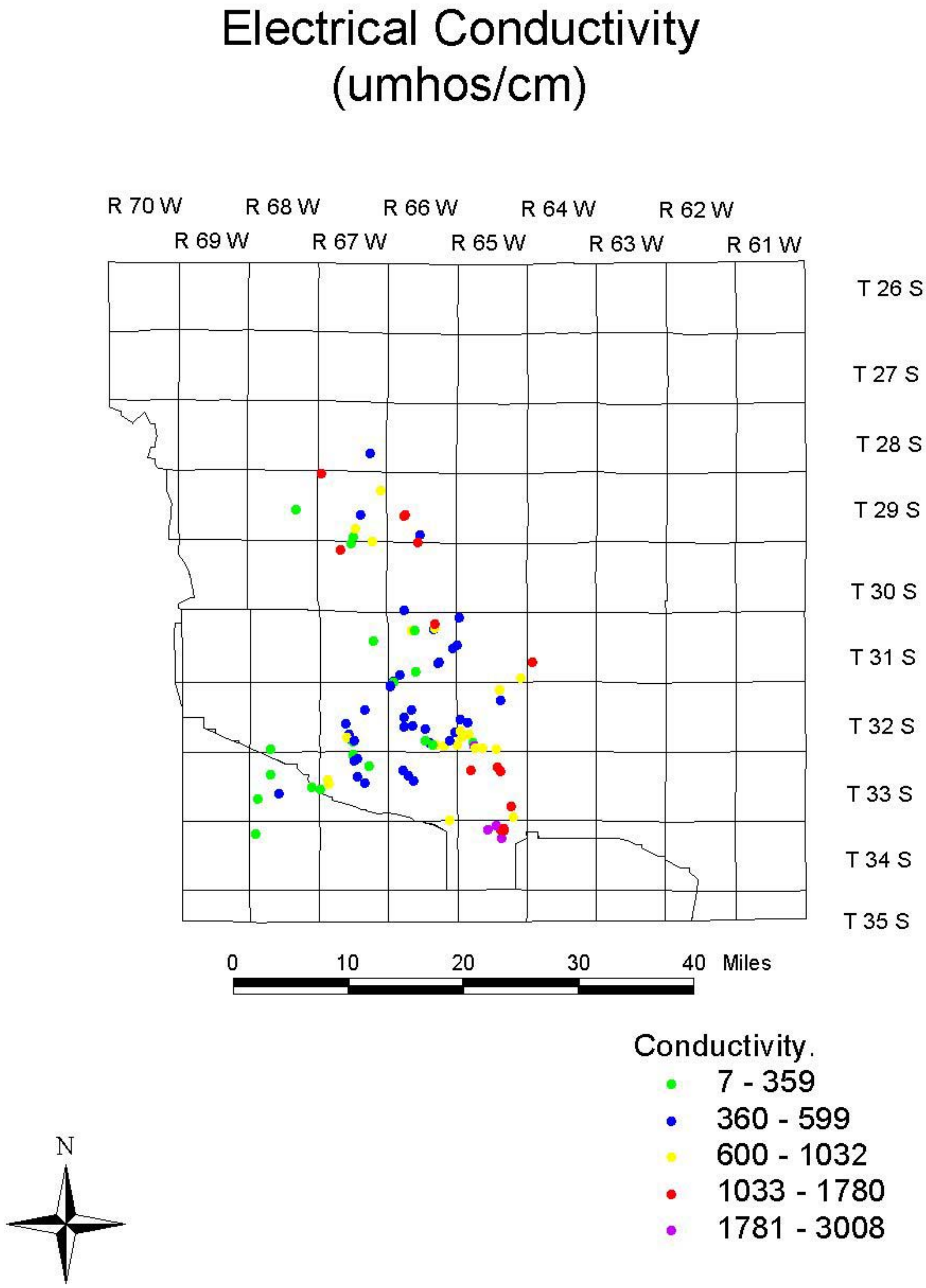


Figure 4. Conductivity in water samples collected in the Raton Basin.

Table 2. Cation concentrations (mg/l) in water samples in the Raton Basin.

Well_Name	ID_NUM	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium
ANS2	1014	ND	82.4	ND	<1	16.6	78.7
ANDRD1	1060	ND	64.3	ND	<1	16.0	89.2
ANDRJ1	1059	ND	7.3	ND	<1	4.1	17.5
ANSI1	1013	<.1	43.6	ND	1.2	16.6	87.0
ASH1	1038	ND	14.8	ND	1.2	9.9	58.9
BAY1	1088	0.1	426.3	ND	1.7	<1	6.2
BESS1	1055	0.1	640.9	ND	2.3	<1	<3
BOW1	1011	<.1	192.7	ND	<1	31.5	150.0
BRE1	1015	ND	25.2	ND	<1	8.3	45.2
BRE2	1017	ND	6.0	ND	<1	4.0	18.1
BROW1	1005	ND	44.1	ND	1.4	11.6	60.9
BUT1	1031	<.1	153.9	ND	<1	<1	6.0
CAR1	1033	ND	3.2	ND	1.0	3.9	38.6
CGAR1	1048	ND	47.8	ND	1.6	16.7	52.7
CHAV1	1039	ND	8.9	ND	1.3	9.9	48.1
CHEAL1	1024	<.1	121.8	ND	<1	<1	7.2
COLT1	1054	0.2	904.3	ND	5.0	7.9	12.2
CORS1	1000	ND	71.6	ND	2.1	17.5	57.7
CTAM1	1050	ND	85.3	ND	1.9	16.2	59.2
CURT1	1089	<.1	478.6	ND	1.6	<1	<3
DAND1	1010	ND	19.4	ND	1.2	10.4	39.6
FODO1	1061	ND	10.2	ND	<1	6.3	27.0
FRA1	1045	ND	149.1	ND	2.5	23.0	46.9
FREN1	1090	0.1	812.7	ND	3.3	<1	<3
GAR1	1037	ND	13.1	ND	1.6	10.7	69.2
GARC1	1046	<.1	205.1	ND	3.0	16.1	17.3
GOLD1	1069	<.1	37.5	ND	1.2	12.9	67.0
GONZ1	1030	ND	60.1	ND	2.2	15.8	66.1
HARR1	1092	<.1	575.9	ND	1.9	1.2	<3
HAY1	1043	ND	54.2	ND	<1	15.6	66.3
HEAL1	1023	ND	53.9	ND	<1	15.5	66.9
HEAL2	1022	ND	184.9	ND	<1	<1	7.1
INC1	1035	ND	8.5	ND	<1	6.8	53.9
JBR1	1028	ND	50.9	ND	1.4	10.5	103.2
JBR2	1029	<.1	52.4	ND	1.3	11.7	98.2
KEI1	1032	ND	3.7	ND	<1	3.7	35.9
KIMB1	1053	0.1	201.7	ND	4.1	27.5	70.6
KLEIN1	1062	0.1	131.9	ND	<1	<1	3.7
KLEIN2	1063	<.1	178.9	ND	<1	<1	7.8
KLEIN3	1064	<.1	294.3	ND	1.8	2.2	17.8
KOSOJ1	1097	<.1	167.1	ND	3.3	29.1	74.0
KOSOT1	1099	<.1	173.1	ND	2.9	22.3	99.9
KOSOT2	1098	<.1	581.4	NND	2.1	36.4	135.4
LASS1	1095	0.1	50.3	ND	1.4	10.5	52.6
LEU1	1025	<.1	56.2	ND	1.5	10.3	61.8

