SUPPLEMENT TO
STORMWATER ANNUAL REPORT
for the CITY OF EUGENE, OREGON

Permit Year 2014 July 1, 2013–June 30, 2014

Submitted by: **City of Eugene**

Submitted to: **Oregon Department of Environmental Quality**

December 1, 2014

National Pollutant Discharge Elimination System (NPDES) Permit 101244

Supplement to
Stormwater Annual Report
Permit Year 2014

1. TMDL Pollutant Load Reduction Evaluation
2. TMDL Wasteload Allocation Attainment Assessment
3. 303(d) Evaluation

Submitted to:
Oregon Department of Environmental Quality

Submitted by:
City of Eugene

Submitted in Accordance with the
Requirements of National Pollutant
Discharge Elimination System (NPDES) Permit
Number 101244, File Number 107989

December 1, 2014

SUMMARY AND ORDER OF CONTENTS

Discharges from municipal stormwater systems into waters of the United States are regulated by the federal Clean Water Act and National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System permit ("MS4 Permit") program. The City of Eugene (City) has operated its stormwater program under a MS4 permit since it was first issued in November 1994. This document, *Supplement to Stormwater Annual Report - Permit Year 2014*, is a compilation of three assessments required during the current permit term, related to Total Maximum Daily Loads (TMDLs) and 303(d)-listed pollutants. The assessments included in this document fulfill specific requirements of the City's NPDES MS4 Permit Number 101244, File Number 107989, issued December 30, 2010.

The first part of this document is the City's **Total Maximum Daily Load (TMDL) Pollutant Load Reduction Evaluation** (fulfills MS4 Permit Schedule D.3.c.), comprised of an updated estimate of pollutant loads from the City's MS4 permit area, an estimate of the pollutant load reduction from stormwater best management practices (BMPs), and a comparison of the estimated pollutant load reduction to benchmarks established in 2008 with the previous permit renewal application. The TMDL Pollutant Load Reduction Evaluation includes, as Appendix A, the City's Year 2014 Monitoring Report, including analysis of water quality sampling data and long-term receiving water quality trends.

The second part of this document is the City's **TMDL Wasteload Allocation Attainment Assessment** (fulfills MS4 Permit Schedule D.3.b.) which reflects an assessment of the attainability of applicable TMDL wasteload allocations, the type and extent of BMPs necessary to achieve wasteload allocations, and an estimate of the associated implementation resources.

The third part of this document is the City's **303(d) Evaluation** (fulfills MS4 Permit Schedule D.2.a.), which is an evaluation pertaining to receiving waters listed by the state of Oregon Department of Environmental Quality (DEQ) as water quality impaired and to which Eugene's stormwater runoff discharges. The 303(d) Evaluation is an update to an evaluation submitted to DEQ in September 2008 with the City's permit renewal application.

Supplement to
Stormwater Annual Report
Permit Year 2014

1. TMDL Pollutant Load Reduction Evaluation
(MS4 Permit Schedule D.3.c.)

Pollutant Load Reduction Evaluation

Prepared for
City of Eugene, Oregon
December 1, 2014

6500 SW Macadam Avenue, Suite 200
Portland, OR 97239
Phone: 503.244.7005
Fax: 503.244.9095

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List of Abbreviations

ac	acre(s)
ACWA	(Oregon) Association of Clean Water Agencies
ASCE	American Society of Civil Engineers
BMP	best management practice
BOD	biological oxygen demand
CFU	colony forming unit
City	City of Eugene
COM	commercial
DEQ	Oregon Department of Environmental Quality
DO	dissolved oxygen
EMC	event mean concentration
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
I-5	Interstate 5
I-105	Interstate 105
IND	industrial
LA	load allocation
LCL	lower confidence limit
LCOG	Lane County Council of Governments
MFR	multi-family residential
mg/L	milligram(s) per liter
mL	milliliter(s)
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
ODOT	Oregon Department of Transportation
POS	parks and open space
SFR	single family residential
TMDL	total maximum daily load
TSS	total suspended solids
UCL	upper confidence limit
UIC	underground injection control
VAC	vacant
VSS	volatile suspended solids
WLA	waste load allocation
WTM	Watershed Treatment Model
WWTP	wastewater treatment plant

Definitions

Load allocation	The amount of pollutant allocated to existing nonpoint sources and natural background in a TMDL. (EPA, 2010, http://toxics.usgs.gov/definitions/tmdl.html)
Pollutant load reduction benchmark	A future pollutant load reduction estimate for a parameter or surrogate, where applicable, for which a waste load allocation (WLA) is established. The benchmark is used to establish progress toward achieving the WLA over an implementation period (typically 5 years).
Pollutant load reduction evaluation	An evaluation of current pollutant load generation for a parameter or surrogate, where applicable, for which a WLA is established. The pollutant load reduction evaluation is used to measure progress toward achieving a WLA or previously established benchmark.
Waste load allocation	The amount of pollutant load allocated to a specified point source (e.g., sewage treatment plant; industrial facility; stormwater) in a TMDL. (EPA, 2010, http://toxics.usgs.gov/definitions/tmdl.html)

Section 1

Introduction

The City of Eugene's (City's) National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Separate Storm Sewer System (MS4) permit, issued December 30, 2010, requires an evaluation of total maximum daily load (TMDL) pollutant loads for the City's permitted area. The evaluation must reflect the estimated pollutant load and estimated pollutant load reduction for all applicable TMDL parameters, representing current (2014) development conditions in the city.

1.1 Applicability

The requirements to evaluate pollutant load reductions are detailed in Schedule D.3.a of the City's NPDES MS4 permit as follows:

> *(a) Applicability: The requirements of this section apply to the co-permittee's MS4 discharges to receiving waters with established TMDLs or to receiving waters with new or modified TMDLs approved by EPA within three years of the issuance date of this permit. Established TMDLs are noted on page 1 of this permit. Pollutant discharges for those parameters listed in the TMDL with applicable WLAs must be reduced to the maximum extent practicable through implementation of BMPs and an adaptive management process.*

TMDLs relevant to stormwater discharge from the City of Eugene are contained in the Willamette Basin TMDL, approved in September 2006 by the EPA. The Upper Willamette Subbasin TMDL and McKenzie Subbasin TMDL are included in the Willamette Basin TMDL document and cover the following water bodies: Upper Amazon Creek, A3 Channel, Amazon Diversion Channel, Fern Ridge Reservoir, and the McKenzie River. The Willamette Basin TMDL includes waterbody-specific allocations, variously, for urban stormwater sources for bacteria, biological oxygen demand (BOD) (used as a surrogate for dissolved oxygen [DO]), nutrients (specifically, total phosphorus as a surrogate for DO), volatile suspended solids (VSS)[1] (specifically, total suspended solids [TSS] used as a surrogate for DO), and TSS (used as a surrogate for turbidity).

Stormwater runoff from approximately 60% of the city of Eugene discharges to the Willamette River indirectly via the Amazon Creek drainage system including tributaries referenced specifically in the Willamette Basin TMDL (Upper Amazon Creek, A3 Channel, Amazon Diversion Channel, and Fern Ridge Reservoir). Runoff from approximately 40 percent of the city discharges relatively directly to the Willamette River via storm system outfalls and local tributaries including Spring Creek and Flat Creek. Runoff from a relatively small portion of the city (500 acres) discharges to the McKenzie River, a major tributary to the Willamette River. Detail related to interpretation of the Willamette Basin TMDL for purposes of this pollutant load reduction evaluation is provided in Section 2.

[1] In the Willamette Basin TMDL, page 10-147, sediment oxygen demand is caused in part due to discharge of VSS. Load reduction is referred to as the reduction of VSS in the TMDL.

1.2 Permit Requirements

In accordance with the City's NPDES MS4 permit, Schedule D.3.c, the City must complete a pollutant load reduction evaluation by December 1, 2014. Per Schedule D.3.c (i–ix), the pollutant load reduction evaluation must include the following:

(i) *The rationale and methodology used to evaluate progress towards reducing TMDL pollutant loads.*

(ii) *An estimate of current pollutant loadings without considering BMP implementation, and an estimate of current pollutant loadings considering BMP implementation for each TMDL parameter with an established WLA.*

(iii) *A comparison of the estimated pollutant loading with and without BMP implementation to the applicable TMDL WLA.*

(iv) *A comparison of the estimated pollutant load reduction to the estimated TMDL pollutant load reduction benchmark established for the permit term, if applicable.*

(v) *A description of the estimated effectiveness of structural BMPs.*

(vi) *A description of the estimated effectiveness of non-structural BMPs, if applicable, and the rationale for the selected approach.*

(vii) *A water quality trend analysis, as sufficient data are available, and the relationship to stormwater discharges for receiving water bodies within the co-permittees jurisdictional area with an approved TMDL.*

(viii) *A narrative summarizing progress towards applicable TMDL WLAs and existing TMDL benchmarks, if applicable.*

(ix) *If the permittee estimates that TMDL WLAs are achieved with existing BMP implementation, the co-permittee must provide a statement supporting this conclusion*.

Per items iv and viii, the City established TMDL pollutant load reduction benchmarks in 2008 for the Upper Willamette River and specified tributaries. The pollutant load reduction benchmarks projected development conditions and associated pollutant load reduction in 2013. As part of this pollutant load reduction evaluation, pollutant load reduction estimates for current (2014) development conditions are compared with the 2013 pollutant load reduction benchmarks. Due to the statistical variability of the underlying data, the pollutant load reduction estimates and benchmarks are presented as ranges in loading. Because benchmarks are pollutant load reduction estimates for estimated future conditions, they are used as a tool and a goal for guiding adaptive management activities and are not considered a numeric effluent limit.

1.3 Document Organization

Following this introductory section, this report is organized according to the following sections:

Section 2 Review of the Willamette Basin TMDL and applicable pollutant load allocations.

Section 3 Description of the City's process for conducting the pollutant load reduction evaluation.

Section 4 Pollutant load modeling methods and assumptions including changes in modeling assumptions from those used in 2008.

Section 5 Results of the pollutant load modeling and pollutant load reduction evaluation, including comparison of results to WLAs and comparison of results to the 2013 pollutant load reduction benchmarks. A summary of the water quality trends analysis is also provided.

Section 6 References.

Section 2

TMDL Applicability

TMDLs are developed to document the projected maximum pollutant load capacity of a water body that should be met so as not to exceed water quality standards. They may be developed for pollutants with direct links to stormwater runoff (e.g., metals, nutrients) and also for pollutants not typically associated with urban stormwater runoff in the Willamette Valley (temperature).

To translate a TMDL into guidelines for NPDES-permitted entities (municipalities, industries, wastewater treatment plants [WWTPs]), WLAs are developed as a means to regulate discharges from defined point sources of pollution that operate under an NPDES discharge permit (e.g., permitted municipalities, industries and WWTPs). Load allocations (LAs) are developed to allocate pollutant discharges from nonpoint sources that do not generally operate under an NPDES discharge permit (e.g., agriculture and forestry).

With the implementation of NPDES MS4 permits (considered to be point source discharge permits), by definition, WLAs would ordinarily be used to regulate discharges from urban stormwater runoff for areas covered by the permits. However, the Willamette Basin TMDL uses LAs to define pollutant load discharges from urban land uses including the City's NPDES MS4 permit area. Because the pollutant load discharge is managed through implementation of the City's NPDES MS4 permit, for purposes of this report, it is assumed that these LAs are, for all intents and purposes, WLAs. The term WLA is used in this report.

2.1 Willamette Basin TMDL Overview

The U.S. Environmental Protection Agency (EPA) approved the Willamette Basin TMDL on September 29, 2006. The City submitted a pollutant load reduction evaluation and TMDL pollutant load reduction benchmarks as part of its Phase I NPDES MS4 permit renewal submittal in September 2008.

The Willamette Basin TMDL addresses elevated in-stream temperatures, bacteria (*E. coli*), and mercury for the Willamette River and tributaries. Additional pollutant parameters are included in the Willamette Basin TMDL for select tributaries. For Eugene, the Upper Amazon Creek, A3 Channel, Amazon Diversion Channel, and Fern Ridge Reservoir are individually referenced for bacteria, DO, and/or turbidity.

Temperature can be considered both a point and nonpoint source pollutant, but it is not typically considered by the Oregon Department of Environmental Quality (DEQ) to be a pollutant parameter associated with urban stormwater runoff. Temperature is regulated by the DEQ and addressed by the City under its NPDES Wastewater Discharge permit and TMDL Implementation Plan, but not under the NPDES MS4 permit.

Mercury is identified as a pollutant with direct ties to stormwater runoff, but currently DEQ has not completed their analysis and establishment of WLAs for mercury. Therefore, no pollutant load reduction estimates are required, as there is not an established WLA.

Bacteria are considered to be a pollutant with direct ties to stormwater runoff; thus, bacteria are regulated under the City's NPDES MS4 permit as a point source pollutant. Therefore, the City is required to conduct a pollutant load reduction evaluation for bacteria.

DO itself is not considered to be a pollutant, but rather an effect of elevated temperature, low flows, excessive algal growth, and the discharge of pollutants such as nutrients that exacerbate the growth of algae and other autotrophs, resulting in changes to pH levels and DO concentrations. Low DO concentration can impact aquatic health. DO levels have a direct tie to stormwater runoff when considering impacts of the discharge of other pollutants such as nutrients, BOD, and sediment. These pollutant parameters are often used as surrogates for DO, and the City is required to conduct a pollutant load reduction evaluation for these parameters.

Like DO, turbidity is also not commonly considered to be a pollutant in and of itself. Elevated turbidity levels can be the result of total and suspended sediment discharges and the resuspension of previously settled solids. Turbidity does have a direct tie to stormwater runoff when considering external sources of sediment (not the resuspension of sediment). TSS is often used as a surrogate pollutant parameter to regulate turbidity, and the City is required to conduct a pollutant load reduction evaluation for TSS.

2.2 Application for Eugene

The Willamette Basin TMDL was reviewed for this report to verify the appropriate WLAs for the City's MS4 contribution. The TMDL was previously reviewed in 2008 in conjunction with the City's permit renewal submittal and TMDL benchmarks. Identified WLAs by TMDL water body are listed in Table 2-1.

Table 2-1. Willamette River WLAs (applicable to the City's MS4)

Water body	Parameter	WLA
Upper Amazon Creek	Bacteria *(E. coli)*	84% (annual reduction)
A3 Channel	Bacteria *(E. coli)*	33% (annual reduction)
Fern Ridge Reservoir	Bacteria *(E. coli)*	64% (annual reduction)
	Turbidity (TSS surrogate)	54.6% (annual reduction)
Amazon Diversion Channel	Biological oxygen demand	40% (annual reduction)
	Volatile suspended solids (TSS surrogate)	40% (annual reduction)
	Nutrients (total phosphorus surrogate)	40% (annual reduction)
Upper Willamette River (main and unreferenced tributaries)	Bacteria *(E. coli)*	65% (annual reduction)
McKenzie River	Bacteria *(E. coli)*	65% (annual reduction)

The TMDL watershed area for the Amazon Diversion Channel is the same as the Fern Ridge Reservoir.

WLAs for bacteria are established for individual tributaries (e.g., Upper Amazon Creek, A3 Channel, Amazon Diversion Channel, Fern Ridge Reservoir) and for discharge to the Upper Willamette River directly (see Willamette Basin TMDL, Chapter 10). The DO TMDL is specific for the Amazon Diversion Channel and identifies nutrients, BOD, and VSS as pollutant parameters contributing to reduced DO levels. WLAs are then applied for total phosphorus (as a surrogate for nutrients), BOD, and TSS (as a surrogate for VSS). The turbidity TMDL is specific for the Fern Ridge Reservoir and identifies TSS as a surrogate pollutant parameter.

The WLAs for bacteria (*E. coli*), nutrients, BOD, and TSS are calculated as a percent load reduction for each water body and applied to the contributing watershed area based on land use (e.g., urban, agricultural, etc.). The MS4 contribution is assumed to equate to the urban land use (when not

otherwise specified). As described in the Willamette Basin TMDL, the water quality criterion for bacteria (monthly log mean concentration of 126 *E. coli* per 100 milliliters [mL]) was used to establish the required bacteria WLAs for the Upper Willamette River, Upper Amazon Creek, A3 Channel, and Amazon Diversion Channel. The water quality criterion for bacteria (maximum concentration of 406 *E. coli* per 100 mL) was used to establish the required bacteria WLAs for the Fern Ridge Reservoir. The water quality criterion for DO (cool water criterion of 6.5 milligrams per liter [mg/L]) and DEQ's CE-QUAL-W2 model were used to establish the nutrient, BOD, and TSS WLAs.

The McKenzie River is a major tributary to the Willamette River, discharging to the Willamette in the northeast portion of Eugene. Approximately 500 acres of the Eugene NPDES MS4 permit area is located in the McKenzie River Subbasin. Upon review of the Willamette Basin TMDL, although the McKenzie Subbasin does not have an individual TMDL for bacteria, it appears that the McKenzie River TMDL watershed area in Eugene should be evaluated for bacteria as an unreferenced tributary to the Upper Willamette River (see Willamette TMDL, Chapter 11, page 11-3). This assumption varies from the 2008 evaluation effort as the McKenzie River Subbasin was not included in the City's September 2008 benchmarks.

As noted in the footnote to Table 2-1, the TMDL watershed area for the Amazon Diversion Channel and Fern Ridge Reservoir is the same for purposes of evaluating the MS4 contribution from the city of Eugene. A pollutant load analysis has been conducted for this TMDL watershed area and values were compared to WLAs established for both the Amazon Diversion Channel and Fern Ridge Reservoir (see Section 5.1.5).

Section 3

Overall Process for Developing Pollutant Load Reduction Estimates

Conducting a pollutant load reduction evaluation relies on the use of a pollutant loading model to calculate pollutant loads for select parameters and select scenarios, under select development conditions.

The pollutant load reduction evaluation is an exercise to estimate TMDL pollutant load generation and TMDL pollutant removal based on current development conditions and best management practice (BMP) implementation. Pollutant loads with and without BMP implementation are calculated using the pollutant loads model and compared to the applicable WLA from the TMDL. Pollutant load reductions (based on the implementation of BMPs) are calculated and compared to previously established TMDL benchmarks, as applicable. The pollutant load reduction evaluation can be used to estimate the effectiveness of stormwater management facilities and show how BMPs are making progress toward achieving pollutant load reduction.

In 2008, the City conducted a pollutant load reduction evaluation and established pollutant load reduction benchmarks. Both the pollutant load reduction evaluation and pollutant load reduction benchmarks were submitted with the permit renewal application in September 2008, in accordance with requirements of the City's 2004 NPDES MS4 permit.

The City's current (2010) NPDES MS4 permit requires submission of the pollutant load evaluation (including comparison to previously established benchmarks) by December 1, 2014, six months prior to submission of pollutant load reduction benchmarks in June 2015 for the next permit period. Because the process for conducting the pollutant load reduction evaluation has been updated from 2008, a general process flow chart was developed to document the pollutant load reduction evaluation process and to show the relationship to the benchmark development efforts (Figure 3-1).

Figure 3-1 identifies the overall process for conducting the pollutant load reduction evaluation and the relationship to the pollutant load reduction benchmarks. Steps 1–6 are associated with the pollutant load reduction evaluation and include review of TMDL assumptions, data compilation, pollutant load calculations, pollutant load evaluation, and comparison of pollutant loads with WLAs and benchmarks established for the current permit period. Step 7 is associated with development of pollutant load reduction benchmarks for the upcoming permit period. This overall process is loosely based on the process collectively developed through the Oregon Association of Clean Water Agencies (ACWA) in 2005 (updated in 2008) to conduct pollutant loads modeling for TMDL compliance.

If benchmarks were previously established, Figure 3-1 identifies the points at which model assumptions and model results are to be reviewed and referenced. If benchmarks were not previously established, such activities are not required. For the City, a few modeling assumptions changed between 2008 and 2014. Therefore, documentation of changes is necessary in order to accurately review and interpret model results.

As shown on Figure 3-1, three general categories of BMPs are considered in the process:

1. Structural BMP systems for which pollutant removal can be reported quantitatively and are based on the results of scientific research (i.e., effluent concentrations). These BMPs include traditional ponds, swales, infiltration facilities, proprietary treatment systems, and wetlands.

2. Structural and/or source control BMP applications or practices where pollutant removal potentially could be reported in objective, quantitative terms, but effectiveness information is generally limited or unavailable. These BMPs (particularly source control BMPs) may be reflected in the modeling effort by simulating their specific coverage area with adjusted model assumptions (impervious area, land use event mean concentrations [EMCs], etc.). These BMPs include downspout disconnection programs, street sweeping, and catch basin cleaning.
3. Non-structural/source control BMP applications where pollutant removals are not likely to be reported in objective, quantitative terms. These BMPs include public education, illicit discharge detection programs, and spill prevention.

The overall process reflected in Figure 3-1 is intended to be conservative, because it does not directly estimate pollutant load removal achieved by BMPs with limited or no quantifiable effectiveness information. Instead, pollutant loads are generated after applying structural BMPs (Category 1) and any selected structural/source control BMPs under Category 2 to provide a relative picture as to how close or how far off the stormwater program is with regard to meeting the WLAs and previous benchmarks. It is acknowledged that implementation of non-structural or non-quantifiable BMPs (Category 3) has the potential to reduce pollutant loads further; however, utilization of such BMPs in the pollutant load evaluation is qualitative in nature, not reflected in any quantitative (numeric) reduction in pollutant loads.

This report reflects the City's pollutant load reduction evaluation (through Step 6). Pollutant load reduction benchmarks will be developed based on the pollutant load reduction evaluation and submitted with the City's August 2015 permit renewal application.

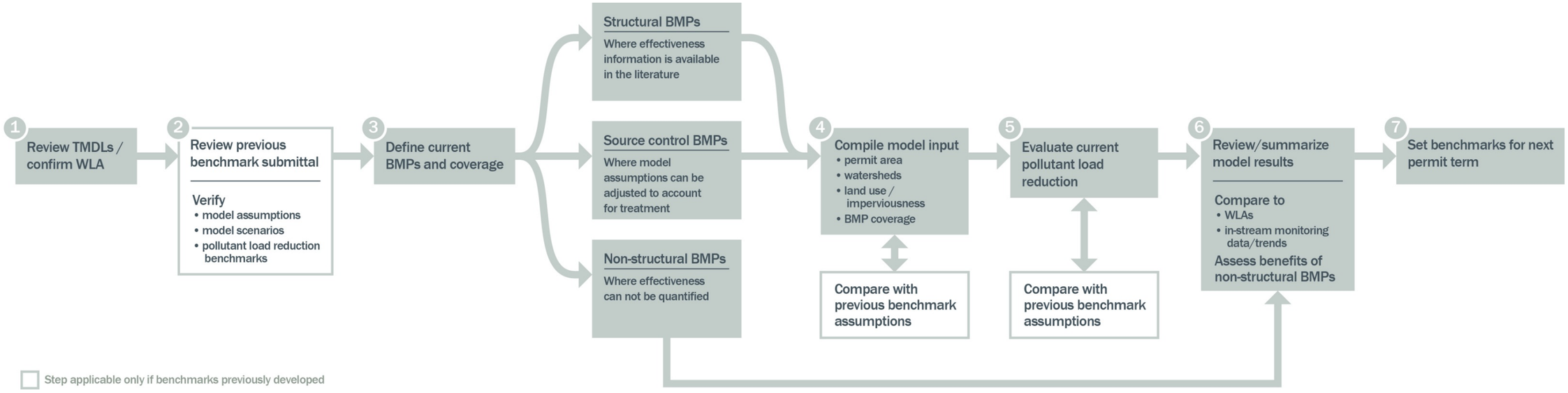

Figure 3-1. Pollutant load reduction evaluation and relationship to benchmark development efforts (2014)

Section 4

Modeling Methods and Assumptions

To conduct the pollutant load reduction evaluation, the City used a spreadsheet loads model that uses the EPA simple method for pollutant load calculations. The model was used to calculate bacteria, BOD, total phosphorus, and TSS loads within the City's NPDES MS4 permit boundary in conjunction with the Willamette Basin TMDL.

This section describes the modeling methods and assumptions associated with developing the spreadsheet loads model for 2014 conditions. The subsections below include information regarding model development, model areas, model scenarios, model input, and model assumptions related to land use and BMP effectiveness. As applicable, 2008 modeling assumptions are provided for comparison.

4.1 Model Description

A spreadsheet loads model was developed in 2008 for multiple Oregon Phase I NPDES MS4 jurisdictions including the City to calculate pollutant loads and to develop pollutant load reduction benchmarks. The same spreadsheet loads model was used for this 2014 pollutant load reduction evaluation with the following modifications:

- New BMP categories were added to account for the following BMP facility types not modeled in 2008: porous pavement, lined planters/filtration rain gardens, and eco roofs.
- BMP effluent concentration data were refined based on a collective effort among ACWA jurisdictions to update BMP effectiveness information with new literature information.

Detail related to the model modifications is described later in this section.

Rainfall, land use, and BMP coverage information is entered into the model; the model has been configured with average pollutant concentration information for various land uses and BMP categories. Pollutant loads are automatically calculated. The model was used to estimate pollutant loads reflective of current (2014) development conditions and structural BMP implementation. Quantitative data are not currently available to assess the effectiveness of source control or non-structural BMPs for the City. Therefore, effectiveness of source control and non-structural BMPs are not included in the model but are qualitatively incorporated in the pollutant load evaluation based on best professional judgment and summarized in Section 5.

4.2 Model Area

The City's NPDES MS4 permit covers "all existing and new discharges of stormwater from the municipal separate storm sewer system within the incorporated areas of the City of Eugene." As a result, the City's NPDES MS4 permit area is its city limits. The current city limits boundary, reflective of annexations through September 2014, was used for the modeling effort.

As described in Section 2, individual WLAs are defined for five TMDL watersheds; therefore, each TMDL watershed is modeled separately and pollutant load generation is compared to the respective WLAs. A geographic information system (GIS) was used to define and delineate the modeled area. Separate WLAs are defined for the Amazon Diversion Channel and Fern Ridge Reservoir TMDL watersheds. However, these watersheds reflect the same contributing drainage area so they were modeled as a single TMDL watershed, and model results were compared to the respective WLAs. The

Amazon Diversion Channel/Fern Ridge Reservoir TMDL watershed reflects the combined Upper Amazon Creek and A3 Channel watersheds.

Figure 4-1 shows the Eugene stormwater basins within the respective TMDL watersheds. City limits is not shown on Figure 4-1 for simplicity, although the pollutant load calculations are based upon city limits area (or NPDES MS4 permit area) within the TMDL watersheds.

Areas within the city limits that are the responsibility of the Oregon Department of Transportation (ODOT) and Lane County were omitted from the modeled area, as ODOT and Lane County have separate NPDES MS4 permit for discharge from these areas. For the City, this includes the Interstate 5 (I-5) corridor, the I-105 corridor, the Beltline highway, and Delta Highway between I-105 and Beltline. In addition, the Willamette River itself was omitted from the modeled area. Such exclusions, which were not considered in 2008, result in a reduction of 1,068 acres of modeled area in 2014.

Table 4-1 summarizes the total area, exclusion area, and modeled area by TMDL watershed.

Table 4-1. Modeled Areas

TMDL/subbasin	TMDL watersheds	2014 pollutant load reduction evaluation[b]		
		Total TMDL watershed area (ac)	Total exclusion area (ac)	Total modeled area (ac)
Willamette Basin/ Upper Willamette and McKenzie River	Upper Amazon Creek	10,762.5	35.3	10,727.1
	A3 Channel	2,258.0	56.9	2,201.1
	Upper Willamette River	14,751.4	975.5	13,775.9
	McKenzie River	522.7	0.0	522.7
	Amazon Diversion Channel/ Fern Ridge Reservoir [a]	13,020.4	92.2	12,928.2

[a] *The Amazon Diversion Channel/Fern Ridge Reservoir watershed reflects the combined area of the Upper Amazon Creek and A3 Channel watershed.*

[b] *The total watershed area, exclusion area, and modeled area are reflective of area within the city limits (or NPDES MS4 permit boundary).*

The breakdown of modeled area by land use and structural BMP coverage is outlined in Tables 4-2 and 4-3.

Figure 4-2 shows the land use breakdown by TMDL watershed.

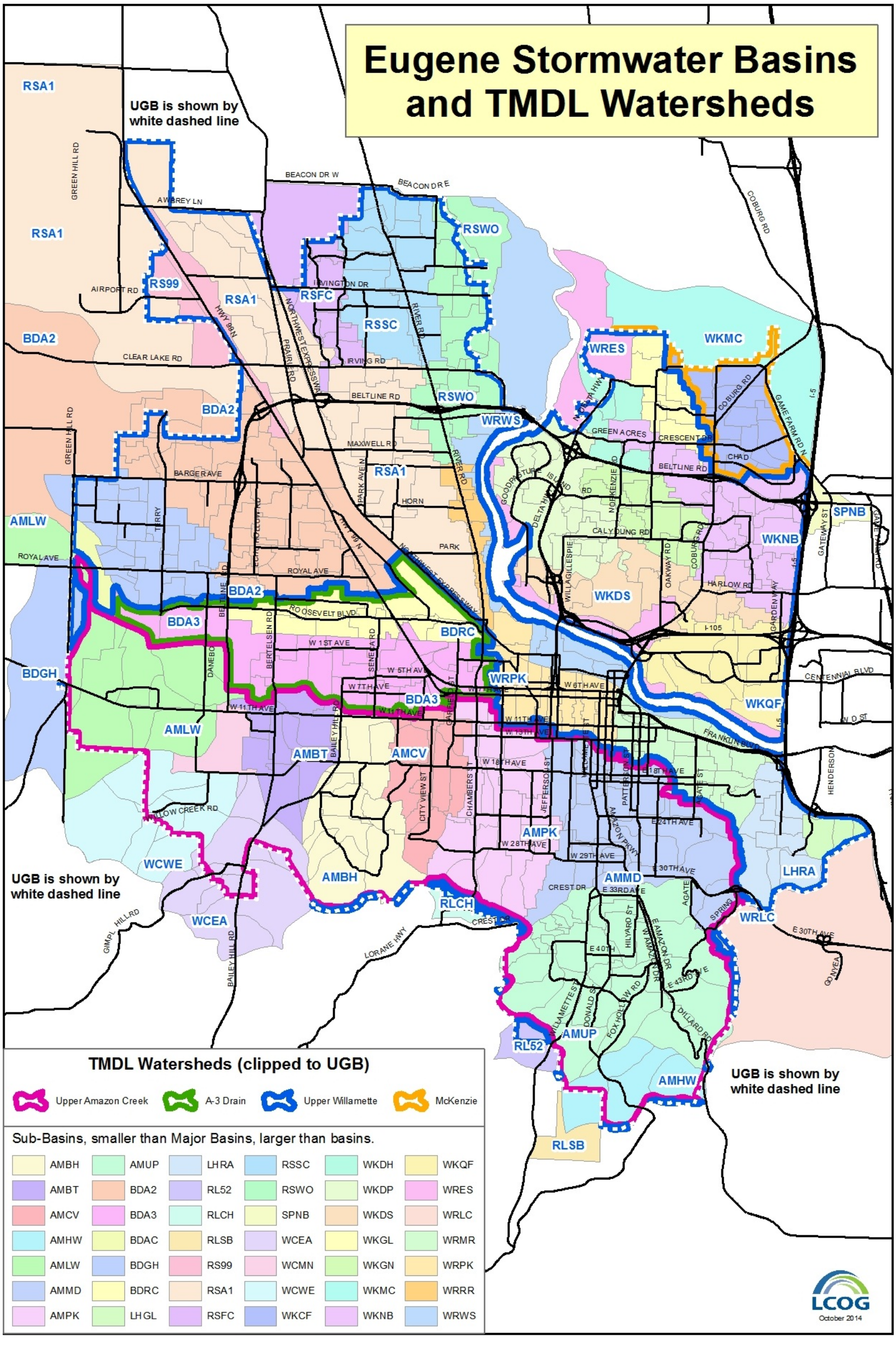

Figure 4-1. Eugene stormwater basins and TMDL watersheds

(Source: City of Eugene)

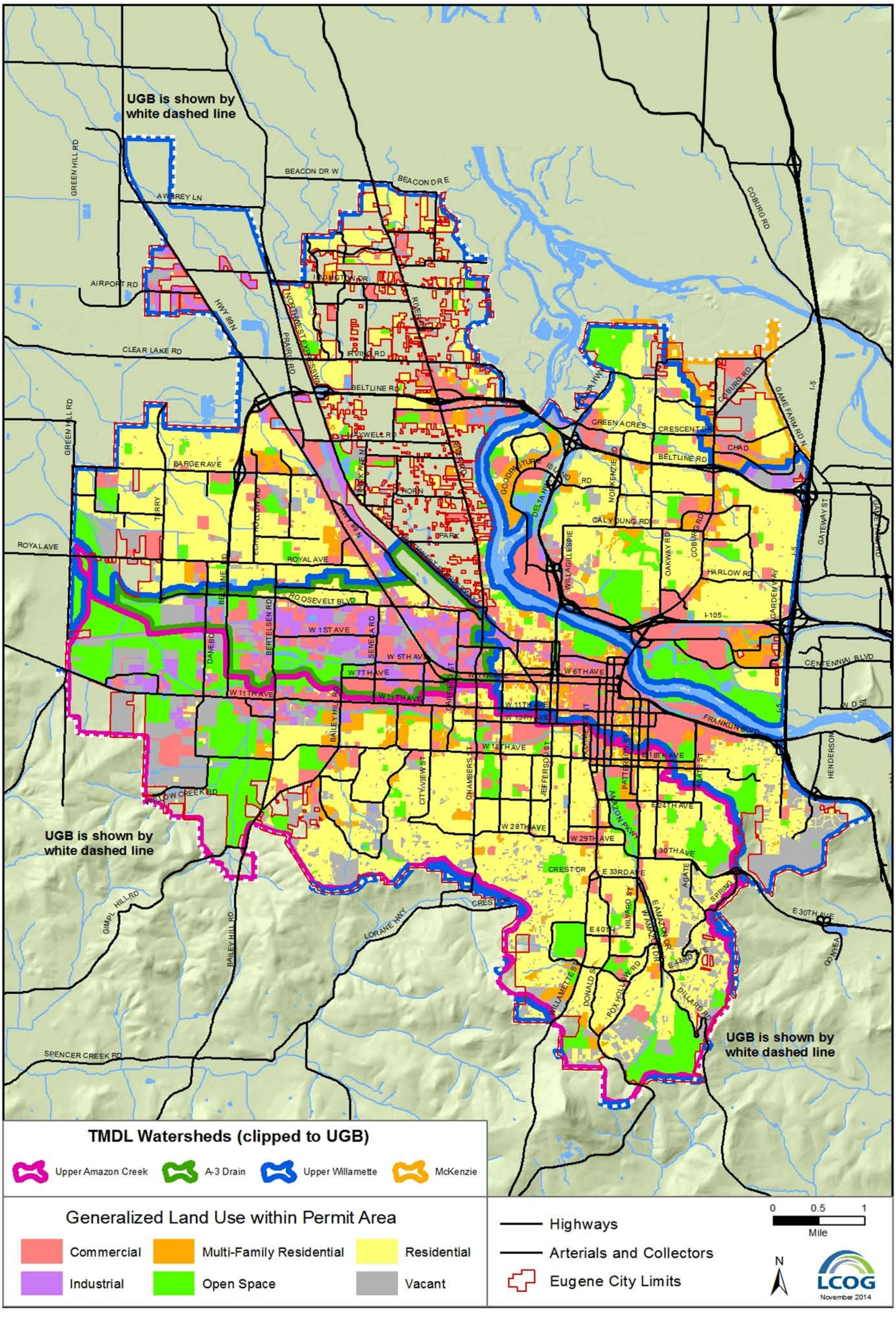

Figure 4-2. Eugene TMDL watershed and land use

(Source: City of Eugene)

Table 4-2. Summary of Model Input Parameters (Land Use)

TMDL/subbasin	TMDL water body	Total modeled area (ac)	Land use breakdown (acres)					
			Commercial	Industrial	Single family residential	Multi-family residential	Vacant	Parks and open space
Willamette Basin/ Upper Willamette and McKenzie River	Upper Amazon Creek	10,727.1	1,139.3	209.1	5,164.4	566.2	1,543.3	2,104.8
	A3 Channel	2,201.1	731.5	560.3	291.9	10.1	257.8	349.5
	Upper Willamette River	13,775.9	2,587.0	385.3	6,755.5	885.4	1,186.6	1,976.1
	McKenzie River	522.7	139.1	0.1	203.2	22.9	153.5	4.0
	Amazon Diversion Channel/Fern Ridge Reservoir [a]	12,928.2	1,870.8	769.3	5,456.3	576.3	1,801.1	2,454.3

[a] *The Amazon Diversion Channel/Fern Ridge Reservoir watershed reflects the combined area of the Upper Amazon Creek and A3 Channel watershed.*

Table 4-3. Summary of Model Input Parameters (BMP Coverage)

TMDL/subbasin	TMDL water body	BMP coverage area (% model area)	BMP coverage (ac)										
			Filters	Dry, detention ponds	Wet, retention ponds	Swale/ filter strip	Wetlands	Sedimentation manholes	Hydro-dynamic devices	Eco-Roofs	Infiltration rain garden/porous pavement	Filtration rain garden/lined planter	UIC/ drywell
Willamette Basin/ Upper Willamette and McKenzie River	Upper Amazon Creek	1.5	0.0	11.0	0.0	97.8	0.0	16.7	34.6	0.0	0.0	2.6	0.0
	A3 Channel	6.1	0.0	0.0	0.0	78.3	0.0	7.2	49.7	0.0	0.0	0.0	0.0
	Upper Willamette River	9.6	0.0	0.2	0.0	273.3	0.0	155.9	885.2	0.9	0.0	6.6	0.0
	McKenzie River	4.6	0.0	0.0	0.0	1.6	0.0	11.8	10.6	0.0	0.0	0.2	0.0
	Amazon Diversion Channel/Fern Ridge Reservoir [a]	2.3	0.0	11.0	0.0	176.1	0.0	23.9	84.3	0.0	0.0	2.7	0.0

[a] *The Amazon Diversion Channel/Fern Ridge Reservoir watershed reflects the combined area of the Upper Amazon Creek and A3 Channel watershed.*

4.3 Model Assumptions and Input Data

To generate pollutant loads, a number of assumptions were made with regard to the acquisition, processing, and utilization of land use concentration data and BMP effluent concentration data. Assumptions were also made with respect to land use categories, BMP categories, and modeling methods. These assumptions are described below.

4.3.1 Land Use and BMP Effluent Data

Development of land use pollutant load concentration data and BMP effluent data for use by Oregon Phase I NPDES MS4 permittees for pollutant load modeling began in 2004. In anticipation of future pollutant load reduction benchmark requirements in their NPDES MS4 permits, select Phase I jurisdictions coordinated efforts to maintain consistency with respect to interpretation and implementation of the benchmark requirement. The statewide coordination process was facilitated through the Oregon ACWA Stormwater Committee. One item that ACWA coordinated was the determination of appropriate, typical land use-based pollutant load concentrations and BMP effluent concentrations for use in pollutant loads modeling.

Tables of pollutant concentration by land use, referred to in this report as “event mean concentrations” (EMCs), and BMP effluent concentrations were originally developed in 2005 for Phase I jurisdictions required to develop pollutant load reduction benchmarks as part of their Interim Evaluation Report submittals (in 2006). The tables of original concentration data were developed using published, statistically verified national data and data obtained by local jurisdictions.

For the 2008 pollutant load reduction benchmark submittals, the original land use EMC and BMP effluent concentrations developed in 2005 were revisited. The original land use concentration data were adjusted to include additional data reflective of the open space land use category and revisions to the statistical method of dealing with non-detects and outliers. As was done in 2005, the data were *bootstrapped*, a statistical method to estimate upper and lower confidence intervals. The original BMP effluent values were reviewed for inconsistencies and questionable values (e.g., data points where the dissolved concentration is greater than the total concentration, and data points where the BMP effluent concentration is greater than local land use EMCs).

For this (2014) pollutant load reduction evaluation effort, Phase I jurisdictions again coordinated to revisit and refine BMP categories and BMP effluent data per updated information contained in the American Society of Civil Engineers (ASCE) BMP database and locally obtained data. No changes were made to the 2008 land use EMC data. BMP updates were made and focused on inclusion of refined flow reduction values for infiltration-related BMPs. New BMP categories and effluent concentration data reflecting lined planters/filtration rain gardens, eco roofs, and porous pavement were also added.

Land use concentration data, including the upper and lower confidence intervals, are provided in Table 4-4. These values are consistent with 2008 data assumptions. The mean BMP effluent concentration values are provided in Table 4-5. As described previously, these values were collectively developed and reviewed by the ACWA Stormwater Committee in 2014. Analysis of *E. coli* is conducted via use of a geomean land use EMC, due to calculation procedures.

Table 4-4. Land Use-based Pollutant Load Concentration Values Used in Benchmarking

Parameter	Land use	Count[c]	Bootstrapped mean		
			95% lower confidence level	Mean	95% upper confidence level
Total phosphorus (mg/L)	Commercial	26	0.28	0.38	0.50
	Industrial	25	0.40	0.51	0.64
	Open space[a]	8	0.01	0.12	0.15
	Residential[b]	36	0.23	0.34	0.48
Biological oxygen demand (mg/L)	Commercial	22	8.5	11.9	16.6
	Industrial	23	26.1	39.6	56.1
	Open space[a]	3	2.4	3.3	4.2
	Residential[b]	28	5.9	8.1	10.8
Total suspended solids (mg/L)	Commercial	72	64	82	103
	Industrial	48	117	184	284
	Open space[a]	10	16	31	50
	Residential[b]	65	44	66	99
Parameter	**Land use**	**Count**	**Bootstrapped geomean**		
			95% lower confidence level	Geomean	95% upper confidence level
Fecal coliform, coliform colony forming units (CFU)/100 milliliters (mL) (geomean)	Commercial	52	707	1,540	2,974
	Industrial	58	190	541	1,240
	Open space[a]	9	96	117	141
	Residential[b]	65	1197	2,045	3,273
E. coli, CFU/100 mL (geomean)	Commercial	52	573	1,247	2,409
	Industrial	58	154	438	1,004
	Open space[a]	9	57	87	124
	Residential[b]	65	970	1,656	2,651

Data range (+/- 95%) provided by the City of Portland. Based on modified ACWA data set (2008).

[a] *Land use EMCs for open space are used to simulate vacant land use.*

[b] *Land use EMCs for residential are used to simulate single family residential and multi-family residential.*

[c] *Reflects the sample size for the source land use concentration data.*

Table 4-5. BMP Effluent Concentration Values Used in the Benchmark Model

Parameter	Units	Centrifugal separator hydrodynamic devices	Filters (leaf/sand/other)	Ponds, dry vegetated detention ponds	Ponds-wet retention basin	Swales-vegetated filter strips	Water quality wetlands	Sedimentation manhole	Green roofs	Porous pavement/UIC	Soakage trenches/infiltration rain gardens	Lined planters/filtration rain gardens
		Mean										
Total phosphorus	mg/L	0.22	0.15	0.34	0.17	0.21	0.15	0.22	0.48	N/A	N/A	0.15
BOD	mg/L	6.0	3.4	12.2	6.1	5.4	6.1	6.0	2.4	N/A	N/A	3.4
TSS	mg/L	115	42	44	41	24	25	66	5.4	N/A	N/A	42
E. coli	CFU/100 mL	5,587	91	1,922	499	1,922	499	5,587	20	N/A	N/A	91
Flow reduction	decimal %	0.00	0.00	0.23	0.05	0.29	0.00	0.00	0.50	1.00	1.00	0.30

Values in red are consistent with the ACWA data set (2008) and consistent with 2008 data assumptions.

Values in green are updated values per the 2014 ACWA Stormwater Committee reanalysis of BMP effectiveness. Underlined values reflect an increase from 2008 values.

Values in purple are new values per the 2014 ACWA Stormwater Committee reanalysis of BMP effectiveness.

Effluent concentrations shown as N/A are provided for BMP facilities that achieve 100% flow reduction, as no effluent is generated with which to analyze.

4.3.2 Land Use and BMP Categories

As stated in Section 4.2, the City updated the land use coverage for the 2014 pollutant load modeling effort. The source of the land use coverage used for the pollutant load update was the regional GIS land use data, which includes developed and vacant land use. As was done in 2008, the regional GIS land use categories were reviewed and consolidated into those categories for which land use runoff concentration data had been developed by ACWA. The City maintained a consistent process to consolidate land use categories with the 2008 pollutant load reduction evaluation and benchmark effort assumptions. Some site-specific refinement was conducted in the parks and open space land use category to more accurately distinguish large stadium structures and associated parking areas from adjacent open space.

Similar to the 2008 pollutant load evaluation, transportation was not treated as a stand-alone, separate, land use category with an associated pollutant load. Land use EMC data reflects some transportation area within the other land use categories; therefore transportation area is not separately modeled. For the City's 2014 modeling effort, the way in which the streets and rights-of-way were assigned to generalized land use categories was refined as compared to the 2008 modeling effort. In 2014, the generalized land use was extended into adjacent rights of way to allow streets and other transportation areas to be designated as a model land use category and included in the land use GIS coverage. This method allows transportation areas to be modeled in a more site-specific way. Previously, in 2008, transportation areas were separately calculated by TMDL watershed. Then, the transportation areas were assigned to a land use category based on the percent of that land use category in the watershed. Detail related to the 2014 GIS land use processing and assignment of transportation by

land use is available from the City of Eugene (Methodology Notes 2014 Pollutant Loads Update – Land Use Data and Spatial Infill, LCOG).

The City developed a more robust GIS BMP inventory for the 2014 pollutant load modeling effort. The City's BMP inventory is continually being improved to ensure accurate representation of public and private structural BMPs and associated treatment areas. The 2014 modeling effort included public and private structural BMPs with a documented drainage area. The 2008 modeling effort did not include private BMPs as the City's post-construction stormwater development standards were implemented in 2006 and by 2008, very few private water quality facilities had been constructed.

For some of the City's structural BMP facilities, the associated drainage areas are currently not documented. These BMPs were therefore not included in the model. Not accounting for these BMPs is a conservative assumption as these BMPs are also providing some level of pollutant load reduction.

The BMP effluent concentrations listed in Table 4-5 do not include all of the City's BMP categories. Therefore, some of the City's BMP categories were modeled using concentration data from a comparable BMP category. Table 4-6 identifies the BMP category from Table 4-5 that was used to represent each of the City's BMP categories.

Table 4-6. Structural BMP Categories Used in the City's Pollutant Loads Model

City's structural BMP designation (number modeled)	Modeled BMP category
Structural detention facility (7)	Ponds, dry vegetated detention ponds
Swale (173) Vegetated filter strip (11)	Swales, vegetated filter strips
Manufactured stormwater treatment technology (105) Polk Street water quality vault (1)	Centrifugal separators, hydrodynamic devices
Sedimentation manhole (103)	Sedimentation manholes
Rain garden (60) Stormwater planter (16)	Lined planters/filtration rain gardens
Eco roof and roof garden (1)	Green roofs

As mentioned previously, source control and non-structural BMPs were not included in the model.

4.3.3 Impervious Values

Effective impervious percentages by land use that were used in 2008 were also used for this 2014 pollutant load modeling effort. The percentages are consistent with values used for the City's adopted Stormwater Basin Master Plans.

The EPA formula was used to translate between percent impervious and a runoff coefficient, for use in the pollutant loads model:

Runoff coefficient = 0.05 * 0.009 (percent impervious)

Table 4-7 summarizes the percent impervious areas used to calculate runoff coefficients by land use category.

Table 4-7. Land Use Categories Used in the City's Pollutant Loads Model	
City modeled land use classification	2014 modeled impervious percentage
Single family residential (SFR)[a]	44
Multi-family residential (MFR)[a]	59
Commercial (COM)	71
Industrial (IND)	61
Vacant (VAC)[a]	2
Parks and open space (POS)	18

[a] *The land use EMCs listed in Table 4-4 do not include all of the City's land use categories. Therefore, some City land use categories were modeled using concentration data from a comparable land use category. This occurred for the SFR and MFR categories (modeled using residential concentration data), and the VAC category (modeled using open space concentration data).*

4.3.4 Modeling BMPs

Current public and private structural BMP information (BMP types and drainage areas) was compiled into one GIS shapefile. The City's current BMP inventory includes the number of acres for BMP drainage areas but not the actual spatial delineation of that drainage area. Therefore, circles representing the drainage area acreages were generated surrounding each BMP, reflective of the documented drainage area. This was done so that the GIS information could be used to estimate the BMP drainage areas and coverage for use in the model. One exception to this approach was made for a structural BMP with a large, known and delineated drainage area: the Polk Street vault retrofit facility.

Following the delineation effort, some areas were shown as being treated by multiple BMPs (i.e., there were overlapping drainage area circles). This may be representative of structural BMPs working together in series to achieve pollutant removal or reflective of limited delineation of actual drainage areas. For those overlapping drainage areas, the structural BMP that provided the better overall treatment was generally selected as the representative BMP for the drainage area. This method does not give credit for additional load removal likely achieved with BMPs that perform in series.

Most structural BMPs are not capable of treating all runoff that may enter a facility in any given year. Generally, BMPs are designed to treat a proportion of the total annual rainfall/runoff that occurs. The Eugene City Code and Stormwater Management Manual reflect what the NPDES MS4 permit requires which is water quality treatment for 80 percent of the average annual runoff volume. Thus, structural BMPs included in the model were assumed to capture and treat 80 percent of the average annual rainfall and bypass additional runoff.

4.4 Model Input Files

The City generated GIS shapefiles to populate the pollutant loads model with areal information reflecting model area, model land use, and BMP coverage. Source GIS files are available from the City upon request and are documented in the internal memorandum from LCOG: *Methodology Notes 2014 Pollutant Loads Update – Land Use Data and Spatial Infill*.

4.5 Model Simulation

In accordance with Schedule D.7.a of the City's NPDES MS4 permit, the City is required to conduct a pollutant load reduction evaluation for all applicable TMDL parameters reflective of development conditions in 2014. The pollutant load reduction evaluation must include an estimate of current pollutant loading without BMP implementation and an estimate of current pollutant loading with BMP implementation. Results of the pollutant load reduction evaluation must be compared to previously established pollutant load reduction benchmarks and applicable WLAs.

As described in Section 2, the Upper Willamette Subbasin includes tributary-specific WLAs for bacteria, total phosphorus (as a surrogate for DO), BOD (as a surrogate for DO), and TSS (as a surrogate for DO and turbidity). WLAs are identified as a single percent reduction and, for purposes of this evaluation, are evaluated on an annual basis.

An annual rainfall of 46 inches was used in the model to simulate annual pollutant loading. The modeled rainfall volume is consistent with assumptions from the 2008 pollutant load evaluation and benchmark development.

Areas reflecting current land use and BMP coverage were calculated for each TMDL watershed and input into the spreadsheet loads model. Model scenarios reflecting both BMP implementation and no BMP implementation were simulated to evaluate pollutant load reduction, consistent with requirements of Schedule D.3.c of the NPDES MS4 permit. The BMP implementation scenario reflects implementation of public and private structural facilities.

4.6 Model Output and Comparison to WLAs

The pollutant load spreadsheet model is capable of calculating loads for a variety of pollutant parameters. Specific for this pollutant load reduction evaluation and the future development of pollutant load reduction benchmarks, annual bacteria loads (as counts) and total phosphorus, BOD, and TSS loads (in pounds) are calculated for each scenario (no-BMP and with-BMP). Pollutant loads are calculated for the upper confidence limit (UCL), the mean (or geomean for bacteria), and the lower confidence limit (LCL), to yield a range in the resulting loads. Pollutant loads are graphically provided for each scenario.

The WLA is calculated as the specified percent load reduction from the no-BMP pollutant load range. The WLA is graphically shown as a range next to the pollutant loads generated for each watershed and pollutant parameter.

The estimated pollutant load reduction is calculated as the difference between the no-BMP pollutant load and the with-BMP pollutant load. Because loads are presented as a range, the pollutant load reduction is also identified as a range, reflecting the difference between the no-BMP and with-BMP pollutant load for the UCL and the difference between the no-BMP and with-BMP pollutant load for the LCL.

Section 5

Pollutant Load Reduction Evaluation Results

Pollutant load model results, including calculation of the pollutant load reduction by TMDL watershed, comparison of model results to WLAs, and comparison of model results to the 2013 pollutant load benchmarks, are described below. Section 5.1 presents the model results by TMDL watershed, Section 5.2 provides a comparison of model results to 2008 benchmarks, and Section 5.3 provides an evaluation of model results with respect to water quality trends and expectations.

It should be emphasized that the pollutant load model results portray the incremental improvements that are estimated with the implementation of structural BMPs. The City implements a significant number of non-structural BMP activities that are required under the City's current NPDES MS4 permit but are not directly reflected in the model results. These measures include public education, illicit discharges elimination, spill prevention, catch basin cleaning, erosion control, etc. Discussion related to the conservative nature of the pollutant load modeling results and interpretation of how source control and non-structural BMPs are accounted for in the model results is provided in Section 5.3.

5.1 Pollutant Load Reduction Evaluation Results

Pollutant loads were calculated for five TMDL watersheds within the Upper Willamette Subbasin with specified WLAs. Pollutant loads are calculated on an annual basis. Model results, provided by TMDL watershed in the subsections below, reflect model assumptions and simulations as described in Section 4. Model results include a numeric estimate of the current pollutant load reduction range (Schedule D.3.c.ii), an estimate of the current pollutant loading to the WLA (Schedule D.3.c.iii), and, a narrative summarizing progress toward existing WLAs (Schedule D.3.c.viii and ix).

The WLA is shown for each pollutant parameter. As described in Section 4.6, the WLA is calculated based on the required load reduction applied to the no-BMP pollutant load range.

5.1.1 Upper Amazon Creek

Figure 5-1 shows the City's bacteria pollutant load estimates for the Upper Amazon Creek TMDL watershed. Both the no-BMP and with-BMP load estimates are shown. The pollutant load reduction estimate is highlighted.

The bacteria WLA for Upper Amazon Creek is an annual 84 percent reduction.

The City shows a mean load decrease of approximately 5.20×10^{11} counts (approximately a 0.2% reduction) when comparing conditions with and without BMPs.

Structural BMP implementation is more limited in this watershed (structural BMP coverage of about 1.5 percent as compared to approximately 6 percent for the city as a whole). In addition, the structural BMPs implemented in this watershed (swales, hydrodynamic separators) generally show limited effectiveness for bacteria removal. Generally, bacteria reduction associated with structural BMPs is due to any flow reduction achieved through the structural BMP (i.e., infiltration) rather than actual removal of the bacteria itself.

Figure 5-1 indicates that the City is not currently estimated to be meeting the WLA for bacteria in the Upper Amazon Creek watershed. Significant additional load reduction would be needed beyond the current structural BMP implementation reflected in the range of loading. Although source control and non-structural BMPs are implemented in this watershed (and not directly considered in the pollutant load reduction estimate), it is unlikely that the additional pollutant removal achieved would result in meeting the WLA. The WLA is considered to be an ultimate discharge goal.

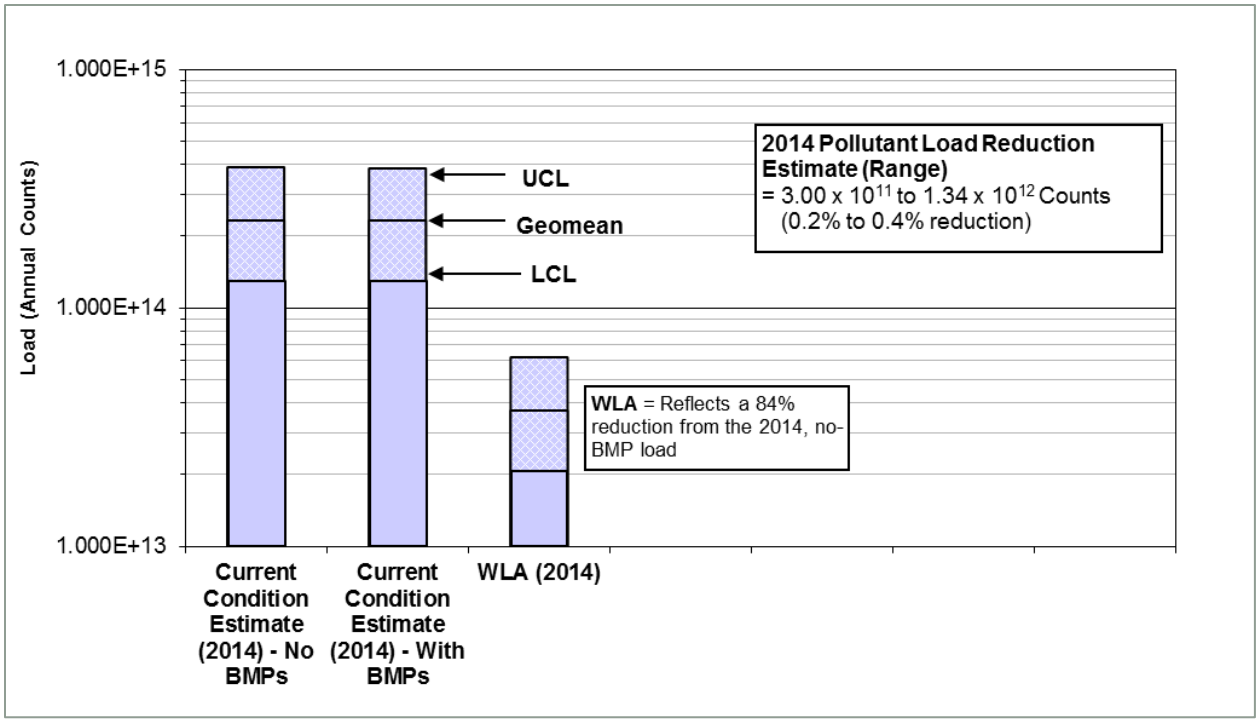

Figure 5-1. Upper Amazon Creek: annual pollutant load reduction evaluation results

5.1.2 A3 Channel

Figure 5-2 shows the City's bacteria pollutant load estimates for the A3 Channel TMDL watershed. Both no-BMP and with-BMP load estimates are shown. The pollutant load reduction estimate is highlighted.

The bacteria WLA for the A3 Channel is a 33 percent annual load reduction.

The City shows a mean load decrease of approximately 2.70 x 10^{11} counts (approximately a 0.6% reduction) when comparing conditions with and without BMPs.

Structural BMP implementation is more prevalent in this watershed, as compared with the Upper Amazon Creek watershed. Figure 5-2 indicates that the City is not estimated to be meeting the WLA for bacteria in the A3 Channel TMDL watershed, when comparing the mean pollutant load estimate with BMPs to the mean WLA. However, the WLA does fall within the current condition—with-BMP pollutant loads range. Because the pollutant load reduction estimate reflects structural BMP implementation alone, potentially non-structural and source control BMP implementation (as implied by the range in pollutant loading) may further reduce pollutant loads to meet the WLA. However, adherence to the WLA is not known at this time.

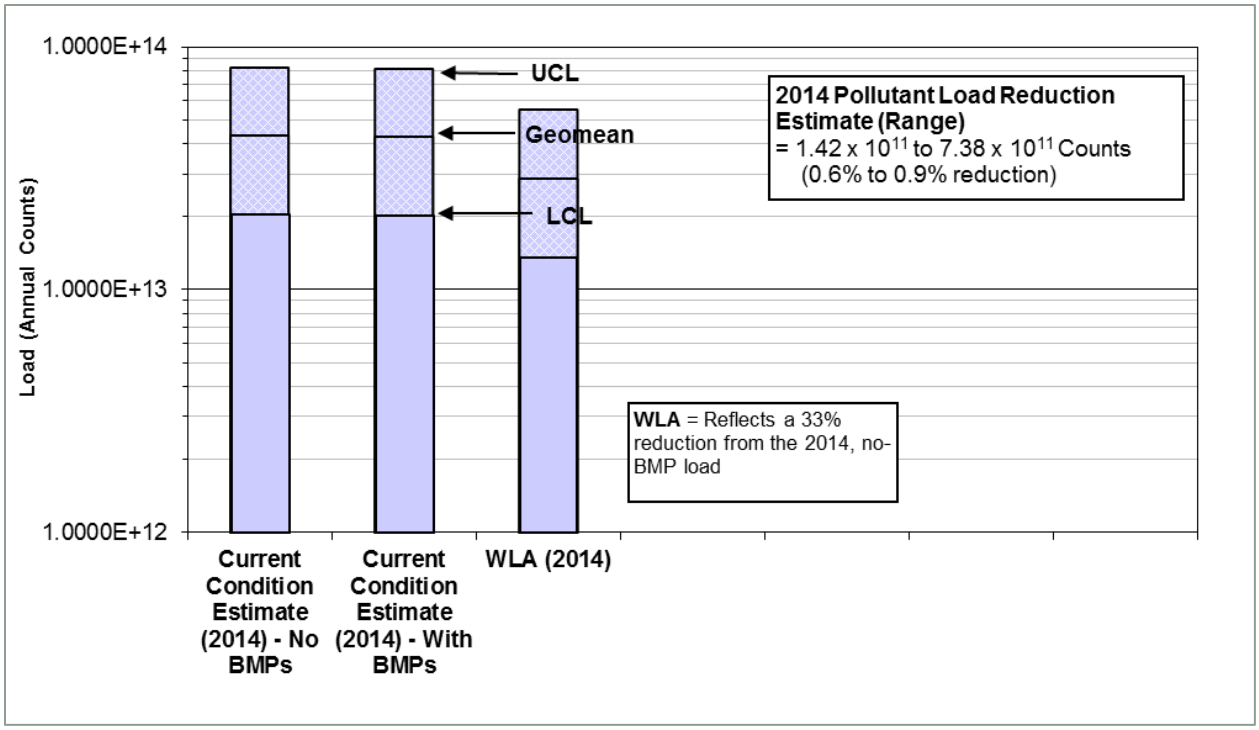

Figure 5-2. A3 Channel: annual pollutant load reduction evaluation results

5.1.3 Upper Willamette River

Figure 5-3 shows the City's bacteria pollutant load estimates for the Upper Willamette Basin TMDL watershed. Both no-BMP and with-BMP load estimates are shown. The pollutant load reduction estimate is highlighted.

The bacteria WLA for the Upper Willamette River (unspecified) is a 65 percent annual load reduction.

The City shows a mean load decrease of approximately 1.80 x 10^{12} counts (approximately a 0.5% reduction) when comparing conditions with and without BMPs.

Structural BMP implementation is more prevalent in this watershed, with swales, sedimentation/hydrodynamic systems, and sediment manholes being the dominant BMP categories. Sedimentation-based systems (hydrodynamic systems, sedimentation manholes) show limited effectiveness for bacteria removal, so although the coverage of BMPs is greater, the relative bacteria load reduction may not be optimal.

Figure 5-3 indicates that the City is not estimated to be meeting the WLA for bacteria in the Upper Willamette River watershed, when comparing the mean pollutant load estimate with BMPs to the mean WLA. However, the relative range in current pollutant loading is not exceedingly far from the WLA. Source control and non-structural BMPs implemented in this watershed (and not directly considered in the pollutant load reduction estimate) would be expected to result in additional load reduction, but it is unknown at this time whether the additional pollutant removal achieved would result in meeting the WLA.

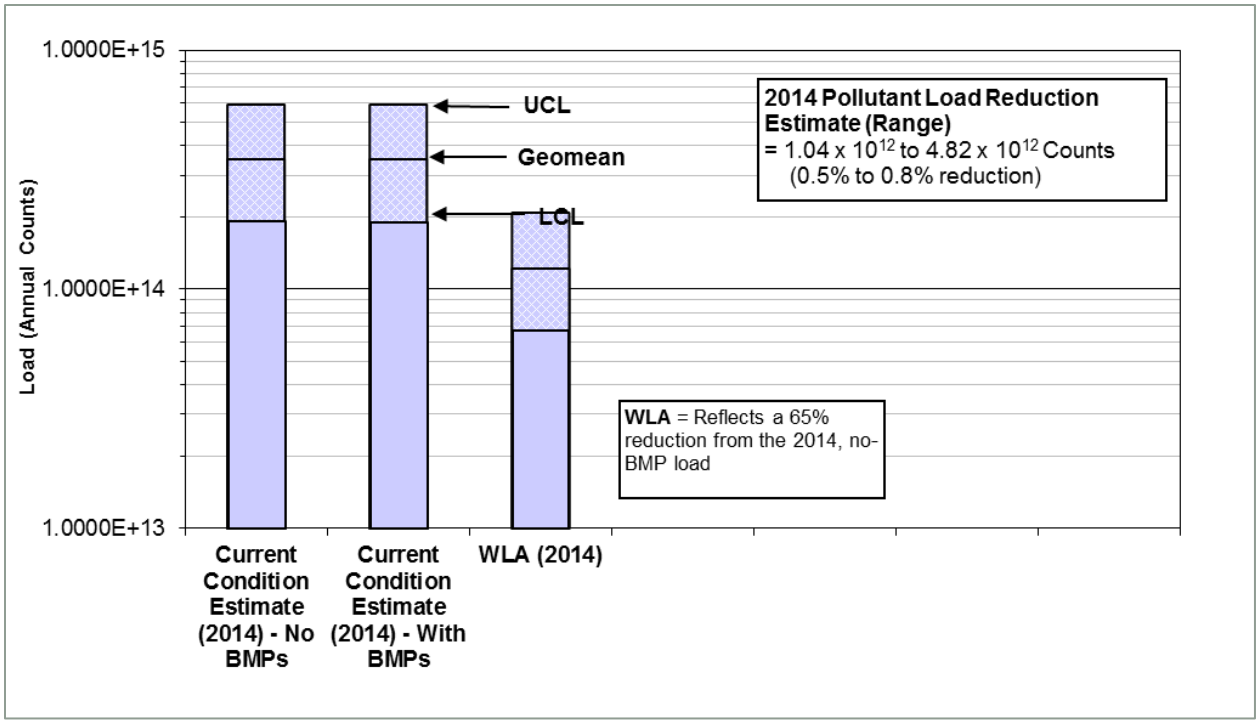

Figure 5-3. Upper Willamette River: annual pollutant load reduction evaluation results

5.1.4 McKenzie River

Figure 5-4 shows the City's bacteria pollutant load estimates for the McKenzie River TMDL watershed. Both no-BMP and with-BMP load estimates are shown. The pollutant load reduction estimate is highlighted. This TMDL watershed was not specifically modeled in 2008, due to interpretation of the TMDL documents.

The bacteria WLA for the McKenzie River is an annual 65 percent reduction, consistent with the Upper Willamette River.

The City shows a mean load decrease of approximately 2.00 x 10^{10} counts (approximately a 0.2% reduction) when comparing conditions with and without BMPs.

Structural BMP implementation is more limited in this watershed as compared to other TMDL watersheds. As with the other TMDL watersheds, sedimentation-based BMP systems (hydrodynamic systems, sedimentation manholes) are the dominant BMPs applied, which show limited effectiveness for bacteria removal.

Figure 5-4 indicates that the City is not currently estimated to be meeting the WLA for bacteria in the McKenzie River watershed when comparing the mean pollutant load estimate with BMPs to the mean WLA. As with the Upper Willamette River watershed, additional load reduction would be needed beyond the current structural BMP implementation reflected in the range of load reduction. Source control and non-structural BMPs implemented in this watershed (and not directly considered in the pollutant load reduction estimate) would be expected to result in additional load reduction, but it is unknown at this time whether the additional pollutant removal achieved would result in meeting the WLA.

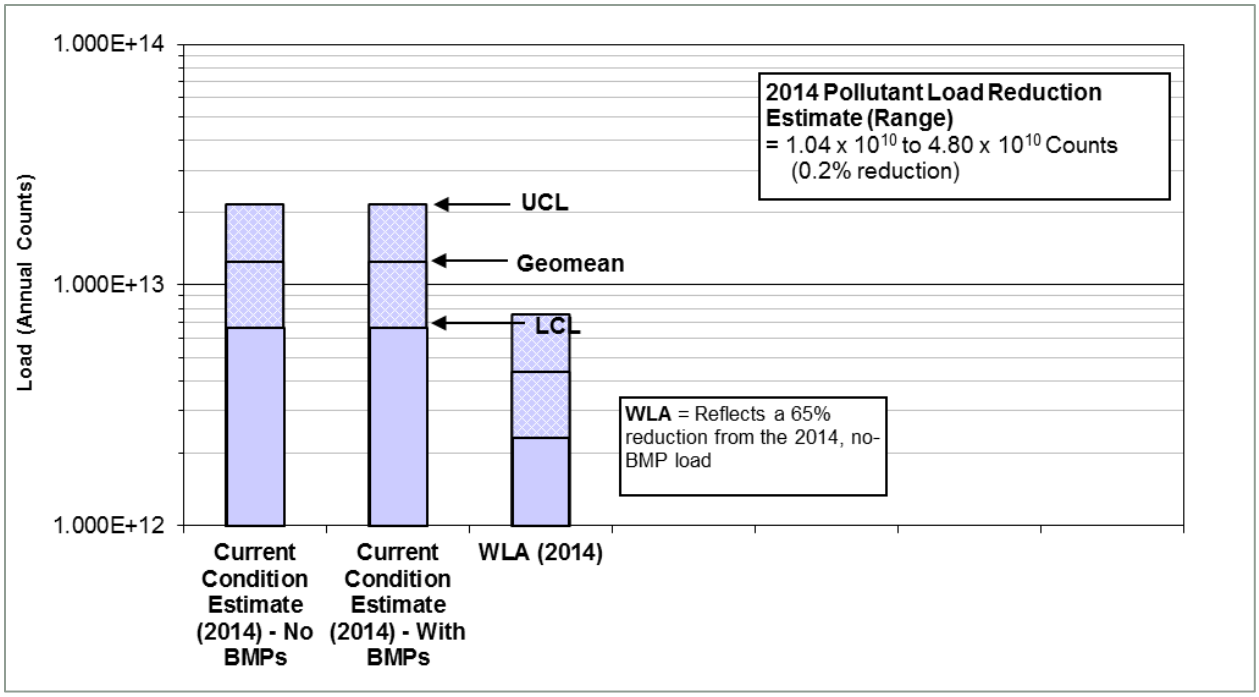

Figure 5-4. McKenzie River: annual pollutant load reduction evaluation results

(This watershed was not specifically modeled in 2008.)

5.1.5 Amazon Diversion Channel and Fern Ridge Reservoir

Figures 5-5, 5-6, 5-7, and 5-8 show the City's pollutant load estimates for the Amazon Diversion Channel and Fern Ridge Reservoir TMDL watershed. This TMDL watershed reflects the combined area from the Upper Amazon Creek and A3 Channel watersheds. Both no-BMP and with-BMP load estimates are shown for each pollutant parameter. The pollutant load reduction estimate is highlighted.

Figure 5-5 shows the pollutant load estimate for total phosphorus for the Amazon Diversion Channel. The total phosphorus WLA is a 40 percent annual load reduction. The City shows a mean load decrease of approximately 140 pounds (approximately a 0.9% reduction) when comparing conditions with and without BMPs.

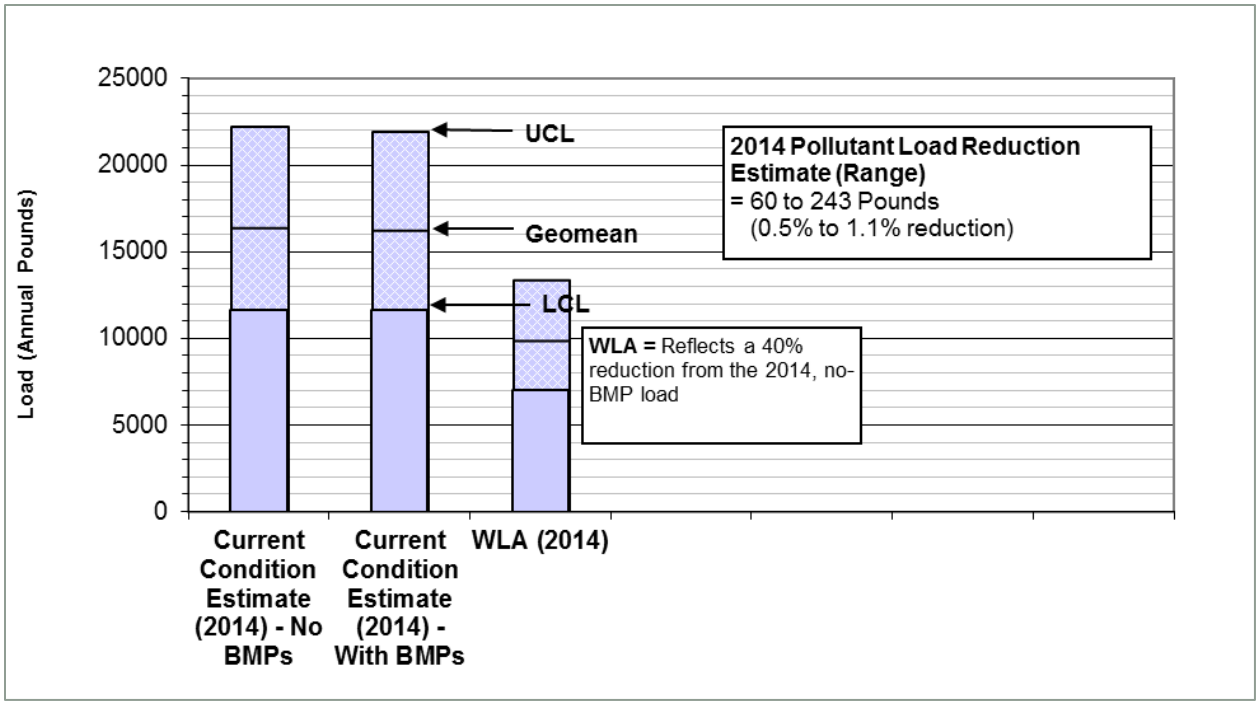

Figure 5-5. Amazon Diversion Channel: total phosphorus annual pollutant load reduction evaluation results

Figure 5-6 shows the pollutant load estimate for BOD for the Amazon Diversion Channel. As with total phosphorus, the WLA is a 40 percent annual load reduction. The City shows a mean load decrease of approximately 5,300 pounds (approximately a 1% reduction) when comparing conditions with and without BMPs.

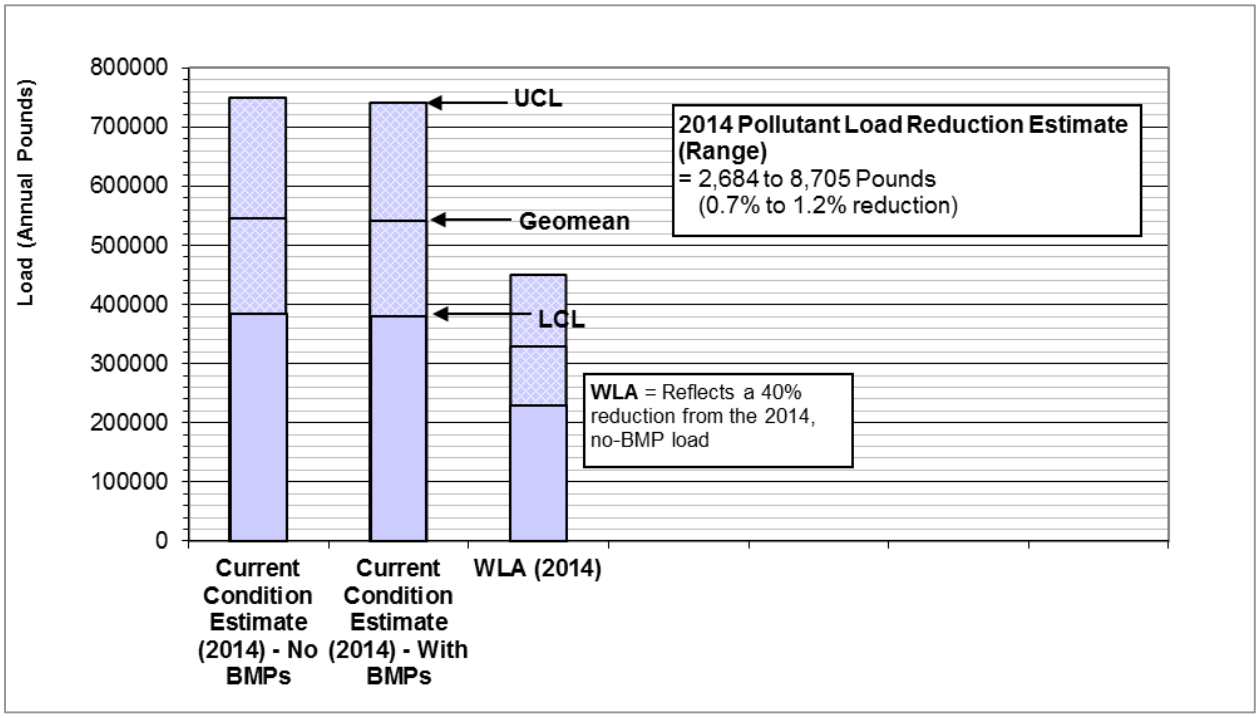

Figure 5-6. Amazon Diversion Channel: BOD annual pollutant load reduction evaluation results

Figure 5-7 shows the pollutant load estimate for bacteria for the Fern Ridge Reservoir. The WLA is a 64 percent annual load reduction. The City shows a mean load decrease of approximately 8.00 x 10^{11} counts (approximately a 0.3% reduction) when comparing conditions with and without BMPs. This parameter was not specifically modeled in 2008 for the Fern Ridge Reservoir TMDL watershed, as bacteria were evaluated for the contributing areas (Upper Amazon Creek and A3 Channel) and associated WLAs. However, comparison to the specific Fern Ridge WLA was not conducted, so this comparison is now included.

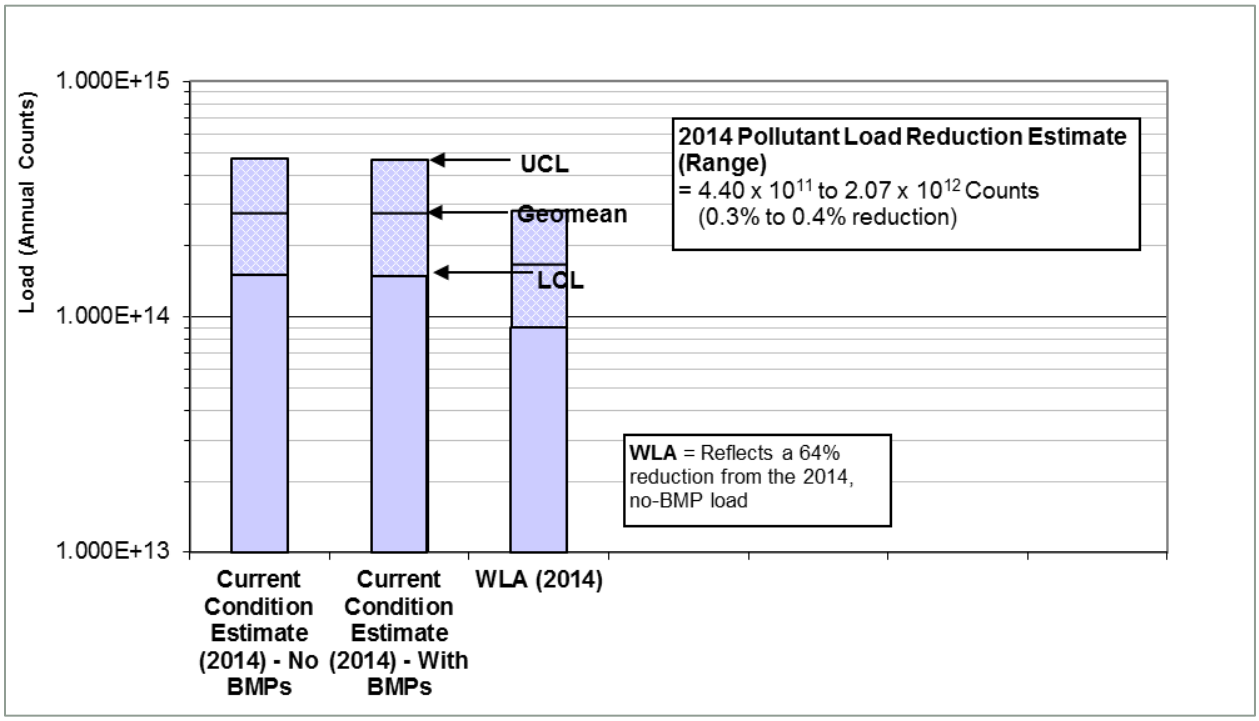

Figure 5-7. Fern Ridge Reservoir: bacteria annual pollutant load reduction evaluation results

(This parameter was not specifically modeled in 2008 for this watershed.)

Finally, Figure 5-8 shows the pollutant load estimate for TSS for the Amazon Diversion Channel/Fern Ridge Reservoir. The WLA is a 40 percent annual load reduction for the Amazon Diversion Channel and a 54.6 percent annual load reduction for the Fern Ridge Reservoir. The City shows a mean load decrease of approximately 26,400 pounds (approximately a 0.7% reduction) when comparing conditions with and without BMPs.

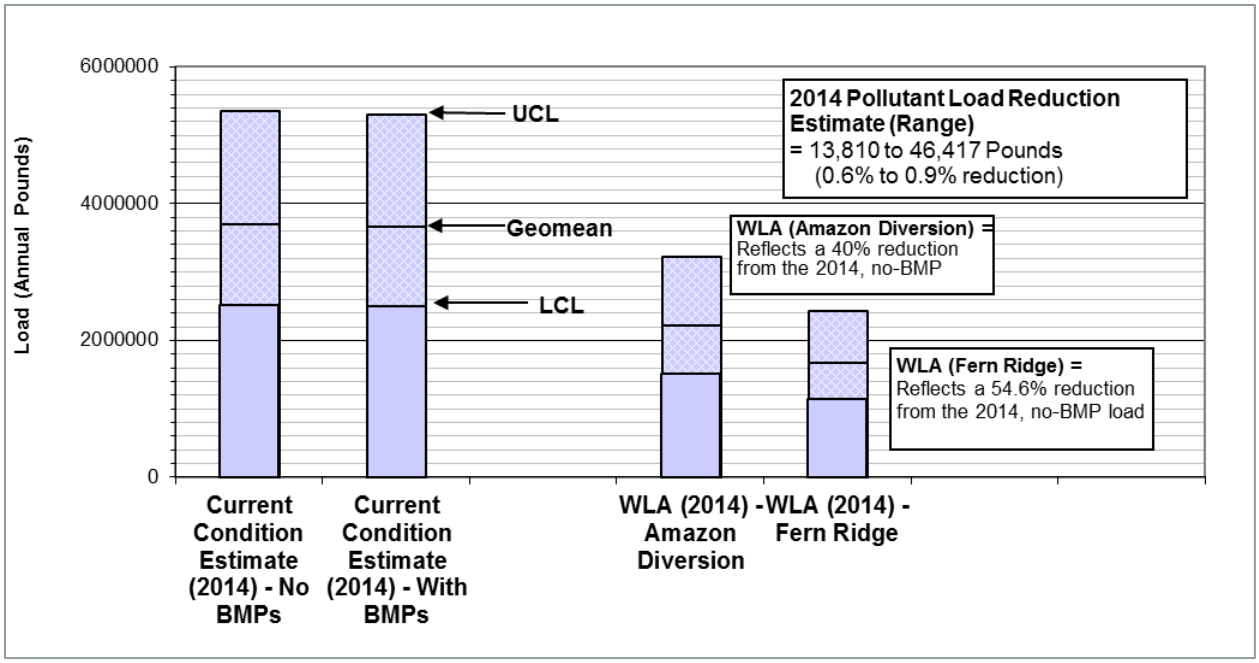

Figure 5-8. Amazon Diversion Channel/Fern Ridge Reservoir: TSS annual pollutant load reduction evaluation results

Figures 5-5, 5-6, and 5-8 indicate that the City is not currently estimated to be meeting the WLA for total phosphorus, BOD, or TSS in the Amazon Diversion Channel, when comparing the mean pollutant load estimate with BMPs to the mean WLA. Figure 5-7 indicates that the City is not currently estimated to meet the WLA for bacteria in the Fern Ridge Reservoir when comparing the mean pollutant load estimate with BMPs to the mean WLA. However, the WLA range does fall within the current condition—with-BMP pollutant loads range for select parameters. Because the pollutant load reduction estimate reflects structural BMP implementation alone, potentially non-structural and source control BMP implementation (as implied by the range in pollutant loading) may further reduce pollutant loads to meet the WLA. However, adherence to the WLA is not known at this time.

5.2 Benchmark Comparison

As part of the pollutant load evaluation effort, pollutant load reduction estimates must be compared to previously established pollutant load reduction benchmarks as applicable (Schedule D.3.c.iv). The City established pollutant load reduction benchmarks for select TMDL watersheds within the Upper Willamette Subbasin in 2008. The pollutant load reduction benchmarks were intended to represent development and BMP implementation conditions in 2013. Pollutant load reduction benchmarks for bacteria were established for the Upper Amazon Creek, A3 Channel, and Upper Willamette River TMDL watersheds. Pollutant load reduction benchmarks were not established for bacteria for the Fern Ridge Reservoir TMDL watershed, as the watershed area was evaluated for bacteria in conjunction with other WLAs. Pollutant load reduction benchmarks were established for total phosphorus, BOD, and TSS for the Amazon Diversion Channel TMDL watershed.

Calculation of pollutant load reduction benchmarks in 2008 required the City to project where annexations would occur (change in permit coverage area), where development would occur (change in land use conditions), and where future BMPs would be implemented (based on projected development and retrofit activities). With the economic downturn in 2008, such activities did not occur as estimated.

Changes in modeling assumptions for 2014 (see Section 4) also resulted in differences in the model area and land use coverage from 2008 assumptions. As a result, the 2008 model assumptions for permit area, land use area, and BMP coverage area are not directly reflected in the 2014 pollutant load reduction evaluation.

Table 5-1 shows the difference in modelled areas and BMP coverage areas between the 2008 modeling effort and the current 2014 modeling effort. Such differences in assumptions directly affected the 2014 pollutant load reduction results and comparison to the 2008 benchmarks.

Table 5-1. Model Comparison

Water body	2008 benchmark effort		2014 Pollutant load reduction evaluation effort
	2008 (actual)	2013 (projected)	2014 (actual)
Total model area (ac)	27,763	28,220	27,227
Total BMP coverage area (%)	1.5	7.2	6.0

Based on changes in modeling assumptions and methods (described above), direct comparison of the 2014 pollutant load reduction estimates to the pollutant load reduction benchmarks projected for the 2013 condition is not possible. However, the City is providing results of the benchmark comparison effort specifically to meet permit requirements outlined in Schedule D.3.c.iv. Results of the comparison effort are documented in Table 5-2 and reflect the 2014 pollutant load reduction range versus the 2013 pollutant load reduction benchmark (defined as a range).

Table 5-2. Upper Willamette Subbasin: Comparison to 2013 Benchmarks

Water body	Parameter (units)	2014 pollutant load reduction estimate[a]			2013 benchmarks (counts), as a range	Met bench-marks[b]
		Upper confidence limit	Mean	Lower confidence limit		
Upper Amazon Creek	Bacteria (counts)	1.40×10^{12}	5.00×10^{11}	3.00×10^{11}	7.50×10^{11} to 3.40×10^{12}	Possibly met
A3 Channel	Bacteria (counts)	7.40×10^{11}	2.70×10^{11}	1.40×10^{11}	6.50×10^{10} to 5.70×10^{12}	Likely met
Upper Willamette River	Bacteria (counts)	4.80×10^{12}	1.80×10^{12}	1.10×10^{12}	2.30×10^{12} to 1.10×10^{13}	Possibly met
McKenzie River	Bacteria (counts)	5.00×10^{10}	2.00×10^{10}	1.00×10^{10}	N/A	N/A
Amazon Diversion Channel	Total phosphorus (pounds)	243	141	60	82 to 317 pounds	Likely met
	BOD (pounds)	8,705	5,318	2,684	4,120 to 12,768 pounds	Likely met
	TSS (pounds)	46,417	26,419	13,810	16,018 to 66,410 pounds	Likely met
Fern Ridge Reservoir	Bacteria (counts)	2.00×10^{12}	8.00×10^{11}	5.00×10^{11}	N/A	N/A
	TSS (pounds)	46,417	26,419	13,810	16,018 to 66,410 pounds	Likely met

[a] *The pollutant load reduction estimate is based on the difference between the no-BMP and with-BMP pollutant loads. The UCL pollutant load reduction range is the difference between the no-BMP and with-BMP pollutant load for the UCL; the mean pollutant load reduction range is the difference between the no-BMP and with-BMP pollutant load for the mean load; the LCL pollutant load reduction range is the difference between the no-BMP and with-BMP pollutant load for the LCL.*

[b] *This column is provided to comply with a permit requirement. However, the City believes that refined GIS files and changes in development projections have a significant impact on the ability to simulate pollutant reductions representative of the benchmarks than changes in the City's BMP implementation commitments.*

For purposes of this benchmark comparison effort, the mean 2014 pollutant load reduction estimate was compared to the 2013 pollutant load reduction benchmark range. Where the mean 2014 pollutant load reduction estimate falls within the benchmark range, the benchmarks are interpreted to likely be met. Where the 2014 pollutant load reduction range falls within the benchmark range, the benchmarks are interpreted to potentially be met.

5.3 Pollutant Load Reduction Evaluation Discussion

Due to the variable nature of stormwater runoff and the variety of undefined sources contributing to stormwater pollutant discharges, there are inherent difficulties in applying WLAs to MS4 discharges and quantitatively tracking pollutant load discharges to ensure that progress toward the WLA is being made.

In conducting a quantitative pollutant load reduction evaluation, the City has chosen a conservative approach to avoid overestimating the effectiveness of its program. The pollutant load reduction estimates reflect the maximum extent practicable standard defined by the City and implemented with structural BMPs. With adaptive management efforts, the recent adoption of updated stormwater development standards for new development and re-development that promote more infiltration and filtration-based stormwater facilities, construction of stormwater retrofit projects, and the potential for new information and/or new, more cost-effective technologies in the future, it is expected that pollutant load reductions will continue to increase.

The pollutant load reduction estimates, as detailed in Sections 5.1 and 5.2, are conservative (i.e., greater reductions are likely achieved) for several reasons, as described below.

5.3.1 Non-Structural BMP Effectiveness

While numeric values for non-structural or source control BMP effectiveness were not specifically accounted for in the City's pollutant loads model, pollutant loads are presented as a range, and this range likely reflects the variable nature of stormwater runoff and the non-structural and source control practices implemented upstream.

The estimated range of pollutant load reductions in this report is anticipated to reflect the City's implementation of its overall stormwater management program. Structural BMP implementation (as directly accounted for in pollutant modeling) composes a small component of the overall program. However, measuring the effectiveness of source control and non-structural practices requires significant assumptions in order to determine how to reflect pollutant reduction associated with a behavioral or conditional practice and how to translate that interim practice into reduction of a singular pollutant over the course of a season or year. Thus, the City has chosen to account for the effectiveness of source control and non-structural BMPs in narrative form only.

The City conducts a variety of programmatic activities that are directly attributable to bacteria, nutrient, and TSS reduction. Such activities include erosion control, illicit discharge detection and elimination, street sweeping, catch basin cleaning, facility maintenance, operations and maintenance, pet waste programs, and public education.

Research has been conducted related to literature values for non-structural BMP effectiveness. One such data source is the Watershed Treatment Model (WTM) (Caraco, 2010), a planning-level model developed by the Center for Watershed Protection. The model is a simple spreadsheet used to estimate pollutant loading and evaluate effects of proposed structural and non-structural management practices and future development on pollutant loads.

The WTM provides default values for the effectiveness of certain non-structural BMPs while it encourages the user to input values for others. In each case, the model provides guidance to select appropriate values. Although not used in this pollutant loads modeling effort, the efficiencies of non-structural practices, including street sweeping, riparian buffer protection, catch basin cleanouts, and erosion and sediment control, are provided in the form of percent removals in Tables 5-3 and 5-4 for additional background.

Table 5-3. Example Pollutant Load Removal Efficiencies of Street Sweeping

Sweeper type	Efficiency (%)			
	Residential		Other roads	
	Nutrients	TSS	Nutrients	TSS
Mechanical	24	30	4	5
Regenerative air	51	64	18	22
Vacuum assisted	62	78	63	79

Source: WTM.

Table 5-4. Example Pollutant Load Removal Efficiencies of Non-Structural BMPs (Other)

BMP	Efficiency (%)		
Erosion and sediment control	70		
Catch basin cleanouts	Nutrients	Total suspended solids	
Monthly cleaning	15	25	
Semiannual cleaning	8	13	
Riparian buffers	TP	TSS	TN
	10	70	30

Source: WTM.

For other non-structural practices, removal efficiencies are included in the WTM based on treatability and discount factors that the user inputs into the model. Treatability is defined as the fraction of the population that can be reached for education programs. Discount factors account for imperfect practice application and upkeep, inability of educational programs to reach all citizens, and inadequate funding to implement all practices, for example. The pollutant removal efficiencies associated with the non-structural stormwater management practices used in the WTM are based on existing research and studies by the Center for Watershed Protection (1999) and Winer (2000) and are not locally based.

The WTM makes many simplifying assumptions, and it is not calibrated. Therefore, the results of the model simulations should be compared on a relative basis rather than used as absolute values. Per results of the WTM, up to 79 percent removal efficiency was estimated depending on the parameter and the non-structural practice implemented. It should be noted that for bacteria the efficiency is more limited than for other parameters (e.g., TSS) and was thus not presented. Also, any non-structural BMP effectiveness estimate needs to be qualified based on best professional judgment and continued ability to update and refine the effectiveness numbers based on improved non-structural practices. This information is presented to show the potential significance and additional

load reduction that may be achieved through the City's non-structural practices. These additional load reductions are not reflected in the City's quantitative analysis.

5.3.2 Water Quality Trends Analysis

In accordance with Schedule D.3.c.vii of the NPDES MS4 permit, the pollutant load reduction evaluation includes a water quality trends analysis. The City prepared its water quality trends analysis in conjunction with its 2014 NPDES annual report submittal. Full documentation is included as Section 4 and Appendices A and B of the NPDES annual report and is also provided as Appendix A of this pollutant load reduction evaluation.

The City's overall monitoring program includes instream (ambient) water quality monitoring, MS4 (stormwater) monitoring, biological monitoring, and physical condition monitoring. For the 2013/2014 reporting year and for this pollutant load reduction evaluation, the City evaluated its ambient monitoring data over the reporting year in conjunction with its historical ambient monitoring data to assess long-term trends in receiving water quality (see Appendix A, Section 4.4.4.2). The City compared its MS4 and ambient water quality data to state water quality standards and compared MS4 monitoring data to ambient water quality data to help assess the potential influence of MS4 discharges on receiving water quality (see Appendix A, Section 4.4.2).

Ambient water quality trends were calculated for the City's 12 instream sites that are monitored bimonthly. Ambient monitoring has been conducted by the City of Eugene since 1997. The Seasonal Kendall test was used for analysis on screened data sets, sorted into seasons by sampling date. Results from the trends analysis indicate significant trends at 9 of the 12 instream sites for various parameters. No significant trends were observed at 3 of the 12 instream sites. As the 2014 NPDES annual report indicates, ambient water quality trends tend to be subtle and are influenced by the most recent water quality data; thus the trends vary with each year's data analysis.

Table 5-5 summarizes results of the 2014 ambient water quality trends evaluation for water bodies and parameters where observed trends are noted. Depending on the water body, decreasing concentration trends generally existed for nutrients (nitrogen, phosphorus), BOD, select metals (arsenic, nickel, etc.), TSS/turbidity, and temperature. Increasing trends existed for select metals (lead, zinc) and certain instances of conductivity and DO. Decreasing pollutant trends are prevalent and attributed in part to stormwater program implementation citywide. For TMDL parameters not specifically shown in Table 5-5 (e.g., bacteria), no trends were identified. Graphs identifying monitoring results and trends lines are provided in Appendix A, Attachment B.

The trends analysis shows improving trends for many parameters, which may be an indicator of the conservative nature of the quantitative pollutant load reduction evaluation.

Table 5-5. Summary of Seasonal Kendall Water Quality Analyte Trends Analysis

Monitoring location	Trends of water quality analyte[a]	
	Decreasing concentration trends	Increasing concentration trends
Amazon Creek Basin sites		
Willow Creek	Total Kjeldahl nitrogen	• Lead, dissolved • Zinc, dissolved and total
Amazon Creek at 29th Avenue	Lead, total[b]	• Zinc, dissolved and total • Chemical oxygen demand
Amazon Creek at railroad tracks	• Cadmium, total • Chromium, dissolved and total • Lead, total[b] • Mercury, dissolved and total • Nickel, dissolved	Zinc, dissolved and total
Amazon Diversion Channel at Royal Avenue	• Arsenic, dissolved and total[b] • Mercury, dissolved[b] • Molybdenum, dissolved • Nickel, dissolved and total • Biochemical oxygen demand • Total Kjeldahl nitrogen	Zinc, total
A3 Channel at Terry Street	• Arsenic, dissolved and total[b] • Cadmium, total • Chromium, dissolved and total • Lead, total[b] • Mercury, dissolved and total[b] • Molybdenum, dissolved • Nickel, dissolved and total • Silver, total • <u>Biochemical oxygen demand</u> • <u>Phosphorus, total</u> • Temperature • Total Kjeldahl nitrogen	None
Amazon Creek at Royal Avenue	• Chromium, dissolved and total • Lead, total[b] • Mercury, total • Nickel, total • Temperature • <u>Total suspended solids</u> • <u>Turbidity</u>	Zinc, dissolved and total
Willamette River Basin sites		
Knickerbocker Bridge	<u>Ortho phosphorus</u>	Specific conductance
Downstream of Beltline Bridge	<u>Ortho phosphorus</u>	None
Delta Ponds	Molybdenum, dissolved and total	Dissolved oxygen[b]

Source: 2014 Stormwater Annual Report, City of Eugene, December 2014. TMDL parameters are underlined.

[a] *Significant at 2p = 0.01*

[b] *On Oregon 2004/2006 303(d) list.*

Section 6

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Appendix A: Water Quality Trends Analysis

4 MONITORING PROGRAM

4.1 Monitoring Results Summary

Water quality results for surface water samples collected from Amazon Basin ambient monitoring locations in Eugene, Oregon indicate statistically significant long-term decreasing concentration trends occur at specific sites for arsenic, cadmium, chromium, lead, mercury, molybdenum, nickel, silver, biochemical oxygen demand, phosphorus, nitrogen, suspended solids, temperature, and turbidity. Statistically significant long-term increasing concentration trends occur at specific sites for lead, zinc and chemical oxygen demand.

