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Lathrop Urban Runoff Study

Final Technical Report

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Acronyms and Abbreviations

BMP	best management practice
CDPH	California Department of Public Health
cfs	cubic feet per second
CMP	coordinated monitoring program
CVP	Central Valley Project
D/DBP	disinfectant/disinfection byproduct
Delta	Sacramento-San Joaquin Delta
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
EC	electrical conductivity
EPA	Environmental Protection Agency
ESWTR	Enhanced Surface Water Treatment Rule
FGL	Fruit Growers Laboratory
FLIMS	Field and Laboratory Information Management System
GIS	geographic information system
HAA	Haloacetic acid
HAAFP	haloacetic acid formation potential
HMP	hydromodification management plan
I-5	Interstate 5
IESWTR	Interim Enhanced Surface Water Treatment Rule

ISC	impervious surface coefficient
Jones Pumping Plant	C.W. “Bill” Jones Pumping Plant
LID	low impact development
LUC	land use category
MCL	maximum contaminant level
MPN/L	most probable number per liter
µg/L	micrograms per liter
µm	micrometers
mg/L	milligrams per liter
MWQI	DWR Municipal Water Quality Investigations
NAIP	National Agricultural Imagery Program
NEMDC	Natomas East Main Drainage Canal
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Units
OEHHA	Office of Environmental Health Hazard Assessment
pH	negative log of the hydrogen ion concentration
QA/QC	quality assurance/quality control
RPD	relative percent difference
SCADA	Supervisory Control and Data Acquisition
SJR	San Joaquin River
STV	statistical threshold value
$SUVA_{254}$	specific UVA_{254}
SWC	State Water Contractors

SWMP	storm water management plan
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
TDS	total dissolved solids
THM	trihalomethane
THMFP	trihalomethane formation potential
TOC	total organic carbon
TSS	total suspended solids
TTHM	total trihalomethanes
TTHMFP	total trihalomethane formation potential
USBR	U.S.Bureau of Reclamation
UVA_{254}	ultraviolet absorbance measured at a wavelength of 254 nanometers
WDL	Water Data Library
WTP	water treatment plant
WWTP	wastewater treatment plant
WY	water year

Metric Conversion Table

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit, Multiply Customary Unit By
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi) feet head of water	0.14505	6.8948
	kilopascals (kPa)		0.32456	2.989
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0

Quantity	**To Convert from Metric Unit**	**To Customary Unit**	**Multiply Metric Unit By**	**To Convert to Metric Unit, Multiply Customary Unit By**
Electrical Conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

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Executive Summary

Due to increasing urbanization in the Sacramento-San Joaquin Delta and the potential negative effects of urbanization on water quality, the Municipal Water Quality Investigations Program began conducting the Lathrop Urban Runoff Study in 2009. The purpose of this study was to assess the water quality impacts from urban runoff on the San Joaquin River. To achieve this goal, water quality samples were collected on the San Joaquin River and from 8 of the city of Lathrop's storm water pumping stations which discharge directly into the San Joaquin River. MCC Control Systems, a contractor employed by the city of Lathrop to manage the storm water pumping system, provided data records of the storm water pumps during storm events. This information was required for load calculations of constituents discharged by Lathrop.

This report summarizes findings of data collected over three wet seasons, between October 2009 and October 2012. However, due to a change in sampling procedure, the data primarily discussed in this report focuses on the second and third seasons (October 2010-October 2012). During these two wet seasons, there were 10 sampling events. A number of analytes were sampled; however, this report focuses on constituents of most concern to drinking water: total and dissolved organic carbon (TOC and DOC), total trihalomethane formation potential (THMFP), haloacetic acid formation potential (HAAFP), ultraviolet absorbance (UVA_{254}), electrical conductance (EC), total dissolved solids (TDS), bromide, ammonia, dissolved nitrate, dissolved nitrate plus nitrite, total nitrogen, dissolved orthophosphate, total phosphorus, total coliforms, fecal coliforms, *Escherichia coli* (*E.coli*), and pyrethroids.

Concentrations of most constituents were significantly lower in the San Joaquin River than in the city pumping stations with the exceptions of dissolved nitrate, dissolved nitrate plus nitrite, EC, TDS and bromide. Pyrethroid samples were too infrequent to draw trends; however, the concentrations sampled were high enough to cause toxicity to the benthic organism, *Hyalella azteca*. For all constituents, the samples collected from the San Joaquin River were less variable than the samples collected from the city pumping stations.

Analysis of UVA_{254} showed a difference in the strength of the correlations between DOC and UVA_{254}, and between THMFP and UVA_{254}. This shows that UVA_{254} is not a reliable indicator of disinfection byproduct precursors. The differences in correlations between the San Joaquin River (SJR) samples and the city pumps station samples indicates that the city pumping stations' carbon quality was different than the SJR at Mossdale carbon.

Loads were calculated for TOC, bromide, ammonia, total nitrogen, and total phosphorus. The load that Lathrop contributed to the San Joaquin River was generally low. The city's discharge is released sporadically, resulting in an inconsistent flow for the duration of the storm. Therefore, load was calculated as the mass discharged per storm event. Data gaps in pumping data were attributed to signal or download error, not from a lack of pumping. Most load calculations showed that Lathrop contributed less than 3% of the total load of the San Joaquin River. The exceptions to this were during a first flush event in season three when Lathrop contributed 6.8% of the organic carbon load and 7.3% of the total bromide load. Ammonia loads varied; during approximately half of the storm events Lathrop's discharges resulted in less than 6% of the total ammonia load on the river and approximately half resulted in more than 10% of the total load.

Concentrations of TOC, DOC, THMFP, and HAAFP decreased over the rainy season with the exception of the June 2011 storm event. During this event, concentrations were elevated for TOC, DOC and THMFP. These patterns were not consistent between San Joaquin River samples and city pump station samples. For these constituents, the trends were mostly observed in the city pump stations. In the city pumping stations, all pathogens had high counts during the first storm events sampled in each season, indicating first flush effects. Concentrations for the SJR at Mossdale remained low for most of the wet season. After the first flush event, concentrations for total and fecal coliforms remained relatively low.

A land use analysis was used to estimate the overall impervious cover of Lathrop currently and at build-out. Results indicated that Lathrop currently has an impervious cover of 25.4%, and will have an impervious cover of 53.5% at build-out. This increase in impervious cover may result in increased storm water flows with undiluted concentrations of contaminants being discharged to the San Joaquin River.

Results of the study showed that storm water discharged from the city of Lathrop will continue to increase as development continues which may result in further water quality affects on the San Joaquin River. The analysis of organic carbon loads showed that there is a reservoir of organic carbon that builds up during the dry months, and gets flushed into the river throughout the season, with decreasing levels of organic carbon through successive storms. The water quality differed between the San Joaquin River and the city pump stations, with the San Joaquin River having generally higher water quality. Overall, Lathrop's discharges did not contribute susbstantial load to the San Joaquin River, with most Lathrop loads being less than 5% of the total load of the San Joaquin River.

It is recommended that this study be revisited in approximately 5 years, after additional development has occurred and the population of Lathrop has increased. A re-assessment of this study should include an analysis of the concentrations and loads analyzed in this study, and the development of a metric that will correlate population growth and land use with water quality. This second study should include monitoring for approximately 5 years to develop a more robust analysis than this study was able to obtain, and the land use analysis should be extended to the Delta. Then the metric developed could be applied to the other small, growing communities in the Delta for a Delta-wide assessment of the effects of storm water discharges from these communities on Delta water quality.

Chapter 1. Introduction

Lathrop is a small city located in the southern Sacramento-San Joaquin Delta (Delta). This is an area that was rapidly urbanizing prior to the housing market collapse of the late 2000s. Because the Delta provides drinking water for more than 25 million Californians, impacts to its water quality in this area are particularly important. To determine the potential effects of small, growing cities on the Delta's water quality, the Municipal Water Quality Investigations (MWQI) Program investigated the effects of Lathrop's storm water discharge into the San Joaquin River.

The focus of this study was to evaluate the water quality effects of Lathrop's storm water discharges into the San Joaquin River from October 2010 to September 2012. Because the city primarily discharges during storm events for flood control, the study focused on storm events. The data collected for this study provides a good background condition of the San Joaquin River and will be helpful in analyzing the effects of other small, but growing cities in the Delta. The baseline information will be very important in the future as a basis for comparison of water quality conditions. As development continues to grow, we will be able to see at what population size urbanization negatively effects drinking water quality. This may be useful in management decisions regarding monitoring of storm water and mitigation of negative effects on drinking water quality from urban runoff. This study also includes a land use analysis which is necessary in understanding the system due to the inverse relationship between impervious land cover and aquatic ecosystem health.

Specifically, this study quantified background concentrations and loads in the river and loads of specific constituents discharged into the river from the city of Lathrop. Knowing both the background loads in the river and the urban load discharged to the river provides a relative contribution of urban loading to the river. Using discharge rates and riverine flow measurements, urban and riverine loads were calculated for organic carbon, bromide and nutrients. Concentration data was collected for all other constituents. Land use was analyzed by quantifying the percentage of impervious cover. This will enhance our understanding of water quality effects from urban drainage by linking particular land uses to loads. By linking the percent of impervious cover to discharges from different land uses, storm water discharge information from Lathrop may also prove useful in predicting loading from other urban areas.

Objectives

- Assess the effects of urban storm water runoff from Lathrop on the San Joaquin River Watershed with special attention paid to first flush events.
- Develop a baseline of water quality conditions for the area.
- Develop a baseline of land use patterns for the area.
- Quantify background concentrations and loads in the river, and loads of specific constituents discharged into the San Joaquin River from the city of Lathrop.

Report Organization

The report is organized as follows:

Chapter 1	Introduction
Chapter 2	Background- This chapter discusses the background and rationale for the study and gives detailed information about the regulatory background, site description, and methods.
Chapter 3	Study Design- This chapter focuses on specifics about the study site and overall study design.
Chapter 4	Hydrology- This chapter focuses on the description of the watershed, climate, precipitation, and sampling decisions based on storm events.
Chapter 5	Water Quality- This chapter contains the results and analysis of concentrations and loads of the constituents that were sampled.
Chapter 6	Land Use Analysis- This chapter focuses on the estimates of impervious cover for the city of Lathrop in 2010 and at build-out.
Chapter 7	Summary, Conclusions, and Recommendations - This chapter contains a review of the key findings of the study and recommendations for further investigation.
Chapter 8	Cited References- This chapter contains all the references that were used in the development of this report.
Appendix A	Results from Season One Data- Season one data is largely not discussed in the report because of a major change in sampling procedures. This appendix contains the preliminary results of that season's data.
Appendix B	Data Quality Control

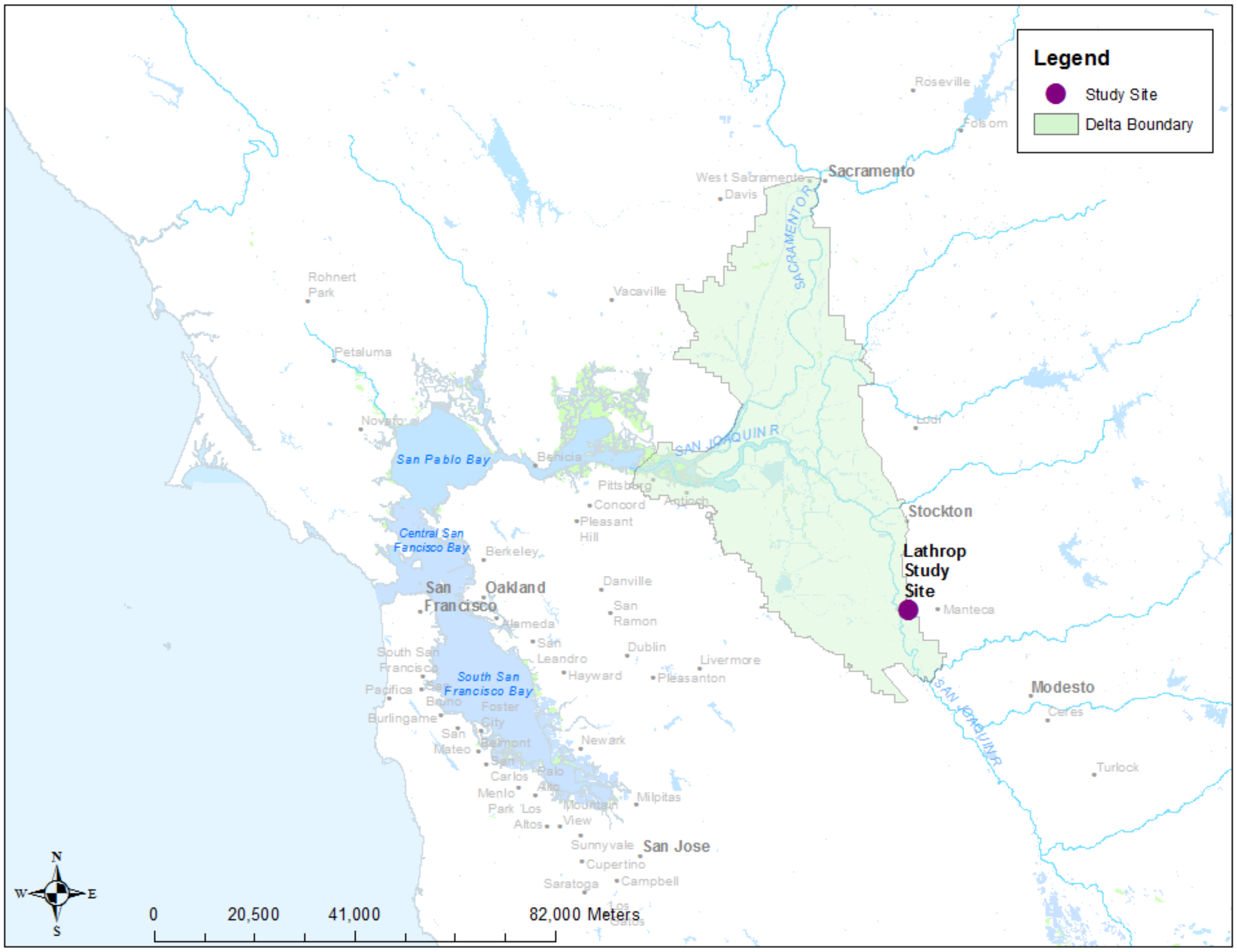
Chapter 2. Background

Study Area Characteristics

The study area was the city limits of Lathrop, which is located in the south Delta. The city is located just south of Stockton, and west of Manteca (Figure 2-1). Interstate 5 (I-5) is the major highway that goes through Lathrop, and State Route 120 goes through the southern portion of the city. The Union Pacific railroads go through the eastern portion of the city. The city area is approximately 14,035 acres (U.S. Census Bureau, 2014).

Lathrop is a small community of approximately 18,023 people (U.S. Census Bureau, 2014). Population growth was rapidly increasing prior to the economic decline of the late 2000s. With the improving economy, a large housing development on Stewart Tract (the River Islands development) began construction in 2014. This is a large scale development that will nearly triple Lathrop's current population at its completion. The development plans consist of 11,000 homes, a town center, a business park, several marinas, and two golf courses.

Figure 2-1. General Map of Study Site



Water Quality Concerns

Water quality impacts from urbanization primarily come from increased urban drainage, increased wastewater discharge, and recreational uses. Increases in the volume of urban drainage are mainly due to impervious cover. Agriculture and open space landscapes are pervious and generally allow for percolation of storm water through the soil. To a large degree, soils filter, adsorb, or attach to contaminants such as heavy metals, oil and grease, pesticides, and nutrients, as compared to compacted or developed areas which allow less percolation and result in more runoff. Urban land uses are mainly characterized by pavement and do not allow water infiltration. Instead, water flows as sheets over the impervious surface to the river, or is channeled through storm drainage systems. This typically results in higher runoff volumes, with shorter durations, but larger magnitude peak flows in response to rainfall. Impervious and semi-impervious surfaces (e.g.commercial and residential landscapes) also catch and store urban contaminants between storm events. Typical urban contaminants include vehicle emissions, vehicle maintenance wastes, landscaping chemicals, household chemicals, pet wastes, and trash. Increases in impervious surfaces and installation of storm sewer systems provide a faster and more direct route for the transport of accumulated pollutants to nearby waterways (Shaver, 2007).

Typical water quality constituents in storm water include sediment, nutrients, minerals, trace metals, petroleum hydrocarbons, pathogens and organic chemicals (Shaver, 2007). Sediment is typically measured as total suspended solids (TSS) and/or turbidity, and it can be particularly harmful for aquatic organisms living in receiving waters. Nutrients (nitrogen and phosphorus based constituents including ammonia) are typically present in storm water and are necessary for a healthy ecosystem, but in high quantities they can cause algal blooms. These blooms can use up the majority of the oxygen in the water, depriving fish and other organisms of oxygen. They can also cause taste and odor issues in finished drinking water. The most common sources of nutrients are fertilizers, soil erosion, and animal wastes. Minerals such as chloride and bromide are found in runoff due to agricultural and wastewater influences.

Trace metals may be found in particulate or dissolved forms. Common sources of metals include industrial activities, vehicle maintenance, and roadways. In storm water, petroleum hydrocarbons are typically composed of automobile fuels and lubricants, which normally attach to sediments in runoff. Pathogens are often found in high concentrations in runoff, particularly during first flush events. Pathogen sources in urban runoff are wildlife, urban rodents, pets, and homeless encampments. Pesticides found in storm water can come from agricultural sources, but more commonly come from residential sources. Residents often spray their lawns and gardens in high concentrations which are washed directly into the storm drain during storm events. Organic carbon has been found to be in higher concentrations in storm water (DWR, 2008), and is a concern for drinking water quality. Organic carbon present in raw water can react with disinfectants in the drinking water treatment process to form disinfection byproducts (DBPs). These DBPs can be carcinogenic and cause other health problems. This study included monitoring for many of the constituents found in storm water; however, the focus of this report is on key drinking water constituents of concern.

Regulatory Background

The major regulatory program in place to protect California's water quality from harmful discharges, such as storm water, is the National Pollutant Discharge Elimination System (NPDES) program. This program is authorized by the Clean Water Act administered by the U.S. Environmental Protection Agency (EPA), and is implemented by the California State Water Resources Control Board (State Water Board). Permits through the program provide two levels of control: technology based limits and water quality based limits. The type of NPDES permit applicable in this report is a Municipal Separate Storm Sewer System permit. Municipalities must be covered under a NPDES permit to discharge into state waters, and cities larger than 100,000 people must apply for a Phase I NPDES permit. The Phase I permits are written specifically for the city applying for the permit, and address water quality issues specific to that area. These permits usually require dischargers to monitor their discharge. The Phase II NPDES permit is a general permit that applies to all discharging communities greater than 10,000, but less than 100,000 people, which are not already covered under a NPDES permit.

During the study period, Lathrop was covered under the Phase II NPDES general permit that was administered in 2003, permit number CAS000004. The permit did not require the permittees to monitor storm water runoff discharged to source waters. This was a significant reason why the focus of this study was on a smaller municipality. The 2003 general permit requires that permittees develop and implement a storm water management plan (SWMP). The SWMP is required to cover six key program areas: public education, public participation, illicit discharge detection and elimination, construction site storm water control runoff, post construction site runoff, and pollution prevention or good housekeeping (SWRCB, 2003). Recently, the State Water Board reviewed the SWMPs created and implemented by permittees covered under the general permit and found that many of the SWMPs lacked a strong baseline program that protects source waters from storm water runoff. Central Valley Regional Water Quality Control Board (Regional Board) staff also found it difficult to determine permittee compliance with the general permit due to a lack of specific requirements. As a result, a more robust Phase II general permit was written and went into effect on July 1, 2013 (SWRCB, 2013).

The approach for the new Phase II NPDES permit is to establish implementation levels and public accessibility of the results. There are specific requirements to reduce discharges of pollutants in storm water in an effort to achieve and maintain compliance with water quality regulations and objectives. The most critical water quality objectives are delineated in the permit. A major change in the new permit is that a SWMP is no longer required, but a guidance document for storm water management is required. The new permit more clearly spells out specific best management practice (BMP) requirements. The requirements pertain to total maximum daily loads (TMDL), post-construction storm water management, water quality monitoring and BMPs, and storm water program effectiveness assessments. With respect to development, the permit requires that site design and low impact development (LID) BMPs be incorporated. During this permit term, runoff retention and hydromodification control criteria will be included. Hydromodification is hydrologic change to a watershed due to urbanization.These criteria will be linked to specific watershed processes within defined watershed management zones (SWRCB, 2013). With all of these changes, the new Phase II permit is more comparable to the Phase I NPDES permits of larger municipalities.

In addition to the NPDES regulations, many of the constituents discussed in this report are regulated federally and locally. Specific details about regulated constituents will be discussed in the water quality chapter.

The Need for Study

The Delta is a region that had been rapidly growing at a rate much faster than the rest of California and the United States until the housing collapse of the late 2000s. Because of the geographic location of this urban growth, there is a significant potential for negative effects on drinking water quality. The Delta provides drinking water to more than 25 million Californians (American Rivers, 2010; Metropolitan Water District, 2012); therefore, the effects of urban runoff on water quality are particularly important in this region.

Because the Delta provides drinking water for such a large population, it is important to understand the broad scale of effects of discharges on the system and their potential impacts to drinking water quality. The majority of storm water research available pertains to impacts from large dischargers, and there is limited information about the effects from smaller dischargers, like the city of Lathrop. Therefore, this study provides additional information on smaller dischargers and focuses on the effects of Lathrop’s urban runoff during storm events, when Lathrop primarily discharges. Special attention was given to first flush events when it is common to see a higher concentration of contaminants being discharged into the river. This study focuses on a wide range of water quality constituents including organic carbon, DBP formation potential, minerals, nutrients, salinity, pesticides, and pathogens. Loads are calculated for organic carbon, bromide, and select nutrients. These constituents were chosen based on their effects on drinking water quality, and on their inclusion in regional NPDES permits. Lathrop is an ideal study site due to its small size and location in the south Delta. It also represents a simple system; the city's discharge is the only discharge in the local stretch of the San Joaquin River. Although the discharge from Lathrop is small, its effects on Delta drinking water quality have the potential to be significant due to Lathrop's location.

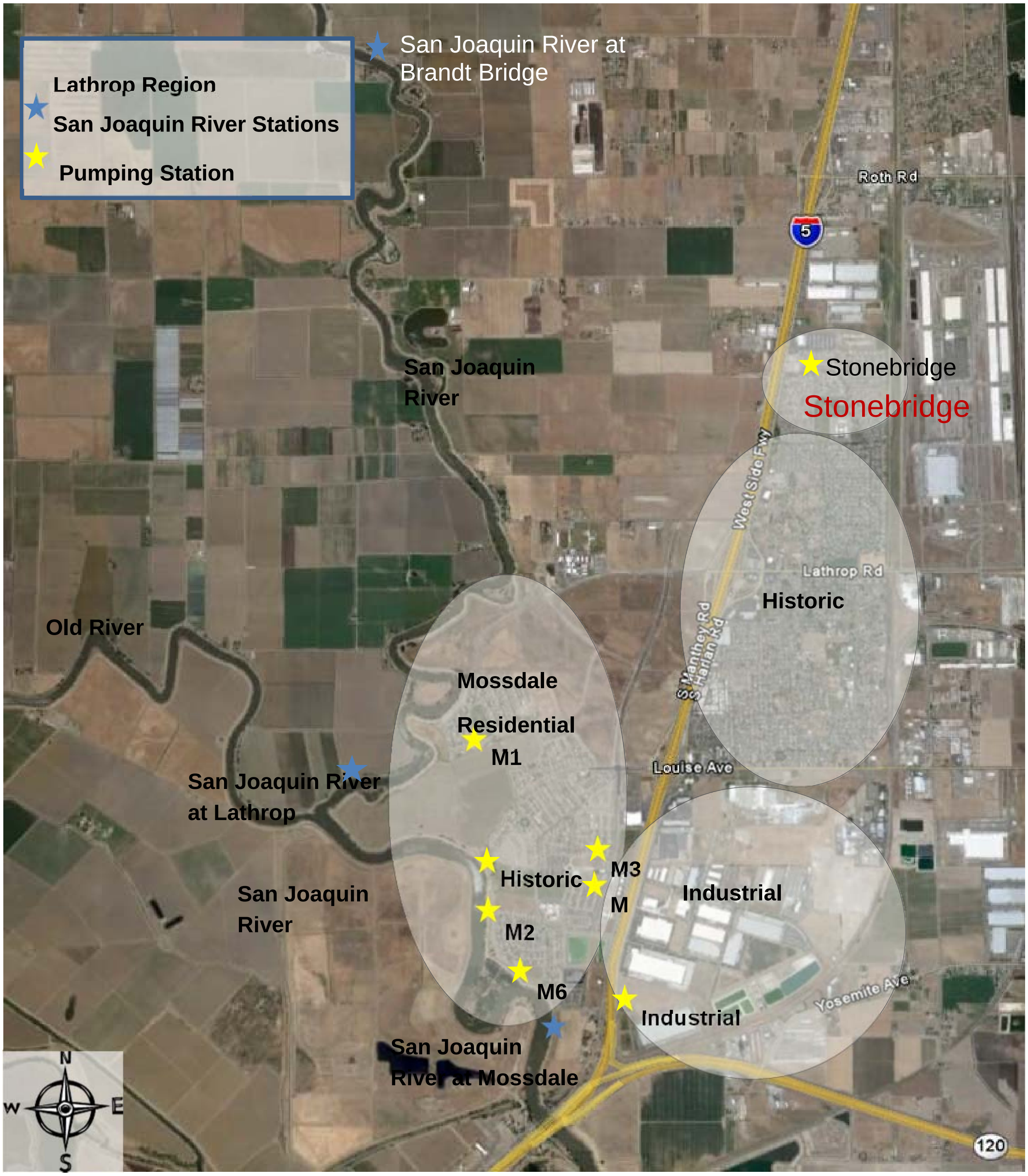
Chapter 3. Study Design

Site Description

Lathrop is located approximately 53 miles south of Sacramento and 62 miles east of San Francisco (Figure 2-1). The population of the city was 18,023 according to the 2010 census. This area is characterized by a Mediterranean climate with cool, wet winters, and warm, dry summers. Due to the flat topography of the area, Lathrop is prone to flooding from the San Joaquin River which flows from the south to the north as it enters the Delta. Due to its proximity to the ocean, the river is weakly tidal. During very strong flood tides, the river can reverse direction, but it primarily flows downstream.

Storm water is handled differently in the four regions of the city (Figure 3-1). In this report, those regions are referred to as Industrial, Historic, Mossdale, and Stonebridge. Storm water is primarily handled through the use of storm water pumping stations and detention basins. However, many of the undeveloped areas and some industrial areas in Lathrop have no installed storm drain system. The storm water in these areas is handled through detention ponds when necessary, where most of the water will percolate into the groundwater. The portion of the Industrial region of the city that does have a storm water drainage system has a detention basin and a pumping station. The Historic region, which represents the original town, has no in-ground storm sewer. Runoff is collected in detention basins and is then channeled to the Louise Road pumping station which then pumps the water to the Historic pumping station on the other side of town. The Historic pumping station discharges directly into the San Joaquin River and is the station that was sampled for this study. The Mossdale region of Lathrop has a developed storm drain system which utilizes 5 pumps that discharge into the river (M1, M2, M3, M5, and M6). The M4 station is not currently in use. The Stonebridge region has a detention basin and a pumping station. The current land uses within the city limits of Lathrop are approximately 65% open space or agriculture, and 35% urban.

Figure 3-1. Map of Lathrop Pump Stations and Regions



Study Design

To accomplish the study objectives, water quality samples were collected from the San Joaquin River and Lathrop's storm water pumping stations from October 1, 2009 through September 30, 2012. The city's storm water flows through these pumping stations immediately prior to being discharged into the San Joaquin River. San Joaquin River samples were collected to evaluate the proportion of load in the river attributable to urban runoff. The sampling focused on first flush events because these events have the greatest potential to affect water quality, and would provide a better understanding of the maximum effect that Lathrop's discharge has on the water quality of the San Joaquin River. Over the course of the study, 13 storm events were sampled. In addition to water quality samples, data was collected from rain gauges to determine precisely how much precipitation occurred during each event.

To complement these analyses, a geographic information system (GIS) was used to conduct a land use analysis. All the layers necessary to conduct the analysis were obtained from the California Department of Water Resources (DWR) and National Agricultural Imagery Program (NAIP).

Storm Water Pumping Stations

Lathrop handles its storm water using detention basins and storm water pumping stations. The detention basins impound the storm water prior to being conveyed to storm water pumping stations. Pump stations discharge into the river and are comprised of a wet well, a low-flow pump, and up to 5 main pumps. The Supervisory Control and Data Acquisition (SCADA) system controls and monitors the pumps. When water rises to a set level, the SCADA turns the low flow pump on. If the water in the wet well continues to rise and the low flow pump cannot accommodate the flow, the SCADA system turns the low flow pump off and turns on the main pumps. The SCADA system also records the amount of water discharged from each pump.

Eight Lathrop storm water pumping stations were sampled (Figure 3-1). This includes all stations which pump directly into the river, and encompasses all the regions of Lathrop. With the exception of pathogen samples, all pump station samples were collected by autosamplers (ISCO 3700 or ISCO 6712). Because of short holding times and the need for sterile sampling containers, pathogen samples were collected as grab samples. Composite and grab samples were processed according to constituent requirements of the laboratories. Further details in sample processing are discussed in the Analytical Methods section.

Autosampler Programming

DWR contracted with MCC Control Systems to wire the autosamplers into the city's SCADA system at each pumping station. Each autosampler was triggered to sample by receiving a signal (or pulse) from the SCADA; one signal for every 1,000 gallons that was pumped in each pumping station. Each pump was programmed differently based on how much the pump typically pumped during a storm event. For example, an autosampler may be programmed to take a sample every 20 pulses. The autosampler would not receive its first signal to sample during an event until after the pumps had run a sufficient time, allowing standing water to be flushed out. This ensured that water collected by the autosampler reflected the water quality of storm water runoff, and not the quality of the residual water that was in the pipes prior to storm water discharge. The autosamplers were programmed to receive SCADA signals based on the time that the storm was forecast to begin.

For each storm event, the goal was to collect a 9 liter (L) composite sample at each of the 8 pumping stations. At each pumping station, 24 samples (375 mL each) were collected and composited into a 9 L sample. Due to the unpredictability of the exact precipitation volume of storm events and occasional equipment malfunctions, less than 9 L was often collected. In many cases there was not enough sample collected to process all constituents at all stations. In cases where there was not enough sample volume, a priority was put on processing the constituents in the following order: physical parameters (dissolved oxygen, turbidity, temperature and pH), total and dissolved organic carbon, bromide, total trihalomethane and haloacetic acid formation potentials, total dissolved and suspended solids, absorbance, nutrients, minerals, metals, and pesticides. Pyrethroid pesticides were sampled twice each year, but were only sampled if there was enough sample water to process for all constituents. See summary statistics tables in Chapter 4 for number of samples collected for each constituent at each station.

The storm duration determined if the event would be sampled multiple times. If the storm only lasted 24 hours, one set of samples were taken for that 24 hours and then were processed. If the storm was expected to last for multiple days, the sample was processed after the first 24 hours and then the autosampler was re-programmed to collect a second set of samples for the next 24-hour period, after which they would be processed. The sampling pattern would continue up to three days. See Table 3-1 for storm duration, sampling duration and precipitation amount per storm.

Table 3-1. Precipitation Amount, and Precipitation and Sampling Duration

	Date of Storm	Average Precipitation*	Precipitiation Duration	Sampling Duration **
Season 1	10/13/2009	1.86 in.	10/13/2009 05:00- 10/13/2009 22:00 (17 hours)	Start and end time based on liquid level sensors at each station
	12/11/2009	1.14 in.	12/11/2009 00:00- 12/13/2009 15:00 (37 hours)	Start and end time based on liquid level sensors at each station
	1/17/2010	1.78 in.	1/17/2010 04:00- 1/21/2010 23:00 (67 hours)	Start and end time based on liquid level sensors at each station
Season 2	11/7/10	0.49 in.	11/7/2010 07:00- 11/8/2010 05:00 (22 hours)	11/7/2010 6:00- 11/8/2010 09:30 (27.5 hours)
	11/20/2010	0.95 in.	11/19/2010 22:00- 12/21/2010 12:00 (38 hours)	11/19/2010 22:00- 11/21/2010 09:30 (35.5 hours)
	12/17/2010	1.09 in.	12/17/2010 04:00- 12/19/2010 10:00 (54 hours)	12/17/2010 16:00- 12/19/2010 09:30 (38.50 hours)***
	3/19/2011	0.67 in.	3/19/2011 20:00- 3/21/2011 10:00 (38 hours)	3/19/2011 19:00- 3/21/2011 09:30 (38.50 hours)
	3/24/2011	0.73 in.	3/24/2011 12:00- 3/25/2011 9:00 (21 hours)	3/24/2011 5:00- 3/25/2011 09:30 (28.50 hours)
	6/4/2011	0.34 in.	6/4/2011 18:00- 6/5/2011 12:00 (42 hours)	6/3/2011 19:00- 6/5/2011 09:30 (38.5 hours)
Season 3	10/4/2011	0.77 in.	10/4/2011 23:00- 10/6/2011 09:30 (34.5 hours)	10/4/2011 22:00- 10/6/2011 09:30 (31.5 hours)
	1/19/2012	0.94 in.	1/19/2012 18:00- 1/21/2012 07:00 (37 hours)	1/19/2012 12:30- 1/21/2012 09:30 (45 hours)
	3/16/2012	0.67 in.	3/16/2012 18:00- 3/17/2012 19:00 (25 hours)	3/16/2012 09:00- 3/17/2012 09:30 (24.5 hours)
	3/24/2012	0.37 in.	3/25/2012 00:00- 3/25/2012 05:00 (5 hours)	3/24/2012 8:00- 3/25/2012 09:30 (25.5 hours)

* Average precipitation of the Stonebridge and Historical station locations

** Sampling start and end times were the time periods that the autosampler was active to receive signals from the SCADA to sample. The end time was approximate time of sample processing

*** Sampling start was based on forecasts, and was programmed earlier than the storm actually came in.

River Station Samples

To assess the load in the river, grab samples at Mossdale were collected. Originally, samples were also taken at the San Joaquin River at Lathrop and at Brandt Bridge (Figure 3-1). Data from the first season showed that sampling downstream of the discharges was not a good representation of the baseline load plus Lathrop's load. This was due to the inconsistency of storm water discharge pumped from each station. It was rare for all pumps to be discharging at the same time, and it was impossible to know when to sample based on the number of pumps discharging. (The pumps are not programmed; they turn on and off based on the amount of storm water in the well.) Furthermore, Lathrop discharges contribute approximately 2% of the flow of the San Joaquin River. For these reasons, samples were collected at the Mossdale station during an ebb tide when the river flows out through the Delta to give a good representation of the baseline water quality of the San Joaquin River.

All Mossdale station samples were taken as grab samples the day of the storm. These samples were processed the same way as the autosampler samples and were the same volume as the autosample samples (9 L). Due to logistics and availability of staff, there was only 1 set of river samples taken per storm. Grab samples were collected for the San Joaquin River at Mossdale station for all constituents including pathogens.

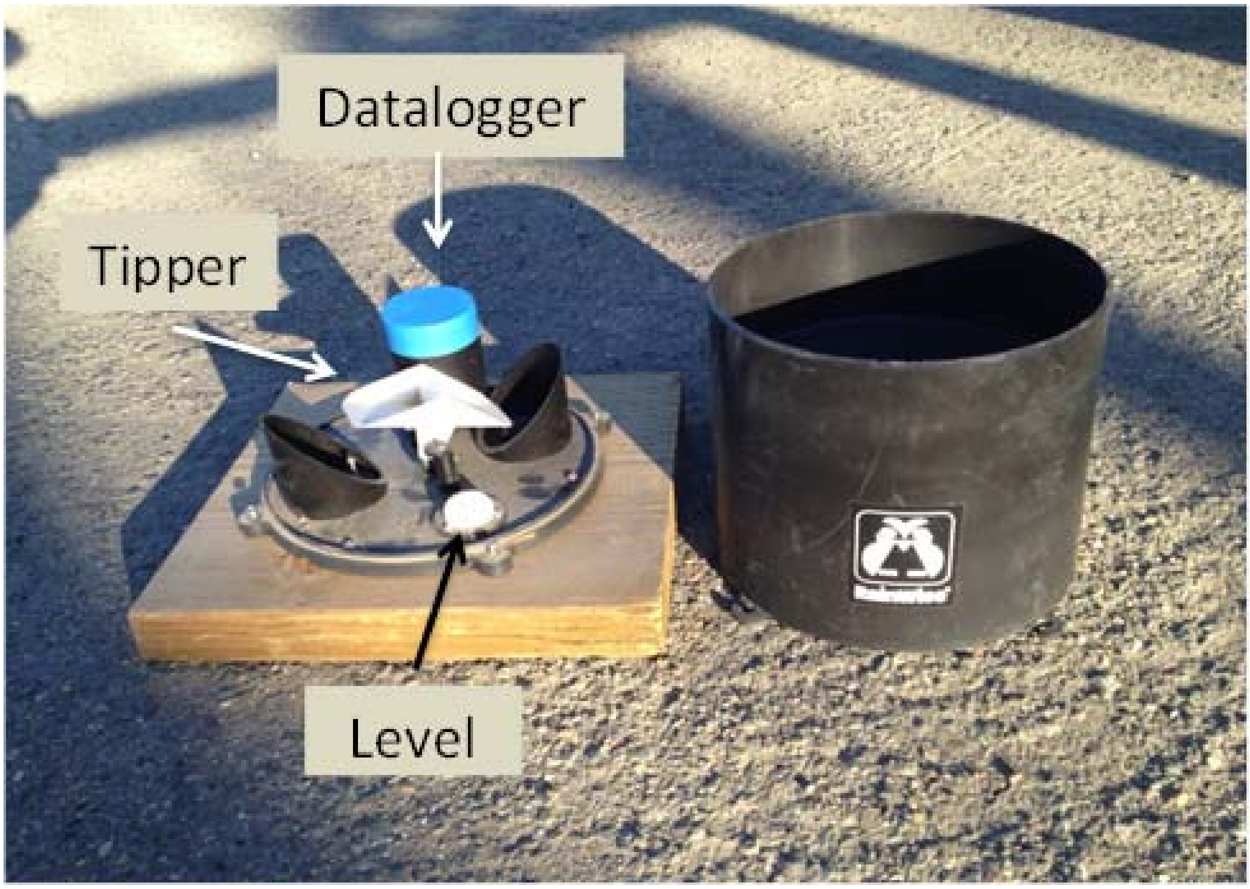
Weather Monitoring and Precipitation Data

Precipitation was monitored closely throughout the study's duration. Sampling of first flush storms occurred when a storm of 0.5 predicted inches of precipitation followed a dry period of 30 days or more. If there was a major storm event within a 30-day dry period, sampling also occurred. For the purpose of this study, a major storm event is defined as a storm producing at least 1.5 inches of precipitation during a 24-hour period. These were general guidelines for sampling protocol, and storm sampling was modified as appropriate for each storm.

RainWise 8-inch diameter tipping bucket rain gauges, equipped with dataloggers, were installed at 2 of the storm water pump stations (Figure 3-2 and 3-3). The locations were at the Stonebridge and Historic stations. The dataloggers stored up to 365 days worth of rainfall data and recorded data every minute throughout the course of the study. The two gauges were geographically separated to account for regional differences in precipitation.

Figure 3-2. Constructed Tipping Bucket Rain Gauge

Figure 3-3. Deconstructed Tipping Bucket Showing Internal Mechanisms



Flow Data

One of the focuses of this study was to make a determination of carbon, bromide, and nutrient loads. Load is a function of concentration and flow. The San Joaquin River at Mossdale station has continuous flow data; however, there is no continuous flow data at the autosampler stations. Flow data at these sites was determined by the pump rating curves and were provided by MCC Control Systems. The pump rates and duration of pumping during an event enabled calculations of the approximate flow.

Analytical Methods

Physical Parameters

Physical parameters were taken in the field as soon as possible after collection. Physical parameters measured included dissolved oxygen, pH, electrical conductivity, temperature and turbidity.

Samples Prepared for Bryte Laboratory

All samples, with the exception of pathogens, pyrethroids, THMFP, and HAAFP, were processed at DWR's Bryte Laboratory in West Sacramento, California. Samples prepared for Bryte Laboratory were processed in accordance with the laboratory's guidelines. This includes filtration, acidification, and agitation of the matrix when applicable. All samples were put on ice until returned to the lab.

Samples Prepared for Weck Laboratory

Pyrethroid, THMFP and HAAFP samples were processed at Weck Laboratory in the City of Industry, California. These samples were filtered in the field, with the exception of pyrethroids. All samples were processed in accordance with Weck Laboratory's guidelines. Samples were shipped overnight to the laboratory to accommodate the holding times.

Samples Prepared for Fruit Growers Laboratory (FGL)

Pathogen samples were analyzed at FGL in Stockton, California. These samples were collected as grab samples at the San Joaquin River sampling site and the autosampler stations. Pathogens cannot be collected from an autosampler due to the need for sterile sampling containers, and the probability of bacteria death or reproduction during the time between collection and processing. Immediately after collection, pathogen samples were put on ice and delivered to FGL within the 6-hour holding time. For a complete list of analyses and methods, see Table 3-2.

Table 3-2. Laboratory Analyses

Method	Analyte
Std Method 2340 B, Hardness By Calculation	All
EPA 200.7 (D), ICP Metals and Trace Elements (Dissolved)	Dissolved Calcium
EPA 200.7 (D), ICP Metals and Trace Elements (Dissolved)	Dissolved Magnesium
EPA 200.7 (D), ICP Metals and Trace Elements (Dissolved)	Dissolved Potassium
EPA 200.7 (D), ICP Metals and Trace Elements (Dissolved)	Dissolved Sodium
EPA 300.0 28d Hold, Inorganic Anions 28d hold	Dissolved Sulfate
EPA 300.0 28d Hold, Inorganic Anions 28d hold	Dissolved Chloride
EPA 200.7 (D), ICP Metals and Trace Elements (Dissolved)	Dissolved Boron
Std Method 2540 C, Total Dissolved Solids (TDS)	All
Std Method 2320 B, Alkalinity	All
Std Method 2510-B, Electrical Conductivity (EC)	All
EPA 300.0 28d Hold, Inorganic Anions 28d hold	Dissolved Nitrate
Std Method 4500-NO3-F (28Day), Nitrite, Nitrate (DWR Modified) (Dissolved)	Dissolved Nitrate + Nitrite
EPA 350.1, Ammonia, Nitrogen (Dissolved)	All
EPA 351.2, Kjeldahl Nitrogen	All
EPA 365.1 (DWR Modified), DWR Othro-Phosphate (Dissolved)	All
EPA 365.4, Phosphorus (Total)	All
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Silver
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Aluminum
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Antimony
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Arsenic
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Cadmium
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Nickel
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Zinc
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Selenium
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Molybdenum
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Manganese
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Lead
EPA 200.8 (D), ICP/MS Trace Elements (Dissolved)	Dissolved Copper
EPA 200.8 (T), ICP/MS Trace Elements (Total)	Total Iron
EPA 200.8 (T), ICP/MS Trace Elements (Total)	Total Lead
EPA 200.8 (T), ICP/MS Trace Elements (Total)	Total Copper
EPA 200.8 (T), ICP/MS Trace Elements (Total)	Total Chromium
EPA 200.8 (T), ICP/MS Trace Elements (Total)	Total Aluminum
EPA 415.1 (D) Ox, Organic Carbon (Dissolved) by Wet Oxidation	All
EPA 415.1 (T) Ox, Organic Carbon (Total) by Wet Oxidation	All
Std Method 5910B, UVA_{254}	All
EPA 608, Chlorinated Organic Pesticides	All
EPA 614, Phosphorus / Nitrogen Pesticides	All
EPA 160.2, Total Suspended Solids	Total Suspended Solids
DWR THMFP (Buffered), DWR THMFP (Buffered)	All
DWR HAAFP (Buffered), Haloacetic Acid Formation Potentials (Buffered)	All
Std Method 9221B,E, Total and Fecal Coliform[1]	All
Std Method 9223B, Total and E.Coli Coliform[1]	All
GC/MS NCI-SIM, Pyrethroid Pesticides[2]	All
Std Method SM 5710B, THMFP, HAAFP[2]	All

[1]Analysis conducted by FGL Laboratory, Stockton, California.

[2]Analysis conducted by Weck Laboratory, City of Industry, California.

Data Quality Control

Throughout the study, quality assurance and quality control measures were taken to validate the data (Appendix B). This included both field and laboratory procedures. The data review indicated that the project data were of acceptable quality overall. In cases where the data quality was questionable, those data were not incorporated in the analysis. This ensured that the data analysis was of the highest quality.

Field Procedures Quality Control

For each storm water sampling run, replicates were taken at one station for all constituents. For all constituents with the exception of pathogens, the duplicate station was at M5 or at the Historic station. The replicate sample was collected from an autosampler outfitted with a 19-Liter (L) glass jar. This sampler was initially installed at the M5 pumping station, but was later moved to the Historic station which pumped a more reliable volume during storm events. All other autosamplers were outfitted with a 9-L glass jar. Nine liters was a sufficient volume to collect a sample for all the analyses, but was not sufficient to collect a sample for replicates. Due to the large size of the 19-L jar and the complex set up at each of the stations, frequently switching out this jar with other stations was not feasible. Both the regular sample and replicate sample were collected from the same 19-L container. Replicates were processed for both total and dissolved constituents. For the study period, 706 replicates were processed and 112 (15.9%) exceeded the relative percent difference (RPD) limit.

During each event, pathogen sample duplicates were taken. The duplicate station was rotated among the autosampler stations. The duplicate was a second sample taken directly from the water source using the identical sample method as that of the parent sample. The results of the duplicates for the pathogen samples were much more variable than those of the other water quality constituents. This is due to the nature of the pathogens in which it is common to have clumping of organisms, resulting in large differences between the duplicate and parent sample. The average RPD for total coliforms was 10%, for fecal coliforms it was 35%, and for *Escherichia coli* (*E. coli*) it was 15%.

In addition to replicates, field blanks were taken for every field run. Field blanks check for contamination during the collection and processing of water quality samples. Unfiltered field blanks were used to check that there was no contamination from the containers or preservatives. Filtered field blanks were used to check for contamination from sample processing procedures. For samples collected throughout the study, 659 field blanks were processed and 4 (0.6%) of those blanks exceeded the control limit of below the reporting limit. Three of the 4 samples were at the reporting limit.

Chapter 4. Hydrology

Introduction

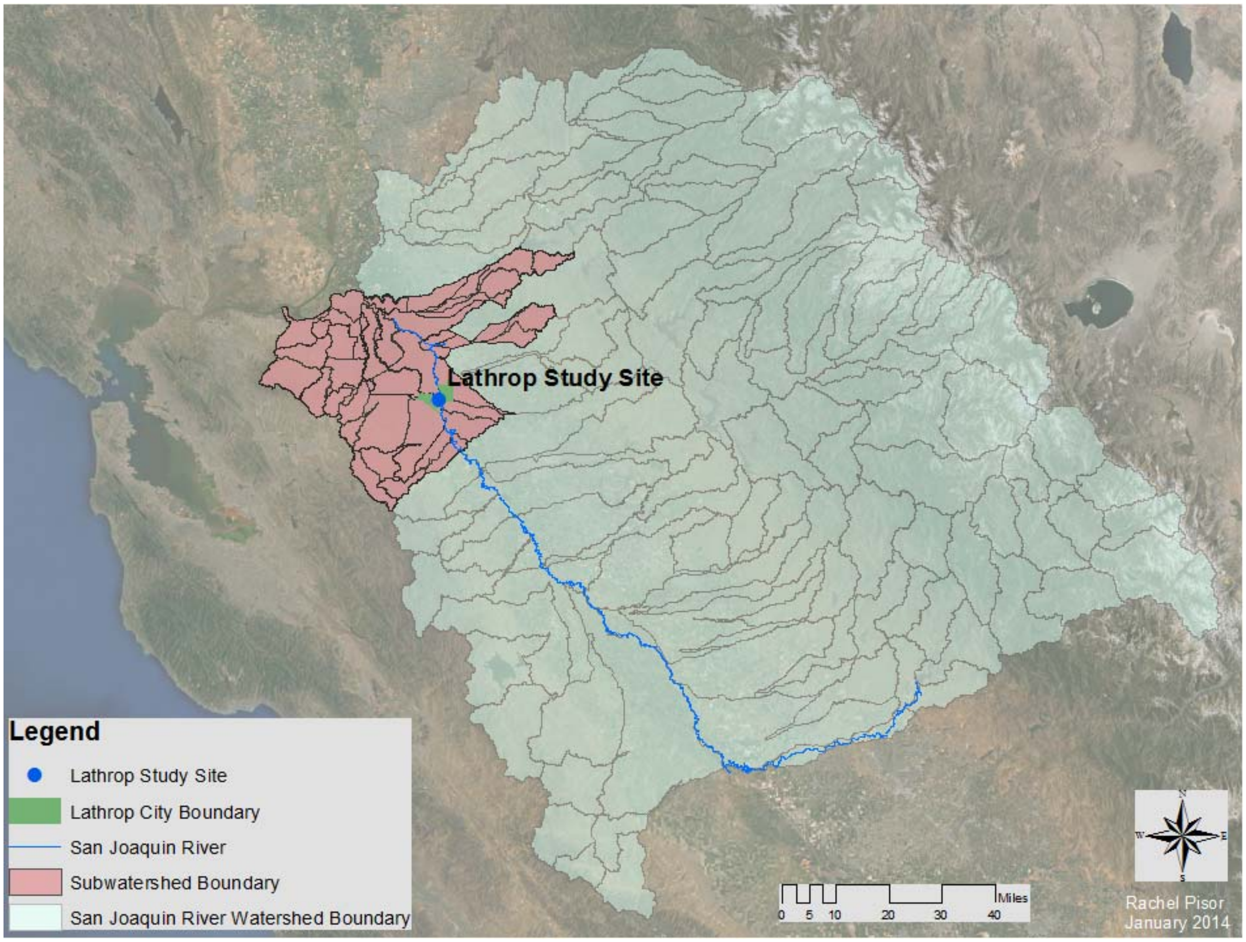
The hydrologic characteristics of Lathrop, such as flow and precipitation, were the principal drivers in the sampling plan. The hydrology of the San Joaquin River watershed, hydrology of Lathrop, storm water management by the city of Lathrop, climate of the region, and hydrologic data results are described in this section.

Throughout the study, precipitation and flow data were collected to coincide with the water quality analysis. The precipitation provided a gauge for when to conduct a sampling event, and is the driver for storm water discharges into the San Joaquin River. Flow data was approximated by the storm water pump rates, and was used with the water quality data collected to determine the load of specific constituents discharged from the city into the San Joaquin River.

Hydrology of the Watershed

Lathrop is in the San Joaquin River watershed, which is drained by the Delta. The San Joaquin River watershed is highly agricultural, with approximately 2 million acres in agriculture, which was 18% of the total irrigated acreage in California as of 2007 (USDA, 2007; USDA, 2007a). This watershed encompasses 15,664,799 acres (approximately 40% of the state's land surface). Lathrop encompasses a very small portion of the San Joaquin River watershed (approximately 0.1%) and subwatershed (approximately 1.8%) (Figure 4-1). The subwatershed is a smaller watershed within the San Joaquin River watershed. The area is geographically very flat and was historically a wetland. As a result of the flatness of the terrain and the size of the watershed and subwatershed, this study focused on the political boundaries of Lathrop rather than the watershed or subwatershed boundaries.

Figure 4-1. The San Joaquin River Watershed, Subwatershed, and Lathrop's Location



Hydrology of the City of Lathrop

Within the boundaries of Lathrop, the hydrology is characterized by soil type, groundwater characteristics, and surface water flows. The soils are primarily alluvial fan terraces, composed of loamy sands and silty clays that overlay the hardpan. Groundwater levels in the area vary from approximately 7 to 20 feet below the soil surface (City of Lathrop, 2003). Surface waters in Lathrop include the San Joaquin River and Paradise Cut. The San Joaquin River flows north through Lathrop toward the Delta. Lathrop's current development is bounded on the west by the San Joaquin River. The River Islands development (Stewart Tract) will be bounded on the east by the river (Figure 3-2). The San Joaquin River is the water body that Lathrop discharges its storm water into through the use of storm water pumps.

The stretch of the San Joaquin River that passes through Lathrop is weakly tidal, due to its proximity to the ocean. Generally, the San Joaquin River water flows through the Delta and out to the ocean. However, during low flow events or under very strong flood tides, the San Joaquin River can reverse direction and flow upstream. Paradise Cut, a small branch of the San Joaquin River, flows through the southwest region of Lathrop. There are currently no developed lands surrounding Paradise Cut. This waterway will eventually be part of the River Islands development, but the immediate area surrounding Paradise Cut will remain as open space or recreational land uses.

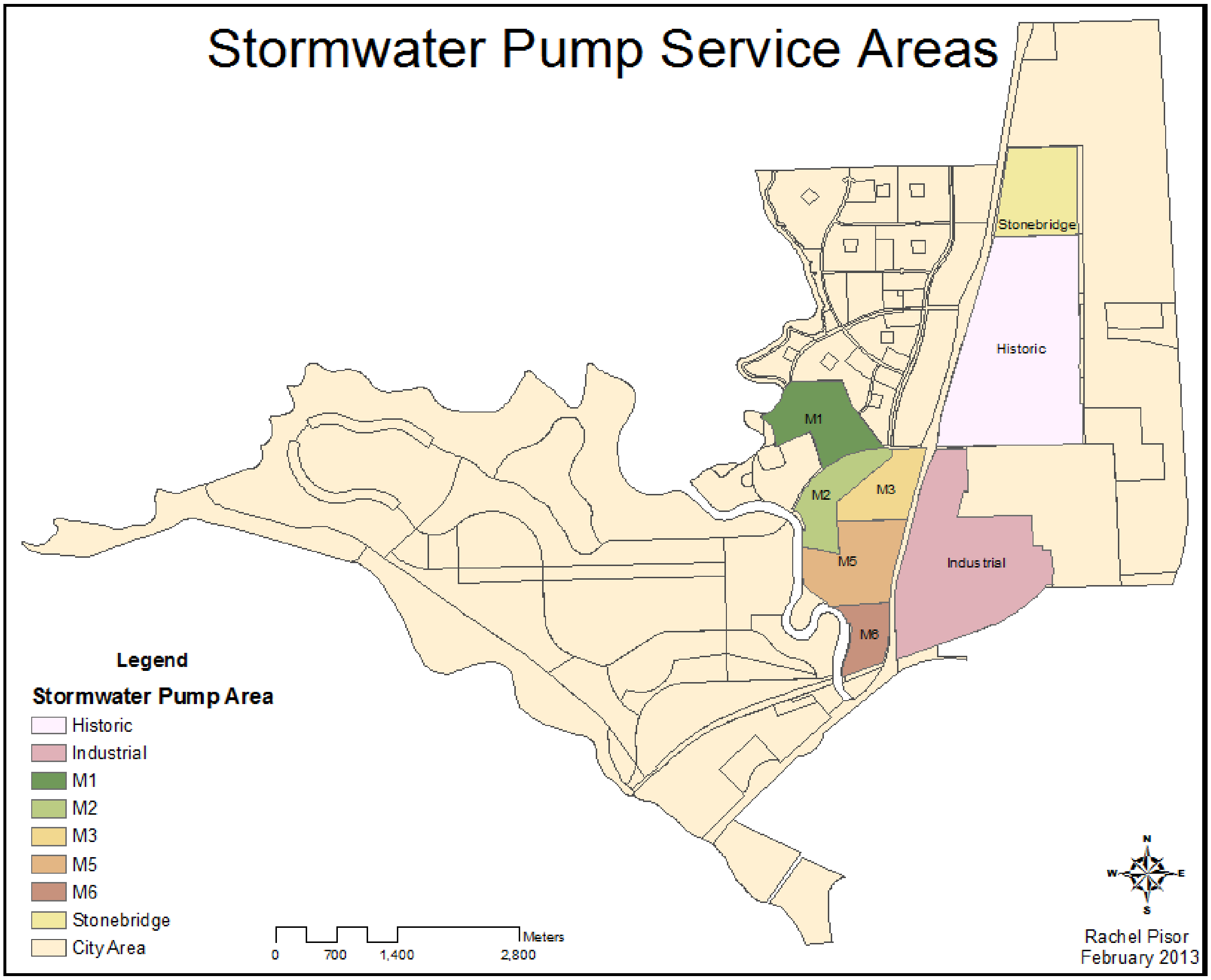
Discharges into the San Joaquin River from the City of Lathrop

Discharges from Lathrop come primarily from the storm water pumping stations. Wastewater for the city is handled by its recycled water plant or by Manteca's waste water treatment plant (WWTP). The recycling plant handles the wastewater from the areas west of I-5 and south of Louise Avenue and is recycled to be used on agricultural crops. Discharges from Manteca's WWTP are discharged upstream of the study area. In the areas of the city where there is no storm sewer, storm water infiltrates into the groundwater or is managed through detention basins. There is very little direct runoff from the City to the SJR that is not conveyed trhough the storm water system. This would be the runoff that comes from the levees into the River.

Lathrop's storm water pumping stations pump runoff from the city into the San Joaquin River for flood protection. The pumps are programmed to turn on when certain set levels are reached. (As an example, if the level of water in the well reaches 5 feet, the pump would turn on and discharge into the river.) The nuisance pumps discharge at a low flow, and if flows become too high for this pump to accommodate, the larger pumps turn on to discharge a larger volume of water. These larger pumps rarely turn on during the dry season and are primarily used during major storm events.

Although the city uses storm water pumps to accommodate storm water, there are differences depending on the region of the city. The Mossdale region is an area of recent and ongoing development that is primarily residential, with some commercial uses. This region does not have any detention basins, but uses five different pumping stations to pump storm water into the San Joaquin River. These stations are M1, M2, M3, M5, and M6. The M1 station serves 190 acres, M2 serves 139 acres, M3 serves 132 acres, M5 serves 217 acres, and M6 serves 88 acres. The Historic region represents the original town of Lathrop, and has no in-ground storm sewer. Storm water in this area is handled through several detention basins. Water is funneled to the Louise pumping station, where it pumps water to the Historic pumping station which then discharges into the San Joaquin River. The total area served by the Historic station is approximately 793 acres and is primarily residential, with some commercial uses. The Stonebridge region is a residential area of recent development and has a detention basin and a pump station. The pumping station serves an area of 217 acres, which may be expanded in the future. The Industrial region has a detention basin and a pump station. However, not all of the Industrial region is served by the detention basin and pump station; some of the industries in this region deal with storm water through percolation ponds and evaporation. The area served by the storm water pumping station is primarily industrial and commercial, and encompasses 626 acres. Much of the existing open space areas in Lathrop that are anticipating development do not currently have a storm drain system in place (Figure 4-2). As development continues, existing storm water stations may accommodate more area and additional storm water pumping stations may come online.

Figure 4-2. Areas Served by Each Pumping Station



Climate and Weather Patterns

The San Joaquin Valley climate is Mediterranean, characterized by cool, mild winters, and hot, dry summers. Typically, very little rainfall occurs between the months of May and October, with most rain falling between November and April. There is also a climate trend of decreasing precipitation from north to south. Lathrop has an average annual precipitation of approximately 14 inches, as compared to the San Francisco Bay area (to the west) which receives about 20 inches annually, and to the Sacramento Valley (to the north) which receives 15 inches annually. Lathrop lies within the San Joaquin Valley which receives about 8 inches annually (WRCC, 2012, weatherDB, 2014). Due to precipitation trends in space and time, sampling was concentrated during the winter months and precipitation forecasts were heavily relied upon to determine when to sample.

Hydrologic Data Results

Throughout this study, precipitation and flow data were collected alongside water quality samples. Sampling was conducted based on the water year which starts on October 1 and ends on September 30. Throughout this report the term "season" refers to the water year in which samples were collected. Season one was from October 1, 2009 through September 30, 2010; season two was from October 1, 2010 through September 30, 2011; and season three was from October 1, 2011 through September 30, 2012. Season one was classified as an "above normal" water year, and was preceded by a "below normal" water year and two "critical" water years. Season two was classified as "wet", and season three was classified as a "dry" water year (Table 4-1). Weather forecasts were used to determine if a storm was large enough to sample and precipitation gauges were used to collect that data. Due to the lack of reliable weather forecasts, not all storms were captured. In the third season of the study, additional measures were taken to ensure capture of storm events. This included setting up for a storm event, although the forecasted precipitation was well below the 0.5 inches threshold. Two Rainwise precipitation gauges were installed; one at the Stonebridge station, and the other at the Historic station. The purpose for having the 2 gauges was to catch any regional differences in rainfall. The rain gauges were tipping bucket style gauges, each equipped with a datalogger that recorded precipitation data every minute throughout the study period (Figures 3-3 and 3-4). Precipitation during sampled storm events ranged from 0.36 inches to 0.98 inches. The average precipitation was 0.70 inches and the median was 0.74 inches (Table 4-2, Figure 4-3). Some of the data was not available from the rain gauge installed at Stonebridge due to errors with the battery or clogging of the rain gauge.

Flow data was necessary to calculate loads for select water quality constituents. Flow of the San Joaquin River was taken from the California Data Exchange Center at the Mossdale station (http://cdec.water.ca.gov/). This station is just upstream from the site where samples were collected from the San Joaquin River in this study. Due to the tidal nature of the San Joaquin River, there was a range of flows during the course of each storm (Table 4-2) from 12 cubic feet per second (cfs) to 15,700 cfs during the sampled storm events. These flows were well within the normal range of flows seen on the San Joaquin River (see Figure 4-4 for historical San Joaquin River flows at the San Joaquin River at Vernalis station, a nearby station upstream of the Lathrop study site).

