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Assessment of TMDL Implementation and Water Quality Status and Trends in Amazon Creek and Coyote Creek Watersheds

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Acronyms

AgWQMPs	Agricultural Water Quality Management Area Plans
BLM	Bureau of Land Management
BOD	Biological Oxygen Demand
CAFO	Confined Animal Feeding Operation
COD	Chemical Oxygen Demand
DMAs	Designated Management Agencies
DO	Dissolved Oxygen
ESM	Environmental Sciences and Management
FPA	Forest Practices Act
MEM	Masters of Environmental Science
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rule
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODF	Oregon Department of Forestry
PSU	Portland State University
SOD	Sediment Oxygen Demand
SWCD	Soil Water Conservation District
TMDLs	Total Maximum Daily Loads
USFS	United States Forest Service
WQMPs	Water Quality Management Plans
WQRP	Water Quality Restoration Plans

Executive Summary

In this project, I analyzed the status and trends of water quality data describing fecal bacteria (*E. coli*) and DO in the Amazon and Coyote Creek watersheds of the Southern Willamette Valley, Oregon. I also examined TMDL implementation plans produced by DMAs, determined if and how implementation activities corresponded to changes in water quality, compared management and planning of DMAs in the watersheds, discussed aspects of the current TMDL, and compared state regulations and standards in other states. I concluded by making management recommendations to better facilitate future status and trend analysis.

Amazon Creek, Amazon Diversion Channel, A-3 Drain, and Coyote Creek are listed year-round on Oregon's Category 4A 303(d) list for exceeding State bacteria criterion for *E. coli.* Upper Amazon Creek, Amazon Diversion Channel, and Coyote Creek are listed on Oregon's 303(d) Category 4A list for exceeding the State DO criteria. These stream segments were separated by watershed (Upper Amazon Creek, Lower Amazon Creek, and Coyote Creek) and analyzed at each sample station and as a whole with available data.

Ultimately, the lack of data hindered my status and trend analyses. However, existing data indicated Upper Amazon Creek and Coyote Creek continue to be impaired for DO, while DO concentrations in Lower Amazon Creek have increased above state single sample exceedance criterion for cool water (5.0 mg/L). The current protocol for monitoring bacteria and DO in these streams makes detecting exceedances difficult. The sample stations and seasons which are near exceedances can only be assumed to exceed 7-day criterion because grab sampling does not necessarily capture the lowest level of DO nor the highest level of bacteria concentration on the day of sampling. Sparse grab samples only convey instantaneous measures, which makes detailed assessments of seasonal or annual trends in water quality incomplete.

Coyote Creek had not been tested for TMDL-related water quality parameters since 2003 until sample collection was conducted as part of this project by ODEQ during the summer of 2015. Data obtained through the 2015 collection could therefore only be used to help inform the current status of water quality. Furthermore, the A-3 Drain allocated bacteria concentration reduction set by ODEQ (decrease 33%) was determined from data taken during December of 2002. The allocated reduction percentage was difficult to analyze due to the season which reduction was calculated for. Bacteria concentration reduced by 48% overall, on average, when comparing data collected before and after 2008, but when comparing data collected after December of 2002 until present, during late October through the end of December, *E. coli* concentration only decreased by 3%. It is recommended that the TMDL be reassessed to minimize any confusion toward the allocated reduction percentages.

DMAs in the Amazon and Coyote Creek watersheds have implemented BMPs or water quality management actions for decades prior to TMDL issuance, and have continued those actions. Therefore, analyzing and linking any water quality trends before and after the 2008 TMDL could not be directly attributed to specific implementation activities. The paucity of data and sample stations also minimized the ability to understand pollutant sources, loading locations, and trends in water quality data. If data are to be used to assess water quality status and trends or determine if TMDL implementation activities are achieving load allocations, sampling procedures and requirements in both Amazon Creek and Coyote Creek watersheds needs to be improved. Neither Amazon Creek nor Coyote Creek had flow measurements. Without flow measurements, agencies cannot assess where specific loading is occurring nor whether certain areas are affected during high flow events or low flow events. Using seasonality as a surrogate for flow measurements does not portray possible rain or system flush events.

Based on my analysis, I recommend that TMDL implementation plans require DMAs to describe specific responses anticipated for implementation activities and timelines for attainment to each implementation activity. This would help ODEQ as well as DMAs assess implementation success and areas for improvement. In order to fully achieve these objectives, updates to ODEQ and DMA data collection requirements for 303(d) listings are needed by increasing data collection and the number of sampling sites.

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Introduction

In September 2006, the Oregon Department of Environment Quality (ODEQ) issued a pollution reduction plan for temperature, bacteria, dissolved oxygen (DO), turbidity, and mercury in the Willamette River Basin. ODEQ ordered the plan as a Total Maximum Daily Load (TMDL). A TMDL is a quantitative analysis for attaining and maintaining water quality standards (OAR 340-042-0030(15)). In Oregon, ODEQ establishes sector and source-specific pollution reduction requirements needed to attain and maintain state water quality standards as part of a TMDL.

Oregon Administrative Rules OAR 340-042 sets forth the process for developing and implementing TMDLs and may be found on ODEQ's webpage: http://arcweb.sos.state.or.us/pages/rules/oars_300/oar_340/340_042.html

Once a TMDL has been issued, Designated Management Agencies (DMAs)--government authorities with purview over specific land use/land cover types--submit an implementation plan designed to reduce nonpoint source (load) inputs to ODEQ for review and approval (OAR 340-042-0080(4)). ODEQ is the DMA for point source (wasteload) inputs, and regulates pollution discharges through the following: National Pollutant Discharge Elimination System (NPDES) permitting; Water Pollution Control Facilities (WPCF) permitting; and enforcement of Municipal Separate Storm Sewer System (MS4) discharge permits. Each DMA is responsible for source assessment and identification, as well as identifying the appropriate management strategies that will be used to address source loading. The Oregon Department of Forestry (ODF) and Oregon Department of Agriculture (ODA) have Memorandums of Understanding (MOUs) with ODEQ stating that each agency's administrative rules are designed to meet water quality standards. ODA implements their rules through their Agricultural Water Quality Management Plan (AgWQMP) and ODF implements their rules through their Forest Practices Act (FPA). Non-point source discharges of pollutants from forest operations on state or private lands are subject to best management practices (BMPs) and other control measures established by ODF under ORS 527.610 to 527.992 and according to OAR 629-600 through 665 (OAR 340-042-0080(2)). Such forest operations, when conducted in good faith compliance with the FPA requirements, are assumed to meet water quality standards as provided in ORS 527.770. AgWQMPs and rules must be deemed by ODA to be sufficient to meet the TMDL load allocations and are subject to public comment by ODEQ (OAR 340-042-0080(3)).

Once load allocations have been estimated, ODEQ designs Water Quality Management Plans (WQMPs) to help DMAs develop and establish TMDL Implementation Plans. The implementation plans produced must identify management strategies used to achieve load allocations, provide a timeline to complete measurable goals, provide monitoring and a plan for periodic review and revision, provide evidence of compliance, and provide any other analyses or information specified in the WQMP produced by ODEQ (OAR 340-042-0080(4)). Implementation plans augment previous management strategies designed to reduce pollutants established within the TMDL.

This project provides a comprehensive analysis of the types of strategies that DMAs in the Upper Willamette Basin, specifically Amazon Creek and Coyote Creek watersheds, committed to use for DO and bacterial pollution reductions in their 2008 implementation plans. I examined the successes and impediments to implementing those pollution reduction strategies up to 2015, and conducted a quantitative evaluation of the status, trends, and changes in water quality pre- and post- 2008. The Amazon Creek and Coyote Creek watersheds served as case studies for this project because they recently surpassed their 5-year TMDL review cycles, thus water quality and TMDL implementation data were readily available. Specific project objectives included:

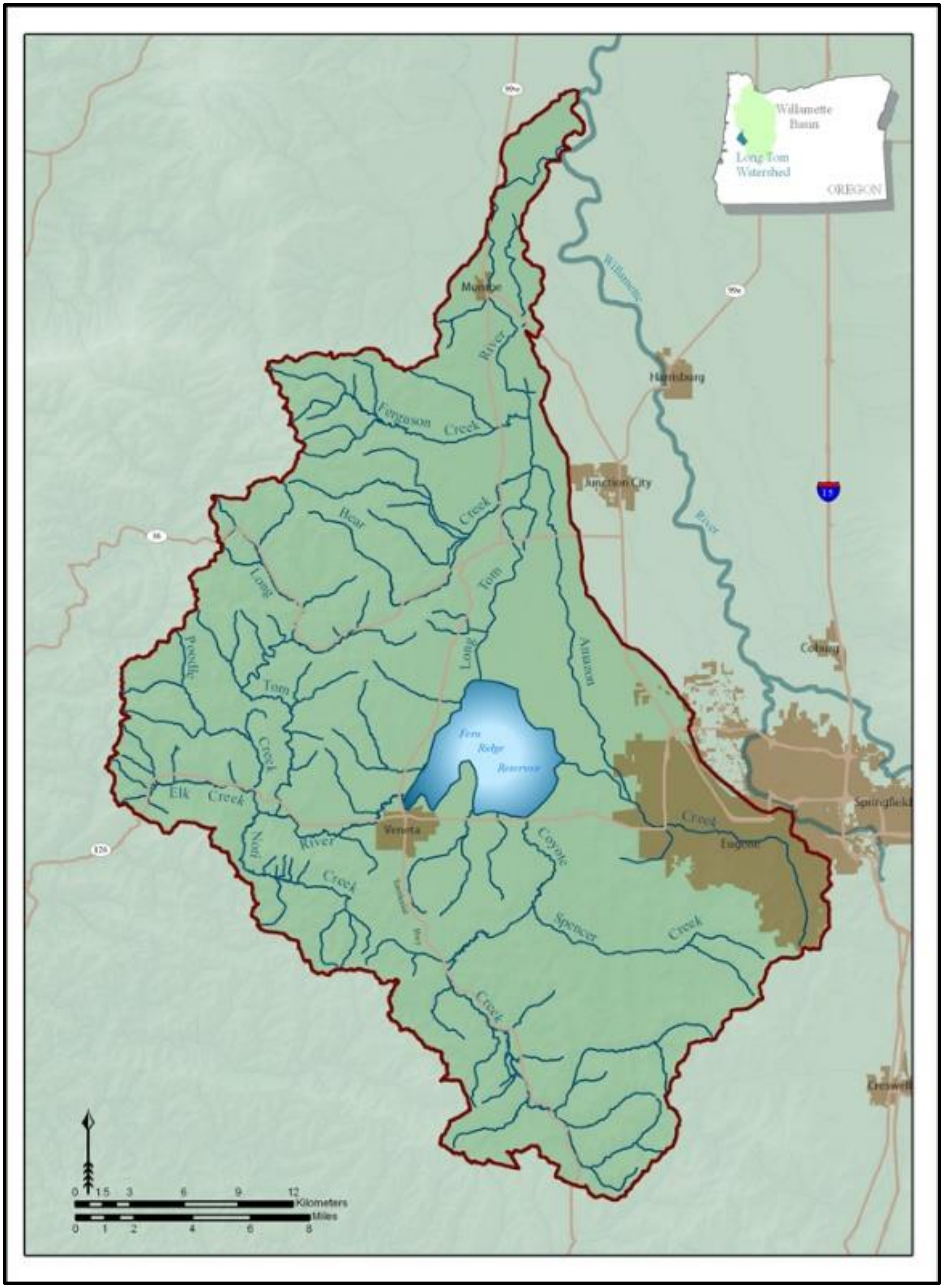
1) Describing current status and trends of DO and bacteria levels in Amazon and Coyote Creeks;
2) Determining if TMDL implementation and other management activities had influenced DO and bacteria levels in Amazon and Coyote Creeks; and,
3) Examining ways in which new data collection and stakeholder communication could improve adaptive management approaches for DO and bacteria TMDL implementation activities.

This project did not evaluate or establish compliance with issued permits or TMDL orders.

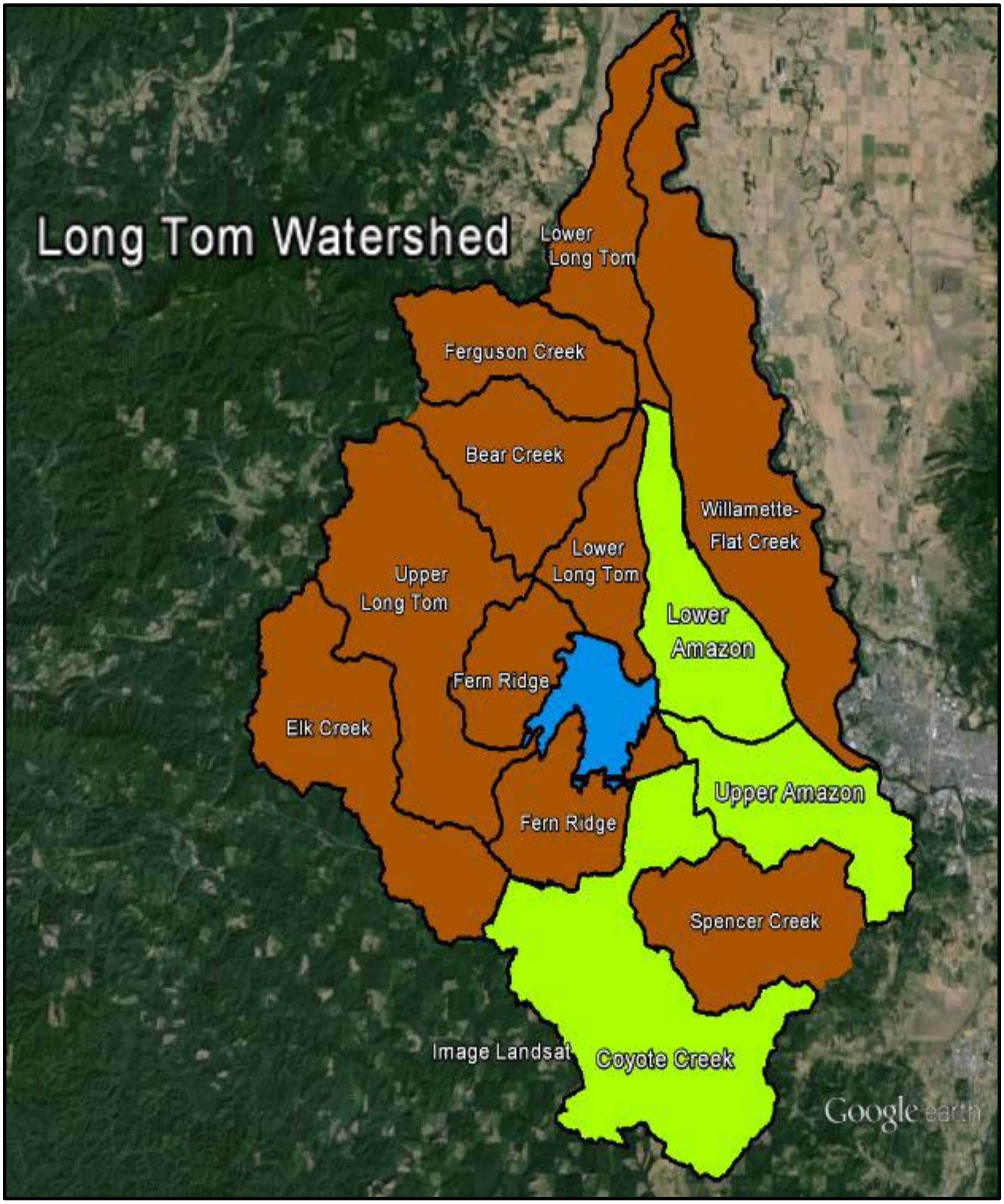
Watershed Overview

Amazon Creek and Coyote Creek watersheds are located in the Long Tom Watershed in the Southern Willamette Valley (Map 1 and 2). The Upper Amazon Creek Watershed drains 7,976 ha and the Lower Amazon Basin drains 7,807 ha (LTWC 2000). Amazon Creek originates in the hills south of Eugene at the peak of Spencer Butte, and flows through the southeastern and western portions of Eugene before entering flat agricultural land north of Eugene until draining into the Long Tom River. A-3 Drain conveys through urban, industrial, and rural residential areas (Map 3). Amazon Diversion Channel is fed from Amazon Creek and flows into Fern Ridge Reservoir. Willow Creek is a major tributary to Amazon Creek and drains primarily forest land and rural residential areas before it flows north and enters Amazon Creek, west of downtown Eugene.

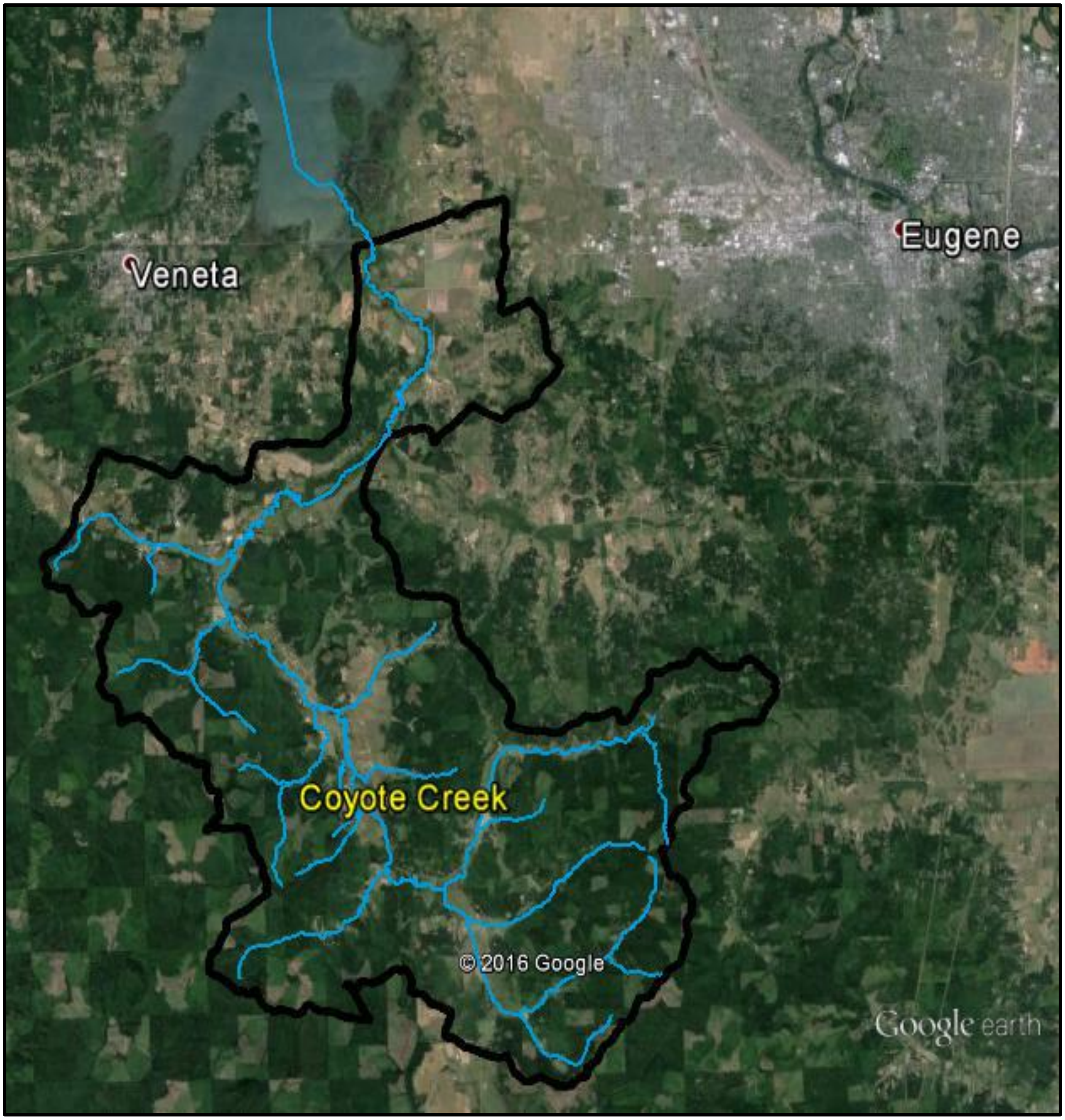
The Coyote Creek watershed drains 26,952 ha (Willamette Basin TMDL, 2006). Coyote Creek is a tributary of the Long Tom River via Fern Ridge Reservoir (Map 4). Located southwest of the City of Eugene, Coyote Creek flows through semi-forested agricultural land.



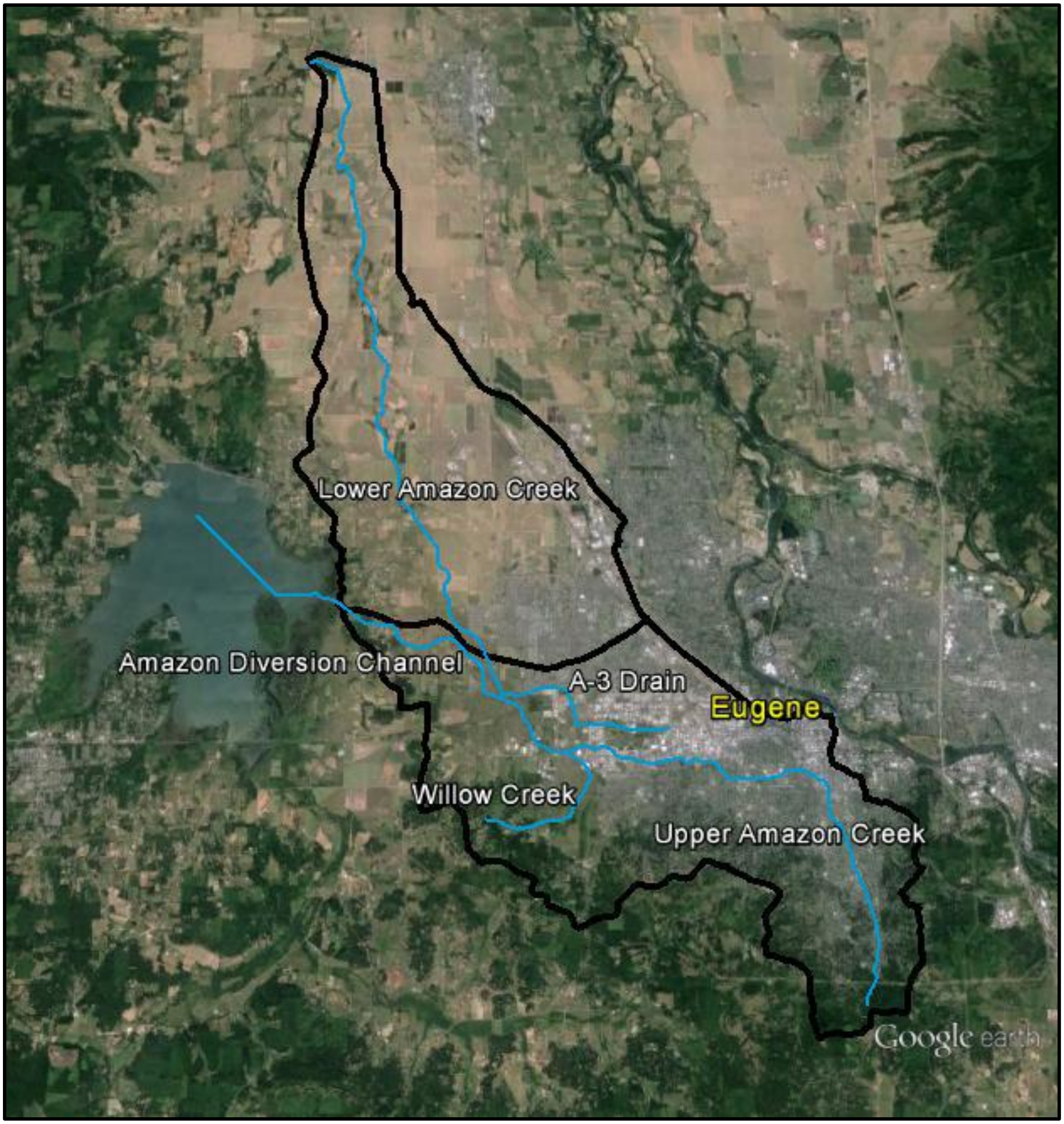
Map 1. (A & B) Upper and Lower Amazon Creek and Coyote Creek watersheds located within Long Tom Watershed in the Southern Willamette Valley (Ecology and Society).



Map 2. Upper and Lower Amazon Creek and Coyote Creek watersheds located within Long Tom Watershed

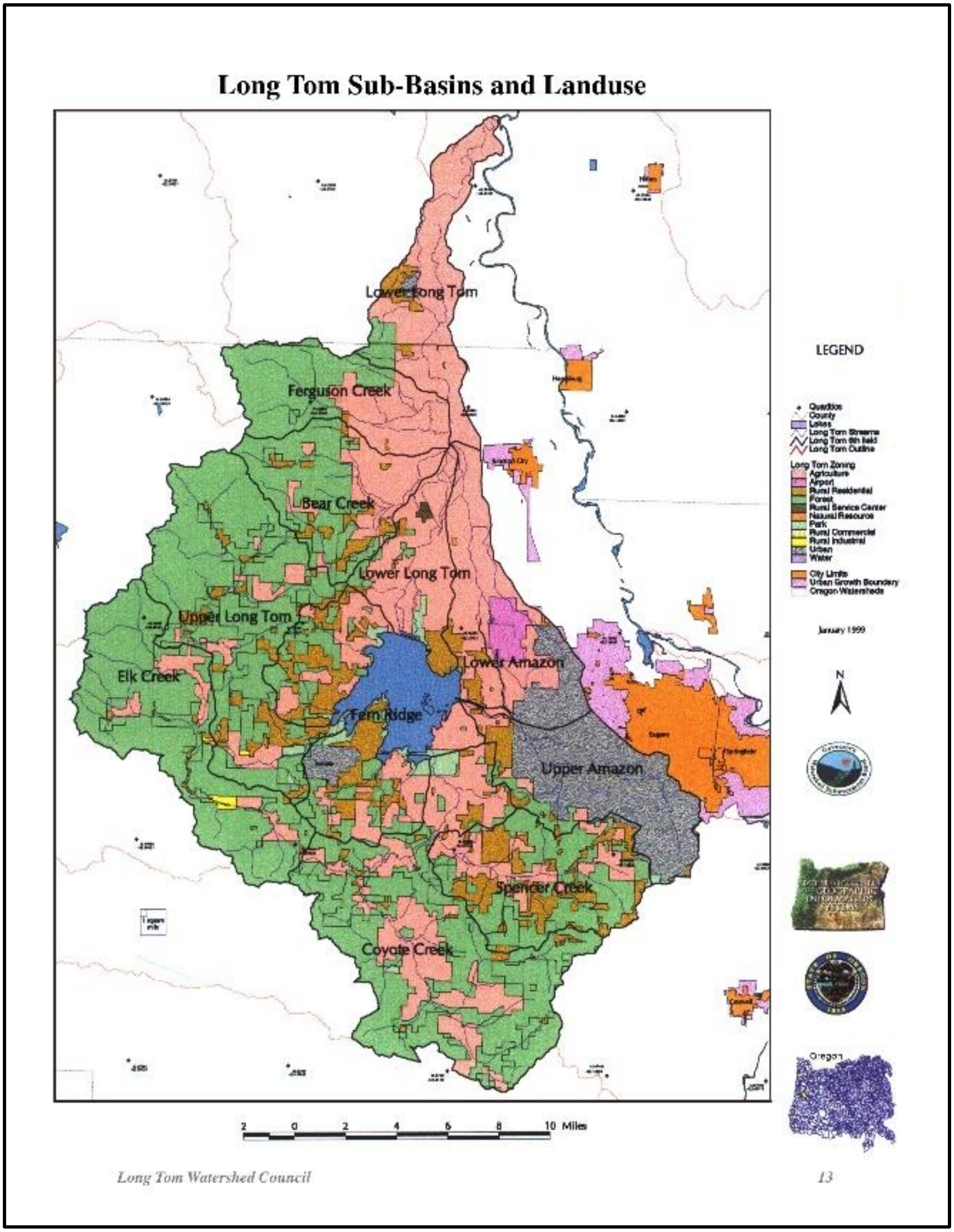


Map 4. Coyote Creek watershed



Map 3. Upper and Lower Amazon Creek watersheds.

The Upper Amazon Creek Basin consists of 80% urban, 7% rural residential, 6% forestry, and 6% agriculture land cover types as of 2006 (LTWC 2003) (Map 5). The largest urban portion of the watershed falls within the City of Eugene. The Lower Amazon consists of 62% agriculture, 21% urban, 6% rural residential, and 11% other land cover types as of 2006 (LTWC 2003). Land use in Coyote Creek is a mixture of forestry (59%), agriculture (28%), and rural residential land, (11%) (LTWC 2003). Population density in Upper and Lower Amazon Creek was 10.6 people/hectare and 5.2 people/hectare, respectively, while Coyote Creek had 0.2 people/hectare as of 2010 (LTWC 2003). The majority of precipitation in the watersheds comes as rain. Precipitation ranges from 89 to 188 cm/yr (LTWC 2003). Most of the precipitation falls from November through March and generally corresponds to increased stream flow (LTWC 2003). However, the largest storms tend to come in November and December, whereas peak stream flows come in December and January (LTWC 2003). This is because in early winter, soils are not saturated and there is little, if any, overland flow (LTWC 2003). Later in the winter, as soils become saturated, increased amounts of overland flow lead to higher stream flows (LTWC 2003).



Map 5. Land Use Map of the Coyote and Amazon Creek basins (LTWC)

Downstream of Martin Street in Eugene, Amazon Creek has been extensively altered. Extensive channelization has occurred in the agricultural and urban portions of the watershed: 62% of the stream length in Lower Amazon and 36% in Upper Amazon (LTWC 2000). Upper Amazon Creek channel modification includes 25 km of channelization, 9 km of streamside roads, two impoundments, one flow check dam, 13 km of levees, and 5 km of road crossings (LTWC

2000). At 24th Avenue Amazon Creek enters a concrete-lined channel for 2.8 km before entering a trapezoidal levee channel at Jefferson Street, near the Lane County Fairgrounds. A diversion channel (Amazon Diversion Channel) connects the Fern Ridge Reservoir to Amazon Creek south of Royal Avenue. The construction of the Diversion Channel to Fern Ridge Reservoir took place between 1951 and 1958, with additional widening and deepening of the channel up to 33rd and Hilyard Street, and the construction of the concrete channel between Jefferson and 24th Street (LTWC 2000). Lower Amazon Creek channel modification includes 69 km of channelization, 0.5 km of streamside roads, four impoundments, three quarries, and 2 km of road crossings (LTWC 2000).

The Coyote Creek watershed has 15 impoundments, which aside from Fern Ridge Reservoir located at the lower end of the watershed, are small agricultural impoundments used for livestock watering, fishponds, or unspecified domestic use (Willamette Basin TMDL, 2006).Coyote Creek channel modifications include: 30 km of channelization; 4 km of streamside roads; and 2 km of road crossings (LTWC 2000).

<u>TMDL Pollutants</u>

Bacteria

Coliform bacteria are a collection of microorganisms that live in the intestines of humans and animals (Oram 2014). Fecal coliform bacteria make up a specific subgroup of this collection, the most common of which is *Escherichia coli* (*E. coli*) (Oram 2014). Although these specific bacteria are generally not harmful, these microbes indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans (Oram 2014). The Environmental Protection Agency (EPA) recommends *E. coli* as the best indicator of health risk from water contact in recreational waters (EPA, 5.11 2012). When fecal bacteria numbers are above water quality standards, people exposed may exhibit fever, diarrhea, chest pains, abdominal cramps, and have an increased risk to gastrointestinal illnesses (Oram 2014).

Amazon Creek, Amazon Diversion Channel, A-3 Drain and Coyote Creek are listed year round on Oregon’s Category 4A (water quality limited, TMDL approved) 303(d) list for exceeding state bacteria criteria for *E. coli*. The load capacity for bacteria is defined as a 30-day mean of 126 *E. coli* counts per 100 mL, based on a minimum of 5 samples, with no 90th percentile calculation exceeding 406 *E. coli* counts per 100 mL (OAR 340-41-0009).

Fecal bacteria reach surface waters from a variety of non-point sources during both base flow and storm events (Willamette Basin TMDL, 2006). Upper Amazon loading sources include urban and rural residential runoff and waste from pets and wildlife. Lower Amazon and Coyote Creek loading sources are primarily rural residential runoff, wastes from pet, livestock, and wildlife, and failing septic systems. Based on NPDES permit compliance, ODEQ determined that point source discharges were not violating the terms of their NPDES permits for *E. coli* (Willamette Basin TMDL, 2006). There is one Confined Animal Feeding Operation (CAFO) in Coyote Creek watershed, located below the confluence of Spencer Creek. However, CAFOs are under NPDES permitting and therefore determined to be in compliance.

In the 2006 TMDL, ODEQ calculated percent reductions (allocations) by using a percentile of the measured concentrations that met the maximum criterion and the greatest reduction that resulted in meeting the log mean criterion (Willamette Basin TMDL, 2006). The greatest percent reduction needed to meet state criterion along the waterbody was applied to the entire waterbody as a conservative assumption to meet criteria along all sections of stream (Willamette Basin TMDL, 2006). The percent reductions of instream bacteria concentrations were applied to land-use specific categories: agriculture, forestry, and urban (Table 1). A margin of safety was applied through a conservative calculation of the 90th percentile and log mean to compare the 126 *E. coli* counts per 100 mL 30-day log mean exceedance criterion (Willamette Basin TMDL, 2006). No reserve capacity was allotted for bacteria. Future permitted sources of bacteria will be required to meet the water quality criteria (Willamette Basin TMDL, 2006). Wasteload allocations for NPDES permits were equivalent to the load capacity for a 30-day mean and an instantaneous limit of 406 *E. coli* counts per 100 mL; CAFOs were allocated zero (Willamette Basin TMDL, 2006).

Table 1: Summary of percent reductions of bacteria loads required by the Willamette TMDL.

Reach	Land Use	Percentage of Land Use	Percent Reduction
Upper Amazon Creek (includes Diversion Channel)			
	Urban	59 %	84 %
	Agriculture	13 %	58 %
	Forest	28 %	0 %
A-3 Drain			
	Urban	59 %	33 %
	Agriculture	41 %	33 %
Coyote Creek			
	Urban	3 %	66 %
	Agriculture	12 %	66 %
	Forest	85 %	0 %

Dissolved Oxygen

DO in lakes, rivers, and streams is critical for aquatic life. Sufficient DO in water is needed by aerobic organisms, including microbes, macroinvertebrates, such as aquatic insects, and vertebrates, such as fish. A stream gains oxygen from physical exchange with the atmosphere and from plants via photosynthesis, while respiration by aquatic organisms, decomposition, and various chemical reactions consume oxygen (EPA, 5.2 2012). DO concentrations have both seasonal and diel fluctuations. Seasonally, DO concentrations are highest in winter and early spring, when water temperatures are lowest. DO concentrations tend to be lower in summer and fall when water temperatures are warm, although daily DO concentration maximums may exceed winter/spring daily averages due to high rates of primary production. Decreased DO levels may indicate organic matter or nutrient contamination and excess biological oxygen demand (BOD) (Oram 2014). Nutrients from agricultural and residential runoff stimulate aquatic plant growth, creating larger diel fluctuations. If the weather becomes cloudy for extended periods, plant respiration will exceed photosynthesis resulting in DO depletion (Oram 2014). When excessive aquatic plant growth senesces, resulting detritus decomposes and consumes DO (Oram 2014).

Upper Amazon Creek, Amazon Creek Diversion Channel, and Coyote Creek are listed on Oregon's Category 4A 303(d) list for exceeding the State DO criteria (Table 2). The Upper Amazon Creek and Amazon Diversion Channel have been designated by ODEQ as cool-water, while Coyote Creek has been designated as cold-water (Willamette Basin TMDL, 2006).

Table 2: Dissolved Oxygen Criterion (OAR 340-041-0016)

Class	30-day	7-day	Min	Use/Level of Protection
Cold Water	8.0	6.5	6.0	Principally cold-water aquatic life. Salmon, trout, cold-water invertebrates, and other native cold-water species exist throughout all or most of the year. Juvenile anadromous salmonids may rear throughout the year. No measurable risk level for these communities.
Cool water	6.5	5.0	4.0	Mixed native cool-water aquatic life, such as sculpins, smelt, and lampreys. Waterbodies includes estuaries. Salmonids and other cold-water biota may be present during part or all of the year but do not form a dominant component of the community structure. No measurable risk to cool-water species, slight risk to cold-water species present.

Warm Water	5.5		4.0	Waterbodies whose aquatic life beneficial uses are characterized by introduced, or native, warm-water species.

Point sources in Amazon Creek and Amazon Diversion Channel discharge via stormwater runoff *(*Willamette Basin TMDL, 2006*)*. These facilities may contribute loads of oxygen demanding pollutants during rainfall events, but are otherwise not permitted to discharge to surface waters (Willamette Basin TMDL, 2006*)*. ODEQ has determined that none of the point sources appear likely to discharge significant quantities of nutrients, including ammonia, or oxygen-demanding organic matter *(*Willamette Basin TMDL, 2006*)*. NPDES permitted facilities do not exist within the Coyote Creek watershed; the CAFO shows no indication of violating the terms of its permit (Willamette Basin TMDL, 2006). ODEQ determined that low DO levels were due to riparian habitat degradation, high bacteria levels, excessive loads of suspended solids, excessive algal growth due to excessive solar radiation levels, high stream temperatures, and high nutrient concentrations (Willamette Basin TMDL, 2006). Lack of riparian habitat has caused the streams to warm above natural conditions, due to lack of shading, and has caused low nutrient retention in the riparian zone and high levels of in-stream algal growth (Willamette Basin TMDL, 2006).

ODEQ determined increasing shading would increase DO concentrations due to the reductions in stream temperature (Willamette Basin TMDL, 2006). ODEQ models indicated increasing shade from current conditions to system potential would reduce diel DO fluctuations (Willamette Basin TMDL, 2006). ODEQ determined if shading increased, standards for DO would be met without the need for additional reductions in BOD, nutrients, or SOD (Willamette Basin TMDL, 2006).

Load allocations for Amazon Creek and the Amazon Creek Diversion Channel aim to reduce BOD, SOD, and nutrient concentration by 40% and bring average solar radiation load to 421 Ly/day (Table 3) (Willamette Basin TMDL, 2006). In Coyote Creek above the Spencer Creek confluence, no reductions were required for BOD, nutrients or volatile suspended solids (Willamette Basin TMDL, 2006). Below the Spencer Creek confluence, where pollutant concentrations are high, 20% reductions in ammonia, BOD, nutrients, and SOD were designated (Willamette Basin TMDL, 2006). The load allocation for average solar radiation for Coyote Creek was 248.2 Ly/day (Willamette Basin TMDL, 2006). All specified concentration reductions were assigned to urban and agriculture land use categories because the analysis determined that forestlands did not contribute significantly to BOD, nutrient, and SOD concentration (Willamette Basin TMDL, 2006). Mandated concentration reductions for these pollutants apply year-round for both Coyote and Amazon Creek (Willamette Basin TMDL, 2006).

Table 3: Land-use based load allocations for the Amazon Creek and Coyote Creek watersheds.

Watershed	Land Use Categories	Percent of Land Use	Percent Reduction in ammonia, BOD loads, nutrient loads, and SOD	Solar Radiation Load
Amazon Creek	Urban	59 %	40%	421 Ly/day
	Agriculture	13%	40%	
	Forest	28%	0%	
Coyote Creek (below Spencer Creek Confluence)	Urban	3 %	20 %	248 Ly/day
	Agriculture	12 %	20 %	
	Forest	85 %	0 %	

The TMDL did not include a reserve capacity. ODEQ determined the conservative margin of safety applied in establishing TMDL load allocations would effectively function as reserve capacity. The margin of safety (MOS) was included to account for uncertainty in the relationship between load allocations and water quality. Amazon Creek load allocations provide for margins of safety by:

1.) Targeting cool-water (5.0 mg/L minimum) rather than warm-water DO standards (4.0 mg/L minimum);
2.) Basing load allocations for BOD, nutrients, and volatile suspended solids loads on loads needed to meet standards for the system potential shade condition; and,
3.) Setting the load capacity and required concentration reductions to 40%. This was the upper range of required concentration reductions (Willamette Basin TMDL, 2006).

Coyote Creek load allocations provide for margins of safety by:

1.) Targeting cold-water rather than cool-water DO standards;
2.) Targeting a minimum DO concentration of 6.5 mg/L rather than 6.0 mg/L; and,
3.) Providing an explicit 20% MOS for ammonia, BOD, and other parameters. This was meant to ensure that the TMDL would be protective of designated beneficial uses (Willamette Basin TMDL, 2006).

Willamette Basin WQMP

WQMPs describe the overall framework for TMDL implementation. These plans include activities, programs, legal authorities, and other measures by which ODEQ and other DMAs can regulate management activities. Entities identified as DMAs must develop and implement controls on non-point source pollution under their jurisdiction via a TMDL Implementation Plan. DMAs in the Amazon Creek and Coyote Creek watersheds include the City of Eugene, Lane County, ODA, Bureau of Land Management (BLM), US Forest Service (USFS), and ODF.

Federal lands fall under the purview of the BLM and USFS. These agencies have developed Water Quality Restoration Plans (WQRPs) equivalent to implementation plans. ODF is responsible for regulating non-point source pollutants resulting from forest operations on non-federal forestlands. Surface waters in lands where forest operators conduct operations in accordance with the FPA are assumed to meet water quality standards.

ODA regulates agricultural activities that can affect water quality through the Agricultural Water Quality Management Act (SB1010). Senate Bill 502 and Senate Bill 1010 directed ODA to work with local communities, including farmers, ranchers, and environmental representatives, to develop AgWQMPs and rules in the Willamette Basin. Local management agencies, such as the Soil and Water Conservation Districts (SWCD) working under contract with ODA to conduct outreach and education, developed individual farm plans for operations in the planning area, worked with landowners to implement management practices, and helped landowners secure funding to cost-share water quality improvement practices.

ODEQ administers two different types of storm water permits based on population size. Phase 1 MS4 permits apply to jurisdictions with a population >100,000, while Phase 2 MS4 permits apply to jurisdictions with >50,000 but <100,000. The City of Eugene has a Phase 1 MS4 permit. Lane County has a Phase 2 MS4 permit. ODEQ expects DMAs covered by an MS4 permit to demonstrate that they will address temperature and non-point sources of TMDL pollutants not addressed by the MS4 storm water management plan. For any storm water management plan that covers all TMDL parameters, the storm water management plan would suffice as an implementation plan.

DMAs are required to address water quality protection through Statewide Planning Goals 5 and 6. Goal 5 requires all Oregon cities and counties to conserve open space and protect natural and scenic resources. Goal 6 requires management agencies to maintain and improve water quality. ODEQ believes public involvement is essential for successful water quality improvement (Willamette Basin TMDL, 2006). DMAs determine how public involvement within their jurisdictions is managed. DMAs must also provide monitoring efforts consisting of the following activities:

- Reports on the numbers and locations of projects;
- BMPs implemented and education activities completed;
- Water quality monitoring to assess the effectiveness of implementation activities and track progress toward achieving water quality numeric criterion; and,
- Monitoring riparian vegetation communities and shade to assess progress towards achieving system potential targets established in the TMDL.

DMAs will be expected to provide a fiscal analysis of the resources needed to develop, execute, and maintain the management strategies described in their implementation plans. Grants are available on a competitive basis for improvement projects. Agency personnel assist landowners in identifying, designing, and submitting eligible projects for these funds.

Implementation Plans

City of Eugene

Planned to be Implemented

The City of Eugene submitted a TMDL Implementation Plan to ODEQ in 2008. Eugene NPDES permits for point source discharges to Amazon Creek include Phase 1 MS4 permit and General 1200Z Industrial Storm-water Permit for Eugene's Airport. These permits serve as the TMDL Implementation plans for the covered discharges (City of Eugene Oregon, 2006*)*. The City received its first MS4 permit in 1994, their second-term permit in 2004, and their third-term permit was submitted in 2008. The General 1200Z permit for Eugene Airport permits the discharges of storm-water runoff from the airport to Amazon Creek and A1 Channel (City of Eugene Oregon, 2006*)*. Eugene plans to implement Goal 5 by protecting riparian areas, upland wildlife habitat areas, and wetlands. Eugene plans to implement Goal 6 by creating WQ (Water Quality) overlay zones for waterways with significant relationships to the 303(d) listed streams. The overlay zones would regulate uses and activities within and adjacent to impaired waterways.

Eugene's strategy for bacteria management includes eleven key strategies; eight from the Phase 1 MS4 permit; one focused upon non-point source/TMDL/Goal 6; one focusing upon Goal 5; and one focused upon the TMDL program (Table 4) (City of Eugene Oregon, 2006).

Table 4: City of Eugene bacteria strategy elements

Bacteria Strategy Element	Governing Permit/Program
1. Education and outreach related	Phase 1 MS4 permit
2. Field investigation program and illicit discharge programs	Phase 1 MS4 permit
3. Maintenance programs	Phase 1 MS4 permit
4. Administer stormwater development standards	Phase 1 MS4 permit
5. Protection of riparian vegetation	Phase 1 MS4 permit
6. Monitoring	Phase 1 MS4 permit
7. Evaluate the effectiveness of the BMPs and bacteria pilot study	Phase 1 MS4 permit
8. Comply with MS4 permit conditions related to TMDLs, including establishing benchmarks and bacteria pollutant load reductions	Phase 1 MS4 permit
9. Establish setback buffers by means of a Water Quality Overlay Zone	Non-point source/ TMDL / Goal 6
10. Track and support the implementation of natural resource waterway protections	Goal 5
11. Develop TMDL web page, including links to related web sites, the City's TMDL Implementation Plan, and staff contact information	TMDL

Eugene's management strategy for DO consists of eleven key strategies; including eight from the Phase 1 MS4 permit and one each focusing upon the non-point source/TMDL/Goal 6 program, Goal 5, and the TMDL program (Table 5) (City of Eugene, Oregon, 2006).

Table 5: City of Eugene DO strategy elements

DO Strategy Element	Governing Permit/Program
1. Educational brochures and newsletters about causes of low DO and the actions private landowners and businesses can take to minimize depletion of stream water DO	Phase 1 MS4 permit
2. System maintenance efforts related to system cleaning, open waterway maintenance, street sweeping, leaf pick up, and vegetation management	Phase 1 MS4 permit
3. Erosion control program	Phase 1MS4 permit
4. Riparian tree planting and vegetation management programs	Phase 1MS4 permit
5. Stormwater development standards	Phase 1MS4 permit
6. Protection of riparian vegetation	Phase 1MS4 permit
7. Comply with MS4 permit conditions related to TMDLs, including establishing benchmarks for DO	Phase 1MS4 permit
8. Improve channel complexity of Eugene's waterways	Non-point source/ TMDL / Phase 1MS4 permit
9. Consider adoption of an ordinance to establish setback buffers by means of a Water Quality Overlay Zone on waterways with a significant relationship to 303(d) listed streams, and which are not already protected by some other means (namely Goal 5).	Non-point source/ TMDL / Goal 6
10. Natural resource waterway protections	Goal 5
11. Develop TMDL web page, including links to related web sites, the City's TMDL Implementation Plan, and staff contact information.	TMDL

Key TMDL implementation plans proposed in the City's 2008 implementation plan include:

1. Implement water quality overlay zones ordinance by June 2009;
2. Annually track implementation of water resource overlay zones;
3. Plant 400 trees per year along south and west side of Amazon Creek; Plant 4,000 linear feet of willow plantings per year along Amazon Creek;
4. Phase 1 MS4 BMPs implementation/activities
    a. Provide stormwater education
    b. Bacteria Pilot Study
    c. Street sweeping and leaf pick-up program
    d. Plant 600 trees per year through the Neighborhoods volunteer program
    e. On average, plant 5000 linear feet of riparian area each year with native trees and shrubs

Implemented

The City of Eugene submitted annual TMDL implementation plan reviews from 2009 through 2014. They met or exceeded implementation plan goals annually and overall. Key implementation activities focusing on attainment of bacteria and DO water quality standards included, but were not limited to:

- ***Waterway protection, restoration, and shading***
    - Stream Buffers/Riparian Protection
        - 35 water quality overlay zone applications from 2009 through 2015
    - Enhancing Streamside Shading
        - Planted 1,982 trees from 2009 through 2014 (330/year average)
            - Did not plant 2013, due to lack of area to plant
        - Planted 49,230 willows along 76,849 linear feet
            - Did not plant 2013, due to lack of area to plan
- ***NPDES phase 1 MS4 permit***
    - Public Education and Outreach

- 74,350 to 80,300 Biannual Newsletters (Spring and Fall) recipients
- 2,000 to 3,000 students annually informed on stormwater pollution concerns
- Partnership with veterinarians to inform pet owners of effects of pet waste
- Local News and online-article focusing on pet waste and its effects on water quality

Lane County

Planned to be Implemented

Lane County submitted a TMDL Implementation Plan to ODEQ in April 2008. Their Plan focuses on eliminating heat and bacteria through a multi-faceted approach of incentives, land use mechanisms, public operations, partnerships, and education. Lane County has many existing water quality programs, permits, ordinances, and practices which have been implemented and used prior to the 2006 303(d) listing, including their Phase II MS4 permit and others (Table 6) (Lane County, Oregon 2008).

Table 6: Lane County Existing Water Quality Related Program and Policy Inventory (*bib, 08lanimpplan)*

Existing Programs, Ordinances, and Practices
Roadside vegetation management and last resort herbicide use policy (Lane Code 15.500 to 15.530)
Riparian modification standards (Lane Code 16.253)
Tree conservation and protection standards (Lane Code 9.90)
Floodplain modification standards (*Lane Code 16.244 & 10.271-5-45)
Integrated Vegetation Management Program and Vegetation Management Advisory Committee
Leaf pick-up program
Storm-water maintenance program
Existing Documents
Lane County Comprehensive Plan Rural Areas [Comprehensive Plan]
Lane County Storm-water Management Plan (2004)
NPDES Phase II MS4 permit

Lane County determined education and training, riparian area protection and management, septic system management, and animal waste management were the highest concerns (Lane County, Oregon 2008). Within Lane County's TMDL Implementation Plan are pledges to increase and/or continue the use of and distribution of prior ordinances, programs, and county codes. These pledges include:

- Increase distribution of educational materials, strengthen relationships with regional watershed councils;
- Planting and recording riparian vegetation (with a minimum of two riparian restoration plantings annually);
- Determine the feasibility of retaining or creating easements for County-owned critical riparian areas proposed for sale as tax foreclosed properties by establishing a framework to review and identify critical riparian areas; and,
- Research opportunities to promote low impact development in parks (Lane County, Oregon 2008).

