Analysis of Water Quality Trends in the Bear Creek Watershed in Southern Oregon (2011-2018)

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February 2020

Table of Contents

List of Tables

List of Figures

Background & Purpose:

The State of Oregon has established Total Maximum Daily Loads (TMDLs) for multiple water quality parameters in the Bear Creek watershed, a tributary to the Rogue River, in southern Oregon. The Rogue Valley Council of Governments (RVCOG) samples Bear Creek and its major tributaries on a monthly basis in order to evaluate water quality through time and to inform management actions. This project analyzed data collected at 24 sample locations from July 2011 – December 2018 to determine the impact of restoration and management actions on water quality and to communicate to designated management agencies, other interested entities, and the public about the condition of the creek and its major tributaries. The project focuses on three parameters: *Escherichia coli* (E. coli), total phosphorus, and water temperature.

For each water quality parameter, the objectives are to: 1) evaluate attainment, or progress towards achieving attainment, of water quality standards specified in their respective TMDLs and 2) determine the presence and magnitude of statistically significant trends of improving or declining water quality through time.

Introduction

RVCOG sampled water quality at 24 locations on Bear Creek and its major tributaries (Figure 1 and Table 1). Eleven sample locations were located on the mainstem. Neil and Walker Creeks were sampled near their mouths. Two sample locations were located on Ashland Creek, above and below the City's wastewater treatment plant. Jackson Creek had four sample locations; Griffin Creek was sampled at two locations. Two sample sites were located on irrigation system conveyance infrastructure, one below the Talent Irrigation District diversion structure and one below the Medford Irrigation District diversion structure.

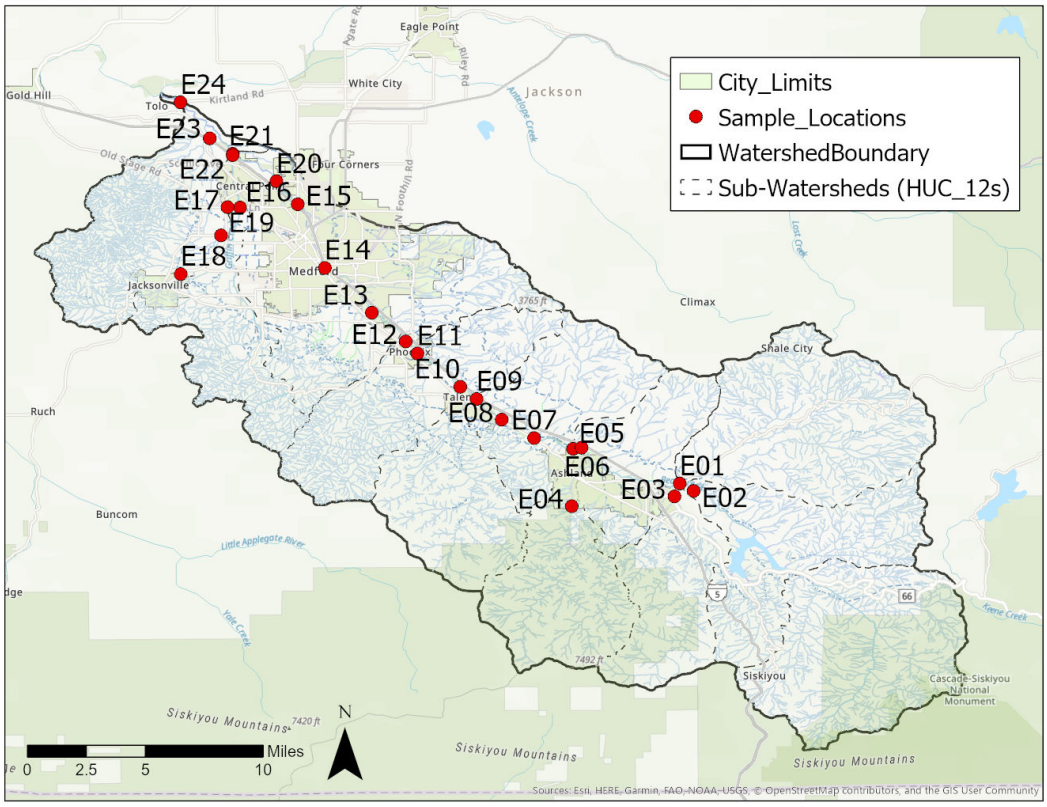

Figure 1. Water quality sample locations in the Bear Creek watershed.

Table 1 displays summary information on the name, location, and coordinates of the water quality sample locations. Site names were modified from the raw dataset provided by RVCOG.

Table 1. Name and location of water quality sample locations.

Site Name	Site Number	Latitude	Longitude
Walker Creek on Dead Indian Memorial Highway	E01	42.19343	-122.651
Emigrant Creek at Mouth	E02	42.18889	-122.643
Neil Creek at Dead Indian Memorial Highway	E03	42.18557	-122.654
Ashland Creek at Granite Street	E04	42.17953	-122.717
Ashland Creek below STP	E05	42.21467	-122.716
Talent Irrigation District Canal at Eagle Mill Road	E06	42.21537	-122.711
Bear Creek at S. Valley View Road	E07	42.22127	-122.74
Bear Creek at Greenway (S. Talent)	E08	42.23258	-122.76
Bear Creek at Lynn Newbry Park	E09	42.2452	-122.776
Medford Irrigation District Diversion at Suncrest Road	E10	42.25268	-122.786
Bear Creek at Blue Heron Park (Phoenix)	E11	42.27305	-122.812
Bear Creek at Fern Valley Road	E12	42.28045	-122.819
Bear Creek at Coyote Trails Center* (S. Medford)	E13	42.29806	-122.84
Bear Creek at 9th Street (Medford)	E14	42.32548	-122.869
Bear Creek at Table Rock Road	E15	42.36447	-122.885
Griffin Creek at Beall Lane	E16	42.36249	-122.921
Jackson Creek at Beall Lane	E17	42.36273	-122.928
Jackson Creek at Jacksonville	E18	42.32174	-122.957
Jackson Creek at W. Ross Lane	E19	42.34545	-122.932
Bear Creek at Pine St. (Central Point)	E20	42.37862	-122.898
Bear Creek above Griffin Creek (Central Point)	E21	42.39544	-122.925
Griffin Creek at I-5	E22	42.39458	-122.925
Jackson Creek at Blackwell Road	E23	42.40487	-122.939
Bear Creek at Kirtland Road	E24	42.42698	-122.957

* Formerly known as the Jefferson Nature Center.

Methods

RVCOG provided the dataset with recorded sample values over the period of record in a Microsoft Excel spreadsheet. The Rogue River Watershed Council shared data from the summer months taken from two continuous temperature loggers on Bear Creek in 2016-2018. Data analysis was conducted in R, a free open source statistical language using the R-Studio version 1.2.1335 interface. ArcGIS Pro version 2.4.2 was used to develop the map of the watershed; all other plots and figures were created in R-Studio and Microsoft Office 365 ProPlus version 1902.

Prior to uploading into R-Studio, the raw RVCOG dataset was reviewed and edited for quality assurance and control. Duplicate samples taken at the same site on the same day were averaged, blank fields, values for non-detects and field or lab errors were coded to be “NA” values when imported, fields with “>” or “<” symbols preceding a value were either removed from the analysis or entered as their numeric value based on a judgement of their validity, among other edits. In total, 16 E. coli observations recorded as “>2419.2” were entered as “2419” and one phosphorus observation recorded as “<0.05” was entered as “NA”. Access to Site E02 was blocked for much of the period of record and was excluded from the all analyses due to an insufficient number of observations (22 samples out of 90 possible). Site E17 was not sampled for total phosphorus and, as a

result, was not included in the evaluation of the parameter. A full description of all changes made to the raw dataset are included in the Microsoft Excel file "RVCOG_TMDLData_2011_2018_Master.xlsx" made available with this report[1].

EPA contracted consultants from a consulting firm, TetraTech, to review the analytical approach, the quality-control edits made to the raw data, and R-code developed to conduct the analysis. A combination of analyses was leveraged to evaluate the attainment, or progress towards attainment, of water quality standards: time series plots; boxplot charts and summary statistic tables; average annual concentrations; and the percent of samples meeting the standard per year. Due to the large variability in observed bacteria concentrations, the geometric mean was used to calculate average annual E. coli concentrations; for total phosphorus, the arithmetic mean was used. The analysis of water quality trends through time at each site was evaluated using the Seasonal Kendall test, as recommended for nonparametric data not adjusted for a covariate in the Chapter 12 of U.S. Geological Survey's Statistical Methods in Water Resources, EPA's 2011 Technical Guidance for Exploring TMDL Effectiveness Monitoring Data[2] and the National Nonpoint Source Monitoring Program Tech Notes 6: Statistical Analysis for Monotonic Trends[3]. Statistical significance was evaluated at an alpha level of 0.05, which means the acceptable level of risk of finding a statistically significant trend where there is none was considered to be 5%.

Summary Conclusions:

- Sites in the upper portion of the watershed had the best water quality. Specifically, sites E04 and E05 on Ashland Creek, and sites E07-E09 on Bear Creek reported some of the lowest median concentrations of E. coli and total phosphorus. However, compared to other upper watershed tributaries, water quality at site E03 at the mouth of Neil Creek was not as good – the site had the fourth and tenth highest median concentrations of E. coli and total phosphorus, respectively.