It was not possible to measure flow volumes from the storm water pumping stations directly. Therefore, flow was approximated through the data records of volume of water discharged by the pumps during storm events. Reports of calculated flow data was received from MCC Control Systems. During some storm events, there were complications with the SCADA system. The SCADA system controls the pumps to turn on and off, and records the discharge data.When there were errors with the SCADA system, the pump data was lost. There were also times when a pump did not discharge. For example, the Stonebridge results are not shown because this station did not discharge for the duration of the study. Table 4-3 shows approximations of flow from the pump records.

Flow for the pump stations is broken down into gallons discharged per storm. This is a more appropriate metric because of the inconsistent flow of the discharge from the pumps throughout a storm event. The pumps will turn on when needed to discharge and may only discharge for a few hours during the storm before turning off, or they will turn on for a few minutes frequently throughout the storm. Results of the pump records show that the Industrial and Historic stations were the largest dischargers of all the pump stations. These are also the stations that serve the largest areas, as compared to the Mossdale and Stonebridge station areas. The number of gallons discharged during storm events by the Industrial station had a mean of 3.0 million gallons and a median of 2.9 million gallons. The Historic station discharged slightly fewer gallons with a mean of 2.0 million gallons, and a median of 2.2 million gallons. The M2 station also had a comparable amount of discharge with a mean of 2.0 million gallons and a median of 1.8 million gallons. The M6 station had the lowest amount of discharge for all stations with an average of 208,400 gallons and a median of 199,500 gallons. The widest range of flows was at the Industrial station with a range from 3,477 gallons to 6.39 million gallons. The summary statistics for all stations are shown in Table 4-4.

Table 4-1. Water Year Classification for the San Joaquin River Basin

Water Year	San Joaquin Basin
1990	Critical
1991	Critical
1992	Critical
1993	Wet
1994	Critical
1995	Wet
1996	Wet
1997	Wet
1998	Wet
1999	Above Normal
2000	Above Normal
2001	Dry
2002	Dry
2003	Below Normal
2004	Dry
2005	Wet
2006	Wet
2007	Critical
2008	Critical
2009	Below Normal
2010 (season 1)	Above Normal
2011 (season 2)	Wet
2012 (season 3)	Dry
2013	Critical

Table 4-2. Precipitation and Flows during Sampling Events

	Date of Storm	Stonebridge Rain Gauge (in.)*	Historic Rain Gauge (in.)*	Range of San Joaquin River Flows at Mossdale (cfs)
Season1	10/13/2009	1.75	1.96	12-2,111
	12/11-12/13/2009	0.79	0.87	-515-2,555
	1/17-1/21/2010	1.73	1.82	-484-3,894
Season 2	11/7/-11/8/2010	N.A.+	0.49	410-3,020
	11/20-11/21/2010	N.A.+	0.95	368-2,460
	12/18-12/19/2010	0.97	0.91	5,050-6,770
	3/19-3/20/2011	0.60	0.74	7,980-1,080++
	3/24-3/25/2011	0.74	0.72	14,300-15,700
	6/4-6/5/2011	N.A.+	0.34	10,500-11,900++
Season 3	10/4-10/6/2011	0.78	0.76	5,050-5,470
	1/19-1/21/2012	0.98	0.90	818-2,620
	3/16-3/17/2012	0.68	0.67	574-2,650
	3/24-3/25/2012	0.39	0.36	1,610-2,490

Note: negative flows indicate a reversal of direction (flood tide)
*rain gauges located at the sampling sites shown in Figure 3-2
+rain gauge data was not available (N.A.)
++some of the data in this range was estimated

Figure 4-3. Precipitation and Sample Dates

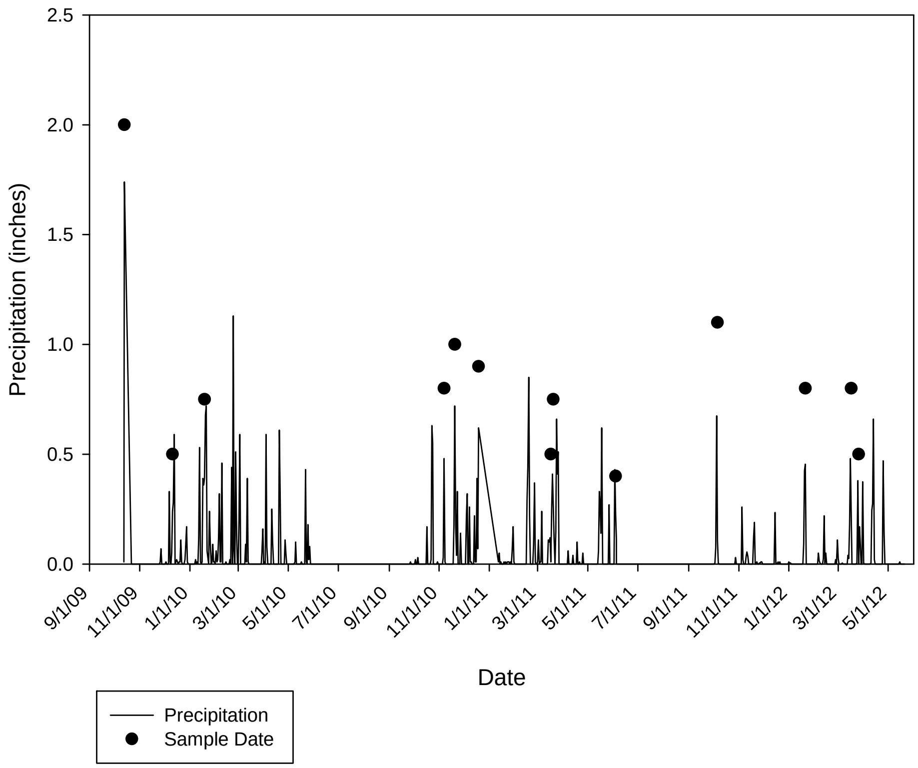


Figure 4-4. Historical Flows at the San Joaquin River at Vernalis

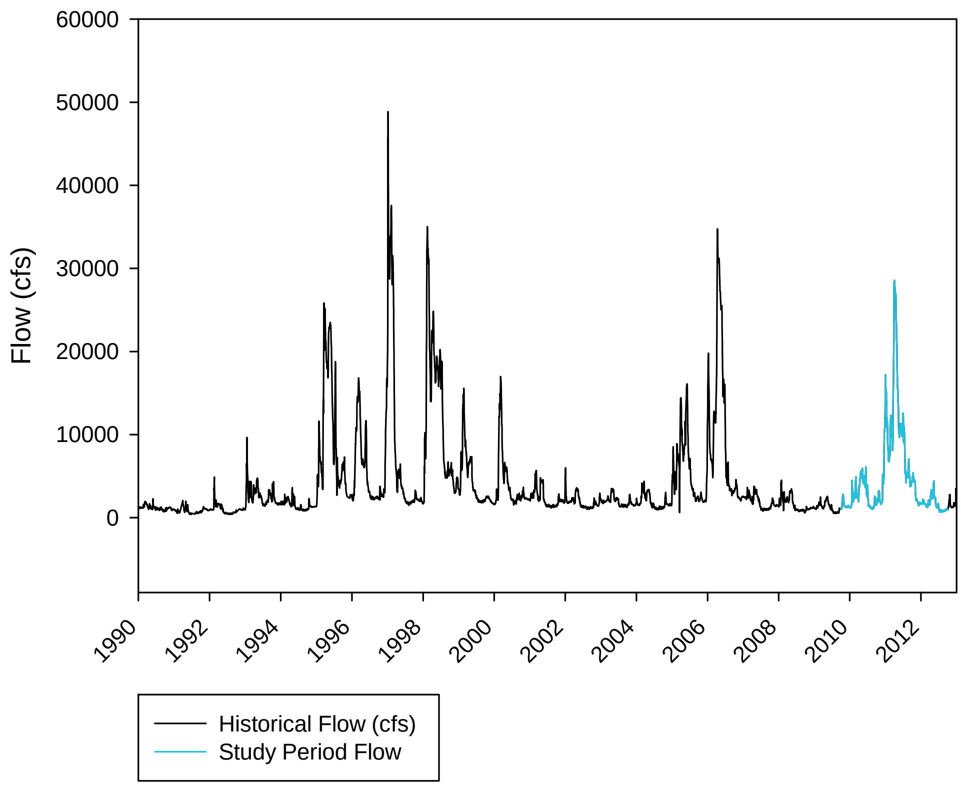


Table 4-3. Approximations of Flow from Pump Records (in gallons discharged per event)

	Pump Station						
Date	**M1**	**M2**	**M3**	**M5**	**M6**	**Historic**	**Industrial**
11/7/2010	723,000	724,000	374,000	N/A	107,000	840,000	2,153,000
11/20/2010	1,922,000	2,119,000	873,000	646,000	197,000	3,347,000	4,463,000
12/17/2010	742,000	1,976,000	729,000	N/A	226,000	1,950,000	3,816,000
3/19/2011	849,000	1,888,000	897,000	N/A	259,000	3,110,000	N/A
3/24/2011	3,287,000	6,375,000	1,331,000	N/A	417,000	1,680,000	N/A
6/3/2011	0	626,000	641,000	0	251,000	2,332,000	1,718,000
10/4/2011	2,622,000	1,844,000	885,000	265,000	177,000	2,552,000	6,096,000
1/19/2012	835,000	1,126,000	2,851,000	1,110,000	202,000	2,295,000	6,393,000
3/16/2012	1,070,000	1,237,000	668,000	376,000	186,000	2,216,000	3,477
3/24/2012	192,000	2,297,000	217,000	195,000	62,000	486,000	91,000

Note: N/A refers to lost pump data due to error with the SCADA. A “0” denotes the pump did not discharge during a storm event.

Table 4-4. Summary Statistics for Flow Calculations (in gallons discharged)

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	10	1,224,200	842,000	0	3,287,000	1,057,237.7
M2	10	2,021,200	1,866,000	626,000	6,375,000	1,637,683.1
M3	10	946,600	801,000	217,000	2,851,000	735,203.7
M5	6	432,000	320,500	0	1,110,000	394,790.6
M6	10	208,400	199,500	62,000	417,000	95,202.9
Historic	10	2,080,800	2,255,500	486,000	3,347,000	898,920.8
Industrial	8	3,091,685	2,984,500	3,477	6,393,000	2,496,826.7

Summary

Lathrop’s hydrological system is highly managed due to flat geography of the area and the way that Lathrop manages its storm water. Therefore, the study focused on Lathrop’s city boundaries rather than the applicable watershed boundaries. The climate of the study area is Mediterranean and tends to be dry with only about 14 inches of precipitation per year. During the study, the water year classification for the San Joaquin Basin ranged from “dry” to “wet.” Precipitation data and flow, or approximations of flow, were collected. The sampled storm events ranged from 0.34 inches to 1.86 inches of precipitation. Flows on the San Joaquin River during storm events ranged from -595 cfs to 15,700 cfs. The volume discharged from individual pump stations during storm events ranged from no discharge to 6.39 million gallons.

Chapter 5. Water Quality

Introduction

The California Department of Water Resources (DWR) Municipal Water Quality Investigations (MWQI) Program began investigating storm water discharges from Lathrop in the fall of 2009. The site was chosen for its location in the south Delta and for its relatively simple hydrology. Drinking water quality constituents of concern, as well as a few ecological water quality constituents, such as pyrethroid pesticides, were monitored for 3 water years (October 2009-September 2012).

This chapter focuses on the water quality results primarily for seasons two and three. The method used to program and collect samples from autosamplers changed between season one and two; therefore, season one is not comparable to seasons two and three. The method of collection for pathogen samples did not change throughout the study. As a result, this chapter presents the water quality results for pathogens from seasons one through three, and for all other constituents from seasons two and three. Prelimary study results for season one are available in Appendix A.

Constituents of Concern

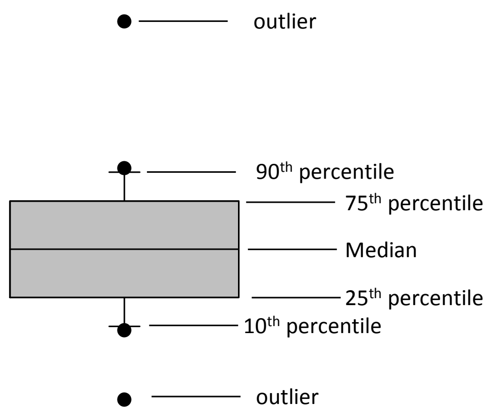
This report focuses primarily on drinking water quality constituents of concern and secondarily on ecological constituents of concern. The constituents covered in this chapter are:

- Total and dissolved organic carbon
- Turbidity
- Total suspended and dissolved solids
- Total trihalomethane formation potential
- Haloacetic acid formation potential
- Absorbance
- Minerals
- Nutrients
- Salinity
- Pyrethroid pesticides
- Pathogens

Statistical Analysis

All statistical analyses were conducted using the statistical software Minitab 16. Summary statistics for each station were calculated in Microsoft Excel. These statistics include the number of samples, mean, median, minimum, maximum and standard deviation. Box plots are also shown for a graphical depiction of the summary statistics. See Figure 5-1 for an explanation of the boxplots. Statistical analyses conducted in Minitab include regression analysis and the Mann-Whitney test. A regression analysis explains the relationship between two constituents. A high r^2 indicates that there is a strong relationship. The p-value associated with the regression explains how significant the relationship is (a p-value less than 0.05 is considered significant). The Mann-Whitney test is a non-parametric test of the equality of two populations. Similar to regression analysis, a low p-value indicates that the populations being tested are not equivalent.

Figure 5-1. Definition of a Box Plot



Analysis of Loads

Load calculations were calculated for nutrients, bromide and organic carbon. Loads are a function of flow and concentration. They can be computed as the integral of the instantaneous discharge multiplied by the concentration for a defined time period (dt):

$$L = \int_0^t K \cdot Q_t \cdot C_t \, dt$$

Where L is load for interval 0 to t, K is a unit conversion factor, Q_t is the instantaneous discharge, C_t is instantaneous concentration (Coats, 2002). Because the data collected from the pumping stations is not in real time for all flows and concentrations, loads were computed as the product of the total flow and the average concentration for a defined time period:

$$L_{0-t} = \overline{Q}_{0-t} \cdot \overline{C}_{0-t}$$

Where L_{0-t} is load from time interval 0 to t, $\overline{Q}_{0-t}$ is the total flow from 0 to t and $\overline{C}_{0-t}$ is the average concentration from 0 to t.

At the San Joaquin River at Mossdale station, only one grab sample was collected during each storm and could therefore not be computed using averages. For this station, load was computed as an instantaneous load at time (t):

$$L_t = Q_{0-t} \cdot C_t$$

Where L_t is the load at time t, Q_{0-t} is the median flow from 0 to t and C_t is the concentration at time t.

For this study, the flow for the load calculations came from pump data collected from the storm water pumps. These pumps operate sporadically, turning on when a certain level of water in the well is reached, and turning off when the water drops below that level. Because this flow rate is not constant, the load is calculated as the gallons of water pumped over the course of the storm multiplied by the concentration of the composite sample. The flow used to calculate the load on the San Joaquin River was the median flow for the whole storm. This flow was multiplied by the concentration of the grab sample taken at the San Joaquin River at Mossdale. To ensure comparability between the pumping station load and the San Joaquin River load, the San Joaquin River load was then multiplied by a conversion factor to approximate the total load discharged from the river during the storm.

Organic Carbon

Organic carbon present in an aquatic system is composed of particulate and dissolved materials from plant, animal, and bacterial sources, in varying stages of degradation. Although organic carbon is a necessary part of the aquatic food chain, it can be of concern for drinking water quality due to its ability to form DBPs when treated with disinfectants in the drinking water treatment process.

Organic carbon is composed of a multitude of compounds which fall into 2 categories: humic and non-humic substances. Humic substances are high molecular weight compounds, formed through plant decomposition, largely from bacterial and fungal activity and are primarily humic and fulvic acids with lignin, cutin, and tannin. Humic substances are highly chemically reactive, yet do not biodegrade readily (IHSS, 2007). It is the humic component of organic carbon that is most reactive with disinfectants to form DBPs. The non-humic portion includes proteins, carbohydrates, and other small molecular weight molecules. Non-humic substances are more readily broken down by bacteria than humic substances.

Organic carbon on its own does not directly pose a drinking water quality problem, and is not regulated. However, it causes health concerns in drinking water when it reacts with disinfectants to form DBPs such as trihalomethanes (THMs) and haloacetic acids (HAAs) (Fleck et al., 2004). Eleven of the DBPs are regulated due to their properties as human carcinogens and agents of adverse reproductive or developmental effects (EPA, 2001; Demarini, 2008). Currently, there are no maximum contaminant levels (MCLs) for organic carbon; however, there are requirements for drinking water treatment plant operators to remove total organic carbon (TOC) based on the TOC concentration and alkalinity concentrations in the water (EPA, 2001) (Table 5-1).

While many DBPs have been identified, only a few are currently regulated. Concern over potential health effects of total trihalomethanes (TTHMs) and five haloacetic acids (HAA5) has resulted in federal and state drinking water regulations controlling their presence in treated drinking water. The Stage 1 Disinfectants and Disinfection Byproducts (D/DBP) Rule reduced the TTHM maximum contaminant level from 0.10 mg/L to 0.080 mg/L and established an MCL for HAA5 of 0.060 mg/L (EPA, 2001b). In addition, this rule established treatment requirements based on the concentrations of organic carbon and the levels of alkalinity in source waters, as shown in Table 5-1. The Stage 2 D/DBP rule requires that the MCLs be met at all monitoring sites throughout the distribution system (EPA, 2005). Additionally, the California Department of Public Health (CDPH) is currently drafting a public health goal for TTHMs (OEHHA, 2010).

Table 5-1. Required Percent Removal of TOC

TOC (mg/L)	Alkalinity (mg/L as $CaCO_3$)		
	0-60	>60-120	>120
>2.0-4.0	35%	25%	15%
>4.0-8.0	45%	35%	25%
>8.0	50%	40%	30%

Organic Carbon Concentrations

Analysis of Seasons Two and Three

TOC and dissolved organic carbon (DOC) were collected during storm events throughout both years. TOC concentrations at the San Joaquin River at Mossdale were significantly lower than those from the city pumping stations (p-value<0.001, Mann-Whitney). Median TOC concentration during the 2 year period for the San Joaquin River at Mossdale was 3.4 mg/L (Table 5-2). The medians of the pumping stations ranged from 5.4 mg/L at M6 to 11.6 mg/L at the Historic station. The concentrations at the San Joaquin River at Mossdale ranged from 1.8 mg/L to 5.4 mg/L, whereas the concentrations for the city pumping stations ranged from 2.8 mg/L to 21.3 mg/L. The results for the city pumping stations showed that the Industrial station and M1 station had lower concentrations of organic carbon, although the San Joaquin River at Mossdale had the lowest concentrations overall (Figure 5-2).

For DOC, the concentrations at the San Joaquin River at Mossdale were also statistically lower than the concentrations from the city pumping stations for both years (p-value< 0.001, Mann-Whitney). The medians of the pumping stations ranged from 3.9 mg/L to 10.1 mg/L, and the median at the San Joaquin River at Mossdale was 3.2 mg/L (Table 5-3). The patterns for DOC were very similar to TOC, in which the Industrial and M1 stations had generally lower concentrations for the city pumping stations, and the lowest concentrations overall was at the San Joaquin River at Mossdale (Figures 5-2 and 5-3).

Table 5-2. Summary Statistics of TOC (in mg/L) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	6.2	5.8	4	8.4	1.9
M2	10	9.8	8.0	3.6	20.3	5.9
M3	9	8.3	6.8	2.9	21.3	5.8
M5	4	8.0	6.0	5.4	14.4	4.3
M6	9	6.1	5.4	2.8	11.5	2.8
Historic	9	11.5	11.6	4	19.4	4.9
Industrial	7	6.4	6.3	4.7	8.3	1.2
SJR at Mossdale	10	3.6	3.4	1.8	5.4	1.3

Figure 5-2. Boxplot of TOC for Seasons Two and Three

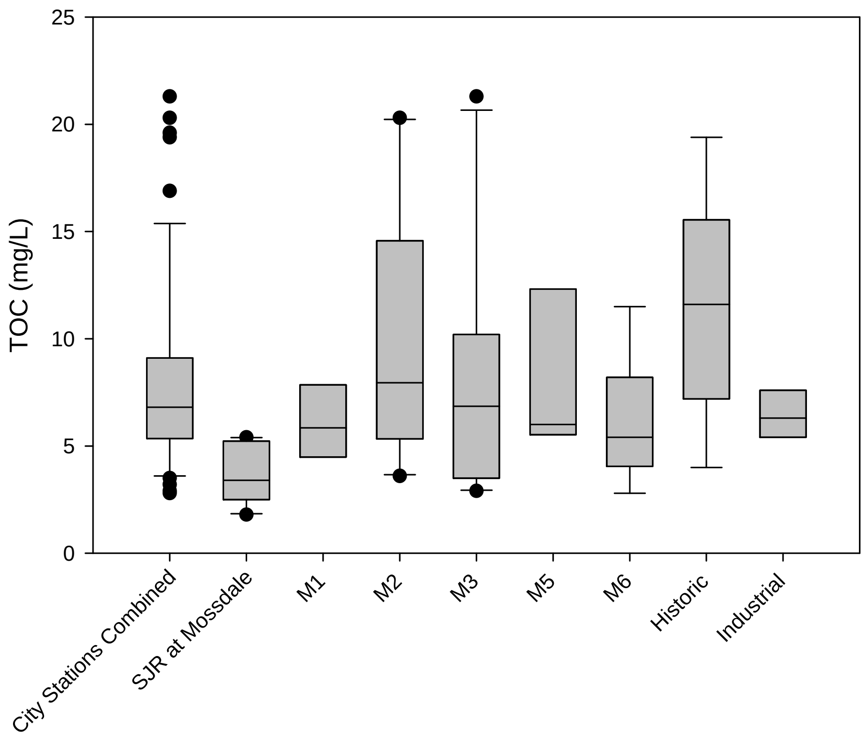
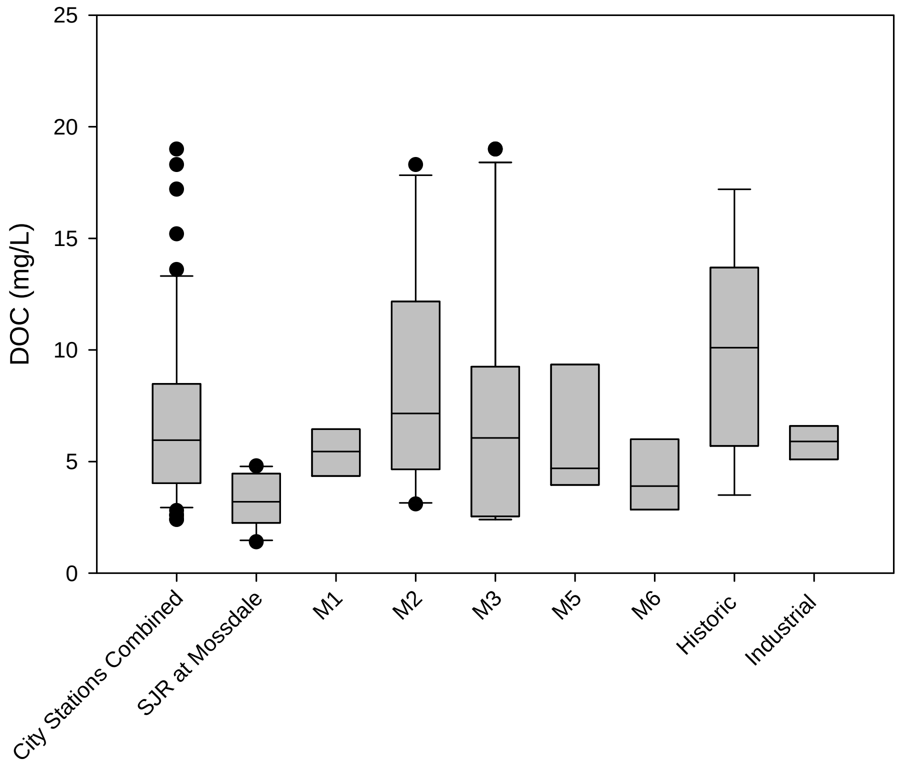


Table 5-3. Summary Statistics of DOC (in mg/L) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	5.6	5.5	3.4	8.1	1.4
M2	10	8.5	7.2	3.1	18.3	4.8
M3	10	7.1	6.0	2.4	19.0	5.2
M5	4	6.9	5.1	4.1	13.2	4.2
M6	8	4.9	3.9	2.6	11.1	2.8
Historic	9	9.9	10.1	3.5	17.2	4.6
Industrial	7	5.8	5.9	4.0	7.5	1.1
SJR at Mossdale	10	3.2	3.2	1.4	4.8	1.1

Figure 5-3. Boxplot of DOC for Seasons Two and Three



Comparison between Seasons Two and Three

For both seasons, the TOC concentrations on the San Joaquin River at Mossdale were significantly lower than those of the city pumping stations with a p-value of 0.004 for season two, and a p-value of 0.001 for season three. These differences in p-values are likely due to the limited number of samples collected during each year. The TOC patterns looked very similar between seasons (Figures 5-4 and 5-5). The San Joaquin River at Mossdale had the lowest concentrations although there was a wider range of concentrations during season three (Tables 5-4 and 5-5). Of the city pumping stations, M1 and the Industrial station had generally lower concentrations. There was much variability in concentrations higher than the Mossdale residential region. The Historic station and M2 tended to have higher concentrations, and the M3 concentrations shifted slightly higher from season two to three. In season two, the range was 2.9 mg/L to 15.0 mg/L, whereas in season three it was 5.9 mg/L to 21.3 mg/L (Tables 5-4 and 5-5).

The patterns between seasons two and three were less similar for DOC than TOC. For seasons two and three, the DOC concentrations on the San Joaquin River at Mossdale were significantly lower than the concentrations from the city pumping stations with a p-value of 0.012 for season two, and a p-value of 0.002 for season three. The San Joaquin River at Mossdale DOC concentrations were lower than the city pumping stations throughout seasons two and three, although the range was a little wider in season three (Tables 5-6 and 5-7). The patterns for the M1 and Industrial stations were similar, although the ranges differed slightly between years (Figures 5-6 and 5-7). The greatest differences were recorded at the M2, M3, and M6 stations. During season three, the ranges for these stations increased, as did the maximum concentrations (Tables 5-6 and 5-7).

Figure 5-4. Boxplot of TOC for Season Two

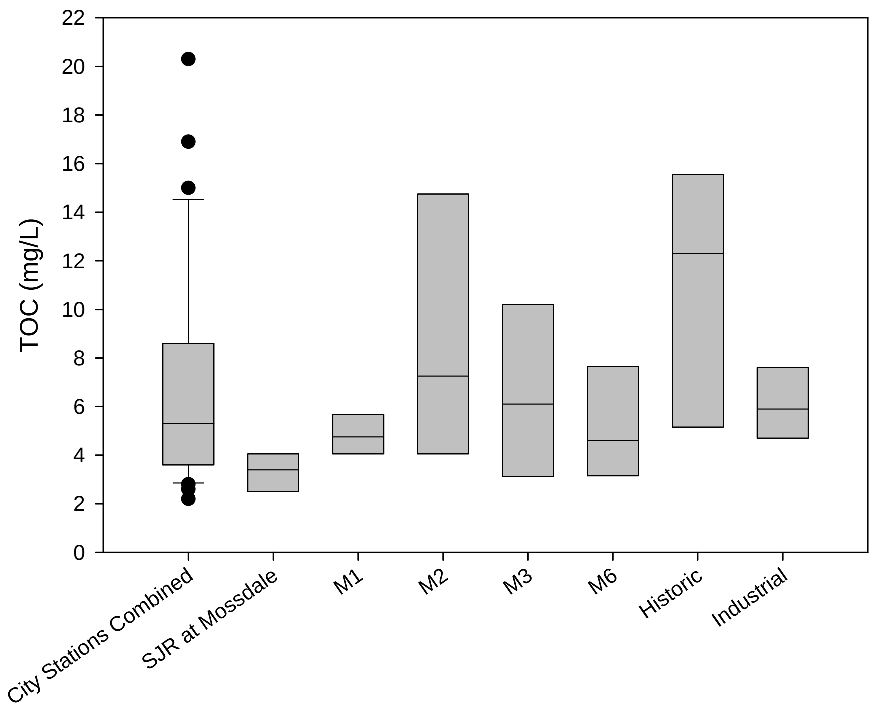


Figure 5-5. Boxplot of TOC for Season Three

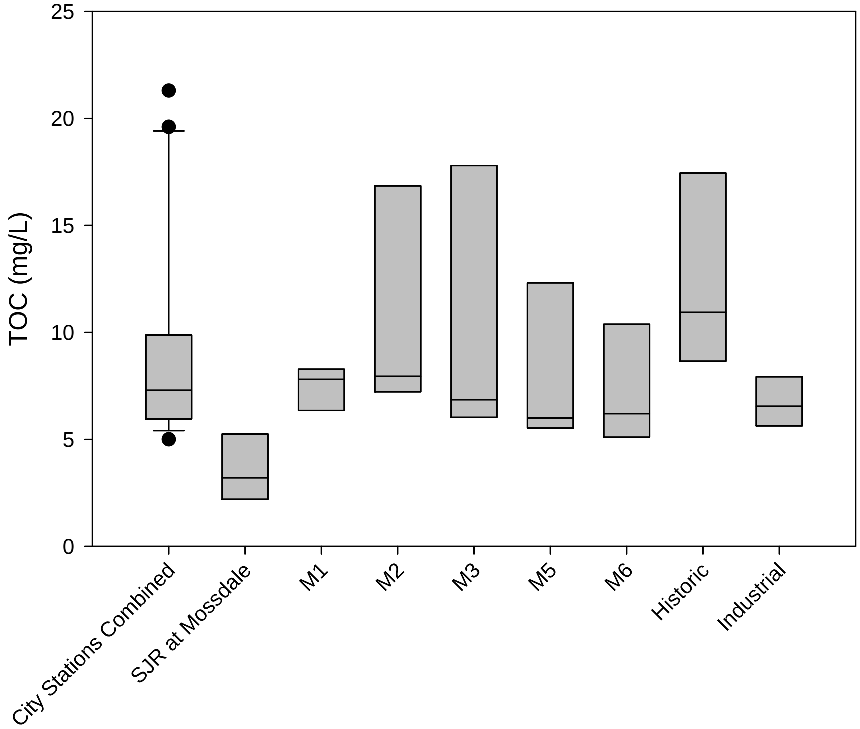


Table 5-4. Summary Statistics of TOC (in mg/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	4.8	4.8	4.0	5.8	0.9
M2	6	9.3	7.3	3.6	20.3	6.4
M3	6	7.0	6.1	2.9	15.0	4.7
M6	5	5.2	4.6	2.8	9.4	2.6
Historic	5	10.7	12.3	4.0	16.9	5.4
Industrial	3	6.1	5.9	4.7	7.6	1.4
SJR at Mossdale	6	3.4	3.4	2.2	5.4	1.1

Table 5-5. Summary Statistics of TOC (in mg/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	7.5	7.8	5.9	8.4	1.1
M2	4	10.7	8.0	7.2	19.6	6
M3	4	10.2	6.9	5.9	21.3	7.4
M5	4	8.0	6.0	5.4	14.4	4.3
M6	3	7.2	6.2	5.0	11.5	3
Historic	4	12.4	11.0	8.1	19.4	5
Industrial	4	6.7	6.6	5.4	8.3	1.2
SJR at Mossdale	4	3.9	4.2	1.8	5.3	1.7

Table 5-6. Summary Statistics of DOC (in mg/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	4.5	4.6	3.4	5.4	0.9
M2	6	7.6	6.9	3.1	13.6	4.4
M3	6	5.8	4.6	2.4	13.0	4.2
M6	5	3.7	3.0	2.6	6.1	1.4
Historic	5	9.2	11.2	3.5	15.2	5.2
Industrial	3	5.7	5.7	4.0	7.5	1.8
SJR at Mossdale	6	3.2	3.2	2.1	4.8	1.0

Table 5-7. Summary Statistics of DOC (in mg/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	6.6	6.4	5.5	8.1	1.1
M2	4	9.7	7.2	6.2	18.3	5.8
M3	4	9.1	6.0	5.2	19.0	6.6
M5	4	6.9	5.1	4.1	13.2	4.3
M6	3	6.9	5.7	3.8	11.1	3.8
Historic	4	10.9	9.4	7.5	17.2	4.4
Industrial	4	5.9	6.0	5.1	6.6	0.6
SJR at Mossdale	4	3.4	3.8	1.4	4.6	1.5

Figure 5-6. Boxplot of DOC for Season Two

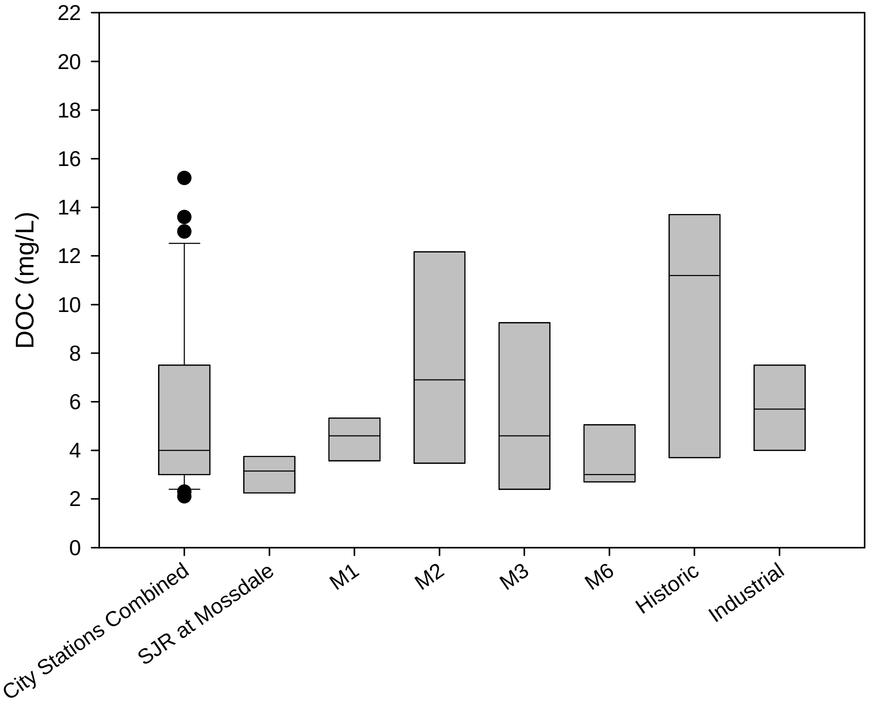
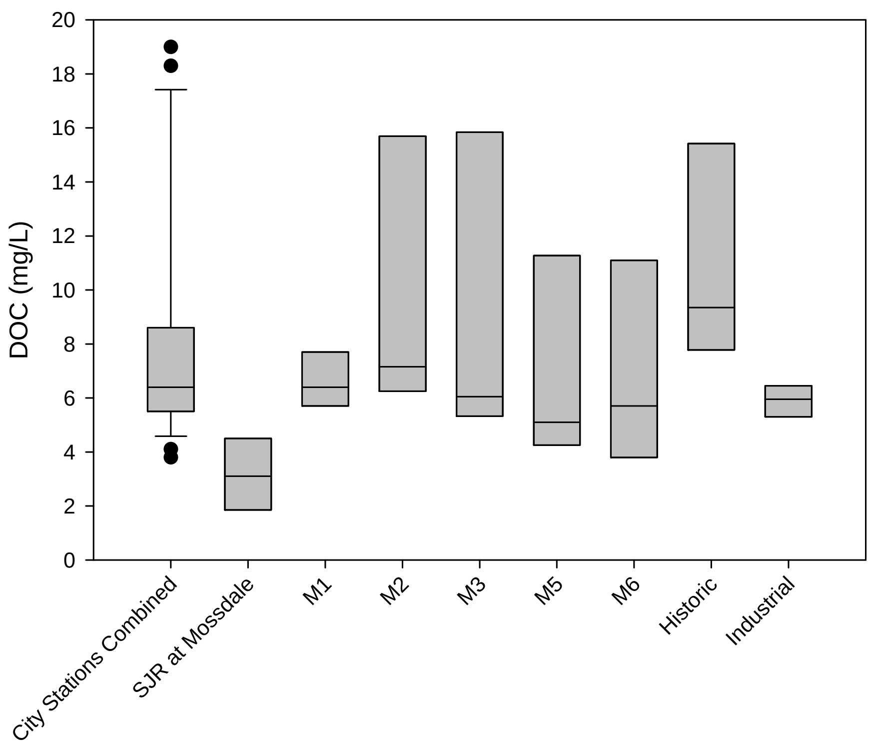


Figure 5-7. Boxplot of DOC for Season Three



Trends

In both years for TOC and DOC, the trend over the wet season showed high concentrations in storm water during the fall, with decreasing concentrations through the spring (Figures 5-8 and 5-9). These high concentrations in the fall are due to first flush events. In October 2010, the first major storm of the season (season two) was not captured due to problems with weather forecasts. However, Lathrop's storm water pumps did not pump very much during that storm. The city typically increases the level of water required for the pumps to activate during the summer so that energy is not wasted on nuisance water from irrigation runoff, pool drainages, etc. The city did not lower the pump activation levels until after this storm. The next major storm event was on November 7, and showed the pattern of a first flush event with a median TOC concentration from the city pumping stations of 16.0 mg/L. During the following fall (season three), the first major storm of the season was captured, and the median TOC concentration of the city pumping stations was 14.4 mg/L. Organic carbon concentrations in both of these years had similar patterns after these first flush events in which the median concentrations of the city pumping stations gradually decreased over the season with successive storms. This is an indication of a reservoir of organic carbon that builds up during the dry season. It is continuously washed into the system during the storms of the wet season, and builds up again during the dry season. During the storm event of June 2011, the process of organic carbon building up was already beginning. The median TOC concentration of the city pumping stations was 8.6 mg/L. The increasing concentrations and the build-up of organic carbon over the summer of 2011 resulted in the high concentrations that were seen in the first flush event on October 8, 2011.

Figure 5-8. Trends for TOC for Seasons Two and Three

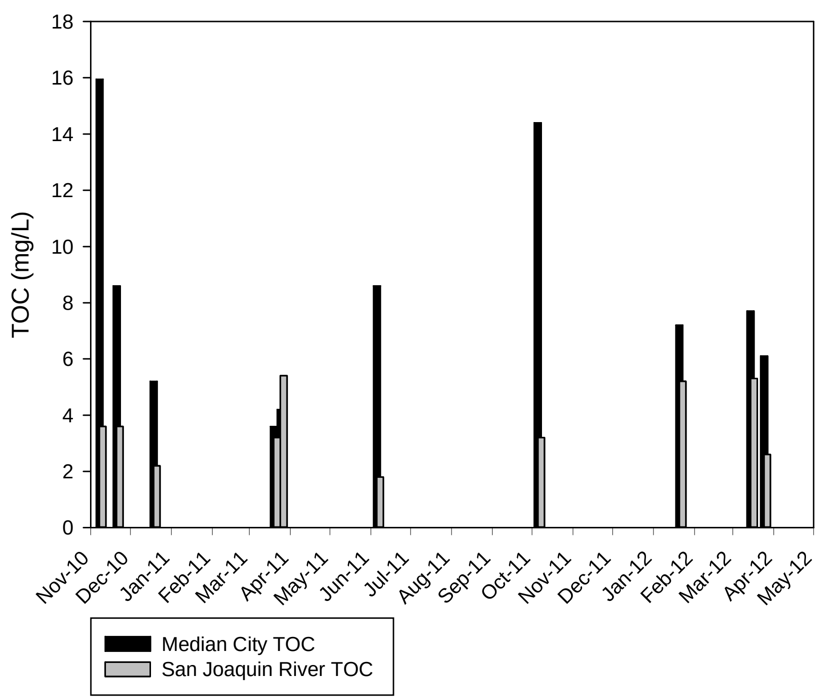
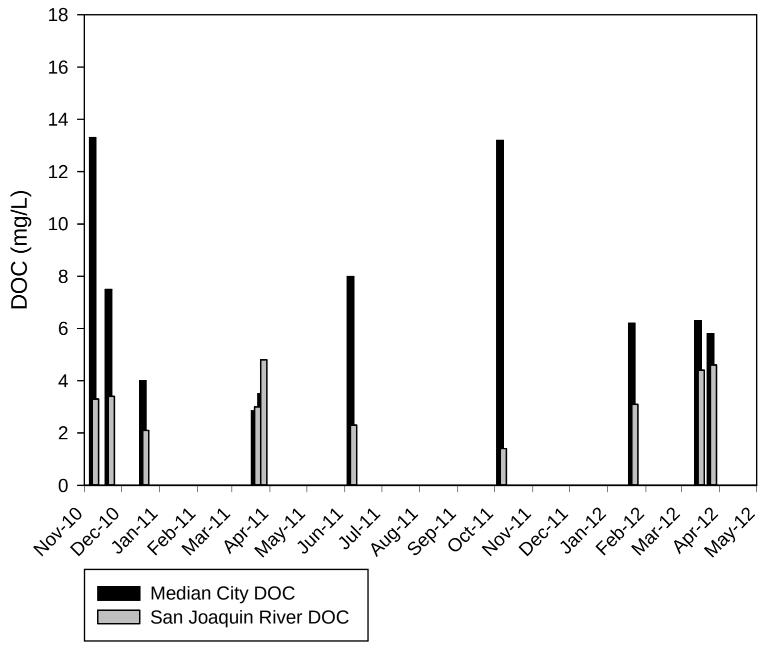


Figure 5-9. Trends for DOC for Seasons Two and Three



Organic Carbon Composition

Differences in organic carbon composition, measured as the fraction of TOC that was made up of DOC, were seen between the San Joaquin River and the city pumping stations, and between years (Table 5-8). In season two, the average percentage for all stations was 86% with a median of 88%.The percentage on the San Joaquin River was 92% with a median of 93%. The percentage for the city pumping stations was 84% with a median of 86%. These differences indicate that there was a difference in the organic carbon composition between the San Joaquin River and the city pumping stations. These differences were not seen in season three. In season three, the average percentage for all stations was 88% with a median of 88%. On the San Joaquin River, the average was 86% with a median of 86%. In the city pumping stations, the average was 87% and the median was 88%.

Table 5-8. Percentage of Total Organic Carbon Composed of Dissolved Organic Carbon

	Season Three		
	SJR	**City**	**Combined**
Mean	0.86	0.87	0.88
Median	0.86	0.88	0.88
Maximum	0.97	0.96	0.97
Minimum	0.78	0.76	0.76
	Season Two		
	SJR	**City**	**Combined**
Mean	0.92	0.84	0.86
Median	0.93	0.86	0.88
Maximum	0.95	1.00	1.00
Minimum	0.88	0.56	0.56
	Seasons Two and Three		
	SJR	**City**	**Combined**
Mean	0.90	0.86	0.86
Median	0.89	0.88	0.88
Maximum	0.97	1.00	1.00
Minimum	0.78	0.56	0.56

Organic Carbon Concentrations and Other Studies

Organic carbon concentrations sampled during this study were comparable to concentrations collected from other studies throughout the state. The TOC concentrations from the San Joaquin River at Mossdale ranged from 1.8 mg/L to 5.4 mg/L, and DOC concentrations ranged from 1.4 mg/L to 4.8 mg/L (Tables 5-2 and 5-3). These concentrations are similar to storm water samples collected on the Sacramento River by the Sacramento Coordinated Monitoring Program (Sacramento CMP) from 2011 to 2012. Concentrations on the Sacramento River for TOC ranged from 3.1 mg/L to 5.8 mg/L, and DOC ranged from 1.6 mg/L to 5.6 mg/L (Sacramento CMP, 2012).

Lathrop's discharge concentrations were also comparable to those of regional studies. Lathrop's median TOC concentration from the pumping stations was 6.8 mg/L, and the DOC median was 6.0 mg/L. The TOC median concentration was a little higher than the median TOC concentration of 4.25 mg/L that was collected by Stockton for the 2010-2011 NPDES annual report (City of Stockton, 2011). Lathrop's median concentrations, while similar, were on the low end when compared to the concentrations analyzed by the Sacramento Stormwater Partnership in the Urban Runoff Sources and Control Evaluation (Geosyntec, 2011; Geosyntec, 2010). The Sacramento Stormwater Partnership analyzed concentrations from four urban drainage areas in the Sacramento region (Strong Ranch Slough, Sump 104, Sump 111, and Natomas Basin). These areas were mixed land uses; Strong Ranch Slough drained 4,446 acres of mixed land uses, Sump 104 drained 867 acres of mostly light industrial land, Sump 111 drained 439 acres of industrial lands, and the Natomas Basin drained 470 acres of residential lands. The median TOC concentrations for these areas ranged from 6.8 mg/L to 11.0 mg/L and DOC medians ranged from 6.1 to 10.4 mg/L.

During the Lathrop study, organic carbon concentrations were higher during first flush events which occurred during the first rain events of each season. The decrease in concentrations over time indicates that there is a reservoir of organic carbon that builds upduring the dry season that is continuously drained during the wet season. The observation was consistent with the Steelhead Creek study's findings (DWR, 2008). The study, conducted in Sacramento, collected organic carbon samples from 1997 to 2006. Lower carbon concentrations (4 mg/L to 6 mg/L) were seen in the summer when the reservoir was building up; concentrations increased to 6 mg/L to 10 mg/L during the first flush and storm events. The highest TOC concentration recorded during a first flush event was 36.6 mg/L. In comparison, Lathrop's discharge concentrations ranged from 1.8 mg/L to 20.3 mg/L. For both studies, concentrations gradually decreased over the wet season as the runoff depleted the reservoir.

The organic carbon concentrations sampled on the San Joaquin River during this study are similar to concentrations observed historically (Figure 5-10). The San Joaquin River's carbon concentrations are typically influenced by agricultural discharge and upstream dam releases. During this study, there were slightly elevated concentrations on the San Joaquin River during the March 2011 storm events. During these events, the concentrations discharged by Lathrop were not particularly high and this resulted in the San Joaquin River having higher concentrations than the median city pumping concentrations. Agricultural discharge is the likely cause for these concentrations on the San Joaquin River. Agricultural discharges add to the amount of organic carbon in the system and typically occur during the months of February through April (DWR, 1994; DWR, 1996; DWR, 2007; Deverel et al., 2007). Alternately, due to the diluting effect of increased discharges from upstream dams, organic carbon concentrations on the San Joaquin River can be reduced. Major releases typically occur in the summer and are lower in the winter. During the study period, the releases were typically low in the rainy season; however, they were slightly elevated during the March 2011 storm event (Figure 5-11). Therefore, it is unlikely that the releases had an effect on the carbon concentrations in the river during the March 2011 storm events.

The organic carbon patterns seen in this study were similar to those of other studies. In the Steelhead Creek study, concentrations were elevated in the early part of the storm season, and especially during first flush events (DWR, 2008). In the Willow Slough study, which focused on an agricultural watershed just west of Sacramento, concentrations of samples taken in 2006 were also found to increase during storm events (Hernes et al., 2008). Studies in Portland, Oregon and Los Angeles, California found that DOC was contributed from urbanized areas, increasing the DOC concentrations in the stream or river water (Hook and Yeakley, 2005; Izbicki et al., 2007).

Figure 5-10. Organic Carbon Concentrations during the Last 10 Years at the San Joaquin River at Vernalis, Downstream of Lathrop

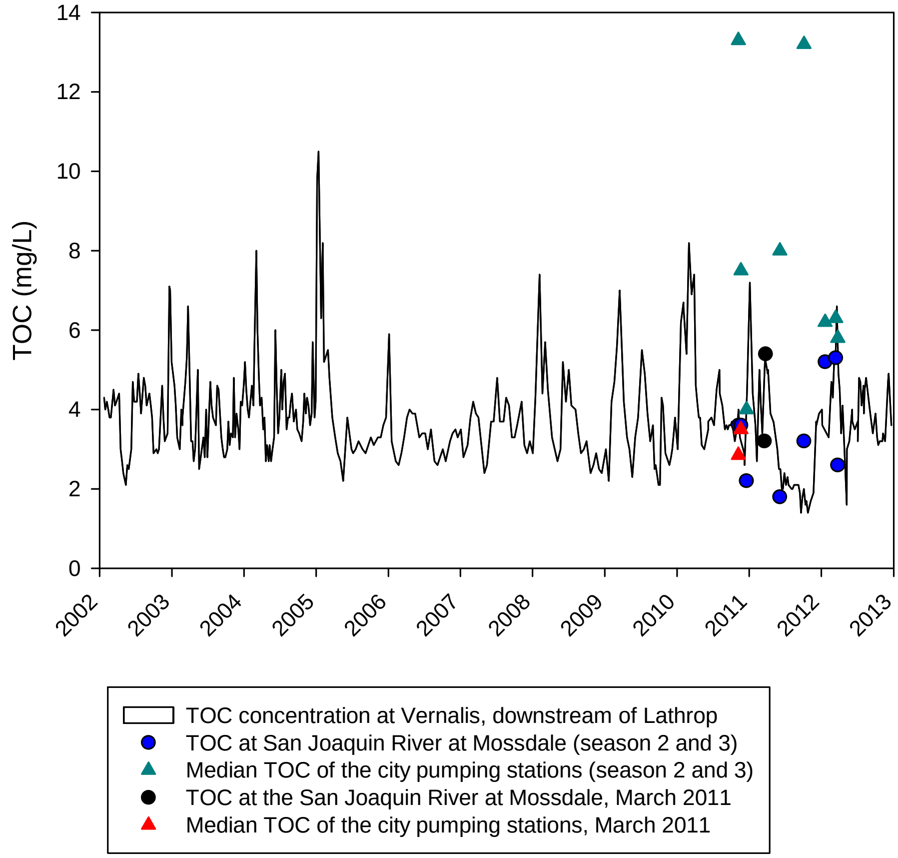
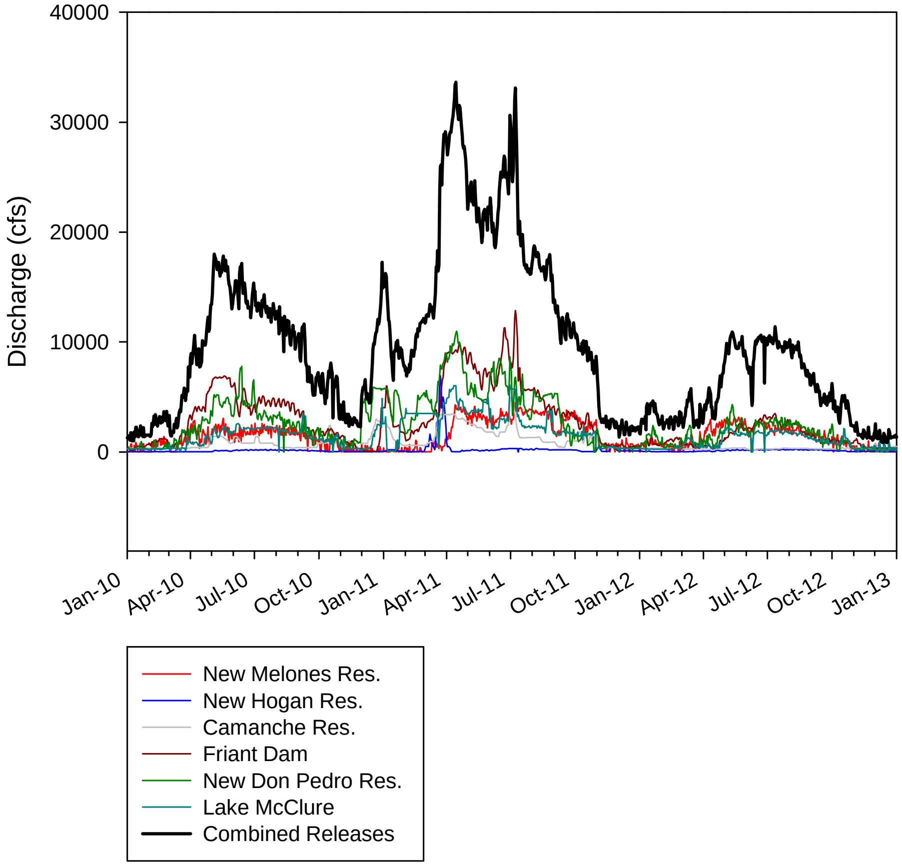


Figure 5-11. Combined Releases from Major Dams into the San Joaquin River Watershed



Organic Carbon Loads

Analysis of Seasons Two and Three

For seasons two and three, Lathrop's discharges made up a small fraction of the San Joaquin River's total load (Table 5-9). Total load was calculated as the San Joaquin River load plus Lathrop's discharged load. The highest contribution from Lathrop was 6.8% of the total load; however, for all other storm events, the contribution was less than 2% of the total load. Lathrop's load for individual stations ranged from 0 kg to 187.4 kg of carbon per storm. During season two there were some data gaps in pump flow data received from MCC Control Systems, the consultant hired to provide MWQI with pump reports from Lathrop's SCADA. These gaps were due to an error in the signal from the SCADA system or an error during download of the pump data.

The loads are from an area that only makes up 0.1% of the San Joaquin River watershed. The largest load discharged by Lathrop was 755.7 kg of carbon during the course of a 10-hour storm. During storm events, the background load of the San Joaquin River ranged between 6,457.1 kg and 174,576.5 kg per storm event.

Table 5-9. TOC Loads (in kg) per Storm Event for Seasons Two and Three

	Date of Storm Event - Season Two					
	11/7/2010	**11/20/2010**	**12/17/2010**	**3/19/2011**	**3/24/2011**	**6/4/2011**
Approximate Precipitation (in.)	0.49	0.95	0.94	0.68	0.73	0.34
Station						
M1	N/A	38.6	16.3	12.9	52.3	0
M2	55.6	103.5	42.6	25.7	101.4	20.9
M3	21.2	28.4	8.8	12.2	14.6	20.9
M6	3.8	N/A	5.0	3.4	7.3	2.7
Historic	53.7	155.8	29.5	N/A	40.1	125.4
Industrial	N/A	128.4	67.9	N/A	N/A	38.4
SJR at Mossdale	16,149.2	25,104.7	70,370.13	112,940.0	174,576.5	124,691.4
Lathrop's Percentage	<1%	1.8%	<1%	<1%	<1%	<1%
Lathrop's Total	134.4	454.7	170.2	54.2	215.6	208.1

	Date of Storm Event - Season Three			
	10/4/2011	**1/19/2012**	**3/16/2012**	**3/24/2012**
Approximate Precipitation (in.)	0.77	0.94	0.68	0.38
Station				
M1	83.4	25.0	31.2	4.3
M2	136.8	30.7	40.3	63.5
M3	71.4	78.8	16.2	4.8
M5	144.4	24.8	7.7	4.5
M6	7.7	3.8	4.9	1.3
Historic	187.4	89.5	97.3	14.9
Industrial	124.6	164.6	0.1	2.2
SJR at Mossdale	10,347.4	25,107.9	26,374.9	6,457.1
Lathrop's Percentage	6.8%	1.6%	<1%	1.5%
Lathrop's Total	755.7	417.1	197.7	95.4

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or there was a communication problem with the SCADA resulting in no sample and pump data. Load from the pump stations was calculated as total kilograms discharged during the storm. Load at the SJR at Mossdale station was calculated as an instantaneous load and was converted to total kilograms discharged during the storm.

Comparison between Seasons Two and Three

With the exception of the storm event on October 4, 2011, the percent of the total load that Lathrop contributed was relatively the same between storms and between years, resulting in no significant trends. When comparing the total kilograms of load between comparable storms, the totals were similar (Table 5-9). However, there are two storms worth noting. In the second season, Lathrop load contribution on June 4, 2011, was a little higher than expected for such a small storm. The load from this storm totaled 208.1 kg with 0.34 inches of precipitation. This is a little high in comparison to the March 24, 2011 or the March 24, 2012 storms. The load discharged on March 24, 2011 totaled 215.6 kg with 0.73 inches of precipitation. The TOC load discharged on March 24, 2012 totaled 95.4 kg with 0.38 inches of precipitation. During the June 4, 2011, storm event, concentrations of organic carbon were already starting to build up in the system, but the high flows on the San Joaquin River resulted in a low load contribution from Lathrop. The other storm of interest is the event on October 4, 2011, a first flush event in season three. The higher load discharge on that date reflects this phenomenon. The reason that this higher load was not seen during the first storm of the second season (November 7, 2010) was because this was not the first flush event of that season. The first flush event of season two took place on October 14, 2011, but was not sampled due to inaccuracies with weather forecasts and complications with State-mandated furloughs. The flows on the San Joaquin River were twice as high on November 7, 2011, as they were on October 4, 2011, which further lead to a higher contribution of organic carbon load from Lathrop. Also, it should be noted that season two was classified as a wet water year and season three was a dry water year. This difference in water year classification is clearly seen in the number of storms sampled, the volumes of those storms, and the flows on the San Joaquin River throughout the year.

Organic Carbon Loads and Other Studies

Comparing loads calculated from this study with other studies is a challenge because of the small scale of this study. Also, Lathrop only discharges a significant volume during storm events; therefore, load throughout the year could not be calculated. Lathrop's load discharged during storm events ranged from 1 kg/d/sq.km to 30 kg/d/sq.km. The Steelhead Creek study focused on a 469 square kilometer watershed in which the load in the Sacramento River ranged from 2 kg/d/sq.km during the dry season to 213 kg/d/sq km during the wet season. Steelhead Creek, an urban creek, contributed between 3% and 93% of the total river load (DWR, 2008). In comparison to the Steelhead Creek study, Lathrop's discharges appear to be on the low end. Lathrop's discharges should be more comparable to Steelhead Creek's wet season results, and Lathrop's maximum load is much lower than that of Steelhead Creek per square kilometer. On the Trinity River in Texas, the watershed was 47,998square kilometers. During storm events, the river had a load up to 20 kg/d/sq.km of carbon (Warnken and Santschi, 2004). The Trinity River study is more comparable to Lathrop because it focused on storm events and showed that Lathrop's maximum carbon load was slightly higher than that of the Trinity River per square kilometer.

Relationship of TOC with Other Constituents

Concentrations of TOC, turbidity, and total suspended solids (TSS) were analyzed to determine a relationship between the constituents. The data was separated out between the San Joaquin River and the city pumping stations to determine if there were relationships between these two areas (Figures 5-12 and 5-13). There does not appear to be a relationship between TOC, TSS, and turbidity, which was confirmed with a regression analysis. TSS and turbidity did not appear to be influenced by first flush effects, as would be expected. The highest median values for TSS and TDS were during the second storm event of the second season. The first flush storm of that year was not captured due to inconsistencies with weather forecasts. Therefore, the first storm sampled was the second storm of the season. In the third season, the first flush event was preceded by several months of dry weather and did not result in elevated TSS or turbidity concentrations. The reason for the lack of relationship between TOC, and TSS and turbidity may be due to a higher proportion of minerals to TOC in the TSS samples.

Turbidity and TSS had a significant relationship. The data was not normally distributed; therefore the data was log-transformed for the regression. The result is a significant relationship that explains 73.7% of the data (Figure 5-14).

