Assessment of Water Quality in the Irrigation Drainage Canals as a Source of Reusable Irrigation Water

By

Kai Williams, Graduate Student

Civil Engineering Department

New Mexico State University

Faculty Advisors:

A. Salim Bawazir, Associate Professor

Nirmala Khandan, Professor

Civil Engineering Department

New Mexico State University

TECHNICAL COMPLETION REPORT

DISCLAIMER

The purpose of the Water Resources Research Institute (WRRI) technical reports is to provide a timely outlet for research results obtained on projects supported in whole or in part by the institute. Through these reports the WRRI promotes the free exchange of information and ideas and hopes to stimulate thoughtful discussions and actions that may lead to resolution of water problems. The WRRI, through peer review of draft reports, attempts to substantiate the accuracy of information contained within its reports, but the views expressed are those of the authors and do not necessarily reflect those of the WRRI or its reviewers. Contents of this publication do not necessarily reflect the views and policies of the Department of the Interior, nor does the mention of trade names or commercial products constitute their endorsement by the United States government.

Problem Statement

Main irrigation canals in the Rincon and Mesilla Valleys were designed to convey irrigation return flow (also flood runoff at some of the locations) back to the Rio Grande River where it is mixed with the river water for downstream use. However, due to several decades of dwindling flows and in some cases no-flow in the river, the mixing of poor quality water from the irrigation drainage canals further degrades the quality of river water downstream.

Research Objectives

The Rio Grande River in southern New Mexico is experiencing poor mixing and degrading water quality as a result of decreased flows due to many years of drought. The objectives of this research are to a) assess water quality in the irrigation drainage canals specifically in southern Mesilla Valley for downstream irrigation reuse and b) identify pollutants and their point and non-point sources.

Methodology

Grab samples of irrigation drainage water were analyzed on a bi-weekly basis near and at the Sunland Park Urban Test Bed Site to assess how the water quality in the drains changed over time and geographical location (See Map, Figure 1). The water quality parameters that were tested for include Total Organic Carbon (TOC), Ammonia-Nitrogen, Chemical Oxygen Demand (COD), Escherichia coli (E. coli), anions, metals, pH, salinity, Total Dissolved Solids (TDS), and temperature. Temperature was simultaneously assessed with dissolved oxygen (DO) on site using a DO probe, and the conductivity and pH were assessed using the Hach 160 Multi-Parameter probe in the lab. Also, flowrate readings were measured at sampling point 3 (SP3) and used to estimate the flowrate throughout the Sunland Park Test Site. Grab samples for water analysis, excluding anions and metals were preserved by refrigeration. Preservation methods for anion and metal analysis of water samples will be discussed in the methodology below.
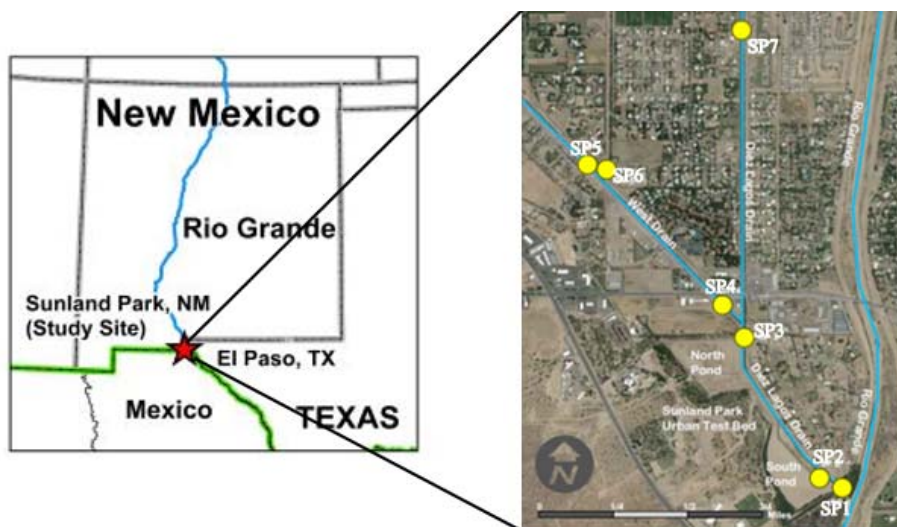
Figure 1. Map of Water Quality Sampling Points (SP)

For Total Organic Carbon analysis, the non-purgeable organic carbon analysis procedure was used due to its wide use. Samples were put into glass vials without dilution along with 1 mgC/L and 10 mgC/L standards. Standards were prepared by accurately weighing 2.125 g of reagent grade potassium hydrogen phthalate which was dried at approximately 120 ˚C for one hour and dried in a desiccator. This was transferred to a 1 L volumetric flask and dissolved in de-ionized (DI) water. The solution was well mixed so that the final concentration was 1000 mgC/L which was further diluted to 1 mgC/L and 10 mgC/L concentrations. A lab blank was added throughout the run to prevent carryover during sample analysis. Total organic carbon analysis was conducted using the Shimadzu Total Organic Carbon Analyzer.

Chemical Oxygen Demand (COD) was measured using the Hach TNTplus™ 821 Low Range kit following the US EPA Reactor Digestion Method. Samples were well mixed before 2 mL of sample were pipetted into the Hach kit vials. Vials were capped and inverted several times to mix the solution well. Afterwards, the vials were put into a 150 ˚C DRB200 Reactor for two hours and allowed to cool to 120 ˚C. Vials were inverted while still hot and placed in a rack to cool to room temperature. Vials were cleaned and then read in the Hach DR 6000 machine.

Water samples were analyzed for E.coli using the IDEXX Coliert-18 Method. In this method, 100 mL of sample was placed into a plastic vessel with pre-measured sodium thiosulfate which neutralizes 15 mg/L of chlorine that could be potentially present in the sample. The sample was, then, mixed well and set aside until foaming subsided. After the foaming subsided, the sample/reagent solution was put into sterile Quanti-trays and bubbles removed from solution. The trays were sealed with the Quanti-tray sealer and then incubated for 18 hours in 35 ˚C temperature. After samples incubated for 18 hours, sample were read under a UV light in a dark viewing cabinet, compared against the IDEXX E.coli comparable, and analyzed for the number of illuminated (or E.coli positive) wells. The number of small and large illuminated wells represented the most probable number of E.coli in 100 mL (MPN/100 mL).

Grab samples for anion analysis were taken in the field in 50 mL plastic vials without air to prevent volatilization of anions and prepared for analysis on the same day. Water samples were diluted with deionized (DI) water to prevent oversaturation and clogging of the ion chromatograph column. 100 μL (1000X dilution) and 1000 μL (10X dilution) were inserted into

two separate 10 mL volumetric flasks, and the rest of the volume was filled with DI water. After dilution samples were put into plastic polyvials while preventing air from being in the vial and capped with a filter cap. Dilutions ensured that accurate data is acquired for, both, analytes of low and high concentration. Calibration standards were prepared with a concentrated IC standard (phosphate, sulfate, bromide, nitrite, nitrate, chloride, and fluoride) which was diluted to the concentrations shown in Table 1. Specific standard anion analyte concentrations are in Appendix B. Matrix spikes were prepared by mixing 10 mL of diluted sample of choice and standard to compare the method sensitivity and accuracy. To ensure that anion peaks were separated in the IC program, 20 mg/L sulfate and 4 mg/L carbonate samples were prepared separately. Samples were then put into the Dionex ICS-2100 RFIC to be analyzed.