Implementation of Plan strategies requires a combination of existing funding, future budgeting, and partnerships for grants (Lane County, Oregon 2008). Lane County will continue to seek grant opportunities to address pet waste disposal, riparian restoration and protection, septic sanitation programs, and education of staff, regional landowners, and developers about storm-water management (Lane County, Oregon 2008).

Implemented

Lane County road maintenance staff have committed 2,517 hours on planning, research, and development of fish-friendly culvert projects incorporating riparian restoration work. No land parcels were retained for environmental attributes. A preliminary process has been set up to monitor and evaluate county surplus properties that go to auction, but no parcels with significant riparian attributes have been offered for auction. Pet waste stations are maintained and cleaned daily by County staff. Dog owners are provided informational materials on dog etiquette and pet waste disposal. Lane County distributed 245 brochures entitled "*A Homeowner's Guide to Septic System Maintenance*", providing relevant information on septic system maintenance. These brochures are distributed when residents contact the department for septic system related applications. County staff presented to local high schools and a community college about stormwater management. Fiscal deficiency is the emphasized reason for the low amount of projects and/or restoration activities.

Oregon Department of Agriculture

Planned to be Implemented

ODA's AgWQMP for the Upper Willamette and Upper Siuslaw was designed to prevent and control water pollution from agricultural activities and soil erosion (*OAR 603-095-2600(2)*). Control measures designed to prevent pollutant loading include: development of riparian vegetation, control of sediment and animal waste runoff, elimination of visual indicators of erosion (sheet erosion, active gullies, multiple rills, etc.), and prevention of contaminant runoff from heavily-used areas (*OAR 603-095-2640*). Investigation of pollution from any of the above stated prevention and control measures are found through complaints received by ODA from landowners or the public.

Strategies for the plan include educational programs to promote public awareness of water quality issues, partnerships with agribusinesses and agencies to promote water quality, encouragement of agricultural producers to improve water quality, information to landowners to initiate improvements, financial assistance for implementation, funding for technical and/or resource management planning assistance, education, and water quality monitoring, and monitoring to evaluate the effectiveness of the Area Plan and Area Rules (*ODA 2007*).

The Plan does not regulate. It is guidance for landowners to address water quality issues. In it, they can find contacts for technical and financial assistance that will help them meet their business and conservation goals and attain water quality standards at the same time.

Implemented

The areas within Amazon and Coyote watersheds managed by ODA do not currently have a focus area. A focus area will be chosen for implementation, with a timeline and objectives made by ODA and SWCD at the 2015 biennial review. District staff distributed 2,000 "Rural and Suburban Living" handbooks. Over 400 landowners have been provided assistance for locating information regarding the Area Plans and Rules. District staff completed 37 site visits with landowners to address water quality concerns associated with agricultural activities on their land. From these visits, 11 small projects were developed, 7 have been completed and 4 were in progress at the time of this project. The majority of these projects involved livestock operations working to address livestock waste concerns, while the other projects addressed riparian area enhancement and irrigation efficiency. District staff provided technical assistance to 37 landowners pertaining to agricultural. District staff worked with 12 landowners to provide planning assistance to implement conservation practices. These plans and practices, funded through OWEB, focused on nutrient management, pasture renovation/rotation, installation of native trees/shrubs in riparian areas, rainwater harvesting for irrigation, and riparian area restoration. Impediments to implementation include, but are not limited to, funding and resources for project implementation, lack of awareness of Area Plans and Rules, landowners lack time to implement projects due to busy farming, communication amongst local partners lacked, and communication with landowners conveying their responsibility (voluntary action and regulatory enforcement) and public funds to landowners for projects.

Oregon Department of Forestry

Planned to be Implemented

OAR 629-605 requires the operator, landowner, or timber owner to comply with the forest practices statues and rules governing water protection rules (OAR 629-(635:660)) unless approval has been obtained for alternate practices designed to result in the same effect as described in those rules. The overall goal of the water protection rules is to provide protection during forest operations in and around streams, lakes, wetlands, and other riparian areas so that water quality is not impaired. Monitoring of both vegetation and waters shall be conducted on a continual basis to evaluate the effectiveness of the protection rules as well as determine if the FPA goals are being met. Annual reports of monitoring efforts are to be submitted to the Board of Forestry. Rules, regulations, and plans are designed to the stream classification type: Streams that have fish use, including fish use streams that have domestic water use, shall be classified as Type F; Streams that have domestic water use, but not fish use, shall be classified as Type D; and, All other streams shall be classified as Type N (OAR 629-635-0200(4, a:c)). Neither Coyote Creek nor Amazon Creek are used for domestic use yet bot are designated as fish use streams, therefore both are classified as F. The rules are focused upon available tree removal widths from stream and tree and riparian vegetation retention stream side.

ODF is responsible for reviewing pre-operation plans, overseeing operations, ensuring reforestation, investigating complaints, and enforcing corrective actions when violations occur. ODF works with landowners and operators to help them comply with requirements to avoid issuing citations or criminal/civil penalties. Operations requiring notification include road construction, slash disposal, pre-commercial thinning, harvesting, applying chemicals, quarry development, site preparation for reforestation, and changing the use of forestland to non-forest use.

Implemented

Forest operations in accordance with ODF BMPs are considered to be in compliance with Oregon's water quality standards.

Water Quality Analyses

Analyses were used to determine if standards were or are currently being met, trends over time, if concentrations increased or decreased with stream flow, if changes had occurred before and after 2008 (TMDL implementation start date), and if implementation activities were influencing concentration levels. Water quality data were obtained from the ODEQ Laboratory Analytical Storage and Retrieval (LASAR) and ELEMENT databases. Available data sets obtained through LASAR and ELEMENT contained data which were either too low (<) or too high (>) for laboratory assessment. Data found to be below or above the minimum or maximum concentration levels were changed to half the amount entered for data entered with a < sign and changed to the amount present for data entered with a > sign; i.e., >2400 was changed to 2400 and <1 was changed to 0.5. Data were visually (graphing or mapping) and quantitatively assessed to examine temporal trends. All statistical testing, modeling, and plot/figure construction were completed using R, version 2.15.0 (R Core Development Team 2016).

Monitoring on Upper Amazon Creek consisted of ten sampling stations, four of which were sampled continuously: Amazon Creek at 29th Avenue, Amazon Creek at the Railroad Crossing;

Amazon Creek at Royal Avenue, and Willow Creek 180 North of 18th Avenue (Figure 6). Nineteen consecutive years (1997-2015) of data have been collected with an average of six samples collected per year (years and average samples per year collected vary per site). The Amazon Diversion Channel consists of two sampling stations, one of which is continually sampled, Royal Avenue. Royal Avenue has been sampled for 19 consecutive years (1997-2015) with an average of six samples taken per year (seasonal sampling varies per year). The A-3 Drain consists of five sampling stations, one of which is continually sampled, Terry Street. Terry Street has been sampled for 16 consecutive years (2000-2015) with an average of six samples taken per year (seasonal sampling varies per year). Lower Amazon Creek consists of five sampling stations, two of which were used for analyses. Amazon Creek at High Pass Road was sampled from the winter of 1999 through the summer of 2003 continuously (twice a month on average) and has been sampled on a continual basis from the winter of 2011 to present. Amazon Creek at RM 5.82 was only sampled during mid-summer through early-fall 2015. Amazon Creek at RM 5.82 was chosen because it is halfway between the furthest downstream sampling station in the Upper Amazon (at Royal Avenue) and the furthest downstream sampling station in the Lower Amazon (at High Pass Road). There were ten sampling stations along Coyote Creek, yet few data were available along Coyote Creek. Most stations were sampled one to eight total times. Three stations were sampled continuous (more than twice a month on average) from late summer in 1999 through 2003 at Hamm Road, Powell Road, and at Petzold Road. These three stations were sampled, twice a month, during mid-summer through early-fall 2015 to compare prior trend and current status of *E. coli* and DO concentration. These stations had the most available data and were located in the headwaters (Hamm Road), the middle of the watershed (Powell Road), and before the confluence of Spencer Creek (Petzold Road).

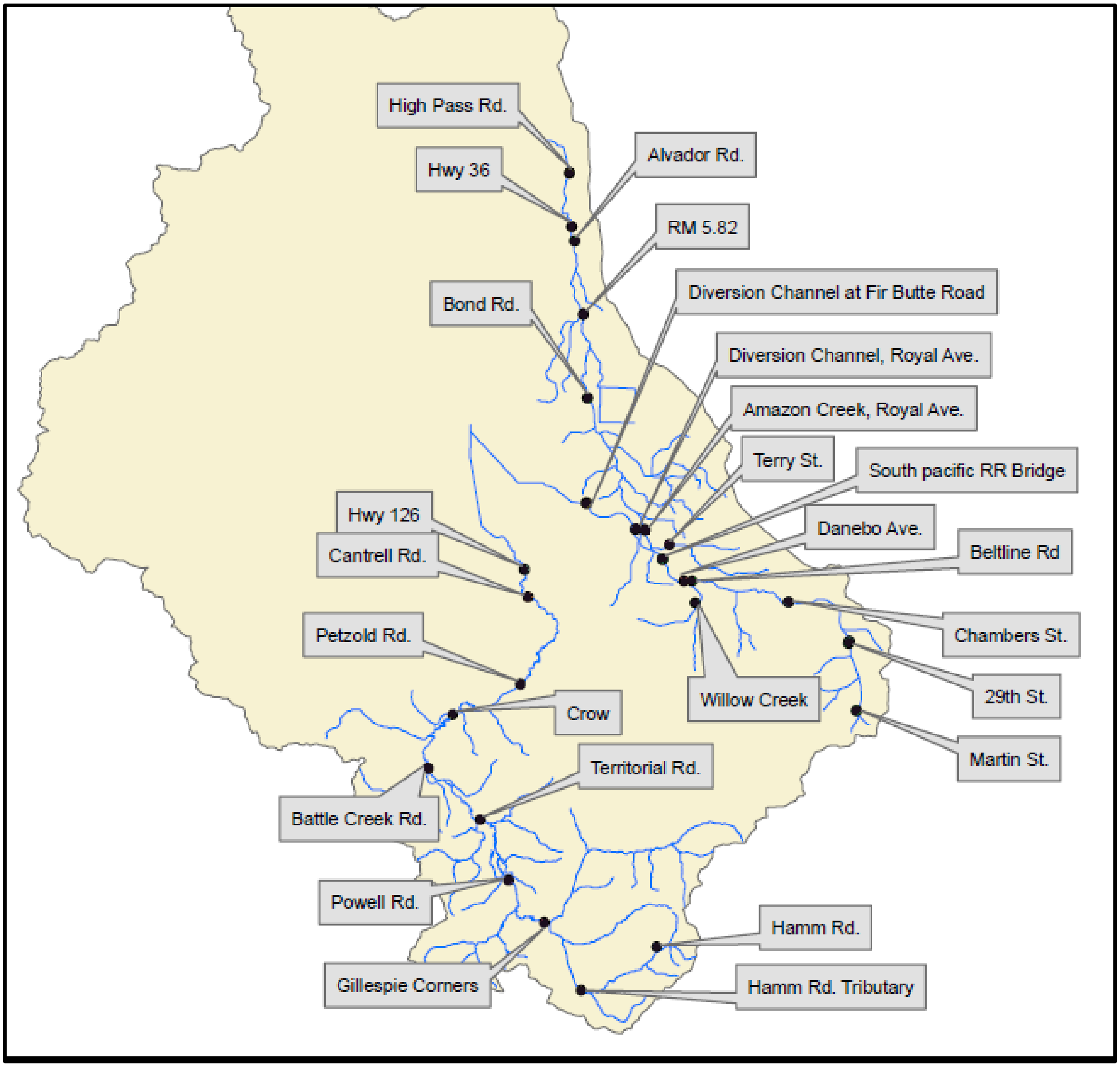


Figure 6. Location of collection stations on Amazon Creek and Coyote Creek

Methods

Descriptive Statistical Analysis

Descriptive statistics were used to summarize sample sets through visual analysis prior to analyses of correlations, changes, and trends. A box and whisker plot is a standardized way of displaying the distribution of data, based on the first quartile and third quartile (upper and lower 25^{th} percentile or 25^{th} and 75^{th} percentile), second quartile (median), the whiskers (minimum and maximum), and outliers (greater than 1.5 interquartile ranges away from the 25^{th} and/or 75^{th} percentiles). These plots show the central tendency, range in data, and the skew of the distribution. Box and whisker plots were constructed for annual and seasonal data. These data sets were split into before and after 2008. Exceedance percentages of each collection station, both overall and seasonally, before and after 2008 was built to display increasing, decreasing, or no change in the single sample exceedance criterion. Both box and whisker plots and percentages of exceedances were not used for statistical analyses. They were used only to examine data distributions for statisitcal testing procedures.

Testing for Dependence

To test whether the occurrence of single sample exceedances were seasonally dependent, a Fischer's exact test was applied. A Fischer's exact test is similar to a Chi-square test, testing whether observed distribution is due to random chance. The Fischer's exact test is used when sample size is small to avoid approximation of a *p-value*. To perform the Fischer's exact test, contingency tables were designed based on exceedances of single sample criterion and non-exceedance of State single sample criterion of both *E. coli* and DO before and after 2008. The contingent parameters were seasonal (winter, spring, summer, and fall). The null hypothesis was that exceedance of single sample criterion was seasonally independent. The null hypothesis was rejected, and found to be dependent, with a *p-value* <0.10.

Testing for Change in Means Before and After 2008

To determine if TMDL implementation activities after 2008 had possible influences to bacteria and DO concentrations, Wilcoxon rank-sum tests were used. The Wilcoxon rank-sum test is a non-parametric alternative to the Student's t-sest used for examing the differences in observations to assess whether their population means differ. The Wilcoxon rank-sum test is used when populations cannot be assumed to be normally distributed and also allows for unpaired and/or independent data sets. The null hypothesis for Wilcoxon rank-sum test is that concentration means before and after 2008 are the same. The null hypothesis was rejected, if the *p-value* was <0.10.

Testing forTrends and Changes in Trends Before and After 2008

I used linear regression analysis to examine data trends before and after 2008, both seasonally and for the entire data set. *E. coli* datasets were log transformed to meet assumptions of normality. Adjusted R^2 values and *p-values* were used to assess linear trends. Linear models were deemed statistically significant if the *p-value* was <0.10. A Chow test was used to determine if linear regression models before and after 2008 were different. A Chow test determines whether the slopes and intercepts of the linear regression of one group are different from those of another group by using the error sum of squares from separate regressions, error sum of squares from the pooled regression, the number of parameters, and the number of observations in each groups. Rejection of the null hypothesis (*p-value* <0.10) will conclude there was a significant difference in models before and after 2008.

Forecasting *E. coli* and DO Concentration

In order to forecast future *E. coli* and DO concentration levels, ARIMA models where developed. ARIMA modeling is a technique that projects future values of a series based on previous values. ARIMA stands for Autoregressive-Integrated-Moving Average; "AR" extracts the influence of the previous periods' values on the current period, "I" subtracts the time series with its lagged series to extract trends from the data making the data stationary (log transformation will be used to create stationary data), and "MA" extracts the influence of the previous periods' error terms on the current periods' error. An ARIMA model's main application is short-term forecasting of >40 historical data points, and works best when data exhibit a stable or consistent pattern over time with minimal outliers (Hyndman and Athanasopoulos 2016). Auto ARIMA modeling was used as a function, which automates the ARIMA modeling procedure to identify the best fit ARIMA model. Five–year forecasts of collection stations were used to determine short-term trends in bacteria and DO levels.

Results

Bacteria

Upper Amazon

Amazon Creek at 29th Avenue

Amazon Creek at 29th Avenue exceeds single sample criterion for *E. coli* year-round, both before and after 2008 (Figure 1, Appendix A: Figure 1, Table 1). The change in the percentage of single sample exceedance before and after 2008 decreased 20% during the spring, yet increased by 15% and 21% during the summer and fall, respectively. Overall, the percentage of exceedances before and after 2008 increased by 6%. The geometric means during all seasons, both before and after 2008, exceeded State single sample criterion. Based on these data, the allocated percent reduction in bacterial concentration (84%) has not been met since TMDL implementation. *E. coli* concentrations have increased by 4%, on average.

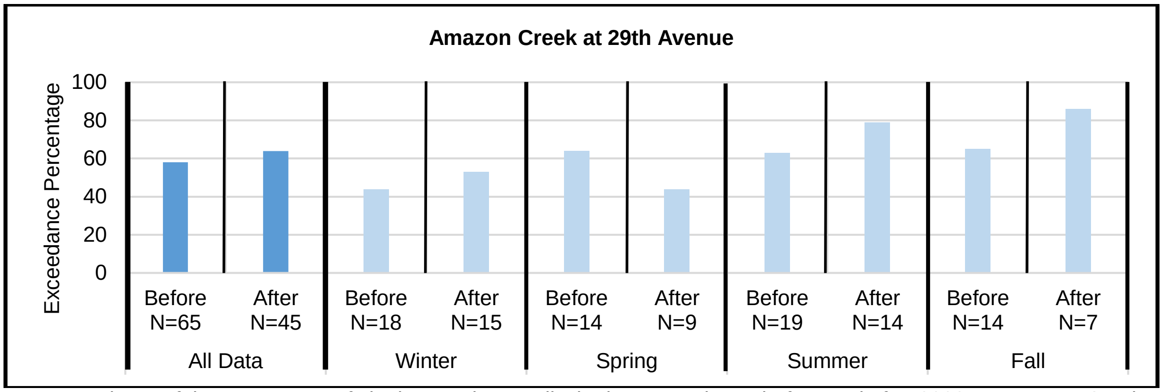
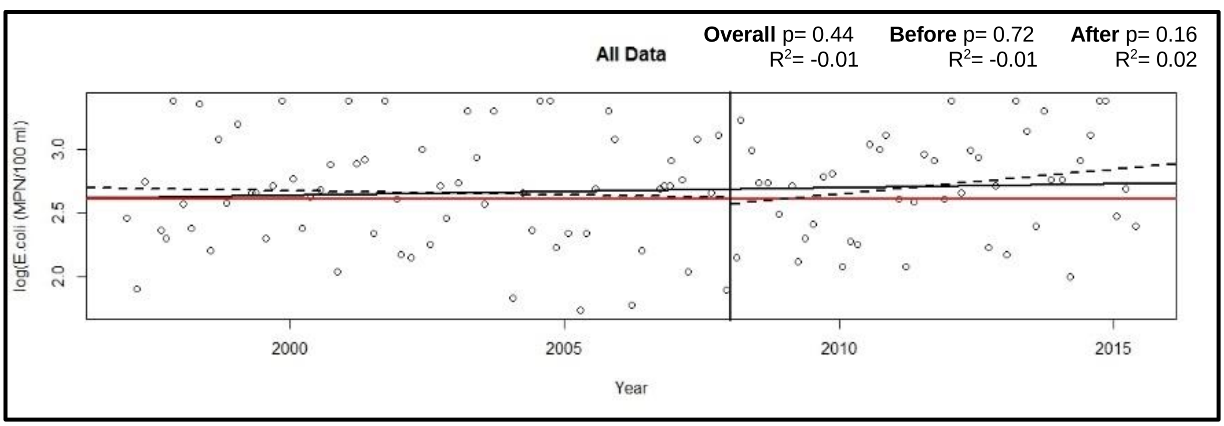


Figure 1: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Amazon Creek at 29th Avenue. The charts are split seasonally, as well as all data.

Frequency of single sample exceedance criterion at 29th Avenue was not seasonally dependent before or after 2008 (Appendix B: Table 1 and 2). There were no significant changes found for the means before and after 2008 for any data set (Appendix C: Table 1). The spring before 2008 was the only data set found to have a significant linear trend (decreasing) (Figure 2, Appendix D: Table 1). There were no significant changes found in the slopes before and after 2008 in any data set. The high variability of each sample collection, along with minimal seasonal/yearly data collection caused uncertainty in the ability to forecast *E. coli* concentration through ARIMA modeling. The model forecasted a mean near the present median (490 *E.coli* organisms (MPN)/100 ml) and the 95% confidence interval is well above the State single sample criterion (Appendix E: Figure 1).



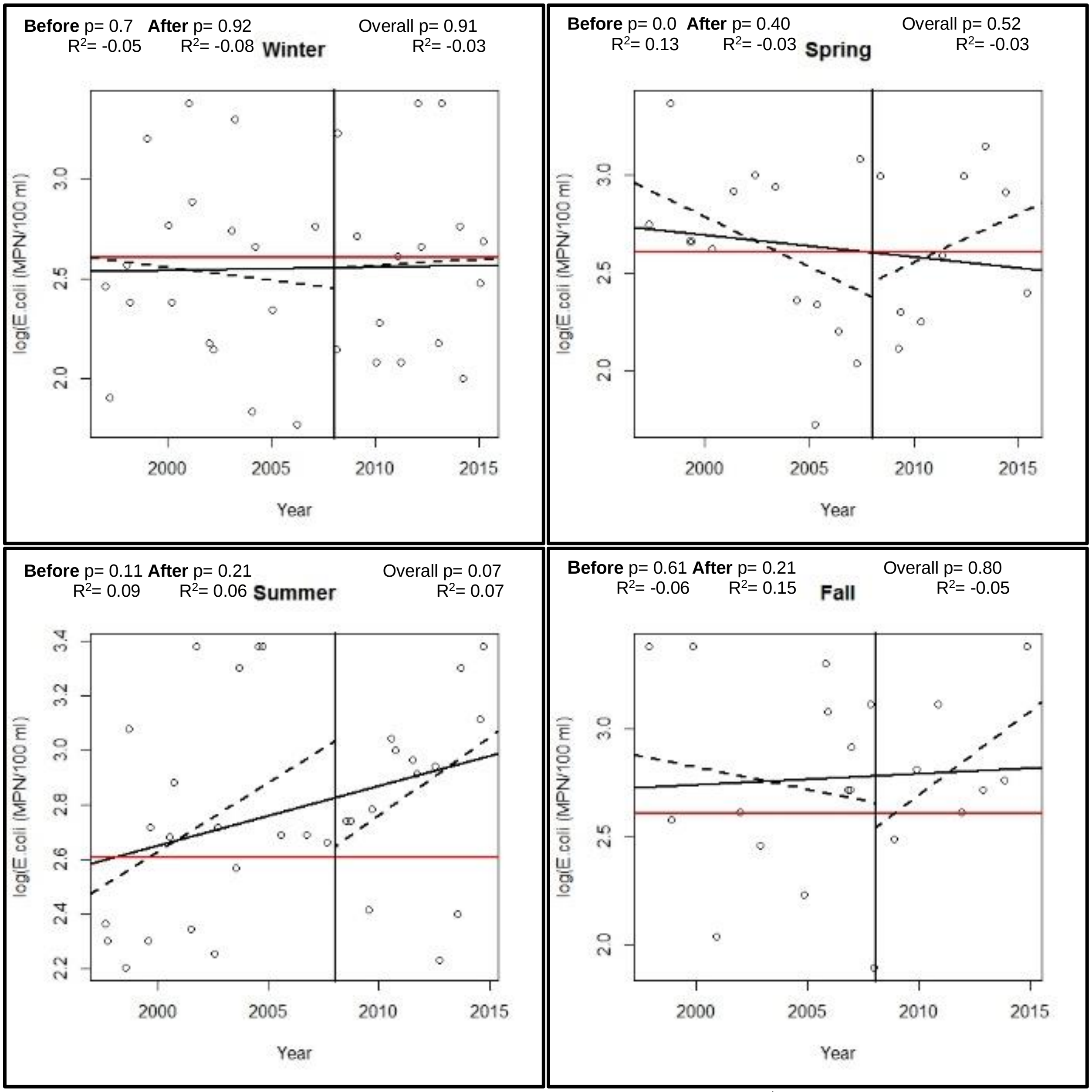


Figure 2: Linear regression of all *E. coli* data, as well as seasonally, on Amazon Creek at 29th Avenue. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Amazon Creek at Railroad Crossing

Amazon Creek at Railroad Crossing exceeds State single sample criterion for *E. coli* year-round, both before and after 2008 (Figure 3, Appendix A: Figure 2, Table 2). Single sample exceedances during the spring decreased by 38%; in summer, exceedances increased by 28%. Overall, the exceedances increased by 10% after 2008. The geometric mean after 2008 was above the single sample criterion. The allocated percent reduction in bacterial concentration (84%) has not been met since 2008. *E. coli* concentrations have increased by 11%, on average.

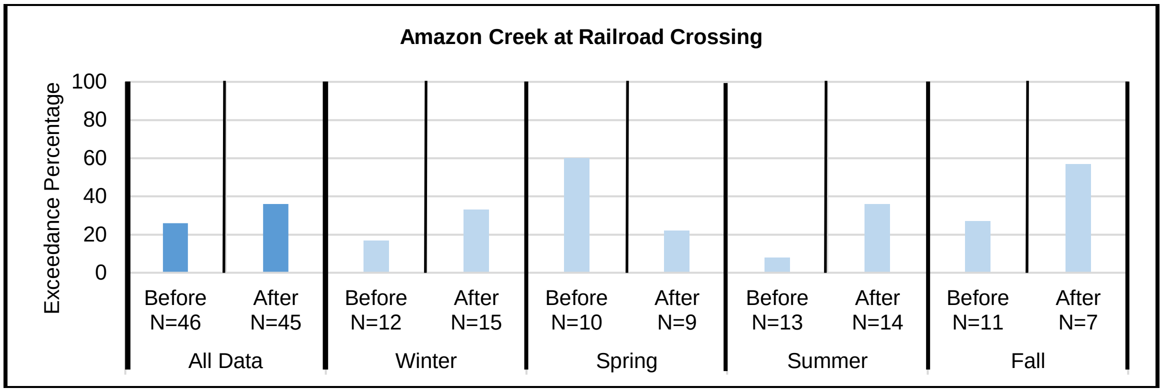
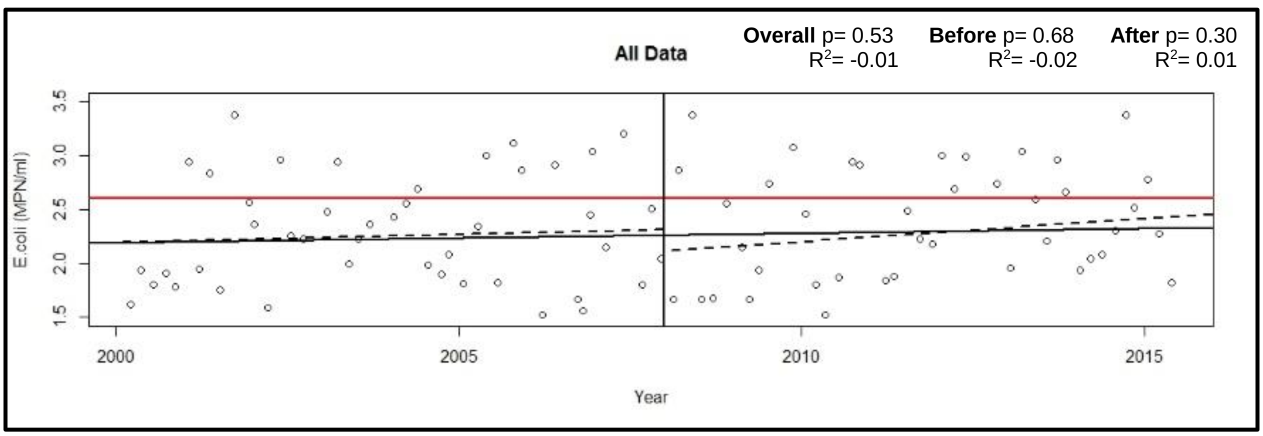


Figure 3: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Amazon Creek at Railroad Crossing. The charts are split seasonally, as well as all data.

Single sample exceedance criterion at Railroad Crossing was significantly seasonally dependent before but not after 2008 (Appendix B: Table 1 and 2). There were no significant changes in the means before and after 2008 for any dataset (Appendix C: Table 2). There were no significant linear trends for any dataset (Figure 4, Appendix D: Table 2). There were no significant differences in the slopes before and after 2008 for any dataset. The high variability of samples along with minimal seasonal/yearly data collection caused uncertainty in forecasting *E. coli* concentrations with ARIMA modeling. The model forecasted a mean below the single sample criterion, yet the upper 95% confidence interval falls above single sample criterion (Appendix E: Figure 2).



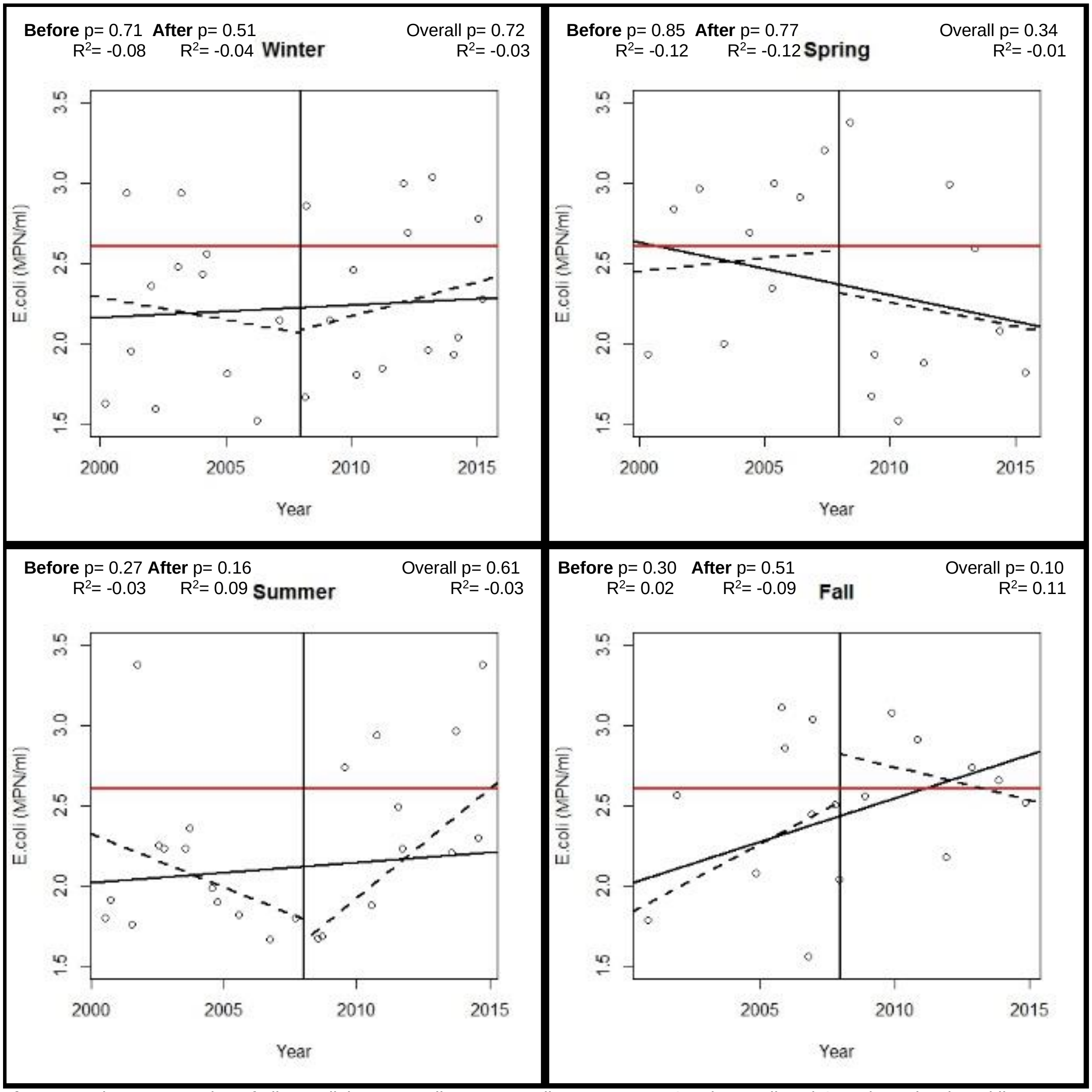


Figure 4: Linear regression of all *E. coli* data, as well as seasonally, on Amazon Creek at Railroad Crossing. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Amazon Creek at Royal Avenue

Amazon Creek at Royal Avenue exceeds single sample criterion for *E. coli* year round before and after 2008 (Figure 5, Appendix A: Figure 3, Table 3). Single sample exceedances increased during the winter by 29%, decreased during the summer by 35%, and decreased overall by 7%. The allocated percent reduction in bacterial concentration (84%) has not been met since 2008. *E. coli* concentrations have decreased by 9%, on average.

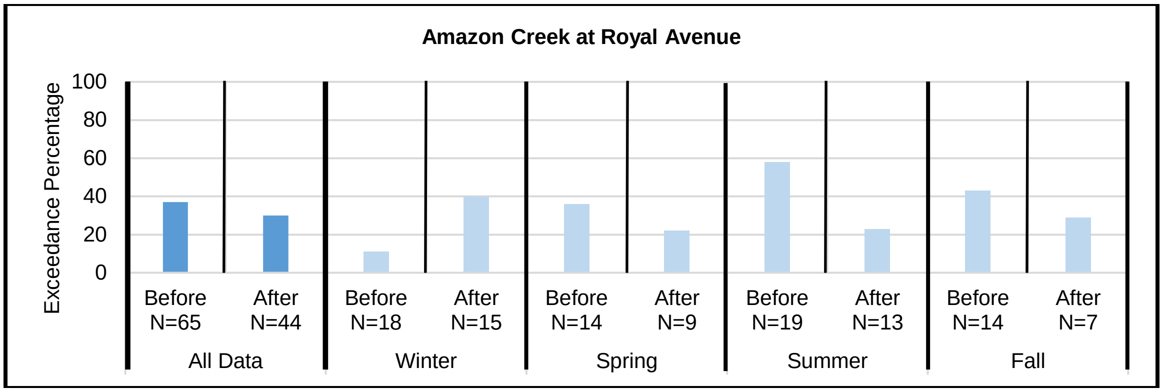
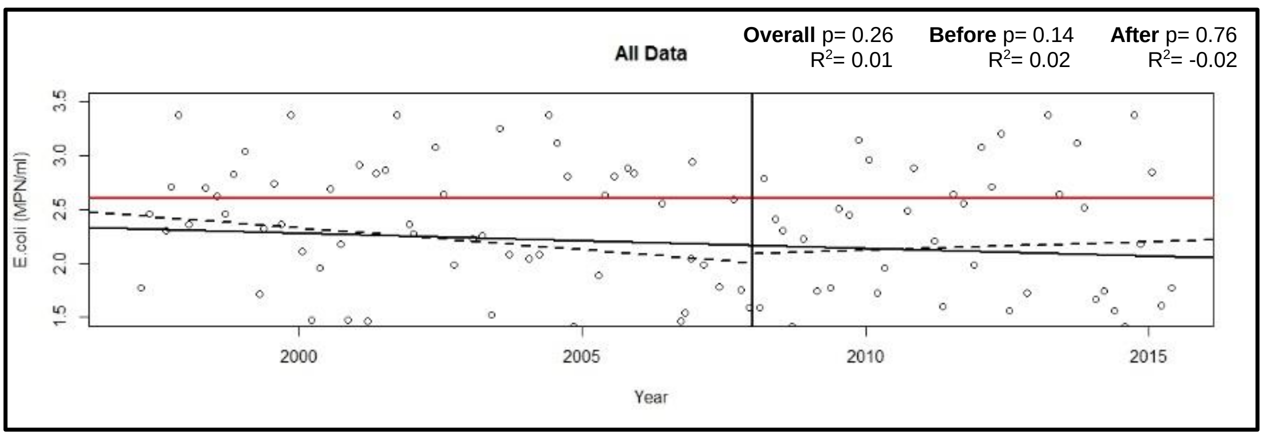


Figure 5: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Amazon Creek at Royal Avenue. The charts are split seasonally, as well as all data.

Single sample exceedances at Royal Avenue were significantly seasonally dependent before but not after 2008 (Appendix B: Table 1 and 2). The means during the summer, before and after 2008, were the only datasets found to have significant differences (Appendix C: Table 3). Linear regression analysis found no significant trends for any of the datasets (Figure 6, Appendix D: Table 3). There were no significant differences in the slopes before and after 2008 in any data set. The high variability of each sample collection, paired with minimal seasonal/yearly data collection led to uncertain forecasts of *E. coli* concentrations through ARIMA modeling. The model forecasted a mean below single sample criterion, yet the upper 95% confidence interval was above single sample criterion (Appendix E: Figure 3).



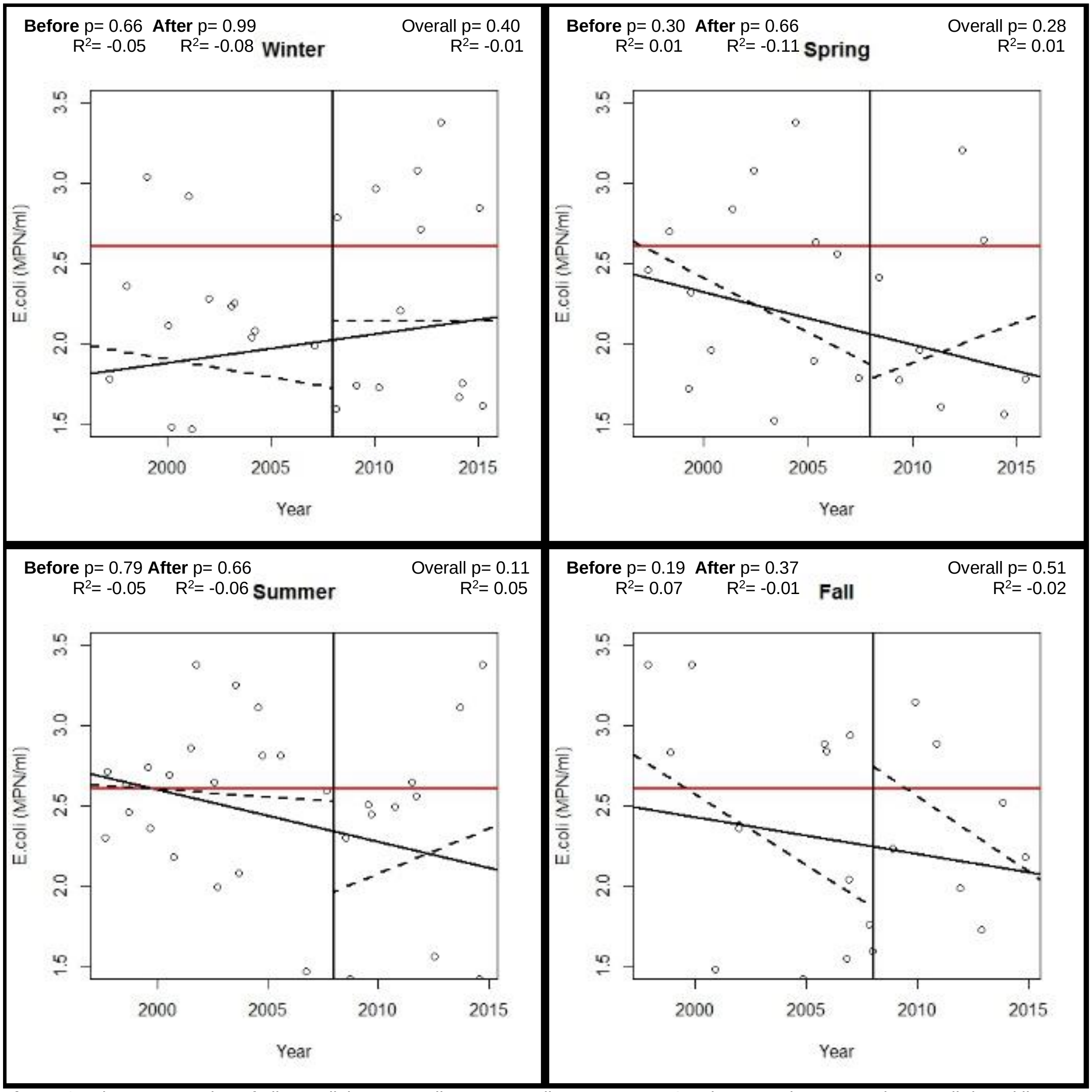


Figure 6: Linear regression of all *E. coli* data, as well as seasonally, on Amazon Creek at Royal Avenue. The E. coli dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Willow Creek at 18th Avenue

Willow Creek at 18th Avenue exceeds single sample criterion for *E. coli* year-round, both before and after 2008, except for the winter before 2008 (Figure 7, Appendix A: Figure 4, Table 4). The winter before 2008 had did not exceed single sample criterion. The highest percentage of exceedances occurred in the summer after 2008 (50%), although the summer after 2008 was only sampled twice. Exceedances increased by 7%. The geometric means and the first and third quartiles during the all seasons, other than the summer after 2008, were below single sample criterion. The allocated percent reduction in bacterial concentration (84%) has not been met. *E. coli* concentrations have increased by 62%, on average.

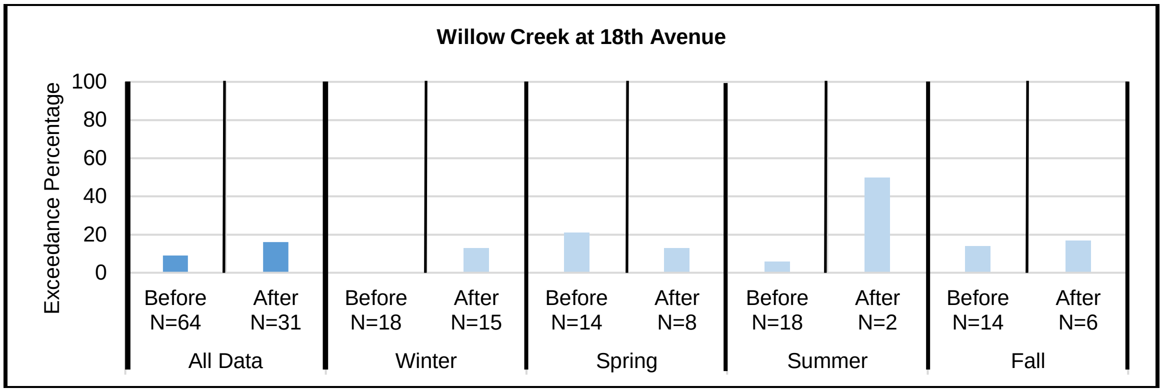
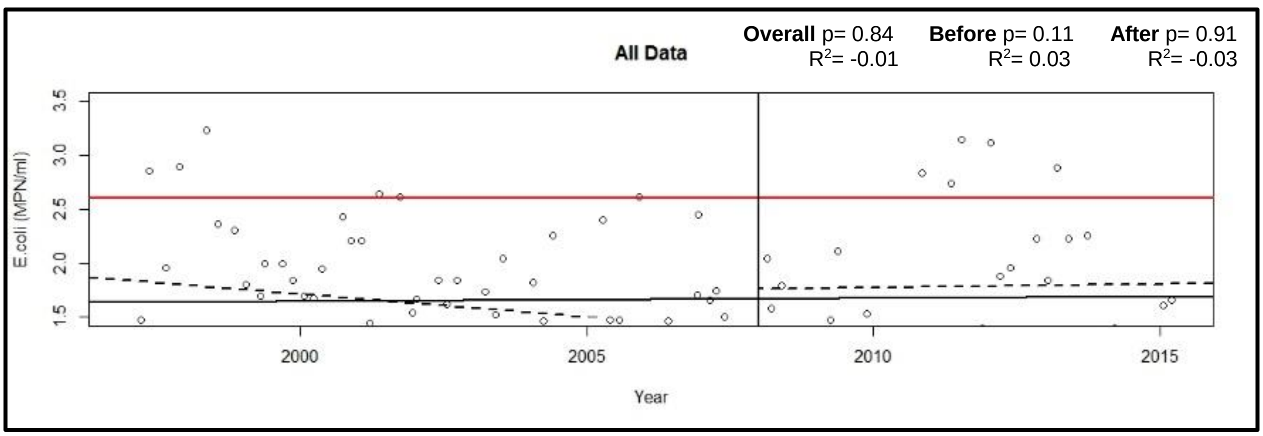


Figure 7: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Willow Creek at 18th Avenue. The charts are split seasonally, as well as all data.

Single sample exceedance criterion at on Willow Creek at 18th Avenue was not found to be seasonally dependent found before or after 2008 (Appendix B: Table 1 and 2). There were no significant changes found for the means before and after 2008 for any data set (Appendix C: Table 4). The spring before 2008 was the only data set to have a significant decreasing linear trend (Figure 8, Appendix D: Table 4). The lack of seasonal/yearly data did not permit auto ARIMA modeling.



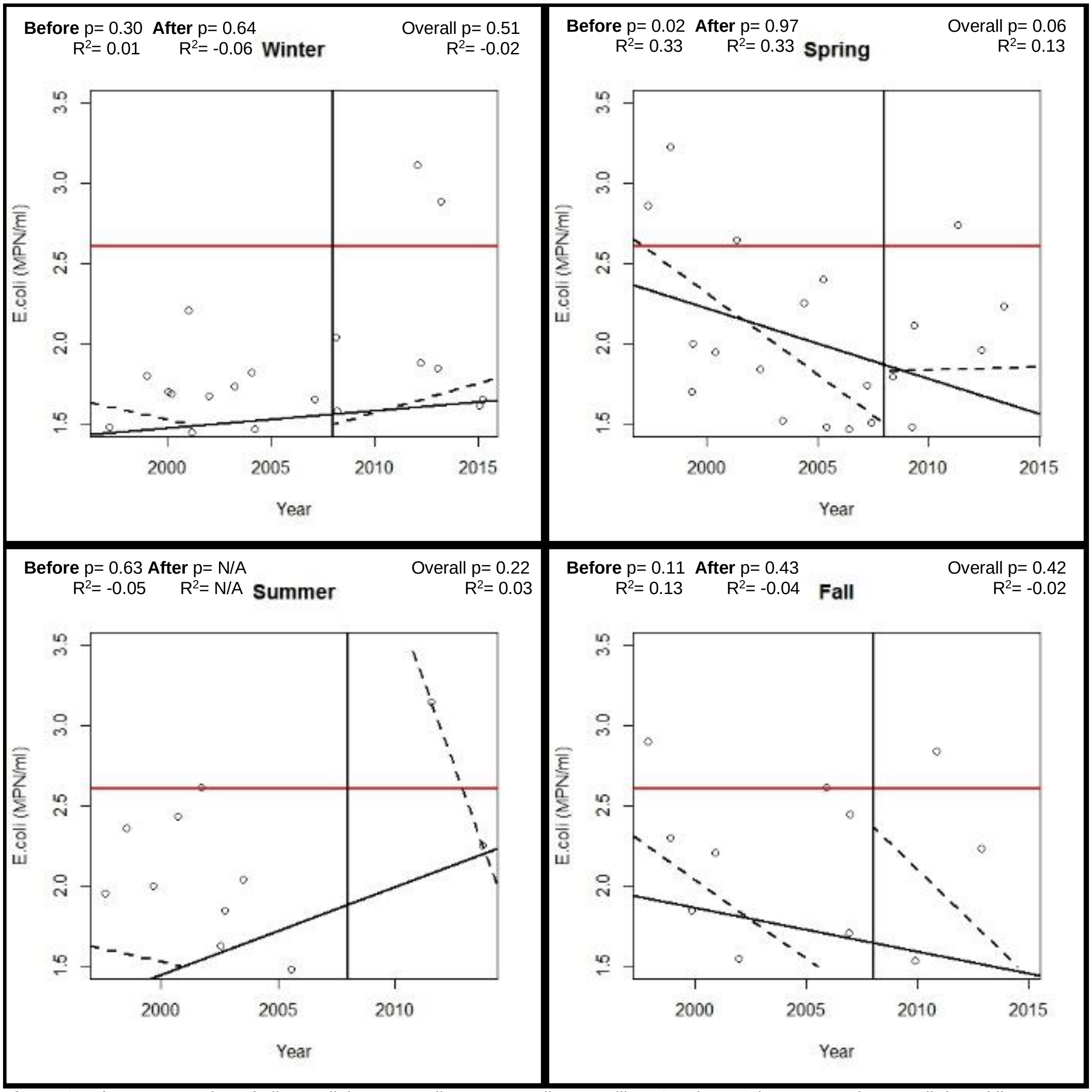


Figure 8: Linear regression of all *E. coli* data, as well as seasonally, on Willow Creek at 18th Avenue. The E. coli dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Amazon Diversion Channel at Royal Avenue

Amazon Diversion Channel at Royal Avenue exceeded single sample criterion for *E. coli* year-round, both before and after 2008, except for the spring after 2008 (Figure 9, Appendix A: Figure 5, Table 5). The highest percentage of exceedances was the summer before 2008 (58%), although the summer after 2008 decreased 31%. Exceedance percentage also decreased 15% during the spring after 2008. The overall exceedance percentage decreased by 10%. The geometric mean was above single sample criterion during the summer before 2008, yet decreased to just under single sample criterion after 2008. The allocated percent reduction in bacterial concentration (84%) has not been met since 2008. *E. coli* concentrations have decreased by 27%, on average.