Figure 5-12. Trends for TOC, TSS and Turbidity on the San Joaquin River

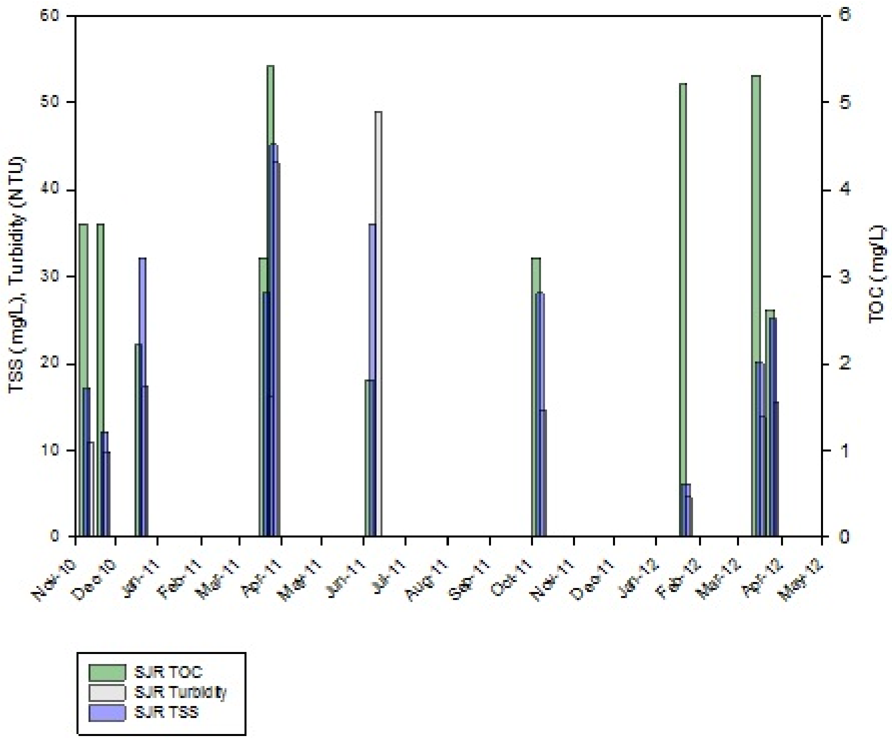


Figure 5-13. Trends for TOC, TSS and Turbidity for the City Pumping Stations

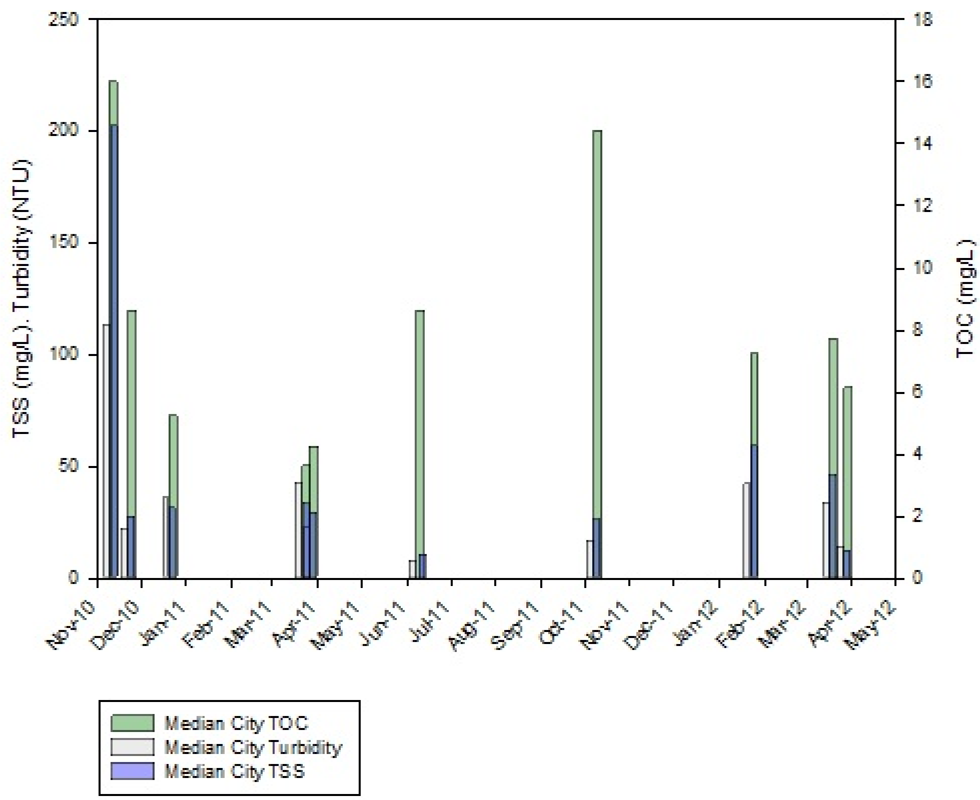
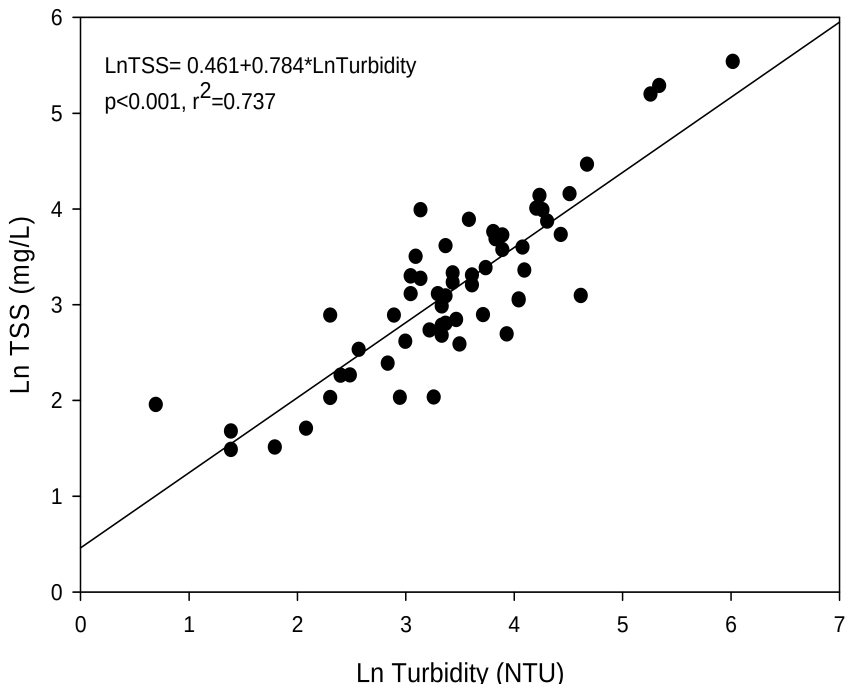


Figure 5-14. Relationship between TSS and Turbidity



Absorbance

Organic carbon reactivity (aromaticity) was analyzed by specific UVA_{254} absorbance (SUVA), defined as the ratio between DOC and UV absorbance. UV absorbance at 254 nm (UVA_{254}) is a measure of carbon composition. The aromatic portion is measured by how much UV light at 254 nm is absorbed by the organic carbon, thereby estimating the portion that has the potential to form DBPs. Although UVA_{254} is useful in measuring this, it is not a reliable indicator of DBP formation potential because not all DBP forming compounds absorb UV light and not all UV light absorbing compounds are DBPs.

Analysis of Seasons Two and Three

During the two seasons, there was considerable variability for UVA_{254} values. The values from the San Joaquin River at Mossdale were significantly lower than the median pumping stations values (Mann-Whitney, $p<0.001$), and this is illustrated in Figure 5-15. This also indicates there is a difference in organic carbon quality between the San Joaquin River and the city pumping stations. The UVA_{254} values for both seasons at the San Joaquin River at Mossdale ranged from 0.060 abs/cm to 0.184 abs/cm, and for the city pumping stations the values ranged from 0.075 abs/cm to 0.768 abs/cm (Table 5-10). The median concentration for the San Joaquin River at Mossdale was 0.082 abs/cm and the medians at the city pumping stations ranged from 0.116 abs/cm to 0.278 abs/cm.

A regression analysis between DOC and UVA_{254} shows a significant correlation ($r^2=0.944$, $p<0.001$). A LOWESS curve indicates that the relationship between DOC and UVA_{254} may differ in the higher concentrations (DOC>10 mg/L, Figure 5-16). A regression using only city pumping station data also shows a significant relationship ($p<0.001$, $r^2=0.943$, Figure 5-17); however, a regression only using the San Joaquin River data showed a much weaker relationship ($p=0.007$, $r^2=0.567$, Figure 5-18). Although this regression of the San Joaquin River data is still significant, the regression only explains 56.7% of the data. This is another indication of a difference in carbon quality between the San Joaquin River and the city pumping stations.

Figure 5-15. Boxplot of UVA_{254} for Seasons Two and Three

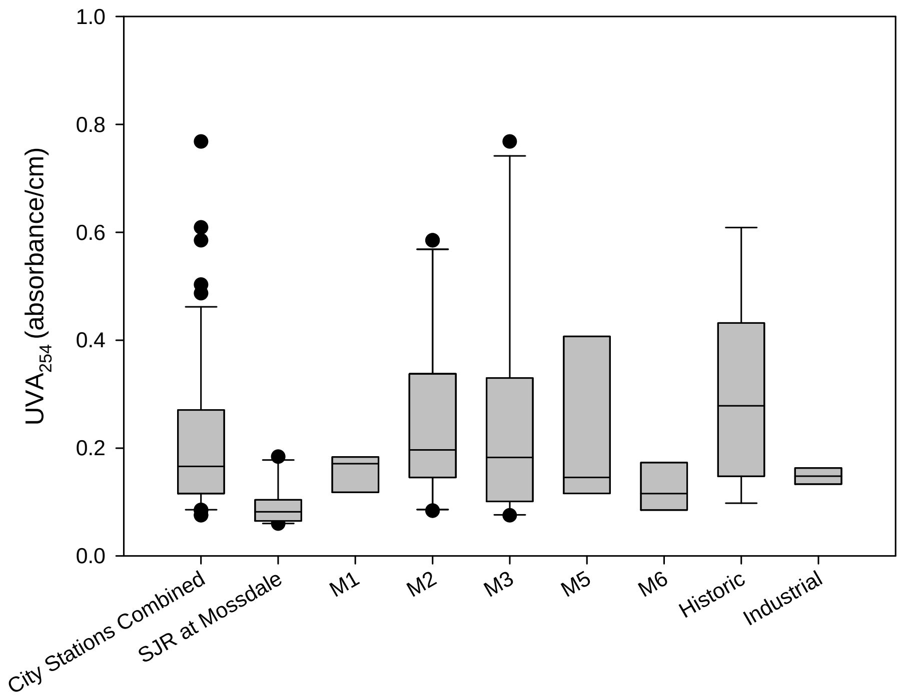


Table 5-10. Summary Statistics of UVA_{254} (in abs/cm) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	0.169	0.171	0.103	0.279	0.055
M2	10	0.249	0.197	0.084	0.585	0.155
M3	10	0.254	0.183	0.075	0.768	0.219
M5	4	0.223	0.146	0.113	0.487	0.178
M6	8	0.153	0.116	0.076	0.426	0.116
Historic	9	0.295	0.278	0.098	0.609	0.170
Industrial	7	0.159	0.148	0.131	0.233	0.035
SJR at Mossdale	10	0.092	0.082	0.060	0.184	0.037

Figure 5-16. Relationship between DOC and UVA_{254}, with LOWESS curve

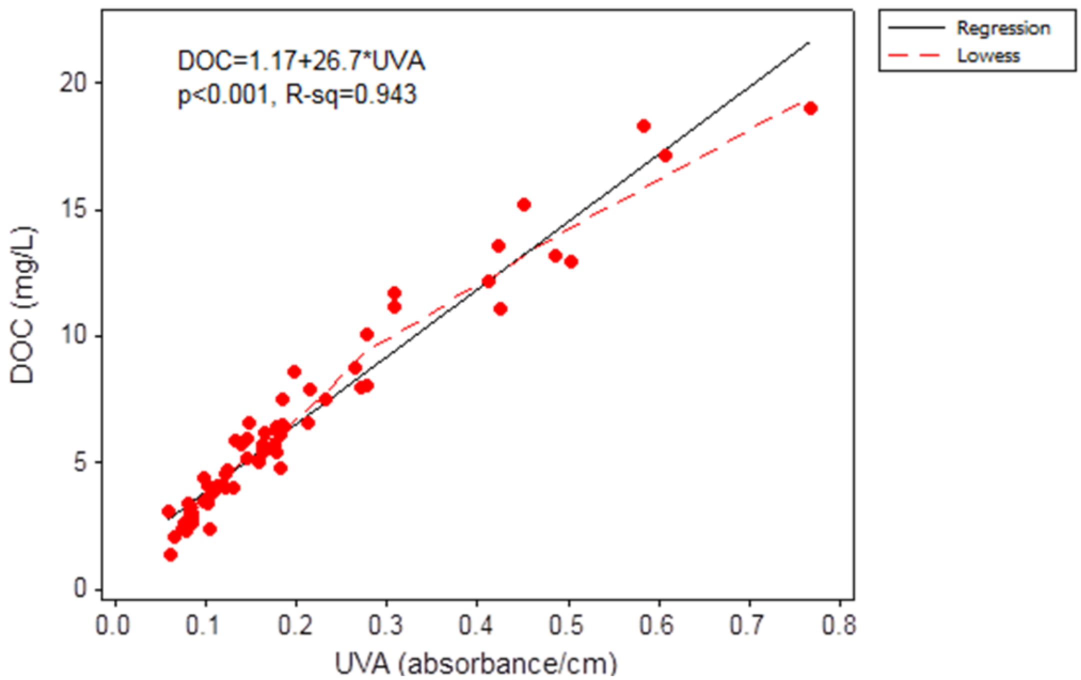


Figure 5-17. Relationship between City DOC and UVA_{254}

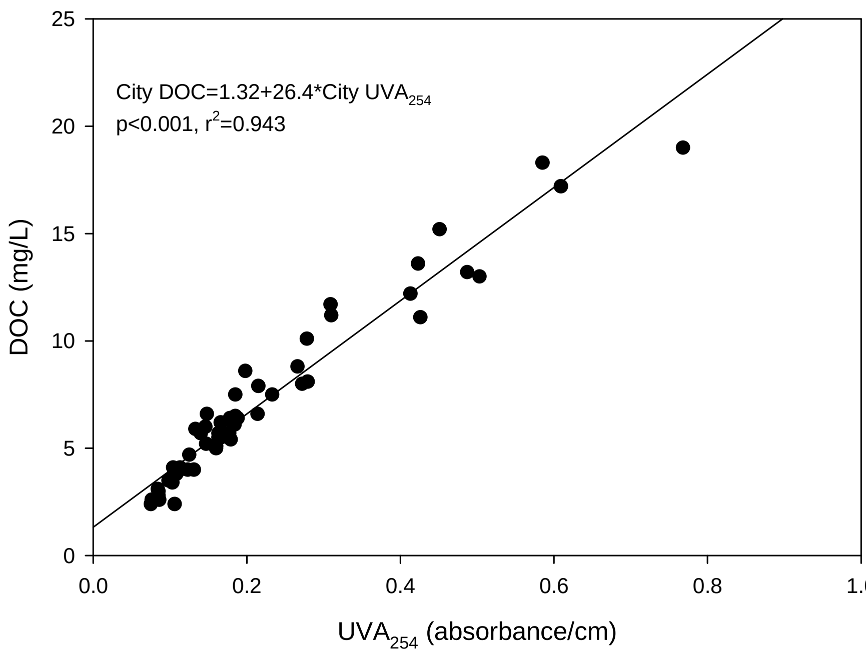
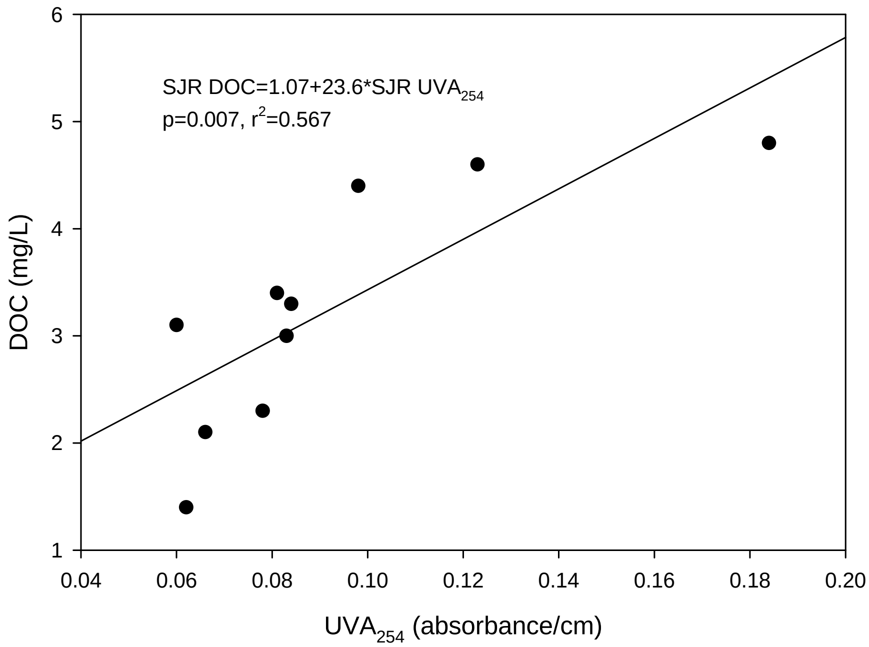


Figure 5-18. Relationship between SJR DOC and UVA_{254}



Comparison between Seasons Two and Three

For seasons two and three, the median absorbance (UVA_{254}) concentrations for San Joaquin River at Mossdale was significantly lower than the median concentration for all city pumping stations (season two Mann-Whitney, p=0.005; season three, Mann-Whitney p=0.001). Also, the M1 and Industrial stations had lower UVA_{254} values, and the values at the Historic station were similar between the two seasons. There was considerable variability in ranges between the two seasons for the Mossdale residential stations (stations M1-M6). In season two, their ranges were relatively smaller than in season three although the medians did not differ significantly (Tables 5-11 and 5-12, Figures 5-19 and 5-20). The differences may be indicative of a difference in water year type. Season two was classified as a wet water year, and it may be the additional water in the system resulted in less carbon in the system, and of carbon that was less aromatic. The third season was very dry which allowed for more of a build-up of carbon between storms.

Table 5-11. Summary Statistics of UVA_{254} (in abs/cm) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.137	0.132	0.103	0.179	0.039
M2	6	0.224	0.213	0.084	0.423	0.132
M3	6	0.209	0.160	0.075	0.503	0.164
M6	5	0.111	0.085	0.076	0.184	0.045
Historic	5	0.276	0.310	0.098	0.451	0.166
Industrial	3	0.176	0.163	0.131	0.233	0.052
SJR at Mossdale	6	0.096	0.082	0.066	0.184	0.044

Table 5-12. Summary Statistics of UVA_{254} (in abs/cm) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.202	0.182	0.163	0.279	0.052
M2	4	0.286	0.197	0.166	0.585	0.200
M3	4	0.320	0.183	0.147	0.768	0.299
M5	4	0.223	0.146	0.113	0.487	0.178
M6	3	0.225	0.140	0.108	0.426	0.175
Historic	4	0.318	0.238	0.185	0.609	0.199
Industrial	4	0.147	0.147	0.133	0.160	0.011
SJR at Mossdale	4	0.086	0.080	0.060	0.123	0.030

Figure 5-19. Boxplot of UVA_{254}, Season Two

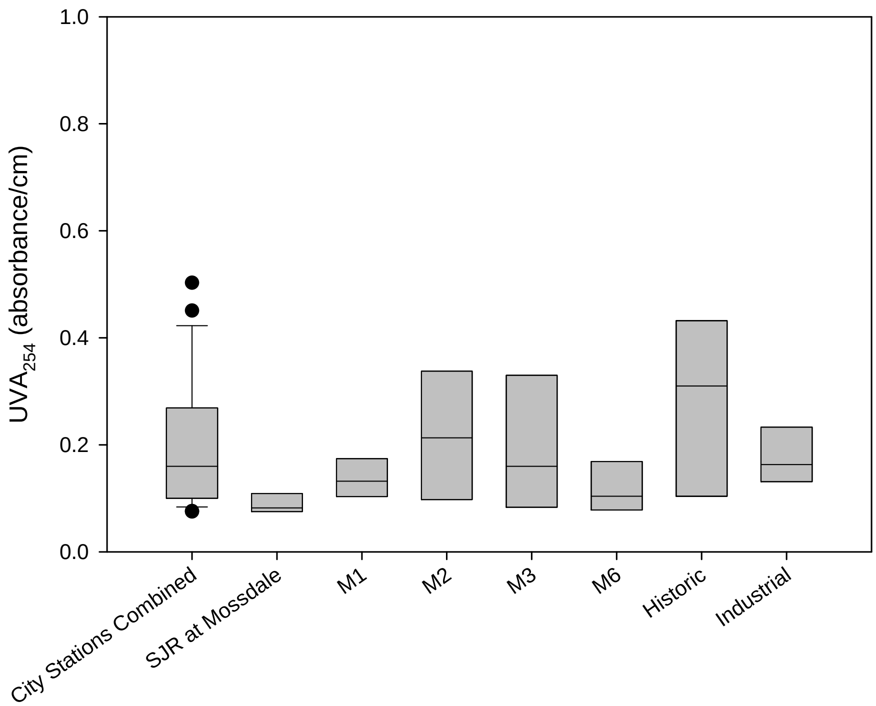
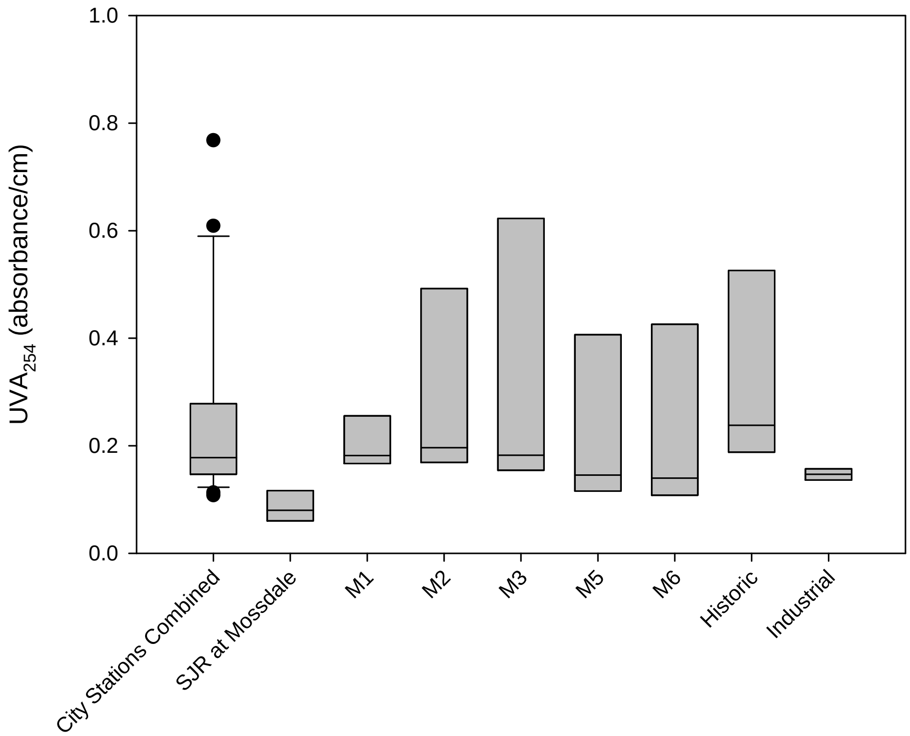


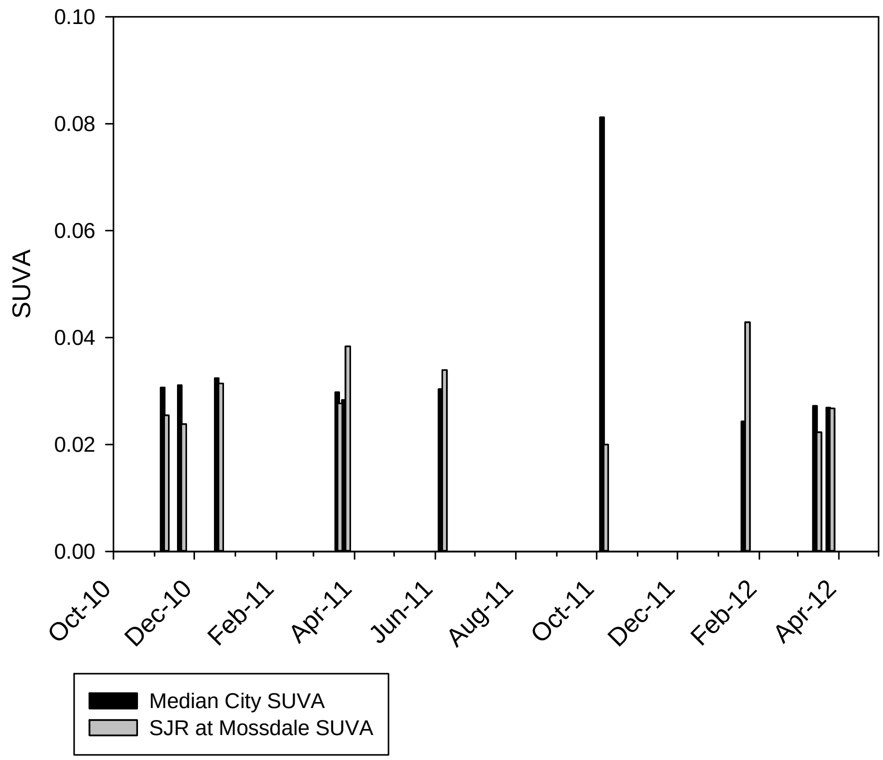
Figure 5-20. **Boxplot of UVA_{254}, Season Three**



Trends

SUVA (the ratio of DOC to UVA_{254}) is commonly used to predict the humic fraction of DOC. During the course of the season, there were no significant trends in SUVA, which indicated that the carbon quality of the samples did not change dramatically over time, with the exception of the October 2011 storm event median SUVA for the city pumping stations (Figure 5-21). In the third season, samples taken during the first storm event had a median SUVA value that was more than twice the other values. This shows that there was a difference in organic carbon quality during that storm. The first flush event of the second season was not captured; therefore it is not possible to compare this unusually high median value to another first flush event.

Figure 5-21. Seasonal Trends for SUVA



Trihalomethane Formation Potential (THMFP) and Haloacetic Acid Formation Potential (HAAFP)

The THMFP and HAAFP results were analyzed by Weck Laboratories using standard methods (Std method 5710B/EPA 524.2 for THMFP; EPA 552.2 for HAAFP). THMFP was calculated as a sum of bromodichloromethane, bromoform, chloroform, and dibromochloromethane. HAAFP was calculated as a sum of dibromoacetic, dichloroacetic, monobromoacetic, monochloroacetic, and trichloroacetic acids. Formation potential results are commonly used to determine the potential for a source water to form THMs and HAAs during the disinfection process.

Analysis of Seasons Two and Three

Median concentrations of THMFP on the San Joaquin River at Mossdale were significantly lower than those of the city pumping stations (Mann-Whitney, p=0.007). Overall, the concentrations at the Industrial station were relatively low; there was much variability throughout the Mossdale residential region (Figure 5-22). The most variation in concentrations was from the Historic station with a maximum value of 1,817.3 µg/L and a minimum of 183.5 µg/L for the two seasons. The THMFP median for the San Joaquin River at Mossdale was 195.2 µg/L and the city pumping station medians ranged from 202.2 µg/L to 491.4 µg/L. The concentrations at the San Joaquin River at Mossdale ranged from 105.7 µg/L to 341.6 µg/L and the range of concentrations for the city pumping stations was from 137.8 µg/L to 1817.3 µg/L (Table 5-13).

Median concentrations of HAAFP on the San Joaquin River at Mossdale were also significantly lower than the median city concentrations (Mann-Whitney, p=0.012). Like THMFP, the Industrial station had lower HAAFP concentrations than the other city pumping stations (Figure 5-23); however, the Historic station did not have concentrations that were dramatically higher than the other pumping stations (Table 5-14). The median concentration at the San Joaquin River at Mossdale was 146.0 µg/L and the city pumping stations concentrations ranged from 193.0 µg/L to 586.4 µg/L. The San Joaquin River at Mossdale values ranged from 118 µg/L to 640 µg/L and the range of values at the city pumping stations was from 87.0 µg/L to 1,537.0 µg/L. The highest value (1537 µg/L) was collected from the Historic station.

A regression analysis of THMFP, HAAFP, and DOC reveals that DOC is not a reliable predictor of THMFP and HAAFP. A regression between THMFP and DOC was significant at $p<0.001$, but the relationship was not very strong, and it only explained 65.6% of the data (Figure 5-24). The relationship between HAAFP and DOC was also significant ($p<0.001$), but the relationship only explained 73.5% of the data (Figure 5-25). It is possible that these relationships would be better explained with additional data. Regressions were calculated between UVA_{254} and THMFP and HAAFP, but the relationships did not explain much more of the data spread. The relationship between THMFP and UVA_{254} explained 61.6% of the data, and the relationship between HAAFP and UVA_{254} explained 77.0% of the data. Both regressions had p-values <0.001.

Figure 5-22. Boxplot of THMFP for Seasons Two and Three

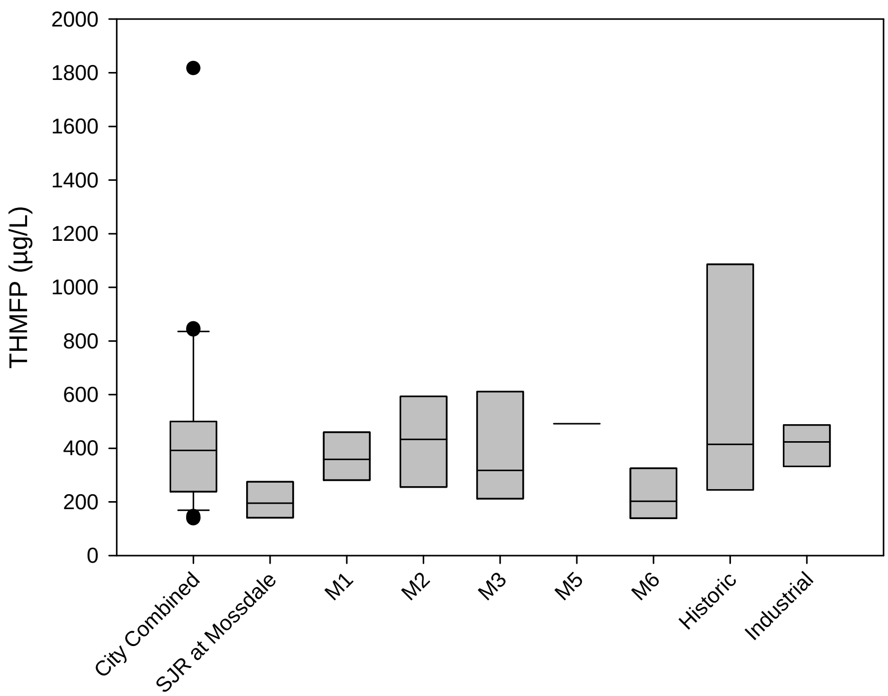


Table 5-13. Summary Statistics of THMFP (in µg/L) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	366.5	358.6	274.7	474.0	94.8
M2	7	430.3	432.7	174.5	846.5	230.9
M3	7	395.3	317.4	146.7	833.6	247.7
M5	2	491.4	491.4	265.9	716.9	318.9
M6	6	247.9	202.2	137.8	558.8	158.0
Historic	6	656.2	414.7	183.5	1817.3	612.6
Industrial	5	412.3	423.0	272.7	525.0	92.2
SJR at Mossdale	7	206.8	195.2	105.7	341.6	79.6

Figure 5-23. Boxplot of HAAFP for Seasons Two and Three

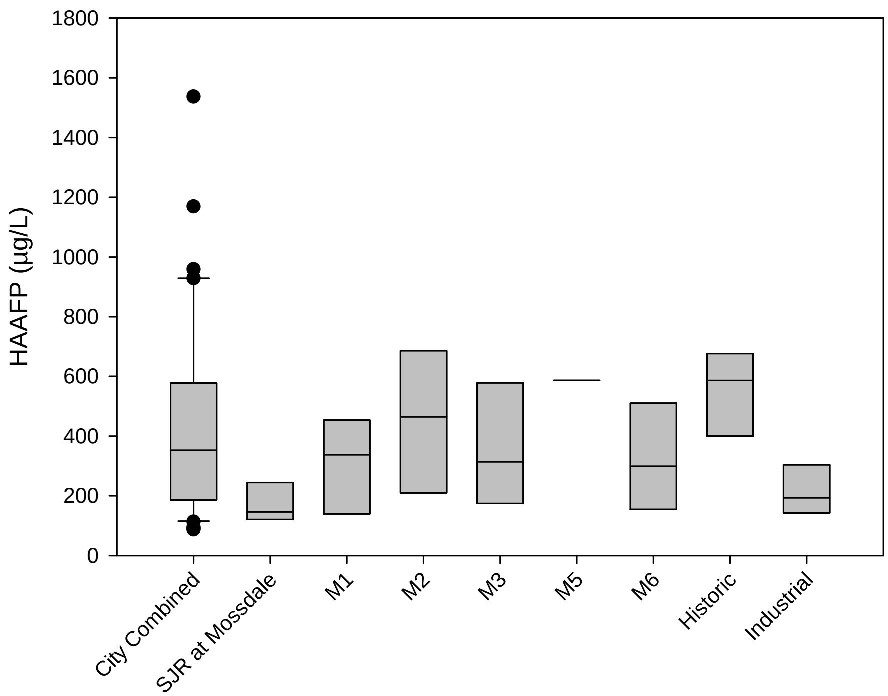


Table 5-14. Summary Statistics of HAAFP (in µg/L) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	5	309.8	337.1	95.0	470.0	165.3
M2	8	477.7	463.9	140.0	958.7	275.8
M3	8	413.7	313.7	87.0	1169.2	350.0
M5	2	586.4	586.4	245.4	927.4	482.2
M6	6	360.7	299.1	90.4	929.3	296.0
Historic	7	656.9	585.9	312.5	1537.0	409.8
Industrial	5	216.9	193.0	113.0	337.7	87.9
SJR at Mossdale	8	221.0	146.0	118.0	640.0	176.4

Figure 5-24. Relationship between THMFP and DOC

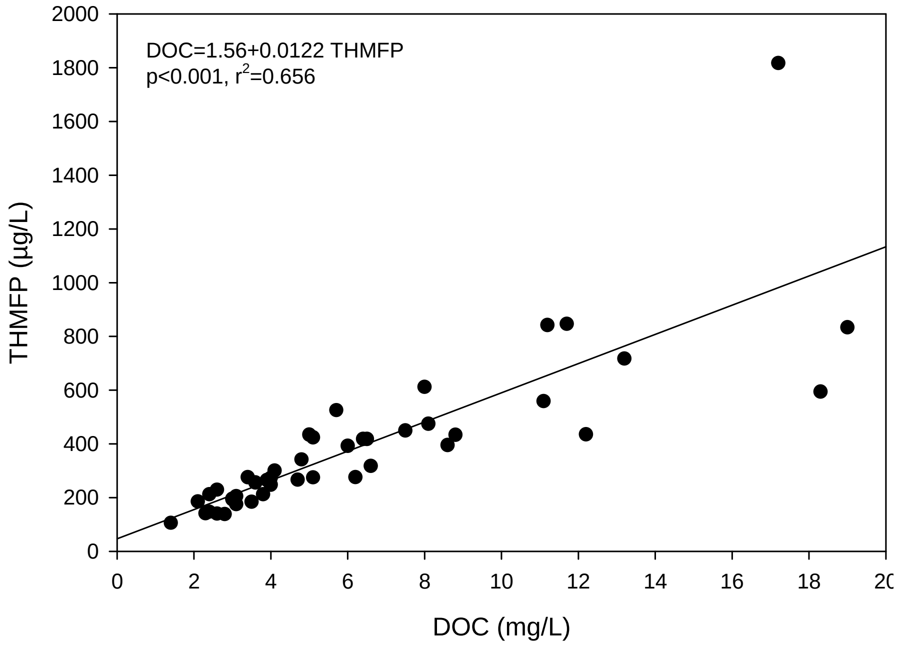
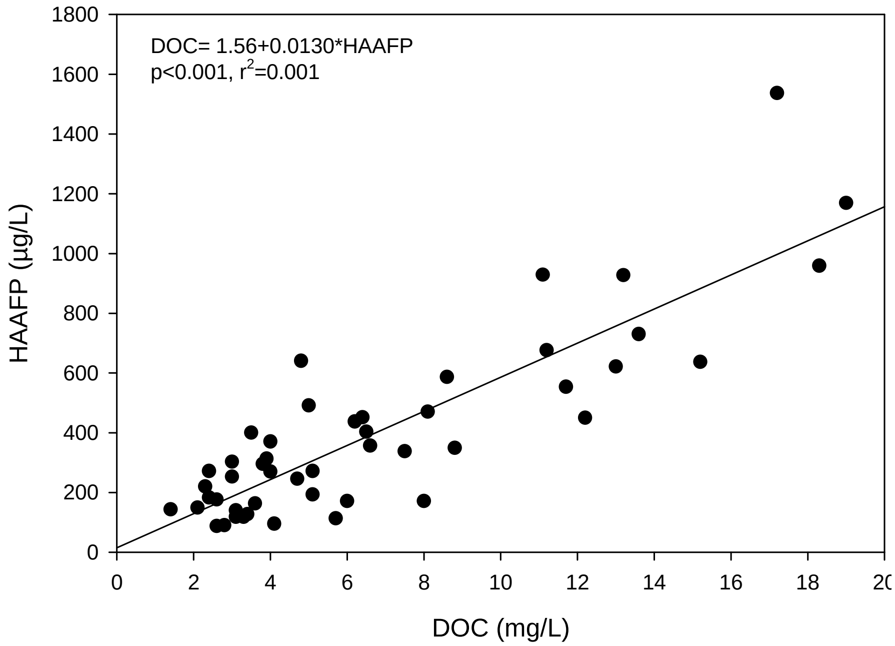


Figure 5-25. Relationship between HAAFP and DOC



Comparison between Seasons Two and Three

For season two, the concentrations for THMFP and HAAFP were not statistically lower on the San Joaquin River than the city pumping stations (Mann-Whitney, $p=0.169$ for THMFP, $p=0.433$ for HAAFP).

Comparisons between the city pumping stations and the San Joaquin River were not able to be made for season three due to the lack of samples. Although samples were collected on the San Joaquin River for all 4 storms, there was not enough sample water to collect THMFP and HAAFP for the March storm events, resulting in data for only 2 storms of that season.

A comparison of THMFP boxplots between seasons shows the characteristics of the two seasons. The season three boxplots show the city stations combined as a boxplot, and as a scatter plot to show where the data fell for each station (Figures 5-26 and 5-27). The patterns of the concentrations between years are similar, with more variability throughout the Mossdale residential region, higher concentrations in the Historic station, and medium range concentrations for the Industrial station. However, it is very clear that there were higher concentrations in season three, especially at the Historic station. This is likely due to a first flush event. However, the minimum concentrations for season three are also higher than the minimums for season two (Tables 5-15 and 5-16). This is due to the differences in water years. During season two, the year was classified as a wet year and there were many storms throughout the wet season, the largest of which were captured. In season three, there were fewer storms and there were longer dry periods between storms. This resulted in a build-up of organic carbon between storms that resulted in higher concentrations throughout the season.

For HAAFP, the comparisons between years were also similar, with higher concentrations at the Historic station and lower concentrations at the Industrial station. Mossdale residential region had the most variability. Just like in THMFP, there are higher concentrations overall for season three (Figures 5-28 and

5-29, Tables 5-17 and 5-18). This is due to the higher concentrations present during the first flush event and higher concentrations due to longer dry periods between storms.

Figure 5-26. Boxplot of THMFP for Season Two

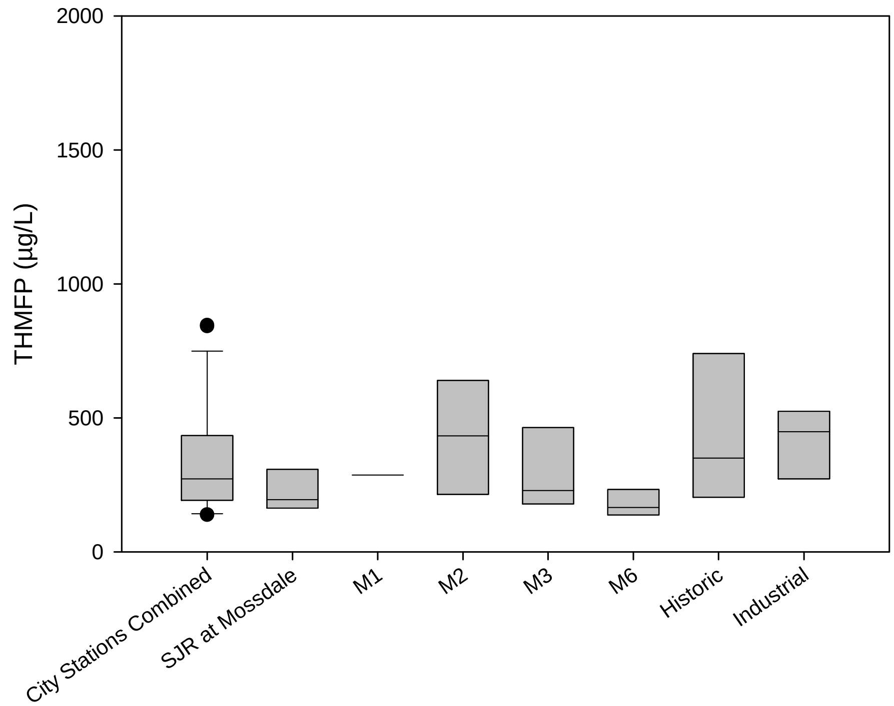


Figure 5-27. Boxplot and Scatterplot of THMFP for Season Three

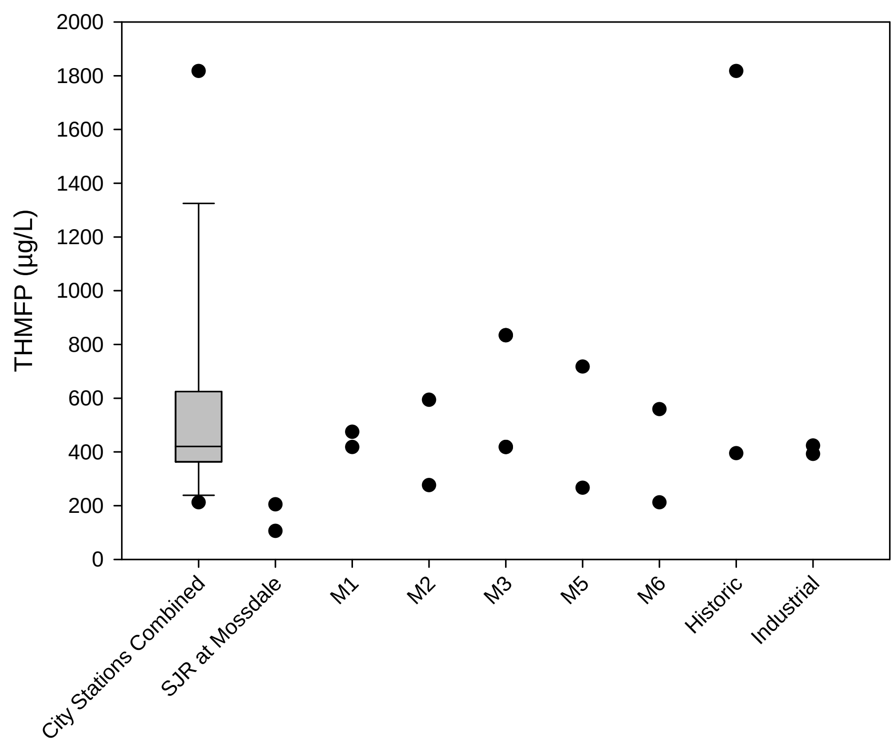


Table 5-15. Summary Statistics of THMFP (in µg/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	2	287.4	287.4	274.7	300.0	17.9
M2	5	428.5	432.7	174.5	846.5	259.5
M3	5	303.2	229.0	146.7	611.0	182.5
M6	4	179.3	166.2	137.8	246.9	51.8
Historic	4	431.3	349.8	183.5	841.9	293.1
Industrial	3	415.4	448.6	272.7	525.0	129.4
SJR at Mossdale	5	227.6	195.2	141.1	341.6	80.0

Table 5-16. Summary Statistics of THMFP (in µg/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	2	445.6	445.6	417.2	474.0	40.2
M2	2	434.7	434.7	275.9	593.6	224.7
M3	2	625.5	625.5	417.4	833.6	294.3
M5	2	451.0	451.0	451.0	451.0	318.9
M6	2	385.2	385.2	211.5	558.8	245.6
Historic	2	1106.0	1106.0	394.7	1817.3	1005.9
Industrial	2	407.5	407.5	392.0	423.0	21.9
SJR at Mossdale	2	154.9	154.9	105.7	204.2	69.7

Figure 5-28. Boxplot of HAAFP for Season Two

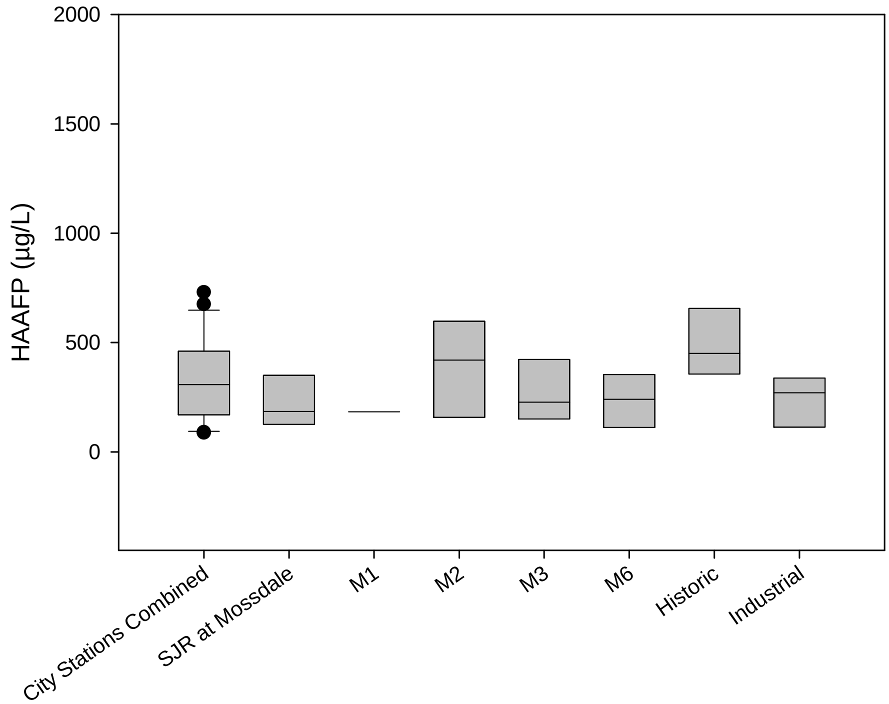


Figure 5-29. Boxplot and Scatterplot of HAAFP for Season Three

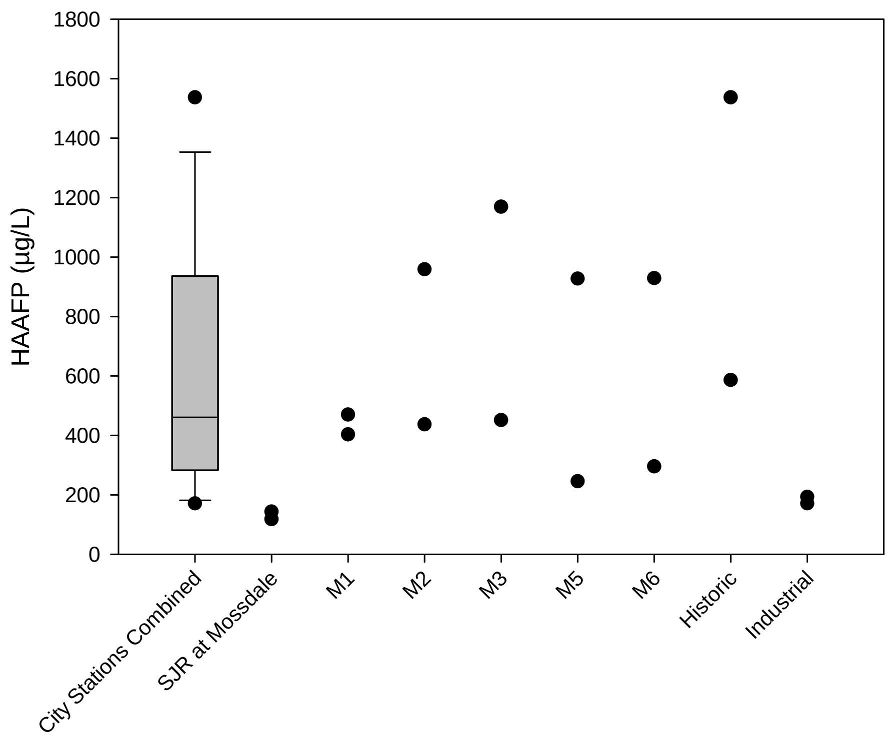


Table 5-17. Summary Statistics of HAAFP (in µg/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	2	183.1	183.1	95.0	271.2	124.6
M2	6	404.4	420.0	140.0	730.2	231.1
M3	6	281.5	227.0	87.0	620.9	190.1
M6	4	234.9	239.6	90.4	370.0	125.4
Historic	5	495.0	450.0	312.5	676.2	155.9
Industrial	3	240.2	270.0	113.0	337.7	115.3
SJR at Mossdale	6	251.2	184.4	118.2	640.0	197.9

Table 5-18. Summary Statistics of HAAFP (in µg/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	2	436.5	436.5	403.0	470.0	47.4
M2	2	697.8	697.8	436.8	958.7	369.0
M3	2	810.3	810.3	451.4	1169.2	507.6
M5	2	586.4	586.4	245.4	927.4	482.2
M6	2	612.3	612.3	295.3	929.3	448.3
Historic	2	1061.4	1061.4	585.9	1537.0	672.5
Industrial	2	182.0	182.0	171.0	193.0	15.6
SJR at Mossdale	2	130.6	130.6	118.0	143.1	17.7

Trends

During the course of the two seasons, there did not appear to be strong THMFP trends for the samples collected at the San Joaquin River at Mossdale (Figure 5-30), although there were trends from the city pumping stations. In season two, there were higher concentrations at the city pumping stations at the beginning of the wet season. Although the first flush event was not captured, these earlier storms are showing higher concentrations washing out of the system as the season progressed. The higher concentrations in June 2011 indicate that the organic carbon had already started to build up. Although it is not appropriate to draw trends in the third season because there were only 2 storms sampled, it is evident that higher concentrations were collected in this season. The first event sampled was a first flush event and this is illustrated by high concentrations during that storm. The second storm sampled may also be classified as a flush event because there was no wet weather between the two storms. This explains why the concentrations in January 2012 were so high.

The seasonal trends seen for HAAFP are very similar to that of THMFP. In the second season, a decreasing trend in HAAFP concentrations is seen, indicating a washing of organic carbon into the system (Figure 5-31). Unlike THMFP, there were no elevated concentrations in June 2011, showing an increase of organic carbon in the system. However, during the first event of season three, it is very clear that there was a first flush event due to the high concentrations of HAAFP. Again, we see relatively high concentrations in the second storm of the third season, indicating a much drier storm season.

Figure 5-30. Trends for THMFP

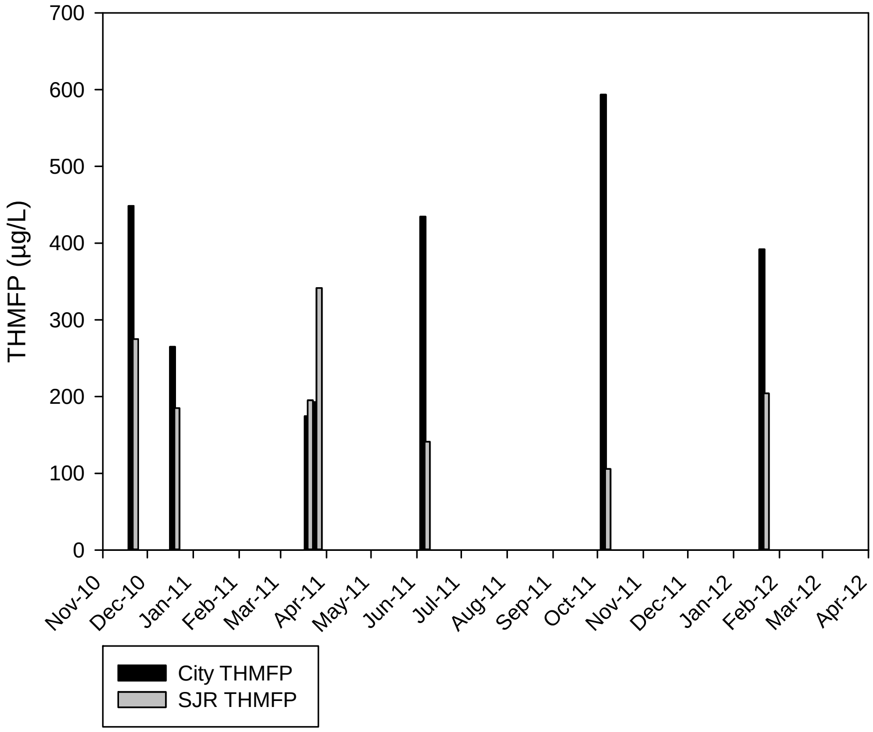
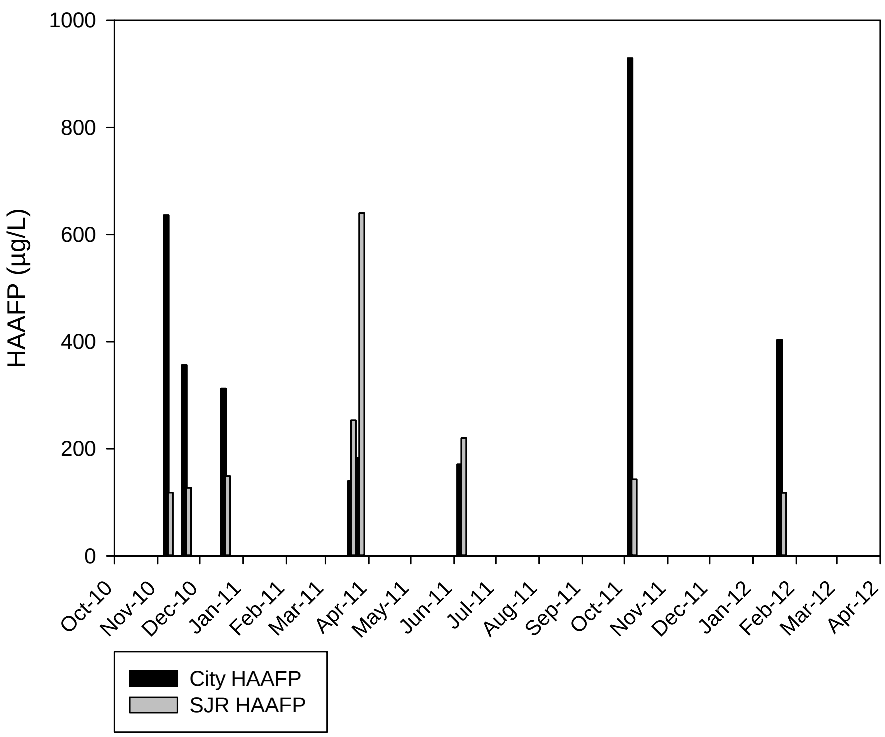


Figure 5-31. Trends for HAAFP



Nutrients

Nutrients, compounds composed of nitrogen and phosphorus, are an essential part of a healthy ecosystem, but adverse effects can occur when levels of nutrients exceed natural background levels. In storm water, a major source of nutrients is lawn and garden fertilizer. Other sources of nutrients include atmospheric deposition, automobile exhaust, soil erosion, animal waste, and detergents. Readily available nutrients, in combination with environmental factors such as warm temperatures and sunlight, can cause algal blooms which can clog waterways, block sunlight to below-surface layers, and consume oxygen that would otherwise be available for fish and other aquatic wildlife. Ammonia is of particular interest since studies have shown that delta smelt (*Hypomesus transpacificus*), an endangered species that is endemic to the Delta, exhibits symptoms of toxicity from elevated levels of ammonia/ammonium (Werner, et al., 2009; Connon, et al., 2011). Ammonia may also inhibit diatom production which has the potential to reduce productivity, therefore affecting the food chain detrimentally (Wilkerson et al., 2006; Dugdale et al., 2007). In addition to the ecosystem impacts, higher levels of nutrients may cause drinking water quality issues. The resulting algal blooms can cause taste and odor issues in drinking water, the algae can clog filters, and the blooms increase the volume and cost of solid waste disposal at the water treatment facility.

For the protection of aquatic life, the EPA has developed criteria for nutrients. The major implication for aquatic life from nutrients is algal blooms that can result in a lack of oxygen for aquatic species, and in the potential for ammonia to result in a reduction in productivity. The EPA developed reference conditions for total nitrogen and total phosphorus for Ecoregion I, subecoregion 7, which includes the Delta. These reference conditions are 0.31 mg/L for total nitrogen and 0.77 mg/L for total phosphorus (EPA, 2001a). The EPA has also developed draft acute and chronic criteria for ammonia for protection of aquatic life (Table 5-19) (EPA, 2009).

For the protection of human health, the EPA has developed MCLs for nitrate (10 mg/L as N), nitrite (1 mg/L as N), and nitrate plus nitrite (10 mg/L as N) (CDPH, 2008). The CDPH has adopted these MCLs as regulations. The MCLs are equivalent to public health goals (PHGs) established by the California EPA Office of Environmental Health Hazard Assessment (OEHHA) (OEHHA, 1997). These PHGs are based on nitrate's ability to cause methemoglobinemea (blue baby syndrome).

The nutrients that were monitored during this study include ammonia, dissolved nitrate, dissolved nitrate plus nitrite, Kjeldahl nitrogen, orthophosphate, and total phosphorus. Comparisons of Lathrop's concentrations to other studies were made for ammonia, nitrate, nitrite plus nitrate, and total phosphorus.

Table 5-19. Draft 2009 Ammonia Criteria at pH=8

	Temperature	Freshwater Mussels Present	Fish Early Life Stages Present	Criteria (mg/L as N)
Acute	30°C	Yes	N/A	1.90
		No	N/A	3.29
	0°C	Yes	N/A	9.81
		No	N/A	9.99
Chronic	30°C	Yes	N/A	0.186
		No	Yes	1.33
		No	No	1.33
	0°C	Yes	N/A	0.817
		No	Yes	2.32
		No	No	5.87

EPA, 2009

Ammonia

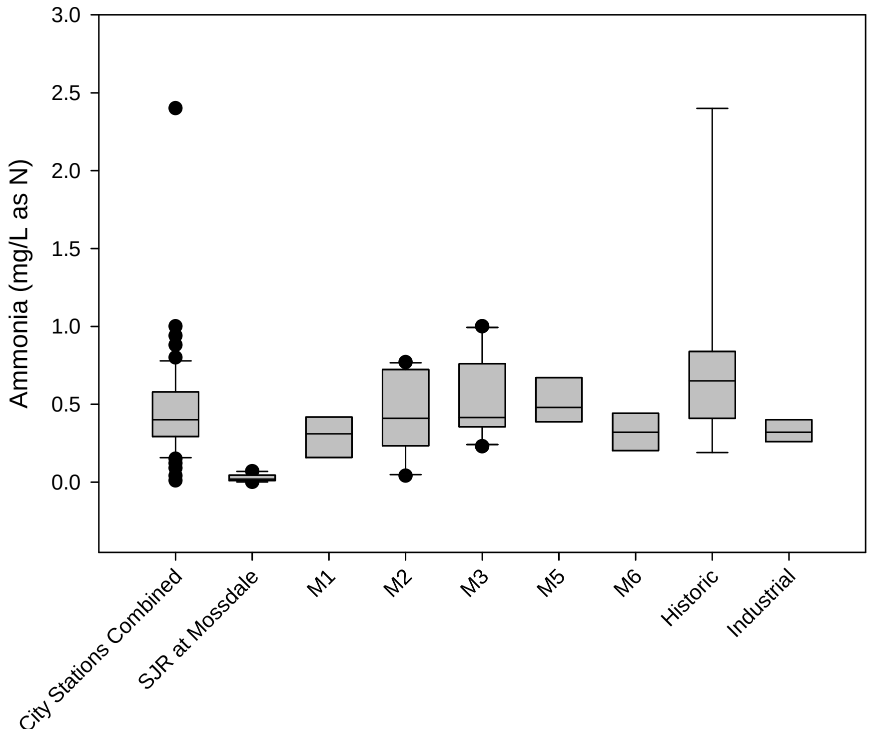
Analysis of Seasons Two and Three

For seasons two and three, the concentrations on the San Joaquin River were significantly lower than the city pumping station concentrations (Mann-Whitney, p=0.001). (One sample was below the reporting limit; half of the reporting limit was used in the test.) The median concentration for the San Joaquin River at Mossdale was 0.02 mg/L and the medians for the city pumping stations ranged from 0.31 mg/L to 0.65 mg/L. The range of concentrations at the San Joaquin River at Mossdale was from below the reporting limit to 0.07 mg/L and for the city pumping stations the range was from 0.01 mg/L to 2.4 mg/L (Table 5-20). During the two seasons, the concentrations from the Industrial station were relatively low, and the concentrations in the Mossdale residential region were somewhat variable. However, the concentrations from the Historic station were generally higher, with an unusually high outlier (Figure 5-32). This station serves the historic part of the city, which does not have a built-in sewer system, and serves the largest area of all the pumping stations. For both seasons, all concentrations sampled at the pumping stations were below the draft acute and chronic criteria developed by the EPA for water bodies that do not contain mussels, with the exception of the sample from the Historic station that was 2.4 mg/L as N (Table 5-19).

Table 5-20. Summary Statistics of Ammonia (in mg/L as N) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	0.32	0.31	0.09	0.68	0.19
M2	10	0.42	0.41	0.04	0.77	0.25
M3	10	0.52	0.42	0.23	1.00	0.26
M5	4	0.51	0.48	0.36	0.73	0.16
M6	8	0.33	0.32	0.16	0.58	0.14
Historic	9	0.78	0.65	0.19	2.40	0.64
Industrial	7	0.30	0.32	0.01	0.46	0.14
SJR at Mossdale	4	0.03	0.02	<R.L.	0.07	0.02

Figure 5-32. Boxplot of Ammonia for Seasons Two and Three



Comparison between Seasons Two and Three

The concentrations on the San Joaquin River at Mossdale were significantly lower than the concentrations of the city pumping stations for both years (Mann-Whitney, $p<0.001$ for season two, $p=0.002$ for season three). There was no statistical difference in the city pumping stations between years, even though one year was classified as wet, and the other dry (Mann-Whitney, $p=0.12$). The patterns between the pumping stations are very similar for all of the stations, except for the Historic station in season three (Figures 5-33 and 5-34, Tables 5-21 and 5-22). In season three, the Historic station had the highest maximum of 2.4 mg/L (Table 5-22). A replicate sample was also taken at this station and the concentration was 2.2 mg/L. There were no significant trends during the course of the 2 seasons.