Table 1. Anion Standard Preparation

|	Standard Amount (mL)	D.I. Water Amount (mL)	Final Concentration (mg/L)
Standard 1	0.1	9.9	1.50
Standard 2	0.2	9.8	3.00
Standard 3	0.4	9.6	6.00
Standard 4	1.0	9.0	15.0
Standard 5	2.5	7.5	37.5
Standard 6	5.0	5.0	75.0

Grab samples taken in 50 mL plastic vials from the field were preserved with trace metal grade nitric acid to bring the pH of the sample to pH 2 for metal analysis following EPA Method 200.8. Samples were prepared in the lab by diluting the sample with 1% nitric acid (99% DI) solution to prepare 10X and 1000X dilutions. Samples were diluted in 50 mL plastic vials, and then 385 μL of the sample was taken out of that vial so that 385 μL of internal standard dilution could be added without changing the total volume of the sample solution. Internal standard dilution was made by taking 1 mL of 10 μg/mL internal standard (Bismuth, Indium, Lithium 6, Scandium, Terbium, and Yttrium) and bringing the total volume up to 10 mL with the 1% nitric acid solution mentioned previously. Then, external standards with different analytes and concentrations (Appendix A) were prepared as seen in Table 2. Two different external standards were used to prepare the calibration standards due to the wide range of metal analytes targeted. Then, 385 μL of the internal standard dilution was added to the prepared standards to keep the same concentration of internal standard as in the water samples. Samples were analyzed using the Perkin Elmer Sciex Induced Coupled Plasma-Mass Spectrometer.

Table 2. Metal External Standard Preparation

	10 µg/mL Standard	1 µg/mL Standard	1% Nitric Acid	Final Concentration
Standard 1	0.01	0.1	99.89	1.50
Standard 2	0.10	1.0	98.90	3.00
Standard 3	1.00	10	89.00	6.00
Standard 4	5.00	0.0	95.00	15.0
Standard 5	10.0	0.0	90.00	37.5

Results and Recommendations

Comparing the changes in anion concentration over time in Sampling Point 3 (SP3), 5 (SP5), and 7 (SP7) (Figure 2 and Figure 3) show that chloride, sulfate, and fluoride concentrations were relatively consistent throughout the research period. Sulfate and chloride anions were the highest among the other anion fluoride, nitrite, nitrate, and bromide. However, nitrite, nitrate, and bromide concentrations were too low in concentration for the anion analysis software to register. In addition, higher concentrations of sulfate and chloride were observed in SP3 than in SP5 and SP7.
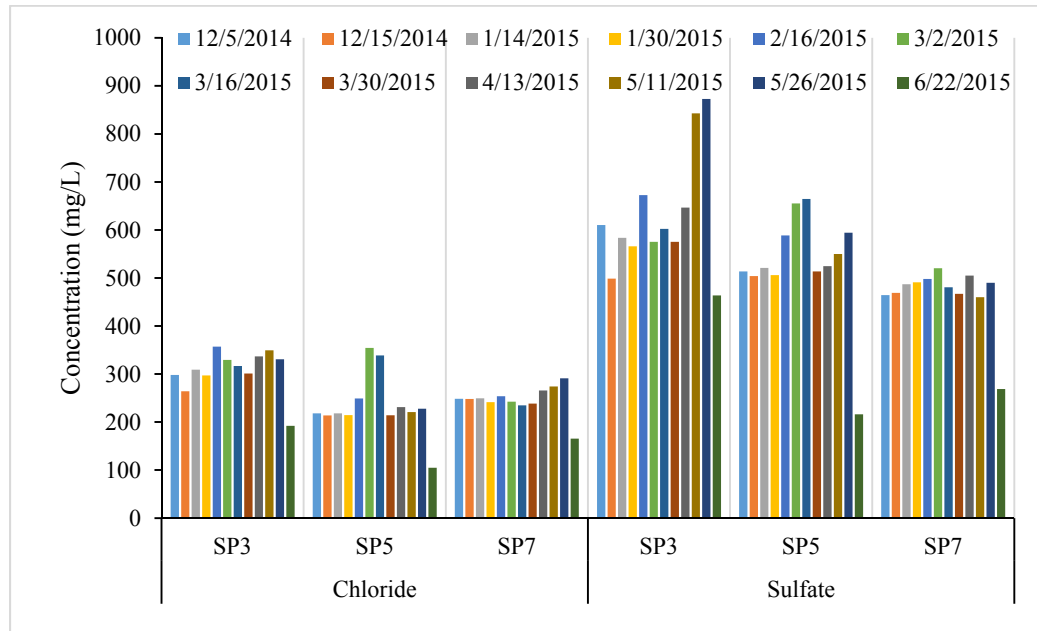

Figure 2. Sulfate and Chloride Concentration (mg/L) in Sampling Points (SP) 3, 5, and 7
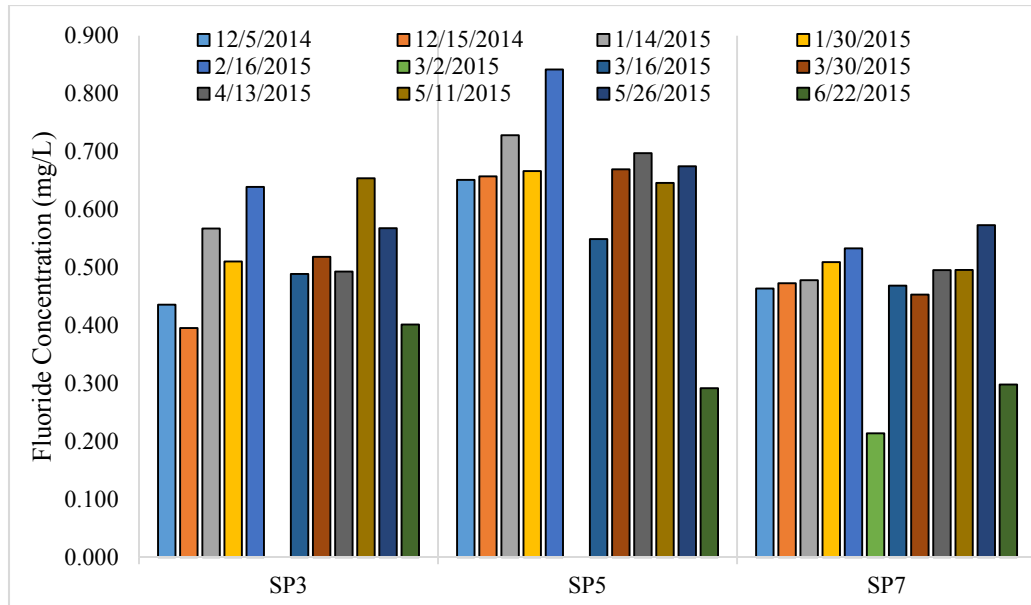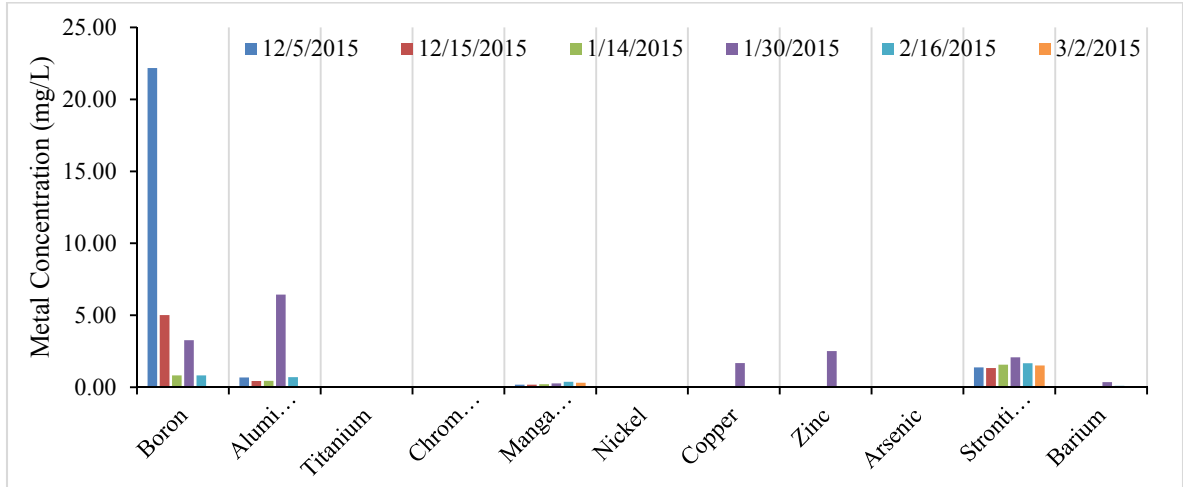
Figure 3. Fluoride Concentration (mg/L) at Sampling Points (SP) 3, 5, and 7