Well_Name	ID_NUM	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium
LIZ1	1049	ND	82.7	ND	3.5	24.8	67.1
LUJA1	1058	0.2	507.4	ND	2.4	1.5	5.6
MASO1	1096	ND	85.3	ND	1.6	12.9	69.6
MENEL1	1065	ND	78.5	ND	<1	2.7	34.7
MENEL2	1066	ND	140.5	ND	1.3	26.6	182.2
MEST1	1026	ND	35.4	ND	1.2	15.1	85.9
MEST2	1027	ND	29.4	ND	1.1	10.3	56.2
MIL1	1052	<.1	297.2	ND	3.7	34.4	97.7
NAND1	1018	ND	257.5	ND	<1	38.7	220.3
NAND2	1019	ND	43.7	ND	1.1	19.0	85.4
NEE1	1042	ND	38.7	ND	1.7	13.1	56.5
NICK1	1008	ND	146.1	ND	<1	<1	5.0
NUNN1	1020	ND	55.7	ND	2.3	14.9	59.3
OGRAD1	1071	<.1	127.1	ND	<1	<1	<3
OGRAD2	1073	<.1	196.8	ND	<1	<1	9.5
OGRAD2	1072	ND	145.9	ND	<1	<1	9.5
OGRAD3	1076	<.1	117.0	ND	<1	1.0	16.9
PAIN1	1082	ND	90.0	ND	1.9	11.9	67.1
PAR1	1034	ND	3.5	ND	<1	5.7	38.6
PAT1	1041	ND	29.9	ND	1.5	8.8	37.8
PED1	1003	<.1	158.1	ND	<1	<1	9.2
PED2	1004	<.1	125.0	ND	1.4	<1	5.0
PETE1	1070	<.1	153.6	ND	<1	<1	7.6
PHIL1	1006	ND	37.9	ND	1.2	13.7	66.1
POND1	1016	ND	24.3	ND	<1	5.6	26.7
PORT1	1007	ND	211.4	ND	<1	<1	4.1
RAY1	1009	ND	66.1	ND	1.4	17.0	60.9
ROB1	1083	<.1	52.1	ND	2.1	14.3	60.1
ROB2	1084	ND	57.5	ND	1.4	12.8	53.5
ROB3	1085	ND	43.6	ND	1.9	14.2	57.4
ROB4	1087	ND	144.8	ND	<1	<1	10.0
ROBIN1	1057	<.1	170.1	ND	3.4	9.3	29.4
RRID1	1012	ND	142.5	ND	<1	<1	3.8
SAK1	1036	<.1	70.6	ND	1.4	7.3	30.8
SHA1	1002	<.1	55.8	ND	1.5	14.8	60.3
SHAN1	1093	0.1	478.9	ND	3.4	29.6	39.7
SHANJ1	1094	ND	178.0	ND	1.0	<1	7.1
STIL1	1040	ND	331.0	ND	1.7	<1	<3
SWIL1	1078	ND	49.8	ND	1.3	12.6	76.0
SWIL2	1079	ND	50.3	ND	1.3	14.1	86.2
SWIL3	1080	ND	38.2	ND	1.9	15.6	78.5
TAM1	1047	<.1	106.8	ND	3.0	21.4	5.3
TAYL1	1056	<.1	199.8	ND	1.3	39.9	88.2
THEIG1	1074	<.1	178.5	ND	1.5	<1	10.3
THO1	1086	ND	231.1	ND	2.4	5.6	11.4

Well_Name	ID_NUM	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium
TOK1	1001	ND	77.8	ND	1.9	17.9	64.2
TROM1	1077	ND	49.6	ND	1.2	15.7	80.3
UNK1	1051	<.1	188.8	ND	3.3	9.5	31.2
VAN1	1081	ND	184.0	ND	<1	<1	20.1
WEB1	1075	<.1	219.2	ND	1.7	<1	7.1
WOOD1	1091	0.1	673.2	ND	2.1	<1	<3
WW1	1044	ND	177.7	ND	2.5	23.2	51.9
YOU1	1021	ND	89.3	ND	1.1	24.9	133.4
ZUBA1	1067	ND	167.2	ND	<1	22.4	142.5
ZUBA2	1068	ND	137.0	ND	<1	19.1	126.8
AVERAGE			153.8			14.8	53.0
STANDARD DEVIATION			174.9			8.9	41.8

ND = not detected at reporting limit
NA = Not analyzed

Table 3. Anion concentrations (mg/l) in water samples collected in the Raton Basin.

Well_Name	ID_NUM	Fluoride	Chloride	Nitrite	Phosphate	Bromide	Nitrate	Sulfate	Bicarbonate	Carbonate
ANS2	1014	0.5	14.7	ND	ND	ND	8.5	199.0	392	0.9
ANDRD1	1060	0.2	49.2	ND	ND	ND	101.0	86.5	513	1.1
ANDRJ1	1059	0.2	<1	ND	ND	ND	<1	20.4	93	0.1
ANSI1	1013	0.5	9.4	ND	ND	ND	<1	80.9	381	0.9
ASH1	1038	0.2	9.0	ND	ND	ND	<1	60.9	277	0.0
BAY1	1088	1.3	13.8	ND	ND	ND	ND	<1	1037	4.0
BESS1	1055	2.6	42.8	ND	ND	ND	ND	44.0	1422	13.7
BOW1	1011	1.1	178.2	ND	ND	1.0	9.5	626.2	194	3.0
BRE1	1015	0.3	5.0	ND	ND	ND	2.7	21.2	294	0.3
BRE2	1017	0.2	<1	ND	ND	ND	<1	7.0	100	0.1
BROW1	1005	0.3	16.0	ND	ND	ND	4.3	91.8	275	0.0
BUT1	1031	0.3	2.9	ND	ND	ND	ND	55.5	303	0.1
CAR1	1033	0.2	<1	ND	ND	ND	2.1	9.7	157	0.0
CGAR1	1048	0.2	15.0	ND	ND	<1	<1	93.1	514	0.0
CHAV1	1039	0.2	6.2	ND	ND	ND	1.7	28.4	230	0.0
CHEAL1	1024	1.8	6.1	ND	ND	ND	ND	21.8	278	0.3
COLT1	1054	0.3	20.0	ND	ND	ND	ND	1164.0	820	5.0
CORS1	1000	0.3	13.6	ND	ND	ND	1.4	113.0	319	0.6
CTAM1	1050	0.2	28.8	ND	ND	ND	<1	14.0	473	0.0
CURT1	1089	3.0	16.0	ND	ND	ND	ND	3.3	1047	12.1
DAND1	1010	0.6	2.2	ND	ND	ND	<1	37.8	222	0.3
FODO1	1061	<.1	1.4	ND	ND	ND	<1	25.2	143	0.1
FRA1	1045	0.4	114.9	ND	ND	<1	ND	38.0	678	0.0
FREN1	1090	3.1	62.3	ND	ND	<1	<1	37.1	1943	45.9
GAR1	1037	0.3	2.3	ND	ND	ND	<1	38.9	308	0.0
GARC1	1046	0.6	69.4	ND	ND	<1	<1	53.1	658	9.8
GOLD1	1069	0.5	7.6	ND	ND	ND	<1	71.4	391	0.9
GONZ1	1030	0.3	15.0	ND	ND	ND	1.2	41.7	414	0.1
HARR1	1092	5.3	20.0	ND	ND	ND	ND	14.0	1332	46.5
HAY1	1043	0.4	6.1	ND	ND	ND	<1	66.8	388	0.0
HEAL1	1023	0.4	5.9	ND	ND	ND	<1	67.8	367	0.1
HEAL2	1022	4.6	44.3	ND	ND	ND	ND	15.2	324	2.7
INC1	1035	0.2	<1	ND	ND	ND	<1	17.8	227	0.0
JBR1	1028	0.2	7.5	ND	ND	ND	ND	151.8	342	0.0
JBR2	1029	0.3	8.0	ND	ND	ND	ND	142.9	357	0.0
KEI1	1032	0.2	<1	ND	ND	ND	<1	9.9	157	0.1
KIMB1	1053	0.4	159.0	ND	ND	1.1	ND	237.0	445	0.9
KLEIN1	1062	2.5	3.2	ND	ND	ND	ND	23.6	267	11.7
KLEIN2	1063	1.4	7.9	ND	ND	ND	ND	116.0	362	6.8
KLEIN3	1064	0.6	5.1	ND	ND	ND	ND	345.2	337	2.9