- Median E. coli concentrations on Bear Creek between the City of Phoenix and the City of Medford (sites E11-15; E20-21) were higher than at the mouth of Bear Creek near Kirtland Road (site E24).

- While site E10 below the Medford Irrigation Diversion structure reported the highest concentrations of E. coli, the site had the 7th lowest median total phosphorus concentration. The results suggest factors specific to E. coli are influencing water quality conditions at the site.

- There was a large difference in the median E. coli concentrations during the irrigation season at the two sites located on irrigation infrastructure. Site E10 on the Medford Irrigation District conveyance system reported the highest median concentration (687 MPN/100ml) and less than 25% of samples were below the standard. In contrast, site E06 on the Talent Irrigation District conveyance system reported a median bacteria concentration of 243 MPN/100ml and more than 75% of samples were below the standard.

- For E. coli concentrations, the results of the Seasonal Kendall test indicated only one site in the watershed had a statistically significant trend. Average E. coli concentrations on Walker Creek (site E01) increased by 13 MPN/100ml per year during the period of record (p-value = 0.03), indicating declining

[1] Contact Bill Meyers at the Oregon Department of Environmental Quality or Greg Stabach at the Rogue Valley Council of Governments to request an electronic copy of the file.
[2] Document URL: https://www.epa.gov/sites/production/files/2015-07/documents/techguide_explore_tmdl_effective_monitor_data_123011.pdf
[3] Document URL: https://www.epa.gov/sites/production/files/2016-05/documents/tech_notes_6_dec2013_trend.pdf

water quality conditions. Site E10, located on the conveyance infrastructure below the Medford Irrigation diversion dam, had a marginally significant trend (p-value = 0.08) of improving water quality. Average annual E. coli concentrations at E10 decreased by 35 MPN/100ml over the period of record.

- For total phosphorus, the Seasonal Kendall test identified three sites on tributaries in the upper watershed had statistically significant trends – all of which indicated declining water quality. Average annual total phosphorus concentrations increased 0.01 mg/l at site E01 on Walker Creek (p-value <0.01) and site E03 on Neil Creek (p-value <0.01), and by 0.003 mg/l on the upstream sampling location at site E04 on Ashland Creek near Granite Street (p-value = 0.03).

- Walker Creek (site E01) had the third lowest median concentrations of E. coli and total phosphorus over the period of record. However, the Seasonal Kendall test found statistically significant increasing concentration trends for both parameters, indicating deteriorating water quality at the site. The percent of samples that attain the water quality standard for E. coli at this site decreased over the period of record during the irrigation season but have remained flat during the winter months – suggesting activities or conditions between May 1 and October 15 may be a contributing cause of exceedances.

- For both E. coli and total phosphorus, the Seasonal Kendall test showed the majority of sites did not have a statistically significant trend over the period of analysis.

- The applicable water quality criteria for water temperature is evaluated as a 7-day average daily maximum. As a result, it was not possible to evaluate attainment of the water temperature with data from single grab samples taken on a monthly frequency. Additionally, due to sample bias imposed by diel variation in water temperature, the Seasonal Kendall test for trend analysis was not conducted.

- 7-day average daily maximum water (7DADM) temperature was calculated using continuous water temperature data taken from July – September in 2016-2018 at two sites on Bear Creek – downstream of Lynn Newbry park in Talent, and at Blue Heron Park in Phoenix. The data were analyzed against the water quality standard of 18 °C. At both sites, the 7DADM standard was exceeded from July through the middle of September. The lowest frequency of exceedances was 84% (77 out of 92 days), which occurred in 2018, and the maximum frequency was 90% (83 out of 92 days), which occurred in 2016.

Results

Attainment of Water Quality Standards:

The following section summarizes the results of the analyses used to evaluate attainment of water quality standards for the parameters of interest.

E. coli:

Under OAR 340-041-0009, the recreational contact standard for E. coli is expressed as a 30-day log mean of 126 E. coli organisms per 100 milliliters (ml), based on a minimum of five samples, with no single sample exceeding 406 E. coli organisms per 100ml. The monthly sampling frequency prohibited an analysis of the 30-day log mean value. Therefore, the samples were evaluated against the single sample threshold. To meet the acute water quality criterion for E. coli, no sample should exceed 406 most probable number [of E. coli organisms] per 100 milliliters (MPN/100ml) at any time during the year. Sampling procedures resulted in maximum reportable E. coli concentration of 2,419.2 MPN/100ml. For sample values reported at this level, the concentration of E. coli in the

water column is greater than or equal to 2,419 MPN/100ml. As a result, the mean values reported in Table 2 likely underestimate E. coli concentrations.

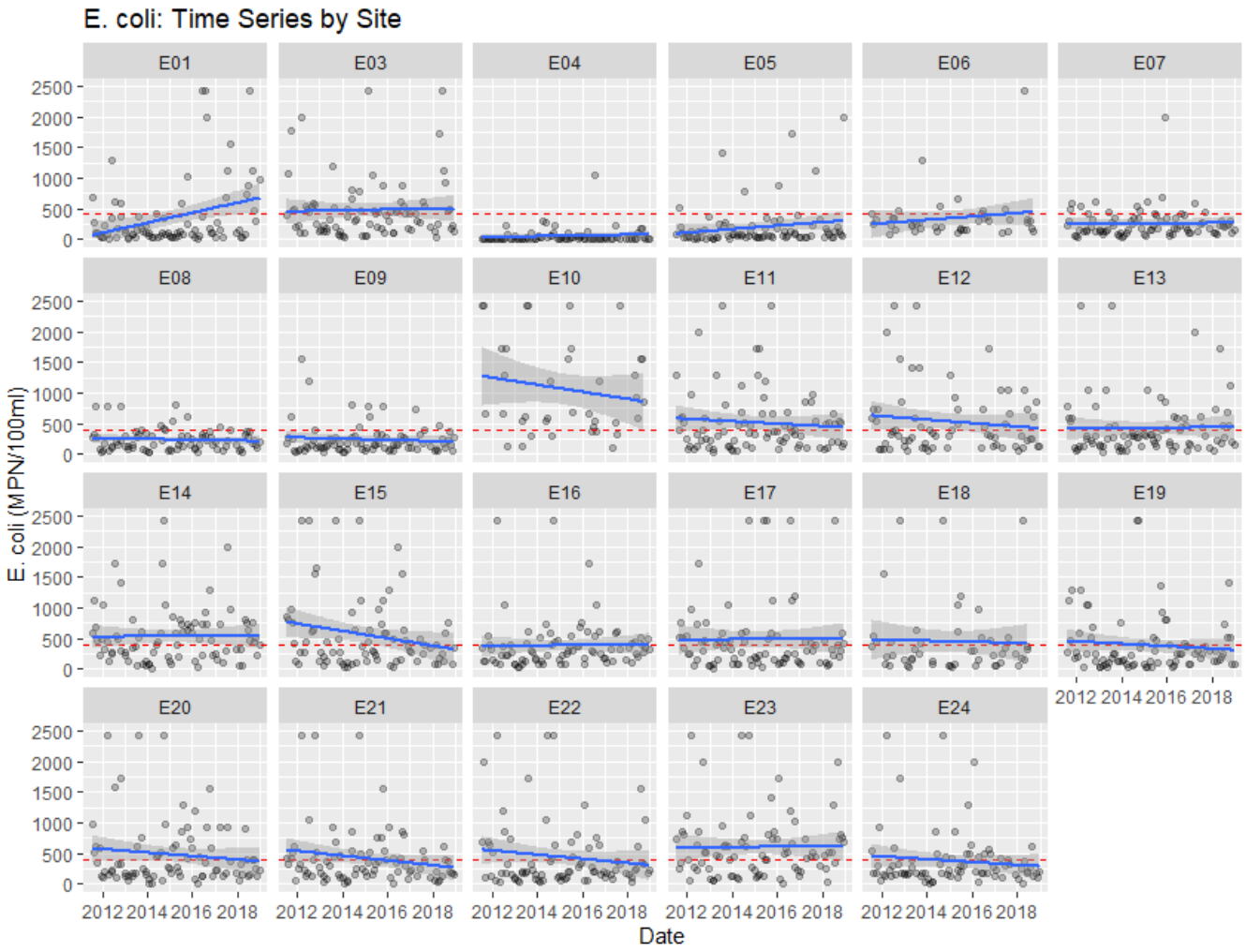

Figure 2. Time series of E. coli concentrations by site. The dashed red line displays the water quality criterion of 406 MPN/100ml. The solid blue line shows a linear regression trend line (concentration by date) and gray shaded background displays the linear regression line's 95% confidence interval. Due to sample procedures, the maximum reporting value for E. coli concentrations was greater than or equal to 2,419 MPN/100ml; therefore, the values should be interpreted as being at least 2,419 MPN/100ml.

Observed E. coli concentrations frequently exceeded the water quality criterion in many locations in the watershed over the period of record (Figure 2). Median E. coli concentrations exceeded the criterion at three sites: site E10 on the conveyance infrastructure below the Medford Irrigation District diversion dam, site E23 at the mouth of Jackson Creek, and site E14 on the mainstem Bear Creek in the City of Medford. The sites with the lowest median observed E. coli values were concentrated in the upper portion of the watershed: Sites E04 and E05 on Ashland Creek, site E01 at the mouth of Walker Creek, and sites E07-E09 on the mainstem Bear Creek between S. Valley View Road and Newbry Park (Figure 3). Only one sample taken at site E04 exceeded the water quality standard. Site E08 on Bear Creek immediately upstream of Talent, OR was the only sample location with a maximum detected E. coli concentration below 1,000 MPN/100ml. For a description of how to interpret boxplot figures, refer to Appendix A.