Metal concentrations in the Diez Lagos and West drain (Figure 1) results show that aluminum concentrations were less than 1 mg/L throughout the research period except the aluminum spike observed on January 30th. Also, Manganese was lower in concentration in the winter compared to the summer but lower 1 mg/L throughout the sampling period. The measured concentration of arsenic (As), zinc (Zn), and barium (Ba) (Figures 4-6) in the drains ranged from 0.009-0.017 mg/L As, 0.004-2.52 mg/L Zn, and 0.04-0.36 mg/L Ba. Under New Mexico State recommended concentration for domestic water supply arsenic and barium concentration should not exceed 0.05 mg/L As and 2 mg/L Ba. In addition, EPA's 2015 National Recommended Human Health Criteria state that zinc concentration should not exceed 7.4 mg/L to be safe for human consumption of water and organisms.
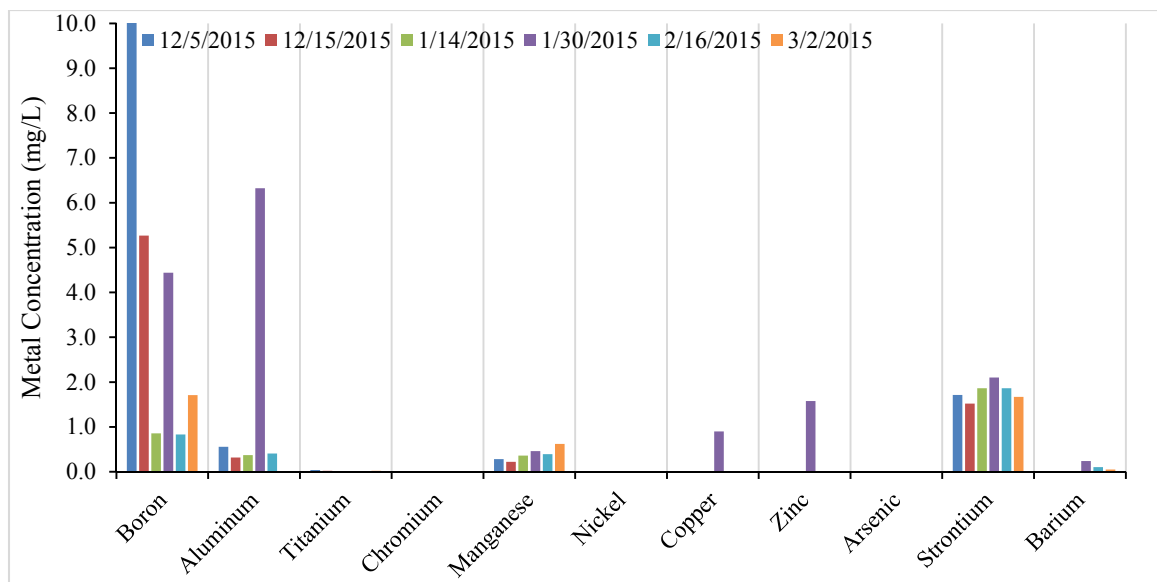
Figure 4. Metal Concentration (mg/L) at Sampling Point 3 (SP3)

Figure 5. Metal Concentration (mg/L) at Sampling Point 5 (SP5)
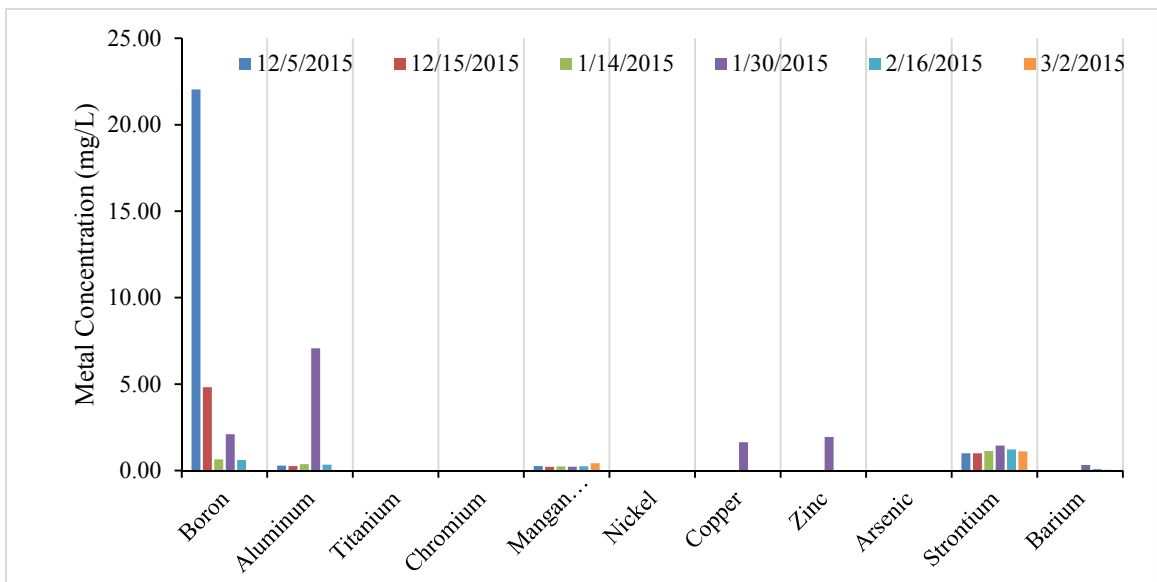
Figure 6. Metal Concentration (mg/L) at Sampling Point 7 (SP7)