Well_Name	ID_NUM	Fluoride	Chloride	Nitrite	Phosphate	Bromide	Nitrate	Sulfate	Bicarbonate	Carbonate
KOSOJ1	1097	0.2	62.0	ND	ND	ND	7.5	211.0	634	1.0
KOSOT1	1099	0.4	12.1	ND	ND	ND	ND	386.0	540	1.0
KOSOT2	1098	0.3	55.9	ND	ND	<1	11.8	833.0	1282	1.5
LASS1	1095	0.4	3.9	ND	ND	ND	<1	83.2	321	0.7
LEU1	1025	0.3	5.7	ND	ND	ND	1.4	134.0	282	0.1
LIZ1	1049	0.3	16.0	ND	ND	ND	ND	220.0	341	0.0
LUJA1	1058	1.5	138.0	ND	ND	1.1	ND	9.4	1024	8.0
MASO1	1096	0.4	57.0	ND	ND	<1	<1	51.8	414	0.5
MENEL1	1065	0.5	6.6	ND	ND	ND	<1	90.5	245	1.3
MENEL2	1066	0.5	37.9	ND	ND	<1	<1	665.9	428	0.4
MEST1	1026	0.3	6.1	ND	ND	ND	4.6	146.0	164	0.0
MEST2	1027	0.3	5.7	ND	ND	ND	ND	94.9	382	0.0
MIL1	1052	0.5	19.5	ND	ND	ND	18.7	478.9	725	0.0
NAND1	1018	0.6	56.6	ND	ND	<1	36.4	863.3	634	0.4
NAND2	1019	0.4	22.9	ND	ND	<1	ND	292.0	352	0.1
NEE1	1042	0.3	8.0	ND	ND	ND	<1	99.0	271	0.0
NICK1	1008	2.4	9.5	ND	ND	ND	ND	18.8	309	1.0
NUNN1	1020	0.4	7.3	ND	ND	ND	ND	30.9	356	0.0
OGRAD1	1071	5.4	10.0	ND	ND	ND	ND	2.8	287	29.6
OGRAD2	1073	1.7	14.7	ND	ND	<1	ND	17.1	416	1.7
OGRAD2	1072	1.7	14.4	ND	ND	ND	ND	13.6	338	1.6
OGRAD3	1076	21.0	6.7	ND	ND	ND	ND	27.8	235	0.0
PAIN1	1082	0.3	21.4	ND	ND	ND	14.2	138.7	313	0.1
PAR1	1034	0.2	<1	ND	ND	ND	ND	13.1	169	0.0
PAT1	1041	0.3	4.3	ND	ND	ND	1.0	74.5	188	0.1
PED1	1003	1.0	23.5	ND	ND	ND	ND	70.8	262	1.9
PED2	1004	3.0	16.2	ND	ND	ND	ND	9.1	175	1.3
PETE1	1070	0.7	23.8	ND	ND	<1	ND	84.2	314	10.2
PHIL1	1006	0.4	9.7	ND	ND	ND	<1	108.3	309	0.2
POND1	1016	0.4	<1	ND	ND	ND	1.4	5.7	229	0.4
PORT1	1007	6.4	206.5	ND	ND	1.1	ND	<1	268	1.9
RAY1	1009	0.3	6.1	ND	ND	ND	ND	76.4	421	0.2
ROB1	1083	0.3	8.6	ND	ND	ND	<1	100.2	297	0.4
ROB2	1084	0.3	9.4	ND	ND	ND	1.1	89.3	290	0.0
ROB3	1085	0.3	8.5	ND	ND	ND	<1	122.6	295	0.0
ROB4	1087	2.6	6.1	ND	ND	ND	ND	53.5	282	3.3
ROBIN1	1057	0.5	16.3	ND	ND	ND	<1	126.0	375	1.0
RRID1	1012	4.6	28.5	ND	ND	ND	ND	50.0	213	20.5
SAK1	1036	0.3	14.6	ND	ND	ND	1.3	35.6	272	0.0
SHA1	1002	0.3	12.6	ND	ND	ND	ND	78.4	319	0.5
SHAN1	1093	2.5	13.0	<1	ND	ND	<1	363.0	1022	4.3
SHANJ1	1094	2.0	10.0	ND	ND	ND	ND	<1	429	8.0
STIL1	1040	4.0	6.6	ND	ND	ND	ND	<1	756	1.6
SWIL1	1078	0.3	7.2	ND	ND	ND	2.7	118.2	402	0.1
SWIL2	1079	0.2	6.7	ND	ND	ND	<1	147.7	386	0.3

Well_Name	ID_NUM	Fluoride	Chloride	Nitrite	Phosphate	Bromide	Nitrate	Sulfate	Bicarbonate	Carbonate
SWIL3	1080	0.2	22.0	ND	ND	ND	44.1	104.0	350	0.4
TAM1	1047	0.3	48.7	ND	ND	<1	1.8	79.6	468	0.0
TAYL1	1056	0.6	63.5	ND	ND	<1	<1	424.0	517	0.5
THEIG1	1074	0.8	30.2	ND	ND	ND	ND	5.7	454	4.5
THO1	1086	2.8	10.5	ND	ND	ND	ND	48.7	575	0.1
TOK1	1001	0.4	13.6	ND	ND	ND	<1	80.8	419	0.1
TROM1	1077	0.3	41.8	ND	ND	ND	6.9	81.2	364	0.3
UNK1	1051	0.4	10.7	ND	ND	ND	2.3	238.0	270	0.0
VAN1	1081	3.7	94.2	ND	ND	<1	ND	38.2	289	0.8
WEB1	1075	3.2	32.8	ND	ND	<1	ND	<1	546	10.0
WOOD1	1091	3.4	53.0	ND	ND	<1	ND	<1	1543	19.6
WW1	1044	0.3	204.0	ND	ND	1.6	4.2	52.5	509	0.0
YOU1	1021	0.3	8.8	ND	ND	ND	<1	63.4	409	0.0
ZUBA1	1067	0.3	18.0	ND	ND	ND	37.2	569.0	346	0.9
ZUBA2	1068	0.4	15.0	ND	ND	ND	31.0	580.0	336	0.7
AVERAGE		**1.3**	**28.9**					**141.4**	**441**	**3.1**
STANDARD DEVIATION		**2.4**	**41.6**					**206.4**	**314.5**	**7.8**

ND = not detected at reporting limit

Table 4. Average and standard deviation of major cation/anion concentrations measured in the 100 water samples in the Raton Basin.