Significant decreasing and increasing concentration trends for pollutants in the Amazon Basin occur at monitoring locations downstream of the urban environment, and serve as an indicator of the effectiveness of the sum of stormwater program elements as described in the previous sections of this report.

While significant water quality improvements have occurred at downstream monitoring locations, activities within the permit area continue to have a measurable impact on levels of pollutants observed in Amazon Basin streams and channels. Intra-basin upstream and downstream water quality comparisons indicate the concentration of metals, temperature, chemical oxygen demand, occasionally nitrogen, suspended solids, and turbidity increase as Amazon Creek flows through the urban environment. Counts of *E. coli* and fecal Coliform, dissolved oxygen, pH, water hardness, dissolved solids, nutrients (nitrogen and phosphorus), and dissolved zinc decrease. Analytes for the A3 Channel are greater than those measured for Amazon Creek; dissolved arsenic and mercury are exceptions. Amazon Creek analyte concentrations are greater than those measured for Willow Creek; total arsenic, and total and dissolved chromium are exceptions. The Willow Creek drainage basin serves as a background water quality site because of its relatively low development compared to the urbanized permit area, although recent trends indicate some degradation of water quality.

Statistical tests also indicate Amazon Basin water samples collected during the 2013/2014 permit year at specific sites had significantly lower analyte concentrations when compared to historical data, including cadmium, chromium, lead, nickel, magnesium (hardness), dissolved solids, chemical oxygen demand and nitrogen; however, lead, selenium, zinc, magnesium, and dissolved oxygen concentrations were found to increase at other monitoring sites.

Within the Willow Creek drainage basin, a statistically significantly concentration increase was observed for dissolved zinc during the most recent monitoring period.

Water quality results for ambient samples collected from the Willamette River indicate statistically significant long-term decreasing concentration trends occur at two sites for ortho phosphorus, and at one for dissolved and total molybdenum; an increasing trend is observed at one site for conductivity. An increasing dissolved oxygen trend is also observed for Delta Ponds.

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As the Willamette River flows through the Eugene urban environment, analyte concentrations increase for arsenic, copper, lead, mercury, nickel, silver, and zinc metals; nutrients (nitrogen and phosphorus), dissolved and suspended solids, hardness (calcium and magnesium), conductance, and bacteria (*E. coli* and fecal Coliform) also increase. Field pH decreases across the river reach through the urban environment.

A comparison of water quality for Delta Ponds, its riparian habitat recently restored, to the Willamette River at Owosso Bridge indicates the former site has higher metal concentrations for arsenic, copper, lead, nickel, and zinc; chromium and mercury concentrations are higher in the Willamette River at Owosso Bridge. Other analytes with statistically significant concentrations that are higher in Delta Ponds include hardness (calcium and magnesium), conductance, total phosphorus, nitrogen, and dissolved solids; pH values dissolved oxygen concentrations are higher in the Willamette River at Owosso Bridge. It is expected that long-term water quality characteristics for Delta Ponds will continue to change under flow management to restore hydraulic connectivity of Delta Ponds with the Willamette River to enhance riparian habitat.

In some instances the concentration of pollutants measured at Amazon Basin and Willamette River sites exceed Oregon water quality standards and beneficial uses for surface waters defined in Chapter 340, Division 41 of the Oregon Administrative Rules (OAR). For example, arsenic concentrations and bacteria counts in Amazon Basin streams and channels commonly exceed the human health criterion established for drinking water or recreational use. Toxicity criteria applicable to aquatic species are commonly exceeded for cadmium, copper, lead, mercury, zinc, dissolved oxygen, pH, and temperature at Amazon Basin sites, and periodically at Willamette River sites. Note, however, that exceedances of some of these pollutants also occur at the monitoring location upstream of the Eugene urban area, indicating some of these analytes either occur naturally in aquatic environments, or are affected by human activities upstream and outside of the permit boundary.

Water quality trends and comparisons indicate measurable progress is being made toward improving the water quality of channels, streams and rivers receiving stormwater runoff from the City of Eugene. Continued improvements are anticipated through continuation and refinement of existing BMPs, and implementation of new ones as needed.

4.2 Objectives of the Monitoring Program

Permits issued under the Stormwater National Pollutant Discharge Elimination System (NPDES) regulations for Municipal Separate Storm Sewer Systems (MS4) require ongoing water-quality monitoring to assess the chemical, biological, and physical effects of stormwater on receiving water bodies. The monitoring described in this report was conducted under the City's NPDES Stormwater Discharge Permit Number 101244 issued on 30 December 2010, and the City's Stormwater Monitoring Plan (SMP), incorporated by permit reference. For the purposes of the SMP, the term monitoring includes water quality monitoring (sample collection), monitoring activities (such as construction) in a watershed, monitoring changes in a watershed, or monitoring the success of BMPs. This section describes the overall program effectiveness by

means of analysis of water quality data and assessment of water quality trends for representative major surface water bodies receiving stormwater discharges from the City's MS4.

In addition to the regulatory requirements specified in the permit, the objectives of the Stormwater Monitoring Plan have been to:

- Identify pollutants of concern and their source;
- Identify the degree to which stormwater discharges may be contributing to water quality criteria exceedances in receiving waters;
- Identify, to the best practical extent, the impact of stormwater discharges to the aquatic environment of receiving waters;
- Identify the most effective best management practices (control measures);
- Refine estimates of annual and seasonal pollutant loads;
- Determine the frequency of monitoring required to reveal water quality trends and assess the effectiveness of control measures; and
- Maintain efficient and effective tools for storage, retrieval, and analysis of data collected, and assure data quality.

The monitoring plan was designed to provide technical information to assist in meeting the stated objectives to the maximum practical extent given available resources.

4.3 Organization of the Water Quality Monitoring Program

Water quality monitoring for the annual period covered by this report, includes three program elements:

- Storm event water quality monitoring;
- Ambient water quality monitoring of water bodies receiving MS4 discharges;
- Data management, analysis, and reporting.

Every third year biological assessments through macroinvertebrate surveys of the MS4 receiving water bodies, as well as physical field condition assessments are performed and results summarized in this report section. These field monitoring program elements were recently performed in 2014; biological and macroinvertebrate results will be reported in the 2015 annual report.

The following sections will focus on analysis of monitoring activities to assess overall stormwater program effectiveness by reviewing historical water quality trends for those water bodies receiving stormwater. Sampling sites are located in or near the permit boundary for the City of Eugene. Maps of the sampling locations to assess ambient and stormwater quality are referenced in the following paragraphs and included at the end of Section 4. All sampling follows the protocol established in the Stormwater Monitoring Plan (SMP), including appropriate sampling, handling, and analysis methods described by the EPA and in the guidelines of 40CFR136 establishing test procedures for the analysis of pollutants. Quality assurance and controls were applied to all elements of the monitoring program, including sample collection,

handling, laboratory analysis, and reporting. The Eugene/Springfield Environmental Laboratory performed analytical services under a DEQ-approved Quality Assurance Plan. Documentation and data management activities follow environmental management systems described in ISO 14001:2004(E); the Eugene/Springfield Wastewater Management Facility is registered as conforming to the ISO 14001 standard.

4.4 Program Activities

Program activities for the permit period primarily consisted of storm event monitoring, ambient water quality monitoring, and bacteria monitoring in the MS4 as well as receiving water bodies. Figure 4-5 is a small-scale map showing the overall locations of surface water and piped system sampling sites, as well as drainage basin areas. Larger-scale maps are provided and referenced in report discussions below.

4.4.1. Underground Injection Control (UIC) Monitoring

Stormwater flow to sedimentation manhole UIC devices were sampled during two storm events over the most recent reporting period. Table 4-1 presents a summary of laboratory results for the three UIC sites; their location is shown in Figure 4-5a; Tables A.6 through A.7 in Appendix A present a detailed summary. Boxplots for the data are presented in Appendix B, Figures B.21 through B.23. The concentrations reported for all analytes are less than the Permit Action Level.

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Table 4-1 UIC Storm Event Monitoring Summary					
Location	**Analyte**	**2014 GeoMean**	**Historical Data GeoMean**	**Permit Action Level**	**Units**
Anderson & Briana: MH 75938	Copper, Total	2.09		1,300	µg/L
	Lead, Total	0.450	0.376	500	µg/L
	Zinc, Total	19.8		50,000	µg/L
	Benzo(a)pyrene	< 0.077		2	µg/L
	Pentachlorophenol	0.455		10	µg/L
	Dissolved Oxygen	11		NA	mg/L
	Field pH	6.5		NA	Std. Units
	Temperature	8.9		NA	˚C
Marjorie & Downing: MH 99302	Copper, Total	1.64		1,300	µg/L
	Lead, Total	0.233		500	µg/L
	Zinc, Total	60.7		50,000	µg/L
	Benzo(a)pyrene	< 0.077		2	µg/L
	Pentachlorophenol	< 0.568		10	µg/L
	Dissolved Oxygen	11		NA	mg/L
	Field pH	6.6		NA	Std. Units
	Temperature	8.1		NA	˚C
Shenstone & Tyson: MH 73919	Copper, Total	1.12		1,300	µg/L
	Lead, Total	0.205		500	µg/L
	Zinc, Total	688		50,000	µg/L
	Benzo(a)pyrene	<0.077		2	µg/L
	Pentachlorophenol	0.436		10	µg/L
	Dissolved Oxygen	11		NA	mg/L
	Field pH	6.8		NA	Std. Units
	Temperature	8.6		NA	˚C
Shaded cells indicate the higher analyte concentration exceeds the Permit Action Level. Sampled Storm Events: 1/28/2014 & 2/14/2014					

4.4.2. Storm Event Water Quality Monitoring

Storm event monitoring was conducted at multiple sites to assess stormwater quality; Table 4-2 summarizes the sampling locations and types of samples collected for the analytes indicated (see Figures 4-5 through 4-5d for monitoring locations). Sampling locations include sites within the MS4 and respective receiving water bodies in both the Amazon basin and Willamette River. Willow Creek is used to represent background conditions for comparison purposes because its drainage basin is relatively undeveloped.

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Water quality is characterized through a variety of analytical tests, including field measures of dissolved oxygen, pH, and temperature; a suite of conventional water quality tests, including bacteria, hardness, solids, and oxygen demand; nitrogen and phosphorus nutrients; and metals. The sample type – either grab or flow proportional – is also shown in Table 4-2 for each sampling location. In addition, a few surface water and piped-system MS4 sites were tested for dioxin, chlorinated hydrocarbons, and methyl mercury.

Table 4-2
2013/2014 Storm Event
Water Quality Monitoring Sites

Location	MS4 System Type	Sample Type	Analyte Type
Amazon Basin Sampling Sites:			
Chambers at 18th Avenue, NE; MH 55402 NE Loading Dock Catch Basin Parking Lot CB Morse Ranch Dog Park Up and Downstream W 18th Avenue; E Side Storm Runoff to MH 67386	Piped System	Grab	Field, Bacteria
Chambers at 18th Avenue, NE; MH 55404	Piped System	Grab & Flow Proportional	Field, Metals, MeHg, Conventional, Nutrients, and Chlorinated Organics
West 5th at Seneca; MH 63693	Piped System	Grab & Flow Proportional	Field, Metals, MeHg, Conventional, Nutrients, Chlorinated Organics
Willow Creek at 18th Avenue	Surface Water	Grab & Flow Proportional	Field, Metals, Conventional, Nutrients
Willamette River Basin Sampling Sites:			
Copping; MH 77793 Altura; MH 99365	Piped System	Grab & Flow Proportional	Metals, Conventional, Nutrients, Dioxin

Flow-proportional stormwater samples collected from the 5th Avenue/Seneca monitoring site receives runoff from industrial and commercial properties; samples from the Chambers at 18th Avenue monitoring site is primarily from commercial, recreational and educational land uses; the Altura and Copping sites are residential. Within the Willow Creek drainage basin, primarily parks (25%), timber (17%), single family residential (6%), roads (4%), general services (5%), and vacant lands (44%) comprise the land use categories.

Laboratory data for stormwater samples collected from these five locations are presented in Appendix A, Tables A.1 through A.4 and color coded to indicate percent change of geomeans of the 2013/2014 samples compared to historical data. Boxplots of all data are shown in Appendix B, Figures B.1 through B.19. The boxplots also include a comparison to an Oregon water quality standard when available. While the water quality standard is not directly applicable to stormwater data, these comparisons are helpful in assessing whether stormwater pollutants contribute toward exceedance of a water quality standard for an impaired water body, or has potential to cause acute or chronic aquatic toxicity. Boxplots consist of a horizontal line in the middle of the box and marks the median of the sample set; the median splits the ordered sample

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set in half. The box represents the central 50 percent of data values; the outer edge of each box mark the 25th and 75th percentiles. Whiskers extending from the box mark the range of values that fall within 1.5 box-lengths from the 25th or 75th percentile. Outliers and extreme values are also depicted in the figures, values that are more than 1.5 box-lengths from the 25th or 75th percentiles are identified as outliers and are denoted by an open circle; extreme values are more than 3 box-lengths and are denoted by an asterisk.

In general, water quality comparisons of storm-event data shown in the tables are for a small number of sampling events for the 2013/2014 sampling period; the historical data set for the Chambers at 18th and W. 5th at Seneca sites consists of between 12 and 15 events for the full suite of water quality parameters. Thus, the observed water quality changes may appear to exhibit large changes over short time periods; however, when these data are compared to ambient historical monitoring data – spanning 16 years – the storm-event data tend to be within the observed range of ambient water quality. Exceptions will be described in the sections below. Note that Willow Creek is an exception – surface water samples collected during storm events are indicative of stream water quality and are directly comparable to the ambient historical data set.

4.4.2.1. Willow Creek – Background Location – Surface Water

One storm event was sampled for an abbreviated suite of water quality analytes during the 2013/2014 monitoring period (see Figure 4-5d for the sampling location). *Escherichia coli*, fecal coliform and temperature were greater than historical values (see Appendix A, Table A.1). The value for E. coli is greater than 75th percentile of historical ambient water quality data (see Appendix B, Figure B.145), pH and temperature is less than the 25th percentile (Figures B.148 and B.149 respectively). The differences observed for the recent storm-event data compared to the historical data set are perhaps indicators of overall water quality changes observed for the Willow Creek drainage basin area where increasing concentration trends are observed for lead and zinc, which is described in a later section of this report.

Comparisons of the Willow Creek stormwater data to state water quality standards indicate copper and lead values (Figures B.4 and B.5) exceed the State's chronic criterion for fish; TDS and bacteria values (Figures B.15 and B.16) also exceed the associated water quality standard; occasionally dissolved oxygen (Figure B.11) is lower than the minimum standard. For pH, multiple values are below the minimum freshwater criterion of 6.5 and one at the maximum criterion of 8.5 (Figure B.14). Turbidity (Figure B.15) values are compared to an estimated flow-based turbidity target defined in the Willamette Basin TMDL, which is derived for Amazon Creek using Long Tom River flows near Noti as a reference river discharge. Flow data are not available for Willow Creek so stormwater data in this instance are compared to the highest turbidity standard of 27 NTU for Amazon Creek. In general, on occasion stormwater turbidity data exceed the Amazon Creek criterion at this highest turbidity standard and, as the boxplot suggests, would likely exceed the turbidity standard during lower stream flows.

4.4.2.2. Chambers & West 18th Avenue, NE Lot: MH 55404 – MS4 Piped System

This drainage basin includes commercial properties, portions of Westmoreland Park, and Jefferson Middle and Magnet Arts schools (see Figure 4-5b). Impervious surfaces, including rooftops and paved parking areas at these properties, as well as a section of West 18th Avenue, a

minor arterial roadway, are sources of stormwater runoff influencing water quality characteristics at this MS4 piped system monitoring location (MH 55404). Three flow-proportional storm events were sampled for the full suite of water quality analytes, 23% of which had geomean concentrations modestly lower than or equal to historical values. Arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, fecal coliform, chemical oxygen demand, nitrogen, phosphorus, hardness (calcium and magnesium), solids, conductance, turbidity, and dissolved oxygen were greater than historical values; *E. coli*, biochemical oxygen demand, silver pH, and showed modest decreases. Decreases for chlorinated hydrocarbons are less significant because of lower reporting limits during this reporting period. Table A.2 summarizes these stormwater quality results.

Comparison of stormwater quality values for this piped system location to state water quality standards indicate concentrations of arsenic, cadmium, copper, lead, mercury, zinc, and dissolved solids, turbidity, bacteria, and chlorinated hydrocarbons in stormwater are greater than the lowest listed acute, chronic or human health criterion (see Figures B.1 through B.19). Amazon Creek, which is the receiving water body for stormwater from this location, frequently exceeds applicable state water quality standards for the same pollutants both upstream and downstream of the outfall to which this stormwater monitoring site discharges. In addition, statistically significant concentration increases occur for most of these pollutants in the reach of Amazon Creek 2.5 miles upstream to the 29th Avenue monitoring site and 4.5 miles downstream to the Railroad Track Crossing monitoring site with respect to the location of this MS4 outfall. Later sections of this report discuss significant water quality trends for stormwater receiving water bodies in the ambient monitoring program.

Three storm events were sampled at this location for dissolved and total methyl mercury; the maximum observed dissolved methyl mercury concentration was reported at 0.126 ng/L with a reporting limit of 0.0249 ng/L. The maximum total methyl mercury was reported at 0.0.298 ng/L, also with a reporting limit of 0.0249 ng/L.

Chlorinated hydrocarbons were also analyzed for the three storm events at this piped system location, including 1,1-dichloroethene, trans-1,2-dichloroethene, trichloroethene (TCE), and tetrachloroethene (PCE); dichloroethene is a degradate of TCE. Amazon Creek is impaired for these pollutants (2004 303(d) listed). One value for PCE was J-flagged, that is, analysis indicated the possible presence of these compounds; the detected concentration was less than the reporting limit of 5 µg/L. While J-flagged values are lower than the criteria and the waterbody is not presently used for fish and water consumption by humans, the presence of these pollutants in stormwater may contribute to degradation of Amazon Creek. A second sample had a PCE concentration of 0.140 µg/L. Note that the human health criterion for TCE is 1.4 µg/L and that for PCE is 0.24 µg/L for fish and water consumption; these pollutants have no toxics criteria for fish. Reporting limits for chlorinated compounds were significantly reduced beginning in 2014 to enable valid comparisons with water quality criteria.

No land use activities typically associated with these types of pollutants are located within the drainage basin area. However, consumer products such as cleaners and solvents containing small amounts of these chlorinated hydrocarbons may be available to the public from

commercial businesses within the basin. Businesses within the basin also may utilize these consumer products for operations/maintenance purposes.

Comparison of MS4 stormwater quality to ambient receiving water body quality is useful in assessing relative pollutant loading. Figure 4-1 compares mean stormwater quality data for the site to the historical means at the nearest upstream ambient monitoring site, in this case Amazon Creek at 29th Avenue. Multiple analytes exceed an equivalence ratio of one, that is, the concentration ratio of the stormwater analyte value to that of the receiving water body value.

Red bars represent analytes measured in the respective receiving water body exceed applicable Oregon water quality standards for ambient monitoring samples. Given the magnitude of the concentration ratios, it can be presumed stormwater pollutant loads contribute toward exceedance of water quality standards.

The equivalent ratios are useful in terms of assessing which pollutants are of potential concern in stormwater runoff when compared to receiving water body quality. Additional sampling events conducted over the course of the permit term will be evaluated to refine pollutant mass loading estimates and BMP strategies that target activities and/or sources for these and other pollutants of concern. Water quality ratios obviously depend on the relative analyte concentrations in the water bodies being compared. Pollutant loads are calculated for the drainage basin areas as defined by the sampling location within the MS4 (see Figures 4-5a and 5b). Charts in Figures B.26 through B.35 present boxplots of pollutant loads for the NE lot at Chambers & 18th sampling location, in units per acre, for all storm event sampling performed since 2010. Bacteria and turbidity pollutant load contributions to Amazon Creek appear to be significant given the stream is water-quality impaired for these two parameters; the median bacteria loading is about 800 million per acre for *E. coli*, and turbidity loading is nearly 90,000 NTU per acre. Pollutant loads for the remaining analytes at this site are below estimates documented in the City's September 2008, Permit Renewal Report.

One storm event hydrograph for the MS4 piped system was recovered for flow proportional sampling at this site and is shown in Figures B.198. Unfortunately, data could not be recovered for other flow-proportional storm events to generate storm hydrographs; only total sampled volumes could be recovered from the chain-of-custody forms to enable calculation of pollutant loads.

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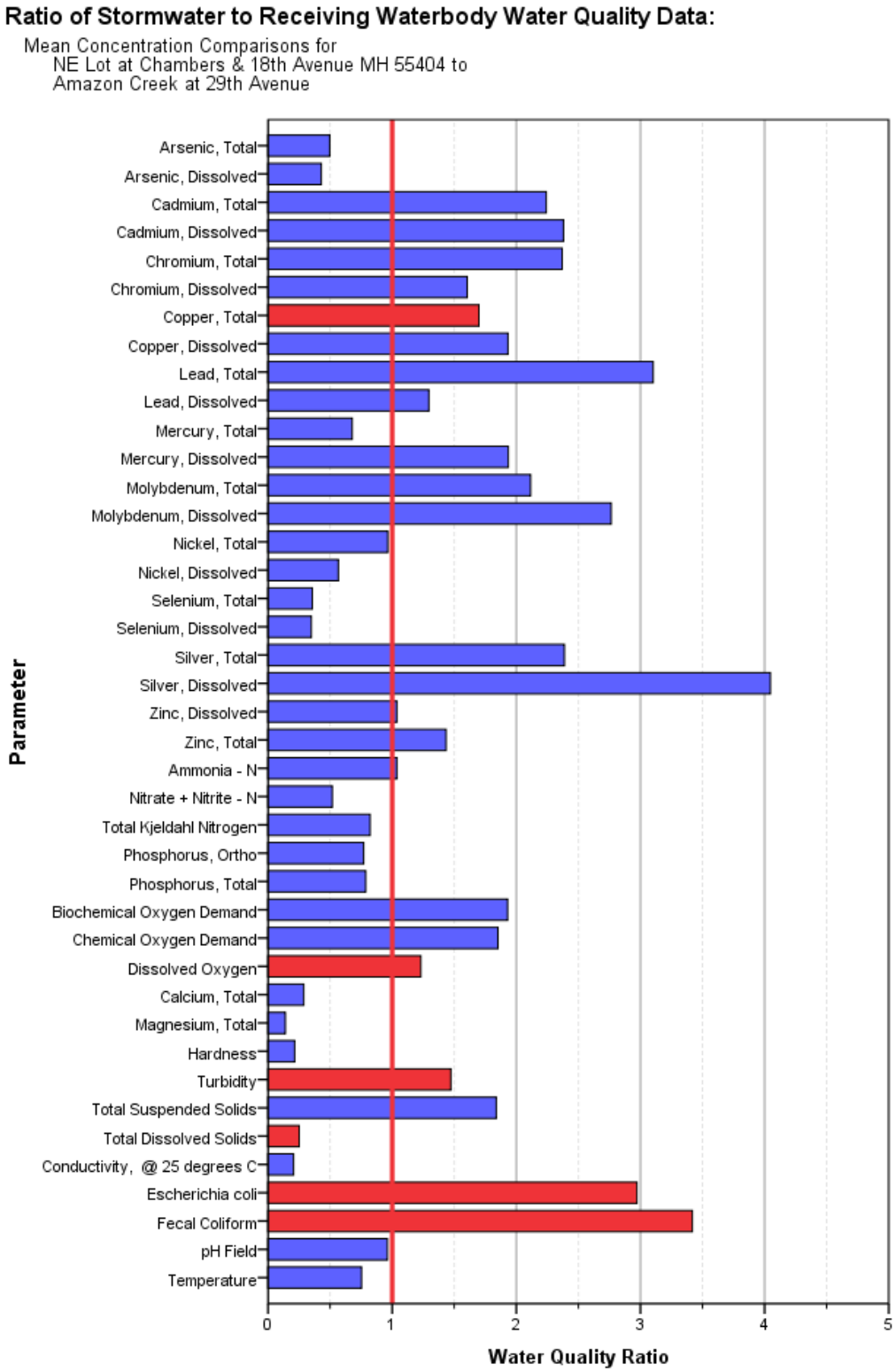
Figure 4-1



Red Analytes = Water quality criterion exceeded in receiving waterbody during 2013/2014 monitoring period.

4.4.2.3. Copping Street – MS4 Piped System

Two storm events were sampled at this residential MS4 site during the 2013/2014 monitoring season for an abbreviated suite of conventional pollutants (see Figure 4-5a for the location and areal extent of this drainage basin). Bacteria counts were significantly greater than the historical data set, and dissolved oxygen concentrations decreased slightly. Table A.3 summarizes stormwater quality data for this sampling site.

While state water quality standards are not directly applicable to stormwater data, comparisons here are helpful in assessing whether stormwater pollutants contribute toward exceedance of a water quality standard for an impaired water body (see Figures B.1 through B.19). The Willamette River was listed in the 2004/2006 303(d) as impaired for dioxin, and currently as water quality limited for mercury, bacteria, and temperature. Loading calculations for the abbreviated conventional pollutant list was not be determined for the two sampling events; however, storm event data suggest that the Copping drainage basin area is not a significant source of listed pollutants, nor a source of significant pollutant loads to the Willamette River, as estimated in Figures B.26 through B.35.

The results of these storm event studies will be used to assess development and implementation of appropriate BMPs focusing on pollutant contributions from the MS4 identified as potentially effecting impairment of water bodies within the NPDES permit area.

4.4.2.4. W 5th Avenue at Seneca: MH 63693 – MS4 Piped System

Two storm events were sampled at this monitoring location for the full suite of metals, field measurements, conventional analytes, and chlorinated hydrocarbons; additionally, one storm event was sampled for dissolved and total mercury and methyl mercury (see Table A.4 for a summary of stormwater quality results). The W 5th Avenue at Seneca site was selected to assess pollutant sources of 1,1-dichloroethene (DCE), trans-1,2-dichloroethene and tetrachloroethene (PCE) to the A3 Channel because it is on Oregon's 303(d) list of impaired water bodies for these pollutants. Dichloroethene is a degradate of trichloroethene. One value each of DCE and PCE were J-flagged, that is, analysis indicated the possible presence of these compounds; the concentrations were 0.06 µg/L and 0.66 µg/L respectively, less than the reporting limit of 5 µg/L. Beginning in 2014, samples were analyzed using more sensitive analytical techniques; the maximum observed concentration of DCE was 1.2 µg/L, indicating the presence of TCE, and 14 µg/L for PCE. Additionally, trans-1,2-Dichloroethene was detected at 0.040 µg/L, just above the analytical method reporting limit of 0.032 µg/L. As stated in the section above, the human health criterion for PCE is 0.24 µg/L for fish and water consumption; the observed concentration of PCE in stormwater is six times greater than the criterion. While the water body is not presently used for fish and water consumption by humans, the presence of these pollutants in stormwater may contribute to degradation of the A3 Channel, as well as Amazon Creek immediately downstream.

Potential sources of chlorinated hydrocarbons within this industrial and commercial drainage basin area include multiple businesses. Recent revisions to General 1200 Z stormwater discharge permits require permittees to monitor for chlorinated hydrocarbons and institute compliance benchmarks. The combination of industrial, stormwater, and ambient monitoring efforts will greatly assist in minimizing release of these pollutants to Oregon's waterbodies.

Of the 47 analytes tested on the three sets of stormwater samples, 24 percent of results had geomean concentrations that were equal to or lower than historical data for this site. Overall, changes were mostly modest with the exception of cadmium, selenium, zinc, bacteria, suspended solids, and turbidity where concentrations for the 2013/2014 monitoring period were between two and nearly three times greater than historical values.

Two storm events were sampled at this location for dissolved and total methyl mercury; the maximum observed concentration for dissolved methyl mercury was 0.083 ng/L with a reporting limit of 0.0249 ng/L. The maximum observed concentration for total methyl mercury was 0.211 ng/L, also with a reporting limit of 0.0249 ng/L.

Comparison of stormwater runoff from this MS4 piped system to state water quality standards indicates concentrations of arsenic, cadmium, copper, lead, mercury, silver, zinc, dissolved solids, turbidity, and bacteria in stormwater are greater than state water quality criteria (see Figures B.1 through B.20).

The nearest ambient monitoring location on the A3 Channel at Terry Street is downstream of the W 5th and Seneca MS4 monitoring site so a comparison would include the pollutant contributions from this MS4 site. Instead, a comparison of stormwater quality from this industrial and commercial MS4 to ambient water quality as measured on Amazon Creek at the Railroad Crossing, which is upstream of the confluence with the A3 Channel. Figure 4-2 indicates that the geomean stormwater concentration of cadmium and lead is over 10 times the ambient concentration in Amazon Creek. Multiple other pollutant ratios are nearly five times greater, including copper, silver, zinc; bacteria concentrations in stormwater are about seven times greater than the receiving water body..

Currently, stormwater runoff from the W 5th and Seneca location likely contributes toward exceedance of water quality standards in the Amazon Creek for copper, lead, mercury, zinc, ammonia, bacteria, and turbidity (see applicable Figures B.110 through B.149). Pollutant loads are calculated for the drainage basin areas as defined by the sampling location within the MS4 (see Figure 4-5a). Charts in Figures B.26 through B.35 present boxplots for pollutant loads at the W 5th and Seneca sampling location, in units per acre, for all storm events sampled since 2010. Bacteria and turbidity pollutant load contributions to the A3 Channel appear to be significant given Amazon Creek, to which the A3 Channel discharges, is water-quality impaired for these two parameters. Fecal coliform bacteria loading is 100 billion per acre (*E. coli* loading is about 60 billion per acre), turbidity is about 400,000 NTU per acre. Pollutant loads for the remaining analytes at this site are below estimates documented in the City's Permit Renewal Report.

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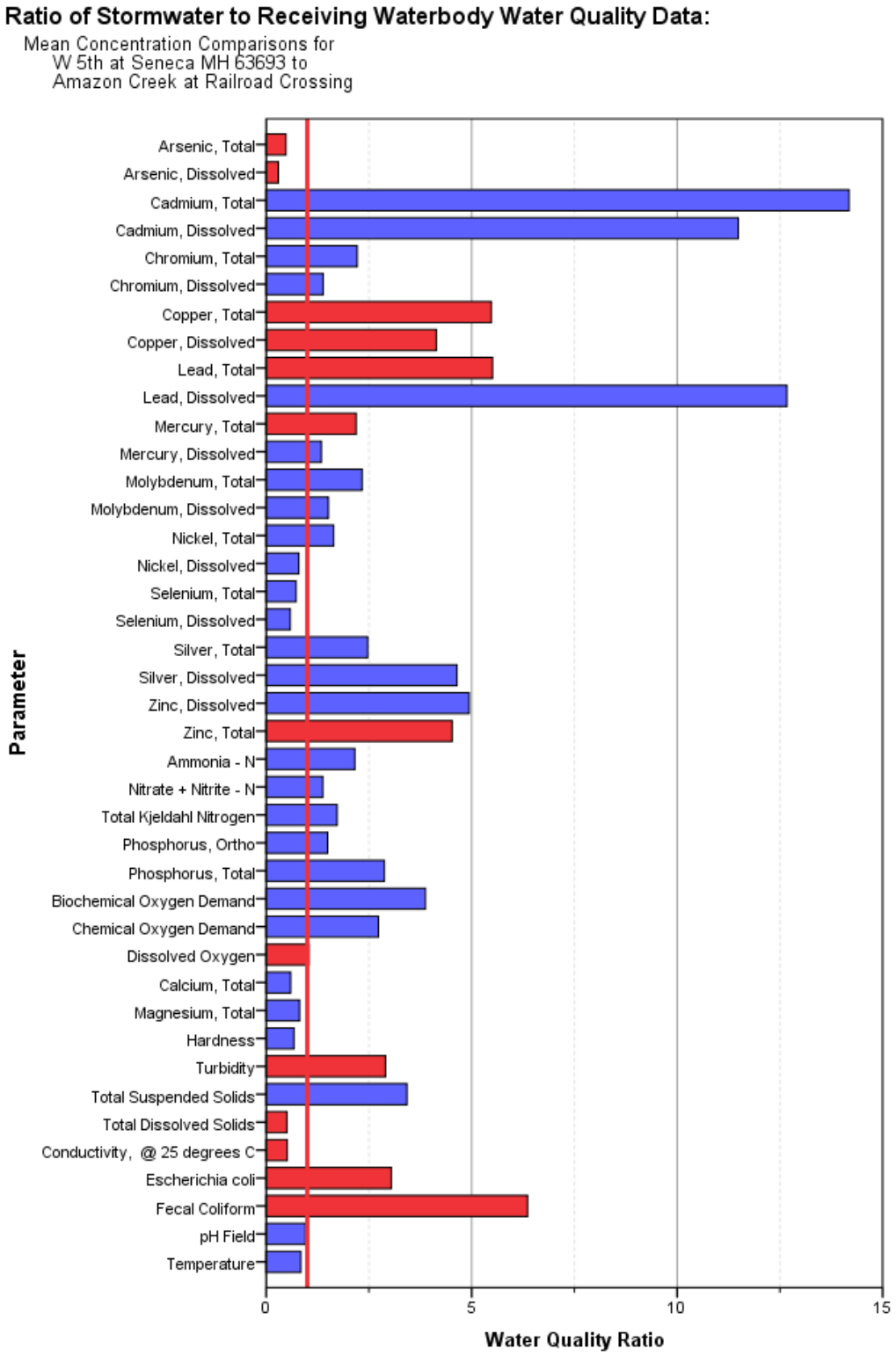
Figure 4-2



Red Analytes = Water quality criterion exceeded in receiving waterbody during 2013/2014 monitoring period.

4.4.2.5. Altura: MH99365 – MS4 Piped System

One storm event was sampled at this residential MS4 site during the 2013/2014 monitoring season for the full suite of metals and conventional pollutants (see Figure 4-5a for the location and areal extent of this drainage basin). No historical data have been generated to make water quality comparisons for samples collected during this monitoring period. Table A.4 summarizes stormwater quality data for this sampling site. A laboratory error precluded testing of the stormwater sample for total metals.

While state water quality standards are not directly applicable to stormwater data, comparisons here are helpful in assessing whether stormwater pollutants contribute toward exceedance of a water quality standard for an impaired water body (see Figures B.1 through B.18). The Willamette River was listed in the 2004/2006 303(d) as impaired for dioxin, and currently as water quality limited for mercury, bacteria, and temperature. Storm event data suggest that the Altura drainage basin area is not a significant source of listed pollutants. Loading could not be determined for the single sampling event at the Altura location because electronic flow data were inadvertently erased before downloading.

While the Altura drainage basin area flows into Spring Creek, the receiving water body is eventually the Willamette River. Figure 4-3 is a comparison of the water quality ratio between stormwater samples from the Altura site to the Willamette River downstream of Beltline Bridge. The concentration of dissolved zinc at 137 µg/L is over 10 times higher than those measured in the Willamette River and is nearly five times the average concentration observed in Spring Creek at Beacon Drive East (see Table A.12). Zinc is commonly used as a moss control agent in the Willamette valley and concentrations at several ambient monitoring locations are trending upward, as discussed in the trends section below.

The results of these storm event studies will be used to assess development and implementation of appropriate BMPs focusing on pollutant contributions from the MS4 identified as potentially effecting impairment of water bodies within the NPDES permit area.

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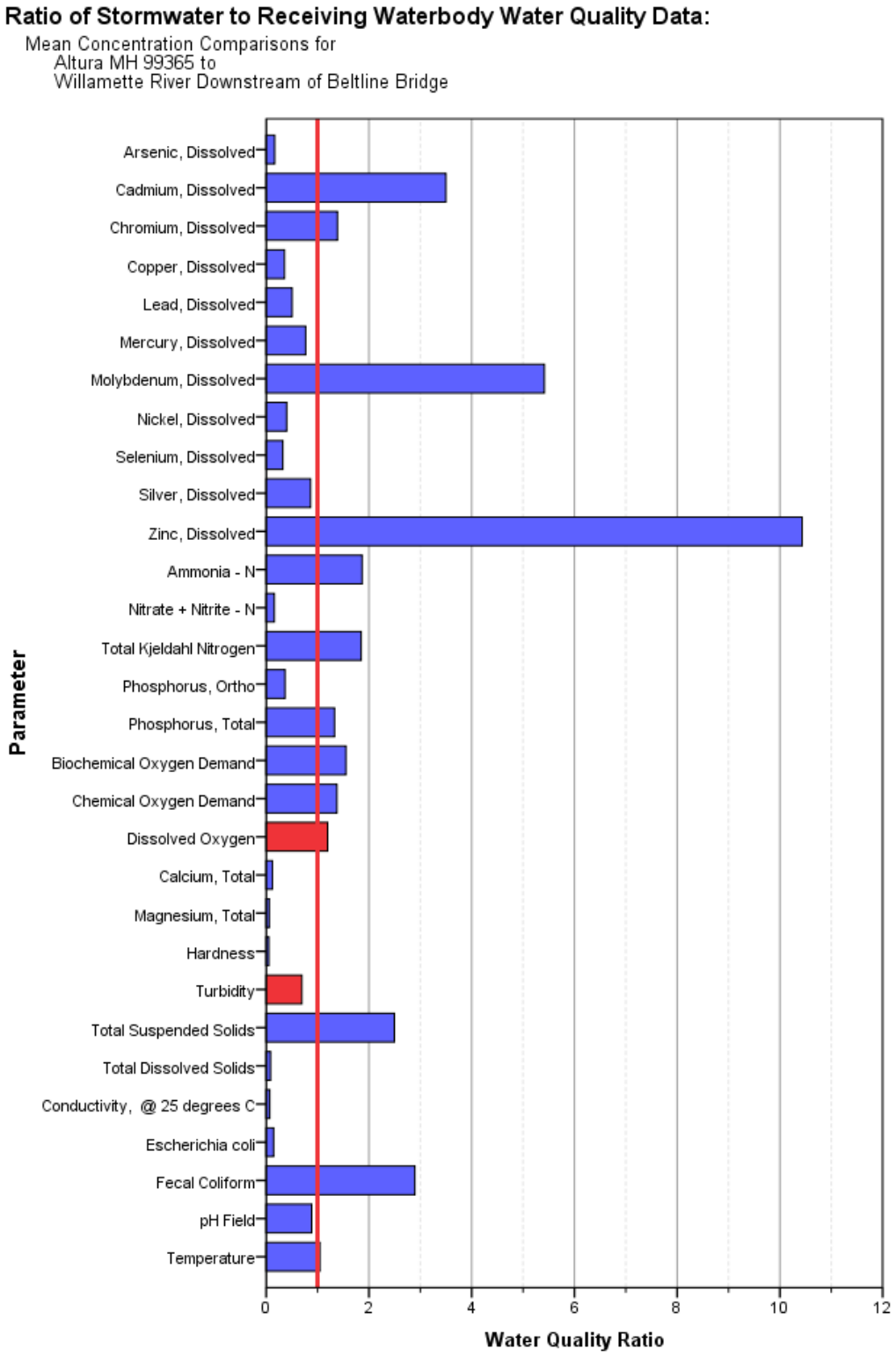
Figure 4-3



Red Analytes = Water quality criterion exceeded in receiving waterbody during 2013/2014 monitoring period.

4.4.3. Bacteria Study – Westmoreland Park, Polk Sub-Basin

The A3 Channel, Amazon Diversion Channel, and Amazon Creek are water quality limited for bacteria and in 2006 the State of Oregon issued the Willamette Basin TMDL for Bacteria. It specifies bacteria load reductions for these water bodies which range from 33% in the A3 Channel to 84% in Amazon Creek. Stormwater monitoring data analysis suggests bacteria concentrations in Eugene's stormwater contribute toward exceedance of the state water quality criterion; hence the City has implemented a number of measures focused on identifying bacteria sources and reducing bacteria loads.

Under ideal conditions a multitude of variables would be measured to enable assessment of bacteria source contributions adequately, including stream flow, stormwater runoff flow from various land use types, storm event magnitude and duration, MS4 basin characteristics, focused land use sampling, and, among others, an ability to predict precisely storm event properties to enable collection of representative stormwater samples. Recognizing resource constraints and the complexity of collecting this information, the City of Eugene has focused on specific drainage basin areas with known characteristic from which information can be acquired while minimizing project complexity.

Our bacteria study was first outlined in the December 2005, Second Annual Report. Goals of the study include: 1) to better understand bacteria source contribution areas through observation and monitoring; 2) design and implement BMPs to reduce bacteria loads to stormwater; and 3) assess through additional monitoring BMP effectiveness in reducing bacteria loads to stormwater and, ultimately, to Amazon Creek. The most effective BMPs would likely be considered for other areas within the Amazon basin with the objective of reducing bacteria in the A3 Channel, Amazon Diversion Channel, and Amazon Creek. During the 2013/2014 permit year our investigations continued with sampling and analysis of bacteria in stormwater from piped and open channel systems, as well as Amazon and Willow Creeks, and an unnamed creek flowing through the Morse Ranch Dog Park. Field surveys were also performed to characterize field conditions that might provide insights to bacteria sources. Additionally, BMPs were initiated to mitigate bacteria sources as described in previous sections of this report.

Figures 4-5, 4-5b through 4-5d delineate drainage basin areas and sampling locations. The Willow Creek drainage comprises the largest area at about 1200 acres; the smallest delineated area is a portion of the Westmoreland Park at 6.1 acres. Non-delineated areas include two catch basins with limited areal extent in a commercial business parking lot located at NE Chambers & 18th Avenue. A third site was located on W 18th Avenue immediately south of the commercial business; flow from the road surface was collected before it entered the catch basin.

In addition to sampling for *Escherichia coli* and fecal Coliform from the three piped-system locations within the study area, stream samples were collected upstream and downstream Morse Ranch Dog Park. Flow from this stream enters the MS4 piped-system a short distance downstream and eventually enters Amazon Creek above an ambient monitoring location on 29th Avenue. Lastly, Willow Creek at 18th Avenue was sampled for background comparison purposes.

Bacteria data for the storm events and investigative sampling are summarized in Table 4-3 and coded to indicate percent change of the 2013/2014 geometric mean compared to historical data. Boxplots of all bacteria data are presented in Figure B.24, including previously monitored locations within the Westmoreland Park study area, for comparison purposes; field measures of dissolved oxygen, pH and temperature associated with the bacteria sampling events are presented in Figure B.25. The vertical line in the box marks the median of the sample set; the median splits the ordered sample set in half. Each box represents the central 50 percent of data values; the outer edges of the box mark the 25th and 75th percentiles. Whiskers extending from the box mark the range of values that fall within 1.5 box-lengths from the 25th or 75th percentile. Values that are more than 1.5 box-lengths from the 25th or 75th percentiles are identified as outliers and are denoted by an open circle; extreme values are more than 3 box-lengths and are denoted by an asterisk.

Escherichia coli and/or fecal Coliform data for the 2013/2014 monitoring period (see Table 4-3 and Figure B.24) with few exceptions have bacteria geomeans that exceed the bacteria human health water quality criterion of 406 colonies per 100 mL, except that for Willow Creek at 18th Avenue.

Geometric means for bacteria at Morse Ranch suggest bacteria counts increase as the stream flows through the dog park (see Figure 4-5c). During winter months when precipitation events are more frequent, field observations have found that the upslope area in the dog park west of the stream becomes saturated and overland flow occurs from seeps – this flow likely transport bacteria to the creek causing in increase in *E. coli* and fecal Coliform bacteria counts. During dryer periods overland flow from the seeps does not occur and bacteria counts are often lower downstream than at the upstream monitoring site. The stream is fenced off to protect the riparian area surrounding the stream; however, the seeps are outside the protected area and dog fecal matter is commonly observed, as documented in bacteria field assessment surveys.

Several sites were selected at Chambers and W 18th Avenue to assess bacteria contributions from a commercial area (see Figure 4-5b for monitoring locations delineation of catch basin areas). Bacteria geometric mean counts for the MH 55402/55404 site combines the data for two catch basins but they are sampled for different storm events. No measurable change has occurred at these two sites and the bacteria counts are three to four times higher than the Oregon human health water quality criterion; the historical data set includes as many as 42 separate bacteria sampling events.

The bacteria loads calculated for the Chambers and 18th, MH 55404 site, suggest bacteria contributions from this drainage basin may be significant source, estimated at about 800 million bacteria per acre based on flow-proportional sampling for other water quality parameters. The receiving water body, Amazon Creek, is water quality limited for bacteria and under the 2006 TMDL, bacteria loads must be reduced by 84%.

Additional site characterization monitoring occurred at the Chambers & W 18th Avenue site, including two catch basins, one each in a parking lot and loading dock area; these private catch basins are connected to the City's MS4. Geometric means for *E. coli* at 3300 counts per 100/mL and fecal coliform at 8600 counts per 100/mL from the loading dock catch basin are potentially

significant in terms of bacteria loads to the MS4 but load calculations cannot be estimated because flow-proportional sampling has not occurred at this site.

Bacteria counts for the single sampling event from the commercial parking lot catch basin were significantly less than the loading dock site. Likewise, stormwater runoff from W 18th Avenue contained relatively small numbers of bacteria. Sampling from these sites was discontinued because the areas are believed to contribute relatively low amounts of bacteria to Amazon Creek. Outreach to the commercial business at Chambers & 18th Avenue has been ongoing to mitigate potential bacteria loads from the loading dock catch basin.

Table 4-3
Bacteria & Field Data
2013/2014 Monitoring Period
Westmoreland Park and Polk Sub-Basin Sites

Location	Parameter	N	GeoMean	Mean	Mean Std. Deviation	Median	Minimum	Maximum	% Change from Historical GeoMean
Willow Creek at W 18th Ave	Dissolved Oxygen	1	10.3	10.3		10.3	10.3	10.3	21
	Escherichia coli	1	160	160		160	160	160	315
	Fecal Coliform	1	60	60		60	60	60	130
	pH Field	1	6.7	6.7		6.7	6.7	6.7	-5
	Temperature	1	11.1	11.1		11.1	11.1	11.1	40
Morse Ranch Downstream	Dissolved Oxygen	3	9.2	10.0	4.7	10.8	5.0	14.2	13
	Escherichia coli	3	5120	9067	9793	6100	1100	20000	412
	Fecal Coliform	3	5695	13533	19461	2700	1900	36000	469
	pH Field	3	6.9	6.9	0.2	6.9	6.7	7.1	-9
	Temperature	3	10.5	11.2	4.8	10.3	6.9	16.4	22
Morse Ranch Upstream	Dissolved Oxygen	3	8.9	9.7	4.4	11.0	4.8	13.4	1
	Escherichia coli	3	5721	9967	12190	3900	2000	24000	565
	Fecal Coliform	3	6372	26933	43362	2400	1400	77000	624
	pH Field	3	6.8	6.8	0.2	6.8	6.6	6.9	-2
	Temperature	3	10.7	11.3	4.8	10.2	7.2	16.6	15
Chambers & W 18th Ave, NE: MH 55402/55404	Dissolved Oxygen	9	8.9	9.3	2.8	10.4	5.5	13.3	-1
	Escherichia coli	9	1318	1741	1143	1400	230	3200	-12
	Fecal Coliform	9	2064	3122	3005	1700	400	10000	96
	pH Field	9	6.9	6.9	0.3	6.8	6.5	7.6	-2
	Temperature	9	11.3	11.8	3.7	11.9	7.3	17.4	8
Chambers & W 18th Ave, NE: NE Loading Dock Catch Basin	Dissolved Oxygen	4	9.0	9.2	2.2	9.4	6.9	11.1	New Data
	Escherichia coli	4	3316	7868	10934	3450	570	24000	New Data
	Fecal Coliform	4	8554	24200	39251	6000	1800	83000	New Data
	pH Field	4	6.8	6.8	0.1	6.8	6.7	6.9	New Data
	Temperature	4	10.2	10.9	5.0	9.7	6.4	18.0	New Data
Chambers & W 18th Ave, NE: Parking Lot Catch Basin	Dissolved Oxygen	1	5.8	5.8		5.8	5.8	5.8	New Data
	Escherichia coli	1	98	98		98	98	98	New Data
	Fecal Coliform	1	2700	2700		2700	2700	2700	New Data
	pH Field	1	7.6	7.6		7.6	7.6	7.6	New Data
	Temperature	1	14.3	14.3		14.3	14.3	14.3	New Data
W 18th Ave; E Side Storm Runoff to MH 67386	Dissolved Oxygen	2	5.9	6.0	0.5	6.0	5.6	6.3	New Data
	Escherichia coli	2	375	375	7	375	370	380	New Data
	Fecal Coliform	2	1273	1350	636	1350	900	1800	New Data
	pH Field	2	8.2	8.2	0.7	8.2	7.7	8.7	New Data
	Temperature	2	15.4	15.4	0.7	15.4	14.9	15.9	New Data

Units:		
	mg/L	Dissolved Oxygen
	MPN	Escherichia coli
	col./ 100 mL	Fecal Coliform
	Std. Units	pH Field
	˚C	Temperature

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In summary, geometric means summarized in Table 4-2 indicate that most of the storm event samples collected for the 2013/2014 monitoring period exceed the state's water quality criterion for bacteria of 406 organisms per 100 mL; only Willow Creek – the relatively undeveloped background site – has consistently had means that are less than the criterion. All bacteria data were used to generate the boxplots in Figure B.24 and are compared to the state water quality criterion, which is marked by the vertical green line.

Six field condition assessment surveys for bacteria were done during the 2013/2014 monitoring period. These surveys are used to document basin conditions such as amount, type, and location of wildlife and domestic pets; human behaviors; location and number of wildlife and domestic animal waste; conditions within commercial loading areas, recycling areas, and garbage dumpster areas, etc. At this time bacteria field surveys have been focused within a portion of the Polk Street sub-basin and the Morse Ranch dog park. A semi-quantitative review of all the surveys has been done of the field observations. At this time the review suggests there is likely a combination of field conditions that contribute toward high bacteria counts/loads, although the predominant source of bacteria appears to be avian.

Restoration of riparian habitat along sections of Amazon Creek and grassy parklands adjacent to the water body has attracted populations of nesting ducks and geese. Field survey findings indicated areas along Amazon Creek with significant amounts of avian waste which contributes to bacteria loads in the water body and exceedance of Oregon's bacteria water quality standard. Other sources of avian waste bacteria noted during field surveys include populations of swallows, starlings, gulls, crows, and sparrows, and large numbers of their waste deposits on sidewalks and parking lots, and even rooftops. These impervious surfaces within the bacteria study area are easily flushed by seasonal rains and directly transported via the MS4 to Amazon Creek. Over time, outreach to commercial businesses such as that done at Chambers & W 18th Avenue to improve waste handling and disposal to reduce bacteria vectors should help reduce loads.

Nutria have also been observed within urban riparian areas, and evidence of beaver activity was recently noted. Within the Tiara drainage basin wild turkey, deer, and domestic fowl have been observed along the small urban stream. Domestic animal waste has also been noted within the study area, both canine and feline, and on occasion illegal camping was observed in dense woods and shrubs along the creek.

In summary, field surveys suggest sources of bacteria to Amazon Creek within the study area are predominantly avian, followed by domestic animals, other wildlife, and potentially some human contributions. Field surveys will continue and will be assessed in combination with quantitative bacteria studies, including ambient and stormwater monitoring programs. We anticipate the combined information will prove helpful in adaptively managing Eugene's existing BMPs to improve their effectiveness. One such program is the city's Canines for Clean Water outreach program implemented citywide several years ago. A description of this educational outreach BMP can be found under the BMP section of this report.

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4.4.4. Ambient Water Quality Monitoring

Ambient water quality monitoring has continued at twelve monitoring locations, including six within the Willamette River basin; four sites on the Willamette River, one near the Delta Ponds outlet, one on Spring Creek; and six in the Amazon Basin, three on Amazon Creek, and one each on Willow Creek, the A3 Channel, and the Amazon Diversion Channel. Surface flows through the Delta Ponds, which consists of sloughs and former aggregate excavation sites, are to the Willamette River. Extensive riparian restoration efforts were made by the US ACOE and the City of Eugene to create and enhance riparian habitat for fish spawning and rearing. The Delta Ponds also receives stormwater discharges from surrounding development; thus assessment of water quality from this area is important to determine the effects of stormwater on Delta Ponds and the Willamette River. The ambient sampling sites are listed in Table 4-3 below and locations shown in Figures 4-6 and 4-7. Sampling is generally conducted at each site every other month such that sampling events are representative of both the rainy season (October through April), and drier months (May through September). All ambient sampling is conducted utilizing clean sampling techniques; both total and dissolved metals are analyzed as well as conventional water quality parameters.

Analytical results and statistical analyses characterizing receiving water quality at the monitored sites are described here. For the most part grab samples collected every other month represent snapshots of ambient water quality – analytical results may not necessarily represent average water quality, or the full range of water quality variability. Six additional sampling events were done since the last annual reporting period, although a few locations could not be sampled because of dry streambeds. Data generated for these latest sampling events have been added to the historical data set that begins in January 1997. For the current permit year sampling events occurred between July 2013, and June 2014.

Table 4-4 **Ambient Water Quality Monitoring Sites**
Amazon Creek Basin Sampling Sites: Amazon Creek at 29th Avenue Willow Creek 450 feet north of 18th Avenue Amazon Creek at Railroad Track Crossing Amazon Diversion Channel at Royal Avenue A3 Channel at Terry Street Amazon Creek at Royal Avenue
Willamette River Basin Sampling Sites: Upstream of Urban Growth Boundary (River Mile 186.9) At Knickerbocker Bridge (RM 183.9) At Owosso Bridge (RM 178.6) Delta Ponds North of Beltline Bridge & Upstream of Willamette River Confluence Downstream of Beltline Bridge (RM 176.8) Spring Creek at Beacon Drive East

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4.4.4.1. Results

Ambient water quality data were screened for outliers before applying statistics tests. In general, outliers are anomalous measurements that do not appear to be within the bounds of an historical data set. Outliers may result from any number of factors, including sample collection and handling procedures, analytical methodologies, transcription error, etc. Inclusion of anomalous measurements in statistical tests used to assess water quality characteristics can skew results and lead to erroneous conclusions. However, distinguishing anomalous measurements from an actual elevated pollutant concentration due to some site disturbance can be difficult if methodical evaluation of all probable factors is not performed. The methods commonly used to test for outliers include skewness, kurtosis, and Shapiro-Wilk assume normal distribution of water quality measurements; it was found, however, that most of the analytes did not follow a normal distribution. Identification of an outlier using these methods does not preclude investigation into the anomaly and its possible cause. Outliers were investigated and corrected if possible, including traceable error such as transcription and dilution error.

For data sets whose distributions are not normal, best professional judgment was applied when selecting outliers to exclude from further statistical analysis. Best professional judgment may include reanalysis of the sample provided the holding time has not been exceeded.

Multiple outliers were identified in the 2013-2014 ambient dataset; copper and zinc values, were found to be inconsistent with historical data. Multiple values for dissolved oxygen were identified as outliers and attributed to instrument malfunction. Additionally, multiple total dissolved solids were identified as outliers and attributed to sample labelling errors. Excluded values are denoted as “Outlier” in report tables. Outliers were also identified in the historical data set, and while these are ultimately excluded from final statistical analysis results, the outliers are only temporarily excluded; they are added to the data pool at the beginning of each annual data analysis for distribution tests as applicable. Analytical data for the most recent monitoring period are presented in Tables A.9 through A.11. Note there are no data for one or two sampling dates at the A3 Channel at Royal, Amazon Creek at Royal, Willow Creek, Delta Ponds, and Spring Creek because these sites were dry at the time of sample collection.

Censored data, those values reported as less than the reporting limit, are included in the summaries utilizing the restricted maximum likelihood estimation technique for miscellaneous parameters, and the delta distribution estimator for the metals data. These estimators reduce the problems associated with censored data when calculating mean and standard deviation, and are superior to substitution of censored data with one-half the reporting limit. Means and standard deviations for the ambient historical data set are summarized in Tables A.12 and A.13.

4.4.4.2. Seasonal Trends

The Seasonal Kendall statistic, Z, is used here to describe long-term analyte trend with consideration given to seasonal variation. This trend estimator is free of distributional

assumptions. Developed by the U.S. Geological Survey[1], the Seasonal Kendall statistic is the most frequently used test to assess trend in environmental data. In assessing analyte trends, we presume in-stream flow is the result of multiple water pathways in the hydrologic cycle, including overland flow, ground-water discharge, and precipitation; precipitation directly and indirectly influences the concentration of analytes as measured in samples collected from the Amazon and Willamette basins, and may also contribute trace amounts of pollutants through atmospheric deposition, such as mercury. The temporal distribution of the precipitation events, including intensity and duration, influences analyte concentration; however, data for these factors are not available, are not easily obtained, and their effects on seasonal pollutant concentration difficult to assess.

Our simplified approach assumes these factors are intrinsic to the period during which the sampling event occurs. Average monthly precipitation for Eugene was divided into four "seasons," or periods, based on average monthly precipitation and trend increase or decrease. The periods should help to identify seasonal variations in analyte concentration. The wet season (Period 1: November, December, January) is followed by a drying trend extending into July. The drying trend is subdivided into Period 2 (February, March, April) and Period 3 (May, June, July), the latter being the driest period. Months leading to the wet season comprise Period 4 (August, September, October) and are progressively wetter. Precipitation data is from the Eugene, Oregon airport weather station (#352709) with a period of coverage from 1939 to 2011. Each sampling event for the entire data set (historical and current year data) is assigned to a period based on the sampling date.

The USGS has developed a DOS-executable program to run the Seasonal Kendall test statistic. In this application, rejection of the null hypothesis of no trend is calculated at $2\rho = 1\%$, that is, a 2ρ value of 0.01 indicates there is a 1% probability of the observed trend due to random sample variability. Program output includes slope estimator, *m*, to describe the overall analyte trend.

Results of trend analysis using the Seasonal Kendall test statistic indicate significant trends at 9 of 12 monitoring locations, including Willow Creek, Amazon Creek at 29th Avenue, Amazon Creek at the Railroad Crossing, the Amazon Diversion Channel at Royal Avenue, the A3 Channel at Terry Street, Amazon Creek at Royal Avenue, and the Willamette River Upstream at the Knickerbocker Bridge, downstream of the Beltline Bridge, and the Delta Ponds sites. No significant water quality trends were observed for Spring Creek, the Willamette River at Upstream of the Urban Growth Boundary, and the Owosso Bridge.

Water quality trends for the water bodies tend to be subtle; hence, those noted in previous reports but not observed here and vice versa are commonly influenced by the most recent water quality data such that statistical significance of the trend changes upon addition of new analyte results.

Figures B.36 through B.92 (Appendix B) show the historical data sets plotted against time with trend lines, which are averages of the four differentiated seasons based on precipitation; a summary of the program output is presented in Table A.14 in Appendix A. All significant long-term concentration trends are summarized in Table 4-5 below. A number of pollutants listed are

[1] Dennis R. Helsel, Mueller, David K., and Slack, James R., Computer Program for the Kendall Family of Trend Tests: U.S. Geological Survey SIR 2005-5275.

on Oregon's 2004 303(d) list and several have approved TMDLs. Results of the Seasonal Kendall test statistic indicate significant progress is being made to reduce pollutants in the listed impaired water bodies.

We noted long-term decreasing concentration trends for at least some analytes at most monitoring locations; these sites are located upstream, downstream or within the urban environment and are influenced by the sum of human activities that occur within respective drainage basin areas. We attribute the decreasing pollutant trend to the sum of stormwater program BMPs applied within these drainage basins to control stormwater pollutants caused by human activities within the urban environment. Decreasing trends in the Amazon and Willamette basins are primarily observed for metals, including arsenic, cadmium, chromium, lead, mercury, molybdenum, nickel, and silver. Nutrients (nitrogen and phosphorus), suspended solids, turbidity, biochemical oxygen demand, and temperature also showed decreasing trends at a few monitoring sites.

Arsenic is naturally occurring in Willamette valley soils due to their volcanic origin, and is commonly mobilized through soil disturbance and other anthropogenic activities. Decreasing concentration trends at the A3 Channel site, whose drainage basin primarily consists of industrial and commercial properties, is positive progress, however, observed concentrations (see Table A.9) tend to exceed the human health water quality criterion of 2.1 µg/L. The decreasing arsenic trend observed at the Amazon Diversion Channel site is perhaps indicative of the effectiveness of the West Eugene Wetlands in trapping suspended particulate; arsenic concentrations, however, also tend to exceed the water quality criterion and emphasize the need for continued progress applying sediment control BMPs.

Mercury also occurs naturally in Willamette valley soils and accounts for about 48% of the mercury load to Willamette basin water bodies. The next largest source of mercury in Willamette valley is atmospheric deposition to land; at 42%, a significant portion of this load originates in China, but also originates locally from the combustion of fossil fuels, forest fires, and anthropogenic activities. Mobilization of land-deposited atmospheric mercury occurs readily during precipitation events. About 5.9% of atmospheric mercury is deposited directly into water bodies. Sources of mercury were assessed in the 2006 Willamette Basin TMDL for Mercury. As with arsenic, effectual sediment control BMPs are perhaps the best tools for mercury reduction in Eugene's urban waterways.

Other trace metals with significant decreasing concentration trends in Eugene's waterways such as cadmium, chromium, lead, molybdenum, nickel, and silver, are commonly associated with automobiles, as well as some industrial and commercial activities. Of these metals cadmium and lead have been found to exceed chronic toxicity criterion in samples collected nearly all Amazon Basin ambient monitoring locations; samples collected for total lead analysis during the 2013/2014 monitoring period from the A3 Channel, Amazon Diversion Channel, and Amazon Creek have exceeded the chronic toxicity (see Table A.9 and Figure B.119); fewer historical water quality exceedances and no current data were observed to exceed the chronic criterion for the more bioavailable dissolved lead fraction. Current BMPs minimizing road grit from the MS4 and maintenance of the MS4, and industrial source control establishing pollutant benchmarks

and permit required monitoring, have proven effective mechanisms in reducing these metals in water bodies receiving stormwater flow.

Table 4-5
Summary of Seasonal Kendall
Water Quality Analyte Trend Analysis [1]

Monitoring Location	Trend of Water Quality Analyte	
	Decreasing Concentration Trends	**Increasing Concentration Trend**
Amazon Creek Basin Sites:		
Willow Creek	Total Kjeldahl Nitrogen	Lead, Dissolved Zinc, Dissolved & Total
Amazon Creek at 29th Avenue	[2] Lead, Total	Zinc, Dissolved & Total Chemical Oxygen Demand
Amazon Creek at Railroad Tracks	Cadmium, Total Chromium, Dissolved & Total [2] Lead, Total Mercury, Dissolved & Total Nickel, Dissolved	Zinc, Dissolved & Total
Amazon Diversion Channel at Royal Avenue	[2] Arsenic, Dissolved & Total [2] Mercury, Dissolved Molybdenum, Dissolved Nickel, Dissolved & Total Biochemical Oxygen Demand Total Kjeldahl Nitrogen	Zinc, Total
A3 Channel at Terry Street	[2] Arsenic, Dissolved& Total Cadmium, Total Chromium, Dissolved & Total [2] Lead, Total [2] Mercury, Dissolved & Total Molybdenum, Dissolved Nickel, Dissolved & Total Silver, Total Biochemical Oxygen Demand Phosphorus, Total Temperature Total Kjeldahl Nitrogen	None
Amazon Creek at Royal Avenue	Chromium, Dissolved & Total [2] Lead, Total Mercury, Total Nickel, Total Temperature Total Suspended Solids Turbidity	Zinc, Dissolved & Total
Willamette River Basin Sites:		
Knickerbocker Bridge	Ortho Phosphorus	Specific Conductance
Downstream of Beltline Bridge	Ortho Phosphorus	None
Delta Ponds	Molybdenum, Dissolved & Total	[2] Dissolved Oxygen

[1] Significant at $2\rho = 0.01$
[2] On Oregon 2004/2006 303(d) list.

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An increasing trend is observed zinc at multiple locations, including Willow Creek, Amazon Creek at 29th Avenue, the Railroad Crossing, and Royal Avenue, and within the Amazon Diversion Channel at Royal Avenue. Zinc concentrations at all Amazon Basin monitoring sites as well as Delta Ponds and Spring Creek, have exceeded the acute or chronic water quality criteria (see Figures B.130, B.131, B.170, and B.171). Data for the 2013/2014 for all locations except Amazon Creek at 29th, also had reported concentrations above the water quality criteria (see Table A.9). Zinc is a widely used agent for moss control in the Pacific northwest and increasing concentration trends for this metal in local water bodies is being actively addressed through educational BMPs that provide property owners with information on alternative products for moss control. Interestingly, chemical oxygen demand in Amazon Creek at 29th Avenue also is trending upward; this analyte measures oxygen depletion due to chemical oxidation processes.

The trend for dissolved lead also is increasing in Willow Creek. At this time the causes of this increasing trend is unknown.

A slight increasing trend for conductance in the Willamette River at the Knickerbocker could be related to a combination of factors, such as weathering and dissolution processes of soils. An increasing trend is also noted for dissolved oxygen in Delta Ponds and is likely due to regulated Willamette River diversions of flow through the ponds. We also noted a decreasing trend for molybdenum.

Water quality trends are often associated with anthropogenic activities; however, in some instances measurement technique and/or instrumentation can influence trends. For example, instrument sensitivity for the testing of trace metals and other analytes has increased significantly over the years since monitoring was begun in 1997. This instrument sensitivity evolution may in part explain a discernible change in data variability, which is noticeably more pronounced in early sampling events when compared with those taken later.

There is a small probability that some decreasing or increasing metals trends may not have been identified by the Seasonal Kendall test because the laboratory used to perform the metals analysis was changed in February 2007, though after careful review of the data it is believed all likely and significant trends have been summarized. Beginning with the February 2007 sampling event, the Eugene/Springfield Water Pollution Control Facility (E/S WPCF) Laboratory performed all metals analysis. While the laboratory uses the same analytical methodology, specifically, EPA 200.8, the reporting limits are somewhat greater than those observed prior to February 2007, when a contract laboratory performed the analyses. Analytical results reported since early 2008 indicate that the E/S WPCF laboratory was able to achieve lower reporting limits for nearly all metals when compared to the first few sampling events in 2007. The facility continues to review its analytical procedures to ensure optimum instrumentation performance is attained so that continuity of historical trends observed in previous years is maintained to the fullest extent possible.

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4.4.4.3. Water Quality Changes: 2013/2014 Permit Year vs. Historical Data Set

The Mann-Whitney test statistic is used here to assess whether any water quality changes have occurred over the most recent monitoring period compared to the historical data compiled for each sampling location. Mann-Whitney is a nonparametric calculation based on the sums of ranks for independent samples and is suitable for censored data sets. Table A.15 in Appendix A summarizes significant water quality changes, which consists of comparing sampling events for the 2013/2014 period to historical data. For comparison purposes, averages are reported for the recent monitoring data and the historical data set; data comparisons are statistically significant at $\alpha = 0.05$. The full program output for the statistic is shown in Tables A.16 and A.17.

Note that some analytes in Table A.15 are annotated, indicating that the data set includes some censored values which have been set at one-half the reporting limit. In general, mean corrected averages cannot be reasonably estimated on small data sets with a large number of censored values. For example, with few exceptions cadmium and selenium values for Amazon Basin and Willamette River sites consist of censored values, hence the statistical significance of annotated means if the population of censored values is greater than 50 percent is somewhat questionable and therefore generally excluded from tables summarizing statistically significant comparisons. Consult Tables A.12 and A.13 for all analytes and those reported as INS, that is, insufficient uncensored data available to compute the statistic.

Examination of water-quality changes that have occurred during the most recent monitoring period are helpful in identifying those drainage basin areas where land use activities have had, either directly or indirectly, a significant influence on water quality – either resulting in improved water quality or degradation. A third outcome of this examination is that no water quality change occurs, which is also a significant finding in that this enables assessment of the effectiveness of applied best management practices within specific drainage basin areas.

The city's ambient monitoring program includes 41 regular analytes plus a few special organics at select sites. An ideal outcome of the statistical tests would be that, for all those analytes present above natural or background conditions, an improvement occurs for the recent monitoring year when compared to the historical water quality data – a somewhat unrealistic scenario. In general, water quality improvement of urban streams is achieved gradationally over an extended period of time as is shown by the trends described in the previous section. The following sections assess ambient water quality data and identify basin areas for review consideration of best management practices.

Amazon Basin Sites

Five samples were collected from Willow Creek, A3 Channel at Terry Street, Amazon Creek at Royal Avenue, Delta Ponds, and four samples from Spring Creek during the monitoring year, one or two less samples than planned because the stream was dry for the July or September sampling event. An extended dry period has been observed in Willamette valley during the fall and winter of 2013, and spring of 2014; similarly dry conditions occurred on at least six other occasions since ambient monitoring began in 1997 precluding sample collection due to lack of stream flow.

Willow Creek originates just south of a preserve held by The Nature Conservancy and has similar geomorphologic characteristics to the upper reaches of Amazon Creek; its headwaters flow through some rural residential properties and the creek receives some stormwater from the former Hynix facility (a silicon chip manufacturer whose operations ceased during the 2007/2008 period although maintenance of stormwater facilities and monitoring continue). The water quality characteristics of Willow Creek, which is for the most part a local, minimally-urbanized stream, has served as a reasonably good baseline for comparing the water quality characteristics observed for Amazon Creek; however, recent water quality trends indicate some degradation, specifically dissolved lead, and total and dissolved zinc.

Referring to Table A.15 in Appendix A, all six Amazon basin monitoring sites, including Willow Creek have recent analyte averages that differ from historical means. Overall 14 of 28 analytes, or about 48%, show statistically significant concentration decreases. All six sites had statistically significant analyte values that are higher in 2013/2014 than observed historical means. Dissolved lead, and dissolved and total zinc concentrations are frequently higher; total lead is lower. Zinc concentration differences are the most pronounced in this comparison, although differences for lead are also notable. The statistically significant two to three-fold increase in zinc concentrations in Amazon and Willow Creeks, in addition to increasing concentration trends, indicates mobilization of soluble zinc within the urban area during the 2013/2014 monitoring period was greater than the historical average concentration.

Hardness (calcium and magnesium) decreased in lower Amazon Creek and Diversion Channel but increased in the upper Amazon and A3 Channel. A few other analytes also showed statistically significant change, including cadmium, chromium, nickel, chemical oxygen demand, and dissolved oxygen.

Willamette River Sites

Analyte comparisons summarized in Appendix A Table A.15 show that all four sites on the Willamette River, Delta Ponds, and Spring Creek had recent analyte averages differing significantly from historical means. Overall, 18 of 20 analyte values show statistically significant decreases during the 2013/2014 monitoring period compared to historical averages.

Phosphorus, suspended solids and turbidity showed modest decreases at nearly all sites on the Willamette River; additionally, lead, chemical oxygen demand, and Kjeldahl nitrogen decreased slightly at the Beltline Bridge site. At the Delta Ponds site, calcium, Kjeldahl nitrogen and turbidity decreased slightly. At Spring Creek, lead decreased while calcium and magnesium (hardness) increased slightly. The range of water quality variability is unfolding as the database for the Spring Creek site becomes established.

The improving water quality trends described above for the Amazon and Willamette basin sites, and to some extent the improvements of recent water quality data when compared to historical data, are positive indicators that BMPs applied within the permit area are effective and have resulted in measurable pollutant decreases in receiving water bodies that have approved TMDLs or that are on the state's 303(d) list.

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4.4.4.4. Intra-Basin Water Quality Differences

In addition to temporal changes in water quality, intra-basin differences are of interest because water quality comparisons are made between an upstream and downstream monitoring site, which provides a means of assessing whether urban activities affect a waterbody as the water flows through the urban area. The Mann-Whitney test statistic is used here to assess water quality differences between any two sites within the same stream basin or between drainage basin areas. Mann-Whitney is a nonparametric calculation based on the sums of ranks for independent samples and is suitable for censored data sets. Comparisons described utilize the all data for each monitoring location, including the data recently acquired in 2013/2014. Table A.18 and A.19 in Appendix A summarize significant average analyte values; comparisons are significant at $\alpha = 0.05$. The full program output for the statistic is shown in Tables A.20 and A.21.

Amazon Basin Monitoring Locations

Intra-basin comparisons include the analysis of the 29th Avenue site on Amazon Creek compared to the site on Willow Creek (see Figure 4-6 for sampling locations and basin extent), streams which originate in the same low hills south of Eugene but drain different sub-basins. In addition, the 29th Avenue site, comprised predominately of residential land use, is compared to Spring Creek at Beacon Drive East, also comprised of mostly residential land use but originating within the urbanized Santa Clara – River Road stormwater basin.

The concentration of metals, nutrients and bacteria are higher in Amazon Creek at the 29th Avenue site in comparison to Willow Creek. Of the 41 water quality analytes monitored, the concentrations of 16 analytes were found to be statistically higher in Amazon Creek at the 29th Avenue site, including total cadmium, dissolved and total copper, lead, molybdenum, and zinc, as well as *E. coli*, fecal Coliform, nitrate+nitrite as nitrogen, ortho and total phosphorus, total magnesium, and field pH. Total arsenic, and total and dissolved chromium, are higher at the Willow Creek site.

Relative percent concentration differences (the difference divided by the mean of the two values) range from 1% for total cadmium, to 107% for total zinc; for non-metal parameters the relative percent difference ranges from 1% for total magnesium, to 140% for *E. coli*. Total cadmium is 80% higher in Amazon Creek at 29th Avenue, dissolved and total copper are 37 and 38% higher, dissolved and total lead are 36 and 75% higher, dissolved and total molybdenum 81 and 85% higher, and dissolved and total zinc 98 and 107% higher, respectively, at the Amazon Creek at 29th Avenue site. Only total arsenic is higher in Willow creek by 25%, as is dissolved and total chromium at 1% and 88% respectively.

Nutrients and bacteria are also greater at the 29th Avenue site; fecal Coliform and *Escherichia coli* averages are 3 and 5 times greater than, respectively, bacteria counts observed at Willow Creek. These bacteria ratios have decreased from previous reporting periods; as mentioned above, bacteria counts in Willow Creek have been noticeably higher over the last few years. Ortho and total phosphorus, nitrate+nitrite, and pH are also higher at the Amazon Creek site. The higher metal, nutrient and bacteria concentrations observed in Amazon Creek are pollutants

commonly associated with urbanized environments. These comparisons are summarized in Table 4-6 below.

Intra-basin comparisons are also shown for the 29th Avenue site and Spring Creek at Beacon Drive East; statistically significant differences were found for 20 of 41 analytes, including metals, nutrients, calcium, pH, and dissolved solids. For the 13 metals, all values except one are higher in Amazon Creek at 29th Avenue, including dissolved and total fractions for arsenic, chromium, copper, lead, mercury, and nickel. Relative percent differences range from 49% for dissolved lead to 156% for dissolved mercury. The average dissolved zinc concentration in Spring Creek is more than twice that of Amazon Creek at 29th. Amazon Creek has a slightly higher pH, higher concentrations of total calcium, dissolved solids, and bacteria than Spring Creek, the latter having higher concentrations of nutrients (nitrate+nitrite as nitrogen.

Comparing water quality data for at Amazon basin monitoring sites we generally find that as stream flow passes through the urban environment the concentrations of metals, oxygen demand, suspended solids, turbidity, and temperature <u>increase</u> at respective downstream monitoring sites; dissolved oxygen, *E. coli*, fecal Coliform, NO_3+NO_2, ortho phosphorus, and dissolved zinc concentrations tend to <u>decrease</u> at respective downstream monitoring sites. The 29th Avenue site is the uppermost monitoring location on Amazon Creek, followed by Amazon Creek at the Railroad Crossing; the Amazon Diversion Channel at Royal Avenue and Amazon Creek at Royal Avenue are farthest downstream monitoring sites. The A3 Channel at Terry Street drains into the lower Amazon Creek (see Figure 4-6). There are a few notable exceptions to these water quality characteristics:

- A3 Channel at Terry Street (upstream) compared to Amazon Creek at Royal Avenue (downstream)
    - 22 of 24 analytes having statistically significant difference have historical averages that are greatest <u>upstream</u> at the Terry Street site, including BOD, COD, hardness (calcium and magnesium), conductivity, TDS, and nutrients (nitrate+nitrite as nitrogen, Kjeldahl nitrogen, and ortho and total phosphorus); metals include total and dissolved cadmium, molybdenum, nickel and zinc, and total copper, lead and mercury.
    - Dissolved mercury and arsenic averages are greater <u>downstream</u> at the Amazon Creek Royal Avenue site.
- Amazon Creek at 29th Avenue (upstream) compared to Amazon Creek at Railroad Track Crossing (downstream)
    - 11 of 30 analytes having statistically significant difference have historical averages that are greatest <u>upstream</u> at the Amazon Creek at 29th Avenue. Dissolved zinc is greatest upstream, as are DO, hardness (calcium and magnesium), pH, nutrients (nitrate+nitrite as nitrogen and ortho phosphorus), and bacteria (*E. coli* and fecal Coliform).

- COD, temperature, TSS, and turbidity, as well as total and dissolved arsenic, lead, mercury, molybdenum, and nickel, as well as total cadmium, copper, selenium, silver, and zinc average concentrations are greatest downstream at the Railroad Track Crossing monitoring site.

- Amazon Creek at 29th Avenue (upstream) compared to Amazon Diversion Channel at Royal Avenue (downstream)

  - 3 of 26 analytes having statistically significant difference have historical averages that are greatest upstream at the Amazon Creek at 29th Avenue site. Dissolved zinc is greatest upstream, as are bacteria (*E. coli* and fecal Coliform).

  - Total and dissolved arsenic, cadmium, copper, lead, molybdenum, nickel, and total chromium, mercury, selenium, and silver have higher average concentrations at the downstream monitoring location. COD, magnesium (hardness), total phosphorus, Kjeldahl nitrogen, TSS, and turbidity are also greater downstream.

- Amazon Creek at Railroad Track Crossing (upstream) compared to Amazon Diversion Channel at Royal Avenue (downstream)

  - 4 of 19 analytes having statistically significant difference have historical averages that are greatest upstream at the Amazon Creek at Railroad Track Crossing, including dissolved mercury and arsenic, and bacteria (*E. coli* and fecal Coliform).

  - Total and dissolved copper, molybdenum, nickel, and total cadmium and mercury, as well as COD, hardness (magnesium), total phosphorus, Kjeldahl nitrogen, TSS, and turbidity are greater downstream.

Average concentrations for analytes with statistically significant differences are summarized in Tables A.14 and A.15 in Appendix A.

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Table 4-6
Intra-Basin Water Quality Comparison of Willow, Amazon, and Spring Creeks [1] Using Mann-Whitney Statistic [2]

Analyte	Units	Willow Creek	Amazon Creek at 29th Avenue	Spring Creek at Beacon Drive East
Arsenic – Total	(*µg/L*)	1.41	1.09	0.392
Arsenic - Dissolved			0.888	0.329
Cadmium – Total		0.00256	0.00598	
Chromium – Total		0.885	0.344	0.287
Chromium – Dissolved		0.600	0.592	0.151
Copper – Total		2.30	3.38	1.05
Copper – Dissolved		1.21	1.76	0.663
Lead – Total		0.270	0.595	0.342
Lead – Dissolved		0.0269	0.0389	0.0235
Mercury - Total			0.00254	0.00078
Mercury – Dissolved			0.00099	0.00012
Molybdenum – Total		0.114	0.284	
Molybdenum – Dissolved		0.115	0.271	
Nickel – Total			2.06	0.826
Nickel - Dissolved			1.43	0.701
Zinc – Total		6.87	22.7	
Zinc – Dissolved		4.40	12.9	28.9
Escherichia coli	(*Col./100 mL*)	147	830	328
Fecal Coliform		116	362	
Calcium - Total	(*mg/L*)		24	17
Magnesium - Total		8.2	8.3	
Nitrate+Nitrite – as Nitrogen	(*mg/L*)	< 0.05	0.31	2.05
Phosphorus – Ortho		0.02	0.05	0.07
Phosphorus – Total		0.06	0.10	0.15
Field pH	(*Units*)	7.1	7.6	6.9
Total Dissolved Solids	(*mg/L*)		153	100

[1] Comparisons made: Willow Creek ↔ Amazon Creek; Amazon Creek ↔ Spring Creek
[2] Mann-Whitney test statistic comparisons significant at $\alpha = 0.05$.
Shaded cells indicate the higher analyte concentration in the comparison.

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Willamette River Monitoring Locations

Results of the Mann-Whitney test statistic applied to historical data for the Willamette River monitoring locations indicate that analytes statistically significant at $\alpha = 0.05$, had concentrations that were greater at downstream sites than at corresponding upstream sites. Most of these water quality differences occur at two monitoring locations, upstream of the Urban Growth Boundary and downstream of Beltline Bridge (see Figure 4-7). Of the 41 analytes compared between these two sites, 27 are statistically different, 26 of which have higher average concentrations downstream of Beltline Bridge. Table 4-7 below summarizes those pollutants whose concentrations increase as the Willamette River flows through the urban growth area. Increases include total and dissolved arsenic, copper, lead, mercury, nickel, and zinc, as well as total silver. Bacteria counts (*E. coli* and fecal Coliform), as well as hardness (calcium and magnesium), dissolved solids and conductance, and nutrient (nitrate+nitrite as nitrogen, and ortho and total phosphorus) concentrations also increase as the Willamette River courses through the urban area. The pH decreases slightly.

An examination of water quality changes over shorter stream reaches indicates fewer statistically significant differences in analyte concentrations. Comparing data sets for the uppermost site above the Urban Growth Boundary to the Knickerbocker Bridge resulted in nine statistically significant differences among the analytes tested, including total and dissolved arsenic and copper, conductivity, calcium (hardness), and bacteria (*E. coli* and fecal Coliform), all of which have higher values downstream.

Between the Knickerbocker Bridge and the Owosso Bridge, the concentration of total lead, and *E. coli* and fecal Coliform increase over the stream reach.

Between the Owosso Bridge and the site downstream of Beltline Bridge above the McKenzie River confluence, nine analytes have statistically significant values, all of which are greater at the downstream monitoring location, including total and dissolved copper and zinc, conductivity, and nutrients (Kjeldahl nitrogen, nitrate+nitrite as nitrogen, and ortho and total phosphorus).

Tables A.18 and A.19 in Appendix A includes a summary of all Willamette River monitoring site analytes having statistically significant differences using the Mann-Whitney test statistic; Tables A.20 and A.21 present the full program output.

A final comparison is between Delta Ponds and the Willamette River at the Owosso Bridge; 16 of 22 analytes having statistically significant differences are associated with higher concentrations at the Delta Ponds site. Average values for total and dissolved arsenic, lead, nickel and zinc, dissolved copper, as well as total phosphorus, Kjeldahl nitrogen, dissolved solids, hardness (calcium and magnesium), and conductance values are also higher for the Delta Pond site. Average dissolved oxygen, pH, and interestingly, total and dissolved chromium and mercury values were higher in the Willamette River at the Owosso Bridge site. As mentioned in a previous section, flow management of the Delta Ponds along with extensive restoration of riparian habitat has been conducted by the City of Eugene and the US Army Corps of Engineers. The effect of these activities has been to alter the water quality characteristics of Delta Ponds, particularly during periods when flow management through Delta Ponds provides for higher flows to simulate more closely seasonal changes.

Table 4-7
Comparison of Willamette River Average Analyte Concentrations Upstream and Downstream of the Urban Growth Boundary Using Mann-Whitney Statistic [1]

Analyte	Units	Upstream of Urban Growth Boundary (RM 186.9)	Downstream of Beltline Bridge (RM 176.8)
Arsenic – Total	(*µg/L*)	0.268	0.330
Arsenic – Dissolved		0.203	0.245
Copper – Total		0.569	0.794
Copper – Dissolved		0.301	0.439
Lead – Total		0.0805	0.107
Lead – Dissolved		0.00655	0.0171
Mercury – Total		0.00161	0.00188
Mercury - Dissolved		0.00073	0.00086
Nickel – Total		0.308	0.360
Nickel - Dissolved		0.191	0.230
Silver – Total		0.00201	0.00525
Zinc – Total		1.34	1.88
Zinc – Dissolved		0.397	0.997
Escherichia coli	(*col./100 mL*)	20	43
Fecal Coliform		15	37
Nitrate+Nitrite – as Nitrogen	(*mg/L*)	< 0.05	0.11
Total Kjeldahl Nitrogen		< 0.2	0.2
Phosphorus – Ortho		0.02	0.05
Phosphorus – Total		0.04	0.08
Total Dissolved Solids		40	42
Total Suspended Solids		4.3	5.1
Turbidity	NTU	6.8	7.3
Calcium - Total	(*mg/L*)	4.6	5.1
Magnesium – Total		1.5	1.7
Hardness	(*mg eq $CaCO_3$/L*)	18	20
Specific Conductance	(*µmhos/cm*)	47	54
pH	Standard Units	7.4	7.1

[1] Mann-Whitney test statistic comparisons significant at $\alpha = 0.05$.
Shaded cells indicate analyte value at downstream monitoring site greater than upstream site.

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The Willamette River was 303(d) listed in 2004 for dioxin (2,3,7,8-TCDD) and ambient samples were collected at two locations during the 2013/2014 monitoring period; all results were reported as not detected (see Table A.10) with reporting limits ranging from 5 to 10 pg/L.

4.4.4.5. Comparison of Ambient Water Quality Data to Oregon Standards

Water quality standards and beneficial uses for surface waters are defined in Chapter 340, Division 41 of the Oregon Administrative Rules (OAR). Analytical results for surface water samples collected from Amazon Basin and Willamette River sites are assessed in this section for overall conformance to Oregon water quality standards.

Boxplot charts are shown in Appendix B Figures B.93 through B.109 of water quality data from the Amazon Basin and Willamette River monitoring sites and compared to Oregon standards. The horizontal line in the middle of the box for each analyte marks the median of the sample set; the median splits the ordered sample set in half. The box represents the central 50 percent of data values; the outer edge of each box mark the 25th and 75th percentiles. Whiskers extending from the box mark the range of values that fall within 1.5 box-lengths from the 25th or 75th percentile. Outliers and extreme values are also depicted in the figures and are defined using different criteria than those used to identify anomalous measurements. Values that are more than 1.5 box-lengths from the 25th or 75th percentiles are identified as outliers and are denoted by an open circle; extreme values are more than 3 box-lengths and are denoted by an asterisk.

All six monitoring stations in the Amazon Basin are grouped together to obtain a visual synopsis of the analytical data, as are the data for the Willamette River, Spring Creek, and Delta Ponds. Note that all total and dissolved metals values are grouped together for each analyte. The boxplots provide a means of quickly characterizing the data sets graphically in terms of the types of analytes and percentile of sampling events exceeding the applicable water quality standard. Appendix B (Figures B.110 through B.197) presents boxplots for all data charting each water quality parameter by individual monitoring location. Boxplots also depict applicable Oregon water quality standard for each analyte. The water quality standard is defined by a vertical line through the concentration axis with the applicable criterion listed at the top of the chart. Metals toxicity criteria are adjusted for hardness using the equations of Table 20 in OAR 340-041. In all instances the lowest criterion is indicated.

In the case of arsenic (Figure B.93), Amazon Basin monitoring locations about 40 percent of the values exceed the human health criterion, which is 2.1 µg/L; the highest observed concentrations from Amazon basin sites exceed the standard by about seven times, while data for Willamette basin sites exceeded the standard in one instance, an extreme value from Delta Ponds where the concentration was about 2.5 µg/L. Willamette valley soils are volcanic in origin and contain relatively high concentrations of naturally occurring arsenic; in some locations total arsenic concentrations in soil can be as high as 20 mg/kg.

Cadmium concentrations exceeded the chronic toxicity criterion in both Amazon and Willamette basin monitoring sites, all of which are identified as extreme values. Most of the Amazon basin exceedances are associated with total values from the A3 Channel at Terry Street, while a

handful of values scattered at the three Willamette River sites within the urban area accounted for exceedances in the Willamette basin. Cadmium data for Amazon basin sites are up to three times greater than the chronic criterion Unlike previous reports where cadmium data were evaluated against a higher toxicity standard effective at that time, no water quality exceedances were observed. The cadmium toxicity criterion was recently updated by the Oregon DEQ, which has resulted in multiple exceedances (Figure B.94).

Copper concentrations measured at monitoring sites from the Willamette Basin (Figure B.97) are for the most part less than the chronic criterion with the exception of a few extreme values. In the Amazon Basin about 30% of values in the data set exceed the chronic criteria by up to seven times the 3.5 µg/L chronic criterion; values within 1.5 times the 75th percentile as defined by the extent of the whisker (about 7.0 µg/L) exceed both the chronic and acute toxicity criteria.

About 40% of the stream samples collected from the Amazon Basin exceed the chronic criterion for lead at 0.54 µg/L (Figure B.97). For the Willamette Basin monitoring sites a few extreme values exceed the chronic criterion.

Multiple extreme values and outliers at Amazon Basin sites exceed the mercury criterion of 0.012 µg/L (see Figure B.98); the extent of the whisker at 1.5 times the 75th percentile is near the mercury criterion. At the Willamette Basin sites a couple of extreme values exceed the chronic criterion for mercury.

The chronic criterion for silver is 0.085 µg/L and is exceeded by a few extreme values in the Amazon Basin; no Willamette Basin values exceed this water quality standard (Figure B.102).

Amazon Basin samples occasionally exceed both the acute and chronic criteria for zinc (Figure B.103), which are 36.2 µg/L and 36.5 µg/L, respectively. The extent of the whisker exceeds both criteria. A few samples collected from the Willamette Basin sites exceed both water quality criteria for zinc.

Exceedances of non-metal water quality standards are also observed for samples collected from the Amazon and Willamette Basins. These included DO, bacteria, pH, temperature, and turbidity. Minimum DO criteria are not met at either the Amazon or Willamette Basin sites for at least some periods of the year. For the Amazon Basin samples this would typically occur during summer months when water temperatures are warmer and stream flows are lower. Boxplots in Figure B.104 indicate that over a quarter of samples from the Amazon Basin may not meet the 6.5 mg/L minimum DO criterion. Sampling protocol does not strictly meet the 30-day mean definition of the criterion given a sampling frequency of six times per year; however, the values are strong evidence that depleted oxygen conditions may persist in the waterbody. The DO criterion for the Willamette River is for the period extending from October 15 to May 15 (the spawning period for salmonids); about 60% of the samples measured at Willamette Basin sites did not meet the 11.0 mg/L minimum DO criterion, though this may be somewhat skewed by the Delta Ponds and Spring Creek samples which, on average, have 5.9 and 8.1 mg/L DO, respectively. Boxplots in Figure B.179 indicate that only about half of the samples collected from Willamette Basin sites met the 11.0 mg/L DO criterion during the spawning period. Note that half of the samples did not meet the DO criterion at the site upstream of the urban growth

boundary, thus the Willamette River was found to be oxygen depleted even before passing through Eugene urban area. Median DO concentrations are lowest near the Owosso Bridge monitoring site but improve somewhat downstream of Beltline Bridge. Pollutants transported by stormwater likely contribute to oxygen depletion of the river through biological and chemical processes.

Escherichia coli counts exceed the criterion of 406 organisms per 100 mL in about 30 percent of samples collected from the Amazon Basin sites (Figure B.105); a few outliers exceeded the criterion from Willamette Basin sites, primarily from the Spring Creek site (see Figure B.187). The magnitude of exceedance for outliers and extreme values at the Amazon Basin sites is nearly two orders greater than the criterion. Unlike the Amazon Basin sites where bacteria counts tend to decrease downstream, bacteria counts in samples from the Willamette River increase slightly as the river flows through the urban growth area (see Table 4-7 above); however, values for monitoring sites on the Willamette River did not exceed the water quality criterion for bacteria. Fecal Coliform values exceed the criterion less frequently as shown in Figure B.106; the few outliers for the Willamette Basin are associated with the Spring Creek site (see Figure B.188), samples from the Willamette River did not exceed the bacteria criterion.

Field pH measurements from Amazon Basin sites sometimes exceed both the minimum and maximum pH criteria of 6.5 and 8.5 pH units respectively; some samples from the Willamette River sites exceed the minimum pH criterion (Figure B.107). Most of these exceedances are associated with field measurements performed during the early years of the monitoring program where greater pH variability is observed. In addition to the influences of natural conditions and anthropogenic activities, the greater variance may be associated with sampling technique and/or instrumentation used at that time.

Nearly 60% of the samples collected from the Amazon Basin exceed the salmon and trout rearing and migration temperature criterion of 18 ˚C (Figure B.109), effective from May 16th through October 14th; a few samples from the Willamette Basin also exceed this criterion. The salmon and steelhead spawning temperature criterion of 13 ˚C (Figure B.108) is applicable to the Willamette River and is effective from October 15th through May 15th; samples collected from the four main-stem monitoring sites occasionally exceed this criterion.

Figures B.192 through B.197 in Appendix B are boxplots of turbidity measurements compared to the applicable flow-based turbidity target defined in Chapter 10 on page 212 of the Willamette Basin TMDL; boxplots in Figure B.192 summarize the data by criterion. DEQ derived the Amazon Creek turbidity targets using Long Tom River flows near Noti as a reference river discharge. Collection dates for historical turbidity values measured under the ambient monitoring program were correlated to river flows on the Long Tom recorded by the USGS. The applicable turbidity target was then derived for each turbidity value; boxplots of the data sets are grouped by the applicable turbidity target, as defined on each chart. Most of the turbidity values exceed the applicable criterion, though it is instructive to note that the median of turbidity values for Willow Creek tends to center on the target at higher turbidity values. Turbidity values for Amazon Creek at 29th Avenue are comparable to – and often times less turbid than – Willow Creek, suggesting the upper reach of Amazon Creek may already exhibit turbidity levels that are similar to a relatively undisturbed stream originating within this basin. Additional efforts will be

needed at downstream sites to improve water quality such that it meets the turbidity targets required by DEQ.

OAR 340-041-0036 describes the turbidity criterion applicable to the Willamette River, which states that no more than a ten percent cumulative increase in natural stream turbidities may be allowed as measured relative to a control point immediately upstream. A statistically significant difference was observed for turbidity between the uppermost monitoring site on the Willamette River upstream of the urban growth boundary, and the lowermost site downstream of the Beltline Bridge (see Tables 4-7 above). Figure B.185 presents turbidity boxplots for the Willamette River sites.

Figures 8a through 8c and 9a through 9c, graphically summarize trends and water quality criteria for each monitoring location within the Amazon and Willamette Basins. Figures 8a and 9a summarize the Seasonal Kendal trends, green text analytes indicate decreasing trends while analytes in red text indicate an increasing trend. Green may be presumed to be a "good" indicator, while red a "poor" indicator, with the exception of Dissolved Oxygen in Figure 9a, in this instance decreasing trends are not desired and are indicative of water quality degradation.

Figures 8b and 9b compares water quality data for the most recent monitoring period (2012/2013) to Oregon water quality standard; all analytes listed indicate an exceedance of a water quality standard, green text analytes indicate the analyte has a decreasing concentration trend for the entire data set, red text indicates an increasing trend, and black text indicates no trend in the data set.

Finally, Figures 8c and 9c compare statistically significant water quality changes across the Amazon and Willamette drainage basins. Each analyte is color coded to its respective drainage basin area; for example, in the comparison of Amazon Creek at 29th Avenue to Amazon Creek at the Railroad Crossing, analytes in brown text indicate concentrations are greater at the 29th Avenue site, while those analytes in blue text indicate concentrations are greater at the Railroad Crossing site. Comparisons are for the entire water quality data set.

4.4.4.6. Water Quality Correlations

Factor analysis of the ambient water quality data was done to study the interrelated water quality analytes at each monitoring location. This concept is important because it may provide important characteristics of the water body and the types of pollutants detected both during dry and wet seasons. For example, suspended solid and turbidity increases in a water body may be associated with increases of other pollutants, hence application of specific BMPs to control solids and turbidity would prove beneficial in controlling other pollutants that are problematic in the same water body.

Our analysis consisted of reviewing the entire water quality data set using commercially available software to perform factor analysis. In addition to the 41 water quality analytes, three additional variables were added to the analysis; precipitation, river flow, and seasonality. River flow for sites other than the Willamette River utilizes flow measurements in the Long Tom River

near Noti, and seasonality is as defined in the Seasonal Trends section above. While derivation of a model summarizing the many analytes into a few factors is possible, our interest at this initial stage of review was generation of a correlation matrix of all analytes and their interrelationships. Correlations, or r values, measure the strength of linear associations between each analyte. Upon obtaining the correlations, all analyte pairs exceeding an r value of 0.3 and whose comparison was significant at $\alpha = 0.05$, were selected as "significant" analytes. A simple correlation index was developed whereby the sum of significant analyte pairs is divided by the total number of possible significant pairs. The index was calculated for four analyte groupings including; all analytes, metals, nonmetals, and metal-nonmetal correlations. If all analytes are linearly correlated within their respective group, an index of 1 (one) would be observed.

Figure 4-4 summarizes the correlation indexes for each ambient monitoring location. In general, the lowest correlation indexes are located at Willow Creek and Willamette River sites; by comparison, Amazon Creek, the A3 and Diversion Channels, Spring Creek, and Delta Ponds had significantly higher indexes. The highest correlation index observed for all analytes was 0.46 for Amazon Creek at the Railroad Crossing, followed closely by Spring Creek with a 0.44 correlation index.

Spring Creek had the highest metals correction index at 0.52, followed closely by Amazon Creek at the Railroad Crossing at 0.50. At Spring Creek, copper, zinc, chromium, lead, molybdenum, and cadmium had the greatest number of metal-metal correlations. For the non-metals, rainfall, nitrate+nitrite as nitrogen, and hardness (calcium and magnesium) had the greatest number of correlations.

Amazon Creek at the Railroad Crossing had the highest non-metal correlation index at 0.45, including hardness (calcium and magnesium), conductivity, dissolved oxygen, suspended solids, and temperature. For metals, the greatest number of correlations occurs for arsenic, copper, lead, molybdenum, nickel, and selenium. Total lead had the highest number of significant correlations at 33 analyte pairs, followed by total arsenic at 31, and total nickel at 30 analyte pairs; dissolved oxygen had 31 analyte pairs, temperature and suspended solids 30 pairs, and calcium 28 analyte pairs.