Diurnal fluctuations of temperature throughout the sampling period (Figure 7) were observed due to New Mexico's cooler mornings and warmer afternoons. However, the temperature measured in the drains ranged between 7 ˚C to 26 ˚C (44.6 ˚F to 78.8 ˚F). US Environmental Protection Agency recommends a temperature of 34 ˚C or less to prevent the Rio Grande from water quality degradation.
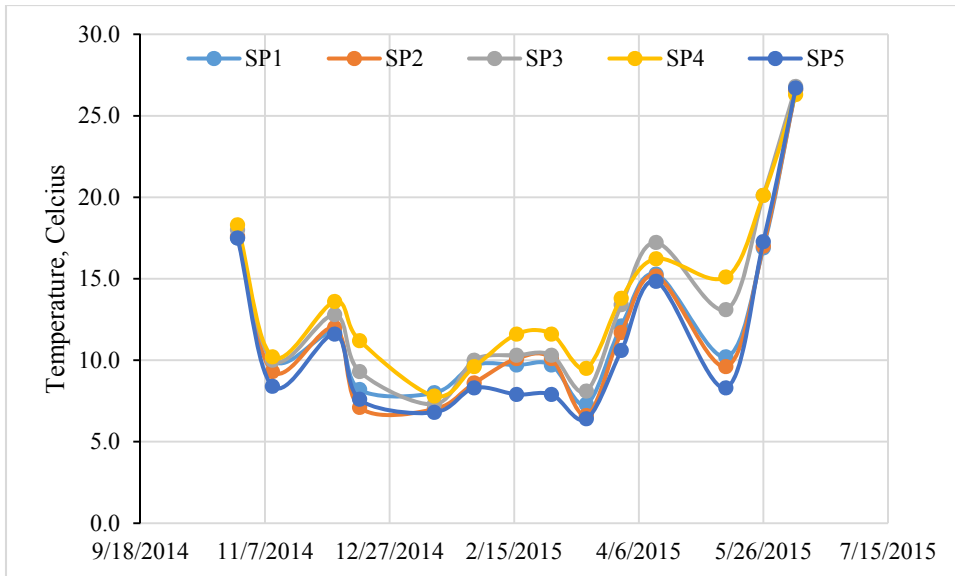
Figure 7. Irrigation Return Flow Temperature (˚C); SP represents sampling point

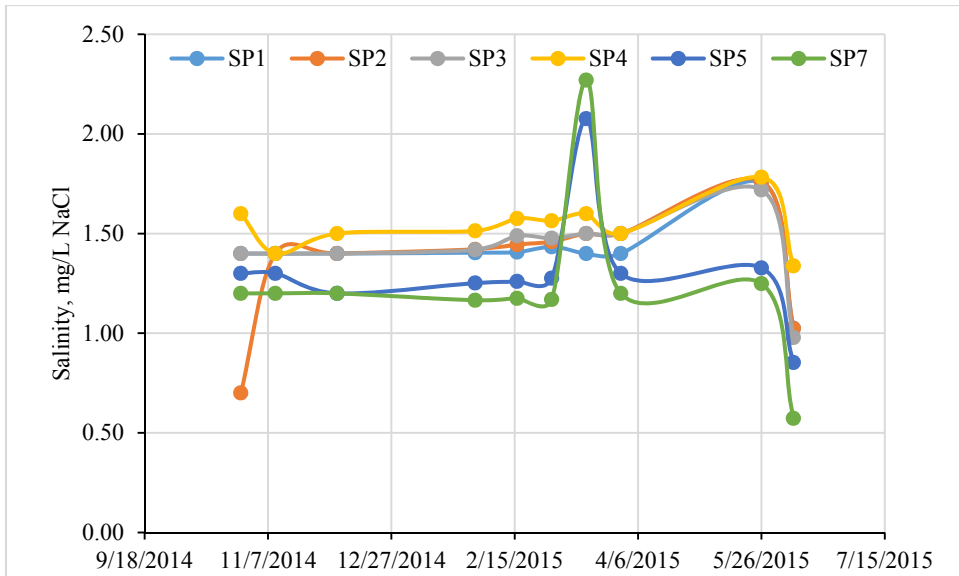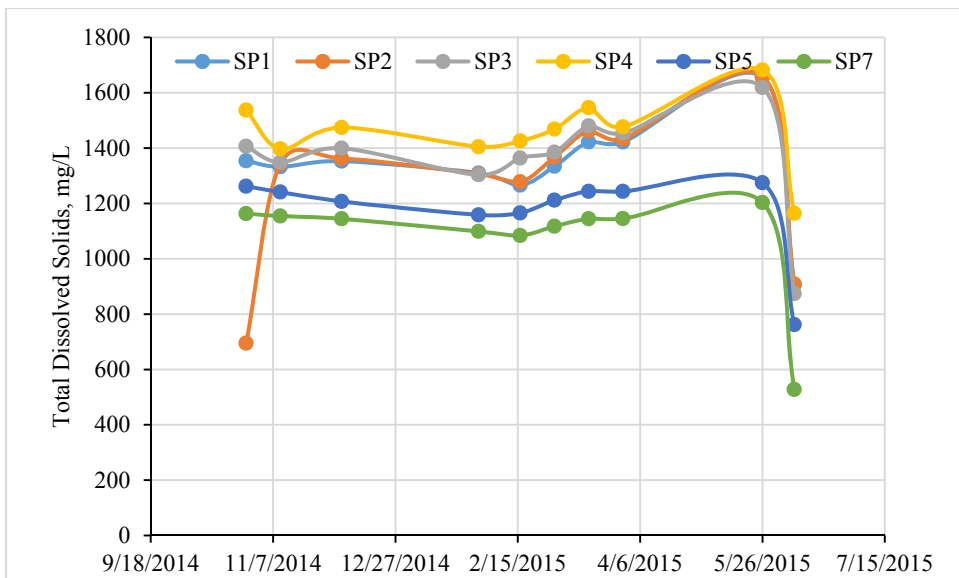Salinity and TDS in the irrigation return drains were measured shown in Figure 8 and Figure 9. U.S EPA's (EPA) Water Quality Standards for the Interstate and Intrastate Surface Waters recommends a maximum TDS concentration of 2000 mg/L for the Rio Grande River. In addition, the Food and Agriculture Organization of the United Nations states that drip irrigation systems have a slight to moderate chance of clogging due to TDS concentrations between 500 and 2000 mg/L TDS. On March 13, 2015 a spike in salinity was observed for SP5 and SP7 which is characteristic of increased flows that occurred and minimum amount of vegetation in those drains compared to the other drains. Sampling point 4 (SP4) had high salinity consistently (1.34– 1.78 mg/L as NaCl) compared to the other drains (1.02-1.76 mg/L as NaCl) which is evident of SP4 consistently having a salt layer on the water bank. However, the salinity concentration limit for irrigation will depend on the land's use, irrigation system, and vegetation salinity tolerance level.