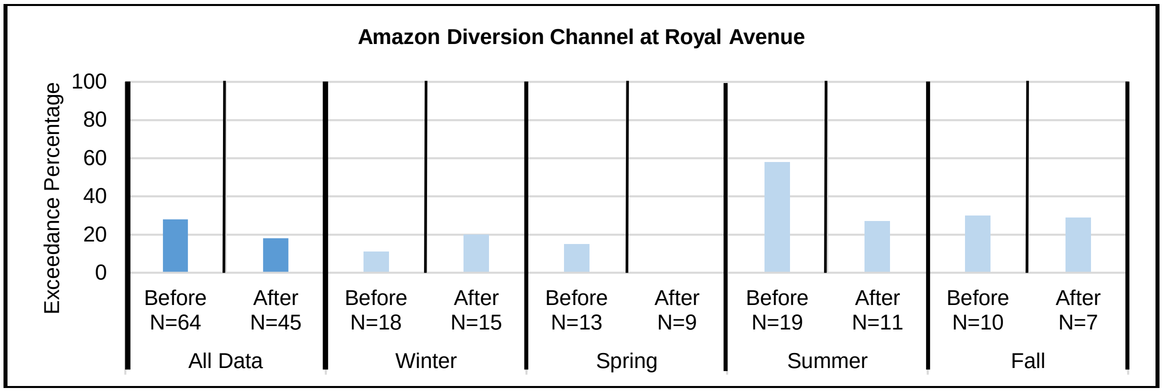
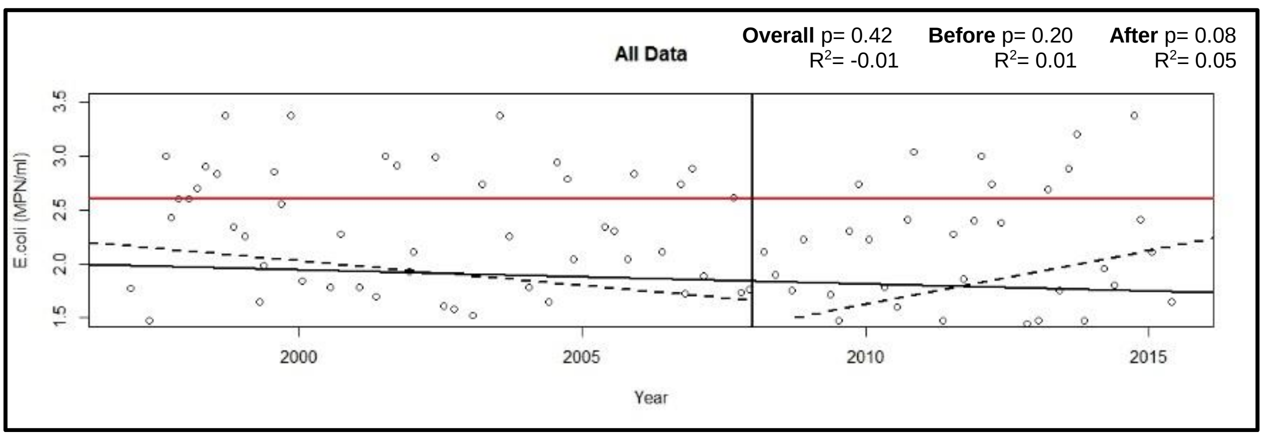


Figure 9: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Amazon Diversion Channel at Royal Avenue. The charts are split seasonally, as well as all data.

Single sample exceedance criterion on the Amazon Diversion Channel at Royal Avenue was found to be significantly seasonally dependent before 2008 only (Appendix B: Table 1 and 2). E. coli concentrations in the summers before and after 2008 were the only seasonal datasets found to be significantly different (Appendix C: Table 5). Linear regression analysis found the overall data set after 2008 to be the only data set to have a significant trend (decreasing) (Figure 10, Appendix D: Table 5). Summers were significantly different in trends before and after 2008. The slope before 2008 was decreasing and the slope after 2008 had an increasing trend. The high variability of samples along with minimal seasonal/yearly data collection caused uncertain forecasts of *E. coli* concentrations via ARIMA modeling. The model forecasted a mean below the single sample criterion, yet the upper 95% confidence interval was above the single sample criterion (Appendix E: Figure 4).



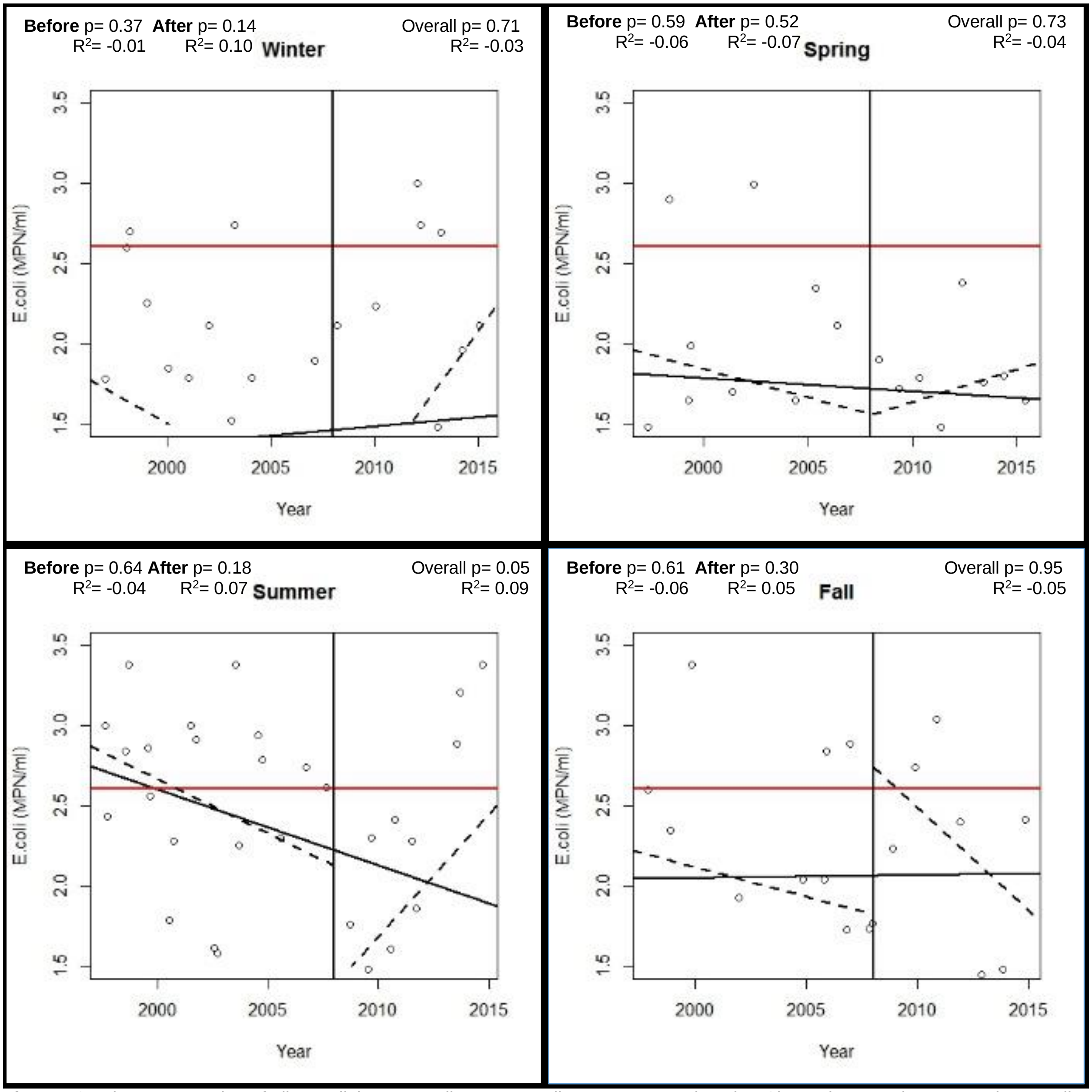


Figure 10: Linear regression of all *E. coli* data, as well as seasonally, on Amazon Diversion Channel at Royal Avenue. The E. coli dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

A-3 Drain at Terry Street

A-3 Drain at Terry Street exceeded State single sample criterion for *E. coli* year-round, both before and after 2008 (Figure 11, Appendix A: Figure 6, Table 6). The highest percentage of exceedances was during the summer both before (62%) and after (67%) 2008. Exceedance percentage decreased during the spring by 45% after 2008. The overall exceedance percentage decreased by 11%. The allocated percent reduction in bacterial concentration (33%) has been met since 2008. *E. coli* concentrations have decreased by 48%, on average. However, the exceedance percentage of the 40 samples was 28%.

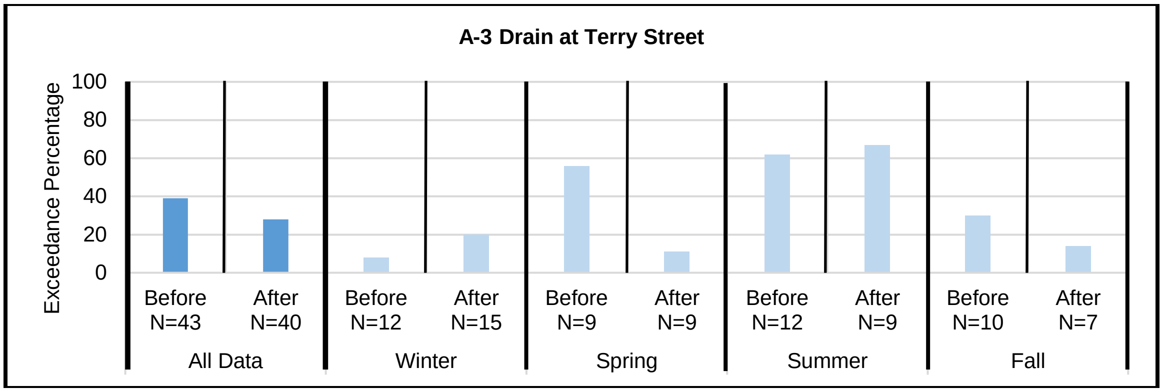
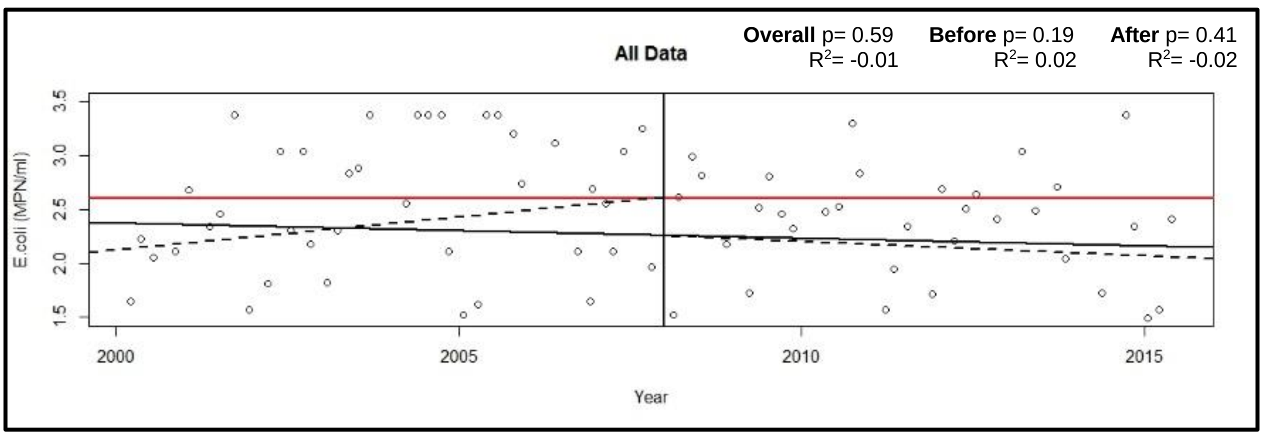


Figure 11: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on A-3 Drain at Terry Street. The charts are split seasonally, as well as all data.

Single sample exceedances in the A-3 Drain were significantly seasonally dependent (Appendix B: Table 1 and 2). There were no significant differences in the means before and after 2008 for any dataset (Appendix C: Table 6). There were no significant linear trends for any dataset (Figure 12, Appendix D: Table 6). There were no significant differences in the slopes before and after 2008 for any dataset. The high variability among samples along with minimal seasonal/yearly data collection caused uncertain forecasts of *E. coli* concentrations via ARIMA modeling. The model forecasted a mean concentration below single sample criterion. However, the forecasted, upper 95% confidence interval for mean concentration was above the single sample criterion (Appendix E: Figure 5).



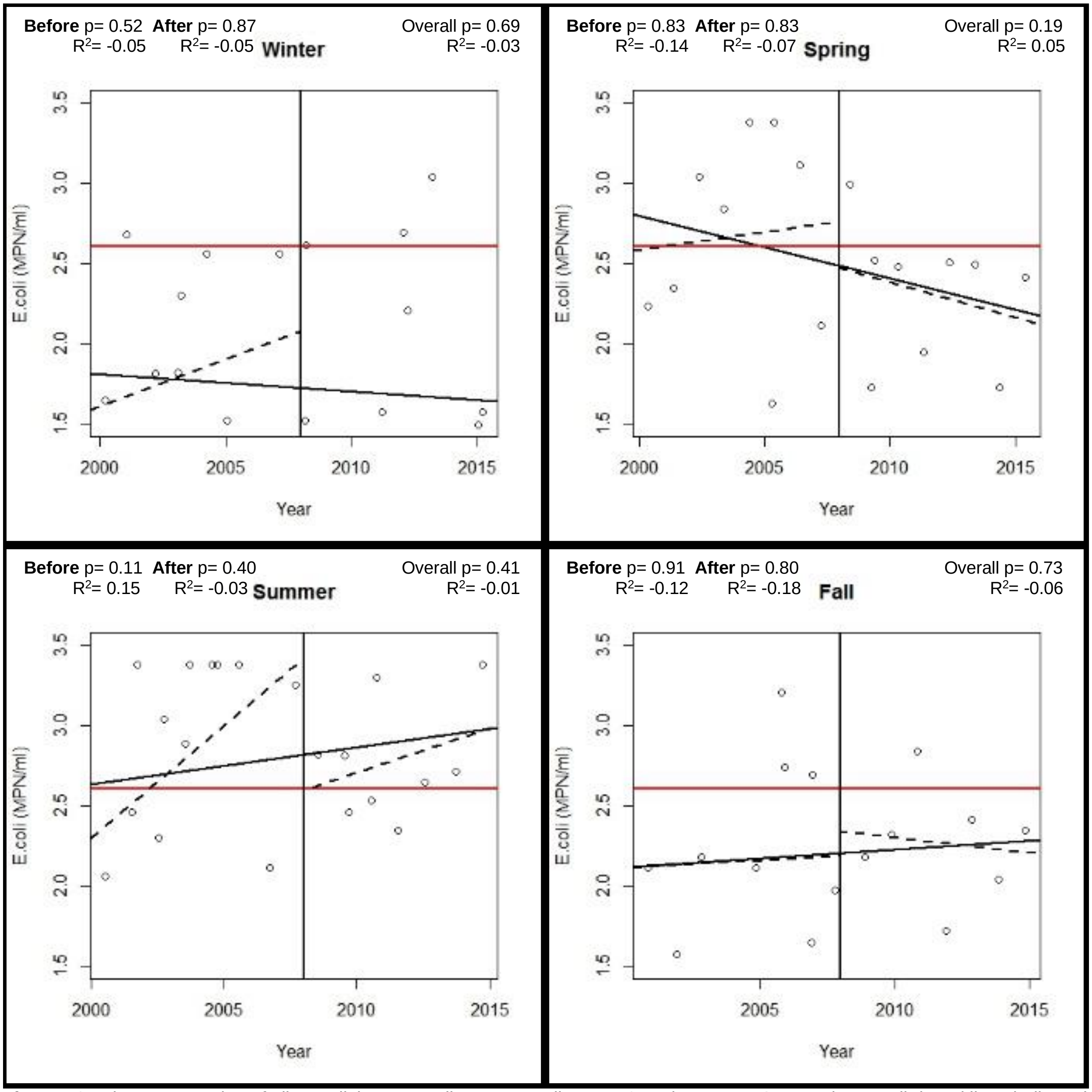


Figure 12: Linear regression of all *E. coli* data, as well as seasonally, on A-3 Drain at Terry Street. The E. coli dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

<u>Lower Amazon</u>

Amazon Creek at RM 5.82

Amazon Creek at RM 5.82 was not sampled before 2008, but it exceeded the single sample criterion for *E. coli* in summer 2015 (Figure 13, Appendix A: Figure 7, Table 7). The allocated percent reduction in bacterial concentration (58%) could not be assessed due to lack of data prior to 2008.

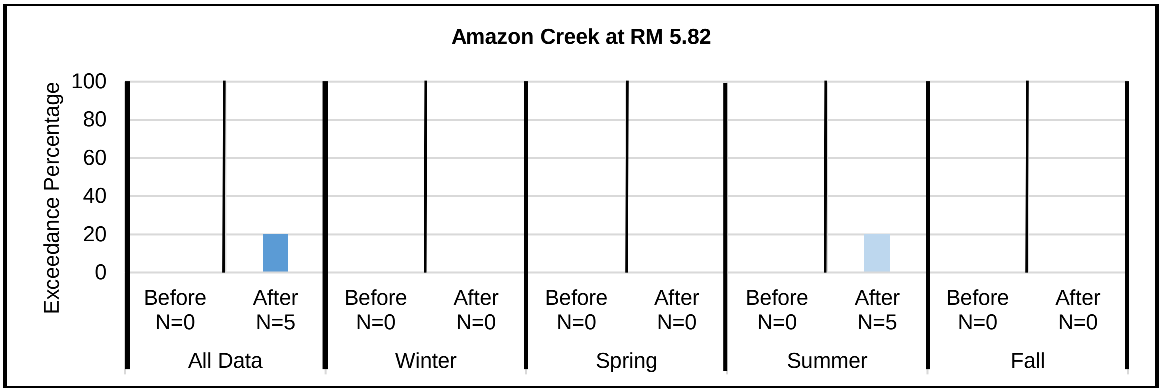


Figure 13: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Amazon Creek at RM 5.82. The charts are split seasonally, as well as all data.

Seasonal, mean, and trend differences before and after 2008 at RM 5.82 could not be tested due to the lack of data. However, linear regression analysis could be performed during the summer sampling of 2015, yet no significant trend was found (Figure 14, Appendix D: Table 7).

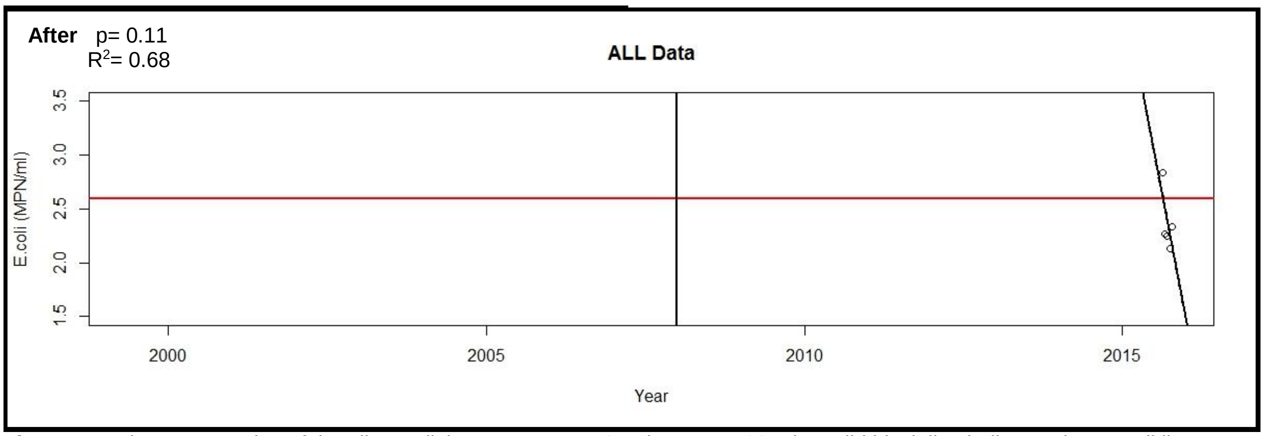


Figure 14: Linear regression of the all *E. coli* data on Amazon Creek at RM 5.82. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Amazon Creek at High Pass Road

Amazon Creek at High Pass Road exceeded the single sample criterion for *E. coli* year-round before and after 2008 (Figure 15, Appendix A: Figure 8, Table 8). The highest percentage of exceedances was during the winter after 2008 (60%). Exceedances increased during all seasons after 2008 except in the fall, when it decreased 16%. The overall exceedance percentage increased by 3%. The allocated percent reduction in bacterial concentration (58%) has not been met since 2008. *E. coli* concentrations have decreased by 10%, on average.

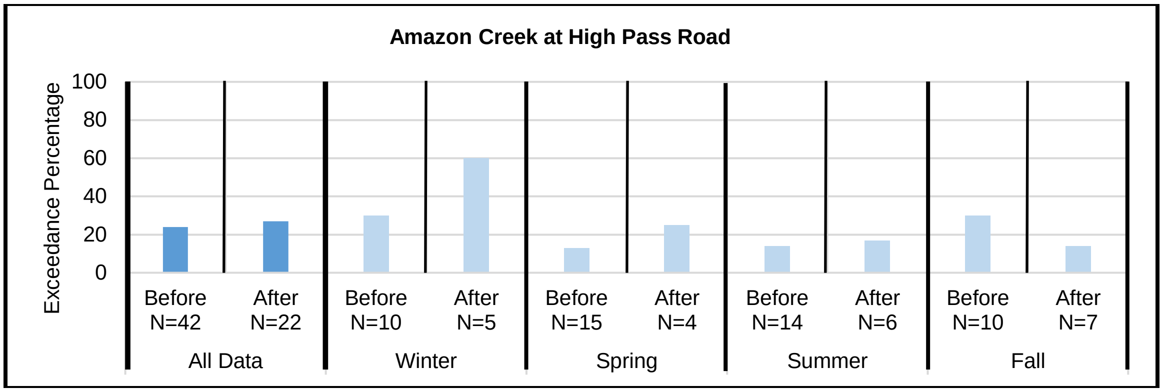
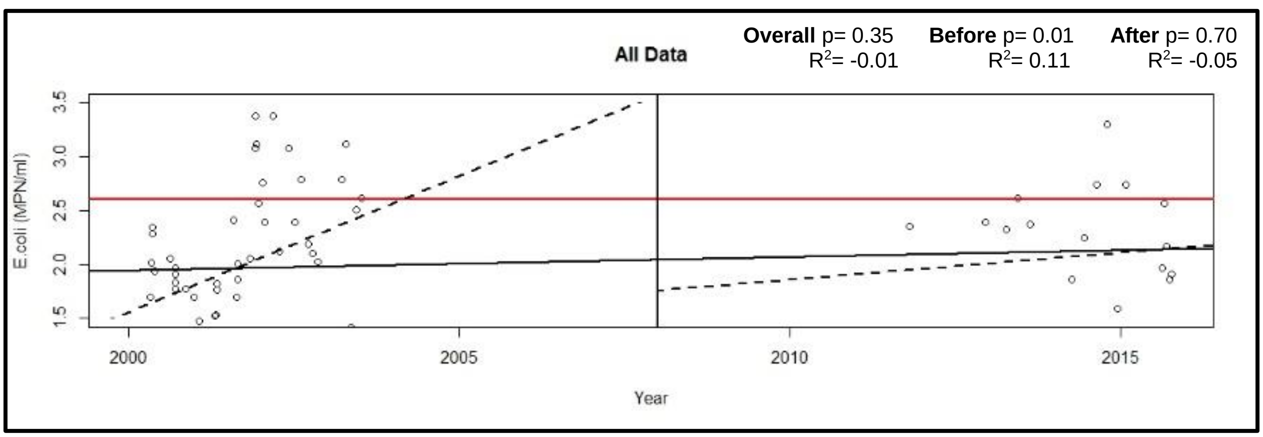


Figure 15: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Amazon Creek at High Pass Road. The charts are split seasonally, as well as all data.

Single sample exceedance criterion at High Pass Road was not found to be significantly seasonally dependent before or after 2008 (Appendix B: Table 1 and 2). There were no significant changes found for the means before and after 2008 for any data set (Appendix C: Table 8). Linear regression analysis found a significant increasing trend during the summer and fall before 2008; but no other dataset was found to be significant (Figure 16, Appendix D: Table 8). There were significant changes found in trend slopes during the summer and the overall data set, although the lack of data during the summer may have affected results. Data had not been collected at High Pass Road from the summer of 2003 through the summer of 2011. The eight year gap in data may have affected the results showing a change in slopes, before and after 2008. The lack of seasonal/yearly data does not allow ARIMA modeling.



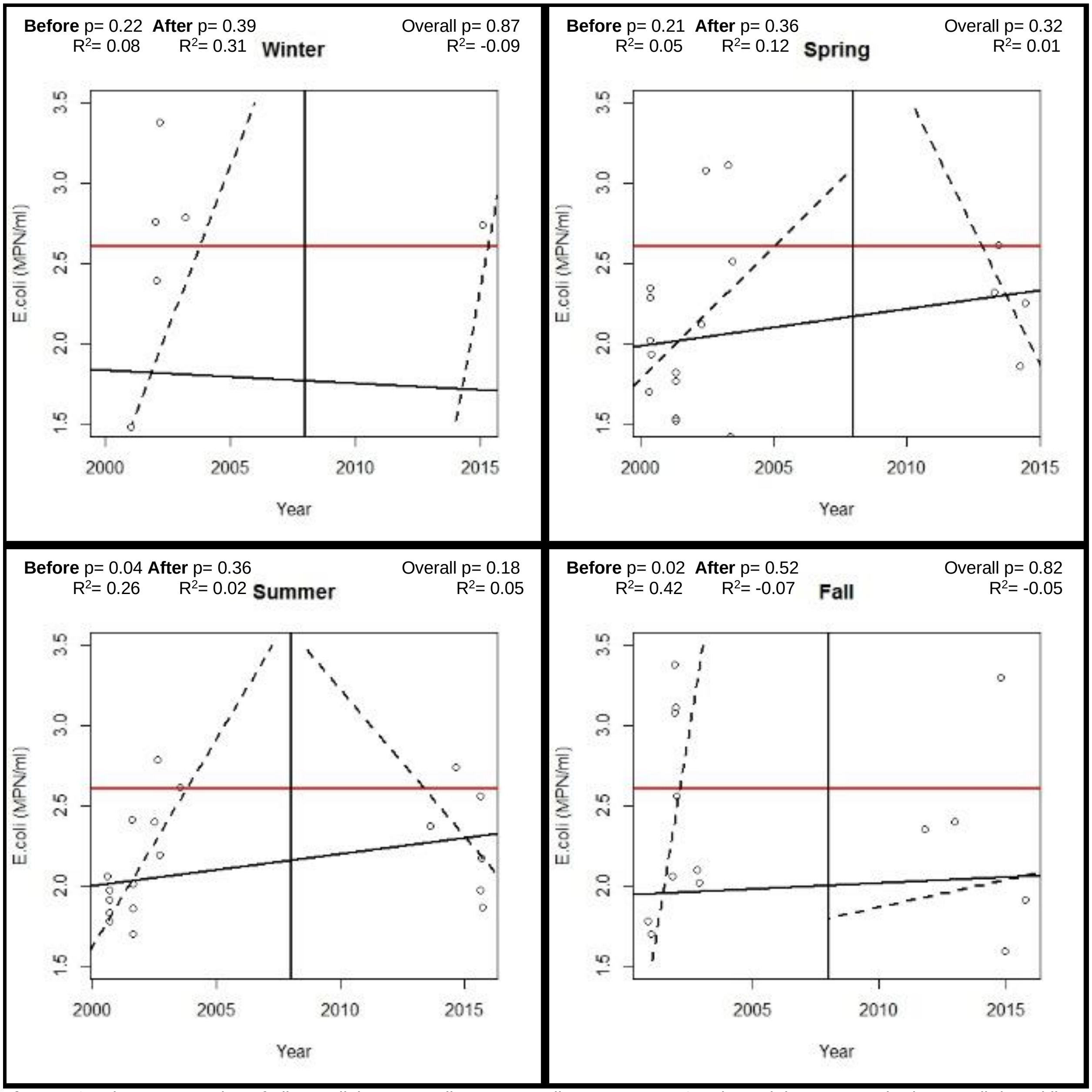


Figure 16: Linear regression of all *E. coli* data, as well as seasonally, on Amazon Creek at High Pass Road. The E. coli dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

<u>Coyote Creek</u>

Coyote Creek at Hamm Road

Coyote Creek at Hamm Road did exceed the single sample criterion for *E. coli* both before and after 2008 (Figure 17, Appendix A: Figure 9, Table 9). Coyote Creek at Hamm Road had not been sampled since the summer of 2001 until the summer of 2015. Single sample exceedance criterion at Hamm Road was not found to be significantly seasonally dependent before 2008, and could not be tested for seasonal dependence after 2008 (Appendix B: Table 1 and 2). The allocated percent reduction in bacterial concentration (66%) has not been met since 2008. *E. coli* concentrations have decreased by 25%, on average.

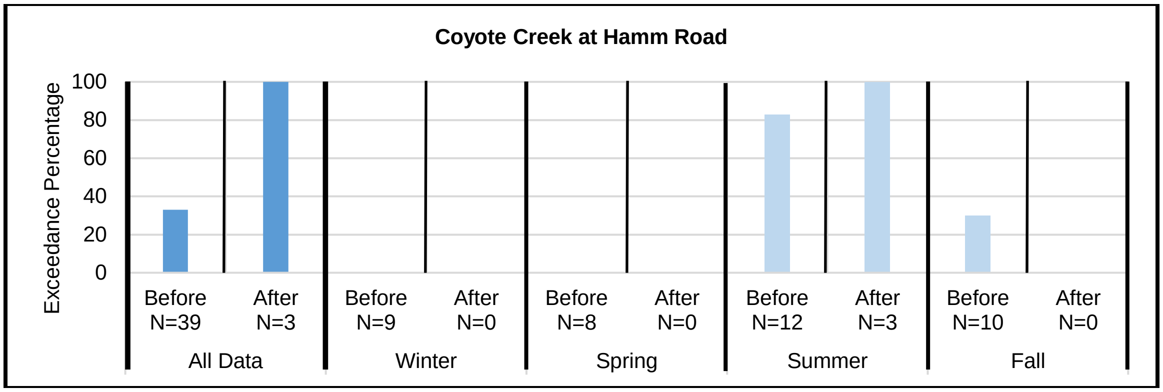
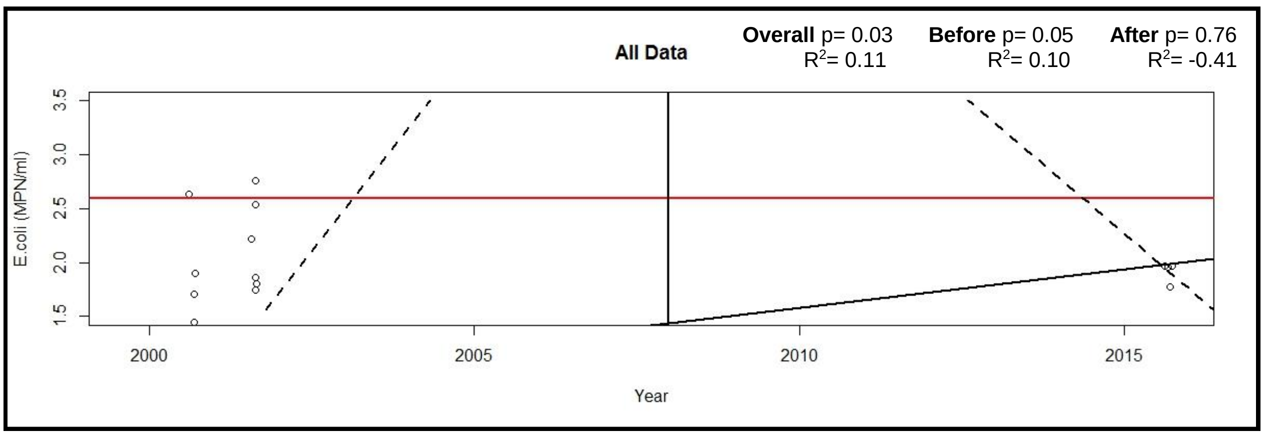


Figure 17: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Coyote Creek at Hamm Road. The charts are split seasonally, as well as all data.

Means at Hamm Road were not significantly different during the summer before and after 2008 (Appendix C: Table 9). No other season could be tested due to lack of sampling after 2008. Linear regression analysis found no significant trends and no change in trends during the summer (Figure 18, Appendix D: Table 9). No other season could be tested due to the absence of data after 2008. The lack of seasonal/yearly data did not allow ARIMA modeling.



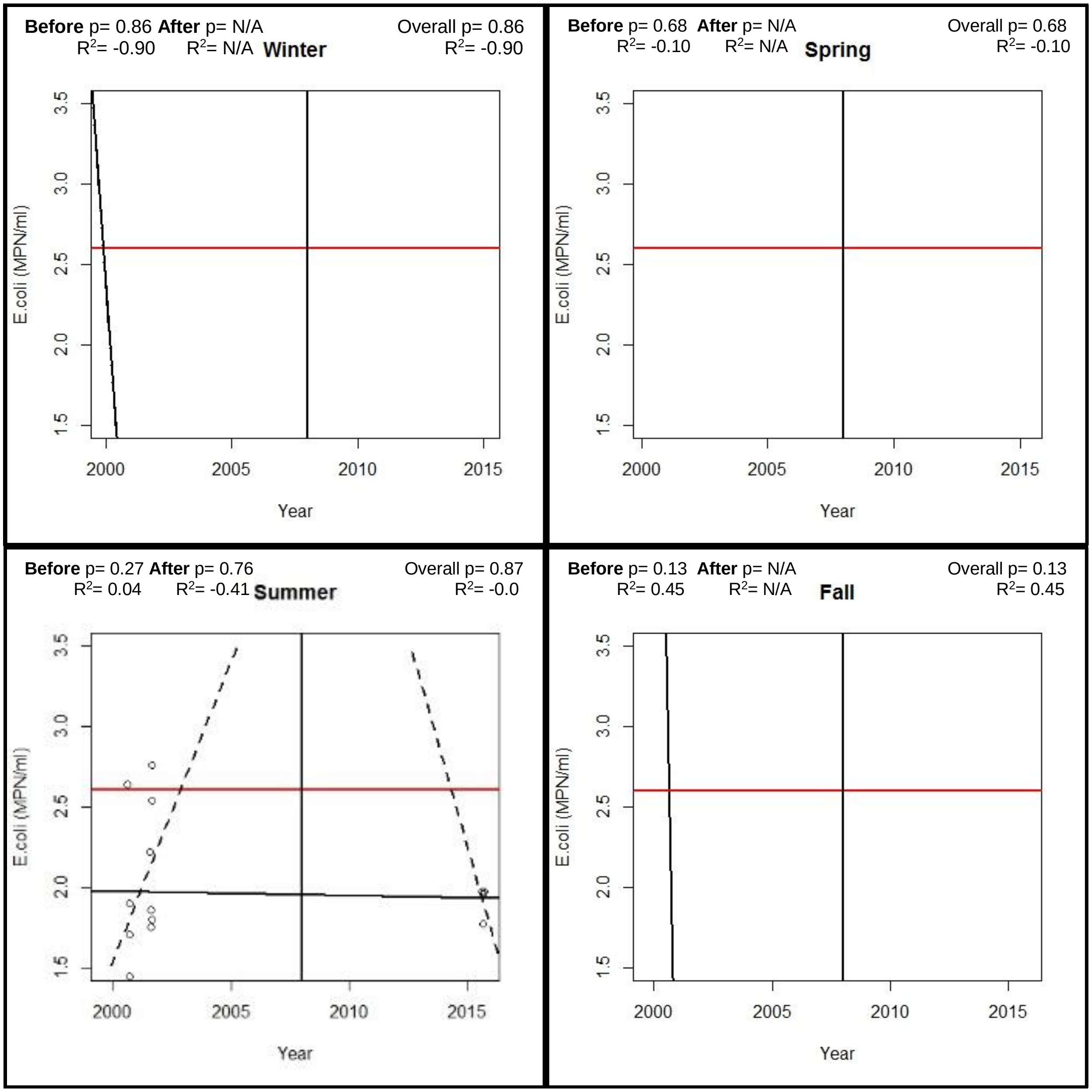


Figure 18: Linear regression of all *E. coli* data, as well as seasonally, on Coyote Creek at Hamm Road. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Coyote Creek at Powell Road

Coyote Creek at Powell Road exceeded single sample criterion for *E. coli* during the spring and fall before 2008; but did not exceed after 2008 (Figure 19, Appendix A: Figure 10, Table 10). After samples were collected in the summer of 2001, Coyote Creek at Powell Road had not been sampled until the summer of 2015. Single sample exceedance criterion at Powell Road was found to be significantly seasonally dependent before 2008, yet could not be tested for seasonal dependence after 2008 (Appendix B: Table 1 and 2). The allocated percent reduction in bacterial concentration (66%) has not been met since 2008. *E. coli* concentrations have decreased by 41%, on average.

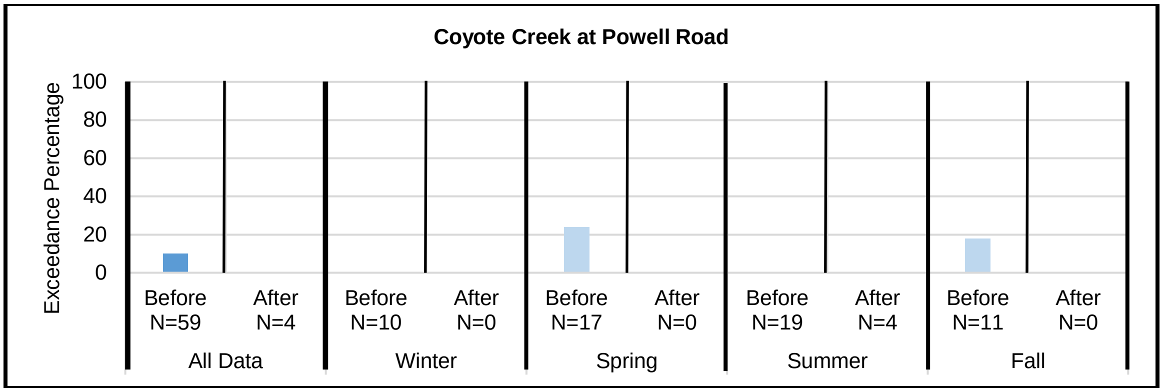
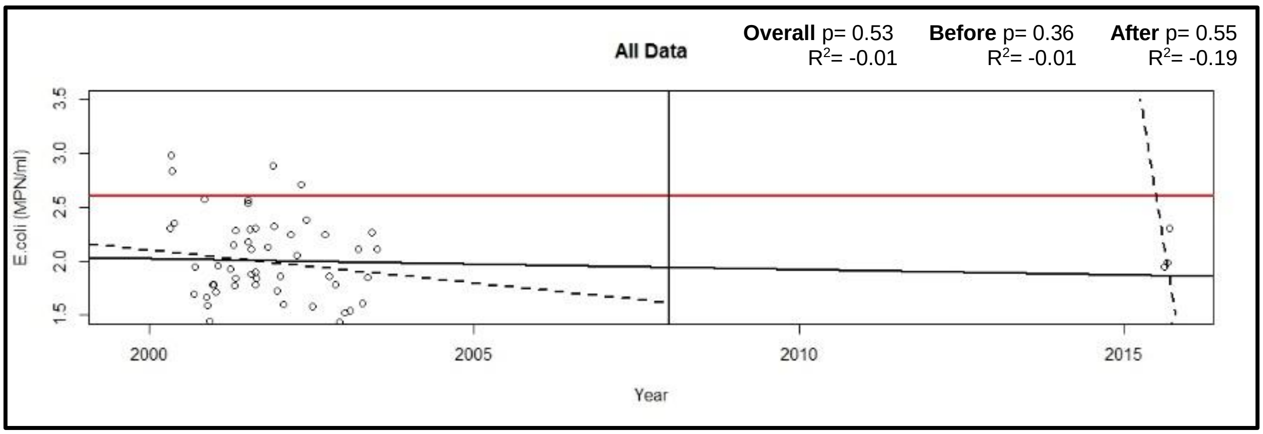


Figure 19: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Coyote Creek at Powell Road. The charts are split seasonally, as well as all data.

Means at Powell Road were not significantly different before and after 2008 during the summer (Appendix C: Table 10). No other season could be tested due to lack of sampling after 2008. The spring before 2008 was found to have a significantly decreasing trend, yet no other significant trends where found (Figure 20, Appendix D: Table 10). There were no significant changes in trends before and after 2008 the summer at Powell Road. No other season could be tested due to the absence of data after 2008. The lack of data did not allow ARIMA modeling.



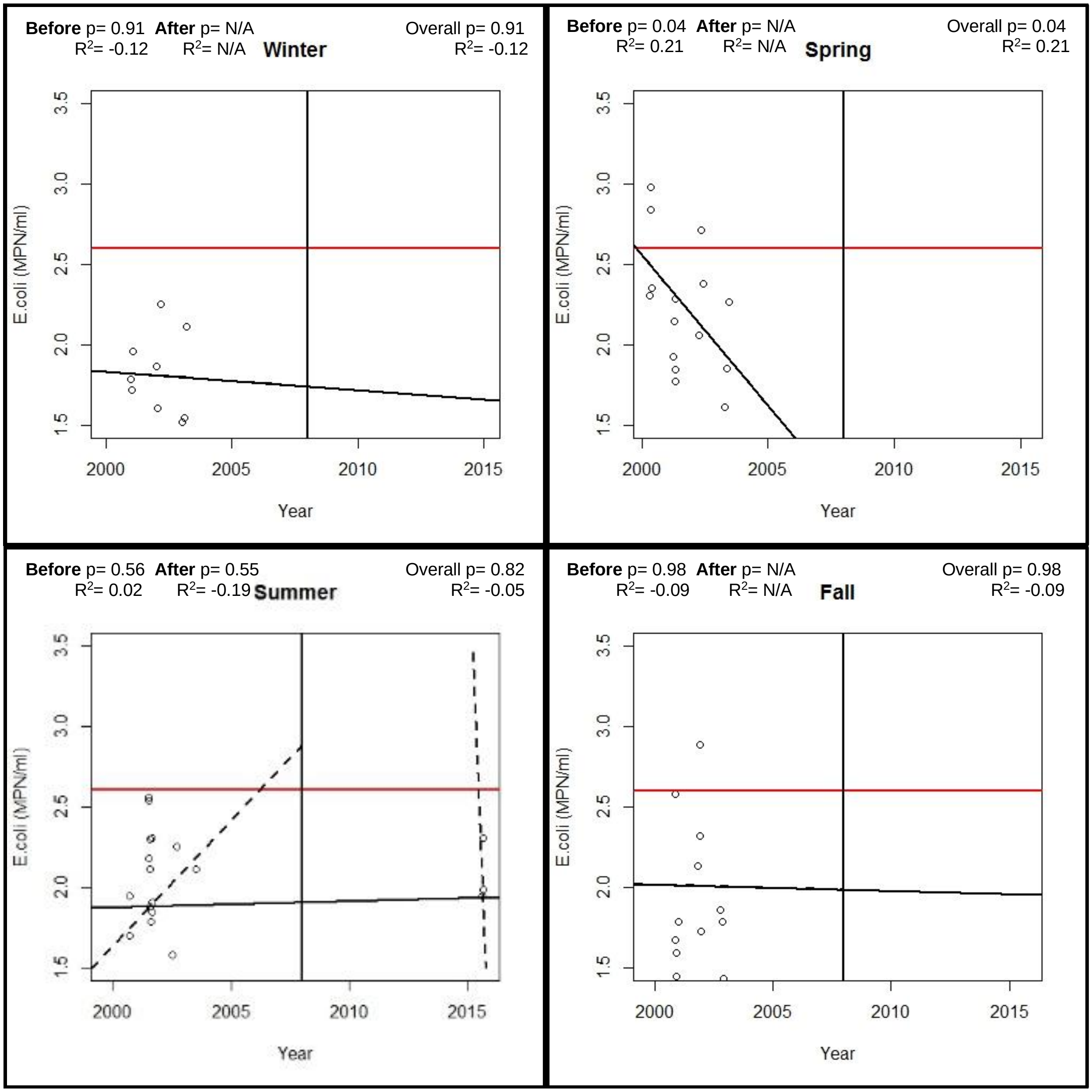


Figure 20: Linear regression of all *E. coli* data, as well as seasonally, on Coyote Creek at Powell Road. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level 406 *E. coli* organisms (MPN)/100 ml).

Coyote Creek at Petzold Road

Coyote Creek at Petzold Road exceeded single sample criterion for *E. coli* during the winter, spring, and fall before 2008, yet did not exceed after 2008 (Figure 21, Appendix A: Figure 11, Table 11). Coyote Creek at Petzold Road had not been sampled since the summer of 2001 until the summer of 2015. Single sample exceedance criterion at Petzold Road was not found to be significantly seasonally dependent before or after 2008 (Appendix B: Table 1 and 2). The allocated percent reduction in bacterial concentration (66%) has not been met since 2008. *E. coli* concentrations have decreased by 32%, on average.

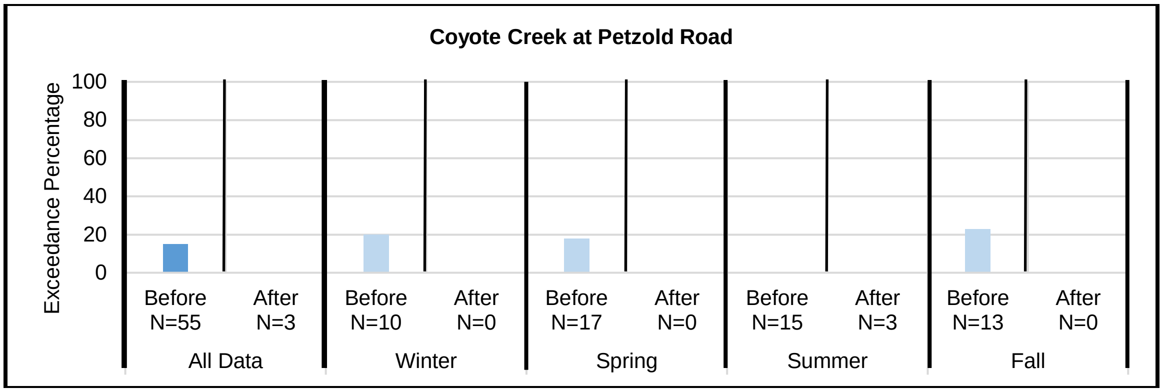
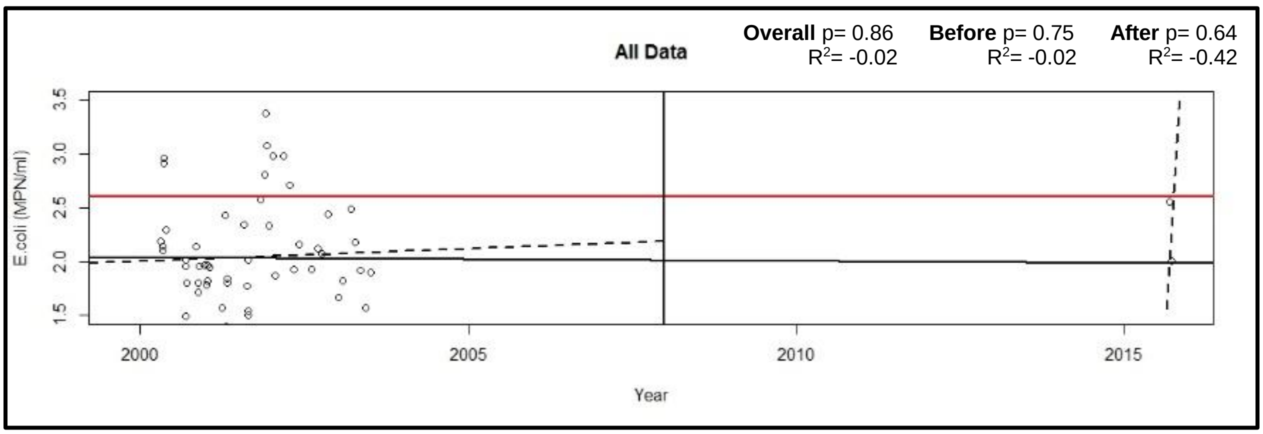


Figure 21: Bar charts of the percentage of single sample *E. coli* criterion exceedance before and after 2008 on Coyote Creek at Petzold Road. The charts are split seasonally, as well as all data.

Means at Petzold Road were not significantly different before and after 2008 during the summer (Appendix C: Table 11). No other season could be tested due to lack of sampling after 2008. Linear regression analysis found no significant trends or change in trends during the summer (Figure 22, Appendix D: Table 11). No other season could be tested due to the absence of data after 2008. The lack of seasonal/yearly data does not allow ARIMA modeling to forecast as well.



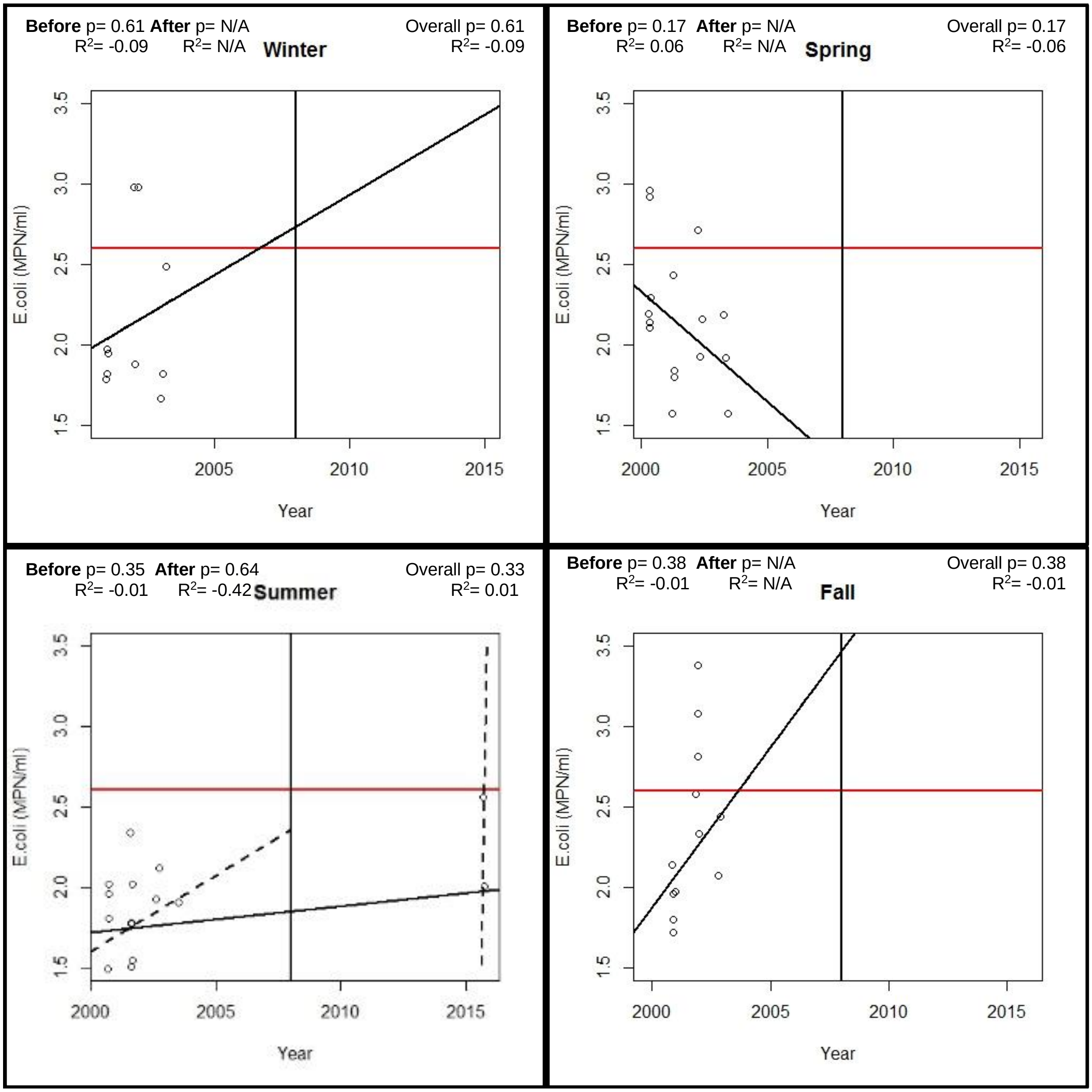


Figure 22: Linear regression of all *E. coli* data, as well as seasonally, on Coyote Creek at Petzold Road. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Dissolved Oxygen

Upper Amazon

Amazon Creek at 29th Avenue

Amazon Creek at 29th Avenue exceeded the single sample criterion for DO during the summer before and after 2008 (Figure 23, Appendix A: Figure 12, Table 12). Single sample exceedances at 29th Avenue were found to be significantly seasonally dependent before 2008 but not after 2008 (Appendix B: Table 3 and 4). During the summer before 2008, single sample criterion was exceeded 16% of the times sampled. Exceedances have decreased by 9% since 2008. The allocated percent reduction in nutrient concentration, BOD concentration, and SOD concentration (40%) has not been met since 2008; ammonia has decreased by 17%, nitrate/nitrite as N has increased by 9%, total phosphorus has decreased by 9%, TSS has increased by 15%, and BOD has increased by 97% (Appendix F: Tables 1, 3, 5, 6, and 7). The average temperature before and after 2008 has not changed (Appendix F: Table 2).