Figure 5-33. Boxplot of Ammonia for Season Two

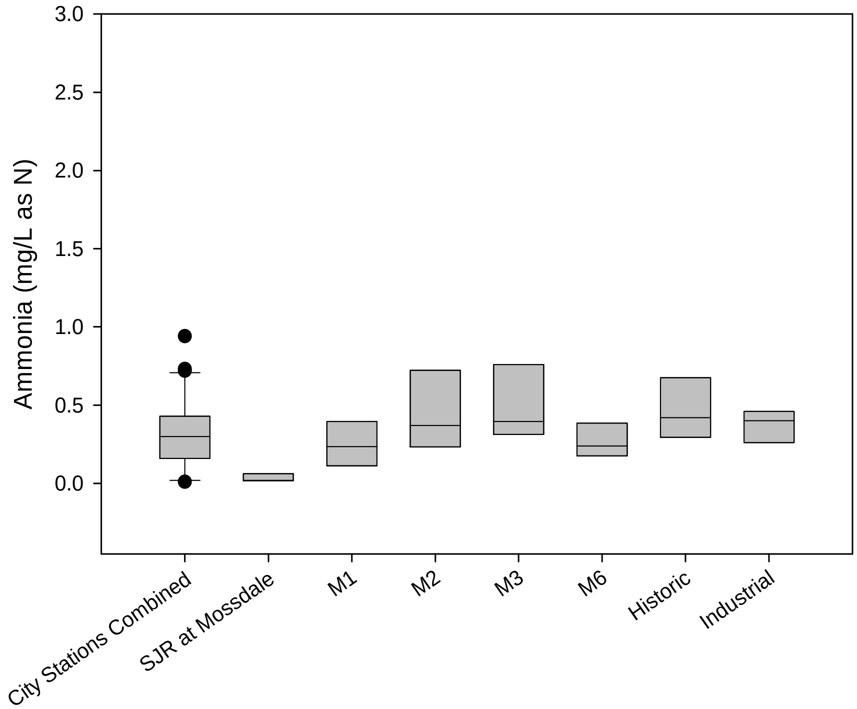


Figure 5-34. Boxplot of Ammonia for Season Three

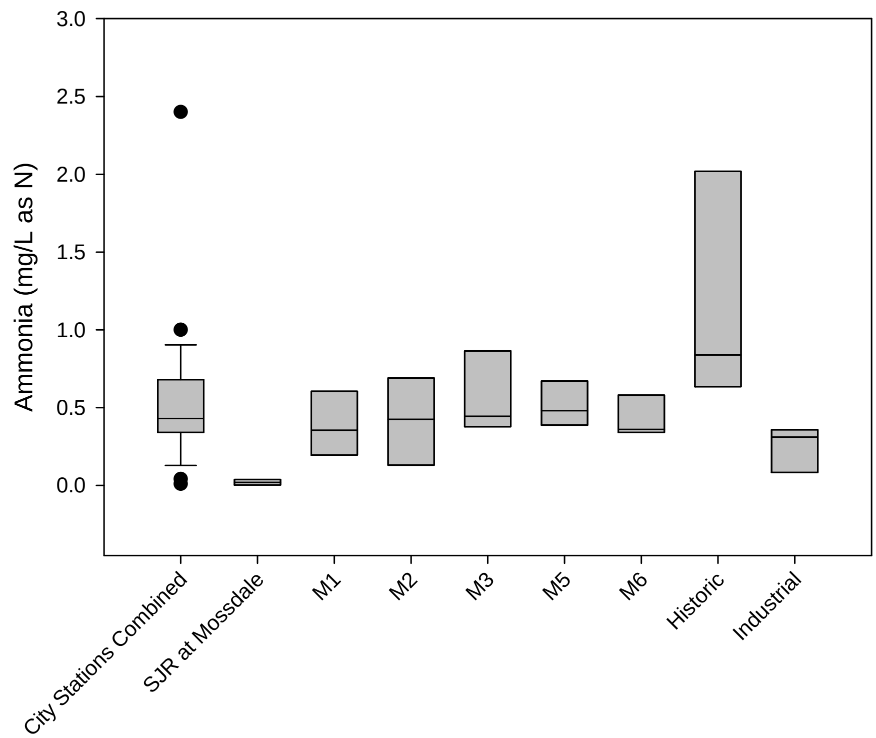


Table 5-21. Summary Statistics of Ammonia (in mg/L as N) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.24	0.24	0.09	0.43	0.15
M2	6	0.37	0.43	0.12	0.73	0.25
M3	6	0.40	0.50	0.23	0.94	0.27
M6	5	0.24	0.27	0.16	0.47	0.12
Historic	5	0.42	0.47	0.19	0.70	0.21
Industrial	3	0.40	0.37	0.26	0.46	0.10
SJR at Mossdale	6	0.02	0.03	0.01	0.07	0.02

Table 5-22. Summary Statistics of Ammonia (in mg/L as N) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.39	0.36	0.15	0.68	0.22
M2	4	0.42	0.43	0.04	0.77	0.30
M3	4	0.56	0.45	0.36	1.00	0.29
M5	4	0.51	0.48	0.36	0.73	0.16
M6	3	0.43	0.36	0.34	0.58	0.13
Historic	4	1.17	0.84	0.58	2.40	0.83
Industrial	4	0.25	0.31	0.01	0.37	0.16
SJR at Mossdale	4	0.03	0.03	<R.L.	0.04	0.02

Note: <R.L. indicates the concentration was below the reporting limit

Comparison with Other Studies

Throughout the Lathrop study, the mean concentration on the San Joaquin River at Mossdale was 0.03 mg/L as N, and the maximum concentration was 0.07 mg/L as N (Table 5-20). These concentrations were very comparable to what was sampled in the Steelhead Creek study. The mean concentration in Steelhead Creek during storm events sampled between 1997 and 2005 was 0.08 mg/L (DWR, 2008). These concentrations are also comparable to the storm water samples that the Sacramento CMP collected on the Sacramento River. Of the 4 storm events sampled in the 2011-2012 wet season, the means were all 0.04 mg/L with the exception of the February 29, 2012, sampling event in which ammonia sampled at Veteran's Bridge was 0.15 mg/L, and the concentration at Freeport was 0.18 mg/L (CMP, 2012).

Concentrations from the city pumping stations in Lathrop had medians that ranged from 0.31 mg/L as N to 0.65 mg/L as N (Table 5-20). These concentrations were comparable to concentrations found by the Sacramento Stormwater Partnership in the Urban Runoff Source Control Evaluation (Geosyntec, 2011). In the evaluation, the Sacramento Stormwater Partnership analyzed data collected from 4 drainage areas in the Sacramento area (Strong Ranch Slough, Sump 104, Sump 111, and Natomas Basin). These areas drained a total of approximately 6,400 acres. Strong Ranch Slough drained mixed land uses, Sump 104 drained primarily light industrial land uses, Sump 111 drained industrial lands, and the Natomas Basin drained primarily residential lands. The medians of the wet weather events for each of these areas were similar to those from the city pumping stations. The median ammonia concentrations from the Sacramento Stormwater Partnership's evaluation ranged from 0.40 mg/L as N to 0.60 mg/L as N.

Lathrop's pumping station concentrations were also compared with 7 drainage areas monitored in the 2011-2012 wet season for the Los Angeles Phase I NPDES permit (Los Angeles County, 2012). These areas drained a total of 1.31 million acres. Like the Sacramento Stormwater Partnership evaluation, the Los Angeles medians overlapped those of Lathrop (0.31 mg/al as N to 0.65 mg/L as N). The wet weather medians collected for the NPDES permit ranged for 0.16 mg/L as N to 0.94 mg/L as N.

The result of comparing ammonia concentrations sampled during the Lathrop study with other studies shows that although Lathrop does discharge ammonia to the San Joaquin River during storm events, the concentrations are not significantly higher than seen for other studies in the Central Valley or Los Angeles.

Ammonia Loads

Ammonia loads discharged from the city pumping stations during storm events were quite variable, and the load on the San Joaquin River was low throughout the study period. The low load on the San Joaquin River may be explained by the conversion of ammonia into nitrate from nitrifying bacteria. This makes it difficult to assess the significance of Lathrop's ammonia load. During season two, most loads from Lathrop made up less than 6% of the total load on the San Joaquin River (Table 5-23). The exception was during the November 20, 2010, storm event in which Lathrop made up 14.7% of the river's total load. A comparison of ammonia concentrations between the stations showed that Lathrop's concentrations during the November 20, 2011, event were not abnormally high. For example, during the November 7, 2010, event, many of the pumping stations had higher concentrations than during the November 20, 2010, event. However, during the November 20, 2010, event, the storm was nearly twice the volume of the November 7, 2010, event (Table 5-23), and Lathrop discharged approximately twice of what it did during the November 7, 2010, event. Therefore, the increased discharge from Lathrop is responsible for the increase in load. This was coupled with low flows and low load on the San Joaquin River.

During the third season, the ammonia loads were generally higher for each storm. During the first flush event of the third season, the ammonia concentration on the San Joaquin River was below the reporting limit. The other storm events sampled also had relatively high contribution of ammonia, especially in comparison to most of the storms from season two. With the exception of the sample collected at the Historic station on March 16, 2012 (2.4 mg/L as N), the samples collected during season three were within the same range as those collected in season two (Figures 5-35 and 5-36, Tables 5-21 and 5-22). However, because season three was a dry water year, the San Joaquin River flows were much lower than in season two (Tables 4-1 and 4-2). The result of lower flows and ammonia conversion to nitrate in the river translated to a lower load on the San Joaquin River and this resulted in Lathrop contributing a larger percentage of the total load.

Table 5-23. Ammonia Loads (in kg) per Storm Event for Seasons Two and Three

	Date of Storm Event - Season Two					
Station	**11/7/2010**	**11/20/2010**	**12/17/2010**	**3/19/2011**	**3/24/2011**	**6/45/2011**
M1	N/A	3.12	0.81	0.58	1.12	0
M2	2.00	5.78	3.14	1.93	2.90	0.76
M3	1.33	2.31	1.10	1.33	1.12	0.82
M6	0.19	N/A	0.26	0.24	0.30	0.15
Historic	2.07	5.07	3.10	N/A	1.20	6.18
Industrial	N/A	7.78	5.78	0	0	1.70
SJR at Mossdale	89.72	139.47	639.72	,.63	2,263.03	439.62
Lathrop's Percentage	5.9%	14.7%	2.2%	<1%	<1%	2.1%
Lathrop's Total	5.59	24.06	14.19	4.07	6.68	9.60

	Date of Storm Event - Season Three			
Station	**10/4/2011**	**1/19/2011**	**3/16/2012**	**3/24/2012**
M1	1.48	2.14	1.34	0.28
M2	0.28	3.28	1.87	3.91
M3	1.21	10.79	1.09	0.38
M5	0.49	3.07	0.51	0.35
M6	0.24	0.44	0.24	0
Historic	5.60	7.64	2.01	1.47
Industrial	0.23	7.74	<0.01	0.10
SJR at Mossdale	<R.L.	313.85	50.72	36.55
Lathrop's Percentage	N/A	10.1%	12.2%	15.1%
Lathrop's Total	9.54	35.12	7.07	6.49

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or that there was a communication problem with the SCADA resulting in no sample and pump data. <R.L. indicates the concentration was below the reporting limit. Load from the pump stations is listed as total kilograms discharged during the storm. Load at the SJR at Mossdale station is calculated as an instantaneous load and is converted to kilograms discharged during the storm.

Figure 5-35. Scatterplot of Ammonia for Season Two

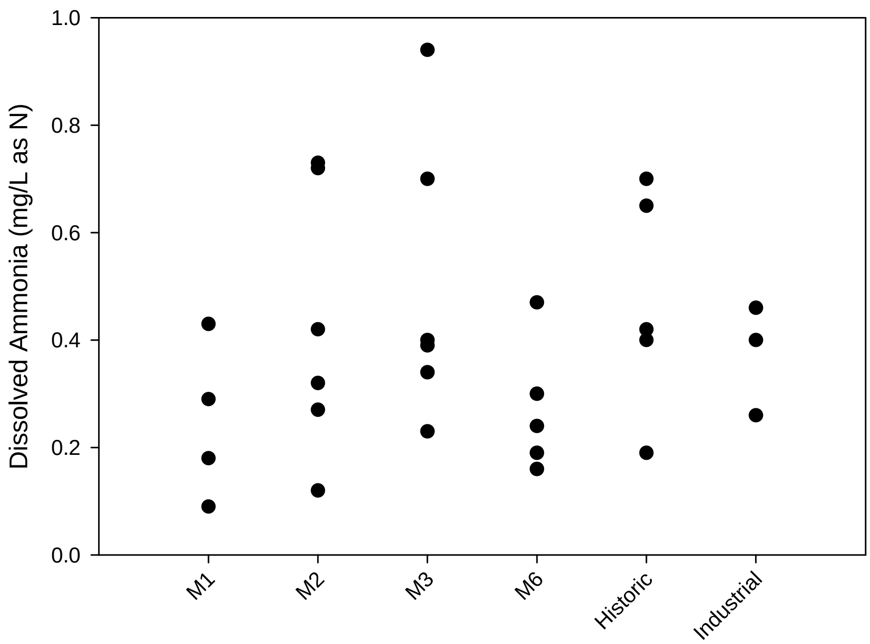
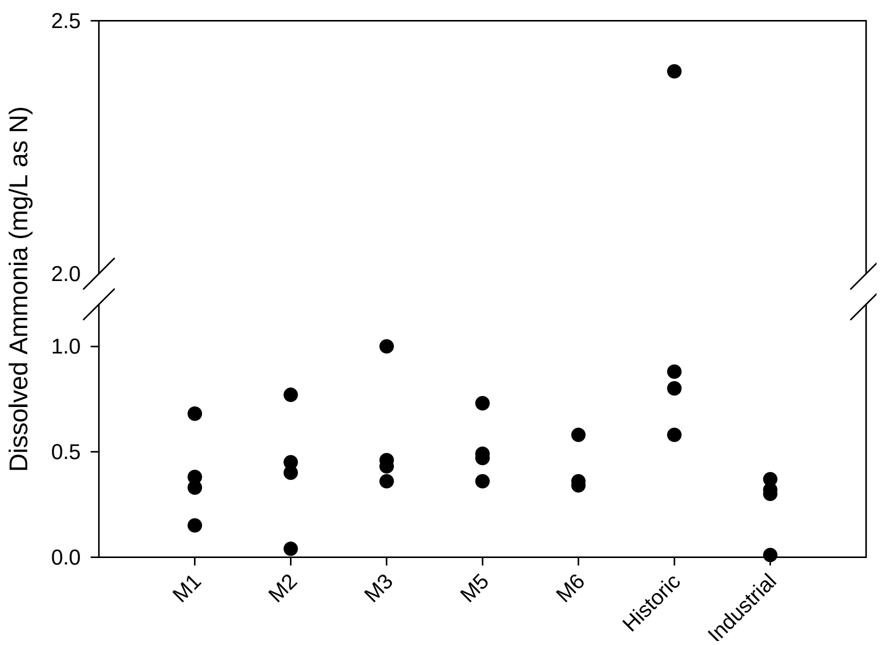


Figure 5-36. Scatterplot of Ammonia for Season Three



Dissolved Nitrate

Analysis of Seasons Two and Three

For dissolved nitrate, there were no statistical differences between the San Joaquin River and the city pumping stations. The San Joaquin River at Mossdale samples had relatively higher concentrations than several of the city pumping stations (Figure 5-37). The medians for all stations ranged from 2.4 to 5.6 mg/L as N and the overall range of concentrations was from 1.2 mg/L as N to 16.6 mg/L as N

(Table 5-24).The concentrations sampled at the city pumping stations were generally high, often exceeding EPA's MCL of 10 mg/L as N.

Figure 5-37. Boxplot of Nitrate for Seasons Two and Three

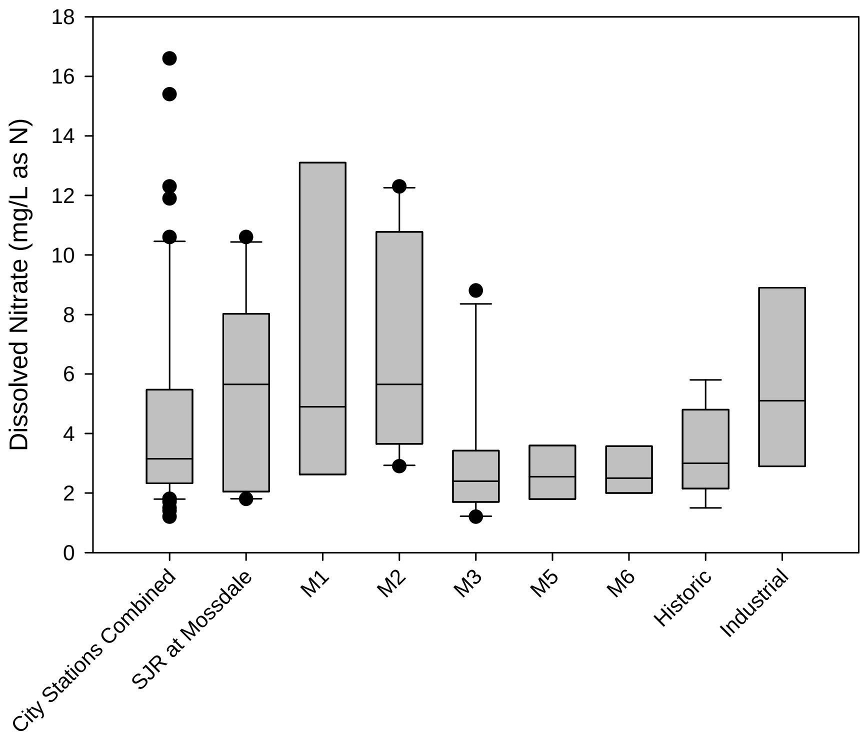


Table 5-24. Summary Statistics of Nitrate (in mg/L as N) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	7.0	4.9	2.3	16.6	5.8
M2	10	6.7	5.6	2.9	12.3	3.6
M3	10	3.0	2.4	1.2	8.8	2.2
M5	4	2.6	2.6	1.7	3.8	0.9
M6	8	2.7	2.5	1.8	3.9	0.8
Historic	9	3.5	3.0	1.5	5.8	1.5
Industrial	7	5.8	5.1	2.5	10.6	3.1
SJR at Mossdale	4	5.4	5.6	1.8	10.6	3.3

Comparison between Seasons Two and Three

There was no statistical difference in concentrations between seasons two and three; however the data patterns between the two years have some differences. The concentrations on the San Joaquin River at Mossdale increased slightly from season two to season three. The M2 and Industrial stations had some elevated concentrations from season two to season three although the maximum concentrations for these stations did not reflect this (Tables 5-25 and 5-26, Figures 5-38 and 5-39). The M1 station still had the largest range of all stations. There were no seasonal trends for dissolved nitrate.

Table 5-25. Summary Statistics of Nitrate (in mg/L as N) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	6.7	4.6	2.3	15.4	6.0
M2	6	8.2	8.6	3.8	12.3	3.8
M3	6	3.1	2.0	1.2	8.8	2.9
M6	5	3.0	2.9	2.0	3.9	0.9
Historic	5	3.8	4.6	1.5	5.8	2.2
Industrial	3	5.5	3.5	2.5	10.6	4.4
SJR at Mossdale	6	3.4	2.1	1.8	9.0	3.1

Table 5-26. Summary Statistics of Nitrate (in mg/L as N) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	7.2	4.9	2.5	16.6	6.4
M2	4	4.4	4.0	2.9	6.4	1.6
M3	4	2.9	2.5	2.3	4.4	1.0
M5	4	2.6	2.6	1.7	3.8	0.9
M6	3	2.2	2.0	1.8	2.8	0.5
Historic	4	3.0	2.7	1.9	4.8	1.3
Industrial	4	5.9	6.0	2.9	8.9	2.5
SJR at Mossdale	4	7.3	6.9	4.8	10.6	2.4

Figure 5-38. Boxplot of Nitrate for Season Two

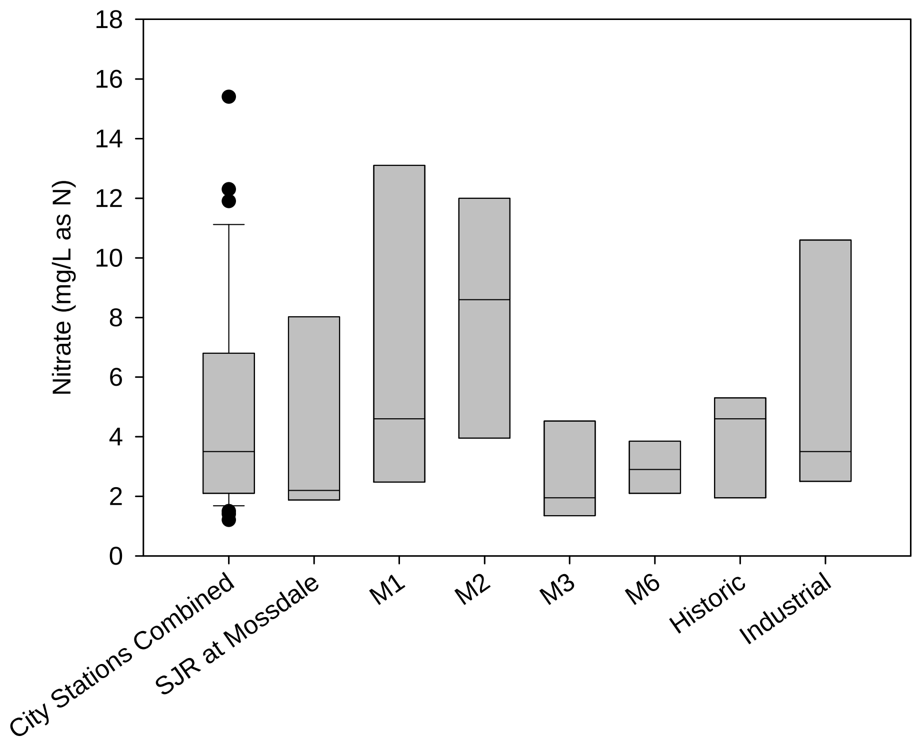
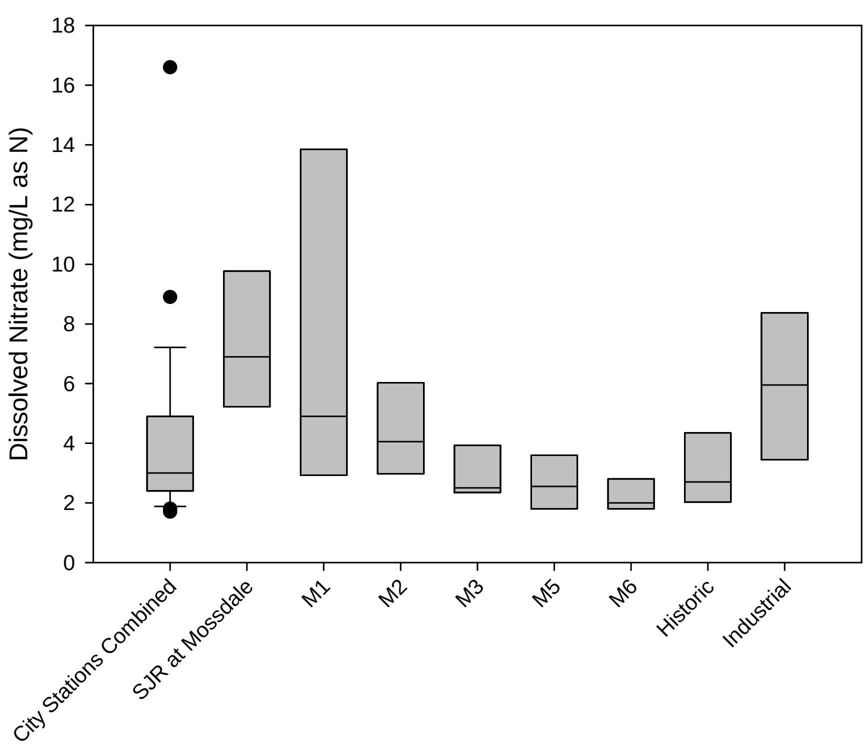


Figure 5-39. Boxplot of Nitrate for Season Three



Comparison with Other Studies

When the San Joaquin River concentrations were compared to those of the Sacramento River collected by the Sacramento CMP in the 2011-2012 sampling period, the San Joaquin concentrations were elevated. The Sacramento River concentrations ranged from 0.04 mg/L as N to 0.54 mg/L as N, whereas the San Joaquin River concentrations ranged from 1.8 mg/L as N to 10.6 mg/L as N (Table 5-24). This difference in concentration between the two rivers is largely due to the greater amount of agriculture lands that drain into the San Joaquin River. Agricultural drainage contains more nutrients due to fertilizer use.

Lathrop concentrations were slightly low in comparison to those collected in the Steelhead Creek study (DWR, 2008). Samples collected during storm events from 1997 to 2005 in the Steelhead Creek study had a mean of 5.01 mg/L as N, a median of 4.2 mg/L as N, and ranged from 1.8 mg/L as N to 22.8 mg/L as N. Lathrop concentrations had means ranging from 2.6 mg/L as N to 7.0 mg/L as N, medians from 2.4 mg/L as N to 5.6 mg/L as N, and the range of all concentrations was from 1.2 mg/L as N to 16.6 mg/L as N (Table 5-24). The median concentrations analyzed by the Sacramento Stormwater Partnership and concentrations summarized in the Urban Sources and Control Evaluation were very similar to those sampled in Lathrop (Geosyntec, 2011). The medians in the Sacramento Stormwater Partnership evaluation ranged from 0.45 mg/L as N to 2.2 mg/L as N. Lathrop's concentrations were also comparable when compared to the sampled collected for the Los Angeles Phase I NPDES permit (Los Angeles County, 2012). The concentrations during the 2011-2012 wet season had medians that ranged from 0.85 mg/L as N to 3.0 mg/L as N. These comparisons show that Lathrop's nitrate discharge concentrations were not unusually high compared to other studies throughout California.

Dissolved Nitrate plus Nitrite

Analysis of Seasons Two and Three

The dissolved nitrate plus nitrite concentrations at the San Joaquin River at Mossdale stations were not statistically different than those at the city pumping stations. This is seen in the boxplot of all the stations (Figure 5-40), which shows several pumping station ranges below the San Joaquin River at Mossdale range. The M1 and M2 stations had relatively higher concentrations in nitrate plus nitrite with the M3, M5, and M6 stations having the lowest concentrations. The median concentrations for all stations ranged from 0.46 mg/L as N to 1.2 mg/L as N. The overall range of concentrations was 0.21 mg/L as N to 3.90 mg/L as N. The maximum concentration at the M1 station (3.90 mg/L as N) was more than 1 mg/L as N higher than the maximums for all the other stations (Table 5-27).

Figure 5-40. Boxplot of Nitrate plus Nitrite for Seasons Two and Three

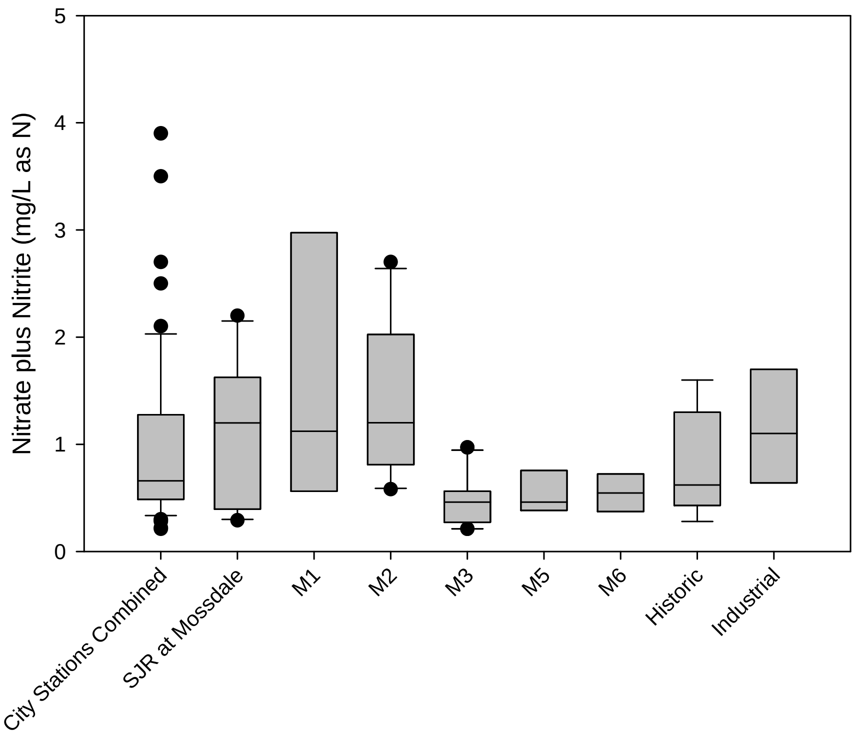


Table 5-27. Summary Statistics of Nitrate plus Nitrite (in mg/L as N) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	1.59	1.12	0.52	3.90	1.34
M2	10	1.38	1.20	0.58	2.70	0.70
M3	10	0.47	0.46	0.21	0.97	0.23
M5	4	0.53	0.46	0.38	0.83	0.21
M6	8	0.56	0.54	0.30	0.90	0.20
Historic	9	0.83	0.62	0.28	1.60	0.48
Industrial	7	1.21	1.10	0.50	2.50	0.71
SJR at Mossdale	10	1.09	1.20	0.29	2.20	0.68

Comparison between Seasons Two and Three

There was no statistical difference between the San Joaquin River at Mossdale station samples and the city pumping stations samples for season two. However, in season three the San Joaquin River concentrations were significantly higher than the city pumping station concentrations (Mann-Whitney, $p= 0.022$). The reason there is a significant difference in season three may be due to a difference in water year type or because of a low sample size at the San Joaquin River at Mossdale station; season two was classified as a wet water year whereas season three was classified as a dry water year. There was no statistical difference between the San Joaquin River at Mossdale samples for season two and three. Additional sampling would be required to determine if there is a trend of higher concentrations of nitrate plus nitrite in the river in dry water years versus wet water years. The patterns of the data between seasons two and three were similar and there was no statistical difference between season two and season three samples. The only differences were that the concentrations for the San Joaquin River at Mossdale station had a broader spread in season two than three (Figures 5-41 and 5-42, Tables 5-28 and 5-29). There were no significant trends during the course of the two seasons.

Figure 5-41. Boxplot of Nitrate plus Nitrite for Season Two

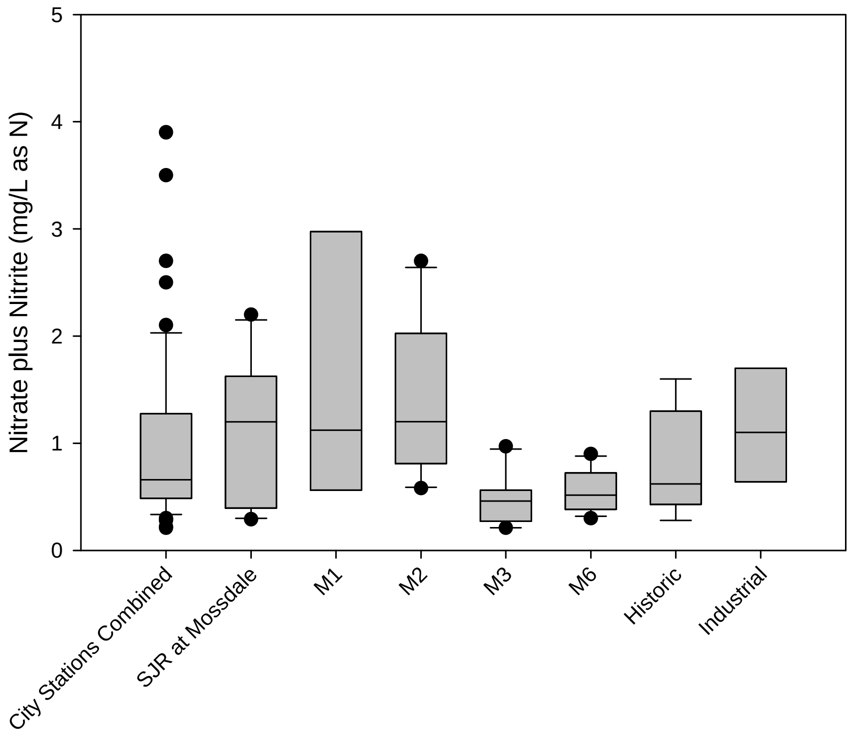


Figure 5-42. Boxplot of Nitrate plus Nitrite for Season Three

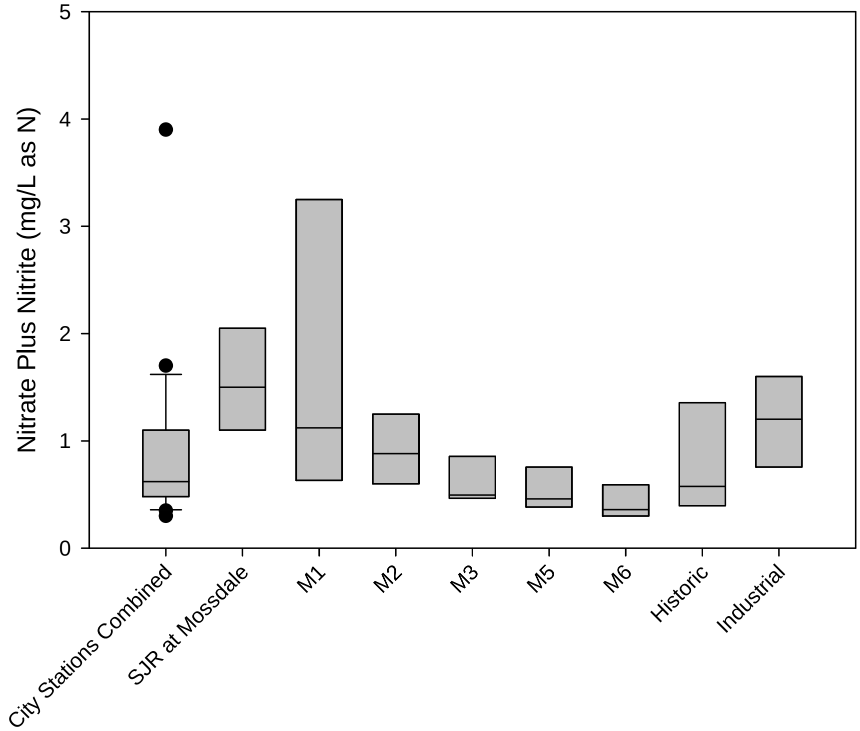


Table 5-28. Summary Statistics of Nitrate plus Nitrite (in mg/L as N) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	1.52	1.03	0.52	3.50	1.38
M2	6	1.69	1.80	0.86	2.70	0.73
M3	6	0.39	0.36	0.21	0.72	0.19
M6	5	0.64	0.64	0.41	0.90	0.20
Historic	5	0.88	0.99	0.28	1.40	0.47
Industrial	3	1.24	0.72	0.50	2.50	1.10
SJR at Mossdale	6	0.78	0.41	0.29	1.70	0.64

Table 5-29. Summary Statistics of Nitrate plus Nitrite (in mg/L as N) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	1.67	1.12	0.53	3.90	1.52
M2	4	0.91	0.88	0.58	1.30	0.35
M3	4	0.61	0.50	0.46	0.97	0.24
M5	4	0.53	0.46	0.38	0.83	0.21
M6	3	0.42	0.36	0.30	0.59	0.15
Historic	4	0.78	0.58	0.35	1.60	0.56
Industrial	4	1.19	1.20	0.64	1.70	0.44
SJR at Mossdale	4	1.55	1.50	1.00	2.20	0.50

Comparison with Other Studies

Lathrop's nitrate plus nitrite concentrations were very comparable to other studies in the area. Lathrop's mean and median concentrations were lower than those of the Steelhead Creek study and of the Stockton 2011 NPDES annual report (Table 5-30) (DWR, 2008; City of Stockton, 2011). Lathrop's minimum concentration was slightly higher than these 2 studies, but Lathrop's maximum concentration was lower. When comparing Lathrop's concentrations to samples collected on the Sacramento River in 2011 and 2012 by the Sacramento CMP, Lathrop's concentrations appear to be slightly elevated. The means of the Sacramento River samples ranged from 0.04mg/L to 0.54 mg/L, whereas Lathrop's means for all stations ranged from 0.47 mg/L as N to 1.59 mg/L as N (Table 5-27). Similar to nitrate, these higher concentrations on the San Joaquin River reflect a higher amount of agricultural fertilizer use in the watershed.

In comparison to the Urban Runoff Sources and Controls Evaluation, Lathrop's concentrations are quite similar (Geosyntec, 2011). The medians in the drainage areas in the evaluation ranged from 0.61 mg/L as N to 0.98 mg/L as N. These concentrations were similar to what was sampled in Lathrop, with Lathrop's medians ranging from 0.46 mg/L as N to 1.00 mg/L as N.

Table 5-30. Nitrate plus Nitrite Concentrations (in mg/L as N)

Study	Mean	Median	Minimum	Maximum
Lathrop	0.98	0.69	0.21	3.90
Steelhead Creek	1.14	0.99	N.D.	5.4
Stockton NPDES	1.86	1.20	0.11	4.80

Total Nitrogen

Total nitrogen was calculated as a sum of Kjeldahl nitrogen and dissolved nitrate plus nitrite.

Analysis of Seasons Two and Three

Total nitrogen samples from the San Joaquin River at Mossdale were significantly lower than samples taken at the city pumping stations (Mann-Whitney, $p=0.011$). However, the concentrations sampled from the San Joaquin River and the city pumping stations were generally high, and mostly exceeded the EPA's reference conditions of 0.31 mg/L as N. The boxplot for total nitrogen shows the Mossdale region concentrations had a lot of variability in concentrations (Figure 5-43). Overall, the M6 pumping station and the Industrial station had the lowest concentrations. The median concentration for the San Joaquin River at Mossdale was 1.50 mg/L and the medians for the city pumping stations ranged from 1.66 mg/L as N to 4.53 mg/L as N. The range of concentrations for the San Joaquin River at Mossdale was 0.49 mg/L as N to 3.40 mg/L as N and the concentrations at the city pumping stations ranged from 0.62 mg/L as N to 11.20 mg/L as N (Table 5-31). There was much variability throughout the other stations in the Mossdale residential region. The Historic station also had a wide range of concentrations.

Figure 5-43. Boxplot of Total Nitrogen for Seasons Two and Three

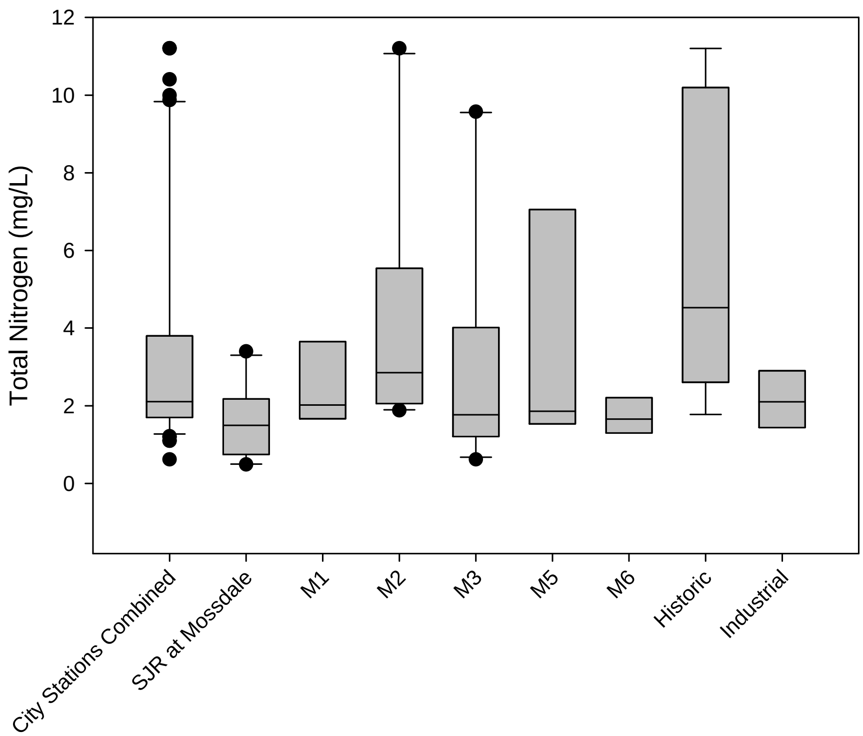


Table 5-31. Summary Statistics of Total Nitrogen (in mg/L as N) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	2.66	2.02	1.52	5.70	1.46
M2	10	4.32	2.85	1.88	11.20	3.38
M3	10	3.13	1.77	0.62	9.57	3.38
M5	4	3.48	1.86	1.48	8.73	3.51
M6	8	1.72	1.66	1.10	2.39	0.49
Historic	9	6.23	4.53	1.78	11.20	4.00
Industrial	7	2.12	2.10	1.10	3.20	0.76
SJR at Mossdale	4	1.59	1.50	0.49	3.40	0.90

Comparison between Seasons Two and Three

There was no significant difference in total nitrogen concentrations between seasons two and three. In season two, the San Joaquin River at Mossdale concentrations were significantly lower than the city pumping station concentrations (Mann-Whitney, p=0.09); however, they were not significantly different in season three (Mann-Whitney, p=0.28). The reason the third season did not show a significant difference in concentrations between the city pumping stations and the San Joaquin River may be due to the small sample size, but it is also likely that it could be due to season three being a dry water year, whereas season two was a wet year (Figure 4-1). The overall pattern of data between season two and three is similar, although the M2 and M3 stations had a much broader range in season three (Figures 5-44 and 5-45, Tables 5-32 and 5-33). The M5 station was not sampled in season two due to forecasting issues and problems with the signal from the SCADA. However, in season three, the M5 station was sampled and had a wide range of concentrations (Figures 5-44 and 5-45, Tables 5-32 and 5-33). There were no significant trends during the two seasons.

Figure 5-44. Boxplot of Total Nitrogen for Season Two

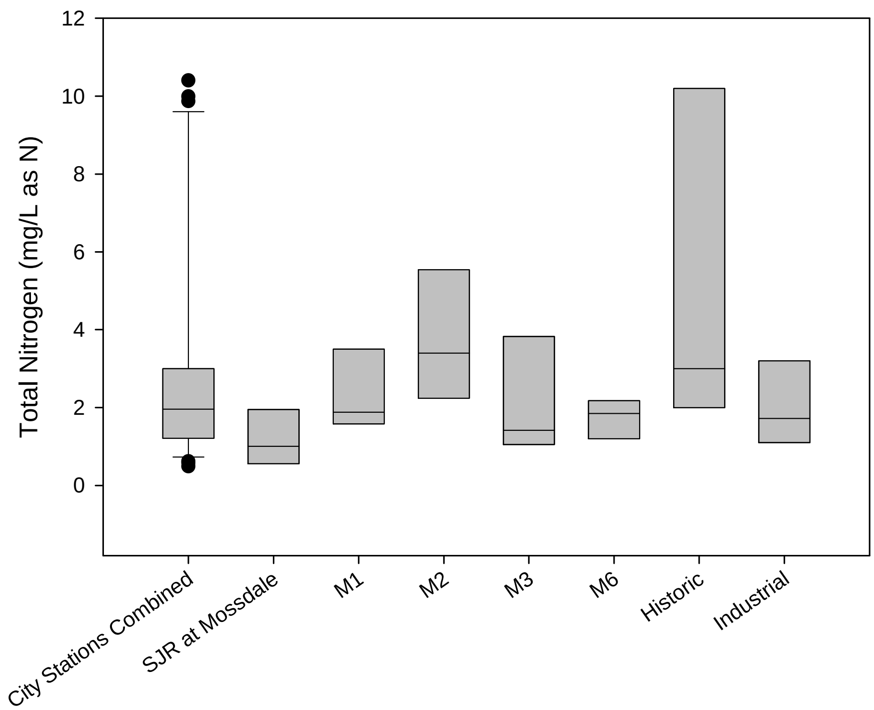


Figure 5-45. Boxplot of Total Nitrogen for Season Three

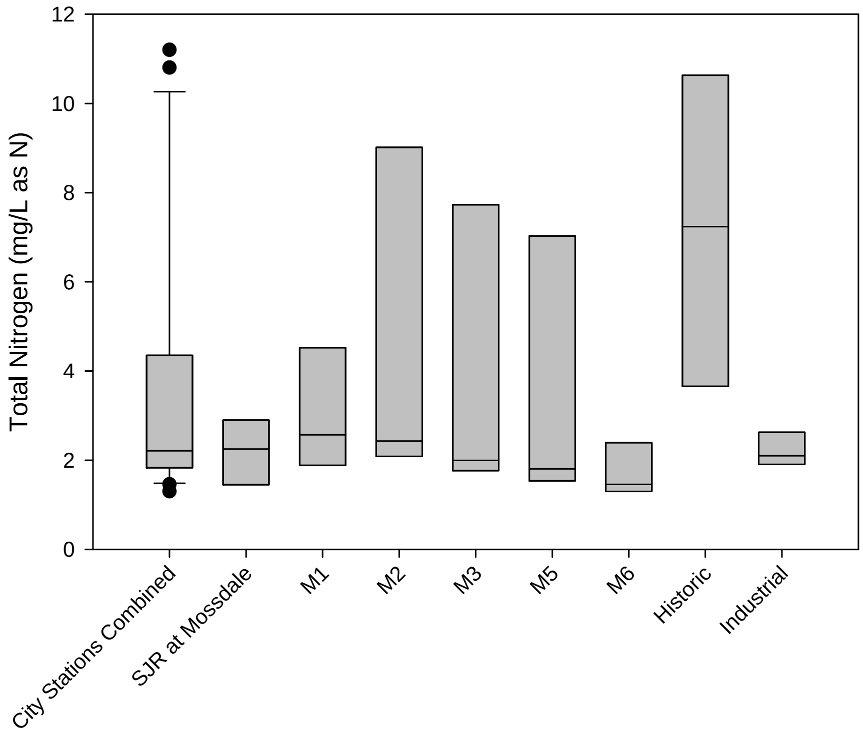


Table 5-32. Summary Statistics of Total Nitrogen (in mg/L as N) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	2.32	1.88	1.52	4.00	1.14
M2	6	4.19	3.40	2.06	9.87	2.91
M3	6	2.67	1.42	0.62	9.42	3.34
M6	5	1.72	1.85	1.10	2.24	0.50
Historic	5	5.48	3.00	1.78	10.40	4.33
Industrial	3	2.01	1.72	1.10	3.20	1.08
SJR at Mossdale	6	1.18	1.01	0.49	2.10	0.69

Table 5-33. Summary Statistics of Total Nitrogen (in mg/L as N) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	2.99	2.32	1.63	5.70	1.85
M2	4	4.51	2.48	1.88	11.20	4.48
M3	4	3.83	2.00	1.76	9.57	3.83
M5	4	3.48	1.86	1.48	8.73	3.51
M6	3	1.72	1.46	1.30	2.39	0.59
Historic	4	7.18	7.18	3.15	11.20	3.93
Industrial	4	2.21	2.25	1.44	2.90	0.61
SJR at Mossdale	4	2.20	2.05	1.30	3.40	0.92

Total Nitrogen Composition

Total nitrogen is composed of organic nitrogen (total Kjeldahl nitrogen minus dissolved ammonia) and inorganic nitrogen (the sum of ammonia, nitrate and nitrite). Both forms of nitrogen are present in fertilizers and can be present in storm water. During the study period, the Historic station had generally higher proportions of organic nitrogen (Figure 5-46). The percentage of organic nitrogen for the two seasons for all stations had a median of 38% (Table 5-34). This statistic was different between the San Joaquin River and the city pumping stations. The median for the pumping stations was 42%, whereas the San Joaquin River at Mossdale median was 32%. This is a notable difference in nutrient composition between the San Joaquin River and the storm water discharged from the city pumping stations. This difference was also seen during season three, but the difference was insignificant in season two. Again, this may be due to wet water year versus dry water year effects. In season two, the median of organic nitrogen was 38% for all stations combined, and 38% for the city pumping stations. For the San Joaquin River at Mossdale, the median was only 35%. In season three, the percent of organic nitrogen for all stations was 43%. The city pumping stations had a median of 45%, whereas the San Joaquin River had a median of 27%.

Figure 5-46. Total Nitrogen Composition

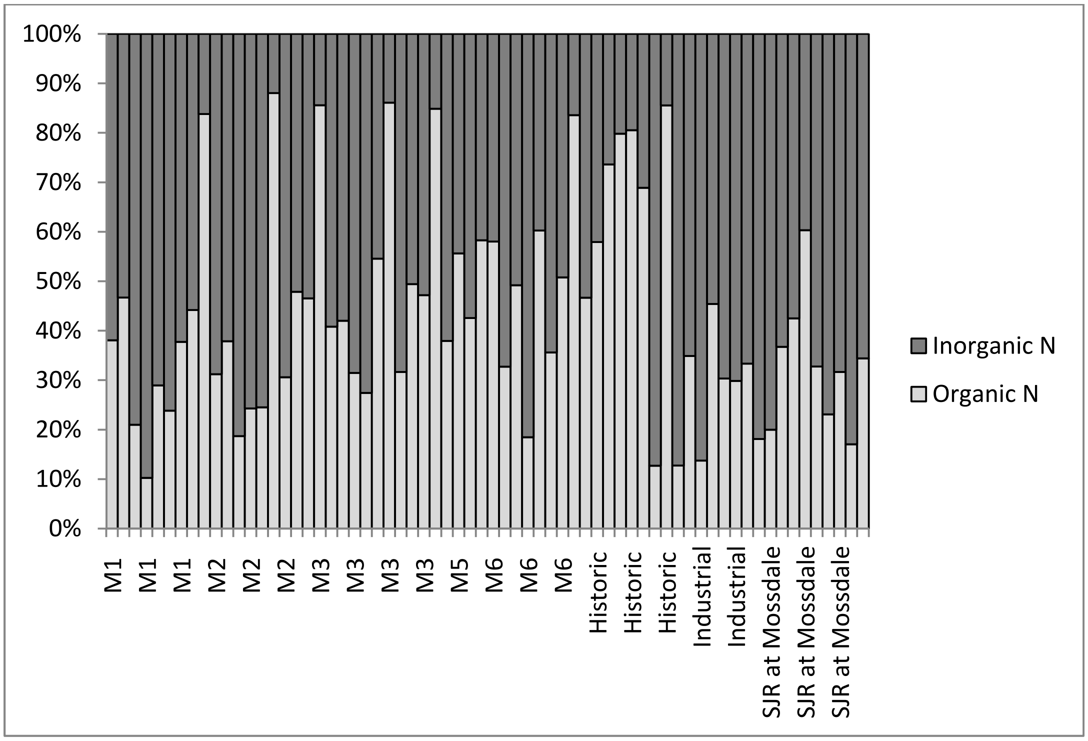


Table 5-34. Percent of Total Nitrogen composed of Organic Nitrogen (Total Kjeldahl Nitrogen minus Dissolved Ammonia)

	Season Three		
	SJR	**City**	**Combined**
Mean	0.27	0.49	0.46
Median	0.27	0.45	0.43
Minimum	0.17	0.13	0.13
Maximum	0.34	0.88	0.88
	Season Two		
	SJR	**City**	**Combined**
Mean	0.35	0.43	0.41
Median	0.35	0.38	0.38
Minimum	0.18	0.10	0.10
Maximum	0.60	0.86	0.86
	Seasons Two and Three		
	SJR	**City**	**Combined**
Mean	0.32	0.46	0.43
Median	0.32	0.42	0.38
Minimum	0.17	0.10	0.10
Maximum	0.60	0.88	0.88

Total Nitrogen Loads

Although the concentrations for Lathrop were significantly higher than the San Joaquin River for season two, and for seasons two and three combined, the city did not contribute a significant load to the San Joaquin River. For season two, the city's portion of the total nitrogen load on the San Joaquin River was less than 1% for all storms (Table 5-35). In season three, the city's total nitrogen concentrations were not significantly different from those sampled on the San Joaquin River, and the total load contributed by the city was also insignificant. With the exception of the first flush event in season three in which the city contributed 1.5% of the total load on the San Joaquin River, the city contributed less than 1% of the load throughout the storm season.

Table 5-35. Total Nitrogen Load (in kg) per Storm Event for Seasons Two and Three

	Season Two - Date of Storm Event					
Station	**11/7/2010**	**11/20/2010**	**12/17/2010**	**3/19/2011**	**3/24/2011**	**6/4/2011**
M1	N/A	12.80	4.27	6.34	49.77	0
M2	27.05	32.89	15.41	16.44	67.57	9.48
M3	13.34	6.48	3.29	5.50	3.12	2.94
M6	0.85	N/A	1.91	1.08	2.92	0
Historic	31.77	38.01	16.31	N/A	11.32	1.24
Industrial	N/A	18.58	24.85	0	0	91.81
SJR at Mossdale	9,420.37	13,249.68	15,673.35	28,234.99	39,118.06	27,815.77
Lathrop's Percentage	<1%	<1%	<1%	<1%	<1%	<1%
Lathrop's Total	73.00	108.76	66.04	29.44	134.70	126.27

	Season Three - Date of Storm Event			
Station	**10/4/2011**	**1/19/2012**	**3/16/2012**	**3/24/2012**
M1	164.76	17.70	17.01	1.82
M2	44.67	12.36	14.98	42.61
M3	14.74	24.82	6.32	2.05
M5	3.81	12.61	2.99	1.25
M6	1.87	1.53	1.27	N/A
Historic	46.37	20.85	15.94	5.52
Industrial	156.92	215.38	0.04	1.76
SJR at Mossdale	27,593.10	57,277.45	32,968.73	12.914.26
Lathrop's Percentage	1.5%	<1%	<1%	<1%
Lathrop's Total	433.15	305.25	58.55	55.01

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or there was a communication problem with the SCADA resulting in no sample and pump data. Load from the pump stations was calculated as total kilograms discharged during the storm. Load at the SJR at Mossdale station was calculated as an instantaneous load and was converted to total kilograms discharged during the storm.

Orthophosphate

Seasons Two and Three

Orthophosphate concentrations for seasons two and three on the San Joaquin River were significantly lower than those in the city pumping stations (Mann-Whitney, p=0.047). The boxplot of the data shows that the San Joaquin River at Mossdale samples had a reasonably large range of values that overlap many of the city pumping stations values (Figure 5-47). The medians for the San Joaquin River at Mossdale was 0.08 mg/L as P and for the city pumping stations the medians ranged from 0.07 mg/L as P to 0.16 mg/L as P. The range of concentrations at the San Joaquin River at Mossdale was 0.02 mg/L as P to 0.17 mg/L as P, and the range for the city pumping stations was 0.03 mg/L as P to 0.27 mg/L as P (Table 5-36). There was much variability over the Mossdale residential region. Of all the city pumping stations, the Historic station had the widest variability.

Figure 5-47. Boxplot of Orthophosphate for Seasons Two and Three

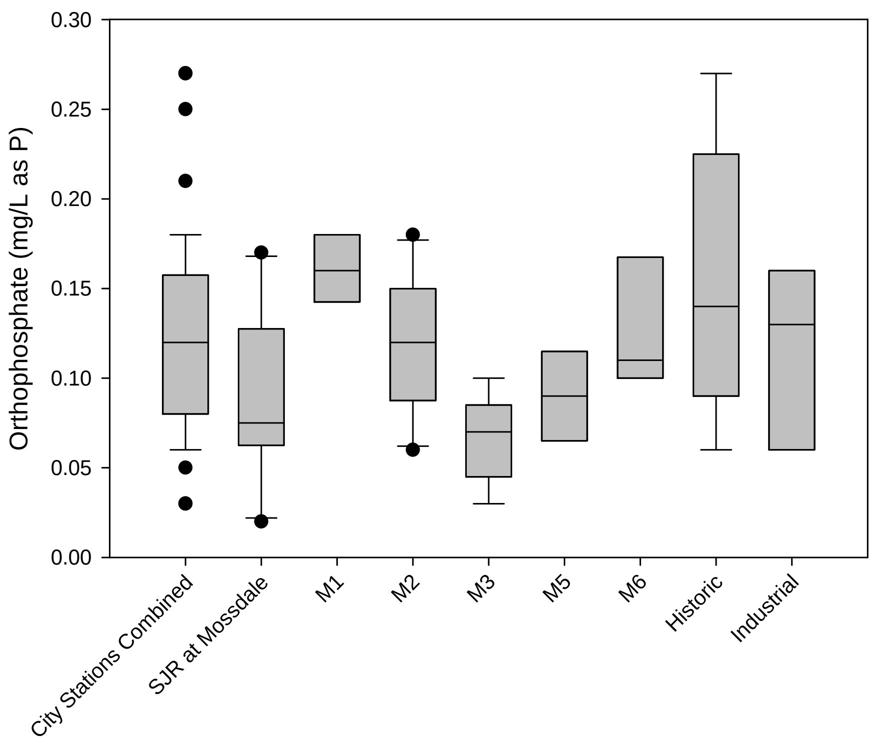


Table 5-36. Summary Statistics of Orthophosphate (in mg/L as P) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	0.17	0.16	0.12	0.25	0.04
M2	10	0.12	0.12	0.06	0.18	0.04
M3	10	0.07	0.07	0.03	0.10	0.02
M5	4	0.09	0.09	0.06	0.12	0.03
M6	8	0.13	0.11	0.09	0.21	0.04
Historic	9	0.15	0.14	0.06	0.27	0.08
Industrial	7	0.12	0.13	0.06	0.17	0.04
SJR at Mossdale	4	0.09	0.08	0.02	0.17	0.05

Comparison between Seasons Two and Three

There was no significant difference in orthophosphate concentrations between seasons two and three. In season two, the San Joaquin River at Mossdale concentrations were significantly lower than the city pumping station samples (Mann-Whitney, p=0.015). There was no significant difference in concentrations between the city pumping stations and the San Joaquin River at Mossdale station for season three. Although there were no significant differences between the two seasons, the patterns of the data had differences between seasons (Figures 5-48 and 5-49). The concentrations for the San Joaquin River at Mossdale increased from season two to season three (Tables 5-37 and 5-38). The Mossdale residential region data was more tightly clustered in season two than season three. As a result, the boxes on the boxplots show more variation for the region. The Historic station changed the most from season two to three, showing a much wider range of concentrations in season three. The Industrial station did not show significant change from season two to three. These differences in data between seasons two and three may be due to hydrology. Season two was a wet year preceded by a wet year possibly resulting in slightly higher concentrations of orthophosphate, whereas season three was a dry year. There were no trends during the two year period.