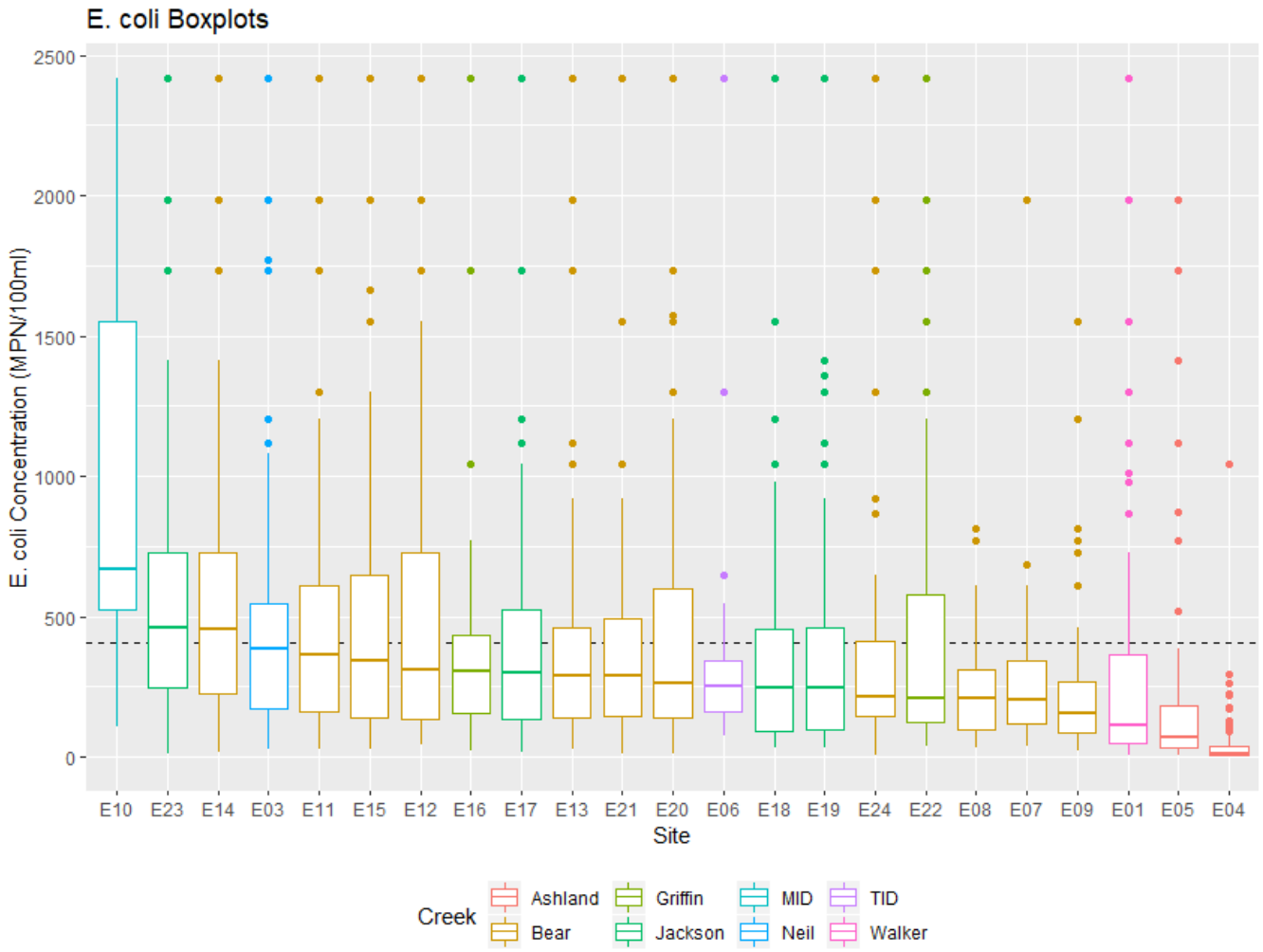

Figure 3. Boxplots of E. coli concentrations by site (July 2011 – December 2018). The black dashed line displays the water quality standard of 406 MPN/100ml. Dots on the boxplot chart indicate one *or more* samples were recorded at that value. Due to sample procedures, the maximum reporting value for E. coli concentrations was greater than or equal to 2419 MPN/100ml; therefore, the values should be interpreted as being at least 2,419 MPN/100ml.

Summary information for all E. coli concentrations by site is included in Table 2. Numeric values are rounded to the nearest integer.

Table 2. Summary table of all E. coli concentrations (July 2011 – December 2018) by site.

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E01	4	49	113	354	365	2419	83
E02	NA	NA	NA	NA	NA	NA	NA
E03	31	172	387	474	548	2419	85
E04	1	4	10	50	38	1046	84
E05	4	36	70	192	183	1986	84
E06	77	163	255	343	345	2419	42
E07	39	118	206	257	345	1986	85
E08	34	96	208	235	312	816	82

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E09	20	89	157	235	270	1553	85
E10	110	525	668	1058	1553	2419	38
E11	30	161	365	509	613	2419	85
E12	46	135	313	529	727	2419	69
E13	27	142	291	424	461	2419	85
E14	19	223	457	533	727	2419	84
E15	27	138	345	553	649	2419	79
E16	25	157	308	385	435	2419	85
E17	19	137	299	483	525	2419	84
E18	31	95	248	447	455	2419	50
E19	35	99	248	386	461	2419	85
E20	13	140	261	477	598	2419	85
E21	11	145	288	415	496	2419	84
E22	41	126	210	437	579	2419	85
E23	10	249	461	602	727	2419	85
E24	6	148	214	373	411	2419	83

To provide insight into possible causes of contamination, E. coli concentrations were segmented into two seasons: the irrigation season and the winter (non-irrigation) season. In the Bear Creek watershed, the practical irrigation season starts on April 15 and ends on October 15th. The winter season covers the remainder of the year, October 16 – April 14.

During the irrigation season, eight sites reported median E. coli concentrations above the water quality standard of 406 MPN/100ml – site E10 on the Medford Irrigation District diversion infrastructure, four sites on Bear Creek, site E03 on Neil Creek, and two sites on Jackson Creek (Figure 4). In the winter, all sites in the watershed except for E06 (2 total samples) and E10 (1 total sample) on the Talent and Medford irrigation district infrastructure reported median bacteria concentrations below the standard (Figure 5). Notably, these sites were typically not sampled during the winter (because the irrigation infrastructure is not in use) and only had two or fewer samples. Median E. coli concentrations were higher in the irrigation season at all sites except for site E06 on the Talent Irrigation District diversion infrastructure.

There was a large difference in the median E. coli concentrations during the irrigation season at the two sites located on irrigation infrastructure (Table 3). Site E10 on the Medford Irrigation District conveyance system reported the highest median concentration (687 MPN/100ml) and less than 25% of samples were below the standard. In contrast, site E06 on the Talent Irrigation District conveyance system reported a median bacteria concentration of 243 MPN/100ml and more than 75% of samples were below the standard.
The mean increase in median concentrations across all the sites (excluding sited E06 and E10) between the seasons was 164 MPN/100ml. The sites with the largest increase in median concentrations between the two seasons were on Bear Creek between the Cities of Phoenix and Medford. Site E11, E12, and E14 reported increases in median bacteria concentrations of 287, 317, and 337 MPN/100ml, respectively. Notably, the data show site E13, located in the middle of this river reach at the Coyote Trails Center in Medford, reported a comparatively lower increase of 154 MPN/100ml between the irrigation and non-irrigation seasons.