Figure 8. Irrigation Return Flow Salinity (mg/L as NaCl); SP represents sampling point

Figure 9. Irrigation Return Flow Total Dissolved Solids (mg/L TDS); SP represents sampling point

The pH (Figure 10) in the irrigation return drains ranged from 7.87 to 8.73 which coincides with the EPA's National recommended pH range (6.5-9 pH) aquatic life criteria for freshwater. In addition, Bauder et al (2014) state that the pH of irrigation water normally ranges between 6.5 and 8.4, but waters with pH above 8.5 were attributed to regions with bicarbonate and carbonate abundant areas such as the gypsum sands present in New Mexico. Therefore, the irrigation water is acceptable for both aquatic life and irrigation re-use throughout the year using these guidelines.
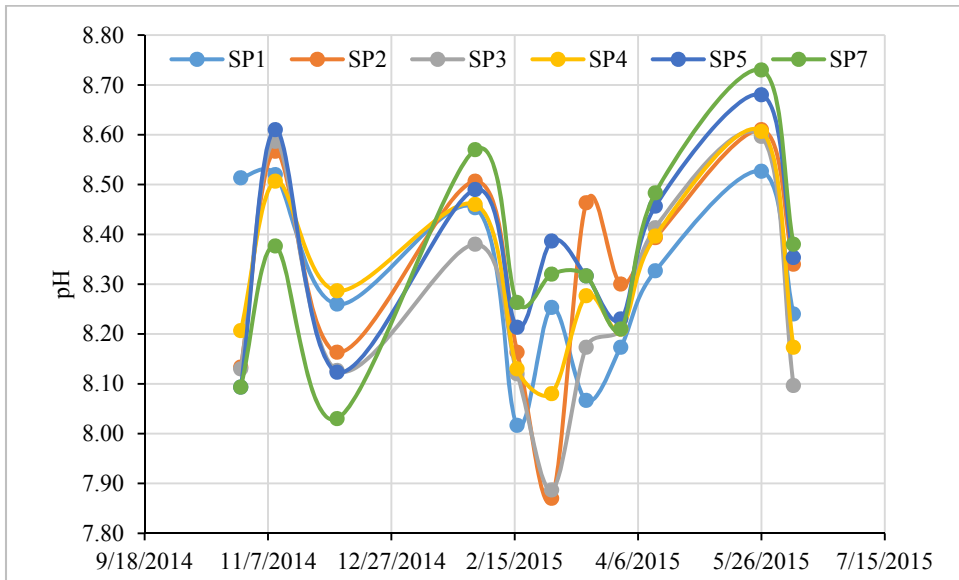
Figure 10. pH at Sampling Points (SP)

The chemical oxygen demand (COD) concentration observed in the irrigation drainage canals varied from sampling period to sampling period (Figure 11). However, COD concentrations ranged from 0 mg/L to 43 mg/L COD. Sampling point 5 was observed as having higher COD concentrations than the other sampling points which could correlate with the high E.coli concentrations characteristic of SP5. High chemical oxygen demand (COD) concentrations in irrigation systems can have a direct impact on the amount of microbial growth that is seen throughout irrigation systems, but water quality recommendations for irrigation water reuse will have to be further investigated.
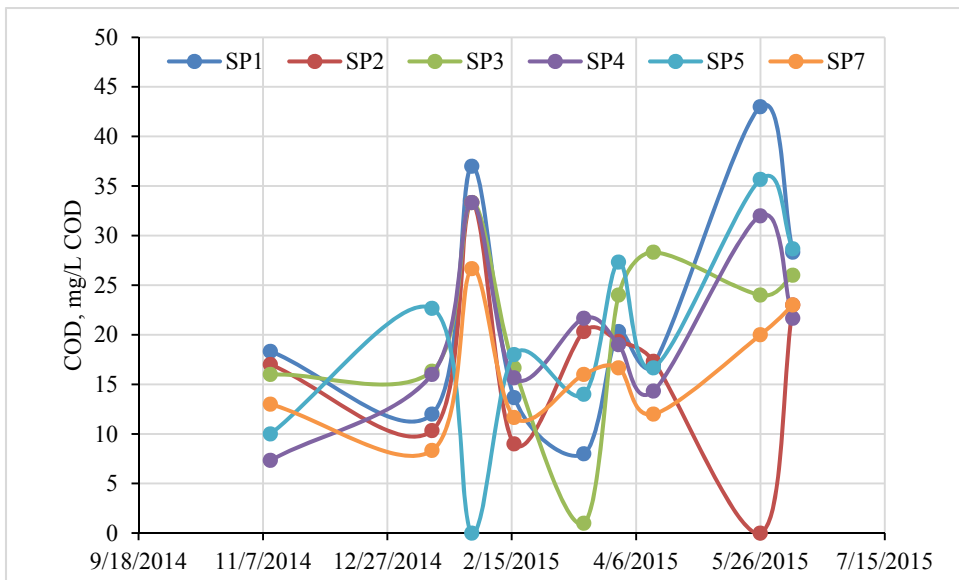
Figure 11. Chemical Oxygen Demand (mg/L COD) at Sampling Points; SP represents sampling points

11

Total Organic Carbon maximum and minimum concentration in the drains were approximately 6 mgC/L and 2 mgC/L (Figure 12). The majority of the sampling points experienced a decrease in TOC concentration over time, except sampling point 5 which varied each sampling event. However, the EPA does not have any TOC concentration recommendations for agricultural reuse or environmental reuse according to the 2012 EPA Guidelines for Water Reuse.
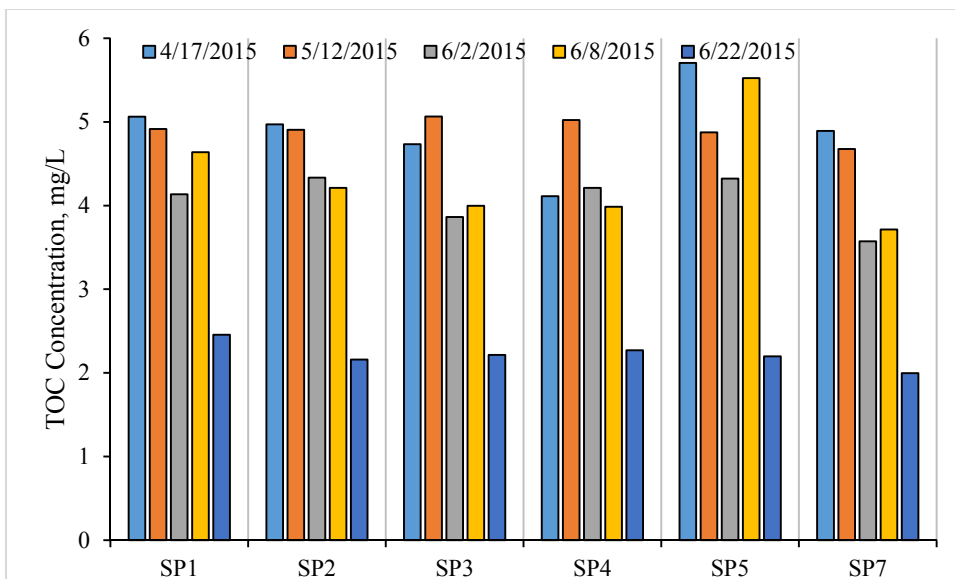
Figure 12. Total Organic Carbon (TOC) Concentration (mgC/L) at Sampling Points (SP)