Figure 5-48. Boxplot of Orthophosphate for Season Two

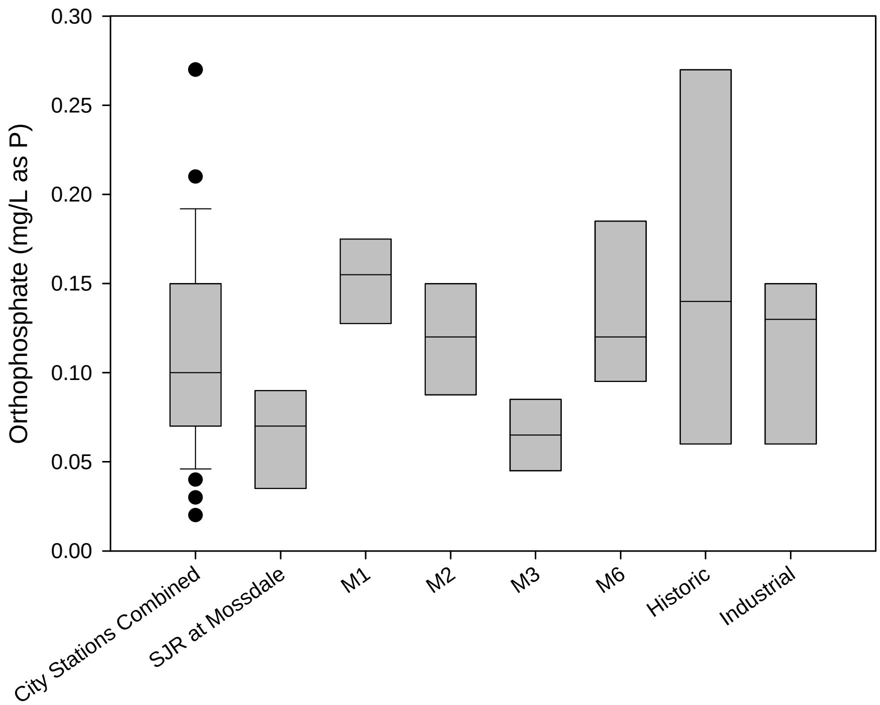


Figure 5-49. Boxplot of Orthophosphate for Season Three

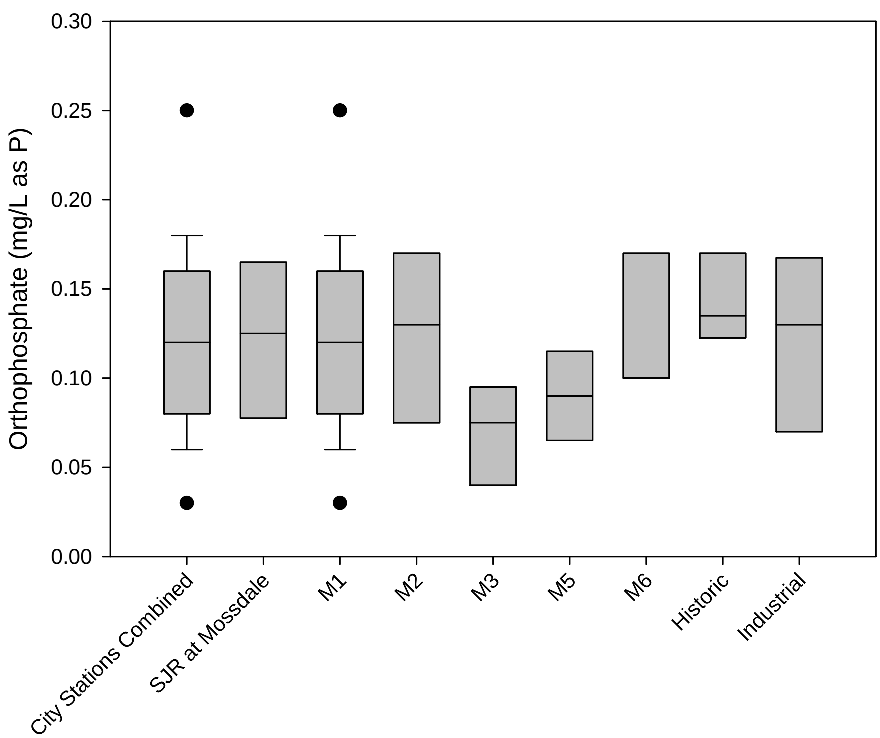


Table 5-37. Summary Statistics of Orthophosphate (in mg/L as P) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.15	0.16	0.12	0.18	0.03
M2	6	0.11	0.12	0.08	0.15	0.03
M3	6	0.07	0.07	0.03	0.10	0.02
M6	5	0.14	0.12	0.09	0.21	0.05
Historic	5	0.16	0.16	0.06	0.27	0.11
Industrial	3	0.11	0.13	0.06	0.15	0.05
SJR at Mossdale	6	0.07	0.07	0.02	0.12	0.03

Table 5-38. Summary Statistics of Orthophosphate (in mg/L as P) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.18	0.17	0.14	0.25	0.05
M2	4	0.13	0.13	0.06	0.18	0.05
M3	4	0.07	0.08	0.03	0.10	0.03
M5	4	0.09	0.09	0.06	0.12	0.02
M6	3	0.12	0.10	0.10	0.17	0.04
Historic	4	0.14	0.14	0.12	0.18	0.03
Industrial	4	0.12	0.13	0.06	0.17	0.05
SJR at Mossdale	4	0.12	0.13	0.07	0.17	0.04

Total Phosphorus

Analysis of Seasons Two and Three

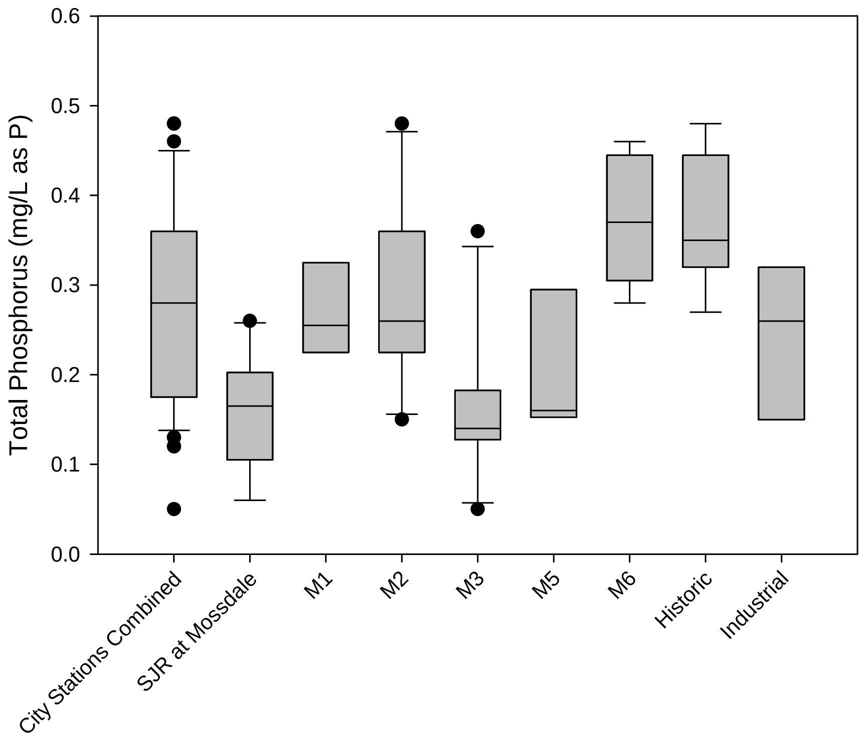
For seasons two and three combined, the concentrations on the San Joaquin River at Mossdale were significantly lower than the concentrations sampled from the city pumping stations (Mann-Whitney, p=0.001). The median concentrations for the city pumping stations ranged from 0.14 mg/L as P to 0.38 mg/L as P. The median of 0.14 mg/L as P was lower than that of the San Joaquin River (0.16 mg/L as P), showing that the San Joaquin River concentrations were not dramatically lower than those in the city pumping stations. The overall range of concentrations was from 0.05 mg/L as P to 0.48 mg/L as P (Table 5-39).

There was much variability in concentrations throughout the Mossdale residential region (M stations) with M2 and M3 having the widest range of concentrations (Figure 5-50, Table 5-39). The M3 station also had the lowest concentration of all stations. Samples collected from the M6 and Historic stations were generally high. The Industrial station concentrations were generally in the middle of the range of all concentrations.

Table 5-39. Summary Statistics of Total Phosphorus (in mg/L as P) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	0.27	0.26	0.17	0.39	0.07
M2	10	0.29	0.26	0.15	0.48	0.10
M3	10	0.16	0.14	0.05	0.36	0.08
M5	4	0.20	0.16	0.15	0.34	0.09
M6	8	0.38	0.38	0.28	0.46	0.07
Historic	9	0.38	0.35	0.27	0.48	0.07
Industrial	7	0.26	0.26	0.12	0.45	0.11
SJR at Mossdale	10	0.16	0.17	0.06	0.26	0.07

Figure 5-50. Boxplot of Total Phosphorus for Seasons Two and Three



Comparison between Seasons Two and Three

Unlike orthophosphate, there was a significant difference in total phosphorus concentrations between season two and season three, with season two concentrations being significantly lower than season three samples (Mann-Whitney, p=0.016). The total phosphorus concentrations on the San Joaquin River were significantly lower than the city pumping stations in season two (Mann-Whitney, p= 0.09), but not for season three. The data patterns also differed slightly from season two to three. In season two, the data for each station was more tightly clustered and there was more variation between stations (Figures 5-51 and 5-52). In season three, the data for each station was more spread out, the concentrations at the M3 and Industrial stations increased, and there was more overlap of concentrations from the city pumping stations with the San Joaquin River at Mossdale concentrations. Except for the Industrial station, all medians for the stations increased from season two to season three (Tables 5-40 and 5-41). As demonstrated in the boxplots, the ranges also increased between seasons two and three (Figures 5-51 and 5-52). These differences in water quality may be due to wet water year (season two) versus dry water year (season three) effects.

Figure 5-51. Boxplot of Total Phosphorus for Season Two

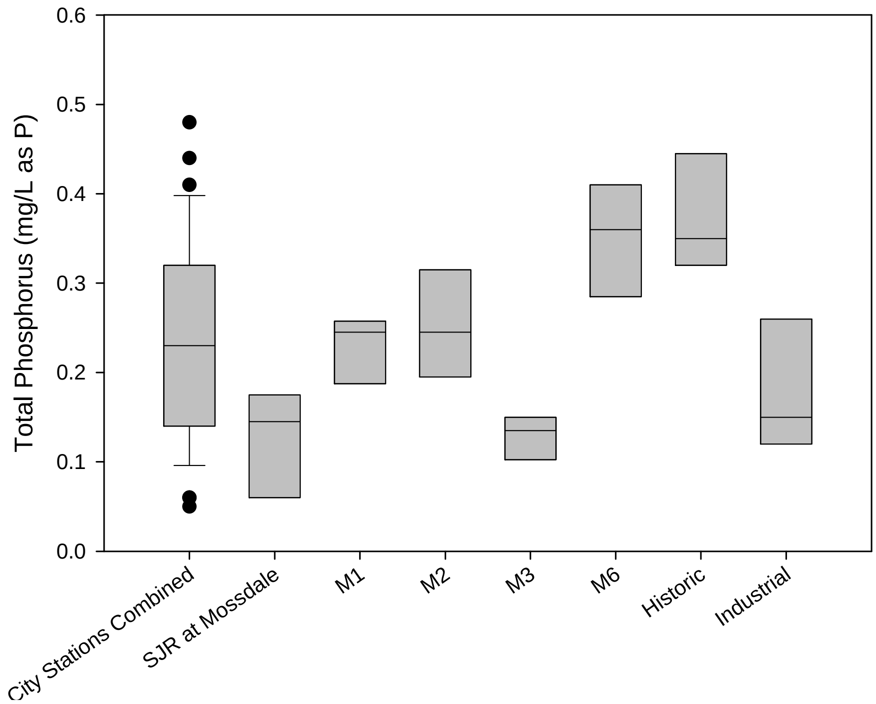


Figure 5-52. Boxplot of Total Phosphorus for Season Three

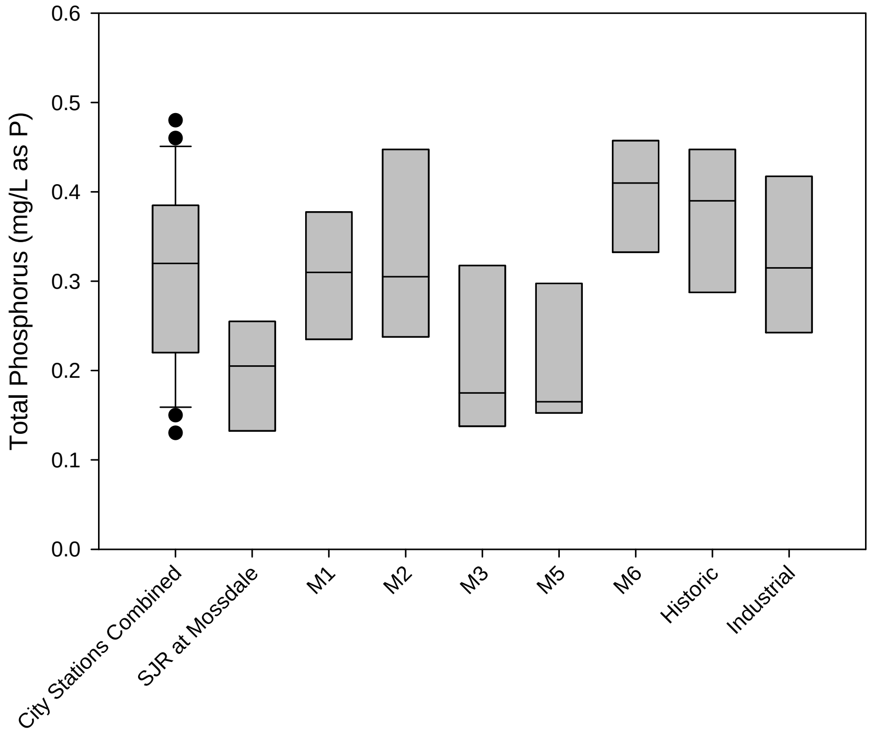


Table 5-40. Summary Statistics of Total Phosphorus (in mg/L as P) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.23	0.25	0.17	0.26	0.04
M2	6	0.26	0.25	0.15	0.39	0.08
M3	6	0.13	0.14	0.05	0.18	0.04
M6	5	0.35	0.36	0.28	0.44	0.07
Historic	5	0.38	0.35	0.32	0.48	0.07
Industrial	3	0.18	0.15	0.12	0.26	0.07
SJR at Mossdale	6	0.13	0.14	0.06	0.19	0.06

Table 5-41. Summary Statistics of Total Phosphorus (in mg/L as P) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.31	0.31	0.22	0.39	0.07
M2	4	0.33	0.31	0.23	0.48	0.11
M3	4	0.21	0.18	0.13	0.36	0.10
M5	4	0.21	0.17	0.15	0.34	0.09
M6	4	0.40	0.41	0.32	0.46	0.07
Historic	4	0.38	0.39	0.27	0.45	0.09
Industrial	4	0.33	0.32	0.22	0.45	0.09
SJR at Mossdale	4	0.20	0.20	0.12	0.26	0.06

Total Phosphorus Composition

Throughout the study period, phosphorus composition remained relatively constant, with a few samples at the Industrial and San Joaquin River at Mossdale stations having a higher component of dissolved phosphorus (orthophosphate) (Figure 5-53). The median of total phosphorus for both seasons composed of orthophosphate was 49% (Table 5-42). The difference in total phosphorus composition between the San Joaquin River and the city pumping stations was not as dramatic as it was for total nitrogen. The median in the city was 53%, compared to the San Joaquin River at Mossdale median of 49%. In season two, the difference was very small with the San Joaquin River at Mossdale having a median of 45%, and the city pumping stations having a median of 50%. The difference between the San Joaquin River and city pumping stations was larger in season three, with the San Joaquin River at Mossdale having a median of 60%, and the city pumping stations having a median of 44%. However, these differences in season three were not significantly different according to the Mann-Whitney test.

Figure 5-53. Total Phosphorus Composition

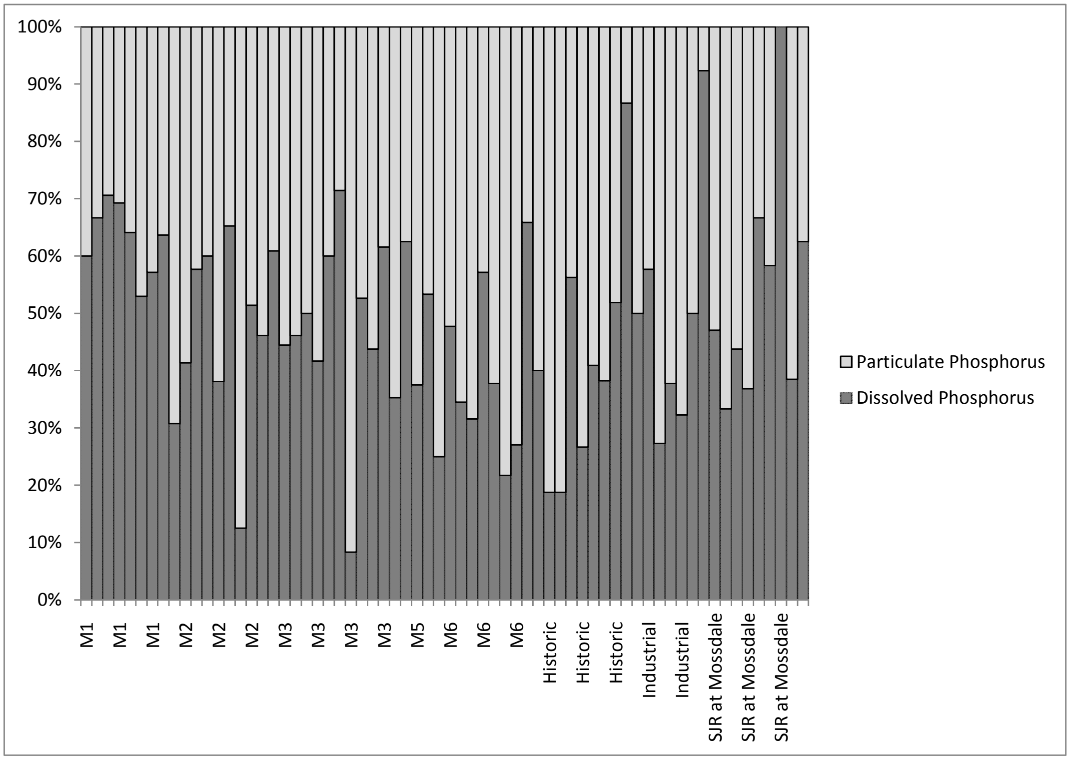


Table 5-42. Percent of Total Phosphorus Composed of Dissolved Orthophosphate

	Season Three		
	SJR	**City**	**Combined**
Mean	0.65	0.43	0.46
Median	0.60	0.44	0.46
Minimum	0.38	0.08	0.83
Maximum	1.00	0.64	1.00
	Season Two		
	SJR	**City**	**Combined**
Mean	0.53	0.50	0.51
Median	0.45	0.50	0.50
Minimum	0.33	0.19	0.19
Maximum	0.92	0.87	0.92
	Seasons Two and Three		
	SJR	**City**	**Combined**
Mean	0.58	0.47	0.48
Median	0.53	0.49	0.49
Minimum	0.33	0.08	0.08
Maximum	1.00	0.87	1.00

Comparison to Other Studies

Lathrop's pumping station total phosphorus concentrations were comparable to other studies throughout California, although there were differences in the San Joaquin River at Mossdale concentrations when compared with other studies. Samples taken on the Sacramento River by the Sacramento CMP in 2011 and 2012 were slightly lower than the San Joaquin River at Mossdale concentrations. The San Joaquin River concentrations ranged from 0.06 mg/L as P to 0.26 mg/L as P (Table 5-39). All the storm samples collected on the Sacramento River were less than 0.06 mg/L as P with the exception of a 0.53 mg/L as P sample collected. These differences in total phosphorus concentrations reflect differences in water quality between the Sacramento and San Joaquin rivers. The San Joaquin River generally has higher phosphorus concentrations as a result of agricultural application of fertilizers.

Lathrop's discharge concentrations were lower or comparable to other studies throughout California. Lathrop's median concentration of 0.26 mg/L as P was lower than the median concentration of 0.34 mg/L as P of samples collected between 1997 and 2005 in the Steelhead Creek study (DWR, 2008). Lathrop's median concentration of 0.26 mg/L as P was comparable to the means of the 4 drainage areas evaluated in the Sacramento Stormwater Partnership's urban runoff sources and control evaluation (Geosyntec, 2011). The means of these 4 drainage areas ranged from 0.26 mg/L as P to 0.54 mg/L as P. Lathrop's concentrations were also comparable to storm samples collected for the Los Angeles NPDES annual report for 2010-2011 (Los Angeles County, 2012). Los Angeles median concentrations ranged from 0.15 mg/L as P to 0.43 mg/L as P, as compared to Lathrop median ranges for all station of 0.26 mg/L as P to 0.46 mg/L as P. These comparisons illustrate that Lathrop's discharge concentrations are not unusually high as compared to other studies in the state.

Total Phosphorus Load

The San Joaquin River had total phosphorus concentrations that were significantly lower than the city stations for season two, and seasons two and three combined; however, the levels did not significantly impact the total load on the San Joaquin River. In season two, Lathrop contributed less than 1% of the total load on the river for every storm sampled. In season three, Lathrop contributed 2.7% during the first storm and 1.5% during the second storm, but contributed less than 1% for the remaining storms in the season (Table 5-43). It is likely that the reason that Lathrop contributed more in the first two storms is because they were both flush events. The October 4, 2011, storm (season three) was the first storm after a long, dry summer. The storm on January 19, 2012, was also preceded by a long dry period as the October 4, 2011, storm was the storm that preceded it. Overall, Lathrop’s discharges did not significantly affect the total load on the San Joaquin River.

Table 5-43. Total Phosphorus Load (in kg) per Storm Event for Seasons Two and Three

	Season Two - Date of Storm Event					
Station	**11/7/2010**	**11/20/2010**	**12/17/2010**	**3/19/2011**	**3/24/2011**	**6/4/2011**
M1	N/A	1.82	0.67	0355	3.24	0
M2	1.07	2.33	1.94	1.07	5.07	0.55
M3	0.25	0.43	0.39	0.41	0.25	0.34
M6	0.15	N/A	0.38	0.28	0.60	0.27
Historic	1.30	4.43	2.36	N/A	2.04	4.24
Industrial	N/A	2.53	1.73	0	0	1.70
SJR at Mossdale	583.16	1,185.50	1,919.19	5,647.00	6,142.51	2,877.49
Lathrop's Percentage	<1%	1%	<1%	<1%	<1%	<1%
Lathrop's Total	2.78	11.54	7.48	2.31	11.19	7.08

	Season Three - Date of Storm Event			
Station	**10/4/2011**	**1/19/2012**	**3/16/2012**	**3/24/2012**
M1	3.87	1.07	1.13	0.16
M2	3.35	1.49	1.22	2.00
M3	1.21	2.05	0.40	0.11
M5	0.34	0.68	0.23	0.11
M6	0.30	0.35	0.26	0.08
Historic	4.35	3.82	2.85	0.50
Industrial	5.08	10.89	<0.01	0.11
SJR at Mossdale	689.83	1,333.86	1318.75	292.40
Lathrop's Percentage	2.7%	1.5%	<1%	<1%
Lathrop's Total	18.5	20.35	6.10	3.06

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or there was a communication problem with the SCADA resulting in no sample and pump data. Load from the pump stations was calculated as total kilograms discharged during the storm. Load at the SJR at Mossdale station was calculated as an instantaneous load and was converted to total kilograms discharged during the storm.

Minerals

Bromide is a constituent of concern in drinking water because of its ability to create DBPs. When chlorine is the disinfectant being used, the chlorine and TOC react with bromide to create THMs and HAA5s. Of the regulated DBPs, there are 5 that contain the bromide ion. Three of these are THMs (bromodichloromethane, dibromochloromethane and bromoform), and 2 are HAAs (bromoacetic acid and dibromoacetic acid). Bromate, another DBP, is created when ozone is used for disinfection. Bromate has a MCL of 0.010 mg/L for drinking water treatment plants that use ozone.

Alkalinity and hardness are separate constituents but are closely related through common ions. The ions that are part of the carbonate and bicarbonate fraction of alkalinity are the principal ions that cause hardness. When hardness is greater than alkalinity, it is due to non-carbonate hardness. Alkalinity is a measure of the acid-neutralizing capacity of water and is a measure of all titratable bases. This constituent is of importance to the drinking water community because drinking water treatment plants are required to remove TOC based on the concentration of alkalinity in the water (EDIS, 2012). Hardness is a measure of the polyvalent cation concentrations dissolved in water. The most common polyvalent cations in drinking water are calcium (Ca^{2+}) and magnesium (Mg^{2+}) (EDIS, 2012). Water that is hard requires more soap to adequately clean, and can lead to scaling on boiler and other industrial equipment. See Table 5-44 for hardness ranges (USGS, 2012).

Table 5-44. Water Hardness

Hardness (Mg/L as $CaCO_3$)	Classification
0-60	Soft
61-120	Moderately hard
121-180	Hard
>180	Very hard

Bromide

Analysis of Seasons Two and Three

Bromide concentrations at the city pumping stations and at the San Joaquin River at Mossdale were not significantly different between seasons two and three. The median concentrations ranged from 0.04 mg/L to 0.61 mg/L (Table 5-45). The overall range of concentrations was from below the reporting limit to 1.15 mg/L.

The city pumping stations concentrations were similar to the San Joaquin River at Mossdale, with the exception of the Industrial and M1 stations (Figure 5-54). There was also an outlier from the M3 station that was 1.15 mg/L. This was the highest concentration for the 2-year period. The higher concentrations at the Industrial station were expected because of the high amount of groundwater intrusion that station has due to its type of construction (poured in place). However, the other stations are susceptible to some groundwater intrusion, and this caused higher values at M1 and M3. It is likely that the M6 and Historic stations had lower values due to a lack of groundwater intrusion and because bromide is not a constituent that is common in surface runoff. Major sources of bromide are seawater, leaching of bromide containing soils (marine salts) into groundwater, and some industrial processing.

The regression between bromide and chloride shows a strong relationship between the two constituents (Figure 5-55). This is very close to the ratio of bromide/chloride in seawater (0.0034) and supports the conclusion that the bromide concentrations are, at least indirectly, attributed to seawater intrusion in the Delta or from marine salts leaching into the groundwater.

Although there were no distinct trends over the course of the 2 seasons, a trends plot shows how different the water quality between the San Joaquin River and the city pumping stations are for bromide (Figure 5-56). A Mann-Whitney test showed there were no significant differences. This is largely due to the "flip flopping" of which source had higher concentrations during each storm. There is no clear pattern showing when the San Joaquin River was higher than the pumping stations and vice versa. If there is a trend, additional data, preferably throughout the year, would need to be collected.

Table 5-45. Summary Statistics of Bromide (in mg/L) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	0.34	0.25	0.07	0.88	0.31
M2	10	0.17	0.15	0.02	0.36	0.12
M3	10	0.27	0.19	0.06	1.15	0.32
M5	4	0.19	0.16	0.08	0.35	0.12
M6	8	0.07	0.07	0.02	0.19	0.05
Historic	9	0.04	0.04	<R.L.	0.10	0.04
Industrial	7	0.54	0.61	0.05	1.11	0.41
SJR at Mossdale	10	0.20	0.20	0.05	0.37	0.14

Figure 5-54. Boxplot of Dissolved Bromide for Seasons Two and Three

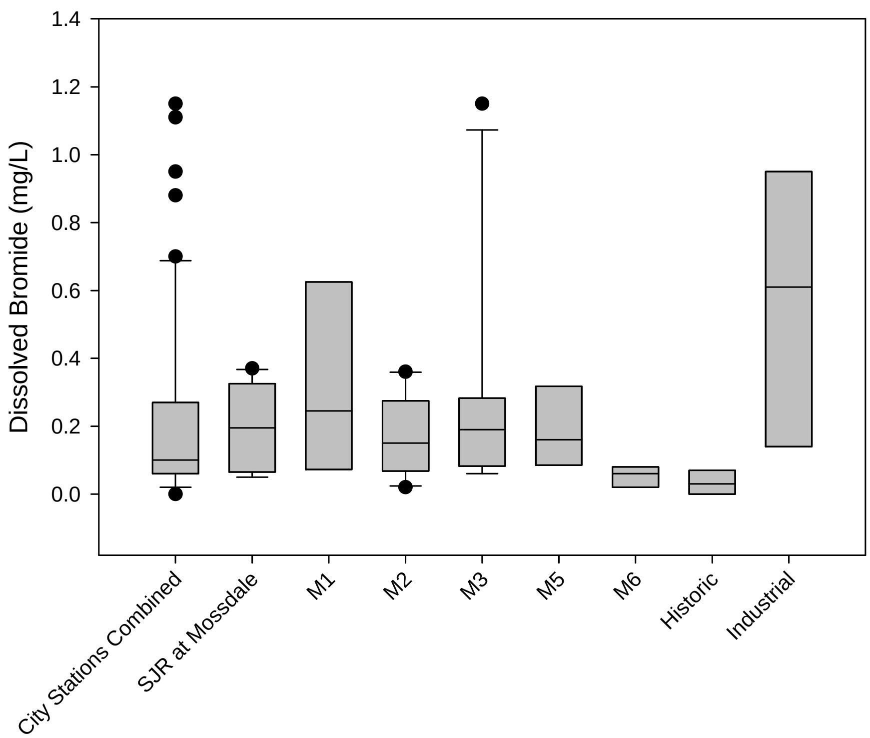


Figure 5-55. Relationship between Bromide and Chloride, Seasons Two and Three

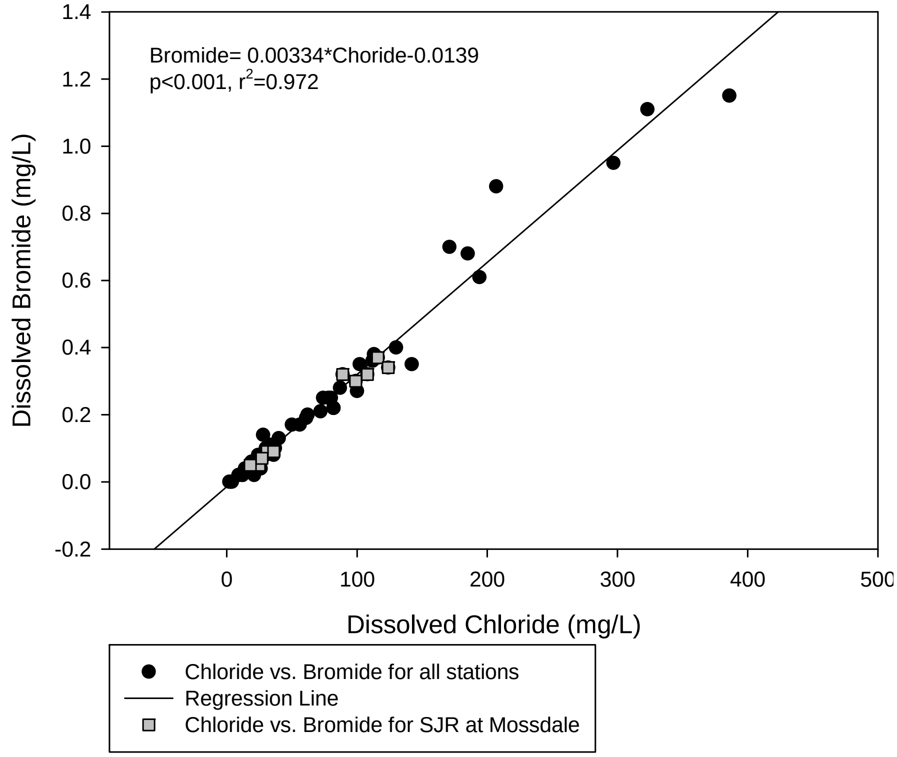
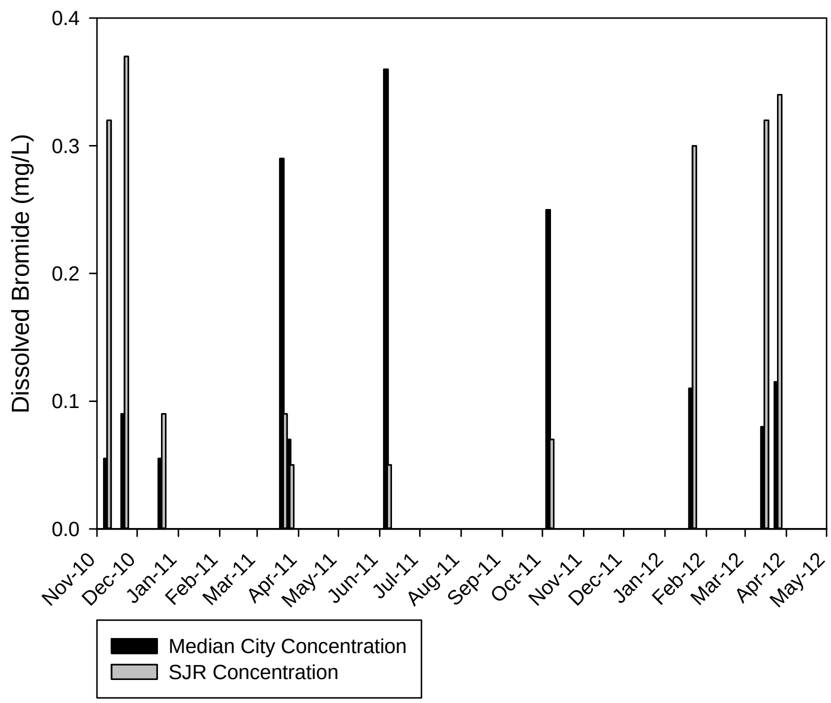


Figure 5-56. San Joaquin River Concentrations versus Median Pumping Station Concentrations of Bromide



Between Seasons

Similar to the analysis of seasons two and three, there were no significant statistical differences in bromide between the San Joaquin River and the city pumping stations for season two or three (Figures 5-57 and 5-58). There were also no statistical differences for all samples between season two and three. The patterns of data between the two seasons are similar although season two had lower minimum values for a few stations, and higher maximum values for nearly all stations (Tables 5-46 and 5-47).

Figure 5-57. Boxplot of Dissolved Bromide for Season Two

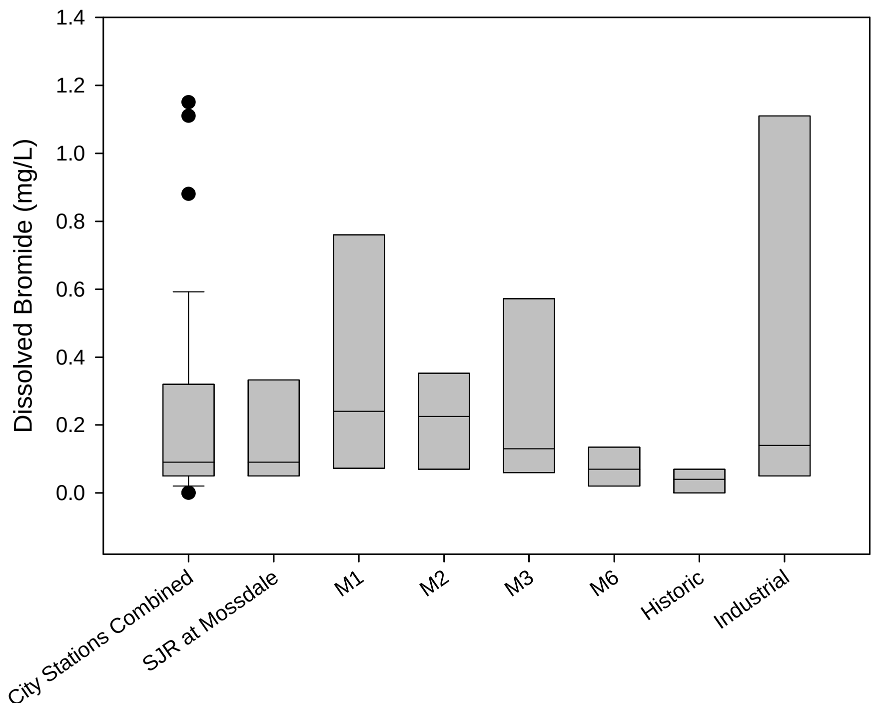


Figure 5-58. Boxplot of Dissolved Bromide for Season Three

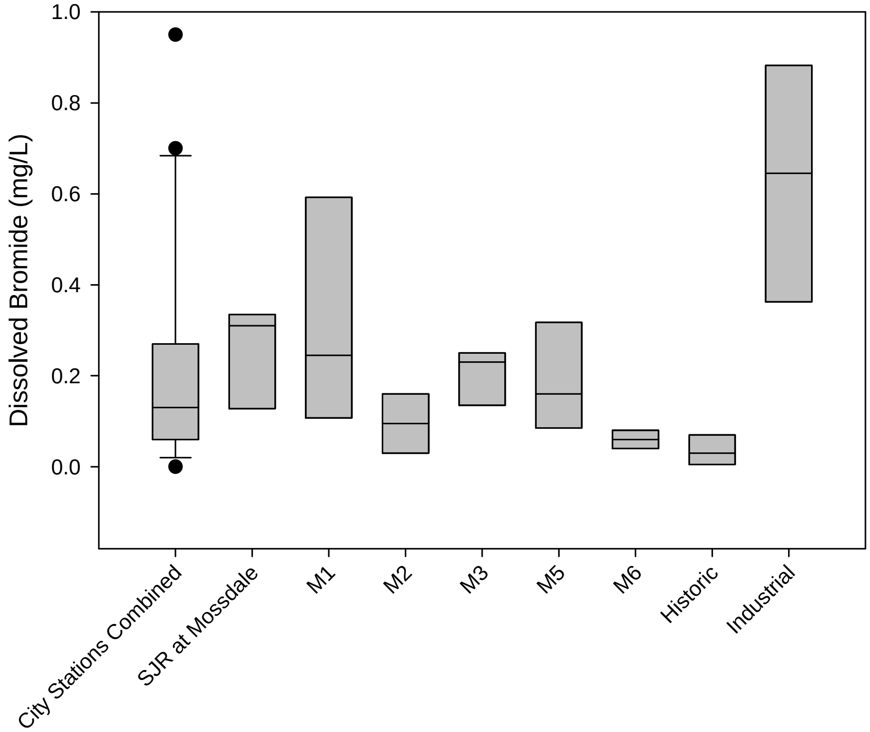


Table 5-46. Summary Statistics of Bromide (in mg/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.36	0.24	0.07	0.88	0.38
M2	6	0.22	0.23	0.07	0.36	0.13
M3	6	0.32	0.13	0.06	1.15	0.42
M6	5	0.08	0.07	0.02	0.19	0.07
Historic	5	0.04	0.04	0.01	0.10	0.04
Industrial	3	0.43	0.14	0.05	1.11	0.59
SJR at Mossdale	6	0.16	0.09	0.05	0.37	0.14

Table 5-47. Summary Statistics of Bromide (in mg/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	0.32	0.25	0.07	0.70	0.27
M2	4	0.10	0.10	0.02	0.17	0.07
M3	4	0.21	0.23	0.11	0.25	0.07
M5	4	0.19	0.16	0.08	0.35	0.12
M6	3	0.06	0.06	0.04	0.08	0.02
Historic	4	0.04	0.03	<R.L.	0.08	0.03
Industrial	4	0.63	0.65	0.28	0.95	0.28
SJR at Mossdale	4	0.26	0.31	0.07	0.34	0.13

Note: <R.L. indicates the concentration was below the reporting limit.

Dissolved Bromide Loads

During seasons two and three, dissolved bromide loads remained low. With one exception, Lathrop contributed less than 1% of the total load on the San Joaquin River. The exception occurred during the first flush event in season three (October 4, 2011) when Lathrop contributed 7.3% of the total bromide load to the San Joaquin River (Table 5-48). The cause for this elevated contribution is due to many factors. During this storm, the concentrations at the M1 and Industrial stations were the highest for the study period. The Industrial station load was unusually high due to this elevated concentration, and because it pumped a high volume of water during that storm.

While the load discharged from the Industrial station was high, the load in the San Joaquin River was unusually low. This is largely due to the inverse relationship between flows and bromide concentration in the river (Figure 5-59 and Table 5-49). The relationship stems from characteristics of bromide sources: seawater intrusion and marine soil leaching. Seawater intrusion occurs as the San Joaquin River flows reverse direction during tides or low-flow events. This does not occur during high-outflow events, such as storms, which result in low bromide concentrations on the San Joaquin River. With increasing flows, the amount of bromide leached from the soils decreases because leaching occurs at a steady rate over time, regardless of flow. Therefore, in high-flow events, there is proportionally less bromide in the river from leaching.

Additionally, the October 4, 2011, storm event was a shorter event, resulting in a smaller river load. During this storm, the median flows on the San Joaquin River were 5,370 cfs and the bromide concentration was 0.07 mg/L. The load per day was 906.07 kg/d, but because the storm only lasted 10.5 hours, this load is rated to 402.40 kg of bromide for the whole storm. A comparable storm is from December 17, 2010 (season two), when the median flows were 5,810 cfs and the bromide concentration was 0.09 mg/L. The load per day was 1,279.46 kg; however, the storm was the longest storm sampled: 41 hours. This resulted in a higher load overall. Therefore, the high load on the San Joaquin River during the October 4, 2011, storm is a result of high flows on the San Joaquin River and a low bromide concentration. The higher load from the pumping stations is a result of short storm duration, elevated bromide concentrations at the Industrial station, and a high volume of water discharged from the Industrial station.

Table 5-48. Dissolved Bromide Loads (in kg) per Storm Event for Seasons Two and Three

	Date of Storm Event- Season Two					
Station	**11/7/2010**	**11/20/2010**	**12/17/2010**	**3/19/2011**	**3/24/2011**	**6/4/2011**
Approximate Precipitation (in.)	0.49	0.95	0.94	0.68	0.73	0.34
M1	N/A	0.51	0.22	1.29	10.95	0
M2	0.19	2.00	0.52	1.43	8.45	0.85
M3	0.24	0.30	0.16	1.29	0.30	2.80
M6	0.01	N/A	0.01	0.08	0.11	0.18
Historic	0.13	0.51	N/A	N/A	N/A	0.88
Industrial	N/A	2.36	0.72	0	0	7.22
SJR at Mossdale	1,435.48	2,580.20	2,878.78	3,176.45	1,616.45	2,397.91
Lathrop's Percentage	<1%	<1%	<1%	<1%	1.2%	<1%
Lathrop's Total	0.57	5.68	1.65	4.08	19.81	11.92

	Date of Storm Event- Season Three			
Station	**10/4/2011**	**1/19/2012**	**3/16/2012**	**3/24/2012**
Approximate Precipitation (in.)	0.77	0.94	0.68	0.38
M1	3.95	0.85	0.89	0.15
M2	1.19	0.085	0.28	1.13
M3	0.84	1.19	0.63	0.17
M5	0.35	0.92	0.11	0.07
M6	0.04	0.03	0.06	N/A
Historic	0.77	<R.L.	0.17	0.07
Industrial	21.92	16.46	0.01	0.21
SJR at Mossdale	402.40	2,353.87	1,6230.8	414.23
Lathrop's Percentage	7.3%	<1%	<1%	<1%
Lathrop's Total	32.06	19.53	2.15	1.71

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or there was a communication problem with the SCADA resulting in no sample and pump data. Load from the pump stations was calculated as total kilograms discharged during the storm. Load at the SJR at Mossdale station was calculated as an instantaneous load and was converted to total kilograms discharged during the storm.

Figure 5-59. Relationship between SJR Flow and Bromide Concentration

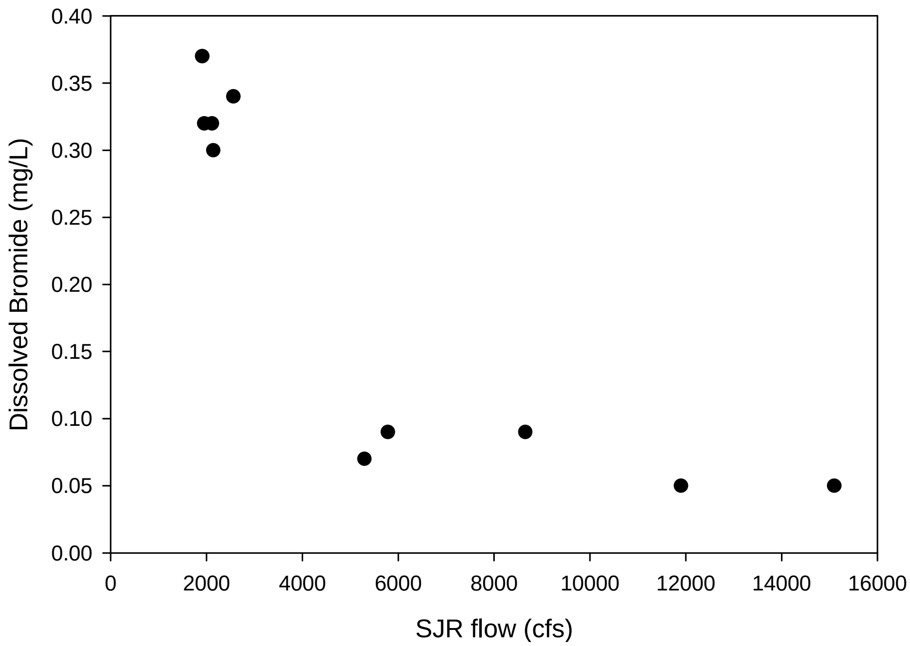


Table 5-49. Flow and Bromide Concentration on the San Joaquin River

Date	SJR Flow (cfs)	SJR at Mossdale Bromide (mg/L)
11/20/2010	1910	0.37
11/7/2010	1950	0.32
3/14/2012	2110	0.32
1/20/2012	2140	0.30
3/24/2012	2560	0.34
10/5/2012	5290	0.07
12/19/2010	5780	0.09
3/19/2011	8650	0.09
6/3/2011	11900	0.05
3/25/2011	15100	0.05

Total Alkalinity and Dissolved Hardness

Analysis of Seasons Two and Three

There was no significant difference between the San Joaquin River and city pumping station concentrations for total alkalinity or dissolved hardness. The San Joaquin River at Mossdale generally had lower concentrations, but they were not significantly lower than the city pumping stations (Figures 5-60 and 5-61, Tables 5-50 and 5-51). For alkalinity, the medians ranged from 49 mg/L as $CaCO_3$ to 200 mg/L as $CaCO_3$. The alkalinity range of concentrations was from 33 mg/L as $CaCO_3$ to 334 mg/L as $CaCO_3$ (Table 5-50). Hardness medians ranged from 51 mg/L as $CaCO_3$ to 280 mg/L as $CaCO_3$. The overall hardness range was from 18 mg/L as $CaCO_3$ to 511 mg/L as $CaCO_3$ (Table 5-51). Due to the similarity of the 2 constituents, the data patterns are very similar. The Industrial station had elevated concentrations with the largest range of all the stations. The Historic station had generally lower concentrations. There was much variability through the Mossdale residential stations with M3 having a few high concentration outliers.

Figure 5-60. Boxplot of Alkalinity for Seasons Two and Three

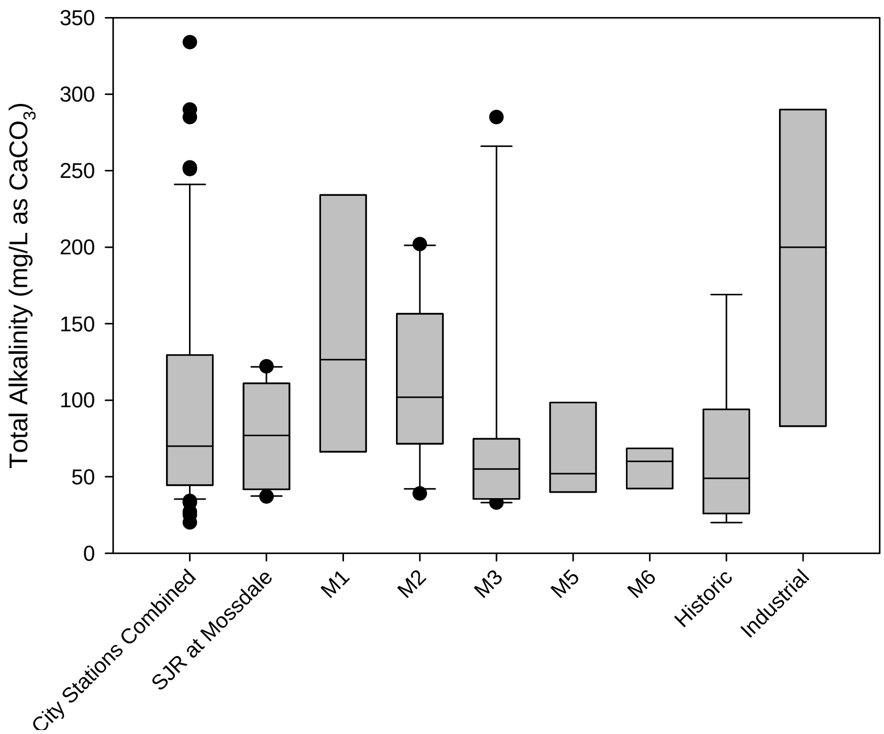


Table 5-50. Summary Statistics of Alkalinity (in mg/L of CaCo₃) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	142	127	60	252	79
M2	10	113	102	39	202	54
M3	10	76	55	33	285	76
M5	4	64	52	40	110	33
M6	8	64	60	40	131	29
Historic	9	65	49	20	169	49
Industrial	7	185	200	51	334	110
SJR at Mossdale	10	78	77	37	122	36

Figure 5-61. Boxplot of Hardness for Seasons Two and Three

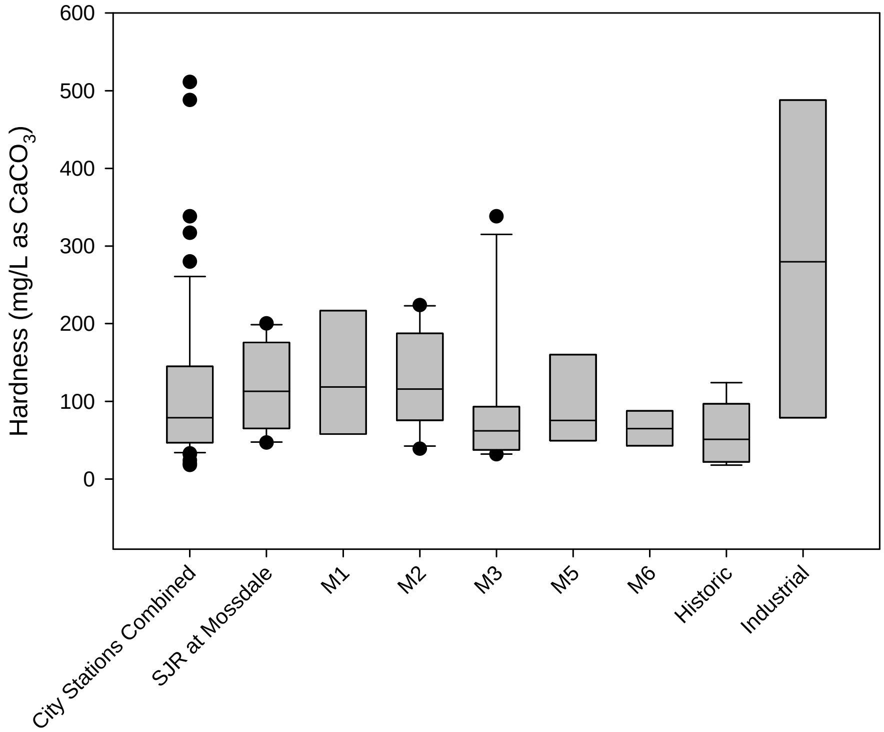


Table 5-51. Summary Statistics of Hardness (in mg/L of $CaCo_3$) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	132	119	47	248	79
M2	10	127	116	39	224	64
M3	10	88	62	32	338	91
M5	4	95	76	49	180	61
M6	7	71	65	41	146	37
Historic	9	60	51	18	124	40
Industrial	7	266	280	46	511	188
SJR at Mossdale	10	118	113	47	200	60

Comparison between Seasons Two and Three

There was no significant difference in concentrations between the San Joaquin River at Mossdale and the city pumping stations for season two or three for alkalinity and hardness. There was also no significant difference in concentrations between years for alkalinity and hardness. Alkalinity and hardness followed the same data distribution patterns from year to year. Both constituents exhibited similar differences in the data distribution between seasons two and three. Season two, a wet water year, had wider ranges of concentrations and higher maximums for most stations, than what was observed in season three (Figures 5-62 through 5-65, Tables 5-52 through 5-55).

Figure 5-62. Boxplot of Alkalinity for Season Two

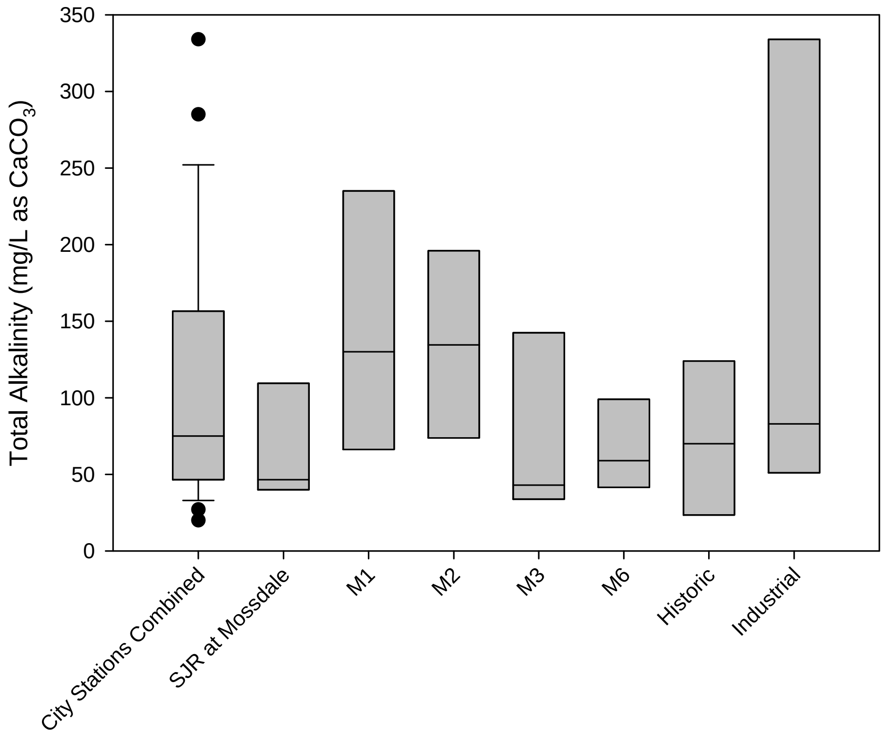


Figure 5-63. Boxplot of Alkalinity for Season Three

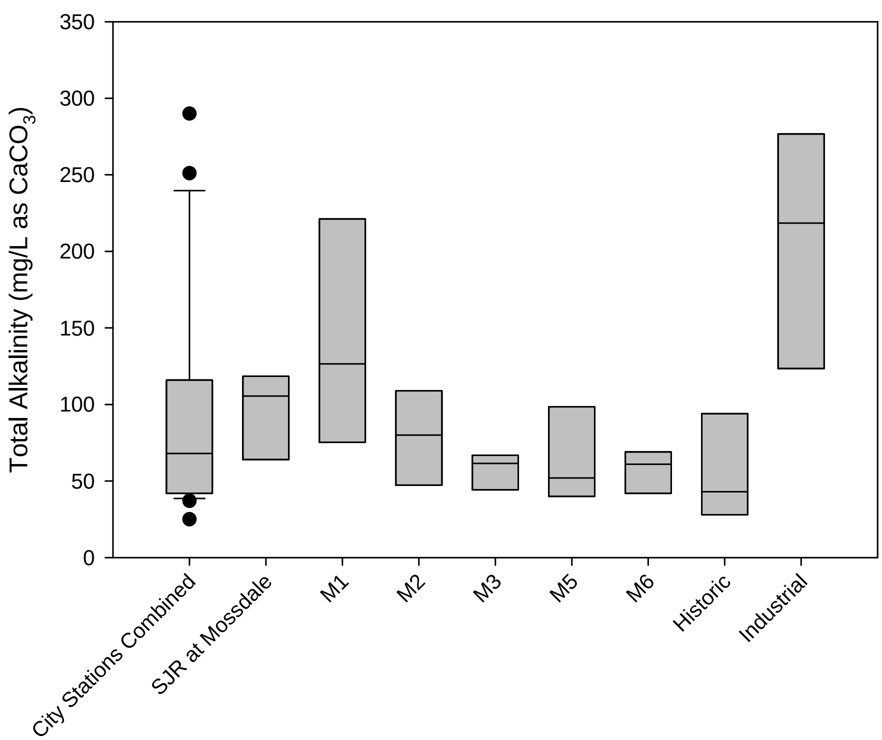


Table 5-52. Summary Statistics of Alkalinity (in mg/L of $CaCo_3$) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	144	130	63	252	90
M2	6	135	135	70	202	56
M3	6	89	43	33	285	99
M6	5	68	59	40	131	37
Historic	5	73	70	20	169	60
Industrial	3	156	83	51	334	155
SJR at Mossdale	6	66	47	37	120	37

Table 5-53. Summary Statistics of Alkalinity (in mg/L of $CaCo_3$) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	141	127	60	251	80
M2	4	79	80	39	116	32
M3	4	58	62	39	68	13
M5	4	64	52	40	110	33
M6	3	57	61	42	69	14
Historic	4	55	43	25	109	37
Industrial	4	206	219	98	290	81
SJR at Mossdale	4	96	106	51	122	31

Figure 5-64. Boxplot of Hardness for Season Two

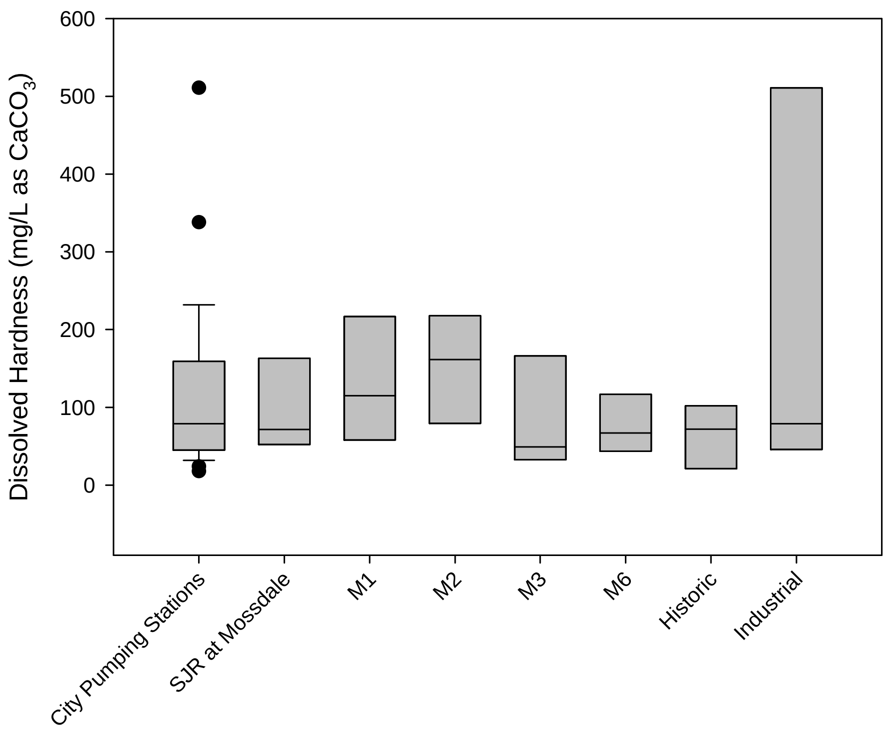


Figure 5-65. Boxplot of Hardness for Season Three

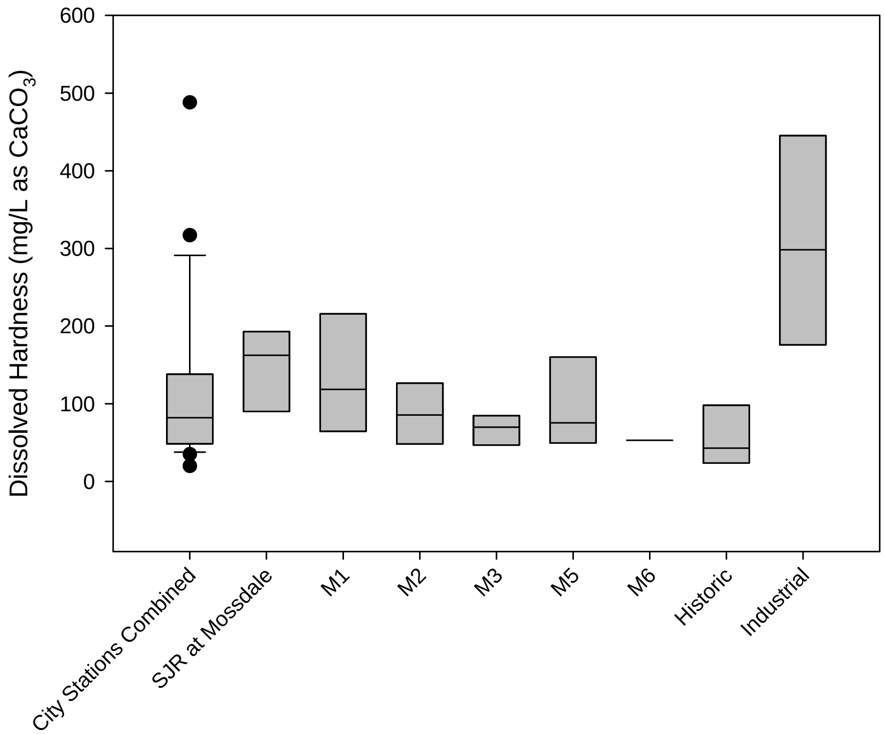


Table 5-54. Summary Statistics of Hardness (in mg/L of $CaCo_3$) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	130	115	58	232	87
M2	6	153	162	75	224	65
M3	6	102	49	32	338	119
M6	5	78	67	43	146	42
Historic	5	64	72	18	124	44
Industrial	3	212	79	46	511	259
SJR at Mossdale	6	98	72	47	187	59

Table 5-55. Summary Statistics of Hardness (in mg/L of $CaCo_3$) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	133	119	47	248	84
M2	4	87	86	39	137	41
M3	4	67	70	41	88	20
M5	4	95	76	49	180	61
M6	2	53	53	41	65	17
Historic	4	55	43	20	114	41
Industrial	4	307	299	141	488	143
SJR at Mossdale	4	149	163	69	200	56

Salinity

Salinity is the quantity of dissolved ions in water.Two measures of salinity are total dissolved solids (TDS) and conductivity (EC). TDS is an approximate measure of the total quantity of dissolved salts, whereas EC is a measure of the total salt content by the water's ability to conduct an electrical current. High salinity can cause finished drinking water to have an unpleasant taste, resulting in complaints from consumers. The CDPH has developed secondary standards for 4 constituents related to salinity (Table 5-56).

Table 5-56. Secondary Maximum Contaminant Levels for Salinity

Constituent, Units	Maximum Contaminant Level Ranges		
	Recommended	Upper	Short Term
Total Dissolved Solids (mg/L) or	500	1,000	1,500
Specific Conductance (uS/cm)	900	1,600	2,200
Chloride (mg/L)	250	500	600
Sulfate (mg/L)	250	500	600

Source: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chemicalcontaminants.aspx

Analysis of Seasons Two and Three

For both EC and TDS, the concentrations on the San Joaquin River at Mossdale were not significantly lower than the city pumping station concentrations. Salinity in the San Joaquin River and the groundwater in this region are relatively high due to elevated levels of salts in irrigation returns from agricultural lands and from recirculation of salts from the Delta. This is largely why the concentrations in the San Joaquin River at Mossdale had such a wide range for EC and TDS (Tables 5-57 and 5-58). For EC, concentrations at all stations had medians that ranged from 214 uS/cm to 1324 uS/cm (Table 5-57). For TDS at all stations, the medians ranged from 125 mg/L to 389 mg/L (Table 5-58). The EC and TDS concentrations, as shown in the boxplots, have a highly significant relationship that is very strong ($p<0.001$, $r^2= 0.986$, Figure 5-66).