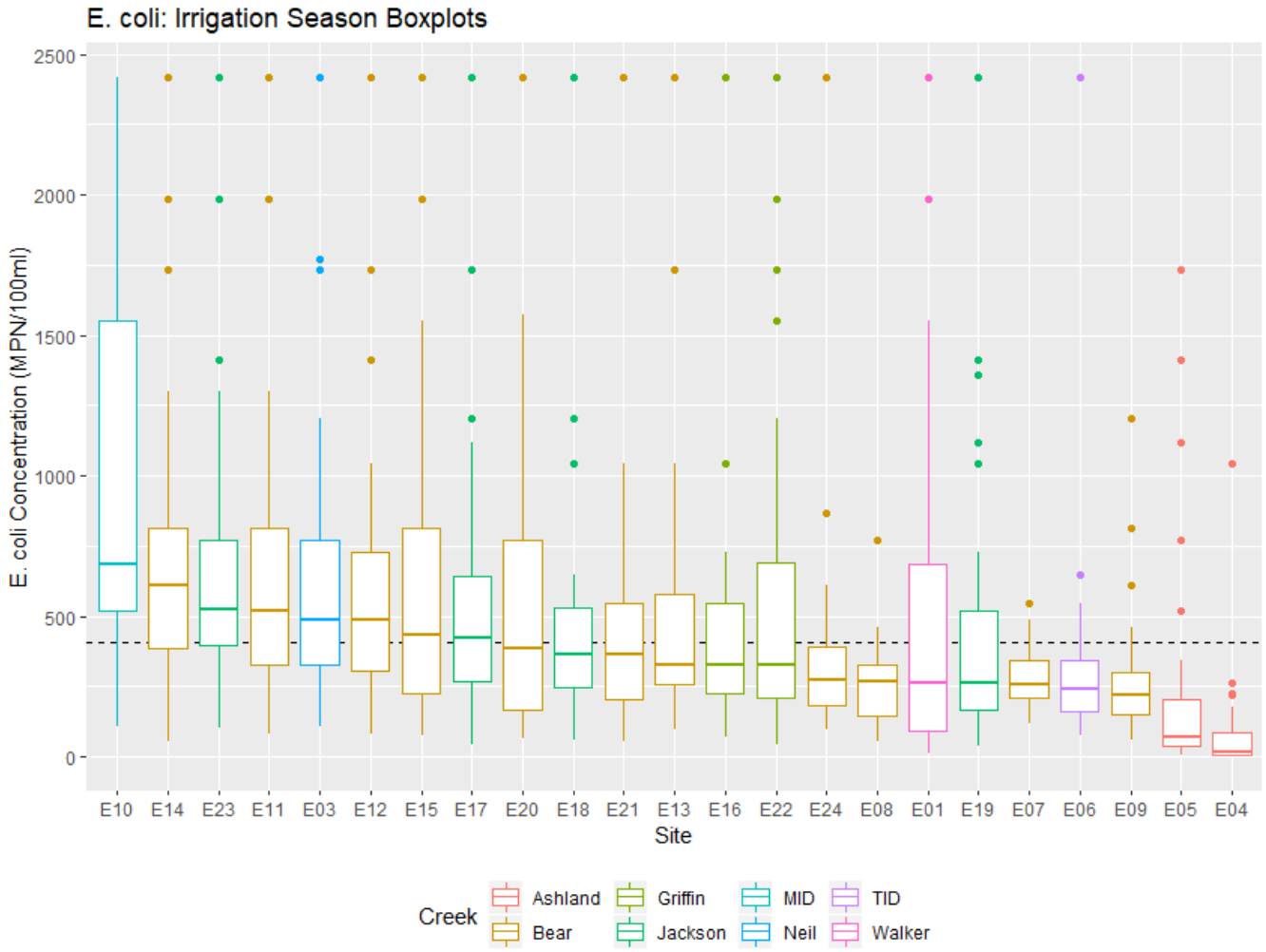

Figure 4. Boxplots of E. coli concentrations during irrigation season by site (July 2011 – December 2018). The black dashed line displays the water quality standard of 406 MPN/100ml. Dots on the boxplot chart indicate one *or more* samples were recorded at that value. Due to sample procedures, the maximum reporting value for E. coli concentrations was greater than or equal to 2,419 MPN/100ml; therefore, the values should be interpreted as being at least 2,419 MPN/100ml.

Table 3Table 4 displays the summary information for the boxplots shown in Figure 4Figure 5.

Table 3. Summary table of E. coli concentrations during the irrigation season.

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E01	14	91	261	560	687	2419	41
E02	NA	NA	NA	NA	NA	NA	NA
E03	111	326	488	633	770	2419	41
E04	1	6	17	76	89	1046	41
E05	4	37	72	224	206	1733	40
E06	77	159	243	320	345	2419	40
E07	118	210	260	280	345	548	41
E08	53	148	268	262	326	770	38
E09	60	148	219	267	299	1203	41
E10	110	517	687	1069	1553	2419	37

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E11	82	326	517	659	816	2419	41
E12	82	308	488	682	727	2419	33
E13	96	260	326	480	579	2419	41
E14	54	387	613	699	816	2419	41
E15	78	225	435	670	816	2419	37
E16	71	225	326	425	548	2419	41
E17	43	270	423	694	642	2419	40
E18	62	249	365	513	532	2419	23
E19	37	169	261	488	517	2419	41
E20	66	166	387	563	770	2419	41
E21	54	206	365	453	548	2419	41
E22	43	210	326	583	689	2419	41
E23	101	397	523	728	770	2419	41
E24	96	183	272	359	393	2419	39

Across both seasons, Ashland Creek (sites E04-05) and the upper Bear Creek (sites E07-E09) reported some of the lowest median E. coli concentrations and experienced very little variation over the year: concentrations only increased by 11 MPN/100ml in the irrigation season on Ashland Creek and by less than 150 MPN/100ml on the two Bear Creek sites. And, throughout the year, median bacteria levels at the mouth of Bear Creek (E24) were modestly lower than at site E21, upstream of the confluences of Griffin and Jackson Creeks.

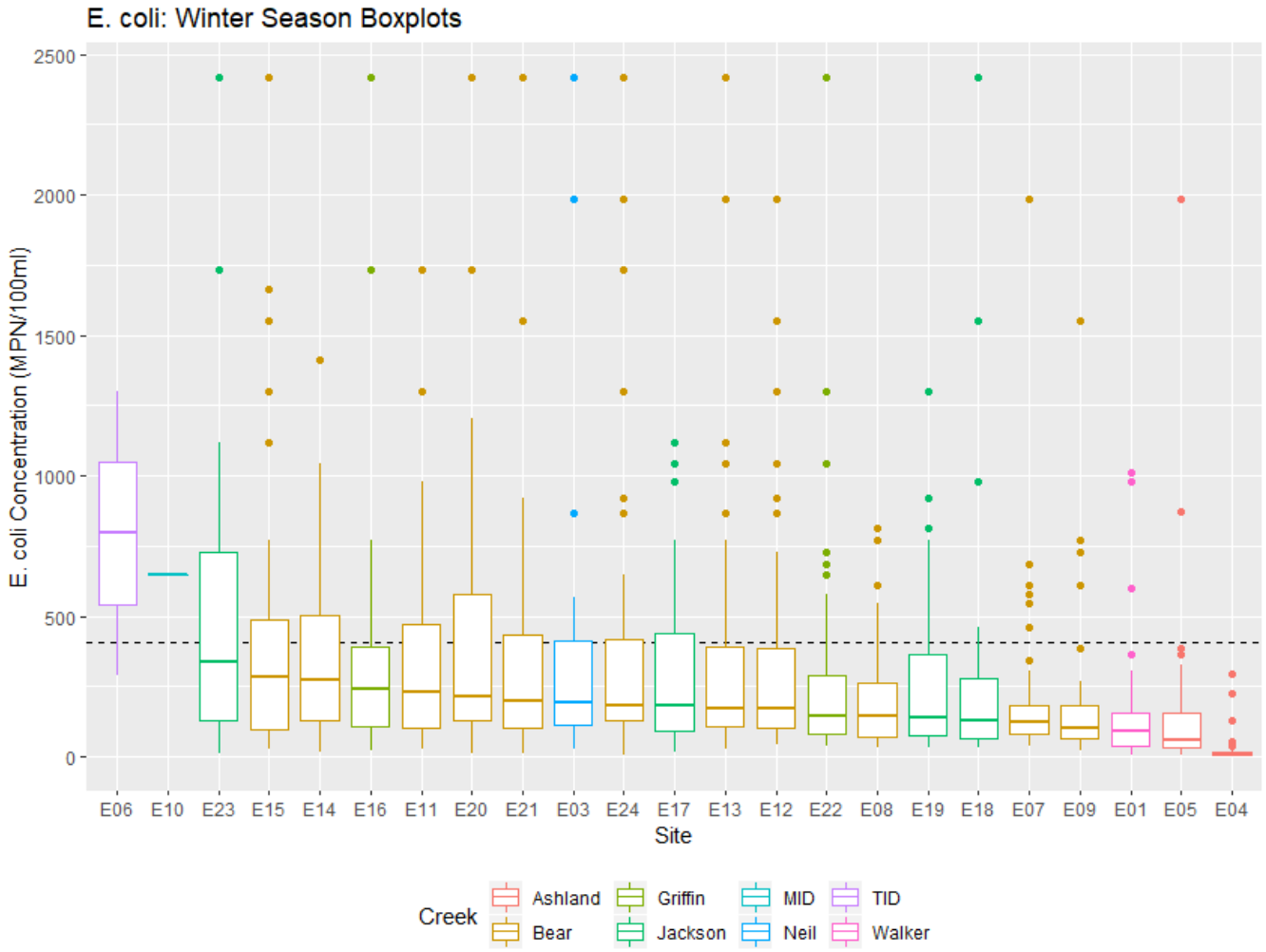

Figure 5. Boxplots of E. coli concentrations during the winter season by site (July 2011 – December 2018). The black dashed line displays the water quality standard of 406 MPN/100ml. Dots on the boxplot chart indicate one *or more* samples were recorded at that value. Due to sample procedures, the maximum reporting value for E. coli concentrations was greater than or equal to 2,419 MPN/100ml; therefore, the values should be interpreted as being at least 2,419 MPN/100ml.

Table 4 displays the summary information for the boxplots shown in Figure 5.

Table 4. Summary table of E. coli concentrations during the winter season.