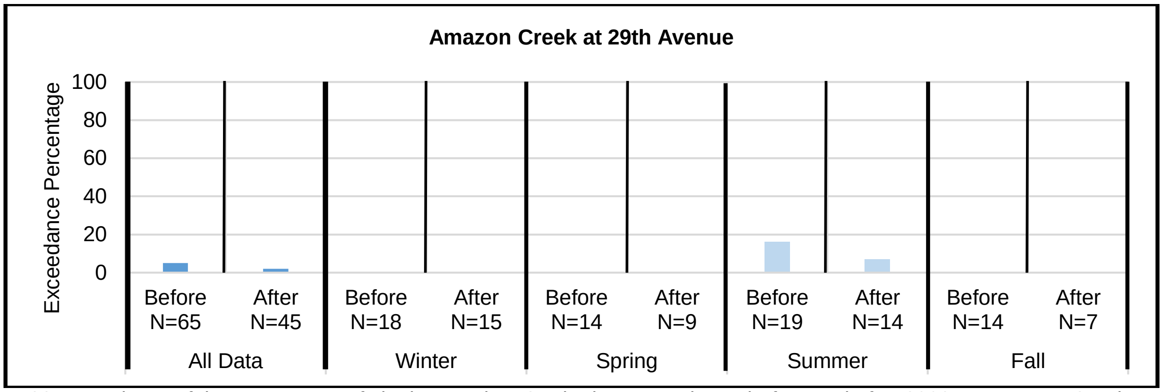
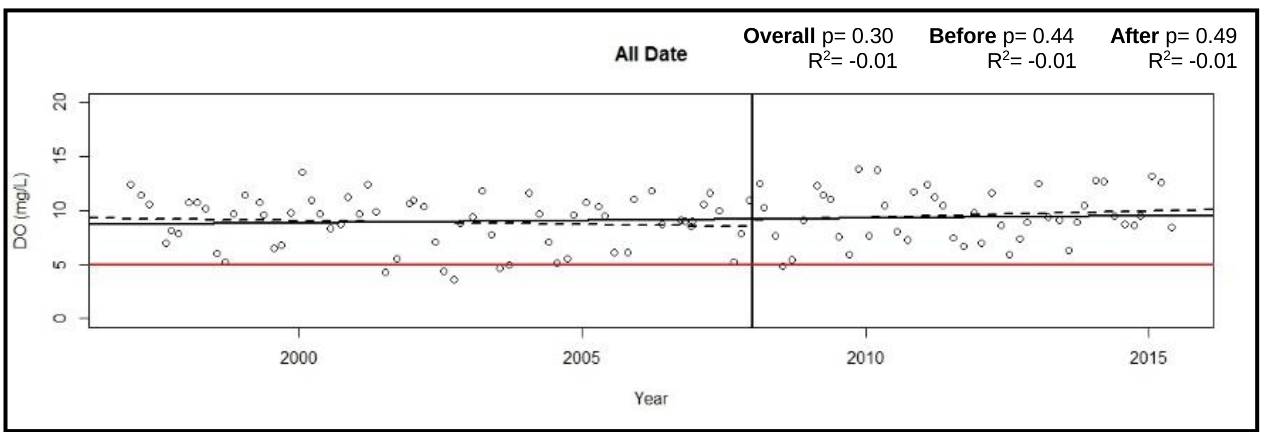


Figure 23: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Amazon Creek at 29th Avenue. The charts are split seasonally, as well as all data.

29th Avenue was found to have significant change in means during the summer (Appendix C: Table 12). Linear regression analysis found a significantly increasing trend during the summer after 2008 (Figure 24, Appendix D: Table 12). The summers before and after 2008 also had significantly different slopes. The high variability among samples along with minimal seasonal/yearly data collection made forecasting DO concentration with auto ARIMA modeling unreliable. The model forecasted a slightly decreasing mean, yet the lower 95% confidence interval does not extend below the single sample criterion (Appendix E:Figure 6).



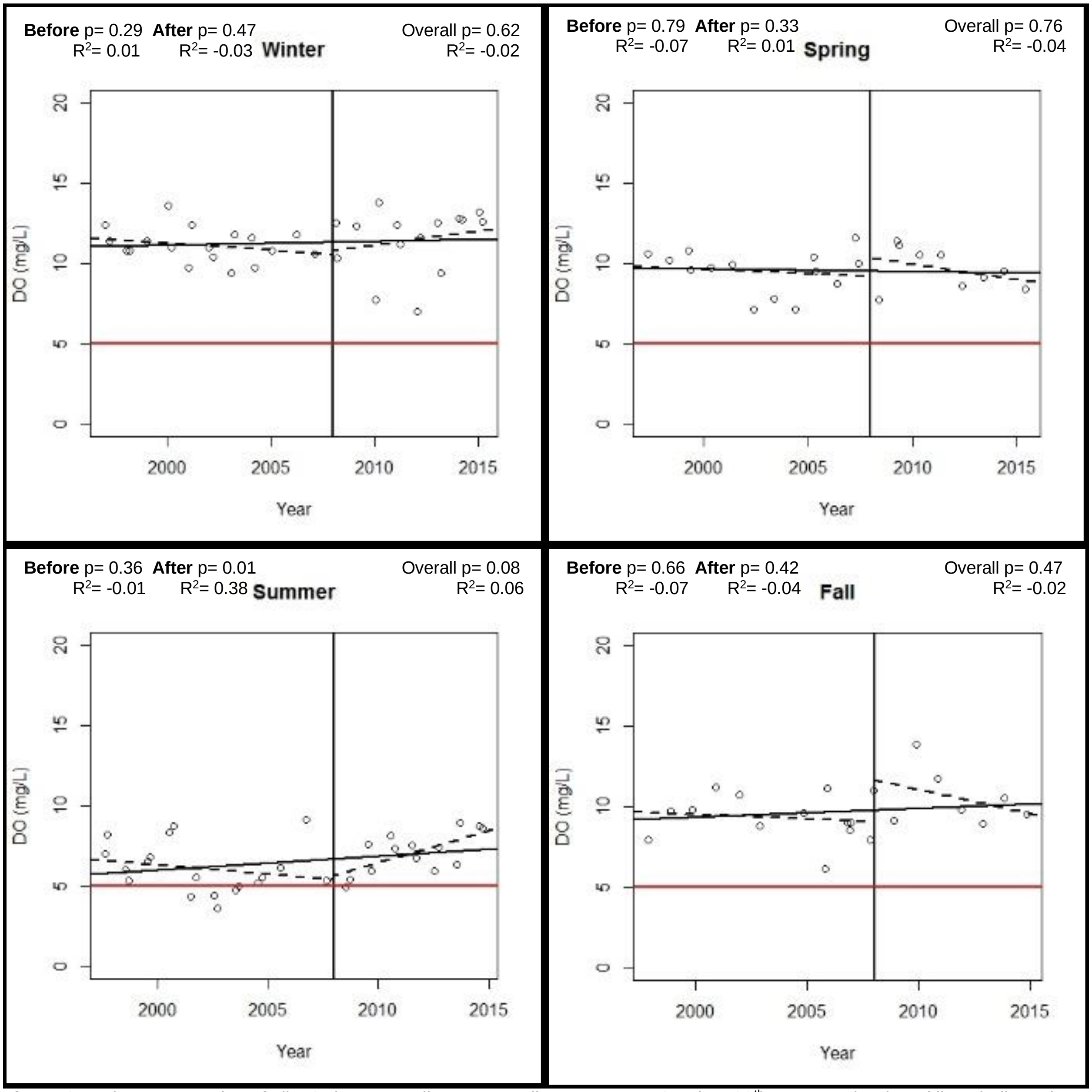


Figure 24: Linear regression of all DO data, as well as seasonally, on Amazon Creek at 29th Avenue. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

Amazon Creek at Railroad Crossing

Amazon Creek at Railroad Crossing exceeded single sample criterion for DO during the spring, summer, and fall before 2008 and winter, spring, and summer after 2008 (Figure 25, Appendix A: Figure 13, Table 13). Overall exceedances have decreased by 4%. Single sample exceedances at Railroad Crossing was found to be significantly seasonally dependent before 2008 but not after 2008 (Appendix B: Table 3 and 4). The allocated percent reduction in nutrient concentration, BOD concentration, and SOD concentration (40%) has not been met since 2008; ammonia has increased by 40%, nitrate/nitrite as N has increased by 20%, total phosphorus has increased by 9%, TSS has increased by 4%, and BOD has increased by 19% (Appendix F:

Tables 9, 11, 13, 14, and 15). The average temperature before and after 2008 has decreased by 7% changed (Appendix F: Table 10).

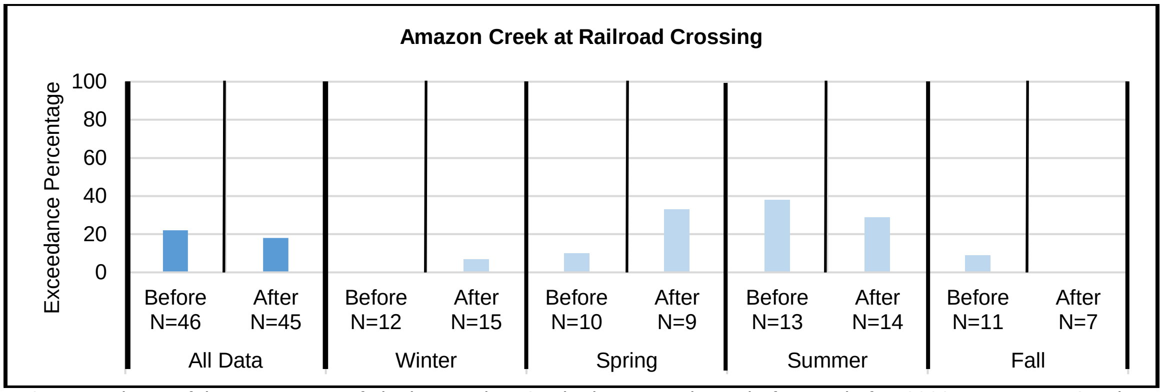
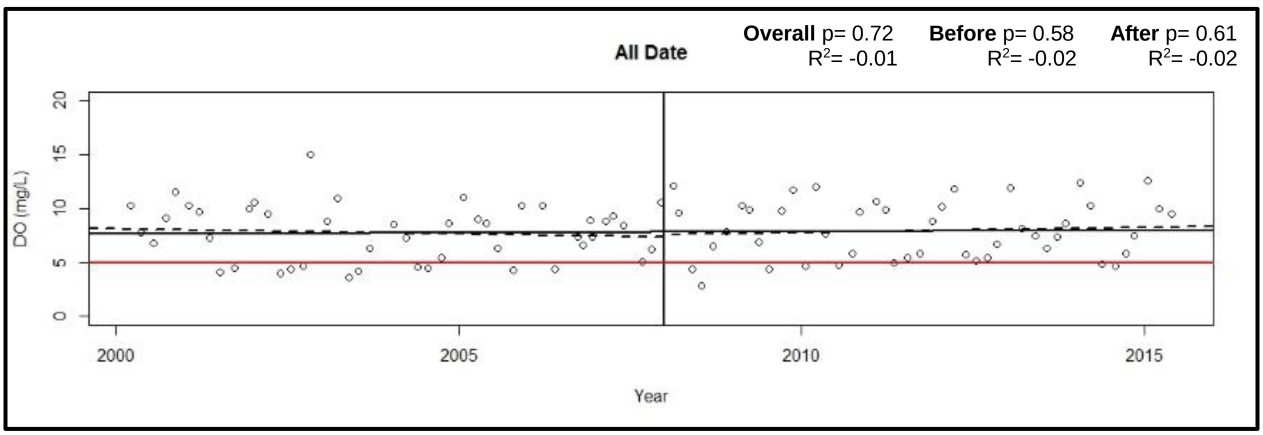


Figure 25: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Amazon Creek at Railroad Crossing. The charts are split seasonally, as well as all data.

Railroad Crossing did not have significant differences in means for any data set (Appendix C: Table 13). Linear regression analysis found a significantly decreasing trend during the fall before 2008, yet no other data set was found to be significant (Figure 26, Appendix D: Table 13). There were no significant changes found in any of the slopes before and after 2008. The high variability among samples along with minimal seasonal/yearly data collection caused uncertainty in DO forecasting via ARIMA modeling. The model forecasted a slightly increasing mean, yet the lower 95% confidence interval does extend below the single sample criterion year-round (Appendix E: Figure 7).



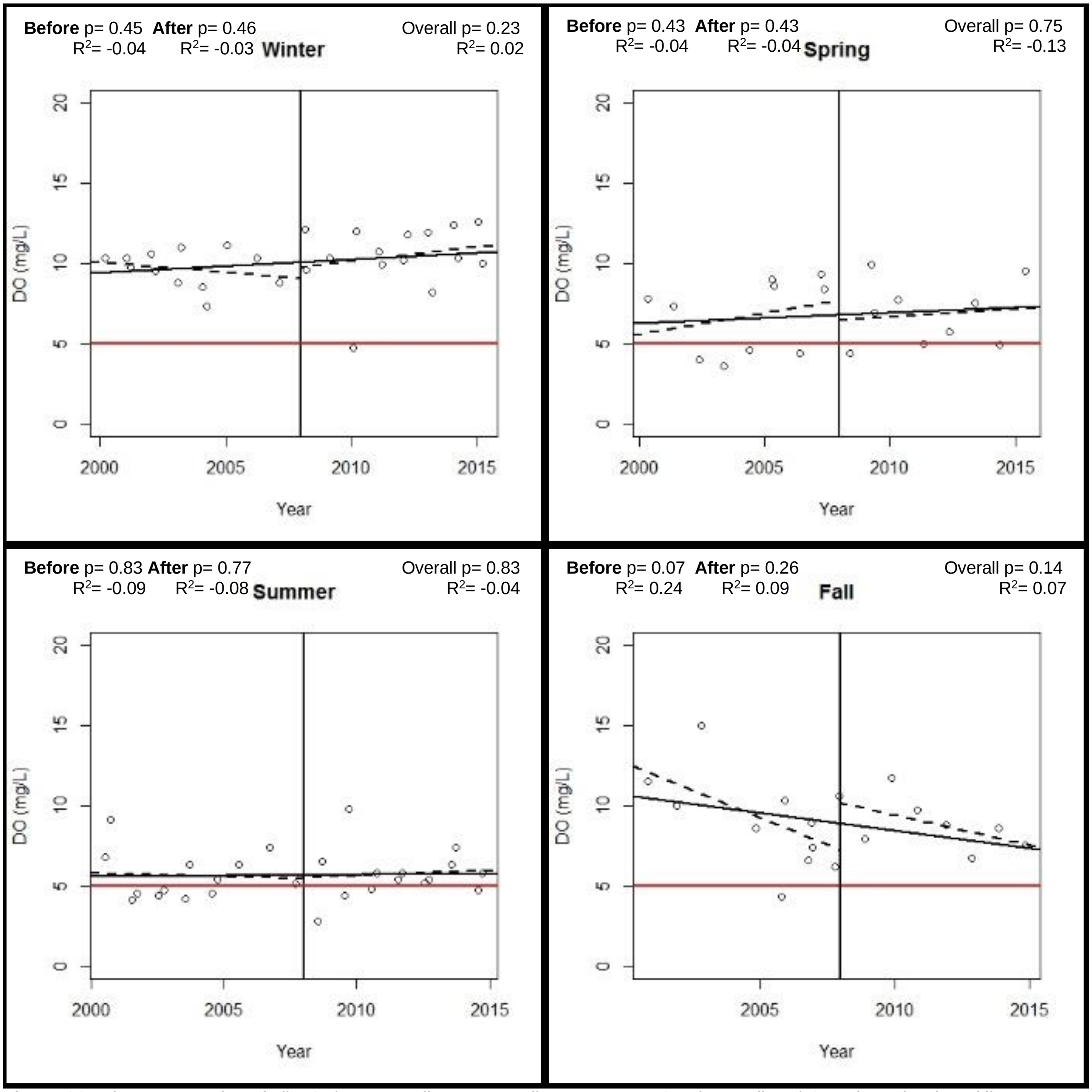


Figure 26: Linear regression of all DO data, as well as seasonally, on Amazon Creek at Railroad Crossing. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

Amazon Creek at Royal Avenue

Amazon Creek at Royal Avenue exceeded the single sample criterion for DO during the spring and summer before and after 2008 (Figure 27, Appendix A: Figure 14, Table 14). The percentage of exceedances during the spring and summer has increased by 8% and 10% respectively. DO data during the both the winter and fall, both before and after 2008, did not exceeded the single sample criterion. Single sample exceedances at Royal Avenue were found to be significantly seasonally dependent both before and after 2008 (Appendix B: Table 3 and 4). The allocated percent reduction in nutrient concentration, BOD concentration, and SOD concentration (40%) has not been met since 2008; ammonia has decreased by 75%, nitrate/nitrite as N has decreased by 27%, total phosphorus has decreased by 17%, TSS has decreased by 21%, and BOD has decreased by 11% (Appendix F: Tables 16, 18, 20, 21, and 22). The average temperature before and after 2008 has decreased by 15% changed (Appendix F: Table 17).

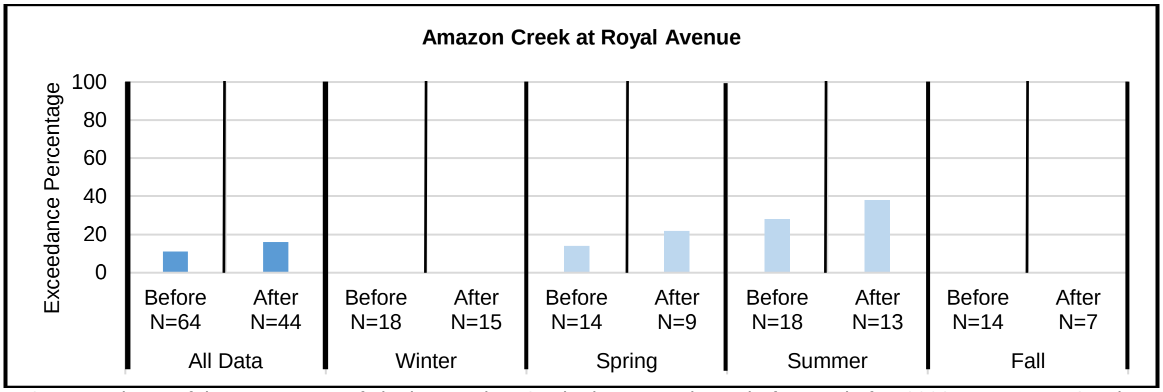
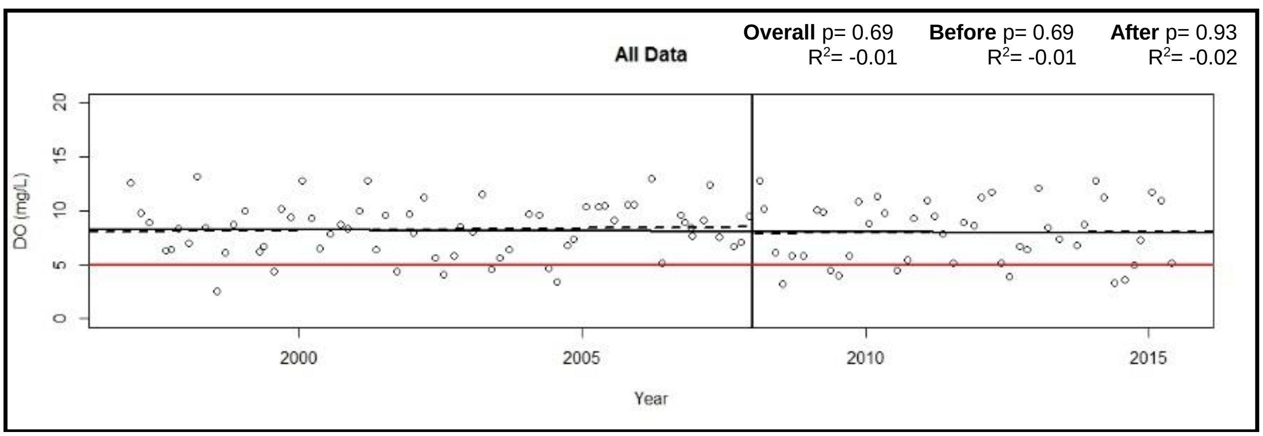


Figure 27: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Amazon Creek at Royal Avenue. The charts are split seasonally, as well as all data.

Royal Avenue was found to have a significant change in means during the summer (Appendix C: Table 14). Linear regression analysis did not find any significant trends within any data set (Figure 28, Appendix D: Table 14). There were no significant changes found in the slopes of any data set before and after 2008. The high variability of each sample collection, paired with minimal seasonal/yearly data collection caused unreliability to forecast DO concentration through auto ARIMA modeling. The model forecasted a little to no change in the overall mean, yet the lower 95% confidence interval does extend below the State single sample criterion year-round (Appendix E: Figure 8).



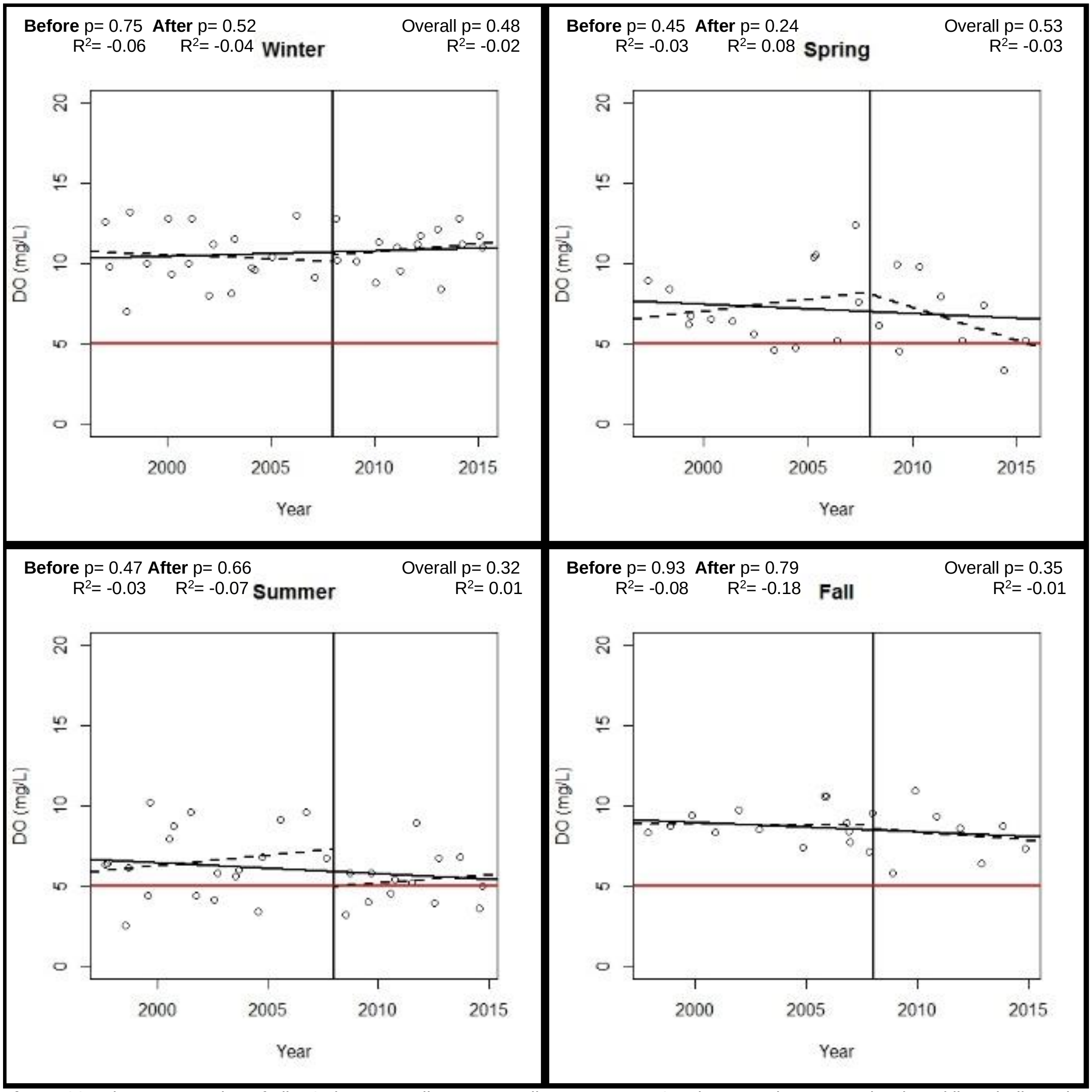


Figure 28: Linear regression of all DO data, as well as seasonally, on Amazon Creek at Royal Avenue. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

Willow Creek at 18th Avenue

Willow Creek at 18th Avenue exceeded single sample criterion for DO during the winter after 2008 and the summer before 2008 (Figure 29, Appendix A: Figure 15, Table 15). Single sample criterion was only exceeded once before and once after 2008. Single sample exceedances at Willow Creek were not significantly seasonally different before 2008 or after 2008 (Appendix B: Table 3 and 4). The allocated percent reduction in nutrient concentration, BOD concentration, and SOD concentration (40%) has not been met since 2008; ammonia has increased by 67%, nitrate/nitrite as N has decreased by 38%, total phosphorus has not changed, TSS has decreased by 31%, and BOD has decreased by 27% (Appendix F: Tables 24, 26, 28, 29, and

30). The average temperature before and after 2008 has decreased by 15% changed (Appendix F: Table 25).

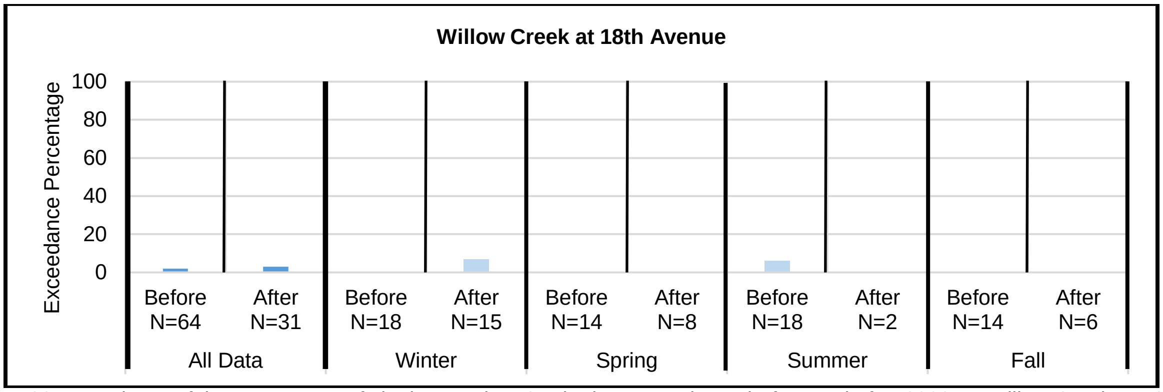
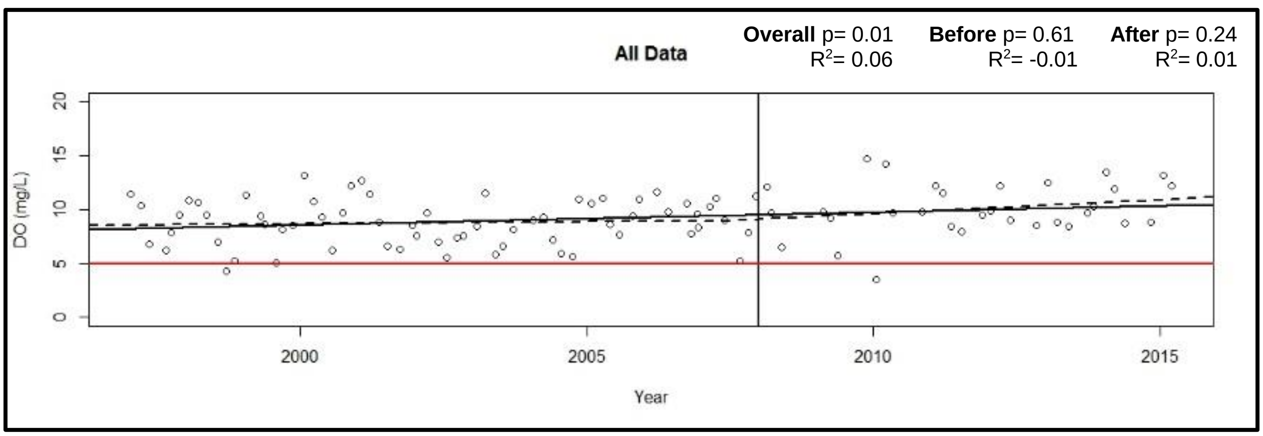


Figure 29: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Willow Creek at 18th Avenue. The charts are split seasonally, as well as all data.

Willow Creek had a significant difference in means during the winter as well as the overall data concentration levels (Appendix C: Table 15). Overall trend for all seasons, as well as the overall data set, was increasing, implying improving DO concentration levels after 2008. Linear regression analysis found that the winter before 2008 had a significantly decreasing trend (Figure 30, Appendix D: Table 15). There was a significant difference in the trends during the winter. The lack of data during the summer after 2008 did not allow linear regression analysis or testing for changes in means or slopes. Also, the lack of seasonal/yearly data did not allow ARIMA modeling.



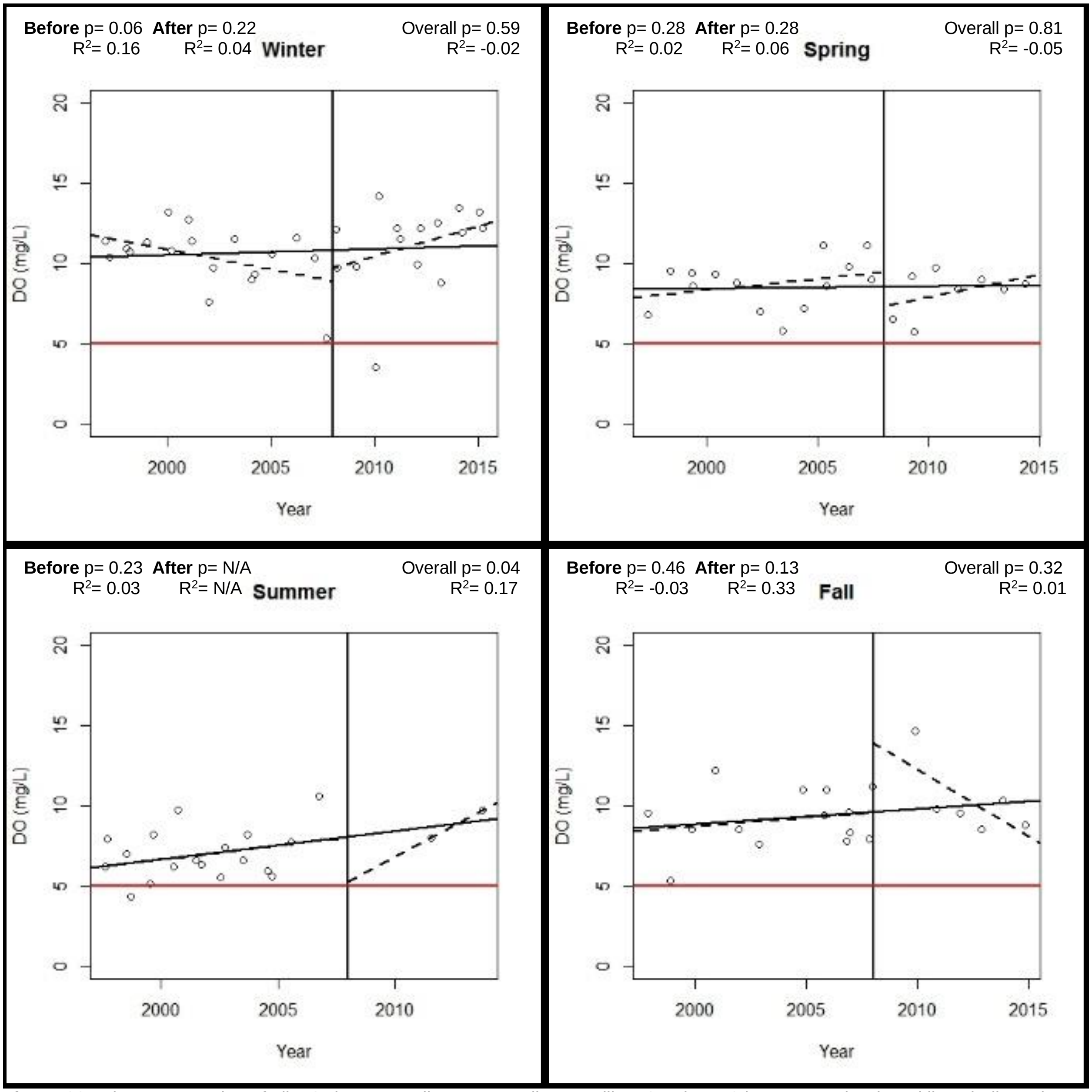


Figure 30: Linear regression of all DO data, as well as seasonally, on Willow Creek at 18th Avenue. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

Amazon Diversion Channel at Royal Avenue

Amazon Diversion Channel at Royal Avenue exceeded the single sample criterion for DO during the summer before 2008 and during spring, summer, and fall after 2008 (Figure 31, Appendix A: Figure 16, Table 16). Single sample exceedances increased by 22% during the spring and decreased by 25% during the summer after 2008. Single sample exceedances in the Amazon Diversion Channel at Royal Avenue were significantly seasonally different before 2008 but not after 2008 (Appendix B: Table 3 and 4). The allocated percent reductions in nutrient concentration, BOD concentration, and SOD concentration (40%) has not been met since 2008; ammonia did not change, nitrate/nitrite as N has decreased by 13%, total phosphorus has decreased by 11%, TSS has increased by 14%, and BOD has decreased by 20% (Appendix F:

32, 34, 36, 37, and 38). The average temperature before and after 2008 has decreased by 11% changed (Appendix F: Table 33).

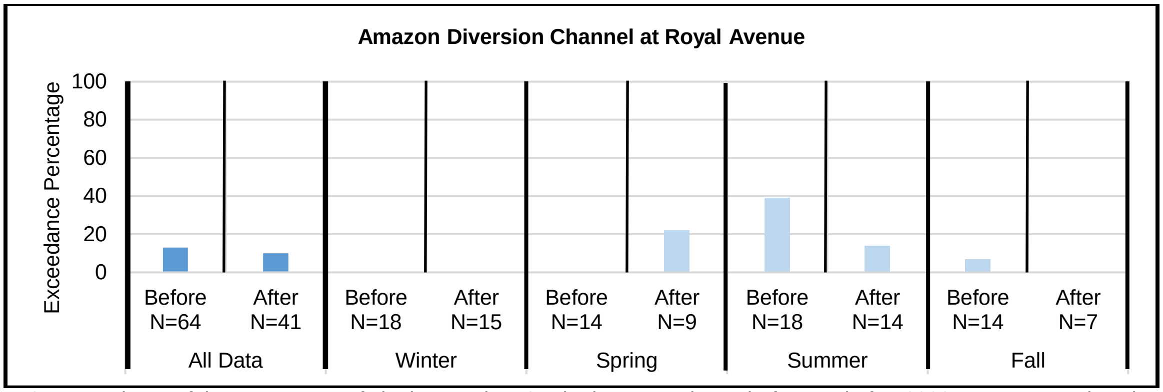
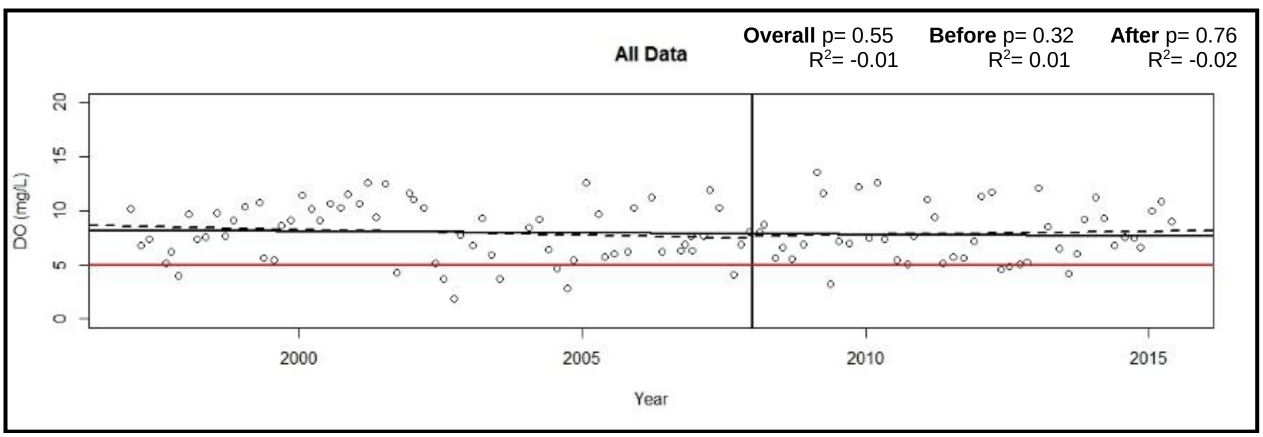


Figure 31: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Amazon Diversion Channel at Royal Avenue. The charts are split seasonally, as well as all data.

Amazon Diversion Channel did not have a significant difference in means before and after 2008 (Appendix C: Table 16). Linear regression analysis found the summer before 2008 to be the only data set with a significant trend (Figure 32, Appendix D: Table 16). There were no significant differences in the trends of any dataset. The high variability among samples along with minimal seasonal/yearly data collection caused uncertain forecasting of DO concentrations via ARIMA modeling. The model forecasted no change in the mean, yet the lower 95% confidence interval did extend below the State single sample criterion year-round (Appendix E: Figure 9).



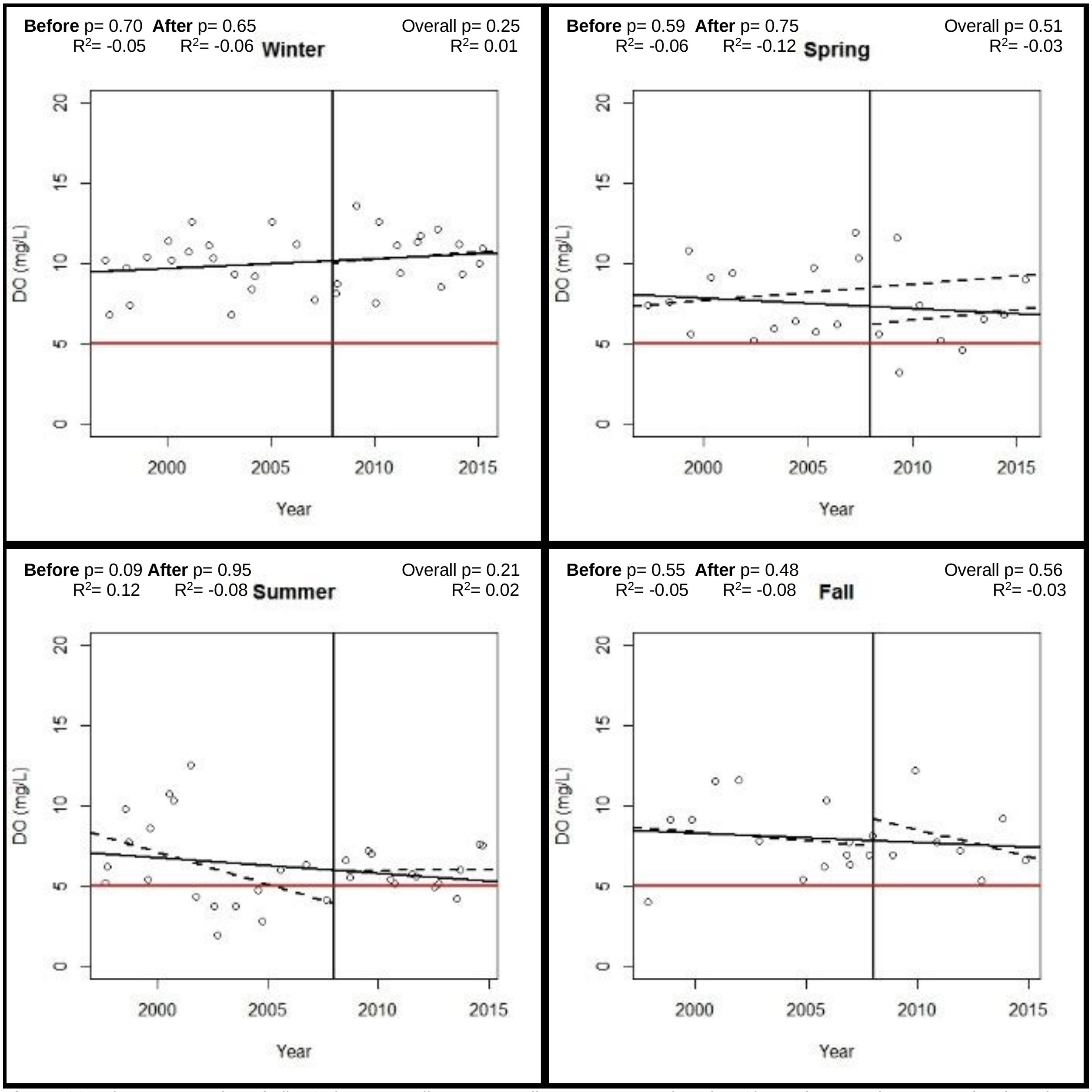


Figure 32: Linear regression of all DO data, as well as seasonally, on Amazon Diversion Channel at Royal Avenue. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

A-3 Drain at Terry Street

A-3 Drain at Terry Street exceeded the single sample criterion for DO during the summer and fall before and after 2008 (Figure 33, Appendix A: Figure 17, Table 17). Samples collected during the spring and winter did not exceed State single sample criterion. The percentage of exceedances during the summer increased 31% during the summer and 19% during the fall. Single sample exceedances on A-3 Drain at Terry Street were significantly seasonally different after 2008 but not before 2008 (Appendix B: Table 3 and 4). The allocated percent reduction in nutrient concentration, BOD concentration, and SOD concentration (40%) has not been met since 2008; ammonia has decreased by 24%, nitrate/nitrite as N has decreased by 16%, total phosphorus has decreased by 32%, TSS has decreased by 47%, and BOD has decreased by

35% (Appendix F: tables 40, 42, 44, 45, and 46). The average temperature before and after 2008 has decreased by 23% changed (Appendix F: Table 41).

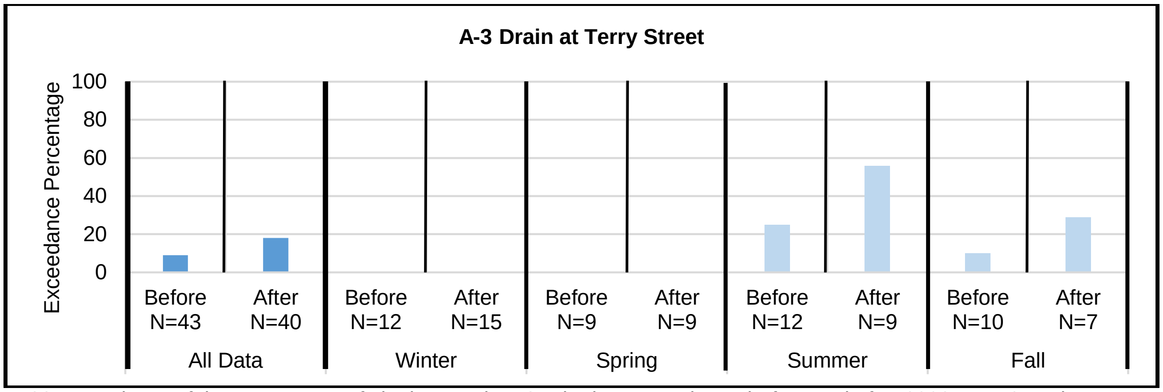
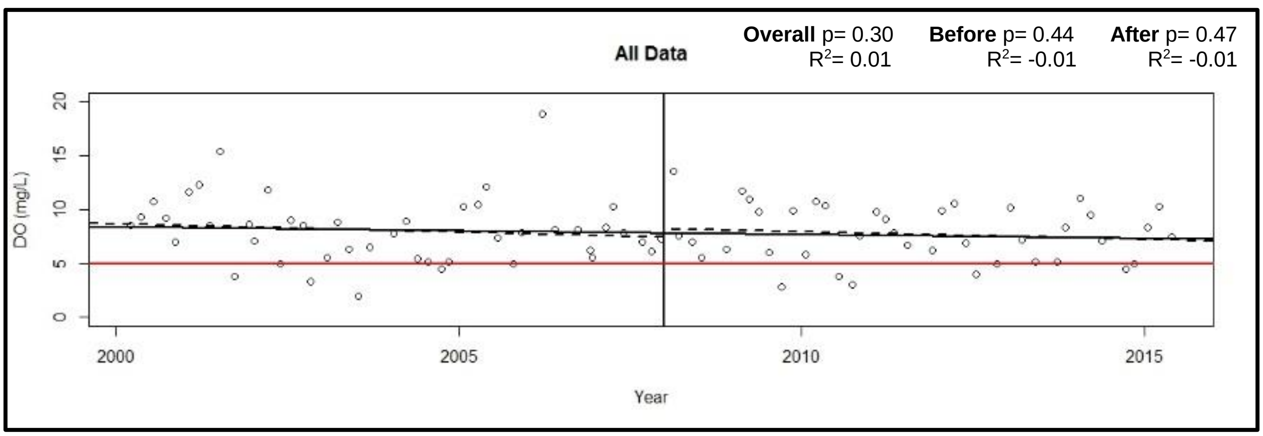


Figure 33: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on A-3 Drain at Terry Street. The charts are split seasonally, as well as all data.

A-3 Drain was found to have a significant change in the means during the summer before and after 2008 (Appendix C: Table 17). Linear regression analysis found no data sets to have a significant trend (Figure 34, Appendix D: Table 17). There were no significant changes found in the trends of any data set. The high variability among samples along with minimal seasonal/yearly data collection caused forecasting DO concentration through auto ARIMA modeling to be unreliable. The model forecasted no change in the mean; however, the mean is forecasted to be above the single sample criterion. The lower 95% confidence interval is forecasted to exceed the single sample criterion year round (Appendix E: Figure 10).



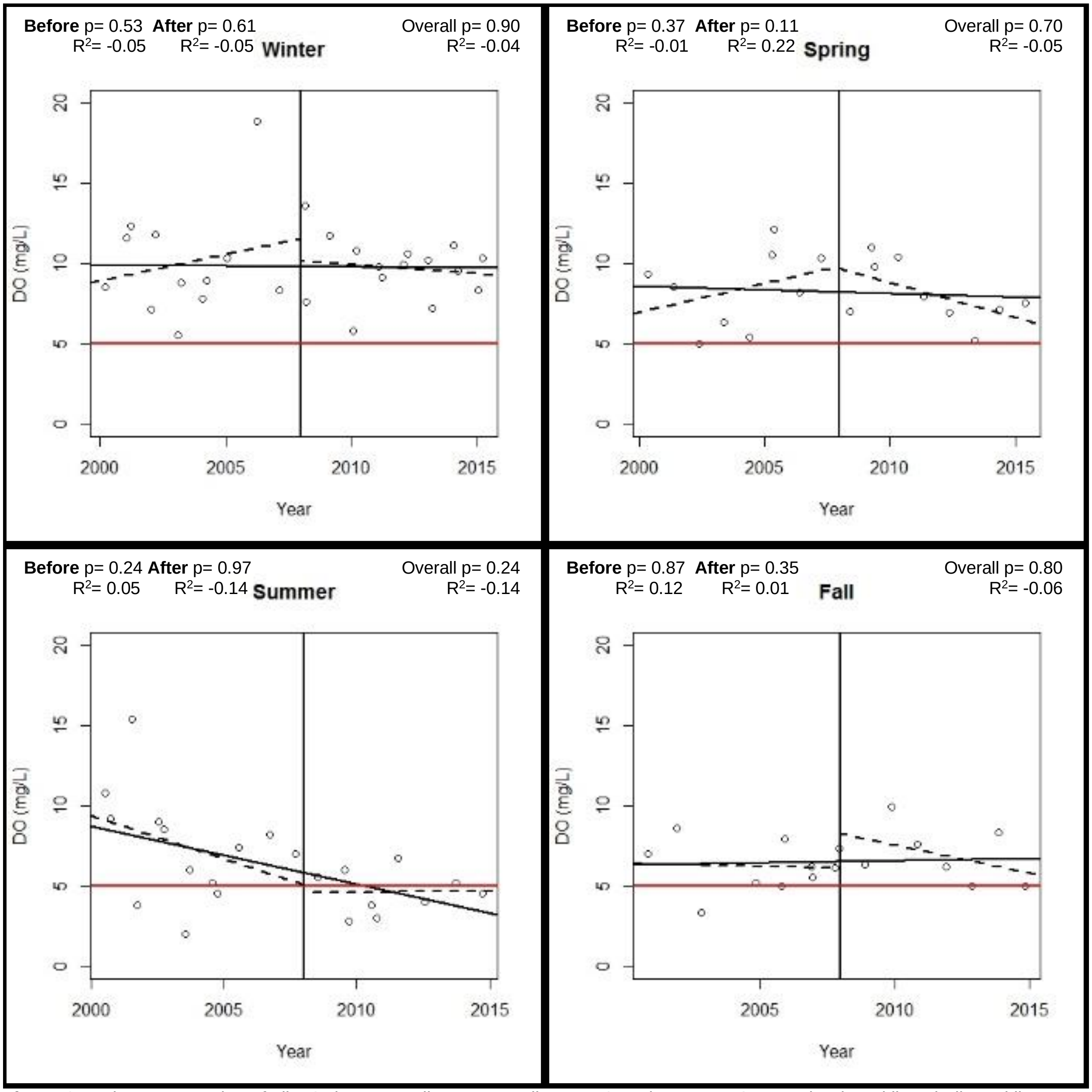


Figure 34: Linear regression of all DO data, as well as seasonally, on A-3 Drain at Terry Street. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

Lower Amazon

Amazon Creek at RM 5.82

Amazon Creek at RM 5.82 was not sampled before 2008. After 2008, it was sampled a total of six times for DO concentration and did not exceed the single sample criterion (Figure 35, Appendix A: Figure 18, Table 18). RM 5.82 could not be tested for seasonal dependence due to the lack of seasonal data (Appendix B: Table 3 and 4). The lack of data did not allow sufficient analysis towards the allocated percent reduction.