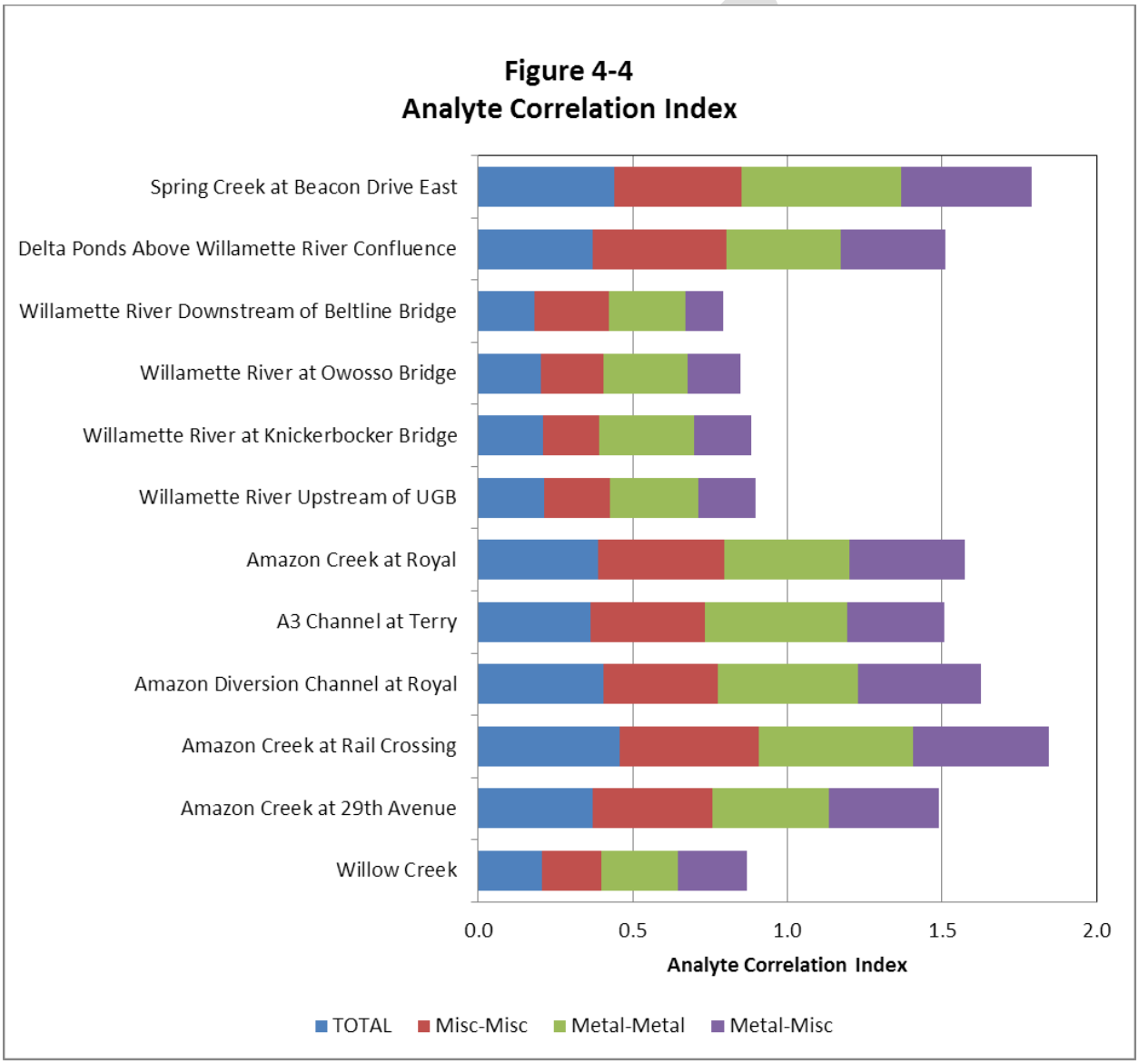
The Willamette River at Knickerbocker Bridge had the highest correlation index at 0.31 for the metal group. The correlation matrix for this group indicates copper, arsenic, zinc, mercury, nickel and chromium had the highest number of significant correlations.

A final comparison was made to evaluate the metal-nonmetal relationships. Once again, the Amazon Creek at the Rail Crossing had the highest correlation index at 0.44, followed closely by Spring Creek at 0.42. Analyte pair combinations in this group with the highest number of correlations include arsenic, lead, nickel, copper, molybdenum, selenium, zinc, temperature, suspended solids, dissolved oxygen, hardness (calcium and magnesium), and conductivity.

Additional review of the data will be done during the next few monitoring periods to better characterize the types of correlations observed. For example, there is a strong negative correlation between arsenic and dissolved oxygen, and a strong positive correlation with

hardness at the Rail Crossing site, that is, as dissolved oxygen decreases and water hardness increases, the arsenic concentration increases.

A review the correlation analysis data is planned to assess whether a distillate of indicator analytes can be used as a broad indicator of BMP effectiveness, particularly in stormwater drainage basins where storm event sampling is being done, and within basins defined by ambient monitoring sites. Correlation analysis of the stormwater data is planned as additional storm event data is acquired, thereby providing a more robust data set upon which to perform the analysis and improving the predictive capabilities of models.



4.4.5. Data Management, Documentation and Record-Keeping

Laboratory analysis performed at the Eugene/Springfield Water Pollution Control Facility is performed under an Environmental Management System (EMS) for which the facility has earned certification under the International Organization for Standardization (ISO). Organizations that earn ISO certification under the 14001:2004(E) standard commit to develop an environmental policy, establish objectives and processes to achieve policy commitments, take action as needed to improve its performance and demonstrate the conformity of the system to the requirements of the ISO standard. ISO 14001 elements include establishing, implementing and maintaining procedures applicable to legal requirements, documentation and records determined to be necessary to ensure effective planning, operation and control of processes, control of records and documents, evaluation of legal compliance, defining roles, responsibilities and authority of staff, competence and training requirements, and management review. In addition, the E/S WPCF's EMS is audited by internal and external auditors on a frequent basis to ensure conformance and compliance to the policies and objectives established by and applicable to the E/S WPCF.

As such, all sampling and analysis of stormwater, stream, and MS4 samples performed by staff at the E/S WPCF falls under the umbrella of the EMS program. Documents and records associated with stormwater monitoring elements are readily available through the E/S WPCF electronic document control system, including the facility's QAP and all SOPs associated with sample collection, handling, analysis, and reporting. All laboratory and field measurements collected to meet the stormwater NPDES monitoring requirements is controlled through the E/S WPCF's Laboratory Information Management System (LIMS), which has strict controlled data entry requirements and access restrictions.

The Stormwater Monitoring Plan documents the sampling and analysis protocol followed the requirements specified in Schedule B of the city's NPDES MS4 discharge permit. At this time no substantive revisions have been made to the SMP. Any modifications to the SMP will be documented under revision history at the end of the document. Revision 1.0 is the latest and current plan version and is available to the public at any time via the City of Eugene's Stormwater Program internet web site.

All water quality data collected during this monitoring period as well as historical data, are also posted to the City's Stormwater Program internet web site at http://www.eugene-or.gov/index.aspx?nid=476 .

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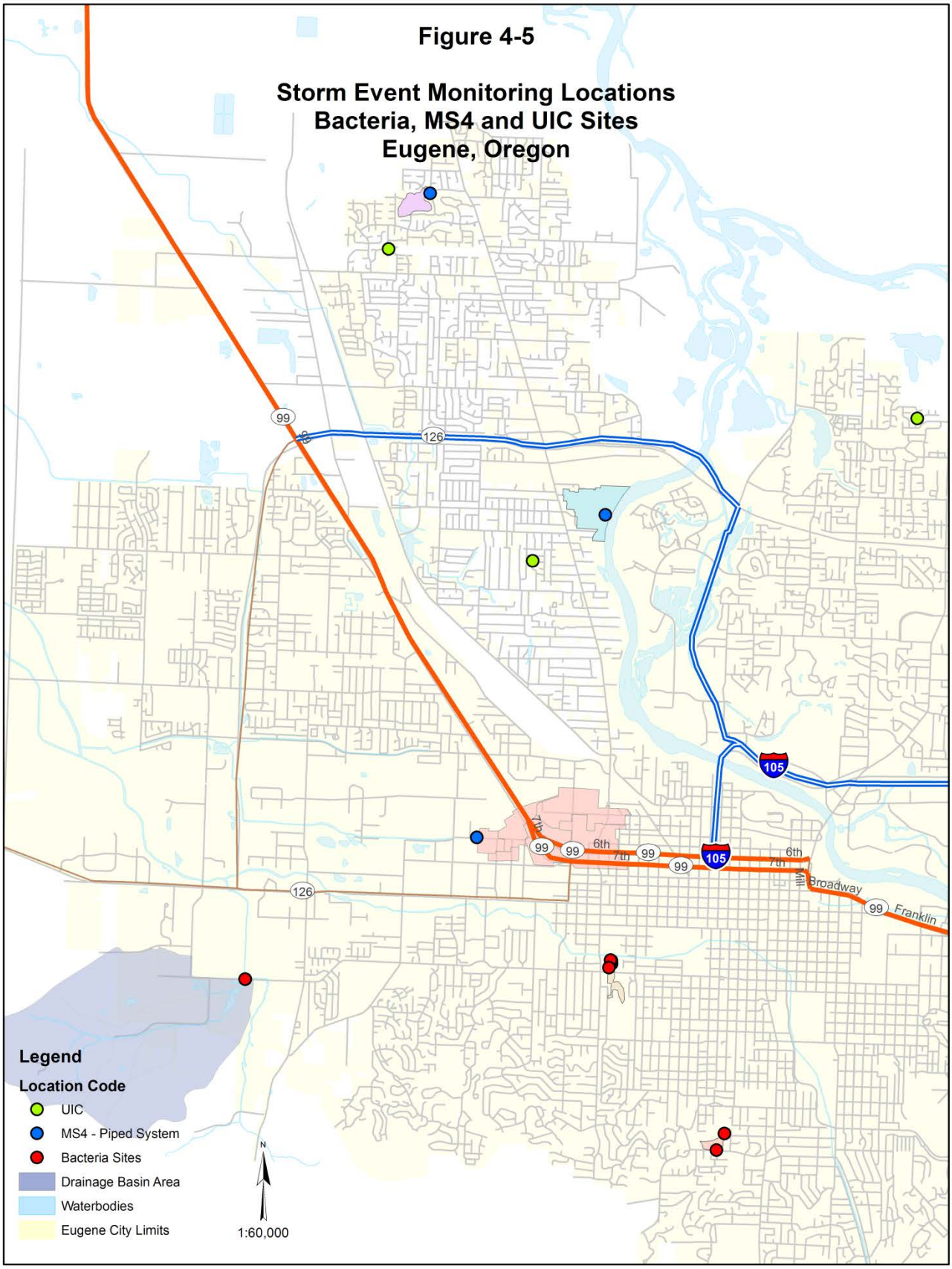
Figure 4-5
Storm Event Monitoring Locations
Bacteria, MS4 and UIC Sites
Eugene, Oregon
99
126
105
6th
7th
Broadway
Franklin
Legend
Location Code
UIC
MS4 - Piped System
Bacteria Sites
Drainage Basin Area
Waterbodies
Eugene City Limits
N
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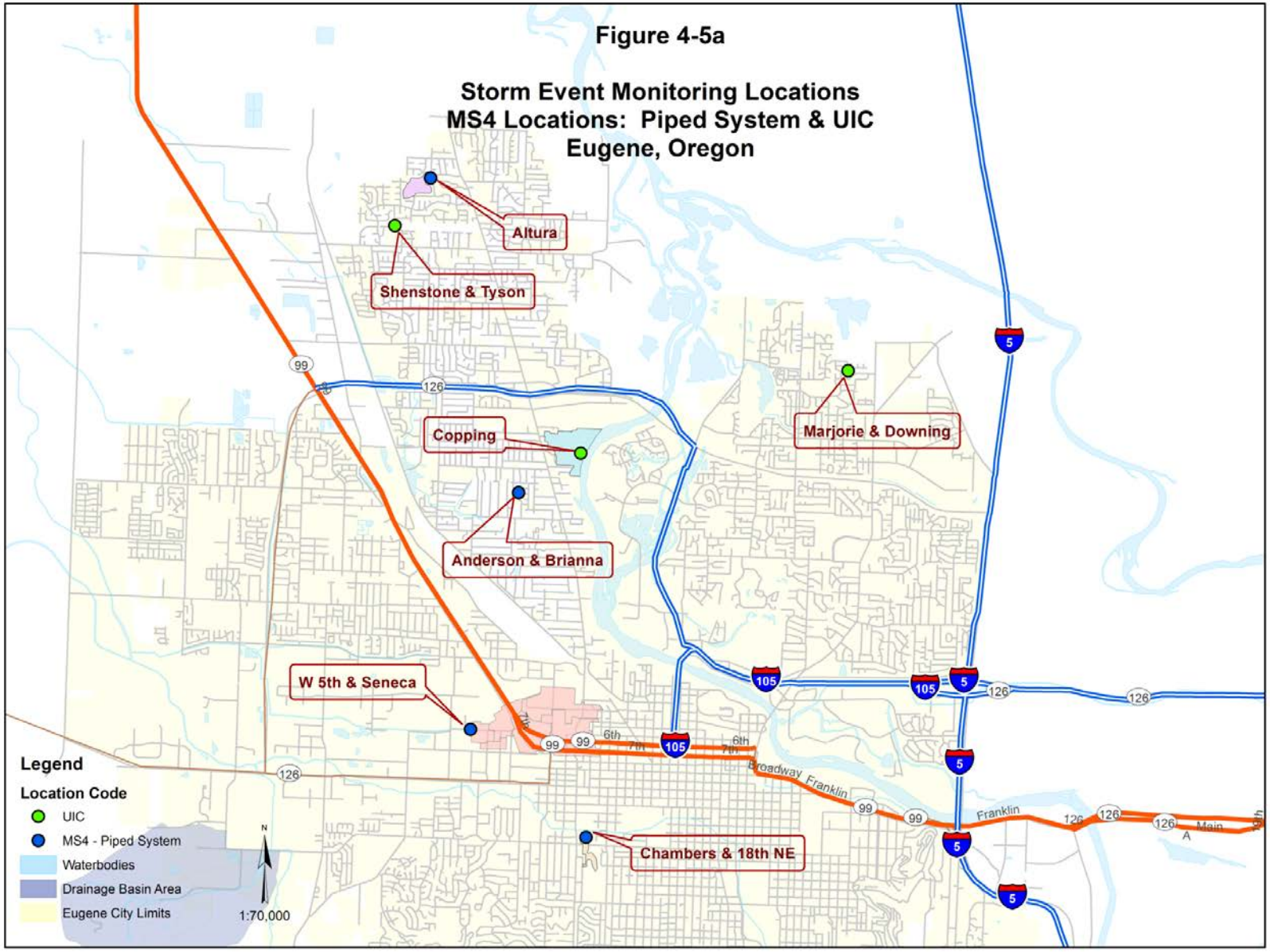
Figure 4-5a
Storm Event Monitoring Locations
MS4 Locations: Piped System & UIC
Eugene, Oregon
Altura
Shenstone & Tyson
Copping
Marjorie & Downing
Anderson & Brianna
W 5th & Seneca
Chambers & 18th NE
Legend
Location Code
UIC
MS4 - Piped System
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000
N
99
126
105
5
6th
7th
Broadway
Franklin
Main
A

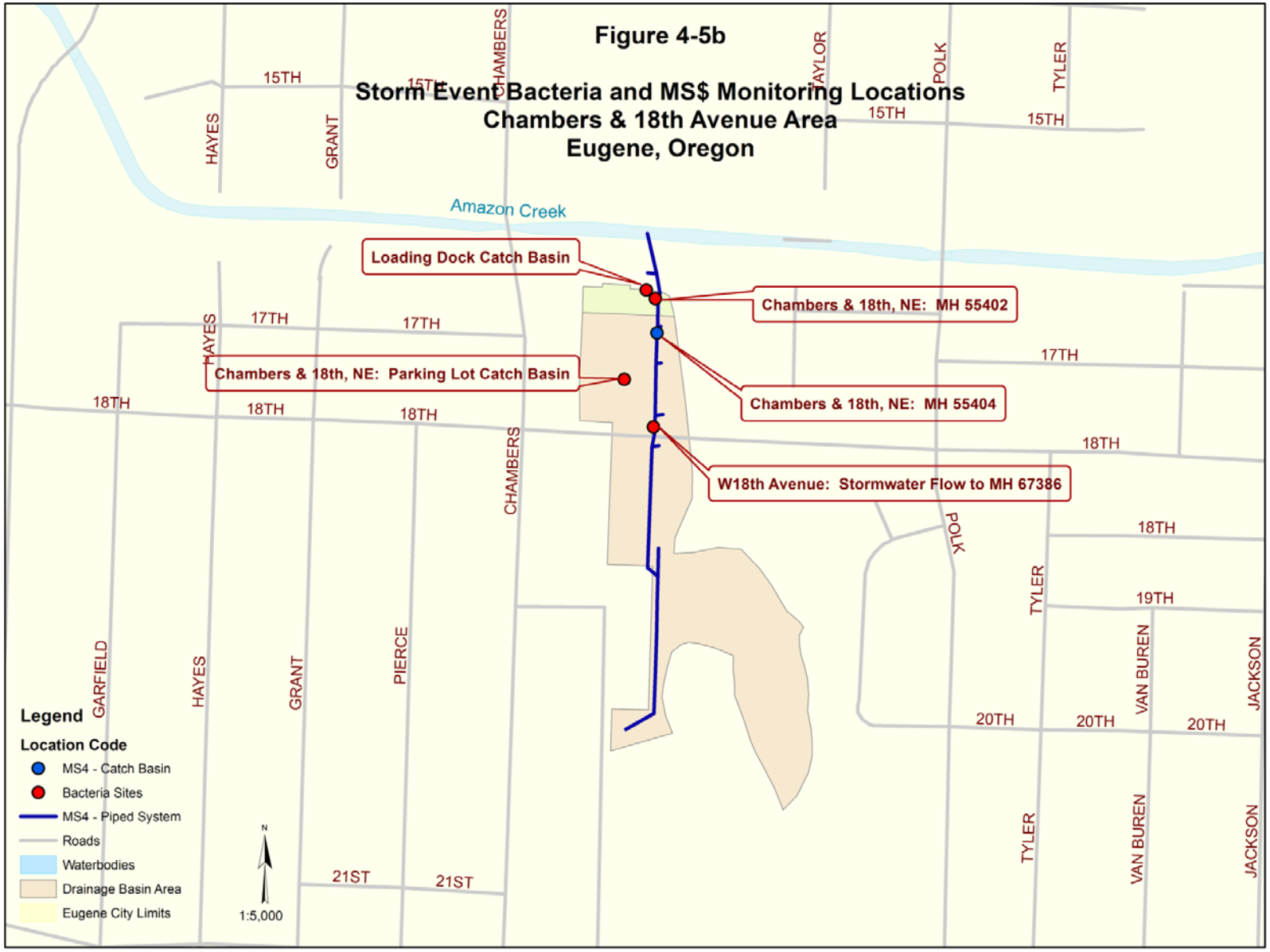
Figure 4-5b
Storm Event Bacteria and MS$ Monitoring Locations
Chambers & 18th Avenue Area
Eugene, Oregon
Amazon Creek
Loading Dock Catch Basin
Chambers & 18th, NE: MH 55402
Chambers & 18th, NE: Parking Lot Catch Basin
Chambers & 18th, NE: MH 55404
W18th Avenue: Stormwater Flow to MH 67386
15TH
17TH
18TH
19TH
20TH
21ST
HAYES
GRANT
CHAMBERS
TAYLOR
POLK
TYLER
GARFIELD
PIERCE
VAN BUREN
JACKSON
Legend
Location Code
MS4 - Catch Basin
Bacteria Sites
MS4 - Piped System
Roads
Waterbodies
Drainage Basin Area
Eugene City Limits
N
1:5,000

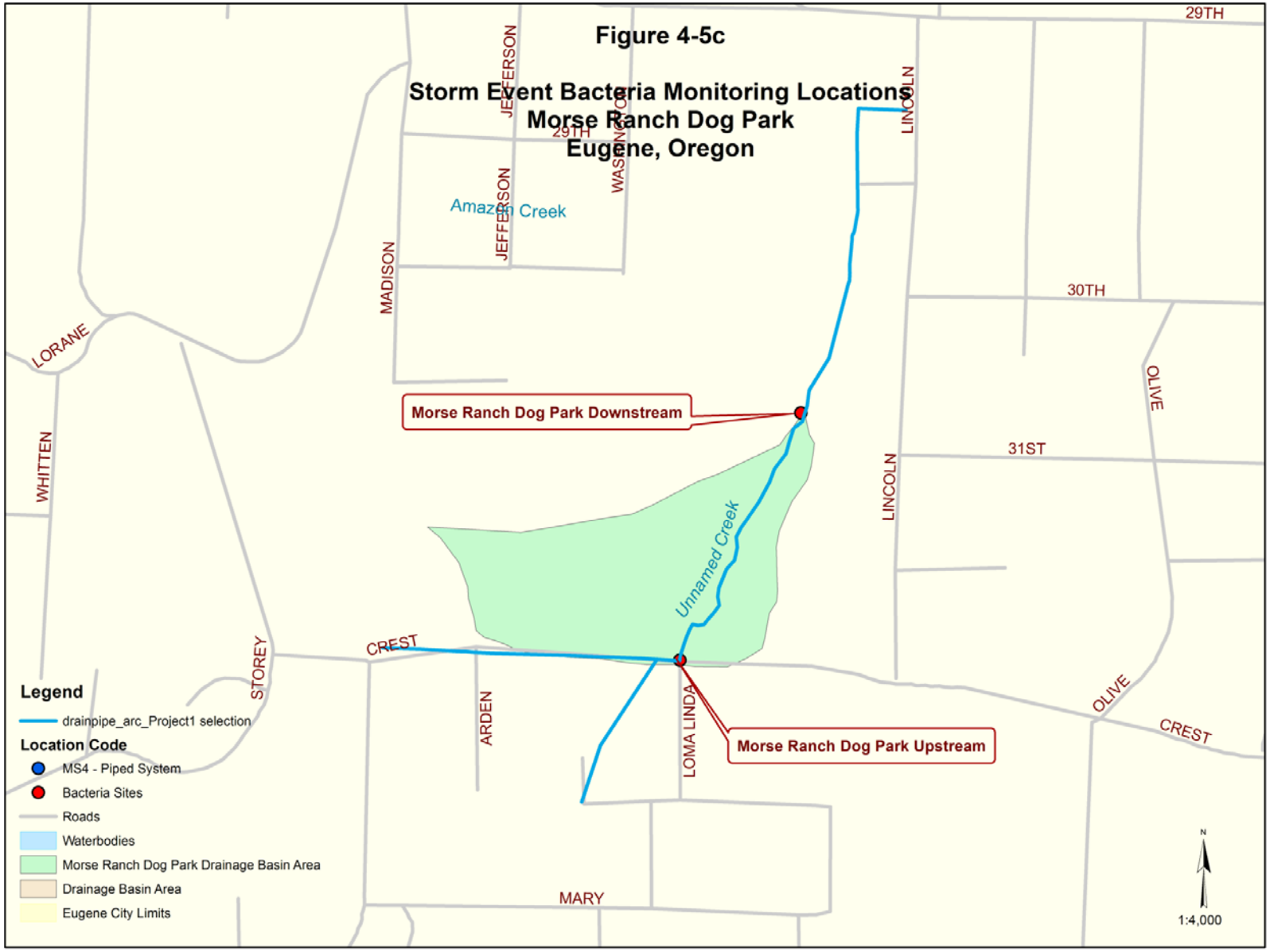
Figure 4-5c
Storm Event Bacteria Monitoring Locations
Morse Ranch Dog Park
Eugene, Oregon
29TH
JEFFERSON
WASHINGTON
LINCOLN
Amazon Creek
MADISON
30TH
LORANE
OLIVE
Morse Ranch Dog Park Downstream
WHITTEN
31ST
Unnamed Creek
CREST
STOREY
ARDEN
LOMA LINDA
Morse Ranch Dog Park Upstream
MARY
Legend
drainpipe_arc_Project1 selection
Location Code
MS4 - Piped System
Bacteria Sites
Roads
Waterbodies
Morse Ranch Dog Park Drainage Basin Area
Drainage Basin Area
Eugene City Limits
N
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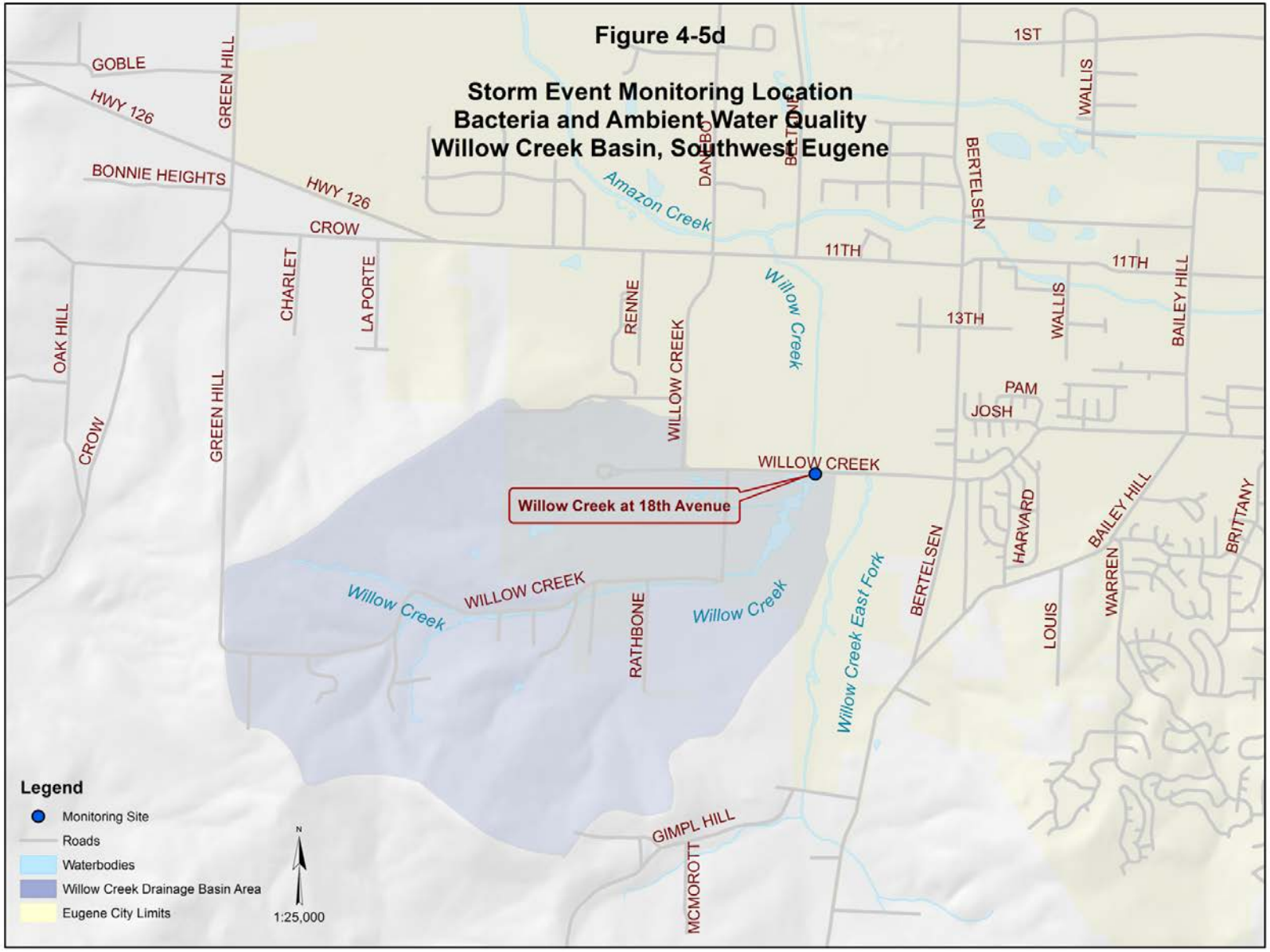
Figure 4-5d
Storm Event Monitoring Location
Bacteria and Ambient Water Quality
Willow Creek Basin, Southwest Eugene
GOBLE
HWY 126
GREEN HILL
BONNIE HEIGHTS
HWY 126
CROW
Amazon Creek
DANBO
BETTNE
1ST
WALLIS
BERTELSEN
11TH
11TH
13TH
WALLIS
BAILEY HILL
CHARLET
LA PORTE
RENNE
WILLOW CREEK
Willow Creek
OAK HILL
CROW
GREEN HILL
PAM
JOSH
WILLOW CREEK
Willow Creek at 18th Avenue
HARVARD
BAILEY HILL
BRITTANY
BERTELSEN
Willow Creek
WILLOW CREEK
Willow Creek
RATHBONE
Willow Creek East Fork
LOUIS
WARREN
GIMPL HILL
MCMOROTT
Legend
Monitoring Site
Roads
Waterbodies
Willow Creek Drainage Basin Area
Eugene City Limits
N
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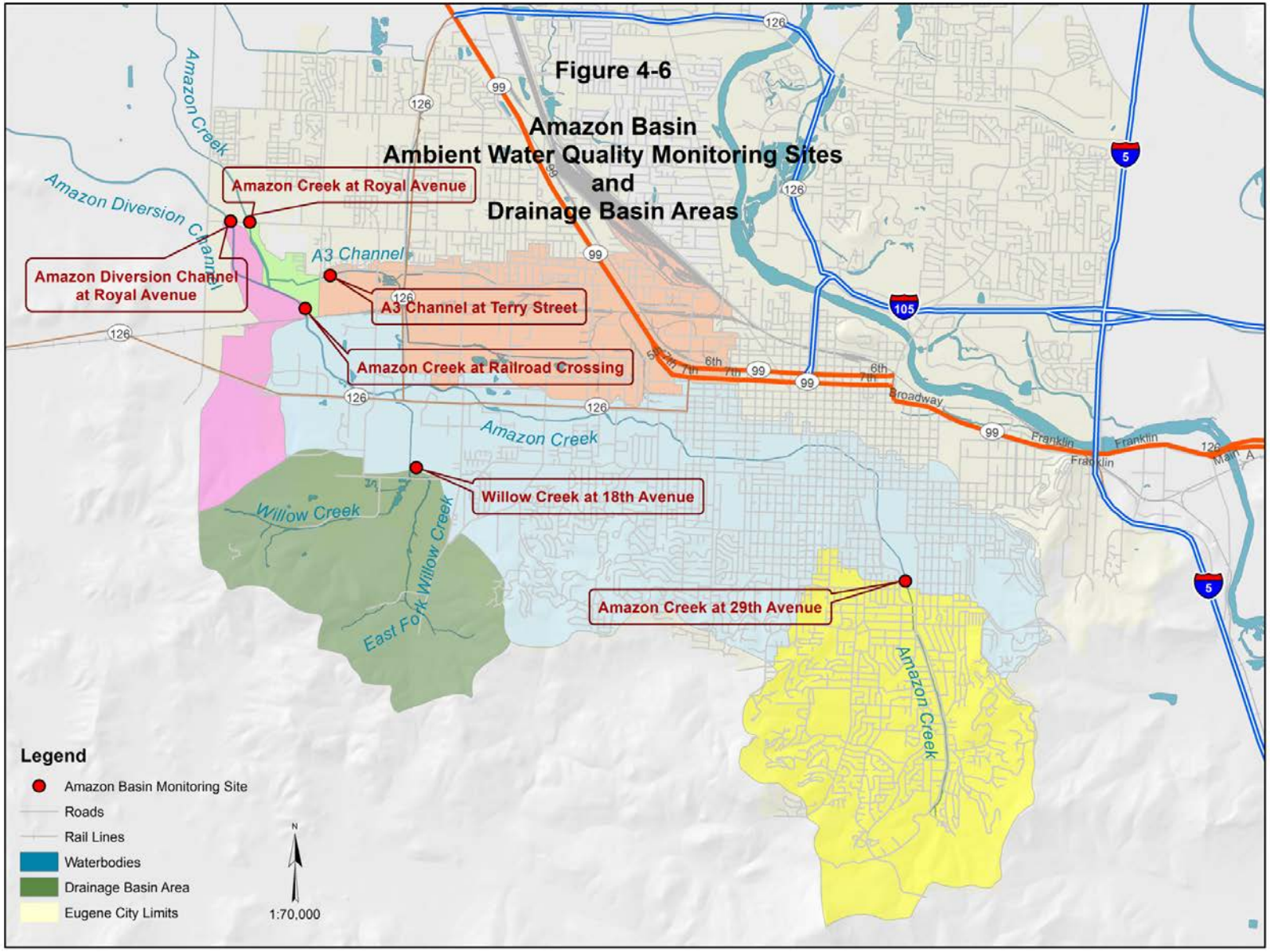
Figure 4-6
Amazon Basin
Ambient Water Quality Monitoring Sites
and
Drainage Basin Areas
Amazon Creek at Royal Avenue
Amazon Diversion Channel at Royal Avenue
A3 Channel at Terry Street
Amazon Creek at Railroad Crossing
Willow Creek at 18th Avenue
Amazon Creek at 29th Avenue
Amazon Creek
Amazon Diversion Channel
A3 Channel
Willow Creek
East Fork Willow Creek
Broadway
Franklin
Legend
Amazon Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
N
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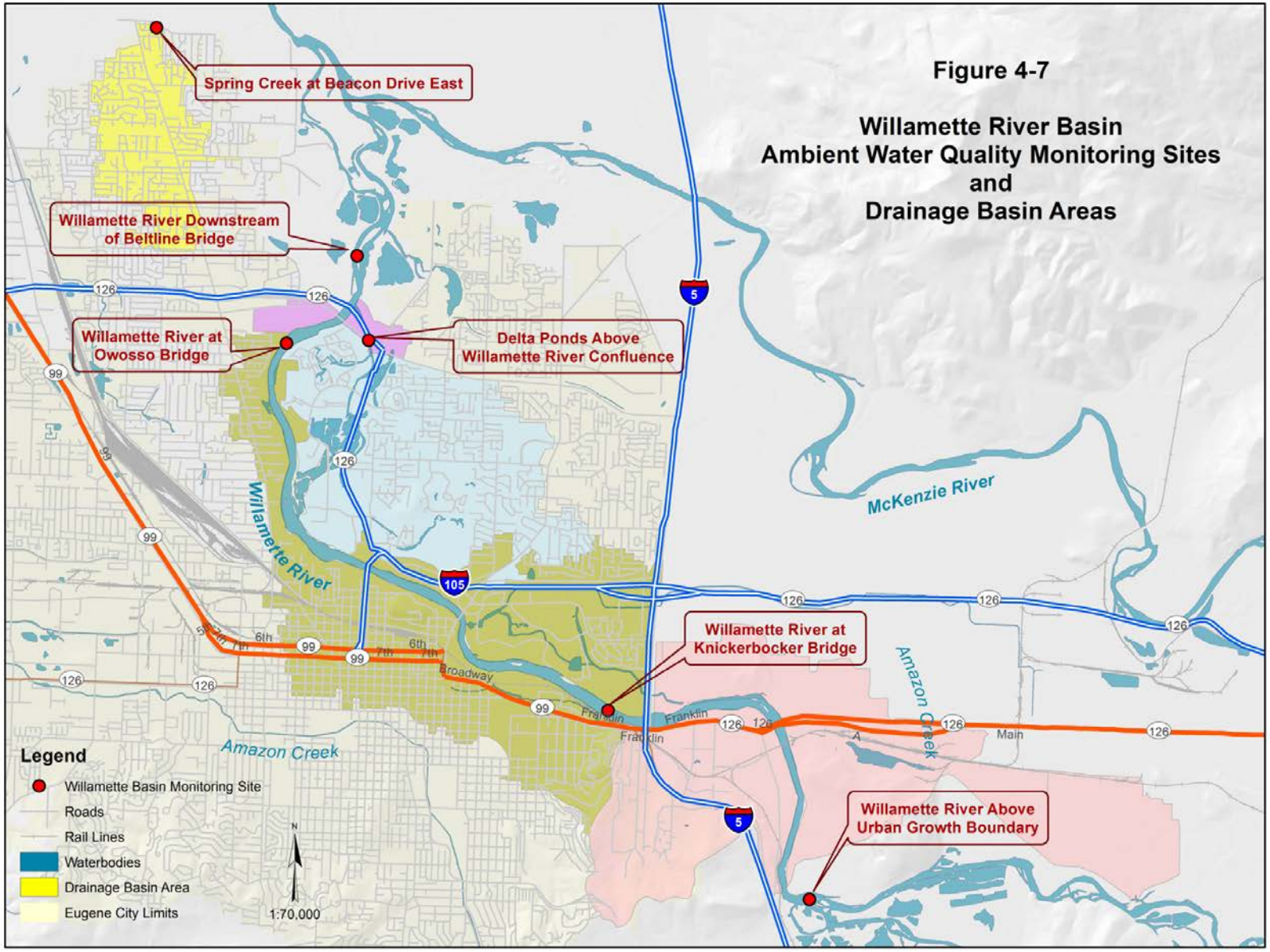


Figure 4-7
Willamette River Basin
Ambient Water Quality Monitoring Sites
and
Drainage Basin Areas
Spring Creek at Beacon Drive East
Willamette River Downstream of Beltline Bridge
Willamette River at Owosso Bridge
Delta Ponds Above Willamette River Confluence
Willamette River at Knickerbocker Bridge
Willamette River Above Urban Growth Boundary
McKenzie River
Willamette River
Amazon Creek
Legend
Willamette Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000

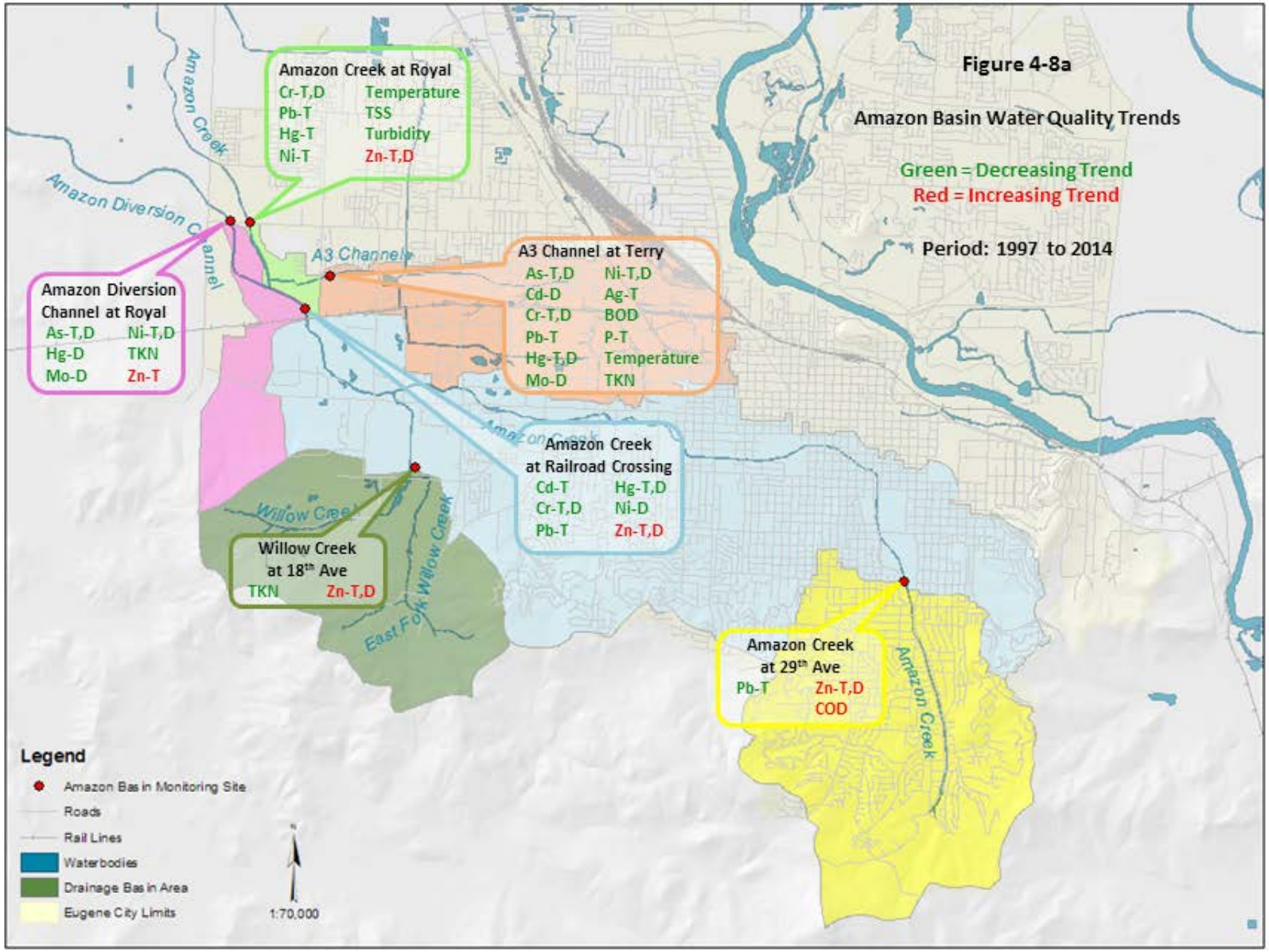


Figure 4-8a
Amazon Basin Water Quality Trends
Green = Decreasing Trend
Red = Increasing Trend
Period: 1997 to 2014
Amazon Creek at Royal
Cr-T,D Temperature
Pb-T TSS
Hg-T Turbidity
Ni-T Zn-T,D
Amazon Diversion Channel at Royal
As-T,D Ni-T,D
Hg-D TKN
Mo-D Zn-T
A3 Channel at Terry
As-T,D Ni-T,D
Cd-D Ag-T
Cr-T,D BOD
Pb-T P-T
Hg-T,D Temperature
Mo-D TKN
Amazon Creek at Railroad Crossing
Cd-T Hg-T,D
Cr-T,D Ni-D
Pb-T Zn-T,D
Willow Creek at 18th Ave
TKN Zn-T,D
Amazon Creek at 29th Ave
Pb-T Zn-T,D
COD
Amazon Creek
Amazon Diversion Channel
A3 Channel
Willow Creek
East Fork Willow Creek
Legend
Amazon Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000

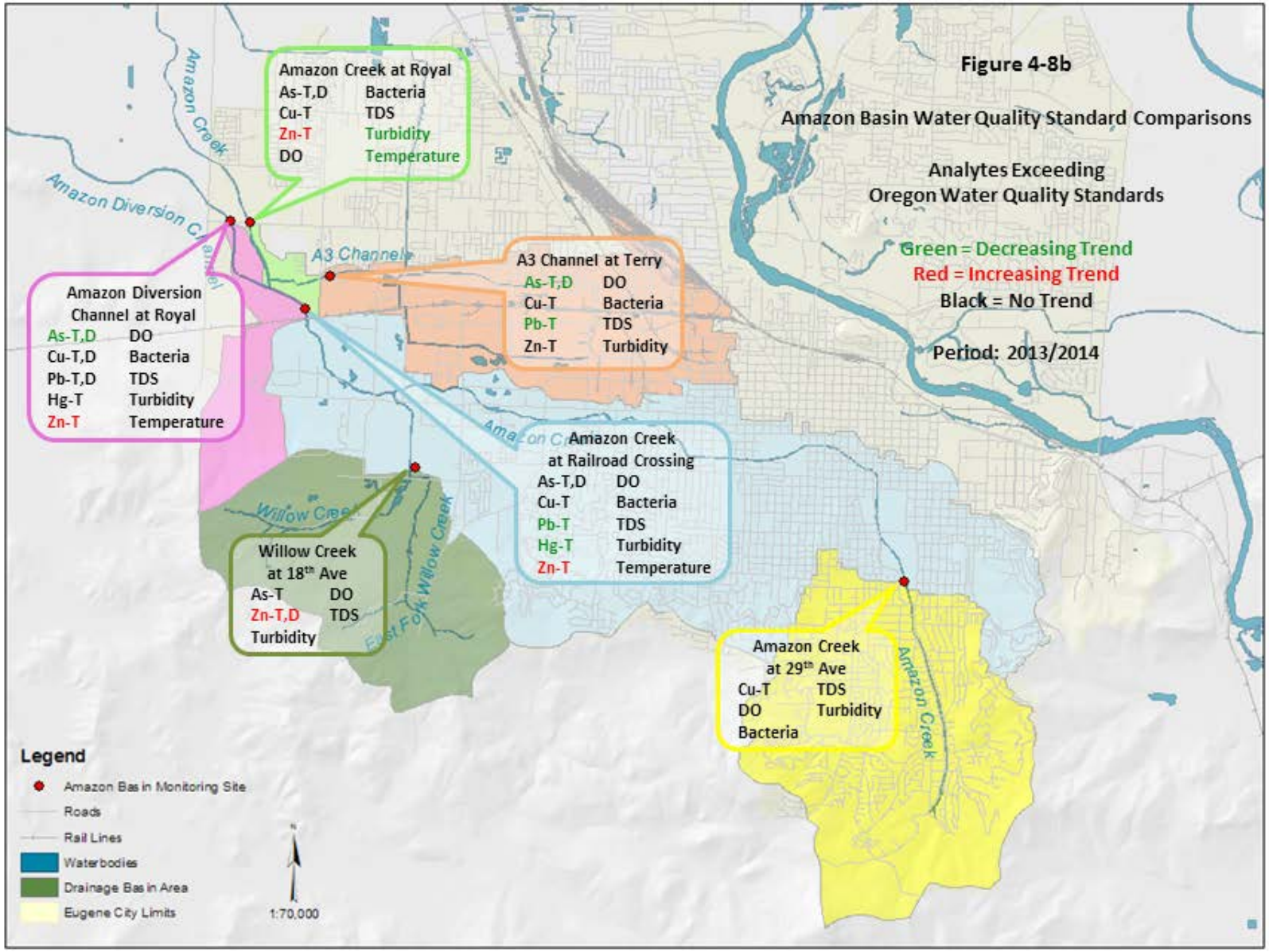


Figure 4-8b
Amazon Basin Water Quality Standard Comparisons
Analytes Exceeding
Oregon Water Quality Standards
Green = Decreasing Trend
Red = Increasing Trend
Black = No Trend
Period: 2013/2014
Amazon Creek at Royal
As-T,D Bacteria
Cu-T TDS
Zn-T Turbidity
DO Temperature
Amazon Diversion Channel at Royal
As-T,D DO
Cu-T,D Bacteria
Pb-T,D TDS
Hg-T Turbidity
Zn-T Temperature
A3 Channel at Terry
As-T,D DO
Cu-T Bacteria
Pb-T TDS
Zn-T Turbidity
Amazon Creek at Railroad Crossing
As-T,D DO
Cu-T Bacteria
Pb-T TDS
Hg-T Turbidity
Zn-T Temperature
Willow Creek at 18th Ave
As-T DO
Zn-T,D TDS
Turbidity
Amazon Creek at 29th Ave
Cu-T TDS
DO Turbidity
Bacteria
Amazon Creek
Amazon Diversion Channel
A3 Channel
Willow Creek
East Fork Willow Creek
Legend
Amazon Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000

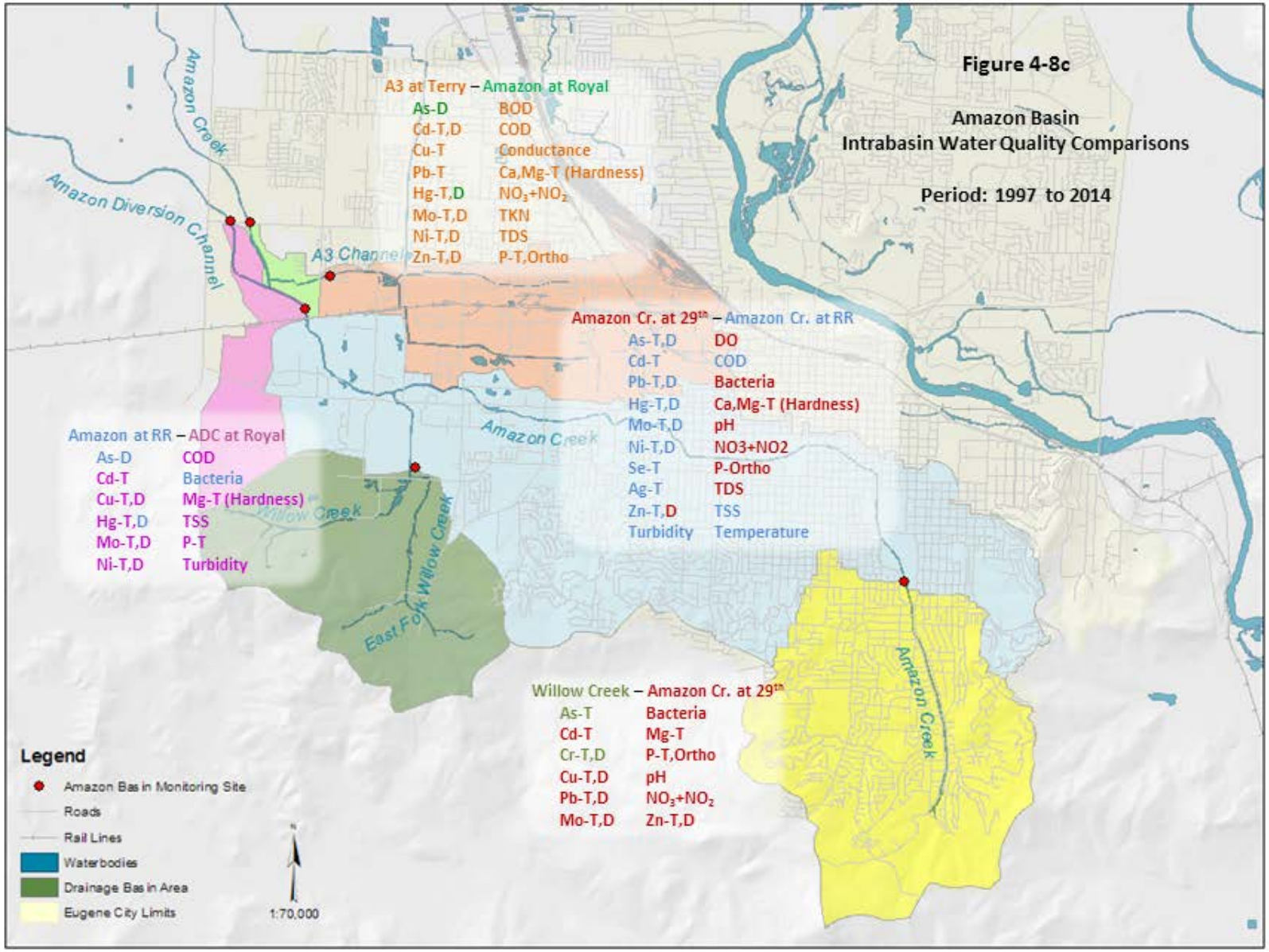


Figure 4-8c
Amazon Basin
Intrabasin Water Quality Comparisons
Period: 1997 to 2014
A3 at Terry – Amazon at Royal
As-D
Cd-T,D
Cu-T
Pb-T
Hg-T,D
Mo-T,D
Ni-T,D
Zn-T,D
BOD
COD
Conductance
Ca,Mg-T (Hardness)
NO3+NO2
TKN
TDS
P-T,Ortho
Amazon Cr. at 29th – Amazon Cr. at RR
As-T,D
Cd-T
Pb-T,D
Hg-T,D
Mo-T,D
Ni-T,D
Se-T
Ag-T
Zn-T,D
Turbidity
DO
COD
Bacteria
Ca,Mg-T (Hardness)
pH
NO3+NO2
P-Ortho
TDS
TSS
Temperature
Amazon at RR – ADC at Royal
As-D
Cd-T
Cu-T,D
Hg-T,D
Mo-T,D
Ni-T,D
COD
Bacteria
Mg-T (Hardness)
TSS
P-T
Turbidity
Willow Creek – Amazon Cr. at 29th
As-T
Cd-T
Cr-T,D
Cu-T,D
Pb-T,D
Mo-T,D
Bacteria
Mg-T
P-T,Ortho
pH
NO3+NO2
Zn-T,D
Amazon Creek
Amazon Diversion Channel
A3 Channel
Amazon Creek
Willow Creek
East Fork Willow Creek
Amazon Creek
Legend
Amazon Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000

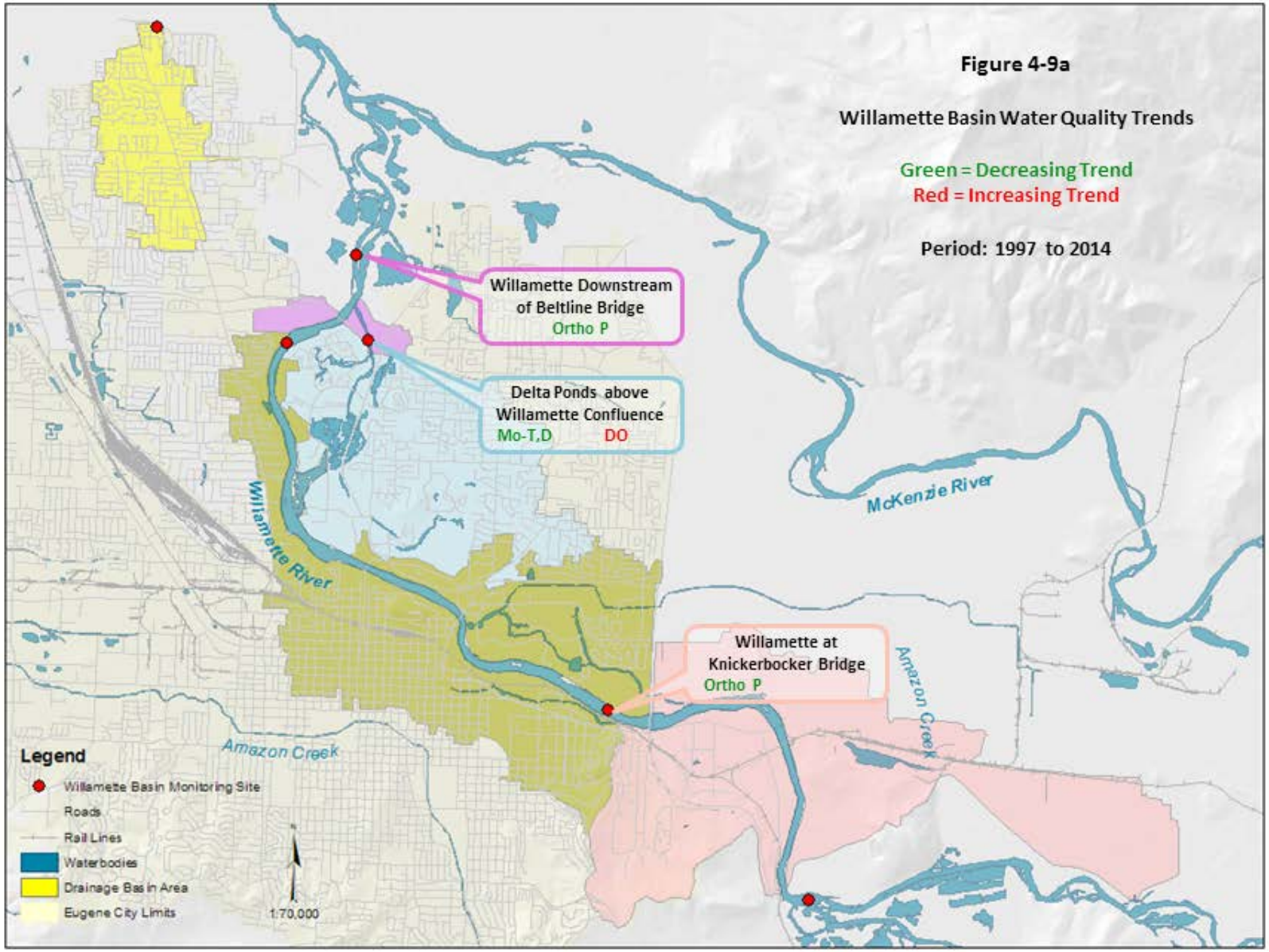


Figure 4-9a
Willamette Basin Water Quality Trends
Green = Decreasing Trend
Red = Increasing Trend
Period: 1997 to 2014
Willamette Downstream of Beltline Bridge
Ortho P
Delta Ponds above Willamette Confluence
Mo-T,D
DO
Willamette at Knickerbocker Bridge
Ortho P
Willamette River
McKenzie River
Amazon Creek
Amazon Creek
Legend
Willamette Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000

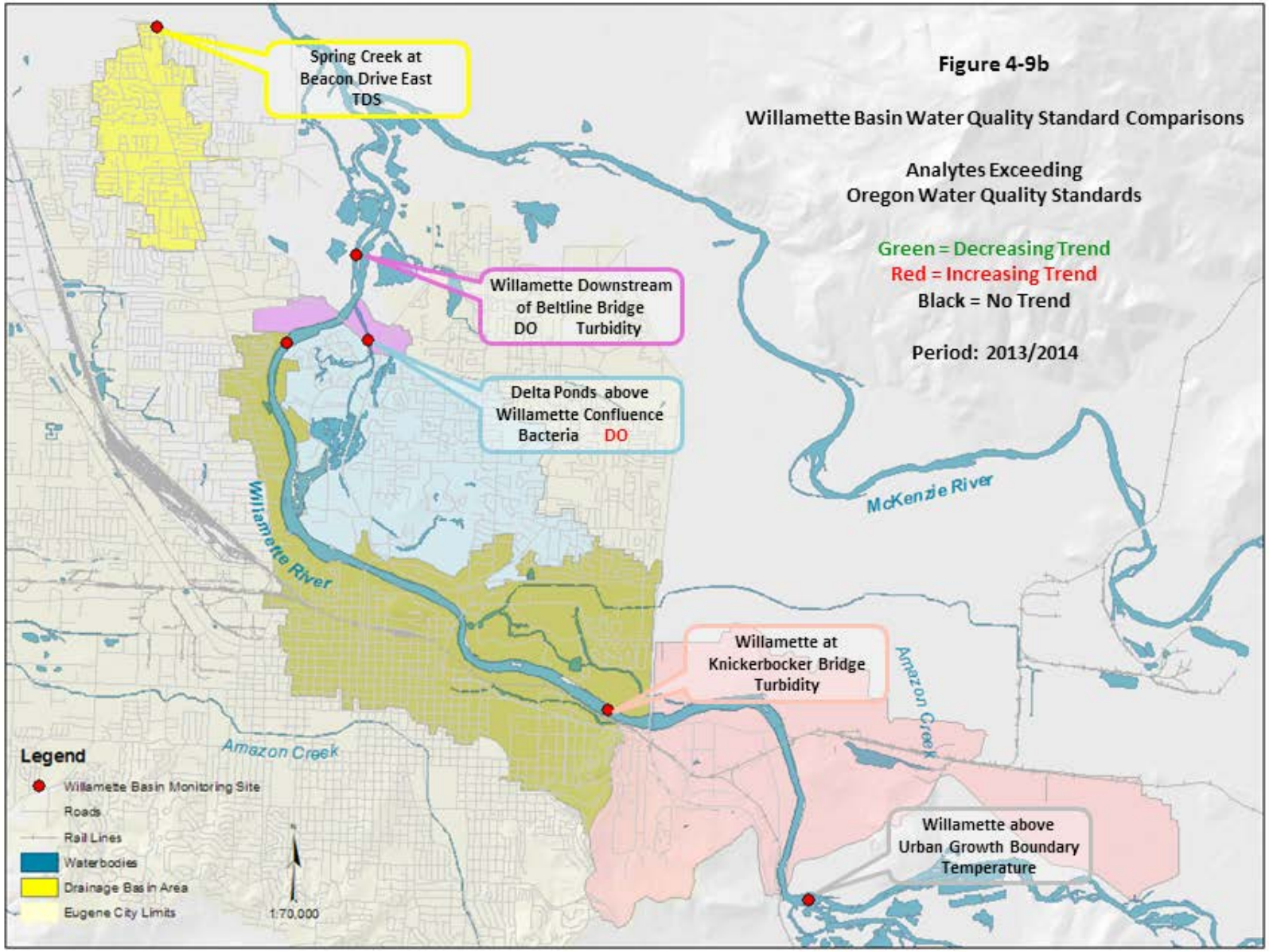


Figure 4-9b
Willamette Basin Water Quality Standard Comparisons
Analytes Exceeding
Oregon Water Quality Standards
Green = Decreasing Trend
Red = Increasing Trend
Black = No Trend
Period: 2013/2014
Spring Creek at
Beacon Drive East
TDS
Willamette Downstream
of Beltline Bridge
DO Turbidity
Delta Ponds above
Willamette Confluence
Bacteria DO
Willamette at
Knickerbocker Bridge
Turbidity
Willamette above
Urban Growth Boundary
Temperature
Willamette River
McKenzie River
Amazon Creek
Amazon Creek
Legend
Willamette Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000

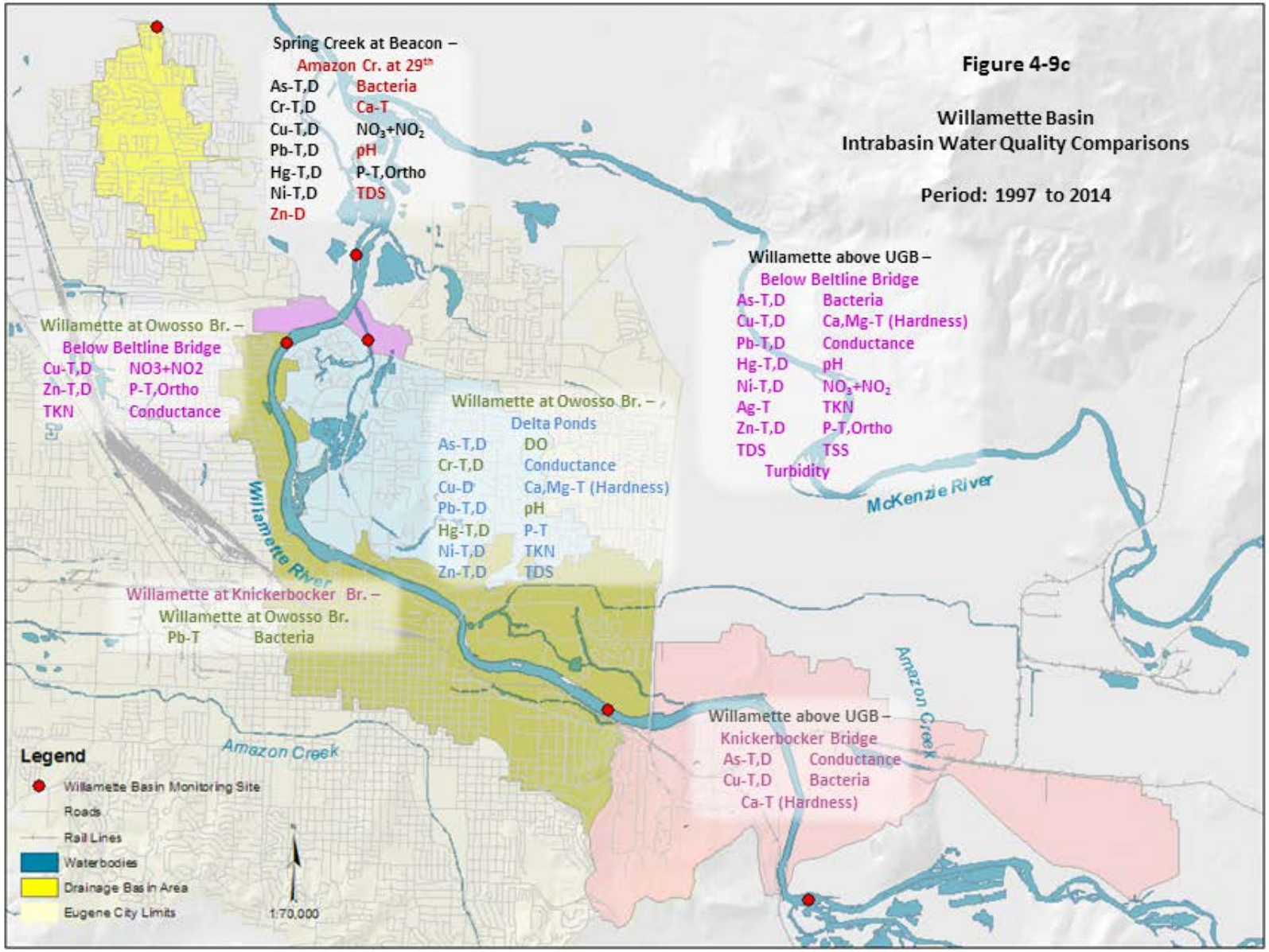


Figure 4-9c
Willamette Basin
Intrabasin Water Quality Comparisons
Period: 1997 to 2014
Spring Creek at Beacon –
Amazon Cr. at 29th
As-T,D Bacteria
Cr-T,D Ca-T
Cu-T,D NO3+NO2
Pb-T,D pH
Hg-T,D P-T,Ortho
Ni-T,D TDS
Zn-D
Willamette above UGB –
Below Beltline Bridge
As-T,D Bacteria
Cu-T,D Ca,Mg-T (Hardness)
Pb-T,D Conductance
Hg-T,D pH
Ni-T,D NO3+NO2
Ag-T TKN
Zn-T,D P-T,Ortho
TDS TSS
Turbidity
Willamette at Owosso Br. –
Below Beltline Bridge
Cu-T,D NO3+NO2
Zn-T,D P-T,Ortho
TKN Conductance
Willamette at Owosso Br. –
Delta Ponds
As-T,D DO
Cr-T,D Conductance
Cu-D Ca,Mg-T (Hardness)
Pb-T,D pH
Hg-T,D P-T
Ni-T,D TKN
Zn-T,D TDS
Willamette River
McKenzie River
Willamette at Knickerbocker Br. –
Willamette at Owosso Br.
Pb-T Bacteria
Amazon Creek
Willamette above UGB –
Knickerbocker Bridge
As-T,D Conductance
Cu-T,D Bacteria
Ca-T (Hardness)
Legend
Willamette Basin Monitoring Site
Roads
Rail Lines
Waterbodies
Drainage Basin Area
Eugene City Limits
1:70,000

ATTACHMENT A

Storm Event Monitoring Data
Descriptive Statistics

Table A.1

Waterbody: Willow Creek
System Type: Surface Water
System Location: (MH 76010)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
Willow Creek at W 18th Ave	Dissolved Oxygen	1	10.300		10.300	10.300	10.300	NA	mg/L	21
	Escherichia coli	1	160.000		160.000	160.000	160.000	1	per 100 mL	315
	Fecal Coliform	1	60.000		60.000	60.000	60.000	1	per 100 mL	130
	pH Field	1	6.700		6.700	6.700	6.700	NA	pH Units	-5
	Silica Gel Treated Hexane Ext. Material	1	5.000		5.000	5.000	5.000	5	mg/L	0
	Temperature	1	11.100		11.100	11.100	11.100	NA	˚C	40

Storm Event Monitoring Data
Descriptive Statistics

Table A.2

Receiving Waterbody: Amazon Creek
System Type: Piped
System Location: (MH 55402/55404)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
Chambers & 18th, NE: MH 55404/55402	1,1-Dichloroethene	4	0.157	2.474	0.060	0.039	5.000	5	µg/L	-97
	Ammonia - N	3	0.100	0.000	0.100	0.100	0.100	0.1	mg/L	-14
	Arsenic, Dissolved	3	1.563	0.822	1.350	1.080	2.620	0.0178	µg/L	97
	Arsenic, Total	3	2.074	0.763	2.580	1.300	2.660	0.0222	µg/L	59
	Biochemical Oxygen Demand	3	3.915	2.082	5.000	2.000	6.000	2	mg/L	-16
	Cadmium, Dissolved	3	0.063	0.029	0.078	0.035	0.090	0.0142	µg/L	89
	Cadmium, Total	3	0.125	0.054	0.127	0.081	0.189	0.0115	µg/L	35
	Calcium, Total	3	11.955	3.559	12.000	8.900	16.000	1	mg/L	119
	Chemical Oxygen Demand	3	53.639	33.045	43.000	37.000	97.000	5	mg/L	43
	Chromium, Dissolved	3	2.033	1.705	1.870	1.040	4.320	0.0437	µg/L	187
	Chromium, Total	3	6.213	3.697	6.770	3.310	10.700	0.017	µg/L	146
	Conductivity, @ 25 degrees C	3	72.366	21.733	66.000	58.000	99.000	5	µmhos/cm	60
	Copper, Dissolved	3	4.544	0.913	4.460	3.770	5.580	0.0115	µg/L	8
	Copper, Total	3	13.292	5.758	11.400	10.000	20.600	0.0144	µg/L	46
	Dissolved Oxygen	9	8.881	2.755	10.400	5.500	13.300	NA	mg/L	-1
	Escherichia coli	9	1318.032	1142.721	1400.000	230.000	3200.000	1	per 100 mL	-12
	Fecal Coliform	9	2064.447	3004.903	1700.000	400.000	10000.000	1	per 100 mL	96
	Hardness	3	38.653	9.292	35.000	33.000	50.000	5	mg eq CaCO3/L	133
	Lead, Dissolved	3	0.242	0.213	0.179	0.149	0.532	0.0051	µg/L	82
	Lead, Total	3	7.137	9.580	5.280	3.310	20.800	0.0061	µg/L	58
	Magnesium, Total	3	1.983	0.666	2.400	1.300	2.500	0.5	mg/L	62
	Mercury, Dissolved	7	0.003	0.002	0.003	0.001	0.006	0.00006	µg/L	43
	Mercury, Total	7	0.007	0.003	0.007	0.005	0.012	0.00006	µg/L	29
	Methyl Mercury, Dissolved	3	0.105	0.019	0.106	0.087	0.126	0.0249	ng/L	36
	Methyl Mercury, Total	3	0.192	0.083	0.161	0.147	0.298	0.0249	ng/L	35
	Molybdenum, Dissolved	3	2.835	8.548	1.260	1.130	16.000	0.0105	µg/L	280
	Molybdenum, Total	3	3.291	8.299	1.900	1.180	15.900	0.0337	µg/L	254
	Nickel, Dissolved	3	1.504	0.984	1.330	0.916	2.790	0.0134	µg/L	73
	Nickel, Total	3	3.428	2.216	3.560	1.820	6.220	0.0227	µg/L	54
	Nitrate + Nitrite - N	3	0.178	0.050	0.190	0.130	0.230	0.05	mg/L	5
	pH Field	9	6.885	0.347	6.800	6.500	7.570	NA	pH Units	-2
	Phosphorus, Ortho	3	0.036	0.032	0.030	0.020	0.080	0.01	mg/L	2
	Phosphorus, Total	3	0.189	0.017	0.200	0.170	0.200	0.01	mg/L	28
	Selenium, Dissolved	3	0.084	0.053	0.095	0.042	0.148	0.0416	µg/L	69
	Selenium, Total	3	0.083	0.026	0.082	0.061	0.113	0.0416	µg/L	16
	Silica Gel Treated Hexane Ext. Material	3	5.192	0.346	5.000	5.000	5.600		mg/L	4
	Silver, Dissolved	3	0.007	0.002	0.006	0.006	0.009	5	µg/L	-74
	Silver, Total	3	0.027	0.015	0.023	0.019	0.046	0.0059	µg/L	-23
	Temperature	9	11.288	3.737	11.900	7.300	17.400	0.0113	˚C	8
	Tetrachloroethene	4	0.079	0.045	0.095	0.032	0.140	NA	µg/L	-97
	Total Dissolved Solids	3	53.495	9.000	54.000	45.000	63.000	0.099	mg/L	64
	Total Kjeldahl Nitrogen	3	0.838	0.436	0.700	0.600	1.400	10	mg/L	62
	Total Suspended Solids	3	61.446	126.737	32.000	29.000	250.000	0.2	mg/L	130
	trans-1,2-Dichloroethene	3	0.042	0.023	0.032	0.032	0.072	1	µg/L	-99
	Trichloroethene	4	0.176	2.469	0.072	0.044	5.000	0.032	µg/L	-93
	Turbidity	3	52.183	62.426	35.000	29.000	140.000	0.1	NTU	124
	Zinc, Dissolved	3	32.473	18.939	34.600	17.800	55.600	1	µg/L	105
	Zinc, Total	3	72.592	35.600	78.400	42.800	114.000	0.0287	µg/L	60

Storm Event Monitoring Data
Descriptive Statistics

Table A.3

Receiving Waterbody:
Willamette River
System Type: Piped
System Location: (MH 77793)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
Copping St: MH 77793	2,3,7,8-TCDD *	1	5.00E-06		5.00E-06	5.00E-06	5.00E-06	5.00E-06	µg/L	-39
	Dissolved Oxygen	2	7.694	0.424	7.700	7.400	8.000	NA	mg/L	-16
	Escherichia coli	2	1250.600	551.543	1310.000	920.000	1700.000	1	per 100 mL	217
	Fecal Coliform	2	3633.180	2687.006	4100.000	2200.000	6000.000	1	per 100 mL	589
	pH Field	2	6.248	0.212	6.250	6.100	6.400	NA	pH Units	-7
	Silica Gel Treated Hexane Ext. Material	1	5.000		5.000	5.000	5.000	5	mg/L	-6
	Temperature	2	16.211	2.404	16.300	14.600	18.000	NA	˚C	40

Storm Event Monitoring Data
Descriptive Statistics

Table A.4

Receiving Waterbody:
Willamette River
System Type: Piped
System Location: (MH 99365)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
Altura St: MH 99365	2,3,7,8-TCDD	1	1.00E-06		1.00E-06	1.00E-06	1.00E-06	5.00E-06	µg/L	New Data
	Ammonia - N	1	0.100		0.100	0.100	0.100	NA	mg/L	New Data
	Arsenic, Dissolved	1	0.148		0.148	0.148	0.148	0.0178	µg/L	New Data
	Biochemical Oxygen Demand	1	2.000		2.000	2.000	2.000	2	mg/L	New Data
	Cadmium, Dissolved	1	0.031		0.031	0.031	0.031	0.0176	µg/L	New Data
	Calcium, Total	1	2.900		2.900	2.900	2.900	1	mg/L	New Data
	Chemical Oxygen Demand	1	14.000		14.000	14.000	14.000	5	mg/L	New Data
	Chromium, Dissolved	1	0.799		0.799	0.799	0.799	0.0437	µg/L	New Data
	Conductivity, @ 25 degrees C	1	16.000		16.000	16.000	16.000	5	µmhos/cm	New Data
	Copper, Dissolved	1	0.640		0.640	0.640	0.640	0.0115	µg/L	New Data
	Dissolved Oxygen	1	10.700		10.700	10.700	10.700	NA	mg/L	New Data
	Escherichia coli	1	130.000		130.000	130.000	130.000	1	per 100 mL	New Data
	Fecal Coliform	1	1400.000		1400.000	1400.000	1400.000	1	per 100 mL	New Data
	Hardness	1	5.000		5.000	5.000	5.000	5	mg eq CaCO3/L	New Data
	Lead, Dissolved	1	0.021		0.021	0.021	0.021	0.0051	µg/L	New Data
	Magnesium, Total	1	0.500		0.500	0.500	0.500	0.5	mg/L	New Data
	Mercury, Dissolved	1	0.001		0.001	0.001	0.001	0.00050	µg/L	New Data
	Molybdenum, Dissolved	1	1.500		1.500	1.500	1.500	0.0105	µg/L	New Data
	Nickel, Dissolved	1	0.572		0.572	0.572	0.572	0.0134	µg/L	New Data
	Nitrate + Nitrite - N	1	0.050		0.050	0.050	0.050	0.05	mg/L	New Data
	pH Field	1	6.700		6.700	6.700	6.700	NA	pH Units	New Data
	Phosphorus, Ortho	1	0.020		0.020	0.020	0.020	0.01	mg/L	New Data
	Phosphorus, Total	1	0.140		0.140	0.140	0.140	0.01	mg/L	New Data
	Selenium, Dissolved	1	0.061		0.061	0.061	0.061	0.0416	µg/L	New Data
	Silica Gel Treated Hexane Ext. Material	1	5.000		5.000	5.000	5.000	5	mg/L	New Data
	Silver, Dissolved	1	0.006		0.006	0.006	0.006	0.0059	µg/L	New Data
	Temperature	1	12.300		12.300	12.300	12.300	NA	˚C	New Data
	Total Dissolved Solids	1	13.000		13.000	13.000	13.000	10	mg/L	New Data
	Total Kjeldahl Nitrogen	1	0.700		0.700	0.700	0.700	0.2	mg/L	New Data
	Total Suspended Solids	1	22.000		22.000	22.000	22.000	1	mg/L	New Data
	Turbidity	1	11.000		11.000	11.000	11.000	1	NTU	New Data
	Zinc, Dissolved	1	137.000		137.000	137.000	137.000	0.0287	µg/L	New Data

Storm Event Monitoring Data
Descriptive Statistics

Table A.5

Receiving Waterbody: A3 Channel
System Type: Piped
System Location: (MH 63693)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
W 5th at Seneca: MH 63693	1,1-Dichloroethene	3	0.171	0.655	0.070	0.060	1.200	5	µg/L	-97
	Ammonia - N	2	0.100	0.000	0.100	0.100	0.100	0.1	mg/L	-15
	Arsenic, Dissolved	2	0.594	0.083	0.597	0.538	0.656	0.0178	µg/L	-18
	Arsenic, Total	2	1.709	0.728	1.785	1.270	2.300	0.0222	µg/L	6
	Biochemical Oxygen Demand	2	6.481	0.707	6.500	6.000	7.000	2	mg/L	9
	Cadmium, Dissolved	2	0.122	0.264	0.223	0.036	0.409	0.0142	µg/L	73
	Cadmium, Total	2	0.714	0.820	0.920	0.340	1.500	0.0115	µg/L	243
	Calcium, Total	2	6.961	1.980	7.100	5.700	8.500	1	mg/L	-33
	Chemical Oxygen Demand	2	70.000	36.062	74.500	49.000	100.000	5	mg/L	83
	Chromium, Dissolved	2	0.404	0.014	0.404	0.394	0.414	0.0437	µg/L	-36
	Chromium, Total	2	4.718	3.352	5.280	2.910	7.650	0.0428	µg/L	66
	Conductivity, @ 25 degrees C	2	37.789	5.657	38.000	34.000	42.000	5	µmhos/cm	-60
	Copper, Dissolved	2	4.917	1.393	5.015	4.030	6.000	0.0115	µg/L	-25
	Copper, Total	2	33.135	5.940	33.400	29.200	37.600	0.0144	µg/L	81
	Dissolved Oxygen	4	7.336	1.774	7.175	5.800	9.800	NA	mg/L	-7
	Escherichia coli	4	2101.800	3233.120	2350.000	640.000	7700.000	1	per 100 mL	109
	Fecal Coliform	4	1467.674	4549.948	1300.000	290.000	10000.000	1	per 100 mL	83
	Hardness	2	29.394	8.485	30.000	24.000	36.000	5	mg eq CaCO3/L	-33
	Lead, Dissolved	2	0.215	0.067	0.221	0.173	0.268	0.0051	µg/L	-54
	Lead, Total	2	11.381	8.033	12.720	7.040	18.400	0.0061	µg/L	16
	Magnesium, Total	2	2.898	0.778	2.950	2.400	3.500	0.5	mg/L	-33
	Mercury, Dissolved	6	0.003	0.002	0.003	0.001	0.006	0.00006	µg/L	48
	Mercury, Total	6	0.016	0.007	0.017	0.012	0.029	0.00006	µg/L	4
	Methyl Mercury, Dissolved	3	0.071	0.013	0.075	0.057	0.083	0.0249	ng/L	5
	Methyl Mercury, Total	3	0.175	0.029	0.161	0.159	0.211	0.0249	ng/L	23
	Molybdenum, Dissolved	2	0.606	0.182	0.620	0.491	0.749	0.0105	µg/L	72
	Molybdenum, Total	2	0.244	0.901	0.683	0.045	1.320	0.0337	µg/L	-82
	Nickel, Dissolved	2	0.745	0.117	0.750	0.667	0.832	0.0227	µg/L	-40
	Nickel, Total	2	5.489	2.942	5.870	3.790	7.950	0.0500	µg/L	59
	Nitrate + Nitrite - N	2	0.154	0.021	0.155	0.140	0.170	0.05	mg/L	-50
	pH Field	4	6.823	0.189	6.750	6.700	7.100	NA	pH Units	-4
	Phosphorus, Ortho	2	0.032	0.021	0.035	0.020	0.050	0.01	mg/L	-27
	Phosphorus, Total	2	0.237	0.113	0.250	0.170	0.330	0.01	mg/L	-19
	Selenium, Dissolved	2	0.042	0.000	0.042	0.042	0.042	0.0416	µg/L	-64
	Selenium, Total	2	0.283	0.696	0.568	0.075	1.060	0.0476	µg/L	261
	Silica Gel Treated Hexane Ext. Material	3	5.000	0.000	5.000	5.000	5.000	5	mg/L	-7
	Silver, Dissolved	2	0.006	0.000	0.006	0.006	0.006	0.0059	µg/L	-79
	Silver, Total	2	0.054	0.032	0.059	0.036	0.082	0.0123	µg/L	9
	Temperature	4	12.542	4.146	13.200	7.900	18.000	NA	˚C	14
	Tetrachloroethene	3	2.230	7.551	1.200	0.660	14.000	5	µg/L	-59
	Total Dissolved Solids	2	28.249	16.263	30.500	19.000	42.000	10	mg/L	-51
	Total Kjeldahl Nitrogen	2	0.917	0.566	1.000	0.600	1.400	0.2	mg/L	64
	Total Suspended Solids	2	134.164	125.865	161.000	72.000	250.000	1	mg/L	194
	trans-1,2-Dichloroethene	3	0.186	2.866	0.040	0.032	5.000	5	µg/L	-96
	Turbidity	2	134.164	56.569	140.000	100.000	180.000	1	NTU	188
	Zinc, Dissolved	2	40.060	2.546	40.100	38.300	41.900	0.0287	µg/L	-13
	Zinc, Total	2	151.552	57.983	157.000	116.000	198.000	0.0584	mg/L	147

Storm Event Monitoring Data
Descriptive Statistics

Table A.6

Receiving Waterbody: Groundwater
System Type: Underground Injection Control Device
System Location: (MH 75938)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
Anderson & Briana: MH 75938	Benzo(a)pyrene	2	0.077	0.112	0.111	0.031	0.190	0.190	µg/L	New Data
	Copper, Total	2	2.086	0.339	2.100	1.860	2.340	0.0241	µg/L	New Data
	Dissolved Oxygen	2	11.050	0.071	11.050	11.000	11.100	NA	mg/L	New Data
	Lead, Total	2	0.450	0.045	0.451	0.419	0.483	0.0348	µg/L	20
	Pentachlorophenol	2	0.455	0.191	0.475	0.340	0.610	0.950	µg/L	New Data
	pH Field	2	6.493	0.424	6.500	6.200	6.800	NA	pH Units	New Data
	Temperature	2	8.947	3.323	9.250	6.900	11.600	NA	˚C	New Data
	Zinc, Total	2	19.786	8.839	20.750	14.500	27.000	0.0792	µg/L	New Data

Table A.7

Receiving Waterbody: Groundwater
System Type: Underground Injection Control Device
System Location: (MH 99302)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
Marjorie & Downing: MH 99302	Benzo(a)pyrene	2	0.077	0.112	0.111	0.031	0.190	0.190	µg/L	New Data
	Copper, Total	2	1.642	0.148	1.645	1.540	1.750	0.0241	µg/L	New Data
	Dissolved Oxygen	2	11.337	1.697	11.400	10.200	12.600	NA	mg/L	New Data
	Lead, Total	2	0.233	0.059	0.237	0.195	0.279	0.0217	µg/L	New Data
	Pentachlorophenol	2	0.568	0.431	0.645	0.340	0.950	0.950	µg/L	New Data
	pH Field	2	6.588	0.566	6.600	6.200	7.000	NA	pH Units	New Data
	Temperature	2	8.142	2.616	8.350	6.500	10.200	NA	˚C	New Data
	Zinc, Total	2	60.688	21.425	62.550	47.400	77.700	0.0792	µg/L	New Data

Table A.8

Receiving Waterbody: Groundwater
System Type: Underground Injection Control Device
System Location: (MH 73919)

Location	Parameter	N	GeoMean	Mean Std. Deviation	Median	Minimum	Maximum	RL	Units	% Change from Historical GeoMean
Shenstone & Tyson: MH 73919	Benzo(a)pyrene	2	0.077	0.112	0.111	0.031	0.190	0.190	µg/L	New Data
	Copper, Total	2	1.122	0.184	1.130	1.000	1.260	0.0241	µg/L	New Data
	Dissolved Oxygen	2	10.640	0.636	10.650	10.200	11.100	NA	mg/L	New Data
	Lead, Total	2	0.205	0.008	0.206	0.200	0.211	0.0217	µg/L	New Data
	Pentachlorophenol	2	0.436	0.156	0.450	0.340	0.560	0.950	µg/L	New Data
	pH Field	2	6.797	0.283	6.800	6.600	7.000	NA	pH Units	New Data
	Temperature	2	8.570	2.828	8.800	6.800	10.800	NA	˚C	New Data
	Zinc, Total	2	687.823	1626.346	1340.000	190.000	2490.000	0.0792	µg/L	New Data

Table A.9
2013/2014 QA/QC Qualified Ambient Water Quality Data
Amazon Basin and Willamette River Monitoring Sites
Metals (µg/L)

Date / Site	As (D)	As (T)	Cd (D)	Cd (T)	Cr (D)	Cr (T)	Cu (D)	Cu (T)	Pb (D)	Pb (T)	Hg (D)	Hg (T)	Mo (D)	Mo (T)	Ni (D)	Ni (T)	Se (D)	Se (T)	Ag (D)	Ag (T)	Zn (D)	Zn (T)
Amazon Creek at 29th Avenue																						
7/31/2013	1.28	1.44	<0.0176	<0.0201	0.192	0.272	0.941	1.50	0.0279	0.240	<0.0005	<0.0005	0.571	0.603	1.46	1.68	0.174	0.213	<0.0059	<0.0190	16.4	19.2
9/25/2013	0.937	1.06	<0.0176	<0.0201	0.489	1.08	2.98	4.24	0.124	0.375	0.00126	0.00258	0.243	0.248	1.58	1.85	0.203	0.198	0.0117	<0.0190	19.3	23.3
11/6/2013	0.851	0.985	<0.0176	<0.0201	0.302	0.478	1.82	2.32	0.0467	0.151	0.00087	0.00168	0.262	0.288	1.49	1.48	0.153	0.138	0.0121	<0.0190	23.6	29.4
1/22/2014	0.660	0.823	<0.0176	<0.0201	0.537	1.42	1.47	2.87	0.0788	0.434	0.00102	0.00128	0.170	0.199	1.40	1.98	0.158	0.238	0.0063	<0.0190	21.5	33.2
3/19/2014	0.605	0.732	<0.0176	<0.0201	0.880	1.48	2.12	3.69	0.0582	0.224	0.00159	0.00285	0.154	0.161	1.41	1.66	0.094	0.162	0.0091	<0.0190	17.2	25.3
5/21/2014	0.917	1.03	<0.0176	<0.0201	0.0680	0.303	1.15	1.55	0.0242	0.113	0.00061	0.00108	0.299	0.297	1.46	1.60	0.234	0.166	<0.0059	<0.0190	21.2	25.6
Willow Creek near 18th Avenue																						
7/31/2013*																						
9/25/2013	0.856	1.01	<0.0176	<0.0201	0.200	0.276	1.25	1.49	0.0403	0.110	<0.0005	0.00081	0.363	0.358	4.03	4.12	0.176	0.220	0.0168	<0.0190	37.0	39.4
11/6/2013	0.717	0.889	<0.0176	<0.0201	Outlier	0.0851	Outlier	1.49	0.0110	0.0293	<0.0005	0.00108	0.122	0.131	2.97	2.75	0.285	0.239	0.0099	<0.0190	10.2	11.2
1/22/2014	0.755	1.08	<0.0176	<0.0201	0.461	0.948	1.88	2.66	0.170	0.237	0.00229	0.00225	0.068	0.077	1.19	1.44	0.129	0.190	0.0131	<0.0190	3.08	4.59
3/19/2014	0.935	1.37	<0.0176	<0.0201	0.494	0.823	1.92	3.01	0.0879	0.254	0.00186	0.00431	0.079	0.088	1.17	1.42	0.079	0.120	0.0099	<0.0190	6.80	9.88
5/21/2014	1.47	2.24	<0.0176	<0.0201	0.070	0.188	1.04	1.33	0.0267	0.0959	0.00090	0.00148	0.207	0.220	2.63	2.72	0.274	0.258	<0.0059	<0.0190	Outlier	Outlier
Amazon Creek at Railroad Crossing																						
7/31/2013	5.15	8.32	<0.0176	<0.0201	0.183	0.959	1.13	2.77	0.116	1.90	<0.0005	0.00291	0.849	0.855	2.17	2.86	0.298	0.360	<0.0059	<0.0190	5.82	28.8
9/25/2013	2.48	2.82	<0.0176	<0.0201	0.464	1.06	3.23	4.51	0.156	0.729	0.00124	0.00354	0.403	0.388	1.46	1.78	0.124	0.115	Outlier	<0.0190	29.5	32.0
11/6/2013	2.77	3.23	<0.0176	<0.0201	0.404	0.562	2.66	3.38	0.224	0.543	0.00254	0.00455	1.05	1.16	1.61	1.65	0.130	0.133	0.0090	<0.0190	24.2	31.7
1/22/2014	2.04	2.62	<0.0176	<0.0201	0.408	0.882	1.70	2.62	0.109	0.466	0.00274	0.00464	0.64	0.634	1.57	1.81	0.277	0.308	<0.0059	<0.0190	15.7	22.7
3/19/2014	1.71	2.29	<0.0176	<0.0201	0.514	0.929	2.19	3.14	0.112	0.441	0.00338	0.00690	0.235	0.272	1.50	1.77	0.126	0.156	<0.0059	<0.0190	18.9	28.7
5/21/2014	2.51	5.21	<0.0176	0.0285	0.0823	2.27	1.80	6.53	0.0901	3.070	0.00146	0.0147	0.539	0.536	1.75	3.21	0.293	0.260	<0.0059	<0.0190	4.31	54.1
Amazon Diversion Channel at Royal Avenue																						
7/31/2013	6.66	9.60	<0.0176	0.0213	0.217	1.80	1.10	4.24	0.134	2.34	<0.0005	0.00394	1.12	1.11	2.28	3.40	0.359	0.364	<0.0059	<0.0190	1.21	20.2
9/25/2013	2.12	2.16	<0.0176	0.0209	0.600	1.05	5.95	7.82	0.343	0.996	0.00188	0.00532	0.672	0.697	1.30	1.68	0.159	0.117	0.0083	<0.0190	26.5	27.9
11/6/2013	1.66	2.07	<0.0176	<0.0201	0.331	0.369	2.89	3.35	0.157	0.430	0.00174	0.00419	1.30	1.31	1.80	1.68	0.165	0.174	<0.0059	<0.0190	14.3	18.1
1/22/2014	0.923	1.48	<0.0176	<0.0201	0.306	0.542	2.67	3.36	0.105	0.555	0.00114	0.00311	0.718	0.735	2.02	2.26	0.265	0.334	<0.0059	<0.0190	23.7	28.6
3/19/2014	1.06	1.72	<0.0176	<0.0201	0.247	0.448	2.55	3.39	0.107	0.523	0.00138	0.00402	0.762	0.784	1.80	1.98	0.157	0.148	<0.0059	<0.0190	19.5	28.2
5/21/2014	1.74	4.93	<0.0176	0.0552	0.0835	4.41	1.23	10.5	0.093	5.150	0.00056	0.0214	0.713	0.718	1.56	4.31	0.188	0.211	<0.0059	0.0293	2.15	62.0
A3 Channel at Terry Street																						
7/31/2013*																						
9/25/2013	1.57	1.59	0.0232	0.0316	0.651	1.04	7.41	9.39	0.522	1.52	0.00404	0.0103	0.922	0.933	1.55	1.94	0.120	0.103	0.0177	0.0261	41.1	38.8
11/6/2013	1.23	1.70	<0.0176	0.0272	0.366	0.685	3.34	4.70	0.246	1.14	0.00127	0.00739	1.06	1.09	1.73	1.84	0.200	0.154	<0.0059	<0.0190	15.4	31.5
1/22/2014	0.791	1.24	<0.0176	0.0202	0.263	0.521	1.74	3.09	0.054	0.933	0.00080	0.00486	0.798	0.795	2.50	2.61	0.330	0.340	<0.0059	<0.0190	26.1	32.5
3/19/2014	0.920	1.79	<0.0176	0.0213	0.186	0.310	1.84	2.93	0.048	0.526	0.00084	0.00407	0.819	0.906	2.28	2.46	0.283	0.260	<0.0059	<0.0190	22.7	31.6
5/21/2014	2.70	4.48	<0.0176	<0.0201	0.0653	0.624	1.32	3.01	0.067	1.62	0.00068	0.00803	1.39	1.56	2.05	2.64	0.258	0.220	<0.0059	<0.0190	12.3	30.7
Amazon Creek at Royal Avenue																						
7/31/2013*																						
9/25/2013	2.29	2.56	<0.0176	<0.0201	0.434	1.13	3.26	4.61	0.128	0.794	0.00099	0.00327	0.388	0.405	1.37	1.78	0.116	0.124	<0.0059	<0.0190	26.1	29.7
11/6/2013	2.33	2.82	<0.0176	<0.0201	0.435	0.596	2.79	3.53	0.215	0.525	0.00172	0.00376	1.73	1.83	1.62	1.64	0.188	0.120	0.0070	<0.0190	21.0	28.2
1/22/2014	1.72	2.36	<0.0176	<0.0201	0.342	0.863	1.74	2.68	0.114	0.461	0.00284	0.00521	0.541	0.576	1.47	1.82	0.234	0.242	<0.0059	<0.0190	16.2	23.1
3/19/2014	1.63	2.35	<0.0176	<0.0201	0.389	1.04	2.12	3.43	0.106	0.564	0.00322	0.00658	0.264	0.311	1.44	1.89	0.157	0.115	<0.0059	<0.0190	27.4	42.6
5/21/2014	1.88	3.45	<0.0176	<0.0201	0.116	1.61	1.65	4.19	0.124	1.56	0.00109	0.00702	0.439	0.438	1.76	2.64	0.191	0.149	<0.0059	<0.0190	17.3	37.4

* No flow; no sample collected.
Values in RED indicate exceedance of applicable Oregon water quality criterion.
Outlier = Value determined to be outside of expected range.