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E01	4	38	91	152	157	1011	42
E02	NA	NA	NA	NA	NA	NA	NA
E03	31	113	195	327	411	2419	44
E04	1	4	6	26	16	294	43
E05	5	34	61	163	156	1986	44
E06	291	543	795	795	1048	1300	2
E07	39	84	127	236	182	1986	44
E08	34	70	144	211	265	816	44
E09	20	64	105	205	182	1553	44
E10	649	649	649	649	649	649	1

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E11	30	105	230	370	470	1733	44
E12	46	104	171	389	387	1986	36
E13	27	106	172	371	393	2419	44
E14	19	128	276	375	503	1414	43
E15	27	100	283	450	488	2419	42
E16	25	109	243	348	393	2419	44
E17	19	95	182	290	441	1120	44
E18	31	65	130	392	278	2419	27
E19	35	77	142	290	365	1300	44
E20	13	127	218	396	579	2419	44
E21	11	102	201	379	436	2419	43
E22	41	79	145	300	289	2419	44
E23	10	128	339	485	727	2419	44
E24	6	131	183	386	417	2419	44

Figure 6 shows a comparison of the annual percent of samples that meet the water quality standard by season by site. The results at several sites showed divergent trends between the irrigation and winter seasons. At site E01 on Walker Creek, the water quality standard was typically met during the winter season, but the percent of samples during the irrigation season that attained the standard declined significantly over the period of record. The data suggests there has been a change in land use or human activities in the Walker Creek subbasin during the irrigation season that has caused water quality impacts. Similarly, at site E03 on Neil Creek, site E11 on Bear Creek in the City of Phoenix, and site E23 at the mouth of Griffin Creek near I-5, the annual percent of samples that met the water quality standards improved during the winter months but declined during the irrigation season.

Figure 6. Percent of E. coli samples that attain the water quality standard per year by season.
Irrigation season (red columns) defined as samples taken April 15th – October 15th; winter season (blue columns) defined as samples taken October 16th – April 14th.

Figure 7 shows the annual geometric mean concentration of E. coli in the irrigation and winter seasons. Bacteria concentrations at sites E04 and E05 on Ashland Creek, sites E07 - E09 on Bear Creek, consistently met the water quality standard. Annual geometric mean concentrations of E. coli at site E03 at the mouth of Neil Creek and site E10 below the Medford Irrigation District consistently exceeded the water quality standard. During the irrigation season, E. coli concentrations on Bear Creek between the City of Phoenix through the City of Medford, sites E12-15, exceeded the standard multiple years over the period of record. At site E17 and E23 on Jackson Creek at Beall Lane and Blackwell Road, respectively geometric mean concentrations in the winter declined, but remain flat or increased during the irrigation season.

Figure 7. Annual geometric mean E. coli concentration by season. Irrigation season (red columns) defined as samples taken April 15th – October 15th; winter season (blue columns) defined as samples taken October 16th – April 14th.

Total Phosphorus:

The water quality criterion for total phosphorus concentrations is 0.08 milligrams per liter (mg/l) between May 1 and November 15. Other than the time series plot, which shows all observed total phosphorus concentrations, the evaluation of attainment of water quality standards only included samples taken when the water quality criterion was in effect (112 observations excluded).

Over the period of record, total phosphorus concentrations frequently hovered at or above the water quality standard at nearly every site; multiple sites had one or more outliers of high total phosphorus concentrations that significantly exceeded the standard (Figure 8). The two highest recorded concentrations of total phosphorus, 0.93 and 0.89 mg/l, were recorded at site E06 and E10 on the conveyance infrastructure of the Talent Irrigation District and Medford Irrigation District, respectively.

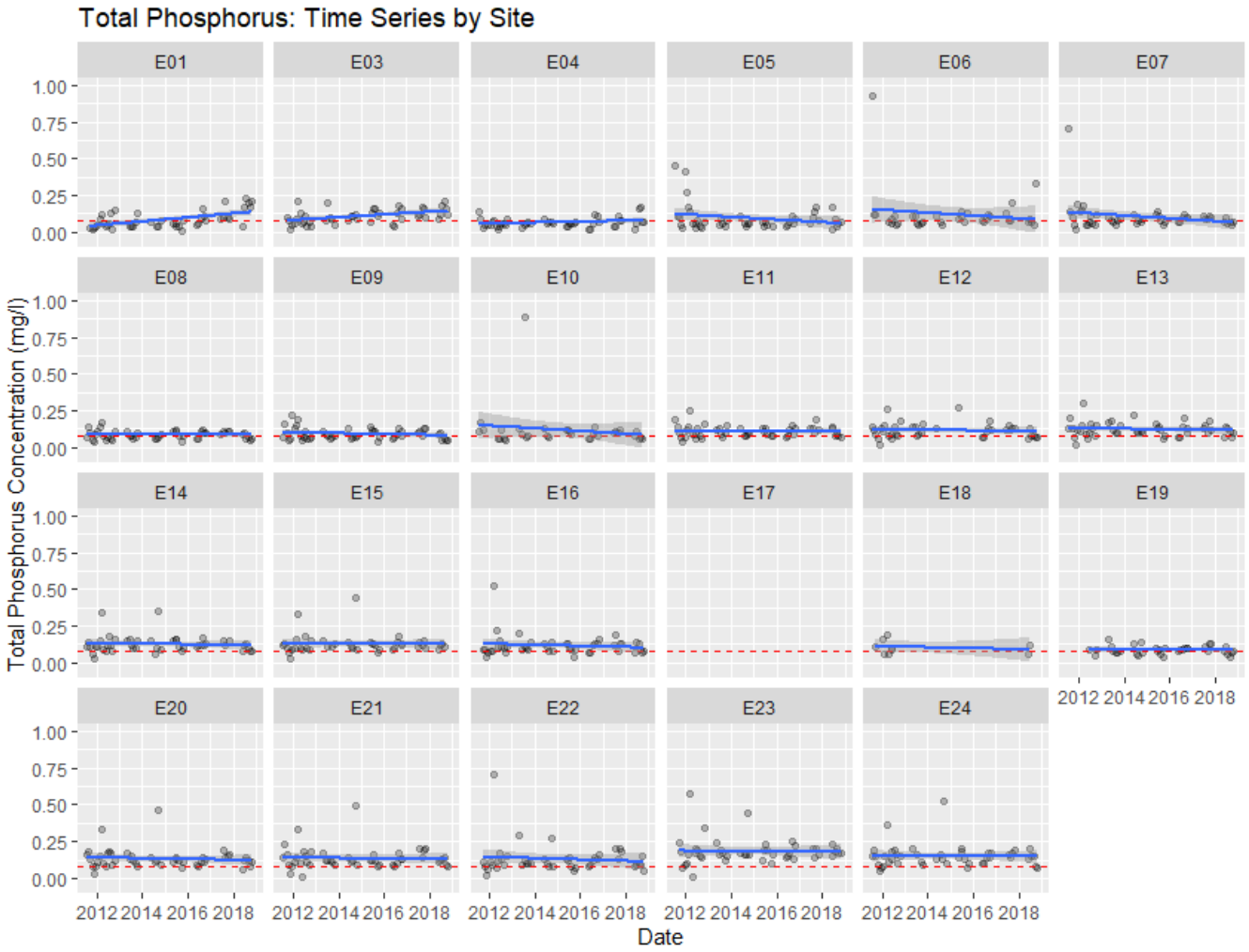

Figure 8. Time series of total phosphorus concentrations by site. The dashed red line displays the water quality criterion of 0.08 mg/l in effect between May 1 – November 15. The solid blue line and gray shaded background show a linear regression trend line (concentration by date) and its 95% confidence interval.

Overall, there was little variation in sampled phosphorus concentrations (Figure 9). Median total phosphorus concentrations exceeded the water quality criterion at every site except for three locations on two tributary streams in the upper watershed: site E01 on Walker Creek, and sites E04 and E05 on Ashland Creek. Every sample taken during the TMDL season at site E23 at the mouth of Jackson Creek exceeded the standard. Less than 25% of samples at the mouth of Bear Creek (site E24) were below the standard.