The nitrogen concentration in the irrigation return were quantified by ammonia, nitrite, and nitrate concentration. However, nitrite and nitrate concentrations were too low to be registered on the anion analysis software. According to the 2012 EPA Guideline for Water Reuse, the ammonia concentration in the irrigation return drains (Figure 13) is less than the monitored reclamation water quality requirement of 2 mg/L of ammonia (monthly average). However, ammonia, nitrate, and nitrite concentrations will continue to be monitored and compared to water quality and reuse guidelines.
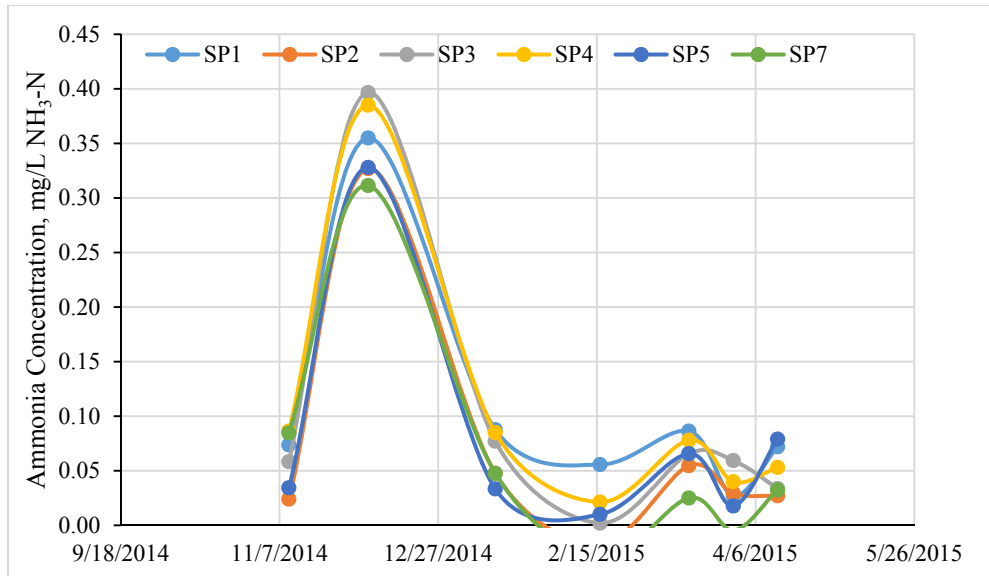
Figure 13. Ammonia Concentration (mg/L NH3-N) at Sampling Points (SP)

U.S EPA's Water Quality Standards for the Interstate and Intrastate Surface Waters state that water from the Rio Grande Basin (20.6.4.102 NMAC) should have an E.coli concentration of less than 235 MPN/100mL or less if designated for irrigation. Considering the E. coli measurements in the sampled drains ranged from 25.3 MPN/100 mL to 2419.6 MPN/100 mL (Figure 14), E. coli concentration were highest in the SP5 compared to the other sampling points. Background concentrations from the Rio Grande support that the increased E.coli is characteristic of the drains and not of the river water, itself. Therefore, special emphasis on the West Drain and South Diez Lagos Drain should be taken to decrease the concentration of E.coli for re-use further downstream (See Map, Figure 1).
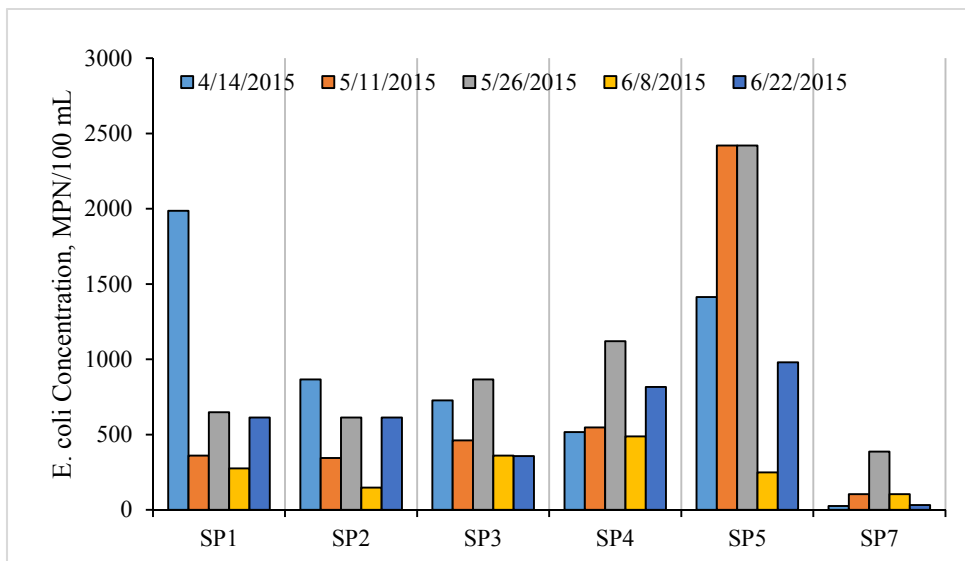
Figure 14. Escherichia coli (E. coli) Concentration (MPN/100 mL) at Sampling Points (SP)

13
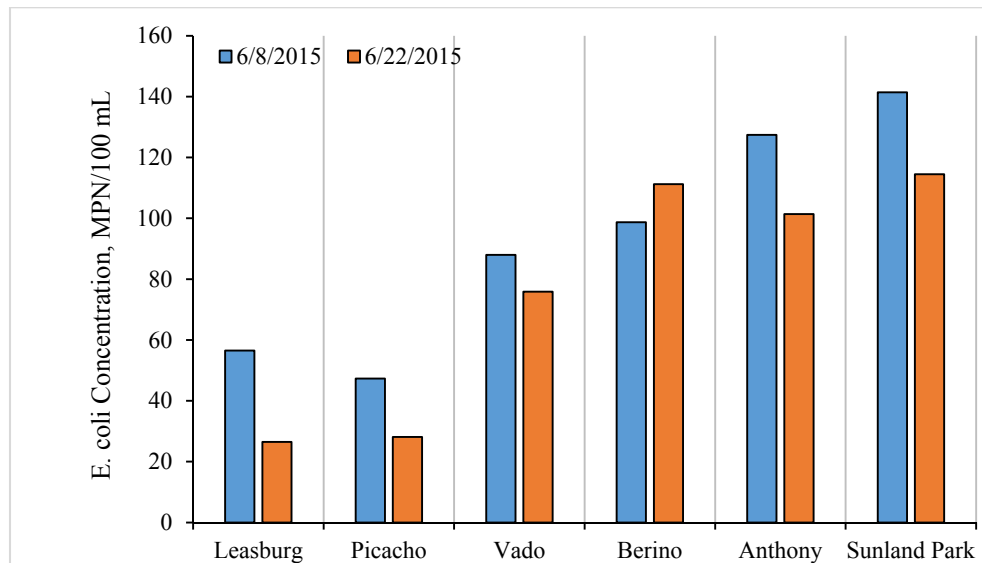
Figure 15. Escherichia coli (E. coli) Concentration (MPN/100 mL) in Rio Grande River in Different Locations

Conclusion

Overall, the water quality (excluding E.coli) in the irrigation drains were below the recommended limits for surface water and agricultural reuse. The measured concentration of arsenic (As) and zinc (Zn) observed in the drains ranged from 0.009–0.017 mg/L and 0.004–2.52 mg/L, and the concentrations were below water quality requirements/recommendations for aquatic life and human health criteria according to the EPA. Total dissolved solid concentration in the drains ranged from 600–1800 mg/L, but sampling point 4 (SP4) consistently had the highest concentration compared to the other locations. Ammonia concentration throughout the sampling period was below 0.4 mg/L, and nitrite and nitrate concentrations were too low to be recognized during anion analysis. However, point and/or non-point source of E. coli in the drains will have to be further investigated by expanding the research radius upstream of the SP5 since SP5 had the highest concentration of E.coli (maximum concentration of 2419.6 MPN/100mL) compared to the other drains (maximum concentration of 1986.3 MPN/100 mL). Therefore, this irrigation return flow has the potential for reuse downstream, but monitoring for E.coli concentrations will have to continue to confirm the potential for agricultural reuse. In conclusion, the data in this report will be used for water quality modeling to further research the transport and source of the environmental constituents.