Table A.9
2013/2014 QA/QC Qualified Ambient Water Quality Data
Amazon Basin and Willamette River Monitoring Sites
Metals (µg/L)

Date / Site	As (D)	As (T)	Cd (D)	Cd (T)	Cr (D)	Cr (T)	Cu (D)	Cu (T)	Pb (D)	Pb (T)	Hg (D)	Hg (T)	Mo (D)	Mo (T)	Ni (D)	Ni (T)	Se (D)	Se (T)	Ag (D)	Ag (T)	Zn (D)	Zn (T)
Willamette River Upstream of Urban Growth Boundary (RM 186.9)																						
7/30/2013	0.170	0.191	<0.0176	<0.0201	0.147	0.102	0.202	0.255	<0.0051	0.0356	<0.0005	<0.0005	0.037	0.053	0.144	0.211	<0.0416	<0.0476	<0.0059	<0.0190	0.192	0.132
9/24/2013	0.229	0.219	<0.0176	<0.0201	0.109	<0.0760	0.274	0.257	<0.0051	<0.0217	<0.0005	0.00054	0.062	0.053	0.171	0.203	0.0602	<0.0476	<0.0059	<0.0190	0.392	0.384
11/5/2013	0.218	0.291	<0.0176	<0.0201	0.162	0.198	0.346	0.405	0.0091	0.0377	0.00070	0.00088	0.061	0.063	0.199	0.229	<0.0416	0.0668	<0.0059	<0.0190	0.259	0.332
1/21/2014	0.194	0.231	<0.0176	<0.0201	0.170	0.126	0.246	0.379	0.0159	0.0400	0.00055	0.00116	0.053	0.048	0.191	0.261	<0.0416	0.0557	<0.0059	<0.0190	0.390	0.618
3/18/2014	0.171	0.261	<0.0176	<0.0201	0.212	0.288	Outlier	0.687	0.0274	0.107	0.00105	0.00210	0.029	0.036	0.231	0.407	<0.0416	0.0638	<0.0059	<0.0190	1.02	2.76
5/20/2014	0.176	0.200	<0.0176	<0.0201	0.0497	0.154	0.267	0.383	0.0156	0.0470	0.00095	0.00136	0.029	<0.0337	0.184	0.269	0.0418	<0.0476	<0.0059	<0.0190	0.169	0.507
Willamette River at Knickerbocker Bridge (RM 183.9)																						
7/30/2013	0.183	0.220	<0.0176	<0.0201	0.107	0.098	0.222	0.266	<0.0051	0.0354	<0.0005	0.00075	0.038	0.049	0.160	0.222	<0.0416	<0.0476	<0.0059	<0.0190	0.201	0.194
9/24/2013	0.396	0.435	<0.0176	<0.0201	0.114	0.125	0.338	0.466	0.0102	0.0602	<0.0005	0.00080	0.057	0.054	0.197	0.241	<0.0416	<0.0476	<0.0059	<0.0190	0.281	0.707
11/5/2013	0.257	0.332	<0.0176	<0.0201	0.194	0.239	0.467	0.482	0.0105	0.0424	0.00059	0.00081	0.059	0.065	0.227	0.230	<0.0416	<0.0476	<0.0059	<0.0190	0.247	0.525
1/21/2014	0.241	0.274	<0.0176	<0.0201	0.193	0.228	0.394	0.559	0.0286	0.0523	0.00099	0.00150	0.040	0.051	0.226	0.296	<0.0416	0.0521	<0.0059	<0.0190	0.450	0.746
3/18/2014	0.202	0.292	<0.0176	<0.0201	0.236	0.306	0.469	0.828	0.0282	0.110	0.00120	0.00230	0.027	<0.0337	0.252	0.410	<0.0416	<0.0476	<0.0059	<0.0190	0.828	1.50
5/20/2014	0.197	0.242	<0.0176	<0.0201	0.091	0.214	0.316	0.482	0.0250	0.0522	0.00107	0.00147	0.032	<0.0337	0.215	0.289	<0.0416	<0.0476	<0.0059	<0.0190	0.356	0.731
Willamette River at Owosso Bridge (RM 178.6)																						
7/30/2013	0.192	0.268	<0.0176	<0.0201	0.115	0.114	0.213	0.323	<0.0051	0.0496	<0.0005	0.00065	0.053	0.055	0.177	0.228	<0.0416	0.0711	<0.0059	<0.0190	0.354	0.457
9/24/2013	0.424	0.458	<0.0176	<0.0201	0.097	0.129	0.369	0.526	0.0128	0.0798	0.00054	0.00102	0.070	0.064	0.203	0.271	0.0431	<0.0476	<0.0059	<0.0190	0.642	1.06
11/5/2013	0.257	0.340	<0.0176	<0.0201	0.181	0.106	0.379	0.515	0.0145	0.0576	0.00090	0.00087	0.064	0.066	0.222	0.239	<0.0416	0.0611	<0.0059	<0.0190	0.456	0.752
1/21/2014	0.243	0.264	<0.0176	<0.0201	0.209	0.203	0.405	0.544	0.0352	0.0560	0.00104	0.00159	0.059	0.057	0.230	0.303	<0.0416	<0.0476	<0.0059	<0.0190	0.754	1.06
3/18/2014	0.190	0.324	<0.0176	<0.0201	0.183	0.328	0.427	0.865	0.0196	0.119	0.00102	0.00248	0.033	0.039	0.219	0.425	<0.0416	<0.0476	<0.0059	<0.0190	0.704	1.37
5/20/2014	0.206	0.257	<0.0176	<0.0201	0.072	0.214	0.342	0.498	0.0310	0.0609	0.00095	0.00145	0.049	0.039	0.221	0.314	0.0449	<0.0476	<0.0059	<0.0190	0.392	0.747
Willamette River Downstream of Beltline Bridge (RM 176.8)																						
7/30/2013	0.203	0.252	<0.0176	<0.0201	0.117	0.096	0.464	0.425	0.0076	0.0574	<0.0005	0.00056	0.199	0.200	0.194	0.260	<0.0416	<0.0476	<0.0059	<0.0190	0.844	0.884
9/24/2013	0.428	0.445	<0.0176	<0.0201	0.144	0.109	0.426	0.539	0.0184	0.0719	<0.0005	0.00062	0.094	0.070	0.263	0.278	<0.0416	0.0501	<0.0059	<0.0190	2.00	2.30
11/5/2013	0.255	0.353	<0.0176	<0.0201	0.203	0.231	Outlier	0.554	0.0180	0.0614	0.00061	0.00073	0.075	0.074	0.260	0.251	<0.0416	0.0720	<0.0059	<0.0190	1.12	1.52
1/21/2014	0.231	0.273	<0.0176	<0.0201	0.208	0.220	0.438	0.598	0.0294	0.0550	0.00100	0.00158	0.060	0.070	0.265	0.328	0.0621	0.0551	<0.0059	<0.0190	1.50	1.68
3/18/2014	0.182	0.303	<0.0176	<0.0201	0.145	0.348	0.453	0.877	0.0157	0.117	0.00099	0.00259	0.093	0.101	0.224	0.435	<0.0416	<0.0476	<0.0059	<0.0190	0.892	1.59
5/20/2014	0.191	0.235	<0.0176	<0.0201	0.0540	0.221	0.373	0.555	0.0219	0.0655	0.00068	0.00138	0.040	0.047	0.201	0.308	0.0746	<0.0476	<0.0059	<0.0190	1.06	1.44
Delta Ponds Above Willamette River Confluence																						
7/30/2013*																						
9/24/2013	0.597	0.588	<0.0176	<0.0201	0.162	<0.0760	0.765	0.758	0.0497	0.0922	<0.0005	0.00066	0.149	0.137	0.989	0.929	0.184	0.184	<0.0059	<0.0190	76.1	80.1
11/5/2013	0.291	0.360	<0.0176	<0.0201	0.223	0.180	0.453	0.436	0.0310	0.0508	<0.0005	<0.0005	0.125	0.124	0.839	0.823	0.112	0.116	<0.0059	<0.0190	2.79	3.11
1/21/2014	0.345	0.404	<0.0176	<0.0201	0.112	<0.0760	0.417	0.495	0.0424	0.0897	<0.0005	0.00075	0.082	0.081	0.571	0.597	0.0742	0.0926	<0.0059	<0.0190	5.89	5.97
3/18/2014	0.220	0.357	<0.0176	<0.0201	0.169	0.259	0.437	0.833	0.0183	0.141	<0.0005	0.00248	0.047	0.050	0.297	0.445	<0.0416	<0.0476	<0.0059	<0.0190	2.28	3.75
5/20/2014	0.587	0.707	<0.0176	<0.0201	<0.0437	<0.0760	0.415	0.514	0.0508	0.0829	<0.0005	<0.0005	0.102	0.101	0.550	0.640	0.055	<0.0476	<0.0059	<0.0190	3.45	4.19
Spring Creek at Beacon Drive East																						
7/31/2013*																						
9/25/2013*																						
11/6/2013	0.504	0.520	<0.0176	<0.0201	0.175	0.395	0.748	0.808	0.0359	0.0761	<0.0005	0.00072	0.162	0.163	0.980	0.954	0.161	0.162	0.0105	<0.0190	57.7	59.6
1/22/2014	0.300	0.330	<0.0176	<0.0201	0.132	0.120	0.346	0.526	0.0167	0.147	<0.0005	<0.0005	0.079	0.078	0.755	0.846	0.233	0.243	<0.0059	<0.0190	10.0	12.7
3/19/2014	0.291	0.310	<0.0176	<0.0201	0.147	0.246	0.512	0.598	<0.0051	0.0528	<0.0005	0.00062	0.085	0.085	0.796	0.806	0.144	0.168	<0.0059	<0.0190	28.1	28.7
5/21/2014	0.287	0.286	<0.0176	<0.0201	<0.0437	<0.0760	0.434	0.473	0.0089	0.0308	<0.0005	<0.0005	0.080	0.075	0.825	0.833	0.205	0.149	0.0094	<0.0190	21.3	20.3

* No flow; no sample collected.
Values in RED indicate exceedance of applicable Oregon water quality criterion.
Outlier = Value determined to be outside of expected range.

Table A.10
2013/2014 QA/QC Qualified Ambient Water Quality Data
Amazon Basin and Willamette River Monitoring Sites
Miscellaneous Parameters

Date / Site	NH_3 (mg/L)	BOD (mg/L)	Ca (T) (mg/L)	COD (mg/L)	Cond (µmho/cm)	DO (mg/L)	E. coli (MPN)	Fecal Coliform (col./100 mL)	Hardness (mg eq/L)	Mg (T) (mg/L)	NO_3+NO_2 (mg/L)	pH (Units)	P (Ortho) (mg/L)	P (T) (mg/L)	Temp (°C)	TDS (mg/L)	TKN (mg/L)	TSS (mg/L)	Turbidity (NTU)	2,3,7,8-TCDD (pg/L)
Amazon Creek at 29th Avenue																				
7/31/2013	<0.1	<2	28	7	310	6.3	250	1000	110	10	0.11	7.4	0.09	0.10	18.0	180	<0.2	2.8	4	
9/25/2013	<0.1	<2	18	14	180	8.9	2000	1000	69	5.8	0.71	7.6	0.08	0.10	15.1	120	<0.2	4.4	12	
11/6/2013	<0.1	<2	23	10	240	10.5	580	490	90	8.0	0.15	7.7	0.08	0.09	13.3	140	<0.2	1.8	6	
1/22/2014	<0.1	<2	25	<5	250	12.8	580	210	100	9.2	1.1	7.6	0.03	0.07	6.2	160	0.4	8.4	15	
3/19/2014	<0.1	<2	21	5	190	Outlier	100	60	85	7.8	0.31	7.6	0.04	0.07	8.8	130	<0.2	5.5	16	
5/21/2014	<0.1	<2	28	<5	270	9.5	820	110	110	10	0.20	7.7	0.05	0.06	13.4	140	<0.2	2.0	6	
Willow Creek near 18th Avenue																				
7/31/2013*																				
9/25/2013	<0.1	<2	28	13	290	9.7	180	130	100	8.2	0.09	7.1	0.03	0.04	15.8	180	<0.2	3.4	3	
11/6/2013	<0.1	<2	44	19	480	10.3	24	20	160	12	<0.05	7.0	<0.01	0.02	12.7	290	<0.2	9.5	5	
1/22/2014	<0.1	<2	18	13	200	13.5	10	20	66	5.2	<0.05	7.4	0.01	0.06	4.2	150	<0.2	3.2	20	
3/19/2014	<0.1	<2	15	8	160	11.9	25	94	58	4.9	<0.05	7.5	0.02	0.07	8.1	130	<0.2	3.0	19	
5/21/2014	<0.1	<2	36	10	360	8.7	17	10	140	11	<0.05	7.2	0.02	0.14	14.3	240	0.3	3.0	8	
Amazon Creek at Railroad Crossing																				
7/31/2013	<0.1	5	26	28	330	6.3	160	630	110	9.8	<0.05	7.5	0.03	0.17	21.4	180	0.6	29	26	
9/25/2013	<0.1	<2	10	16	110	7.4	920	870	38	3.2	0.52	7.1	0.06	0.08	15.4	77	<0.2	6.8	15	
11/6/2013	<0.1	2	16	19	180	8.6	460	470	61	5.2	0.12	7.2	0.07	0.10	12.8	90	<0.2	4.5	9	
1/22/2014	<0.1	2	24	19	250	12.4	86	20	94	8.2	0.49	7.4	0.02	0.06	5.0	150	0.6	8.0	15	
3/19/2014	<0.1	3	21	8	210	10.3	110	50	82	7.2	0.25	7.3	0.03	0.08	9.5	120	0.3	5.0	14	
5/21/2014	<0.1	<2	24	18	250	4.9	120	46	94	8.2	0.26	7.3	0.03	0.17	17.6	Outlier	0.8	46	42	
Amazon Diversion Channel at Royal Avenue																				
7/31/2013	<0.1	5	25	33	320	4.2	770	540	100	10	<0.05	7.0	0.05	0.22	21.2	180	1.1	35	36	
9/25/2013	<0.1	<2	7.0	25	80	6.0	1600	1900	29	2.9	0.22	6.9	0.09	0.13	15.1	62	<0.2	7.8	15	
11/6/2013	<0.1	<2	19	20	220	9.2	30	40	81	8.2	0.16	7.5	0.03	0.06	11.4	130	<0.2	3.0	6	
1/22/2014	<0.1	<2	27	19	290	11.2	7	<10	120	14	0.66	7.1	0.02	0.09	4.3	170	0.6	7.2	13	
3/19/2014	<0.1	<2	24	10	240	9.3	91	31	110	12	0.54	7.4	0.04	0.12	11.5	132	0.4	4.8	9	
5/21/2014	<0.1	3	20	30	200	6.8	63	82	86	8.8	<0.05	7.2	0.09	0.30	19.0	Outlier	0.8	110	97	
A3 Channel at Terry Street																				
7/31/2013*																				
9/25/2013	<0.1	<2	6.4	23	72	5.2	520	900	28	2.9	0.20	6.9	0.08	0.13	15.0	48	<0.2	7.2	17	
11/6/2013	<0.1	<2	19	28	220	8.3	110	190	87	9.6	0.22	7.4	0.04	0.13	12.1	120	0.3	28	16	
1/22/2014	<0.1	<2	37	22	380	11.1	10	30	170	20	0.63	7.2	0.02	0.11	5.4	210	0.4	18	16	
3/19/2014	0.1	<2	36	12	350	9.5	24	30	160	18	0.69	7.1	0.03	0.14	10.6	200	0.6	10	12	
5/21/2014	<0.1	4	29	28	310	7.1	53	170	130	15	<0.05	7.2	0.03	0.21	17.4	250	0.6	20	20	
Amazon Creek at Royal Avenue																				
7/31/2013*																				
9/25/2013	<0.1	<2	9.8	16	100	6.8	1300	TNTC	37	3.0	0.49	7.0	0.05	0.09	15.0	77	<0.2	10	16	
11/6/2013	<0.1	2	17	20	180	8.7	330	430	67	5.9	0.15	7.3	0.05	0.09	11.8	110	<0.2	4.0	9	
1/22/2014	<0.1	<2	23	13	240	12.8	46	30	91	8.1	0.49	7.0	0.02	0.06	4.8	160	0.3	6.4	14	
3/19/2014	<0.1	<2	20	16	200	11.2	56	68	82	7.7	0.23	7.6	0.02	0.09	9.3	130	0.3	5.6	15	
5/21/2014	<0.1	<2	15	16	150	3.3	36	74	58	5.0	0.11	6.8	0.02	0.12	18.3	Outlier	0.4	33	34	

* No flow; no sample collected.
NID: Not determined; sample preserved incorrectly.

Table A.10
2013/2014 QA/QC Qualified Ambient Water Quality Data
Amazon Basin and Willamette River Monitoring Sites
Miscellaneous Parameters

Date / Site	NH_3 (mg/L)	BOD (mg/L)	Ca (T) (mg/L)	COD (mg/L)	Cond (µmho/cm)	DO (mg/L)	E. coli (MPN)	Fecal Coliform (col./100 mL)	Hardness (mg eq/L)	Mg (T) (mg/L)	NO_3+NO_2 (mg/L)	pH (Units)	P (Ortho) (mg/L)	P (T) (mg/L)	Temp (°C)	TDS (mg/L)	TKN (mg/L)	TSS (mg/L)	Turbidity (NTU)	2,3,7,8-TCDD (pg/L)
Willamette River Upstream of Urban Growth Boundary (RM 186.9)																				
7/30/2013	<0.1	<2	4.1	<5	46	9.6	9	11	16	1.4		7.9	0.02	0.03	18.8	29	<0.2	2.0	3	<10
9/24/2013	<0.1	<2	4.8	<5	52	9.7	11	24	19	1.6	<0.05	7.9	0.03	0.03	15.3	42	<0.2	1.4	2	
11/5/2013	<0.1	<2	4.7	<5	54	11.2	17	16	18	1.6	<0.05	7.5	0.02	0.02	12.1	31	<0.2	2.6	3	
1/21/2014	<0.1	<2	5.2	<5	52	Outlier	3	4	20	1.7	0.05	7.2	0.02	0.03	4.7	49	<0.2	2.4	4	
3/18/2014	<0.1	<2	4.4	6	42	12.8	14	5	17	1.4	0.06	7.4	0.03	0.07	7.8	27	<0.2	5.2	12	<6
5/20/2014	<0.1	<2	4.4	<5	44	11.7	17	10	17	1.5	<0.05	7.4	0.02	0.03	11.5	43	<0.2	2.6	5	
Willamette River at Knickerbocker Bridge (RM 183.9)																				
7/30/2013	<0.1	<2	4.2	<5	47	9.5	37	20	17	1.5	<0.05	7.3	0.02	0.02	17.6	21	<0.2	1.4	2	
9/24/2013	<0.1	<2	5.3	<5	55	8.6	47	52	20	1.6	<0.05	7.5	0.02	0.03	15.9	41	<0.2	3.6	3	
11/5/2013	<0.1	<2	5.1	<5	56	11.1	19	17	19	1.6	<0.05	7.6	0.02	0.02	11.9	16	<0.2	3.0	3	
1/21/2014	<0.1	<2	5.4	<5	56	Outlier	5	5	20	1.7	0.08	7.2	0.02	0.03	4.7	44	0.3	1.8	6	
3/18/2014	<0.1	<2	4.7	9	45	12.7	26	13	18	1.5	0.10	7.4	0.03	0.08	7.7	31	<0.2	6.2	12	
5/20/2014	<0.1	<2	4.7	<5	46	11.7	21	12	18	1.5	<0.05	7.3	0.02	0.03	11.4	<10	<0.2	2.0	5	
Willamette River at Owosso Bridge (RM 178.6)																				
7/30/2013	<0.1	<2	4.4	<5	48	8.2	36	26	18	1.6	<0.05	7.4	0.02	0.03	16.9	30	<0.2	2.8	2	
9/24/2013	<0.1	<2	5.2	<5	56	9.2	54	54	20	1.7	<0.05	7.5	0.03	0.04	15.8	43	<0.2	2.8	2	
11/5/2013	<0.1	<2	5.2	<5	57	11.5	31	49	20	1.7	<0.05	7.5	0.02	0.01	11.9	Outlier	<0.2	2.8	4	
1/21/2014	<0.1	<2	5.4	<5	56	Outlier	17	17	20	1.7	0.08	7.1	0.02	0.03	4.7	45	<0.2	1.8	6	
3/18/2014	<0.1	<2	4.8	<5	45	11.2	37	20	18	1.5	0.10	7.4	0.03	0.06	7.6	28	<0.2	5.8	14	
5/20/2014	<0.1	<2	4.8	<5	47	11.9	28	14	19	1.6	<0.05	7.3	0.02	0.02	11.4	36	<0.2	2.6	5	
Willamette River Downstream of Beltline Bridge (RM 176.8)																				
7/30/2013	<0.1	<2	4.5	<5	53	8.7	45	34	18	1.6	0.07	6.9	0.02	0.03	16.1	34	<0.2	2.4	3	<10
9/24/2013	0.2	<2	5.5	<5	62	8.4	66	62	21	1.7	0.12	7.5	0.13	0.12	15.8	44	<0.2	2.4	2	
11/5/2013	<0.1	<2	5.4	5	62	11.3	40	33	21	1.8	<0.05	7.4	0.02	0.03	11.8	28	<0.2	3.2	3	
1/21/2014	0.3	<2	5.6	<5	64	Outlier	6	14	21	1.8	0.09	7.1	0.05	0.05	4.8	55	0.6	4.4	5	
3/18/2014	0.1	<2	5.1	<5	49	11.3	32	20	19	1.6	0.10	7.4	0.04	0.09	7.6	31	<0.2	6.2	14	<5
5/20/2014	<0.1	<2	5.0	<5	51	11.6	32	30	19	1.6	<0.05	7.2	0.02	0.03	11.5	36	<0.2	3.2	5	
Delta Ponds Above Willamette River Confluence																				
7/30/2013*																				
9/24/2013	<0.1	<2	21	12	220	4.4	650	320	93	9.8	<0.05	7.0	0.05	0.09	15.6	100	<0.2	1.6	2	
11/5/2013	<0.1	<2	18	7	180	9.83	23	16	75	7.4	<0.05	7.1	0.01	0.01	10.3	89	<0.2	1.6	2	
1/21/2014	<0.1	<2	13	<5	130	8.3	11	7	56	5.7	0.14	6.8	0.02	0.05	4.8	82	0.6	3.4	5	
3/18/2014	<0.1	<2	6.0	<5	57	11.2	13	24	24	2.2	0.12	7.1	0.02	0.07	7.9	27	<0.2	4.8	11	
5/20/2014	<0.1	<2	12	<5	120	4.4	120	68	51	5.1	<0.05	6.8	0.02	0.07	16.7	71	0.3	2.4	4	
Spring Creek at Beacon Drive East																				
7/31/2013*																				
9/25/2013*																				
11/6/2013	<0.1	<2	18	9	210	8.9	160	120	84	9.4	1.6	7.0	0.10	0.12	13.4	140	<0.2	1.8	2	
1/22/2014	<0.1	<2	20	<5	230	10.1	100	50	95	11	2.4	6.8	0.06	0.09	8.7	160	0.3	3.6	3	
3/19/2014	<0.1	<2	20	<5	220	11.1	52	30	95	11	2.7	6.6	0.06	0.06	10.9	150	<0.2	4.0	2	
5/21/2014	<0.1	<2	20	<5	230	8.3	250	120	95	11	2.6	6.8	0.07	0.07	12.5	Outlier	<0.2	1.4	2	

* No flow; no sample collected.
NID: Not determined; sample preserved incorrectly.

Table A.11
2011 through 2014 QA/QC Qualified Ambient Water Quality Data
Amazon Basin Monitoring Sites
Chlorinated Hydrocarbons

Date / Site	1,1-Dichloroethene (µg/L)	trans 1,2-Dichloroethene (µg/L)	Trichloroethene (µg/L)	Tetrachloroethene (µg/L)
Amazon Creek at Royal Avenue [1]				
7/18/2012	< 5	< 5		< 5
9/19/2012	< 5	< 5		< 5
11/7/2012	< 5	< 5	< 5	< 5
1/16/2013	< 5	< 5	< 5	< 5
3/20/2013	< 5	< 5	< 5	< 5
5/29/2013	< 5	< 5	< 5	< 5
Amazon Creek at Railroad Crossing [1]				
7/18/2012	< 5	< 5		< 5
9/19/2012	< 5	< 5		< 5
11/7/2012	< 5	< 5	< 5	< 5
1/16/2013	< 5	< 5	< 5	< 5
3/20/2013	< 5	< 5	< 5	< 5
9/25/2013	< 5	< 5	< 5	< 5
Amazon Diversion Channel at Royal Avenue				
7/20/2011	< 5	< 5		< 5
9/21/2011	< 5	< 5		< 5
11/30/2011	< 5	< 5		< 5
1/18/2012	< 5	< 5		< 5
3/22/2012	< 5	< 5		< 5
5/23/2012	< 5	< 5		< 5
9/25/2013	< 5	< 5	< 5	< 5
11/6/2013	< 5	< 5	< 5	< 5
1/22/2014	< 0.039	< 0.032	0.13	0.32
3/19/2014	< 0.039	< 0.032	0.14	0.29
5/21/2014	< 0.039	< 0.032	0.08	0.06
A3 Channel at Terry Street [2]				
7/20/2011	< 5	< 5		< 5
9/21/2011*				
11/30/2011	< 5	< 5		< 5
1/18/2012	< 5	< 5		< 5
3/22/2012	< 5	< 5		< 5
5/23/2012	< 5	< 5		< 5
11/6/2013	< 5	< 5		< 5
1/22/2014	0.05	< 5	< 5	< 5
3/19/2014	0.04	< 5	< 5	< 5
5/21/2014	< 0.039	< 0.032	0.13	0.32

[1] 303(d) listed for Dichloroethene, Trichloroethene, and Tetrachloroethene.
[2] 303(d) listed for Dichloroethene and Tetrachloroethene.

* No flow; no sample collected.

Table A.12
Summary Statistics for QA/QC Qualified Ambient Water Quality Data
Metals

Surface Water Sample Location:		Amazon Creek at 29th Avenue	Willow Creek near 18th Avenue	Amazon Creek at Railroad Crossing	Amazon Diversion Channel at Royal Avenue	A3 Channel at Terry Street	Amazon Creek at Royal Avenue	Willamette River Upstream of Urban Growth Boundary (RM 186.9)	Willamette River at Knickerbocker Bridge (RM 183.9)	Willamette River at Owosso Bridge (RM 178.6)	Delta Ponds Above Willamette River Confluence	Willamette River Downstream of Beltline Bridge (RM 176.8)	Spring Creek at Beacon Drive East
Metals (*µg/L*)	**Statistic**												
As (D)	$\hat{\mu}$	0.888	0.911	2.49	2.33	2.19	2.28	0.203	0.236	0.243	0.404	0.245	0.329
	$\hat{\sigma}$	0.336	0.442	1.03	1.22	1.23	1.06	0.0575	0.0604	0.0645	0.175	0.0660	0.0790
As (T)	$\hat{\mu}$	1.09	1.41	3.97	3.95	3.64	3.40	0.268	0.313	0.326	0.543	0.330	0.392
	$\hat{\sigma}$	0.337	0.644	1.76	2.07	3.00	1.41	0.101	0.099	0.106	0.364	0.105	0.0803
Cd (D)	$\hat{\mu}$	0.00066	0.00125	0.00277	0.00462	0.0121	0.00270	0.00062	0.00262	0.00120	INS	0.00149	INS
	$\hat{\sigma}$	0.00117	0.00190	0.00385	0.00776	0.0125	0.00465	0.00246	0.00858	0.00425	INS	0.00430	INS
Cd (T)	$\hat{\mu}$	0.00598	0.00256	0.0161	0.0250	0.0466	0.0146	0.00161	0.00339	0.00180	0.00078	0.00213	INS
	$\hat{\sigma}$	0.00768	0.00324	0.0137	0.0180	0.0274	0.0143	0.00417	0.00685	0.00409	0.00387	0.00542	INS
Cr (D)	$\hat{\mu}$	0.592	0.344	0.600	0.631	0.672	0.590	0.139	0.152	0.151	0.0933	0.170	0.151
	$\hat{\sigma}$	0.403	0.239	0.389	0.419	0.451	0.383	0.109	0.112	0.111	0.0834	0.122	0.0735
Cr (T)	$\hat{\mu}$	1.56	0.885	1.66	1.84	1.53	1.63	0.353	0.389	0.388	0.148	0.379	0.287
	$\hat{\sigma}$	0.902	0.577	0.979	0.95	1.15	0.811	0.238	0.255	0.260	0.121	0.243	0.181
Cu (D)	$\hat{\mu}$	1.76	1.21	1.74	2.31	2.29	1.87	0.301	0.369	0.372	0.486	0.439	0.663
	$\hat{\sigma}$	0.673	0.381	0.572	0.987	1.30	0.622	0.113	0.132	0.122	0.214	0.143	0.424
Cu (T)	$\hat{\mu}$	3.38	2.30	3.96	5.98	6.21	4.02	0.569	0.686	0.697	0.789	0.794	1.05
	$\hat{\sigma}$	1.44	0.902	1.39	3.91	4.12	1.37	0.280	0.336	0.317	0.788	0.345	0.765
Pb (D)	$\hat{\mu}$	0.0389	0.0269	0.0967	0.0996	0.140	0.0980	0.00655	0.0107	0.0110	0.0253	0.0171	0.0235
	$\hat{\sigma}$	0.0251	0.0199	0.0508	0.0539	0.0918	0.0462	0.00784	0.0114	0.00899	0.0161	0.0101	0.0157
Pb (T)	$\hat{\mu}$	0.595	0.270	2.02	2.18	2.29	1.71	0.0805	0.0857	0.099	0.129	0.107	0.342
	$\hat{\sigma}$	0.342	0.161	1.22	1.28	1.52	0.935	0.0455	0.0448	0.0470	0.0697	0.0490	0.406
Hg (D)	$\hat{\mu}$	0.00099	0.00104	0.00205	0.00123	0.00128	0.00169	0.00073	0.00085	0.00084	0.00010	0.00086	0.00012
	$\hat{\sigma}$	0.00050	0.00051	0.00093	0.00072	0.00062	0.00084	0.00034	0.00039	0.00035	0.00012	0.00037	0.00003
Hg (T)	$\hat{\mu}$	0.00254	0.00260	0.00833	0.00718	0.00992	0.00647	0.00161	0.00172	0.00180	0.00078	0.00188	0.00078
	$\hat{\sigma}$	0.00136	0.00141	0.00377	0.00389	0.00499	0.00311	0.00088	0.00085	0.00091	0.00051	0.00096	0.00053
Mo (D)	$\hat{\mu}$	0.271	0.115	0.534	1.00	1.25	0.625	INS	INS	INS	INS	INS	INS
	$\hat{\sigma}$	0.146	0.100	0.292	0.456	0.565	INS	INS	INS	INS	INS	INS	INS
Mo (T)	$\hat{\mu}$	0.284	0.114	0.519	1.030	1.302	0.637	INS	INS	INS	INS	INS	INS
	$\hat{\sigma}$	0.144	0.096	0.273	0.559	0.5796	0.363	INS	INS	INS	INS	INS	INS
Ni (D)	$\hat{\mu}$	1.43	1.83	1.68	2.06	2.15	1.69	0.191	0.205	0.207	0.644	0.230	0.701
	$\hat{\sigma}$	0.374	1.27	0.415	0.671	0.657	0.444	0.0670	0.0691	0.0671	0.207	0.0796	0.186
Ni (T)	$\hat{\mu}$	2.06	2.23	2.40	3.12	2.96	2.44	0.308	0.340	0.341	0.754	0.360	0.826
	$\hat{\sigma}$	0.709	1.30	0.668	1.09	1.00	0.608	0.130	0.150	0.145	0.320	0.168	0.108
Se (D)	$\hat{\mu}$	INS	INS	INS	INS	INS	INS	INS	INS	INS	INS	INS	INS
	$\hat{\sigma}$	INS	INS	INS	INS	INS	INS	INS	INS	INS	INS	INS	INS
Se (T)	$\hat{\mu}$	0.135	0.168	0.269	0.233	0.205	0.215	INS	INS	INS	INS	INS	INS
	$\hat{\sigma}$	0.066	0.104	0.152	0.153	0.0906	0.131	INS	INS	INS	INS	INS	INS
Ag (D)	$\hat{\mu}$	0.00108	0.00081	0.00189	0.00060	0.00062	0.00116	0.00013	0.00036	0.00050	INS	0.00125	0.00133
	$\hat{\sigma}$	0.00203	0.00197	0.00462	0.00197	0.00231	0.00247	0.00001	0.00166	0.00216	INS	0.00259	0.00040
Ag (T)	$\hat{\mu}$	0.00475	0.00230	0.0161	0.0133	0.0101	0.0165	0.00201	0.00194	0.00268	INS	0.00525	INS
	$\hat{\sigma}$	0.00805	0.00434	0.0162	0.00898	0.00917	0.0158	0.00489	0.00419	0.00579	INS	0.00676	INS
Zn (D)	$\hat{\mu}$	12.9	4.40	10.8	11.5	20.1	9.98	0.397	0.498	0.497	5.12	0.977	28.9
	$\hat{\sigma}$	7.66	2.72	13.3	6.61	16.8	6.11	0.285	0.343	0.296	11.77	0.555	21.8
Zn (T)	$\hat{\mu}$	22.7	6.87	26.1	26.5	38.9	22.0	1.34	1.37	1.49	7.40	1.88	31.7
	$\hat{\sigma}$	19.7	3.45	16.9	18.4	22.9	17.0	0.860	0.839	0.870	13.23	0.99	23.2

μ_μ : Mean corrected for censored data
σ_σ : Standard deviation corrected for censored data
INS = Insufficient uncensored data to compute statistic.

Table A.13
Summary Statistics for QA/QC Qualified Ambient Water Quality Data
Miscellaneous Parameters

Surface Water Sample Location:		Amazon Creek at 29th Avenue	Willow Creek near 18th Avenue	Amazon Creek at Railroad Crossing	Amazon Diversion Channel at Royal Avenue	A3 Channel at Terry Street	Amazon Creek at Royal Avenue	Willamette River Upstream of Urban Growth Boundary (RM 186.9)	Willamette River at Knickerbocker Bridge (RM 183.9)	Willamette River at Owosso Bridge (RM 178.6)	Delta Ponds Above Willamette River Confluence	Willamette River Downstream of Beltline Bridge (RM 176.8)	Spring Creek at Beacon Drive East
Miscellaneous Parameters	**Statistic**												
NH_3 – as N (*mg/L*)	μ_μ	1.0	INS	0.3	< 0.1	< 0.1	< 0.1	INS	INS	INS	INS	< 0.1	INS
	σ_σ	2.0	INS	1.1	0.4	0.5	0.6	INS	INS	INS	INS	0.4	INS
$NO_3 + NO_2$ – as N (*mg/L*)	μ_μ	0.31	< 0.05	0.22	0.21	0.33	0.18	< 0.05	< 0.05	< 0.05	0.04	0.11	2.05
	σ_σ	0.23	0.19	0.28	0.39	0.36	0.30	0.09	0.10	0.09	0.19	0.08	0.80
TKN – as N (*mg/L*)	μ_μ	0.3	0.2	0.4	0.8	0.8	0.5	< 0.2	< 0.2	< 0.2	0.2	0.2	0.3
	σ_σ	0.4	0.5	0.4	0.8	0.8	0.4	0.5	0.4	0.5	0.5	0.3	0.4
P – Ortho (*mg/L*)	μ_μ	0.05	0.02	0.03	0.04	0.05	0.03	0.02	0.02	0.02	0.02	0.05	0.07
	σ_σ	0.02	0.03	0.03	0.04	0.04	0.02	0.01	0.01	0.01	0.01	0.03	0.02
P – Total (*mg/L*)	μ_μ	0.10	0.06	0.11	0.16	0.21	0.11	0.04	0.04	0.04	0.07	0.08	0.15
	σ_σ	0.07	0.03	0.06	0.08	0.11	0.07	0.03	0.03	0.04	0.06	0.05	0.07
BOD (*mg/L*)	μ_μ	< 2	< 2	< 2	2.1	2.3	< 2	INS	INS	INS	< 2	INS	4.7
	σ_σ	10	9.3	2.4	2.6	2.7	2.6	INS	INS	INS	4.2	INS	9.3
COD (*mg/L*)	μ_μ	< 5	5	15	23	24	16	INS	INS	INS	< 5	INS	< 5
	σ_σ	16	20	11	14	13	10	INS	INS	INS	10	INS	13
Dissolved Oxygen (*mg/L*)	μ_μ	8.6	8.5	7.6	7.1	6.9	7.4	8.5	8.5	8.2	5.9	8.8	8.1
	σ_σ	2.9	3.0	2.7	3.2	3.3	3.2	4.7	4.5	4.7	2.8	4.2	3.4
Calcium - Total (*mg/L*)	μ_μ	24	34	21	22	26	20	4.6	4.9	4.9	14	5.1	17
	σ_σ	7	72	7	8	9	7	1	1	1	4	1	5
Magnesium - Total (*mg/L*)	μ_μ	8.3	8.2	7.2	10	13	7.2	1.5	1.6	1.6	6.4	1.7	9.1
	σ_σ	2.3	7.6	2.6	4.3	5.1	2.8	0.3	0.2	0.3	2.0	0.2	2.7
Hardness (*mg eq* $CaCO_3$*/L*)	μ_μ	93	118	81	96	117	79	18	19	19	62	20	80
	σ_σ	26	209	27	37	43	29	2	2	2	19	2	23
Turbidity (*NU*)	μ_μ	16	17	23	36	25	26	6.8	7.0	7.2	5.2	7.3	5.8
	σ_σ	15	13	13	29	21	18	8.7	8.3	8.8	5.6	8.6	3.9
TSS (*mg/L*)	μ_μ	8.7	8.2	19	31	25	21	4.3	4.9	4.9	4.6	5.1	10
	σ_σ	13	10	17	31	33	20	12	10	11	12	11	7
TDS (*mg/L*)	μ_μ	153	222	138	149	171	134	40	42	41	81	42	100
	σ_σ	40	386	49	56	59	48	13	13	14	26	14	71
Specific Conductance (*µmos/cm*)	μ_μ	229	320	222	240	278	211	47	49	49	146	54	194
	σ_σ	67	559	73	88	95	76	5	5	7	42	7	56
Escherichia coli (*Col./100 mL*)	μ_μ	830	147	542	394	594	482	20	29	39	85	43	328
	σ_σ	2432	301	1751	1562	1131	1066	34	25	36	133	37	420
Fecal coliform (*Col./100 mL*)	μ_μ	362	116	250	133	342	277	15	21	32	54	37	407
	σ_σ	877	218	419	316	720	770	21	20	32	85	32	584
pH (*Units*)	μ_μ	7.6	7.1	7.4	7.4	7.4	7.5	7.4	7.3	7.3	7.0	7.1	6.9
	σ_σ	0.5	0.8	0.4	0.7	0.5	0.7	0.5	0.4	0.5	0.3	0.8	0.2
Temperature (°*C*)	μ_μ	11.8	11.2	13.8	14.9	14.6	14.4	11.3	11.3	11.2	11.2	11.4	12.5
	σ_σ	3.8	4.9	5.8	6.3	6.2	6.1	3.6	3.8	4.0	4.0	3.8	2.9
2,3,7,8-TCDD (Dioxin; *pg/L*)	μ_μ							INS				INS	
	σ_σ							INS				INS	

μ_μ : Mean corrected for censored data
σ_σ : Standard deviation corrected for censored data
INS = Insufficient uncensored data to compute statistic.

Table A.14
Analytes Showing Significant Seasonal Trend
Utilizing Seasonal Kendall Statistic[1]
Analysis of Water Quality Data Set

Monitoring Location	Analyte	Parameter				
		Tau	*S*	*Z*	*2ρ*	*m*
Willow Creek	[2] Lead, Dissolved	0.285	145	3.074	0.004	0.0012
	Zinc, Dissolved	0.365	179	3.895	0.000	0.2136
	Zinc, Total	0.265	130	2.824	0.009	0.1500
	[2] Total Kjeldahl Nitrogen	-0.313	-159	-3.480	0.001	-0.0167
Amazon Creek at 29th Avenue	[2] Lead, Total	-0.412	-245	-4.713	0.000	-0.0255
	Zinc, Total	0.429	255	4.906	0.000	0.5800
	Zinc, Dissolved	0.304	181	3.479	0.001	0.6333
Amazon Creek at Railroad Track Crossing	[2] Cadmium, Total	-0.313	-127	-3.236	0.002	-0.0006
	[2] Chromium, Dissolved	-0.335	-136	-3.419	0.001	-0.0318
	[2] Chromium, Total	-0.300	-122	-3.065	0.004	-0.0499
	[2] Lead, Total	-0.325	-132	-3.318	0.002	-0.0528
	[2] Mercury, Dissolved	-0.365	-148	-3.726	0.000	-8.8E-05
	Mercury, Total	-0.485	-197	-4.966	0.000	-0.0004
	Nickel, Dissolved	-0.288	-117	-2.939	0.007	-0.0250
	Zinc, Dissolved	0.286	116	2.915	0.007	0.3395
	Zinc, Total	0.276	112	2.812	0.010	0.8925
Amazon Diversion Channel at Royal Avenue	[2] Arsenic, Dissolved	-0.414	-212	-4.534	0.000	-0.0620
	Arsenic, Total	-0.381	-195	-4.170	0.000	-0.1105
	[2] Mercury, Dissolved	-0.345	-200	-3.930	0.000	-4.9E-05
	[2] Molybdenum, Dissolved	-0.429	-45	-2.838	0.009	-0.0674
	[2] Nickel, Dissolved	-0.408	-209	-4.471	0.000	-0.0707
	Nickel, Total	-0.338	-173	-3.697	0.000	-0.0700
	Zinc, Total	0.299	178	3.419	0.001	0.9442
	[2] Biochemical Oxygen Demand	-0.239	-142	-2.810	0.010	-0.0714
	[2] Total Kjeldahl Nitrogen	-0.247	-147	-2.854	0.009	-0.0273

[1] Significant at 2ρ = 0.01
[2] Assumes censored values in data set are one-half the reporting limit.

Table A.14 Continued
Analytes Showing Significant Seasonal Trend
Utilizing Seasonal Kendall Statistic[1]
Analysis of Water Quality Data Set

A3 Channel at Terry Street	[2] Arsenic, Dissolved	-0.573	-212	-5.659	0.000	-0.0709
	Arsenic, Total	-0.573	-212	-5.659	0.000	-0.1742
	[2] Cadmium, Total	-0.541	-200	-5.338	0.000	-0.0046
	[2] Chromium, Dissolved	-0.395	-146	-3.889	0.000	-0.0535
	Chromium, Total	-0.495	-183	-4.883	0.000	-0.1278
	Lead, Total	-0.319	-118	-3.138	0.003	-0.1165
	[2] Mercury, Dissolved	-0.476	-176	-4.697	0.000	-7.7E-05
	[2] Mercury, Total	-0.470	-174	-4.640	0.000	-0.0007
	Molybdenum, Dissolved	-0.489	-44	-3.006	0.005	-0.0750
	Nickel, Dissolved	-0.457	-169	-4.508	0.000	-0.0666
	Nickel, Total	-0.532	-197	-5.259	0.000	-0.1265
	[2] Silver, Total	-0.292	-108	-2.887	0.008	-0.0006
	[2] Biochemical Oxygen Demand	-0.297	-110	-3.009	0.005	-0.1250
	Total Phosphorus	-0.343	-127	-3.386	0.001	-0.0083
	Temperature	-0.349	-129	-3.437	0.001	-0.2620
	[2] Total Kjeldahl Nitrogen	-0.311	-115	-3.081	0.004	-0.0375
Amazon Creek at Royal Avenue	[2] Chromium, Dissolved	-0.305	-156	-3.331	0.002	-0.0323
	Chromium, Total	-0.303	-155	-3.312	0.002	-0.0566
	[2] Lead, Total	-0.509	-303	-5.833	0.000	-0.1050
	[2] Mercury, Total	-0.371	-209	-4.161	0.000	-0.0002
	Nickel, Total	-0.312	-160	-3.418	0.001	-0.0438
	[2] Zinc, Dissolved	0.442	263	5.061	0.000	0.5639
	Zinc, Total	0.345	205	3.940	0.000	0.7713
	[2] Ortho Phosphorus	-0.244	-145	-2.865	0.008	-0.0009
	Temperature	-0.313	-186	-3.577	0.001	-0.1786
	Total Suspended Solids	-0.296	-176	-3.387	0.001	-0.8333
	Turbidity	-0.314	-187	-3.603	0.001	-0.9375
Willamette River at Knickerbocker Bridge	Specific Conductance	0.274	163	3.143	0.003	0.3750
Willamette River Downstream of Beltline Bridge	[2] Ortho Phosphorus	-0.291	-163	-3.302	0.002	-0.0014
Delta Ponds above Willamette River Confluence	[2] Molybdenum, Dissolved	-0.607	-51	-3.581	0.001	-0.0147
	[2] Molybdenum, Total	-0.482	-41	-2.864	0.008	-0.0188
	Dissolved Oxygen	0.568	54	3.531	0.001	0.4500

[1] Significant at 2ρ = 0.01
[2] Assumes censored values in data set are one-half the reporting limit.

Table A.15
Comparison of 2013/2014 Data to Historical Data
Analytes Showing Significant Change
Utilizing Mann-Whitney Statistic[1]
Amazon Basin Monitoring Sites

Monitoring Location	Analyte	Units	Average Analyte Value Monitoring Period	
			Historical	2013/2014
Willow Creek	[2] Zinc, Dissolved	µg/L	4.32	14.3
Amazon Creek at 29th Avenue	[2] Lead, Total	µg/L	0.649	0.256
	Zinc, Dissolved	µg/L	12.7	19.9
	Zinc, Total	µg/L	22.5	26.0
	Magnesium, Total	mg/L	8.3	8.5
Amazon Creek at Railroad Track Crossing	[2] Lead, Dissolved	µg/L	0.0980	0.135
	Zinc, Dissolved	µg/L	10.4	16.4
	Zinc, Total	µg/L	25.6	33.0
	Hardness	mg eq $CaCO_3$/L	81.5	79.8
Amazon Diversion Channel at Royal Avenue	[2] Lead, Dissolved	µg/L	0.102	0.156
	Hardness	mg eq $CaCO_3$/L	97.0	87.7
A3 Channel at Terry Street	[2] Cadmium, Total	µg/L	0.0514	0.0221
	[2] Chromium, Total	µg/L	1.58	0.636
	[2] Lead, Total	µg/L	2.36	1.15
	[2] Chemical Oxygen Demand	mg/L	24	23
	Dissolved Oxygen	mg/L	7.5	8.2
	Magnesium, Total	mg/L	12.9	13.1
	[2] Total Kjeldahl Nitrogen	mg/L	0.83	0.40
Amazon Creek at Royal Avenue	Chromium, Total	µg/L	1.66	1.05
	[2] Lead, Dissolved	µg/L	0.0991	0.137
	[2] Lead, Total	µg/L	1.77	0.781
	Nickel, Total	µg/L	2.47	1.95
	[2] Zinc, Dissolved	µg/L	9.36	21.6
	Zinc, Total	µg/L	21.5	32.2
	Dissolved Oxygen	mg/L	7.9	8.6
	Hardness	mg eq $CaCO_3$/L	79.4	67.0
	Magnesium, Total	mg/L	7.3	5.9
	Total Dissolved Solids	mg/L	137	119

[1] Significant at $\alpha = 0.05$
[2] Assumes censored values in data set are one-half the reporting limit.
Shaded cells indicate the higher average.

Table A.15 Continued
Comparison of 2013/2014 Data to Historical Data
Analytes Showing Significant Change
Utilizing Mann-Whitney Statistic[1]
Willamette River Monitoring Sites

Monitoring Location	Analyte	Units	Average Analyte Value Monitoring Period	
			Historical	2013/2014
Willamette River Upstream of Urban Growth Boundary	Phosphorus, Total	mg/L	0.039	0.035
	Total Suspended Solids	mg/L	5.1	2.7
	Turbidity	NTU	6.9	4.8
Willamette River at Knickerbocker Bridge	Phosphorus, Total	mg/L	0.040	0.035
	Total Suspended Solids	mg/L	5.1	3.0
	Turbidity	NTU	7.1	5.2
Willamette River at Owosso Bridge	Total Suspended Solids	mg/L	5.5	3.1
	Turbidity	NTU	7.3	5.5
Willamette River Downstream of Beltline Bridge	[2] Lead, Total	µg/L	0.116	0.0714
	Chemical Oxygen Demand	mg/L	6.0	2.9
	[2] Phosphorus, Total	mg/L	0.078	0.058
	[2] Total Kjeldahl Nitrogen	mg/L	0.33	0.18
	[2] Total Suspended Solids	mg/L	5.4	3.6
	Turbidity	NTU	7.3	5.3
Delta Ponds above Willamette River Confluence near Beltline Bridge	Calcium, Total	mg/L	14.5	14.0
	[2] Total Kjeldahl Nitrogen	mg/L	0.38	0.24
	Turbidity	NTU	5.2	4.8
Spring Creek at Beacon Drive East	[2] Lead, Total	µg/L	0.438	0.0767
	Calcium, Total	mg/L	16.0	19.5
	Magnesium, Total	mg/L	8.5	10.6

[1] Significant at α = 0.05
[2] Assumes censored values in data set are one-half the reporting limit.
Shaded cells indicate the higher average.

Table A.16
Comparison of Metals Water Quality Data for 2013/2014 to Historical Data Set
Mann-Whitney Statistic

Monitoring Location	As (D)	As (T)	Cd (D)	Cd (T)	Cr (D)	Cr (T)	Cu (D)	Cu (T)	Pb (D)	Pb (T)	Hg (D)	Hg (T)	Mo (D)	Mo (T)	Ni (D)	Ni (T)	Se (D)	Se (T)	Ag (D)	Ag (T)	Zn (D)	Zn (T)
Amazon Creek at 29th Avenue																						
Mann-Whitney U	250	250.5	159	246	209.5	156	290.5	226	188	110	284	194.5	102	102.5	208.5	153.5	85	87	222	180	106	151.5
Z	-0.26	-0.25	-1.86	-0.64	-0.69	-1.73	-0.05	-0.95	-1.42	-2.55	-0.06	-1.33	-0.50	-0.48	-0.93	-1.76	-1.37	-1.04	-0.88	-1.58	-2.62	-1.99
Asymp. Sig. (2-tailed)	0.795	0.801	0.063	0.522	0.492	0.084	0.961	0.343	0.155	0.011	0.955	0.184	0.616	0.628	0.352	0.078	0.170	0.301	0.377	0.114	0.009	0.047
Exact Sig. [2*(1-tailed Sig.)]													0.637	0.637			0.301	0.333				
Willow Creek																						
Mann-Whitney U	148.5	197	132.5	147.5	149.5	98	100.5	176	124.5	118	199	161	44	41.5	124	159.5	55	53	104.5	105	63	82
Z	-0.93	-0.01	-1.36	-1.15	-0.06	-1.91	-1.40	-0.75	-1.58	-1.66	-0.20	-0.94	-1.44	-1.58	-1.42	-0.76	-0.93	-0.96	-1.90	-1.95	-2.12	-1.78
Asymp. Sig. (2-tailed)	0.354	0.992	0.173	0.249	0.956	0.057	0.161	0.454	0.115	0.096	0.845	0.347	0.151	0.115	0.156	0.449	0.355	0.335	0.058	0.051	0.034	0.075
Exact Sig. [2*(1-tailed Sig.)]	0.365	1.000			0.958	0.056	0.168						0.179	0.135	0.163	0.461	0.478	0.367			0.031	0.076
Amazon Creek at Railroad Track Crossing																						
Mann-Whitney U	192	224.5	165	206	157.5	129.5	155.5	220	113	132	227.5	127.5	89.5	86.5	221	174.5	96	99	118	180	120	114.5
Z	-0.73	-0.17	-1.23	-0.54	-1.22	-1.84	-1.36	-0.29	-2.05	-1.77	-0.11	-1.88	-0.92	-1.02	-0.27	-1.07	-0.71	-0.60	-1.50	-0.99	-2.01	-2.10
Asymp. Sig. (2-tailed)	0.466	0.869	0.220	0.591	0.224	0.065	0.173	0.771	0.041	0.076	0.910	0.060	0.358	0.308	0.784	0.284	0.475	0.547	0.133	0.324	0.045	0.036
Exact Sig. [2*(1-tailed Sig.)]													0.368	0.317			0.559	0.568	0.147			
Amazon Diversion Channel at Royal Avenue																						
Mann-Whitney U	235.5	230	213	220	147	162.5	254	268	138	193	271	234	100	104	198.5	176.5	72	109	160.5	219	220.5	227
Z	-0.44	-0.57	-0.98	-1.00	-1.78	-1.60	-0.52	-0.36	-2.11	-1.38	-0.20	-0.77	-0.48	-0.43	-1.05	-1.42	-1.70	-0.27	-1.74	-1.02	-0.96	-0.93
Asymp. Sig. (2-tailed)	0.659	0.571	0.327	0.317	0.075	0.110	0.602	0.717	0.035	0.168	0.840	0.442	0.632	0.664	0.295	0.157	0.089	0.786	0.082	0.310	0.337	0.350
Exact Sig. [2*(1-tailed Sig.)]													0.652	0.684			0.160	0.807				
A3 Channel at Terry Street																						
Mann-Whitney U	142.5	102	178	81	98	75	149	131	162	77	168	135	63	66.5	164.5	102.5	49	85	130	183	139	180
Z	-0.86	-1.70	-0.14	-2.09	-1.67	-2.24	-0.77	-1.12	-0.51	-2.20	-0.39	-1.01	-1.08	-0.94	-0.46	-1.69	-2.03	-0.20	-1.17	-0.04	-0.96	-0.15
Asymp. Sig. (2-tailed)	0.392	0.089	0.886	0.036	0.096	0.025	0.444	0.261	0.612	0.028	0.698	0.314	0.282	0.349	0.648	0.091	0.042	0.841	0.241	0.968	0.335	0.881
Exact Sig. [2*(1-tailed Sig.)]	0.403	0.092	0.899	0.034	0.099	0.023	0.462	0.275	0.629	0.025	0.714	0.329	0.301	0.360	0.657	0.092	0.108	0.862	0.266	0.977	0.351	0.893
Amazon Creek at Royal Avenue																						
Mann-Whitney U	219	176.5	177.5	177.5	164	106.5	143	225.5	111.5	86	206.5	161	89	90	176.5	98	62	74	130	180	45.5	83.5
Z	-0.06	-0.78	-0.99	-1.02	-0.92	-1.98	-1.57	-0.30	-2.01	-2.43	-0.52	-1.21	-0.31	-0.28	-0.81	-2.12	-1.47	-0.88	-1.73	-0.98	-3.06	-2.48
Asymp. Sig. (2-tailed)	0.953	0.438	0.321	0.309	0.357	0.048	0.117	0.765	0.044	0.015	0.600	0.226	0.753	0.782	0.419	0.034	0.141	0.380	0.084	0.329	0.002	0.013
Exact Sig. [2*(1-tailed Sig.)]													0.774	0.802			0.202	0.406				

b. Not corrected for ties.

Shaded cells significant at $\alpha = 0.05$

Table A.16
Comparison of Metals Water Quality Data for 2013/2014 to Historical Data Set
Mann-Whitney Statistic

Monitoring Location	As (D)	As (T)	Cd (D)	Cd (T)	Cr (D)	Cr (T)	Cu (D)	Cu (T)	Pb (D)	Pb (T)	Hg (D)	Hg (T)	Mo (D)	Mo (T)	Ni (D)	Ni (T)	Se (D)	Se (T)	Ag (D)	Ag (T)	Zn (D)	Zn (T)
Willamette River Upstream of Urban Growth Boundary																						
Mann-Whitney U	248	224.5	153	147	198.5	153.5	206.5	204	262	168	223	191	86	16	256.5	204	12	16	120	114	255	160
Z	-0.20	-0.61	-1.88	-2.03	-0.94	-1.74	-0.38	-1.19	-0.25	-1.71	-0.79	-1.35	-1.37	-4.47	-0.02	-0.85	-4.66	-4.02	-2.31	-2.51	-0.18	-1.72
Asymp. Sig. (2-tailed)	0.839	0.541	0.061	0.042	0.347	0.082	0.701	0.232	0.801	0.088	0.432	0.177	0.170	0.000	0.981	0.393	0.000	0.000	0.021	0.012	0.854	0.086
Exact Sig. [2*(1-tailed Sig.)]													.317b	.000b			.000b	.000b				
Willamette River at Knickerbocker Bridge																						
Mann-Whitney U	246.5	236.5	171	153	212	183.5	260.5	236	269	203.5	241	196	82	50	227.5	227.5	3	16.5	123	138	268	191
Z	-0.14	-0.43	-1.66	-1.95	-0.69	-1.28	-0.27	-0.74	-0.19	-1.20	-0.56	-1.28	-1.55	-2.97	-0.52	-0.60	-5.06	-4.11	-2.29	-2.17	-0.12	-1.38
Asymp. Sig. (2-tailed)	0.892	0.671	0.097	0.051	0.492	0.201	0.786	0.460	0.849	0.229	0.577	0.201	0.121	0.003	0.600	0.546	0.000	0.000	0.022	0.030	0.906	0.168
Exact Sig. [2*(1-tailed Sig.)]													.257b	.024b			.000b	.000b				
Willamette River at Owosso Bridge																						
Mann-Whitney U	253	254	165	165	216.5	154.5	267.5	249.5	214.5	162	270	214.5	114	83	238	245.5	14	21	114	138	209.5	228.5
Z	-0.13	-0.15	-1.72	-1.78	-0.66	-1.69	-0.17	-0.55	-1.02	-1.74	-0.13	-1.01	-0.13	-1.46	-0.40	-0.29	-4.57	-3.83	-2.44	-2.14	-1.02	-0.81
Asymp. Sig. (2-tailed)	0.900	0.877	0.085	0.076	0.512	0.090	0.866	0.584	0.309	0.082	0.895	0.311	0.900	0.145	0.688	0.775	0.000	0.000	0.015	0.032	0.308	0.417
Exact Sig. [2*(1-tailed Sig.)]													.935b	.271b			.000b	.000b				
Willamette River Downstream of Beltline Bridge																						
Mann-Whitney U	201	229.5	165	147	255	181.5	231	222.5	265.5	136.5	179	171	69	56	244	230.5	16	18	75	216	157	273.5
Z	-0.86	-0.53	-1.75	-2.03	-0.05	-1.31	-0.02	-0.96	-0.24	-2.13	-1.47	-1.64	-1.81	-2.35	-0.31	-0.56	-4.49	-3.80	-3.03	-1.01	-1.79	-0.21
Asymp. Sig. (2-tailed)	0.388	0.594	0.081	0.042	0.962	0.191	0.981	0.335	0.810	0.033	0.142	0.101	0.070	0.019	0.757	0.577	0.000	0.000	0.002	0.315	0.074	0.837
Exact Sig. [2*(1-tailed Sig.)]													.114b	.047b			.000b	.000b				
Delta Ponds above Willamette River Confluence near Beltline Bridge																						
Mann-Whitney U	79.5	81	32.5	27.5	44.5	75.5	83.5	79	39	50	70	80	42	40	84	74.5	10	77	20	27.5	59.5	73
Z	-0.23	-0.17	-2.49	-2.77	-1.44	-0.40	-0.06	-0.25	-1.95	-1.33	-1.00	-0.21	-1.56	-1.72	-0.04	-0.44	-3.91	-0.03	-3.13	-2.72	-1.07	-0.50
Asymp. Sig. (2-tailed)	0.817	0.867	0.013	0.006	0.149	0.689	0.950	0.801	0.051	0.183	0.316	0.832	0.119	0.085	0.966	0.659	0.000	0.979	0.002	0.006	0.284	0.614
Exact Sig. [2*(1-tailed Sig.)]	.823b	.887b	.024b	.012b	.155b	.699b	.951b	.823b	.054b	.197b	.554b	.855b	.128b	.091b	.984b	.669b	.001b	1.000b	.004b	.012b	.294b	.639b

Table A.17
Comparison of Miscellaneous Water Quality Data for 2013/2014 to Historical Data Set
Mann-Whitney Statistic

Monitoring Location	NH_3	BOD	Ca (T)	COD	Cond	DO	E. coli	Fecal Coliform	Hardness	Mg (T)	NO_3+NO_2	Field pH	Ortho P	Total P	Temp	TDS	TKN	TSS	Turbidity
Amazon Creek at 29th Avenue																			
Mann-Whitney U	250	250.5	159	246	209.5	156	290.5	226	188	110	284	194.5	102	102.5	208.5	153.5	85	87	222
Z	-0.26	-0.25	-1.86	-0.64	-0.69	-1.73	-0.05	-0.95	-1.42	-2.55	-0.06	-1.33	-0.50	-0.48	-0.93	-1.76	-1.37	-1.04	-0.88
Asymp. Sig. (2-tailed)	0.795	0.801	0.063	0.522	0.492	0.084	0.961	0.343	0.155	0.011	0.955	0.184	0.616	0.628	0.352	0.078	0.170	0.301	0.377
Exact Sig. [2*(1-tailed Sig.)]													0.637	0.637			0.301	0.333	
Willow Creek																			
Mann-Whitney U	148.5	197	132.5	147.5	149.5	98	100.5	176	124.5	118	199	161	44	41.5	124	159.5	55	53	104.5
Z	-0.93	-0.01	-1.36	-1.15	-0.06	-1.91	-1.40	-0.75	-1.58	-1.66	-0.20	-0.94	-1.44	-1.58	-1.42	-0.76	-0.93	-0.96	-1.90
Asymp. Sig. (2-tailed)	0.354	0.992	0.173	0.249	0.956	0.057	0.161	0.454	0.115	0.096	0.845	0.347	0.151	0.115	0.156	0.449	0.355	0.335	0.058
Exact Sig. [2*(1-tailed Sig.)]	0.365	1.000			0.958	0.056	0.168						0.179	0.135	0.163	0.461	0.478	0.367	
Amazon Creek at Railroad Track Crossing																			
Mann-Whitney U	192	224.5	165	206	157.5	129.5	155.5	220	113	132	227.5	127.5	89.5	86.5	221	174.5	96	99	118
Z	-0.73	-0.17	-1.23	-0.54	-1.22	-1.84	-1.36	-0.29	-2.05	-1.77	-0.11	-1.88	-0.92	-1.02	-0.27	-1.07	-0.71	-0.60	-1.50
Asymp. Sig. (2-tailed)	0.466	0.869	0.220	0.591	0.224	0.065	0.173	0.771	0.041	0.076	0.910	0.060	0.358	0.308	0.784	0.284	0.475	0.547	0.133
Exact Sig. [2*(1-tailed Sig.)]													0.368	0.317			0.559	0.568	0.147
Amazon Diversion Channel at Royal Avenue																			
Mann-Whitney U	235.5	230	213	220	147	162.5	254	268	138	193	271	234	100	104	198.5	176.5	72	109	160.5
Z	-0.44	-0.57	-0.98	-1.00	-1.78	-1.60	-0.52	-0.36	-2.11	-1.38	-0.20	-0.77	-0.48	-0.43	-1.05	-1.42	-1.70	-0.27	-1.74
Asymp. Sig. (2-tailed)	0.659	0.571	0.327	0.317	0.075	0.110	0.602	0.717	0.035	0.168	0.840	0.442	0.632	0.664	0.295	0.157	0.089	0.786	0.082
Exact Sig. [2*(1-tailed Sig.)]													0.652	0.684			0.160	0.807	
A3 Channel at Terry Street																			
Mann-Whitney U	142.5	102	178	81	98	75	149	131	162	77	168	135	63	66.5	164.5	102.5	49	85	130
Z	-0.86	-1.70	-0.14	-2.09	-1.67	-2.24	-0.77	-1.12	-0.51	-2.20	-0.39	-1.01	-1.08	-0.94	-0.46	-1.69	-2.03	-0.20	-1.17
Asymp. Sig. (2-tailed)	0.392	0.089	0.886	0.036	0.096	0.025	0.444	0.261	0.612	0.028	0.698	0.314	0.282	0.349	0.648	0.091	0.042	0.841	0.241
Exact Sig. [2*(1-tailed Sig.)]	0.403	0.092	0.899	0.034	0.099	0.023	0.462	0.275	0.629	0.025	0.714	0.329	0.301	0.36	0.657	0.092	0.108	0.862	0.266
Amazon Creek at Royal Avenue																			
Mann-Whitney U	219	176.5	177.5	177.5	164	106.5	143	225.5	111.5	86	206.5	161	89	90	176.5	98	62	74	130
Z	-0.06	-0.78	-0.99	-1.02	-0.92	-1.98	-1.57	-0.30	-2.01	-2.43	-0.52	-1.21	-0.31	-0.28	-0.81	-2.12	-1.47	-0.88	-1.73
Asymp. Sig. (2-tailed)	0.953	0.438	0.321	0.309	0.357	0.048	0.117	0.765	0.044	0.015	0.600	0.226	0.753	0.782	0.419	0.034	0.141	0.380	0.084
Exact Sig. [2*(1-tailed Sig.)]													0.774	0.802			0.202	0.406	

b. Not corrected for ties.

Shaded cells significant at $\alpha = 0.05$

Table A.17
Comparison of Miscellaneous Water Quality Data for 2013/2014 to Historical Data Set
Mann-Whitney Statistic

Monitoring Location	NH_3	BOD	Ca (T)	COD	Cond	DO	E. coli	Fecal Coliform	Hardness	Mg (T)	NO_3+NO_2	Field pH	Ortho P	Total P	Temp	TDS	TKN	TSS	Turbidity
Willamette River Upstream of Urban Growth Boundary																			
Mann-Whitney U	248	224.5	153	147	198.5	153.5	206.5	204	262	168	223	191	86	16	256.5	204	12	16	120
Z	-0.20	-0.61	-1.88	-2.03	-0.94	-1.74	-0.38	-1.19	-0.25	-1.71	-0.79	-1.35	-1.37	-4.47	-0.02	-0.85	-4.66	-4.02	-2.31
Asymp. Sig. (2-tailed)	0.839	0.541	0.061	0.042	0.347	0.082	0.701	0.232	0.801	0.088	0.432	0.177	0.170	0.000	0.981	0.393	0.000	0.000	0.021
Exact Sig. [2*(1-tailed Sig.)]													0.317	0			0	0	
Willamette River at Knickerbocker Bridge																			
Mann-Whitney U	246.5	236.5	171	153	212	183.5	260.5	236	269	203.5	241	196	82	50	227.5	227.5	3	16.5	123
Z	-0.14	-0.43	-1.66	-1.95	-0.69	-1.28	-0.27	-0.74	-0.19	-1.20	-0.56	-1.28	-1.55	-2.97	-0.52	-0.60	-5.06	-4.11	-2.29
Asymp. Sig. (2-tailed)	0.892	0.671	0.097	0.051	0.492	0.201	0.786	0.460	0.849	0.229	0.577	0.201	0.121	0.003	0.600	0.546	0.000	0.000	0.022
Exact Sig. [2*(1-tailed Sig.)]													0.257	0.024			0	0	
Willamette River at Owosso Bridge																			
Mann-Whitney U	253	254	165	165	216.5	154.5	267.5	249.5	214.5	162	270	214.5	114	83	238	245.5	14	21	114
Z	-0.13	-0.15	-1.72	-1.78	-0.66	-1.69	-0.17	-0.55	-1.02	-1.74	-0.13	-1.01	-0.13	-1.46	-0.40	-0.29	-4.57	-3.83	-2.44
Asymp. Sig. (2-tailed)	0.900	0.877	0.085	0.076	0.512	0.090	0.866	0.584	0.309	0.082	0.895	0.311	0.900	0.145	0.688	0.775	0.000	0.000	0.015
Exact Sig. [2*(1-tailed Sig.)]													0.935	0.271			0	0	
Willamette River Downstream of Beltline Bridge																			
Mann-Whitney U	201	229.5	165	147	255	181.5	231	222.5	265.5	136.5	179	171	69	56	244	230.5	16	18	75
Z	-0.86	-0.53	-1.75	-2.03	-0.05	-1.31	-0.02	-0.96	-0.24	-2.13	-1.47	-1.64	-1.81	-2.35	-0.31	-0.56	-4.49	-3.80	-3.03
Asymp. Sig. (2-tailed)	0.388	0.594	0.081	0.042	0.962	0.191	0.981	0.335	0.810	0.033	0.142	0.101	0.070	0.019	0.757	0.577	0.000	0.000	0.002
Exact Sig. [2*(1-tailed Sig.)]													0.114	0.047			0	0	
Delta Ponds above Willamette River Confluence near Beltline Bridge																			
Mann-Whitney U	79.5	81	32.5	27.5	44.5	75.5	83.5	79	39	50	70	80	42	40	84	74.5	10	77	20
Z	-0.23	-0.17	-2.49	-2.77	-1.44	-0.40	-0.06	-0.25	-1.95	-1.33	-1.00	-0.21	-1.56	-1.72	-0.04	-0.44	-3.91	-0.03	-3.13
Asymp. Sig. (2-tailed)	0.817	0.867	0.013	0.006	0.149	0.689	0.950	0.801	0.051	0.183	0.316	0.832	0.119	0.085	0.966	0.659	0.000	0.979	0.002
Exact Sig. [2*(1-tailed Sig.)]	0.823	0.887	0.024	0.012	0.155	0.699	0.951	0.823	0.054	0.197	0.554	0.855	0.128	0.091	0.984	0.669	0.001	1	0.004
Spring Creek at Beacon Drive East																			
Mann-Whitney U	17	12	6	10	15.5	16	21	12	11	4	16	11	18.5	17	9	18	19	14	17
Z	-0.65	-1.31	-2.34	-1.71	-0.85	-0.78	-0.13	-1.31	-1.44	-2.35	-1.12	-1.46	-0.47	-0.66	-1.70	-0.52	-0.41	-0.86	-0.45
Asymp. Sig. (2-tailed)	0.514	0.192	0.020	0.087	0.395	0.433	0.896	0.192	0.150	0.019	0.263	0.144	0.641	0.506	0.090	0.602	0.680	0.391	0.651
Exact Sig. [2*(1-tailed Sig.)]	0.571	0.226	0.04	0.138	0.412	0.489	0.949	0.226	0.177	0.018	0.489	0.177	0.661	0.571	0.104	0.661	0.753	0.454	0.733

b. Not corrected for ties.
Shaded cells significant at $\alpha = 0.05$

Table A.18
Intra-Basin Comparison of Water Quality Data
Using Mann-Whitney Statistic[1]
Metals (*µg/L*)

Monitoring Locations	As (D)	As (T)	Cd (D)	Cd (T)	Cr (D)	Cr (T)	Cu (D)	Cu (T)	Pb (D)	Pb (T)	Hg (D)	Hg (T)	Mo (D)	Mo (T)	Ni (D)	Ni (T)	Se (D)	Se (T)	Ag (D)	Ag (T)	Zn (D)	Zn (T)
Amazon Basin Comparisons																						
Amazon Creek at 29th Avenue		1.09		0.00598	0.592	0.344	1.76	3.38	0.0389	0.595			0.271	0.284							12.9	22.7
Willow Creek		1.41		0.00256	0.600	0.885	1.21	2.30	0.0269	0.270			0.115	0.114							4.40	6.87
Amazon Creek at 29th Avenue	0.888	1.09		0.00598				3.38	0.0389	0.595	0.00099	0.00254	0.271	0.284	1.43	2.06		0.135		0.00475	12.9	22.7
Amazon Creek at Railroad Crossing	2.49	3.97		0.0161				3.96	0.0967	2.02	0.00205	0.00833	0.534	0.519	1.68	2.40		0.269		0.0161	10.8	26.1
Amazon Creek at 29th Avenue	0.888	1.09	0.00066	0.00598		1.56	1.76	3.38	0.0389	0.595		0.00254	0.271	0.284	1.43	2.06		0.135		0.00475	12.9	
Amazon Diversion Channel at Royal	2.33	3.95	0.00462	0.0250		1.84	2.31	5.98	0.0996	2.18		0.00718	1.00	1.03	2.06	3.12		0.233		0.0133	11.5	
Amazon Creek at Railroad Crossing	2.49			0.0161			1.74	3.96			0.00205	0.00833	0.534	0.519	1.68	2.40						
Amazon Diversion Channel at Royal	2.33			0.0466			2.31	6.21			0.00123	0.00992	1.00	1.03	2.06	3.12						
A3 Channel at Terry Street	2.19		0.0121	0.0466				6.21		2.29	0.00128	0.00992	1.25	1.30	2.15	2.96					20.1	38.9
Amazon Creek at Royal Avenue	2.28		0.00270	0.0146				4.02		1.71	0.00169	0.00647	0.625	0.637	1.69	2.44					9.98	22.0
Amazon Creek at 29th Avenue	0.888	1.09		0.00598				3.38	0.0389	0.595	0.00099	0.00254	0.271	0.284	1.43	2.06				0.00475	12.9	
Amazon Creek at Royal Avenue	2.28	3.40		0.0146				4.02	0.0980	1.71	0.00169	0.00647	0.625	0.637	1.69	2.44				0.0165	9.98	
Willamette Basin Comparisons																						
Upstream of Urban Growth Boundary	0.203	0.268					0.301	0.569														
Knickerbocker Bridge	0.236	0.313					0.369	0.686														
Knickerbocker Bridge										0.0107												
Owosso Bridge										0.0110												
Owosso Bridge							0.372	0.697													0.497	1.49
Downstream of Belt Line Bridge							0.439	0.794													0.977	1.88
Upstream of Urban Growth Boundary	0.203	0.268					0.301	0.569	0.00655	0.0805	0.00073	0.00161			0.191	0.308				0.00201	0.397	1.34
Downstream of Beltline Bridge	0.245	0.330					0.439	0.794	0.0171	0.107	0.00086	0.00188			0.230	0.360				0.00525	0.997	1.88
Owosso Bridge	0.243	0.326			0.151	0.388	0.372		0.0110	0.099	0.00084	0.00180			0.207	0.341					0.497	1.49
Delta Ponds	0.404	0.543			0.0933	0.148	0.486		0.0253	0.129	0.00010	0.00078			0.644	0.754					5.12	7.40
Amazon Creek at 29th Avenue	0.888	1.09			0.592	1.56	1.76	3.38	0.0389	0.595	0.00099	0.00254			1.43	2.06					12.9	
Spring Creek at Beacon Drive East	0.329	0.392			0.151	0.287	0.663	1.05	0.0235	0.342	0.00012	0.00078			0.701	0.826					28.9	

[1]Significant at α = 0.05 for reported means.
Shaded cells indicate downstream analyte value greater than upstream site. Amazon Creek M2 at 29th Avenue comparisons to Spring Creek and Willow Creek sub-basins are exceptions; greatest values are shaded.

Table A.19
Intra-Basin Comparison of Water Quality Data
Using Mann-Whitney Statistic[1]
Miscellaneous Parameters

Monitoring Location	NH_3 (*mg/L*)	BOD (*mg/L*)	Ca (T) (*mg/L*)	COD (*mg/L*)	Cond (µmhos/cm)	DO (*mg/L*)	*E. coli* (MPN/*100 mL*)	Fecal Coliform (MPN/*100 mL*)	Hardness (*mg eq/L*)	Mg (T) (*mg/L*)	NO_3+NO_2 (*mg/L*)	pH (*Units*)	P (Ortho) (*mg/L*)	P (T) (*mg/L*)	Temp (°C)	TDS (*mg/L*)	TKN (*mg/L*)	TSS (*mg/L*)	Turbidity (*NU*)
Amazon Basin Comparisons																			
Amazon Creek at 29th Avenue							830	362		8.3	0.31	7.6	0.05	0.10					
Willow Creek							147	116		8.2	< 0.05	7.1	0.02	0.06					
Amazon Creek at 29th Avenue			24	< 5		8.6	830	362	93	8.3	0.31	7.6	0.05		11.8	153		8.7	16
Amazon Creek at Railroad Track Crossing			21	15		7.6	542	250	81	7.2	0.22	7.4	0.03		13.8	138		19	23
Amazon Creek at 29th Avenue		< 2		< 5		8.6	830	362		8.3	0.31	7.6	0.05	0.10	11.8		0.3	8.7	16
Amazon Diversion Channel at Royal Ave.		2.1		23		7.1	394	133		10	0.21	7.4	0.04	0.16	14.9		0.8	31	36
Amazon Creek at Railroad Track Crossing				15			542	250	81	7.2				0.11			0.4	19	23
Amazon Diversion Channel at Royal Ave.				23			394	133	96	10				0.16			0.8	31	36
A3 Channel at Terry Street		2.3	26	24	278				117	13	0.33		0.05	0.21		171	0.8		
Amazon Creek at Royal Avenue		< 2	20	16	211				79	7.2	0.18		0.03	0.11		134	0.5		
Amazon Creek at 29th Avenue			24	< 5		8.6	830	362	93	8.3	0.31	7.6	0.05		11.8	153	0.3	8.7	16
Amazon Creek at Royal Avenue			20	16		7.4	482	277	79	7.2	0.18	7.5	0.03		14.4	134	0.5	21	26
Willamette River Comparisons																			
Upstream of Urban Growth Boundary			4.6		47		20	15	18										
Knickerbocker Bridge			4.9		49		29	21	19										
Knickerbocker Bridge							29	21											
Owosso Bridge							39	32											
Owosso Bridge					49						< 0.05		0.02	0.04			< 0.2		
Downstream of Belt Line Bridge					54						0.11		0.05	0.08			0.2		
Upstream of Urban Growth Boundary			4.6		47		20	15	18	1.5	< 0.05	7.4	0.02	0.04		40	< 0.2	4.3	6.8
Downstream of Belt Line Bridge			5.1		54		43	37	20	1.7	0.11	7.1	0.05	0.08		42	0.2	5.1	7.3
Owosso Bridge			4.9		49	8.2			19	1.6		7.3		0.04		41	< 0.2		
Delta Ponds			14		146	5.9			62	6.4		7.0		0.07		81	0.2		
Amazon Creek at 29th Avenue			24				830				0.31	7.6	0.05	0.10		153			
Spring Creek at Beacon Drive East			17				328				2.05	6.9	0.07	0.15		100			

[1]Significant at α = 0.05 for reported means.
Shaded cells indicate downstream analyte value greater than upstream site. Amazon Creek M2 at 29th Avenue comparisons to Spring Creek and Willow Creek sub-basins are exceptions; greatest values are shaded.

Table A.20
Mann-Whitney Statistic Output for
Intra-Basin Comparison of Water Quality Data

Monitoring Location	As (D)	As (T)	Cd (D)	Cd (T)	Cr (D)	Cr (T)	Cu (D)	Cu (T)	Pb (D)	Pb (T)	Hg (D)	Hg (T)	Mo (D)	Mo (T)	Ni (D)	Ni (T)	Se (D)	Se (T)	Ag (D)	Ag (T)	Zn (D)	Zn (T)
Amazon Creek at 29th Avenue : Willow Creek																						
Mann-Whitney U	3776.5	3047.5	4326	3961	2574	2614	2603	2821.5	3398.5	1943	4070	4460.5	353.5	327.5	3644	4049.5	681	700	4336	4326	1634.5	868
Z	-0.62	-2.72	-0.43	-1.76	-3.20	-4.17	-5.33	-5.04	-3.21	-6.95	-1.23	-0.47	-4.10	-4.37	-1.24	-0.09	-0.78	-0.66	-0.31	-1.06	-7.74	-9.83
Asymp. Sig. (2-tailed)	0.537	0.006	0.665	0.079	0.001	0.000	0.000	0.000	0.001	0.000	0.218	0.641	0.000	0.000	0.215	0.931	0.433	0.509	0.759	0.291	0.000	0.000
Amazon Creek at 29th Avenue : Amazon Creek at Railroad Track Crossing																						
Mann-Whitney U	419.5	66.5	3609	2886.5	3555.5	3477.5	4169.5	3017	1296	1298	1668.5	501	516	542	2634	2769	795	627.5	4076.5	2738	3381.5	3393
Z	-10.32	-11.34	-1.88	-4.06	-0.28	-1.71	-0.54	-3.75	-8.04	-8.22	-7.16	-10.40	-4.01	-3.80	-4.11	-3.73	-1.94	-3.15	-0.21	-4.46	-2.78	-2.75
Asymp. Sig. (2-tailed)	0.000	0.000	0.060	0.000	0.782	0.087	0.593	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.002	0.834	0.000	0.006	0.006
Amazon Creek at 29th Avenue : Amazon Diversion Channel at Royal Avenue																						
Mann-Whitney U	1064	403.5	4187	2324.5	4125.5	3579.5	3693.5	2403.5	1716	1256	4448	1390.5	66	54	1756	1654.5	846	774.5	4718.5	2827	3746.5	4601.5
Z	-9.045	-10.84	-2.119	-6.989	-0.166	-2.567	-3.858	-6.923	-8.208	-9.464	-1.682	-9.041	-7.583	-7.736	-7.341	-7.672	-1.452	-1.965	-0.457	-5.817	-3.641	-1.858
Asymp. Sig. (2-tailed)	0.000	0.000	0.034	0.000	0.868	0.010	0.000	0.000	0.000	0.000	0.093	0.000	0.000	0.000	0.000	0.000	0.146	0.049	0.648	0.000	0.000	0.063
Amazon Creek at 29th Avenue : Amazon Creek at Royal Avenue																						
Mann-Whitney U	801	192	4435	3675.5	4084	3834.5	4523	3636.5	1476.5	1405	2800.5	1194.5	496.5	477	2973.5	2713.5	750	774.5	4866.5	3289.5	3787	5228.5
Z	-9.74	-11.36	-1.73	-3.76	-0.16	-1.90	-1.93	-3.99	-8.78	-9.06	-5.62	-9.40	-4.05	-4.21	-4.15	-4.83	-2.34	-1.80	-0.33	-4.67	-3.64	-0.30
Asymp. Sig. (2-tailed)	0.000	0.000	0.083	0.000	0.875	0.058	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.071	0.741	0.000	0.000	0.767
Amazon Creek at Railroad Track Crossing : Amazon Diversion Channel at Royal Avenue																						
Mann-Whitney U	3150.5	3602	4057.5	3426	3700	3713.5	3064.5	2794	4056	3899	2271.5	3284.5	390	350.5	2546	2359.5	922	911.5	3861	4167	3936	4346
Z	-2.32	-1.12	-0.29	-2.57	-0.20	-0.93	-3.43	-4.35	-0.24	-1.16	-5.44	-2.85	-4.92	-5.34	-4.27	-4.89	-0.45	-0.82	-0.60	-0.57	-1.08	-0.20
Asymp. Sig. (2-tailed)	0.020	0.262	0.775	0.010	0.841	0.353	0.001	0.000	0.811	0.246	0.000	0.004	0.000	0.000	0.000	0.000	0.653	0.412	0.550	0.570	0.279	0.843
A3 Channel at Terry Street : Amazon Creek at Royal Avenue																						
Mann-Whitney U	2922.5	3230.5	2697	1668	3273	3201.5	3599	2683	3830.5	3054.5	2813	2635	309.5	279.5	2170	2634	812	899.5	3608	3701.5	2355.5	1825.5
Z	-2.41	-1.60	-3.78	-6.78	-0.71	-1.79	-1.47	-4.04	-0.60	-2.91	-3.51	-3.82	-5.21	-5.47	-4.88	-3.49	-0.93	-0.02	-1.15	-0.94	-4.96	-6.46
Asymp. Sig. (2-tailed)	0.016	0.110	0.000	0.000	0.477	0.073	0.143	0.000	0.550	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.354	0.982	0.250	0.345	0.000	0.000

Shaded cells significant at a = 0.05

Table A.20
Mann-Whitney Statistic Output for
Intra-Basin Comparison of Water Quality Data

Monitoring Location	As (D)	As (T)	Cd (D)	Cd (T)	Cr (D)	Cr (T)	Cu (D)	Cu (T)	Pb (D)	Pb (T)	Hg (D)	Hg (T)	Mo (D)	Mo (T)	Ni (D)	Ni (T)	Se (D)	Se (T)	Ag (D)	Ag (T)	Zn (D)	Zn (T)
Willamette River Upstream of Urban Growth Boundary (RM 186.9) : Knickerbocker Bridge (RM 183.9)																						
Mann-Whitney U	2586	2862	4837.5	5060	3788	4151.5	3121.5	4078	4281.5	4658.5	4193.5	4536	1010	976	3570.5	4024	1005	971	4655	5170	4097	4660
Z	-4.56	-4.17	-0.40	-0.34	-1.11	-0.95	-4.23	-2.67	-1.66	-1.29	-1.65	-1.36	-0.03	-0.39	-1.94	-0.94	-0.08	-0.40	0.00	-0.08	-1.44	-0.83
Asymp. Sig. (2-tailed)	0.000	0.000	0.688	0.733	0.267	0.341	0.000	0.008	0.096	0.197	0.100	0.174	0.979	0.696	0.052	0.350	0.936	0.686	0.998	0.939	0.150	0.409
Willamette River at Knickerbocker Bridge (RM 183.9) : Owosso Bridge (RM 178.6)																						
Mann-Whitney U	4112	4157.5	5006	5086	4053.5	4424.5	4709	4928	4617	3661	4870	4920.5	873	912.5	4329	4368	1009	995	4621.5	4952	4465.5	4791.5
Z	-0.33	-0.70	-0.11	-0.28	-0.37	-0.11	-0.48	-0.65	-1.06	-3.46	-0.08	-0.43	-1.45	-1.05	-0.11	-0.26	-0.04	-0.17	-0.34	-0.48	-0.96	-0.86
Asymp. Sig. (2-tailed)	0.741	0.485	0.914	0.780	0.711	0.914	0.635	0.516	0.290	0.001	0.940	0.665	0.148	0.292	0.910	0.796	0.970	0.865	0.734	0.629	0.335	0.390
Willamette River at Owosso Bridge (RM 178.6) : Downstream of Beltline Bridge (176.8)																						
Mann-Whitney U	3732	4248	5023.5	4889.5	3862	4455.5	3416	4265	3680	4348	4732.5	4908	809	758.5	3709.5	4022.5	1009	971	4481.5	4332.5	2409.5	3596
Z	-1.38	-0.46	-0.07	-0.75	-1.02	-0.03	-3.59	-2.33	-3.34	-1.70	-0.42	-0.46	-1.94	-2.33	-1.90	-1.18	-0.04	-0.39	-0.82	-1.88	-6.18	-3.72
Asymp. Sig. (2-tailed)	0.167	0.649	0.948	0.452	0.306	0.980	0.000	0.020	0.001	0.089	0.677	0.643	0.053	0.020	0.058	0.239	0.970	0.695	0.412	0.061	0.000	0.000
Willamette River Upstream of Urban Growth Boundary (RM 183.9) : Downstream of Belt Line Bridge (RM 176.8)																						
Mann-Whitney U	2227.5	2503	4896	5158	3614.5	4096	1783.5	2946	2622.5	2928	4040	4218.5	698	648	2876.5	3466.5	1008	993.5	4261	4140.5	1811	2985
Z	-5.55	-5.13	-0.26	-0.11	-1.71	-1.10	-7.54	-5.43	-5.77	-5.31	-2.03	-2.12	-3.06	-3.49	-3.94	-2.44	-0.05	-0.18	-1.15	-2.45	-7.40	-4.92
Asymp. Sig. (2-tailed)	0.000	0.000	0.798	0.916	0.087	0.272	0.000	0.000	0.000	0.000	0.042	0.034	0.002	0.000	0.000	0.015	0.961	0.858	0.249	0.014	0.000	0.000
Willamette River at Owosso Bridge (178.6) : Delta Ponds above Willamette River Confluence near Beltline Bridge																						
Mann-Whitney U	622	676.5	1728	1846.5	1172.5	880.5	1222.5	1869	1054.5	1365.5	322.5	638.5	201.5	211.5	136.5	249.5	794	602	1851.5	1939.5	76	260.5
Z	-5.94	-5.72	-1.07	-0.68	-2.36	-4.71	-3.35	-0.55	-4.28	-2.35	-7.71	-6.19	-6.01	-6.10	-8.39	-7.83	-0.20	-2.31	-0.29	-0.14	-8.77	-7.94
Asymp. Sig. (2-tailed)	0.000	0.000	0.284	0.498	0.018	0.000	0.001	0.580	0.000	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.843	0.021	0.769	0.886	0.000	0.000
Amazon Creek at 29th Avenue : Spring Creek at Beacon Drive East																						
Mann-Whitney U	13.5	0	620.5	704	207.5	107	121	109.5	515.5	386.5	136	201.5	101.5	100.5	33	14.5	317.5	285	615.5	755.5	367	576.5
Z	-6.09	-6.21	-1.20	-0.56	-4.28	-5.29	-5.28	-5.37	-2.03	-3.12	-5.15	-4.59	-4.04	-4.06	-5.93	-6.09	-0.41	-0.55	-0.74	-0.14	-3.31	-1.63
Asymp. Sig. (2-tailed)	0.000	0.000	0.231	0.575	0.000	0.000	0.000	0.000	0.042	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.684	0.583	0.458	0.889	0.001	0.103

Shaded cells significant at a = 0.05

Table A.21
Mann-Whitney Statistic Output for
Intra-Basin Comparison of Water Quality Data

Monitoring Location	NH_3	BOD	Ca (T)	COD	Cond	DO	E. coli	Fecal Coliform	Hardness	Mg (T)	NO_3+NO_2	Field pH	Ortho P	Total P	Temp	TDS	TKN	TSS	Turbidity
Amazon Creek at 29th Avenue : Willow Creek																			
Mann-Whitney U	2916	4709	4509.5	4197.5	4773	4385.5	1070	847	4157	3764.5	644	2123	1306.5	2324	4444.5	4439.5	4290.5	4810.5	4810.5
Z	-1.32	-0.57	-0.82	-1.49	-0.16	-0.04	-9.28	-7.04	-1.48	-2.68	-10.60	-6.73	-8.55	-6.32	-0.86	-0.76	-1.41	-0.06	-0.06
Asymp. Sig. (2-tailed)	0.186	0.568	0.413	0.137	0.875	0.969	0.000	0.000	0.139	0.007	0.000	0.000	0.000	0.000	0.392	0.447	0.159	0.949	0.949
Amazon Creek at 29th Avenue : Amazon Creek at Railroad Track Crossing																			
Mann-Whitney U	3361.5	3174.5	3314	2432.5	4195	3012	2546	2069.5	3255	3221.5	3533.5	2515	1989.5	3945	3581.5	3442	3867	2144	2144
Z	-0.83	-4.51	-2.96	-5.35	-0.60	-3.30	-4.78	-2.90	-3.03	-3.21	-2.28	-5.11	-6.25	-1.28	-2.24	-2.17	-1.51	-6.10	-6.10
Asymp. Sig. (2-tailed)	0.407	0.000	0.003	0.000	0.547	0.001	0.000	0.004	0.002	0.001	0.023	0.000	0.000	0.202	0.025	0.030	0.131	0.000	0.000
Amazon Creek at 29th Avenue : Amazon Diversion Channel at Royal Avenue																			
Mann-Whitney U	3197	2370	4734.5	1558.5	4914.5	3398	2372.5	1268.5	5068	3935.5	4148.5	3872.5	3120	2778.5	3769.5	5048.5	2389	1649.5	1649.5
Z	-1.94	-8.04	-1.55	-8.83	-1.14	-3.63	-6.78	-6.12	-0.55	-3.40	-2.81	-3.55	-5.06	-6.00	-3.78	-0.36	-6.96	-8.67	-8.67
Asymp. Sig. (2-tailed)	0.053	0.000	0.120	0.000	0.255	0.000	0.000	0.000	0.579	0.001	0.005	0.000	0.000	0.000	0.000	0.716	0.000	0.000	0.000
Amazon Creek at 29th Avenue : Amazon Creek at Royal Avenue																			
Mann-Whitney U	3194.5	3669	3563	2744	4592	3723	3146	1930.5	3661	3920.5	3692	4356.5	2197	5060	4025	3842.5	3827	1987.5	1987.5
Z	-1.47	-5.08	-4.17	-5.99	-1.77	-2.82	-4.88	-3.42	-3.76	-3.33	-3.68	-2.32	-7.20	-0.45	-3.09	-3.13	-3.51	-7.83	-7.83
Asymp. Sig. (2-tailed)	0.141	0.000	0.000	0.000	0.076	0.005	0.000	0.001	0.000	0.001	0.000	0.020	0.000	0.649	0.002	0.002	0.000	0.000	0.000
Amazon Creek at Railroad Track Crossing : Amazon Diversion Channel at Royal Avenue																			
Mann-Whitney U	3283	2880.5	3945.5	2893.5	3860	4023.5	3323.5	2015	3234	2465	4286.5	4273.5	3892	2670.5	3929.5	3631.5	2393.5	3297	3297
Z	-1.16	-4.37	-1.27	-4.01	-1.50	-0.14	-2.93	-3.74	-3.08	-5.23	-0.36	-0.39	-1.06	-4.61	-1.31	-1.43	-5.39	-3.00	-3.00
Asymp. Sig. (2-tailed)	0.245	0.000	0.204	0.000	0.134	0.886	0.003	0.000	0.002	0.000	0.719	0.694	0.288	0.000	0.190	0.152	0.000	0.003	0.003
A3 Channel at Terry Street : Amazon Creek at Royal Avenue																			
Mann-Whitney U	2441	2752	2538.5	2438	2353	3164	3854	2405	1963.5	1420	3056.5	3594.5	2528	1322	4043.5	2256	3066	3729	3729
Z	-3.68	-4.09	-4.45	-4.67	-4.97	-1.19	-0.61	-1.26	-6.01	-7.60	-2.92	-1.48	-4.46	-7.78	-0.22	-4.83	-2.90	-1.10	-1.10
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.236	0.543	0.207	0.000	0.000	0.004	0.138	0.000	0.000	0.830	0.000	0.004	0.271	0.271

Shaded cells significant at a = 0.05

Table A.21
Mann-Whitney Statistic Output for
Intra-Basin Comparison of Water Quality Data

Monitoring Location	NH_3	BOD	Ca (T)	COD	Cond	DO	E. coli	Fecal Coliform	Hardness	Mg (T)	NO_3+NO_2	Field pH	Ortho P	Total P	Temp	TDS	TKN	TSS	Turbidity
Willamette River Upstream of Urban Growth Boundary (RM 186.9) : Knickerbocker Bridge (RM 183.9)																			
Mann-Whitney U	3321	5304	4038.5	5175	4354.5	3599	3103.5	2236.5	4053	4605	4582	5061.5	4632	4926.5	5236	4624	5106	4649	4649
Z	-1.00	0.00	-2.80	-0.47	-2.23	-0.68	-5.06	-3.70	-2.47	-1.21	-1.62	-0.57	-1.23	-0.91	-0.16	-1.03	-0.61	-1.57	-1.57
Asymp. Sig. (2-tailed)	0.317	0.996	0.005	0.635	0.026	0.494	0.000	0.000	0.013	0.226	0.105	0.568	0.218	0.361	0.873	0.301	0.542	0.116	0.116
Willamette River at Knickerbocker Bridge (RM 183.9) : Owosso Bridge (RM 178.6)																			
Mann-Whitney U	3321.5	5355	4806	5310	4750	3659.5	4240.5	2540	4578	4426	5187.5	5060.5	4920.5	5083.5	5250	4967	5348.5	5140	5140
Z	-1.00	-0.01	-0.99	-0.17	-1.30	-0.50	-2.49	-2.81	-1.29	-1.76	-0.29	-0.69	-0.73	-0.65	-0.13	-0.08	-0.02	-0.51	-0.51
Asymp. Sig. (2-tailed)	0.319	0.992	0.323	0.867	0.194	0.615	0.013	0.005	0.196	0.078	0.768	0.491	0.464	0.515	0.899	0.937	0.982	0.609	0.609
Willamette River at Owosso Bridge (RM 178.6) : Downstream of Beltline Bridge (176.8)																			
Mann-Whitney U	2804	5355	4590	5258.5	3330	3745.5	4934.5	3028.5	4452.5	4439	2451.5	4758.5	1492.5	2233	5245.5	4314.5	3169.5	5340.5	5340.5
Z	-3.44	-0.01	-1.64	-0.38	-4.62	-0.50	-0.98	-1.10	-1.71	-1.83	-6.63	-1.28	-9.03	-7.31	-0.14	-1.34	-5.57	-0.04	-0.04
Asymp. Sig. (2-tailed)	0.001	0.992	0.101	0.703	0.000	0.619	0.328	0.273	0.087	0.067	0.000	0.201	0.000	0.000	0.890	0.180	0.000	0.971	0.971
Willamette River Upstream of Urban Growth Boundary (RM 183.9) : Downstream of Belt Line Bridge (RM 176.8)																			
Mann-Whitney U	2665	5304	3181.5	5216.5	2165.5	3703.5	2255.5	1222	3029	3338.5	1711	4190.5	1982	1978	5259	3973	2969.5	4431.5	4431.5
Z	-4.33	0.00	-5.01	-0.35	-7.35	-0.62	-7.13	-6.97	-5.08	-4.38	-8.35	-2.51	-7.66	-7.84	-0.11	-2.30	-6.05	-2.08	-2.08
Asymp. Sig. (2-tailed)	0.000	0.996	0.000	0.730	0.000	0.535	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.915	0.021	0.000	0.037	0.037
Willamette River at Owosso Bridge (178.6) : Delta Ponds above Willamette River Confluence near Beltline Bridge																			
Mann-Whitney U	1560	1653	63.5	1461	62.5	337	1901	1586.5	55	63.5	1749.5	901.5	1559.5	1111.5	1987.5	299.5	1278.5	1746.5	1746.5
Z	-1.20	-3.85	-9.07	-3.41	-8.90	-7.06	-0.58	-0.18	-9.04	-8.93	-1.36	-5.12	-2.30	-4.24	-0.10	-7.61	-4.00	-1.29	-1.29
Asymp. Sig. (2-tailed)	0.231	0.000	0.000	0.001	0.000	0.000	0.565	0.861	0.000	0.000	0.175	0.000	0.022	0.000	0.924	0.000	0.000	0.198	0.198
Amazon Creek at 29th Avenue : Spring Creek at Beacon Drive East																			
Mann-Whitney U	595	758.5	312	591.5	562	669.5	446.5	454	542	558.5	31.5	136	407.5	388.5	690	397	731	620	620
Z	-0.91	-0.32	-3.75	-1.54	-1.75	-0.26	-2.23	-0.73	-1.87	-1.78	-5.99	-5.18	-2.95	-3.15	-0.72	-2.03	-0.40	-1.29	-1.29
Asymp. Sig. (2-tailed)	0.363	0.750	0.000	0.123	0.081	0.792	0.026	0.465	0.062	0.075	0.000	0.000	0.003	0.002	0.471	0.042	0.687	0.198	0.198