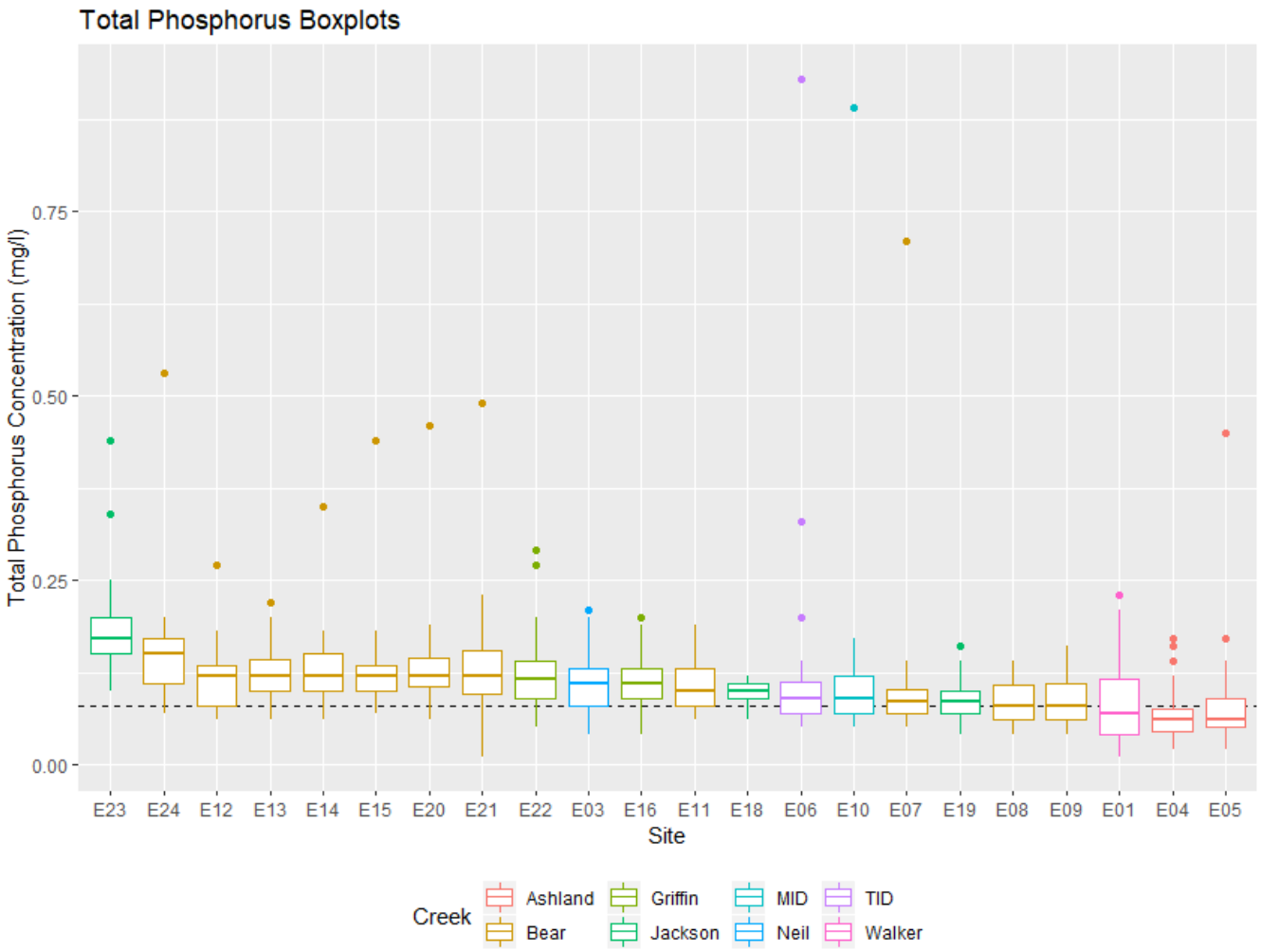

Figure 9. Boxplots of total phosphorus concentration by site. The black dashed line displays the water quality standard of 0.08 mg/l in effect between May 1 – November 15.

Summary information for total phosphorus concentrations by site is included in Table 5. Numeric values are rounded to the nearest hundredths decimal place.

Table 5. Summary table of total phosphorus concentration by site.

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E01	0.01	0.04	0.07	0.09	0.12	0.23	40
E02	NA	NA	NA	NA	NA	NA	NA
E03	0.04	0.08	0.11	0.11	0.13	0.21	41
E04	0.02	0.05	0.06	0.07	0.08	0.17	43
E05	0.02	0.05	0.06	0.08	0.09	0.45	42
E06	0.05	0.07	0.09	0.12	0.11	0.93	36
E07	0.05	0.07	0.085	0.10	0.10	0.71	44
E08	0.04	0.06	0.08	0.08	0.11	0.14	42
E09	0.04	0.06	0.08	0.09	0.11	0.16	44
E10	0.05	0.07	0.09	0.12	0.12	0.89	34
E11	0.06	0.08	0.1	0.11	0.13	0.19	44

Site	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Count
E12	0.06	0.08	0.12	0.11	0.14	0.27	35
E13	0.06	0.10	0.12	0.12	0.14	0.22	44
E14	0.06	0.10	0.12	0.12	0.15	0.35	42
E15	0.07	0.10	0.12	0.13	0.14	0.44	39
E16	0.04	0.09	0.11	0.11	0.13	0.2	42
E17	NA	NA	NA	NA	NA	NA	NA
E18	0.06	0.09	0.1	0.10	0.11	0.12	5
E19	0.04	0.07	0.085	0.09	0.10	0.16	36
E20	0.06	0.11	0.12	0.13	0.15	0.46	43
E21	0.01	0.10	0.12	0.14	0.16	0.49	43
E22	0.05	0.09	0.115	0.12	0.14	0.29	40
E23	0.1	0.15	0.17	0.18	0.20	0.44	41
E24	0.07	0.11	0.15	0.15	0.17	0.53	41

Average annual concentrations of phosphorus did not change substantially at most sites in the watershed (Figure 10). Notably, annual average concentrations exceeded the standard in least one, and often multiple years, at all sites. At site E07 average annual total phosphorus concentrations declined from a peak of 0.25 in 2011 to less than 0.08 in 2018. Average annual concentrations declined modestly each year at the three most downstream sites on Bear Creek: site E20 at Pine Street in Central Point, E21 above the mouth of Griffin Creek, and at site E24 at the mouth near Kirtland Road.

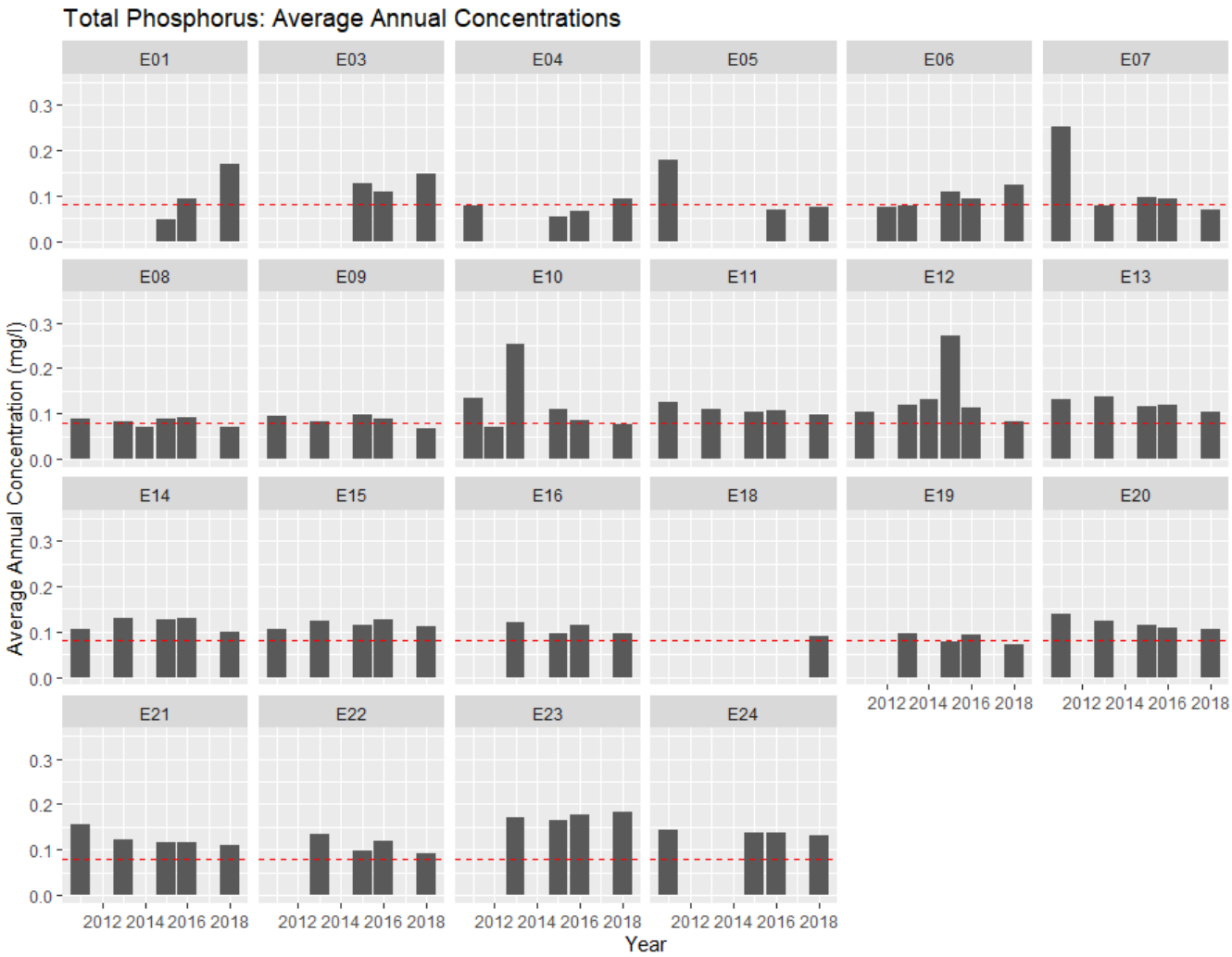

Figure 10. Average annual total phosphorus concentration by site. The red dashed line displays the water quality standard of 0.08 mg/l in effect from May 1 – November 15.

Water Temperature:

The water temperature criteria are based on the 7-day average daily maximum (7DADM) temperature. Between May 16 and October 14, the water quality standard is 18°C to support salmonid rearing; between October 16 and May 14, the water quality standard is 13°C to support salmonid spawning, egg incubation, and fry emergence. The monthly sampling frequency of water temperature prohibited an evaluation of attainment, or progress towards attainment, of water quality standards over the period of record.

However, the Rogue River Watershed Council shared continuous water temperature data collected during summer months in 2016-2018 on Bear Creek. The two locations of the continuous water temperature loggers were located on Bear Creek near the cities of Talent and Phoenix (Table 6). Data for the months of July, August, and September were evaluated for attainment of the water temperature water quality standard.

Table 6. Name and location of continuous water temperature loggers.