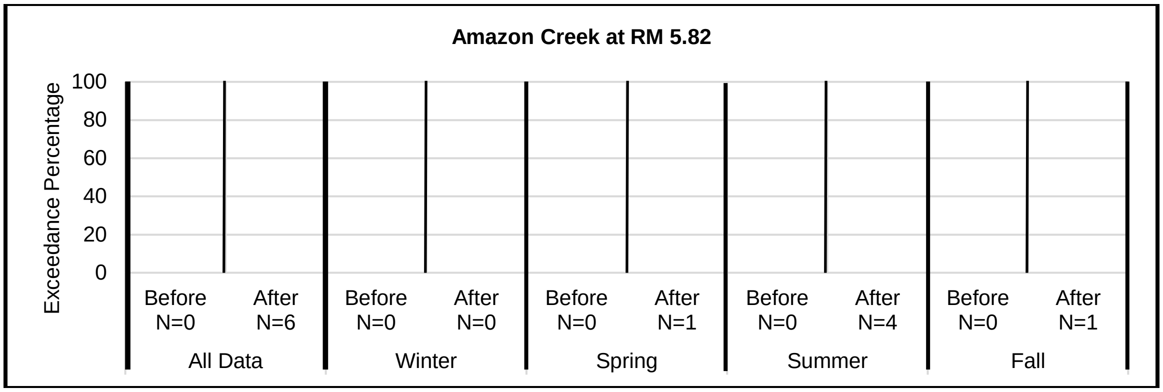


Figure 35: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Amazon Creek at RM 5.82. The charts are split seasonally, as well as all data.

RM 5.82 could not be tested for possible changes in the means for any data set (Appendix C: Table 18). Linear regression analysis found the summer data to have a significantly increasing trend (Figure 36, Appendix D: Table 18). RM 5.82 could not be tested for changes in trends before and after 2008 due to no data before 2008. The lack of seasonal/yearly data does not allow auto ARIMA.

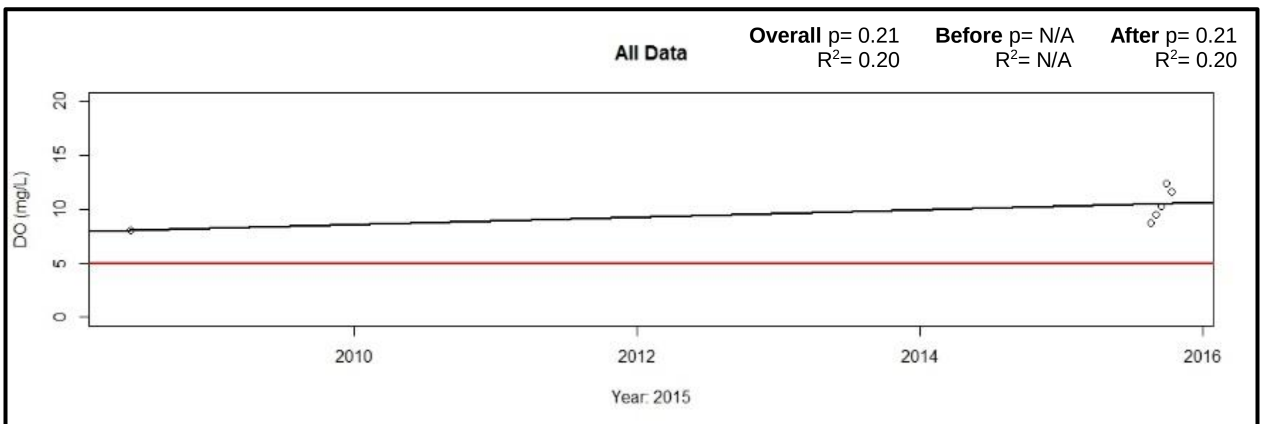


Figure 36: Linear regression of all DO data on Amazon Creek at RM 5.82. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

Amazon Creek at High Pass Road

Amazon Creek at High Pass Road did not exceed State single sample criterion for DO before or after 2008 (Figure 37, Appendix A: Figure 19, Table 19). Single sample exceedances at High Pass Road were not significantly seasonally different (Appendix B: Table 3 and 4). The allocated percent reduction in nutrient concentration for BOD and SOD (40%) has not been met since 2008; there was no before or after data to compare for ammonia, nitrate/nitrite as N, TSS, and BOD (Appendix F). The average temperature decreased by 15% after 2008 (Appendix F: Table 48). Total phosphorus did not change, and temperature decreased by 2% (Appendix F: Table 49). However, the lack of data did not allow sufficient analysis towards the allocated percent reduction.

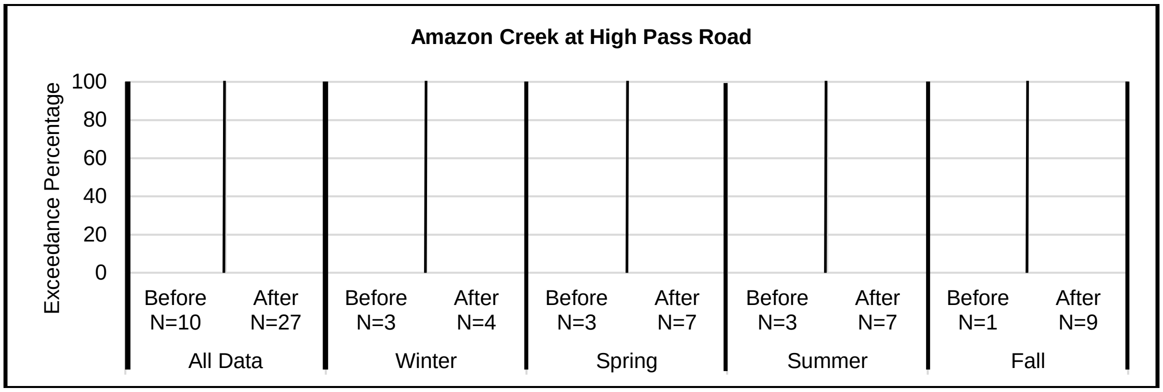
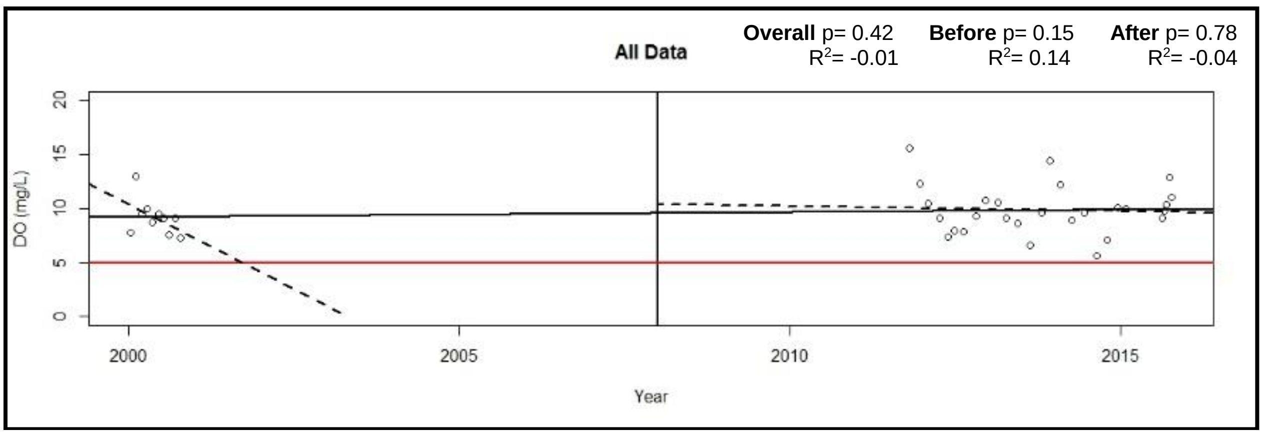


Figure 37: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Amazon Creek at High Pass Road. The charts are split seasonally, as well as all data.

High Pass Road was not found to have a significant change in the means for any data set (Appendix C: Table 19). The overall data set was not tested for a significant change because of only 1 sample collection during the fall before 2008. Linear regression analysis did not find any significant trends in any of the data sets (Figure 38, Appendix D: Table 19). There were no significant differences in the trends of any data sets. The lack of seasonal/yearly data did not allow ARIMA modeling.



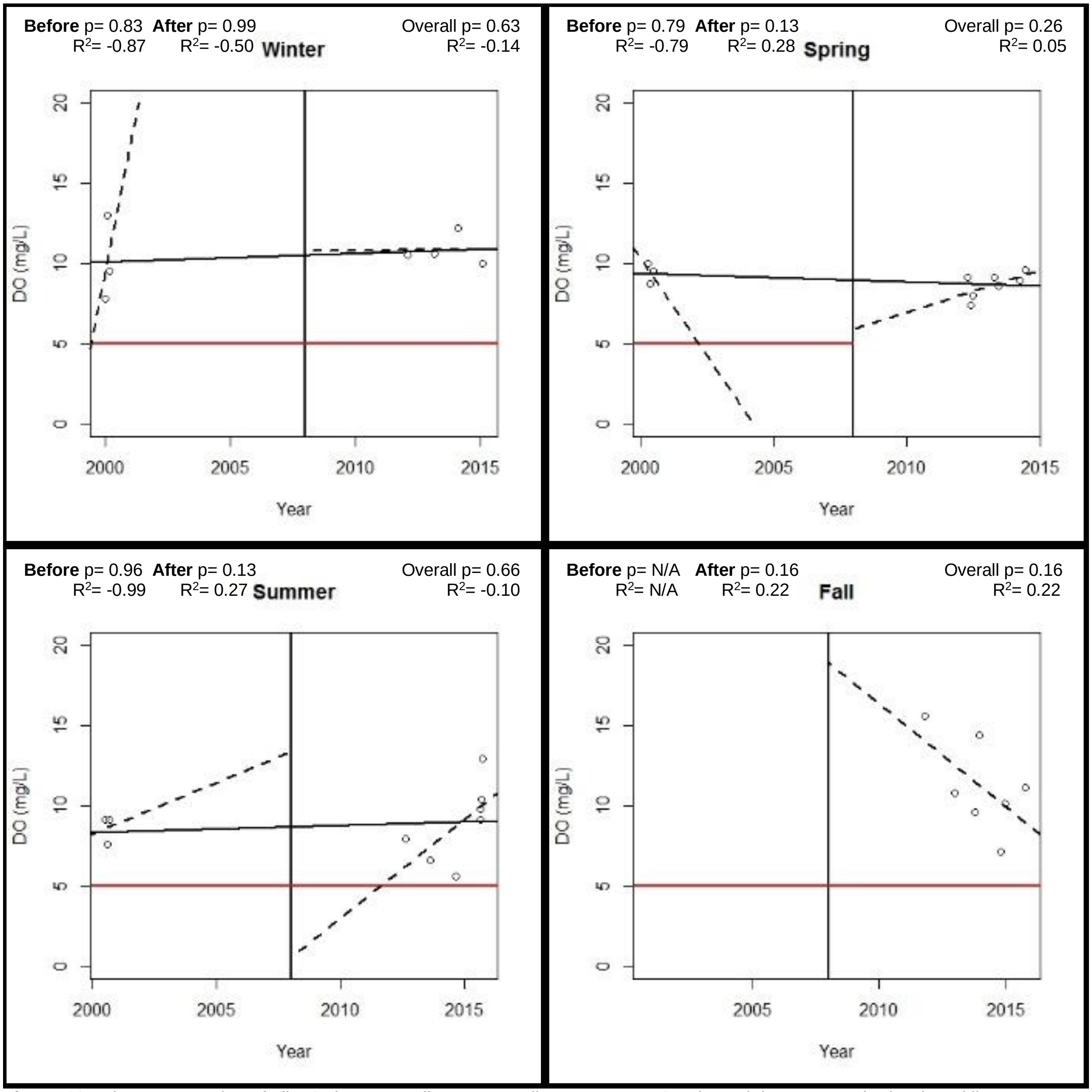


Figure 38: Linear regression of all DO data, as well as seasonally, on Amazon Creek at High Pass Road. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (5.0 mg/L).

<u>Coyote Creek</u>

Coyote Creek at Hamm Road

Coyote Creek at Hamm Road did not exceed single sample criterion for DO before 2008; but exceeded State criterion once during the summer of 2015 (Figure 39, Appendix A Figure 20, Table 20). Coyote Creek at Hamm Road had not been sampled since the summer of 2001 until the summer of 2015. Single sample exceedance criterion at Hamm Road was not seasonally significant before 2008 and could not be tested for seasonal differences after 2008 (Appendix B: Table 3 and 4). The lack of data did not allow sufficient analysis for the allocated percent reduction.

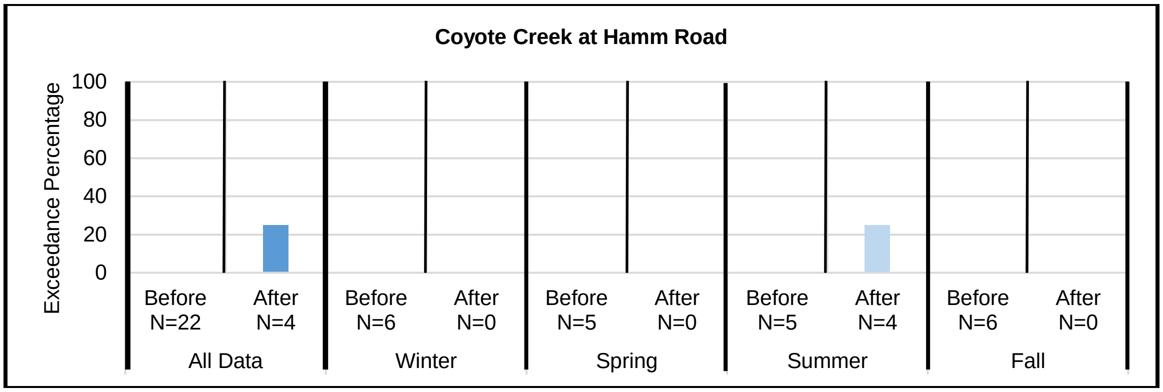
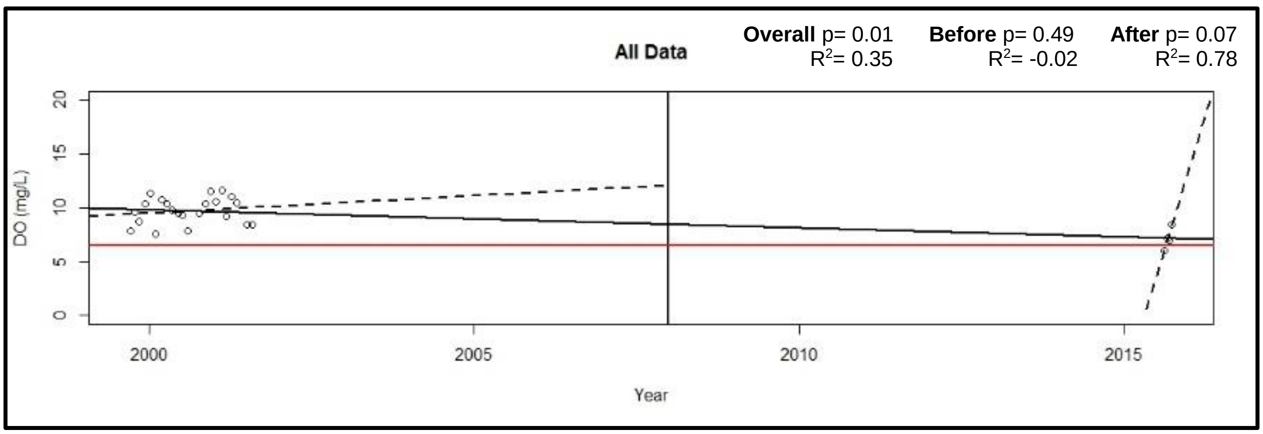


Figure 39: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Coyote Creek at Hamm Road. The charts are split seasonally, as well as all data.

Hamm Road had a significant difference in means during the summer (Appendix C: Table 20). No other season could be tested due to lack of sampling after 2008. Linear regression analysis found the summer after 2008 to have a significantly increasing trend (Figure 40, Appendix D: Table 20). However, there was no significant difference found for changes in trend during the summer before and after 2008. No other season could be tested due to the absence of data after 2008. The lack of seasonal/yearly data does not allow ARIMA modeling.



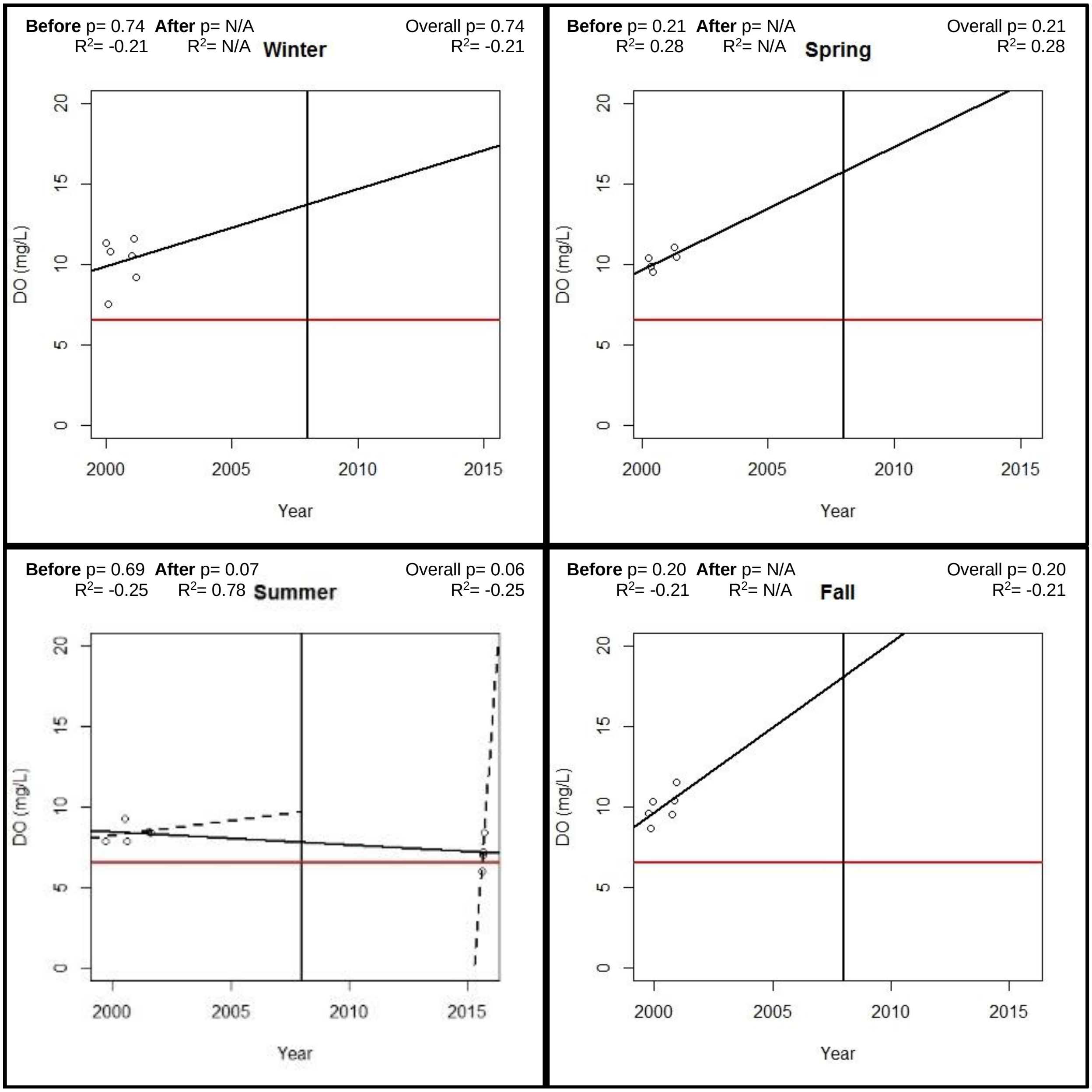


Figure 40: Linear regression of all DO data, as well as seasonally, on Coyote Creek at Hamm Road. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (6.5 mg/L).

Coyote Creek at Powell Road

Coyote Creek at Powell Road exceeded the State single sample criterion for DO during the summer before and after 2008 (Figure 41, Appendix A: Figure 21, Table 21). Powell Road had not been sampled since the summer of 2001 until the summer of 2015. Single sample exceedance criterion at Powell Road was found to be seasonally different before 2008 but could not be tested for seasonal differences after 2008 (Appendix B: Table 3 and 4). The lack of data did not allow sufficient analysis of the allocated percent reduction.

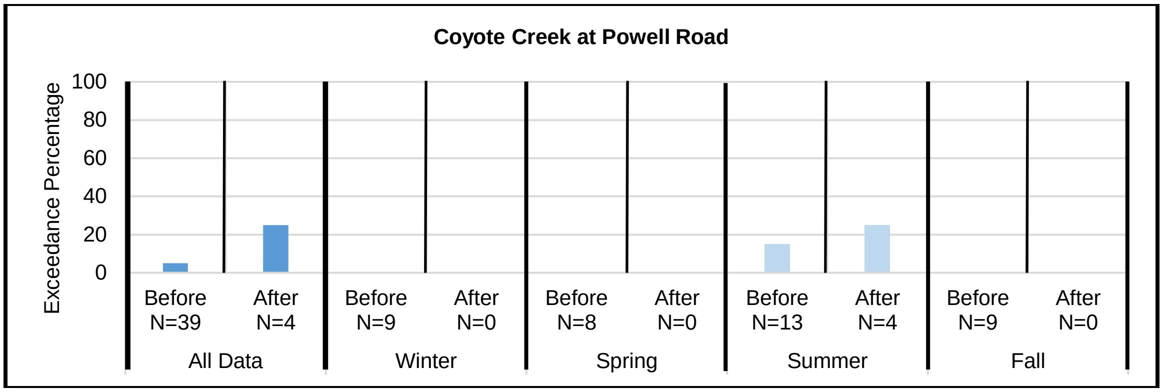
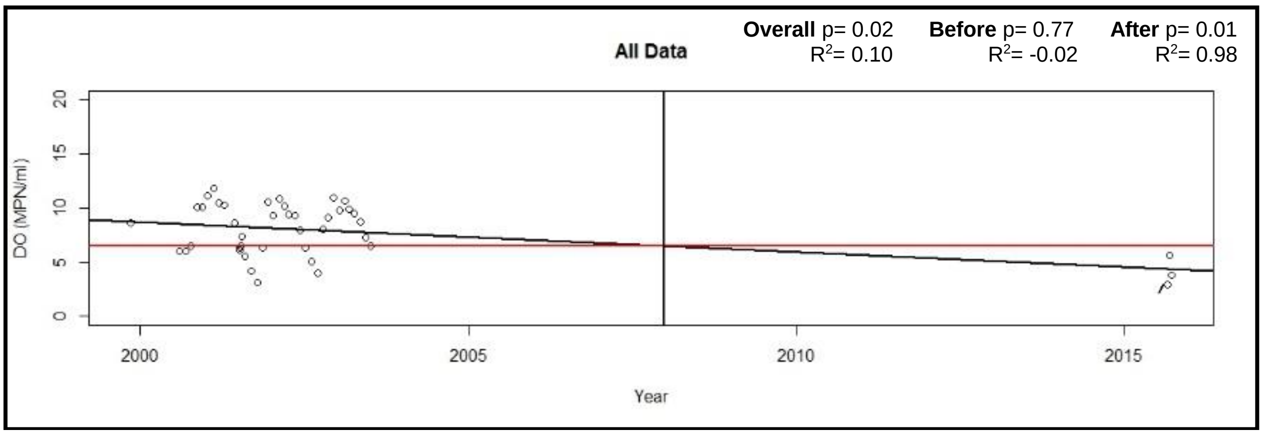


Figure 41: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Coyote Creek at Powell Road. The charts are split seasonally, as well as all data.

Powell Road had a significant difference in means during the summer (Appendix C: Table 21). No other season could be tested due to lack of sampling after 2008. Linear regression analysis did not find significant trends for any dataset (Figure 42, Appendix D: Table 21). There were no significant differences in trends during the summer before and after 2008. No other season could be tested due to the absence of data after 2008. The lack of seasonal/yearly data did not allow ARIMA modeling.



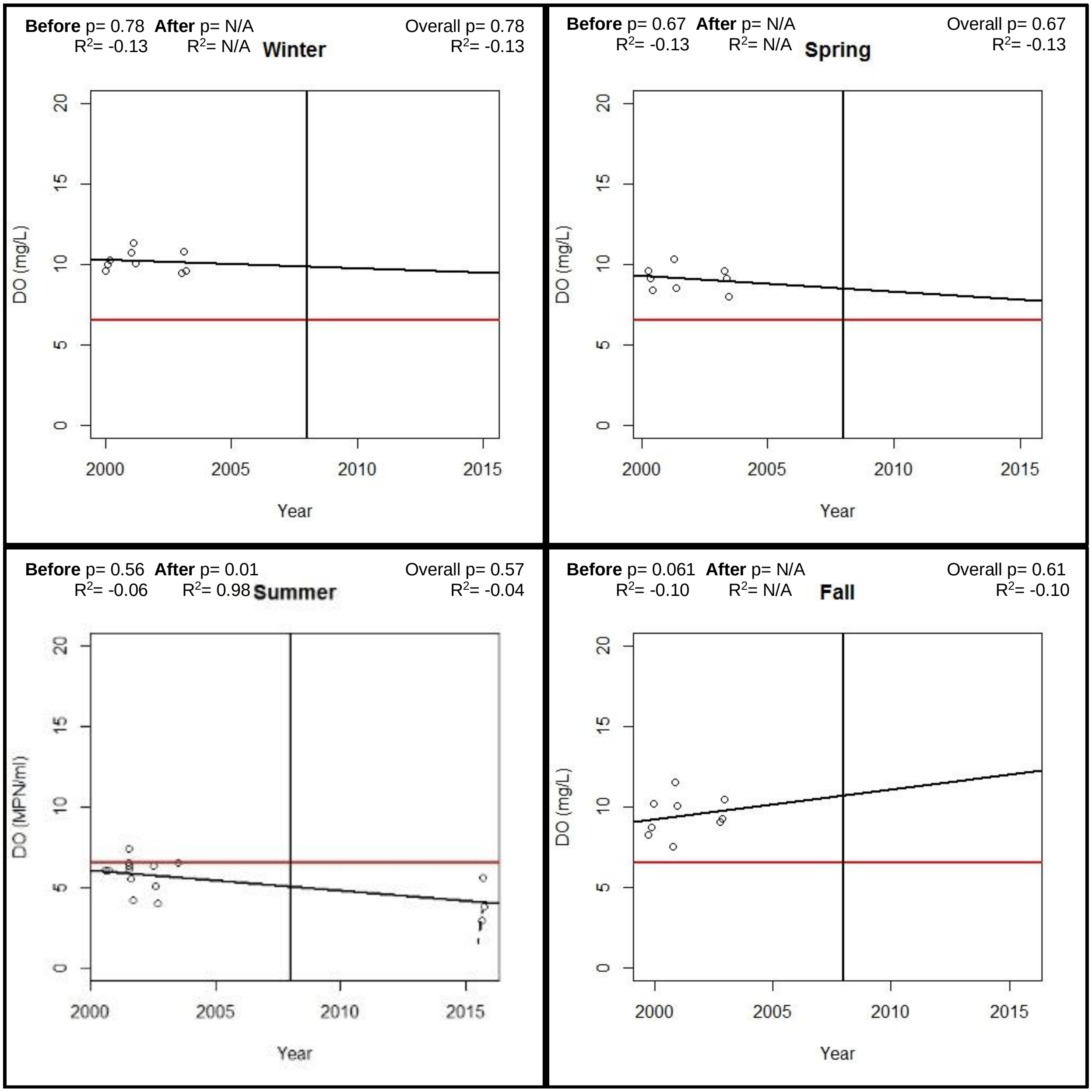


Figure 42: Linear regression of all DO data, as well as seasonally, on Coyote Creek at Powell Road. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (6.5 mg/L).

Coyote Creek at Petzold Road

Coyote Creek at Petzold Road exceeded State single sample criterion for DO during the summer before and after 2008 (Figure 43, Appendix A: Figure 22, Table 22). Petzold Road had not been sampled since the summer of 2001 until the summer of 2015. Single sample exceedances at Petzold Road were not seasonally different before 2008 and could not be tested for seasonal dependence after 2008 (Appendix B: Table 3 and 4). The lack of data did not allow sufficient analysis of the allocated percent reduction.

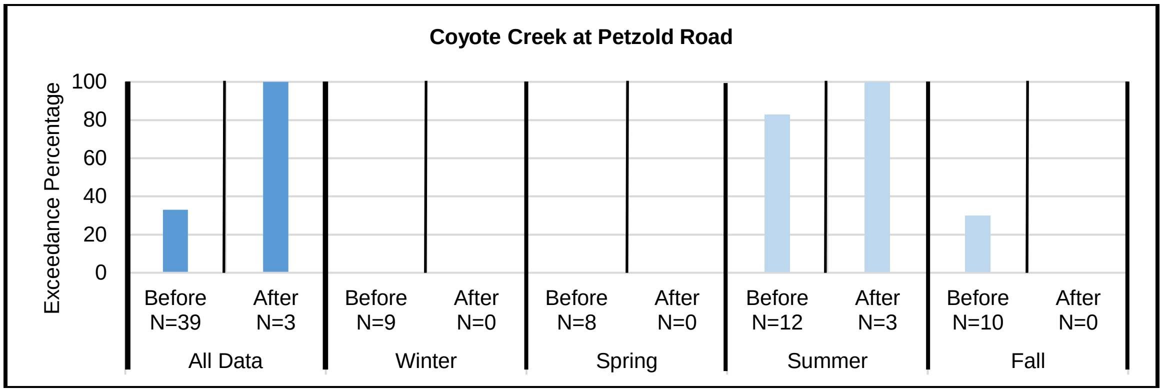
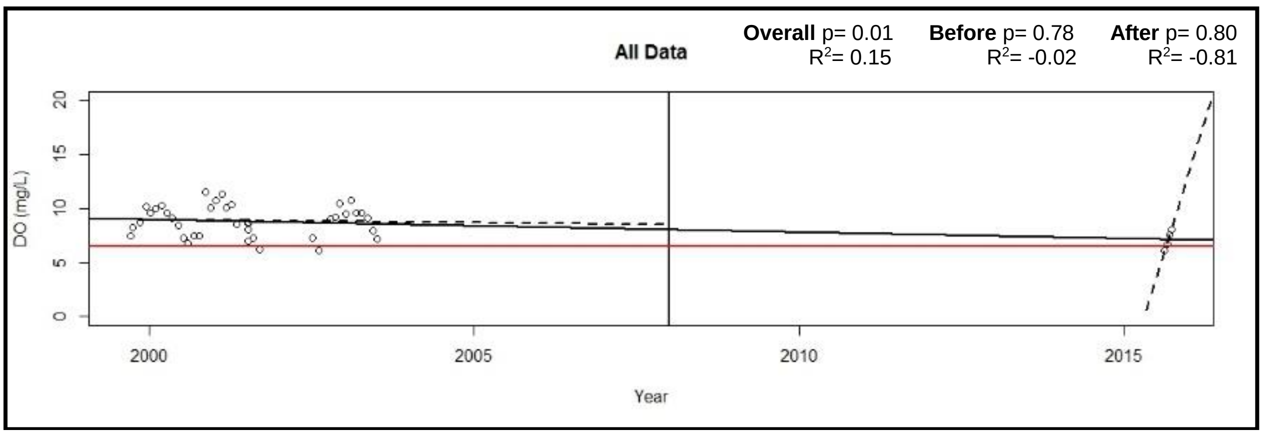


Figure 43: Bar charts of the percentage of single sample DO criterion exceedance before and after 2008 on Coyote Creek at Petzold Road. The charts are split seasonally, as well as all data.

Petzold Road did not have significant differences in means during the summer (Appendix C: Table 22). No other season could be tested due to lack of sampling after 2008. Linear regression analysis found the summer after 2008 to have a significantly increasing trend (Figure 44, Appendix D: Table 22). There was no significant difference in trend during the summer before and after 2008. No other season could be tested due to the lack of data after 2008. The lack of seasonal/yearly data did not allow ARIMA modeling.



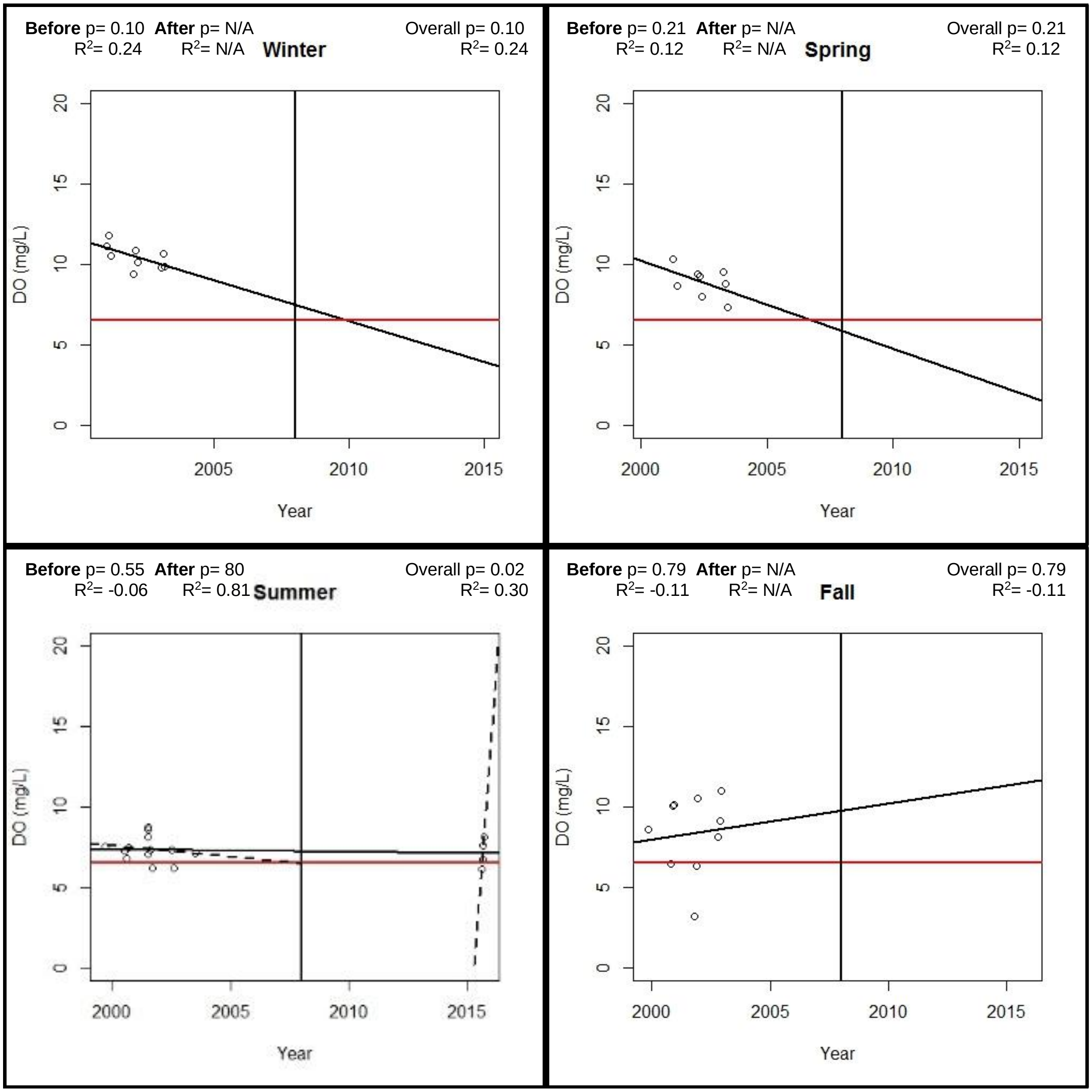


Figure 44: Linear regression of all DO data, as well as seasonally, on Coyote Creek at Petzold Road. The dotted lines indicated linear regression before and/or after 2008. The solid black line indicates the overall linear regression. The horizontal red line is the State single sample exceedance level (6.5 mg/L).

Discussion

There is a need to clearly define the role of DMA monitoring approaches if status and trend analyses are to efficiently and effectively assess progress towards meeting TMDL wasteload and load allocations. Analysis of the effectiveness of DMAs TMDL implementation plan objectives and trend analysis could not be assessed due to sparse data sets. The lack of data in the Amazon Creek and Coyote Creeks watersheds could only be used to assess the current status of pollutant concentration levels. Trend analysis was hindered for both overall data sets as well as seasonal data sets because sparse samples were collected within the same climatic and environmental conditions over time. In order to understand the effectiveness of DMAs

TMDL implementation plan objectives quantitatively, monitoring approaches in whole (amount of sample stations and yearly routine collection amount) needs to be improved upon. Design of these monitoring approaches should not only include where, what, and when sampling occurs, yet a definitive conclusion to why those approaches were chosen and how they will influence water quality must be understood.

Box plots and tabulations of the percentages of exceedances were the most useful for products examining *E. coli* and DO concentrations before and after TMDL implementation began in 2008. However, interpretation of these analyses was still complex. Based on available data, Upper and Lower Amazon Creeks remain impaired from elevated bacteria concentrations. Based on a sparse dataset, evidence suggests that bacteria levels in Coyote Creek have decreased above its confluence with Spencer Creek. Upper Amazon Creek and Coyote Creek continue to be impaired for DO while DO concentrations in Lower Amazon have increased. However, the use of grab samples usually does not allow for adequate analyses of DO dynamics or moving averages that are part of DO standards applicable in these streams. Pollutant reduction allocations have been met for *E. coli* concentrations in the A-3 Drain; yet *E. coli* concentrations remain in exceedance of the single sample State criterion. The allocated reduction percentage was difficult to analyze due to differences in seasonal bacteria concentration. Bacteria concentration reduced by 48% overall on the A-3 Drain at Terry Street, on average, when comparing data collected before and after 2008, but when comparing data collected after December of 2002 until present, during late October through the end of December, *E. coli* concentration decreased by only 3%.

The current protocol for monitoring bacteria and DO in these streams (one grab sample on average per season) hinders the ability to detect of water quality standard exceedances. The sample stations and seasons which show exceedance or are near exceedance can only be assumed to exceed the single sample and, possibly, the 7-day criterion because they likely do not capture the lowest level of DO concentration or the highest *E.* coli concentration on the day of sampling. Sparse grab samples only convey limited instantaneous measures, which makes detailed assessments of seasonal or annual trends in water quality problematic. DO concentration is even more variable based on the time of day, recent precipitation events, temperature variability, and/or nutrient concentration.

Of the 91 trends analyzed through linear regression for increasing or decreasing *E. coli* and DO concentrations before and after 2008 (182 combined), only 15 were found to be significant, seven for *E. coli* and eight for DO. Willow Creek was the only sample station found to have a significant trend (increasing) for the entire data set for DO concentration. None were found for *E. coli* concentrations. However, Willow Creek was not sampled continuously during the summer due to low flows. The lack of summer sampling biased the overall results for both *E. coli* and DO concentration because summer is typically when bacterial concentrations are greatest and DO concentrations are lowest. Sparse sampling resulted in high variability within each dataset, creating low R^2 values (<0.10), high residual standard errors, and ultimately lack of ecologically-meaningful trends.

Understanding how specific implementation activities in the Amazon Creek and Coyote Creek watersheds have or are helping pollutant reductions could not be achieved based on available data. Sparse collection of water quality data led to uncertain status and trend analyses. Coyote Creek had not been tested for TMDL-related water quality parameters between 2001 and the sample collection conducted by ODEQ in the summer of 2015. Data obtained in the 2015 collection only informed current status of water quality. Ultimately, identifying TMDL implementation activities that influenced DO and bacteria levels could not be achieved purely from status and trend analyses.

Restoration and mitigation measures do not usually result in instantaneous remediation of water quality and fail to meet expectations for water quality improvement because of lag time (Meals, Dressing, and Davenport 2009). Even when management changes are well-designed and fully implemented, water quality monitoring efforts may not show definitive results if the monitoring period, program design, and sampling frequency are not sufficient to address the lag between treatment and response (Meals, Dressing, and Davenport 2009). Important processes influencing lag time include hydrology, vegetation growth, transport rate and path, hydraulic residence time, pollutant sorption properties, and ecosystem linkages (Meals, Dressing, and Davenport 2009). The magnitude of lag times for specific processes is highly site and pollutant specific, but may range from months to years for relatively short-lived contaminants such as indicator bacteria or years to decades for excessive nutrient loads (Meals, Dressing, and Davenport 2009).

In both Amazon Creek and Coyote Creek, DMAs had been implementing water quality management actions for decades prior to TMDL issuance. This created difficulties in analyzing trends in water quality before and after the 2008 TMDL, because I was not able to separate and specifically examine particular management activities corresponding to the current water quality status. Furthermore, despite the long-term activities occurring throughout the watershed, there was little evidence of water quality improvements in DO and bacteria. These results cannot be assumed to be due to treatment failure, nor can they be assumed to result from a time lag. However, the lack of conclusive results can be specifically attributed to the lack of sampling stations and data collection. For example, trees planted or other mitigation measures implemented directly below 29th Avenue on Amazon Creek cannot be specifically linked to changes in water quality data unless data are collected above, between, and below the restored areas. Analyses of data 11 km downstream can be confounded by environmental or anthropogenic factors downstream of the restoration location. This is probably the case for Coyote Creek as well, where data have not been consistently collected since 2003. To determine if and how TMDL implementation activities meet or will meet load allocations, monitoring in Amazon Creek and Coyote Creek watersheds needs to be altered in a way in which allows the assessment of data in relation to specific water quality standards.

Management Recommendations

The water quality analyses for Amazon Creek and Coyote Creek led to the conclusion that describing the current status and trends of DO and bacteria levels in the Amazon Creek and Coyote Creek watersheds could not be sufficiently administered due to the lack of data, hindering the ability to understand pollutant sources, loading locations, and trends in water quality. Determining if TMDL implementation and other management activities had influenced DO and bacteria levels was also hindered due lack of data. In order to fully achieve these objectives, updates to state administrative rules for collecting water quality samples. Data collection and the number of sampling sites should be increased and better designed.

Data collection in the Upper Amazon dates back to 1997, and has been sampled on average of six times per year. The World Health Organization (WHO 1996) guide to water quality assessments recommends that more than 24 samples should be taken per year for no less than 10 years to perform trend analyses on streams and small rivers. WHO (1996) also recommended that to analyze or find potential loading sources, sample sites should be placed at plausible areas of potential pollutant loading, as well as above and below any major tributaries (WHO 1996). Adopting this approach, after remote sensing analysis, will better inform where or what types of implementation plans are needed within the area of concern. This approach will better facilitate where sampling stations are located because delineation of sub-regional watersheds will pinpoint where inflows are occurring, as well as allow DMAs to signify possible areas of loading (i.e. homeless camps, dog parks, stormwater conveyance systems inflows, public use areas, etc.).

An emerging and innovative technology is the use of continuous recording water-quality monitoring equipment (CR-WQME) (Maslia et al., 2005). Advantages of using CR-WQME include the ability to continuously record water-quality data at small time intervals, often 15 minutes or less (Maslia et al., 2005). In addition, the labor/time needed to conduct testing and laboratory analysis is greatly reduced. This technique still requires grab samples to be obtained to confirm sufficient calibration, yet the usage of continuous data obtained increases probability of understand and linking loading sources and areas (Maslia et al., 2005). This would specifically help in the Upper Amazon, where DO concentrations and temperature gradients during the spring and summer exhibit variable results, due to current grab sampling procedures. Continuous data also allow the evaluation of state water quality standards that have moving average components, such as the DO standard (OAR 340-041-0016).

Within the Amazon and Coyote Creek watersheds, the ways in which bacteria loading sources are determined should be revised. In the Upper Amazon, where *E. coli* concentrations are highest near the headwaters, current monitoring approaches can only be used to link possible areas above where loading could occur. Increasing collections sites throughout the stream segment would increase the ability to determine locations of influential loading sources.

Currently, the distance between the furthest upstream collection site on Amazon Creek (29th Avenue) and the next downstream collection site (Railroad Crossing) is seven miles. This distance does not allow sufficient analyses of contaminant load trends or sources. I recommend that samples be collected once per month for a minimum of three years at two to three miles intervals in order to obtain sufficient data for status and trend analyses. To improve accuracy of current *E. coli* status, 5 grab samples within a 30 day period during the middle of each season (February (winter), May (spring), August (summer), and November (fall)) should be collected. If this is not possible here and elsewhere, the state should consider reassessing state exceedance criteria (i.e., 7-day and 30-day exceedances (OAR 340-041-0009(1)(a)(A:B)). Lack of data sampling requirements for the 7-day or 30-day state exceedance criteria makes it impossible to tell if the current sampling procedure (grab samples) is biased toward high or low concentrations. Also, neither Amazon Creek nor Coyote Creek had flow measurements. Without flow measurements, agencies cannot easily assess where loading is occurring or whether certain areas are affected during high flow events or low flow events. Using seasonality as a surrogate for flow measurements does not adequately capture individual rain or system flush events.

It is recommended that the TMDL be reassessed to minimize any confusion about the allocated reduction percentages (specifically A-3 Drain). The percent reduction allocation was calculated from a small data set. Thus, TMDL allocations were set without a reasonable amount of seasonal and monthly data. The current amount of data in the Amazon Creek watershed allows determination of new reduction standards; but more data is needed for Coyote Creek to establish new reduction goals. The “phased TMDL” approach of using existing data, even though limited, to develop the TMDL when the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the TMDL load reduction calculation merits development of its second phase TMDL. My recommendations would follow the path of adaptive implementation, where using new data and information can be used to reduce uncertainty and adjust implementation activities. However, under USEPA rules and regulations, if adaptive implementation activities reveal that a TMDL loading capacity needs to be changed, the revision would require EPA approval (EPA 1991). In most cases, adaptive implementation is not anticipated to lead to the re-opening of a TMDL, and is instead used to improve implementation strategies (EPA 1991).

An example of a TMDL resulting in water quality improvements is the one for the Chesapeake Bay (CB). The CB TMDL is a multi-phase, multi-state/agency pollution reduction commitment which has shown beneficial outcomes. The multi-phase management approach was split into short-term reduction/attainment goals and long-term reduction/attainment goals (Chesapeake Bay 2015). This approach has allowed agencies to qualitatively assess immediate changes, with the understanding that some changes will take five to twenty or more years to become fully functional. The CB TMDL implementation plans required DMAs to describe timelines of attainment to each implementation activity. Emulating this requirement would help ODEQ as well as DMAs assess progress in meeting objectives and identify additional work needed to achieve goals. A major issue with DMA implementation plans for Amazon and Coyote Creeks is that they do not provide information on the expected percent reductions that will result from specific actions. The implementation plans provided by the DMAs provide timelines for implementing the measureable milestones; yet how these milestones are expected to reduce pollutants is key to understanding if the implementation activities are or will be successful. In order for this to occur, DMAs should provide a quantitative description on how and what will occur from planned activities.

Modeling uncertainties in the CB TMDL were also a concern. To improve upon the statistical modeling, sampling stations were increased and the time period between sampling was reduced, ultimately leading to a better understanding of how BMPs and implementation activities influenced pollutant loading (Chesapeake Bay 2015). The CB TMDL team is currently working on a report such as this to assess TMDL allocations status and trends, determine if implementation activities can be linked to changing water quality data, and assess for adaptive management.

The World Health Organization has stated that the usefulness of the information obtained from monitoring is severely limited unless administrative and legal frameworks (with institutional and financial commitments) exist at local, regional, or international levels (WHO 1996). At Coyote Creek, where land is primarily private or managed by ODF and ODA, monitoring procedures should follow recommendations stated above. According to OAR 340-042-0080(3), performing monitoring and providing evidence of compliance is not required for land managed by ODF or ODA. However, in order to determine if Coyote Creek is meeting or exceeding criterion and/or load allocations, data must be collected. Furthermore, guidelines to and for ODA and ODF managed lands and/or neighboring lands needs to be reassessed and restructured to require the agencies to perform and implement watershed specific WQMPs for all 303(d) listed streams in their governing lands.

All DMAs were willing to implement activities that would improve water quality. However, funding for these activities has been limited. As per requirements for implementation plans, DMAs must identify primary concerns for the 303(d) listings, identify management strategies which will achieve load allocations and reduce pollutant loading, provide a timeline for implementation and measureable milestones, provide for performance monitoring for periodic review and/or revision to their implementation plan, provide evidence of compliance, and other guidance provided in the WQMP. Completion of these steps requires adequate funding. The recommendations of this study for increased water quality sampling stations and frequency of sampling will add to the financial burden of the DMAs. In the CB, protection and restoration was signed as an executive order of the President in 2009, leading to considerable financial assistance (Chesapeake Bay 2015). However, similar to DMAs in Amazon and Coyote Creek, DMAs in the CB area still have impediments of financial capacity to oversee and implement management activities.