Shaded cells significant at a = 0.05

ATTACHMENT B

Figure B.1

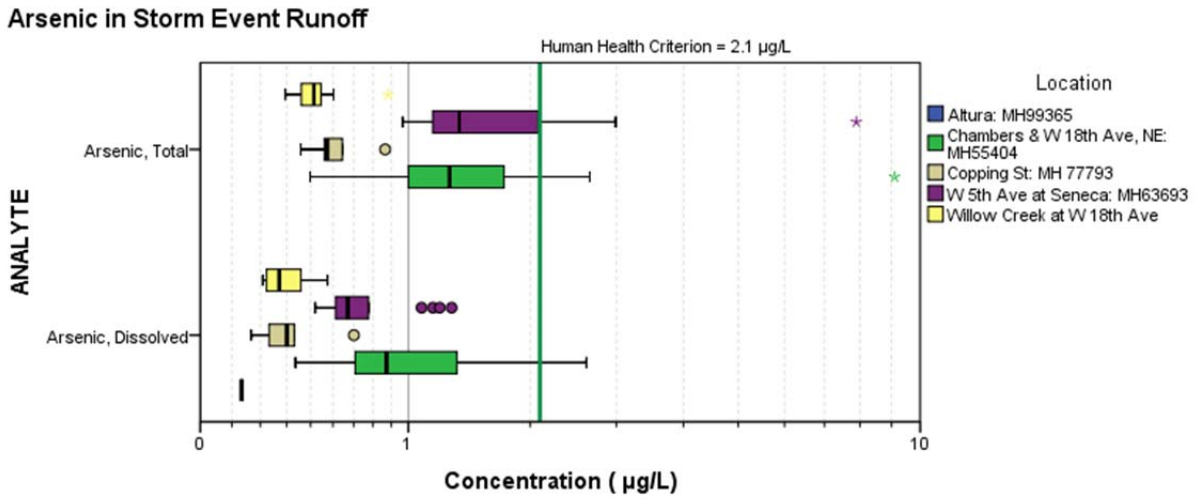


Figure B.2

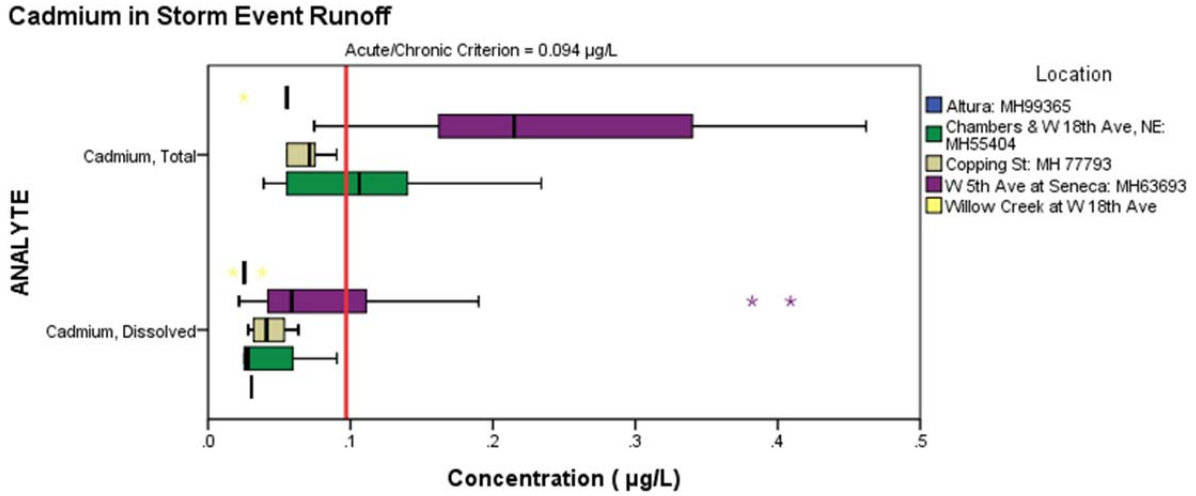


Figure B.3

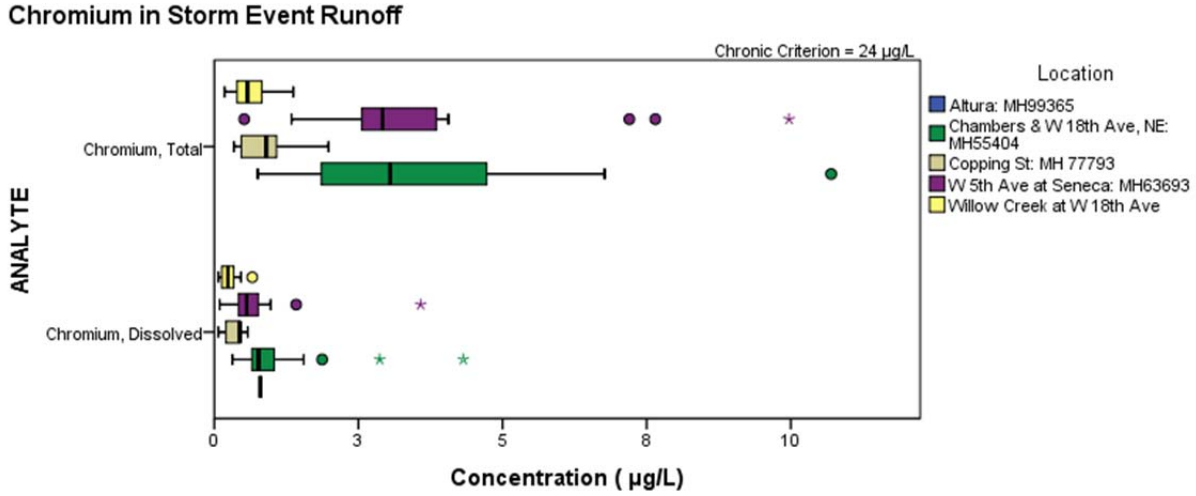


Figure B.4

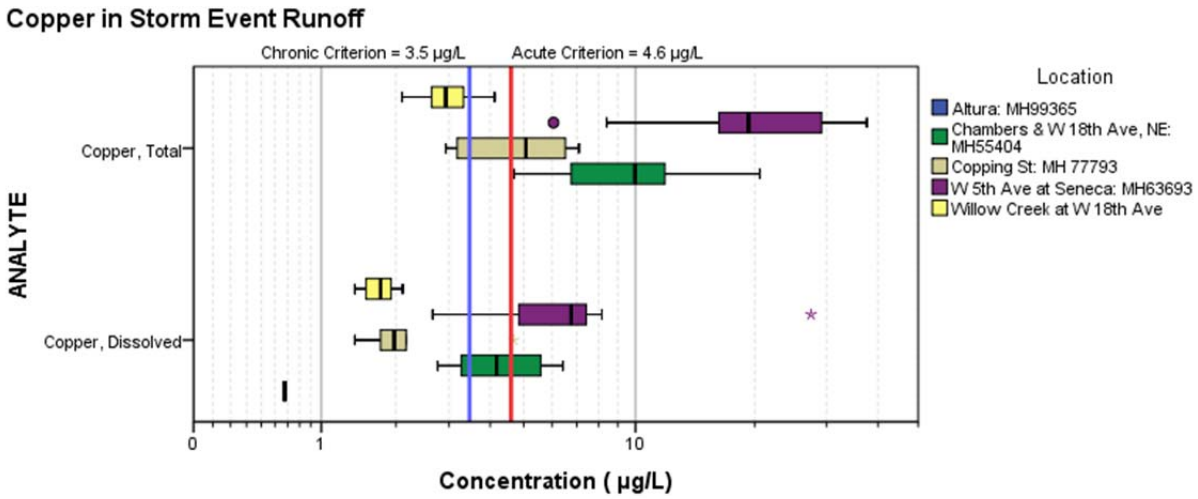


Figure B.5

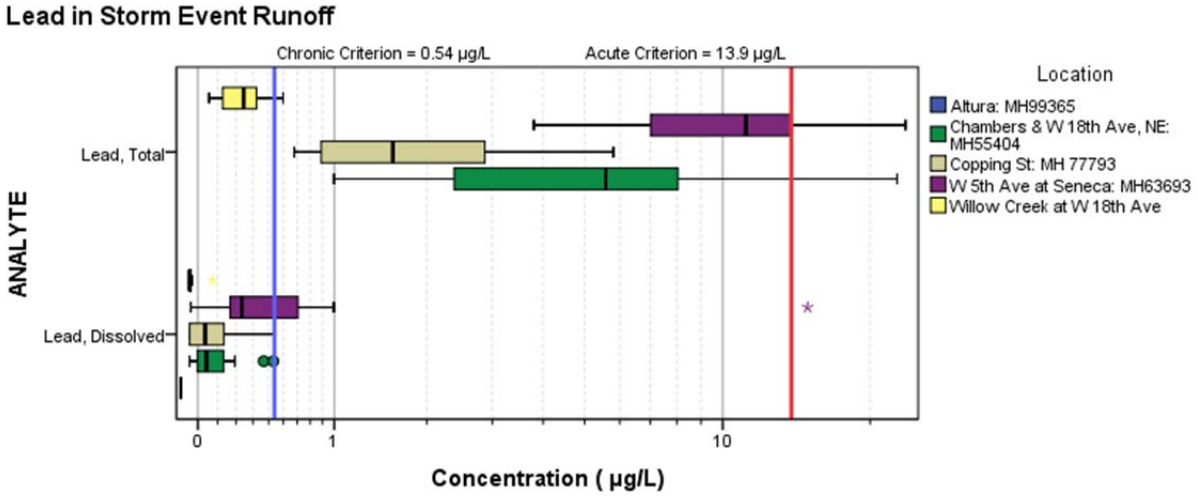


Figure B.6

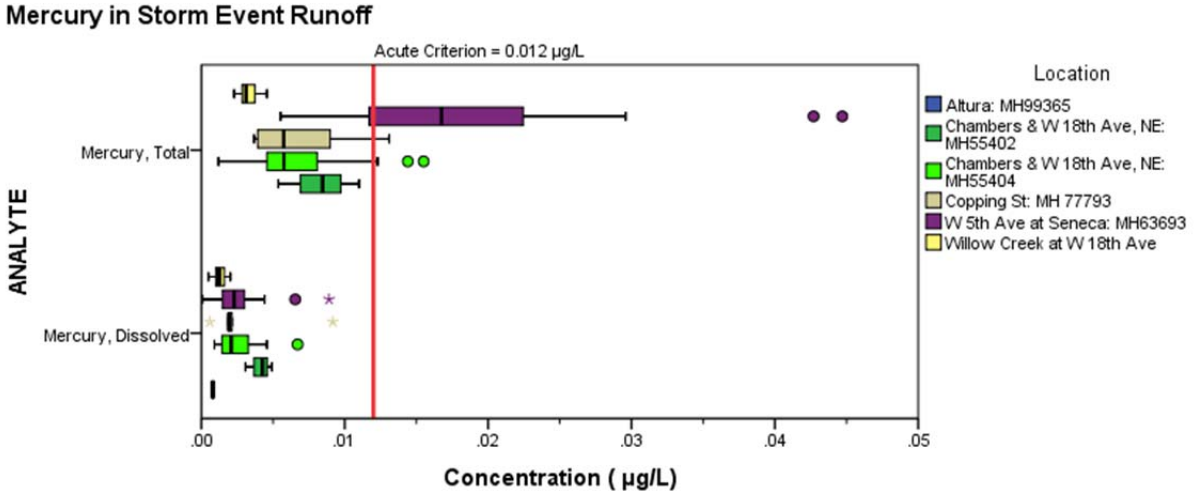


Figure B.7

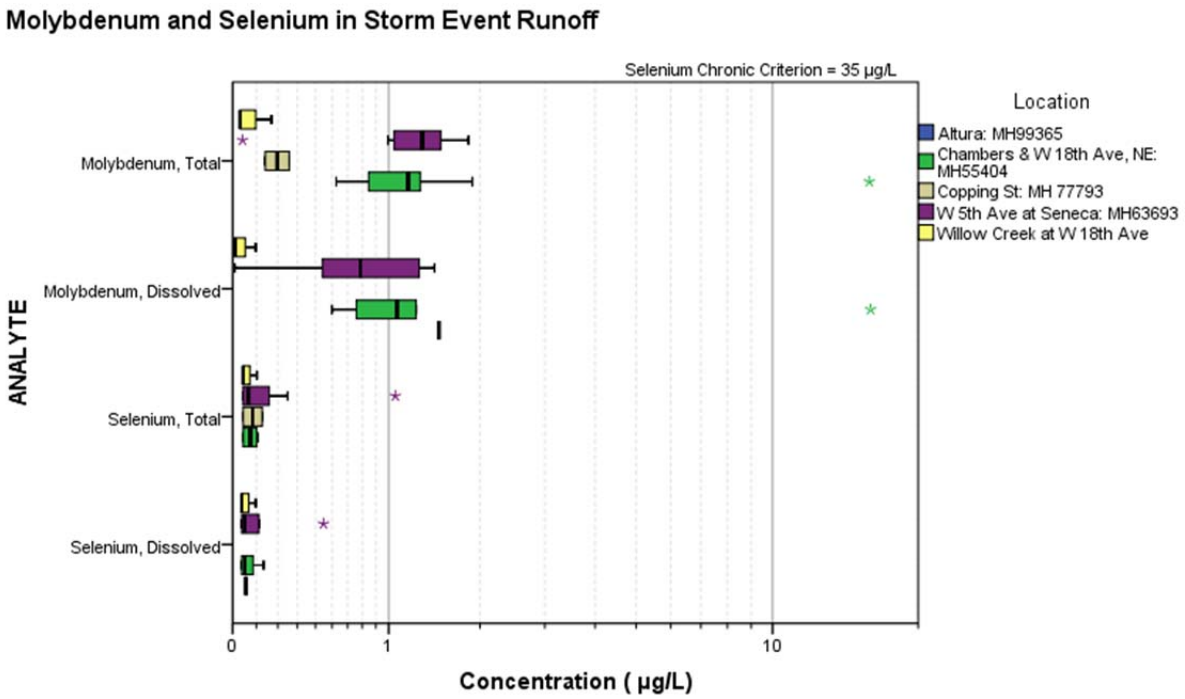


Figure B.8

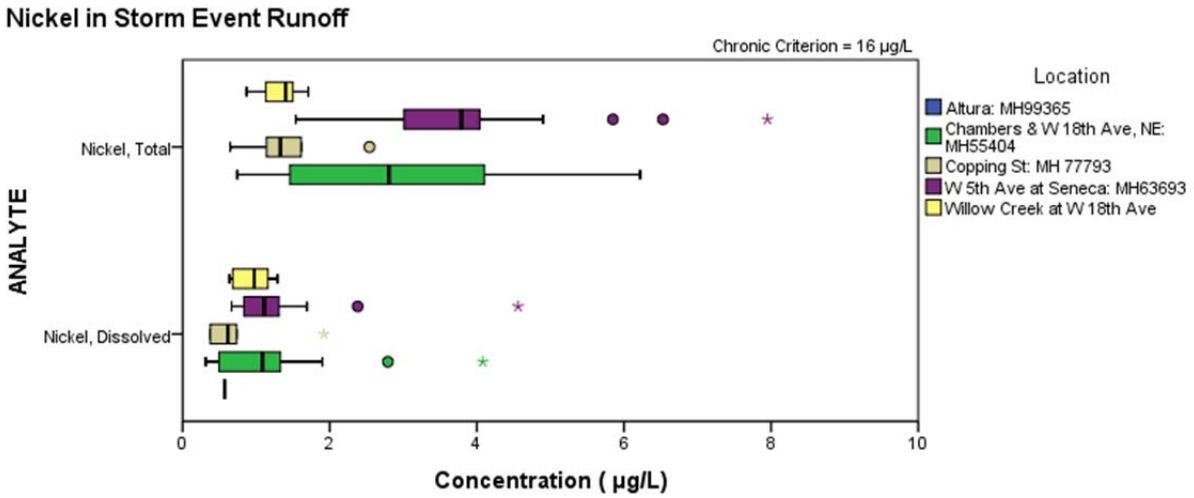


Figure B.9

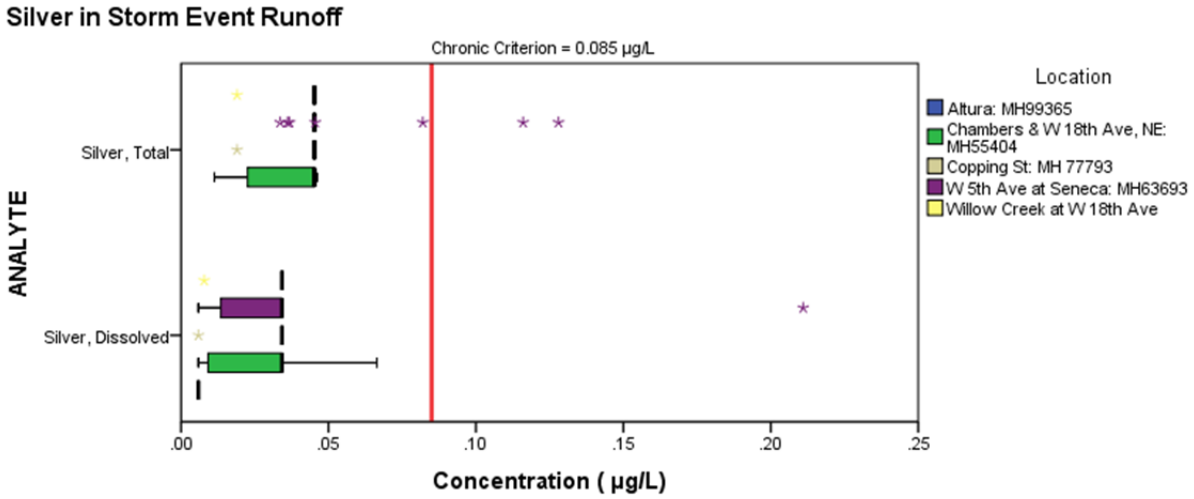


Figure B.10

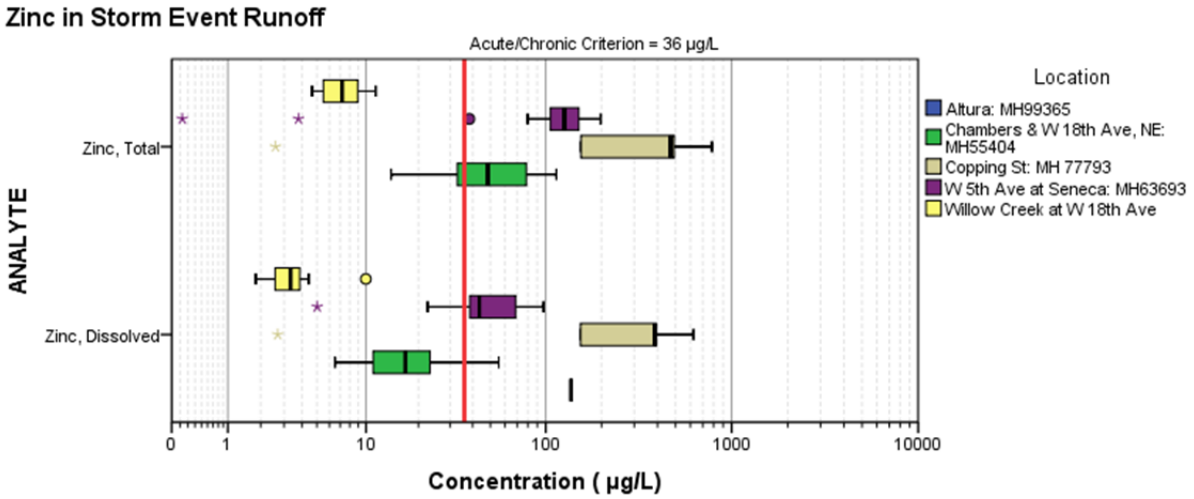


Figure B.11

Oxygen Demand in Storm Event Runoff

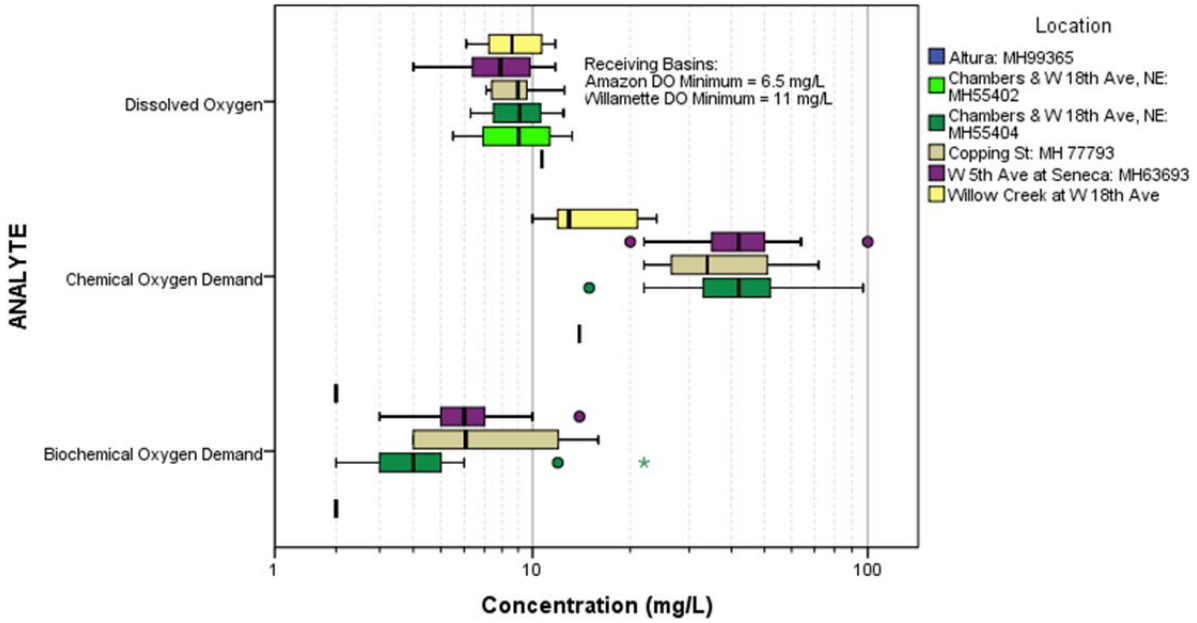


Figure B.12

Hardness of Storm Event Runoff

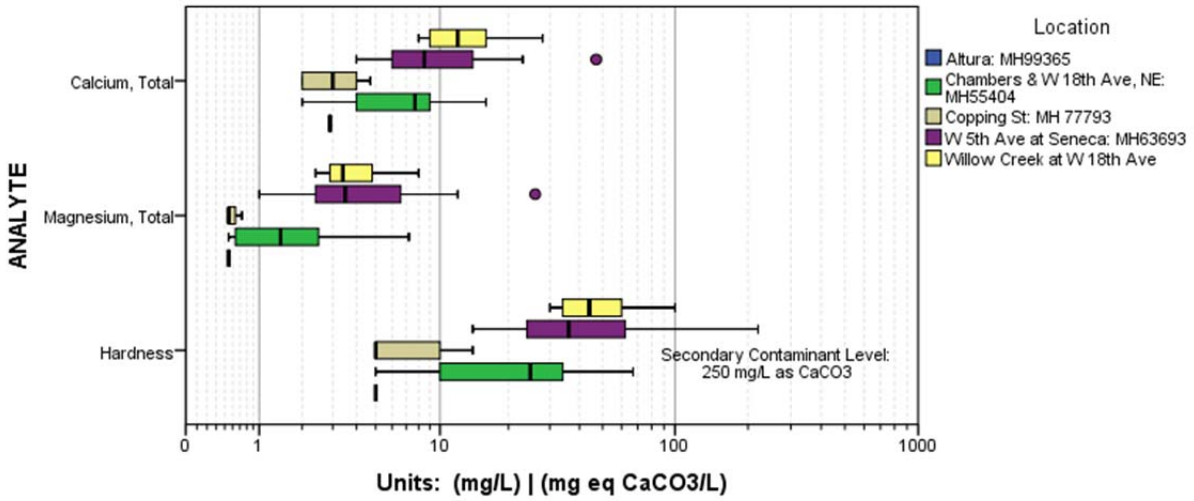


Figure B.13

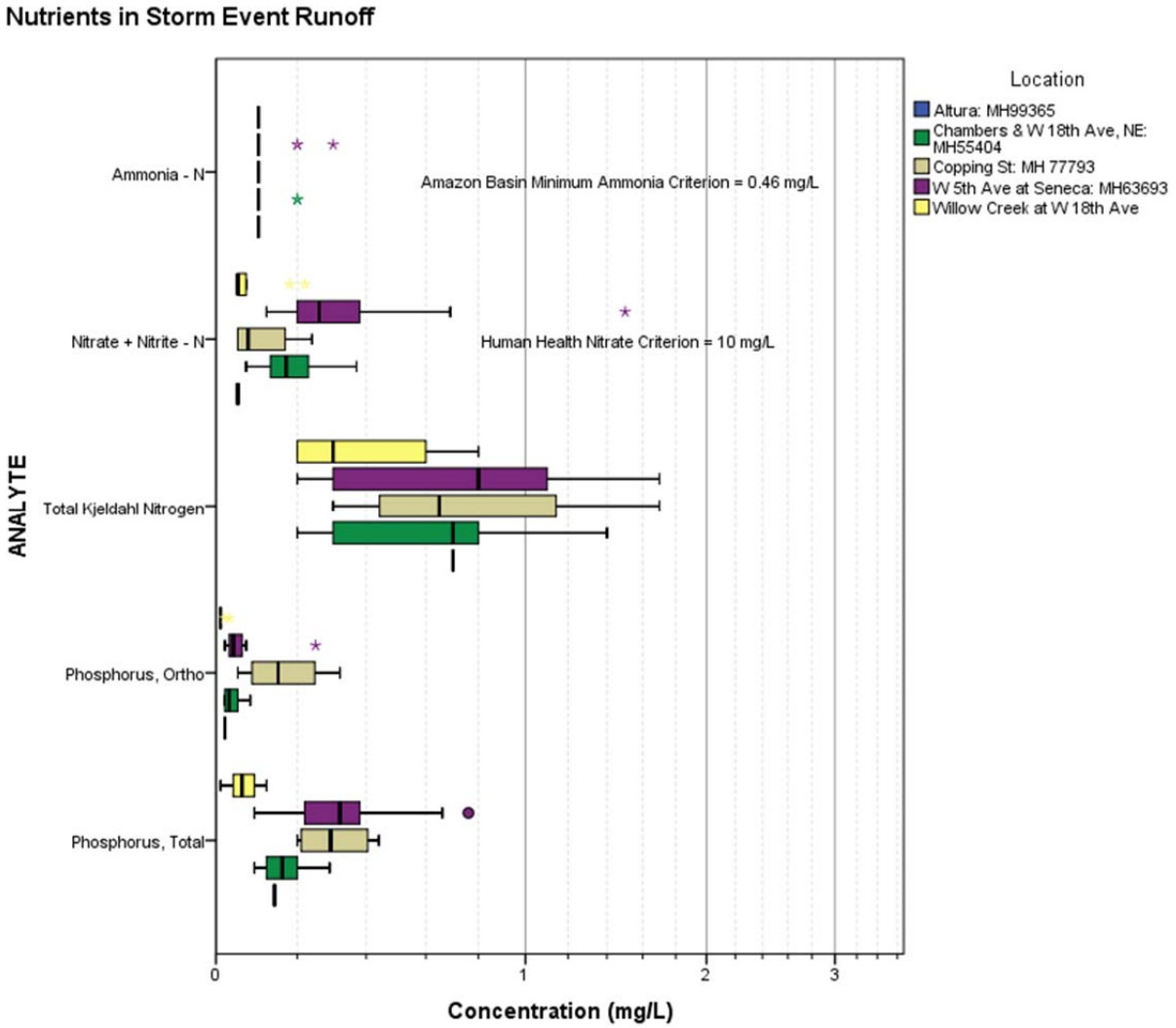


Figure B.14

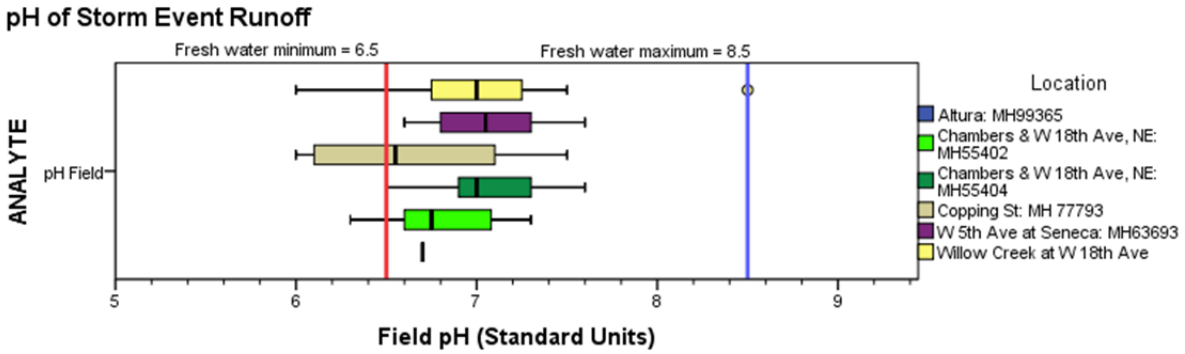


Figure B.15

Solids in Storm Event Runoff

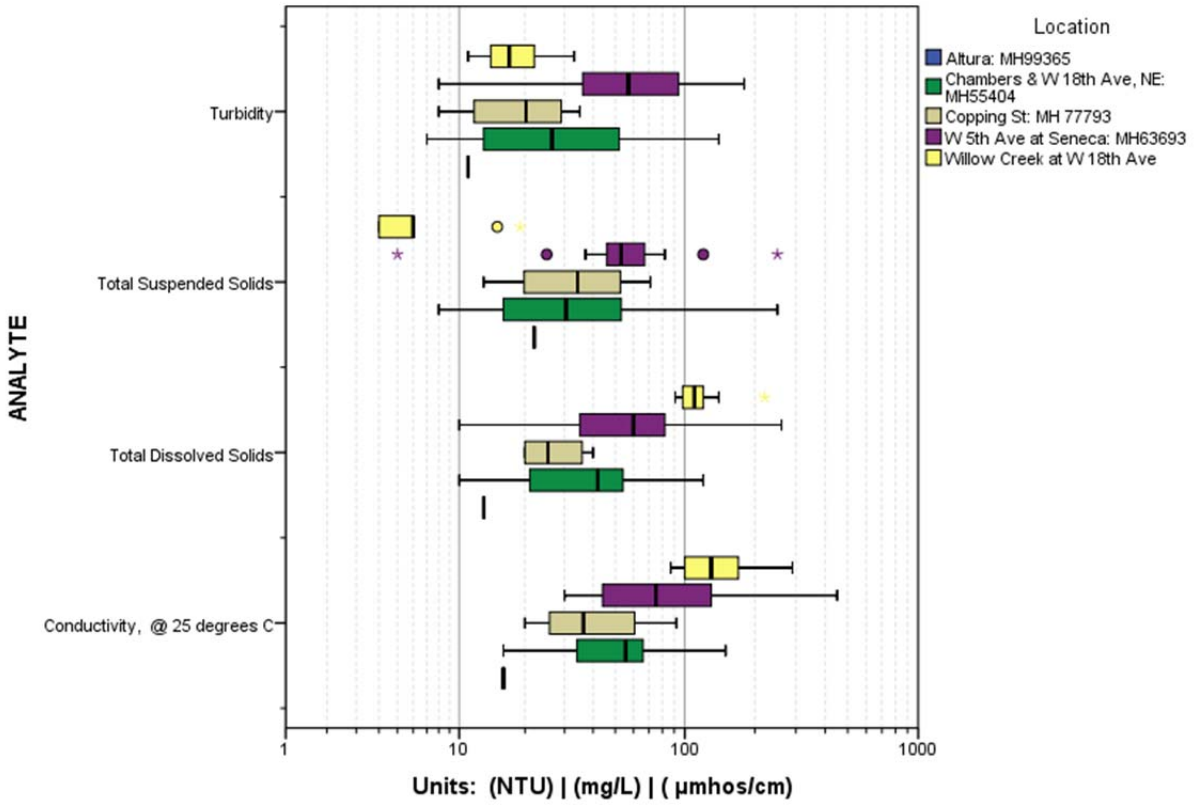


Figure B.16

Bacteria in Storm Event Runoff

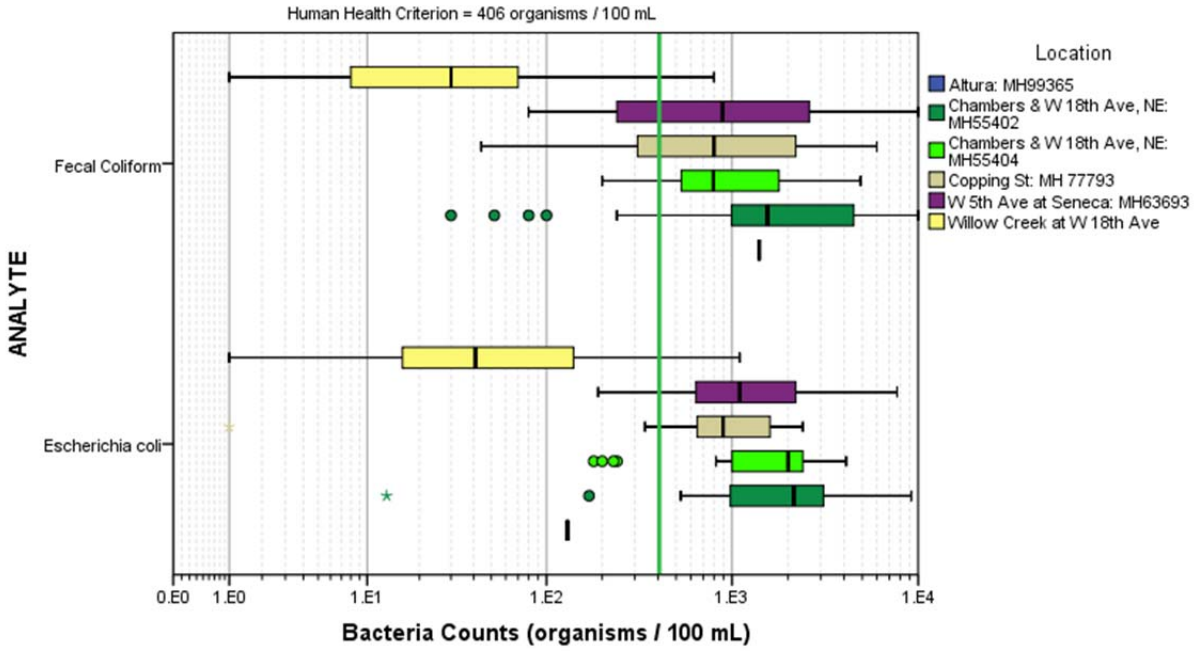


Figure B.17

Organic Carbon in Storm Event Runoff

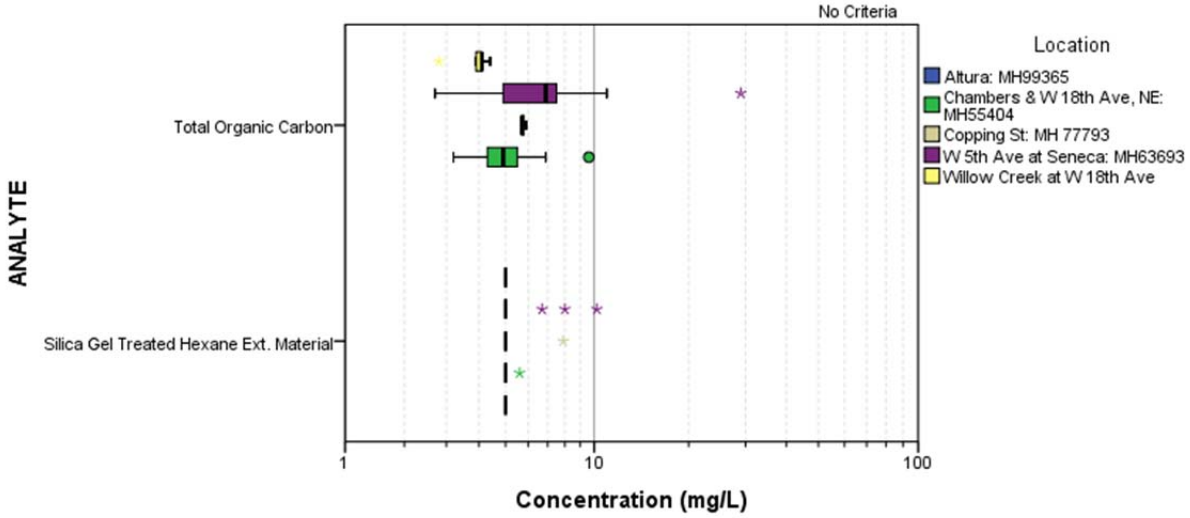


Figure B.18

Temperature of Storm Event Runoff

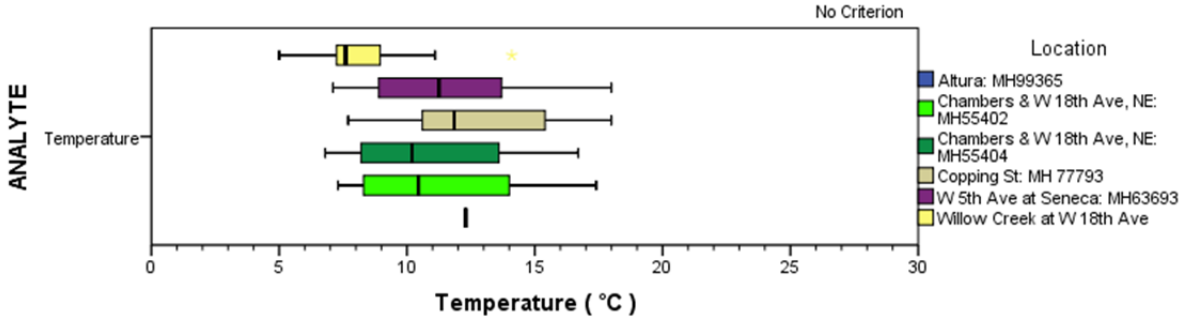
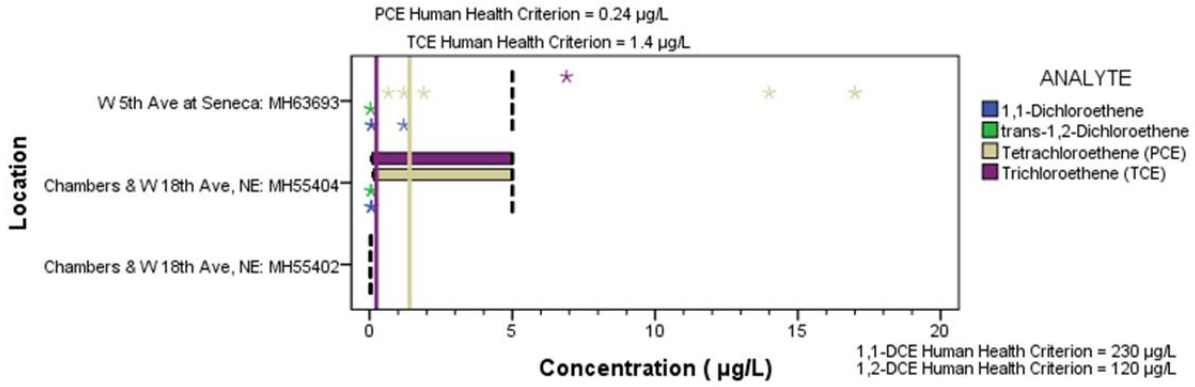


Figure B.19

Chlorinated Compounds in Storm Event Runoff



Values below MRL = J-Flagged

Figure B.20

Methyl Mercury & Dioxin in Storm Event Runoff

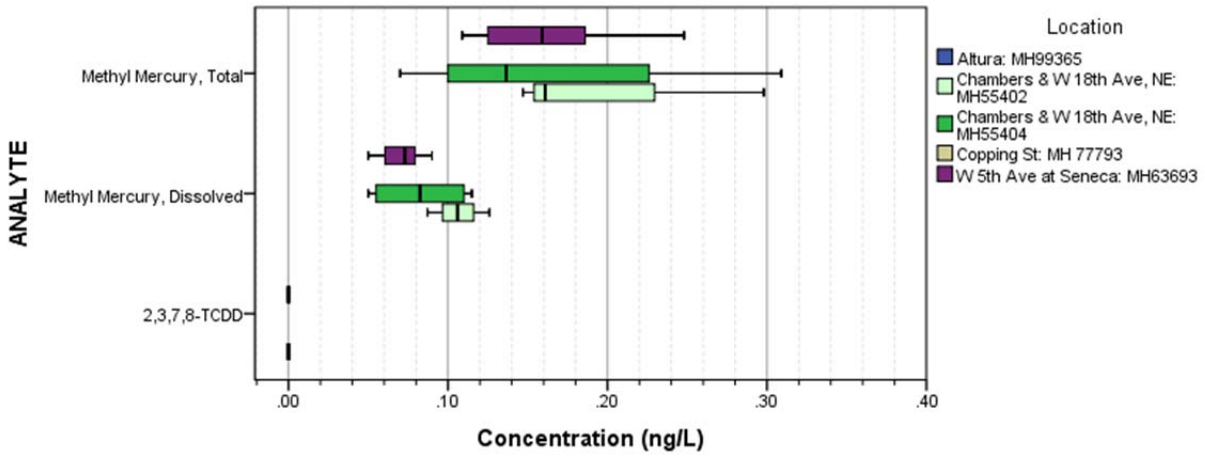


Figure B.21

Organics in Storm Event Runoff to UIC

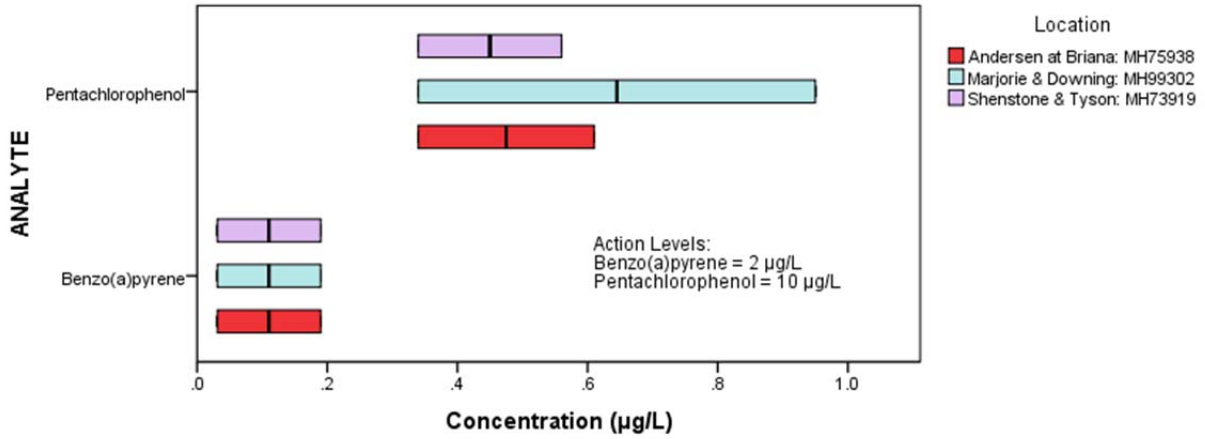


Figure B.22

Metals in Storm Event Runoff to UIC

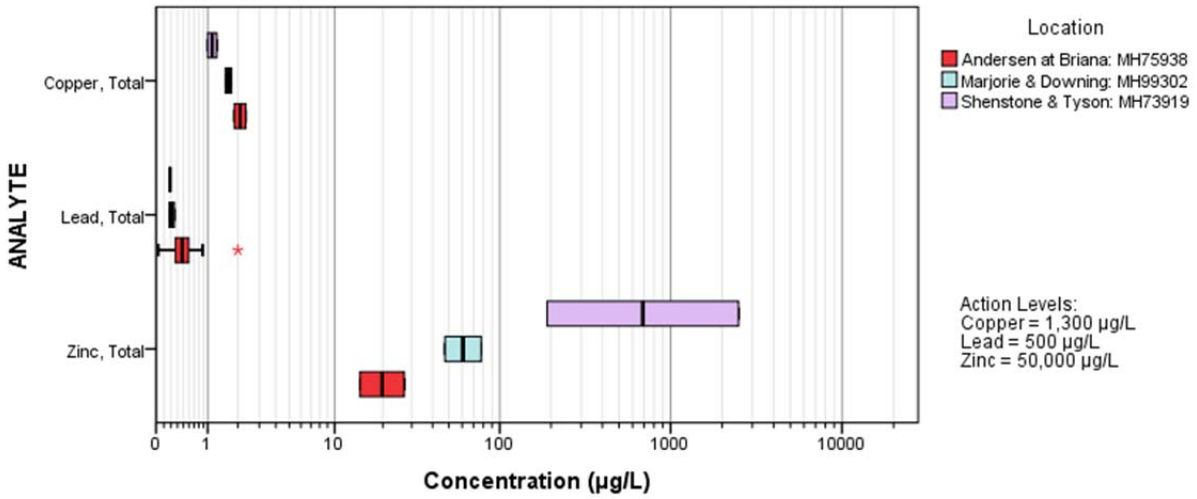


Figure B.23

Field Measures of Storm Event Runoff to UIC

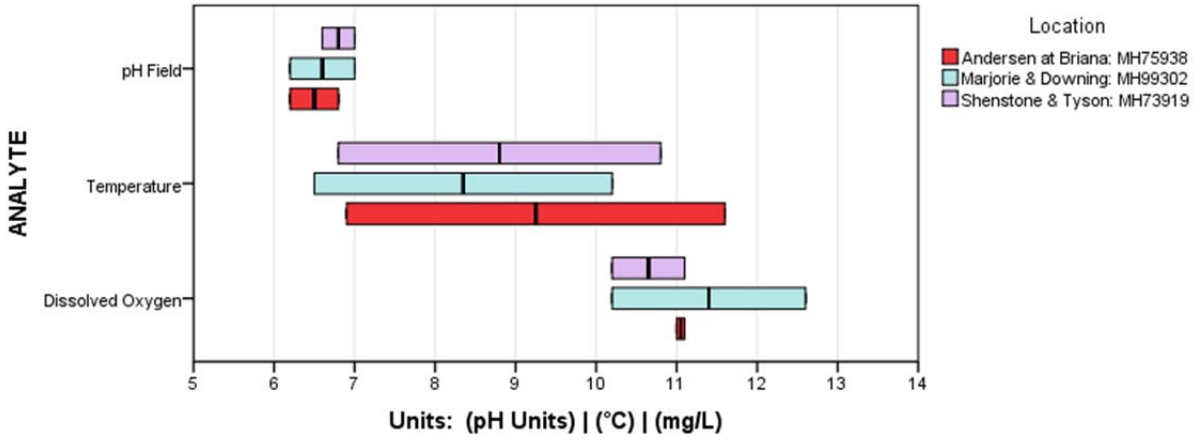


Figure B.24

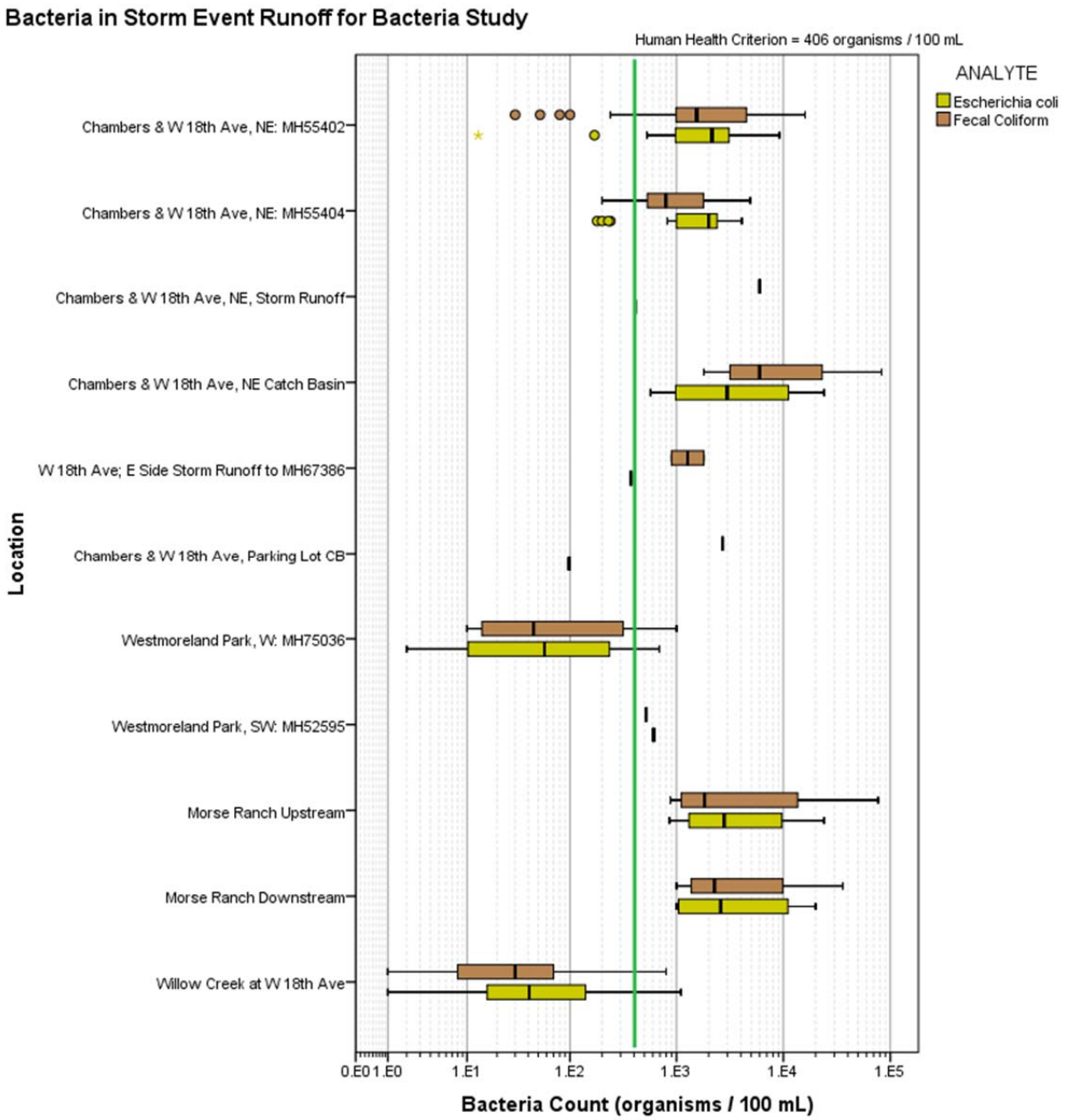

Bacteria in Storm Event Runoff for Bacteria Study
Human Health Criterion = 406 organisms / 100 mL
ANALYTE
Escherichia coli
Fecal Coliform
Location
Chambers & W 18th Ave, NE: MH55402
Chambers & W 18th Ave, NE: MH55404
Chambers & W 18th Ave, NE, Storm Runoff
Chambers & W 18th Ave, NE Catch Basin
W 18th Ave; E Side Storm Runoff to MH67386
Chambers & W 18th Ave, Parking Lot CB
Westmoreland Park, W: MH75036
Westmoreland Park, SW: MH52595
Morse Ranch Upstream
Morse Ranch Downstream
Willow Creek at W 18th Ave
0.E0 1.E0
1.E1
1.E2
1.E3
1.E4
1.E5
Bacteria Count (organisms / 100 mL)

Figure B.25

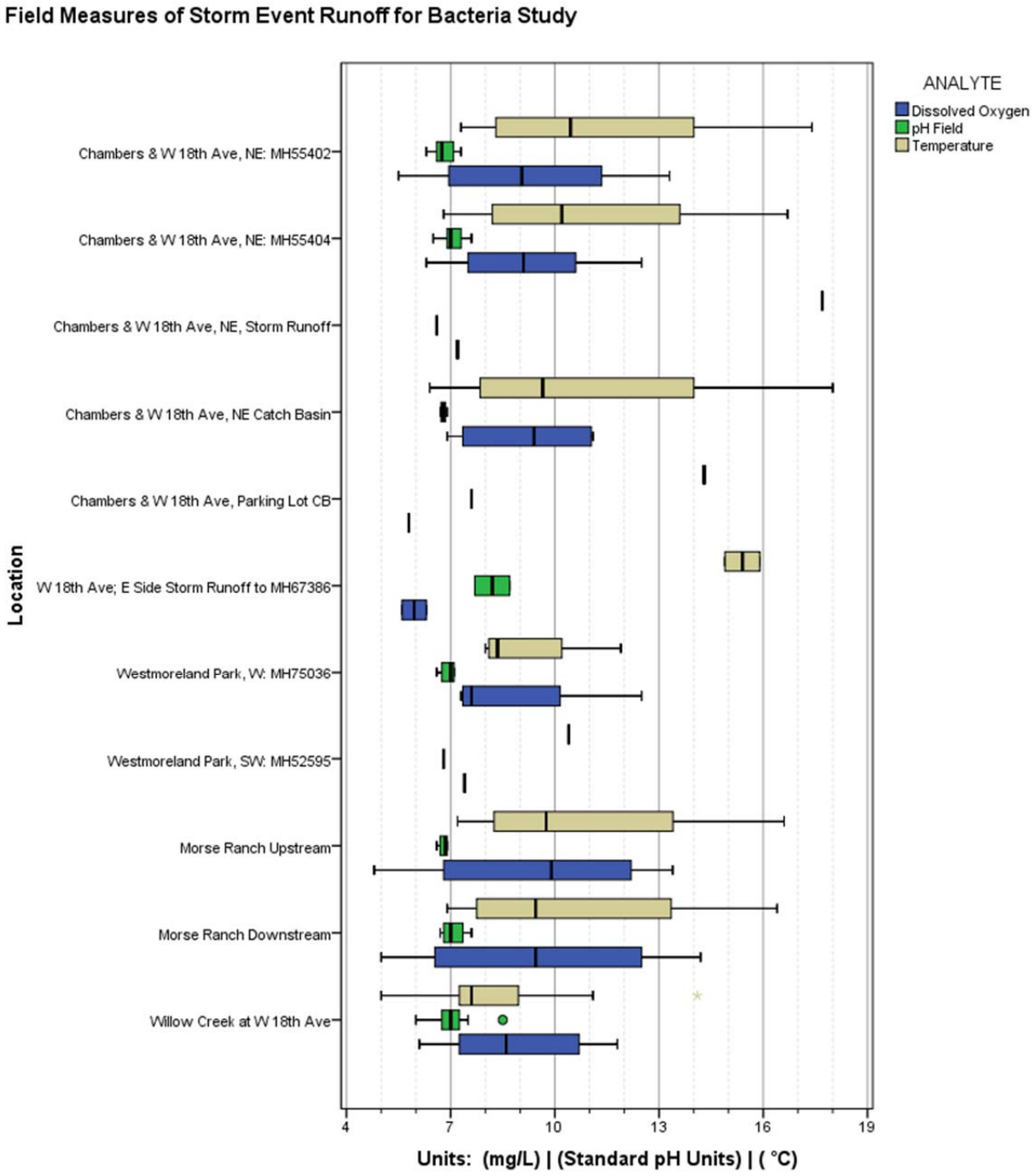

Field Measures of Storm Event Runoff for Bacteria Study
ANALYTE
Dissolved Oxygen
pH Field
Temperature
Location
Chambers & W 18th Ave, NE: MH55402
Chambers & W 18th Ave, NE: MH55404
Chambers & W 18th Ave, NE, Storm Runoff
Chambers & W 18th Ave, NE Catch Basin
Chambers & W 18th Ave, Parking Lot CB
W 18th Ave; E Side Storm Runoff to MH67386
Westmoreland Park, W: MH75036
Westmoreland Park, SW: MH52595
Morse Ranch Upstream
Morse Ranch Downstream
Willow Creek at W 18th Ave
4
7
10
13
16
19
Units: (mg/L) | (Standard pH Units) | (°C)

Figure B.26

Metals Pollutant LoadingStorm Event Flow-Proportional Monitoring

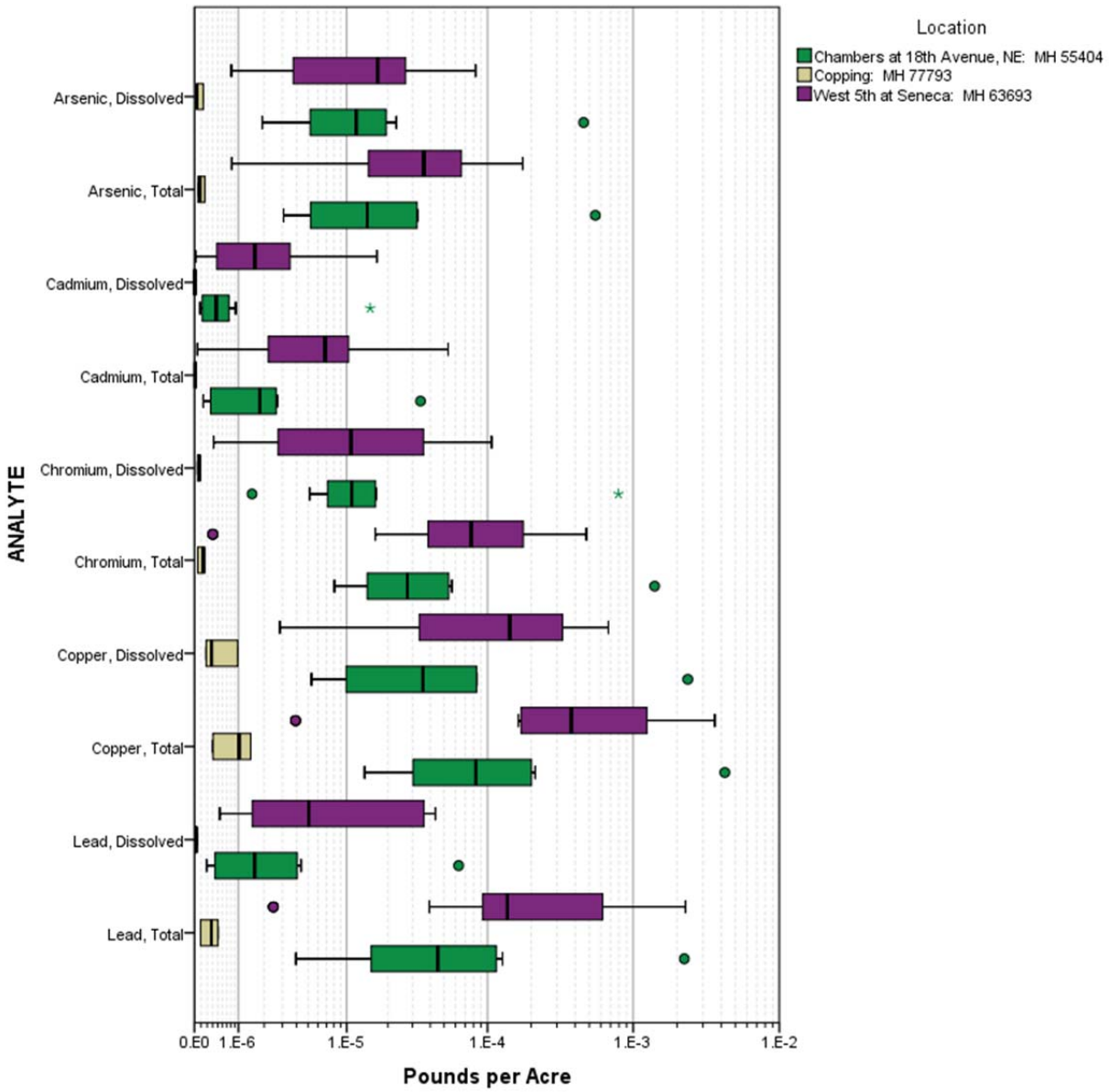


Figure B.27

Metals Pollutant LoadingStorm Event Flow-Proportional Monitoring

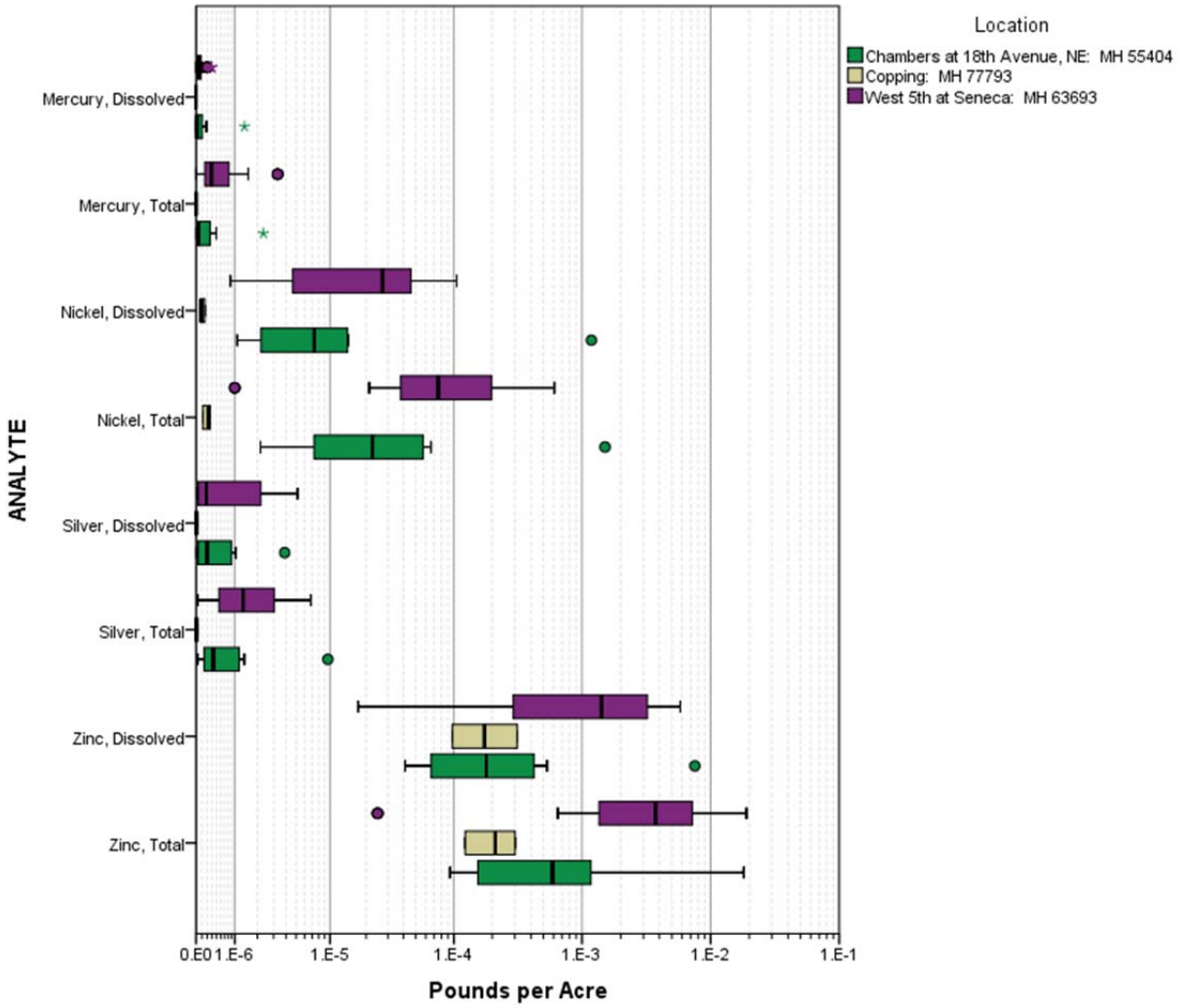


Figure B.28

Turbidity Pollutant LoadingStorm Event Flow-Proportional Monitoring

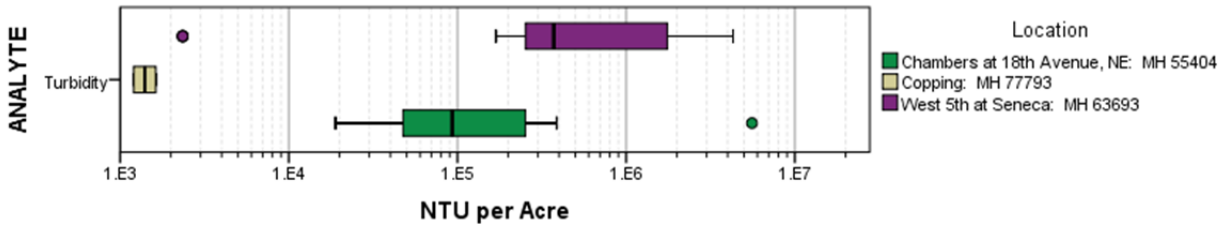


Figure B.29

Solids Pollutant LoadingStorm Event Flow-Proportional Monitoring

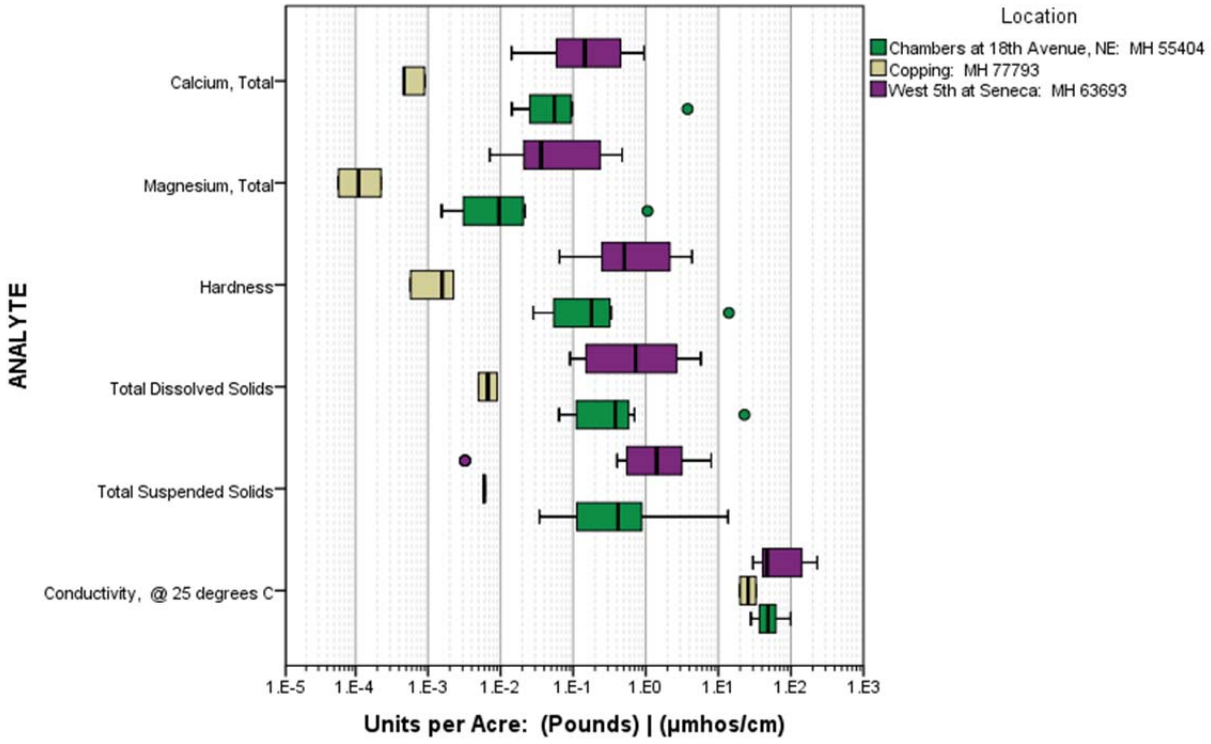


Figure B.30

Oxygen Demand Pollutant LoadingStorm Event Flow-Proportional Monitoring

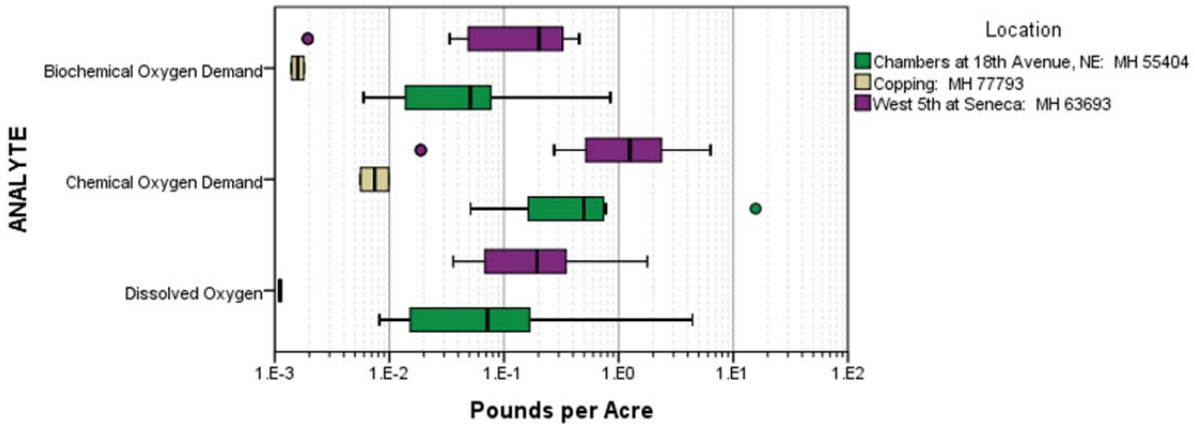


Figure B.31

Nutrient Pollutant LoadingStorm Event Flow-Proportional Monitoring

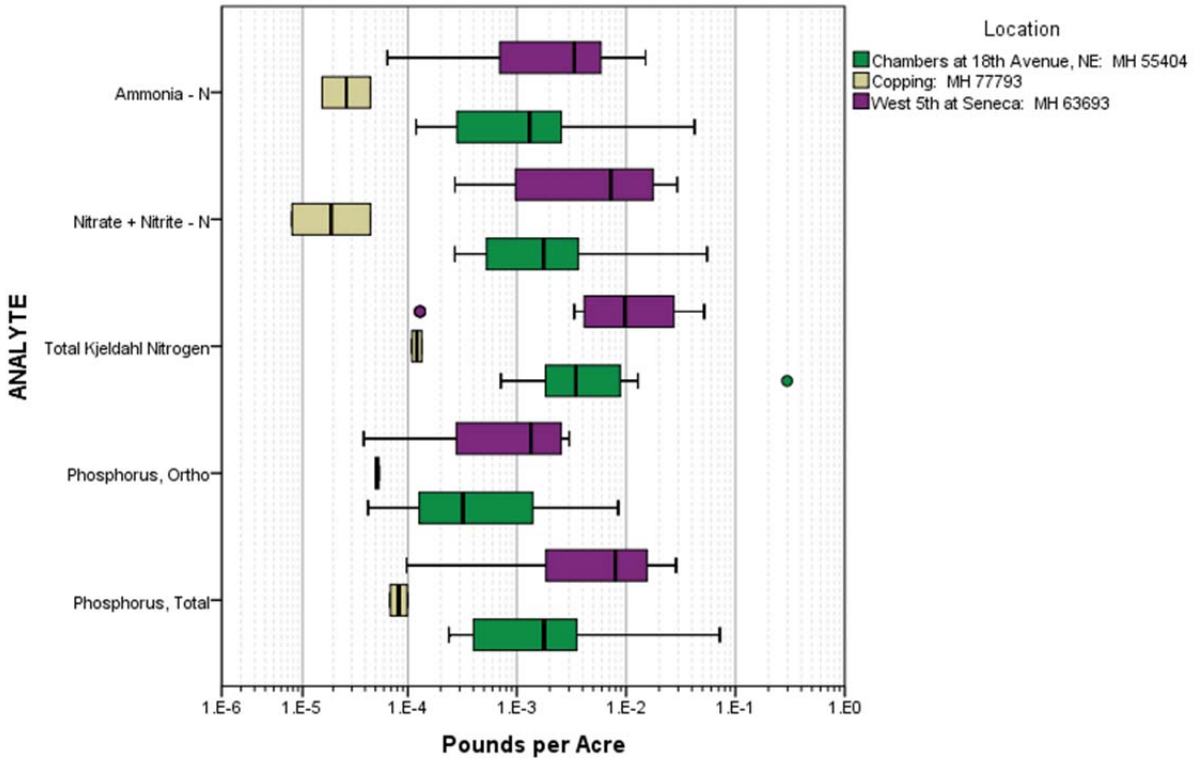


Figure B.32

Bacteria Pollutant LoadingStorm Event Flow-Proportional Monitoring

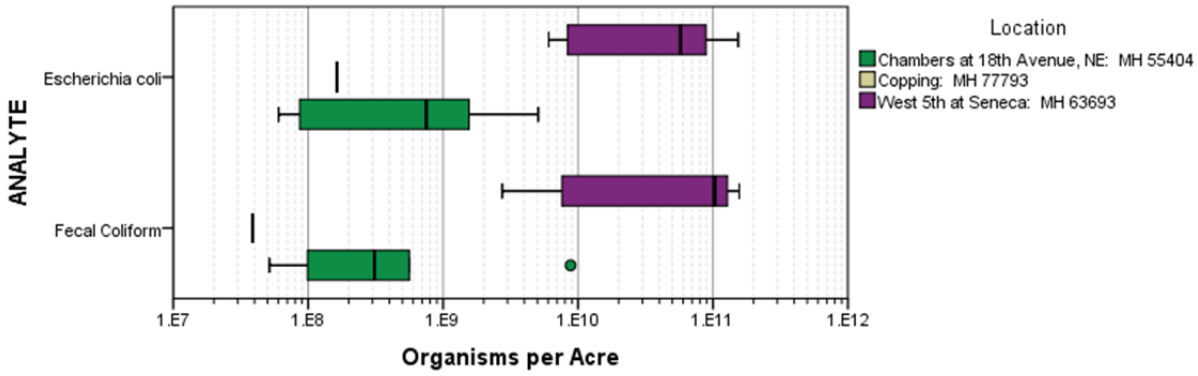


Figure B.33

Organic Carbon Pollutant LoadingStorm Event Flow-Proportional Monitoring

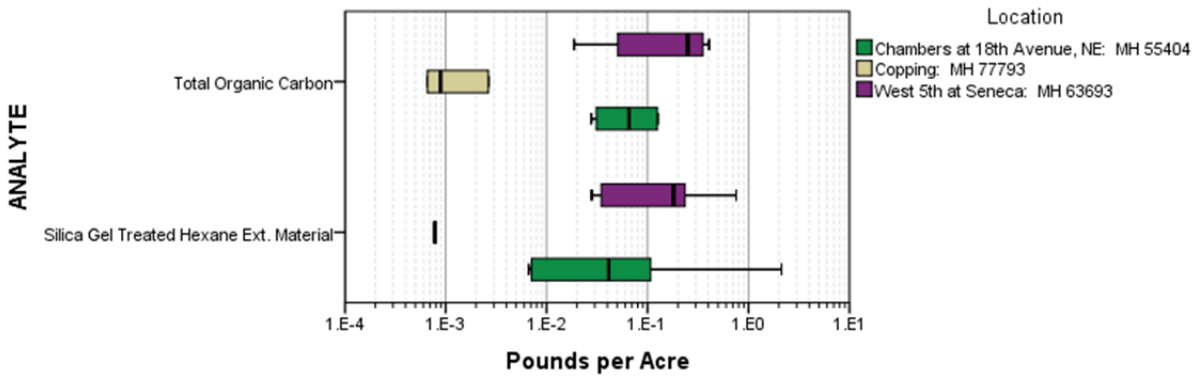


Figure B.34

Organics Pollutant LoadingStorm Event Flow-Proportional Monitoring

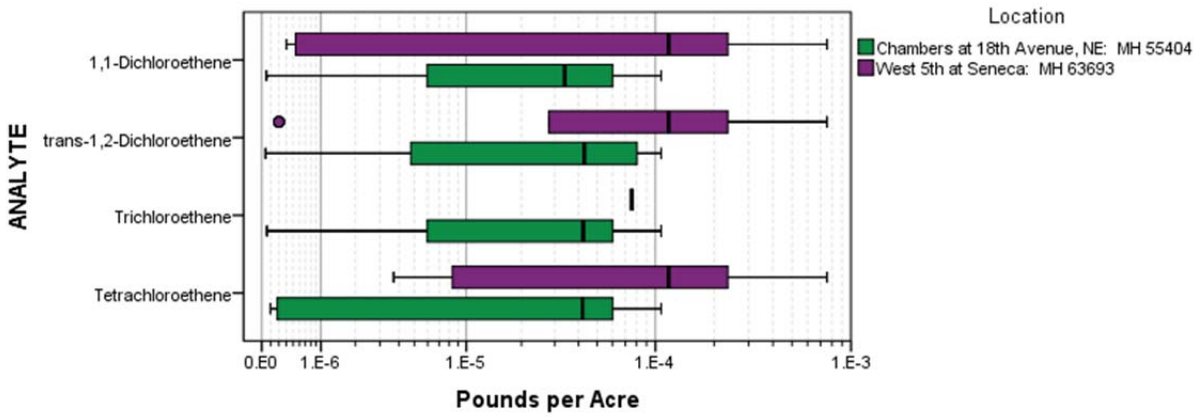


Figure B.35

Dioxin & Methyl Mercury Pollutant LoadingStorm Event Flow-Proportional Monitoring

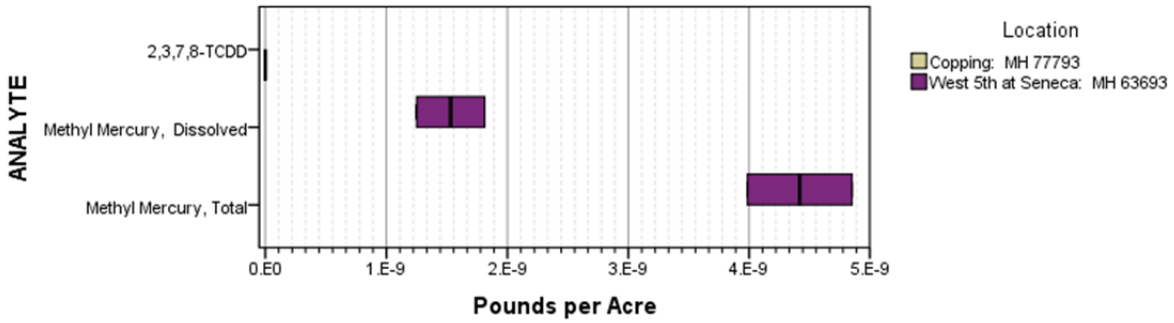


Figure B.36
Willow Creek Near 18th Avenue
Trend for Dissolved Lead

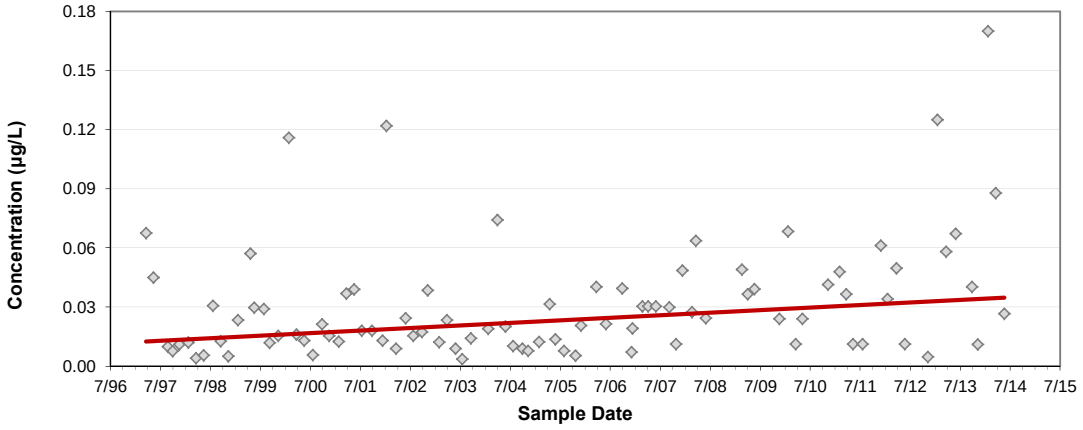


Figure B.37
Willow Creek Near 18th Avenue
Trend for Dissolved Zinc

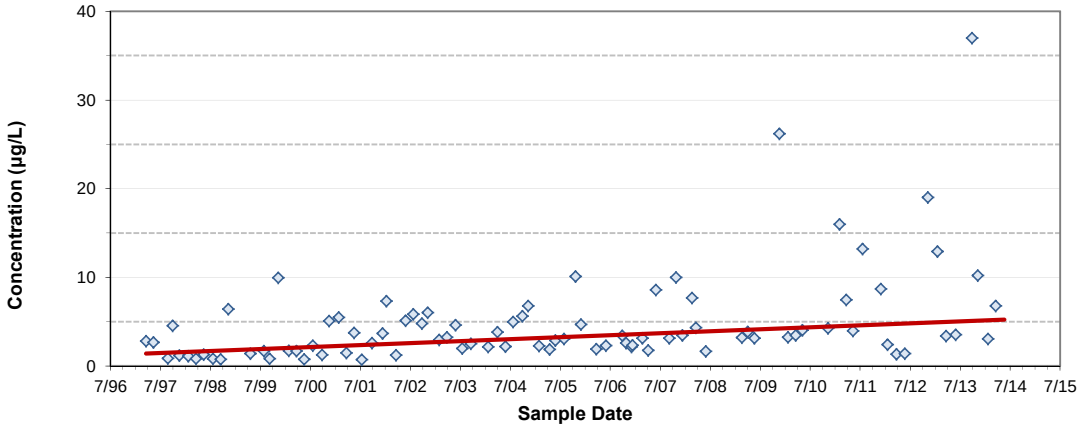


Figure B.38
Willow Creek Near 18th Avenue
Trend for Total Zinc

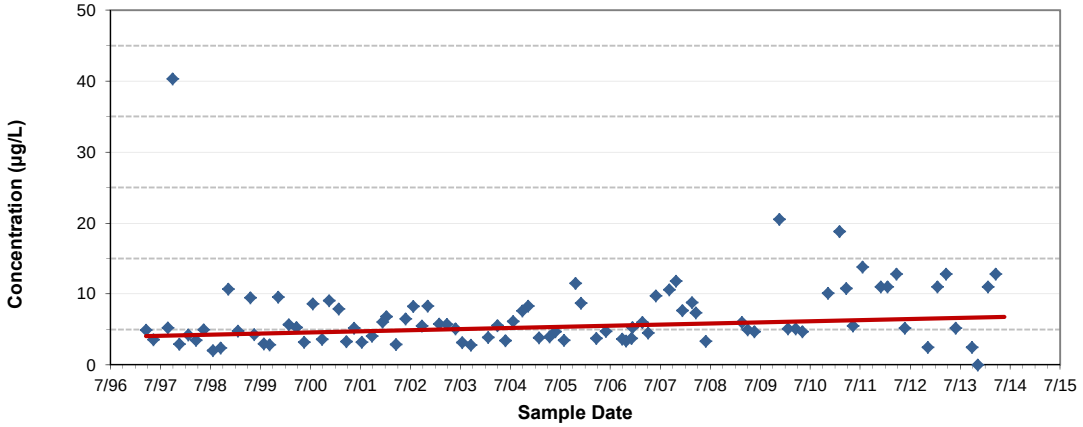


Figure B.39
Willow Creek Near 18th Avenue
Trend for Total Kjeldahl Nitrogen

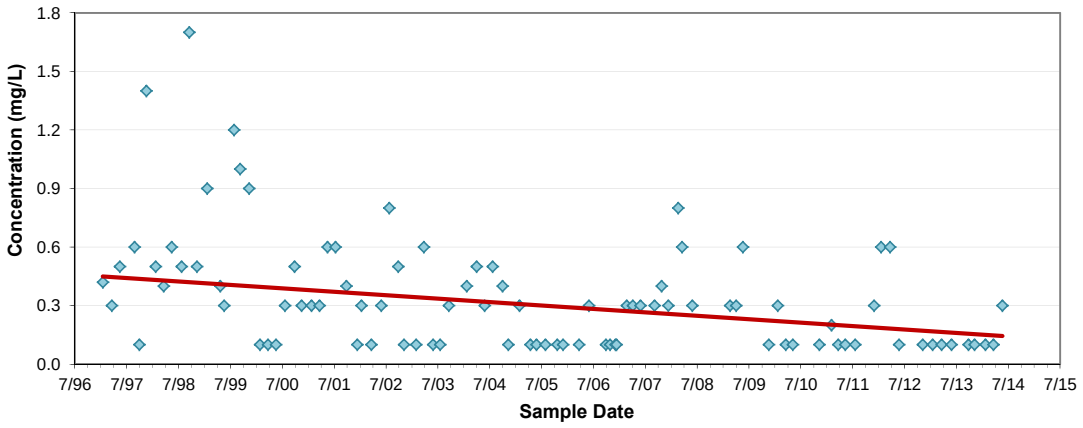


Figure B.40
Amazon Creek at 29th Avenue
Trend for Total Lead

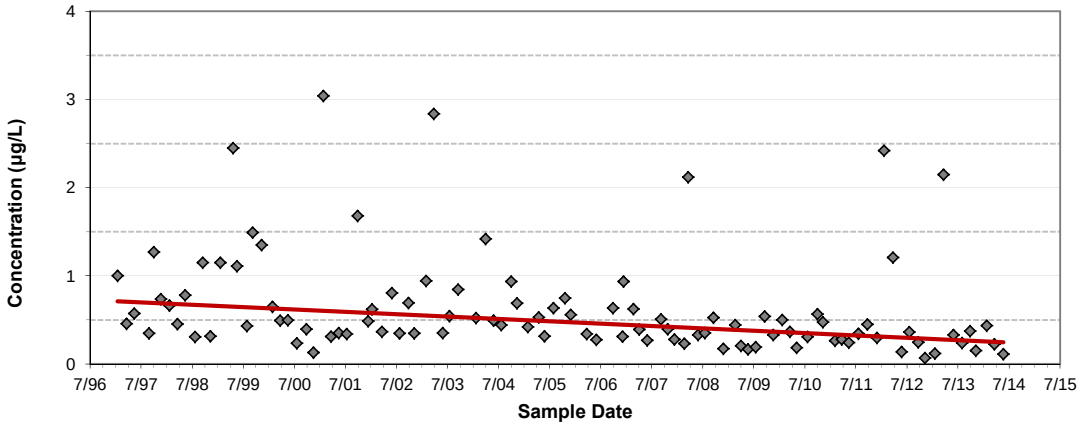


Figure B.41
Amazon Creek at 29th Avenue
Trend for Dissolved Zinc

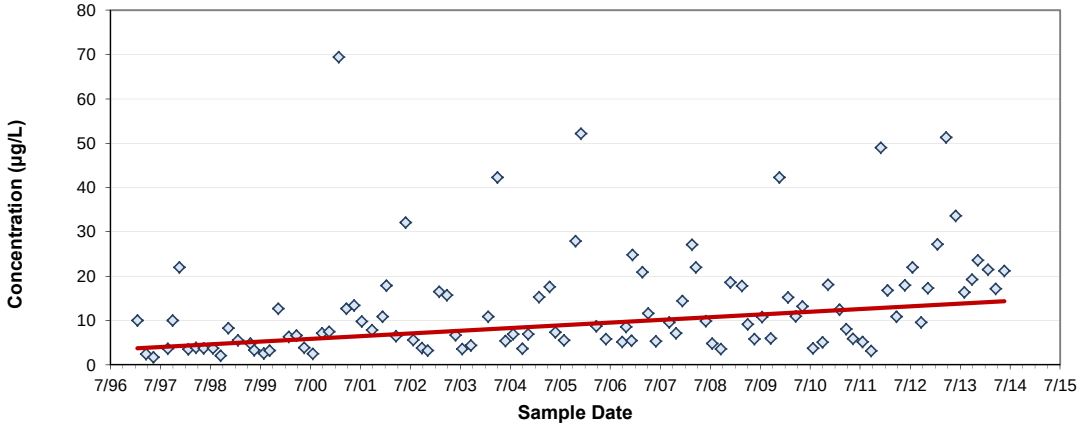


Figure B.42
Amazon Creek at 29th Avenue
Trend for Total Zinc

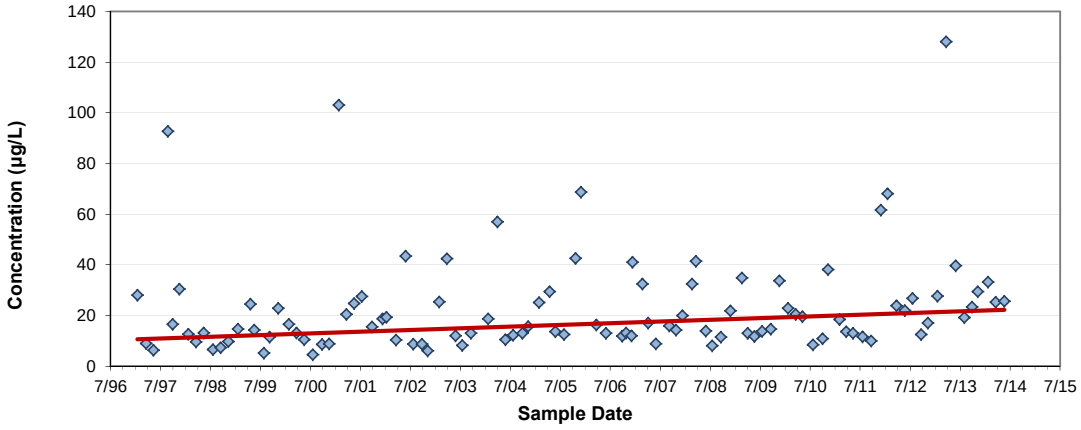


Figure B.43
Amazon Creek at Railroad Crossing
Trend for Total Cadmium

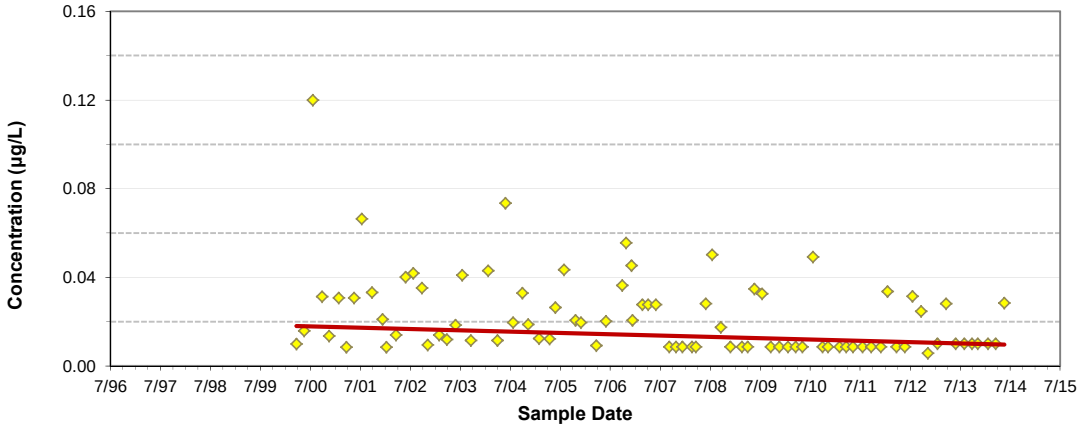


Figure B.44
Amazon Creek at Railroad Crossing
Trend for Dissolved Chromium

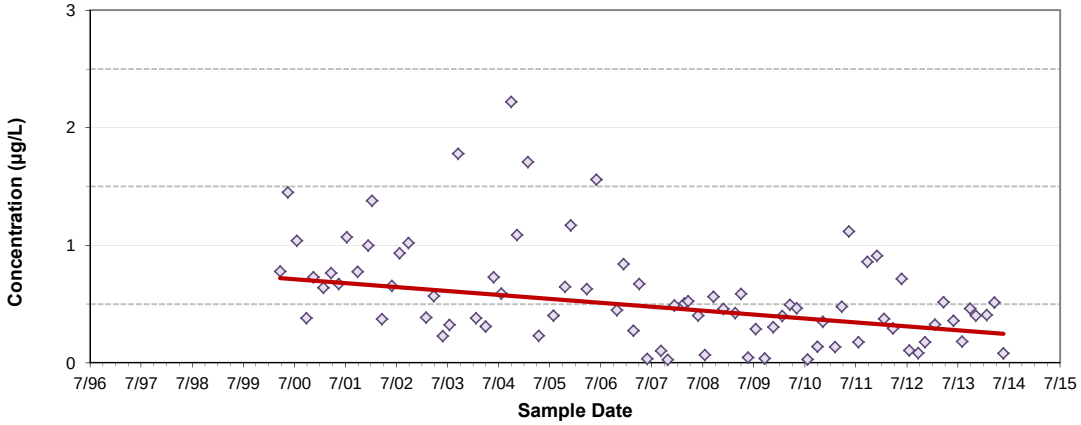


Figure B.45
Amazon Creek at Railroad Crossing
Trend for Total Chromium

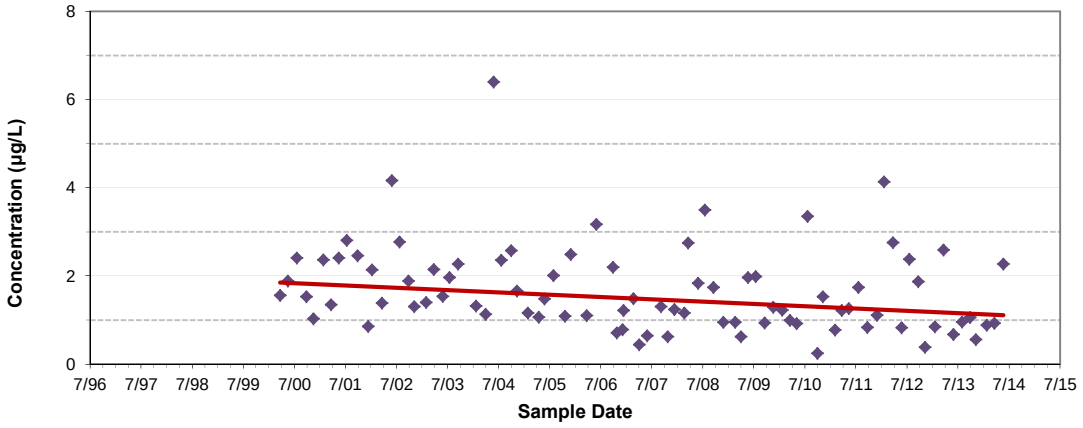


Figure B.46
Amazon Creek at Railroad Crossing
Trend for Total Lead

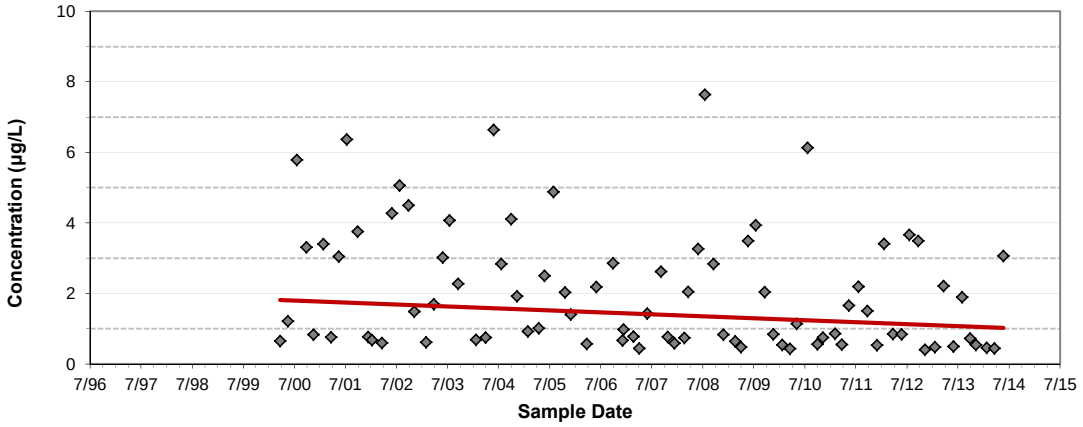


Figure B.47
Amazon Creek at Railroad Crossing
Trend for Dissolved Mercury

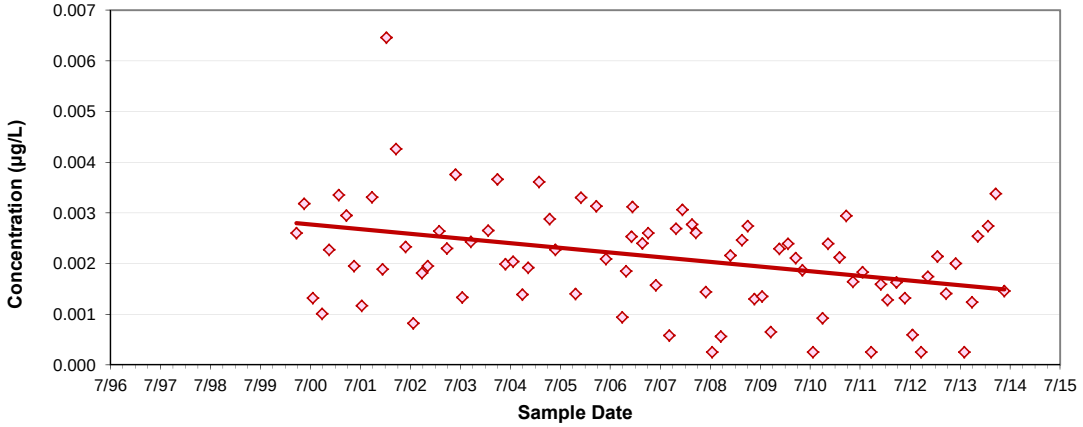


Figure B.48
Amazon Creek at Railroad Crossing
Trend for Total Mercury

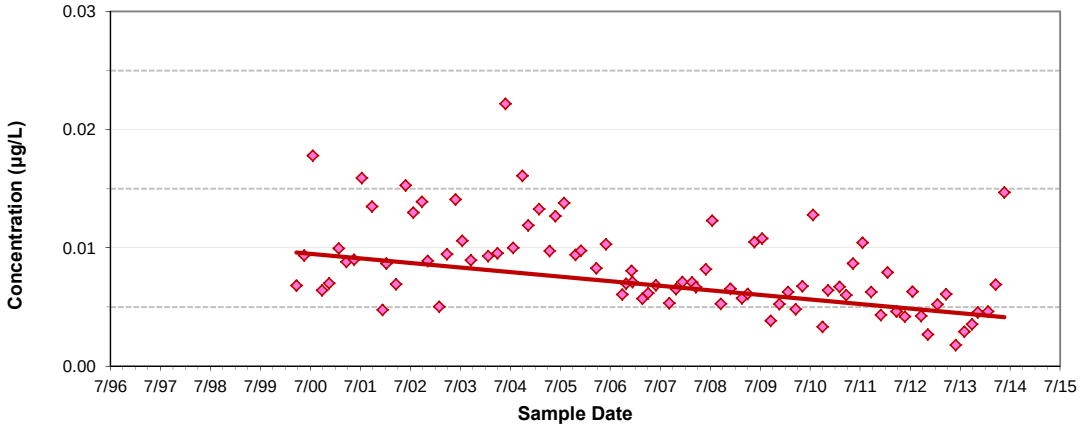


Figure B.49
Amazon Creek at Railroad Crossing
Trend for Dissolved Nickel

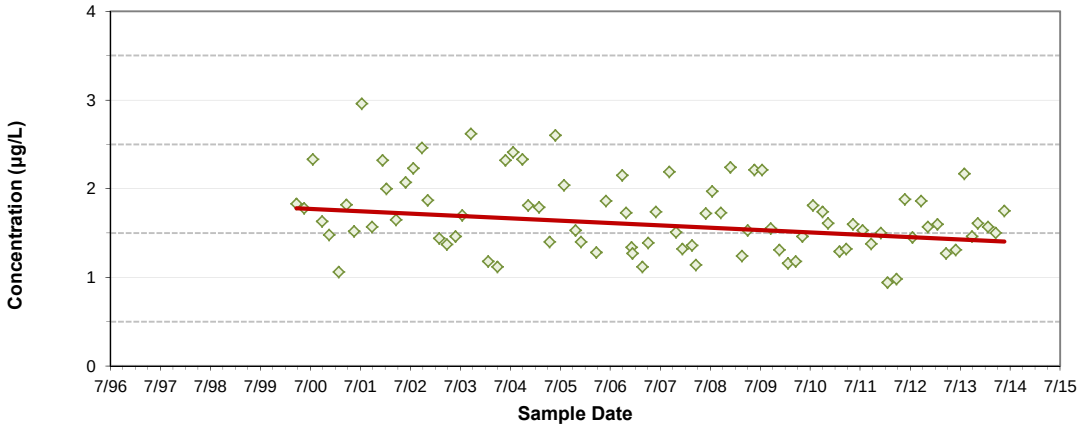


Figure B.50
Amazon Creek at Railroad Crossing
Trend for Dissolved Zinc

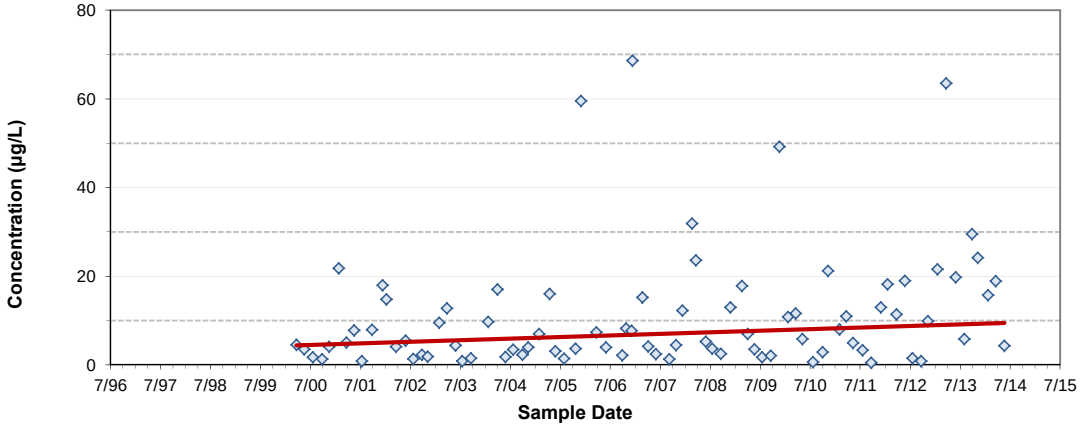


Figure B.51
Amazon Creek at Railroad Crossing
Trend for Total Zinc

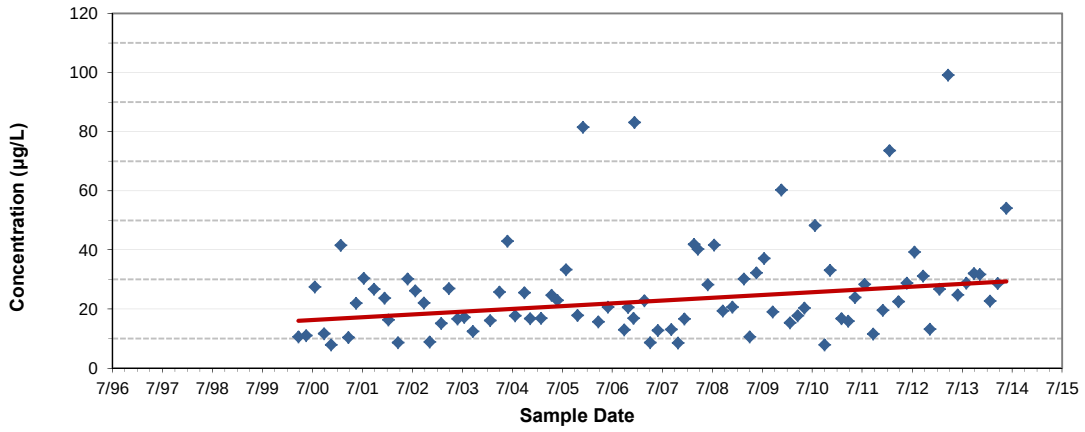


Figure B.52
Amazon Diversion Channel at Royal Avenue
Trend for Dissolved Arsenic

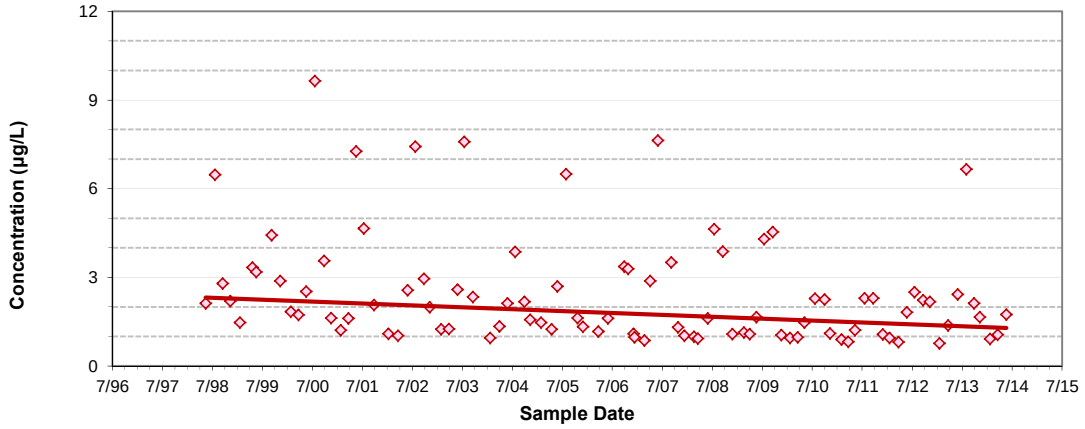


Figure B.53
Amazon Diversion Channel at Royal Avenue
Trend for Total Arsenic

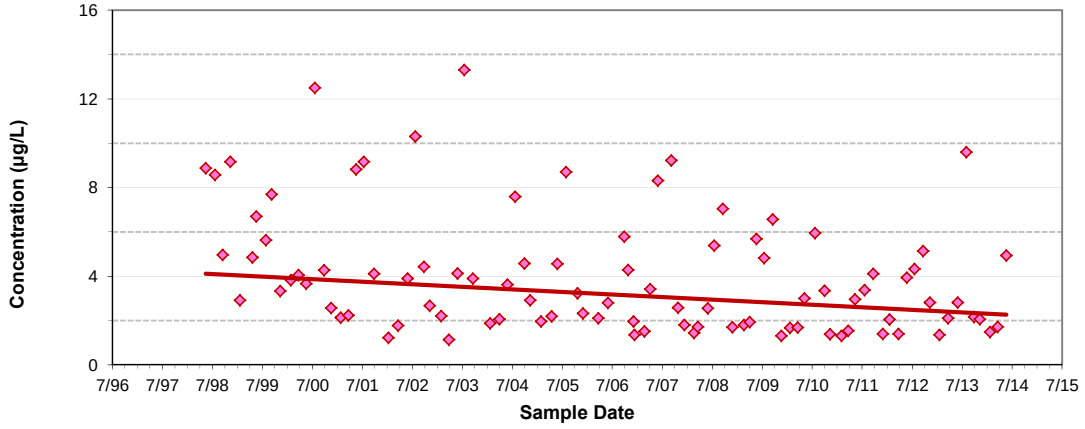


Figure B.54
Amazon Diversion Channel at Royal Avenue
Trend for Dissolved Mercury

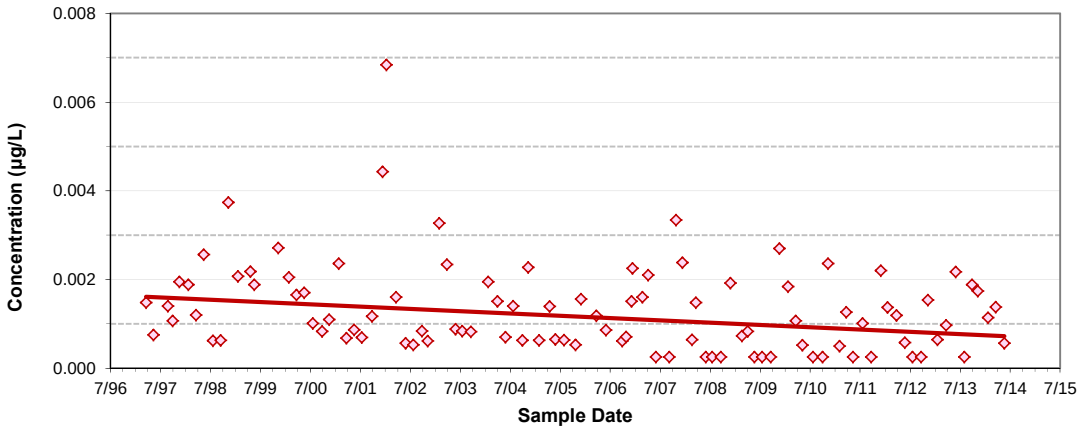


Figure B.55
Amazon Diversion Channel at Royal Avenue
Trend for Dissolved Molybdenum