Site Name	Site	Latitude	Longitude

	Number		
Bear Creek downstream of Lynn Newbry Park (Talent)	T3a	-122.77857	42.24747
Bear Creek Bear Creek at Blue Heron Park (Phoenix)	E11	-122.8117	42.2731

Site T3a

The following tables and figures display the 7-day average daily maximum (7DADM) water temperatures recorded July through September between 2016 and 2018 at site T3a. The temperature profile was consistent over the three years: water temperatures exceeded the standard through the middle of September (Figure 11). There was only modest interannual variation in the number and magnitude of water quality exceedances. In 2016, the highest frequency of exceedances was recorded, 90% of the days had 7DADM values above 18°C. The average and maximum magnitudes of exceedance were 2.15°C and 4.46°C, respectively.

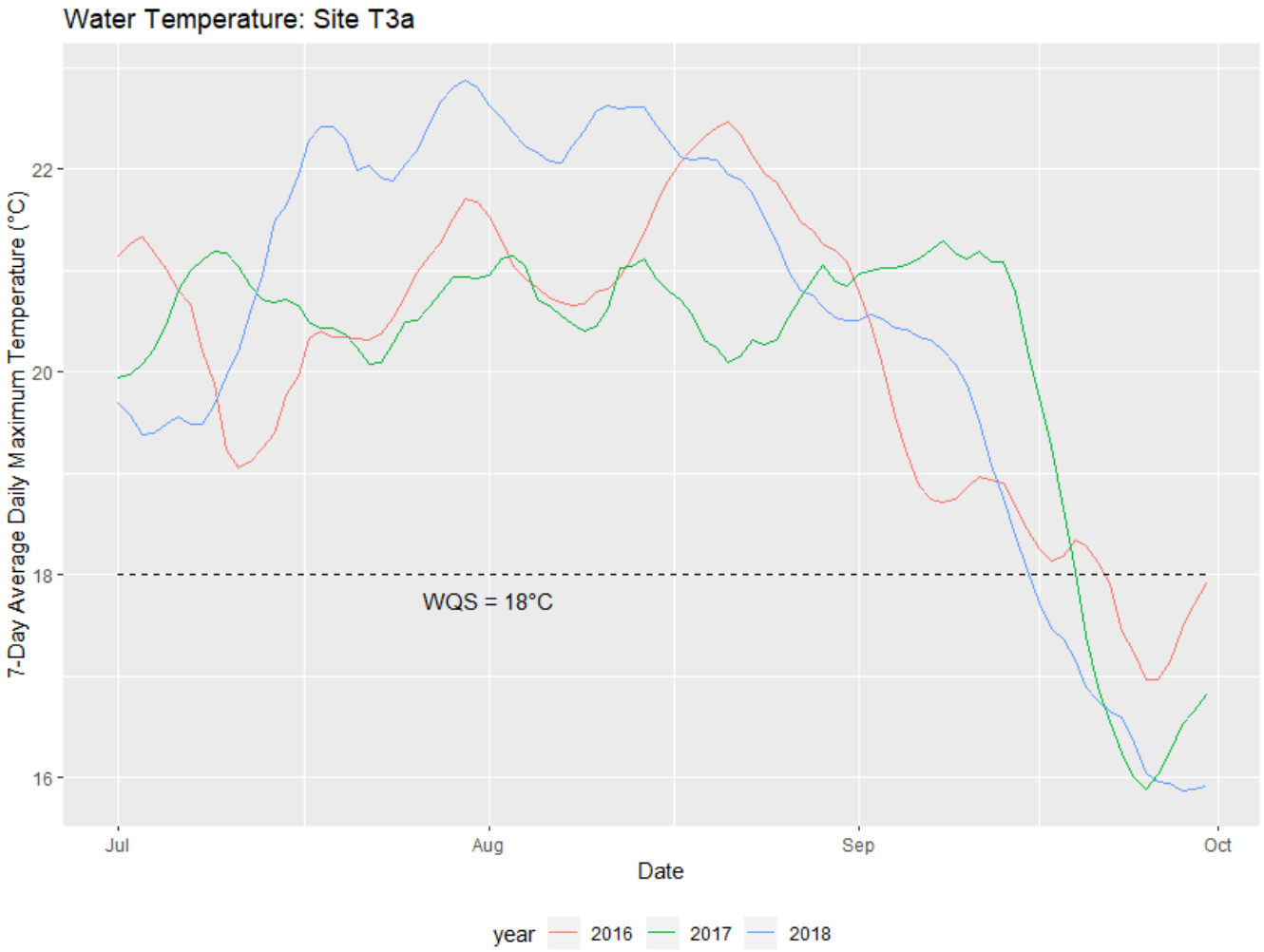

Figure 11. 7-day average daily maximum water temperature July – September at site T3a (2016-2018). The black dashed line displays the water quality standard of 18°C.

In 2017, 88% of the days reported 7DADM water temperatures above the standard, but the average and maximum magnitude of exceedances were the lowest over the three-year period. In 2018, the water quality

standard was exceeded on the fewest number of days (77), but the highest 7DADM water temperatures were recorded, with a maximum exceedance of 4.48°C in late July.

Table 7. Summary of water quality standard exceedances in July - September at site T3a (2016-2018).

Year	Total Days	Number of Days that Exceed the WQS	Percent of Days that Exceed the WQS	Average Exceedance Magnitude (°C)	Maximum Exceedance Magnitude (°C)
2016	92	83	90%	2.15	4.46
2017	92	81	88%	2.13	3.29
2018	92	77	84%	2.46	4.88

Note: WQS = water quality standard for water temperature, defined as a 7-day average daily maximum of 18°C.

Table 8 displays summary information for the 7DADM water temperature data collected at site T3a.

Table 8. Summary statistics for 7-day average daily maximum values in July – September at site T3a (2016-2018).

Year	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
2016	16.96	18.93	20.60	20.15	21.26	22.46
2017	15.89	20.23	20.65	20.13	21	21.29
2018	15.87	19.49	20.78	20.46	22.165	22.88

Note: All values reported in °C.

Site E11

Similar to site T3a, the 7DADM water temperature data recorded at site E11 show little interannual variation between 2016-2018. Starting in July, 7DADM values consistently exceeded the water quality standard through mid-September. The highest frequency (90% of days) and the highest average magnitude of exceedances (2.68 °C) were recorded in 2016. In 2017, 87% of days exceeded the standard by an average of 2.66°C. The fewest number of days that exceeded the standard (84%) occurred in 2018, but the highest exceedance magnitude (5.30°C) was recorded.

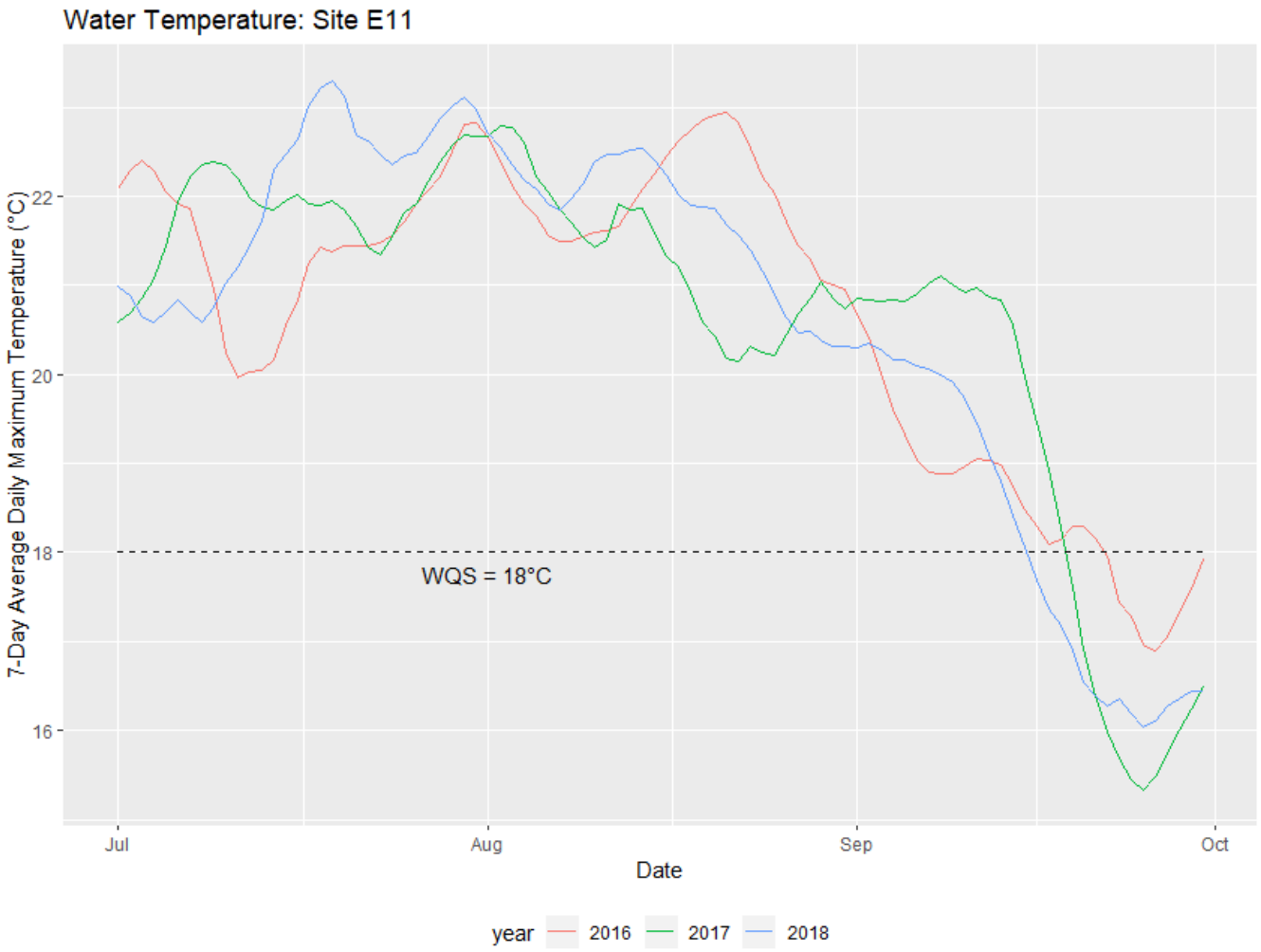

Figure 12. 7-day average daily maximum water temperature July – September at site E11 (2016-2018). The black dashed line displays the water quality standard of 18°C.