There was much variation in EC and TDS concentrations throughout the city pumping stations.The widest range of concentrations was from the Industrial station, which is known to have a high amount of groundwater intrusion due to its "poured in place" type of construction (Tables 5-57 and 5-58, Figures 5-67 and 5-68). Several of the other pumping stations also had wide ranges for EC and TDS, suggesting that groundwater intrusion was occurring at these sites. Groundwater intrusion at these pump stations was confirmed by the City of Lathrop (Milt Daley, pers.comm.).

Table 5-57. Summary Statistics of EC (in μS/cm) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	713	688	126	1461	494
M2	10	494	442	156	942	269
M3	10	491	352	155	1937	529
M5	4	425	351	210	787	267
M6	8	250	206	147	578	141
Historic	9	220	214	57	472	144
Industrial	7	1133	1324	210	2114	755
SJR at Mossdale	10	523	488	192	935	294

Table 5-58. Summary Statistics of TDS (in mg/L) for Seasons Two and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	8	424	389	142	821	277
M2	10	291	274	87	555	157
M3	10	275	200	84	1080	296
M5	4	248	198	118	478	166
M6	8	154	152	83	332	80
Historic	9	132	125	34	287	89
Industrial	7	709	792	117	1480	517
SJR at Mossdale	10	297	277	107	555	171

Figure 5-66. Relationship between EC and TDS

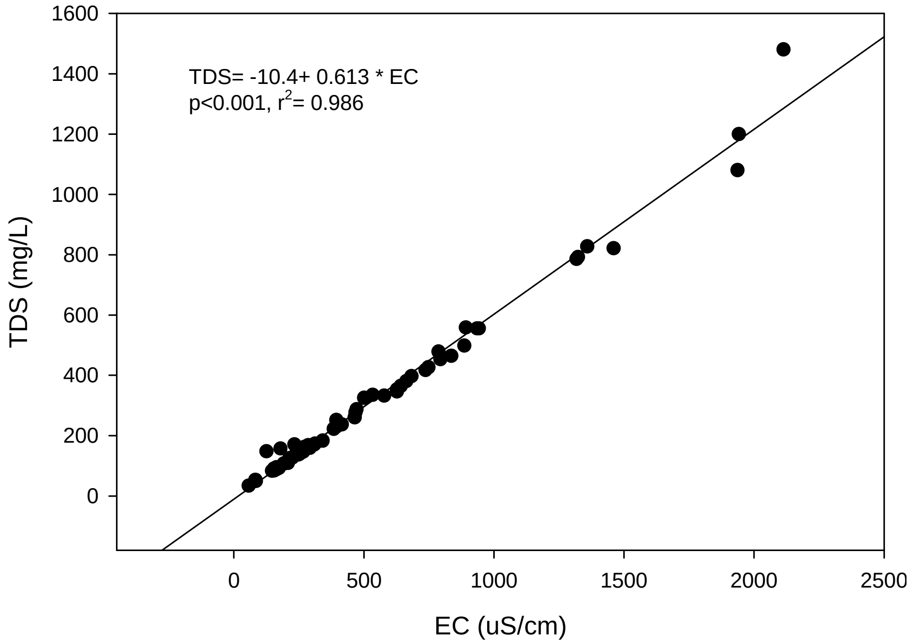


Figure 5-67. Boxplots of EC Concentrations for Seasons Two and Three

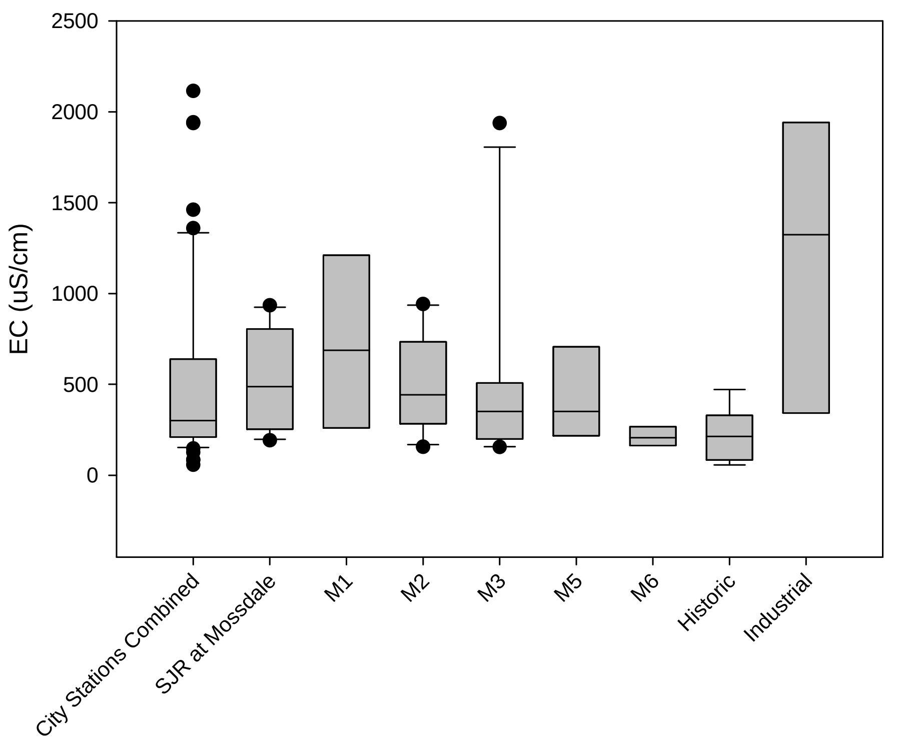
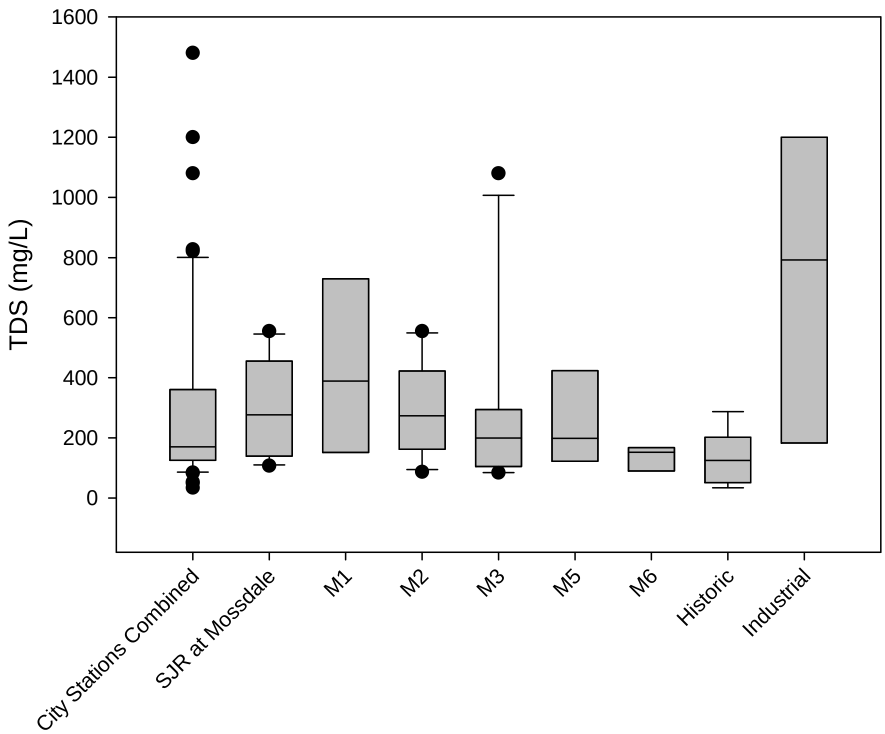


Figure 5-68. Boxplot of TDS Concentrations for Seasons Two and Three



Comparison between Seasons Two and Three

For both EC and TDS, there was no significant difference between season two and season three concentrations. For EC, the patterns of data were similar between the two seasons. For each station, the season two concentrations had a wider range than in season three. This is clearly shown in the boxplots for the M2, M3, and Industrial stations (Tables 5-59 and 5-60, Figures 5-69 and 5-70). This pattern also occurred in the TDS concentrations. The ranges of concentrations for each station were wider in season two than in season three, with the exception of the San Joaquin River at Mossdale station (Tables 5-61 and 5-62, Figures 5-71 and 5-72).

Salinity in the San Joaquin River is characterized by hydrology of the system. In wetter years, there tends to be lower salinity levels due to the amount of freshwater that is in the system from rains, runoff, upstream dam releases, and other discharges. In dry years, upstream freshwater discharges from dams are lower in volume, there are lower freshwater flows from upstream tributaries, a proportionally higher volume of saline agricultural discharges, and an increased volume of seawater intrusion. These hydrological factors result in increased salinity in the San Joaquin River. This pattern was seen in the concentrations at the San Joaquin River at Mossdale. The second season was a wet water year and was preceded by a wet water year. This resulted in slightly lower salinities in season two due to increased freshwater discharges from upstream reservoirs (Table 5-59, Figure 5-11 and 5-69). Season three was classified as a dry water year which had lower discharges from upstream reservoirs during the wet season, lower freshwater drainage from upstream tributaries, and increased agricultural drainage which is higher in salinity. These combined hydrological effects resulted in higher salinity concentrations in the San Joaquin River (Table 5-60, Figures 5-11 and 5-70). However, this was not the pattern of salinity seen in the city pumping stations. At these stations, the concentrations had a wider range in season two than in season three; indicating that surface water hydrology and seawater intrusion are not driving what is going on at these stations. The cause for the high salinity at these stations is groundwater hydrology due to the amount of groundwater intrusion into these pumping stations. The cause for high concentrations of salinity in the second season (wet water year) may be due to additional pumping during that season to accommodate the storm water that was coming into the pumps. If these pumps pumped out water to a lower level than in season three (dry water year), it may have resulted in additional groundwater intrusion into the pumps, which was eventually pumped out. Also, because season two was a wet water year, there may have been additional recharging of the groundwater, raising the level of the water table. This could have resulted in additional water flowing into Lathrop's pumping stations.

Table 5-59. Summary Statistics of EC (in µS/cm) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	690	588	126	1461	611
M2	6	598	592	286	942	286
M3	6	568	568	155	1937	693
M6	5	284	284	147	578	174
Historic	5	227	227	57	472	167
Industrial	3	888	888	210	2114	1063
SJR at Mossdale	5	463	463	249	836	270

Table 5-60. Summary Statistics of EC (in µS/cm) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	736	688	252	1318	442
M2	4	337	330	156	534	161
M3	4	376	404	225	468	105
M5	4	425	351	210	787	267
M6	3	192	179	164	233	36
Historic	4	212	184	83	394	133
Industrial	4	1317	1342	642	1942	532
SJR at Mossdale	5	583	737	192	935	336

Figure 5-69. Boxplot of EC for Season Two

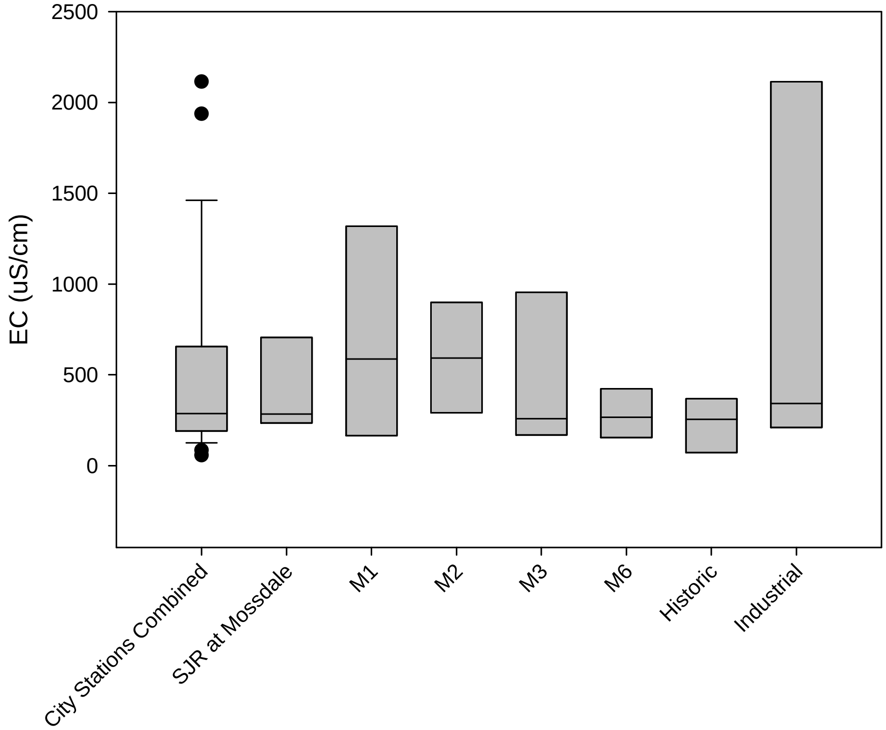


Figure 5-70. Boxplot of EC for Season Three

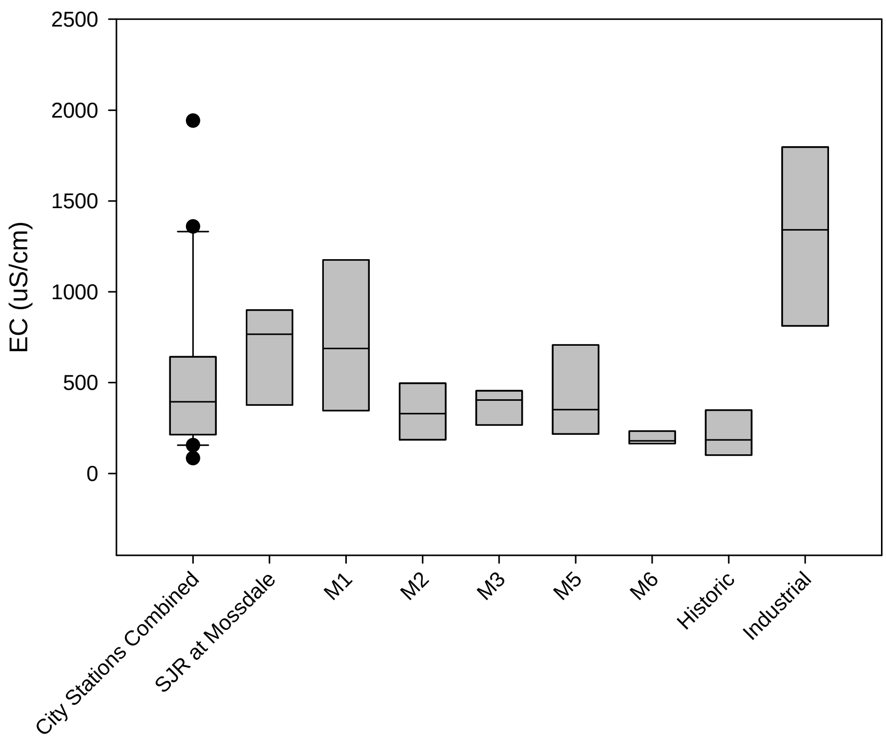


Table 5-61. Summary Statistics of TDS (in mg/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	422	360	148	821	327
M2	6	350	361	159	555	165
M3	6	314	314	84	1080	388
M6	5	162	162	83	332	101
Historic	5	134	134	34	287	101
Industrial	3	593	593	117	1480	769
SJR at Mossdale	5	259	259	137	464	153

Table 5-62. Summary Statistics of TDS (in mg/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	427	389	142	786	268
M2	4	202	192	87	335	105
M3	4	218	233	127	277	64
M5	4	248	198	118	478	166
M6	3	141	157	95	170	40
Historic	4	130	108	53	251	86
Industrial	4	796	810	364	1200	342
SJR at Mossdale	5	336	417	107	555	197

Figure 5-71. Boxplot of TDS for Season Two

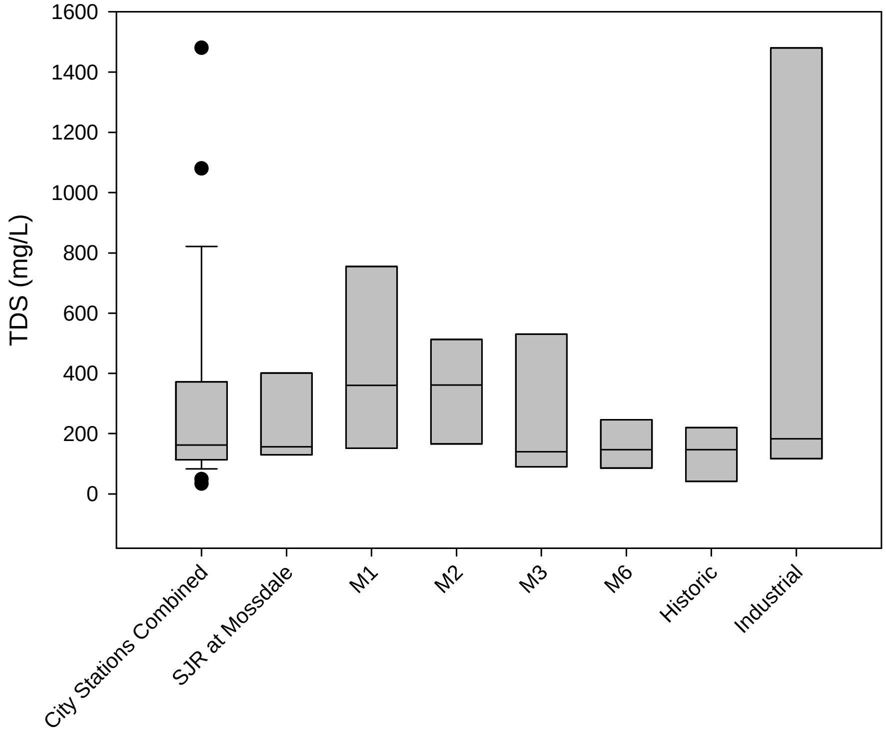
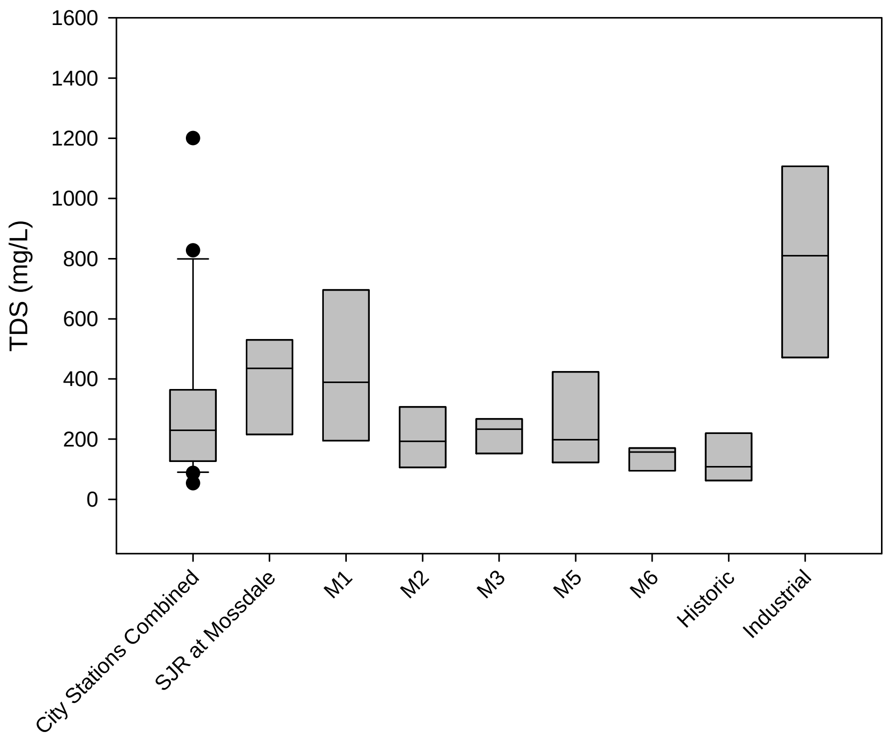


Figure 5-72. Boxplot of TDS for Season Three



Pyrethroids

Pyrethoids are a classification of organic pesticides that are known to be toxic to benthic organisms. Benthos are small crustaceans that inhabit mud and sediments, and pyrethroids have a strong affinity for binding to sediments. Although there are some applications of pyrethroids in agriculture, they are primarily used in lawn and garden applications to control outdoor pests such as ants. Research has shown that pyrethroid concentrations from the urban environment make their way to aquatic systems in concentrations that are lethal to some benthos such as *Hyalella azteca.* These pesticides are generally monitored through sediment sampling. It is estimated that concentrations found in water samples are approximately half of the amount of pyrethroids that are present in the sediments.

Thirteen species of pyrethroids were sampled twice a year in seasons two and three. The sampling events were timed for storm events in the fall and spring to see if there were any trends in concentration between the beginning and end of the storm season. Samples were collected on the San Joaquin River at Mossdale and at the storm water pumping stations. Only a few stations had enough water to process for pyrethroids, and it was common to have many non-detects. It is important to note that the laboratory's detection limit for all pyrethroids, except for permethrin (5.0 ng/L) and sumithrin (10 ng/L), was 2.0 ng/L. This concentration is lower than many studies have shown, but this low detection level was necessary because *H.azteca* has shown effects of toxicity at 2.0 ng/L.

Comparison between Seasons Two and Three

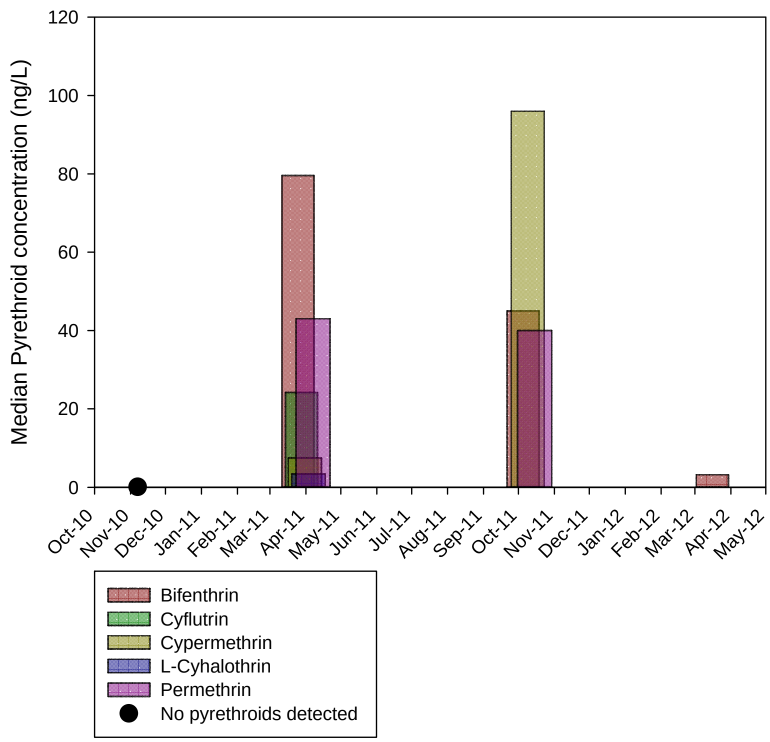
No pyrethroids were detected on the San Joaquin River throughout the study. Two storms were sampled for pyrethroids each year. In season two, no pyrethroids were detected at any stations during the November 7, 2010, sampling event; however, only 2 storm water pumping stations were sampled (Table 5-63). Bifentrhin was detected during every other sampling event (Figure 5-73, Table 5-63). The most pyrethroids detected were during the March 25, 2011, sampling event (season two). During this event, 5 pumping stations were sampled, and 5 of the 13 pyrethroids tested for were detected at concentrations that are likely toxic to benthos.

In the first storm sampled in season three (October 4, 2011), all storm water pumping stations were sampled for pyrethroids, and 3 species were detected at relatively high concentrations. In the March 16, 2012, sampling event (season three), only 2 pumping stations were able to be sampled for pyrethroids. Of these samples, only bifenthrin was detected at relatively low concentrations (Figure 5-73, Table 5-63). Due to the infrequency of sampling both in space and time, there is no trend that can be drawn for pyrethroids. However, it is evident that during storm events, Lathrop can discharge concentrations of pyrethroids that are toxic to benthos in the San Joaquin River.

Table 5-63. Pyrethroid Results (in µg/L) for Seasons Two and Three

		Pyrethroid				
Date	**Station**	**Bifenthrin**	**Cyfluthrin**	**Cypermethrin**	**L-Cyhalothrin**	**Permethrin**
11/7/2010	M1	-	-	-	-	-
	M2	N.D.	N.D.	N.D.	N.D.	N.D.
	M3	-	-	-	-	-
	M6	-	-	-	-	-
	Historic	N.D.	N.D.	N.D.	N.D.	N.D.
	Industrial	-	-	-	-	-
3/24/2011	M1	9.6	3.4	N.D.	N.D.	N.D.
	M2	16.0	N.D.	N.D.	N.D.	N.D.
	M3	-	-	-	-	-
	M6	10.0	N.D.	N.D.	N.D.	N.D.
	Historic	44.0	45.0	7.5	3.4	43.0
	Industrial	-	-	-	-	-
10/4/2011	M1	14.0	N.D.	N.D.	N.D.	11.0
	M2	57.0	N.D.	N.D.	N.D.	11.0
	M3	53.0	N.D.	N.D.	N.D.	11.0
	M5	45.0	N.D.	N.D.	N.D.	11.0
	M6	110.0	N.D.	96.0	N.D.	N.D.
	Historic	20.0	N.D.	N.D.	N.D.	40.0
	Industrial	2.8	N.D.	N.D.	N.D.	N.D.
3/16/2012	M1	3.1	N.D.	N.D.	N.D.	N.D.
	M2	3.2	N.D.	N.D.	N.D.	N.D.
	M3	-	-	-	-	-
	M5	-	-	-	-	-
	M6	-	-	-	-	-
	Historic	-	-	-	-	-
	Industrial	-	-	-	-	-

Figure 5-73. Median Pyrethroid Results for Seasons Two and Three



Comparison to Other Studies

Studies by Weston et al. have shown evidence of the urban environment contributing to pyrethroid toxicity in aquatic systems. One study analyzed sediments in residential areas in Roseville, California. It showed acute toxicity to *H.azteca* (Weston et al., 2005). Weston and Lydy's research in 2010 analyzed pyrethroid concentrations in urban runoff. Although pyrethroids quickly bind to sediments and this type of sampling is ideal for these constituents, water samples were tested to quantify sources of pyrethroid toxicity to benthic organisms. Samples were collected for 3 urban areas, each having populations less than 89,000 in California, Illinois, and Texas. The results were that pyrethroids, with bifenthrin being the most common, were present in 32 of 33 urban sites tested. Bifentrhin was present in 79% of all samples, and exceeded the *H.azteca* EC_{50} in 58% of the samples. Weston has commented that sediment sampling is the preferred method for detecting pyrethroids, and that by sampling the water column, approximately 50% of the pyrethroids present in the system are actually being detected (pers.comm.).

Lathrop is a much smaller community (approximate population of 18,000) than those Weston and Lydy have researched. However, the results show that discharge from the Lathrop's storm water pumping stations contains pyrethroid concentrations that are above the toxicity level for *H.azteca* (2-5 ng/L) (Weston and Lydy, 2010).

Pathogen Indicator Organisms

Pathogens such as *Giardia lamblia* and *Cryptosporidium* in Lathrop's discharge are of concern because the San Joaquin River is used for drinking water and contact recreation. Although these specific pathogens were not monitored, the pathogen indicators total coliforms, fecal coliforms, and *Escherichia coli* were monitored throughout the study. Three seasons of data is presented in this section because the sampling method did not change throughout the study, unlike the other constituents monitored. However, some of the data collected was not included in the analysis because it could not be verified that the pumps actually discharged into the river for those specific dates and/or pumps.

Regulations

Due to health concerns regarding pathogens, the EPA has developed goals and water treatment rules for the protection of treated drinking water. For the protection of recreational water users, the EPA, the CDPH, and the Regional Board have developed recommendations, draft guidance, and objectives.

Drinking water regulations for pathogen indicators consist of the EPA's MCL goals, the Surface Water Treatment Rule (SWTR), the Interim Enhanced Surface Water Treatment Rule (IESWTR) and the Total Coliform Rule. The MCL goal for *Cryptosporidium, Giardia lamblia,* and total coliforms (including fecal coliforms and *E.*coli) is zero (EPA, 2009). The EPA regulations for *Giardia lamblia* and *Cryptosporidium* under the SWTR and IESWTR require that a water treatment process (including disinfection and filtration) be sufficient to achieve a level of removal or inactivation of *Giardia* and *Cryptosporidium.* The SWTR requires 99.9% (3-log) inactivation and/or removal of the organisms and 99.99% (4-log) inactivation and/or removal of viruses. The IESWTR requires 99% (2-log) removal of *Cryptosporidium* (EPA, 2004; EPA, 1991). The CDPH requires additional treatment above the minimum 3-log *Giardia* and 4-log virus reduction when monthly medians exceed 1,000 MPN/L for total coliforms, based on the EPA Guidance Manual for compliance with the filtration and disinfection requirements (EPA, 1991). (Total coliforms levels are used in lieu of *Giardia* due to the expense of sampling.) The EPA also has a total coliform rule which applies to all public water systems. Any routine sample that is tested positive for total coliforms must also be tested for fecal coliforms and *E.coli*. A MCL violation is triggered if a small system has more than one routine/repeat sample that is positive for total coliforms, or if a large system has more than 5% routine/repeat samples that are positive for total coliforms. An acute MCL violation is triggered if any system has a fecal coliform or *E.coli* positive repeat sample or has a fecal coliform of *E.coli* positive routine sample followed by a total coliform-positive repeat sample (EPA, 2010).

For protection of recreational water use, the EPA has developed recommendations, the CDPH has developed draft guidances for freshwater beaches, and the Regional Board has developed objectives. The EPA also has recommendations for protecting public health in recreational waters where body contact is common. The recommendations are for *E.*coli and are based on the geometric mean and a statistical threshold value (STV) within a 30-day period. EPA's first recommendation is a mean of 126 cfu/10 ml and a STV of 410 cfu/100 ml. The second recommendation is a mean of 100 cfu/100 ml and a STV of 320 cfu/100 ml. (EPA, 2012). The CDPH has developed draft guidance for freshwater beaches which required posting a notice when indicator organisms exceed 10,000/100 ml for total coliforms, 400/100 ml for fecal coliforms, and 235/100 ml for *E.coli* (CDPH, 2011). The Regional Board has established an objective for fecal coliforms in the San Joaquin Basin Plan. The objective states, "In waters designated for contact recreation (REC-1), the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period, shall not exceed a geometric mean of 200/100 ml, nor shall more than ten percent of the total number of samples taken during any 30-day period exceed 400/100 ml."

Analysis of Seasons One, Two and Three

For all seasons combined, the values of total coliforms, fecal coliforms, and *E.*coli at the San Joaquin River at Mossdale were significantly lower than those of the city pumping stations (Mann-Whitney, $p<0.001$ for each). This is clearly seen in the boxplots of all seasons (Figures 5-74 through 5-76).

Total coliform values were quite variable for all the stations, except for the San Joaquin River at Mossdale where the values were lower and had a smaller range than city pumping station concentrations. Although the values on the San Joaquin River at Mossdale were low, they were above the CDPH source water level of 1,000 MPN/L. The median count for the San Joaquin River at Mossdale was 7,110 MPN/L and for the city pumping stations, the median ranged from 23,500 MPN/L to 300,000 MPN/L. The range at the San Joaquin River at Mossdale was 1,300 MPN/L to 17,000 MPN/L, and the range for the city pumping stations was 1,110 MPN/L to 11,000,000 MPN/L (Table 5-64). The most variable values were at the M6 station which had a range from 11,000 MPN/L to 11,000,000 MPN/L. The Industrial station had the second widest range, 3,000 MPN/L to 1,300,000 MPN/L (Table 5-64).

Fecal coliforms had similar patterns to those of total coliforms except that it was the Historic station that had the widest range (11 MPN/L to 500,000 MPN/L). The median at the San Joaquin River at Mossdale was 145 MPN/L and the medians for the city pumping stations ranged from 3,000 MPN/L to 9,000 MPN/L. The range of counts for the San Joaquin River at Mossdale was 22 MPN/L to 5,000 MPN/L and the overall range for the city pumping stations was from 11 MPN/L to 500,000 MPN/L (Table 5-65).

The *E.coli* data pattern was similar to fecal coliforms. The Historic station again had the widest spread of values (435 MPN/L to 14,136 MPN/L). The median at the San Joaquin River at Mossdale was 79 MPN/L and at the city pumping stations the counts ranged from 2,143 MPN/L to 6,131 MPN/L. The range for the San Joaquin River at Mossdale was from non-detected to 776 MPN/L and the range for the city pumping stations was from non-detected to 51,720 MPN/L (Table 5-66).

Figure 5-74. Boxplot of Total Coliforms for Seasons One, Two, and Three

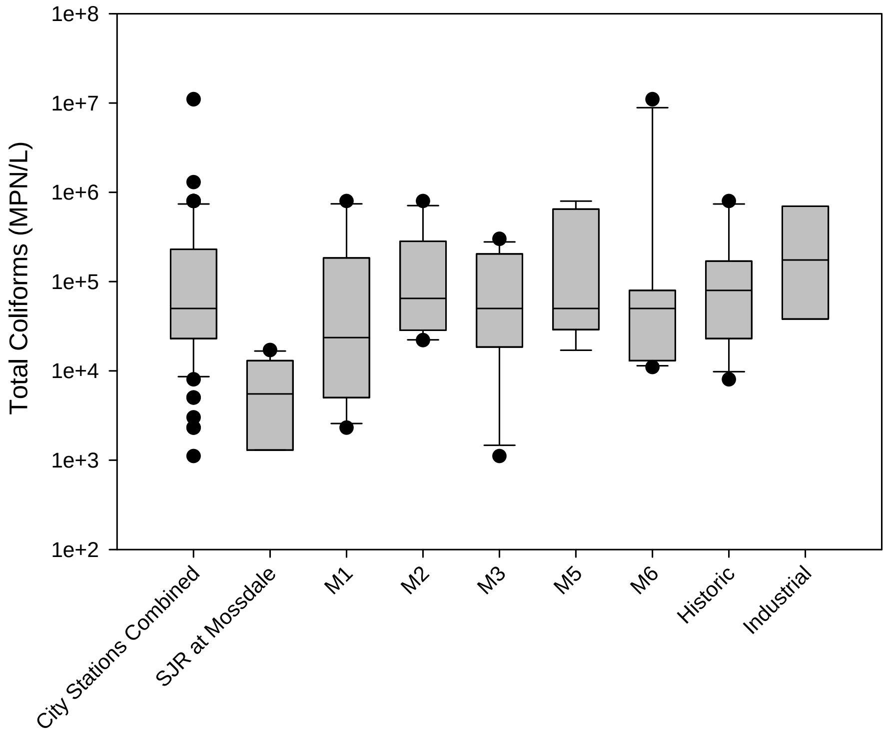


Table 5-64. Summary Statistics of Total Coliforms (in MPN/L) for Seasons One, Two, and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	10	130,230	23,500	2,300	800,000	248,219
M2	12	186,917	65,000	22,000	800,000	242,082
M3	12	94,701	50,000	1,110	300,000	103,851
M5	9	259,444	50,000	17,000	800,000	342,047
M6	11	1,058,182	50,000	11,000	11,000,000	3,298,365
Historic	11	171,636	80,000	8,000	800,000	249,806
Industrial	6	367,167	175,000	3,000	1,300,000	495,205
SJR at Mossdale	10	7,110	5,500	1,300	17,000	6,013

Figure 5-75. Boxplot of Fecal Coliforms for Seasons One, Two, and Three

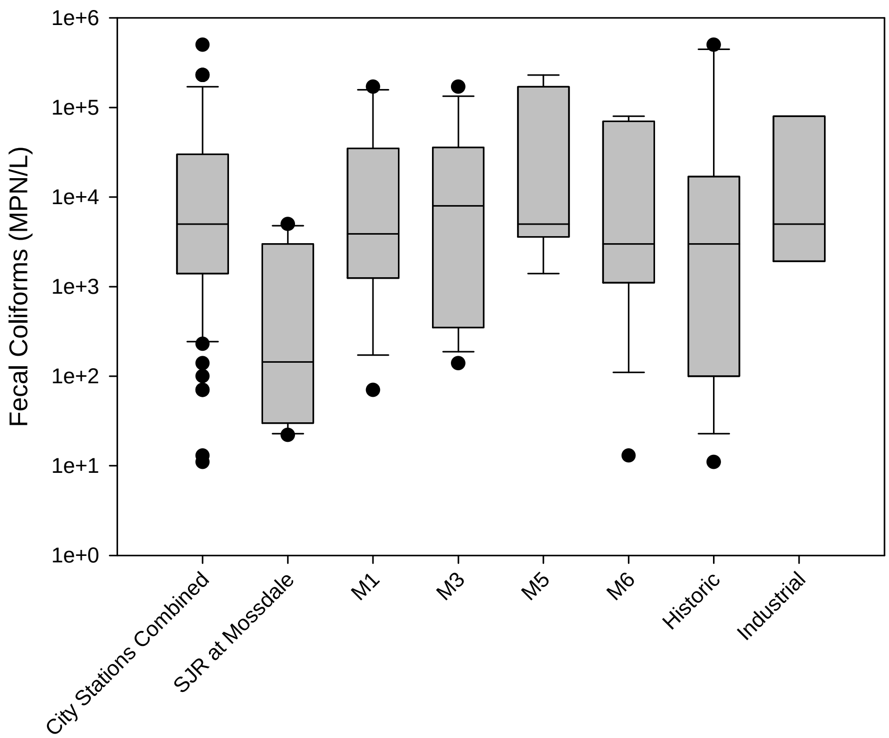


Table 5-65. Summary Statistics of Fecal Coliforms (in MPN/L) for Seasons One, Two, and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	10	27,557	3,900	70	170,000	52,616
M2	12	30,394	9,000	230	230,000	63,975
M3	12	26,512	8,000	140	170,000	48,160
M5	9	66,289	5,000	1,400	230,000	94,405
M6	11	22,520	3,000	13	80,000	34,898
Historic	11	69,726	3,000	11	500,000	158,056
Industrial	6	28,850	5,000	800	80,000	39,674
SJR at Mossdale	10	1,214	145	22	5,000	1,789

Figure 5-76. Boxplot of *E.coli* for Seasons One, Two, and Three

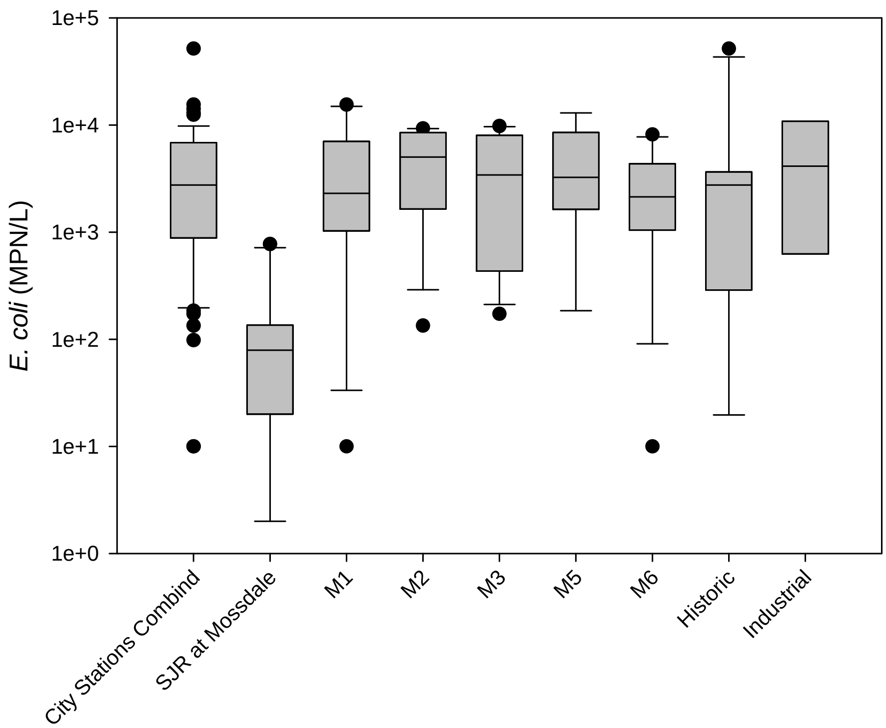


Table 5-66. Summary Statistics of *E. coli* (in MPN/L) for Seasons One, Two, and Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	10	4,334	2,303	10	15,531	4,932
M2	12	5,027	5,043	134	9,330	3,424
M3	12	4,055	3,431	173	9,804	3,776
M5	9	4,759	3,255	185	12,997	4,703
M6	11	2,890	2,143	10	8,164	2,460
Historic	11	7,015	2,755	N.D.	51,720	15,092
Industrial	6	5,557	4,137	435	14,136	5,541
SJR at Mossdale	10	141	79	N.D.	776	230

Comparison of Seasons One, Two, and Three

The data pattern for total coliforms varied over the 3 seasons; however, there were no statistical differences among the seasons. During the first season, the city pumping values were much higher than the San Joaquin River at Mossdale. The only station that the San Joaquin River at Mossdale station had overlapping values with was the M1 station. The M6 station had the widest range of values of all the stations. The other stations had relatively similar ranges (Figure 5-77, Table 5-67). In season two, the total coliform values were more variable over the city pumping stations, with M3 having the widest range. Like season one, the San Joaquin River at Mossdale station samples were lower than the city pumping station samples, but not by as much as the first season. In season two, the San Joaquin River at Mossdale station had overlapping values with all of the city pumping stations except the M2 and Industrial station (Figure 5-78, Table 5-68). In season three, there was also much variability in the pumping stations, and the ranges for each station were wider overall. The San Joaquin River at Mossdale samples were again lower than the city pumping station samples, but the values overlapped the values at the M1, M6, Historic, and Industrial stations (Figure 5-79, Table 5-69). There were no trends during each year for the San Joaquin River at Mossdale samples; however, there were clear trends for the city pumping stations. In each year, there was a first flush effect in which the first storm that was sampled in each water year yielded the highest values (Figure 5-80). Samples during the rest of each season were not as high as this first storm event.

Like total coliforms, there was no significant difference among the seasons, and the patterns of data for fecal coliforms changed from year to year. The San Joaquin River at Mossdale values were the lowest of all the stations. The values for the city pumping stations were generally higher during the first season, despite not being statistically different from seasons two or three (Figure 5-81, Table 5-70). The Historic station had the largest range, with values from 100 MPN/L to 500,000 MPN/L (Table 5-70). In season two, the San Joaquin River at Mossdale station had a slightly smaller range than in season one, and there was more overlap of values between this station and the city pumping stations (Figure 5-82). In this year, the M5 station had the widest range of values (2,200 MPN/L to 170,000 MPN/L) (Table 5-71.). In season three, the San Joaquin River at Mossdale samples again were lowest, but the values overlapped all of the city pumping station values (Figure 5-83). Like season one, the Historic station had the widest range from 11 MPN/L to 230,000 MPN/L (Table 5-72). The trends during each season were very similar to that of total coliforms. The first storm sampled of each season yielded the highest values. These values came down later in the season, although there was still much variability (Figure 5-84).

For *E.coli*, there was no statistical difference between seasons two and three, but season one was significantly different (Mann-Whitney, $p=0.001$). When comparing each season of data separately, it can be seen that season two had lower values over all. For example, the maximum in season two was 9,208 MPN/L whereas the maximum for season one was 51,720 MPN/L and was 14,136 MPN/L in season three (Tables 5-73, 5-74 and 5-75). Figure 5-85 shows the data points for each season, ranked from smallest to greatest. This figure shows that the samples from season two and three were quite similar, although season three had 5 values that were higher than any of those in season two. The values sampled in season one were all higher than those of season two and three when ranked; showing season one was significantly different from seasons two and three. It is not clear why season one had higher values overall, but it may be the result of a change in Lathrop's citizens' dog care. During season one, a new dog park was being constructed, but was not in operation during most of the season. It is possible that once the dog park was in use, dog owners were more conscientious about picking up dog feces than they were before the dog park was in use. This change in habits could contribute to the change in *E.coli* values that were seen in the city pumping stations. Another possibility is that there was a greater flushing of *E.coli* during season one because it was a wet year preceded by 3 dry years. Although these 2 reasons may have had an effect, it is unlikely that they would have affected only *E.coli*.

The season one *E.coli* values at the San Joaquin River at Mossdale were significantly lower than any of the pumping station values, and there was no overlapping of values between the San Joaquin River at Mossdale and the city pumping stations. The season one ranges for most of the city pumping stations were small, compared to coliform values. Medians ranged from approximately 2,500 MPN/L to 8,500

MPN/L. This is a much smaller range than what was seen in total or fecal coliforms. The Historic station had the widest range from 1,281 MPN/L to 51,720 MPN/L; however, the ranges for all the other stations were much smaller (Figure 5-86, Table 5-73). In season two, the San Joaquin River at Mossdale samples were not as low as they were in the first season, and values at this station overlapped with several of the city pumping stations. The median values during this season were not as high as in season one, as shown by the Mann-Whitney statistical test (Figure 5-87, Table 5-74). In season three, the range of values for the San Joaquin River at Mossdale station was the lowest of all the seasons, with a range of non-detected to 98 MPN/L; some values in the city pumping stations overlapped these values (Figure 5-88, Table 5-75). *E.coli* trends over the three seasons followed the same patterns as those of total and fecal coliforms with the highest values occurring during the first flush event of the season and lower values later in the season (Figure 5-89).

Figure 5-77. Boxplot of Total Coliforms for Season One

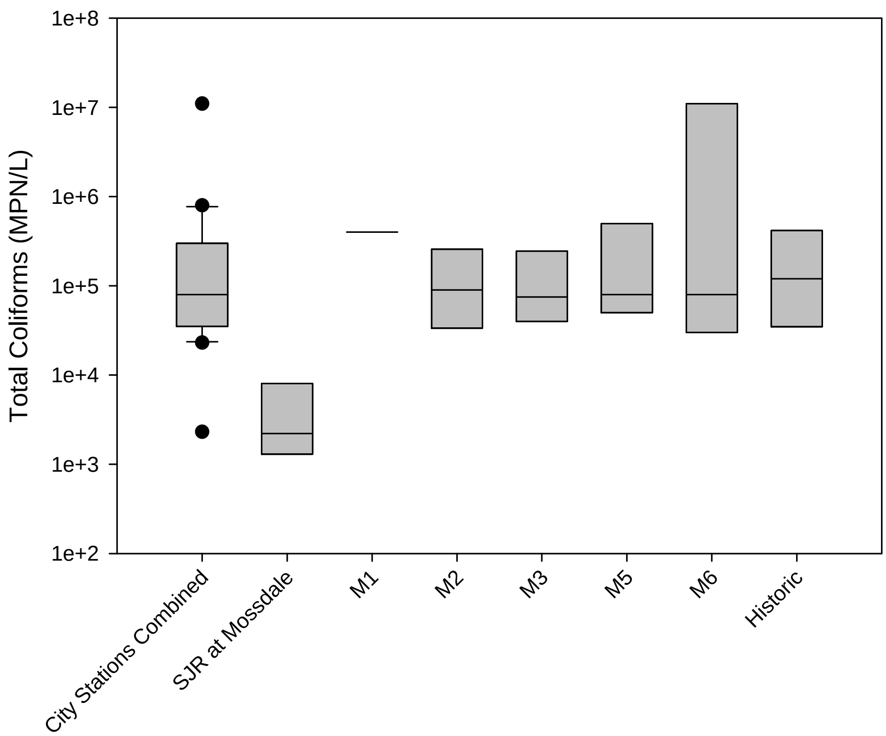


Figure 5-78. Boxplot of Total Coliforms for Season Two

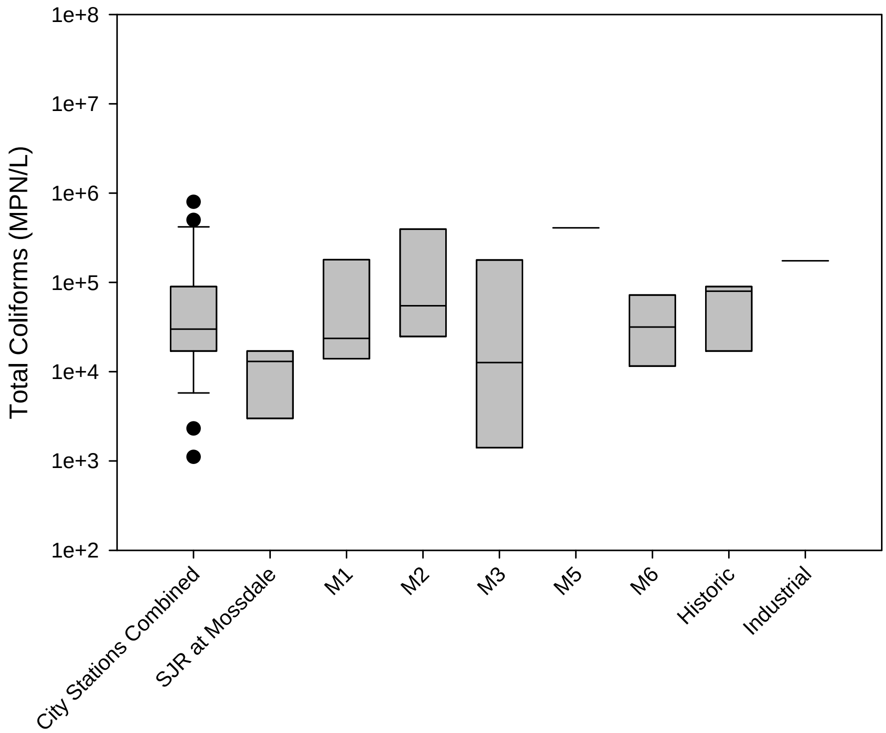


Figure 5-79. Boxplot of Total Coliforms for Season Three

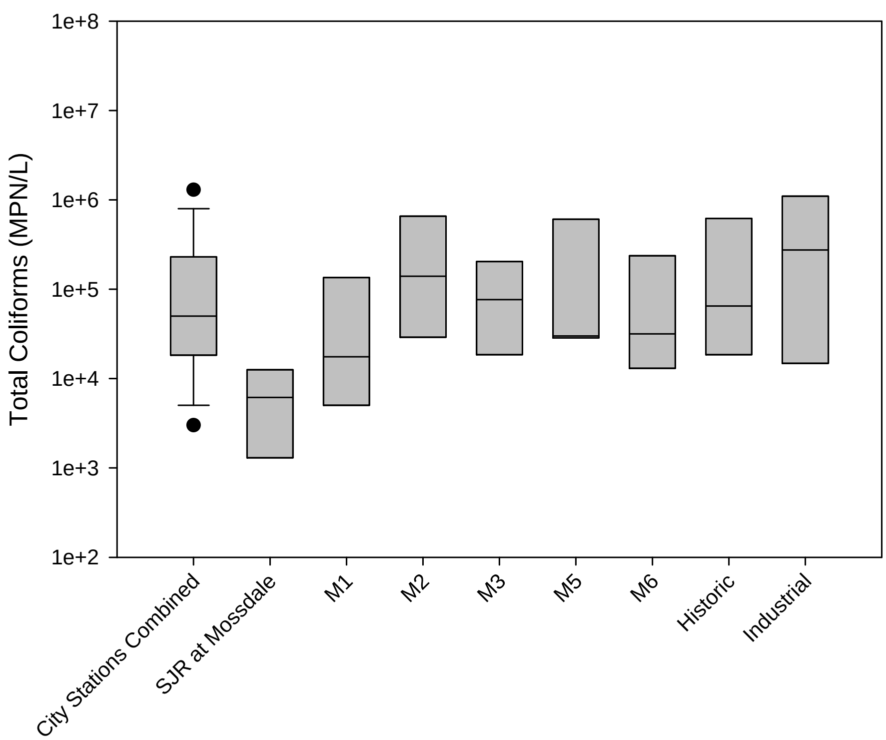


Table 5-67. Summary Statistics of Total Coliforms (in MPN/L) for Season One

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	2	401,150	401,150	2,300	800,000	564,059
M2	3	127,000	90,000	28,000	300,000	123,380
M3	4	120,000	75,000	30,000	300,000	121,929
M5	3	210,000	80,000	50,000	500,000	251,595
M6	3	3,703,333	80,000	30,000	11,000,000	6,319,148
Historic	4	190,750	120,000	23,000	500,000	215,087
SJR at Mossdale	3	3,833	2,200	1,300	8,000	3,636

Table 5-68. Summary Statistics of Total Coliforms (in MPN/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	72,500	23,500	13,000	230,000	105,250
M2	4	158,250	55,000	23,000	500,000	229,243
M3	4	64,103	12,650	1,110	230,000	111,054
M5	2	408,500	408,500	17,000	800,000	553,665
M6	4	38,500	31,500	11,000	80,000	32,970
Historic	3	62,333	80,000	17,000	90,000	39,577
Industrial	2	175,000	175,000	50,000	300,000	176,777
SJR at Mossdale	3	11,000	13,000	3,000	17,000	7,211

Table 5-69. Summary Statistics of Total Coliforms (in MPN/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	52,500	17,500	5,000	170,000	79,215
M2	4	275,500	140,000	22,000	800,000	361,609
M3	4	100,000	76,500	17,000	230,000	101,025
M5	4	222,000	30,000	28,000	800,000	385,334
M6	4	94,000	31,500	13,000	300,000	138,437
Historic	4	234,500	65,000	8,000	800,000	378,155
Industrial	4	463,250	275,000	3,000	1,300,000	601,140
SJR at Mossdale	4	6,650	6,150	1,300	13,000	6,231

Figure 5-80. Total Coliform Trends

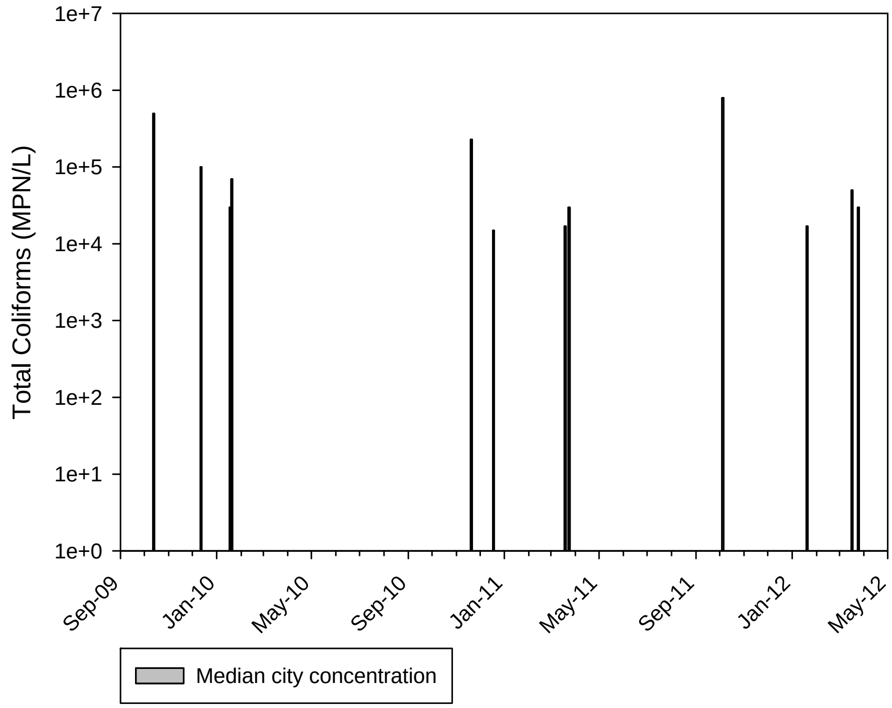


Figure 5-81. Boxplot of Fecal Coliforms for Season One

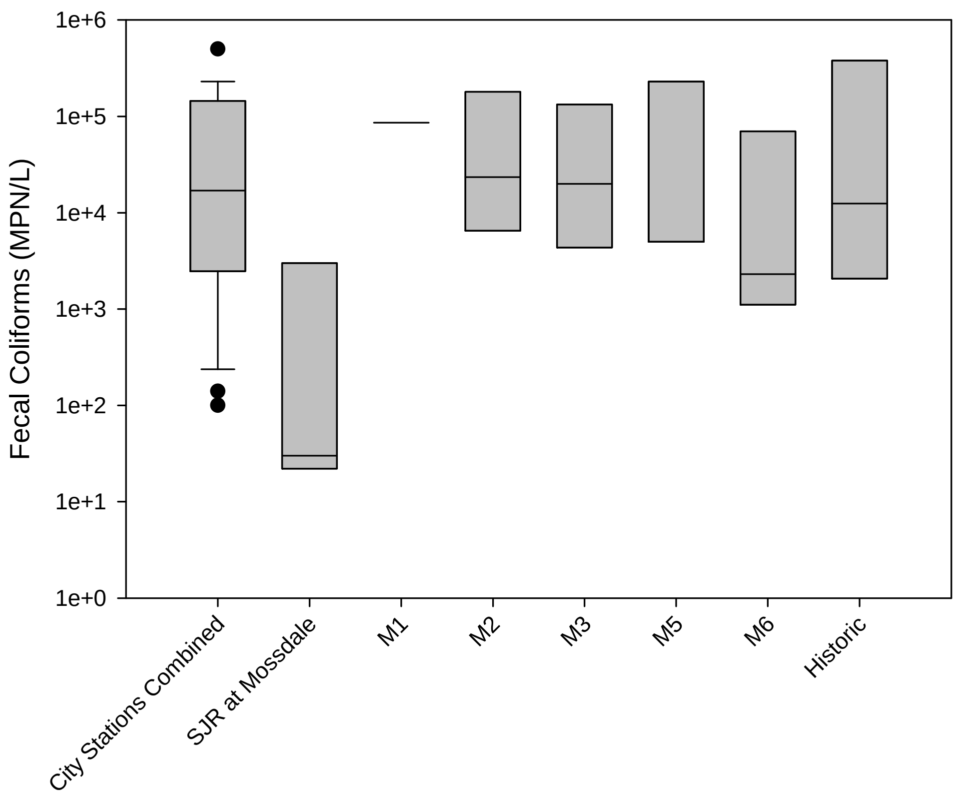


Figure 5-82. Boxplot of Fecal Coliforms for Season Two

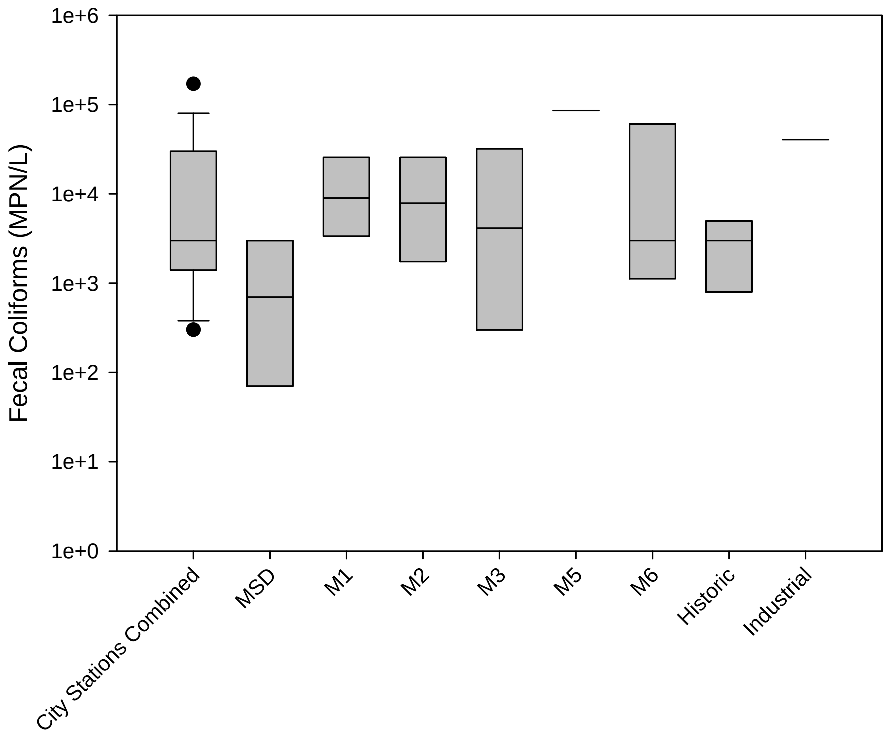


Figure 5-83. Boxplot of Fecal Coliforms for Season Three

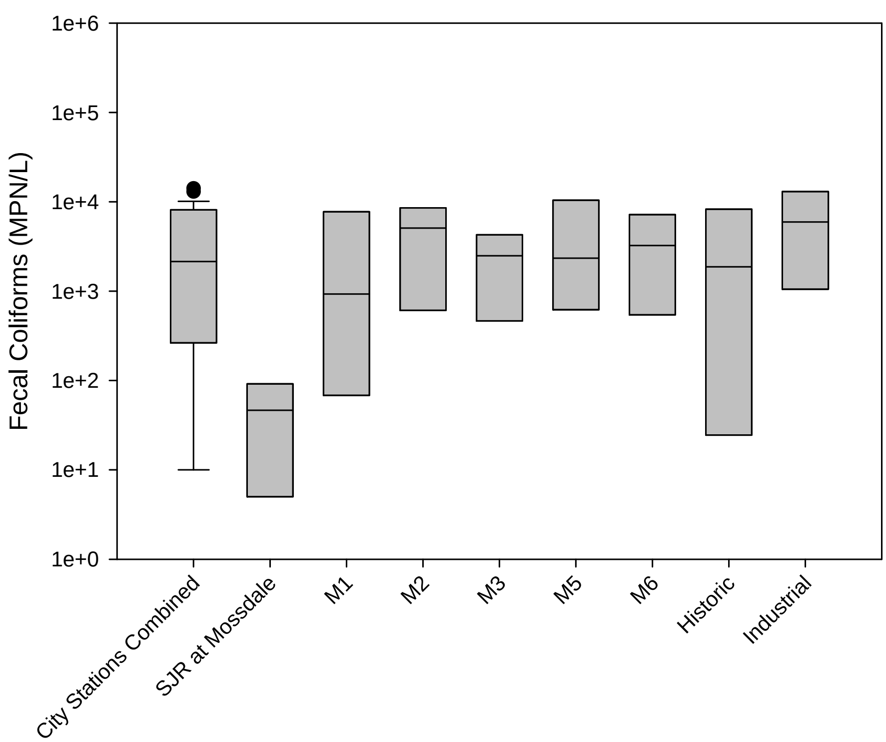


Table 5-70. Summary Statistics of Fecal Coliforms (in MPN/L) for Season One

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	2	86,150	86,150	2,300	170,000	118,582
M2	3	70,000	23,500	3,000	230,000	107,235
M3	4	52,535	20,000	140	170,000	78,906
M5	3	80,000	5,000	5,000	230,000	129,904
M6	3	24,470	2,300	1,110	70,000	39,435
Historic	4	131,275	12,500	100	500,000	245,914
SJR at Mossdale	3	1,017	30	22	3,000	1,717