ION	AVERAGE	STANDARD DEVIATION
Calcium	**53**	**42**
Magnesium	**15**	**9**
Sodium	**154**	**175**
Chloride	**29**	**42**
Sulfate	**141**	**206**
Bicarbonate	**441**	**316**

3.3. Trace Metals

Trace metals concentrations tended to be low at all stations sampled (Table 5). Barium was present in all samples but at less than water quality standards (1.0 mg/l) in all but one sample. Copper and iron were found in some but not all samples. Levels were below water quality standards for copper. Some samples showed levels in which iron is detectable (0.1-0.2 mg/l). The other metals were at non-detect or less than detection levels.

3.4. Dissolved Inorganic Carbon

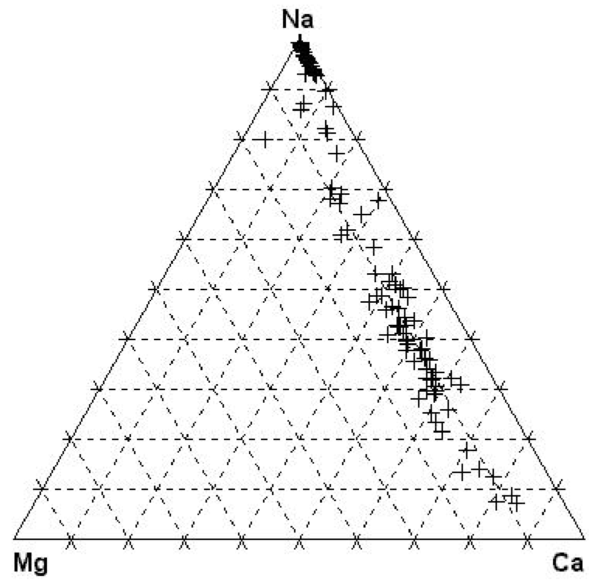
DIC ranged from -18.19 - 13.84 with a mean δC13 value of -8.83 (Table 6). These values are probably indicative of a source of DIC that originates from carbonate weathering in the basin. This could also be consistent with the high levels of bicarbonate present in the waters of the region. Figure 7 shows the geographic distribution of the DIC values. No clear pattern is evident in these distributions.

3.5. Methane

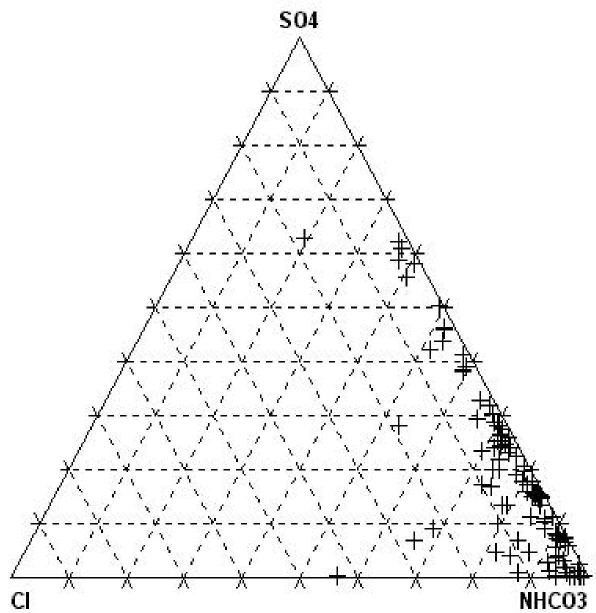
Methane concentrations are provided in Table 7. Nearly 2/3 of the samples had no methane or were at levels in which methane was measured but below detection limits. Eleven samples had levels between 100 and 1000 µg/l. Seven sites had levels > 1000 µg/l with the highest reaching over 12,000 µg/l. No clear pattern of methane concentrations was observed (Figure 8).

3.6. Carbon Isotopes in Gas

Results of the analyses conducted on the gases collected in Tedlar bags for isotope analysis are provided in Appendix 5. Approximately 60% of the collected samples showed some traces of C_1 gas, consistent with the proportion of samples in which methane was detected in the water. Methane concentrations ranged over three orders of magnitude with the highest level at 2.26%.



A



B

Figure 5. Cation (A) and Anion (B) triangle diagrams showing distribution of chemical constituents of water wells sampled in the Raton Basin.

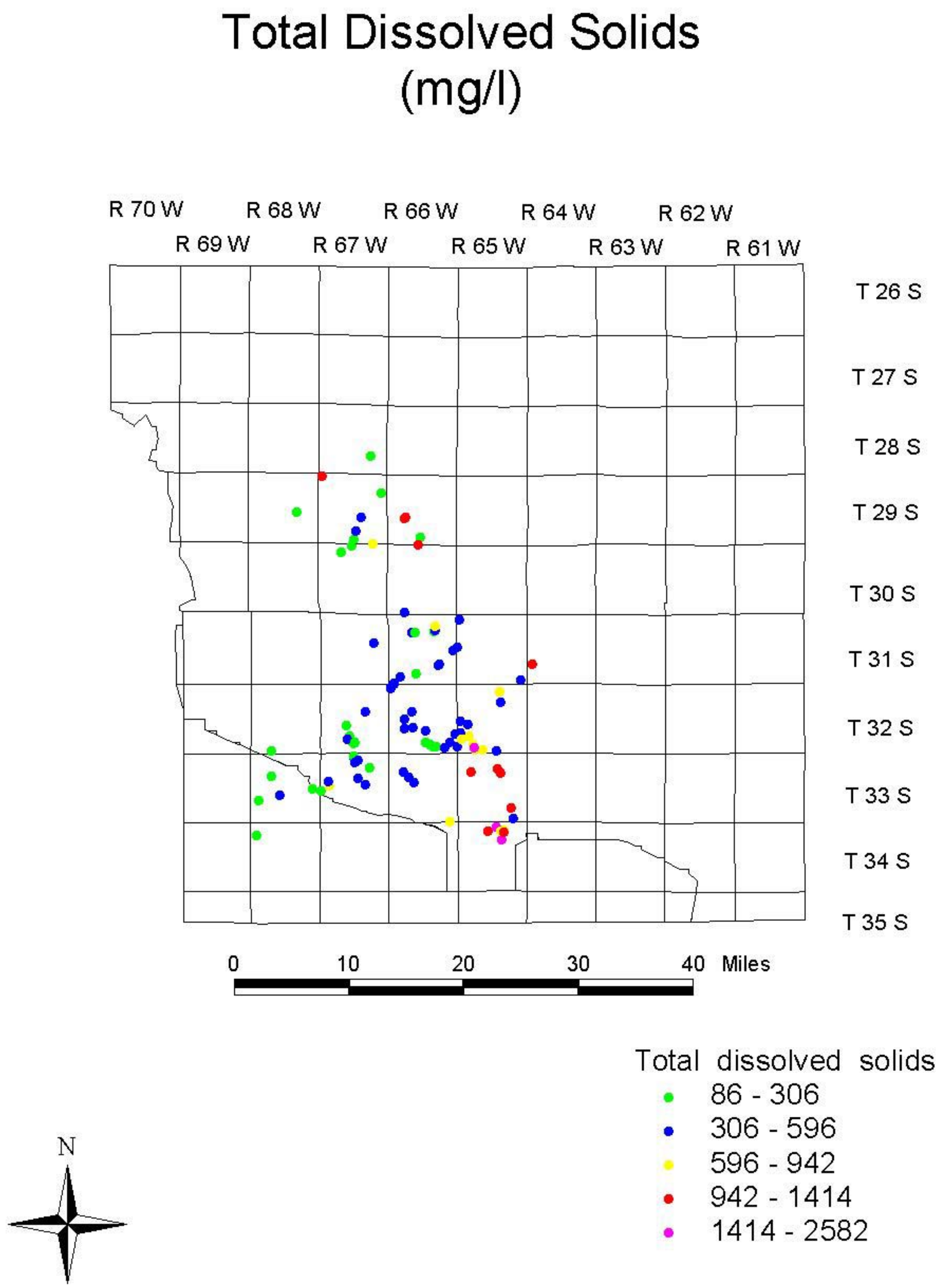


Figure 6. Distribution of total dissolved solids concentrations (mg/l) in water samples in the Raton Basin.