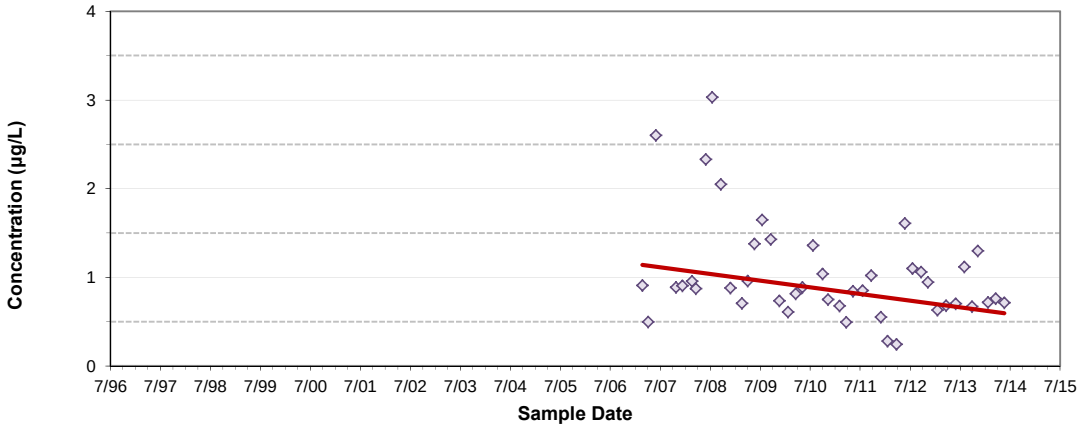


Figure B.56
Amazon Diversion Channel at Royal Avenue
Trend for Dissolved Nickel

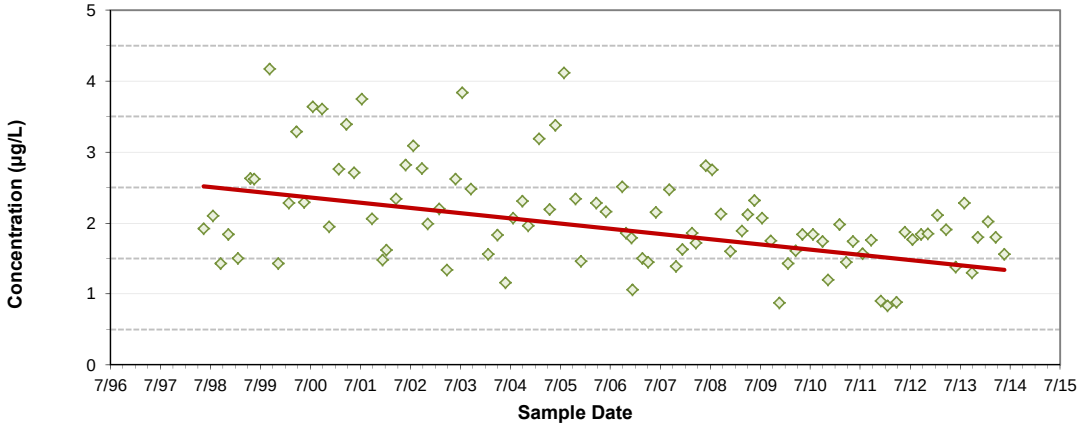


Figure B.57
Amazon Diversion Channel at Royal Avenue
Trend for Total Nickel

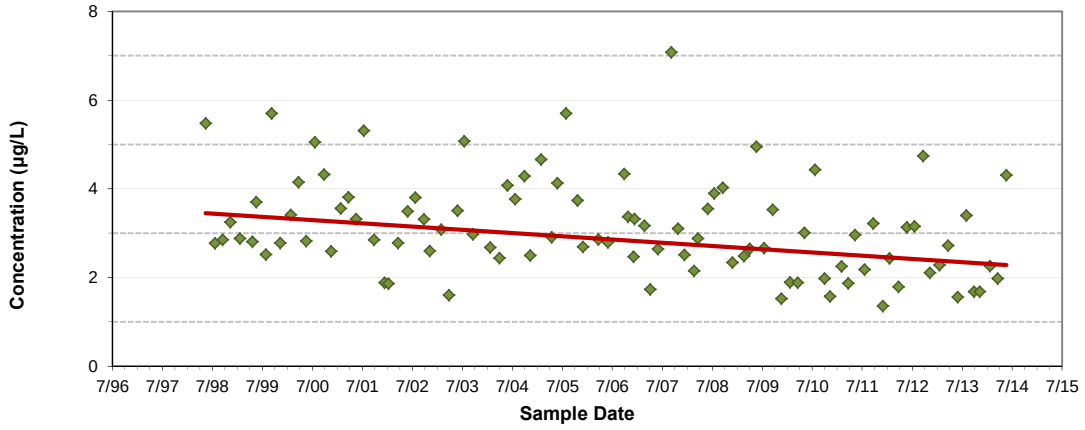


Figure B.58
Amazon Diversion Channel at Royal Avenue
Trend for Total Zinc

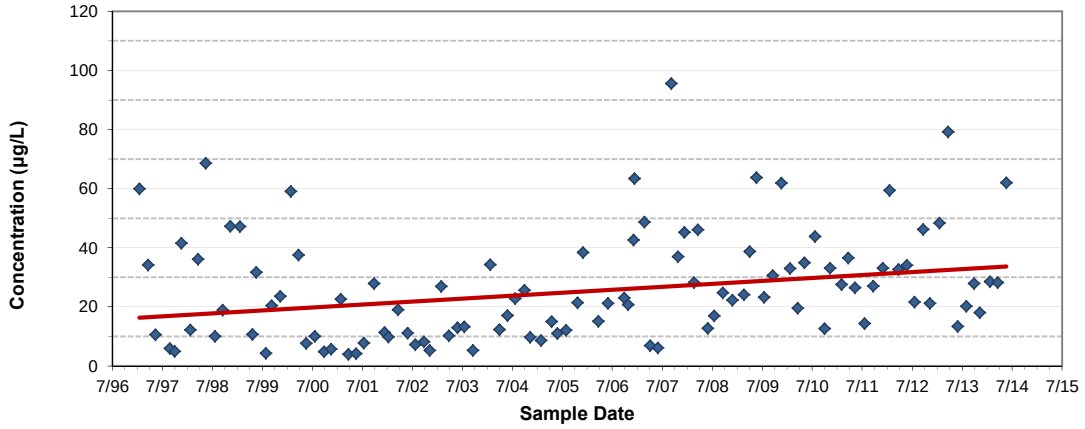


Figure B.59
Amazon Diversion Channel at Royal Avenue
Trend for Biochemical Oxygen Demand

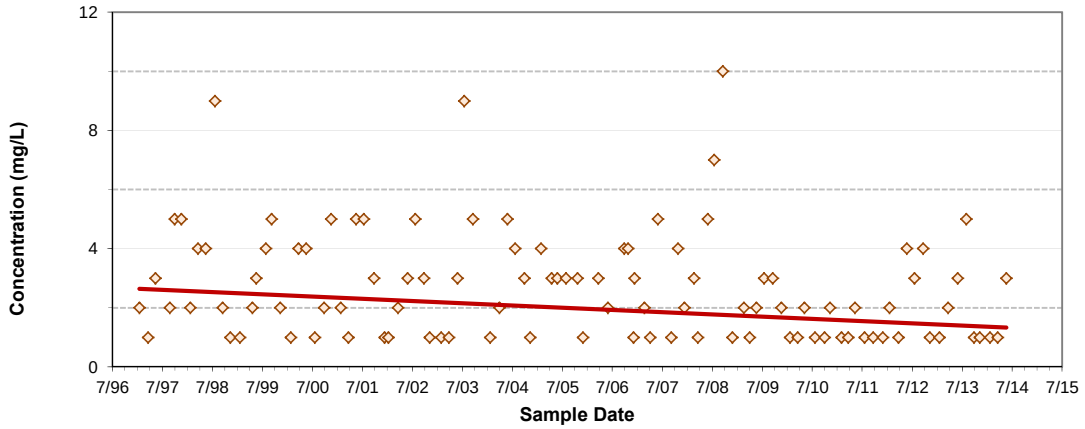


Figure B.60
Amazon Diversion Channel at Royal Avenue
Trend for Total Kjeldahl Nitrogen

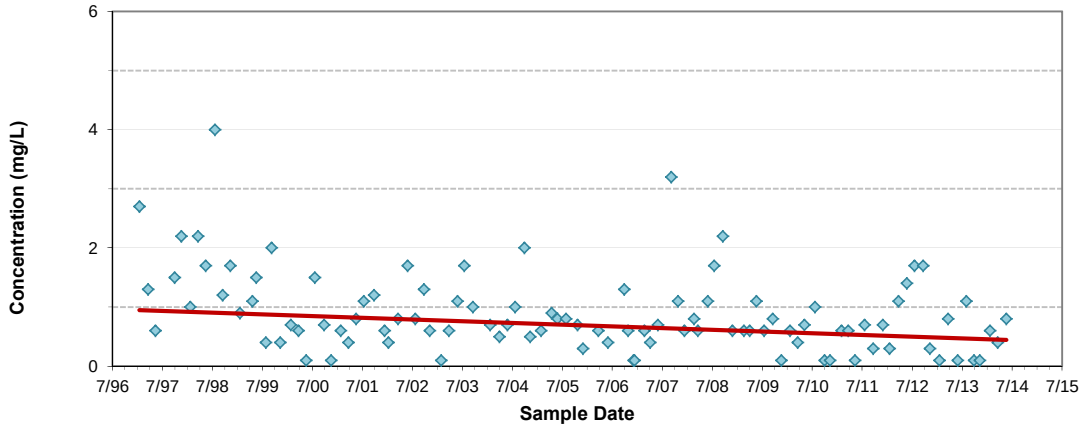


Figure B.61
A3 Channel at Terry Street
Trend for Total Silver

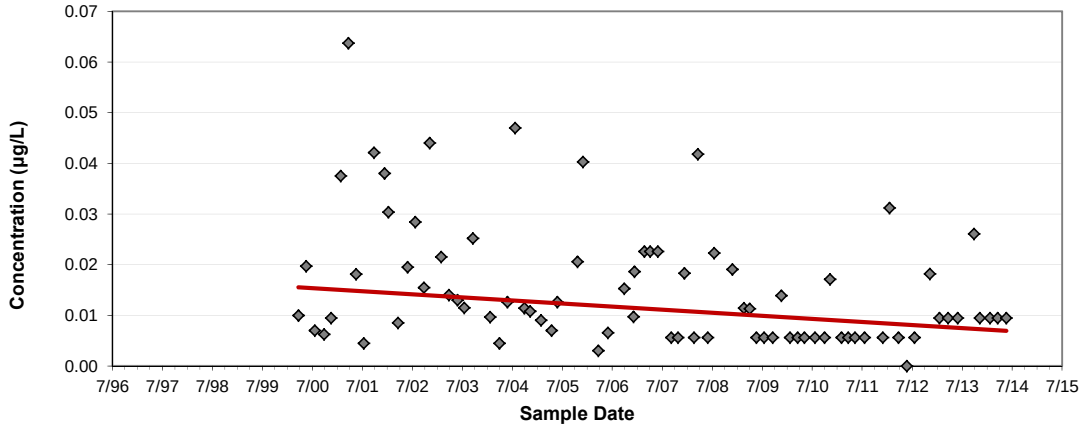


Figure B.62
A3 Channel at Terry Street
Trend for Dissolved Arsenic

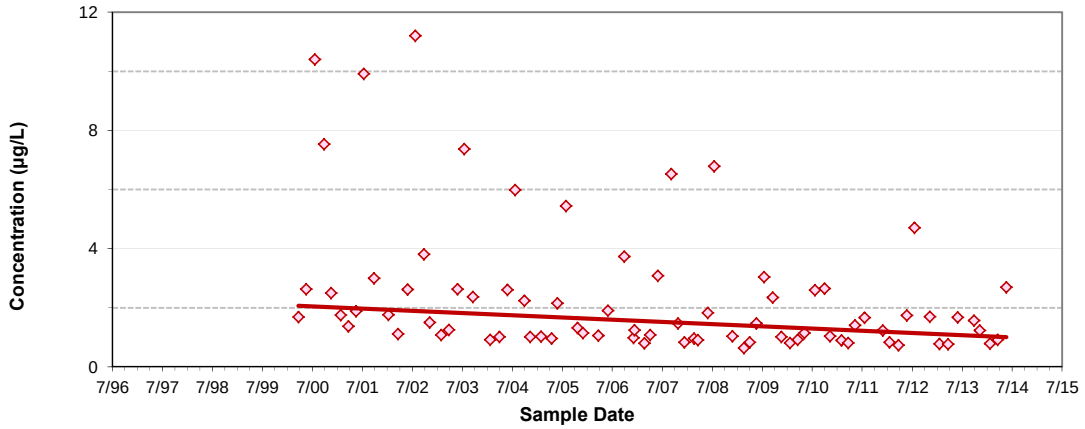


Figure B.63
A3 Channel at Terry Street
Trend for Total Arsenic

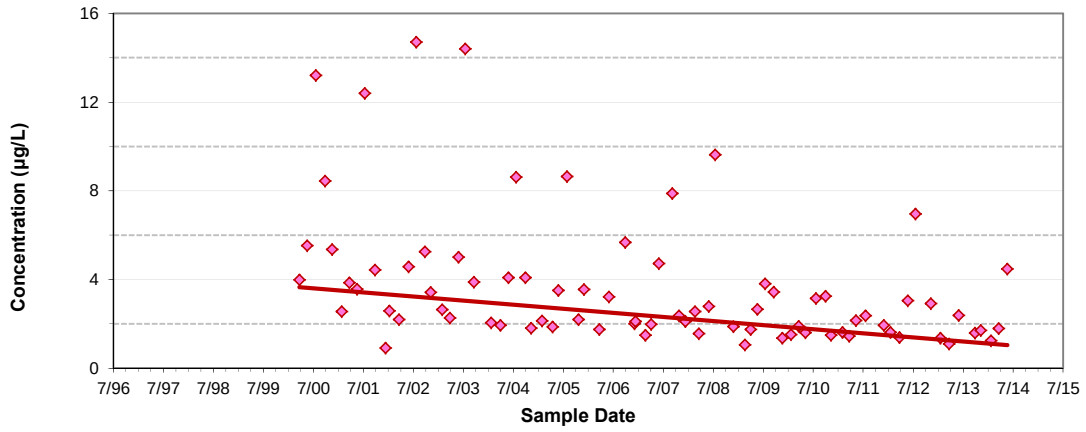


Figure B.64
A3 Channel at Terry Street
Trend for Total Cadmium

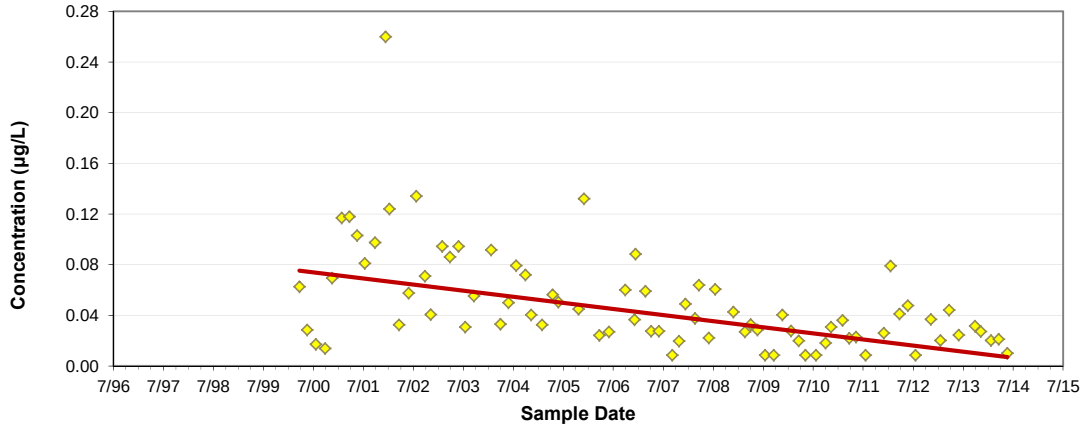


Figure B.65
A3 Channel at Terry Street
Trend for Dissolved Chromium

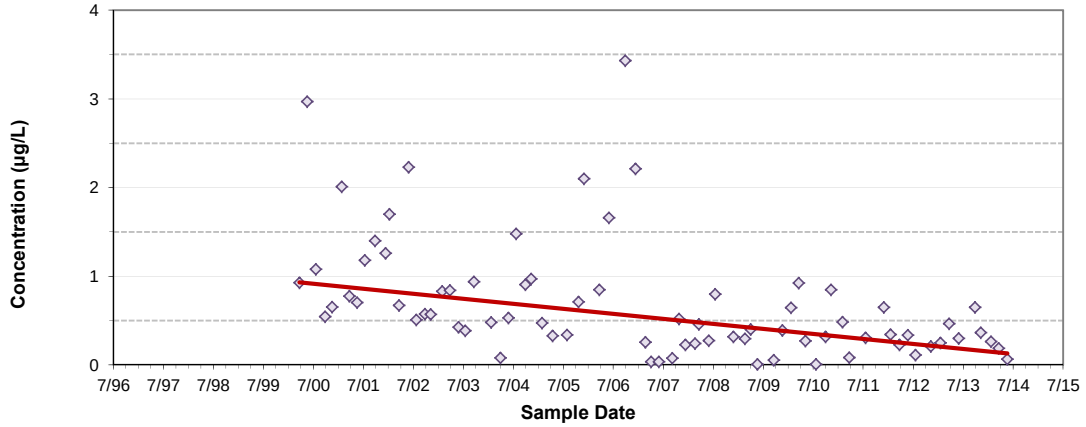


Figure B.66
A3 Channel at Terry Street
Trend for Total Chromium

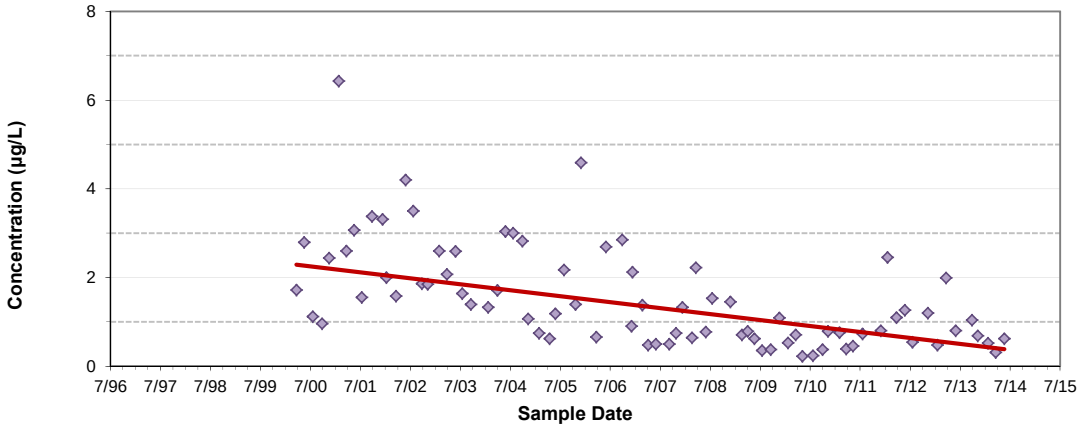


Figure B.67
A3 Channel at Terry Street
Trend for Total Lead

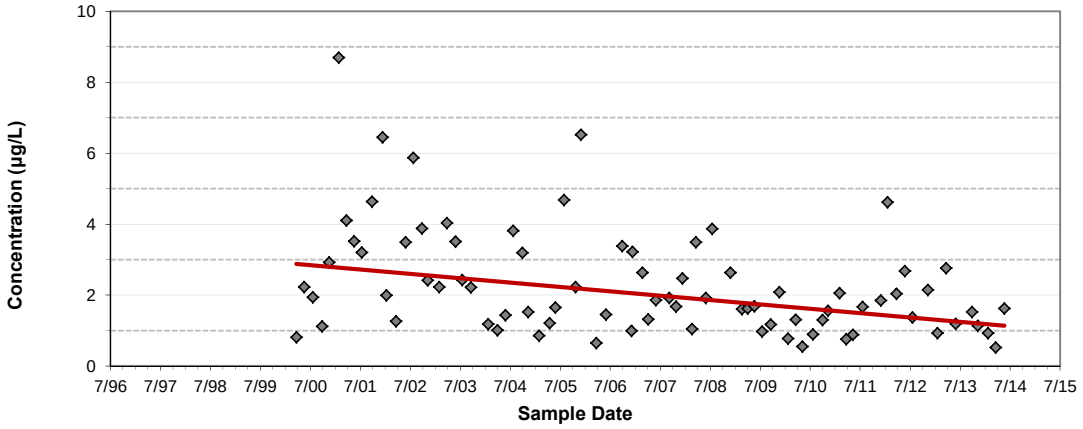


Figure B.68
A3 Channel at Terry Street
Trend for Dissolved Mercury

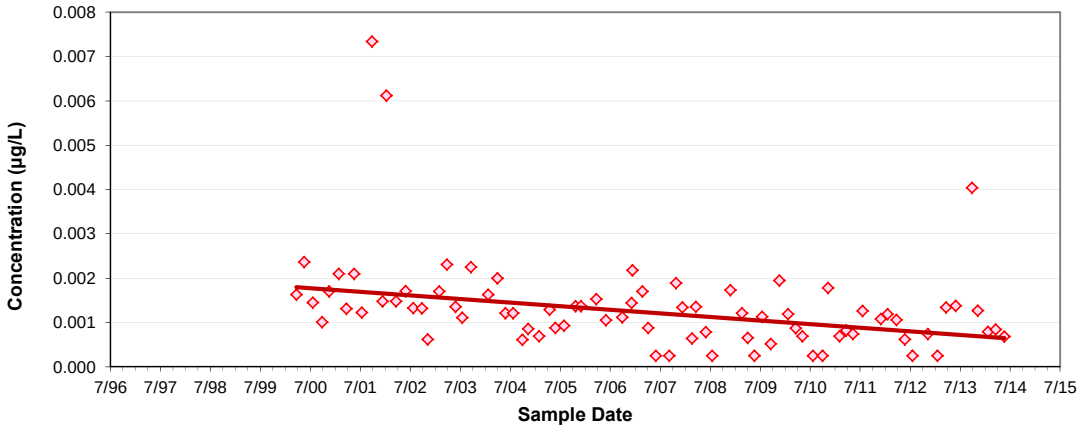


Figure B.69
A3 Channel at Terry Street
Trend for Total Mercury

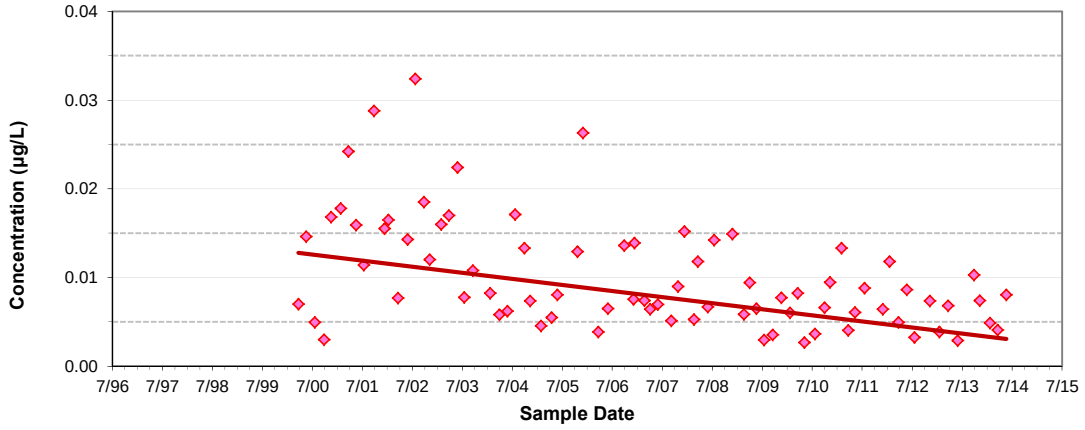


Figure B.70
A3 Channel at Terry Street
Trend for Dissolved Molybdenum

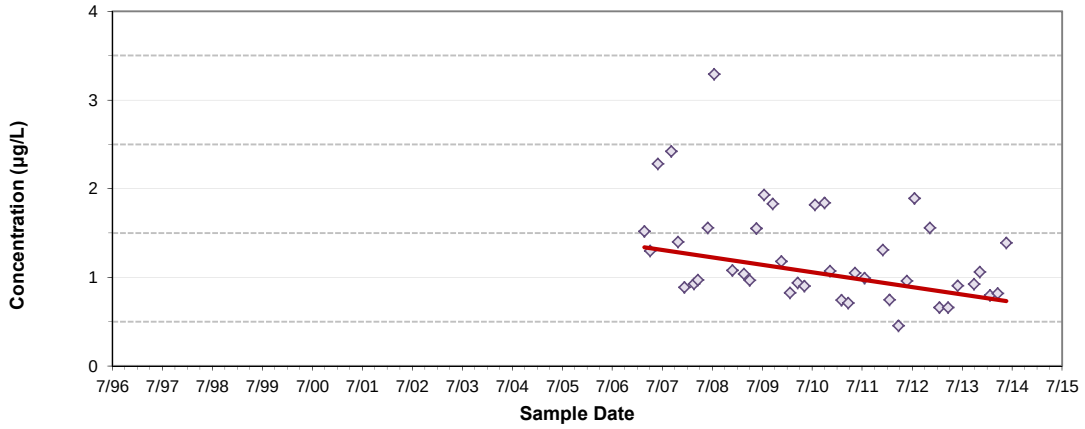


Figure B.71
A3 Channel at Terry Street
Trend for Dissolved Nickel

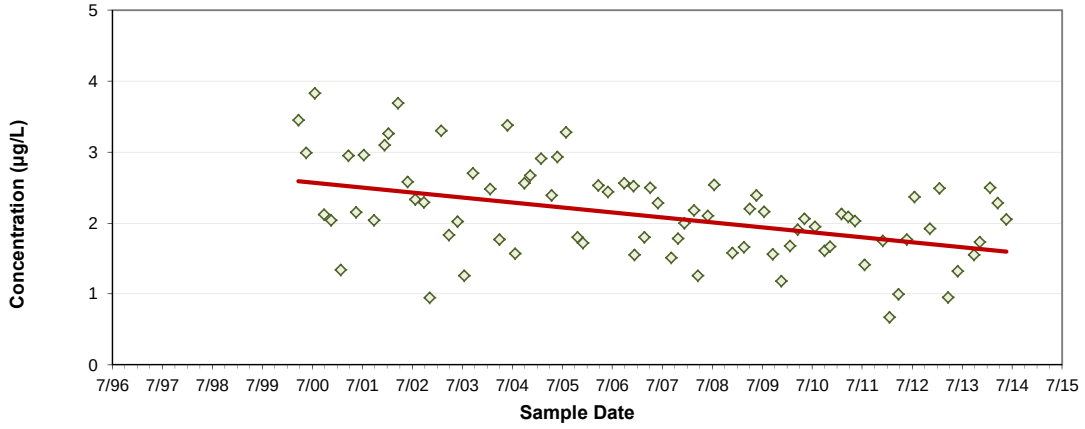


Figure B.72
A3 Channel at Terry Street
Trend for Total Nickel

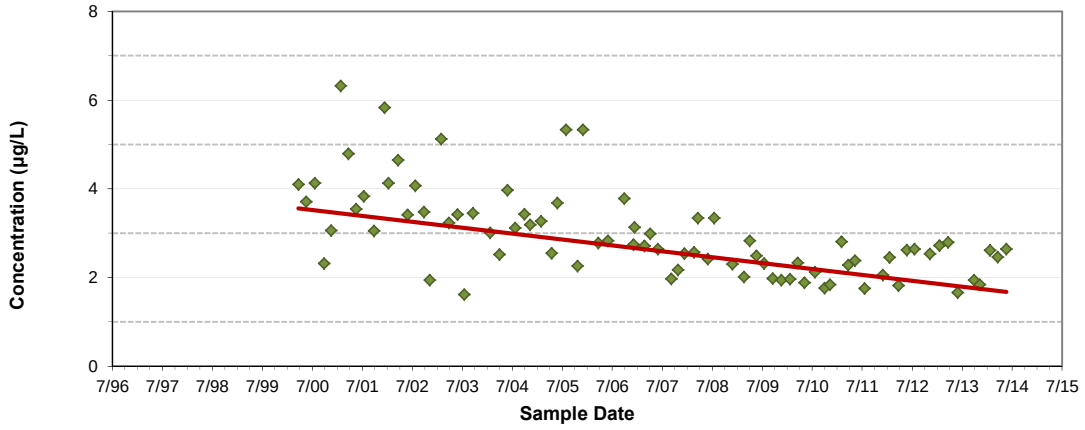


Figure B.73
A3 Channel at Terry Street
Trend for Biochemical Oxygen Demand

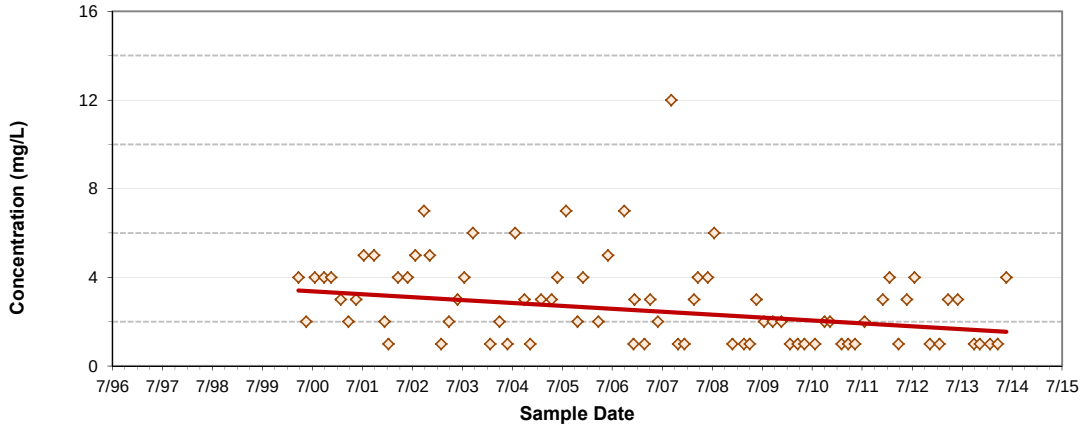


Figure B.74
A3 Channel at Terry Street
Trend for Total Phosphorus

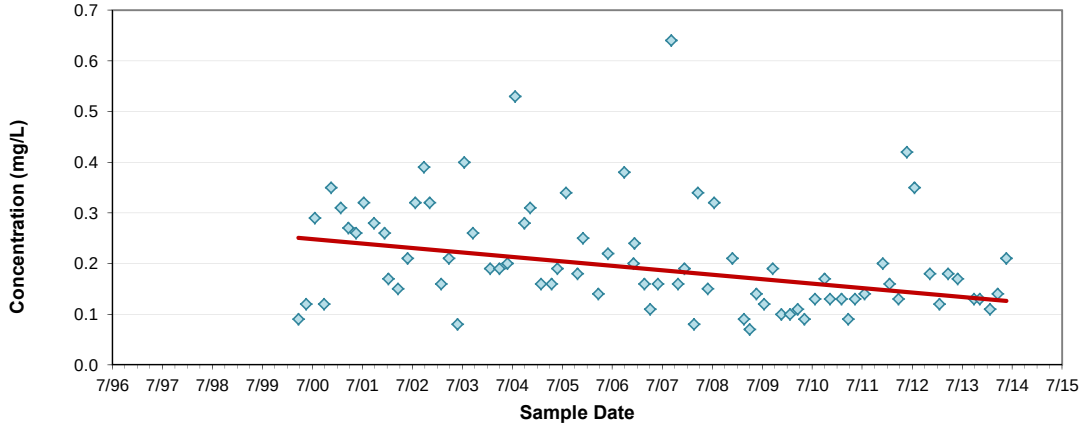


Figure B.75
A3 Channel at Terry Street
Trend for Temperature

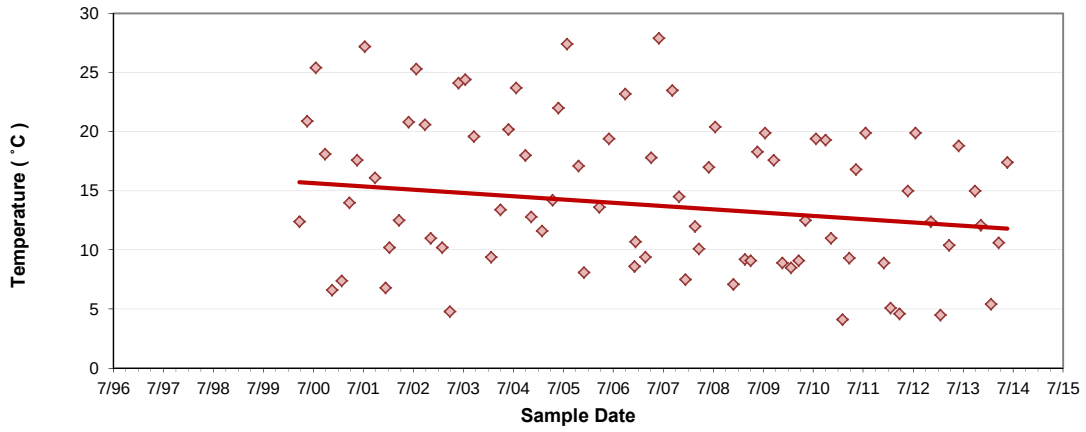


Figure B.76
A3 Channel at Terry Street
Trend for Total Kjeldahl Nitrogen

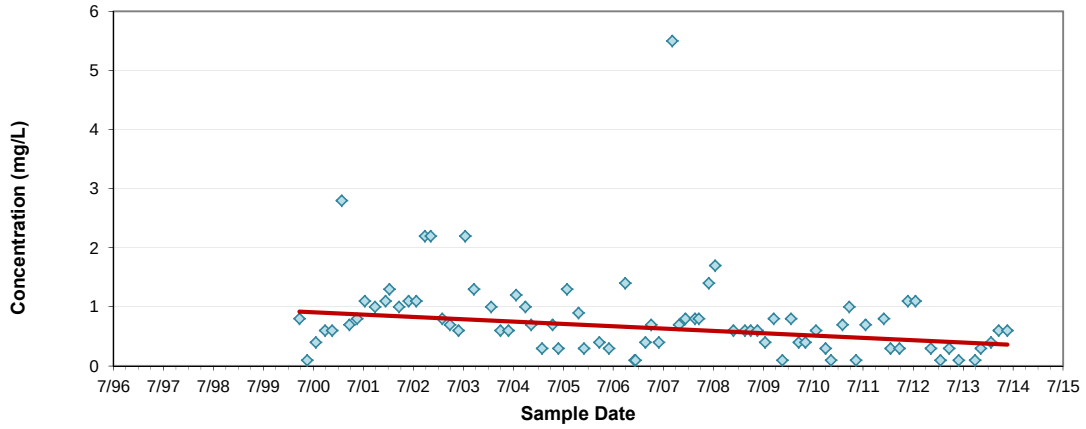


Figure B.77
Amazon Creek at Royal Avenue
Trend for Dissolved Chromium

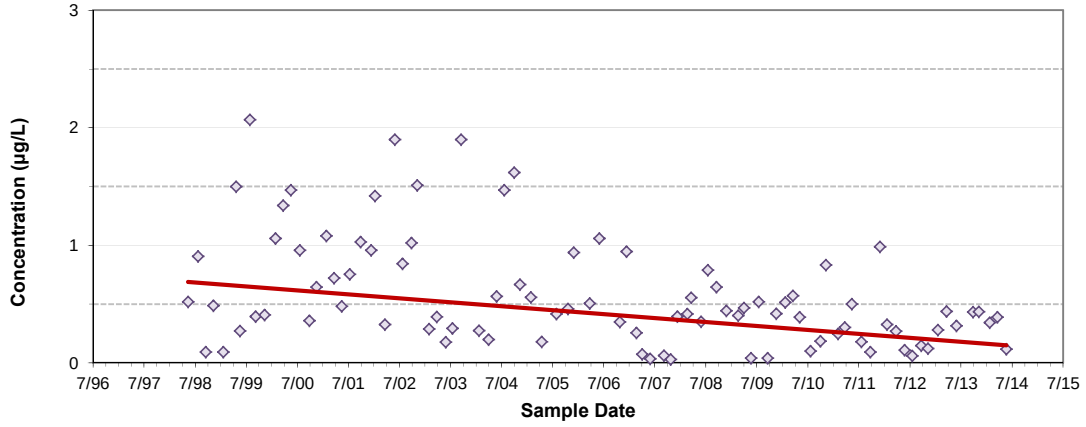


Figure B.78
Amazon Creek at Royal Avenue
Trend for Total Chromium

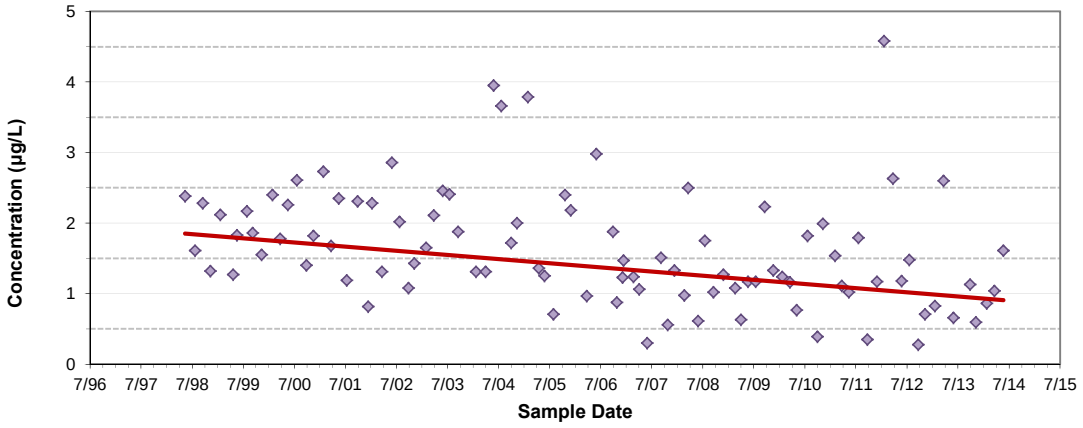


Figure B.79
Amazon Creek at Royal Avenue
Trend for Total Lead

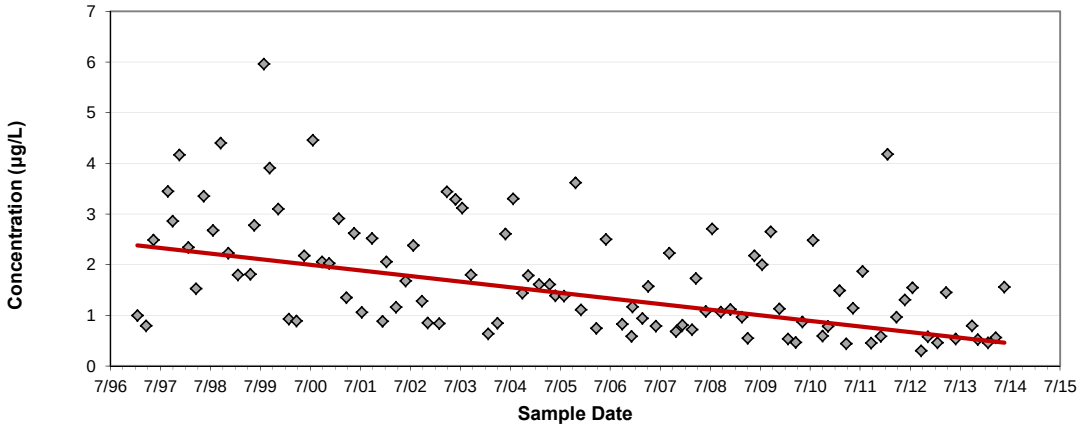


Figure B.80
Amazon Creek at Royal Avenue
Trend for Total Mercury

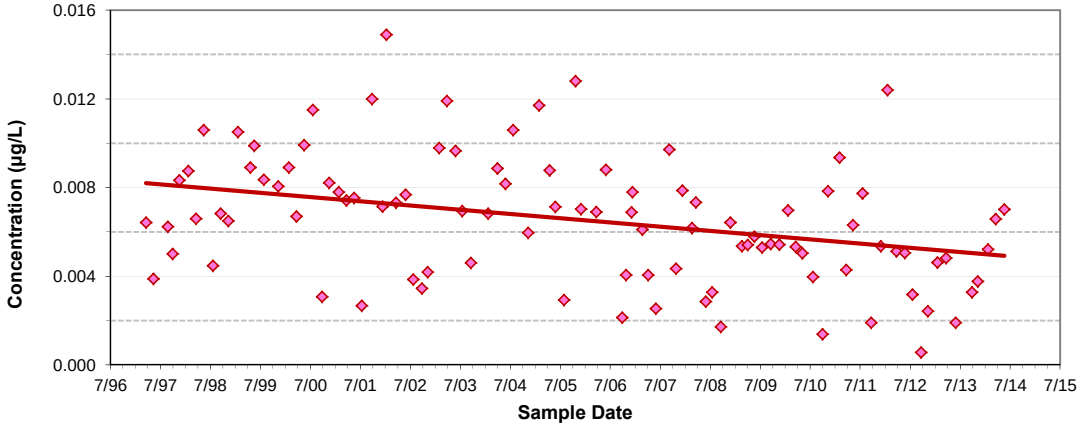


Figure B.81
Amazon Creek at Royal Avenue
Trend for Total Nickel

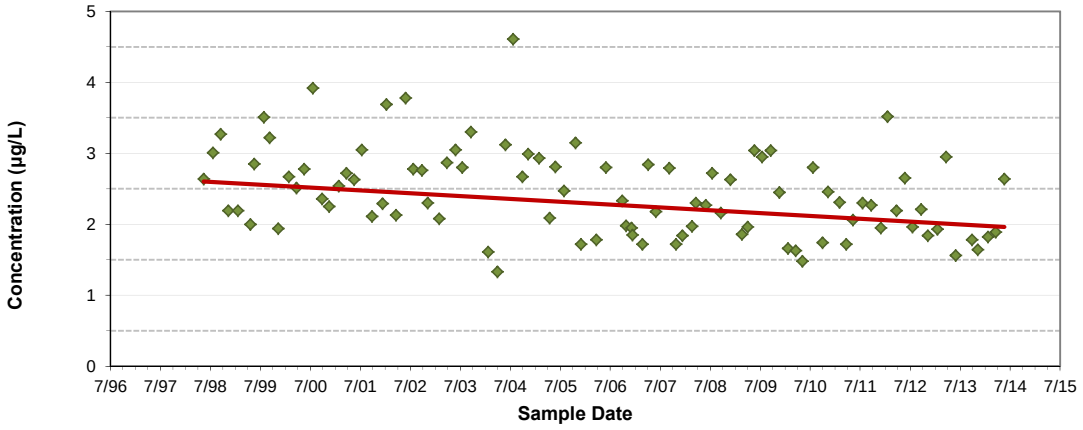


Figure B.82
Amazon Creek at Royal Avenue
Trend for Dissolved Zinc

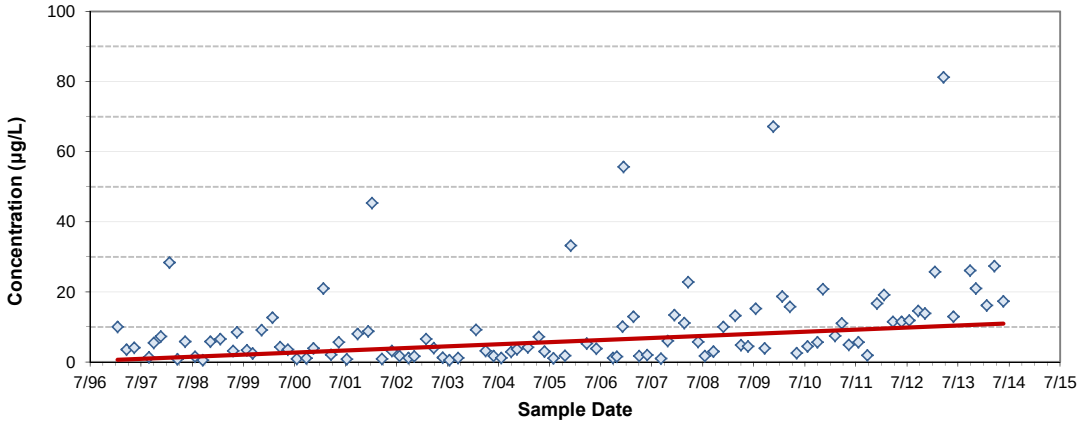


Figure B.83
Amazon Creek at Royal Avenue
Trend for Total Zinc

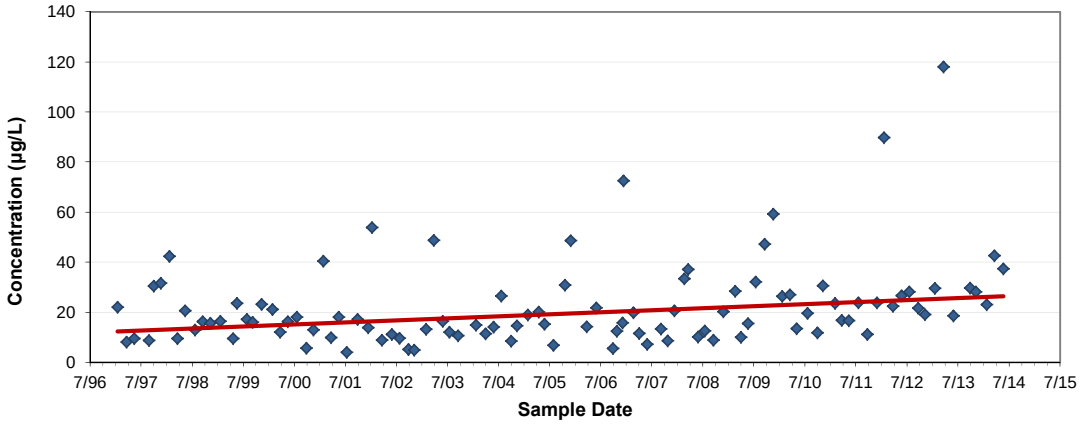


Figure B.84
Amazon Creek at Royal Avenue
Trend for Ortho Phosphorus

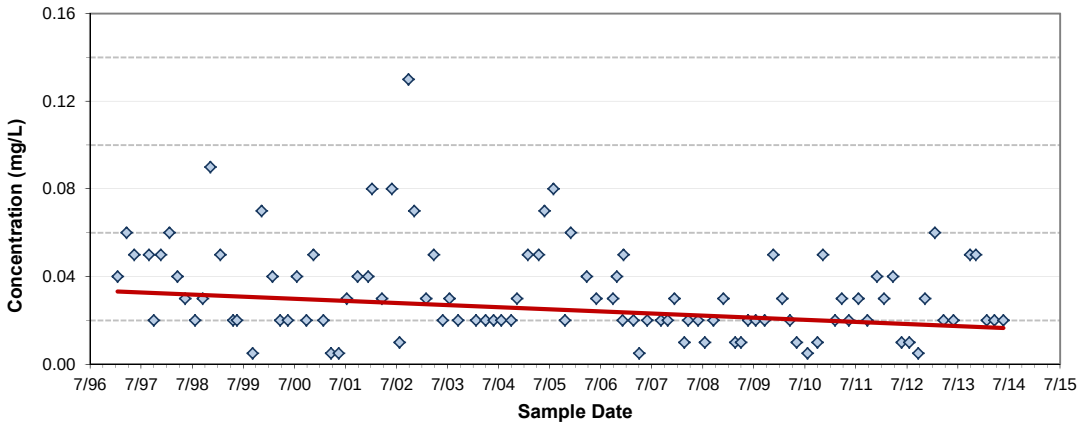


Figure B.85
Amazon Creek at Royal Avenue
Trend for Temperature

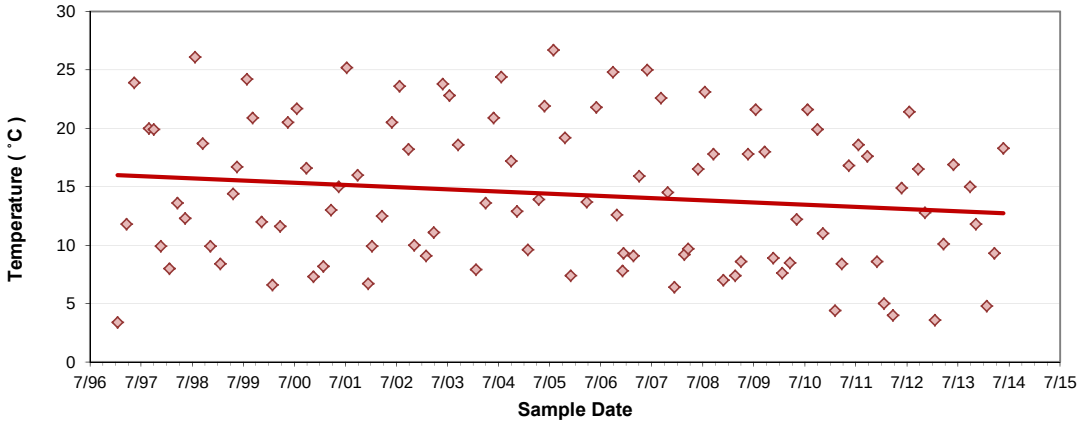


Figure B.86
Amazon Creek at Royal Avenue
Trend for Total Suspended Solids

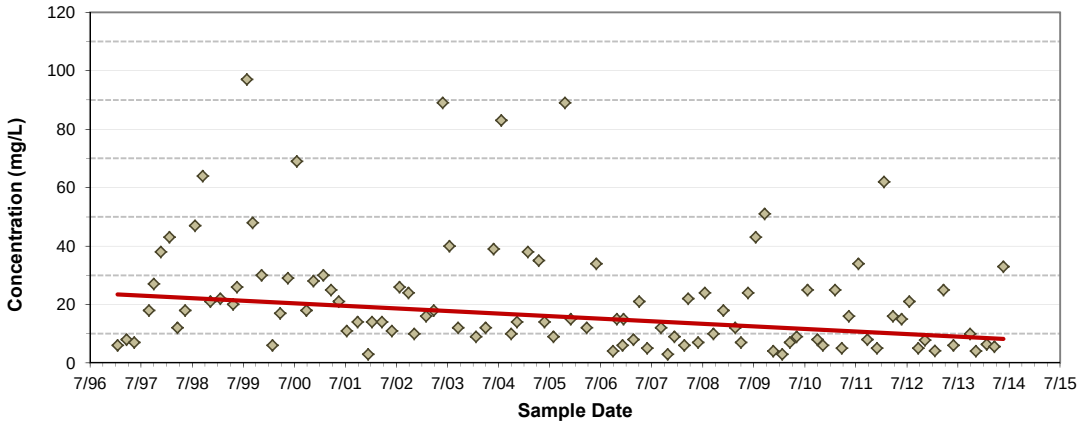


Figure B.87
Amazon Creek at Royal Avenue
Trend for Turbidity

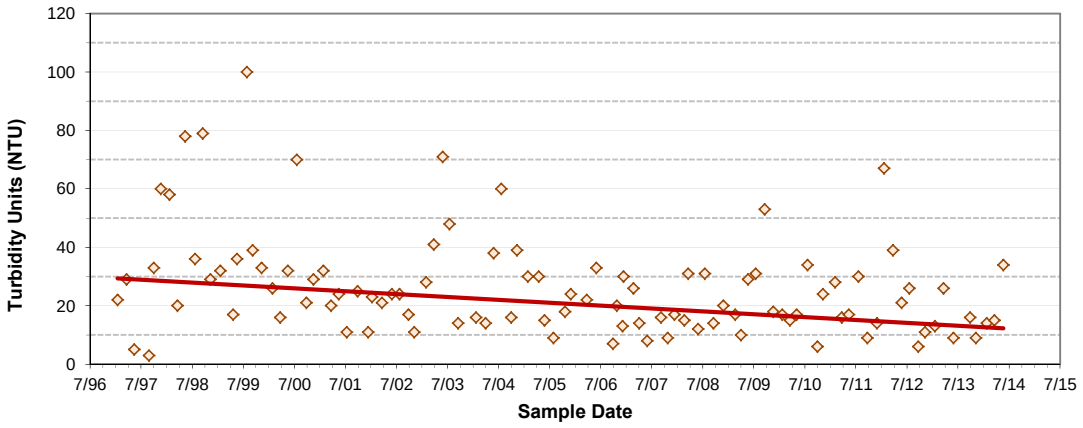


Figure B.88
Willamette River at Knickerbocker Bridge
Trend for Specific Conductance

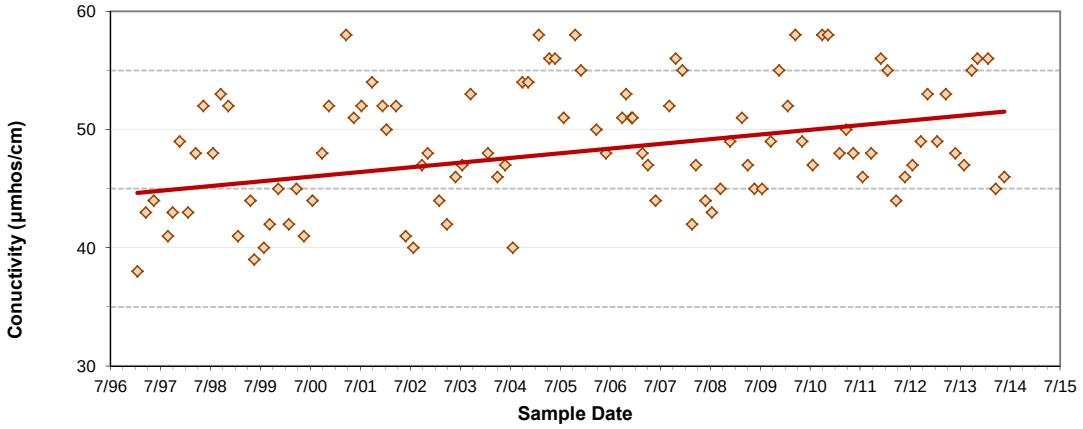


Figure B.89
Willamette River Downstream of Beltline Bridge
Trend for Ortho Phosphorus

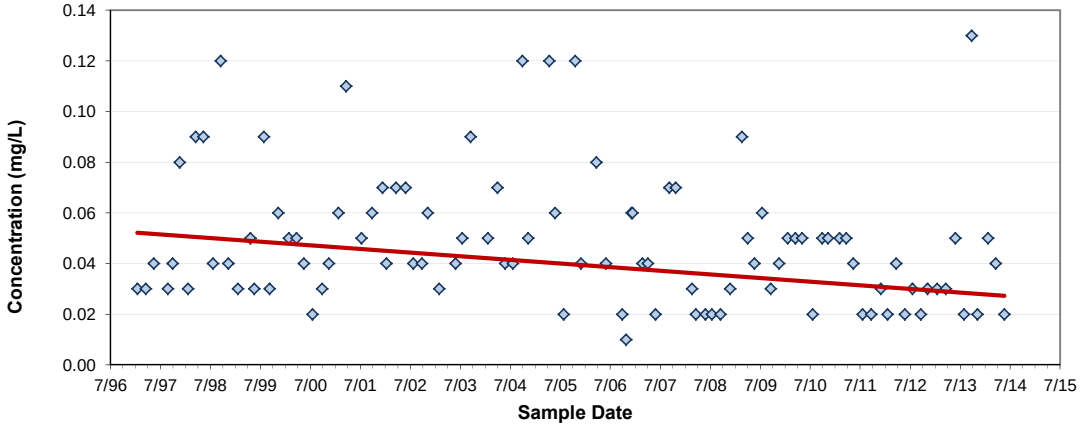


Figure B.90
Delta Ponds Above Willamette River Confluence
Trend for Dissolved Molybdenum

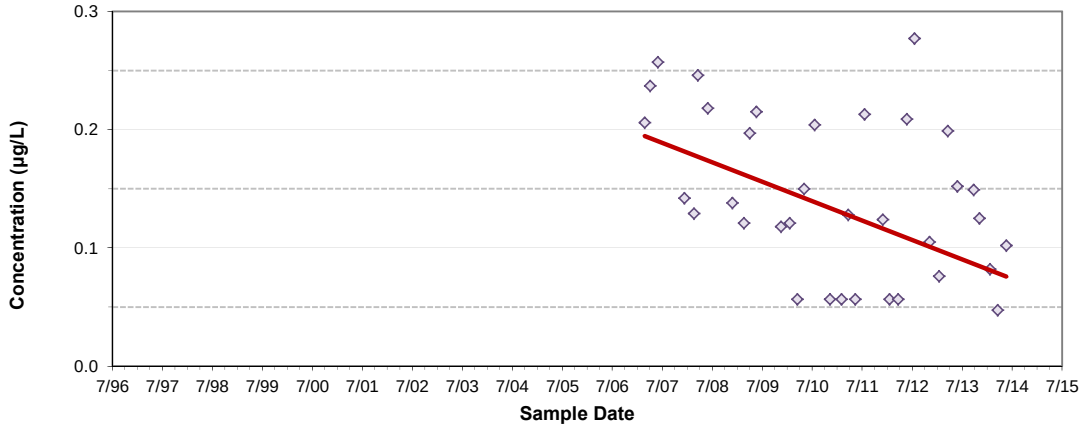


Figure B.91
Delta Ponds Above Willamette River Confluence
Trend for Total Molybdenum

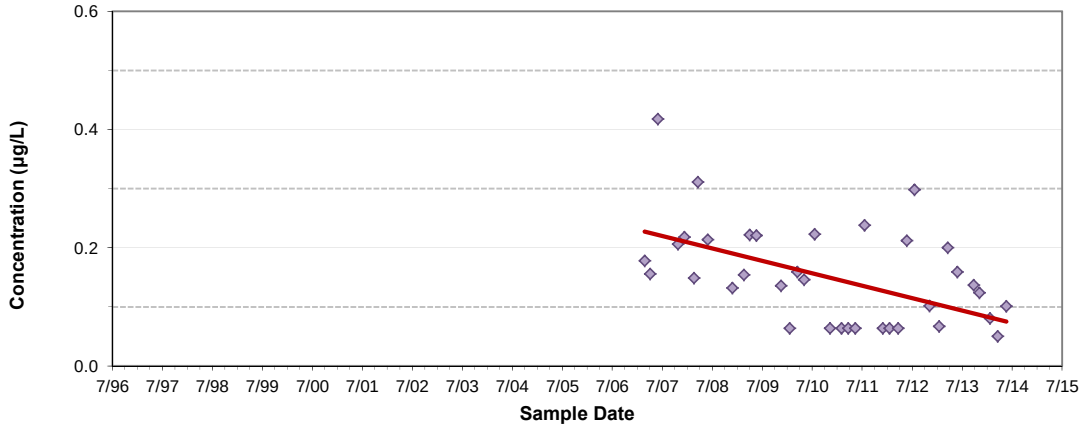


Figure B.92
Delta Ponds Above Willamette River Confluence
Trend for Dissolved Oxygen

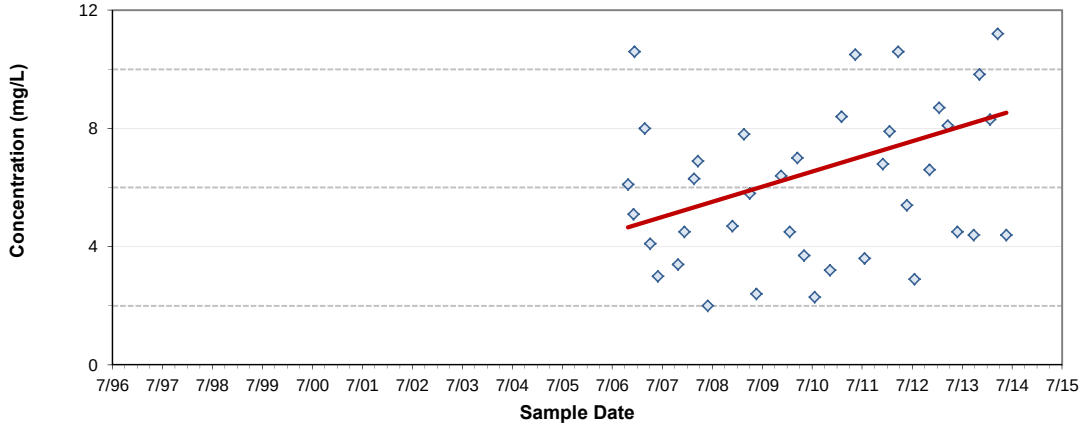


Figure B.93

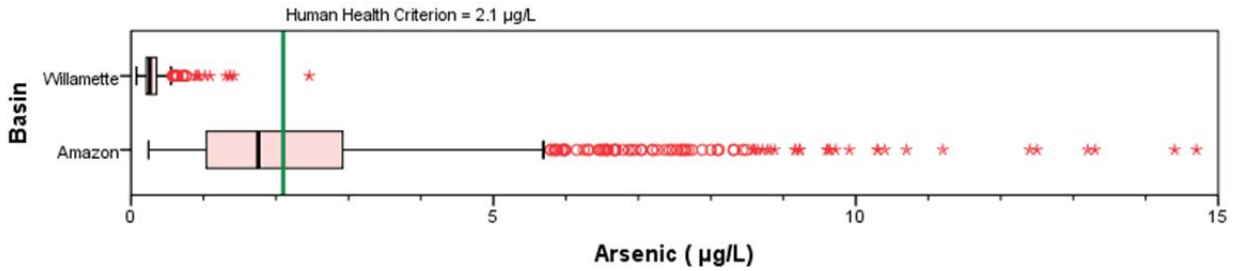


Figure B.94

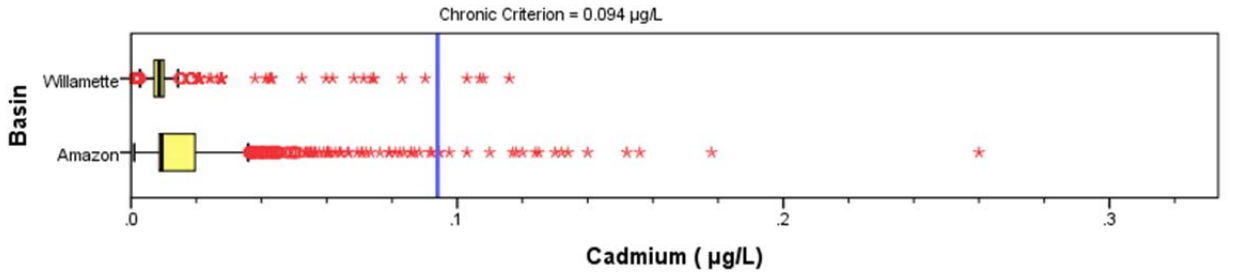


Figure B.95

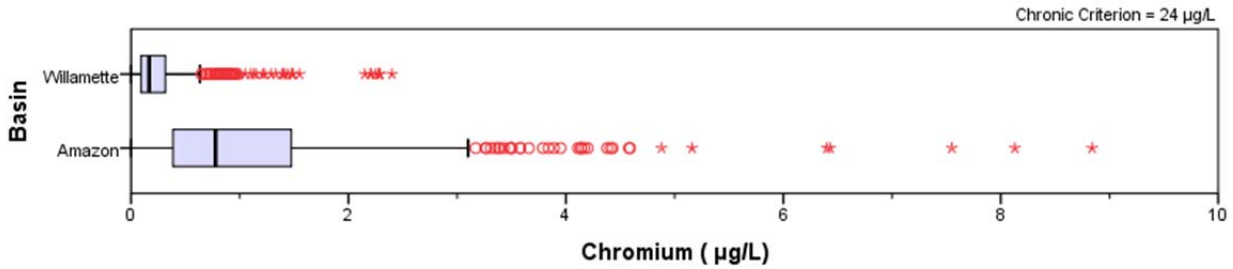
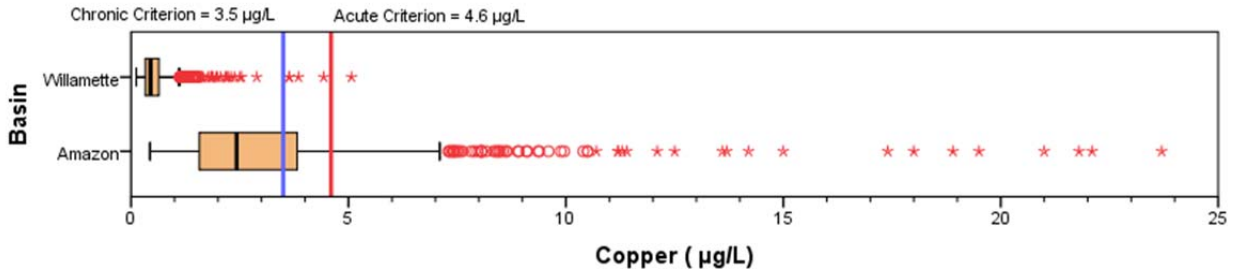


Figure B.96



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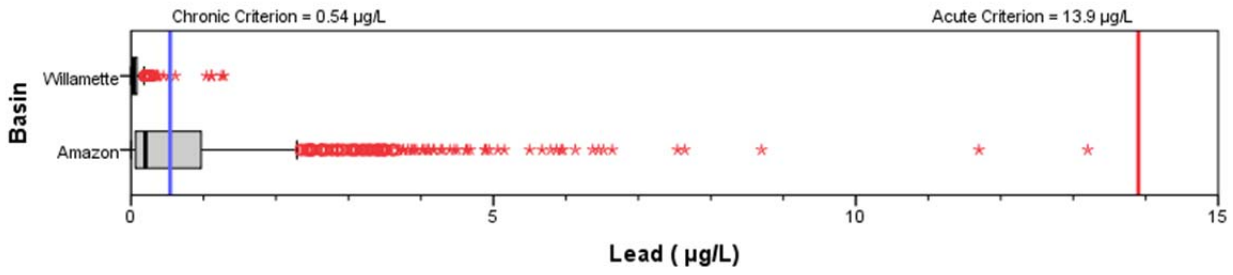


Figure B.98

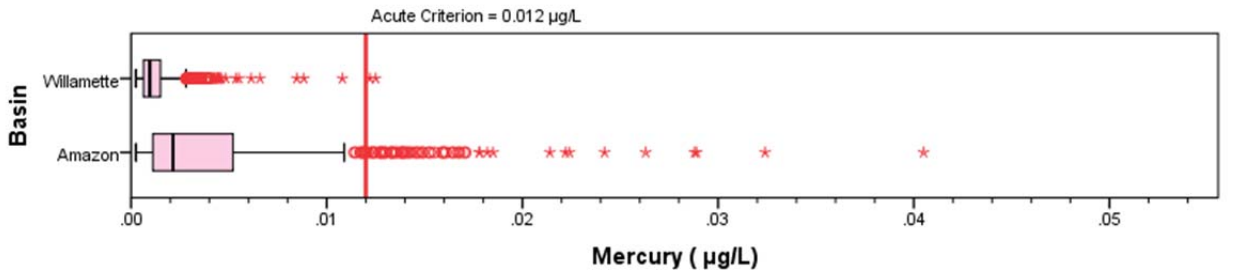
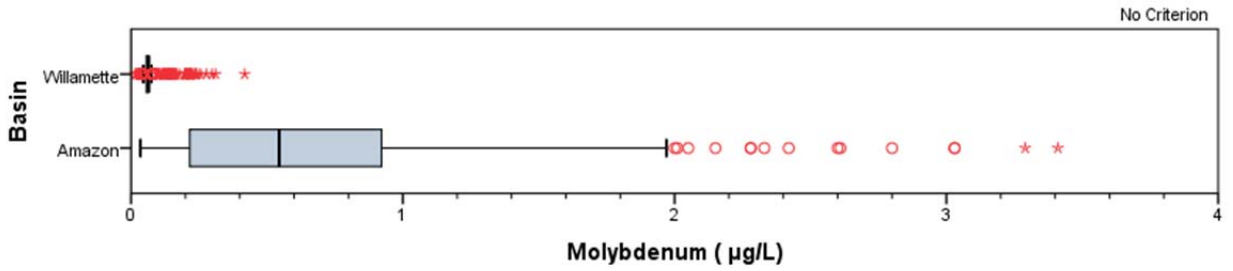


Figure B.99



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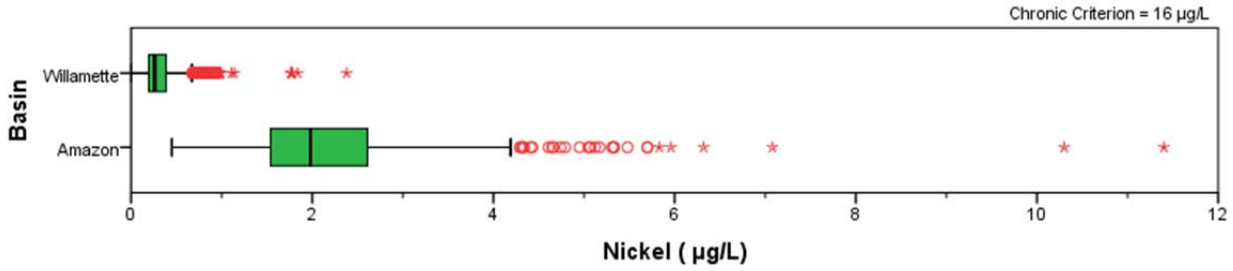

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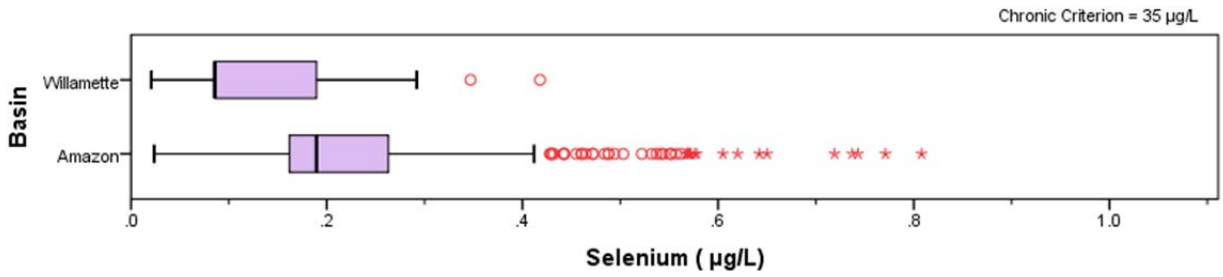

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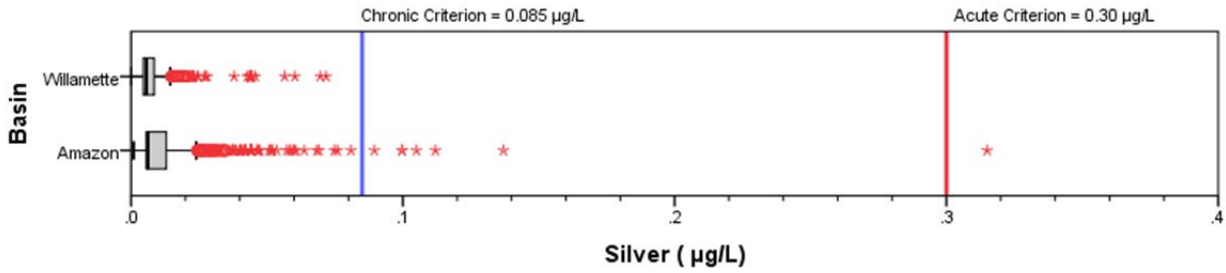

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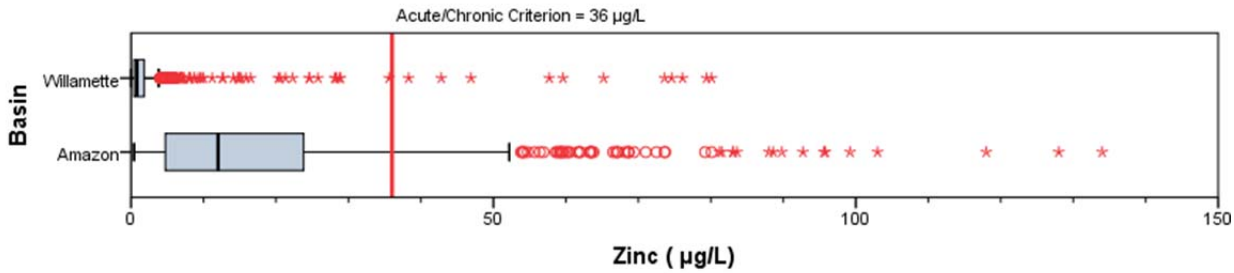

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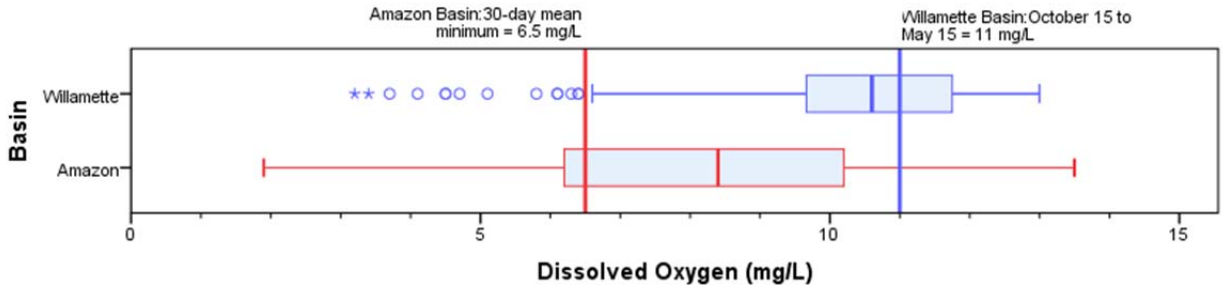

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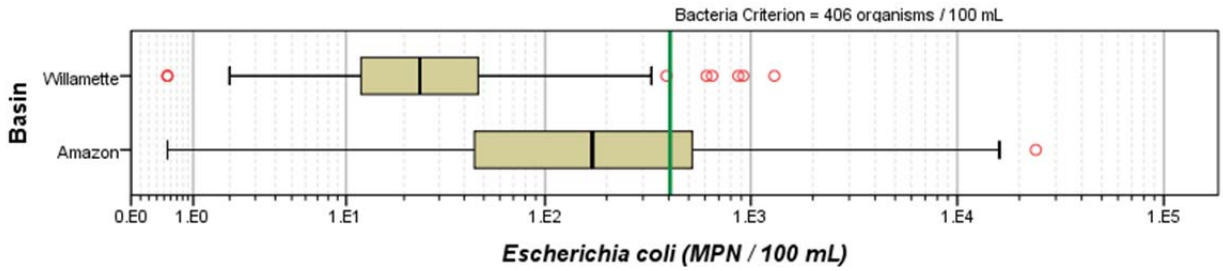

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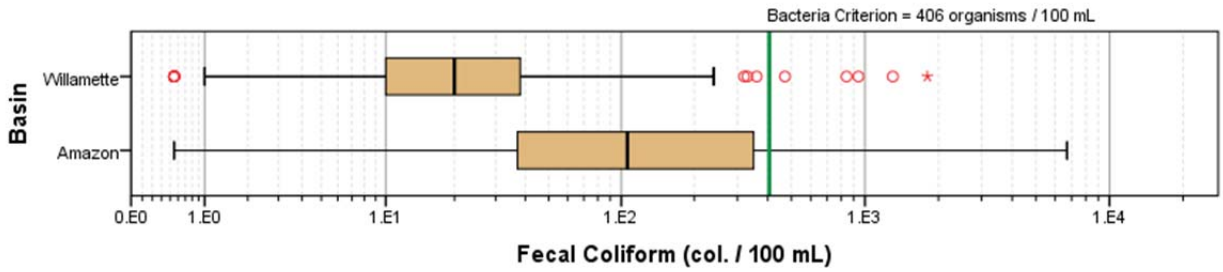

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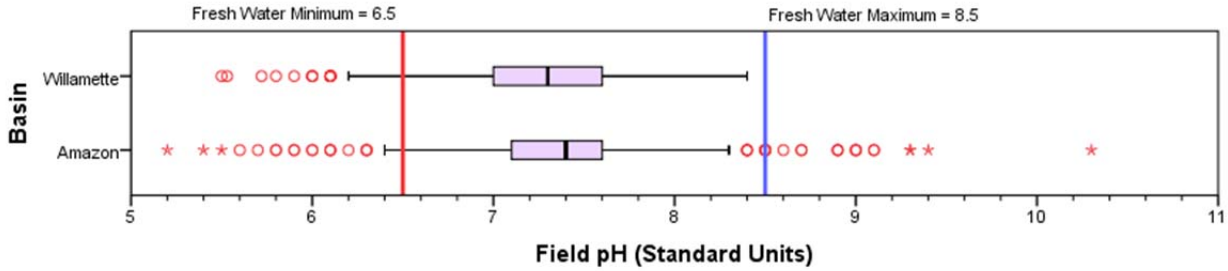

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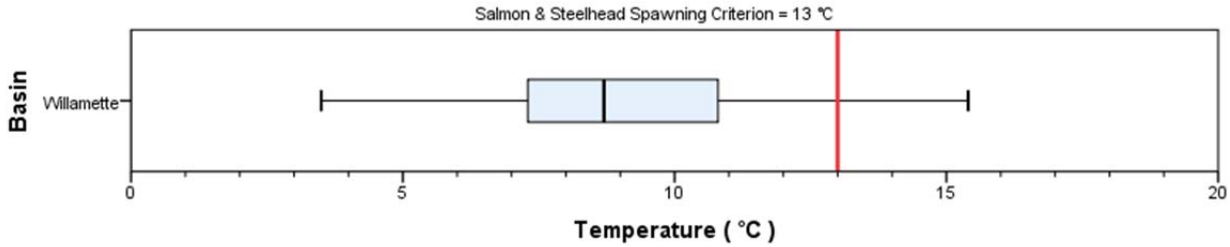

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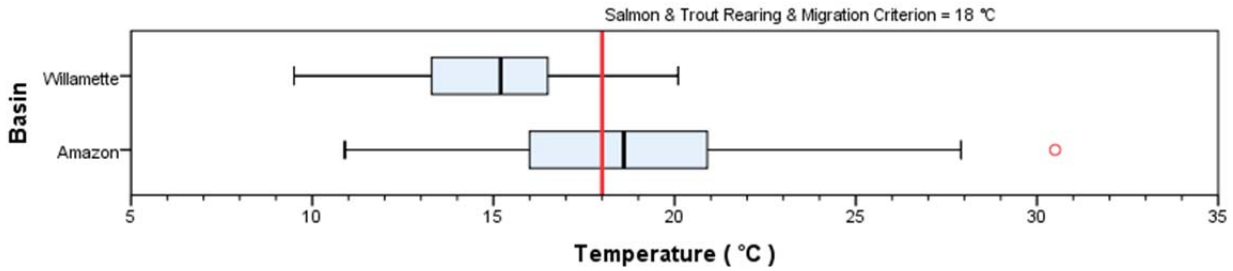

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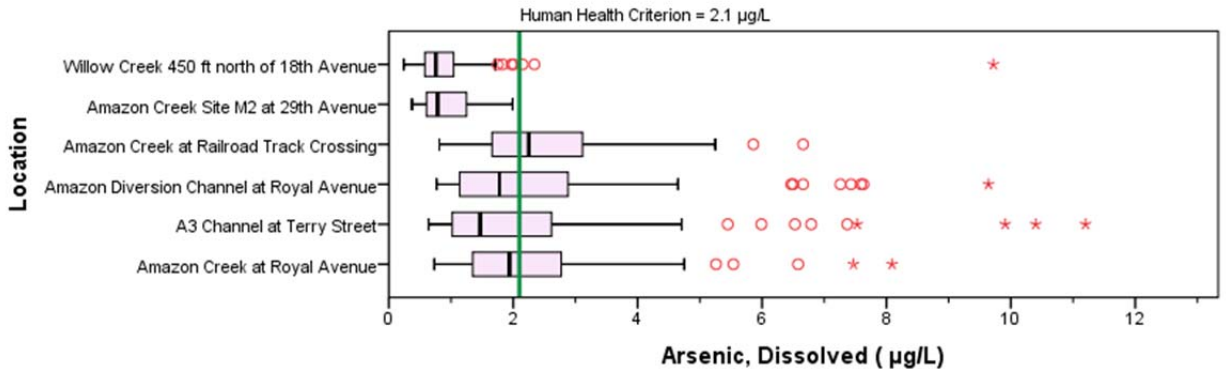

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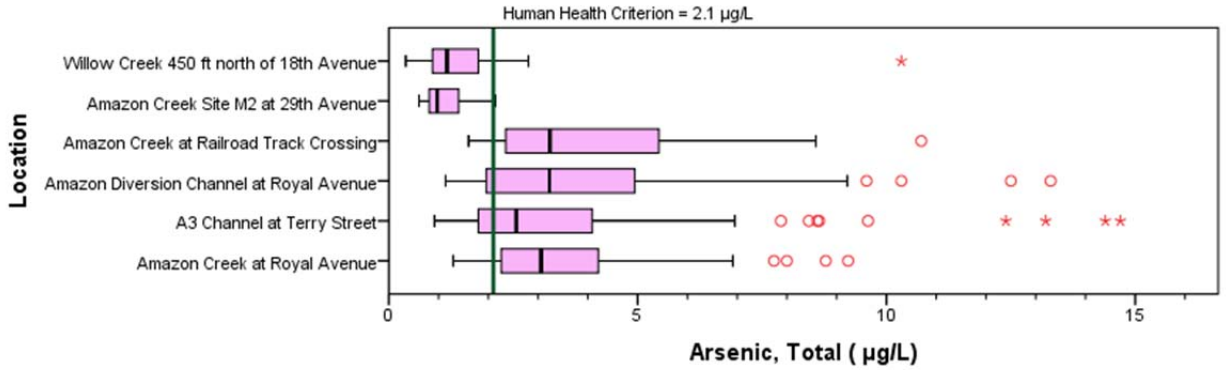

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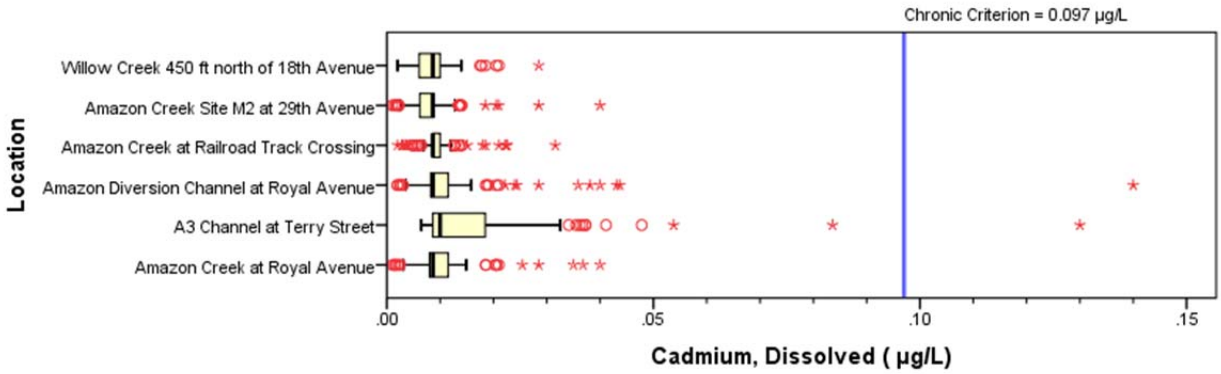

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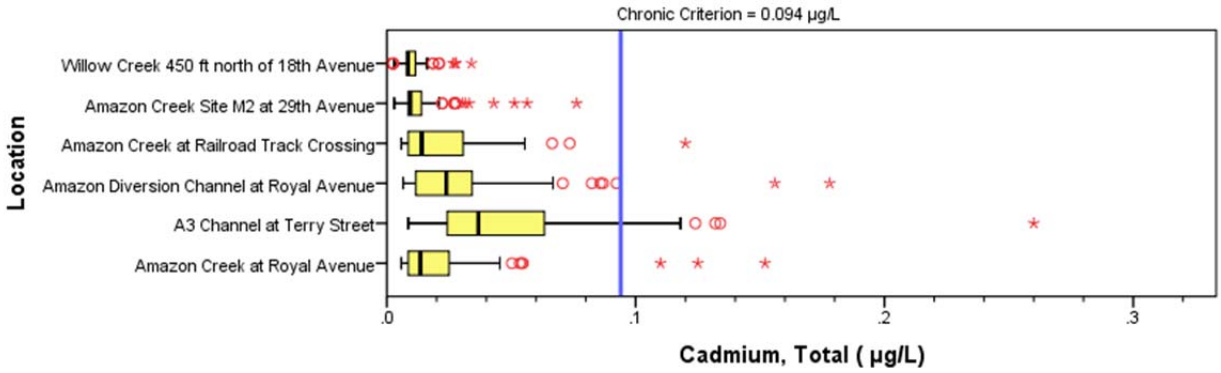

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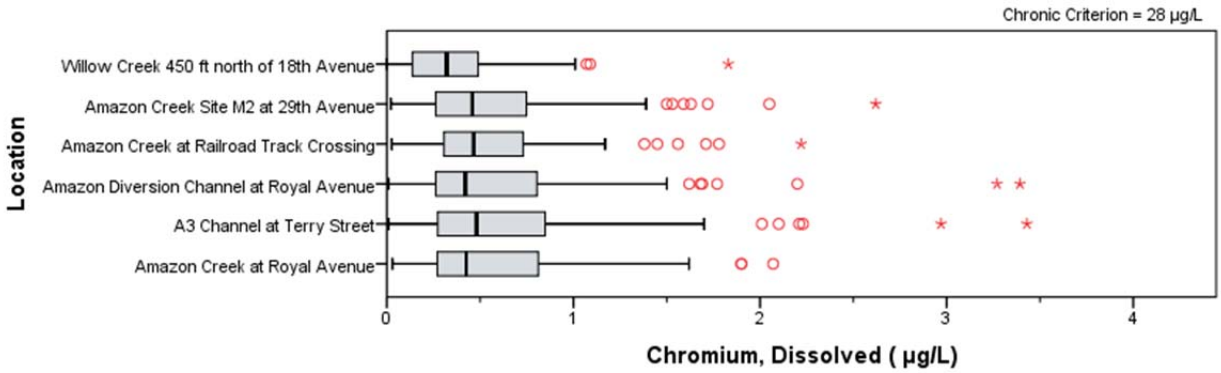

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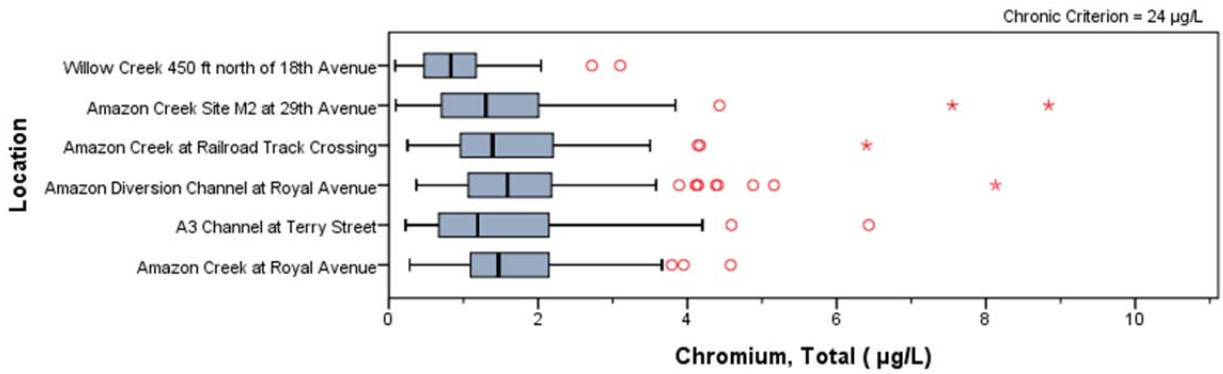

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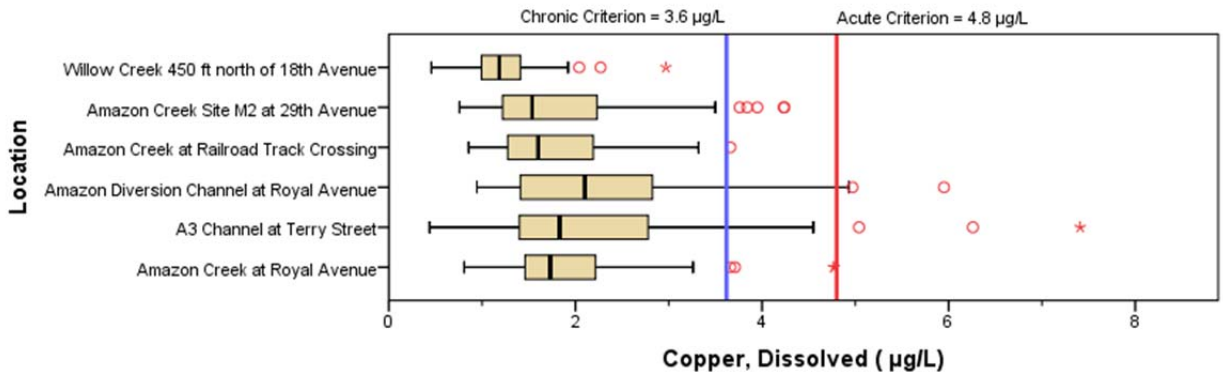

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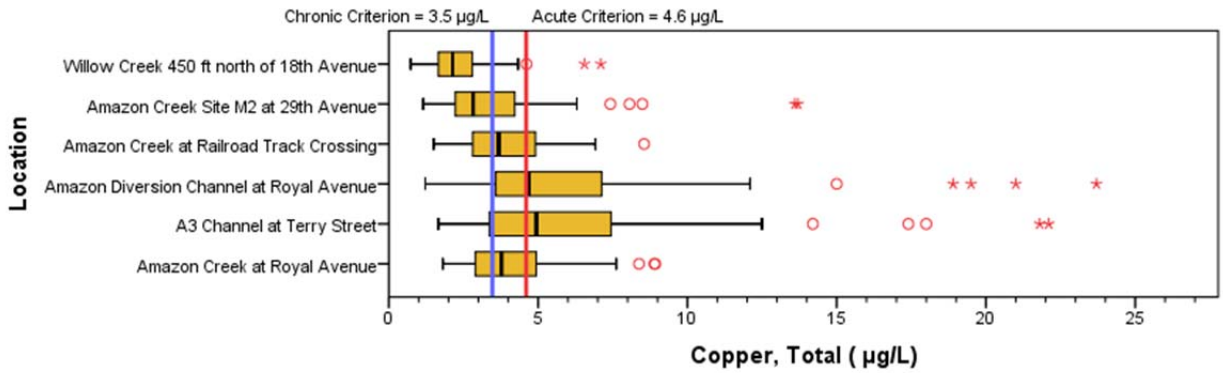

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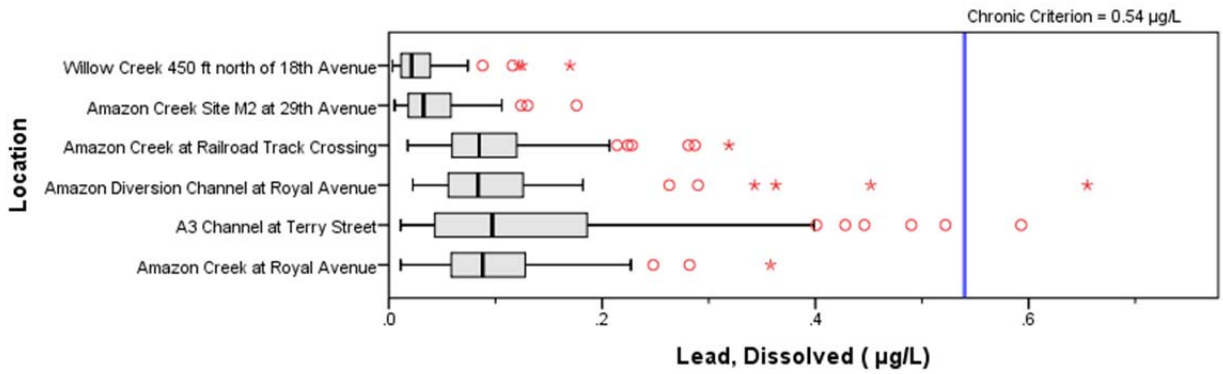