There are several funding avenues that DMAs can use to augment implementation activities. These include: Clean Water Act Section 319(h) funds provided to DMAs to implement their non-point source management programs (however, this funding was reduced by nearly 90% during 2015 as part of the Coastal Zone Act Reauthorization Amendment court settlement); Clean Water State Revolving Fund loan program that provides low-cost loans for planning, design, and construction of water pollution control activities; Oregon Watershed Enhancement Board grants funded through the Oregon Lottery that help restore/enhance streams, rivers, wetlands, and other natural areas to promote the Oregon Plan for salmon recovery; Environmental Quality Incentives Programs that provide financial and technical assistance to agricultural producers to improve soil, water and other natural resources on agricultural lands; and others. Although support from these sources is available, obtaining funding through these programs requires extensive work that cannot always be supported by the DMAs. Implementing these activities is also costly, as well as labor and technologically intensive.

As of 2008, the Eugene-Springfield urban growth boundary had a population of ~240,000, with the population for 2035 forecast to increase by 25% (to ~303,000) (USP 594 2011). This population growth not only means more people, but also more roads, buildings, and amenities built in order to accommodate this growth. Paired with climate change forecasts showing hotter, drier summers and more intense winter rain events, the riparian and vegetative habitat in and around both streams and water conveyance areas will soon be extremely important in moderating water temperatures and DO concentrations (USP 594 2011). The combination of the projected population growth and projected 1°C increase, on average, by 2035 will not only cause DMAs to examine capacity of existing water quality management systems to deal with these changes, but may also force them to develop new ways to manage water quality.

In conclusion, I recommend that in order to adequately assess the current status and trend and/or forecast future status and trends in water quality data, regulatory requirements for DMAs with 303(d) listed streams should be expand and modified. Doing so will enhance the ability of ODEQ, DMAs, and other interested parties to assess water quality status and trends. Grab samples that portray a moment in time on sparse intervals cannot be used to conclude that water quality standards, as written in State Administrative Rules, are being met or will be met in the future. DMAs and ODEQ need more information to evaluate effectiveness of TMDL implementation strategies. The sooner water quality monitoring strategies are improved, the sooner the DMAs and ODEQ can focus on other pressing water quality problems in the watershed and/or around the state, assess effectiveness, and adapt needed management strategies. In addition, increased monitoring data will help keep the public informed about conditions in their watershed and the importance of protecting water quality.

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Appendix A

Data Summaries:
Central Tendency, Range, and Exceedance Percentage
and Change of Before and After 2008

Bacteria (*E. coli*)

Upper Amazon

Amazon Creek at 29th Avenue

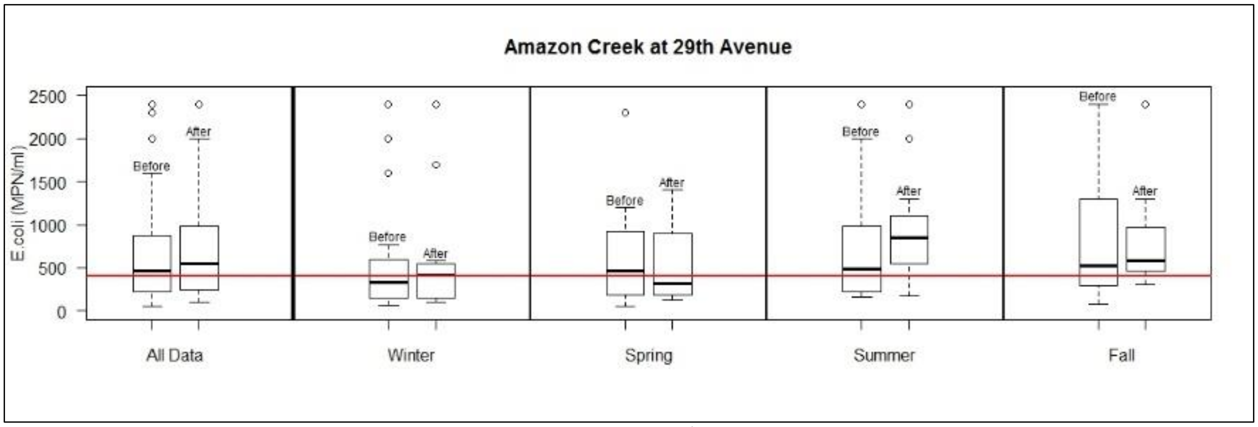

Figure 1: Box and whiskers plots of *E. coli* data on Amazon Creek at 29th Avenue. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 1: Data summaries of *E. coli* on Amazon Creek at 29th Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	Before	65	54	220	**738**	**870**	**2400**	58%	+ 6 %
	After	45	100	250	**764**	**980**	**2400**	64%	
Winter	Before	18	59	168	**600**	**588**	**2400**	44%	+ 9 %
	After	15	100	145	**672**	**550**	**2400**	53%	
Spring	Before	14	54	205	**624**	**898**	**2300**	64%	- 20 %
	After	9	130	200	**592**	**980**	**1400**	44%	
Summer	Before	19	160	225	**825**	**980**	**2400**	63%	+ 15 %
	After	14	170	**550**	**914**	**1075**	**2400**	79%	
Fall	Before	14	79	313	**900**	**1275**	**2400**	65%	+ 21 %
	After	7	310	**465**	**881**	**975**	**2400**	86%	

* Bold and shaded indicate State single sample criterion exceedance

Amazon Creek at Railroad Crossing

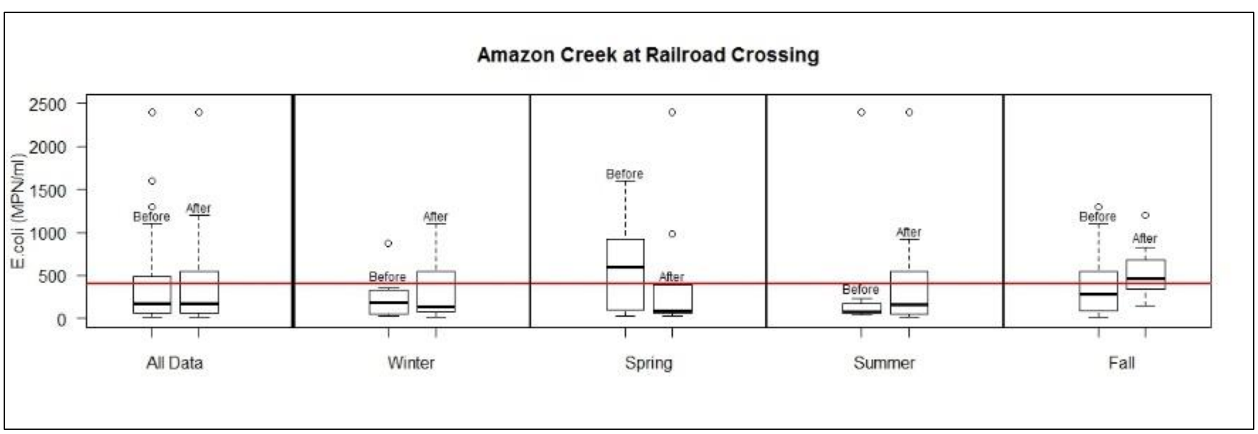

Figure 2: Box and whiskers plots of *E. coli* data on Amazon Creek at Railroad Crossing. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 2: Data summaries of *E. coli* on Amazon Creek at Railroad Crossing.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	**Before**	46	14	65	378	**460**	**2400**	26 %	+ 10 %
	After	45	10	70	**420**	**550**	**2400**	36 %	
Winter	**Before**	12	33	59	276	315	**870**	17 %	+ 16 %
	After	15	15	78	335	**545**	**1100**	33 %	
Spring	**Before**	10	23	130	**595**	**895**	**1600**	60 %	- 38 %
	After	9	33	66	**466**	390	**2400**	22 %	
Summer	**Before**	13	46	63	285	170	**2400**	8 %	+ 28 %
	After	14	10	47	**414**	**490**	**2400**	36 %	
Fall	**Before**	11	14	86	404	**550**	**1300**	27 %	+ 30 %
	After	7	150	345	**553**	**685**	**1200**	57 %	

* Bold and shaded indicate State single sample criterion exceedance

Amazon Creek at Royal Avenue

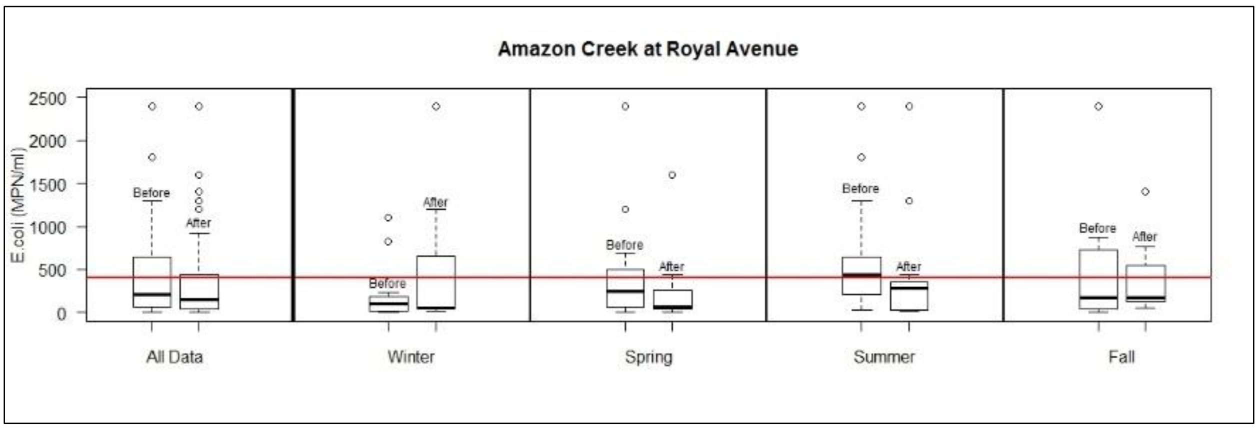

Figure 3: Box and whiskers plots of *E. coli* data on Amazon Creek at Royal Avenue. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 3: Data summaries of *E. coli* on Amazon Creek at Royal Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	**Before**	65	2	57	**454**	**650**	**2400**	37 %	- 7 %
	After	44	5	41	**412**	**460**	**2400**	30 %	
Winter	**Before**	18	9	22	186	178	**1100**	11 %	+ 29 %
	After	15	10	44	**455**	**655**	**2400**	40 %	
Spring	**Before**	14	2	65	**457**	**483**	**2400**	36 %	- 14 %
	After	9	5	40	288	260	**1600**	22 %	
Summer	**Before**	19	29	215	**603**	**650**	**2400**	58 %	- 35 %
	After	13	10	26	**440**	360	**2400**	23 %	
Fall	**Before**	14	5	36	**596**	**750**	**2400**	43 %	- 14 %
	After	7	53	123	424	**550**	**1400**	29 %	

* Bold and shaded indicate State single sample criterion exceedance

Willow Creek at 18th Avenue

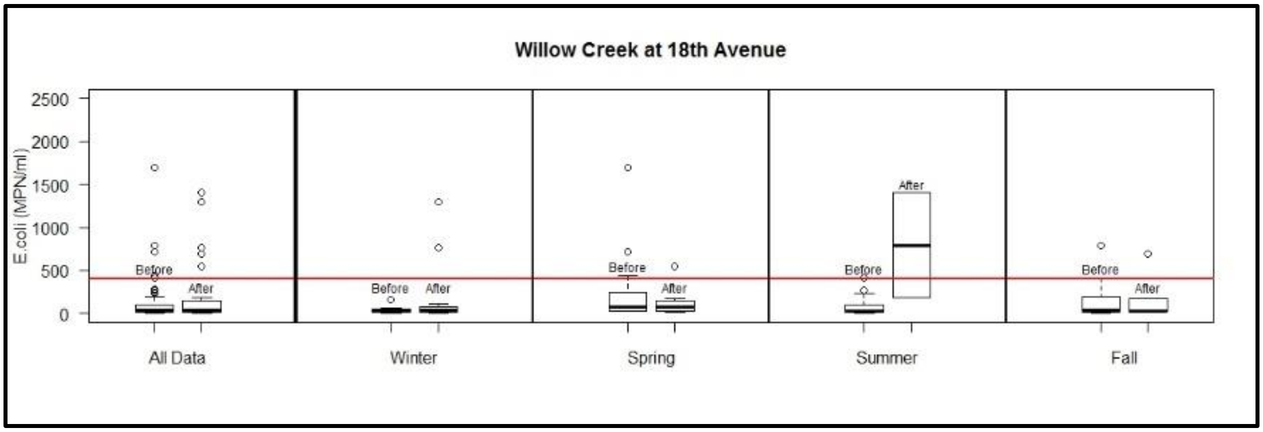

Figure 4: Box and whiskers plots of *E. coli* data on Willow Creek at 18th Avenue. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 4: Data summaries of *E. coli* on Willow Creek at 18th Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	64	1	18	123	100	**1700**	9 %	+ 7 %
	After	31	9	20	199	150	**1400**	16 %	
Winter	**Before**	18	7	19	40	50	160	0 %	+ 13 %
	After	15	9	13	170	73	**1300**	13 %	
Spring	**Before**	14	29	37	270	233	**1700**	21 %	- 8 %
	After	8	15	27	133	140	**550**	13 %	
Summer	**Before**	18	1	12	81	98	**410**	6 %	+ 44 %
	After	2	180	**485**	**790**	**1095**	**1400**	50 %	
Fall	**Before**	14	2	13	147	190	**790**	14 %	+ 3 %
	After	6	21	24	161	136	**690**	17 %	

* Bold and shaded indicate State single sample criterion exceedance

Amazon Diversion Channel at Royal Avenue

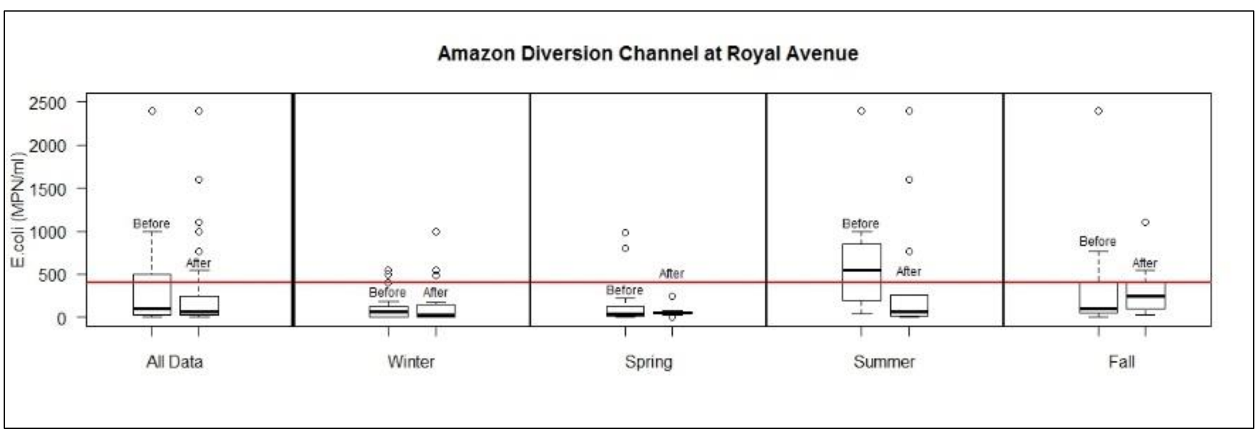

Figure 5: Box and whiskers plots of *E. coli* data on Amazon Diversion Channel at Royal Avenue. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 5: Data summaries of *E. coli* on Amazon Diversion Channel at Royal Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	64	1	33	344	**500**	**2400**	28 %	- 10 %
	After	45	1	24	252	240	**2400**	18 %	
Winter	**Before**	18	1	2	119	117	**550**	11 %	+ 9 %
	After	15	1	6	177	150	**1000**	20 %	
Spring	**Before**	13	5	19	188	130	**980**	15 %	- 15 %

	After	9	7	44	70	63	240	0 %	
Summer	Before	19	38	195	**674**	**845**	**2400**	58 %	- 31 %
	After	11	5	20	404	245	**2400**	27 %	
Fall	Before	10	1	53	356	355	**2400**	30 %	+ 1 %
	After	7	28	100	341	405	**1100**	29 %	

* Bold and shaded indicate State single sample criterion exceedance

A-3 Drain at Terry Street

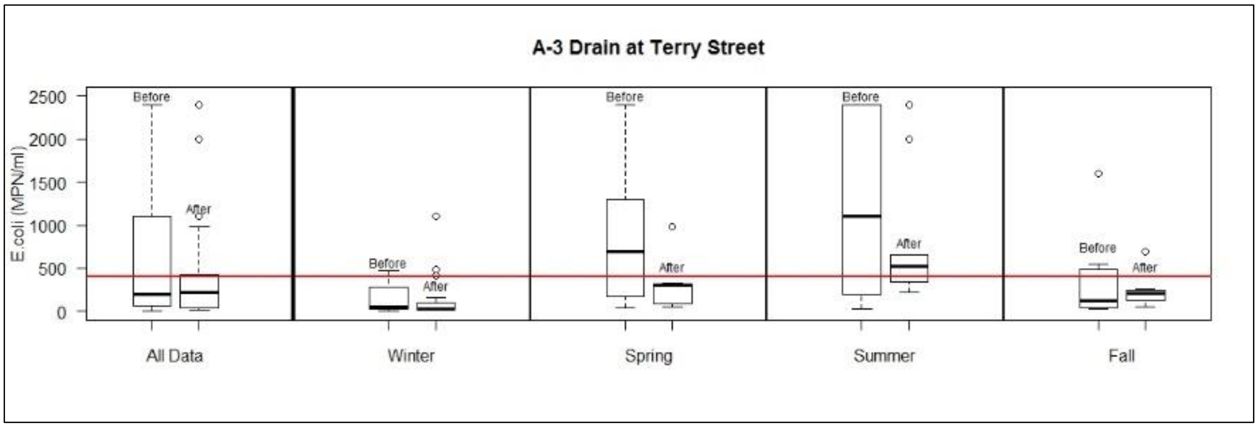

Figure 6: Box and whiskers plots of *E. coli* data on A-3 Drain at Terry Street. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 6: Data summaries of *E. coli* on A-3 Drain at Terry Street.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	Before	43	5	65	**687**	**1100**	**2400**	39 %	- 11 %
	After	40	10	37	358	**418**	**2400**	28 %	
Winter	Before	12	5	24	140	240	**480**	8 %	+ 12 %
	After	15	10	17	160	99	**1100**	20 %	
Spring	Before	9	42	170	**939**	**1300**	**2400**	56 %	- 45 %
	After	9	53	88	299	320	**980**	11 %	
Summer	Before	12	23	200	**1264**	**2400**	**2400**	62 %	+ 5 %
	After	9	220	340	**836**	**660**	**2400**	67 %	
Fall	Before	10	24	56	325	405	**1600**	30 %	- 16 %
	After	7	52	130	242	240	**690**	14 %	

* Bold and shaded indicate State single sample criterion exceedance

Lower Amazon

Amazon Creek at RM 5.82

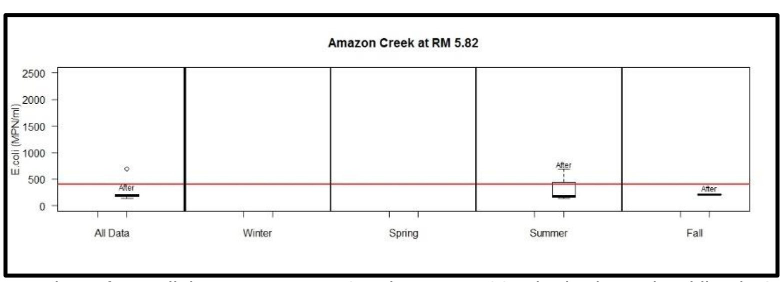

Figure 7: Box and whiskers plots of *E. coli* data on Amazon Creek at RM 5.82. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 7: Data summaries of *E. coli* on Amazon Creek at RM 5.82.

		N	Min	Q1	Median	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	0	N/A							N/A
	After	5	135	178	186	280	214	**687**	20 %	
Winter	**Before**	0	N/A							N/A
	After	0	N/A							
Spring	**Before**	0	N/A							N/A
	After	0	N/A							
Summer	**Before**	0	N/A							N/A
	After	5	135	178	186	280	214	**687**	20 %	
Fall	**Before**	0	N/A							N/A
	After	0	N/A							

* Bold and shaded indicate State single sample criterion exceedance

Amazon Creek at High Pass Road

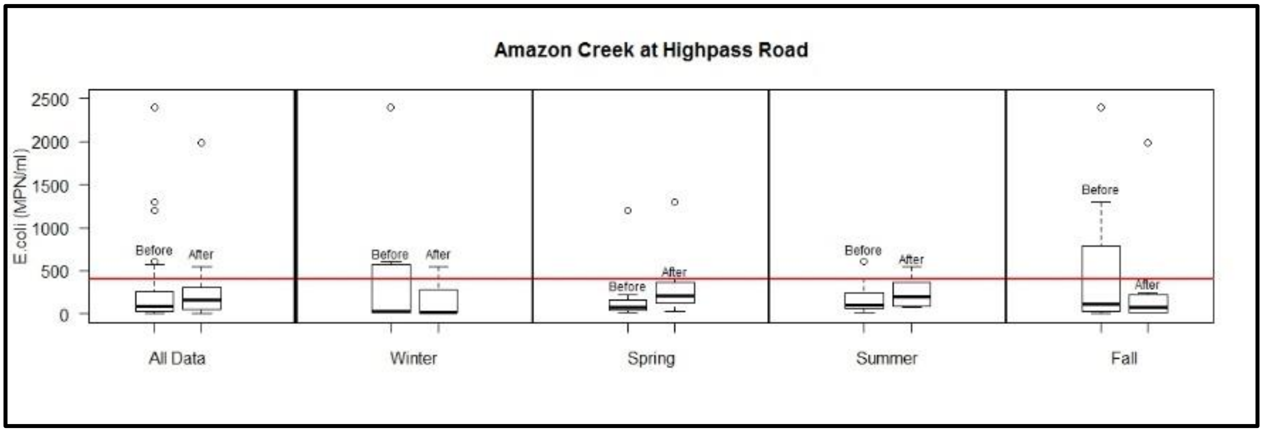

Figure 8: Box and whiskers plots of *E. coli* data on Amazon Creek at High Pass Road. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 8: Data summaries of *E. coli* on Amazon Creek at High Pass Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	42	5	32	306	252	**2400**	24 %	+ 3 %
	After	22	8	64	276	278	**1986**	27 %	
Winter	**Before**	10	10	14	394	**493**	**2400**	30 %	+ 30 %
	After	5	8	11	190	281	**548**	60 %	
Spring	**Before**	15	20	42	257	207	**1300**	13 %	+ 12 %
	After	4	72	152	218	260	**411**	25 %	
Summer	**Before**	14	13	669	167	226	**613**	14 %	+ 3 %
	After	6	73	107	244	333	**548**	17 %	
Fall	**Before**	10	5	31	**513**	**784**	**2400**	30 %	- 16 %
	After	7	14	21	304	225	**1986**	14 %	

* Bold and shaded indicate State single sample criterion exceedance

Coyote Creek

Coyote Creek at Hamm Road

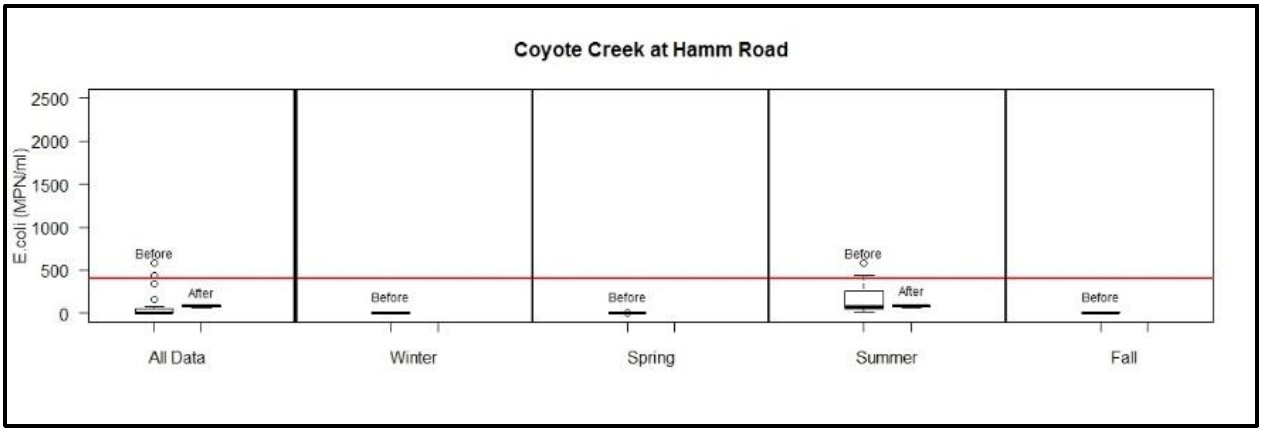

Figure 9: Box and whiskers plots of *E. coli* data on Coyote Creek at Hamm Road. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 9: Data summaries of *E. coli* on Coyote Creek at Hamm Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	Before	28	1	1	67	56	**579**	7 %	- 7 %
	After	4	59	83	84	93	93	0 %	
Winter	Before	3	1	1	2	2	3	0 %	N/A
	After	0	N/A						
Spring	Before	10	1	1	2	2	8	0 %	N/A
	After	0	N/A						
Summer	Before	11	15	54	172	256	**579**	18 %	- 18 %
	After	4	59	83	84	93	93	0 %	
Fall	Before	4	1	2	7	10	14	0 %	N/A
	After	0	N/A						

** Bold and shaded indicates significance was found

Coyote Creek at Powell Road

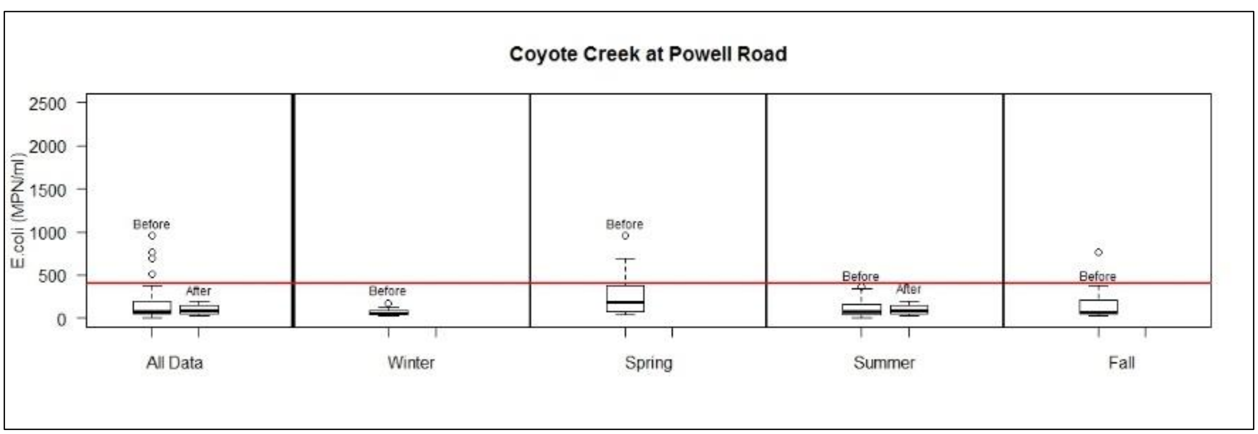

Figure 10: Box and whiskers plots of *E. coli* data on Coyote Creek at Powell Road. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 10: Data summaries of *E. coli* on Coyote Creek at Powell Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	Before	59	9	52	174	197	**961**	10 %	- 10 %
	After	4	25	72	103	122	201	0 %	
Winter	Before	10	33	43	75	87	178	0 %	N/A
	After	0	N/A						
Spring	Before	17	41	81	280	309	**961**	24 %	N/A
	After	0	N/A						

Summer	Before	19	9	44	117	164	365	0 %	0 %
	After	4	25	72	103	122	201	0 %	
Fall	Before	11	27	47	204	210	**770**	18 %	N/A
	After	0	N/A						

** Bold and shaded indicates significance was found

Coyote Creek at Petzold Road

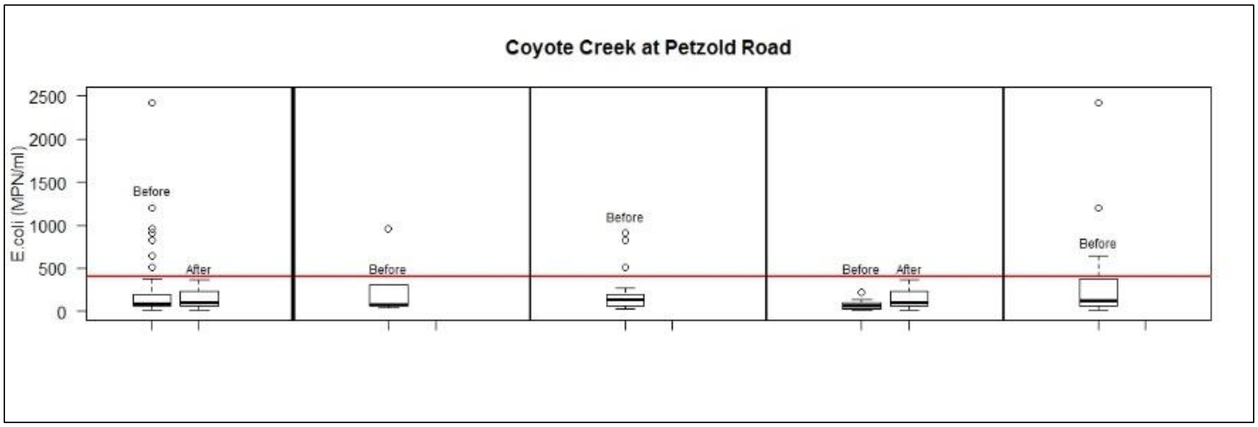

Figure 11: Box and whiskers plots of *E. coli* data on Coyote Creek at Petzold Road. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Table 11: Data summaries of *E. coli* on Coyote Creek at Petzold Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	Before	55	14	60	236	197	**2400**	15 %	- 15 %
	After	3	20	61	161	231	361	0 %	
Winter	Before	10	46	66	**723**	254	**961**	20 %	N/A
	After	0	N/A						
Spring	Before	17	25	69	226	197	**914**	18 %	N/A
	After	0	N/A						
Summer	Before	15	14	32	72	94	219	0 %	0 %
	After	3	20	61	161	231	361	0 %	
Fall	Before	13	19	70	410	353	**2400**	23 %	N/A
	After	0	N/A						

** Bold and shaded indicates significance was found

Dissolved Oxygen

Upper Amazon

Amazon Creek at 29th Avenue

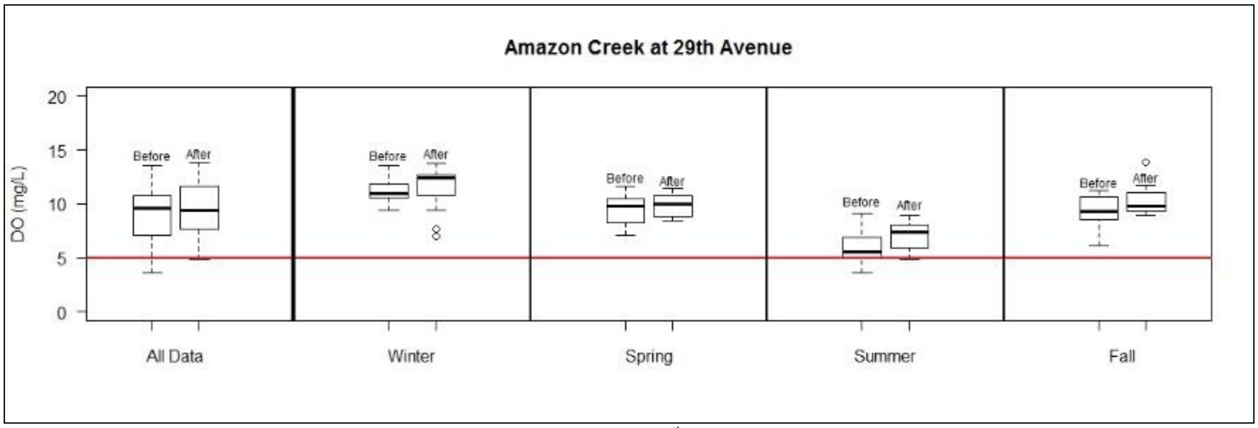

Figure 12: Box and whiskers plots of DO data on Amazon Creek at 29th Avenue. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 12: Data summaries of DO on Amazon Creek at 29th Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	65	**3.6**	7.1	8.9	10.8	13.6	5 %	- 3 %
	After	45	**4.9**	7.7	9.6	11.6	13.9	2 %	
Winter	**Before**	18	9.4	10.7	11.1	11.8	13.6	0 %	0 %
	After	15	7.0	10.8	11.5	12.6	13.8	0 %	
Spring	**Before**	14	7.1	8.5	9.5	10.5	11.6	0 %	0 %
	After	9	7.7	8.6	9.6	10.5	11.4	0 %	
Summer	**Before**	19	**3.6**	5.1	6.1	6.9	9.1	16 %	- 9 %
	After	14	**4.9**	6.0	7.1	8.0	8.9	7 %	
Fall	**Before**	14	6.1	8.6	9.3	10.	11.2	0 %	0 %
	After	7	8.9	9.3	10.5	11.1	13.9	0 %	

* Bold and shaded indicate State single sample criterion exceedance

Amazon Creek at Railroad Crossing

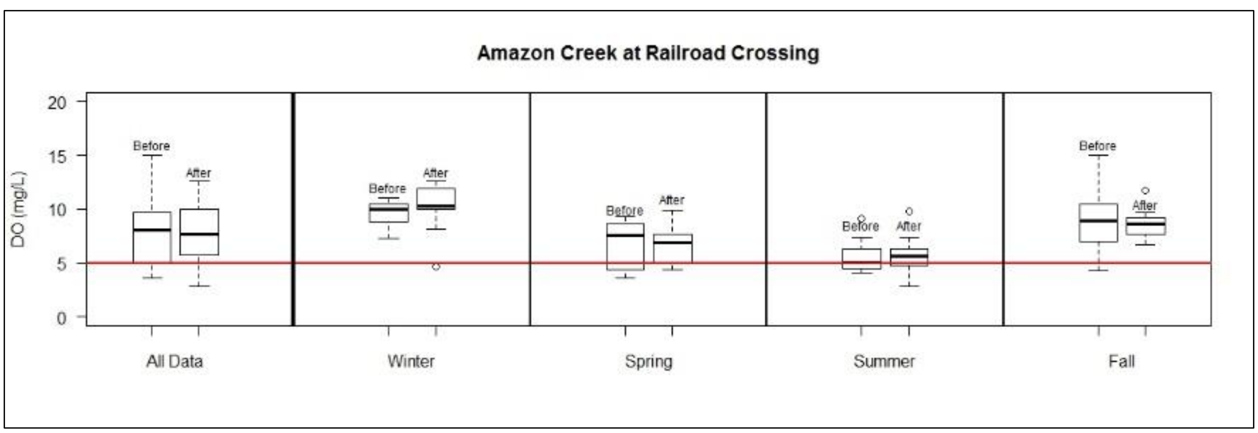

Figure 13: Box and whiskers plots of DO data on Amazon Creek at Railroad Crossing. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 13: Data summaries of DO on Amazon Creek at Railroad Crossing.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	46	**3.6**	5.2	7.7	9.7	15.0	22 %	- 4 %
	After	45	**2.8**	5.7	8.0	10.0	12.6	18 %	
Winter	**Before**	12	7.3	8.8	9.7	10.4	11.1	0 %	+ 7 %
	After	15	**4.4**	5.0	6.8	7.7	9.9	7 %	
Spring	**Before**	10	**4.4**	5.0	6.8	7.7	9.9	40 %	- 7 %
	After	9	**3.6**	**4.5**	6.7	8.6	9.3	33 %	
Summer	**Before**	13	**4.1**	**4.5**	5.6	6.3	9.1	38 %	- 9 %
	After	14	**2.8**	**4.9**	5.7	6.2	9.8	29 %	
Fall	**Before**	11	**4.3**	7.0	9.0	10.5	15.0	9 %	- 9 %
	After	7	6.7	7.7	8.7	9.3	11.7	0 %	

* Bold and shaded indicate State single sample criterion exceedance

Amazon Creek at Royal Avenue

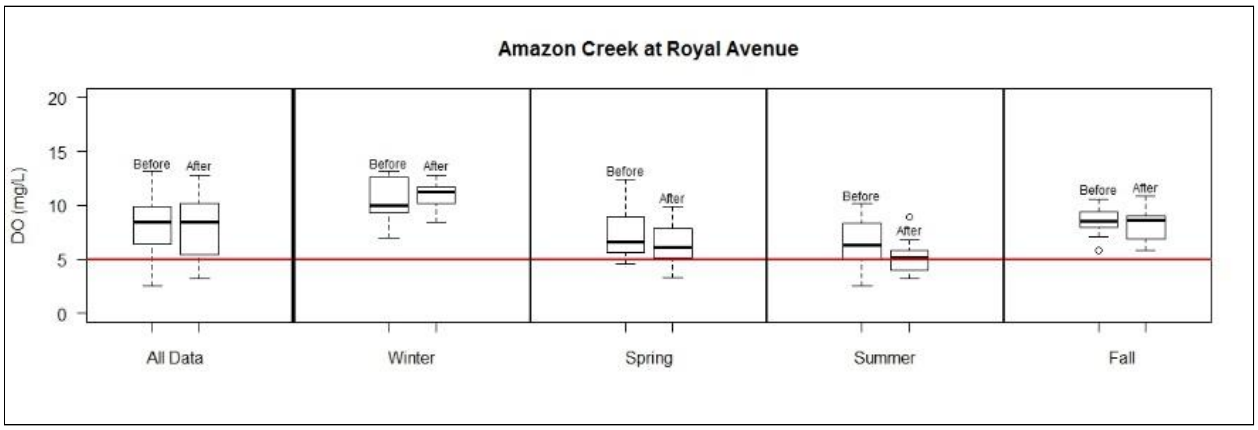

Figure 14: Box and whiskers plots of DO data on Amazon Creek at Royal Avenue. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 14: Data summaries of DO on Amazon Creek at Royal Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	64	**2.5**	6.4	8.3	9.8	13.2	11 %	+ 5 %
	After	44	**3.2**	5.4	7.9	10.4	12.8	16 %	
Winter	**Before**	18	7.0	9.4	10.5	12.3	13.2	0 %	0 %
	After	15	8.4	10.2	10.9	11.7	12.8	0 %	
Spring	**Before**	14	**4.6**	5.8	7.4	8.8	12.4	14 %	+ 8 %
	After	9	**3.3**	5.2	6.6	7.9	9.9	22 %	
Summer	**Before**	18	**2.5**	5.0	6.5	8.3	10.2	28 %	+ 10 %
	After	13	**3.2**	**4.0**	5.3	5.8	8.9	38 %	
Fall	**Before**	14	7.1	8.3	8.8	9.5	10.6	0 %	0 %
	After	7	5.8	6.9	8.1	9.0	10.9	0 %	

* Bold and shaded indicate State single sample criterion exceedance

Willow Creek at 18th Avenue

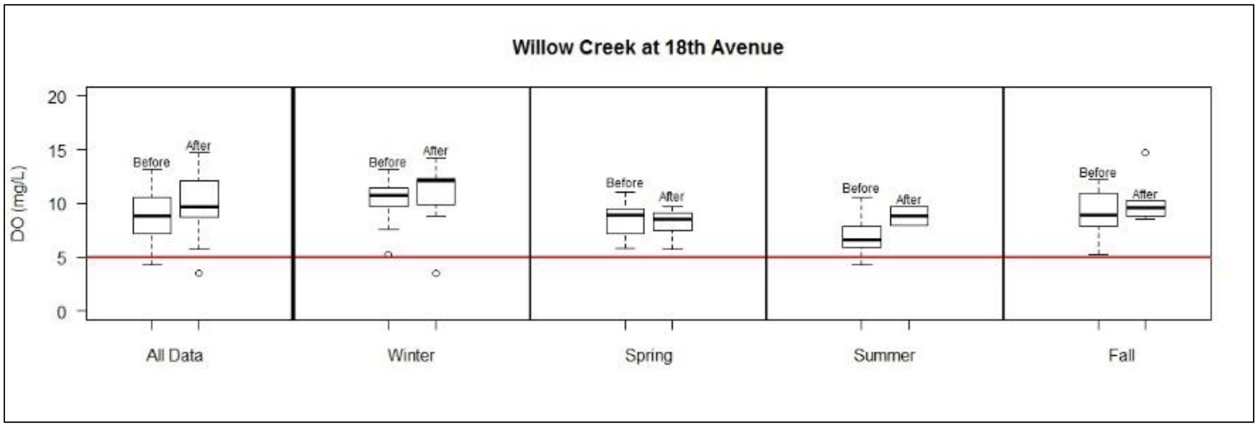

Figure 15: Box and whiskers plots of DO data on Willow Creek at 18th Avenue. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 15: Data summaries of DO on Willow Creek at 18th Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	**Before**	64	**4.3**	7.2	8.8	10.6	13.2	2 %	+ 1 %
	After	31	**3.5**	8.8	10.1	12.2	14.7	3 %	
Winter	**Before**	18	5.3	9.9	10.4	11.4	13.2	0 %	+ 7 %
	After	15	**3.5**	9.9	11.2	12.4	14.2	7 %	
Spring	**Before**	14	5.8	7.6	8.7	9.5	11.1	0 %	0 %
	After	8	5.7	7.9	8.2	9.1	9.7	0 %	
Summer	**Before**	18	**4.3**	6.0	6.9	7.9	10.6	6 %	- 6 %
	After	2	8.0	8.4	8.9	9.3	9.7	0 %	
Fall	**Before**	14	5.3	8.0	9.1	10.6	12.2	0 %	0 %
	After	6	8.5	9.0	10.3	10.2	14.7	0 %	

* Bold and shaded indicate State single sample criterion exceedance

Amazon Diversion Channel at Royal Avenue

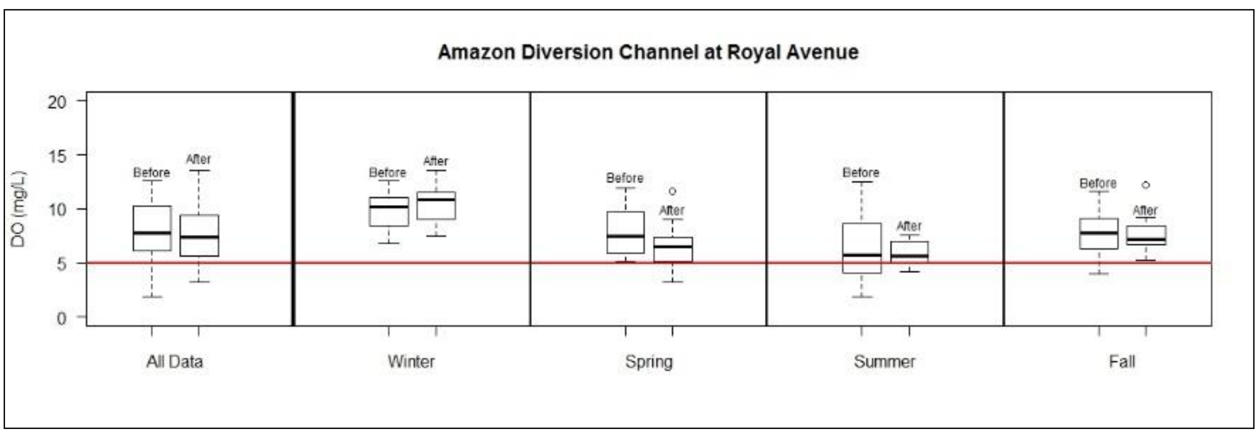

Figure 16: Box and whiskers plots of DO data on Amazon Diversion Channel at Royal Avenue. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 16: Data summaries of DO on Amazon Diversion Channel at Royal Avenue.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	**Before**	64	**1.9**	6.2	8.0	10.3	12.6	13 %	+ 3 %
	After	41	**3.2**	5.6	7.9	9.4	13.6	10 %	
Winter	**Before**	18	6.8	8.6	9.8	11.0	12.6	0 %	0 %
	After	15	7.5	9.0	10.4	11.5	13.6	0 %	
Spring	**Before**	14	5.2	6.0	7.9	9.6	11.9	0 %	+ 22 %
	After	9	**3.2**	5.2	6.7	7.4	11.6	22 %	

Summer	**Before**	18	**1.9**	**4.2**	6.3	8.4	12.5	39 %	- 25 %
	After	14	**4.2**	5.2	6.0	6.9	7.6	14 %	
Fall	**Before**	14	5.3	6.8	7.9	8.5	12.2	7 %	- 7 %
	After	7	**4.0**	6.5	7.9	9.1	11.6	0 %	

* Bold and shaded indicate State single sample criterion exceedance

A-3 Drain at Terry Street

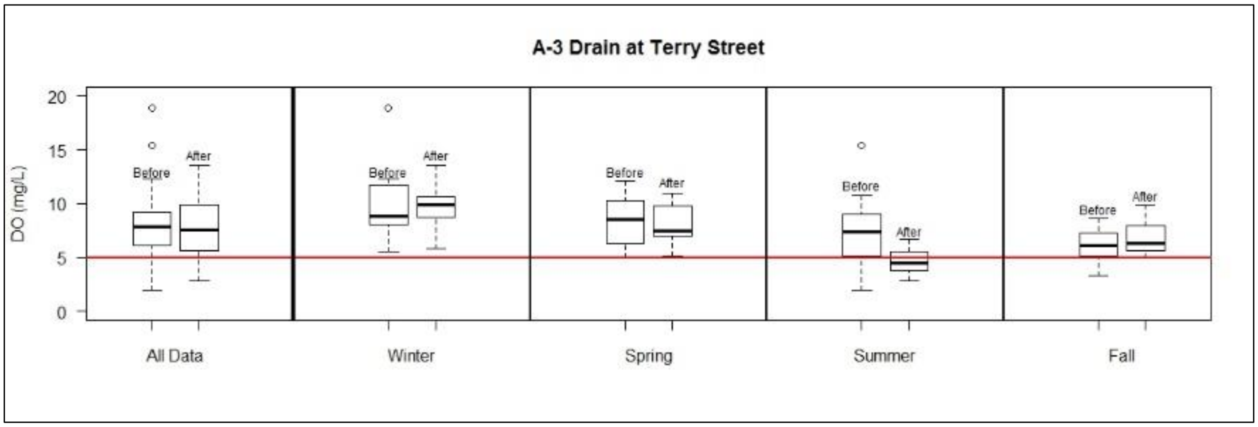

Figure 17: Box and whiskers plots of DO data on A-3 Drain at Terry Street. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 17: Data summaries of DO on A-3 Drain at Terry Street.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	43	**2.0**	6.1	8.1	9.2	18.9	9 %	+ 9 %
	After	40	**2.8**	5.7	7.7	9.9	13.6	18 %	
Winter	**Before**	12	5.5	8.2	10.0	11.7	18.9	0 %	0 %
	After	15	5.8	8.7	9.7	10.7	13.6	0 %	
Spring	**Before**	9	5.0	6.3	8.4	10.3	12.1	0 %	0 %
	After	9	5.2	7.0	8.1	9.8	11.0	0 %	
Summer	**Before**	12	**2.0**	5.2	7.5	9.0	15.4	25 %	+ 31 %
	After	9	**2.8**	**3.8**	**4.6**	5.5	6.7	56 %	
Fall	**Before**	10	**3.3**	5.3	6.2	7.2	8.6	10 %	+ 19 %
	After	7	5.0	5.6	6.9	8.0	9.9	29 %	

* Bold and shaded indicate State single sample criterion exceedance

Lower Amazon

Amazon Creek at RM 5.82

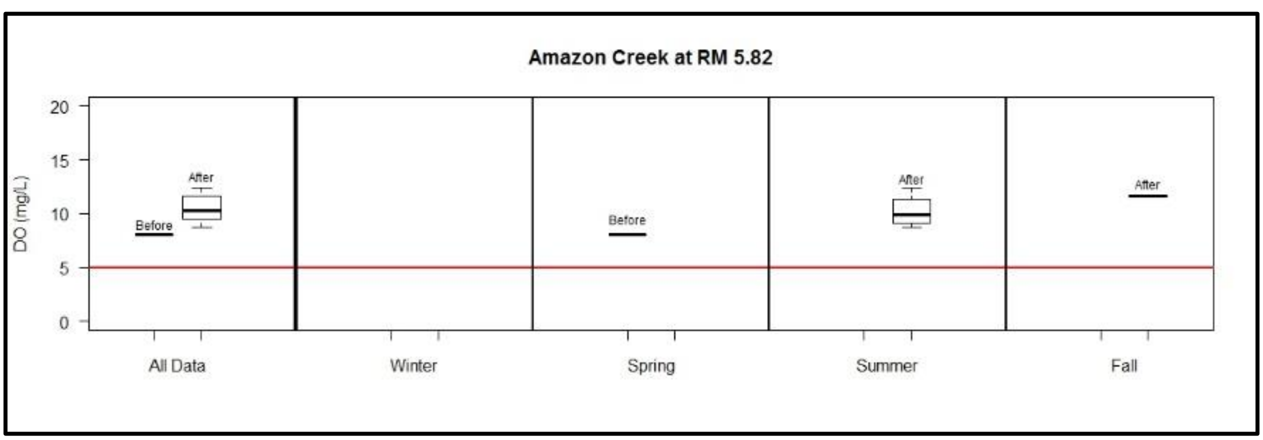

Figure 18: Box and whiskers plots of DO data on Amazon Creek at RM 5.82. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 18: Data summaries of DO on Amazon Creek at RM 5.82.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	**Before**	0	N/A						N/A
	After	6	8.1	8.9	10.1	11.3	12.4	0 %	
Winter	**Before**	0	N/A						N/A
	After	0	N/A						
Spring	**Before**	0	N/A						N/A
	After	1	8.1	8.1	8.1	8.1	8.1	0 %	
Summer	**Before**	0	N/A						N/A
	After	4	8.7	9.3	10.22	10.8	12.4	0 %	
Fall	**Before**	0	N/A						N/A
	After	1	11.6	11.6	11.6	11.6	11.6	0 %	