Table 5. Trace metals concentrations (µg/l) in water samples from the Raton Basin.

Well_Name	ID_NUM	Iron	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Manganese	Selenium	Silver	Mercury
ANS2	1014	<.02	ND	0.034	ND	ND	<.02	ND	< 0.01	ND	ND	ND
ANDRD1	1060	ND	ND	0.088	ND	ND	ND	ND	< 0.01	ND	ND	ND
ANDRJ1	1059	0.060	ND	0.059	ND	ND	ND	ND	< 0.01	ND	ND	ND
ANSI1	1013	ND	ND	0.113	ND	ND	0.037	ND	< 0.01	ND	ND	ND
ASH1	1038	<.02	ND	0.156	ND	ND	0.080	ND	< 0.01	ND	ND	ND
BAY1	1088	ND	ND	0.479	ND	ND	ND	ND	< 0.01	ND	ND	ND
BESS1	1055	<.02	ND	0.614	ND	ND	0.026	ND	< 0.01	ND	ND	ND
BOW1	1011	ND	ND	0.032	ND	ND	ND	ND	< 0.01	<.2	ND	ND
BRE1	1015	0.038	ND	0.189	ND	ND	ND	ND	< 0.01	ND	ND	ND
BRE2	1017	ND	ND	0.075	ND	ND	0.104	ND	< 0.01	ND	ND	ND
BROW1	1005	0.041	ND	0.125	ND	ND	ND	ND	< 0.01	ND	ND	ND
BUT1	1031	ND	ND	0.056	ND	ND	ND	ND	< 0.01	ND	ND	ND
CAR1	1033	0.078	ND	0.100	ND	<.02	ND	ND	< 0.01	ND	ND	ND
CGAR1	1048	<.02	ND	0.066	ND	<.02	0.078	ND	< 0.01	ND	ND	ND
CHAV1	1039	0.050	ND	0.138	ND	ND	0.027	ND	0.02	ND	ND	ND
CHEAL1	1024	ND	ND	0.086	ND	ND	ND	ND	< 0.01	ND	ND	ND
COLT1	1054	ND	ND	0.013	ND	<.02	ND	ND	0.02	ND	ND	ND
CORS1	1000	ND	ND	0.061	ND	ND	0.022	ND	< 0.01	<.2	ND	ND
CTAM1	1050	ND	ND	0.117	ND	ND	ND	ND	< 0.01	ND	ND	ND
CURT1	1089	ND	ND	0.417	ND	<.02	ND	ND	< 0.01	<.2	ND	ND
DAND1	1010	ND	ND	0.063	ND	ND	ND	ND	< 0.01	ND	ND	ND
FODO1	1061	0.022	ND	0.080	ND	ND	0.038	ND	0.038	ND	ND	ND
FRA1	1045	0.026	ND	0.238	ND	<.02	ND	ND	0.039	<.2	ND	ND
FREN1	1090	<.02	ND	1.610	ND	ND	0.029	ND	< 0.01	ND	ND	ND
GAR1	1037	0.110	ND	0.120	ND	ND	ND	ND	< 0.01	ND	ND	ND
GARC1	1046	0.045	ND	0.110	ND	<.02	<.02	ND	0.010	ND	ND	ND
GOLD1	1069	ND	ND	0.134	ND	ND	ND	ND	< 0.01	ND	ND	ND
GONZ1	1030	ND	<.1	0.070	ND	ND	ND	ND	< 0.01	<.2	ND	ND
HARR1	1092	<.02	ND	0.610	ND	ND	ND	ND	< 0.01	ND	ND	ND
HAY1	1043	ND	ND	0.097	ND	ND	0.150	ND	< 0.01	<.2	ND	ND
HEAL1	1023	ND	ND	0.081	ND	ND	ND	ND	< 0.01	ND	ND	ND
HEAL2	1022	0.130	ND	0.231	ND	ND	0.054	ND	0.024	ND	ND	ND
INC1	1035	ND	ND	0.080	ND	ND	ND	ND	< 0.01	ND	ND	ND
JBR1	1028	0.780	ND	0.028	ND	ND	ND	ND	0.48	ND	ND	ND
JBR2	1029	0.280	ND	0.061	ND	ND	ND	ND	0.59	ND	ND	ND
KEI1	1032	ND	ND	0.109	ND	ND	ND	ND	< 0.01	ND	ND	ND
KIMB1	1053	0.020	ND	0.032	ND	ND	ND	ND	0.080	<.2	ND	ND
KLEIN1	1062	ND	ND	0.075	ND	ND	ND	ND	0.012	<.2	ND	ND
KLEIN2	1063	<.02	ND	0.042	ND	ND	ND	ND	0.012	ND	ND	ND
KLEIN3	1064	0.020	ND	0.035	ND	ND	ND	ND	0.086	ND	ND	ND
KOSOJ1	1097	<.02	ND	0.060	ND	ND	0.076	ND	< 0.01	ND	ND	ND
KOSOT1	1099	0.100	ND	0.048	ND	ND	ND	ND	0.801	ND	ND	ND
KOSOT2	1098	<.02	ND	0.026	ND	ND	ND	ND	0.24	ND	ND	ND
LASS1	1095	ND	ND	0.056	ND	ND	ND	ND	< 0.01	ND	ND	ND