Table 5-71. Summary Statistics of Fecal Coliforms (in MPN/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	12,700	9,000	2,800	30,000	12,338
M2	4	11,800	7,900	1,400	30,000	13,189
M3	4	12,150	4,150	300	40,000	18,918
M5	2	86,100	86,100	2,200	170,000	118,653
M6	4	21,625	3,000	500	80,000	38,935
Historic	3	2,933	3,000	800	5,000	2,101
Industrial	2	40,400	40,400	800	80,000	56,003
SJR at Mossdale	3	1,257	700	70	3,000	1,542

Table 5-72. Summary Statistics of Fecal Coliforms (in MPN/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	13,118	1,200	70	50,000	24,594
M2	4	9,383	3,650	230	30,000	13,883
M3	4	14,850	4,450	500	50,000	23,685
M5	4	46,100	6,500	1,400	170,000	82,644
M6	4	21,953	3,900	13	80,000	38,752
Historic	4	58,270	1,535	11	230,000	114,495
Industrial	4	23,075	5,000	2,300	80,000	38,006
SJR at Mossdale	4	1,330	145	30	5,000	2,448

Figure 5-84. Fecal Coliform Trends

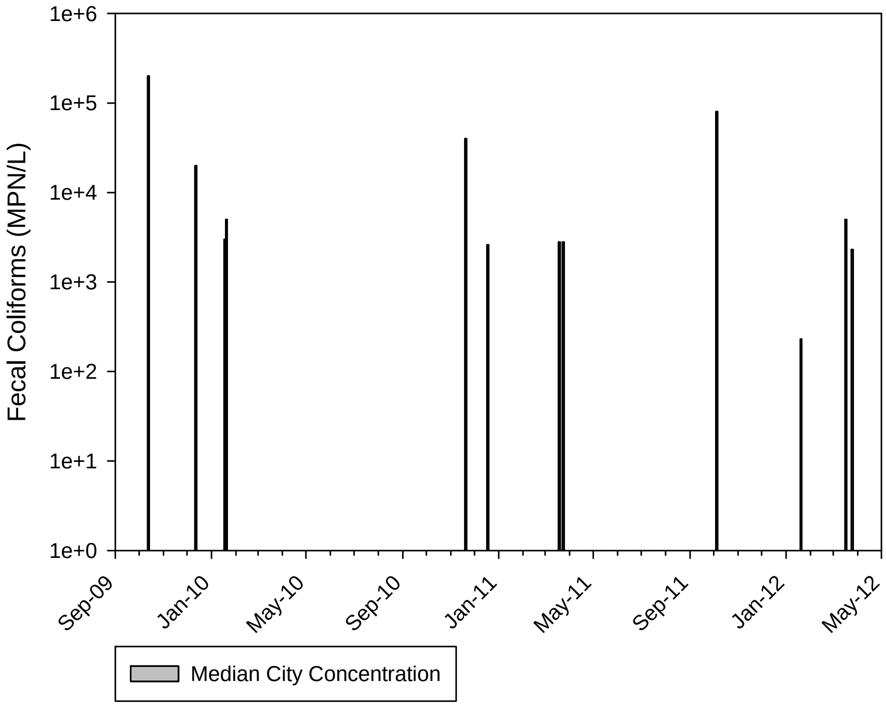


Table 5-73. Summary Statistics of *E. coli* (in MPN/L) for Season One

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	2	8,411	8,411	1,291	15,531	10,069
M2	3	6,332	6,171	3,654	9,330	2,393
M3	4	8,750	8,747	7,701	9,804	982
M5	3	6,337	3,255	3,255	12,500	5,338
M6	3	2,462	2,755	1,850	2,780	530
Historic	4	15,022	3,544	1,281	51,720	24,489
SJR at Mossdale	3	78	31	20	183	91

Table 5-74. Summary Statistics of *E. coli* (in MPN/L) for Season Two

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	3,711	3,244	2,224	6,131	1,825
M2	4	3,998	3,063	657	9,208	3,866
M3	4	997	530	173	2,755	1,199
M5	2	2,974	2,974	1,336	4,611	2,316
M6	4	2,433	1,595	413	6,131	2,567
Historic	3	1,174	480	288	2,755	1,372
Industrial	2	3,283	3,283	435	6,131	4,028
SJR at Mossdale	3	327	120	85	776	389

Table 5-75. Summary Statistics of *E. coli* (in MPN/L) for Season Three

Station	Number of Samples	Mean	Median	Minimum	Maximum	Standard Deviation
M1	4	2,918	930	10	9,804	4,645
M2	4	4,752	5,105	134	8,664	4,305
M3	4	2,417	2,495	327	4,352	2,107
M5	4	4,468	2,345	185	12,997	5,786
M6	4	3,667	3,248	10	8,164	3,483
Historic	4	3,389	1,876	N.D.	9,804	4,602
Industrial	4	6,694	5,974	691	14,136	6,372
SJR at Mossdale	4	48	47	N.D.	98	46

Figure 5-85. Ranked *E.coli* Data for Seasons One, Two, and Three

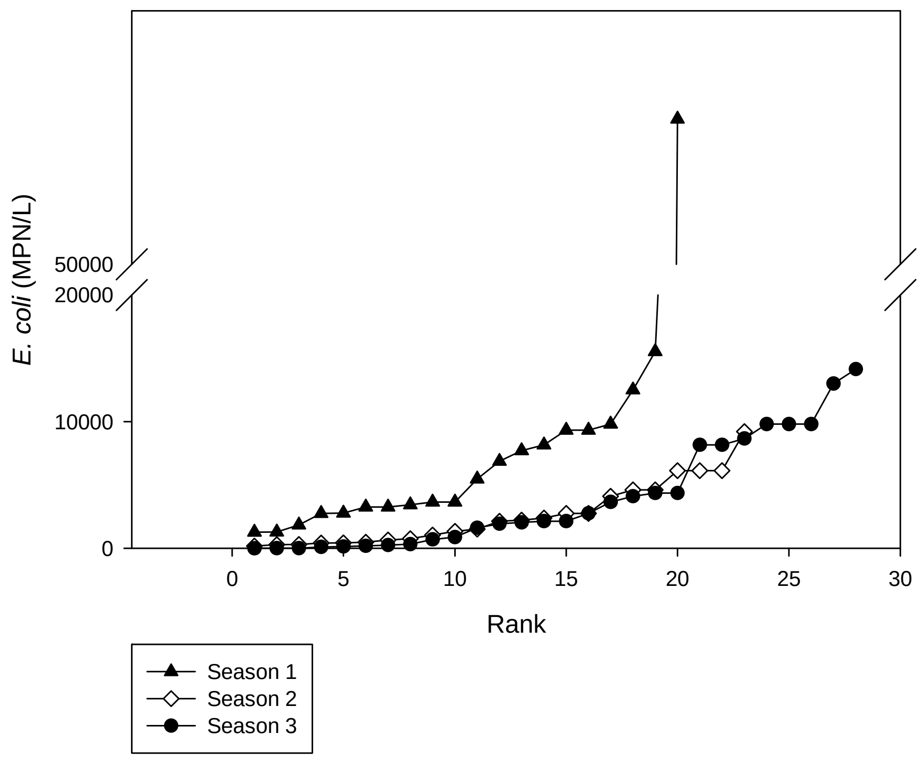


Figure 5-86. Boxplot of *E. coli* for Season One

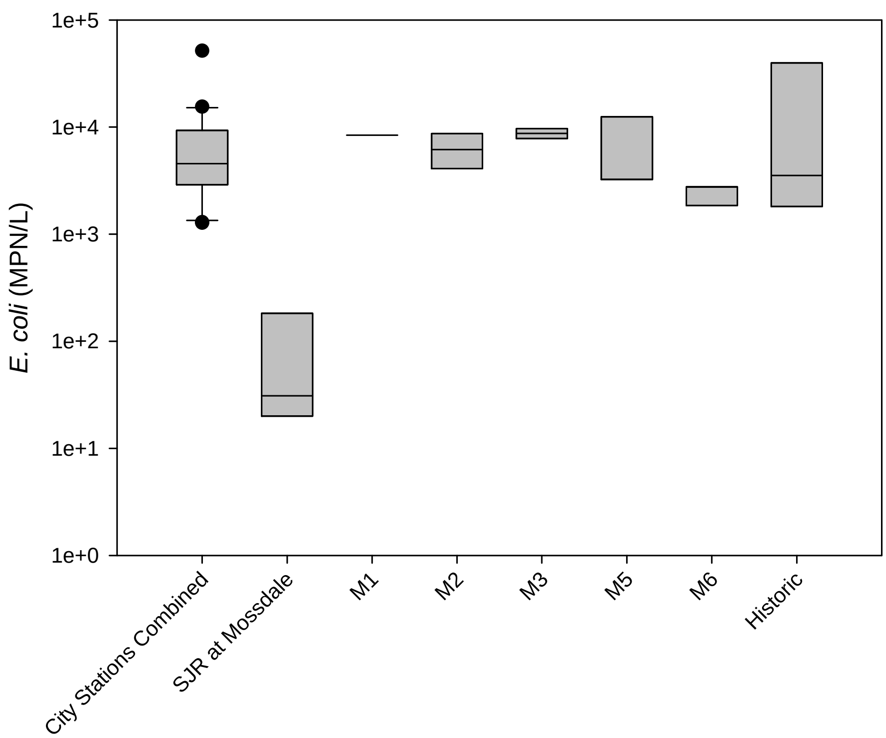


Figure 5-87. Boxplot of *E. coli* for Season Two

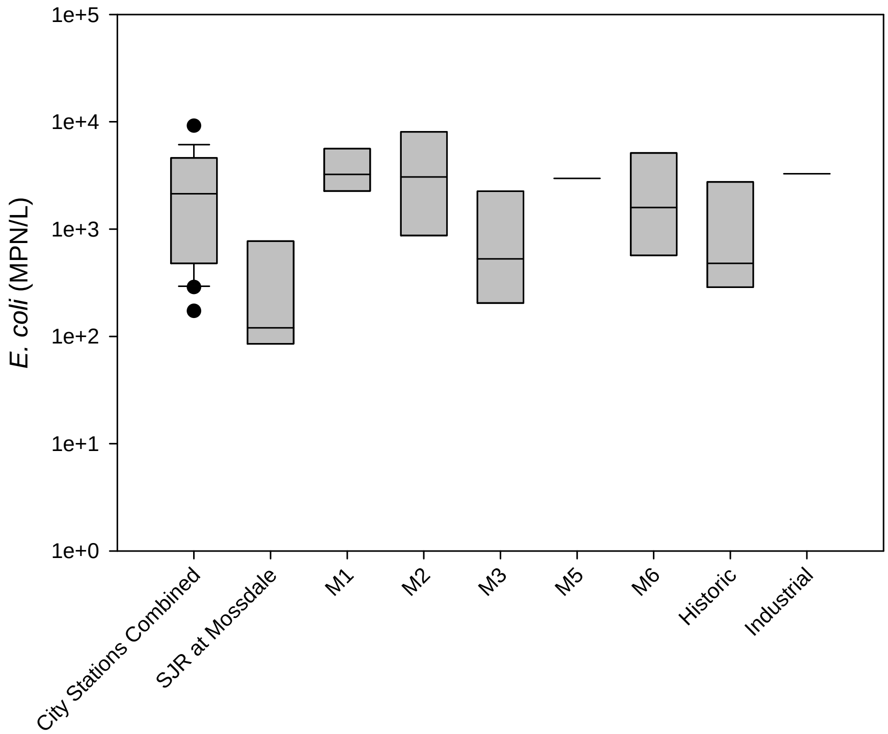


Figure 5-88. Boxplot of *E. coli* for Season Three

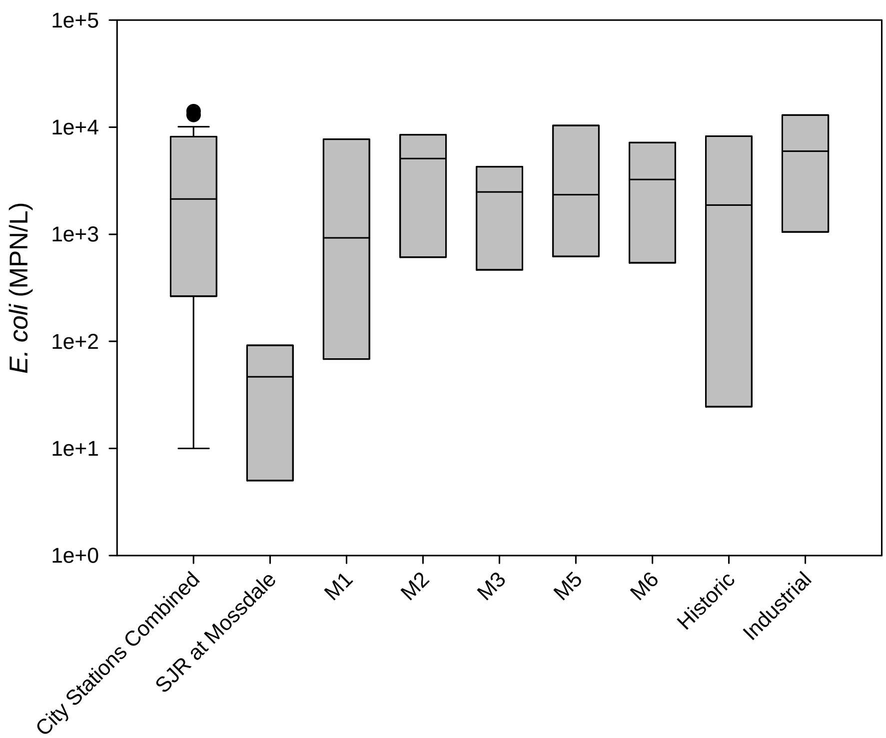
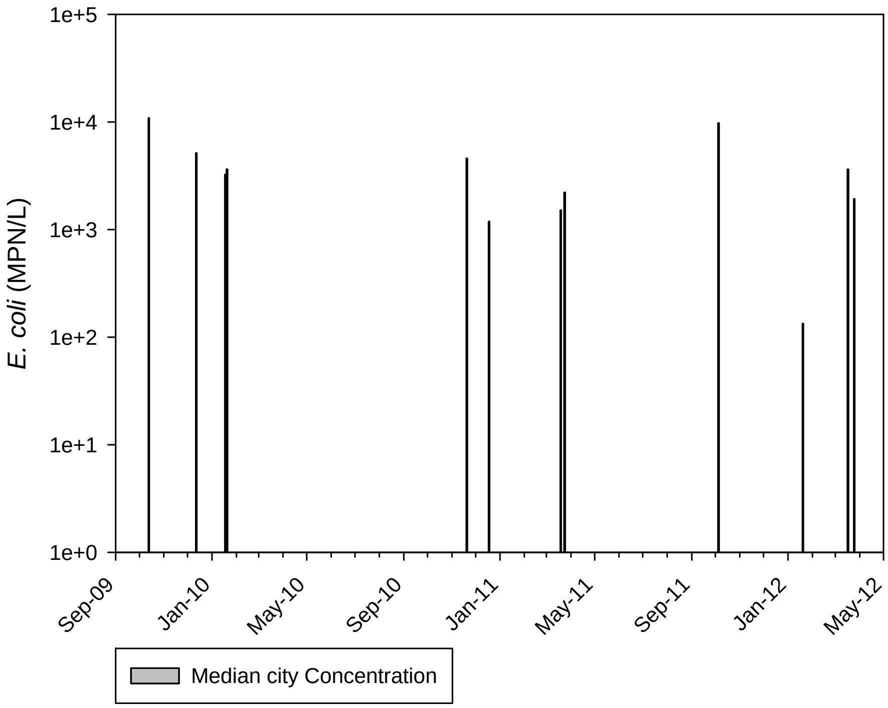


Figure 5-89. *E. coli* Trends



Comparison with Other Studies

Values of total coliforms discharged from the pumping stations were compared with values discharged from other regions in the state.The mean concentration discharged from the city pumping stations was 320,390 MPN/L and the median was 50,000 MPN/L (Table 5-64). These values were compared to those of the Steelhead Creek study (DWR, 2008). The data reviewed for Steelhead Creek did not include the first 2 years of storm data due to limitations in the maximum number of coliforms detectable by the laboratory. The Steelhead Creek median was 35,000 MPN/L which was lower than what was observed in Lathrop, but the mean concentration (3,928,783 MPN/L) was much higher than that of Lathrop. Lathrop's range of total coliform values was 1,110 MPN/L to 11,000,000 MPN/L. Steelhead Creek's range was 80 MPN/L to 90,000,000 MPN/L. Lathrop's values were also within the range of samples analyzed by Sacramento Stormwater Partnership in the Urban Runoff Sources and Control Evaluation (Geosyntec, 2011). The 4 drainage areas in the evaluation had median total coliform values from 141,300 MPN/L to 1,772,175 MPN/L. Lathrop's values were also compared to storm samples collected in Los Angeles for the 2011-2012 NPDES annual report (Los Angeles County, 2012). The range of the Los Angeles values was slightly lower than the Lathrop total coliform range. The Los Angeles range of values from 7 different sampling sites ranged from 1,300 MPN/L to 16,000,000 MPN/L with medians ranging from 90,000 MPN/L to 900,000 MPN/L. Lathrop's range was 1,110 MPN/L to 11,000,000 MPN/L. However, these results show that Lathrop's values are similar to those sampled throughout the state.

Values of fecal coliforms sampled in Lathrop were lower than values sampled in other studies in California. Lathrop's pumping station samples had a mean concentration of 38,631 MPN/L and a median of 5,000 MPN/L (Table 5-65). These values were lower than the Steelhead Creek mean of 1,157,357 MPN/L and median of 16,000 MPN/L (DWR, 2008). The range of values from Steelhead Creek was also significantly larger than Lathrop's range. The Steelhead Creek total coliform values ranged from 2 MPN/L to 28,000,000 MPN. Lathrop's pumping station values ranged from 11 MPN/L to 500,000 MPN/L. Lathrop's values were also low compared to samples analyzed by Sacramento Stormwater Partnership in the urban sources evaluation. The median values for the drainage areas analyzed by Sacramento Stormwater Partnership ranged from 13,000 MPN/L to 130,000 MPN/L (Geosyntec, 2011). In comparison to the storm samples collected in 7 Los Angeles drainage areas, Lathrop's values were low (Los Angeles County 2012). The Los Angeles fecal coliform values had medians that ranged from 17,000 MPN/L to 240,000 MPN/L.

E.coli values sampled from Lathrop's pumping stations were generally much lower than those sampled in the Sacramento region. There was limited data available in other regions in the state. Lathrop's *E.coli* values sampled from the pump stations had a mean of 2,755 MPN/L and a median of 4,752 MPN/L (Table 5-66). Samples collected for the Steelhead Creek study had a mean of 1,155,701 MPN/L and a median of 22,000 MPN/L (DWR, 2008). The values sampled by the Sacramento Stormwater Partnership had medians that ranged from 3,000 MPN/L to 23,000 MPN/L (Geosyntec, 2011). Although there were some interesting trends seen in Lathrop for *E.coli* with the first season having generally higher values than the rest of the study, these values were not significantly high in comparison to other studies in the region.

Summary

The analysis of key water quality constituents and loads shows that the quality of water discharged from the city of Lathrop largely has little effect on the water quality of the San Joaquin River. Organic carbon concentrations from the city pumping stations were higher than those in the San Joaquin River. The concentrations also showed a first flush effect, with high concentrations during the first storm event of the season. However, the loads were generally low, with the city contributing a maximum of 6.8% of the total organic carbon load of the San Joaquin River. All other storms contributed less that 2% of the total load. The composition of organic carbon differed between the river and the city pumping stations, which was supported by the strong relationship between UVA_{254} and DOC, and the variation in UVA_{254} values during the two seasons.

The concentrations of HAAFP and THMFP from the city pumping stations were significantly higher than the San Joaquin River. Concentrations of THMFP and HAAFP in season two also confirmed a first flush effect.

For nutrients, ammonia, nitrate, nitrate plus nitrite, total nitrogen, orthophosphate, and total phosphorus were analyzed for concentrations and loads. Ammonia concentrations in the San Joaquin River were significantly lower than those of the city pumping stations. Lathrop's ammonia loads generally made up less than 5% of the total load of the San Joaquin River with the exception of one storm in which the city contributed 14.2% of the total load of the San Joaquin River. For nitrate, and nitrate plus nitrite, the San Joaquin River concentrations were not significantly lower than the concentrations from the city pumping stations; however, the San Joaquin River concentrations were significantly lower than those of the city pumping stations for total nitrogen. Lathrop's nitrate levels were often high, exceeding the 10 mg/L as N MCL, and total nitrogen levels often exceeded the EPA's 0.31 mg/L as N reference conditions. Total nitrogen loads from the city pumping stations were less than 1% of the total San Joaquin River load for all storm events. The San Joaquin River concentrations were significantly lower than those of the city pumping stations for orthophosphate and total phosphorus. Season two concentrations for total phosphorus were significantly lower than those in season three, which is likely due to wet year versus dry year effects. Total phosphorus load for all storm events was less than 3%; however, the highest loads did occur during the first storms of the wet season, giving evidence of a first flush effect.

The minerals of bromide, alkalinity and hardness were analyzed. Bromide concentrations were not significantly lower in the San Joaquin River than in the city pumping stations. The high concentrations of bromide in the city pumping stations are explained by groundwater intrusion. Bromide loads contributed by the city pumping stations were generally about 1% of the total load of the river with the exception of the first flush event in season three. During this event, Lathrop contributed 7.3% of the total river load. There were no significant differences in alkalinity or hardness concentrations between the San Joaquin River and the city pumping stations.

Salinity concentrations were not significantly different between the San Joaquin River and the city pumping stations. High salinity in the pumping stations was attributed to groundwater intrusion.

Due to infrequent sampling, no trends could be drawn for pyrethroids. Of the events that were sampled, bifenthring, cyfluthrin, cypermethrin L-cyhaolthrin, and permethrin were the species of pyrethroids present. The concentrations of these pyrethroids were at levels that are toxic to benthic organisms such as *Hyalella azteca*.

The pathogen indicator organisms of total coliforms, fecal coliforms, and *E.coli* were analyzed. The San Joaquin River had significantly lower concentrations than Lathrop's pumping stations for total and fecal coliforms, and *E.coli*. Results for all three constituents also showed evidence of a first flush effect, with significantly higher concentrations in the first storms of the wet season.

Chapter 6. Land Use Analysis

Introduction

Geographic information systems (GISs) have been used in numerous applications to analyze the impacts of urbanization based on land use. A GIS is a system that integrates various forms of geographically referenced data to enable the user to manage, analyze, and characterize geographical data in efforts to draw patterns, trends, and relationships between geographic data and associated data, such as census data or land use type (ESRI, 2013).

Many studies have shown a direct link between land use and aquatic ecosystem health. A key measure of land use is impervious cover. Impervious cover is characterized by land uses that are typically urban and are composed of impenetrable surfaces such as asphalt or concrete. In the process of urbanization, permeable land uses, such as open space or agriculture, are converted into impervious surfaces such as roads, buildings, and other hardscape features. These impervious surfaces do not allow water to percolate through soils into the water table. Also, soils cannot filter out contaminants in these urban landscapes. The result is an increased amount of runoff delivered to surface water with undiluted concentrations of contaminants such as pesticides, fertilizers, and pathogens.

Hydrologic effects of urbanization, termed hydromodification, include a change in the characteristics of a storm. This change results in higher peak discharge and increased total runoff with a shorter duration of flows above baseflow than in natural environments with pervious land surfaces. This increase in the streamflow during storm events has many physical effects including increased erosion, higher sediment loading, channel widening, decreased baseflow, shorter lag time from precipitation to runoff, increased stream temperature, and more frequent flooding (EPA, 2013a). These changes due to urbanization can be seen when as little as 10% of the land surface is converted to impervious cover, and is much more evident at greater than 25% impervious cover (CWALUP, 2005).

Ecological ecosystems are further affected with increases in impervious cover. Due to erosion, widening of channels, and changes in hydrology, biological communities are adversely affected. Changes in the morphology of the system result in fragmented and reduced habitat for fish and aquatic insects. Numerous studies have shown a reduction in fish and aquatic insect populations and in their diversity when there is more than 10% impervious cover (Impervious Cover Model, 2000).

In addition to hydrologic and ecological effects, impervious cover results in degradation of water quality as contaminants from the land surfaces are delivered to surface water in the runoff. Studies have shown increased loading from nutrients, organic carbon, metals, pesticides, and pathogens due to urbanization (Pitt and Bozeman, 1982; DWR, 2008; Rhoads and Cahill, 1999). This increase in contaminants to surface waters has significant implications for aquatic ecosystems as well as municipal water uses.

Two key measures of impervious cover used in many studies are land use categories and percentage impervious cover. This analysis involves looking at land uses and determining the percentages of impervious area. Although there are limitations to this type of analysis due to data availability, differences in what is considered “degradation,” and applicability of thresholds (i.e.,10% impervious) to all geographic regions; this analysis method proves to be a strong metric for drawing a relationship between land use, aquatic ecosystem health, and water quality (Brabec, E., S.Schulte and P.L.Richards, 2002).

For this study, the land use component involved an analysis of land use type and impervious cover. The focus of the analysis was to calculate the total impervious cover for the city of Lathrop and was based on political boundaries due to the flatness of the terrain in the watershed. It was not feasible to conduct the analysis for the entire watershed that contains Lathrop because the watershed incorporates most of the Delta. In addition, Lathrop's hydrology is highly managed with storm water being pumped from the city into the San Joaquin River instead of naturally draining into the river. In the areas that are not served by the pumping stations, storm water simply percolates into the groundwater or evaporates from detention basins.

The land use analysis for this study was built upon the work that the Office of Environmental Health Hazard Assessment (OEHHA) did in developing impervious surface coefficients (ISCs) for land uses throughout the state of California. OEHHA's land use types and percent of imperviousness for the land uses were applied to the land uses in Lathrop to determine overall impervious cover for build-out and present day (OEHHA, 2010). Build-out condition refers to the maximum urban development that the city intends to pursue, based on the city's general plan. The city's general plan was most recently updated in 2004 and projected out 20 years.

Hydromodification and State Regulations

Due to the detrimental effects from hydromodification, there are now permit requirements for dischargers throughout California to mitigate these effects. This is done through the Phase I National Pollution Discharge Elimination System (NPDES) permits which require hydromodification management plans (HMPs). The focus of these plans is to restore the biological, chemical, and physical functions of aquatic systems in urban environments with a priority on protecting ecological functionality. The HMPs include requirements for new and redevelopment projects to implement measures to reduce increases in runoff flows if the project increases impervious cover above a certain threshold. These methods are required to be tailored to the watershed that they are to be used in, rather than drawing from standard approaches.

Throughout the state, HMPs have some common elements in design and structure. In general, these plans involve characterizing the watersheds, identifying susceptible water bodies, conducting historical assessments, conducting hydrologic and hydraulic modeling, and developing assessment tools. A large component of these plans involves identifying current and potential future impervious cover. The modeling is used to develop a calculator to accurately size low impact development (LID) and other best management practices (BMPs) to mitigate hydromodification.

The most common requirements for compliance are: (1) post-project design discharge rates and discharge durations match pre-project rates from 10% of the pre-project 2 year peak flow up to the pre-project 10 year peak flow, and (2) the post-project flow duration curve shall not deviate above the pre-project flow duration curve by more than 10% during more than 10% of the length of the curve corresponding to the range of flows (Santa Clara, San Diego, Contra Costa, Vallejo, Fairfield, Sacramento HMPs). In order to comply with these requirements, hydromodification mitigation measures are required.These measures include implementing hydromodification mitigation measures such as LID and other BMPs (Geosyntec Consultants, 2002).The goal of LID is to mimic natural hydrology to the maximum extent possible through project design techniques that store, filter, evaporate, detain, and slow storm water runoff to source waters. Some examples of LID that help to mitigate hydromodification include rain gardens, rooftop gardens, permeable pavers, impervious surface reduction and disconnection, soil amendments, vegetated swales, and general good housekeeping (EPA, 2013).

Although hydromodification mitigation measures were not specifically spelled out in the 2003 NPDES permit that covers Lathrop, it does require long-term post construction BMPs that protect water quality and control runoff. In the new permit that went into effect in July 2013, hydromodification is directly addressed.The permit states, “Within the third year of the effective date of the permit, the Permittee shall develop and implement Hydromodification Management procedures. Hydromodification Management projects are Regulated Projects that increase and/or replace one acre or more of impervious surface” (SWRCB, 2013).

Methods

The land use analysis was conducted using ESRI’s ArcGIS 10.0. The analyses for build-out and present conditions (2010) were conducted slightly differently due to a lack of available GIS layers. Both analyses were conducted with the 2010 orthorectified imagery available from the National Agricultural Imagery Program (NAIP). The NAIP data was one meter imagery (one meter per pixel) with accuracy to 6 meters at a 95% confidence level. The imagery is rectified to the UTM coordinate system. The present conditions (2010) analysis was conducted with a parcel layer available from the California Digital Parcel Database.

Impervious Cover Analysis

The impervious cover analysis was built upon the work that the Ecotoxicology Program in OEHHA did in developing ISCs. The coefficients are used to calculate the percentage of imperviousness for a variety of land use types and can be applied on a variety of scales from watershed to development. Through the program’s work, it developed a set of ISCs that can be applied to California’s development style and therefore can be applied statewide (OEHHA, 2009).

The ISCs are estimated percentages of imperviousness for different land use categories (LUCs). The ISC developed for each LUC is based on a sample of imperviousness for the different LUCs in the cities of Sacramento, Irvine, and Santa Cruz. To analyze an area, such as the city of Lathrop, ISCs are applied to the various LUCs. For example, all parks and open spaces have an ISC of 0.02; therefore, they are only 2% impervious. An open space area of 100 acres would be calculated to have 2 acres of impervious surface. The ISCs are applied to all of the LUCs within the area. Impervious area for a LUC is calculated by multiplying the ISC by the area of the LUC. The total area is calculated, and then the total impervious area is calculated. The ratio of these 2 areas is the average percent of imperviousness for the entire area.

Analysis of Lathrop for Present Conditions (2010)

The purpose of the analysis of Lathrop’s land use at present condition was to determine the overall imperviousness of Lathrop in its current state. GIS parcel and zoning layers were not available from the City of Lathrop. Fortunately, a parcel layer for the study area was available from DWR through Digital Map Products, Inc. This provided a finer resolution than was otherwise available for the analysis of Lathrop at build-out conditions.

The next step was applying Lathrop's LUCs to each parcel throughout the city. Lathrop's zoning map was used to determine the zoning of each parcel. But many changes were made because parcels were not zoned in appropriate categories. For example, many areas that will ultimately be built out as residential are currently open space or agricultural lands. Therefore, these areas were zoned for residential, but were entered as open space or agricultural when appropriate. In addition to areas that had not been built out yet, there were numerous parcels that were zoned as industrial that were changed to agricultural. Many of these industrial parcels were actually open space in the industrial region of the city. There were also different parcels that were not necessarily open space, but were also not as built out as traditional industrial. These parcels were zoned as public quasi-public in the analysis because this land use has a more appropriate percentage of imperviousness for the parcel.These comparisons were done between the zoning map and the NAIP imagery, parcel by parcel, to develop a more accurate picture of Lathrop's current condition. A finer resolution was also taken with the residential areas. Because the area could be calculated for each residence, the applied ISC was determined by the number of units per acre, rather than one generalized ISC for each category of residential area (low, medium or high).

Analysis of Lathrop at Build-Out

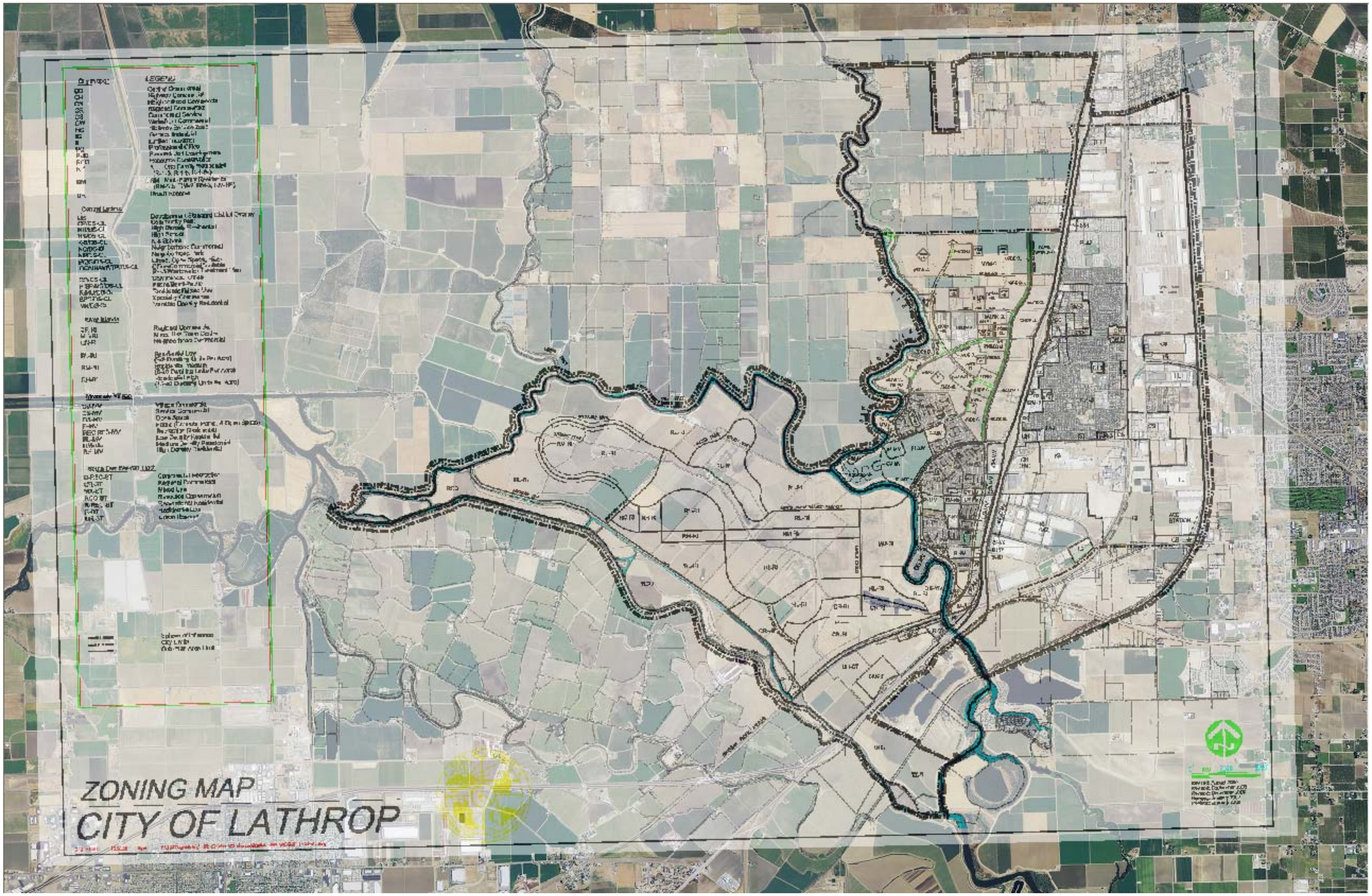
The purpose of this analysis was to determine the overall percentage of impervious cover for the city of Lathrop at build-out conditions according to the city's general plan. This analysis required manipulation of GIS layers for Lathrop's zoning at build-out; however, these layers were not available. In order to accomplish the analysis, a PDF map of Lathrop's zoning at build-out was georeferenced to the NAIP orthographic image of the land. This means that the picture of Lathrop's zones was essentially stretched over the NAIP imagery so that the features matched up (Figure 6-1). After this process was completed, a new GIS layer was created and the zoning map of Lathrop was digitized. This is a process of tracing over all the LUCs in Lathrop to create a GIS layer that has spatial data associated with it; enabling accurate measurement of each LUC. Data was then added to each LUC area for calculation of the impervious area.

The process for calculating imperviousness of the LUCs did not include a calculation of roads. OEHHA was consulted about how to handle the roads because they are a separate LUC from the rest of the land. The recommendation was to use 22% as the proportion of road to land use in residential areas, and to take a sample of a larger industrial area to determine an estimate of road to industrial/commercial land use (Washburn, pers.comm.). Because the proportions of road are consistent throughout the state, this sampling could approximate the condition in Lathrop. A sample of the industrial region in Stockton was chosen to calculate the average area of roads in industrial and commercial regions in Lathrop. Also, the percentage of road in residential regions was adjusted because major roads in the digitized zoning layer were separate from the other LUCs. The percentage of road applied to residential regions in Lathrop was 20% and for industrial and commercial regions it was 15%.

After Lathrop's LUCs were applied to the digitized zoning map, they needed to be converted into the LUCs that are defined in the OEHHA ISCs because each city and county defines their own zoning codes. Lathrop had different zoning codes depending on the region and/or development in the city (Table 6-1). Lathrop's defined ranges for low, medium, and high density residential areas created an issue with transferring Lathrop zoning codes to OEHHA codes. The middle range for each of these densities was chosen for the analysis. After the Lathrop LUCs were converted into OEHHA LUCs, the ISCs were applied and the overall percentage of impervious cover was calculated.

Near the end of the study, a parcel layer was acquired by DWR. This was not used for the land use analysis at build-out because many of the parcels in Lathrop's zoning map have not yet been subdivided. This meant there were regions in the zoning layer that did not match up with parcels on the parcel layer.

Figure 6-1. Lathrop Zoning Map, Georeferenced



Results

The study area encompasses 14,035 acres in the southern end of the Delta (Figure 6-2). This region is located in San Joaquin County and is characterized by very flat terrain which was historically grasslands and wetlands. The study area is bounded on the east by the railroad. The most northern portion of Lathrop is bounded by Roth Road on the north, and I-5 on the west. Central Lathrop is bounded by the San Joaquin River on the west. The southern regions of Lathrop are bounded by the Old River. The southern end of Lathrop is bounded by I-5 and Route 205; the southwestern end is bounded by Paradise Cut. Much of the area that has been planned for future development has not begun construction and is still open space. This is especially true of the southwestern region in Lathrop that is bounded by Paradise Cut and Old River, referred to as the River Islands development. The central region of Lathrop just west of I-5 is primarily new residential development. The central portion of Lathrop just east of I-5 is also residential, but is of older construction. There has been newer residential construction in the northeast portion of Lathrop. Commercial and industrial areas are in the eastern and southeastern regions of the city.

Due to the multiple development phases in the city there are different LUCs depending on the region (Table 6-1). For simplicity, the figures in this chapter will show the land uses translated from Lathrop LUCs to OEHHA LUCs.

Figure 6-2. Study Area

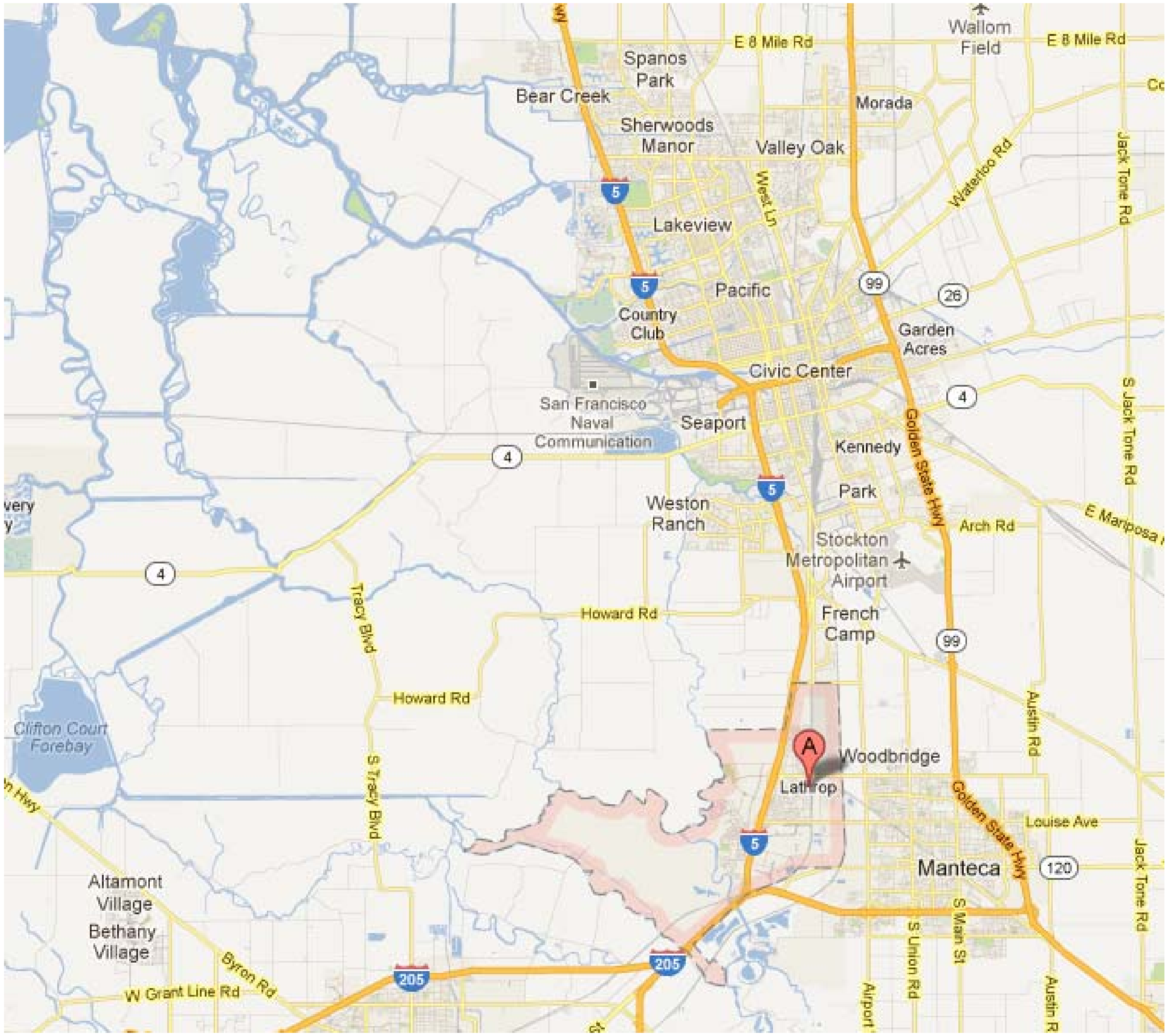


Table 6-1. Land Use Codes (LUCs) and Impervious Surface Coefficients

City Region	Lathrop LUC	Lathrop LUC Description	OEHHA LUC	ISC
City Proper				
	CC	Central Commercial	Light Industrial	0.81
	CH	Highway Commercial	Light Industrial	0.81
	CN	Neighborhood Commercial	Retail/Office	0.81/0.88
	CR	Regional Commercial	Retail/Office	0.81/0.88
	CS	Commercial Service	Retail/Office	0.81/0.88
	CW	Waterfront Commercial	Retail/Office	0.81/0.88
	HS	Highway Service Zone	Light Industrial	0.81
	IG	General Industrial	Heavy Industrial	0.91
	IL	Limited Industrial	Light Industrial	0.81
	PO	Professional Office	Office Park/Office Urban	0.69/0.86
	PUD	Planned Unit Development	Mixed use	0.8
	R-2	One Family Residential	Residential	0.24-0.84
	RCO	Resource Conservation	Open Space	0.02
	RM	Multi-family Residential	Residential	0.24-0.84
	UR	Urban Reserve	Open Space	0.02
Central Lathrop				
	CP/DS-CL	Heavy industrial	Heavy Industrial	0.91
	HR/DS-CL	High Residential	Residential	0.24-0.84
	HS/DS-CL	High School	Public/Quasi Public	0.5
	K-8/DS-CL	Elementary School	Public/Quasi Public	0.5
	NC/DS-CL	commercial	Office Park/Office Urban	0.69/0.87
	NP/DS_CL	Neighborhood Park	Open Space	0.02
	P/OS/DS-CL	open space	Open Space	0.02
	OC/VR/WWTP/DS-CL	Office Commercial	Office Park/Office Urban	0.69/0.88
	CO/DS-CL	Commercial Office	Office Park/Office Urban	0.69/0.89
	P-SP/NC/DS-CL	Public-semi public	Public/Quasi Public	0.5
	R/MU/DSM-CL	Residential Medium	Residential	0.24-0.84
	SPC/DS-CL	Specialty Commercial	Retail/Office	0.81/0.88
	VR/DS/CL	Variable Density Residential	Residential	0.24-0.84
River Islands				
	CR-RI	Regional Commercial	Retail/Office	0.81/0.88
	MU-RI	Mixed Use Town Center	Mixed Use	0.8
	CN-RI	Neighborhood Commercial	Retail/Office	0.81/0.88
	RL-RI	Low Residential	Residential	0.24-0.84
	RM-RI	Medium Residential	Residential	0.24-0.84
	RH-RI	High Residential	Residential	0.24-0.84

Table 6-1. Land Use Codes (LUCs) and Impervious Surface Coefficients (Cont.)

City Region	Lathrop LUC	Lathrop LUC Description	OEHHA LUC	ISC
Mossdale				
	CV-MV	Village Commercial	Retail/Office	0.81/0.88
	CS-MV	Service Commercial	Retail/Office	0.81/0.88
	OS-MV	Open Space	open Space	0.02
	P-MV	Public-semi public	Public/Quasi Public	0.5
	REC RES-MV	Recreation Residential	Open Space	0.02
	RL-MV	Residential Low	Residential	0.24-0.84
	RM-MV	Residential Medium	Residential	0.24-0.84
	RH-MV	Residential High	Residential	0.24-0.84
South East Stewart Tract				
	C-REC-ST	Commercial Recreation	Mixed use	0.8
	CR-ST	Regional Commercial	Retail/Office	0.81/0.88
	MX-ST	Mixed Use Town Center	Mixed use	0.8
	RCO-ST	Resource Conservation	Open Space	0.02
	R-REC-ST	Recreational Residential	Open Space	0.02
	R-ST	Residential Low	Residential	0.24-0.84
	UR-ST	Urban Reserve	Open Space	0.02
Lathrop Gateway				
	IL-IG	Limited Industrial	Light Industrial	0.81
	CS-LG	Service Commercial	Retail/Office	0.81/0.88
	(CO-LG)	Pre-zone Commercial Office	Office Park/Office Urban	0.69/0.90
	(IL-LG)	Pre-zone Limited Industrial	Light Industrial	0.81
	(CS-CL)	Pre-zone Service Commercial	Retail/Office	0.81/0.88

Note: Some land uses had variable ISCs because the LUCs did not directly translate from Lathrop to OEHHA standards.

Current

The current land uses for Lathrop are dominated by open space land uses in the River Islands area of the city, awaiting additional development. There are also many open spaces and parks throughout the rest of the city, both in newer and older developments (Figure 6-3). Open space for Lathrop encompasses 54% of the total area. The next largest proportion of total land is for the industrial uses which make up 16.6% of the total. There are significant residential areas on both sides of I-5, and these land uses account for 6.7% of the total. Agricultural uses make up 10.5% percent of the total and commercial makes up 1.7% (Figure 6-4). Because of the large open space area in the River Islands development, it is helpful to take a look at Lathrop's area minus this development to get a more accurate picture of land use percentages in the city. In this case, open space areas make up 29.9% of the total land, industrial uses makes up 25.3%, agricultural land uses make up 16.0% of the total, and residential uses make up 10.3% (Figure 6-5).

The different land uses translate into a wide range of impervious covers (Figure 6-6). Open space and agricultural land uses result in less than 5% impervious cover. Residential uses have a wider range on imperviousness, depending on how dense the units are. This land use can be as little as 14% impervious to as much as 84% impervious. Lathrop's average imperviousness for residential land use was 55% and the median was 56%. The commercial and industrial land uses tend to have a high amount of pavement and parking lot surrounding the building structures. As a result, these land uses are 81% to 91% impervious. Roads are also highly impervious (91%), although highways have a lower imperviousness (47%) due to the amount of open space buffer zones associated with them. Lathrop's overall imperviousness as of 2010 was 25.4%

Figure 6-3. Lathrop Current Land Use

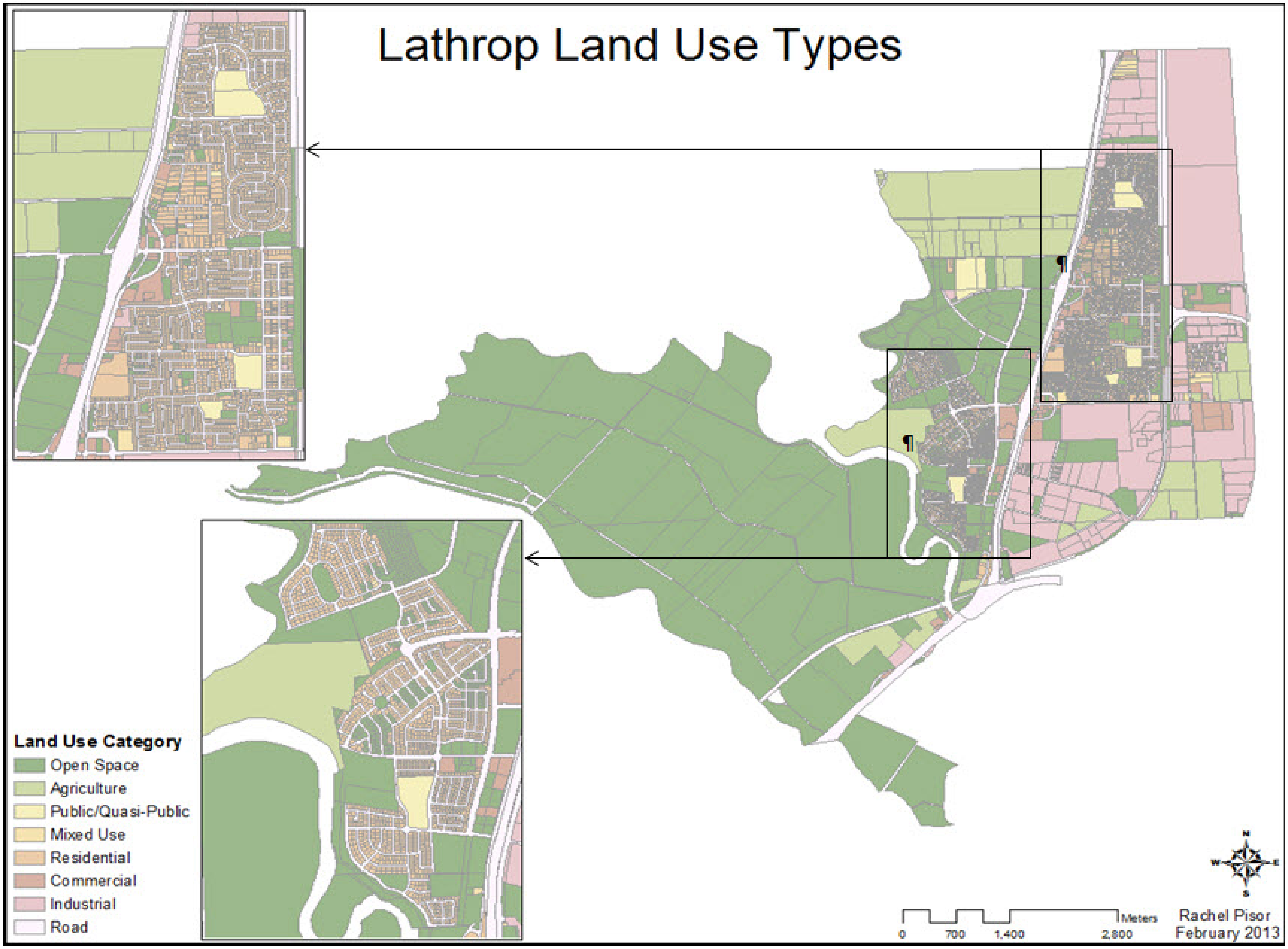


Figure 6-4. Lathrop Land Use, by Percent, with River Island Land Uses

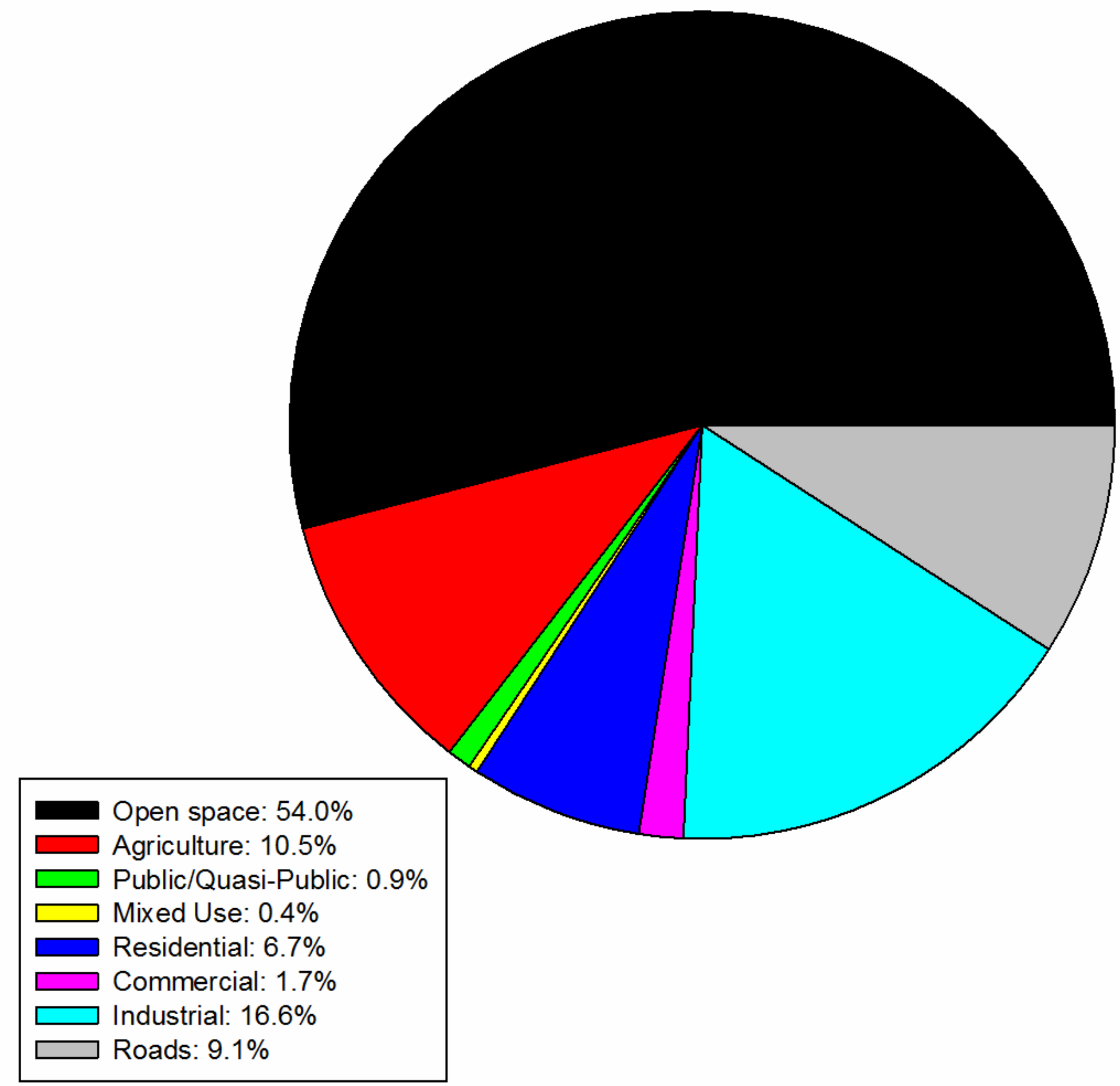


Figure 6-5. Lathrop Land Use, by Percent, without River Islands Land Uses

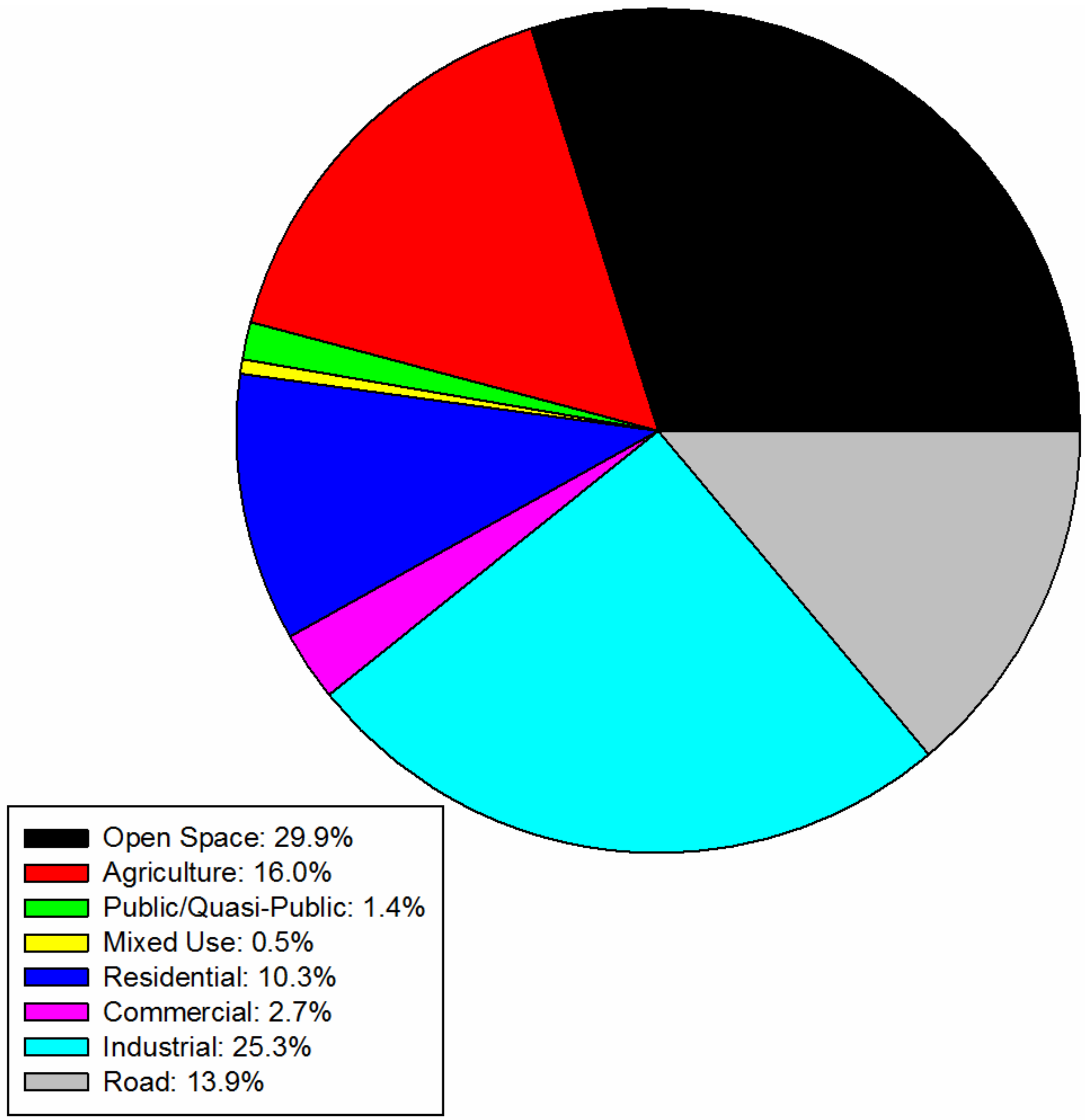
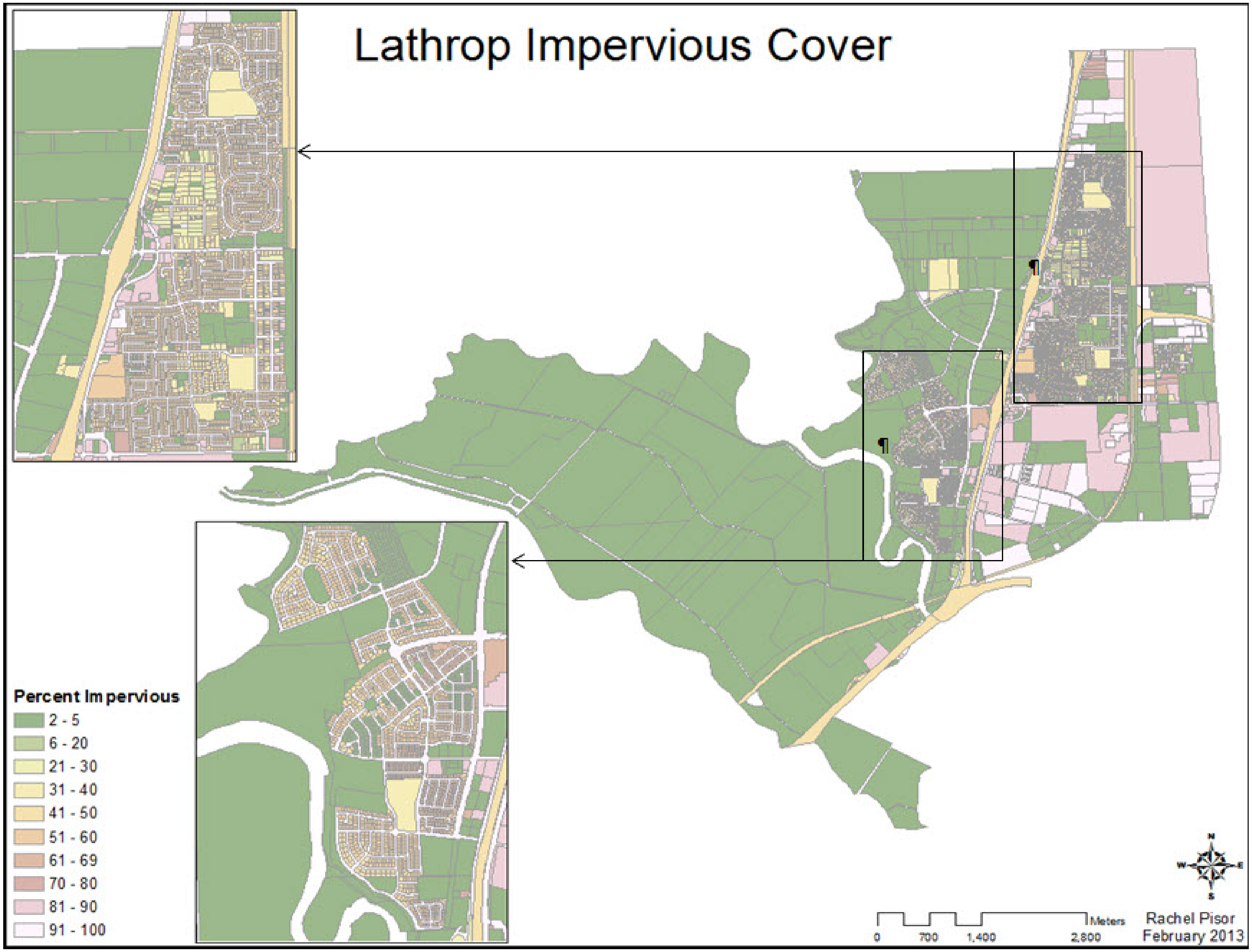


Figure 6-6. Lathrop Impervious Cover



Build-Out

Lathrop's land use at build-out shows quite a different picture than the current land use (Figures 6-3 and 6-7). The maps look slightly different due to the difference in methods. Also, the land use at build-out map includes different categories for the varying densities of residential land use. This is because the city zoned different areas according to a range of densities that were categorized as low, medium or high residential. Low density residential is classified at 3 to 9 units per acre, medium density residential is 6 to 20 units per acre, and high density residential is 15 to 40 units per acre. In Lathrop's general plan for build-out, there are no agricultural areas; this is another difference in the two maps. Agricultural areas are converted into urban development, primarily residential. The map of build-out was not able to show all the parks on the east side of I-5 because they were not shown in Lathrop's zoning map. Therefore, there would be more open space at build-out than depicted, but this area would likely be small. Much of that area is currently built out and the current amount of open space is 622 acres. For land use at build-out, residential uses would be the largest proportion of all uses, and would encompass 34.7% of Lathrop's area. The industrial areas would include 18.7% of the area, commercial lands would be 9.6% and roads were estimated to be 18.8% of the total area (Figure 6-8).