Potential Research Beneficiaries

Once the previously mentioned objectives are met, state and federal environmental entities will have a better understanding of the irrigation return flow water quality in the southern Mesilla Valley, and they will be able to better develop guidelines for designing riparian zones which would act as pollutants' buffers and/or filtration systems. These entities include the US Bureau of Reclamation, the New Mexico Environmental Department, and irrigation districts like the Elephant Butte Irrigation District. Other beneficiaries, including the city of Las Cruces, city of El Paso, farmers, and other entities which use the Rio Grande River as a water source.

7. **Describe how you have spent your grant funds. Also provide your budget balance and how you will use any remaining funds.**

The grant funds provided by WRRI were used to purchase water quality assessment and preservation materials, such as a refrigerator, Hach multi-parameter probe and testing kits, IDEXX Colilert-18 consumables, and pipettes (See Table 3). The funds were fully used since they were an essential part of conducting this research.

Table 3. WRRI Budget

Product Description	Quantity	Unit Cost	Actual Cost
Multiple anion Std.	1	$ 86.40	
Internal Std. (5 rare elements)	1	$ 110.40	$ 532.02
Metals Std.	1	$ 174.40	
NMSU Customized solution	1	$ 119.20	
Multiple anion Std.	1	$ 86.40	
Internal Std. (5 rare elements)	1	$ 110.40	$ 531.89
Metals Std.	1	$ 174.40	
NMSU Customized solution	1	$ 119.20	
Vials to measure COD, Low Range	6	$ 38.49	
Total Alkalinity TNT870 vials (25 package)	6	$ 36.45	$ 783.81
Ammonia, HR TNT831 Reagent Set (25 package)	6	$ 48.75	
Vials to measure COD, Low Range	4	$ 38.99	
Total Alkalinity TNT870 vials (25 package)	4	$ 37.65	$ 551.79
Ammonia, LR TNT830 Reagent Set (25 package)	4	$ 50.89	
Hach Multi-Parameter Probe	1	$ 1,438.96	$ 1,438.96
EC Eluent	1	$ 16.25	$ 16.25
E coli/total coliform	1	$ 1,566.82	$ 1,566.82
Lab Refrigerator	1	$ 478.00	$ 478.00
10-100 ul Pipettor Tips	1	$ 18.50	$ 18.50
1000 PK 50-1000ul Tips	1	$ 53.81	$ 53.81
Polyvials w/ Filter Caps 5 ml 250 Pack	1	$ 117.79	$ 117.79
		Grand Total	$ 5,994.00
		Total Spent	$ 6,089.64
		Remainder	$ (95.64)

8. **List presentations you have made related to the project.**
    - 2014 Annual Water Resources and Research Institute New Mexico Water Conference
    - 2015 RMSAWWA/RMWEA New Mexico Spring Workshop
    - 2015 Re-inventing the Nation's Urban Water Infrastructure (ReNUWIt) Annual Meeting
    - 2015 RMSAWWA/RMWEA 12th Annual Student Conference

9. **List publications or reports, if any, that you are preparing. Remember to acknowledge the NM WRRI funding in any presentation or report that you prepare.**

10. **List any other students or faculty members who have assisted you with your project.**

    Juan Solis, Aldo Piñon-Villareal, Mark Chidester, Barbara Hunter, Leili Abkar, Ashley Jaramillo

Appendix

A. Analytes in External Standards for Metal Analysis
   a. 10 µg/mL standard contains the following analytes: Silver, Aluminum, Arsenic, Boron, Barium, Beryllium, Calcium, Cadmium, Cerium, Cobalt, Chromium-3, Cesium, Copper, Dysprosium, Erbium, Europium, Iron, Gallium, Gadolinium, Holmium, Potassium, Lanthanum, Lutetium, Magnesium, Manganese, Sodium, Neodymium, Nickel, Phosphorus, Lead, Praseodymium, Rubidium, Sulfur, Selenium, Sm, Samarium, Thorium, Thallium, Thulium, Uranium, Vanadium, Ytterbium, Zinc
   b. 1 µg/mL standard contains the following analytes: Molybdenum, Selenium, Silicon, Titanium

B. Analytes in External Standard for Anion Analysis
   a. 150.00 µg/mL ea.: oPhosphate, Sulfate
   b. 100.00 µg/mL ea.: Bromide, Nitrate, Nitrite
   c. 30.00 µg/mL ea.: Chloride
   d. 20.00 µg/mL ea.: Fluoride

C. Irrigation Return Flow and Rio Grande River Data

Table A1. Temperature (˚C) at Sampling Points

	SP1	SP2	SP3	SP4	SP5	SP7
10/27/2014	17.5	17.6	18.0	18.3	17.5	18.6
11/10/2014	10.0	9.3	10.0	10.2	8.4	10.0
12/5/2014	11.7	12.0	12.8	13.6	11.6	13.5
12/15/2014	8.2	7.1	9.3	11.2	7.6	9.8
1/14/2015	8.0	7.0	7.3	7.8	6.8	8.7
1/30/2015	9.7	8.6	10.0	9.6	8.3	11.0
2/16/2015	9.7	10.1	10.3	11.6	7.9	10.0
3/2/2015	9.7	10.1	10.3	11.6	7.9	10.0
3/16/2015	7.3	6.6	8.1	9.5	6.4	10.0
3/30/2015	12.1	11.7	13.4	13.8	10.6	10.0
4/13/2015	15.3	15.2	17.2	16.2	14.8	11.0
5/11/2015	10.2	9.6	13.1	15.1	8.3	13.6
5/26/2015	16.9	17.0	20.1	20.1	17.3	20.0
6/8/2015	26.6	26.6	26.8	26.3	26.7	26.3

Table A2. Salinity Concentration (mg/L as NaCl) at Sampling Points

	SP1	SP2	SP3	SP4	SP5	SP7
10/27/2014	1.40	0.70	1.40	1.60	1.30	1.20
12/5/2014	1.40	1.40	1.40	1.40	1.30	1.20
12/15/2015	1.40	1.40	1.40	1.50	1.20	1.20
1/30/2015	1.40	1.42	1.42	1.51	1.25	1.17
2/16/2015	1.41	1.45	1.49	1.58	1.26	1.18
3/2/2015	1.43	1.46	1.48	1.56	1.28	1.17
3/16/2015	1.40	1.50	1.50	1.60	2.08	2.27
3/30/2015	1.40	1.50	1.50	1.50	1.30	1.20
5/26/2015	1.76	1.76	1.72	1.78	1.33	1.25
6/8/2015	1.03	1.02	0.98	1.34	0.85	0.57