Well_Name	ID_NUM	Iron	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Manganese	Selenium	Silver	Mercury
LEU1	1025	<.02	ND	0.030	ND	ND	<.02	ND	< 0.01	<.2	ND	ND
LIZ1	1049	0.051	ND	0.026	ND	<.02	<.02	ND	0.40	<.2	ND	ND
LUJA1	1058	ND	ND	0.833	ND	<.02	ND	<.1	0.017	ND	<.02	ND
MASO1	1096	<.02	ND	0.472	ND	ND	ND	ND	0.010	ND	ND	ND
MENEL1	1065	ND	ND	0.045	ND	ND	ND	ND	< 0.01	<.2	ND	ND
MENEL2	1066	ND	ND	0.053	ND	ND	ND	ND	< 0.01	ND	ND	ND
MEST1	1026	0.048	ND	0.046	ND	ND	ND	ND	0.759	ND	ND	ND
MEST2	1027	0.038	ND	0.064	ND	ND	ND	ND	< 0.01	ND	ND	ND
MIL1	1052	ND	ND	0.020	ND	ND	ND	ND	< 0.01	ND	ND	ND
NAND1	1018	ND	ND	0.016	ND	ND	ND	<.1	< 0.01	<.2	ND	ND
NAND2	1019	ND	ND	0.136	ND	ND	ND	ND	0.097	ND	ND	ND
NEE1	1042	<.02	ND	0.047	ND	ND	0.056	ND	< 0.01	ND	ND	ND
NICK1	1008	ND	ND	0.130	ND	ND	<.02	ND	< 0.01	ND	ND	ND
NUNN1	1020	0.110	ND	0.214	ND	ND	ND	ND	0.019	<.2	ND	ND
OGRAD1	1071	ND	ND	0.090	ND	ND	<.02	ND	< 0.01	ND	ND	ND
OGRAD2	1073	0.038	ND	0.508	ND	ND	1.100	0.122	0.033	ND	ND	ND
OGRAD2	1072	0.048	ND	0.438	ND	ND	ND	ND	0.023	ND	ND	ND
OGRAD3	1076	<.02	ND	0.137	ND	ND	ND	ND	0.023	ND	ND	ND
PAIN1	1082	ND	ND	0.043	ND	ND	ND	ND	< 0.01	ND	ND	ND
PAR1	1034	ND	ND	0.063	ND	ND	ND	ND	< 0.01	ND	ND	ND
PAT1	1041	ND	ND	0.041	ND	ND	0.170	ND	< 0.01	<.2	ND	ND
PED1	1003	ND	ND	0.084	ND	ND	ND	ND	< 0.01	ND	ND	ND
PED2	1004	ND	ND	0.208	ND	ND	0.040	ND	0.013	ND	ND	ND
PETE1	1070	ND	ND	0.089	ND	ND	ND	ND	< 0.01	ND	ND	ND
PHIL1	1006	ND	ND	0.053	ND	ND	ND	ND	0.75	ND	ND	ND
POND1	1016	ND	ND	0.167	ND	ND	ND	ND	0.010	ND	ND	ND
PORT1	1007	ND	ND	0.344	ND	ND	ND	ND	0.012	ND	ND	ND
RAY1	1009	ND	ND	0.151	ND	ND	ND	ND	< 0.01	ND	ND	ND
ROB1	1083	0.123	ND	0.054	ND	ND	ND	ND	< 0.01	ND	ND	ND
ROB2	1084	ND	ND	0.194	ND	ND	<.02	ND	< 0.01	ND	ND	ND
ROB3	1085	ND	ND	0.066	ND	ND	ND	ND	< 0.01	ND	ND	ND
ROB4	1087	ND	ND	0.389	ND	ND	ND	ND	0.024	ND	ND	ND
ROBIN1	1057	0.053	ND	0.036	ND	ND	ND	ND	< 0.01	ND	ND	ND
RRID1	1012	<.02	ND	0.039	ND	ND	ND	ND	0.014	ND	ND	ND
SAK1	1036	ND	ND	0.181	ND	ND	ND	ND	< 0.01	ND	ND	ND
SHA1	1002	ND	ND	0.068	ND	ND	ND	ND	< 0.01	<.2	ND	ND
SHAN1	1093	ND	ND	0.070	ND	ND	ND	ND	0.012	ND	ND	ND
SHANJ1	1094	<.02	ND	0.440	ND	<.02	ND	<.1	0.021	<.2	ND	ND
STIL1	1040	ND	ND	0.150	ND	ND	ND	<.1	< 0.01	<.2	ND	ND
SWIL1	1078	ND	ND	0.053	ND	ND	ND	ND	< 0.01	ND	ND	ND
SWIL2	1079	<.02	ND	0.064	ND	ND	0.028	ND	< 0.01	ND	ND	ND
SWIL3	1080	0.022	ND	0.069	ND	ND	0.024	ND	< 0.01	ND	ND	ND
TAM1	1047	<.02	ND	0.122	ND	ND	ND	ND	< 0.01	ND	ND	ND
TAYL1	1056	ND	ND	0.023	ND	ND	ND	ND	< 0.01	ND	ND	ND
THEIG1	1074	<.2	ND	0.611	ND	ND	ND	ND	0.030	ND	ND	ND

.

Well_Name	ID_NUM	Iron	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Manganese	Selenium	Silver	Mercury
THO1	1086	0.039	ND	0.338	ND	ND	ND	ND	< 0.01	ND	ND	ND
TOK1	1001	ND	ND	0.081	ND	ND	ND	ND	< 0.01	ND	ND	ND
TROM1	1077	ND	ND	0.069	ND	ND	ND	ND	< 0.01	ND	ND	ND
UNK1	1051	ND	ND	0.072	ND	ND	ND	ND	< 0.01	ND	ND	ND
VAN1	1081	0.060	ND	0.266	ND	ND	<.02	ND	0.022	ND	ND	ND
WEB1	1075	0.034	ND	0.258	ND	ND	ND	ND	< 0.01	ND	ND	ND
WOOD1	1091	<.02	ND	0.924	ND	ND	ND	<.1	< 0.01	ND	ND	ND
WW1	1044	0.023	ND	0.115	ND	<.02	0.090	ND	< 0.01	<.2	ND	ND
YOU1	1021	ND	ND	0.063	ND	ND	<.02	ND	< 0.01	<.2	ND	ND
ZUBA1	1067	<.02	ND	0.02	ND	<.02	ND	ND	< 0.01	<.2	ND	ND
ZUBA2	1068	ND	ND	0.01	ND	ND	ND	ND	0.047	<.2	ND	ND