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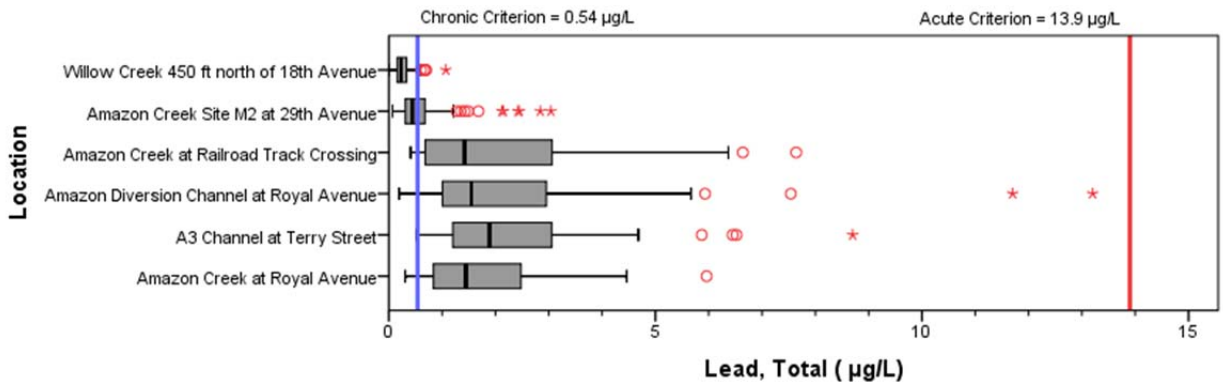

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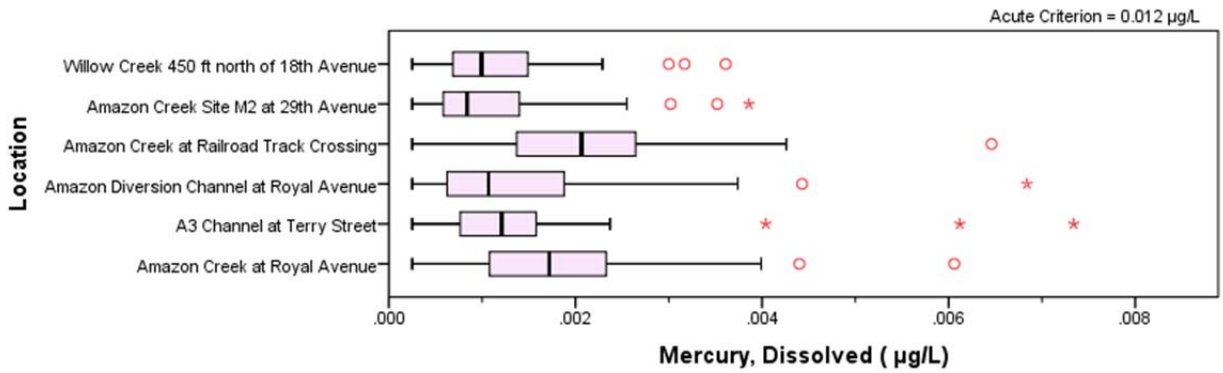

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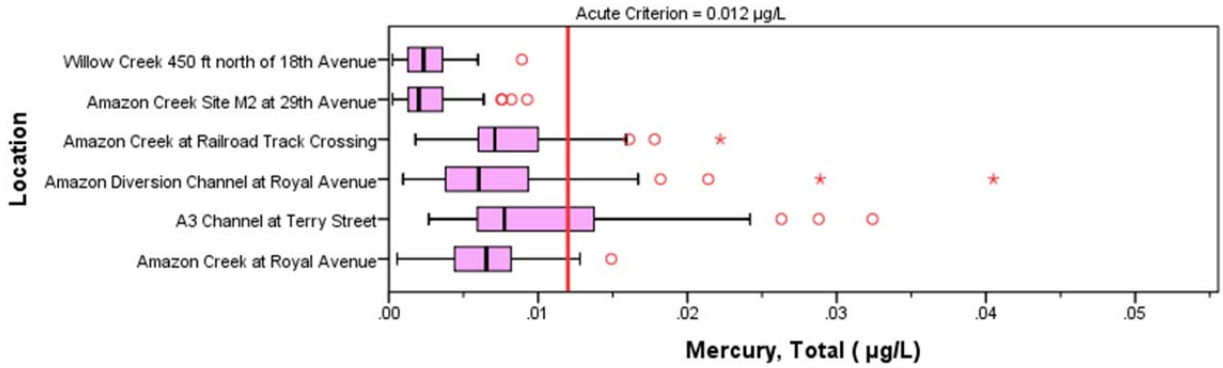

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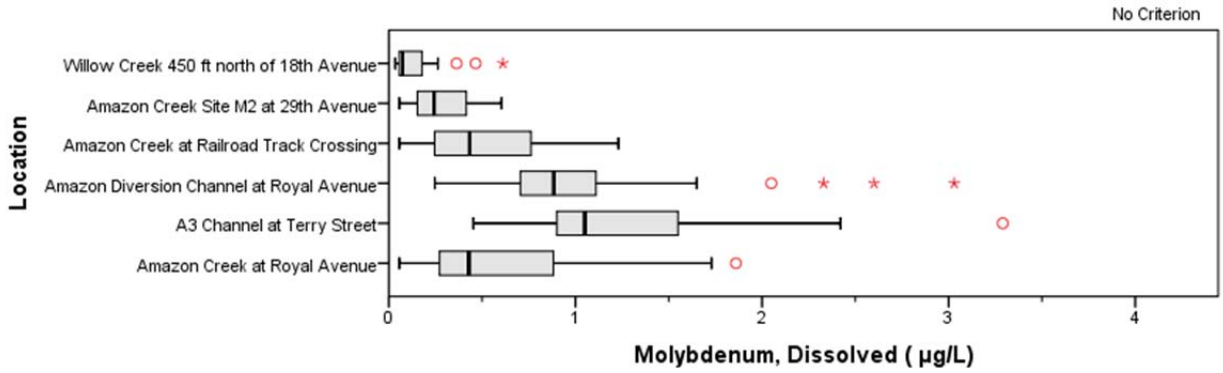

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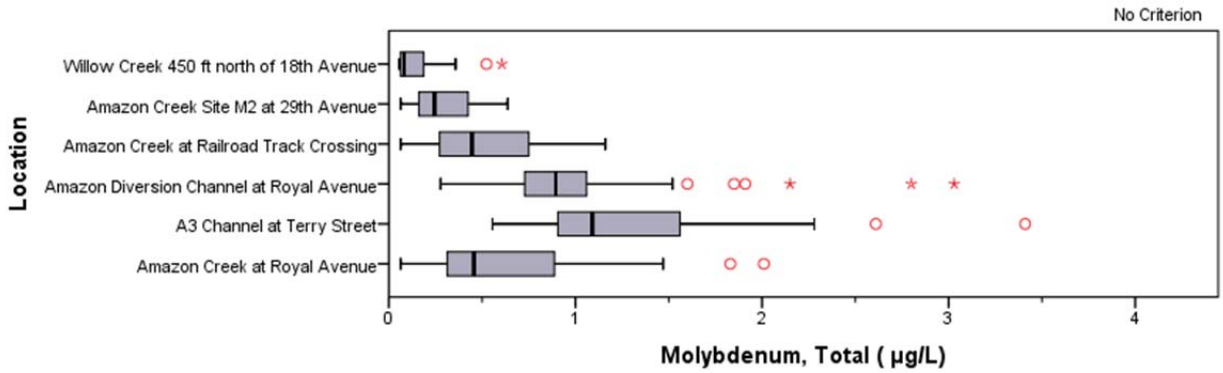

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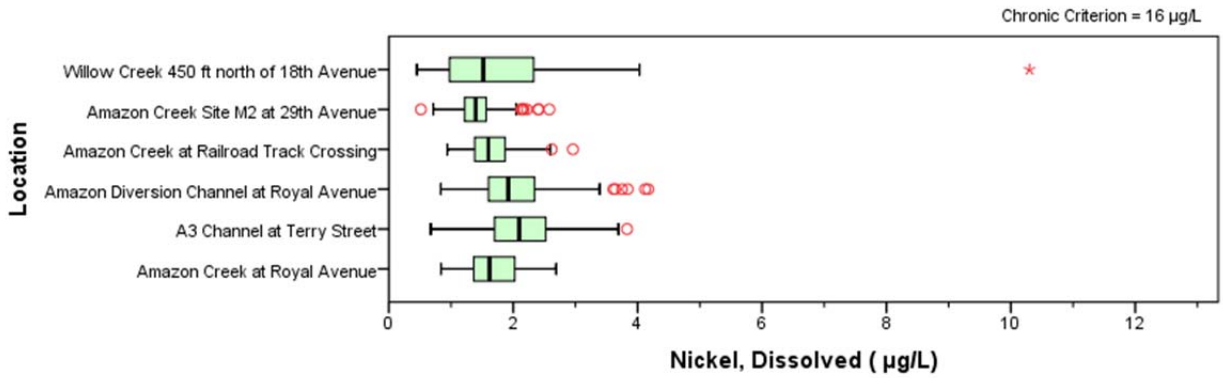

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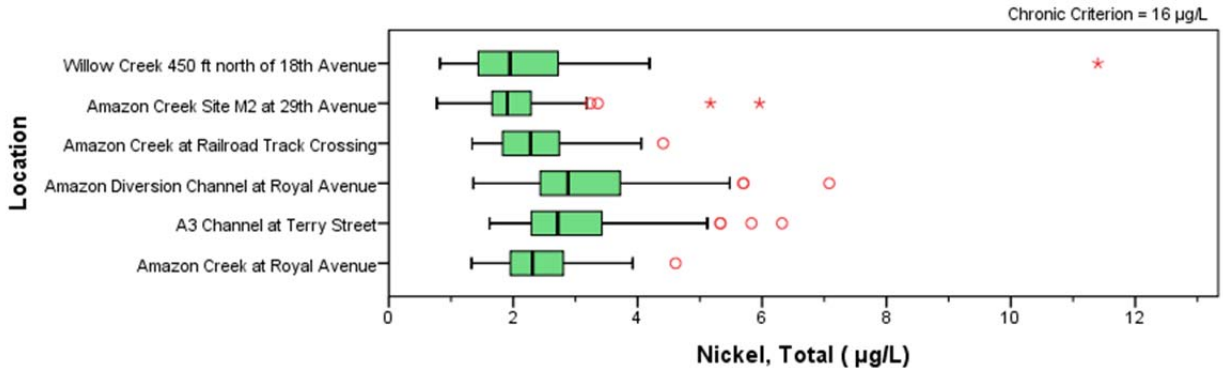

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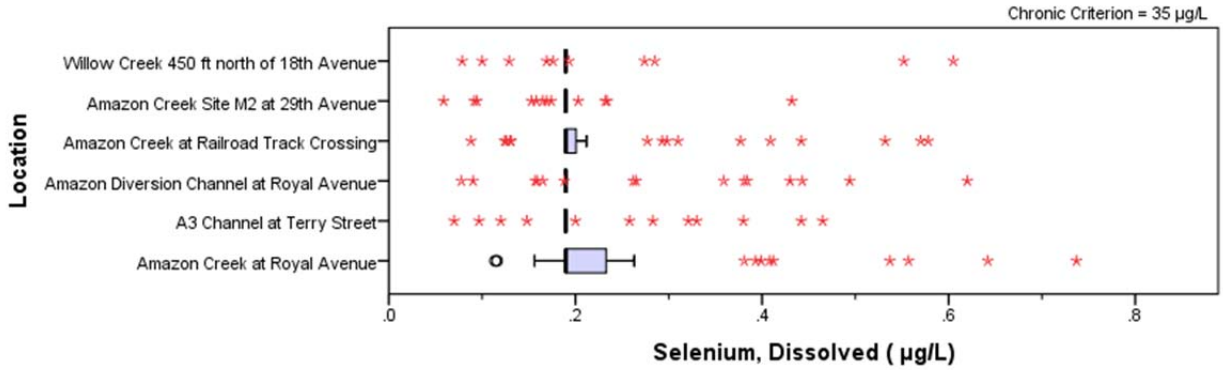

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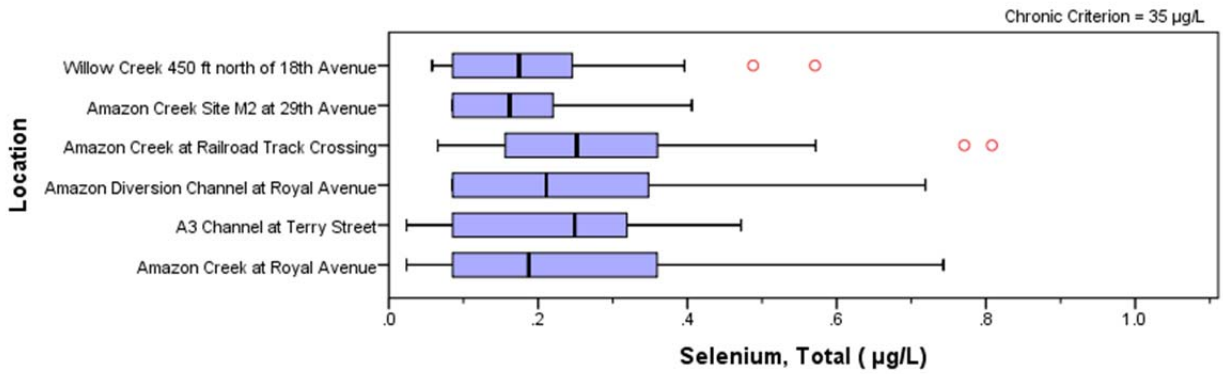

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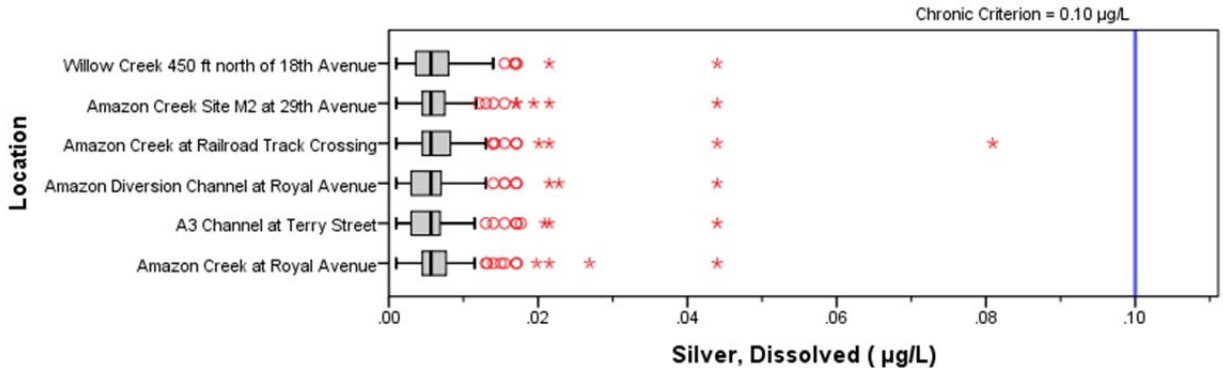

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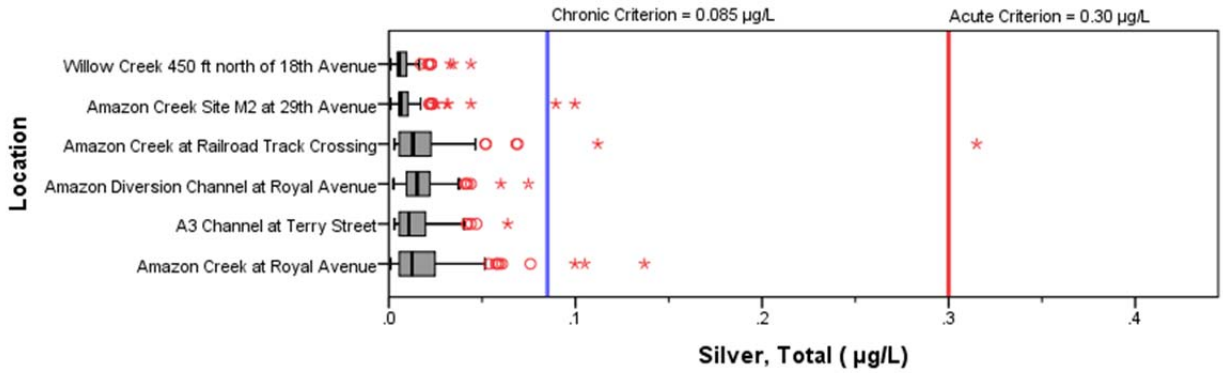

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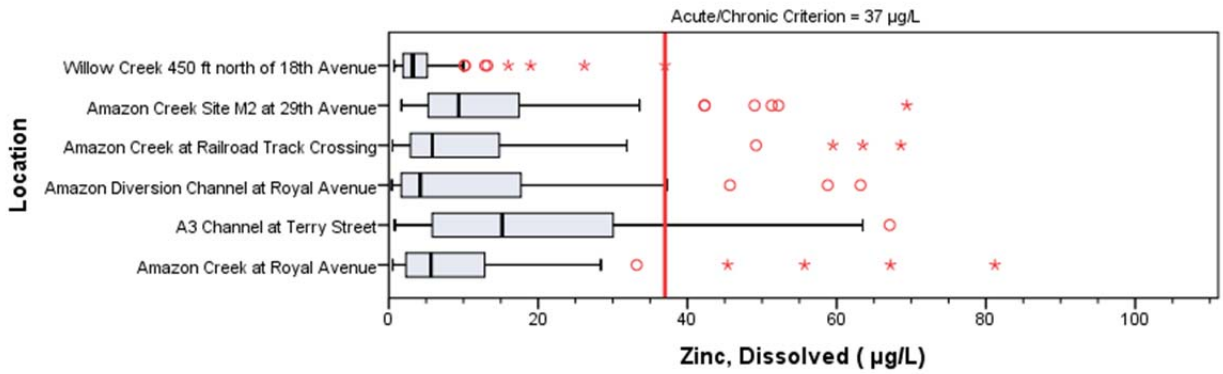

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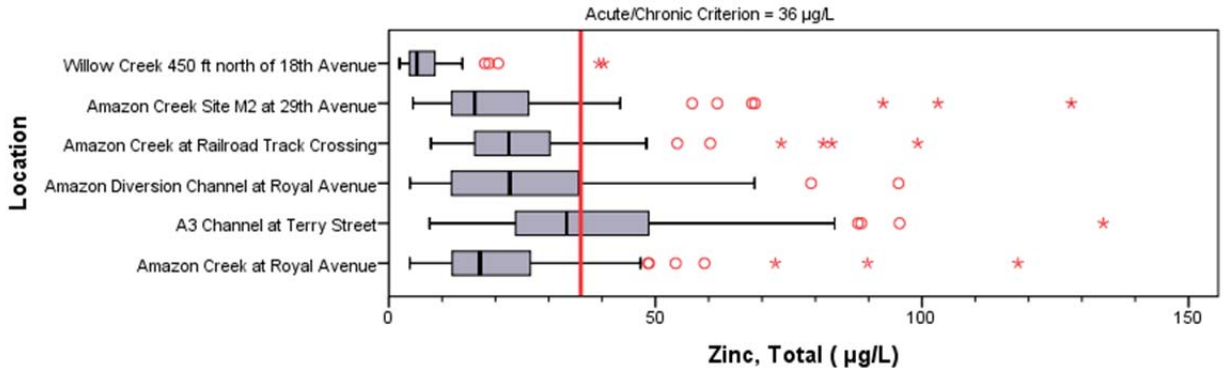

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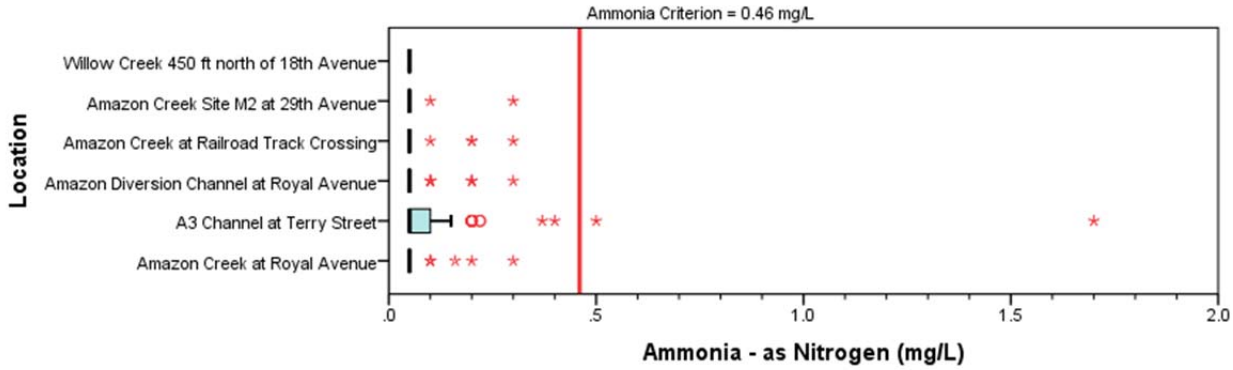

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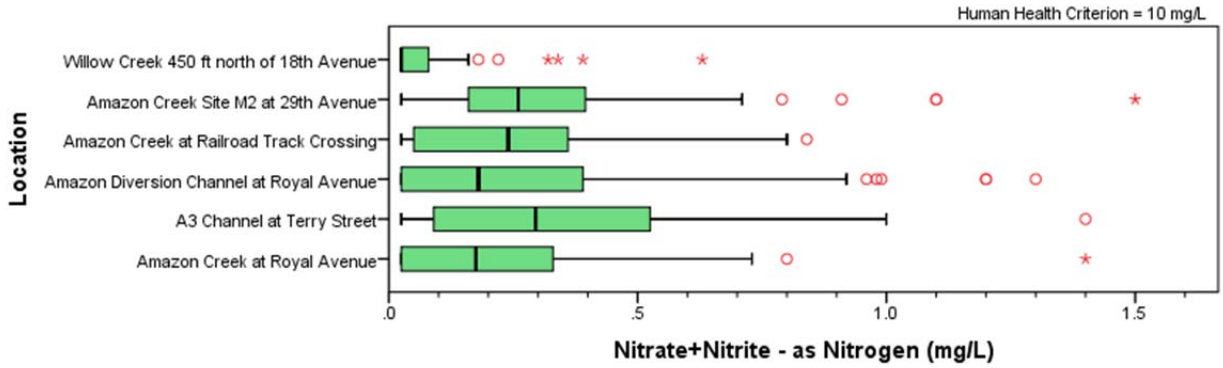

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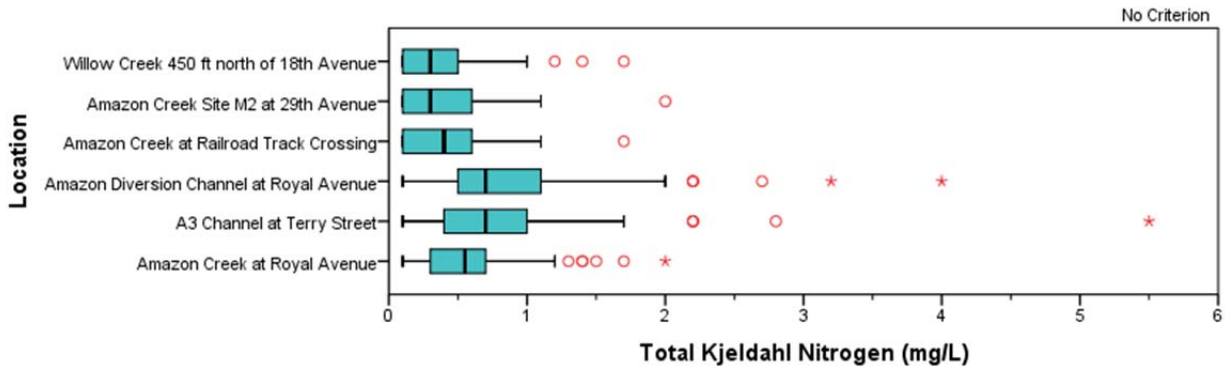

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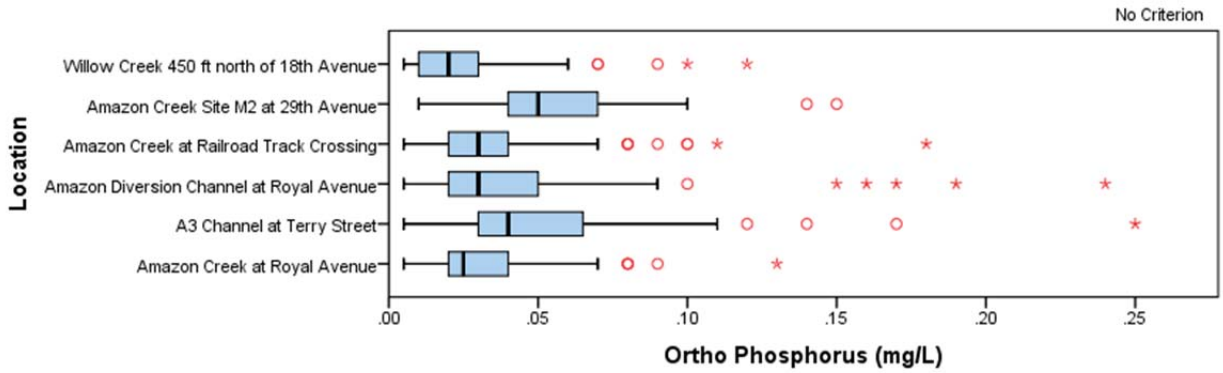

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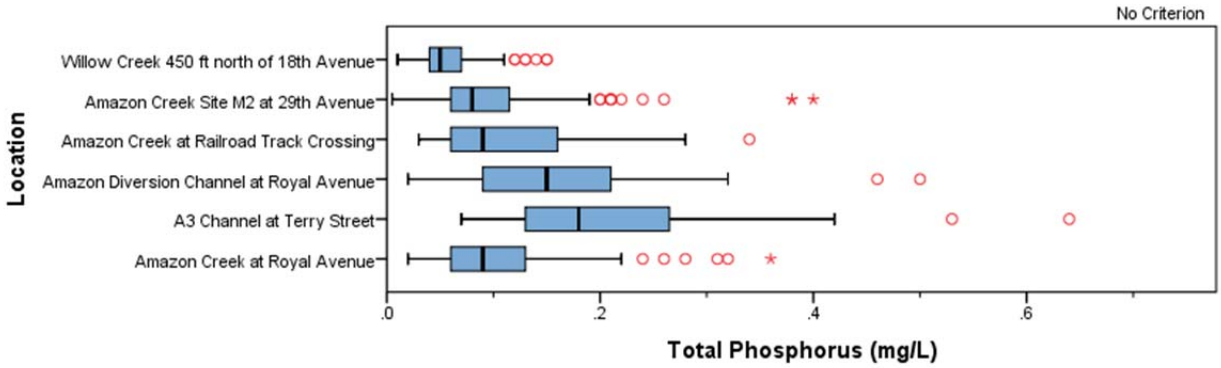

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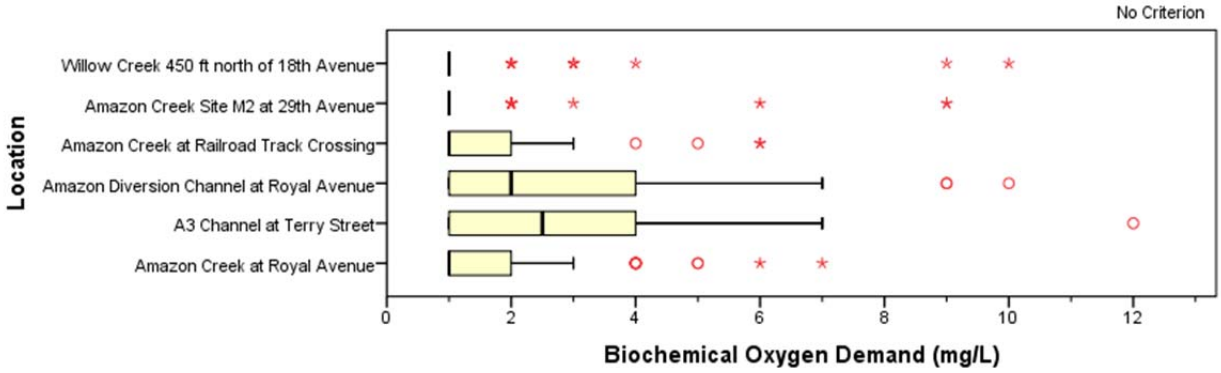

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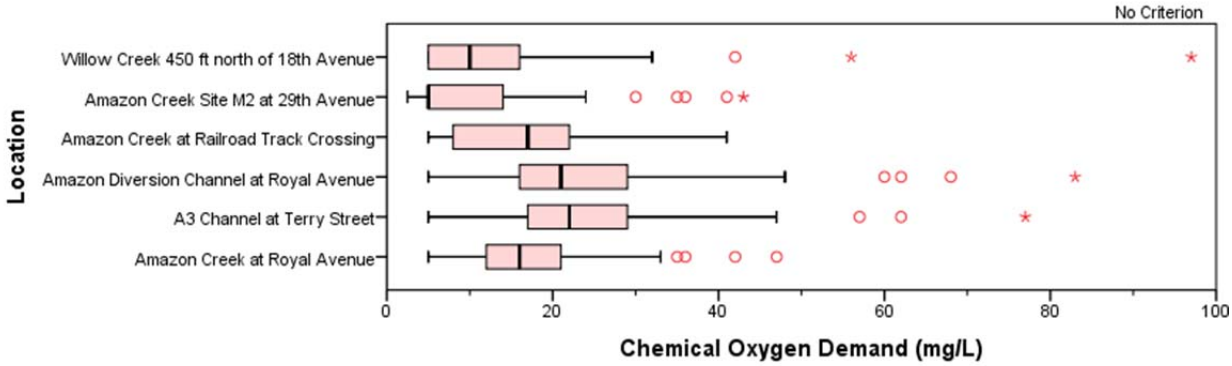

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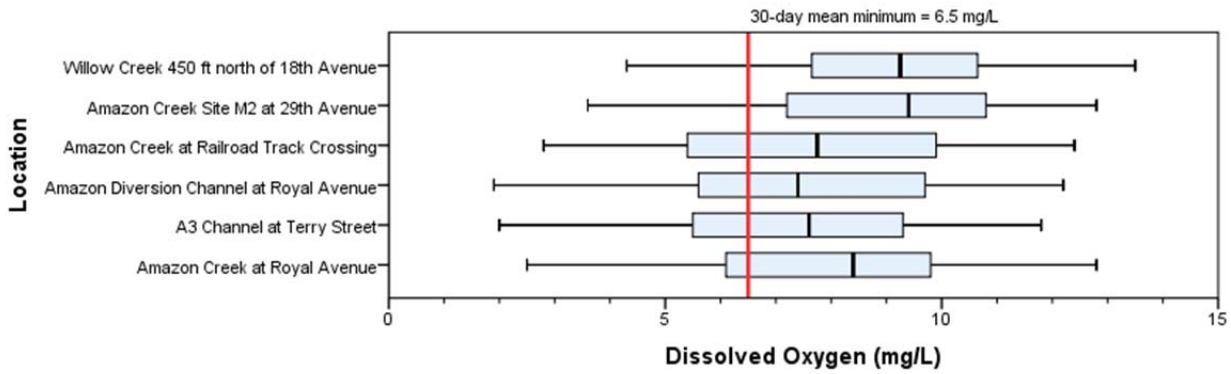

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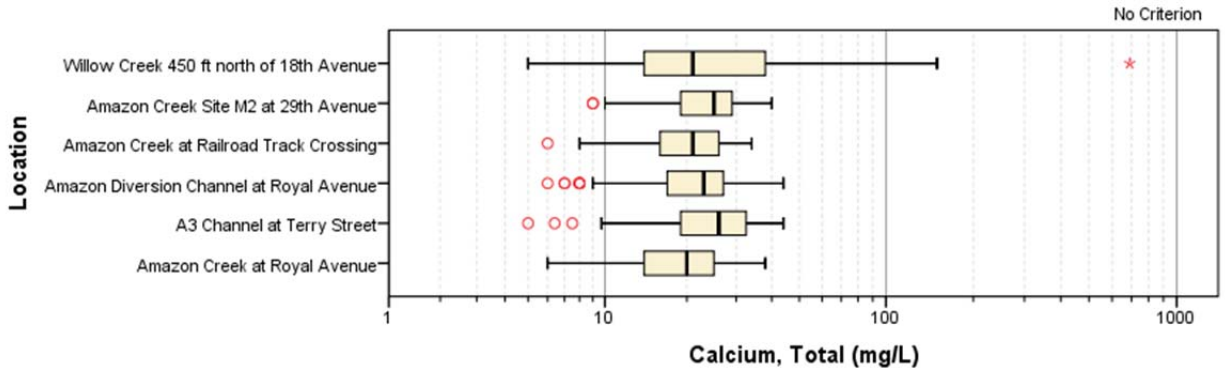

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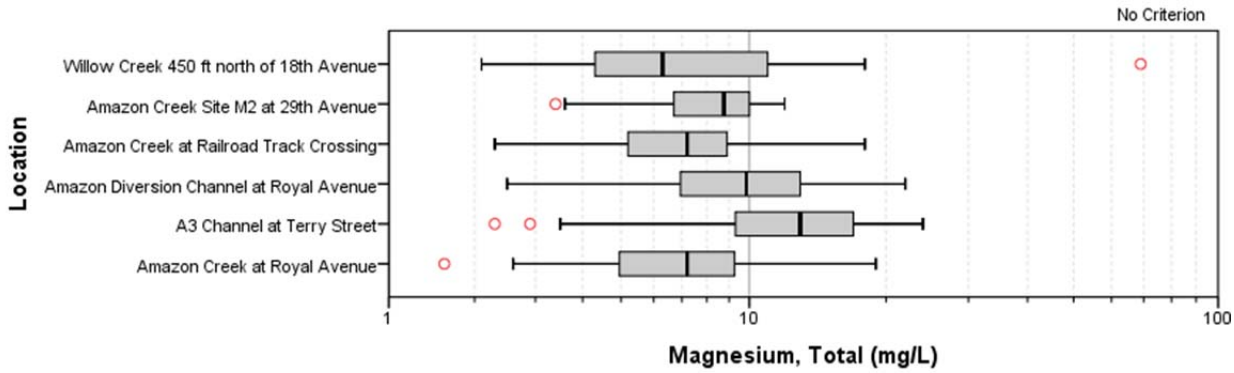

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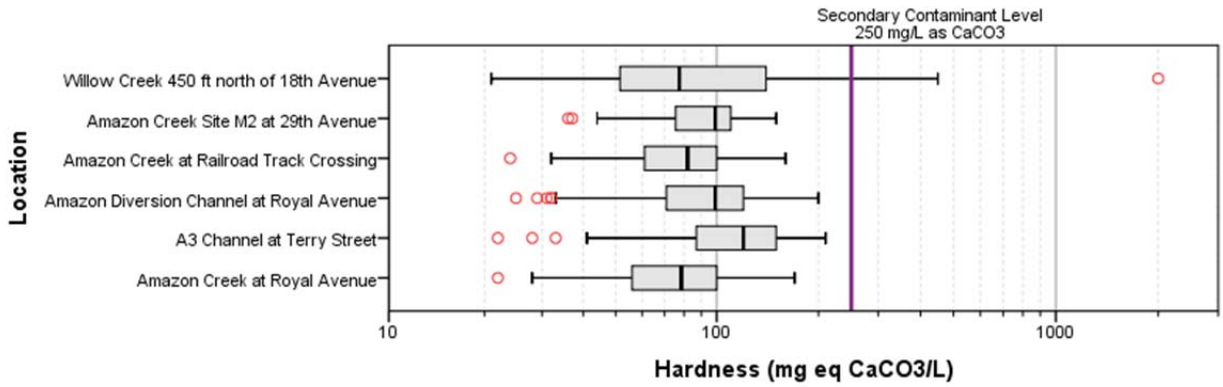

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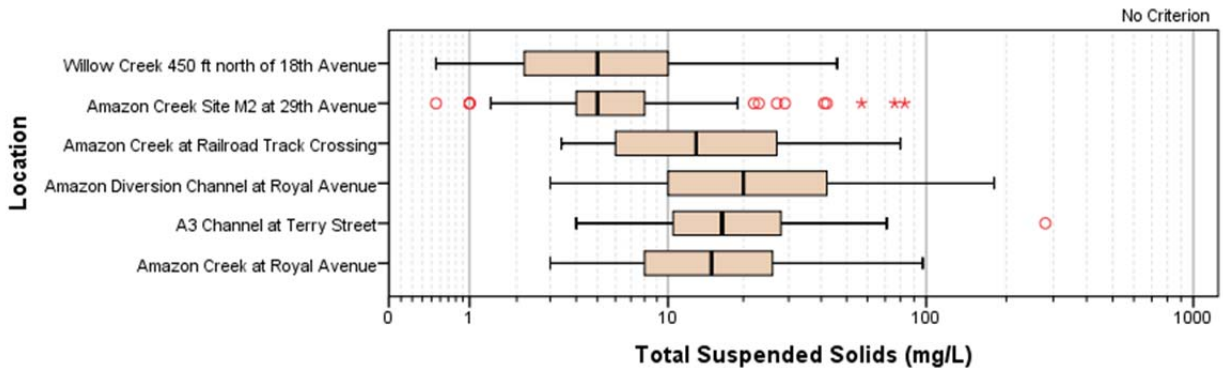

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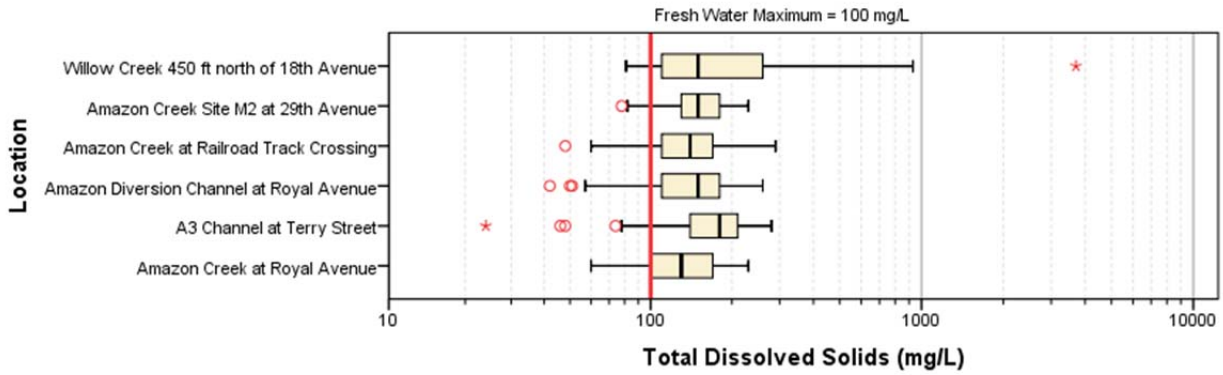

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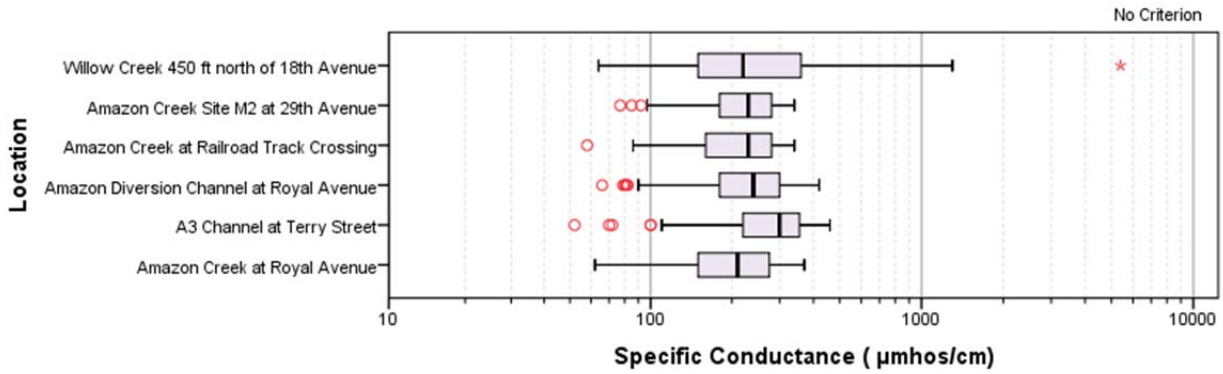

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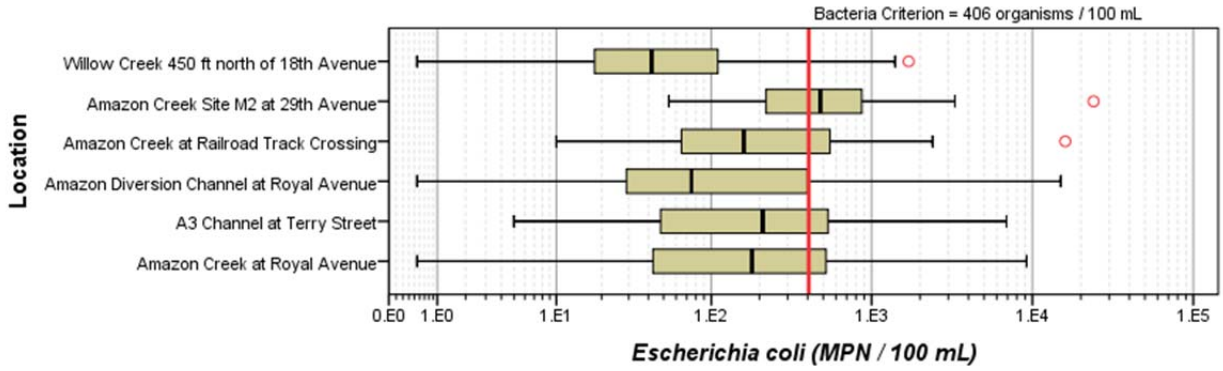

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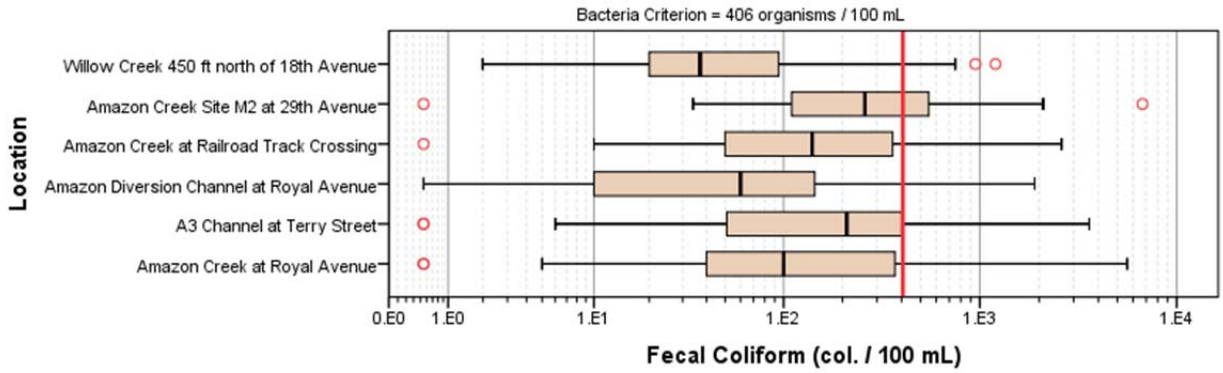

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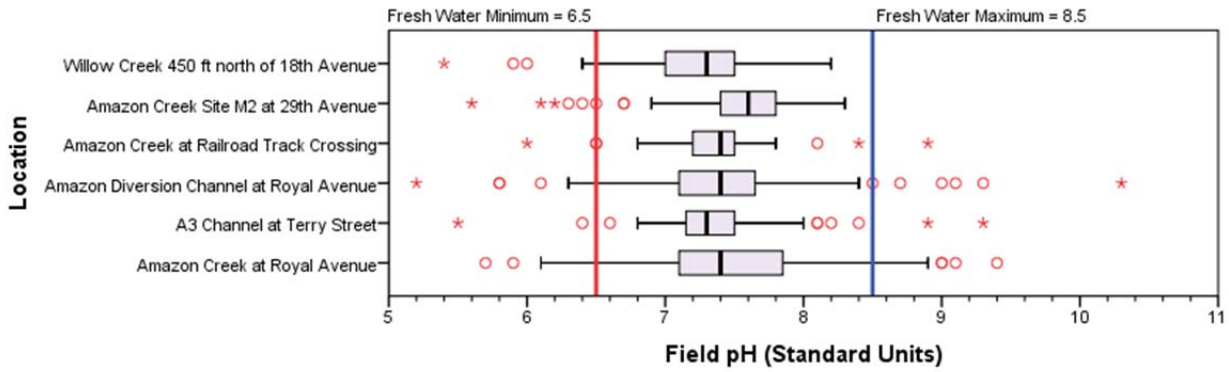

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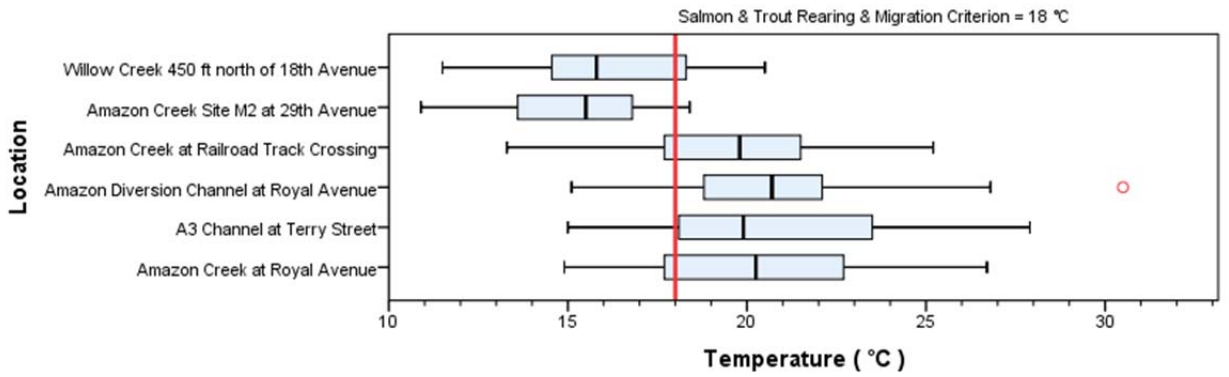

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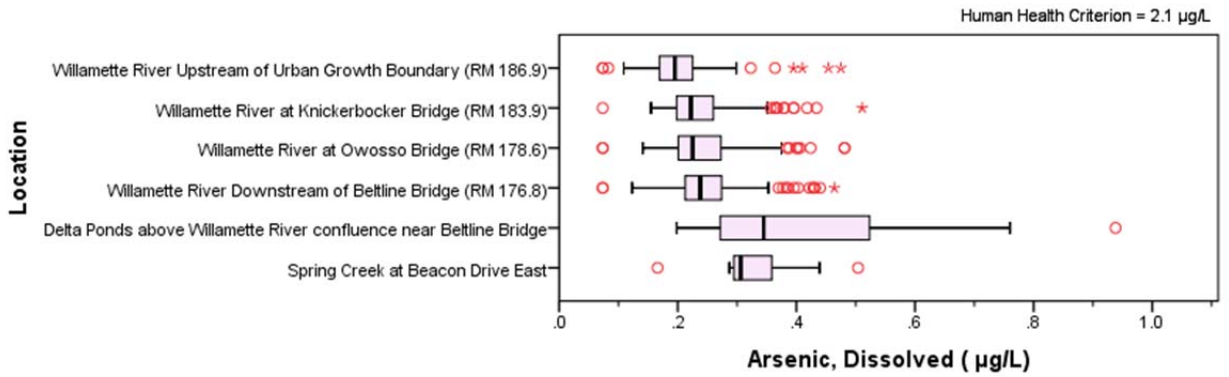

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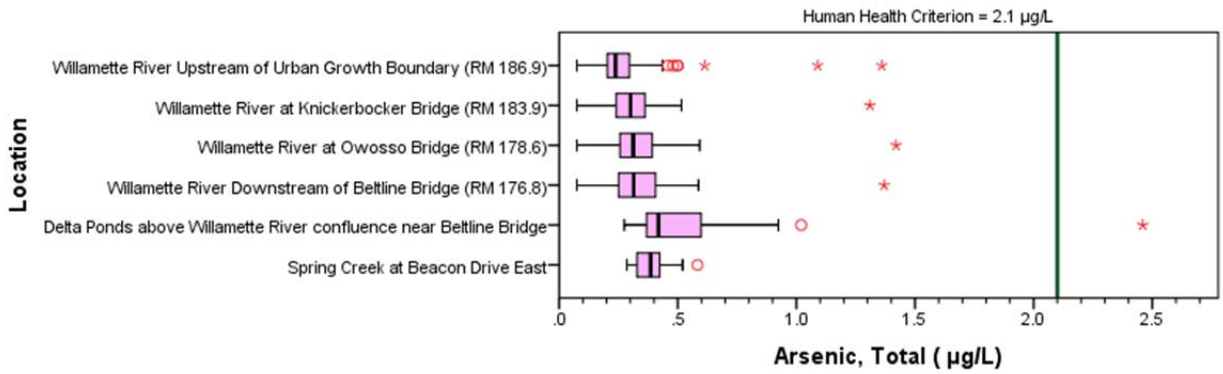

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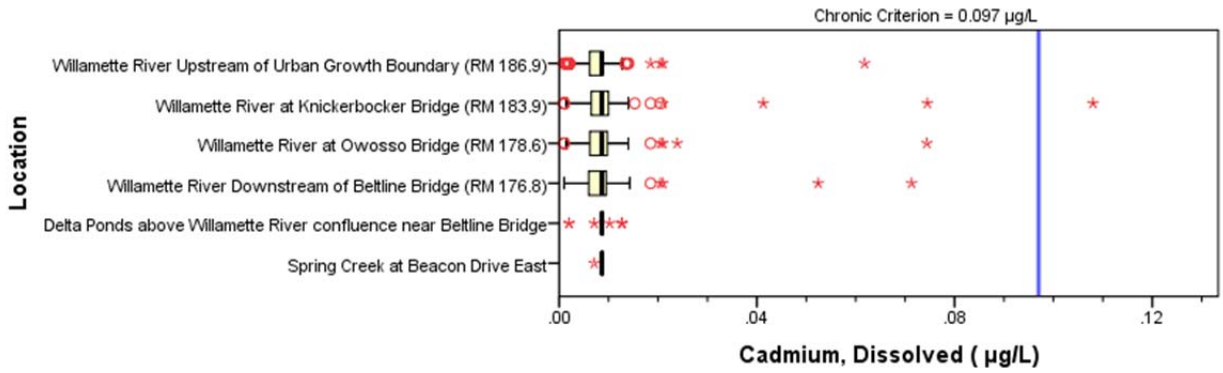

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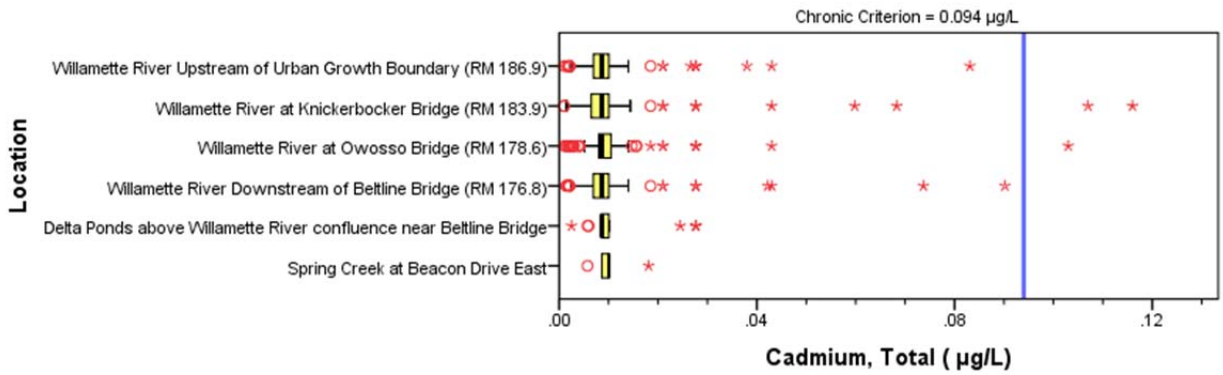

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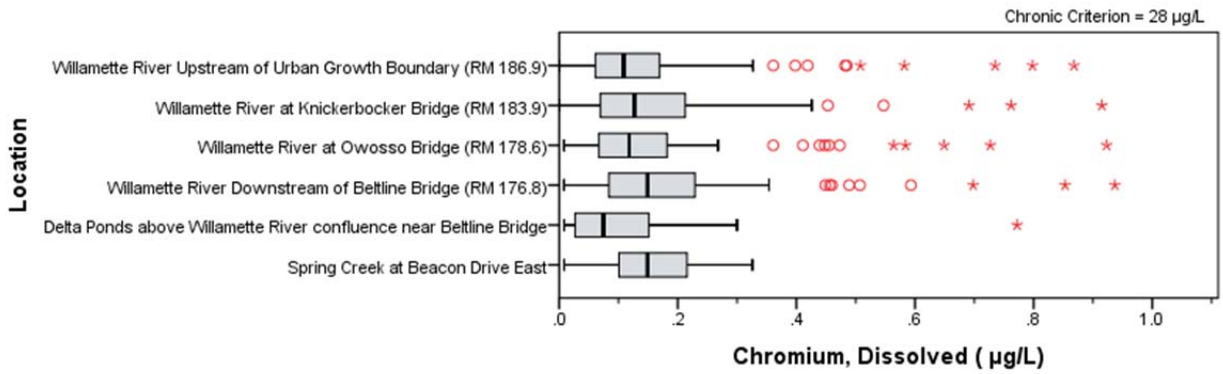

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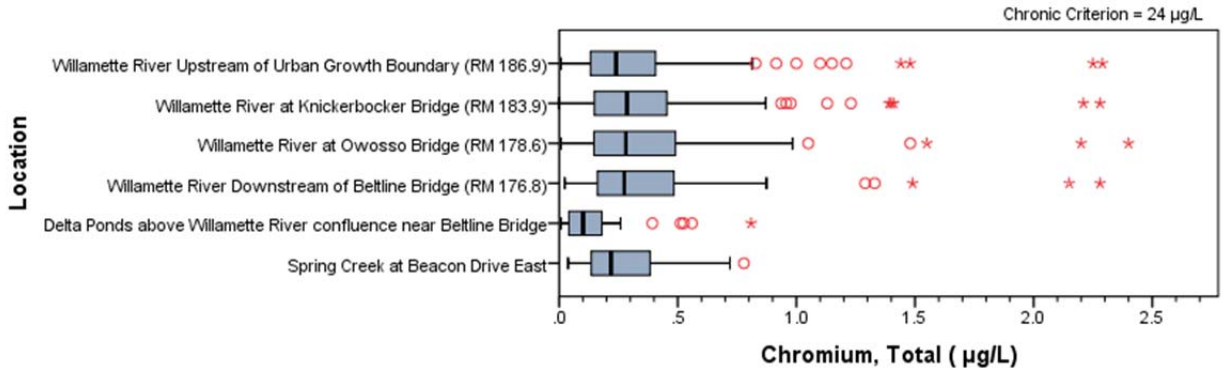

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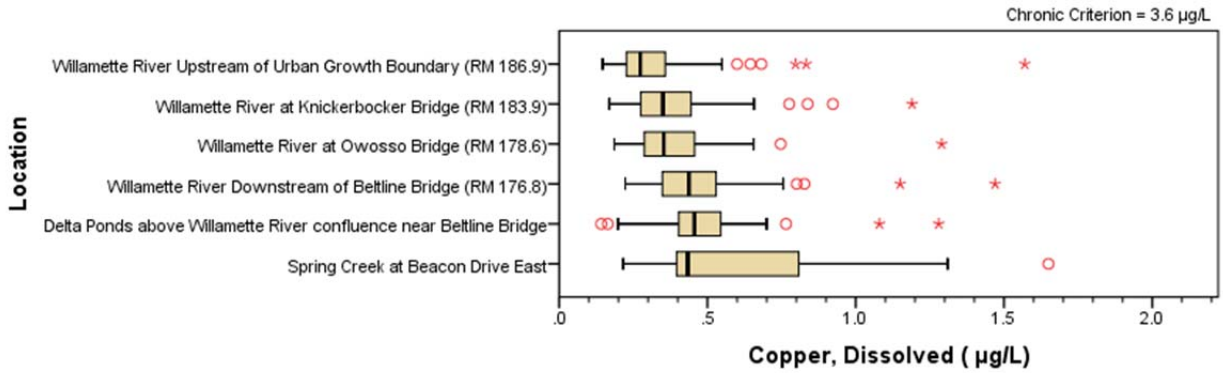

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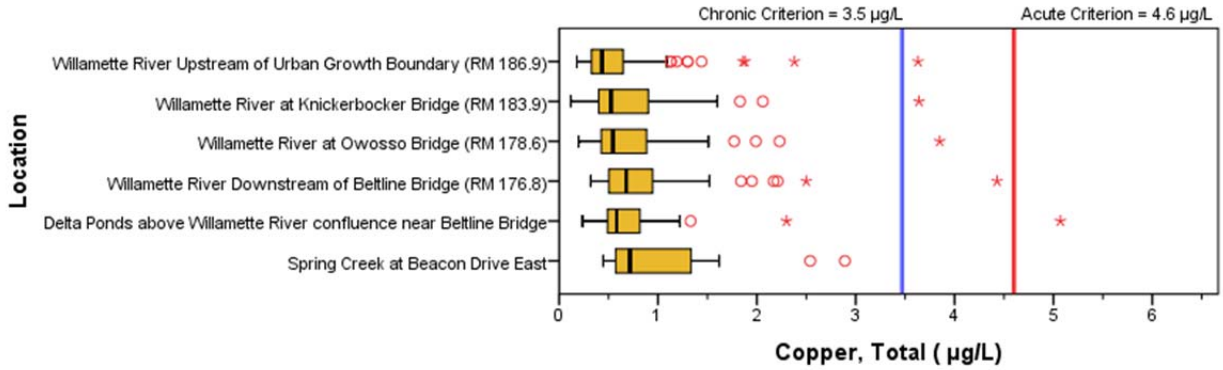

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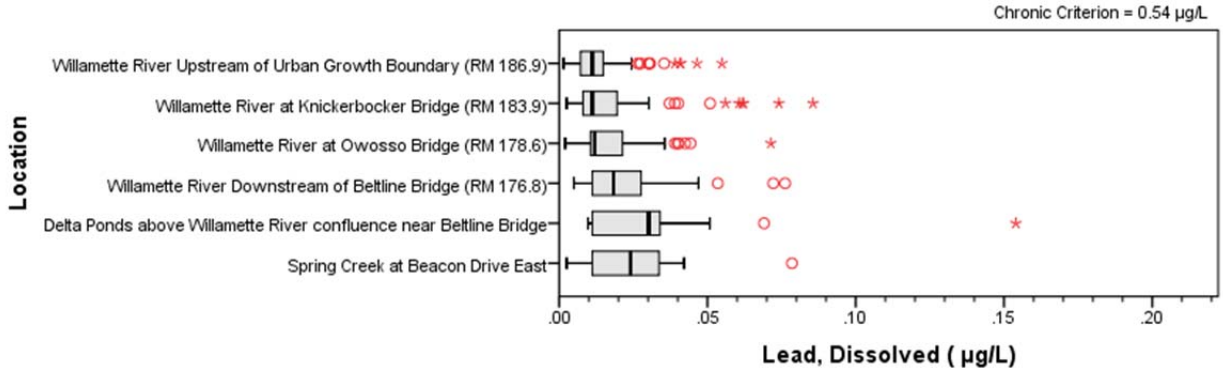

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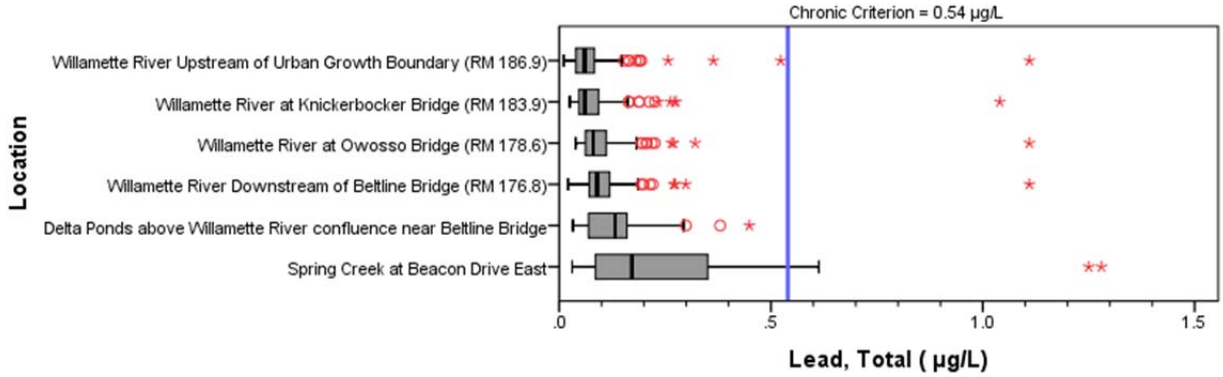

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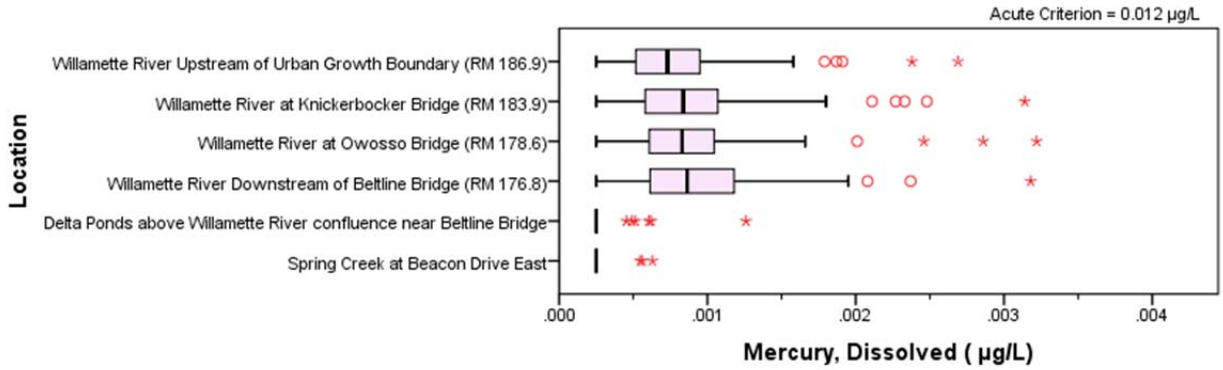

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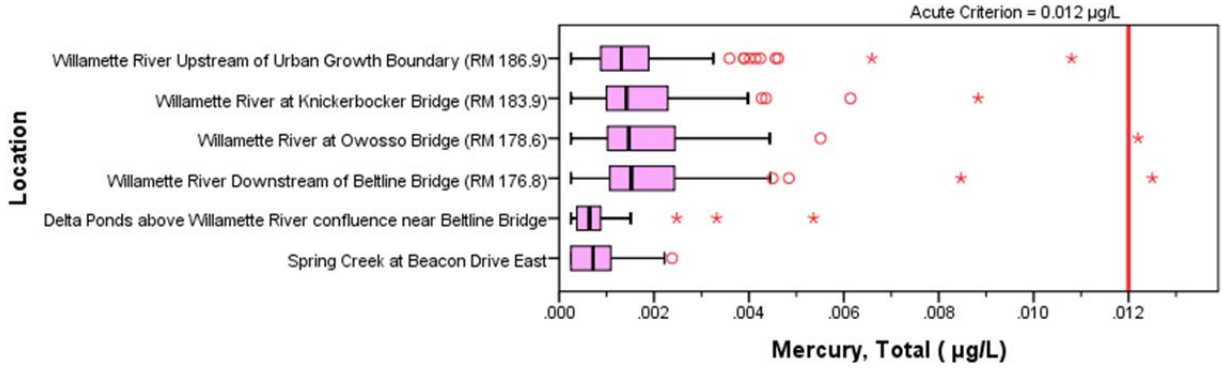

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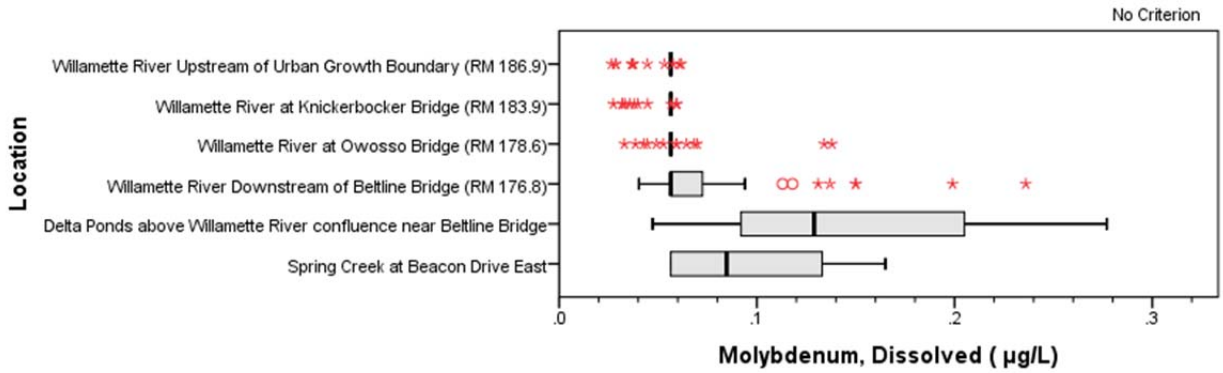

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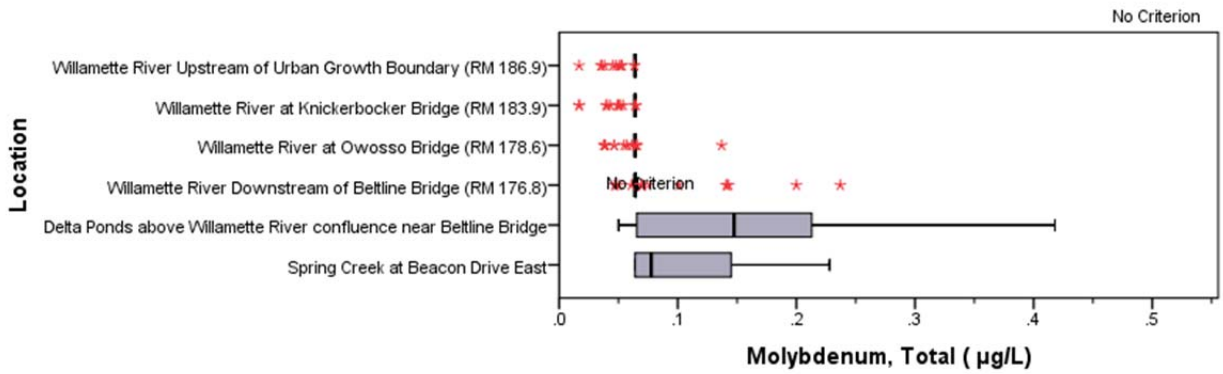

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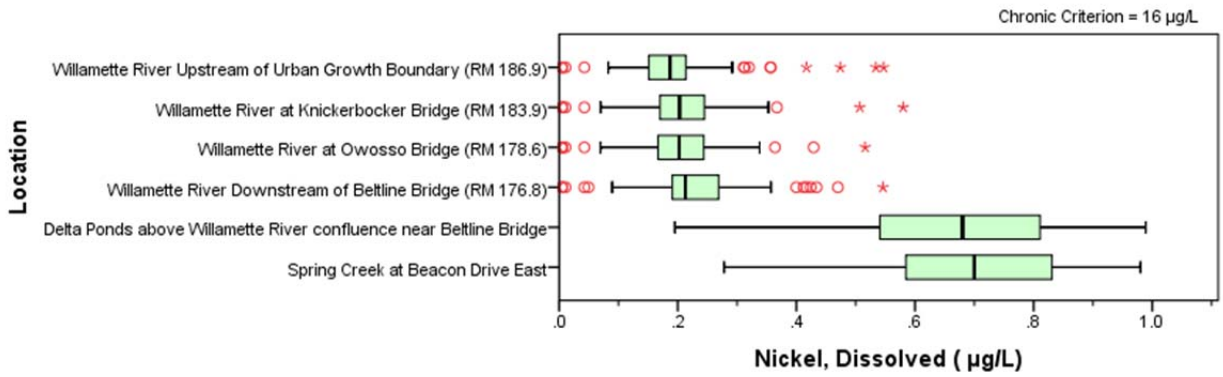

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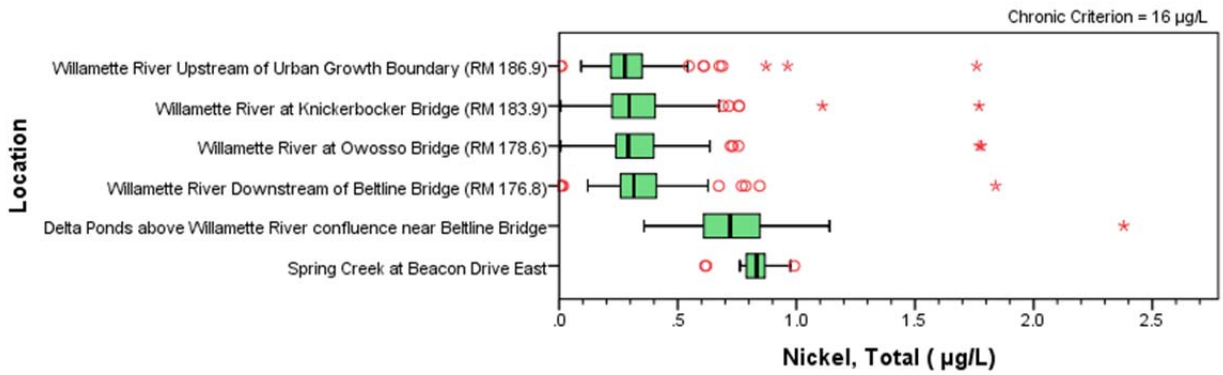

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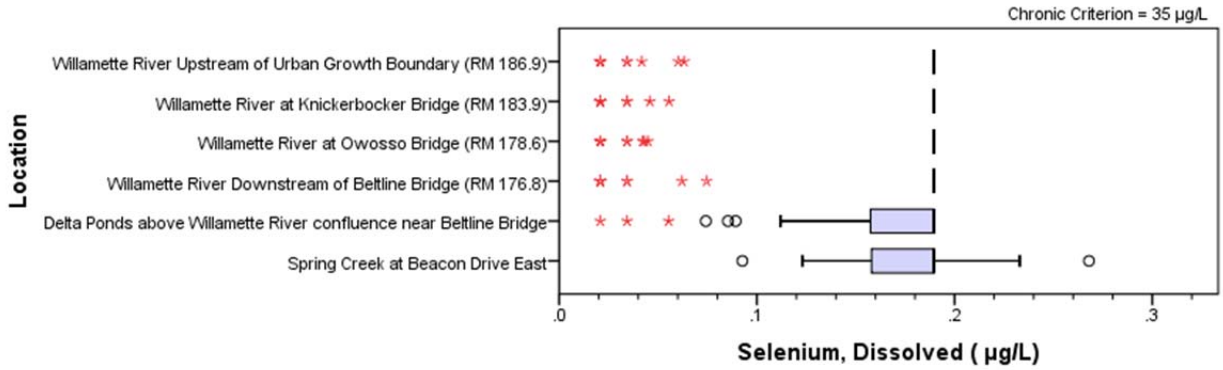

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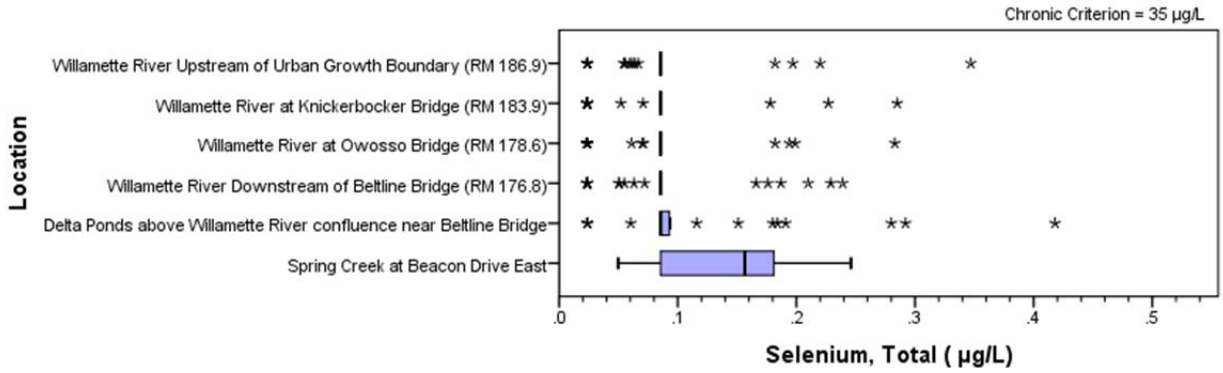

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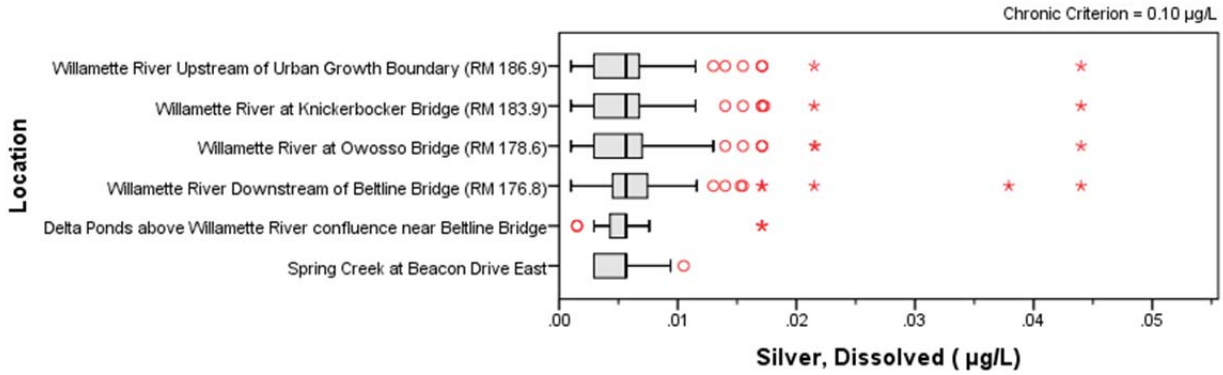

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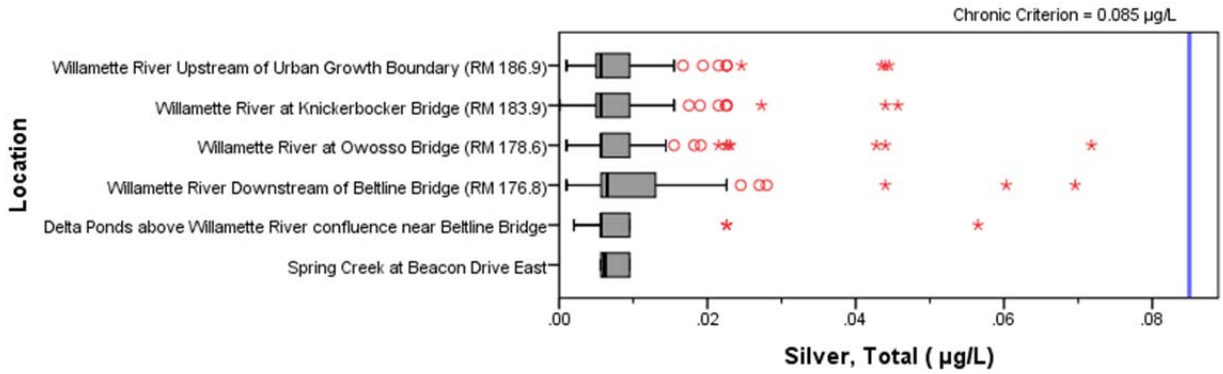

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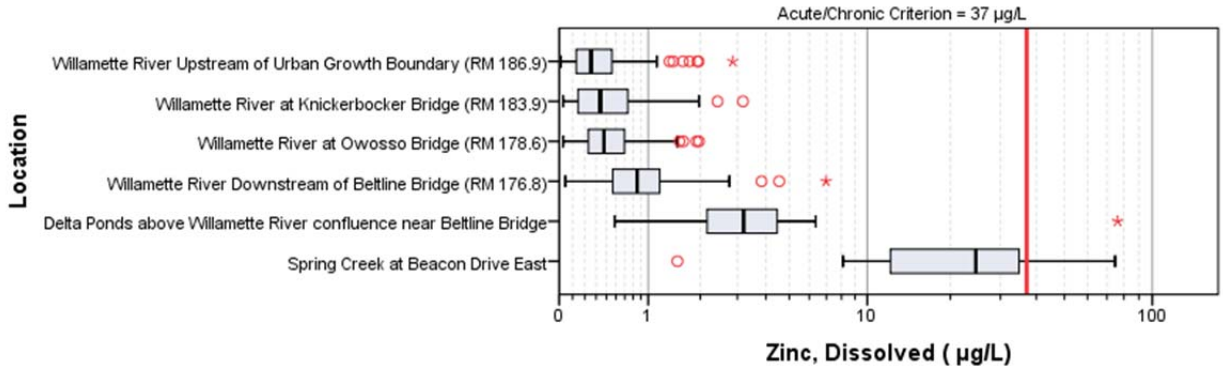

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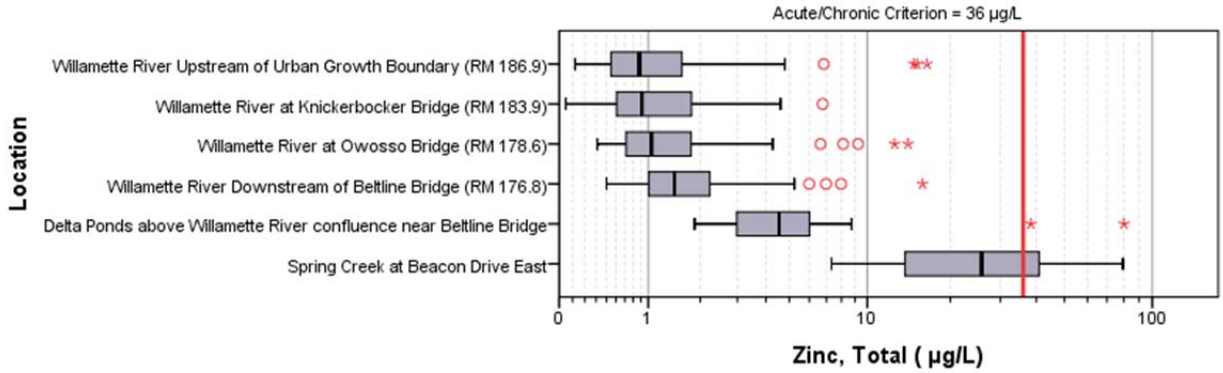

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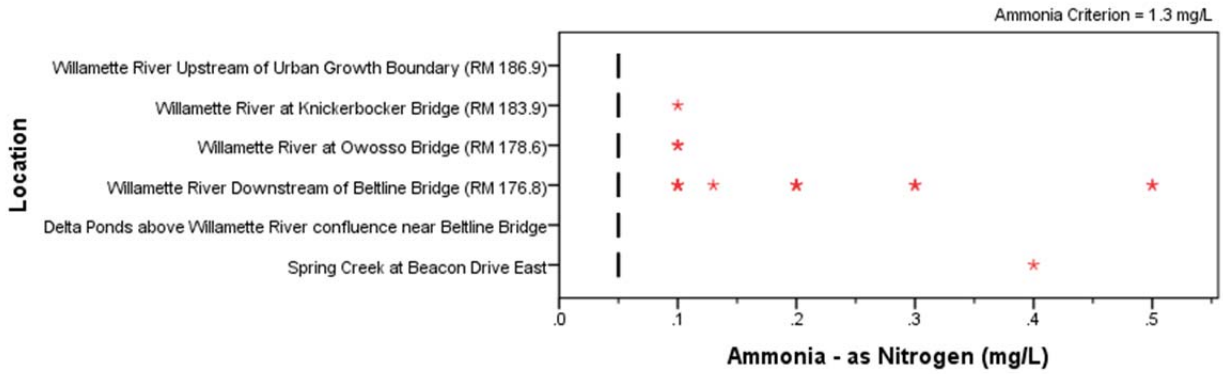

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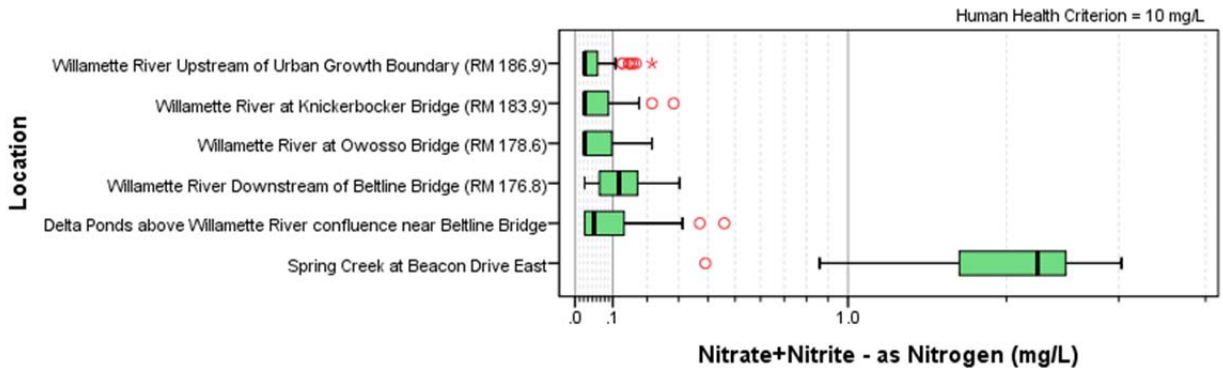

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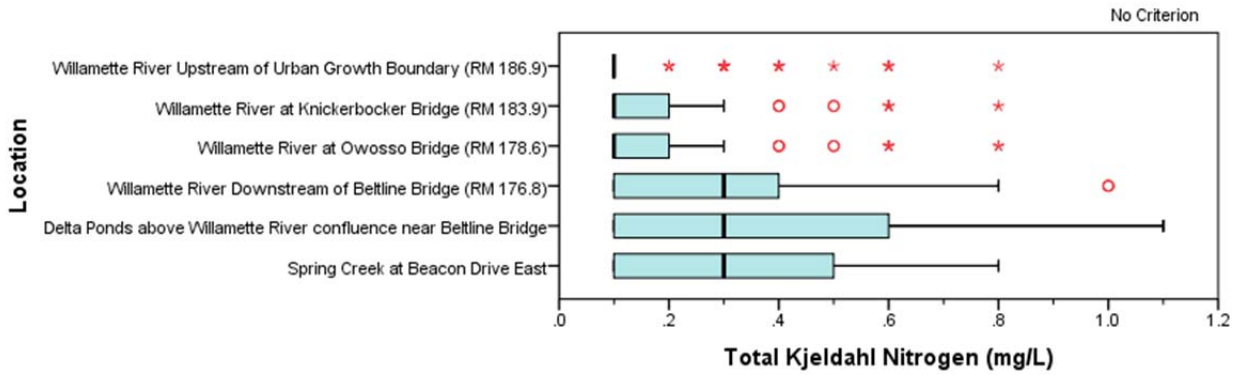

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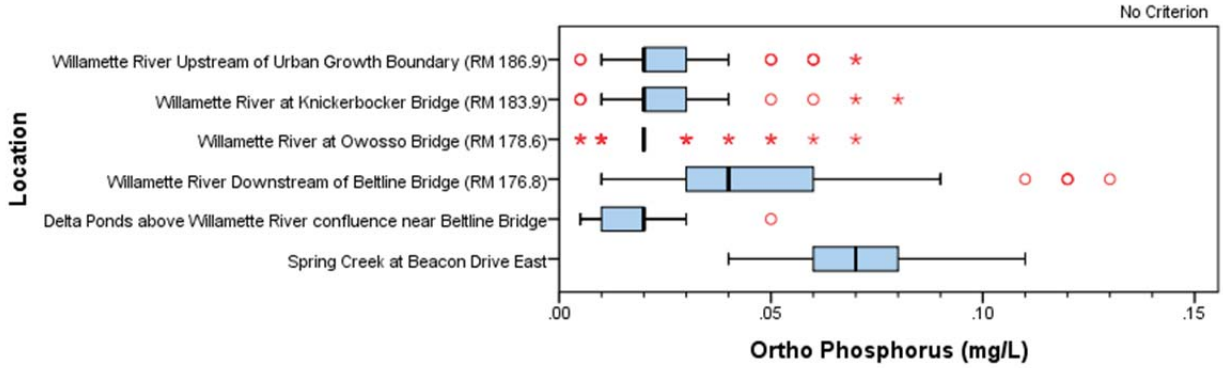

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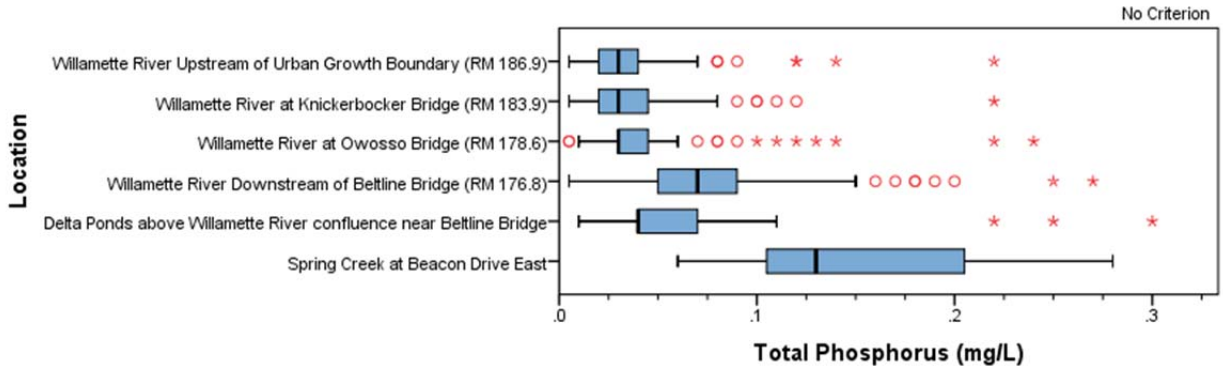

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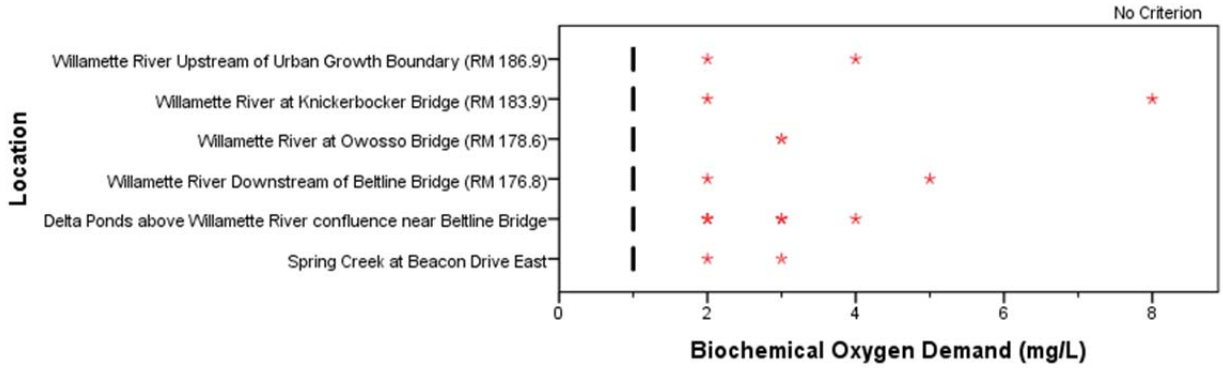

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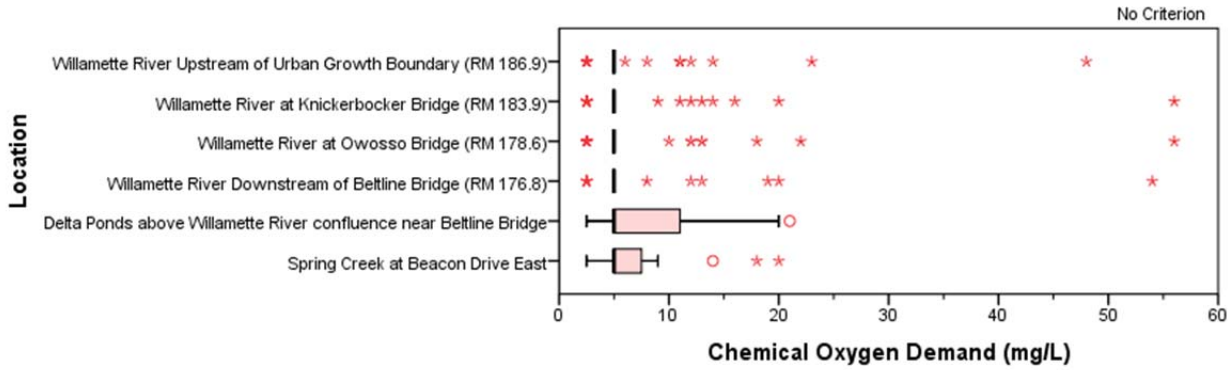

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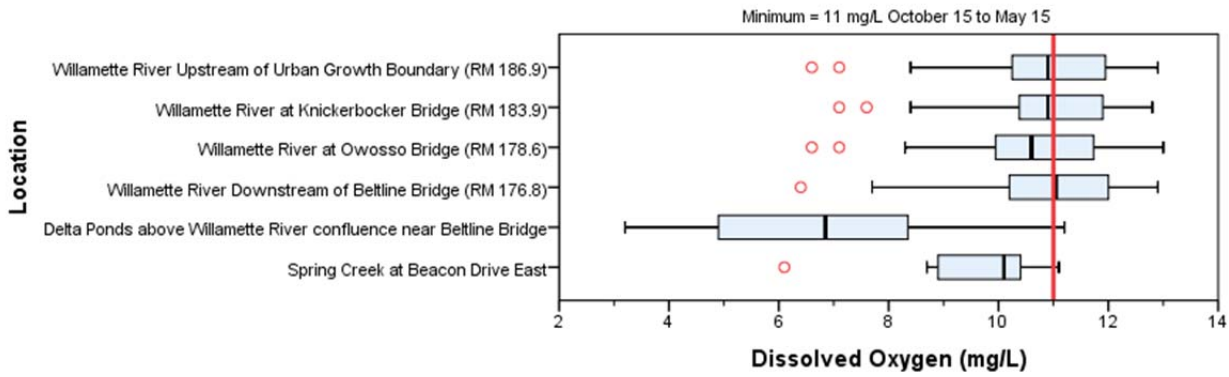

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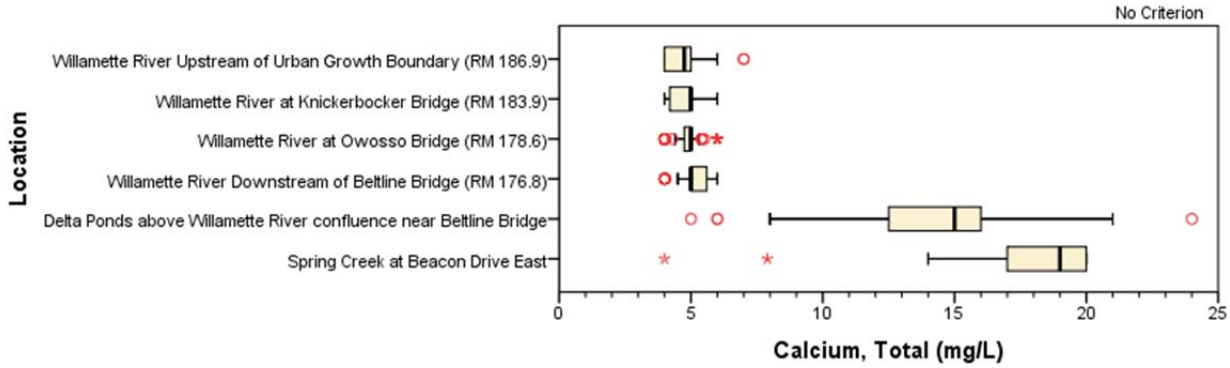

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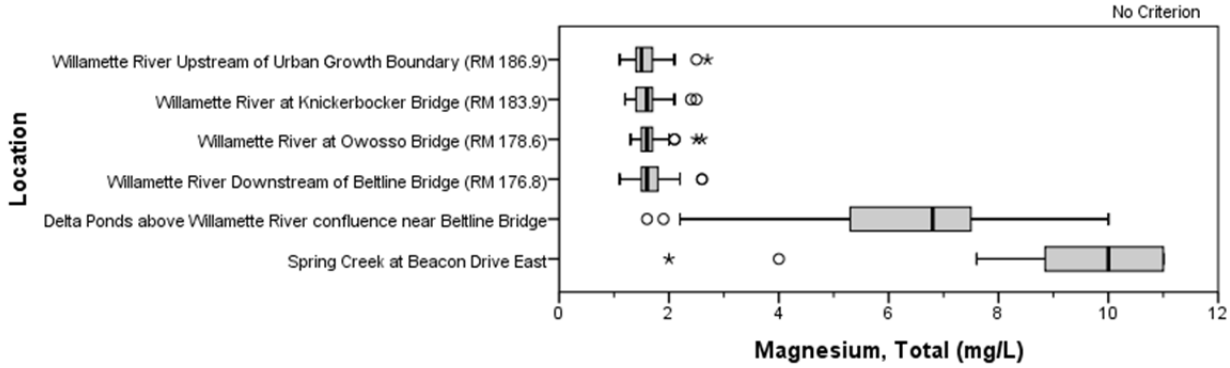

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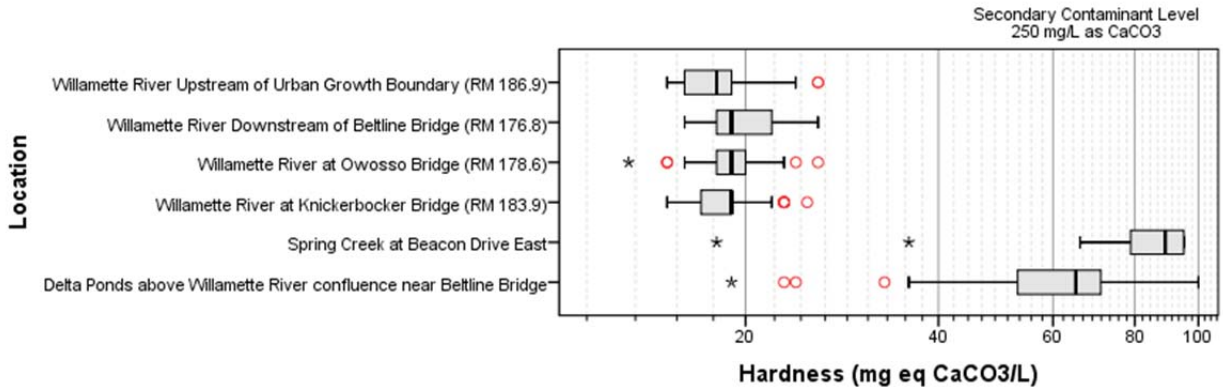

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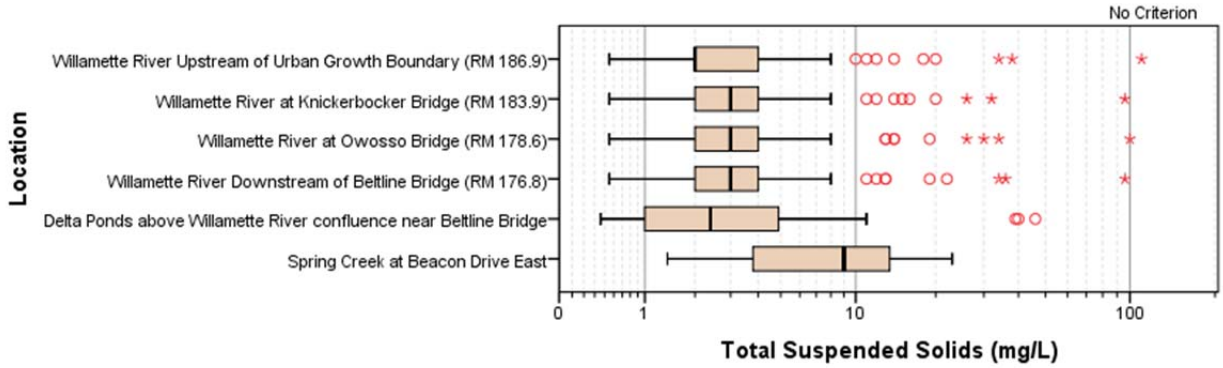

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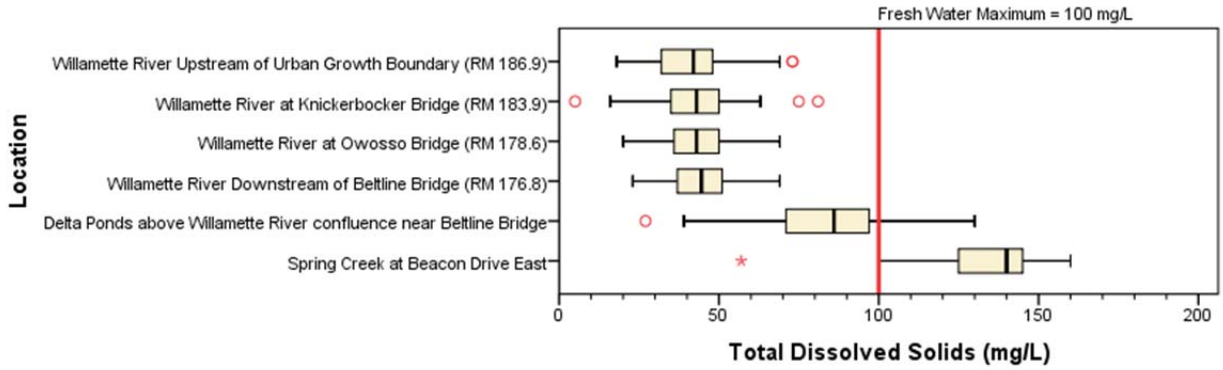