Table 9 displays summary information for water quality exceedances at site E11.

Table 9. Summary of water quality standard exceedances in July - September at site E11 (2016-2018).

Year	Total Days	Number of Days that Exceed the WQS	Percent of Days that Exceed the WQS	Average Exceedance Magnitude (°C)	Maximum Exceedance Magnitude (°C)
2016	92	83	90%	2.68	4.95
2017	92	80	87%	2.66	4.79
2018	92	77	84%	2.64	5.30

Note: WQS = water quality standard for water temperature, defined as a 7-day average daily maximum of 18°C.

Table 10 displays the summary statistics for 7DADM water temperature data at site E11.

Table 10. Summary statistics for 7-day average daily maximum values in July – September at site E11 (2016-2018).

Year	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
2016	16.90	19.03	21.44	20.68	22.06	22.95
2017	15.33	20.53	21.06	20.66	21.91	22.79
2018	16.03	20.05	21.01	20.64	22.39	23.30

Note: All values reported in °C.

Water Quality Trends:

Water quality trends were evaluated using the Seasonal Kendall Test, a highly robust test and powerful analysis for nonparametric data with seasonal variation. The test calculates the Mann-Kendall test for values within seasons (as defined by the user) and then combines the results into an aggregate Kendall Score to determine if there is a monotonic trend through time. Each observed value is compared to all preceding values measured within the same season. For this analysis, monthly seasons are used that correspond to the sampling frequency. Therefore, each parameter's values are compared within the same month, January values to other January values, February to February values, etc.; no comparisons are made between months. A positive Kendall score indicates increasing values (and, therefore in this case, *deteriorating* water quality) through time; a negative score represents a declining value (*improving* water quality) through time. The larger the absolute value of the Kendall Score, the larger the magnitude of change. The median of all slopes between data points within the same season is used to estimate the trend slope. For more information on the Seasonal Kendall test, refer to Chapter 12 of Statistical Methods in Water Resources, EPA's 2011 Technical Guidance for Exploring TMDL Effectiveness Monitoring Data[4], or the National Nonpoint Source Monitoring Program Tech Notes 6: Statistical Analysis for Monotonic Trends [5].

E. coli:

The Seasonal Kendall test showed only one site had a statistically significant trend between July 2011 and December 2018 (Table 11). Concentrations of E. coli increased by an average of 13 MPN/100ml per year at the mouth of Walker Creek, a tributary in the upper portion of the watershed (p-value = 0.03). All other sites lacked statistically significant trends. However, Site E10 on the conveyance infrastructure below the Medford Irrigation District diversion dam had a marginally significant trend of improving water quality (p-value = 0.08), with E. coli concentrations decreasing on average by 35 MPN/100ml per year.

Table 11. Seasonal Kendall test results for E. coli concentrations by site.

Site	Kendall Score	Kendall Score Variance	Seasonal Kendall Slope Estimator (MPN/100ml per year)	p-Value
E01	50	526	12.81	0.03
E02	NA	NA	NA	NA
E03	-3	561	-0.33	0.93
E04	38	537	0.77	0.11
E05	29	547	3.58	0.23
E06	5	259	6.04	0.80
E07	13	539	3.59	0.61

[4] Document URL: https://www.epa.gov/sites/production/files/2015-07/documents/techguide_explore_tmdl_effective_monitor_data_123011.pdf

[5] Document URL: https://www.epa.gov/sites/production/files/2016-05/documents/tech_notes_6_dec2013_trend.pdf

Site	Kendall Score	Kendall Score Variance	Seasonal Kendall Slope Estimator (MPN/100ml per year)	p-Value
E08	-2	513	-0.35	0.96
E09	32	562	6.55	0.19
E10	-26	205	-34.82	0.08
E11	-16	560	-4.36	0.53
E12	-4	307	-2.49	0.86
E13	35	561	11.02	0.15
E14	17	526	6.39	0.49
E15	-19	462	-8.97	0.40
E16	34	538	11.09	0.15
E17	-20	518	-7.91	0.40
E18	15	167	11.99	0.28
E19	9	561	1.97	0.74
E20	-33	541	-8.43	0.17
E21	-27	545	-12.47	0.27
E22	5	541	1.84	0.86
E23	22	560	14.31	0.37
E24	-16	510	-5.48	0.51

Seasonal Kendall tests were run on composite values for streams that had been sampled at two or more locations over the period of record – Ashland, Griffin, Jackson, and Bear Creek (Table 12). There were two sample sites on Ashland and Griffin Creeks, four sites on Jackson Creek, and 11 sites on Bear Creek. For each stream, monthly values were calculated by taking the average (mean) of the observed E. coli concentrations. No statistically significant trends were found.

Table 12. Seasonal Kendall test results for E. coli concentrations aggregated by stream.

Waterbody	Kendall Score	Kendall Score Variance	Seasonal Kendall Slope Estimator (MPN/100ml per year)	p-value
Ashland Creek	32	530	2.80	0.18
Griffin Creek	19	563	8.39	0.45
Jackson Creek	11	563	2.63	0.67
Bear Creek	-6	276	-4.07	0.76

Total phosphorus:

Table 13 shows the results of the Seasonal Kendall tests at each site. Three sites, all located on tributaries in the upper watershed, had statistically significant trends of decreasing water quality (increasing concentrations of total phosphorus): site E01 on Walker Creek, Site E03 on Neil Creek, and site E04 on Ashland Creek. Concentrations of total phosphorus increased on average by 0.01 mg/l per year on Walker and Neil Creeks (p-value <0.01), a relatively large annual increase relative to the water quality standard. In contrast, the magnitude of increasing concentrations of total phosphorus on Ashland Creek were much lower, averaging 0.003 mg/l per year (p-value = 0.03). No other sites in the watershed showed statistically significant trends. Sites E02 (blocked access), E17 (not sampled), and E18 (intermittent flow) had insufficient number of samples to run the Seasonal Kendall test.

Table 13. Seasonal Kendall test results for total phosphorus concentration by site.

Site	Kendall Score	Kendall Score Variance	Seasonal Kendall Slope Estimator (mg/l per year)	p-value
E01	50	238	0.012	0.00
E02	NA	NA	NA	NA
E03	66	259	0.010	0.00
E04	37	278	0.003	0.03
E05	11	271	0.000	0.54
E06	-1	217	0.000	1.00
E07	-7	304	0.000	0.73
E08	13	271	0.001	0.47
E09	14	305	0.002	0.46
E10	-3	182	0.000	0.88
E11	0	303	0.000	1.00
E12	-8	153	-0.002	0.57
E13	-9	306	0.000	0.65
E14	-5	246	0.000	0.80
E15	8	225	0.000	0.64
E16	2	247	0.000	0.95
E17	NA	NA	NA	NA
E18	NA	NA	NA	NA
E19	4	171	0.000	0.82
E20	-10	271	0.000	0.58
E21	-3	288	0.000	0.91
E22	-7	218	0.000	0.68
E23	-1	260	0.000	1.00
E24	-5	249	0.000	0.80

Seasonal Kendall tests were run on composite values for streams had been sampled at two or more locations over the period of record – Ashland, Griffin, Jackson and Bear Creeks (Figure 9). There were two sample sites on Ashland and Griffin Creeks, two sites on Jackson Creek (there were four total sites on the creek, but E17 and E18 lacked a sufficient number of samples for inclusion in the test), and 11 sites on Bear Creek. For each stream, monthly values were calculated by taking the average (mean) of the observed total phosphorus concentrations. No statistically significant trends were found.

Table 14. Seasonal Kendall test results for total phosphorus concentrations aggregated by stream.

Waterbody	Kendall Score	Kendall Score Variance	Seasonal Kendall Slope Estimator (mg/l per year)	p-value
Ashland Creek	23	273	0.002	0.18
Griffin Creek	-4	239	0.000	0.85
Jackson Creek	-17	218	-0.004	0.28
Bear Creek	-15	275	-0.002	0.40

Water Temperature:

Water temperatures experience diel variation. As a result, the time of day when the sample is taken has a significant impact on the observed water temperature. Though water temperature was recorded during each grab sample event, they represent only a single point in time, and because samples were collected in a

systematic manner from the upper watershed down, they contain sample bias. Consequently, no trend analysis was conducted on grab sample temperature data.

Appendix A. Description of Boxplot Figures

In this report, boxplots are used to illustrate the distribution of samples through time or among places. The percentile indicates the percentage of sample values less than the value at that point in the distribution. In example 1 (top), 75% of sample values are lower than 15 and 25% are lower than 5. By definition, the median is the 50th percentile, with 50% of values lower and 50% of values higher than the median.