ND = not detected at reporting limit

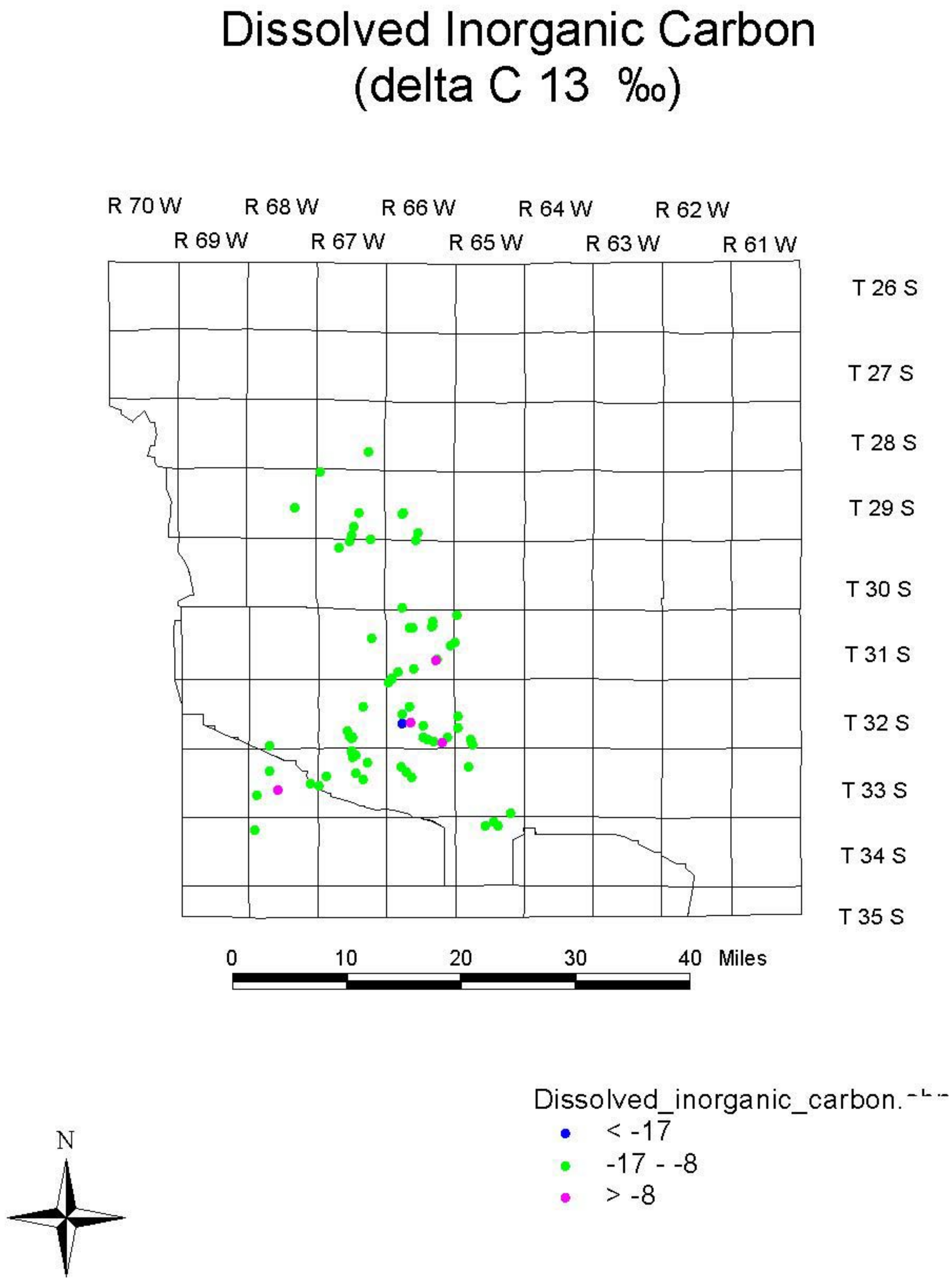


Figure 7. Dissolved inorganic carbon distributions in the Raton Basin.

Table 6. Dissolved inorganic carbon values in water samples collected in the Raton Basin.

WELL_NAME	ID_NUM	VALUE
ANS2	1060	-10.19
ANDRD1	1059	-11.42
ANDRJ1	1014	-11.42
ANS1	1013	-11.22
ASH1	1038	-11.02
BAY1	1088	12.01
BESS1	1055	-16.53
BOW1	1011	-9.56
BRE1	1015	-11.89
BRE2	1017	-9.39
BROW1	1005	-12.03
BUT1	1031	-12.56
CAR1	1033	-9.49
CGAR1	1048	
CHAV1	1039	-10.10
CHEAL1	1024	-14.41
COLT1	1054	-11.75
CORS1	1000	-9.91
CTAM1	1050	
CURT1	1089	-3.53
DAND1	1010	-11.08
FODO1	1061	-10.18
FRA1	1045	
FREN1	1090	12.05
GAR1	1037	-5.36
GARC1	1046	
GOLD1	1069	-11.44
GONZ1	1030	-8.02
HARR1	1092	-2.56
HEAL1	1023	-11.64
HEAL2	1022	-11.13
HEY1	1043	-5.30
INC1	1035	-9.44
JBR1	1028	-2.88
JBR2	1029	-11.54
KEI1	1032	-9.03
KIMB1	1053	-10.68
KLEIN1	1062	-16.34
KLEIN2	1063	-16.11
KLEIN3	1064	-13.58
KOSOJ1	1097	-11.79
KOSOT1	1099	-10.91
KOSOT2	1098	-8.85
LASS1	1095	-11.81
LEU1	1025	-9.17

WELL_NAME	ID_NUM	VALUE
LIZ1	1049	
LUJA1	1058	9.93
MASO1	1096	-10.47
MENEL1	1065	-11.23
MENEL2	1066	-12.60
MEST1	1026	-10.83
MEST2	1027	-10.87
MIL1	1052	
NAND1	1018	-10.51
NAND2	1019	-11.07
NEE1	1042	-11.23
NICK1	1008	-14.02
NUNN1	1020	-8.93
OGRAD1	1071	-11.10
OGRAD2	1073	-2.77
OGRAD2B	1072	-3.40
OGRAD3	1076	-16.20
PAIN1	1082	-9.98
PAR1	1034	-8.94
PAT1	1041	-10.25
PED1	1003	-15.03
PED2	1004	-13.29
PETE1	1070	-12.79
PHIL1	1006	
POND1	1016	-13.60
PORT1	1007	2.01
RAY1	1009	-9.67
ROB1	1083	-11.48
ROB2	1084	-11.66
ROB3	1085	-9.73
ROB4	1087	-12.39
ROBIN1	1057	-8.98
RRID1	1012	-9.78
SAK1	1036	-12.93
SHA1	1002	-10.83
SHAN1	1093	0.37
SHANJ1	1094	-1.29
STIL1	1040	-1.82
SWIL1	1078	-11.32
SWIL2	1079	-11.82
SWIL3	1080	-10.62
TAM1	1047	
TAYL1	1056	-9.51
THEIG1	1074	-5.96
THO1	1086	-8.29
TOK1	1001	-10.19
TROM1	1077	-7.42
UNK1	1051	
VAN1	1081	-18.19
WEB1	1075	

WELL_NAME	ID_NUM	VALUE
WOOD1	1091	13.84
WW1	1044	
YOU1	1021	-12.43
ZUBA1	1067	-9.96
ZUBA2	1068	-10.52
AVERAGE		**-9.11**
STANDARD DEVIATION		**5.84**

Table 7. Methane concentrations (μg/l) in water samples in the Raton Basin.

WELL NAME	SITE ID	CONCENTRATION (ug/l)	COMMENT
ANDRD1	1060	36.08	
ANDRJ1	1059	nd	
ANS1	1014	nd	
ANS2	1013	nd	
ASH1	1038	1.91	J
BAY1	1088	436.61	
BESS1	1055	27.31	
BOW1	1011	nd	
BRE1	1015	nd	
BRE2	1017	nd	
BROW1	1005	3.18	J
BUTT1	1031	nd	
CAR1	1033	nd	
CGAR1	1048	2.49	J
CHAV1	1039	5.64	
CHEAL1	1024	nd	
COLT1	1054	8.69	
CORS1	1000	7.14	
CTAM1	1050	3.39	
CURT1	1089	1732.55	
DAND1	1010	nd	
FODO1	1061	2.53	J
FRA1	1045	2.48	J
FREN1	1090	3,819.15	
GAR1	1037	nd	
GARC1	1046	3.35	
GOLD1	1069	0.95	J
GONZ1	1030	nd	
HARR1	1092	309.73	
HEAL1	1023	nd	
HEAL2	1022	nd	
HEY1	1043	2,269.33	
HEYI	1043	591.58	
INCL1	1035	nd	
JBR1	1028	nd	
JBR2	1029	nd	
KEI1	1032	0.93	J
KIMB1	1053	4.72	
KLEIN1	1062	3.82	
KLEIN2	1063	1.31	J
KLEIN3	1064	1.57	J
KOSOJ1	1097	3.02	J
KOSOJ1	1097	0.31	J
KOSOT1	1099	1.56	J
KOSOT2	1098	20.57	