Table A3. Total Dissolved Solids (mg/L TDS) at Sampling Points

	SP1	SP2	SP3	SP4	SP5	SP7
10/27/2014	1354	695	1406	1537	1262	1163
12/5/2014	1332	1342	1349	1397	1241	1154
12/15/2015	1353	1363	1399	1474	1207	1144
1/30/2015	1310	1306	1303	1405	1159	1099
2/16/2015	1266	1278	1364	1426	1166	1084
3/2/2015	1334	1368	1385	1469	1212	1117
3/16/2015	1422	1462	1480	1546	1244	1145
3/30/2015	1422	1433	1454	1476	1243	1145
5/26/2015	1656	1659	1619	1682	1275	1203
6/8/2015	905	909	874	1164	762	528

Table A4. pH at Sampling Points

	SP1	SP2	SP3	SP4	SP5	SP7
10/27/2014	8.51	8.13	8.13	8.21	8.09	8.09
12/5/2014	8.52	8.57	8.59	8.51	8.61	8.38
12/15/2015	8.26	8.16	8.13	8.29	8.12	8.03
1/30/2015	8.45	8.51	8.38	8.46	8.49	8.57
2/16/2015	8.02	8.16	8.12	8.13	8.21	8.26
3/2/2015	8.25	7.87	7.89	8.08	8.39	8.32
3/16/2015	8.07	8.46	8.17	8.28	8.32	8.32
3/30/2015	8.17	8.30	8.21	8.21	8.23	8.21
4/13/2015	8.33	8.39	8.41	8.40	8.46	8.48
5/26/2015	8.53	8.61	8.60	8.61	8.68	8.73
6/8/2015	8.24	8.34	8.10	8.17	8.35	8.38

Table A5. Chemical Oxygen Demand (mg/L COD) at Sampling Points

	SP1	SP2	SP3	SP4	SP5	SP7
11/10/2014	18	17	16	7	10	13
1/14/2015	12	10	16	16	23	8
1/30/2015	37	33	33	33	0	27
2/16/2015	14	9	17	16	18	12
3/16/2015	8	20	1	22	14	16
3/30/2015	20	19	24	19	27	17
4/13/2015	17	17	28	14	17	12
5/26/2015	43	0	24	32	36	20
6/8/2015	28	23	26	22	29	23

Table A6. Total Organic Carbon in the Southern Mesilla Valley

	4/17/2015	5/12/2015	6/2/2015	6/8/2015	6/22/2015
SP1	5.062	4.915	4.136	4.639	2.456
SP2	4.971	4.906	4.334	4.212	2.159
SP3	4.733	5.064	3.863	3.997	2.214
SP4	4.112	5.023	4.212	3.986	2.27
SP5	5.705	4.875	4.323	5.524	2.198
SP7	4.893	4.676	3.572	3.715	1.996
Leasburg	-	-	5.488	3.835	2.045
Picacho	-	-	-	3.674	2.062
Vado	-	-	-	3.67	2.141
Berino	-	-	-	3.784	2.043
Anthony	-	-	-	3.665	2.141
Sunland Park	-	-	-	3.496	2.04

Table A7. Ammonia Concentration (mg/L NH3-N) at Sampling Points

	11/10/2014	12/5/2014	1/14/2015	2/16/2015	3/16/2015	3/30/2015	4/13/2015
SP1	0.074	0.355	0.088	0.056	0.086	0.027	0.072
SP2	0.024	0.327	0.048	0.000	0.055	0.029	0.027
SP3	0.058	0.397	0.077	0.002	0.066	0.059	0.034
SP4	0.086	0.385	0.085	0.021	0.078	0.040	0.053
SP5	0.034	0.328	0.033	0.010	0.066	0.018	0.079
SP7	0.085	0.311	0.048	0.000	0.025	0.000	0.032

Table 4. Escherichia coli (E. coli) Concentration in Southern Mesilla Valley

	4/14/2015	5/11/2015	5/26/2015	6/8/2015	6/22/2015
SP1	1986.3	360.9	648.8	275.5	613.1
SP2	866.4	344.8	613.1	148.3	613.1
SP3	727	461.1	866.4	360.9	357.8
SP4	517.2	547.5	1119.9	488.4	816.4
SP5	1413.2	2419.6	2419.6	248.9	980.4
SP7	25.3	104.3	387.3	104.3	31.6
Leasburg	-	-	-	56.5	26.5
Picacho	-	-	-	47.3	28.1
Vado	-	-	-	88	75.9
Berino	-	-	-	98.7	111.2
Anthony	-	-	-	127.4	101.4
Sunland Park	-	-	-	141.4	114.5

Figure A1. Water Quality Sampling Point 5 (SP5)

Figure A2. Water Quality Sampling Point 7 (SP7)

Figure A3. Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) Conducting Metal Analysis

Work Cited

Bauder, Waskom, Sutherland, Davis. Fact Sheet, 2014. *Fact Sheet No. 0.506 Irrigation Water Quality Criteria. http://www.ext.colostate.edu/pubs/CROPS/00506.pdf (*May 2015)

Food and Agriculture Organization of the United Nations, 1994. *Water Quality for Agriculture. http://www.fao.org/DOCReP/003/T0234e/T0234E06.htm#ch5.6.1*

Gil Dichter, October 2011. *IDEXX Colilert*-18 and Quanti-Tray* Test Method for the Detection of Fecal Coliforms in Wastewater.* https://www.idexx.com/resource-library/water/water-reg-article15C.pdf (October 2014)

Shimadzu Corporation, 2000. *TOC-VCPH/CPN User Manual (For TOC-Control V Ver. 2). PDF* (December 2014)

United States Environmental Protection Agency (US EPA), 1993. *Method 300.0, Determination of Inorganic Anions by Ion Chromatography.* http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/2007_07_10_methods_method_300_0.pdf (September 2014)

United States Environmental Protection Agency (US EPA), 1994. *Method 200.8, Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry.* http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/2007_07_10_methods_method_200_8.pdf (September 2014)

United States Environmental Protection Agency (US EPA), 2000. *Chapter 6 Water Quality, Part 4 Standards for Interstate and Intrastate Surface Waters.* http://water.epa.gov/scitech/swguidance/standards/wqslibrary/upload/nmwqs.pdf (January 30, 2015)

United States Environmental Protection Agency (US EPA), 2007. *Method 9056A, Determination of Inorganic Anions by Ion Chromatography.* http://www.epa.gov/solidwaste/hazard/testmethods/sw846/pdfs/9056a.pdf (September 2014)

United States Environmental Protection Agency (US EPA), 2008. *New Mexico State Numeric Critieria Vs. EPA Numeric Criteria.* http://www.epa.gov/waters/data/attributes.html (January 12, 2015)

United States Environmental Protection Agency (US EPA), 2012. *Guidelines for Water Reuse.* http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf (February 2015)

United States Environmental Protection Agency (US EPA), 2015. *National Recommended Water Quality Criteria.* http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#C (October 2014)