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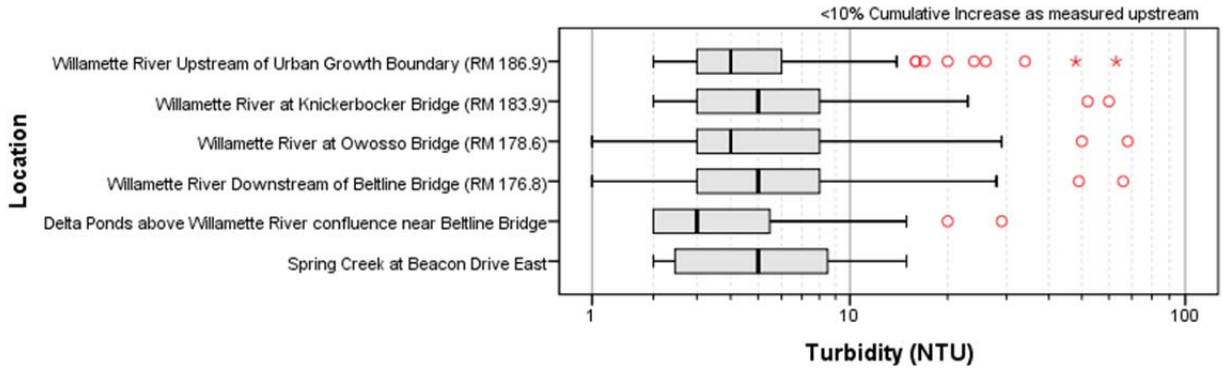

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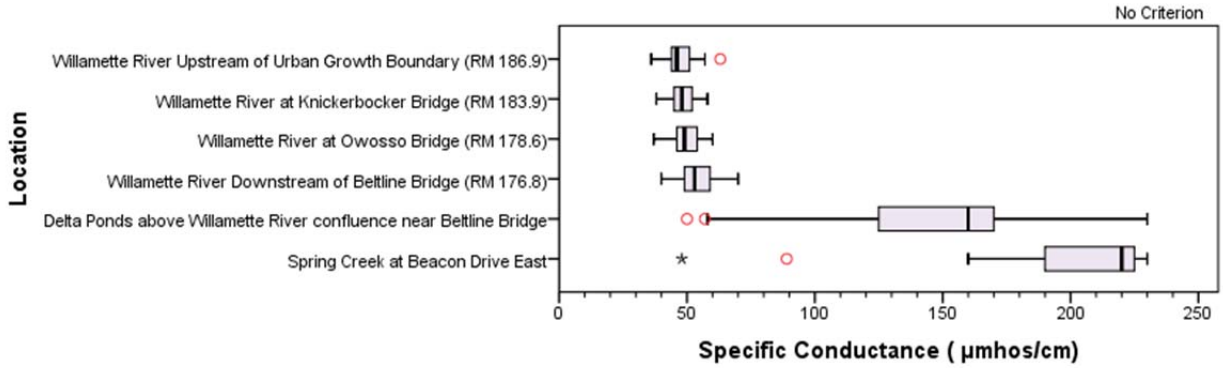

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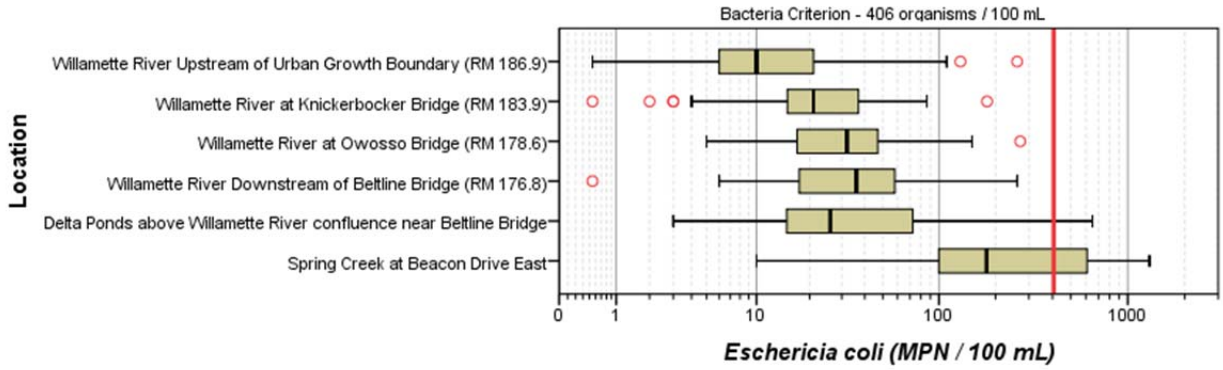

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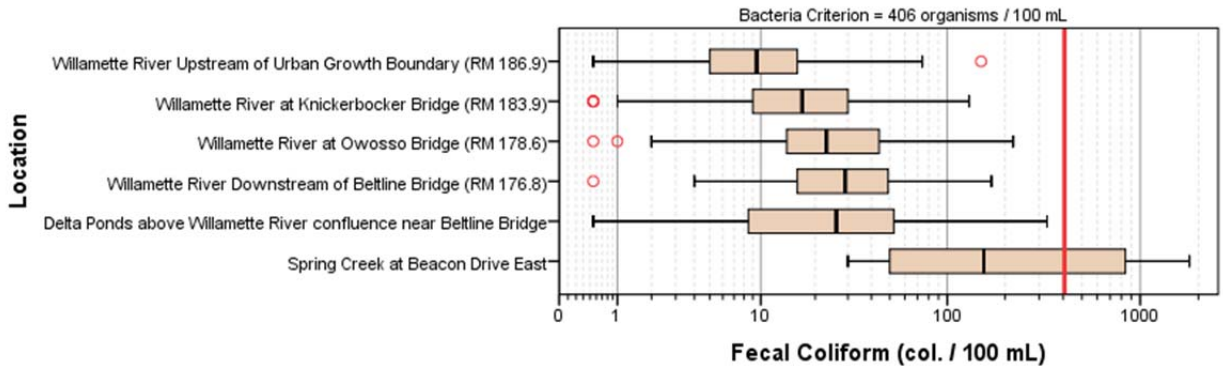

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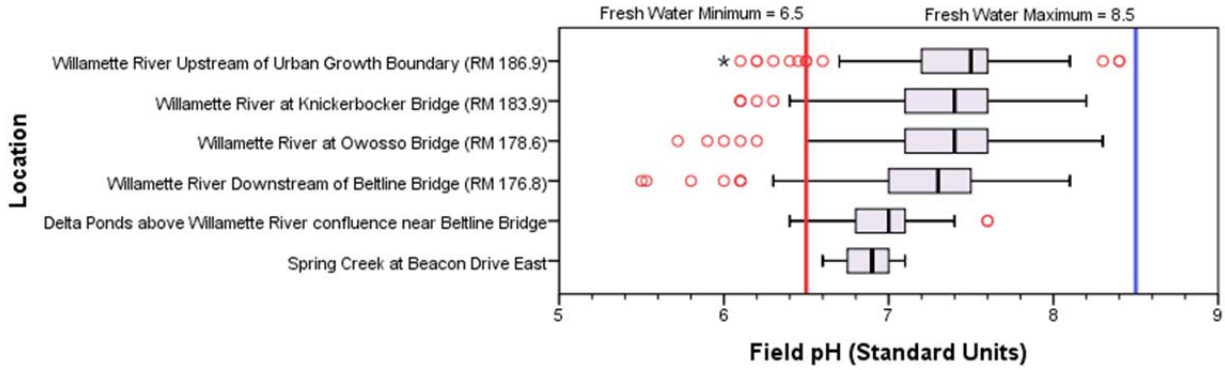

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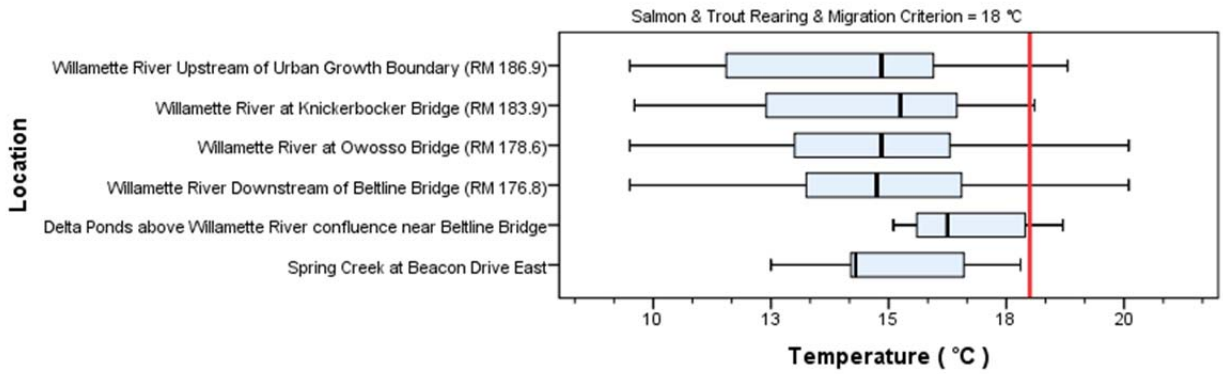

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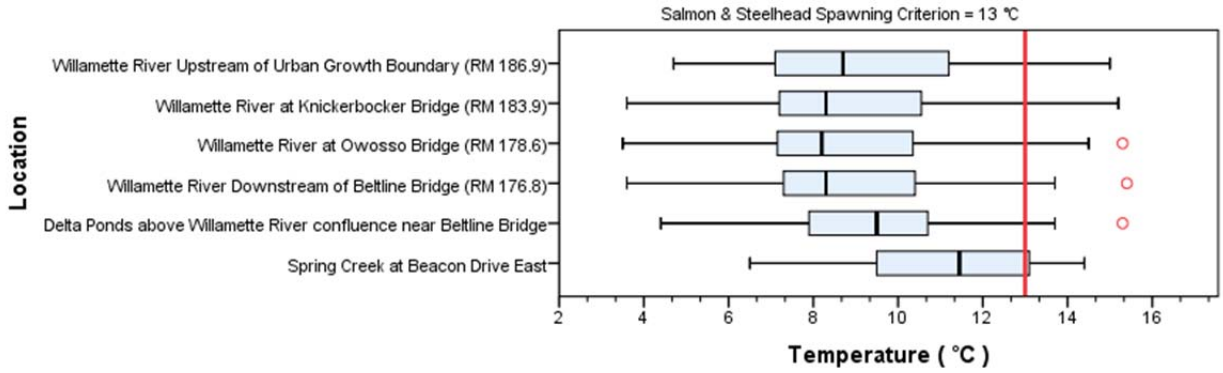

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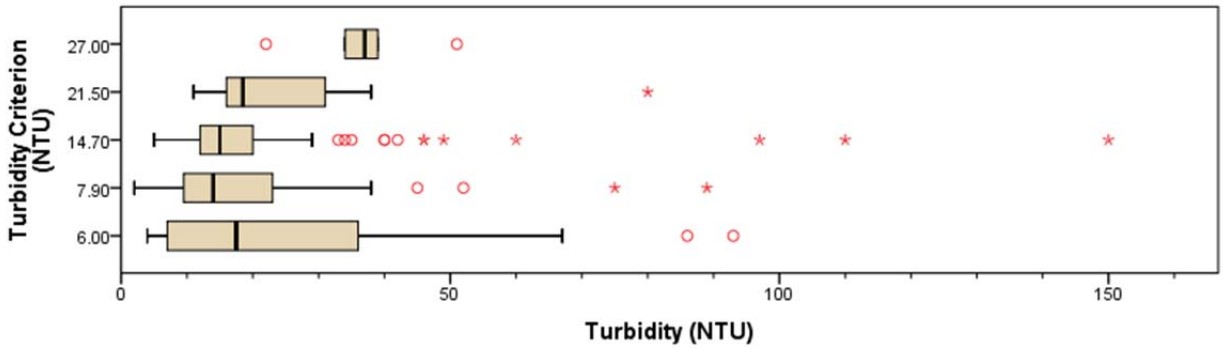

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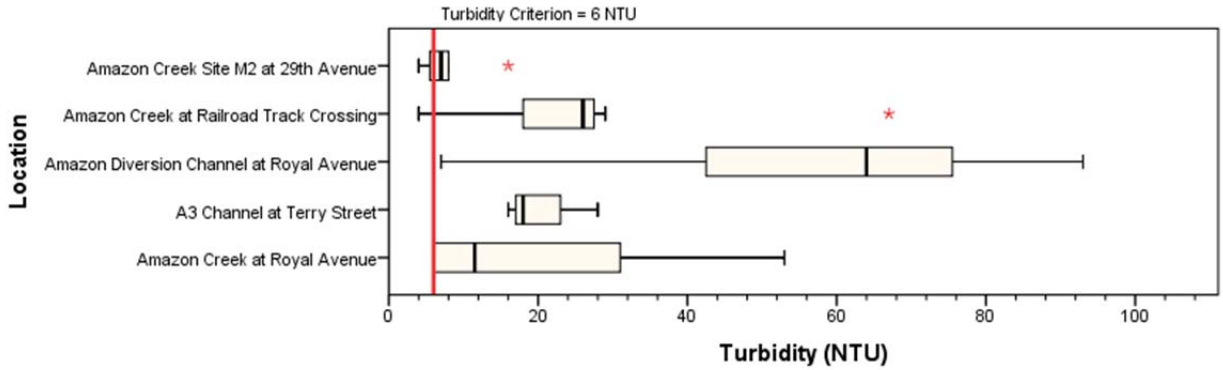

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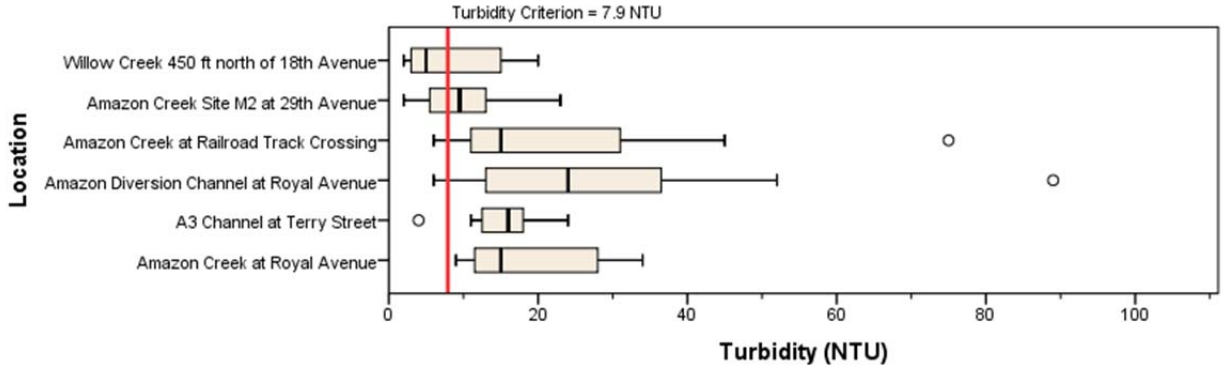

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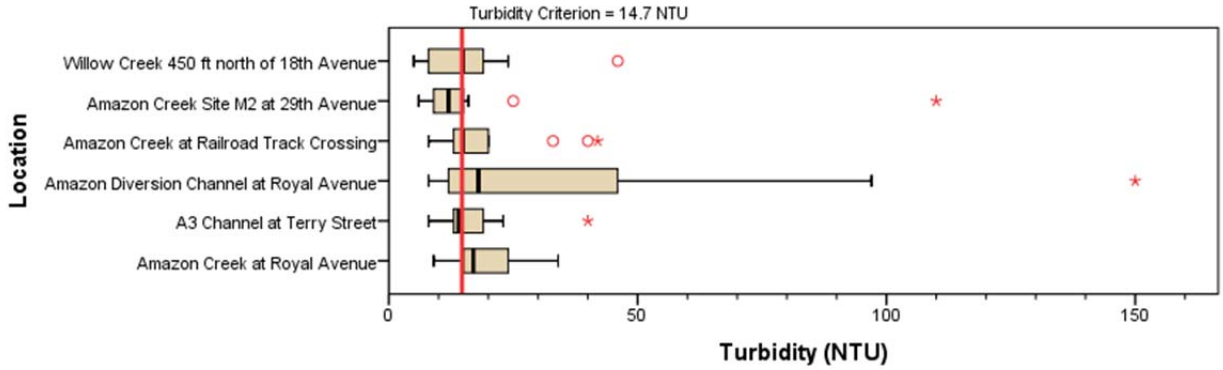

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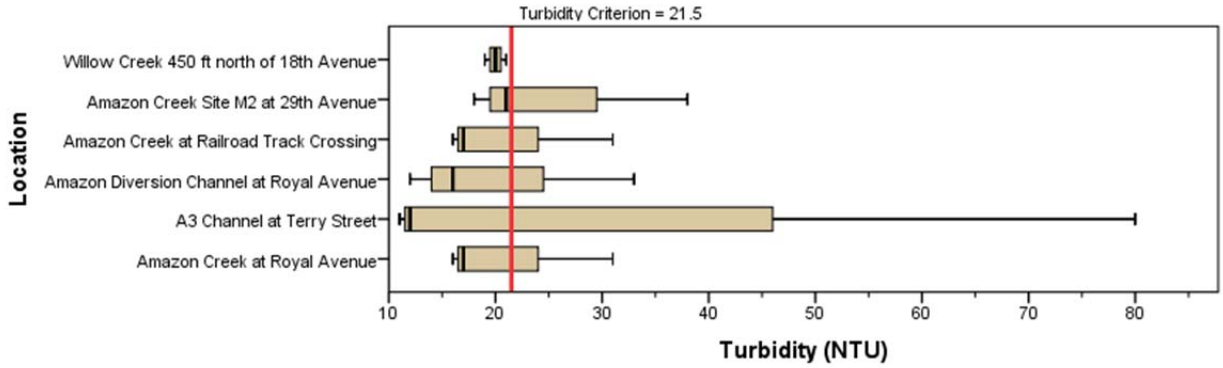

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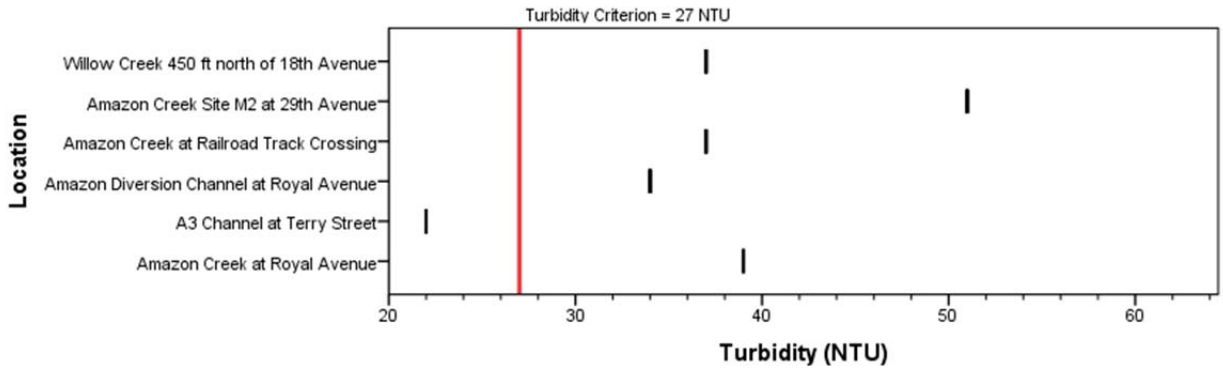
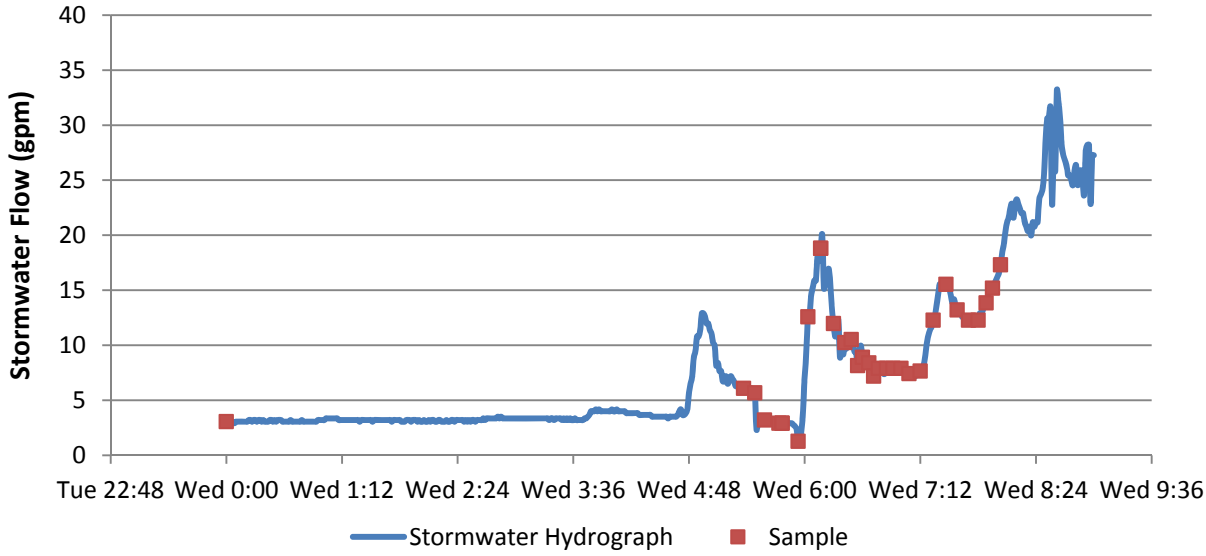


Figure B.198
Storm Event Hydrograph - 3/5/2014
Chambers & 18th Ave.: MH 55404



Supplement to
Stormwater Annual Report
Permit Year 2014

2. TMDL Wasteload Allocation Attainment Assessment
(MS4 Permit Schedule D.3.b.)

Wasteload Allocation Attainment Assessment

Prepared for
City of Eugene, Oregon
December 1, 2014

6500 SW Macadam Avenue, Suite 200
Portland, OR 97239
Phone: 503.244.7005
Fax: 503.244.9095

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List of Abbreviations

Ac	acre(s)
ACWA	Oregon Association of Clean Water Agencies
BOD	biological oxygen demand
BMP	best management practice
CIP	capital improvement program
City	City of Eugene
COM	Commercial *(land use classification)*
EMC	event mean concentration
ft	foot/feet
ft^2	square foot/feet
GI	green infrastructure
GIS	geographic information system
IND	Industrial *(land use classification)*
LA	load allocation
LS	lump sum
MEP	maximum extent practicable
MFR	Multi-family Residential *(land use classification)*
mg/L	milligram(s) per liter
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
POS	Parks and Open Space *(land use classification)*
SCS	Soil Conservation Service
SFR	Single-family Residential *(land use classification)*
SWMP	Stormwater Management Plan
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
VAC	Vacant *(land use classification)*
WLA	wasteload allocation
WLAAA	Wasteload Allocation Attainment Assessment
WWTP	wastewater treatment plant

Section 1

Introduction and Background

The City of Eugene's (City's) National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Separate Storm Sewer System (MS4) permit, issued on December 30, 2010, requires the City to conduct a Wasteload Allocation Attainment Assessment (WLAAA). The assessment must reflect an evaluation of the City's ability to attain wasteload allocations (WLAs) identified in applicable total maximum daily loads (TMDLs).

1.1 Applicability

The requirements to conduct a WLAAA are detailed in Schedule D(3)(b) of the City's NPDES MS4 permit as follows:

> *(b) Wasteload Allocation Attainment Assessment: The permittee must complete an assessment of WLA attainment, including identifying information related to the type and extent of BMPs necessary to achieve pollutant load reductions associated with an established TMDL WLA and the financial costs and other resources that may be associated with the implementation, operation and maintenance of BMPs. The results of the assessment must be submitted to the Department by December 1, 2014.*

The Willamette Basin TMDL, approved in 2006, includes established allocations for bacteria from urban stormwater and MS4 sources. All of the City's MS4 area discharges to the Upper Willamette River either directly or through various tributaries (e.g., Amazon Creek, the McKenzie River, etc.). In addition, specific tributaries in Eugene have their own allocations for urban stormwater sources for bacteria, biological oxygen demand (BOD) (used as a surrogate for dissolved oxygen [DO]), nutrients (specifically, total phosphorus as a surrogate for DO), volatile suspended solids (VSS)[1] (specifically, total suspended solids [TSS] used as a surrogate for DO), and TSS (used as a surrogate for turbidity).

The Willamette Basin TMDL does not define allocations in the form of wasteload allocations (WLAs) for urban stormwater or MS4 permit areas. With the implementation of the NPDES MS4 permits (considered to be point source discharge permits), by definition, WLAs would ordinarily be used to regulate discharges of urban stormwater runoff for areas covered by the permits. The TMDLs instead have defined load allocations (LAs) for the City's MS4 area. The LAs are established as a percentage load reduction for bacteria, total phosphorus, TSS, and BOD. Because stormwater pollutant discharges are managed through implementation of the City's NPDES MS4 permit, for purposes of this report, it is assumed that these LAs are, for all intents and purposes, WLAs. The term WLA is used in this report.

1.2 Assessment Goals

The overall goal of the WLAAA is to determine, conceptually, what it would take in the form of stormwater management strategies to reduce TMDL pollutant discharges from the MS4 to meet required WLAs (loads or concentrations).

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[1] In the Willamette Basin TMDL, page 10-147, sediment oxygen demand is caused in part due to discharge of VSS. Load reduction is referred to as the reduction of VSS in the TMDL.

Stormwater management strategies are outlined in the City's Stormwater Management Plan (SWMP) (updated December 2012), which includes programmatic, planning-related, regulatory, and capital-related activities to address stormwater pollution. Collectively, the stormwater management strategies are referred to as best management practices (BMPs).

In conducting the WLAAA, the City sought answers to the following questions:

- With current evaluation data and methods, is achievement of the WLA for each TMDL watershed and TMDL parameter conceptually possible?
- If achievement of the WLA is shown to be possible, what level/extent of BMP coverage is needed?
- If achievement of the WLA is shown to be possible, what are the financial requirements and financial implications of the required BMP coverage?
- If achievement of the WLA is shown to be possible, is implementation of the required BMP coverage feasible or practicable?
- If achievement of the WLA is not shown to be possible, what are potential reasons why?

1.3 Background

The City initially evaluated TMDL pollutant loads and pollutant load reduction from its MS4 as part of its 2008 NPDES MS4 permit renewal application. Bacteria, total phosphorus, BOD, and TSS loads were evaluated for the Upper Willamette Subbasin in conjunction with established WLAs in the Willamette Basin TMDL. BMP implementation was considered in the evaluation, and BMP implementation projected over the 5-year permit term (2008-2013) was reflected in the analysis in order to establish TMDL pollutant load reduction benchmarks. By definition, a pollutant load reduction benchmark is a pollutant load reduction estimate for the future, typically reflective of the end of the 5-year permit term, and is used as a tool to guide progress and adaptive management of the City's stormwater program.

In accordance with the City's current NPDES MS4 permit Schedule D.3.c. the City must complete a pollutant load reduction evaluation by December 1, 2014. The pollutant load reduction evaluation requires estimation of current (2014) pollutant loads with and without BMP implementation. Pollutant loads are to be compared to applicable TMDL WLAs. Pollutant loads are also to be compared to established pollutant load reduction benchmarks. Progress toward achieving the TMDL WLAs and established benchmarks is evaluated.

The City completed its pollutant load reduction evaluation in November 2014, results of which are used in this WLAAA. The pollutant load reduction evaluation required an inventory of the City's contributing MS4 area, TMDL watersheds, land use, and BMP coverage. A spreadsheet loads model was used for the calculation of TMDL pollutant loads within the City's NPDES MS4 permit boundary in conjunction with the Willamette Basin TMDL. Given data limitations, structural BMPs (i.e., ponds, swales, and rain gardens) with defined drainage areas were the only BMPs directly simulated using the spreadsheet model. Additional structural BMPs are in place, but were not simulated due to undocumented drainage areas. Source control and non-structural BMPs were accounted for in the overall process and described qualitatively in the model results, but the effectiveness of these controls was not directly quantified. As such, simulated model results are expected to conservatively estimate (i.e., under estimate) the TMDL pollutant load reduction.

Figure 1-1 provides a conceptual schematic of how the pollutant load reduction evaluation and pollutant load reduction benchmarks were conveyed in terms of results. The Figure 1-1 schematic also shows how the load reduction required to achieve the WLA (the focus of this WLAAA) is calculated.

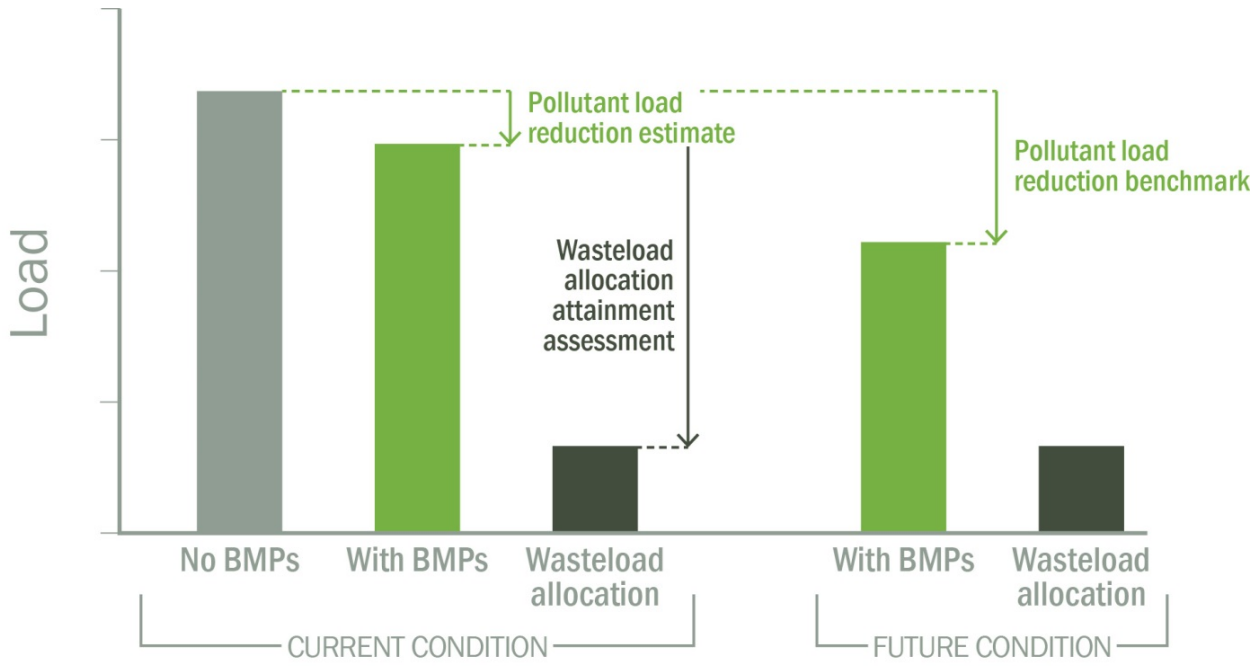

Figure 1-1. Conceptual pollutant load estimation

1.4 Document Organization

This report was prepared to fulfill the City's requirements related to the development of a WLAAA, as required per Schedule D(3)(b) of the City's NPDES MS4 permit. This report is organized according to the following sections:

Section 2 Description of the WLAAA approach and methodology, including a summary of pertinent results from the pollutant load reduction evaluation

Section 3 Results from the WLAAA, including cost estimates for implementation

Section 4 Discussion and conclusions from the WLAAA

Section 5 References

Section 2

Approach and Methods

The overall WLAAA approach for Eugene used model input and results from the 2014 pollutant load reduction evaluation and simulated additional structural BMP implementation scenarios. TMDL pollutant loads and pollutant load reduction were estimated for each BMP implementation scenario. The resulting pollutant load reductions were compared to the WLAs. The scenarios reflecting potential achievement of the WLA were identified and construction and maintenance costs for those scenarios were estimated.

Specific for Eugene, the WLAAA was conducted for five TMDL watersheds in the Upper Willamette Subbasin (per the Willamette Basin TMDL): Upper Amazon Creek, A3 Channel, Upper Willamette (undefined), McKenzie River, and the Amazon Diversion Channel/ Fern Ridge Reservoir. The Amazon Diversion Channel TMDL watershed area is the same as the Fern Ridge Reservoir TMDL watershed area for purposes of evaluating the MS4 contribution from the city of Eugene, and therefore the same model was used for both watersheds. The Amazon Diversion Channel/ Fern Ridge Reservoir TMDL watershed reflects the combined drainage area from the Upper Amazon Creek and A3 Channel TMDL watersheds.

2.1 Model Assumptions

Consistent modeling assumptions as described in Section 4 of the 2014 pollutant load reduction evaluation were assumed for the WLAAA. Specifically, a consistent annual rainfall depth was used in the model simulations. Consistent model area, land use coverages, and structural BMP coverages (reflecting 2014 development conditions) were used. Consistent land use event mean concentrations (EMCs), impervious percentages by land use, and BMP effectiveness information were also maintained. Structural BMPs were simulated based on the assumption that they are sized to treat 80 percent of the average annual runoff volume, consistent with current NPDES MS4 permit requirements.

2.2 2014 Pollutant Load Reduction Evaluation Results

Quantitative pollutant load reduction estimates were based on the simulation of structural BMP coverage over a TMDL watershed. Results of the 2014 pollutant load reduction evaluation reflect an overall increase in structural BMP coverage from 2008 conditions. Current structural BMP implementation generally consists of bioswales and hydrodynamic devices, although there are also a number of other facilities including detention ponds, sedimentation manholes, ecoroofs, and lined planters/ filtration raingardens.

Table 2-1 summarizes current (2014) structural BMP coverage compared with the 2008 structural BMP coverage for each TMDL watershed. Documentation from 2008 included only a general percent BMP coverage for all TMDL watersheds. The relative difference in BMP coverage reflects an estimated and relative rate of structural BMP implementation as a result of new development/ redevelopment and stormwater retrofit activities.

Table 2-1. Current Condition BMP Coverage (2014)

TMDL/subbasin	TMDL watershed	2008 BMP	2014 BMP	2014 dominant BMP	
		Coverage (%)	Coverage (%)	Category	Coverage (as a % of total BMP coverage)
Willamette Basin/Upper Willamette	Upper Amazon	1.5	1.5	Swale	60
	A3 Channel		6.1	Swale	60
	Upper Willamette		9.6	Hydrodynamic Device	67
	Amazon Diversion/ Fern Ridge[a]		2.3	Swale	60
	McKenzie[b]	N/A	4.6	Sediment Manhole	49

a: The Amazon Diversion/ Fern Ridge TMDL watershed area reflects the combined Upper Amazon and A3 Channel TMDL watershed area.

b: The McKenzie River TMDL watershed area was not modeled in 2008, due to interpretation of the TMDL.

The 2014 pollutant load reduction evaluation simulated TMDL pollutant loads with and without structural BMP implementation. The TMDL pollutant loads were calculated as a range using an upper confidence limit and a lower confidence limit, based on the widely variable nature of pollutant concentrations in stormwater runoff. The relative difference in estimated pollutant loading with and without structural BMP implementation was defined as the pollutant load reduction and was compared to the WLA.

The WLAs are defined for all TMDL parameters as a general percent load reduction. For purposes of the pollutant load analysis, the analysis was conducted using annual rainfall and an annual estimate of pollutant load and pollutant load reduction.

Table 2-2 summarizes the results of the pollutant load reduction evaluation by TMDL watershed. The 2014 pollutant load reduction estimate is presented as a percent range and reflects current structural BMP implementation as per the coverage defined in Table 2-1. Pollutant load reduction is dependent on overall BMP coverage, but more specifically on the effectiveness of the BMP for the TMDL parameter of concern. For example, the Upper Willamette TMDL watershed has one of the highest percentages of BMP coverage; however, the relative bacteria load reduction achieved (as a percent) is less than that of other watersheds, because hydrodynamic separators (the dominant BMP implemented) are not effective at removing bacteria per current BMP effluent data from the literature.

Collectively, as shown in Table 2-2, the current pollutant load reduction estimate is significantly less than the WLA for all TMDL watersheds and parameters.

Table 2-2. Pollutant Load Reduction Evaluation Results

Parameter	TMDL watershed	2014 WLA (%)	2014 pollutant load reduction estimate (% range)[a]
Bacteria	Upper Amazon	84%	0.2 – 0.4%
	A3 Channel	33%	0.6 – 0.9%
	Upper Willamette	65%	0.5 – 0.8%
	McKenzie	65%	0.2 – 0.2%
	Fern Ridge	64%	0.3 – 0.4%
TSS	Amazon Diversion	40%	0.6 – 0.9%
	Fern Ridge	54.6%	0.6 – 0.9%
BOD	Amazon Diversion	40%	0.7 – 1.2%
Total Phosphorus	Amazon Diversion	40%	0.5 – 1.1%

Note: WLAs are expressed as a percentage reduction in load.

a. Pollutant Load Reduction Estimate is a range between the upper and lower confidence limit associated with the generated pollutant load.

2.3 BMP Implementation Scenarios

A total of three BMP implementation scenarios were developed to evaluate the extent of structural BMP coverage that would be needed to meet the WLA. The BMP implementation scenarios were simulated using the spreadsheet model developed for the pollutant load reduction evaluation and assume current (2014) land use and structural BMP implementation as the baseline condition.

Scenario 1 reflects hypothetical BMP implementation in which a selected structural BMP (lined planters/ filtration raingardens) was applied to approximately half of the currently untreated area within the TMDL watershed. Under scenario 1, pollutant generating land use that is not currently treated by a structural BMP was considered for this additional BMP implementation. Open space land use was excluded because of the limited amount of impervious surface and associated runoff generated and because limited anthropogenic pollutants are discharged from these areas. Filtration planters were the selected structural BMP due to the fact that the City's recently adopted stormwater design standards encourage the use of vegetated stormwater facilities and low impact development technologies. Additionally, filtration planters are a relatively effective treatment technology for a variety of TMDL parameters.

Scenario 2 expanded on Scenario 1 and included hypothetical BMP implementation of lined planters/ filtration raingardens to all of the currently untreated area within the TMDL watershed (excluding open space land use). Scenario 2 was conducted for TMDL watersheds and/or parameters where WLAs were not achieved under Scenario 1.

Finally, Scenario 3 reflects hypothetical BMP implementation of unlined planters/ infiltration raingardens to all of the currently untreated areas within the TMDL watershed (excluding open space land use). Scenario 3 was conducted for TMDL watersheds and/or parameters where WLAs were not achieved under either Scenarios 1 or 2. While this scenario is infeasible, use of infiltration raingardens at the coverage specified was conducted to verify whether WLAs could ever be achieved based on current evaluation data and methods (see constraint and limitation discussion in Section 4.1).

The breakdown of BMP coverage associated with scenarios 1, 2, and 3 is detailed in Table 2-3.

Table 2-3. WLAAA BMP Coverage Assumptions

TMDL/subbasin	TMDL watershed	2008 BMP Coverage (%)	2014 BMP Coverage (%)	Hypothetical BMP Coverage: Scenario 1 Coverage (%)	Hypothetical BMP Coverage: Scenario 2 and 3 Coverage (%)
Willamette Basin/Upper Willamette	Upper Amazon	1.5	1.5	41.0	80.5
	A3 Channel		6.1	45.5	85.3
	Upper Willamette		9.6	47.9	86.2
	Amazon Diversion/ Fern Ridge[a]		2.3	62.4	81.3
	McKenzie[b]	N/A	4.6	51.9	99.2

Section 3

WLAAA Results and Cost Estimates

Pollutant load reduction calculations reflecting results from pollutant load modeling of the three BMP implementation scenarios that are described in Section 2.3 are provided in Table 3-1. For the TMDL watersheds and BMP implementation scenarios where the WLA is estimated to be met, the construction and maintenance cost of BMP implementation at the scale and coverage simulated is detailed in Section 3.2.

3.1 WLAAA Results Discussion

Table 3-1 lists the TMDL parameters, TMDL watersheds, WLAs, and current 2014 pollutant load reduction estimate as a percentage for each TMDL watershed. For simplicity and comparison, only the mean percent load reduction is shown for the pollutant load reduction estimates (instead of a range as presented in Table 2-2). Table 3-1 also shows the pollutant load reduction associated with each of the three BMP implementation scenarios, as a percentage. TMDL watersheds showing potential achievement of WLAs for select scenarios and associated, hypothetical BMP implementation are shown shaded in gray in the table.

Even with full structural BMP coverage, the bacteria WLA was determined to be unachievable in the Upper Amazon Creek TMDL watershed. In general, achievement of the WLA is shown to be hypothetically possible for the remaining watersheds. Scenario 1 shows achievement of the WLA for bacteria in the A3 Channel and BOD and total phosphorus in the Amazon Diversion Channel. However, this level of BMP coverage would not result in achievement of the WLA for other parameters applicable to the same TMDL watershed area. Scenario 2 shows achievement of the WLA for bacteria in the Upper Willamette, McKenzie, and Fern Ridge TMDL watersheds and achievement of the WLA for TSS in the Amazon Diversion Channel TMDL watershed. Scenario 3 shows additional pollutant load reduction achieved through the use of infiltration as opposed to filtration facilities. Scenario 3 results in achievement of the WLA for TSS in the Fern Ridge TMDL watershed.

Comparing results from Scenarios 1 and 2 (treatment of half of the existing untreated area by filtration rain gardens versus treatment of all existing untreated area), an increase in pollutant load reduction is achieved, as would be expected. The additional pollutant load reduction varies based on the type of pollutant, as the relative increase in TSS removal is not as significant as bacteria removal. That is due to the fact that use of lined planters results in a significant reduction in bacteria load, as compared to the respective land use EMCs. Lined planters are also effective at TSS removal, but the TSS effluent concentration for lined planters is not as significantly lower than the respective land use EMCs.

Comparing results from Scenarios 2 and 3 (treatment by filtration raingardens versus infiltration raingardens) additional pollutant load reduction was achieved when using infiltration raingardens, and results also vary by pollutant parameter. Infiltration raingardens achieve pollutant removal due to the infiltration (removal) of runoff volume as opposed to the filtration of the runoff volume. The incremental improvement between Scenarios 2 and 3 is less for bacteria than for TSS. Again, this is due to the fact that such a significant reduction in bacteria load is already achieved by use of a lined planter (with a significantly lower BMP effluent versus the contributing land use EMC), that the incremental additional removal associated with infiltration of all contributing runoff is not as

pronounced. For TSS, treatment via lined planters does not result in as significant reduction from the contributing land use EMC, but infiltration (as opposed to filtration) of all runoff volume shows a more pronounced effect.

Review of Table 3-1 indicates that achievement of the bacteria WLA for the Upper Amazon TMDL watershed is not achievable, even with the most efficient and widespread BMP implementation. Review of Table 3-1 also indicates that Scenario 2 (and associated hypothetical BMP coverage) is the minimum scenario required to meet the bacteria WLA for the Upper Willamette and McKenzie TMDL watersheds. Although Scenario 1 (and associated hypothetical BMP coverage) results in meeting the WLA for BOD and total phosphorus in the Amazon Diversion TMDL watershed, Scenario 2 results in meeting the WLA for all (BOD, total phosphorus, and TSS) surrogate parameters associated with the DO TMDL. Therefore, Scenario 2 is the minimum scenario associated with meeting the DO WLA in the Amazon Diversion Channel. The same rationale may be applied to the A3 Channel and Fern Ridge TMDL watersheds. Although Scenario 1 results in meeting the WLA for bacteria in the A3 Channel, because the A3 Channel TMDL watershed is part of the Fern Ridge TMDL watershed, Scenario 2 is the minimum scenario associated with meeting the collective Fern Ridge bacteria WLA. Scenario 3 is the minimum scenario associated with meeting the Fern Ridge turbidity TMDL.

Table 3-1. WLAAA Results (by Scenario)

Parameter	TMDL watershed	2014 WLA (%)	2014 pollutant load reduction estimate (average %)	Scenario 1: Lined Planters/ Filtration Raingardens for half of untreated area	Scenario 2: Lined Planters/ Filtration Raingardens for all untreated area	Scenario 3: Unlined Planters/ Infiltration Raingardens for all untreated area
Bacteria (%)	Upper Amazon	84	0.2	37.7	75.1	78.4
	A3 Channel	33	0.6	35.1	---	---
	Upper Willamette	65	0.5	34.3	68.1	---
	McKenzie	65	0.2	36.2	72.3	---
	Fern Ridge	64	0.3	60.8	74.3	---
TSS (%)	Amazon Diversion	40	0.7	33.6	48.8	---
	Fern Ridge	54.6	0.7	33.6	48.8	75.7
BOD	Amazon Diversion	40	1.0	40.9	---	---
Total Phosphorus	Amazon Diversion	40	0.9	40.5	---	---

Shading reflects the minimum modeled BMP implementation scenario that results in achievement of the WLA.

3.2 Cost Estimation

Construction and maintenance costs were estimated for BMP coverage associated with Scenario 2 for the Upper Willamette TMDL watershed, the McKenzie River TMDL watershed, and the Amazon Diversion/ Fern Ridge TMDL watershed. Implementation of BMP coverage in these watersheds associated with Scenario 2 assumptions represents the minimum coverage that would be required to collectively address bacteria WLAs (for the specified watershed and applicable tributary watersheds) and DO WLA.

Although Scenario 3 is the minimum scenario required to result in meeting the turbidity TMDL WLA in Fern Ridge, relative BMP coverage associated with Scenario 3 is consistent with Scenario 2. For this hypothetical assessment and for simplicity, separate unit costs reflecting use of infiltration versus filtration raingardens have not been provided. As such, the costs for implementation of BMPs under Scenarios 2 and 3 are considered equivalent.

Because the bacteria WLA was deemed unachievable with standard structural stormwater BMPs for the Upper Amazon TMDL watershed, this cost estimation does not reflect achievement of the Upper Amazon WLA.

3.2.1 Unit Costs

Unit cost estimates for construction, contingencies, and maintenance activities were compiled through a coordinated effort with other Phase I NPDES MS4 jurisdictions through the Oregon Association of Clean Water Agencies (ACWA). Unit costs based on recent bid tab information for projects within the cities of Portland, Gresham and Fairview were compiled and compared. The City reviewed results of the collective effort and selected appropriate unit costs for use in this analysis. As filtration rain gardens are the structural BMP simulated under Scenario 2, unit cost information specific for filtration rain gardens is presented.

Table 3-2 provides unit costs used in the calculation of the construction and maintenance of BMPs included in Scenario 2. Unit costs do not reflect property acquisition.

Table 3-2. Preliminary Engineering Unit Cost

Item	Unit	Unit cost ($)	Details
Water quality facility installation			
Stormwater planter/rain garden[a]	ft^2	37	Includes walls, inlet and outlet, overflow, underdrain, and plantings
12-inch storm drain pipe, 5- to 10-foot depth	ft	80	Includes excavation, backfill, and asphalt restoration
Markups (as a percentage of the facility subtotal)			
Mobilization/demobilization	LS	10%	Average value, used by Eugene for conceptual level estimate
Erosion control	LS	2%	Average value
Traffic control	LS	2%	Average value
Contingency	LS	30%	Average value
Administration (as a percentage of the facility and markup subtotal)			
Engineering/permitting	27	20%	Average value
Maintenance (annual)			
Rain garden maintenance	ft^2	$1.55	As reported by City of Portland, reflects direct costs (e.g., materials) and indirect costs (i.e., time for inspections, enforcement, etc.)

a. Unit cost is estimated for filtration or infiltration planters. Does not include additional infrastructure (manholes, catch basins, etc.) or connection to existing structures.

3.2.2 Facility Sizing

In order to estimate costs for construction and maintenance of BMP implementation associated with achieving the WLA under Scenario 2, an estimate of the total size (surface area) of filtration rain gardens needed to treat the corresponding drainage area was made.

The equivalent filtration rain garden size was calculated based on the total pollutant-generating area untreated in each applicable TMDL watershed and the associated percent impervious area by land use. The total pollutant-generating area untreated is listed in Tables 3-3, 3-4, and 3-5 by TMDL watershed.

Tables 3-3, 3-4, and 3-5 list the total TMDL watershed area by land use, existing treated area by land use, and assumed additional treatment area reflected in Scenario 2 by land use. Using the calculated impervious area to be treated per Scenario 2, the equivalent filtration rain garden facility size was assumed to be 7.2 percent of the contributing impervious area. This 7.2 percent sizing factor was calculated using the City's Stormwater Surface Filtration/ Infiltration Facility Sizing Spreadsheet, assuming filtration planters would be installed (with walls) and a soil infiltration rate of 0.5" per hour (Eugene Stormwater Management Manual, Appendix C, 2014). With detailed design, the required facility sizes would obviously deviate depending on site-specific conditions. Please note that in Tables 3-3, 3-4, and 3-5, because Scenario 2 does not assume BMP coverage over open space land use, the total BMP coverage (as a %) does not add up to 100 percent.

Using the 7.2 percent sizing factor, approximately 354.7 acres (or 15,449,512 square feet [ft^2]) of filtration rain garden would hypothetically need to be installed in the Upper Willamette watershed. Approximately 14.0 acres (or 610,955 ft^2) of filtration rain garden would need to be installed in the McKenzie watershed, and approximately 321.8 acres (or 14,018,723 ft^2) of filtration rain garden would need to be installed in the Amazon Diversion/ Fern Ridge watershed.

Table 3-3. Scenario 2: Treatment Area Summary (Upper Willamette)

Land use classification	Modeled impervious percentage (%)	Upper Willamette TMDL Watershed			
		Total modeled area (ac)	Existing treated area (ac)	Existing untreated area requiring treatment per Scenario 2 (ac)	Impervious area requiring treatment per Scenario 2 (ac)[a]
Single-family Residential (SFR)	44	6,755.5	538.1	6,217.4	**2,735.7**
Multi-family Residential (MFR)	59	885.4	148.7	736.6	**434.6**
Commercial (COM)	71	2,587.0	424.5	2,162.5	**1,535.4**
Industrial (IND)	61	385.3	60.6	324.7	**198.1**
Vacant (VAC)	2	1,186.6	76.7	1,109.9	**22.2**
Parks and Open Space (POS)[b]	18	1,976.1	73.4	0.0	**0.0**
Total (acreage)		13,775.9	1,322.2	10,551.1	**4,926.0**
Total (% total modeled area)		100%	9.6%	76.6%	

a. *The impervious area requiring treatment is calculated as the product of the existing untreated area requiring treatment per Scenario 2 and the modeled impervious percentage.*

b. *Parks and open space land use are not considered pollutant-generating and treatment of parks and open space property was not considered in Scenario 2.*

Table 3-4. Scenario 2: Treatment Area Summary (McKenzie)

Land use classification	Modeled impervious percentage (%)	McKenzie Watershed			
		Total modeled area (ac)	Existing treated area (ac)	Existing untreated area requiring treatment per Scenario 2 (ac)	Impervious area requiring treatment per Scenario 2 (ac)[a]
Single-family Residential (SFR)	44	203.2	17.4	185.8	**81.8**
Multi-family Residential (MFR)	59	22.9	0.7	22.2	**13.1**
Commercial (COM)	71	139.1	2.9	136.3	**96.8**
Industrial (IND)	61	0.1	0.0	0.1	**0.1**
Vacant (VAC)	2	153.5	3.3	150.2	**3.0**
Parks and Open Space (POS)[b]	18	4.0	0.0	0.0	**0.0**
Total (acreage)		522.7	24.3	494.6	**194.8**
Total (% total modeled area)		100%	4.6%	94.6%	

a. *The impervious area requiring treatment is calculated as the product of the existing untreated area requiring treatment per Scenario 2 and the modeled impervious percentage.*

b. *Parks and open space land use are not considered pollutant-generating and treatment of parks and open space property was not considered in Scenario 2.*

Table 3-5. Scenario 2: Treatment Area Summary (Amazon Diversion/Fern Ridge)

Land use classification	Modeled impervious percentage (%)	Amazon Diversion/Fern Ridge Tributary Watershed			
		Total modeled area (ac)	Existing treated area (ac)	Existing untreated area requiring treatment per Scenario 2 (ac)	Impervious area requiring treatment per Scenario 2 (ac)[a]
Single-family Residential (SFR)	44	5,456.3	121.8	5,334.5	**2,347.2**
Multi-family Residential (MFR)	59	576.3	7.9	568.4	**335.4**
Commercial (COM)	71	1,870.8	52.3	1,818.5	**1,291.1**
Industrial (IND)	61	769.3	12.9	756.4	**461.4**
Vacant (VAC)	2	1,801.1	66.3	1,734.8	**34.7**
Parks and Open Space (POS)[b]	18	2,454.3	36.9	0.0	**0.0**
Total (acreage)		12,928.2	298.1	10,212.6	**4,469.8**
Total (% total modeled area)		100%	2.3%	79.0%	

a. The impervious area requiring treatment is calculated as the product of the existing untreated area requiring treatment per Scenario 2 and the modeled impervious percentage.

b. Parks and open space land use are not considered pollutant-generating and treatment of parks and open space property was not considered in Scenario 2.

3.2.3 Results

Based on the required size of the filtration rain garden to be installed, the construction and maintenance cost estimates for the Upper Willamette TMDL watershed, the McKenzie TMDL watershed, and the Amazon Diversion/Fern Ridge TMDL watershed are provided in Tables 3-6, 3-7 and 3-8, respectively.

It is assumed that piped connections will be required between individual rain garden facilities and the main storm lines. For purposes of this cost estimate, 50 feet of 12-inch-diameter storm pipe was included for every 2,000 ft^2 of infiltration rain garden. Construction markups are applied to the construction subtotal; the administration cost, which accounts for engineering and permitting, was applied as a percentage markup to the total construction cost.

Cost calculations do not account for inflation or property acquisition. Subtotal and total costs were rounded to the nearest $1,000. The total construction and annual maintenance costs are indicated in bold.

Table 3-6. Preliminary Engineering Cost Estimate: Upper Willamette Watershed

Item	Unit	Unit cost ($)	Quantity	Itemized cost ($)
Water quality facility installation				
Stormwater planter/raingarden[a]	ft^2	37	15,449,512	$571,631,944
12-inch storm drain pipe, 5- to 10-foot depth	ft	80	386,238	$30,899,040
Construction facility subtotal				*$602,531,000*
Construction markups (as a % of the construction facility subtotal)				
Mobilization/demobilization	LS	10%	NA	$60,253,100
Erosion control	LS	2%	NA	$12,050,620
Traffic control	LS	2%	NA	$12,050,620
Contingency	LS	30%	NA	$180,759,300
Construction subtotal (includes construction facility cost and markups)				*$867,645,000*
Administration (as a % of the facility and markup subtotal)				
Engineering/permitting	LS	20%	NA	$173,529,000
Total estimated cost (includes construction and administration)				**$1,041,174,000**
Maintenance (annual)				
Rain garden maintenance	ft^2	$1.55	7,423,365	**$23,947,000**

Table 3-7. Preliminary Engineering Cost Estimate: McKenzie Watershed				
Item	Unit	Unit cost ($)	Quantity	Itemized cost ($)
Water quality facility installation				
Stormwater planter/rain garden[a]	ft^2	37	610,955	$22,605,335
12-inch storm drain pipe, 5- to 10-foot depth	ft	80	15,274	$1,221,920
Construction facility subtotal				*$23,827,000*
Construction markups (as a % of the construction facility subtotal)				
Mobilization/demobilization	LS	10%	NA	$2,382,700
Erosion control	LS	2%	NA	$476,540
Traffic control	LS	2%	NA	$476,540
Contingency	LS	30%	NA	$7,148,100
Construction subtotal (includes construction facility cost and markups)				*$34,311,000*
Administration (as a % of the facility and markup subtotal)				
Engineering/permitting	LS	20%	NA	$6,862,200
Total estimated cost (includes construction and administration)				**$41,173,000**
Maintenance (annual)				
Rain garden maintenance	ft^2	$1.55	7,423,365	**$947,000**

Table 3-8. Preliminary Engineering Cost Estimate: Amazon Diversion/Fern Ridge Watershed				
Item	Unit	Unit cost ($)	Quantity	Itemized cost ($)
Water quality facility installation				
Stormwater planter/raingarden[a]	ft^2	37	610,955	$518,692,751
12-inch storm drain pipe, 5- to 10-foot depth	ft	80	15,274	$28,037,440
Construction facility subtotal				*$546,730,000*
Construction markups (as a % of the construction facility subtotal)				
Mobilization/demobilization	LS	10%	NA	$54,673,000
Erosion control	LS	2%	NA	$10,934,600
Traffic control	LS	2%	NA	$10,934,600
Contingency	LS	30%	NA	$164,019,000
Construction subtotal (includes construction facility cost and markups)				*$787,291,000*
Administration (as a % of the facility and markup subtotal)				
Engineering/permitting	LS	20%	NA	$157,458,200
Total estimated cost (includes construction and administration)				**$944,749,000**
Maintenance (annual)				
Rain garden maintenance	ft^2	$1.55	7,423,365	**$21,729,000**

Section 4

Discussion and Conclusions

Results from the WLAAA indicate that for four out of five TMDL watersheds in the city of Eugene, WLAs could hypothetically be achieved with the implementation of highly effective structural BMPs (filtration rain gardens) to treat all pollutant-generating area not currently treated by structural BMPs. For one of the five TMDL watersheds, which has a higher percent reduction WLA than the other watersheds, the WLA cannot be achieved for the scenarios evaluated. The hypothetical implementation scenario (Scenario 2) requires the installation of approximately 30 million ft^2 of filtration rain gardens throughout the City limits, resulting in collective treatment of approximately 85 percent of the total modeled City area.

The implementation of such a hypothetical scenario is limited by practicability and fiscal constraints. In addition, site constraints limit the use of a more effective structural BMP (infiltration raingardens), as necessary to achieve the turbidity WLA in the Fern Ridge Reservoir TMDL watershed per modeling results presented in Section 3.

Section 4.1 outlines constraints and limitations associated with implementation of filtration and infiltration rain gardens at the scale and coverage estimated to meet the WLAAA. Section 4.2 summarizes the City's current strategies towards future TMDL pollutant removal in conjunction with conclusions drawn from this evaluation.

4.1 Constraints and Limitations

Scenario 2 assumes the hypothetical implementation of filtration rain gardens throughout the Upper Willamette, McKenzie River, and Amazon Diversion/Fern Ridge Reservoir TMDL watersheds, to treat all existing untreated land. Coverage excludes area designated as open space but would include all other land use including vacant lands, essentially treating the entire Eugene NPDES MS4 permit coverage area.

4.1.1 Practicability Constraints

Application of filtration rain gardens to the extent assumed under Scenario 2 would require installation of approximately 30 million square feet (or 700 acres) of facilities throughout the City. Property ownership is a major implementation constraint. Collectively, filtration rain gardens proposed under Scenario 2 would need to treat both public and private property, and as such, facilities would need to be installed on both public and private property. If installation is required on private property, the City would need to obtain rights to the property either through the purchase of the property or via easements. The cost estimates in Section 3.2 do not reflect the cost of property acquisition or easements.

Installation of facilities covering that much area is also infeasible due to the fact that the majority of land area is already developed. Developed property, if redeveloped, will be required to treat stormwater runoff in conjunction with the City's Stormwater Management Manual. The pace of redevelopment, however, will naturally limit the extent to which retrofits are installed to treat existing, untreated area in the City as a whole. The City's land use code recognizes the rights and needs for a property owner to develop a site to its full potential based on its designated land use and zoning. In some cases, this could be seen as a "constraint" to implementing lined planters/filtration raingardens for all redevelopment activities.

The City's Envision Eugene process, currently underway, identifies targeted areas for infill/re-development and densification. Development of these areas to incorporate infiltration or filtration may not be feasible given multiple community objectives including limiting expansion of the urban growth boundary while accommodating predicted population growth.

4.1.2 Fiscal Constraints

Per Section 3.2.3, installation of filtration rain gardens at the scope and scale required under Scenario 2 would result in an estimated construction cost of $2 billion and an annual maintenance cost of approximately $45 million.

The City's adopted Fiscal Year 2014-2019 Capital Improvement Program (CIP) describes the stormwater capital projects to be implemented over a 6 year period from July 1, 2014 through June 30, 2019. Stormwater capital projects include stream restoration, flood control, and water quality capital improvement projects as identified in the City's long-term Stormwater Basin Master Plans. In addition to the long-term Stormwater Basin Maser Plan projects, the CIP includes additional water quality improvement projects often opportunistically conducted in conjunction with other programs and initiatives. Such programs and initiatives include the pavement preservation program, the drywell elimination program, maintenance programs to alleviate localized flooding, and Metro-area stream restoration partnership efforts. Collectively, the stormwater capital projects in the FY 2014-2019 CIP comprise an annual budget of $2.5 million and a total budget of $14.8 million.

Assuming, hypothetically, that all allocated funds for stormwater capital projects could be dedicated to installation of filtration rain gardens in accordance with results of this analysis, and that no other types of stormwater projects were constructed, it would take more than 100 years to complete only about 15 percent of the scope and scale of filtration rain garden installations. Given that current efforts and practices are consistent with the City's definition of MEP, as outlined in its NPDES MS4 permit renewal application (2008), such fiscal obligation goes well beyond the definition of MEP and is impractical.

Not directly reflected in the CIP budget are the staff resources (time and materials) to aid in project management and administration, which would also result in significant additional costs.

4.1.3 Physical Site Constraints

As described in Section 2.3, filtration raingardens were used in the WLAAA model scenarios because the City's stormwater design standards encourage the use of vegetated stormwater facilities and low impact development technologies, and filtration raingardens are becoming increasingly utilized. Filtration raingardens were also assumed because a majority of City area is not amenable to the use of infiltration raingardens. The City does not currently have any infiltration raingardens in its BMP inventory used for the pollutant load modeling effort. Filtration raingardens are a more representative BMP in consideration of the City's site constraints.

Infiltration raingardens (in conjunction with current pollutant load modeling methods) are highly effective stormwater treatment BMPs from a pollutant loading perspective, and use of infiltration raingardens (as shown under Scenario 3) would potentially result in meeting the turbidity WLA for the Fern Ridge TMDL watershed. However, their application is limited by the following site characteristics, which are referenced in the Eugene Code Section 9.6792(3) and in Section 2.2.3 of the Eugene Stormwater Management Manual as criteria justifying the use of filtration instead of infiltration:

- Infiltration rates less than 2 inches per hour (typically depicted by soil type C and D).
- Bedrock less than 5 feet below the ground surface
- Groundwater elevations less than 6 feet below ground surface

- Ground surface slopes greater than 10 percent

To illustrate the limitations on the use of infiltration facilities in the City, a desktop evaluation of soil and slope constraints was conducted in GIS for the Upper Willamette, McKenzie, and Amazon Diversion/Fern Ridge TMDL watersheds to estimate the proportion of each watershed where infiltration facilities for treatment would be limited. Table 4-1 summarizes geological, slope and soil constraint areas in acres and as a percentage of the total watershed area.

Table 4-1. Constraint Area Evaluation

TMDL watershed	Total area (ac)	Constraint areas (ac)					
		Slopes (> 10%)	Depth to Bedrock (> 5 ft)	Depth to groundwater (< 6 ft)	Soils (Type C and D)	Total (ac)[a]	Total (% watershed area)
Upper Willamette	14,377	2,043	1,332	5,004	9,739	10,236	71
McKenzie	523	27	---	319	475	478	91
Amazon Diversion/ Fern Ridge	13,002	4,253	7,058	10,223	12,959	12,961	99

a. *Due to overlapping constraint areas, the total constraint area is reflective of the total constraints and not the sum of the soil and slope constraint area.*

As shown in Table 4-1, a majority of the watershed areas are not likely to be suitable for the installation of infiltration rain gardens in accordance with current stormwater design standards.

4.2 Conclusions and Next Steps

Results from this WLAAA indicate that WLAs may be hypothetically achievable, however the financial implications of the hypothetical scenario is considerably beyond the City's current definition of MEP, and the practical implementation issues of ownership, site constraints, physical constraints, and competing priorities with infill/redevelopment are considerable.

Through the pollutant load reduction evaluation and WLAAA planning efforts, the City has confirmed that (as indicated by current pollutant load modeling results), filtration planters are an effective secondary treatment option (as compared to strictly infiltration-based facilities) for addressing bacteria, total phosphorus, BOD, and TSS pollutant loads in stormwater runoff.

The City aims to continue to promote the use of infiltration based treatment processes (where possible) and filtration based treatment processes in future BMP implementation efforts. The City recently (January 2014) revised their stormwater design standards to incorporate a hierarchical process for BMP selection. The updated design standards guide developers and engineers in designing green infrastructure (GI), including filtration and infiltration-based stormwater treatment facilities. The standards include criteria related to the use of infiltration versus filtration-based facilities. The standards also incorporate sizing tools to aid in facility design. With the implementation of revised stormwater design standards, the structural BMP coverage will be expanded throughout the city through increased applications of GI.

The City's current Stormwater Retrofit Plan (dated December 1, 2014) further reinforces the goals of expanded structural BMP coverage. The City's Stormwater Retrofit Plan outlines strategies to:

- Continue policies, stormwater planning, and capital projects to aid in water quality improvement.
- Update existing Stormwater Basin Master Plans and long-term capital project lists in accordance with projected growth and infill priorities.

- Focus stormwater retrofit capital project efforts on developed, high pollutant source areas, and identifying strategic and opportunistic projects (per the pavement preservation program, drywell elimination program, etc.).
- Continue partnerships with local agencies to collaborate and reduce water quality impacts.
- Seek opportunities to utilize capital projects and volunteer efforts to educate the public about water quality issues and demonstrate the functionality and aesthetic appeal of BMPs.

Implementation of retrofit strategies will increase the coverage of structural BMP implementation citywide while offsetting existing stormwater pollutant loads.

Even with increasing BMP coverage and applying effective BMP treatment processes, the City recognizes that current TMDL language and TMDL development methods may simply result in unachievable pollutant loads for MS4s, and as such, it may be necessary to revisit the TMDL calculations and assumptions. Through the pollutant load reduction evaluation and WLAAA development, detailed review of the TMDLs was conducted, and it was observed that the TMDLs are often developed independent of a clear designation of pollutant sources, site-specific monitoring data, and pollutant removal capacity based on current technology. These assumptions have clear implications for MS4 source areas that must continually evaluate pollutant load reduction and progress toward WLAs.

Section 5

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Supplement to
Stormwater Annual Report
Permit Year 2014

3. 303(d) Evaluation
(MS4 Permit Schedule D.2.a.)

City of Eugene

303(d) Evaluation

MS4 Permit Requirement Schedule D.2.a

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I. Introduction

This document represents an evaluation of 303(d)-listed pollutants as they relate to discharges from the City of Eugene's municipal stormwater system which is regulated under the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System permit (MS4 permit). This report includes an evaluation of the likelihood that discharges from the MS4 cause or contribute to water quality degradation as related to specific 303(d) parameters, an assessment of the effectiveness of the City's existing stormwater practices in addressing and reducing applicable 303(d)-listed parameters, and an identification of potential stormwater management program revisions that may be considered to address and reduce the 303(d) pollutants to the maximum extent practicable.

II. Summary of Permit Requirements

In accordance with Schedule D.2.a. of the MS4 permit, the City must:

i. *Review the applicable pollutants that are on the 2004/2006 303(d) list, or the most recent USEPA list if approved within three years of the issuance date of this permit, that are relevant to the permittee's MS4 discharges by December 1, 2014. Based on a review of the most current 303(d) list, evaluate whether there is a reasonable likelihood for stormwater from the MS4 to cause or contribute to water quality degradation of receiving waters.*

ii. *Evaluate whether the BMPs in the existing SWMP are effective in addressing and reducing the 303(d) pollutants. If the permittee determines that the BMPs in the existing SWMP are ineffective in addressing and reducing the applicable 303(d) pollutants, the permittee must describe how the SWMP will be modified or updated to address and reduce these pollutants to the MEP.*

iii. *Submit a report summarizing the results of the review and evaluation, and identifies any modifications or updates to the SWMP that are necessary to reduce applicable 303(d) pollutants to the MEP by December 1, 2014.*

III. Background

Section 303(d) of the federal Clean Water Act requires development of a list of water bodies that do not meet certain water quality standards based upon their beneficial use. In the state of Oregon, the Department of Environmental Quality (DEQ) has the responsibility for designating beneficial uses for water bodies, establishing water quality standards that protect the beneficial uses, and developing the "303(d) list." Oregon's water quality standards for surface waters are described in the Oregon Administrative Rules (OAR) Section 340, Division 41. Examples of beneficial uses include drinking water, fisheries, water supply, recreation and agricultural uses. The 303(d) listing initiates a Total Maximum Daily Load, or TMDL, process, which is a comprehensive assessment of each listed pollutant with the objective of defining how much the pollutant must be reduced in order to meet water quality criteria, and allocating pollutant loadings among sources.

IV. Prior City of Eugene 303(d) Evaluations

The City of Eugene submitted a 303(d) evaluation with its Interim Evaluation Report submittal (December 2005 Stormwater Annual Report), and with its most recent permit renewal submittal (December 2008). This report is essentially an update to the earlier evaluations, incorporating the updated listings and the City's current SWMP.

V. Applicable 303(d) List

For its 303(d) evaluation, the City of Eugene must utilize the 2004/2006 303(d) list unless there is a more up to date list that has been approved by EPA within 3 years of the issuance date of the permit. DEQ's 2010 303(d) list was approved by EPA in December 2012, which is within 3 years of the December 2010 issuance of the current MS4 permit. Therefore, the City has used the 2010 303(d) list for this evaluation.

Eugene's water bodies on Oregon's 2010 303(d) list are shown in Table 1. The list is cumulative which means that previous listings are included with each update. It is possible for pollutants to be "de-listed" if water quality data show that the water body is in compliance with state water quality standards.

Some of the listings are addressed by the 2006 Willamette Basin TMDLs (as noted in the table), and in the case of dioxin, by the 1991 Columbia and Willamette River TMDLs.

VI. Stormwater Management Plan

The City of Eugene's current (December 2012) SWMP includes 24 best management practices (BMPs) designed to reduce the discharge of stormwater pollutants to the maximum extent practicable. Reducing pollutants from the MS4 to receiving water bodies to the maximum extent practicable is the overarching requirement of the City's MS4 permit. This 303(d) evaluation references several of the BMPs. More detailed information about each BMP is included in the SWMP itself and in Eugene's Stormwater Annual Reports.

Each BMP is given a code (for example, A1) for tracking and reporting purposes; the coding is based on the division within the Public Works Department or Planning & Development Department, that has lead responsibility, as follows:

A = Administration Division of Public Works
B = Building Division of Planning and Development
E = Engineering Division of Public Works
M = Maintenance Division of Public Works
P = Parks and Open Space Division of Public Works
W = Wastewater Division of Public Works

The 24 BMPs fall into eight general categories: Public Education; Operations and Maintenance; Illicit Discharge Controls; Waste Management; Construction and Design New Development; Planning, Capital Improvements, and Data Management; Industrial Controls; and Permit Management. The grouping of BMPs and a general description of each category are described below.

Public Education

A1 Stormwater Education
P1 Educational Volunteer Program

Operations and Maintenance

M3 Street Sweeping Program and Leaf Pick-up
M4 Prevent Leaks and Spills from Municipal Vehicles and Equipment
M5 Public Stormwater System Cleaning Program – Piped System
M8 Winter Road Sanding and De-Icing Program
P3 Tree Planting and Information Programs
P4 Public Stormwater System Maintenance – Developed Parks and Rights-of-Way
P5 Public Stormwater System Maintenance – Open Waterways

Illicit Discharge Controls

M1 Management of Illicit Discharges to the Municipal Stormwater System
M2 Spill Response
M7 Systematic Stormwater Field Screening and Investigation
P7 Litter and Illegal Dumping Control

Waste Management

B1 Household Hazardous Waste Disposal
B2 Solid Waste Management

Construction and New Development

E2 Erosion Prevention and Construction Site Management Program
E4 Stormwater Development Standards
P6 Compliance Program for Maintenance of Privately Owned Vegetated Stormwater Facilities
M6 Regulation of Inspection, Maintenance and Reporting of Private Underground Stormwater Structures

Planning, Capital Improvements and Data Management

E1 Stormwater Capital Improvement Projects
E3 Stormwater System Mapping and Data Management
P2 Bacteria Pilot Study

Industrial Controls

W1 Industrial Stormwater Management Program

Permit Management

E5 Permit Management and Reporting

Table 1. 2010 303(d) Listed Water Bodies & Parameters

Water Body	Parameter	Assessment Year	Status***
A3 Channel	Arsenic	1998	303(d)
	Dichloroethylene	1998	303(d)
	Tetrachloroethylene	1998	303(d)
	pH	2004	Category 5
	Dissolved Oxygen	2010*	Category 4A
	E. coli	2010*	Category 4A
	Mercury	2010	Category 5
Amazon Creek	Arsenic	2002	303(d)
	Lead	2002	303(d)
	Copper	2004	Category 5
	Dichloroethylene	2004	Category 5
	Tetrachloroethylene	2004	Category 5
	Trichloroethylene	2004	Category 5
	Dissolved Oxygen	2010	Category 5
	E. coli	2010*	Category 4A
Amazon Diversion Canal	Arsenic	2004	Category 5
	Copper	2004	Category 5
	Lead	2004	Category 5
	E. coli	2010*	Category 4A
	Dissolved Oxygen	2010*	Category 4A
	Mercury	2010	Category 5
Willow Creek	Arsenic	2002	303(d)
Fern Ridge Reservoir	*E. coli*	2010*	Category 4A
	Turbidity	2010*	Category 4A
A2 Channel / Golden Gardens	Aquatic Weeds or Algae	2010	Category 5
Willamette River	Dioxin	1998**	Category 4A
	Arsenic	2002	303(d)
	Dissolved Oxygen	2004	Category 5
	E. coli	2010*	Category 4A
	Iron	2004	Category 5
	Manganese	2004	Category 5
	Mercury	2010	Category 4A
	Temperature	2010*	Category 4A

*Addressed by Willamette Basin TMDL, September 2006

**Addressed by Columbia & Willamette Rivers TMDL, February 1991.

*** Category 4A = Water quality limited, TMDL approved; Category 5 = Water quality limited, 303(d) list, TMDL needed.

VII. 303(d) Evaluation and Summary

The following Tables 2 through 12 represent the results of the City's 303(d) evaluation. The tables are organized by pollutant and include a determination as to whether there is a likelihood that stormwater from Eugene's MS4 is a contributor of the pollutant, a listing of common sources of the pollutant, a list of specific control measures that address the 303(d) pollutant, and identification of any modifications or updates to the SWMP necessary to reduce pollutants to the maximum extent practicable.

In addition to the specific control measures identified, additional reductions in some 303(d)-listed pollutants may be realized by the State of Oregon's efforts to address legacy contributions. The state's Environmental Cleanup Site Information database (168 sites listed as of 8/4/14) lists all sites having known or potential contamination from hazardous substances; of those listed 94 sites in Eugene have confirmed or suspected pollutant releases in various stages of cleanup or remediation. The state's environmental cleanup-site information database includes cases whereby surface or subsurface confirmed or suspected pollutant releases occurred prior to implementation of hazardous substances regulatory controls. Investigation of many of these cases by state authorities is ongoing and in the long term should result in site remediation. In the case of orphaned properties whereby principal parties cannot be identified or are unwilling or unable to perform site cleanup, the state will initiate cleanup measures to protect human health and the environment.

The City's MS4 control measures, including those listed in the tables as addressing 303(d) pollutants are proving to be effective. Additional measures implemented outside of the MS4 permit program, such as waterway protections for 303(d) listed streams and those that directly drain to them, is also helping to protect water quality. As described in detail in the 2014 Stormwater Annual Report, the long-term water quality trends show decreasing concentrations over time for several pollutants at specific in-stream monitoring locations, including lead, mercury, arsenic, and turbidity. The City attributes the decreasing concentrations to the sum of the stormwater program BMPs applied to control stormwater pollutants.

No revisions to the SWMP are proposed at this time as a result of the 303(d) evaluation. The City will consider adding iron, and potentially manganese, to the parameters included in the updated Stormwater Monitoring Plan to be submitted as part of the MS4 permit renewal application package in mid-2015.

Table 2. 303(d) Evaluation for Arsenic

Pollutant	Arsenic
Receiving Waters (2010 303(d)-listed)	• A3 Channel • Amazon Creek • Amazon Diversion Canal • Willow Creek • Willamette River
Does Eugene's Stormwater Contribute to this Pollutant?	Appears yes: Intra-basin statistical analysis of arsenic concentrations for ambient monitoring locations indicates downstream concentrations tend to be higher than upstream concentrations. Storm-event data for total arsenic shows periodic exceedance of the human health criterion.
Common Sources/Uses	• Arsenic is naturally occurring in soil and water in the southern Willamette Basin. • The principal source of arsenic in the MS4 is likely from stormwater overland flow and erosion of disturbed soils. Sediments containing arsenic may also be remobilized through re-suspension. • Off-site vehicle tracking of construction soil onto paved surfaces. • Stormwater mobilization of airborne particulate deposited onto impermeable surfaces. • Arsenic is found in pesticides, weed killers, and wood preservatives; Improper use and disposal of rodenticides • Arsenic is used for hardening copper, lead and other alloys. • Legacy site activities – Surface and subsurface arsenic contamination is potentially mobilized and transported in stormwater via overland flow or subsurface interaction with groundwater. The A-3 Channel traverses industrial land use areas with confirmed or suspected hazardous substance releases.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils and associated naturally occurring trace metals such as arsenic out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterway maintenance (BMPs M3, M5, and P5) which are expected to be effective in preventing soil and road-related particulate that may contain arsenic from entering the MS4 system. 3. Implement multiple-objective capital improvement projects including stream restoration, system rehabilitation, and water quality retrofit projects identified in the adopted six-year capital improvement program (BMP E1). 4. Administer the stormwater development standards program including headwater flow controls, source controls and water quality controls that emphasize low impact development (LID) techniques. Ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 5. Include information in educational materials about proper use of pesticides and promote alternatives to pesticides through information and demonstration (A1, P1). 6. Continue to evaluate monitoring information to identify potential arsenic sources, to better understand the relationship between arsenic and stormwater, and to evaluate through the City's adaptive management process the need for any potential SWMP revisions to further address arsenic.

Pollutant	Arsenic
SWMP Modifications or Updates Necessary?	None.

Table 3. 303(d) Evaluation for Copper

Pollutant	Copper
Receiving Waters (2010 303(d)-listed)	• Amazon Creek • Amazon Diversion Canal
Does Eugene's Stormwater Contribute to this Pollutant?	Appears yes: Intra-basin statistical analysis of copper concentrations for ambient monitoring locations indicates downstream concentrations tend to be higher than upstream concentrations. Storm-event data for total and dissolved copper shows frequent exceedance of both the acute and chronic criteria.
Common Sources/Uses	• Copper is naturally occurring in soil and water in the southern Willamette Basin. • The principal source of copper in the MS4 is likely from stormwater overland flow and erosion of disturbed soils. Sediments containing copper may also be remobilized through re-suspension. • Off-site vehicle tracking of construction soil onto paved surfaces. • Stormwater mobilization of airborne particulate deposited onto impermeable surfaces. • Copper is found in pesticides such as mildewcides, fungicides and insecticides. • Copper is used metal fabrication, electrical equipment, automobile brake pads. • Roof cladding and rain gutters are also potential sources of copper.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils and associated naturally occurring trace metals such as copper out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterways maintenance (BMPs M3, M5, and P5) which are expected to be effective in preventing road particulate that may contain copper from entering the MS4 system. 3. Implement multiple-objective capital improvement projects including stream restoration, system rehabilitation, and water quality retrofits identified in the adopted six-year capital improvement program (BMP E1). 4. Administer the stormwater development standards program including headwater flow controls, source controls and water quality controls that emphasize LID techniques. Ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 5. Include information in educational materials about proper use of pesticides and promote alternatives to pesticides through information and demonstration (A1, P1). 6. Continue to evaluate monitoring information to identify potential copper sources, to better understand the relationship between copper and stormwater, and to evaluate through the City's adaptive management process the need for any potential SWMP revisions to further address copper.
SWMP Modifications Necessary?	None at this time.

Table 4. 303(d) Evaluation for Iron

Pollutant	Iron
Receiving Waters (2010 303(d)-listed)	• Willamette River
Does Eugene's Stormwater Contribute to this Pollutant?	Unknown: The City of Eugene's NPDES Stormwater permit does not require monitoring for iron nor has the City performed monitoring for iron.
Common Sources/Uses	• Iron is naturally occurring in soil and water in the southern Willamette Basin. • The principal source of iron in the MS4 is likely from stormwater overland flow and erosion of disturbed soils. Sediments containing iron may also be remobilized through re-suspension. • Iron accumulates in the organic-rich soil horizon and in the deeper saturated zone where iron accumulates. Storm events mobilizes the iron in the organic-rich soil horizon; continued saturation of the soil horizon leads to riparian groundwater flow, mobilizing the iron accumulated in the deeper saturated zone. • Off-site vehicle tracking of construction soil onto paved surfaces. • Stormwater mobilization of airborne particulate deposited onto impermeable surfaces. • Brake drums and rotors, vehicle wear are potential sources of iron. • Cast pipes and manhole covers are also potential sources of iron in the MS4.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils and associated naturally occurring trace metals such as iron out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterways maintenance (BMPs M3, M5, and P5) which are expected to be effective in preventing road particulate that may contain iron from entering the MS4 system. 3. Implement multiple-objective capital improvement projects including stream restoration, system rehabilitation, and water quality retrofits identified in the adopted six-year capital improvement program (BMP E1). 4. Administer the stormwater development standards program including headwater flow controls, source controls and emphasis on LID techniques. Ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 5. Incorporate into Eugene's Stormwater Monitoring Plan storm-event sampling and analysis for iron to characterize MS4 runoff. Review monitoring information to identify potential iron sources, to better understand the relationship between iron and stormwater, and to evaluate through the City's adaptive management process the need for any potential SWMP revisions to further address iron.
SWMP Modifications Necessary?	None at this time.

Table 5. 303(d) Evaluation for Lead

Pollutant	Lead
Receiving Waters (2010 303(d)-listed)	• Amazon Creek • Amazon Diversion Canal
Does Eugene's Stormwater Contribute to this Pollutant?	Appears yes. Intra-basin statistical analysis of lead concentrations for ambient monitoring locations indicates downstream concentrations tend to be higher than upstream concentrations. Storm-event data for total lead shows frequent exceedance of the chronic criterion and periodic exceedance of the acute criterion.
Common Sources/Uses (Where do we think the pollutant is derived from; causation?)	• Automobiles - Tire weights fallen from vehicle tires and subsequently ground to dust on roadways are the primary source of particulate lead in stormwater (EPA); lead-acid batteries. • Trace quantities of lead are naturally occurring in soil and water, aside from vehicle tire weights additional sources of lead in the MS4 are likely from stormwater overland flow and erosion of disturbed soils. • Road dust and debris from vehicle wear and accidents • Dumping of motor oil in storm drain system • Runoff from auto and radiator repair shops • Lead shot and bullets; fishing sinkers and jigs • Railroad train brake pads • Erosion of paint from structures (legacy source) • PVC products; lead compounds in plastic resins; • Legacy site activities – Surface and subsurface lead contamination is potentially mobilized and transported in stormwater via overland flow or subsurface interaction with groundwater. Amazon Creek traverses industrial land use areas with confirmed or suspected hazardous substance releases.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils and associated naturally occurring trace metals such as lead out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping and system cleaning (BMPs M3 and M5) which are effective means of removing particulate-associated lead from road surfaces and preventing road-related particulate that may contain lead from entering the MS4 system. 3. Support Lane County's Household Hazardous Waste & Solid Waste and Recycling programs (BMP B1, B2), to ensure proper disposal of materials which may contain lead. 4. Support existing systematic field investigation program, illicit discharge and spill response programs (BMPs M1, M2, and M7) including proper disposal of waste material. 5. Include information in educational materials about the sources of lead in stormwater and actions private landowners and business owners can take to eliminate lead from stormwater runoff (BMPs A1 and P1). 6. Continue to evaluate monitoring information to identify potential lead sources, to better understand the relationship

Pollutant	Lead
	between lead and stormwater, and to evaluate through the City's adaptive management process the need for any SWMP revisions to further address lead.
SWMP Modifications Necessary?	None at this time.

Table 6. 303(d) Evaluation for Manganese

Pollutant	Manganese
Receiving Waters (2010 303(d)-listed)	• Willamette River Note: Updates to Oregon's toxic substance criteria were approved by EPA in 2011. DEQ has proposed delisting the Willamette River for manganese; it is included here until the action is finalized.
Does Eugene's Stormwater Contribute to this Pollutant?	Unknown: The City of Eugene's NPDES Stormwater permit does not require monitoring for manganese nor has the City performed monitoring for manganese.
Common Sources/Uses	• Manganese is naturally occurring in soil and water in the southern Willamette Basin. • The principal source of manganese in the MS4 is likely from stormwater overland flow and erosion of disturbed soils. Sediments containing manganese may also be remobilized through re-suspension. • Manganese accumulates in the organic-rich soil horizon and in the deeper saturated zone where manganese accumulates. Storm events mobilizes the manganese in the organic-rich soil horizon; continued saturation of the soil horizon leads to riparian groundwater flow, mobilizing the manganese accumulated in the deeper saturated zone. • Off-site vehicle tracking of construction soil onto paved surfaces. • Stormwater mobilization of airborne particulate deposited onto impermeable surfaces. • Manganese is a component of steel, iron, and aluminum. • Manganese may be added to gasoline as an additive to reduce knock.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils and associated naturally occurring trace metals such as manganese out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterway maintenance (BMPs M3, M5, and P5) which are expected to be effective in preventing soil and road-related particulate that may contain manganese from entering the MS4 system. 3. Implement multiple-objective capital improvement projects including stream restoration, system rehabilitation, and water quality retrofits identified in the adopted six-year capital improvement program (BMP E1). 4. Administer the stormwater development standards program including headwater flow controls, source controls and water quality controls that emphasize low impact development (LID) techniques. Ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 5. Consider include in Eugene's Stormwater Monitoring Plan storm-event sampling and analysis for manganese to characterize MS4 runoff.
SWMP Modifications Necessary?	None at this time.

Table 7. 303(d) Evaluation for Mercury

Pollutant	Mercury
Receiving Waters (2010 303(d)-listed)	• A3 Channel • Amazon Diversion Canal • Willamette River
Does Eugene's Stormwater Contribute to this Pollutant?	Appears yes. Intra-basin statistical analysis of mercury concentrations for ambient monitoring locations indicates downstream concentrations tend to be higher than upstream concentrations. Storm-event data for total mercury shows frequent exceedance of the acute criterion for total mercury.
Common Sources/Uses	• Mercury is naturally occurring in soil and water within the southern Willamette Basin. • Household items containing mercury: thermometers; thermostats (non-electronic); fluorescent and other mercury vapor lighting (metal halide, high-pressure sodium and neon bulbs); automotive headlamps – (blue tint when lit); pilot light sensors (in some gas appliances: stoves, ovens, clothes dryers, water heaters, furnaces, space heaters); gauges (barometers, manometers, blood pressure and vacuum gauges); switches and relays (in some chest freezers, pre-1972 washing machines, sump and bilge pumps, electric space heaters, silent light switches, vehicles and farm equipment); clothes irons (automatic or tilt shut-offs); elemental mercury; vintage toys (toy drawing screens and mercury maze games); LA Gear® athletic shoes (made before 1997 with flashing lights in soles); batteries (mercuric oxide and some alkaline batteries); paint (latex manuf. pre 1990, some oil base-paints); Thimerosal or merbromin (in some antibacterial products). • A significant source of mercury in the MS4 is likely from stormwater overland flow and erosion of disturbed soils. Sediments containing mercury may also be remobilized through re-suspension. Wetlands are significant sources of methyl mercury. • Leaf litter • Off-site vehicle tracking of construction soil onto paved surfaces. • Stormwater mobilization of airborne particulate deposited onto impermeable surfaces. • Geothermal springs are significant sources of Hg in the Willamette Basin. • Mercury thermometers in use by the public and school systems • Automobile scrap yards • Trace quantities of mercury is found in pesticides and fertilizers. • Gold mining within the Willamette Basin • Legacy site activities – Historical surface and subsurface activities have the potential to mobilize mercury via overland flow of stormwater or through subsurface interaction with groundwater. The A3 Channel and Willamette River traverse industrial land use areas with confirmed or suspected hazardous substance releases.
Control Measures to Effectively Address this	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils and associated naturally occurring

Pollutant	Mercury
Pollutant (SWMP BMPs)	trace metals such as mercury out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterway maintenance (BMPs M3, M5, and P5) which are expected to be effective in preventing soil and road-related particulate that may contain mercury from entering the MS4 system. 3. Implement multiple-objective capital improvement projects including stream restoration, system rehabilitation, and water quality retrofits identified in the adopted six-year capital improvement program (BMP E1). 4. Support existing systematic field investigation program, illicit discharge and spill response programs (BMPs M1, M2, and M7) including proper disposal of waste material. 5. Administer the stormwater development standards program and ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 6. Support Lane County's existing Household Hazardous Waste program (BMP B1) to ensure proper disposal of household items that may contain mercury. 7. Support education and outreach related to the mercury problem, sources of mercury, and strategies for keeping the pollutant out of Eugene's waste stream and its waterways (BMP A1). Support local efforts to ensure proper disposal of dental waste including mercury. Continue to support thermometer exchange efforts, with Lane County and City of Springfield. 8. Continue to evaluate monitoring information to identify potential mercury sources, to better understand the relationship between mercury and stormwater, and to evaluate through the City's adaptive management process the need for any SWMP revisions to further address mercury.
SWMP Modifications Necessary?	None at this time.

Table 8. 303(d) Evaluation for Dissolved Oxygen

Pollutant	Dissolved Oxygen
Receiving Waters (2010 303(d)-listed)	• A3 Channel • Amazon Creek • Amazon Diversion Channel • Willamette River
Does Eugene's Stormwater Contribute to Depletion of DO?	Appears yes. Intra-basin statistical analysis of DO concentrations for ambient monitoring locations indicates downstream concentrations tend to be lower than upstream concentrations. Very likely temperature related as well.
Common Sources/Uses	• Loss of riparian vegetation. • Loss of channel complexity through widening, straightening and smoothing out of channel roughness for capacity. • Bacteria and an excess amount of biological oxygen demand (BOD) and chemical oxygen demand (COD) including inorganic and organic discharges, and anoxic discharges which all deplete DO. • Fertilizer runoff from lawns and gardens. Fertilizer meant for land plants will also promote aquatic plant growth. If the weather becomes cloudy for several days, respiring plants will use much of the DO while failing to photosynthesize. When the increased numbers of aquatic plants eventually die, they support increasing amounts of bacteria which use large amounts of DO. • Backwater conditions from Fern Ridge during certain times of the year may also be a contributing factor.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue implementing the tree planting program which has planted extensively along Amazon Creek; continue to identify and plant on available publicly owned streamside locations further up in the creek's tributaries (BMP P3). 2. Seek opportunities to improve channel complexity of Eugene's waterways through stream restoration and rehabilitation capital improvement projects (BMP E1). 3. Continue to implement the City's erosion control program (BMP E2) to keep sediment and associated oxygen-depleting materials out of the MS4 system. 4. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterway maintenance (BMPs M3, M5, and P5) to minimize oxygen-depleting materials entering the MS4 system. 5. Administer stormwater development standards program including headwater flow controls, source controls, and water quality controls that emphasize LID. Ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 6. Include information in educational brochures and newsletters about the causes of low dissolved oxygen in receiving waters, and the actions private landowners and businesses can take to improve DO (BMPs A1 and P1). 7. Continue to evaluate monitoring information to evaluate through the City's adaptive management process the need for any SWMP revisions to further address dissolved oxygen.
SWMP Modifications Necessary?	None at this time.

Table 9. 303(d) Evaluation for Bacteria

Pollutant	*Escherichia coli*
Receiving Waters (2010 303(d)-listed)	• A-3 Channel • Amazon Creek • Amazon Diversion Channel • Willamette River • Fern Ridge Reservoir
Does Eugene's Stormwater Contribute to this Pollutant?	Appears yes. Stormwater monitoring data indicates that bacteria (*E. coli*) counts are above the state water-quality criterion.
Common Sources/Uses	Common sources, potentially an issue for Eugene's MS4: • Bird waste; Wild animal waste (nutria, mice, squirrels…) • Domestic pet waste • Human activities; Homeless encampments • Sediment (Bacteria tend to associate with soil particles and settle out of the water, but can accumulate and concentrate in deposited sediments, presenting a threat to health and safety if the sediments are re-suspended.) Common sources, but not believed to be an issue for Eugene's MS4: • Wastewater discharges (e.g. failing septic systems; leaky pipes; sewer overflows) – existing programs, city code, and enforcement in place for these • Illegal dumping of sanitary waste (RVs, septic haulers) – existing programs at WPCF are well established and utilized. • Livestock waste – not an occurrence in Eugene city limits. Fairgrounds stormwater system has been upgraded to included diversions to sanitary wastewater system when necessary.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Conduct education and outreach related to the bacteria problem, likely sources of bacteria in Eugene's waterways emphasizing appropriate strategies for keeping the pollutant out of our waterways where the City and general public has some control, e.g. proper pet waste disposal (BMPs A1, P1). 2. Support existing systematic field investigation program, illicit discharge and spill response programs (BMPs M1, M2, and M7) including proper disposal of waste material. 3. Support existing system maintenance programs (BMPs M3, M5, P5) to remove sediment from the system including pollutants, such as bacteria, attached to the sediment. 4. Administer the stormwater development standards program and ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 5. Document bacteria pilot study efforts and consider next steps in advance of MS4 permit renewal submittal due mid-2015 (BMP P2).
SWMP Modifications Necessary?	None at this time.

Table 10. 303(d) Evaluation for DCE/TCE/PCE

Pollutants	Dichloroethylenes (DCE), Trichloroethylene (TCE) and Tetrachloroethylene (PCE)
Receiving Waters (2010 303(d)-listed)	• A-3 Channel (DCE & TCE) • Amazon Creek (DCE, TCE, & PCE)
Does Eugene's Stormwater Contribute to these Pollutants?	Appears yes: Storm-event data for TCE and PCE shows periodic exceedance of the human health criterion. Method reporting limits were recently improved to detect lower concentrations of these chlorinated compounds.
Common Sources/Uses	• Consumer products such as cleaners and solvents • Dry-cleaning • Automobile body and repair shops • Electrical/electronic manufacturing • Fleet, trucking, bus terminals, motor pools • Furniture repair and manufacturing • Hardware, lumber, and parts suppliers • Junk, scrap, and salvage yards • Landfills • Machine shops • Medical and veterinarian offices • Metal plating, finishing, and fabricating • Synthetic and plastics production • Rail yards, maintenance and fueling areas • Wood, pulp, and paper processing
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Support existing industrial stormwater program (BMP W1), screening new businesses for those that may require NPDES permits and providing oversight of stormwater discharges from industrial facilities. 2. Support existing systematic field screening and investigation, illicit discharge, and spill response programs (BMPs M1, M2, and M7). 3. Administer stormwater development standards, including source controls for high pollutant source land uses (BMP E4). 4. Support outreach and education to sector-specific businesses and appropriate stormwater BMPs (A1). 5. Continue to evaluate monitoring information to identify potential DCE/TCE/PCE sources and to evaluate through the City's adaptive management process the need for any potential SWMP revisions to further address DCE/TCE/PCE.
SWMP Modifications Necessary?	None at this time.

Table 11. 303(d) Evaluation for Turbidity

Pollutant	Turbidity
Receiving Waters (2010 303(d)-listed)	• Fern Ridge Reservoir
Does Eugene's Stormwater Contribute to this Pollutant?	Appears yes, based upon an evaluation of Eugene's monitoring data as compared to flow dependent suspended solids load capacities. Ambient monitoring data for Amazon Basin sites indicates frequent exceedance of estimated turbidity criteria. Ambient monitoring data for Willamette River sites indicates periodic exceedance of the turbidity criterion specifying less than 10% cumulative increase as measured upstream.
Common Sources/Uses	(Turbidity is related to Total Suspended Solids) • Construction-related activities • Erosion caused by increased runoff volumes and peak flows caused by urbanization • Erosion caused by the removal or reduction of streamside vegetation • (Fine clay soils in the Amazon watershed are easily suspended when disturbed, and do not settle out easily or quickly).
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterway maintenance (BMPs M3, M5, and P5) which are effective means of preventing sediment from entering the MS4. 3. Implement multiple-objective capital improvement projects including stream restoration, system rehabilitation, and water quality retrofit projects identified in the adopted six-year capital improvement program (BMP E1). 4. Administer the stormwater development standards program including headwater flow controls, source controls and water quality controls that emphasize LID techniques. Ensure proper maintenance of stormwater facilities (BMPs E4, P6, and M6). 5. Education and outreach related to the turbidity problem, sources of turbidity, and appropriate strategies for keeping the suspended solids out of Eugene's stormwater system and its waterways (BMP A1 and P1). 6. Continue to evaluate monitoring information and evaluate through the City's adaptive management process the need for any potential SWMP revisions to further address turbidity.
SWMP Modifications Necessary?	None at this time.

Table 12. 303(d) Evaluation for Aquatic Weeds or Algae

Pollutant	Aquatic Weeds or Algae
Receiving Waters (2010 303(d)-listed)	• A2 Channel / Golden Gardens Pond
Does Eugene's Stormwater Contribute to this Pollutant?	Appears yes, based upon an evaluation of Eugene's nutrient monitoring data (nitrogen and phosphorus) as compared to nutrient waste load allocations.
Common Sources/Uses	(Aquatic Weeds or Algae is directly related to nutrient availability) • Nitrogen and phosphorus occur naturally in soils and water and are necessary for healthy aquatic ecosystems; excess nutrient loads promote algal blooms. • Excessive use of fertilizer and runoff from lawns and gardens promotes aquatic plant growth. • Runoff from impervious surfaces containing nutrients such as avian and domestic pet waste and improper application of fertilizers. • Erosion caused by increased runoff volumes and peak flows caused by urbanization. • Loss or removal of streamside vegetation which utilize nutrients.
Control Measures to Effectively Address this Pollutant (SWMP BMPs)	1. Continue to implement the City's erosion control program, tree planting program, and public landscape and natural vegetation management program (BMPs E2, P3, and P4) to keep disturbed soils and associated naturally occurring nutrients out of Eugene's stormwater system. 2. Conduct system maintenance efforts, including street sweeping, system cleaning, and open waterway maintenance (BMPs M3, M5, and P5) which are effective means of preventing nutrient-laden sediment and leaf litter from entering the MS4 system. 3. Education and outreach related to the problems associated with excess fertilizer use, causes of algal blooms, and appropriate strategies for keeping excess nutrients out of Eugene's stormwater system and its waterways (BMP A1 and P1). 4. Continue to evaluate monitoring information to identify potential nutrient sources and to evaluate through the City's adaptive management process the need for any potential SWMP revisions to further address nutrients.
SWMP Modifications Necessary?	None at this time.