* Bold and shaded indicate State single sample criterion exceedance

Amazon Creek at High Pass Road

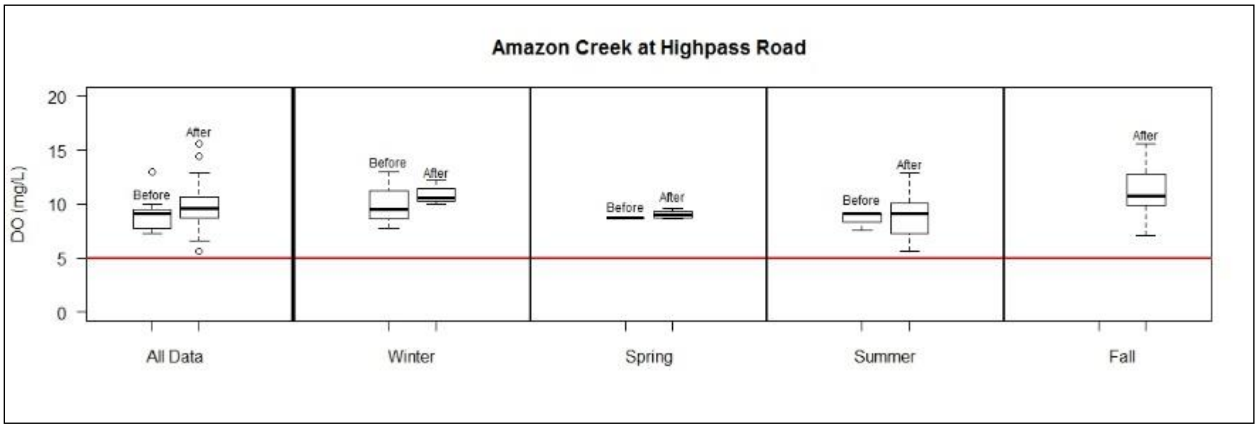

Figure 19: Box and whiskers plots of DO data on Amazon Creek at High Pass Road. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 19: Data summaries of DO on Amazon Creek at High Pass Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	∆ % Exceeded
All Data	**Before**	10	7.3	8.0	9.2	9.5	13.0	0 %	0 %
	After	27	5.6	8.8	8.9	10.7	15.6	0 %	
Winter	**Before**	3	7.8	8.7	10.1	11.3	13.0	0 %	0 %
	After	4	10.0	10.4	10.8	11.0	12.2	0 %	
Spring	**Before**	3	8.7	9.1	9.4	9.8	10.0	0 %	0 %
	After	7	7.4	8.3	8.7	9.1	9.6	0 %	
Summer	**Before**	3	7.6	8.4	8.6	9.1	9.1	0 %	0 %
	After	7	5.6	7.3	8.9	10.1	12.9	0 %	
Fall	**Before**	1	N/A						0 %
	After	9	7.1	9.9	11.2	12.8	15.6	0 %	

* Bold and shaded indicate State single sample criterion exceedance

Coyote Creek

Coyote Creek at Hamm Road

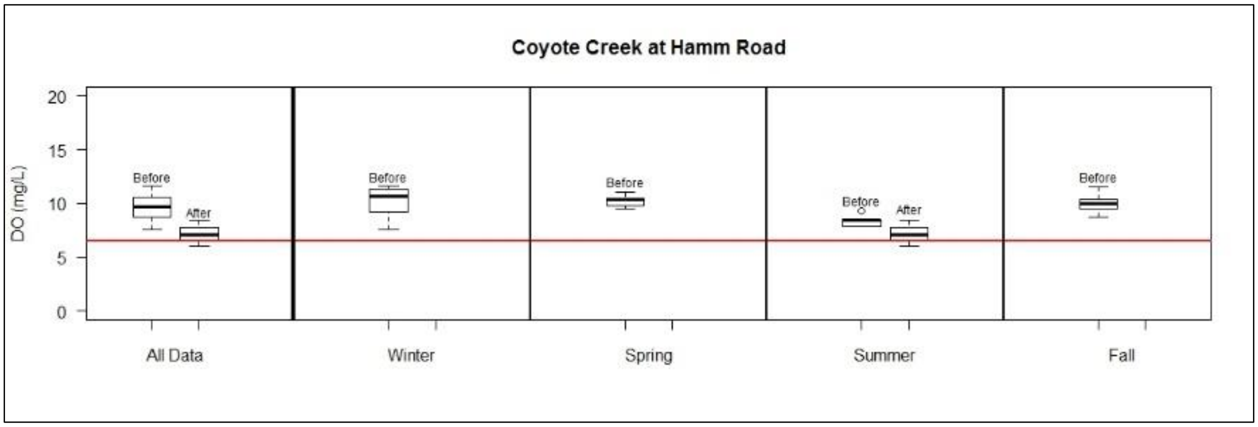

Figure 20: Box and whiskers plots of DO data on Coyote Creek at Hamm Road. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 20: Data summaries of DO on Coyote Creek at Hamm Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	22	7.5	8.8	9.7	10.5	11.6	0 %	+ 25 %
	After	4	**6.0**	6.8	7.2	7.5	8.4	25 %	
Winter	**Before**	6	7.5	9.6	10.2	1.2	11.6	0 %	N/A
	After	0	N/A						
Spring	**Before**	5	9.5	9.8	10.2	10.4	11.0	0 %	N/A
	After	0	N/A						
Summer	**Before**	5	7.9	7.9	8.4	8.4	9.3	0 %	+ 25 %
	After	4	**6.0**	6.8	7.2	7.5	8.4	25 %	
Fall	**Before**	6	8.7	9.5	10.0	10.4	11.5	0 %	N/A
	After	0	N/A						

* Bold and shaded indicate State single sample criterion exceedance

Coyote Creek at Powell Road

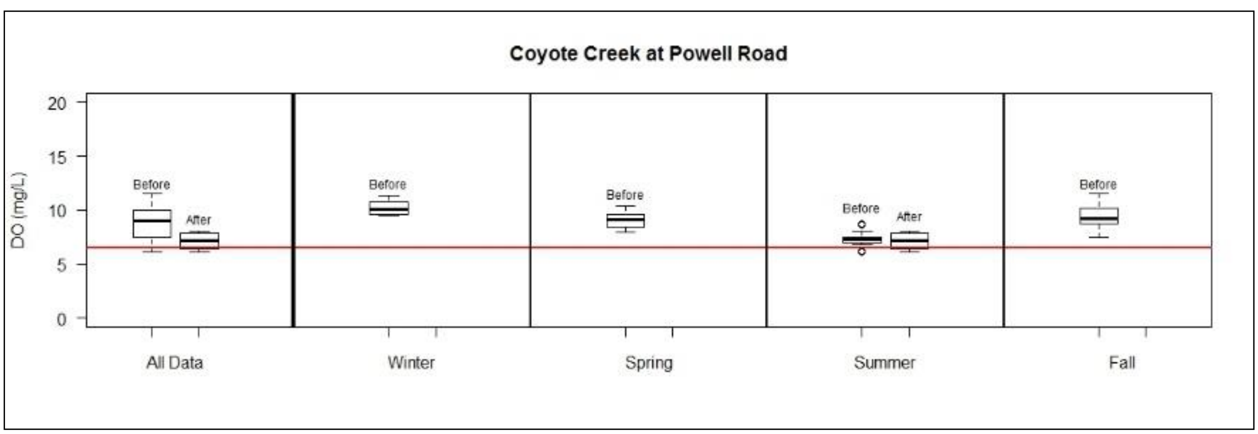

Figure 21: Box and whiskers plots of DO data on Coyote Creek at Powell Road. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 21: Data summaries of DO on Coyote Creek at Powell Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	39	**6.2**	7.5	8.9	10.0	11.5	5 %	+ 20 %
	After	4	**6.1**	6.6	7.1	7.7	8.1	25 %	
Winter	**Before**	9	9.5	9.6	10.2	10.7	11.3	0 %	N/A
	After	0	N/A						
Spring	**Before**	8	8.0	8.5	9.1	9.6	10.4	0 %	N/A
	After	0	N/A						
Summer	**Before**	13	**6.2**	7.0	7.4	7.5	8.7	15 %	+ 10 %

	After	4	**6.1**	6.6	7.1	7.7	8.1	25 %	
Fall	**Before**	9	7.5	8.7	9.4	10.2	11.5	0 %	N/A
	After	0	N/A						

* Bold and shaded indicate State single sample criterion exceedance

Coyote Creek at Petzold Road

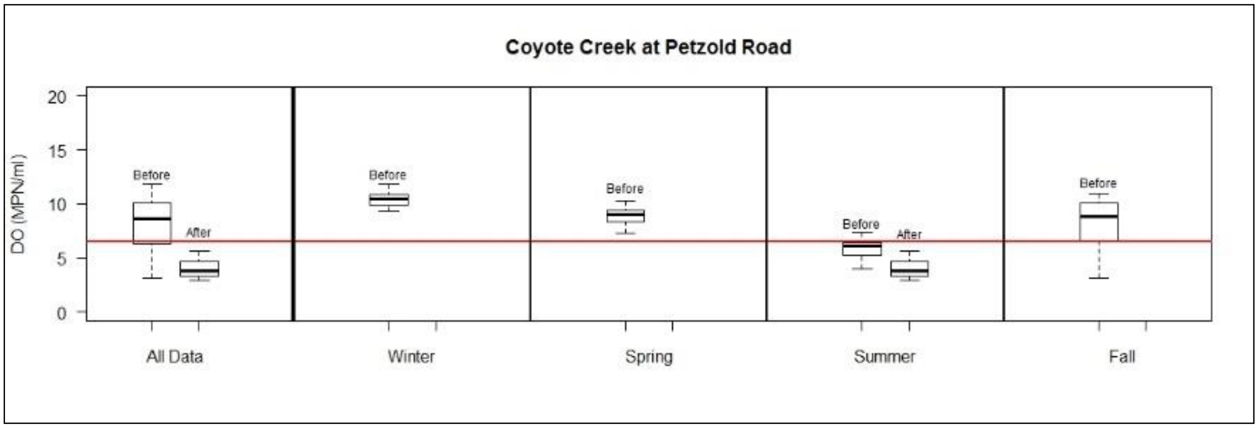

Figure 22: Box and whiskers plots of DO data on Coyote Creek at Petzold Road. The horizontal red line is State single sample exceedance level of DO (5.0 mg/L).

Table 22: Data summaries of DO on Coyote Creek at Petzold Road.

		N	Min	Q1	Geometric Mean	Q3	Max	% Exceeded	Δ % Exceeded
All Data	**Before**	39	**3.2**	**6.3**	8.2	10.1	11.8	33 %	+ 67 %
	After	3	**2.9**	**3.4**	**4.1**	**4.7**	**5.6**	100 %	
Winter	**Before**	9	9.4	9.9	10.5	10.8	11.8	0 %	N/A
	After	0	N/A						
Spring	**Before**	8	7.3	8.5	8.9	9.4	10.3	0 %	N/A
	After	0	N/A						
Summer	**Before**	12	**4.0**	**5.4**	**5.8**	**6.4**	7.4	83 %	+ 17 %
	After	3	**2.9**	**3.4**	**4.1**	**4.7**	**5.6**	100 %	
Fall	**Before**	10	**3.2**	6.9	8.3	10.1	11.0	30 %	N/A
	After	0	N/A						

* Bold and shaded indicate State single sample criterion exceedance

Appendix B

Fisher Exact Test for Independence

Bacteria (*E. coli*)

Before 2008

Table 1: Fisher exact test for seasonal dependence of *E. coli* exceeding single sample standards before 2008

	Upper Amazon						Lower Amazon		Coyote Creek		
	29th Ave.	**RR Cross**	**Royal Ave.**	**Willow**	**Div. Chan.**	**A-3 Drain**	**RM 5.82**	**High Pass Rd.**	**Hamm Rd.**	**Powell Rd.**	**Petzold Rd.**
Exceeds	38	12	24	6	18	17	0	10	2	6	8
Winter	8	2	2	0	2	1	0	3	0	0	2
Spring	9	6	5	3	2	5	0	2	0	4	3
Summer	12	1	11	1	11	8	0	2	2	0	0
Fall	9	3	6	2	3	3	0	3	0	2	3
Not Exceed	27	34	41	58	46	27	0	42	26	53	47
Winter	10	10	16	18	16	11	0	7	3	10	8
Spring	5	4	9	11	11	4	0	13	10	13	14
Summer	7	12	8	17	8	5	0	12	9	19	15
Fall	5	8	8	12	11	7	0	10	4	11	10
p-value	0.60	**0.04**	**0.02**	0.12	**0.01**	**0.03**	1.00	0.70	0.71	**0.05**	0.24

* **BOLD** and shaded indicates significant seasonal difference

After 2008

Table 2: Fisher exact test for seasonal dependence of *E. coli* exceeding single sample standards after 2008

	Upper Amazon						Lower Amazon		Coyote Creek		
	29th Ave.	**RR Cross**	**Royal Ave.**	**Willow**	**Div. Chan.**	**A-3 Drain**	**RM 5.82**	**High Pass Rd.**	**Hamm Rd.**	**Powell Rd.**	**Petzold Rd.**
Exceeds	29	16	13	5	8	11	1	6	0	0	0
Winter	8	5	6	2	3	3	0	3	0	0	0
Spring	4	2	2	1	0	1	0	1	0	0	0
Summer	11	5	3	1	3	6	1	1	0	0	0
Fall	6	4	2	1	2	1	0	1	0	0	0
Not Exceed	16	29	31	26	37	29	4	16	4	4	3
Winter	7	10	9	13	12	12	0	2	0	0	0
Spring	5	7	7	7	9	8	0	3	0	0	0
Summer	3	9	10	1	11	3	4	5	4	4	3
Fall	1	3	5	5	5	6	0	6	0	0	0
p-value	0.22	0.56	0.81	0.55	0.44	**0.04**	1.00	0.38	1.00	1.00	1.00

* **BOLD** and shaded indicates significant seasonal dependence

Dissolved Oxygen

Before 2008

Table 3: Fisher exact test for seasonal dependence of DO exceeding load capacity before 2008

	Upper Amazon						Lower Amazon		Coyote Creek		
	29th Ave.	**RR Cross**	**Royal Ave.**	**Willow**	**Div. Chan.**	**A-3 Drain**	**RM 5.82**	**High Pass Rd.**	**Hamm Rd.**	**Powell Rd.**	**Petzold Rd.**
Exceeds	3	10	7	1	8	4	0	0	0	2	13
Winter	0	0	0	0	0	0	0	0	0	0	0
Spring	0	4	2	0	0	0	0	0	0	0	0
Summer	3	5	5	1	7	3	0	0	0	2	10
Fall	0	1	0	0	1	1	0	0	0	0	3
Not Exceed	62	36	57	63	56	39	0	10	22	37	26
Winter	18	12	18	18	18	12	0	3	6	9	9
Spring	14	6	12	14	14	9	0	3	5	8	8
Summer	16	8	13	17	11	9	0	3	5	11	2
Fall	14	10	14	14	13	9	0	1	6	9	7
p-value	**0.06**	**0.02**	**0.02**	1.00	**0.01**	0.15	1.00	1.00	1.00	0.43	**0.01**

* **BOLD** and shaded indicates significant seasonal dependence

After 2008

Table 4: Fisher exact test for seasonal dependence of DO exceeding load capacity after 2008

	Upper Amazon						Lower Amazon		Coyote Creek		
	29th Ave.	**RR Cross**	**Royal Ave.**	**Willow**	**Div. Chan.**	**A-3 Drain**	**RM 5.82**	**High Pass Rd.**	**Hamm Rd.**	**Powell Rd.**	**Petzold Rd.**
Exceeds	1	8	7	1	4	7	0	0	0	1	3
Winter	0	1	0	1	0	0	0	0	0	0	0
Spring	0	3	2	0	2	0	0	0	0	0	0
Summer	1	4	5	0	2	5	0	0	0	1	3
Fall	0	0	0	0	0	2	0	0	0	0	0
Not Exceed	44	37	37	30	41	33	6	27	4	3	0
Winter	15	14	15	14	15	15	0	4	0	0	0
Spring	9	6	7	8	7	9	1	7	0	0	0
Summer	13	10	8	2	12	4	4	7	4	3	0
Fall	7	7	7	6	7	5	1	9	0	0	0
p-value	0.67	0.14	**0.02**	1.00	0.20	**0.01**	1.00	1.00	1.00	1.00	1.00

* **BOLD** and shaded indicates significant seasonal dependence

Appendix C

Wilcoxon rank-sum test Statistics/Summaries

Bacteria (*E. coli*)

Upper Amazon

Amazon Creek at 29th Avenue

Table 1: Amazon Creek at 29th Avenue *E. coli* Two-Sample Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	738	1594	0.43
After	764		
Winter			
Before	600	137	0.96
After	672		
Spring			
Before	634	62	0.97
After	592		
Summer			
Before	825	170	0.18
After	914		
Fall			
Before	900	56	0.63
After	881		

* **BOLD** and shaded indicates significance

Amazon Creek at Railroad Crossing

Table 2: Amazon Creek at Railroad Crossing *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	378	1068	0.80
After	420		
Winter			
Before	276	98	0.73
After	335		
Spring			
Before	595	31	0.25
After	466		
Summer			
Before	285	96	0.85
After	414		
Fall			
Before	404	54	0.18
After	553		

* **BOLD** and shaded indicates significance

Amazon Creek at Royal Avenue

Table 3: Amazon Creek at Royal Avenue *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	461	1322	0.50
After	403		

Winter			
Before	186	160	0.39
After	455		
Spring			
Before	457	47	0.31
After	288		
Summer			
Before	603	77	**0.08**
After	440		
Fall			
Before	596	56	0.65
After	424		

* **BOLD** and shaded indicates significance

Willow Creek at 18th Avenue

Table 4: Willow Creek at 18th Avenue *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	125	1106	0.44
After	199		
Winter			
Before	40	123	0.80
After	170		
Spring			
Before	270	46	0.49
After	133		
Summer			
Before	N/A		
After			
Fall			
Before	147	47	0.72
After	161		

* **BOLD** and shaded indicates significance

Amazon Diversion Channel at Royal Avenue

Table 5: Amazon Diversion Channel at Royal Avenue *E. coli* Two-Sample t-test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	344	1296	0.31
After	252		
Winter			
Before	119	146	0.70
After	177		
Spring			
Before	188	63	0.81
After	70		
Summer			
Before	674	70	**0.02**
After	404		
Fall			
Before	356	59	0.48
After	341		

* **BOLD** and shaded indicates significance

A-3 Drain at Terry Street

Table 6: A-3 Drain at Terry Street *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	702	734	0.20
After	350		
Winter			
Before	140	72	0.39
After	160		
Spring			
Before	939	28	0.29
After	299		
Summer			
Before	1264	52	0.69
After	836		
Fall			
Before	325	44	0.43
After	242		

*** BOLD** and shaded indicates significance

Lower Amazon

Amazon Creek at RM 5.82

Table 7: Amazon Creek at RM 5.82 *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	N/A		
After			
Fall			
Before	N/A		
After			

*** BOLD** and shaded indicates significance

Amazon Creek at High Pass Road

Table 8: Amazon Creek at High Pass Road *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	306	577	0.48
After	276		
Winter			
Before	394	10	0.47
After	190		

Spring			
Before	257	41	0.31
After	218		
Summer			
Before	167	56	0.28
After	244		
Fall			
Before	443	46	0.82
After	374		

* **BOLD** and shaded indicates significance

Coyote Creek

Coyote Creek at Hamm Road

Table 9: Coyote Creek at Hamm Road *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	172	25	0.74
After	84		
Fall			
Before	N/A		
After			

* **BOLD** and shaded indicates significance

Coyote Creek at Powell Road

Table 10: Coyote Creek at Powell Road *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	117	42	0.78
After	103		
Fall			
Before	N/A		
After			

* **BOLD** and shaded indicates significance

Coyote Creek at Petzold Road

Table 11: Coyote Creek at Petzold Road *E. coli* Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	72	30	0.54
After	161		
Fall			
Before	N/A		
After			

*** BOLD** and shaded indicates significance

Dissolved Oxygen

Upper Amazon

Amazon Creek at 29th Avenue

Table 12: Amazon Creek at 29th Avenue DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	8.91	1644	0.27
After	9.59		
Winter			
Before	11.14	177	0.13
After	11.47		
Spring			
Before	9.50	65	0.95
After	9.64		
Summer			
Before	6.08	185	**0.06**
After	7.09		
Fall			
Before	9.31	67	0.20
After	10.49		

* **BOLD** and shaded indicates significance

Amazon Creek at Railroad Crossing

Table 13: Amazon Creek at Railroad Crossing DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	7.73	1440	**0.01**
After	7.98		
Winter			
Before	9.68	121	0.14
After	10.45		
Spring			
Before	6.70	49	0.81
After	6.83		
Summer			
Before	5.60	104	0.56
After	5.72		
Fall			
Before	9.04	37	0.89
After	8.70		

* **BOLD** and shaded indicates significance

Amazon Creek at Royal Avenue

Table 14: Amazon Creek at Royal Avenue DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	8.28	1329	0.53

	Geometric Mean	Wilcoxon test statistic, W	p-value
After	7.96		
Winter			
Before	10.45	157	0.44
After	10.92		
Spring			
Before	7.44	48	0.36
After	6.59		
Summer			
Before	6.51	79	**0.09**
After	5.29		
Fall			
Before	8.79	39	0.46
After	8.14		

* **BOLD** and shaded indicates significance

Willow Creek at 18th Avenue

Table 15: Willow Creek at 18th Avenue DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	8.76	1334	**<0.01**
After	10.07		
Winter			
Before	10.43	181	**0.10**
After	11.15		
Spring			
Before	8.71	42	0.34
After	8.20		
Summer			
Before	N/A		
After			
Fall			
Before	9.13	56	0.28
After	10.27		

* **BOLD** and shaded indicates significance

Amazon Diversion Channel at Royal Avenue

Table 16: Amazon Diversion Channel at Royal Avenue DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	8.00	1369	0.66
After	7.88		
Winter			
Before	9.78	162	0.35
After	10.40		
Spring			
Before	7.94	42	0.19
After	6.66		
Summer			
Before	6.33	131	0.86
After	5.96		
Fall			
Before	7.92	48	0.94
After	7.87		

* **BOLD** and shaded indicates significance

A-3 Drain at Terry Street

Table 17: A-3 Drain at Terry Street DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	8.08	861	0.73
After	7.69		
Winter			
Before	9.98	95	0.83
After	9.70		
Spring			
Before	8.40	37	0.80
After	8.09		
Summer			
Before	7.46	25	**0.03**
After	4.61		
Fall			
Before	6.21	42	0.56
After	6.90		

* **BOLD** and shaded indicates significance

Lower Amazon

Amazon Creek at RM 5.82

Table 18: Amazon Creek at RM 5.82 DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	N/A		
After			
Fall			
Before	N/A		
After			

* **BOLD** and shaded indicates significance

Amazon Creek at High Pass Road

Table 19: Amazon Creek at High Pass Road DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	10.10	8	0.63
After	10.82		
Spring			
Before	9.40	5	0.25

After	8.67		
Summer			
Before	8.60	12	0.82
After	8.90		
Fall			
Before	N/A		
After			

* **BOLD** and shaded indicates significance

Coyote Creek

Coyote Creek at Hamm Road

Table 20: Coyote Creek at Hamm Road DO Wilcox on rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	8.38	2.5	**0.08**
After	7.15		
Fall			
Before	N/A		
After			

* **BOLD** and shaded indicates significance

Coyote Creek at Powell Road

Table 21: Coyote Creek at Powell Road DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value
All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	7.36	23	0.73
After	7.13		
Fall			
Before	N/A		
After			

* **BOLD** and shaded indicates significance

Coyote Creek at Petzold Road

Table 21: Coyote Creek at Petzold road DO Wilcoxon rank-sum test statistics of means, before and after 2008

	Geometric Mean	Wilcoxon test statistic, W	p-value

All Data			
Before	N/A		
After			
Winter			
Before	N/A		
After			
Spring			
Before	N/A		
After			
Summer			
Before	5.84	4	**0.05**
After	4.10		
Fall			
Before	N/A		
After			

* **BOLD** and shaded indicates significance

Appendix D

Linear Regression Statistics

Bacteria (*E. coli*)

Upper Amazon

Table 1: Summary of linear regression analysis of *E. coli* over time on Amazon Creek at 29th Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	110	0.43	-0.01	1.86	0.44	
	Before	65	0.45	-0.01	-1.99	0.72	NO p = 0.42
	After	45	0.39	0.02	12.23	0.16	
Winter	**Overall**	33	0.47	-0.03	0.51	0.91	
	Before	18	0.49	-0.05	12.39	0.74	NO p = 0.75
	After	15	0.49	-0.08	1.78	0.92	
Spring	**Overall**	23	0.42	-0.03	-3.48	0.52	
	Before	14	**0.40**	**0.13**	**-16.18**	**0.09**	NO p = 0.19
	After	9	0.39	-0.03	15.71	0.40	
Summer	**Overall**	33	0.36	0.07	6.91	0.07	
	Before	19	0.38	0.09	16.05	0.11	NO p = 0.37
	After	14	0.32	0.06	18.16	0.21	
Fall	**Overall**	21	0.43	-0.05	1.61	0.80	
	Before	14	0.49	-0.06	-6.52	0.61	NO p = 0.52
	After	7	0.28	0.15	24.57	0.21	

*Slope is E-10
** Bold and shaded indicate significance was found

Amazon Creek at Railroad Crossing

Table 2: Summary of linear regression analysis of *E. coli* over time on Amazon Creek at Railroad Crossing.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	91	0.57	-0.01	2.73	0.53	
	Before	46	0.55	-0.02	4.63	0.68	NO p= 0.90
	After	45	0.60	0.01	13.7	0.30	
Winter	**Overall**	27	0.53	-0.03	2.48	0.72	
	Before	12	0.52	-0.08	-8.87	0.71	NO p= 0.81
	After	15	0.56	-0.04	13.6	0.51	
Spring	**Overall**	19	0.62	-0.01	-10.4	0.34	
	Before	10	**0.63**	-0.12	5.29	0.85	NO p= 0.28
	After	9	0.68	-0.13	-9.50	0.77	
Summer	**Overall**	27	0.60	-0.03	4.11	0.61	
	Before	13	0.44	0.03	-21.1	0.27	NO p= 0.85
	After	14	0.68	0.09	43.3	0.16	
Fall	**Overall**	18	**0.52**	**0.11**	**17.3**	**0.10**	
	Before	11	0.62	0.02	28.3	0.30	NO p= 0.16
	After	7	0.30	-0.09	-13.1	0.51	

*Slope is E-10
** Bold and shaded indicates significance was found

Amazon Creek at Royal Avenue

Table 3: Summary of linear regression analysis of *E. coli* over time on Amazon Creek at Royal Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	109	0.70	0.01	-4.49	0.26	
	Before	65	0.70	0.02	-12.7	0.14	NO p= 0.50
	After	44	0.71	-0.02	4.91	0.76	

Winter	**Overall**	33	0.69	-0.01	5.71	0.40	
	Before	18	0.64	-0.05	-7.17	0.66	NO p= 0.70
	After	15	0.79	-0.08	-0.05	0.99	
Spring	**Overall**	23	0.75	0.01	-10.4	0.28	
	Before	14	0.77	0.01	-21.5	0.30	NO p= 0.65
	After	9	0.76	-0.11	15.9	0.66	
Summer	**Overall**	32	0.61	0.05	-10.4	0.11	
	Before	19	0.47	-0.05	-3.16	0.79	NO p= 0.46
	After	13	0.78	-0.06	17.7	0.61	
Fall	**Overall**	21	0.74	-0.03	-7.23	0.51	
	Before	14	0.81	0.07	-28.1	0.19	NO p= 0.30
	After	7	0.50	-0.01	-29.8	0.37	

*Slope is E-10
** Bold and shaded indicates significance was found

Willow Creek at 18th Avenue

Table 4: Summary of linear regression analysis of *E. coli* over time on Willow Creek at 18th Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	95	0.67	-0.01	0.83	0.84	
	Before	64	0.67	0.03	-13.4	0.11	NO p= 0.13
	After	31	0.65	-0.03	2.02	0.91	
Winter	**Overall**	33	0.52	-0.02	3.40	0.51	
	Before	18	0.36	0.01	-9.09	0.30	NO p= 0.70
	After	15	0.67	-0.06	11.7	0.64	
Spring	**Overall**	22	0.51	0.13	-13.9	0.06	
	Before	14	**0.46**	**0.33**	**-32.2**	**0.02**	NO p= 0.26
	After	8	0.58	-0.17	1.16	0.97	
Summer	**Overall**	20	0.79	0.03	17.4	0.22	
	Before	18	0.76	-0.05	-10.3	0.63	N/A
	After	2	N/A				
Fall	**Overall**	20	0.73	-0.02	-8.74	0.42	
	Before	14	0.73	0.13	-31.3	0.11	NO p= 0.23
	After	6	0.63	-0.04	-42.6	0.43	

*Slope is E-10
** Bold and shaded indicates significance was found

Amazon Diversion Channel at Royal Avenue

Table 5: Summary of linear regression analysis of *E. coli* over time on Amazon Diversion Channel at Royal Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	109	0.89	-0.01	-4.05	0.42	
	Before	64	0.92	0.01	-14.6	0.20	NO p= 0.12
	After	45	**0.82**	**0.05**	**31.6**	**0.08**	
Winter	**Overall**	33	1.01	-0.03	3.63	0.71	
	Before	18	1.00	-0.01	-21.1	0.37	NO p= 0.21
	After	15	0.99	0.10	56.8	0.14	
Spring	**Overall**	22	0.60	-0.04	-2.63	0.73	
	Before	13	0.72	-0.06	-11.2	0.59	NO p= 0.76
	After	9	0.42	-0.07	13.1	0.52	
Summer	**Overall**	30	**0.71**	**0.09**	**-15.0**	**0.05**	
	Before	19	0.54	-0.04	-6.35	0.64	YES p= 0.05
	After	11	0.82	0.07	48.4	0.18	
Fall	**Overall**	17	0.80	-0.05	0.68	0.95	
	Before	10	0.89	-0.06	-11.6	0.61	NO p= 0.47
	After	7	0.58	0.05	-40.7	0.30	

*Slope is E-10
** Bold and shaded indicates significance was found

A-3 Drain at Terry Street

Table 6: Summary of linear regression analysis of *E. coli* over time on A-3 Drain at Terry Street.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	83	0.70	-0.01	-4.53	0.41	
	Before	43	0.73	0.02	19.6	0.19	NO p= 0.87
	After	40	0.66	-0.02	-8.29	0.59	
Winter	**Overall**	27	0.64	-0.03	-3.36	0.69	
	Before	12	0.63	-0.05	18.6	0.52	NO p= 0.75
	After	15	0.69	-0.07	-4.21	0.87	
Spring	**Overall**	18	0.54	0.05	-12.3	0.19	
	Before	9	0.66	-0.14	7.02	0.83	NO p= 0.75
	After	9	0.44	-0.07	-14.0	0.51	
Summer	**Overall**	21	0.56	-0.01	7.32	0.41	
	Before	12	0.62	0.15	44.8	0.11	NO p= 0.18
	After	9	0.36	-0.03	17.6	0.40	
Fall	**Overall**	17	0.50	-0.06	3.43	0.73	
	Before	10	0.61	-0.12	3.03	0.91	NO p= 0.95
	After	7	0.38	-0.18	-6.00	0.80	

*Slope is E-10
** Bold and shaded indicates significance was found

Lower Amazon

Table 7: Summary of linear regression analysis of *E. coli* over time on Amazon Creek at RM 5.82.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	5	0.18	0.68	-1950	0.11	
	Before	0	N/A				N/A
	After	5	0.18	0.68	-1950	0.11	
Winter	**Overall**	0					
	Before	0	N/A				N/A
	After	0					
Spring	**Overall**	0					
	Before	0	N/A				N/A
	After	0					
Summer	**Overall**	5	0.18	0.68	-1950	0.11	
	Before	0	N/A				N/A
	After	5	0.18	0.68	-1950	0.11	
Fall	**Overall**	0	N/A				
	Before	0					N/A
	After	0					

*Slope is E-10
** Bold and shaded significance was found

Amazon Creek at High Pass Road

Table 8: Summary of linear regression analysis of *E. coli* over time on Amazon Creek at High Pass Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	64	0.66	-0.01	3.99	0.35	
	Before	42	**0.59**	**0.11**	**80.2**	**0.01**	**YES p= 0.04**
	After	22	0.85	-0.05	16.0	0.70	

Winter	**Overall**	15	0.91	-0.09	-2.65	0.87	
	Before	10	0.85	0.08	130	0.22	NO p= 0.20
	After	5	0.82	0.34	270	0.39	
Spring	**Overall**	19	0.52	0.01	7.43	0.32	
	Before	15	0.54	0.05	52.5	0.21	NO p= 0.40
	After	4	0.29	0.12	-107	0.36	
Summer	**Overall**	20	0.40	0.05	6.30	0.18	
	Before	14	**0.36**	**0.26**	**82.4**	**0.04**	**YES** **p= 0.07**
	After	6	0.34	0.02	-58.2	0.36	
Fall	**Overall**	17	0.83	-0.05	2.35	0.82	
	Before	10	**0.70**	**0.42**	**313**	**0.02**	NO p= 0.42
	After	7	0.72	-0.07	10.9	0.52	

*Slope is E-10
** Bold and shaded significance was found

Coyote Creek

Coyote Creek at Hamm Road

Table 9: Summary of linear regression analysis of *E. coli* over time on Coyote Creek at Hamm Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	32	**0.87**	**0.11**	**22.5**	**0.03**	
	Before	28	**0.88**	**0.10**	**245**	**0.05**	N/A
	After	4	0.12	-0.41	-164	0.76	
Winter	**Overall**	3	0.38	-0.90	-699	0.86	
	Before	3	0.38	-0.90	-699	0.86	N/A
	After	0	N/A				
Spring	**Overall**	10	0.32	-0.10	-28.4	0.68	
	Before	10	0.32	-0.10	-28.4	0.68	N/A
	After	0	N/A				
Summer	**Overall**	15	0.44	-0.07	-0.94	0.87	
	Before	11	0.49	0.04	118	0.27	NO p= 0.45
	After	4	0.12	-0.41	-164	0.76	
Fall	**Overall**	4	0.36	0.45	-2430	0.13	
	Before	4	0.36	0.45	-2430	0.13	N/A
	After	0	N/A				

*Slope is E-10
** Bold and increased font size indicates significance was found

Coyote Creek at Powell Road

Table 10: Summary of linear regression analysis of *E. coli* over time on Coyote Creek at Powell Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	63	0.44	-0.01	-3.21	0.53	
	Before	59	0.45	-0.01	-19.3	0.36	N/A
	After	4	0.41	-0.19	-1180	0.55	
Winter	**Overall**	10	0.26	-0.12	-3.63	0.91	
	Before	10	0.26	-0.12	-3.63	0.91	N/A
	After	0	N/A				
Spring	**Overall**	17	**0.37**	**0.21**	**-59.5**	**0.04**	
	Before	17	**0.37**	**0.21**	**-59.5**	**0.04**	N/A
	After	0	N/A				
Summer	**Overall**	23	0.44	-0.05	1.23	0.82	
	Before	19	0.44	0.02	49.4	0.56	NO p= 0.42
	After	4	0.41	-0.19	-1180	0.55	
Fall	**Overall**	11	0.53	-0.09	-1.27	0.98	

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
	Before	11	0.53	-0.09	-1.27	0.98	N/A
	After	0	N/A				

*Slope is E-10
** Bold and increased font size indicates significance was found

Coyote Creek at Petzold Road

Table 11: Summary of linear regression analysis of *E. coli* over time on Coyote Creek at Petzold Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	58	0.51	-0.02	-1.16	0.86	
	Before	55	0.50	-0.02	7.37	0.75	N/A
	After	3	0.75	-0.42	3140	0.64	
Winter	**Overall**	10	0.52	-0.09	31.6	0.61	
	Before	10	0.52	-0.09	31.6	0.61	N/A
	After	0	N/A				
Spring	**Overall**	17	0.44	0.06	-43.5	0.17	
	Before	17	0.44	0.06	-43.5	0.17	N/A
	After	0	N/A				
Summer	**Overall**	18	0.38	0.01	5.29	0.33	
	Before	15	0..31	-0.01	30.1	0.35	NO p= 0.45
	After	3	0.75	-0.42	3140	0.64	
Fall	**Overall**	13	0.62	-0.01	63.2	0.38	
	Before	13	0.62	-0.01	63.2	0.38	N/A
	After	0	N/A				

*Slope is E-10
** Bold and increased font size indicates significance was found

Dissolved Oxygen

Upper Amazon

Amazon Creek at 29th Avenue

Table 12: Summary of linear regression analysis of DO over time on Amazon Creek at 29th Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	110	2.41	0.01	14.1	0.30	
	Before	65	2.39	-0.01	-22.7	0.44	NO p = 0.36
	After	45	2.43	-0.01	36.7	0.49	
Winter	Overall	33	1.56	-0.02	7.58	0.62	
	Before	18	1.05	0.01	-28.7	0.29	NO p = 0.47
	After	15	2.04	-0.03	55.1	0.47	
Spring	Overall	23	1.34	-0.04	-5.18	0.76	
	Before	14	1.48	-0.07	-8.57	0.79	NO p = 0.62
	After	9	1.29	0.01	-61.4	0.33	
Summer	Overall	33	**1.47**	**0.06**	**26.8**	**0.08**	
	Before	19	1.58	-0.01	-37.1	0.36	**YES** **p = 0.05**
	After	14	**1.00**	**0.38**	**126**	**0.01**	
Fall	Overall	21	1.65	-0.02	17.6	0.47	
	Before	14	1.50	-0.07	-17.0	0.66	NO p = 0.24
	After	7	1.81	-0.04	-96.7	0.42	

*Slope is E-10
** Bold and shaded indicate significance was found

Amazon Creek at Railroad Crossing

Table 13: Summary of linear regression analysis of DO over time on Amazon Creek at Railroad Crossing.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	91	2.65	-0.01	7.27	0.72	
	Before	46	2.64	-0.02	-29.7	0.58	NO p = 0.72
	After	45	2.70	-0.02	30.0	0.61	
Winter	Overall	27	1.69	0.02	26.4	0.23	
	Before	12	1.17	-0.04	-40.9	0.45	NO p = 0.61
	After	15	2.05	-0.03	56.8	0.46	
Spring	Overall	19	2.13	-0.04	21.3	0.56	
	Before	10	2.32	-0.04	83.5	0.43	NO p = 0.77
	After	9	2.12	-0.13	31.6	0.75	
Summer	Overall	27	1.55	-0.04	4.40	0.83	
	Before	13	1.57	-0.09	-13.9	0.83	NO p = 0.93
	After	14	1.65	-0.08	20.8	0.77	
Fall	Overall	18	2.36	0.07	-70.1	0.14	
	Before	11	**2.56**	**0.24**	**-215**	**0.07**	NO p = 0.20
	After	7	1.56	0.09	-1.19	0.26	

*Slope is E-10
** Bold and shaded indicate significance was found

Amazon Creek at Royal Avenue

Table 14: Summary of linear regression analysis of DO over time on Amazon Creek at Royal Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	110	2.65	-0.01	-6.00	0.69	
	Before	64	2.50	-0.01	12.1	0.69	NO

	After	44	2.91	-0.02	6.02	0.93	p = 0.78
Winter	Overall	33	1.65	-0.02	11.4	0.48	
	Before	18	1.93	-0.06	-15.8	0.75	NO p = 0.76
	After	15	1.34	-0.04	32.1	0.52	
Spring	Overall	23	2.37	-0.03	-19.1	0.53	
	Before	14	2.42	-0.03	48.4	0.45	NO p = 0.32
	After	9	2.22	0.08	-131	0.24	
Summer	Overall	31	2.04	0.01	-21.7	0.32	
	Before	18	2.25	-0.03	41.1	0.47	NO p = 0.30
	After	13	1.62	-0.07	32.2	0.66	
Fall	Overall	21	1.34	-0.01	-18.5	0.35	
	Before	14	1.12	-0.08	-2.42	0.93	NO p = 0.85
	After	7	1.92	-0.18	-32.2	0.79	

*Slope is E-10
** Bold and shaded indicate significance was found

Willow Creek at 18th Avenue

Table 15: Summary of linear regression analysis of DO over time on Willow Creek at 18th Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	95	**2.23**	**0.06**	**3.77**	**0.01**	
	Before	64	2.12	-0.01	13.3	0.61	NO p = 0.54
	After	31	2.45	0.01	80.0	0.24	
Winter	Overall	33	2.23	-0.02	11.6	0.59	
	Before	18	**1.67**	**0.16**	**-79.1**	**0.06**	**YES** **p = 0.07**
	After	15	2.50	0.04	119	0.22	
Spring	Overall	22	1.52	-0.05	4.94	0.81	
	Before	14	1.54	0.02	44.8	0.28	NO p = 0.24
	After	8	1.34	0.06	89.7	0.28	
Summer	Overall	20	**1.49**	**0.17**	**56.1**	**0.04**	
	Before	18	1.57	0.03	54.1	0.23	N/A
	After	2	N/A				
Fall	Overall	20	1.97	0.01	29.2	0.32	
	Before	14	1.85	-0.03	35.5	0.46	NO p = 0.14
	After	6	1.85	0.33	-265	0.13	

*Slope is E-10
** Bold and shaded indicate significance was found

Amazon Diversion Channel at Royal Avenue

Table 16: Summary of linear regression analysis of DO over time on Amazon Diversion Channel at Royal Avenue.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	105	2.63	-0.01	-8.86	0.55	
	Before	64	2.65	0.01	-32.5	0.32	NO p = 0.66
	After	41	2.64	-0.02	17.8	0.76	
Winter	Overall	33	1.78	0.01	20.0	0.25	
	Before	18	1.84	-0.05	17.9	0.70	NO p = 0.99
	After	15	1.83	-0.06	30.5	0.65	
Spring	Overall	23	2.39	-0.03	-20.4	0.51	
	Before	14	2.28	-0.06	32.9	0.59	NO p = 0.48
	After	9	2.65	-0.12	40.8	0.75	
Summer	Overall	32	2.30	0.02	-30.5	0.21	
	Before	18	**2.81**	**0.12**	**-128**	**0.09**	NO p = 0.18
	After	14	1.10	-0.08	2.71	0.95	
Fall	Overall	21	2.21	-0.03	-19.1	0.56	
	Before	14	2.28	-0.05	-35.3	0.55	NO p = 0.73
	After	7	2.33	-0.08	-107	0.48	

*Slope is E-10
** Bold and shaded indicate significance was found

A-3 Drain at Terry Street

Table 17: Summary of linear regression analysis of DO over time on A-3 Drain at Terry Street.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	83	2.87	0.01	-2.34	0.30	
	Before	43	3.12	-0.01	-49.0	0.44	NO p = 0.82
	After	40	2.63	-0.01	-44.5	0.47	
Winter	Overall	27	2.71	-0.04	-45.4	0.90	
	Before	12	3.55	-0.05	105	0.53	NO p = 0.64
	After	15	1.98	-0.05	-37.4	0.61	
Spring	Overall	18	2.18	-0.05	-14.8	0.70	
	Before	9	2.45	-0.01	114	0.37	NO p = 0.23
	After	9	1.68	0.22	-139	0.11	
Summer	Overall	21	**2.68**	**0.24**	**-115**	**0.01**	
	Before	12	3.35	0.05	-172	0.24	NO p = 0.66
	After	9	1.43	-0.14	2.70	0.97	
Fall	Overall	17	1.70	-0.06	8.56	0.80	
	Before	10	1.65	-0.12	-11.7	0.87	NO p = 0.43
	After	7	1.80	0.01	-111	0.35	

*Slope is E-10
** Bold and shaded indicate significance was found

Lower Amazon

Amazon Creek at RM 5.82

Table 18: Summary of linear regression analysis of DO over time on Amazon Creek at RM 5.82.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	6	1.49	0.20	107	0.21	
	Before	0	N/A				N/A
	After	6	1.49	0.20	107	0.21	
Winter	Overall	0	N/A				
	Before	0					N/A
	After	0					
Spring	Overall	1	N/A				
	Before	0					N/A
	After	1					
Summer	Overall	4	**0.52**	**0.89**	**10700**	**0.04**	
	Before	0	N/A				N/A
	After	4	**0.52**	**0.89**	**10700**	**0.04**	
Fall	Overall	1	N/A				
	Before	0					N/A
	After	1					

*Slope is E-10
** Bold and shaded indicate significance was found

Amazon Creek at High Pass Road

Table 19: Summary of linear regression analysis of DO over time on Amazon Creek at High Pass Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	37	2.12	-0.01	14.9	0.42	
	Before	10	1.50	0.14	-998	0.15	NO p = 0.48
	After	27	2.30	-0.04	-31.2	0.78	
Winter	Overall	7	1.83	-0.14	16.9	0.63	

	Before	3	3.62	-0.87	2520	0.83	NO p = 0.92
	After	4	1.17	-0.50	2.58	0.99	
Spring	Overall	10	0.75	0.05	-15.4	0.26	
	Before	3	0.88	-0.79	-773	0.79	NO p = 0.24
	After	4	0.63	0.28	167	0.13	
Summer	Overall	10	2.15	-0.10	14.9	0.66	
	Before	3	1.22	-0.99	203	0.96	NO p = 0.26
	After	7	2.11	0.27	392	0.13	
Fall	Overall	10	2.57	0.22	-406	0.16	
	Before	1	N/A				N/A
	After	9	2.57	0.22	-406	0.16	

*Slope is E-10
** Bold and shaded indicate significance was found

Coyote Creek

Coyote Creek at Hamm Road

Table 20: Summary of linear regression analysis of DO over time on Coyote Creek at Hamm Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	26	**1.12**	**0.35**	**-52.8**	**0.01**	
	Before	22	1.23	-0.02	103	0.49	N/A
	After	4	**0.46**	**0.78**	**6330**	**0.07**	
Winter	Overall	6	1.68	-0.21	153	0.74	
	Before	6	1.68	-0.21	153	0.74	N/A
	After	0	N/A				
Spring	Overall	5	0.50	0.28	243	0.21	
	Before	5	0.50	0.28	243	0.21	N/A
	After	0	N/A				
Summer	Overall	9	**0.79**	**0.35**	**-25.6**	**0.06**	
	Before	5	0.65	-0.25	58.3	0.69	**YES p= 0.09**
	After	4	**0.46**	**0.78**	**6330**	**0.07**	
Fall	Overall	6	0.87	0.21	336	0.20	
	Before	6	0.87	0.21	336	0.20	N/A
	After	0	N/A				

*Slope is E-10
** Bold and shaded indicate significance was found

Coyote Creek at Powell Road

Table 21: Summary of linear regression analysis of DO over time on Coyote Creek at Powell Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	Overall	43	**1.38**	**0.10**	**-37.0**	**0.02**	
	Before	39	1.43	-0.02	-17.7	0.77	N/A
	After	4	**0.14**	**0.98**	**6180**	**0.01**	
Winter	Overall	9	0.68	-0.13	-16.3	0.78	
	Before	9	0.68	-0.13	-16.3	0.78	N/A
	After	0	N/A				
Spring	Overall	8	0.82	-0.13	-30.6	0.67	
	Before	8	0.82	-0.13	-30.6	0.67	N/A
	After	0	N/A				
Summer	Overall	17	0.80	-0.04	-5.82	0.57	
	Before	13	0.79	-0.06	-43.8	0.56	NO p= 0.84
	After	4	**0.14**	**0.98**	**6180**	**0.01**	
Fall	Overall	9	1.29	-0.10	58.3	0.61	
	Before	9	1.29	-0.10	58.3	0.61	N/A
	After	0	N/A				

*Slope is E-10
** Bold and shaded indicate significance was found

Coyote Creek at Petzold Road

Table 22: Summary of linear regression analysis of DO over time on Coyote Creek at Petzold Road.