WELL NAME	SITE ID	CONCENTRATION (ug/l)	COMMENT
LASS1	1095	2.58	J
LASS1	1095	0.41	J
LEU1	1025	1.54	J
LIZ1	1049	3.88	
LUJA1	1058	2,011.61	
MASO1	1096	0.93	J
MENEL1	1065	0.29	J
MENEL2	1066	11.72	
MEST1	1026	nd	
MEST2	1027	nd	
MIL1	1052	7.82	
NAND1	1018	2.72	J
NAND2	1019	nd	
NEE1	1042	nd	
NICH1	1008	8.03	
NUNN1	1020	1.16	J
OGRADY 1	1071	NA	
OGRADY 2	1073	NA	
O'GRADY 2	1072	196.65	
O'GRADY 3	1076	15.81	
PAIN1	1082	2.46	J
PAR1	1034	nd	
PAT1	1041	0.74	J
PED1	1003	2.12	J
PED2	1004	646.43	
PETE1	1070	4.58	
PHIL1	1006	7.49	
POND1	1016	nd	
PORT1	1007	1110.16	
RAY1	1009	nd	
ROB1	1083	3.02	J
ROB2	1084	1.41	J
ROB3	1085	0.93	J
ROB4	1087	429.49	
ROBIN1	1057	4.32	
ROBIN1	1057	2.38	J
RRID1	1012	948.27	
SAK1	1036	1.93	J
SHA1	1002	13.90	
SHAN1	1093	1.03	J
SHAN1	1093	0.49	J
SHANJ1	1094	980.31	
STIL1	1040	638.30	
SWIL1	1078	0.59	J
SWIL2	1079	1.30	J
SWIL3	1080	11.98	
TAM1	1047	nd	
TAYL1	1056	nd	
THIEG	1074	0.75	J
THO1	1086	199.65	

WELL NAME	SITE ID	CONCENTRATION (ug/l)	COMMENT
TOK1	1001	nd	
TROM1	1077	3.02	
UNK1	1051	2.35	J
VAN1	1081	157.51	
WEB1	1075	1412.89	
WOOD1	1091	12922.89	
WOOD1	1091	12223.12	
WW1	1044	2.35	J
YOU1	1021	nd	
ZUBA1	1067	2.96	J
ZUBA2	1068	2.63	J

nd = not detected; NA = not analyzed
J = measured at a concentration below detection limit

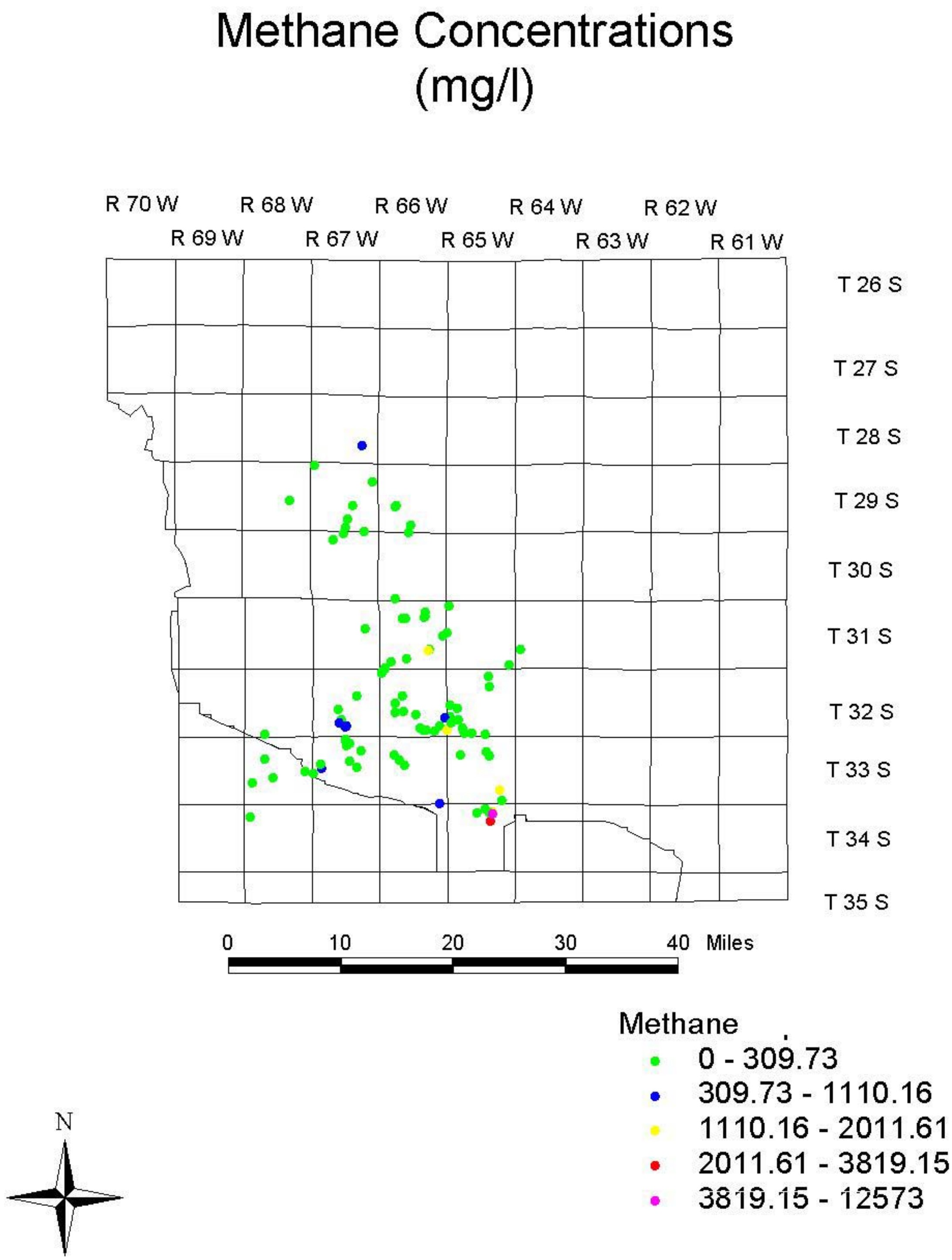


Figure 8. Distribution of methane in water samples across the Raton Basin.

4. DISCUSSION

None of the measured parameters showed any tendency towards distribution patterns that would indicate relationships between the sampled waters. This would probably be expected since most of the samples were taken from shallow wells and would not likely represent a common water source especially spread over such a large region. Correlation was also lacking between methane and dissolved oxygen concentrations.

Most of the waters tended to be high in sodium and bicarbonate concentrations and generally of acceptable water quality for the parameters measured. The biggest problem seems to be in high concentrations of sulfate with one sample showing nitrate levels above water quality standards. The wide range of cation/anion concentrations is also suggestive that the residents of the region are not accessing a common drinking water source for their wells.

Methane concentrations were generally low in the waters although there were some wells that owners reported anecdotally to be explosive at times. As with the other parameters it did not appear that the measured concentrations correlated with any of the other measured parameters.

APPENDIX 1. FIELD DATA SHEETS

Paper copy available at the COGCC office.

APPENDIX 2. SAMPLE LOCATIONS

Paper copy available at the COGCC office.

APPENDIX 3. CHAIN OF CUSTODY FORMS

Paper copy available at the COGCC office.

APPENDIX 4. METHANE CALCULATIONS

Paper copy available at the COGCC office.

APPENDIX 5. RESULTS OF ISOTOPE ANALYSES

Paper copy available at the COGCC office.