		N	Residual Std. Error	Adjusted R^2	Slope*	Trend p-value	Significant Δ Slope
All Data	**Overall**	42	**2.23**	**0.15**	**-86.7**	**0.01**	
	Before	39	2.27	-0.02	36.6	0.78	N/A
	After	3	1.85	-0.81	3890	0.80	
Winter	**Overall**	9	**0.66**	**0.24**	**-161**	**0.10**	
	Before	9	**0.66**	**0.24**	**-161**	**0.10**	N/A
	After	0	N/A				
Spring	**Overall**	8	0.87	0.12	-174	0.21	
	Before	8	0.87	0.12	-174	0.21	N/A
	After	0	N/A				
Summer	**Overall**	15	**1.05**	**0.30**	**-40.3**	**0.02**	
	Before	12	1.02	-0.06	-705	0.55	NO p= 0.13
	After	3	1.85	-0.81	3890	0.80	
Fall	**Overall**	10	2.56	-0.11	70.9	0.79	
	Before	0	2.56	-0.11	70.9	0.79	N/A
	After	0	N/A				

*Slope is E-10
** Bold and shaded indicate significance was found

Appendix E

ARIMA forecast Models

Bacteria (*E. coli*)

Upper Amazon

Amazon Creek at 29th Avenue

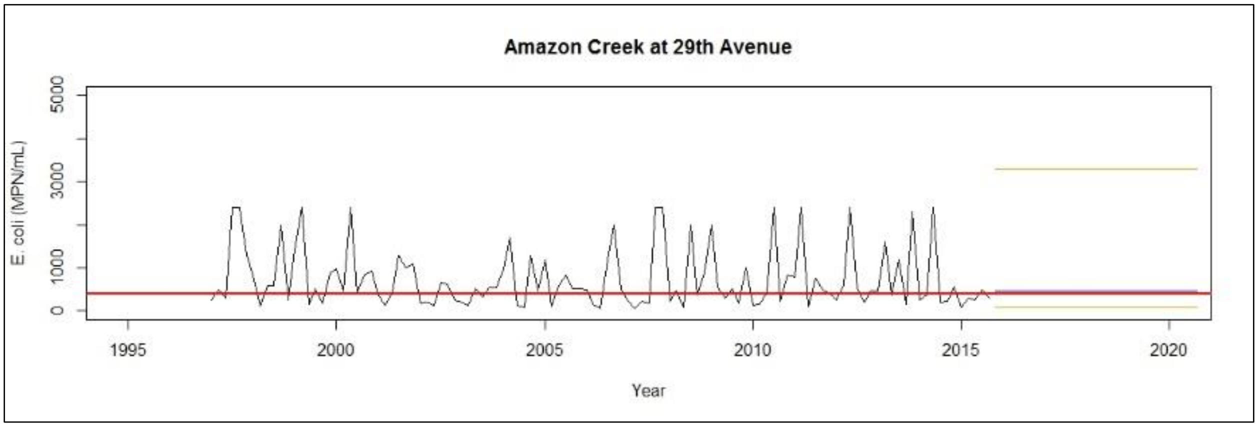

Figure 1: Forecasted *E. coli* concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Amazon Creek at Railroad Crossing

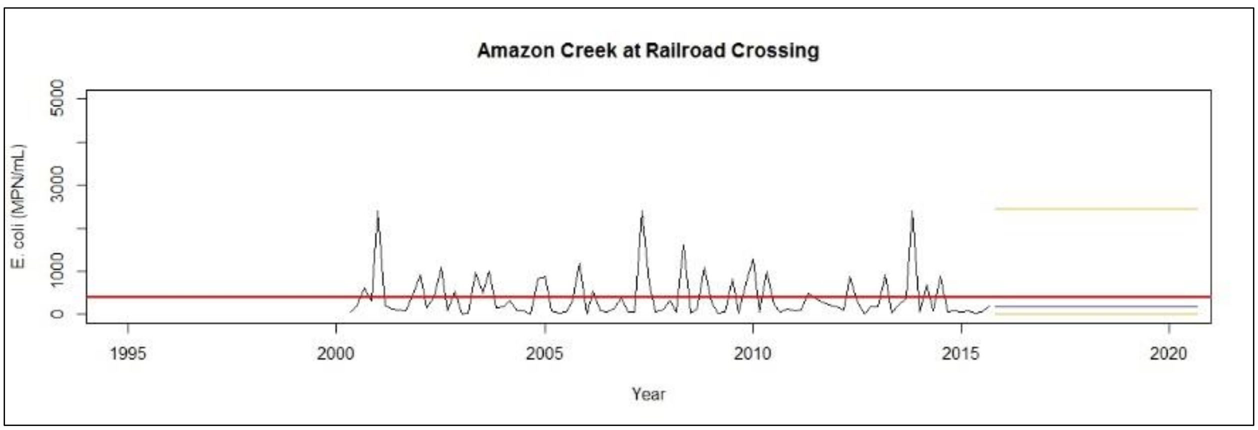

Figure 2: Forecasted *E. coli* concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Amazon Creek at Royal Avenue

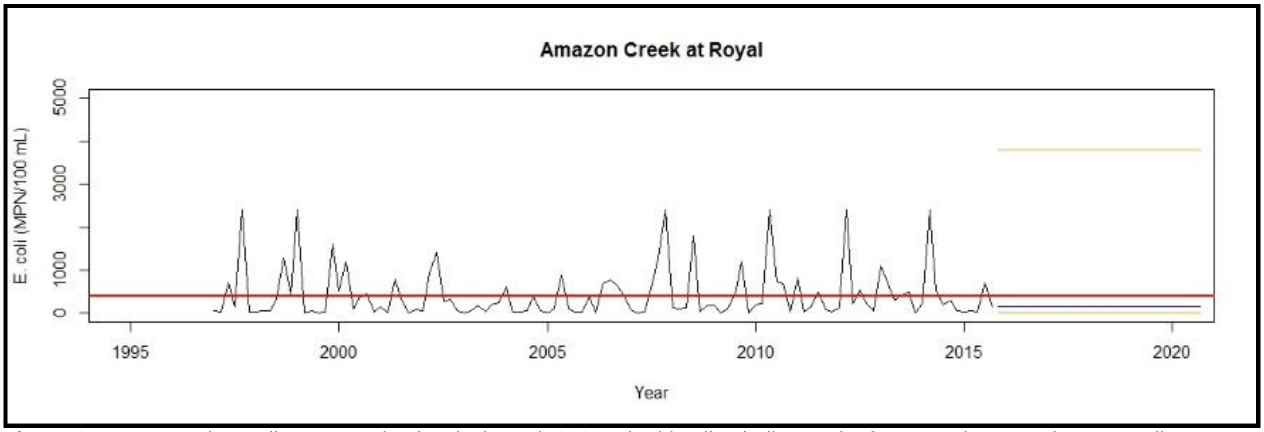

Figure 3: Forecasted *E. coli* concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Amazon Diversion Channel at Royal Avenue

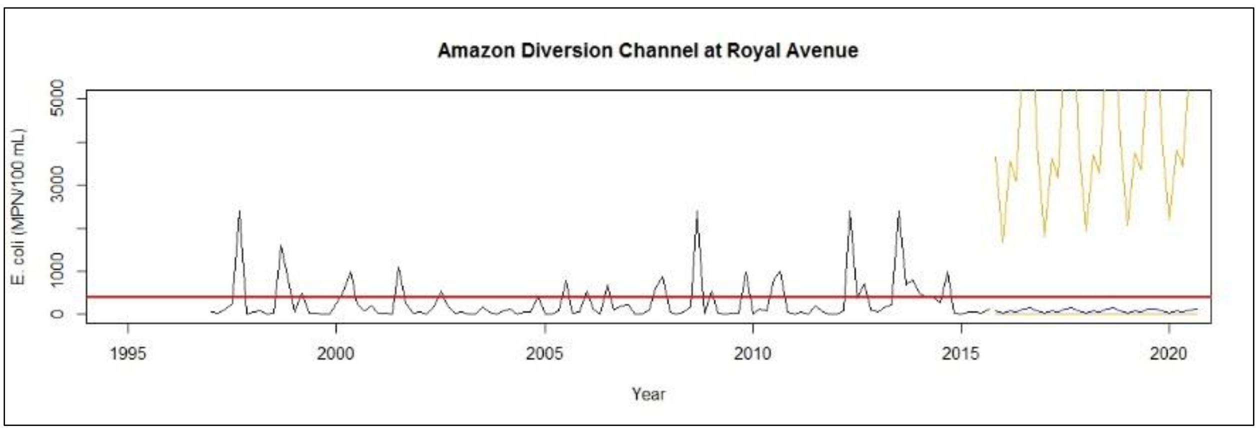

Figure 4: Forecasted *E. coli* concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

A-3 Drain at Terry Street

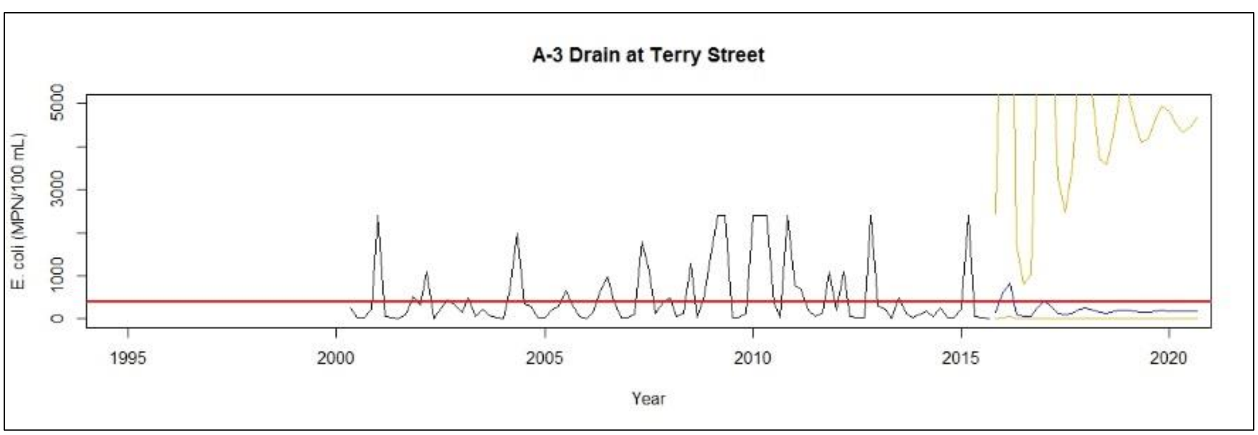

Figure 5: Forecasted *E. coli* concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (406 *E. coli* organisms (MPN)/100 ml).

Dissolved Oxygen

Upper Amazon

Amazon Creek at 29th Avenue

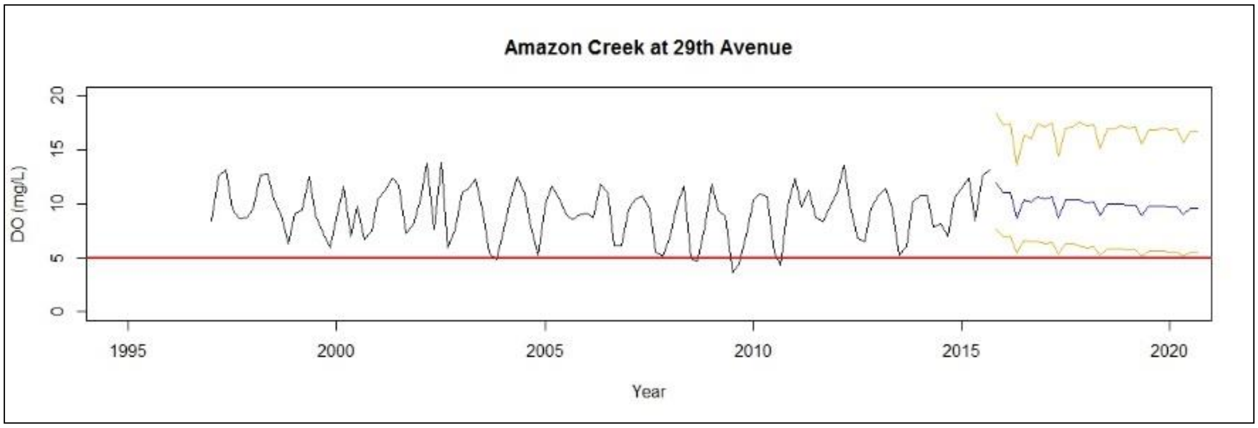

Figure 6: Forecasted DO concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (5.0 mg/L).

Amazon Creek at Railroad Crossing

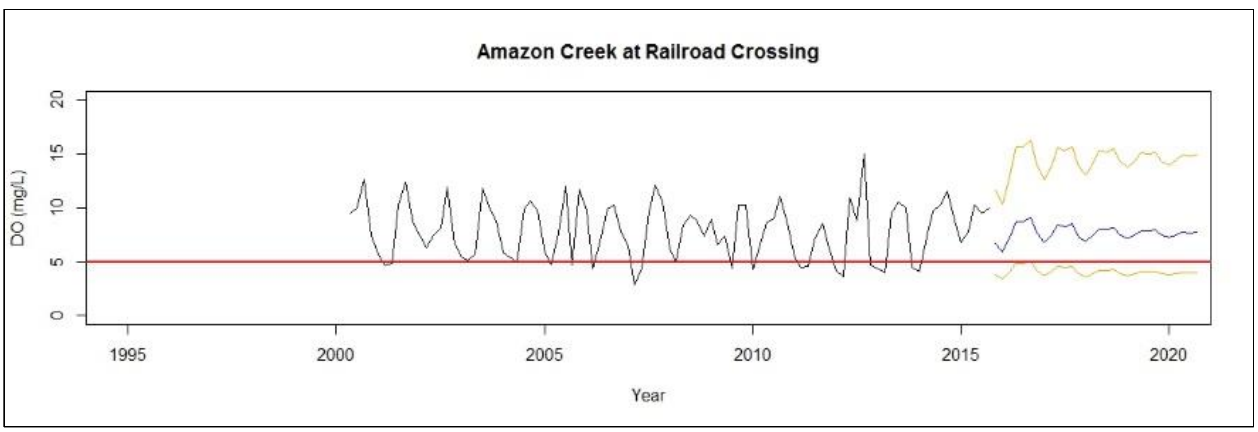

Figure 7: Forecasted DO concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (5.0 mg/L).

Amazon Creek at Royal Avenue

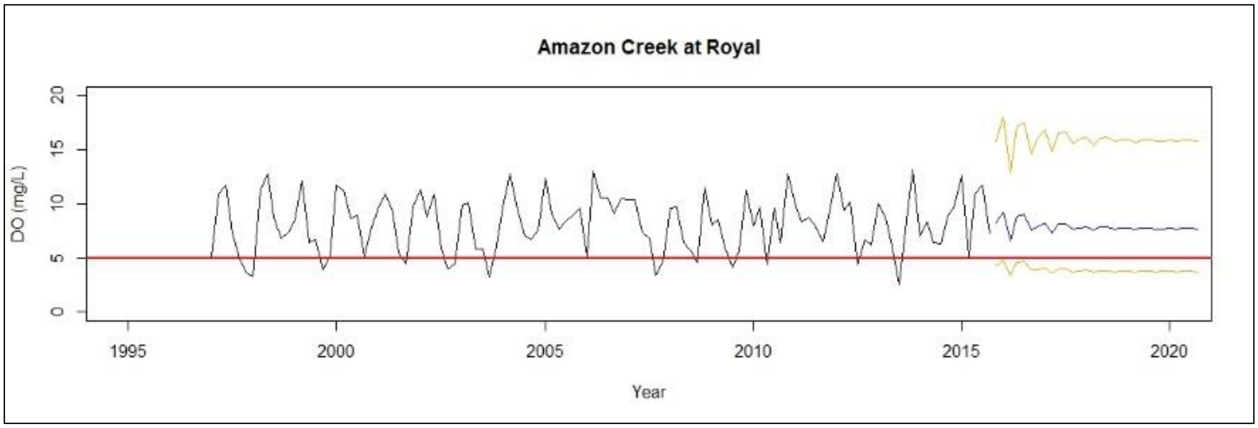

Figure 8: Forecasted DO concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (5.0 mg/L).

Amazon Diversion Channel at Royal Avenue

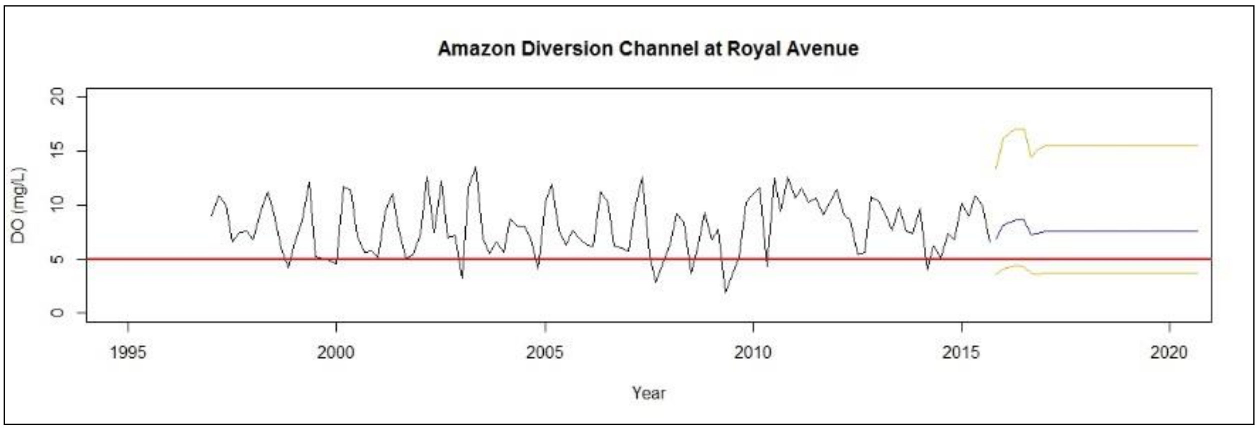

Figure 9: Forecasted DO concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (5.0 mg/L).

A-3 Drain at Terry Street

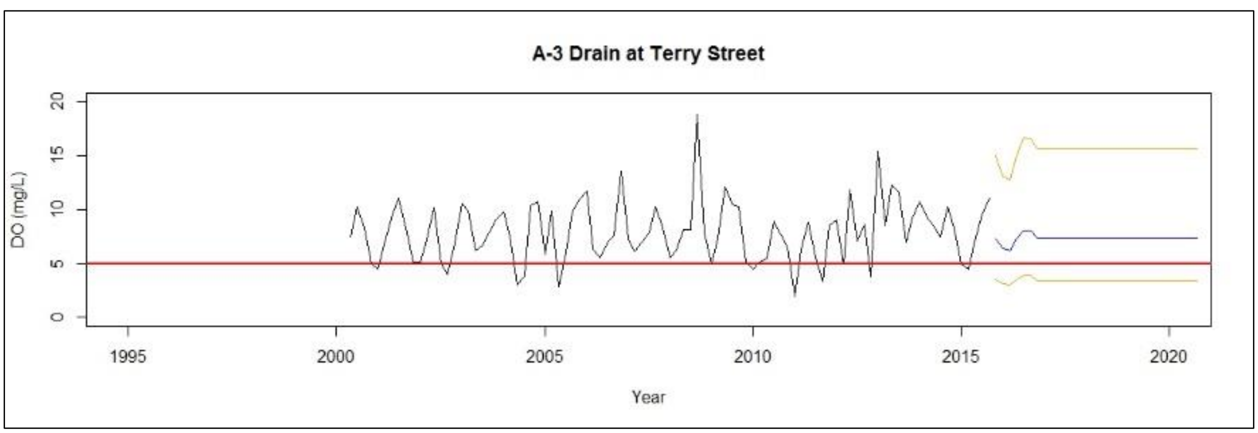

Figure 10: Forecasted DO concentration levels through 2020. The blue line indicates the forecasted mean. The orange lines indicate the upper and lower 95% confidence interval. The horizontal red line is State single sample exceedance level (5.0 mg/L).

Appendix F

Tested Parameters Data Summaries

Amazon Creek at 29th Avenue

Ammonia

Table 1: Overall and seasonal ammonia (mg/L) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.05	0.06	0.30	- 17 %
After	0.05	0.05	0.05	
Winter				
Before	0.05	0.05	0.05	0 %
After	0.05	0.05	0.05	
Spring				
Before	0.05	0.05	0.05	0 %
After	0.05	0.05	0.05	
Summer				
Before	0.05	0.05	0.10	0 %
After	0.05	0.05	0.05	
Fall				
Before	0.05	0.07	0.30	- 29 %
After	0.05	0.05	0.05	

Temperature

Table 2: Overall and seasonal temperature (°C) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	4.2	11.8	18.4	0.0 %
After	5.2	11.8	18.2	
Winter				
Before	4.2	8.2	11.3	- 6%
After	5.2	7.7	10.2	
Spring				
Before	9.5	12.6	15.4	- 3%
After	7.8	12.2	14.7	
Summer				
Before	11.4	15.9	18.4	+ 6%
After	15.1	16.9	19.9	
Fall				
Before	6.8	9.9	14.2	+ 20%
After	8.2	11.9	14.3	

Nitrate/Nitrite as N

Table 3: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.03	0.33	1.5	+ 9 %
After	0.08	0.36	2.7	
Winter				
Before	0.3	0.33	0.54	+ 18 %
After	0.21	0.39	1.10	
Spring				
Before	0.10	0.26	0.48	+ 77 %
After	0.11	0.46	2.70	
Summer				
Before	0.03	0.29	1.10	- 14 %
After	0.08	0.25	0.83	
Fall				
Before	0.09	0.46	1.50	- 13 %
After	0.12	0.40	0.79	

Ortho-phosphorus

Table 4: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.01	0.06	0.32	0 %
After	0.02	0.06	0.20	
Winter				
Before	0.01	0.05	0.08	- 20 %
After	0.02	0.04	0.07	
Spring				
Before	0.02	0.06	0.32	- 33 %
After	0.03	0.04	0.07	
Summer				
Before	0.04	0.07	0.15	+ 14 %
After	0.04	0.08	0.20	
Fall				
Before	0.03	0.07	0.10	- 14 %
After	0.05	0.06	0.09	

Total Phosphorus

Table 5: Overall and seasonal Total Phosphorus (mg/L) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.02	0.11	0.40	- 9 %
After	0.01	0.10	0.24	
Winter				
Before	0.04	0.11	0.22	- 18 %
After	0.01	0.09	0.24	
Spring				
Before	0.02	0.09	0.40	- 33 %
After	0.03	0.06	0.10	
Summer				
Before	0.05	0.13	0.38	- 8 %
After	0.08	0.12	0.23	
Fall				
Before	0.04	0.12	0.38	- 17 %
After	0.06	0.10	0.20	

Total Suspended Solids (TSS)

Table 6: Overall and seasonal TSS (mg/L) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.5	8.1	57.0	+ 15 %
After	1.0	9.3	83.0	
Winter				
Before	3.0	11.7	42.0	+ 57 %
After	1.0	18.4	83.0	
Spring				
Before	2.0	9.2	57.0	- 67 %
After	2.0	3.0	6.0	
Summer				
Before	2.0	5.7	19.0	+ 26 %
After	1.0	7.2	18.0	
Fall				
Before	0.5	5.8	13.0	- 60 %
After	1.0	2.3	4.0	

Biological Oxygen Demand (BOD)

Table 7: Overall and seasonal BOD (mg/L) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	1.0	3.0	24.0	+ 97 %
After	1.0	5.9	43.0	
Winter				
Before	1.0	1.3	6.0	- 15 %
After	1.0	1.1	2.0	
Spring				
Before	1.0	1.1	2.0	- 9 %
After	1.0	1.0	1.0	
Summer				
Before	1.0	1.6	9.0	+ 31 %
After	1.0	2.1	9.0	
Fall				
Before	1.0	1.1	2.0	- 9 %
After	1.0	1.0	1.0	

Chemical Oxygen Demand (COD)

Table 8: Overall and seasonal COD (mg/L) data summary on Amazon creek at 29th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	1.0	6.5	35.0	+ 31 %
After	1.0	8.5	41.0	
Winter				
Before	5.0	7.5	24.0	+ 96 %
After	2.5	14.7	43.0	
Spring				
Before	5.0	8.4	16.0	- 12 %
After	2.5	7.4	18.0	
Summer				
Before	5.0	8.7	35.0	+ 74 %
After	2.5	15.1	41.0	
Fall				
Before	5.0	8.2	16.0	+ 50 %
After	5.0	12.3	17.0	

Amazon Creek at Railroad Crossing

Ammonia

Table 9: Overall and seasonal ammonia (mg/L) data summary on Amazon Creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.00	0.05	0.20	+ 40 %
After	0.05	0.07	0.60	
Winter				
Before	0.05	0.06	0.20	- 17 %
After	0.05	0.05	0.05	
Spring				
Before	0.05	0.05	0.05	0 %
After	0.05	0.05	0.05	
Summer				
Before	0.05	0.05	0.05	+ 80 %
After	0.05	0.09	0.60	
Fall				
Before	0.05	0.05	0.05	+ 80 %
After	0.05	0.09	0.30	

Temperature

Table 10: Overall and seasonal temperature (°C) data summary on Amazon Creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean

All Data				
Before	5.7	14.4	25.2	- 7 %
After	3.7	13.4	24.1	
Winter				
Before	7.4	9.4	13.3	- 22 %
After	3.7	7.3	10.8	
Spring				
Before	11.4	18.0	22.6	- 16 %
After	8.3	15.2	18.9	
Summer				
Before	15.7	20.2	25.2	- 1 %
After	15.4	20.0	24.1	
Fall				
Before	5.7	9.7	15.8	+ 14 %
After	7.4	11.1	13.9	

Nitrate/Nitrite as N

Table 11: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on Amazon Creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.03	0.25	0.79	+ 20 %
After	0.03	0.30	1.20	
Winter				
Before	0.03	0.28	0.56	+ 21 %
After	0.18	0.34	0.63	
Spring				
Before	0.03	0.17	0.31	- 6 %
After	0.03	0.16	0.33	
Summer				
Before	0.03	0.08	0.36	+ 113 %
After	0.03	0.17	0.84	
Fall				
Before	0.03	0.49	0.79	+ 29 %
After	0.12	0.63	1.20	

Ortho-phosphorus

Table 12: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Amazon Creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.01	0.05	0.34	- 20 %
After	0.01	0.04	0.18	
Winter				
Before	0.01	0.06	0.10	- 50 %
After	0.01	0.03	0.08	
Spring				
Before	0.01	0.04	0.11	0 %
After	0.04	0.04	0.18	
Summer				
Before	0.01	0.04	0.24	- 25 %
After	0.01	0.03	0.12	
Fall				
Before	0.01	0.05	0.34	0 %
After	0.03	0.05	0.07	

Total Phosphorus

Table 13: Overall and seasonal Total Phosphorus (mg/L) data summary on Amazon creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.03	0.11	0.28	+ 9 %

After	0.02	0.12	0.34	
Winter				
Before	0.04	0.08	0.17	0 %
After	0.02	0.08	0.18	
Spring				
Before	0.04	0.14	0.20	- 21 %
After	0.03	0.11	0.17	
Summer				
Before	0.03	0.14	0.23	+ 14 %
After	0.08	0.16	0.34	
Fall				
Before	0.05	0.09	0.28	+ 11 %
After	0.08	0.10	0.16	

Total Suspended Solids (TSS)

Table 14: Overall and seasonal TSS (mg/L) data summary on Amazon Creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	4.0	19.0	71.0	+ 4 %
After	3.2	19.8	80.0	
Winter				
Before	4.0	8.4	25.0	+ 39 %
After	3.2	11.7	53.0	
Spring				
Before	5.0	18.2	29.0	+ 15 %
After	4.0	21.0	46.0	
Summer				
Before	21.0	36.8	71.0	- 5 %
After	6.8	34.8	80.0	
Fall				
Before	4.0	10.0	19.0	- 46 %
After	3.4	5.4	8.0	

Biological Oxygen Demand (BOD)

Table 15: Overall and seasonal BOD (mg/L) data summary on Amazon Creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	1.0	1.6	6.0	+ 19 %
After	1.0	1.9	10.0	
Winter				
Before	1.0	1.3	2.0	0 %
After	1.0	1.3	3.0	
Spring				
Before	1.0	1.5	3.0	+ 27 %
After	1.0	1.9	3.0	
Summer				
Before	1.0	2.3	6.0	+ 17 %
After	1.0	2.7	10.0	
Fall				
Before	1.0	1.2	3.0	+ 17 %
After	1.0	1.4	2.0	

Chemical Oxygen Demand (COD)

Table 15: Overall and seasonal COD (mg/L) data summary on Amazon Creek at Railroad Crossing, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	5.0	14.1	41.0	+ 31 %
After	2.5	18.5	46.0	
Winter				
Before	5.0	9.9	21.0	+ 64 %
After	2.5	16.2	32.0	
Spring				
Before	5.0	16.1	33.0	+ 1 %

After	5.0	16.3	30.0	
Summer				
Before	5.0	17.6	41.0	+ 32 %
After	11.0	23.2	46.0	
Fall				
Before	5.0	12.6	22.0	+ 30 %
After	9.0	16.4	26.0	

Amazon Creek at Royal Avenue

Ammonia

Table 16: Overall and seasonal ammonia (mg/L) data summary on Amazon Creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.00	0.04	0.30	+ 75 %
After	0.00	0.07	0.90	
Winter				
Before	0.05	0.06	0.16	- 17 %
After	0.05	0.05	0.05	
Spring				
Before	0.05	0.05	0.05	+ 20 %
After	0.05	0.06	0.10	
Summer				
Before	0.05	0.08	0.30	+ 50 %
After	0.01	0.12	0.90	
Fall				
Before	0.05	0.05	0.10	+ 20 %
After	0.05	0.06	0.10	

Temperature

Table 17: Overall and seasonal temperature (°C) data summary on Amazon Creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	3.4	15.4	26.7	- 15 %
After	3.6	13.1	23.4	
Winter				
Before	3.4	10.1	13.7	- 28 %
After	3.6	7.3	10.8	
Spring				
Before	12.3	19.0	25.0	-18 %
After	8.6	15.5	18.3	
Summer				
Before	16.0	21.5	26.7	- 10 %
After	15.0	19.4	23.4	
Fall				
Before	6.4	10.4	19.2	+ 1 %
After	6.4	10.5	19.2	

Nitrate/Nitrite as N

Table 18: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on Amazon creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.03	0.22	1.40	- 27 %
After	0.03	0.28	1.00	
Winter				
Before	0.03	0.26	0.72	+ 27 %
After	0.16	0.33	0.55	
Spring				
Before	0.03	0.16	0.38	- 31 %
After	0.03	0.11	0.24	
Summer				

Before	0.03	0.05	0.25	+ 200 %
After	0.03	0.15	0.75	
Fall				
Before	0.03	0.44	1.40	+ 14 %
After	0.03	0.50	1.40	

Ortho-phosphorus

Table 19: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Amazon creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.01	0.04	0.49	- 25 %
After	0.01	0.03	0.08	
Winter				
Before	0.01	0.04	0.08	- 25 %
After	0.01	0.03	0.06	
Spring				
Before	0.01	0.03	0.08	- 50 %
After	0.01	0.02	0.03	
Summer				
Before	0.01	0.06	0.49	+ 300 %
After	0.01	0.02	0.06	
Fall				
Before	0.02	0.05	0.09	0 %
After	0.02	0.05	0.09	

Total Phosphorus

Table 20: Overall and seasonal Total Phosphorus (mg/L) data summary on Amazon Creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.02	0.12	0.78	- 17 %
After	0.03	0.10	0.47	
Winter				
Before	0.06	0.14	0.78	- 36 %
After	0.04	0.09	0.17	
Spring				
Before	0.02	0.10	0.26	- 10 %
After	0.03	0.09	0.22	
Summer				
Before	0.02	0.12	0.36	+ 8 %
After	0.04	0.13	0.47	
Fall				
Before	0.05	0.14	0.32	- 7 %
After	0.05	0.13	0.32	

Total Suspended Solids (TSS)

Table 21: Overall and seasonal TSS (mg/L) data summary on Amazon Creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	3.0	24.7	97.0	- 21 %
After	2.6	19.5	170.0	
Winter				
Before	6.0	17.2	43.0	- 19 %
After	2.6	13.9	62.0	
Spring				
Before	5.0	26.4	89.0	- 49 %
After	3.4	13.4	33.0	
Summer				
Before	4.0	33.3	97.0	+ 13 %
After	5.0	37.5	170.0	
Fall				
Before	3.0	21.1	89.0	- 24 %
After	3.0	16.0	89.0	

Biological Oxygen Demand (BOD)

Table 22: Overall and seasonal BOD (mg/L) data summary on Amazon Creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	1.0	1.9	7.0	- 11 %
After	1.0	1.7	6.5	
Winter				
Before	1.0	1.6	5.0	- 19 %
After	1.0	1.3	3.0	
Spring				
Before	1.0	2.1	4.0	- 19 %
After	1.0	1.7	4.0	
Summer				
Before	1.0	2.5	7.0	- 4 %
After	1.0	2.4	6.5	
Fall				
Before	1.0	1.6	4.0	- 6 %
After	1.0	1.5	4.0	

Chemical Oxygen Demand (COD)

Table 23: Overall and seasonal COD (mg/L) data summary on Amazon Creek at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.5	13.8	47.0	+ 54 %
After	0.0	21.3	112.0	
Winter				
Before	0.5	10.9	29.0	+ 6 %
After	2.5	17.2	35.0	
Spring				
Before	0.5	19.2	36.0	- 4 %
After	0.5	15.1	33.0	
Summer				
Before	0.5	14.1	47.0	+ 88 %
After	16.0	26.5	67.0	
Fall				
Before	0.5	11.9	28.0	+ 56 %
After	0.5	18.6	112.0	

Willow Creek at 18th Avenue

Ammonia

Table 24: Overall and seasonal ammonia (mg/L) data summary on Willow Creek at 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.00	0.03	0.05	+ 67 %
After	0.05	0.05	0.05	
Winter				
Before	0.05	0.05	0.05	0 %
After	0.05	0.05	0.05	
Spring				
Before	0.05	0.05	0.05	0 %
After	0.05	0.05	0.05	
Summer				
Before	0.05	0.05	0.05	0 %
After	0.05	0.05	0.05	
Fall				
Before	0.05	0.05	0.05	0 %
After	0.05	0.05	0.05	

Temperature

Table 25: Overall and seasonal temperature (°C) data summary on Willow Creek at 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	3.2	11.6	20.5	- 15 %
After	3.0	9.9	19.2	
Winter				
Before	3.2	8.2	15.3	- 21 %
After	3.0	6.5	9.5	
Spring				
Before	10.1	14.9	20.0	- 11 %
After	7.8	13.3	16.3	
Summer				
Before	11.5	16.4	20.5	+ 7 %
After	15.8	17.5	19.2	
Fall				
Before	4.6	8.6	14.6	+ 28 %
After	8.5	11.0	13.2	

Nitrate/Nitrite as N

Table 26: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on Willow Creek at 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.03	0.08	0.63	- 38 %
After	0.03	0.05	0.39	
Winter				
Before	0.03	0.11	0.63	- 55 %
After	0.03	0.05	0.13	
Spring				
Before	0.03	0.03	0.08	0 %
After	0.03	0.03	0.03	
Summer				
Before	0.03	0.04	0.13	+ 500 %
After	0.09	0.24	0.39	
Fall				
Before	0.03	0.13	0.34	- 77 %
After	0.03	0.03	0.03	

Ortho-phosphorus

Table 27: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Willow Creek at 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.01	0.04	0.49	- 50 %
After	0.01	0.02	0.06	
Winter				
Before	0.01	0.04	0.11	- 50 %
After	0.01	0.02	0.06	
Spring				
Before	0.01	0.03	0.11	- 67 %
After	0.01	0.01	0.02	
Summer				
Before	0.01	0.03	0.12	0 %
After	0.02	0.03	0.03	
Fall				
Before	0.01	0.09	0.49	- 78 %
After	0.01	0.02	0.02	

Total Phosphorus

Table 28: Overall and seasonal Total Phosphorus (mg/L) data summary on Willow Creek 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				

Before	0.01	0.06	0.15	0 %
After	0.02	0.06	0.15	
Winter				
Before	0.01	0.06	0.15	+ 17 %
After	0.02	0.07	0.15	
Spring				
Before	0.02	0.04	0.08	+ 75 %
After	0.02	0.07	0.14	
Summer				
Before	0.04	0.07	0.12	- 43 %
After	0.03	0.04	0.04	
Fall				
Before	0.03	0.06	0.09	0 %
After	0.02	0.06	0.13	

Total Suspended Solids (TSS)

Table 29: Overall and seasonal TSS (mg/L) data summary on Willow Creek at 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.5	9.4	46.0	- 31 %
After	0.5	6.5	26.0	
Winter				
Before	0.5	4.8	12.0	+ 63 %
After	0.5	7.8	26.0	
Spring				
Before	0.5	6.5	13.0	+ 8 %
After	2.0	7.0	25.0	
Summer				
Before	0.5	16.8	46.0	- 85 %
After	2.0	2.6	3.2	
Fall				
Before	0.5	9.2	29.0	- 60 %
After	0.5	3.7	9.5	

Biological Oxygen Demand (BOD)

Table 30: Overall and seasonal BOD (mg/L) data summary on Willow Creek at 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	1.0	1.5	10.0	- 27 %
After	1.0	1.1	3.0	
Winter				
Before	1.0	1.0	1.0	0 %
After	1.0	1.0	1.0	
Spring				
Before	1.0	1.1	2.0	+ 18 %
After	1.0	1.3	3.0	
Summer				
Before	1.0	2.6	10.0	- 62 %
After	1.0	1.0	1.0	
Fall				
Before	1.0	1.2	3.0	- 17 %
After	1.0	1.0	1.0	

Chemical Oxygen Demand (COD)

Table 31: Overall and seasonal COD (mg/L) data summary on Willow Creek at 18th Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	5.0	11.8	97.0	+ 9 %
After	2.5	12.9	32.0	
Winter				
Before	5.0	6.8	16.0	+ 109 %
After	2.5	14.2	32.0	
Spring				

Before	5.0	12.8	28.0	- 29 %
After	5.0	9.1	16.0	
Summer				
Before	5.0	18.8	97.0	- 18 %
After	13.0	15.5	18.0	
Fall				
Before	5.0	8.4	19.0	+ 64 %
After	5.0	13.8	29.0	

Amazon Diversion Channel at Royal Avenue

Ammonia

Table 32: Overall and seasonal ammonia (mg/L) data summary on Amazon Diversion Channel at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.1	0.1	0.30	0 %
After	0.1	0.1	0.8	
Winter				
Before	0.1	0.1	0.1	0 %
After	0.1	0.1	0.1	
Spring				
Before	0.1	0.1	0.3	0 %
After	0.1	0.1	0.2	
Summer				
Before	0.1	0.1	0.2	0 %
After	0.1	0.1	0.8	
Fall				
Before	0.1	0.1	0.1	0 %
After	0.1	0.1	0.1	

Temperature

Table 33: Overall and seasonal temperature (°C) data summary on Amazon Diversion Channel at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	3.2	15.7	30.5	- 11 %
After	3.9	14.0	24.2	
Winter				
Before	3.2	10.3	17.4	- 20 %
After	3.9	8.2	12.9	
Spring				
Before	13.8	20.0	26.8	- 18 %
After	9.2	16.4	19.4	
Summer				
Before	16.4	21.6	30.5	- 6 %
After	15.1	20.2	24.2	
Fall				
Before	5.3	10.2	17.7	+ 6 %
After	6.9	10.8	14.8	

Nitrate/Nitrite as N

Table 34: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on Amazon Diversion Channel at Royal Avenue, before/after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.03	0.31	1.30	- 13 %
After	0.03	0.27	1.20	
Winter				

Before	0.03	0.46	1.2	+ 9 %
After	0.06	0.50	0.99	
Spring				
Before	0.03	0.14	0.55	- 43 %
After	0.03	0.08	0.19	
Summer				
Before	0.03	0.17	0.92	- 6 %
After	0.03	0.16	1.20	
Fall				
Before	0.03	0.44	1.30	- 48 %
After	0.16	0.23	0.28	

Ortho-phosphorus

Table 35: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Amazon Diversion Channel at Royal Avenue, before/after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.01	0.06	0.51	- 50 %
After	0.01	0.03	0.09	
Winter				
Before	0.01	0.06	0.19	- 50 %
After	0.01	0.03	0.09	
Spring				
Before	0.01	0.04	0.15	- 25 %
After	0.01	0.03	0.09	
Summer				
Before	0.02	0.06	0.17	- 67 %
After	0.01	0.02	0.09	
Fall				
Before	0.01	0.09	0.51	- 44 %
After	0.03	0.05	0.07	

Total Phosphorus

Table 36: Overall and seasonal Total Phosphorus (mg/L) data summary on Amazon Diversion Channel at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.02	0.18	0.78	- 11 %
After	0.02	0.16	0.50	
Winter				
Before	0.05	0.15	0.25	- 33 %
After	0.02	0.10	0.15	
Spring				
Before	0.02	0.17	0.70	+ 24 %
After	0.05	0.21	0.50	
Summer				
Before	0.06	0.22	0.78	- 5 %
After	0.09	0.21	0.46	
Fall				
Before	0.03	0.18	0.28	- 39 %
After	0.06	0.11	0.14	

Total Suspended Solids (TSS)

Table 37: Overall and seasonal TSS (mg/L) data summary on Amazon Diversion Channel at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	3.0	29.4	180.0	+ 14 %
After	3.0	33.5	160.0	
Winter				
Before	4.0	17.8	42.0	- 46 %
After	3.0	9.7	23.0	
Spring				
Before	4.0	26.7	64.0	+ 113 %

After	5.0	56.8	160.0	
Summer				
Before	3.0	41.6	180.0	+ 37 %
After	7.8	56.8	110.0	
Fall				
Before	8.0	30.1	89.0	- 74 %
After	3.0	7.7	18.0	

Biological Oxygen Demand (BOD)

Table 38: Overall and seasonal BOD (mg/L) data summary on Amazon Diversion Channel at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	1.0	3.0	9.0	- 20 %
After	1.0	2.4	10.0	
Winter				
Before	1.0	1.9	4.0	- 32 %
After	1.0	1.3	3.0	
Spring				
Before	1.0	3.3	5.0	- 18 %
After	1.0	2.7	5.0	
Summer				
Before	2.0	4.4	9.0	- 7 %
After	1.0	4.1	10.0	
Fall				
Before	1.0	2.4	5.0	- 46 %
After	1.0	1.3	2.0	

Chemical Oxygen Demand (COD)

Table 39: Overall and seasonal COD (mg/L) data summary on Amazon Diversion Channel at Royal Avenue, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	5.0	22.9	83.0	+ 4 %
After	2.5	23.9	48.0	
Winter				
Before	5.0	16.9	30.0	+ 9 %
After	2.5	18.4	48.0	
Spring				
Before	5.0	26.0	83.0	- 11 %
After	11.0	23.2	32.0	
Summer				
Before	5.0	30.6	68.0	+ 6 %
After	18.0	32.4	47.0	
Fall				
Before	5.0	16.8	33.0	+ 17 %
After	16.0	19.6	24.0	

A-3 Drain at Terry Street

Ammonia

Table 40: Overall and seasonal ammonia (mg/L) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.00	0.13	1.70	- 24 %
After	0.05	0.10	0.80	
Winter				
Before	0.05	0.18	0.50	- 50 %
After	0.05	0.09	0.40	
Spring				
Before	0.05	0.07	0.20	- 1 %
After	0.05	0.06	0.10	

Summer				
Before	0.05	0.07	0.20	+ 114 %
After	0.05	0.15	0.80	
Fall				
Before	0.05	0.25	1.70	- 60 %
After	0.05	0.10	0.20	

Temperature

Table 41: Overall and seasonal temperature (°C) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	4.8	16.2	27.9	- 23 %
After	4.1	12.7	20.4	
Winter				
Before	4.8	10.7	14.0	- 23 %
After	4.1	8.2	12.0	
Spring				
Before	14.2	20.5	27.9	- 22 %
After	9.1	15.9	18.8	
Summer				
Before	16.1	22.5	27.4	- 17 %
After	15.0	18.7	20.4	
Fall				
Before	6.6	10.4	17.1	+ 60 %
After	7.1	16.6	14.0	

Nitrate/Nitrite as N

Table 42: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.03	0.51	8.00	- 16 %
After	0.03	0.43	1.40	
Winter				
Before	0.20	0.52	1.00	+ 29 %
After	0.27	0.67	1.40	
Spring				
Before	0.06	0.99	8.00	- 78 %
After	0.03	0.22	0.66	
Summer				
Before	0.03	0.07	0.19	+ 114 %
After	0.03	0.15	0.55	
Fall				
Before	0.18	0.57	0.88	- 9 %
After	0.13	0.52	1.00	

Ortho-phosphorus

Table 43: Overall and seasonal Ortho-phosphorus (mg/L) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.01	0.06	0.25	- 33 %
After	0.01	0.04	0.11	
Winter				
Before	0.01	0.05	0.12	- 40 %
After	0.01	0.03	0.11	
Spring				
Before	0.01	0.06	0.16	- 17 %
After	0.02	0.05	0.11	
Summer				
Before	0.04	0.10	0.25	- 40 %
After	0.04	0.06	0.08	
Fall				
Before	0.02	0.05	0.08	0 %

After	0.03	0.05	0.09	

Total Phosphorus

Table 44: Overall and seasonal Total Phosphorus (mg/L) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.08	0.25	0.64	- 32 %
After	0.06	0.17	0.42	
Winter				
Before	0.09	0.18	0.31	- 28 %
After	0.06	0.13	0.34	
Spring				
Before	0.08	0.20	0.40	- 10 %
After	0.07	0.18	0.42	
Summer				
Before	0.12	0.35	0.64	- 40 %
After	0.12	0.21	0.35	
Fall				
Before	0.16	0.25	0.35	- 36 %
After	0.10	0.16	0.21	

Total Suspended Solids (TSS)

Table 45: Overall and seasonal TSS (mg/L) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	5.0	31.9	280.0	- 47 %
After	4.0	16.8	40.0	
Winter				
Before	7.0	18.1	65.0	- 14 %
After	4.0	15.6	40.0	
Spring				
Before	11.0	21.9	60.0	- 22 %
After	4.0	17.1	33.0	
Summer				
Before	5.0	51.2	280.0	- 61 %
After	4.0	20.1	38.0	
Fall				
Before	7.0	33.2	71.0	- 56 %
After	4.0	14.7	28.0	

Biological Oxygen Demand (BOD)

Table 46: Overall and seasonal BOD (mg/L) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	1.0	3.4	12.0	- 35 %
After	1.0	2.2	8.0	
Winter				
Before	1.0	2.2	4.0	- 23 %
After	1.0	1.7	4.0	
Spring				
Before	1.0	3.0	5.0	- 10 %
After	1.0	2.7	4.0	
Summer				
Before	3.0	5.8	12.0	- 47 %
After	1.0	3.1	8.0	
Fall				
Before	1.0	2.4	5.0	- 33 %
After	1.0	1.6	3.0	

Chemical Oxygen Demand (COD)

Table 47: Overall and seasonal COD (mg/L) data summary on A-3 Drain at Terry Street, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	0.5	24.6	77.0	- 9 %
After	0.5	22.5	44.0	
Winter				
Before	0.5	13.9	22.0	+ 29 %
After	8.0	18.0	31.0	
Spring				
Before	0.5	22.0	42.0	- 4 %
After	0.5	21.1	36.0	
Summer				
Before	0.5	40.0	77.0	- 25 %
After	23.0	30.1	44.0	
Fall				
Before	0.5	20.1	30.0	+ 20 %
After	19.0	24.1	28.0	

Amazon Creek at RM 5.82

(No before or after data to compare)

Amazon Creek at High Pass Road

Ammonia

(No before and after data to compare)

Temperature

Table 48: Overall and seasonal temperature (°C) data summary on Amazon Creek at High Pass Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	3.2	13.0	22.8	- 2 %
After	0.0	12.8	21.1	
Winter				
Before	3.2	7.7	11.9	- 9 %
After	3.4	7.0	10.2	
Spring				
Before	N/A			
After				
Summer				
Before	7.5	19.2	22.8	- 3 %
After	14.5	18.7	21.1	
Fall				
Before	N/A			
After				

Nitrate/Nitrite as N

(No before and after data to compare)

Ortho-phosphorus

(No before and after data to compare)

Total Phosphorus

Table 49: Overall and seasonal Total Phosphorus (mg/L) data summary on Amazon Creek at High Pass Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean

All Data				
Before	0.1	0.2	0.3	0 %
After	0.1	0.2	0.4	
Winter				
Before	0.1	0.2	0.3	- 50 %
After	0.1	0.1	0.3	
Spring				
Before	0.2	0.3	0.3	- 33 %
After	0.1	0.2	0.3	
Summer				
Before	0.2	0.2	0.3	0 %
After	0.1	0.2	0.4	
Fall				
Before	0.1	0.2	0.3	0 %
After	0.1	0.2	0.4	

Total Suspended Solids (TSS)

(No before and after data to compare)

Biological Oxygen Demand (BOD)

(No before and after data to compare)

Chemical Oxygen Demand (COD)

(No before and after data to compare)

Coyote Creek at Hamm Road

Ammonia

(No before and after data to compare)

Temperature

Table 50: Overall and seasonal temperature (°C) data summary on Coyote Creek at Hamm Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	12.4	13.6	14.7	- 6 %
After	10.7	12.8	16.2	
Fall				
Before	N/A			
After				

Nitrate/Nitrite as N

(No before and after data to compare)

Ortho-phosphorus

Table 51: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Coyote Creek at Hamm Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.03	0.04	0.05	- 50 %
After	0.02	0.02	0.02	
Fall				
Before	N/A			
After				

Total Phosphorus

Table 52: Overall and seasonal Total Phosphorus (mg/L) data summary on Coyote Creek at Hamm Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.04	0.05	0.06	0 %
After	0.05	0.05	0.05	
Fall				
Before	N/A			
After				

Total Suspended Solids (TSS)

(No before and after data to compare)

Biological Oxygen Demand (BOD)

(No before and after data to compare)

Chemical Oxygen Demand (COD)

(No before and after data to compare)

Coyote Creek at Powell Road

Ammonia

Table 53: Overall and seasonal ammonia (mg/L) data summary on Coyote Creek at Powell Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			

After				
Spring				
Before	N/A			
After				
Summer				
Before	0.04	0.05	0.05	- 60 %
After	0.01	0.02	0.02	
Fall				
Before	N/A			
After				

Temperature

Table 54: Overall and seasonal temperature (°C) data summary on Coyote Creek at Powell road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	12.8	17.1	22.4	- 14 %
After	11.9	14.7	18.2	
Fall				
Before	N/A			
After				

Nitrate/Nitrite as N

Table 55: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on Coyote Creek at Powell Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.02	0.03	0.06	+ 133 %
After	001	0.07	0.23	
Fall				
Before	N/A			
After				

Ortho-phosphorus

Table 56: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Coyote Creek at Powell Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.02	0.02	0.04	0 %

After	0.02	0.02	0.03	
Fall				
Before	N/A			
After				

Total Phosphorus

Table 57: Overall and seasonal Total Phosphorus (mg/L) data summary on Coyote Creek at Powell Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.02	0.04	0.06	+ 75 %
After	0.06	0.07	0.09	
Fall				
Before	N/A			
After				

Total Suspended Solids (TSS)

(No before and after data to compare)

Biological Oxygen Demand (BOD)

(No before and after data to compare)

Chemical Oxygen Demand (COD)

(No before and after data to compare)

Coyote Creek at Petzold Road

Ammonia

(No before and after data to compare)

Temperature

Table 58: Overall and seasonal temperature (°C) data summary on Coyote Creek at Petzold Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	15.0	18.5	20.6	- 24 %
After	12.3	14.0	16.1	
Fall				
Before	N/A			

After	

Nitrate/Nitrite as N

Table 59: Overall and seasonal Nitrate/Nitrite as N (mg/L) data summary on Coyote Creek at Petzold Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.02	0.04	0.08	- 50 %
After	0.01	0.02	0.03	
Fall				
Before	N/A			
After				

Ortho-phosphorus

Table 60: Overall and seasonal Ortho-phosphorus (mg/L) data summary on Coyote Creek at Petzold Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.02	0.02	0.02	- 50 %
After	0.01	0.01	0.01	
Fall				
Before	N/A			
After				

Total Phosphorus

Table 61: Overall and seasonal Total Phosphorus (mg/L) data summary on Coyote Creek at Petzold Road, before and after 2008

	Minimum	Geometric Mean	Maximum	% Change in Mean
All Data				
Before	N/A			
After				
Winter				
Before	N/A			
After				
Spring				
Before	N/A			
After				
Summer				
Before	0.02	0.04	0.07	+ 50 %
After	0.05	0.06	0.07	
Fall				
Before	N/A			
After				

Total Suspended Solids (TSS)

(No before and after data to compare)

Biological Oxygen Demand (BOD)

(No before and after data to compare)

Chemical Oxygen Demand (COD)

(No before and after data to compare)