When the land uses are translated into impervious cover, there are virtually no changes in the maps (Figures 6-7 and 6-9). The region of the city east of I-5 will be fully built out in industrial and commercial uses, with the existing residential areas. Some minor residential development may still occur. These land uses are pavement intensive, resulting in high impervious cover percentages for the region. The portion of the city to the west of I-5 will have more residential development than is currently in place. This development is in progress, but has slowed due to the economic decline of the late 2000s. At build-out, the River Islands development will be a large residential addition of more than 4,000 homes and 3 million square feet of commercial land uses (River Islands, 2013). The open space areas along Paradise Cut and south of the I-5 and Route 205 interchange will remain unchanged. As the development at River Islands progresses, residential and regional parks may be added, reducing the impervious cover to the area. If Lathrop proceeds with the current general plan, it will have an overall percent of impervious cover of 61.2%.

Figure 6-7. Lathrop Land Use at Build-Out

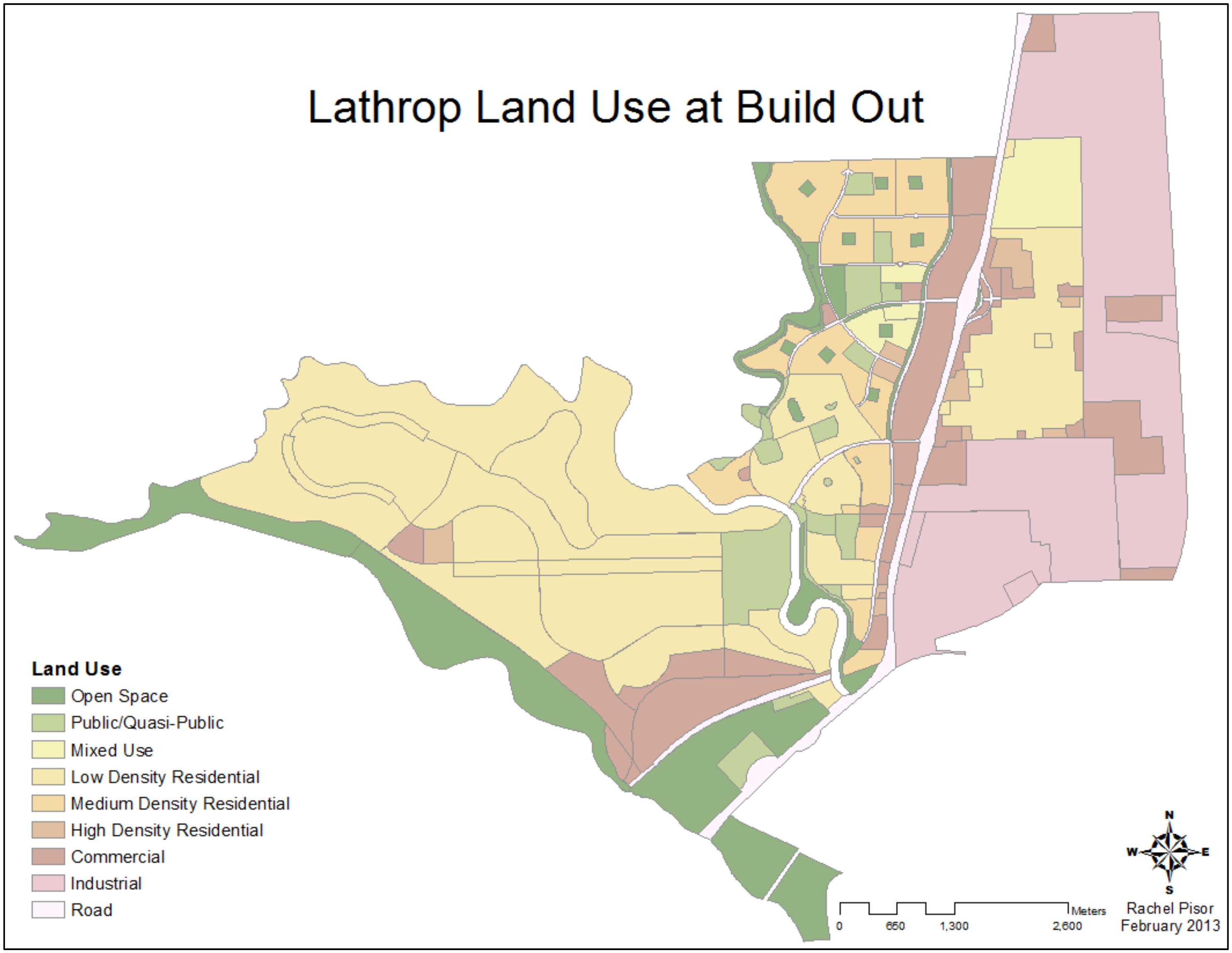


Figure 6-8. Lathrop Land Uses at Build-Out

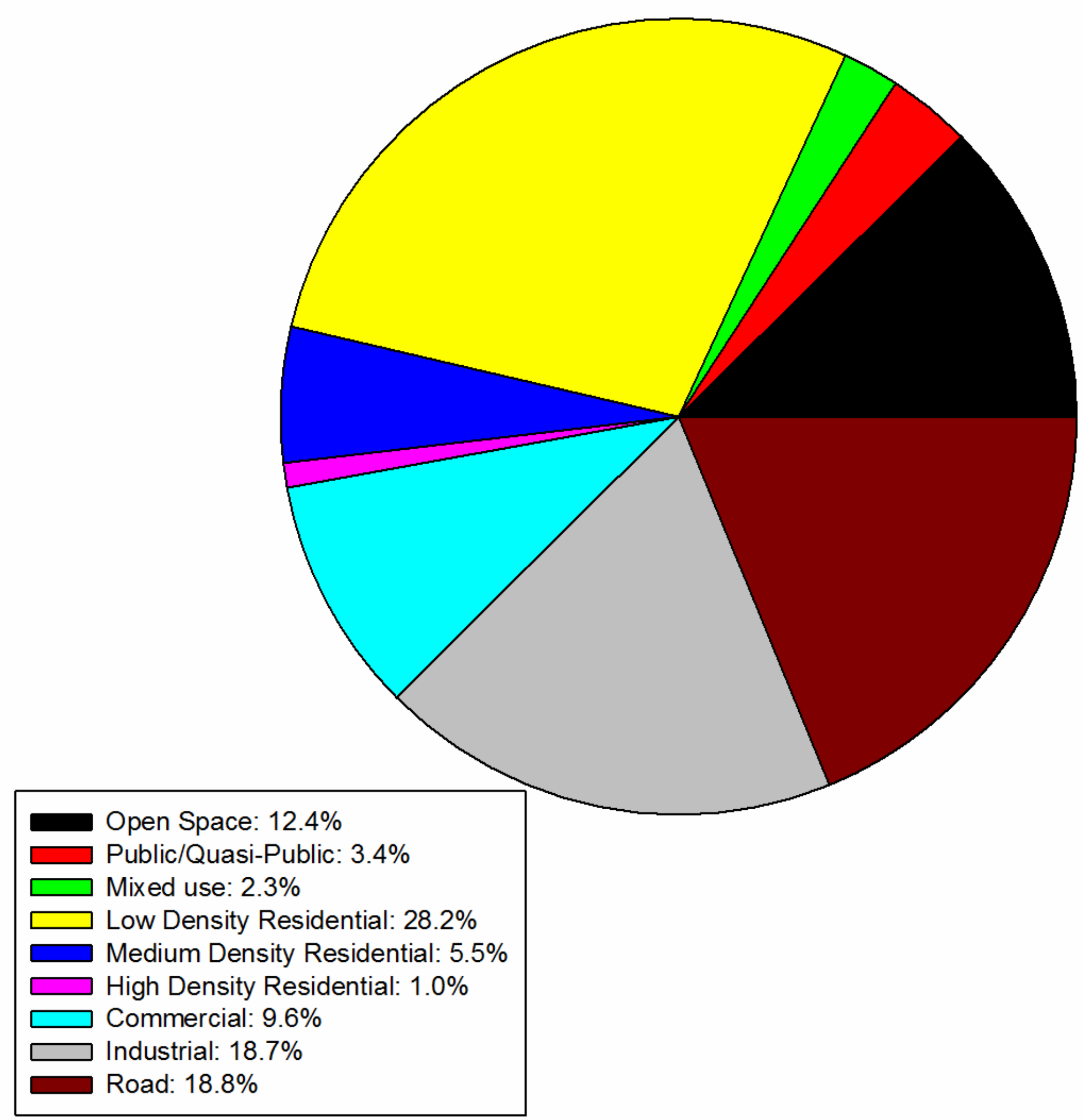
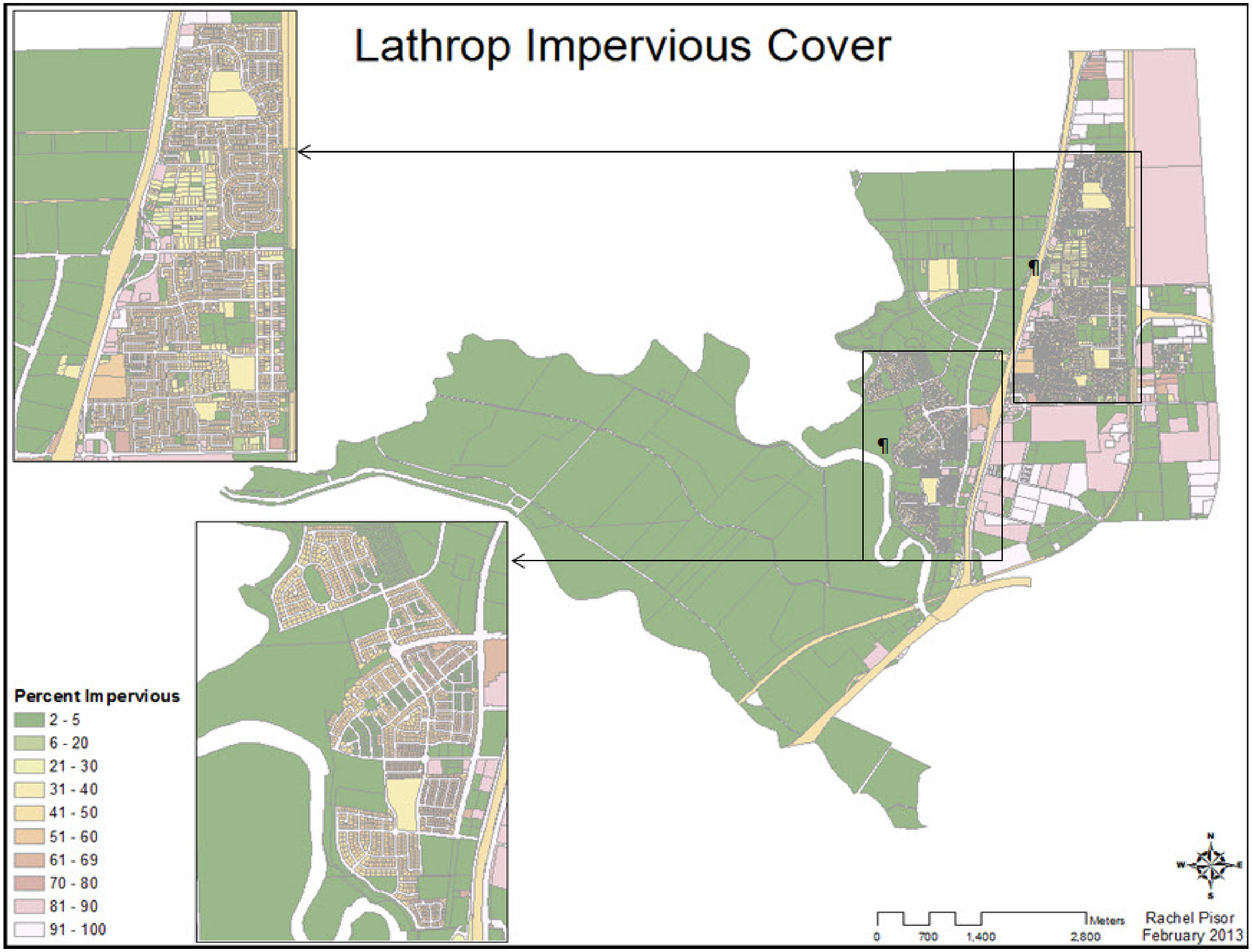


Figure 6-9. Impervious Land Cover at Build-Out



Comparison of Lathrop Land Uses to Other Land Use Analyses

Although there has been much research done about impervious cover and there are requirements throughout the state to mitigate the effects of hydromodification through LID measures, there is relatively few land use analyses similar to what has been conducted in this study. Those that have been conducted have looked at a much larger scale than the city of Lathrop, but can be used as a frame of reference.

In 2006, the Santa Clara Valley Urban Runoff Pollution Prevention Program produced an analysis of impervious thresholds for control of hydromodification (Buchan et al., 2006). The Santa Clara basin drains approximately 462,066 acres in the San Francisco Bay area and is largely urbanized. The basin includes half of Santa Clara County and portions of San Mateo and Alameda counties. There are 13 cities and towns within the basin, with approximately 1.7 million inhabitants as of 2000 (SCVURPP, 2013). The analysis showed that the impervious cover as of 2002 was approximately 141,516 acres (31% of the basin). This is a rough estimate that includes much of the undeveloped hills in the Santa Clara Valley which are not incorporated into the cities. In a build-out scenario, there would only be an increase of 1.6% of total impervious area for the watershed. This is largely because the watershed is currently very close to build-out conditions.

In comparison to Lathrop, the Santa Clara basin is significantly larger and much closer to build-out. The Lathrop area is approximately 3.5% the area of the Santa Clara watershed. Lathrop also had a population of 18,023 in 2010, as opposed to 1.7 million in 2000 in the Santa Clara basin. The Santa Clara watershed had a lower percentage of impervious cover than Lathrop, largely due to the high amount of undeveloped area in the Santa Clara watershed that will likely not be developed. The amount of development also affects the increase of percentage of impervious cover. While Lathrop will develop 45% of its open space into development at build-out, approximately 93% of the Santa Clara watershed is already built out. This accounts for the small increase in impervious cover in the Santa Clara watershed.

MWQI investigated the Steelhead Creek watershed for an urban runoff study in 2008. The Steelhead Creek watershed is 115,840 acres, located in the Sacramento region, and is a highly urbanized watershed. It incorporates the northeastern portion of Sacramento county, and parts of Placer and Sutter counties. The population of Sacramento and Sutter counties which make up the largest portion of the watershed was 1.7 million in 2010. This population is larger than that of the Steelhead Creek watershed because it incorporates only portions of these counties. The California Department of Finance estimates that the Sacramento region will increase in population at a rate of 68% from 2010 to 2050 (Department of Finance, 2012; Census Viewer, 2012), indicating that there will continue to be a strong trend of urbanization in the watershed. The analysis showed that in 2002, the watershed was 24.1% impervious and that this would increase to 30% impervious at build-out.

The Steelhead Creek watershed is also significantly larger than the Lathrop area, but is more comparable because both are located in the Central Valley and have more similarities in geography and climate than Santa Clara does with Lathrop. The Steelhead Creek is also a little closer to Lathrop's size, with Lathrop being 13.5% of the size of the Steelhead Creek watershed. The population increase in Lathrop is expected to continue, with San Joaquin County having a predicted 53% increase in population from 2010 to 2050. Although this is less than expected in Steelhead Creek, it indicates a strong, continuous trend toward developing open space. At build-out, Steelhead Creek is expected to increase its impervious surface by 5.9%. This is a bit higher than Santa Clara, and this may account for the fact that Steelhead Creek is approximately 73% built out as compared to 93% in Santa Clara. Lathrop is currently 55% built out, and therefore it is expected that the increase in impervious surface would be significantly more. This illustrates that the rate of land conversion from pervious to impervious slows down as an area approaches build-out.

Summary

Hydromodification and conversion of open space to impervious area will continue to be an issue as the Delta continues to urbanize. This will also continue to be addressed in discharge permits. As a result, future developments will incorporate more LID BMPs, and these developments will have less impact on the hydrology, ecology, and water quality of the region.

The analysis of Lathrop shows that it has the potential to increase its impervious cover to 61.2%. However, this should be considered as a worst case scenario. The analysis was not able to account for parks, schools, and other relatively open spaces that may be put in place as development continues. It also does not account for the potential LID and other hydromodification mitigation measures that may be used in those developments.

Although there was not enough data to be able to draw a correlation between land use and water quality, this analysis provides a baseline from which future comparisons can be made. This baseline will be helpful for city planners and developers in understanding the current status of hydromodification in the city and it provides a place to start when new developments are being planned and implemented. It will also form a basis of comparison for any future storm water studies in Lathrop or other small, developing communities in the Delta.

Chapter 7. Summary and Conclusions

Summary

Hydrology

The hydrology of Lathrop was the major driver for the study sampling protocols. Precipitation and flows were critical in determining sampling events and in the analysis of water quality constituents discharged into the San Joaquin River. Throughout the study, precipitation data was collected. Flow data from the San Joaquin River, and approximation of water discharged from the pump stations was obtained.

Precipitation

Throughout the study, multiple weather forecasts were heavily relied upon to determine which storm events would be sampled. There were multiple complications with the weather forecasts because the models often did not match actual weather conditions. As a result, multiple storms were missed in the first and second season. In the third season, a real-time rain gauge was installed to aid in setting up for storm sampling. Additionally, the amount of predicted precipitation that triggered set up for a sampling event was lowered. This resulted in setting up for some storms that were too small, but it ensured that the major storms that season were sampled.

Hydrology of Lathrop

During this study, a wide range of hydrologic conditions were present. The first season was classified as “above normal,” the second was “wet,” and the third season was a “dry” water year. This range in conditions resulted in varying water quality conditions.

Throughout the study, the San Joaquin River flows were monitored. Sampling of the river was conducted during an ebb tide to ensure that the river was flowing toward the Delta. This ensured a sample that was representative of the background water quality conditions of the San Joaquin River. During storm events, the flows ranged from 12 cfs to 15,700 cfs, with the higher flows being toward the end of the wet weather season.

Discharge from the City of Lathrop

Lathrop’s hydrology is highly managed through the use of storm water pumping stations that discharge into the San Joaquin River. There are large portions of the city, primarily open space, that do not have storm water infrastructure in place. Of the pumping stations that are currently active, the Industrial and Historic stations discharge the highest volumes, and serve the largest areas. The Historic station serves 793 acres and discharged an average of 2 million gallons during the storm events sampled. The Industrial station serves 626 acres and discharged an average of 3 million gallons during sampled storm events.The smallest area (66 acres) served by a pumping station was the M6 station which also had the lowest average of gallons discharged during sampled storm events (208,400 gallons).

Water Quality

Organic Carbon

Concentrations for both seasons two and three were significantly higher in the storm water pumping stations than in the San Joaquin River. Trends in organic carbon showed a first flush effect, with higher concentrations in the first storms of the wet season, and generally decreasing concentrations in the succeeding storms. The organic carbon composition differed between the San Joaquin River and the city pumping stations with the San Joaquin River having a higher percentage of dissolved organic carbon than the city pumping stations. This difference was seen in in season two, but in season three there was no noticeable difference in composition between the city pumping stations and the San Joaquin River. In season two, agricultural discharge may have influenced the concentrations of organic carbon in the San Joaquin River. During the March storm events of that year, concentrations in the San Joaquin River were slightly elevated due to agricultural discharge, but were well within the normal historic range. Lathrop's organic carbon concentrations and trends were similar to other studies conducted in California.

Lathrop's carbon loads were generally very low. The highest contribution during a storm event was 6.8% of the total load of the San Joaquin River. During all other storm events, Lathrop contributed less than 2% of the total load. Lathrop discharges a relatively low organic carbon load to the San Joaquin River in comparison to the Steelhead Creek study wet season results, but a comparable load when compared to the Trinity River study.

UVA_{254}

UVA_{254} is a measure of organic carbon composition, and results supported the conclusion that the organic carbon composition from the San Joaquin River differs from the pumping stations' organic carbon. There was a strong relationship between UVA_{254} and DOC, although this relationship was much stronger for the city pumping stations than the San Joaquin River. The San Joaquin River had significantly lower UVA_{254} values than the city pumping stations, further supporting the conclusion that the San Joaquin River carbon had a different composition than the city pumping station carbon.

Disinfection Byproducts

Lathrop's discharges had significantly higher concentrations of THMFP and HAAFP than the San Joaquin River. The Industrial station had generally the lowest concentrations of all pumping stations. Although imperfect, UVA_{254} is a good predictor of DOC. However, neither UVA_{254} nor DOC correlated well with THMFP or HAAFP. Although the regressions were very significant, they explained less than 77% of the data. Concentrations of THMFP and HAAFP in season two also confirmed a first flush effect.

Nutrients

Ammonia concentrations in the San Joaquin River were significantly lower than those of the city pumping stations. The Historic station had generally higher concentrations, and had an unusually high concentration of 2.4 mg/L as N. Lathrop's ammonia loads generally made up less than 5% of the total load of the San Joaquin River. However, there was one storm event in which the city contributed 14.2% of the total load. This high load contribution was attributed to low flows on the San Joaquin River, high discharge flows from the city pumping stations during the storm, and low load on the San Joaquin River which may have been due to the conversion of ammonia to nitrate in the river.

For nitrate, and nitrate plus nitrite, the San Joaquin River concentrations were not significantly lower than the concentrations from the city pumping stations; however, the San Joaquin River concentrations were significantly lower than those of the city pumping stations for total nitrogen. Lathrop's nitrate levels were often high, exceeding the 10 mg/L as N MCL, and total nitrogen levels often exceeded the EPA's 0.31 mg/L as N reference conditions. Total nitrogen composition differed between the San Joaquin River and the city pumping stations, with the river having a lower percentage of organic nitrogen than the city pumping stations. Total nitrogen loads from the city pumping stations were less than 1% of the total San Joaquin River load for all storm events.

Although not statistically different, there appeared to be differences in the data distribution of orthophosphate samples between season two and three, with a broader distribution of data points in season two. The difference in distribution of the orthophosphate data between seasons two and three is likely due to wet year versus dry year effects. The San Joaquin River concentrations were significantly lower than those of the city pumping stations for all phosphorus species. Season two concentrations for total phosphorus were significantly lower than those in season three, which is likely due to wet year versus dry year effects. The total phosphorus composition remained relatively constant throughout the study. Although there were differences in composition observed in season three, they were not statistically significant.

Total phosphorus load for all storm events was less than 3%; however, the highest loads did occur during the first storms of the wet season, giving evidence of a first flush effect.

Ammonia, nitrate, nitrate plus nitrite and total phosphorus concentrations were compared with those of other storm water studies throughout California. This comparison showed that Lathrop's concentrations were similar for nitrogen-based constituents and were not elevated in comparison to other regions in the state. For total phosphorus, concentrations for the city pumping stations were comparable to other storm water studies. Samples taken at the San Joaquin River at Mossdale were slightly higher than samples collected on the Sacramento River. This is likely due to the agricultural influence of the San Joaquin River. Total phosphorus discharges from Lathrop pumping stations were either comparable or lower than other samples collected throughout the state.

Minerals

Bromide concentrations were not significantly lower in the San Joaquin River than in the city pumping stations. The high concentrations of bromide in the city pumping stations are explained by groundwater intrusion. Bromide is not a constituent commonly found in storm water. The strong relationship between bromide and chloride indicates that the bromide sources are of marine origin. There was an inverse relationship between bromide concentration and flow. Bromide loads were generally about 1% with the exception of the first flush event in season three. During this event, Lathrop contributed 7.3% of the total river load. This was due to a multitude of factors including low river flows, high concentrations and flows at the Industrial station, high groundwater intrusion at the Industrial station, and the inverse relationship between flow and bromide concentration.

There were no significant differences in alkalinity or hardness concentrations between the San Joaquin River and the city pumping stations.

Salinity

There were no significant differences in salinity between the San Joaquin River and the city pumping stations. High salinity in the pumping stations was attributed to groundwater intrusion. Higher concentrations were seen in season two, which was a wetter year than season three. This is attributed to an increase in the water table due to increased precipitation, and due to increased pumping from wetter storms.In the San Joaquin River, lower salinity was observed in season two than in season three. This is likely due to the increased dam releases in season two, which was a wetter year.

Pyrethroid Pesticides

Due to infrequent sampling, no trends could be drawn for pyrethroids. Of the events that were sampled, bifenthring, cyfluthrin, cypermethrin L-cyhaolthrin, and permethrin were the species of pyrethroids present. The concentrations of these pyrethroids were at levels that are toxic to benthic organisms such as *Hyalella azteca*.

Pathogens

The San Joaquin River had significantly lower concentrations than Lathrop's pumping stations for total and fecal coliforms, and *E.coli*. Results for all three constituents also showed evidence of a first flush effect, with significantly higher concentrations in the first storms of the wet season. The *E.coli* results for the first season had generally higher concentrations than the second or third season.

Land Use

Due to the detrimental affects on the hydrology of watershed that come from urbanization, many new Phase I NPDES permits require hydromodification management plans for new and redevelopment. These plans will ensure that LID and other appropriate BMPs are utilized in these projects to minimize the impact of urbanization. The result of these measures will be no increase in flow from the project area to surface waters, and therefore, minimal effect on the hydrology of the watershed. Although these requirements do not directly apply to Lathrop, the city will be required to directly address hydromodification starting in July 2016.

The land use analysis of impervious cover for 2010 showed that Lathrop's land uses were an average of 25.4% impervious. In the analysis, it was determined that Lathrop land uses were composed of 54.0% open space, 16.6% industrial, 10.5% agricultural, 9.1% roads, 6.7% residential and 1.7% commercial. The analysis at build-out showed that Lathrop's imperviousness would increase to 61.2%, with a total land use mix of 34.7% residential, 18.7% industrial, 12.4% open space, 18.8% road and 9.6% commercial. Lathrop's land use analysis was compared to two similar analyses in California. The results indicate that Lathrop will increase its impervious cover by a much larger percentage, but this is primarily due to the fact that Lathrop has significant open space that is planned for future development. The results of the comparison also indicate the rate of land conversion from pervious to impervious slows down as the city approaches build-out.

Conclusions

The storm water discharged from the City of Lathrop will continue to increase as development continues.

As the city continues to develop north of Mossdale, additional storm water infrastructure will be put in place to handle the storm water resulting in storm water loads being discharged into the San Joaquin River. This region currently has no storm water infrastructure and very little impervious surface, and currently handles storm water locally through percolation and evaporation. Also, it is possible that the Stonebridge pumping station in the northeastern region of the city will accommodate more area in the future. This will result in increased storm water runoff, and therefore more pollutants being discharged from the region into the San Joaquin River. As the development continues, it will be important to consider the increased discharges and how they affect the water quality of the San Joaquin River.

There is a reservoir of organic carbon that gets flushed throughout the storm season.

The trends observed throughout this study showed that organic carbon builds up during the dry weather periods, and is flushed out with the storms that come through in the wet season. The first storm of each season flushed the highest amount of carbon, with decreasing concentrations of organic carbon being flushed with each successive storm. This has important implications for how the San Joaquin River will be affected by increased storm water discharges due to increases in development.

The organic carbon composition differed between the city pumping stations and the San Joaquin River.

The analysis of carbon composition and regression analysis between DOC and UVA_{254} showed that there were differences in organic carbon composition between the San Joaquin River and the city pumping stations. This difference in composition is important to understanding how the city's discharge may affect the water quality of the San Joaquin River. As populations increase and land uses shift towards imperviousness, higher volumes of discharge during storm events may affect the San Joaquin River at a level that his more substantial than what was seen during this study.

Lathrop's discharges do not contribute substantial load to the San Joaquin River.

Over the course of the study, loads from Lathrop were generally low for total organic carbon, bromide, total nitrogen, and total phosphorus, with Lathrop contributing less than 5% of the total load of the San Joaquin River during most storm events. The exception to this was a first flush event in which the city contributed 6.8% of the total organic carbon load and 7.3% of the bromide load. For the ammonia loads, higher contributions from the city of Lathrop were seen as a result of low flows on the San Joaquin River and high volumes of discharge from the city. This resulted in Lathrop contributing 10-15% of the total ammonia load on the San Joaquin River. These results imply that other small communities in the Delta may not contribute substantial loads during most storm events, but may discharge higher loads during first flush events or during large storm events that occur during times of low flows on the rivers.

Lathrop's discharges are generally of lower water quality than the San Joaquin River

Concentrations of TOC and DOC, THMFP, HAAFP, UVA_{254}, ammonia, total nitrogen, orthophosphate, total phosphorus, alkalinity, hardness, pyrethroids, total coliforms, fecal coliforms, and *E.coli* were significantly lower in the San Joaquin River than the city pumping stations. This indicates that the quality of discharge water from the city of Lathrop is of lower quality than the San Joaquin River. These differences in water quality should be considered as development continues in the Delta due to the potential effects of lesser quality discharge on the rivers.

Lathrop discharges concentrations of pyrethroids that are toxic to benthic organisms.
Although the number of samples was limited, the concentrations of pyrethoid pesticides discharged by Lathrop's storm water pumping stations were at levels toxic to benthic organisms, specifically *Hyalella azteca*. These findings are consistent with the studies done by Weston et al. Although not a drinking water constituent of concern, the pyrethroid concentrations being discharged from Lathrop's pump stations have ecological water quality implications because the levels are high enough to be toxic to *Hyalella azteca*.

The city of Lathrop will have a significant increase in impervious cover at build-out.
At build-out, the city is expected to increase its impervious cover by 35.8%. This should be regarded as a worst-case scenario because the build-out analysis could not account for potential open space that may be included in new development. Open space and LID will likely be included in new developments, and hydromodification mitigation measures will also reduce the total impervious acreage at build-out. Although the 35.8% increase is a high estimate, it is important to consider due to the affects that increases in impervious cover have on storm water flows and concentrations of contaminants.

Recommendations

This study should be re-visited in 5 years to assess changes in population growth, discharges during storm events, and in discharge water quality.
A re-assessment of the study would add to our understanding of the relationship between water quality and land use. This re-assessment should include an analysis of all of the constituents monitored in this study, a calculation of loads for TOC, ammonia, total nitrogen, total phosphorus and bromide, and a land use analysis. This second study would build upon what was observed in this study, and would develop a correlation between land use and water quality. This metric would be useful to apply to other small, growing communities in the delta. The comparison between the two studies would also help to determine the differences in water quality in relation to population size, and how that change in population affects volume of discharge.

A revisit to Lathrop should include more in-depth monitoring.
When the study is re-visited, there should be a statistical analysis to determine the duration of monitoring required to create a robust analysis. Due to the complications of sampling storm events, many constituents were not able to be sampled for each storm event. Adding additional years of mornitoring would add much robustness to the results of a future study.

An additional analysis should also include telemetered autosamplers to collect water quality samples. Much time and resources were used inefficiently due to the unpredictability of storm events, and because the study site was remote. The ability to program, and activate autosamplers remotely may substantially increase the ability to sample the storm events efficiently.

The city of Lathrop should make GIS data available.
It is recommended that the city of Lathrop make GIS zoning layers of the study area available. This would provide the information needed to conduct a more accurate analysis and provide the basis for a more robust correlation between land use and water quality.

The land use analysis should be extended to the legal Delta.

A revisitation of the Lathrop study should include a land use analysis of the legal Delta. The metric developed between this study and a future Lathrop study could be applied to the other growing communities in the Delta. This would provide a good gauge on the quality of storm water discharges coming from other communities with similar infrastructure. It would also provide useful information for what to expect from build out of the entire Delta.

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Appendix A

Season One Preliminary Results

Executive Summary

Due to increasing urbanization in the Sacramento-San Joaquin Delta and the potential negative affects of urbanization on water quality, MWQI began conducting the Lathrop Urban Runoff Study in 2009. The purpose of this study was to assess the impacts of urban runoff on the water quality of the San Joaquin River. To achieve this goal, water quality samples were collected along the San Joaquin River and in the 8 storm water pumping stations of the city of Lathrop that discharge directly into the San Joaquin River. The city of Lathrop provided data records of the storm water pumps during storm events which enabled load calculations of constituents discharged by Lathrop.

There were many challenges faced in the first year of the study including inaccurate weather predictions, issues with pumping data and technical difficulties with the autosamplers. For example, some samples contained residual water that had not been flushed out before the storm event occurred.

This report summarizes preliminary findings of data collected between October 2009 and May 2010, the first storm water season of the study. During the season, there were 4 sampling events spanning 3 storms (the final storm lasted 5 days). A number of analytes were sampled for this study, however this report focuses on constituents of most concern to drinking water: total organic carbon (TOC) and dissolved organic carbon (DOC), total trihalomethane formation potential (THMFP), haloacetic acid formation potential (HAAFP), ultraviolet absorbance (UVA_{254}), electrical conductance (EC), total dissolved solids (TDS), bromide, ammonia, dissolved nitrate, total nitrogen, dissolved orthophosphate, total phosphorus, total coliforms, fecal coliforms, *Escherichai coli* (*E.coli*), and pyrethroids.

Concentrations of most constituents were significantly lower in the San Joaquin River than in the pumping stations. The exceptions to this were dissolved nitrate, total nitrogen, THMFP, HAAFP, EC, TDS and bromide. Unlike another recent urban storm water study (Weston and Lydy, 2010), pyrethroids were generally not detected in the city pumping stations. For all constituents, the samples collected from the San Joaquin River were less variable than the samples collected from the city pumping stations.

Analysis of UVA_{254} showed a difference in the strength of the correlations between DOC and UVA_{254}, and between THMFP and UVA_{254}. This shows that UVA_{254} is not a reliable indicator of DBP precursors. These correlations were high for the city pumping stations, but were very low for the San Joaquin River stations. This indicates that the city pumping stations' carbon quality was different than the San Joaquin River stations' carbon.

Loads were calculated for TOC, bromide, ammonia, total nitrogen and total phosphorus. The load that Lathrop contributed to the San Joaquin River was very low. The discharge is released sporadically, resulting in an inconsistent discharge for the duration of the storm. There were data gaps in pumping data due to signal or download error, not from a lack of pumping. Therefore, the loading estimates for Lathrop are quite conservative. Most load calculations showed that Lathrop contributed less than 3% of the total

load of the San Joaquin River. The exception to this is ammonia in which Lathrop contributed 7.7% on January 20, 2010.

In most cases, concentrations of TOC, DOC, and THMFP decreased during the rainy season. However, these patterns were not consistent between San Joaquin River samples and city pump station samples. For TOC, DOC, and THMFP, the trends were mostly observed in the city pump stations. In the city pumping stations, all pathogens had high counts during the first storm of the season, indicating a first flush event. Concentrations for the San Joaquin River stations remained low for the season; however, samples at these stations were not collected during the first flush event. After the first flush event, concentrations for all pathogens remained low. Additional sampling scheduled for both the 2010-11 and 2011-12 seasons should help validate the results from this study.

Introduction

The Sacramento-San Joaquin Delta is a region that, until the late 2000s, had been experiencing rapid urban growth at a rate faster than that of the rest of California. With this increase in urbanization, there is concern regarding drinking water quality because increases in urbanization can detrimentally affect drinking water quality.

Impacts to drinking water quality from urbanization are primarily due to urban runoff, wastewater discharges, and recreational uses. The majority of urban runoff is due to land use changes from pervious land uses (e.g., agriculture and open space) to impervious urban land uses (e.g., concrete and asphalt). Pervious land surfaces allow for infiltration of storm water with soils acting as filters for contaminants. Urban areas do not allow this infiltration and, as a result, water flows directly into the river with high concentrations of contaminants. These issues are particularly important in the Delta because it provides drinking water quality for approximately 23 million Californians.

This multi-year study focuses on the urban storm water discharges from Lathrop, a small community in the south Delta. This community is small, but was rapidly growing prior to the housing market collapse. Much of this growth resulted in agricultural land being converted to urban land use. Because Lathrop is small (approximately 18,000 people), it is covered under the NPDES Phase II general permit which does not require the city to monitor its storm water runoff. However, due to Lathrop's size and geographical location, this study provides information on the contributions a small community has to the drinking water quality of the San Joaquin River and provides a baseline of water quality conditions that will be useful in future analyses of water quality in the area.

Overview

This study started in October 2009. This report presents preliminary data for the 4 storm events sampled during the first season; however, data for all constituents was not available for all storms. Of the many sampling issues faced in the first season, complications with the operation of city storm water pumps were some of the most challenging. In several instances, storm water volumes in the pumping stations, where the autosamplers were sampling, were only able to collect partial samples which resulted in not enough water to analyze for all constituents. Additional complications arose from lack of reliable weather predictions. After receiving pumping data from the first season, it was discovered that some samples were collected by the autosampler prior to the storm water pumping during the storm event. This resulted in collection of residual water from the stilling wells that was not entirely storm water. Therefore, although the data in this report represents all the data collected for the season, concentrations may be biased due to influences from residual water. This issue has now been resolved by having the SCADA system trigger the autosamplers.

Loads were compared between the San Joaquin River at Mossdale and the city pumping stations. The San Joaquin River at Mossdale represents the water quality of the San Joaquin River and the pumping stations collectively represent the water quality of Lathrop's discharge.

This summary provides a synopsis of major constituents of concern or of interest. Therefore, not all constituents are discussed. Data in this report are presented with a series of boxplots and tables. The sampling stations are grouped into regions based on the area they serve. The M1, M2, M3 and M5 stations serve the Mossdale residential region of the city, the Industrial station serves the industrial region, the Historic station serves the historic region and the Stonebridge station serves the Stonebridge region.[1] The Mossdale residential and Stonebridge regions represent areas of new residential development, while the historic region is the original residential section of the city, first built in 1887. The industrial region is primarily commercial and industrial development. Three stations are located on the San Joaquin River and are referred to as SJR at Mossdale, SJR at Lathrop and SJR at Brandt Bridge (Figure A-1).

Study Design

Lathrop has 8 pumping stations grouped into regions of the city, which discharge directly into the San Joaquin River (Figure A-1). Each pump operates independently and discharges when a set level of water has been reached in the well. An autosampler installed at each of these stations was programmed to sample throughout each storm event. Rain gauges were installed at the Historic and Stonebridge stations. The day after the storm, autosampler samples were collected and processed within constituent holding times. Due to its 6-hour holding time, grab samples for pathogens were collected the day of the storm at each station. Grab samples were also collected for all constituents at the 3 stations along the San Joaquin River (Figure A-1). The stations on the San Joaquin River were meant to bracket Lathrop's storm water discharges. Analysis of the city pumping data revealed that the San Joaquin River downstream station samples were not representative of the maximum load during the storm. Because each pump station operates independently, it was impossible to know when the maximum number of pumps was discharging. The San Joaquin River is tidally influenced, and our sampling is timed according to the tides; therefore our sampling schedule rarely coincided with a time when a majority of the pumps were running. This study focuses on the maximum load contribution of Lathrop to the San Joaquin River. Due to inconsistency in pump station discharges, a mass balance approach is used to calculate the total load on the San Joaquin River, which includes Lathrop's discharges and discharges at the San Joaquin River at Mossdale station. The samples collected at the San Joaquin River at Mossdale are representative of the water quality of the San Joaquin River. For these reasons, comparisons between the stations on the San Joaquin River above and below the city were not made; instead, concentrations at the San Joaquin River at Mossdale station were used to compare the effect of urban discharges from the city into the river.

Although not available during the first year, this study also uses a GIS-based land use analysis to determine the percentage of impervious cover of the study area. There is a positive correlation between percent of impervious cover and aquatic ecosystem health, with adverse effects seen in as little as 10%

[1] The Historic station is known as "River station" and the Industrial station is known as "KV station" to Lathrop city staff.

impervious cover (Exum et al., 2005; Center for Watershed Protection, 2003; Schueler, 1995; Booth and Jackson, 1997). Determining the overall impervious cover of Lathrop will provide insight to potential effects of its storm water discharges into the San Joaquin River. The analysis will also provide a baseline of current water quality conditions. After significant development occurs, this baseline could be used to develop correlations and scale-up the effect between water quality and impervious cover.

Results

Precipitation and Flows

During the first season there were 4 sampling events spanning 3 storms (the 2 events in January occurred during a week-long storm). Table A-1 shows the precipitation for each storm recorded at 2 of the city pumping station sites and the range of flows on the San Joaquin River during each storm. A range of flows is given due to the tidal nature of the San Joaquin River in this area. During flood tides, the flows are negative and during ebb tides, flows are positive.

Total and Dissolved Organic Carbon

For both TOC and DOC, the median concentrations of all San Joaquin River stations combined was significantly lower than the median concentrations of all city pumping stations combined (Mann-Whitney, $p<0.001$).

TOC and DOC concentrations for the San Joaquin River stations were generally lower and less variable than at the city pumping stations (Figures A-2, A-3, A-5, and A-6, Tables A-2 and A-3). In the city, concentrations at the Industrial station were generally lower than the rest of the city pumping stations. Concentrations at Stonebridge were generally the highest. The most variability occurred in the Mossdale residential region stations (stations M1 through M6) (Figures A-3 and A-6). Over time, TOC and DOC concentrations in the city pumping stations decreased, however this was not the case for the San Joaquin River stations (Figures A-4 and A-7). The percentage of TOC composed of DOC ranged from 65.0% to 98.9% with a mean of 85.1% and a median of 86.5% (Figure A-8).

Lathrop TOC load discharges were a small fraction of the TOC load in the San Joaquin River at Mossdale (Table A-4). Actual TOC discharged during the storm from city pump stations ranged from 2 kg to 95 kg. The highest load from the city occurred during the January 20, 2010, storm event when Lathrop contributed 2.4% of the total TOC load. This load is discharged sporadically throughout each storm event. The pumps do not run continuously because pumping is based on the level of water in each well. With additional pump data, estimates of pumping will be made for stations with data gaps and will be used for better estimates of load. These data gaps are from data that was lost due to signal or download error, and were not from a lack of pumping.

Total Trihalomethane Formation Potential (THMFP) and Haloacetic Acid Formation Potential (HAAFP)

The THMFP and HAAFP results were analyzed using the DWR modified method. THMFP was calculated as a sum of bromodichloromethane, bromoform, chloroform and dibromochloromethane. HAAFP was calculated as a sum of dibromoacetic, dichloroacetic, monobromoacetic, monochloroacetic and trichloroacetic acids.

The median THFMP concentrations from all San Joaquin River stations was statistically lower than the median concentration from all city pumping stations (Mann-Whitney, $p=0.008$), as was the difference in the median HAAFP concentrations between the San Joaquin River sites and the city pumping stations (Mann-Whitney, $p<0.001$). There was little variability in THMFP and HAAFP among the San Joaquin River stations with the exception of one THMFP sample taken at SJR at Brandt Bridge station (Figures A-9 and A-12, Tables A-5 and A-6). Data from the city's pumping stations were much more variable with Stonebridge having higher values and the Industrial and Historic stations having lower values (Figures A-10 and A-13).

Total organic carbon provides the source material for trihalomethanes and haloacetic acids. Therefore, the patterns of THMFP and HAAFP were similar to those of TOC. This was especially true at the city pumping stations for TOC and THMFP (Figures A-3, and A-10), and was less true for TOC and HAAFP (Figures A-3 and A-13).

Decreasing trends over the course of the season were observed in the city pumping stations for THMFP. These trends are similar to the trends of TOC and DOC (Figures A-4, A-6, and A-11), however less data was available. Because of the limited data available, additional data is needed to confirm if this is a trend or evidence of a first flush. There were no clear trends for HAAFP.

Absorbance

The median absorbance (UVA_{254}) concentrations for all San Joaquin River stations was significantly lower than the median concentration for all city pumping stations (Mann-Whitney, $p<0.001$). The correlation between DOC and $UVA_{254}$was significant ($r^2= 0.991$, $p<0.001$) as was the correlation between UVA_{254} and THMFP ($r^2=0.784$, $p<0.001$) (Figures A-14 and A-15). Although the overall correlations between these constituents (UVA_{254}, THMFP, DOC) were high, the relationships between these constituents at the city pumping stations was much stronger than the relationship at the San Joaquin River stations (Table A-7).

Specific UVA_{254} (SUVA) is the ratio of UVA_{254} to DOC, and is commonly used as an estimation of THMFP. The highest and lowest SUVA ratios were found at M3 (Table A-8).The San Joaquin River SUVA ratios were relatively low (Table A-8, Figure A-16). Overall, the regions in Lathrop, except for the Mossdale residential region (stations M1-M6), had low SUVA ratios comparable to the San Joaquin River (Figures A-16 and A-17). The Mossdale residential region (stations M1-M6) had much more variability and this accounts for much of the difference in medians between the San Joaquin River and city pumping stations. There were no significant decreasing trends in SUVA over the wet season.

Electric Conductance (EC) and Total Dissolved Solids (TDS)

There was no significant difference in median EC concentrations between the San Joaquin River stations and the city pumping stations. Electrical conductivity for the season ranged from 65 µS/cm at the Historic station to 2067 µS/cm at the M5 station (Figures A-18 and A-19, Table A-9). The San Joaquin River station samples had a smaller range than the city pumping station samples and were less variable (Figures A-18 and A-19, Table A-9). Of the city pumping stations, the Historic station had the lowest concentrations with the Stonebridge station having slightly higher concentrations. The highest EC variability was from the stations in the Mossdale residential region (stations M1-M6).

There was no statistical difference in median TDS concentrations between the San Joaquin River stations and the city pumping stations. The pattern of TDS was very similar to that of EC (Figures A-18 to A-21). The range of TDS concentrations was from 36 mg/L at the Historic station to 1140 mg/L at M5. The lowest TDS concentration was at the Historic station with the Stonebridge station having slightly higher concentrations (Figure A-21). The highest variability in TDS concentrations was in the Mossdale residential region (stations M1-M6). Additionally, the correlation between EC and TDS was significant (r^2=0.994, p <0.001) (Figure A-22). There were no clear trends in time for EC and TDS over the rainy season.

Bromide

The median bromide concentrations between the San Joaquin River stations and city pumping stations were not significantly different. Concentrations of bromide ranged from non-detect at the Stonebridge station to 1.18 mg/L at the M5 station (Figure A-24, Table A-11). Relative to other sample sites, concentrations at the San Joaquin River stations were relatively low (0.31 mg/L to 0.42 mg/L).However, bromide was never detected in discharges from the Historic section of the city, or, with one exception, the newer residential developments associated with Stonebridge. (Figures A-23 and A-24, Table A-11). The other new residential area of the city (Mossdale residential) not only had the most variable bromide concentrations but also the highest (Figure A-24).

Lathrop bromide loads were small compared to the bromide loads in the San Joaquin River at Mossdale (Table A-12). Several stations contributed less than 1 kg of bromide during the storm. The highest load contributed by Lathrop was just less than 9 kg, 0.5% of the total load. However, a better estimate of load will be made available by additional pumping data.

Nutrients

Ammonia

The median dissolved ammonia concentrations for all San Joaquin River stations was significantly lower than median concentrations of all city pumping stations combined (Mann-Whitney, p<0.001). Ammonia concentrations ranged from non-detects at SJR at Brandt Bridge station to 0.44 mg/L as N at the Historic station and M3 (Figures A-25 and A-26, Table A-13). The highest concentration of the San Joaquin River stations was 0.06 and the lowest concentration of the city pumping stations was 0.11 (Table A-13). The maximum at both stations was collected during the same storm event (December 12, 2009). In general, the concentrations of the city pumping stations were in the 0.2-0.4 mg/L as N range with the Historic station having the highest and least variable concentrations. There was no clear trend in time over the rainy season.

The highest dissolved ammonia load that Lathrop contributed, taking inconsistent pumping into account, was 12.4 kg or 7.7% of the total load of the river (Table A-14). This occurred during the January 20, 2010, storm event when Lathrop’s flow was approximately 38 cfs and the average flow at SJR at Mossdale ranged from approximately 2,300 to 2,500 cfs. However, due to the gaps in pumping data, Lathrop’s contribution may be more than this estimate. Additional pumping data will provide a better estimate of Lathrop’s contribution of dissolved ammonia to the San Joaquin River.

Dissolved Nitrate

The median dissolved nitrate concentration from all San Joaquin River stations was significantly higher than the median dissolved nitrate concentrations of all city pumping stations combined (Mann-Whitney, p=0.003). Dissolved nitrate concentrations ranged from 1.3 mg/L as N at the Industrial station to 18.7 mg/L as N at the M1 pumping station (Figures A-27 and A-28, Table A-15). Overall, the nitrate concentrations from the city pumping stations were lower than the concentrations from the San Joaquin River stations. The exception to this is the samples taken from M1 which were high by comparison (Figure A-28, Table A-15).

Total Nitrogen

Total nitrogen was calculated by adding dissolved nitrate plus nitrite to total Kjeldahl nitrogen. There was no statistical difference in medians between total nitrogen concentrations of all San Joaquin River stations and all city pumping stations combined. Total nitrogen ranged from 1.01 mg/L at the M3 station to 7.0 mg/L at Stonebridge station (Figures A-29 and A-30, Table A-16). The next highest value was 4.4 mg/L as N at the M1 station. In general, the total nitrogen concentrations sampled from the city pumping stations were similar to that of the San Joaquin River, although the samples from the Stonebridge station and the M1 station were higher (Figures A-29 and A-30, Table A-16).

Total nitrogen loads from Lathrop to the San Joaquin River were low (Table A-17). During the January 20, 2010, storm event, Lathrop contributed the most total nitrogen load to the San Joaquin River (23kg) at 0.6% of the total load. Additional pumping data will provide a better estimate of Lathrop's load.

Dissolved Orthophosphate

Dissolved orthophosphate median concentrations from all San Joaquin River stations were significantly lower than the median from all city pumping stations combined (Mann-Whitney, p=0.012). Concentrations ranged from 0.04 mg/L as P at the M3 and M5 stations to 0.24 mg/L as P at the Stonebridge station (Figures A-31 and A-32, Table A-18). Overall, the concentrations from the San Joaquin River station samples were lower and much less variable than those of the city pumping stations. The pattern of the city pumping station concentrations was similar to that of total nitrogen; they were highest at the Stonebridge station and the M1 station (Figures A-31 and A-32, Table A-18). There was no clear trend over the course of the season.

Total Phosphorus

Total phosphorus median concentrations were significantly lower at the San Joaquin River stations than at the city pumping stations (Mann-Whitney, p=0.005). Concentrations ranged from 0.08 mg/L as P at SJR at Brandt Bridge to 0.46 mg/L as P at the M2 station (Table A-19). Like dissolved orthophosphate, the samples from the San Joaquin River were lower and less variable than those of the city pumping stations (Figures A-33 and A-34). The average percent dissolved orthophosphate of total phosphorus was 53% with a median of 50% and a range of 29% to 78% (Figure A-35). There was no clear trend over the course of the season.

Lathrop contributed little total phosphorus load to the San Joaquin River. Although there were many data gaps, the pumping stations contributed less than 5 kg/d (Table A-20). The Historic pumping station contributed the highest load at 4 kg during the storm. The highest load contribution of approximately 1% occurred during the January 18, 2010, storm event. Due to the lack of pumping data, additional data will help provide a more accurate estimate of phosphorus load.

Pathogens

Total coliforms, fecal coliforms and *Escherichia coli* (*E.coli*) were sampled in the San Joaquin River and at the city pumping stations. Median concentrations for all San Joaquin River stations were statistically lower than the median levels for all city pumping stations combined for total, fecal and *E.coli* (Mann-Whitney, $p<0.001$). Total coliform counts ranged from 230 MPN/L at the SJR at Lathrop station to 11,000,000 MPN/L at the M6 station (Figures A-36 and A-37, Table A-21). The 11,000,000 MPN/L sample was the highest total coliform sample detected in the season. This sample was taken during the October 14, 2009, storm event. The elevated total coliform counts at the city pumping stations were likely the result of a first flush event since this storm was preceded by a dry water year and was the first storm of the season. The city pumping station counts were much higher than the San Joaquin River station counts (Table A-21). There was also greater variability in the concentrations from the city pumping stations (Figure A-37). After the first flush event, total coliform levels remained low (Figure A-38). Because there were no San Joaquin River station samples collected for the October 14, 2009, event, there was no trend in pathogens from these stations.

Fecal coliform concentrations ranged from 4 MPN/L at the SJR at Lathrop station to 500,000 MPN/L at the Historic station (Figures A-39 and A-40 and Table A-22). The concentrations from the San Joaquin River stations were much lower; the median pumping station count was 160 times that of the median San Joaquin River station count. The highest fecal coliform value was at the Historic station. All other pumping station samples were below 200,000 MPN/L. Overall, the highest fecal coliform values for the pumping stations were collected during the October 14, 2009, storm. Like total coliforms, fecal coliform values for the city pumping stations were low after the first flush event and there were no trends for the San Joaquin River stations (Figure A-41).

E.coli concentrations ranged from 10 MPN/L at the SJR at Brandt Bridge station to 51,720 MPN/L at the Historic station (Figures A-42 and A-43, Table A-23). The counts from the city pumping stations were much higher than those from the San Joaquin River. The median city pumping station count was 117 times that of the median San Joaquin River station count. Similar to fecal coliform results, there was more variability in the city pumping station counts. The highest *E.coli* concentration was collected at the Historic station on October 14, 2009 (Figure A-43, Table A-23). The *E.coli* values at the city pumping stations were high during the first flush event, but remained low for the rest of the season (Figure 44). There were no trends over the season for the San Joaquin River stations.

Pyrethroids

Pyrethroid sampling was scheduled for the beginning and the end of the season. However, due to complications with weather and autosamplers, sampling only occurred at the beginning of the season at 3 stations (M3, M6 and Industrial). Samples were analyzed for allethrin, bifenthrin, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, fenvalerate, lambda-cyhaolthrin, permethrin, prallethrin, sumithrin, tefluthrin, and tralomethrin. All pyrethroids were non-detects.

Discussion and Conclusions

TOC/DOC

During the course of the season, pumping stations' TOC and DOC concentrations decreased. This suggests that within the urban environment, there is a reservoir of TOC in the system that builds up during dry periods and is washed into the river with the first major storm event. Successive rainfall events dilute this reservoir resulting in lower levels of TOC by the end of the season. This is consistent with the results of the Steelhead Creek Water Quality Investigation (DWR, 2008). This trend was not apparent for the San Joaquin River stations. There were some samples from the city pumping stations that had relatively high concentrations (TOC>9 mg/L); however, due to inconsistent pumping, the load to the San Joaquin River was quite low. The samples collected from the San Joaquin River stations remained low (TOC<3.5 mg/L) for the entire season.

THMFP/HAAFP

Because TOC provides the source material, there is a close relationship between disinfection byproducts (trihalomethanes and haloacetic acids) and TOC. This explains the similarity in trends over the season between formation potentials and TOC. However, the January 18, 2010, sample collected from the SJR at Brandt Bridge did not follow the typical pattern. In this case, the THMFP concentration was very high (622 ug/L), while the corresponding TOC concentration was relatively low (2.8 mg/L). The corresponding HAAFP sample was also low (159.6 ug/L). Bromide can potentially increase the weight of formation potentials, thus increasing the concentration of total THMFP and HAAFP. Chow et al. stated that when the DOC/Br molar ratio drops to less than 200, incorporation of bromine atoms increases exponentially, thus potentially increasing the formation of brominated trihalomethanes (2007). Although the molar DOC/Br ratio for this date was low (39.63), it was not likely responsible for the unusually high THMFP to TOC ratio of the January 18, 2010, sample. A sample taken 2 days later (January 20, 2010) had similar bromide, DOC, and HAAFP concentrations, and a DOC/Br molar ratio of 41.21, but the THMFP value was 362 ug/L. This is evidence that the bromide concentration alone was not responsible for the elevated THMFP value. Also, if bromide had caused the increase in THMFP, it would have likely caused an increase in HAAFP. Another possibility is that agricultural discharge in the area may have influenced THMFP. However, a characteristic of agricultural discharge is high absorbance, and the corresponding absorbance was also low (0.071 absorbance/cm) (Fram et al., 1999).

Absorbance and Carbon Quality

Absorbance (UVA_{254}) is a measure of the absorbance of ultraviolet (UV) light by disinfection byproduct (DBP) precursors and is commonly used as a quick and affordable gauge for DBP precursors. However, this method is not always accurate; not all organic compounds absorb UV light, and not all UV light absorbing compounds are DBPs.

The formation of DBPs is dependent on the quality of organic carbon. Correlations between DOC and UVA_{254} for the city pumping stations was stronger (r^2= 0.987) than they were for the San Joaquin River stations (r^2=0.538). This indicates a difference in organic carbon quality and that the DOC in Lathrop's discharge is more aromatic than the DOC from the San Joaquin River (UVA_{254} is strongly absorbed by aromatic carbon.). This is consistent with Fram et al.'s findings that DOC derived from the main-stem San Joaquin River contained less aromatic carbon than the DOC derived from Twitchell Island drainage (1999). Fram et al. also concluded that some of the aromatic carbon derived from Twitchell Island must be unreactive (1999).

Because not all organic carbon DBP precursors absorb at UVA_{254}, UVA_{254} is not a reliable measurement of THMFPs. This was observed in this first year of study. For example, there was no relationship between San Joaquin River THMFP and UVA_{254} (r^2 <0.001, p= 0.614), whereas there was a significant relationship for the city pumping stations between THMFP and UVA_{254} (r^2=0.832, p<0.001).

Ammonia

Ammonia sources in urban runoff are primarily from plant and animal decomposition and from fertilizers. Samples collected from the San Joaquin River stations were quite low (≤0.06 mg/L as N) and samples from the city pumping stations ranged from 0.110 mg/L as N to 0.44 mg/L as N. These levels were still low considering the full compliance discharge requirements for the Sacramento Regional Wastewater Treatment Plant's new NPDES permit is 2.2 mg/L per day. However, these concentrations are high in comparison to the concentrations from the San Joaquin River station samples. This difference in concentrations between the two water sources explains why Lathrop contributed up to 7.7% of the ammonia load to the San Joaquin River.

General Conclusions

Most sample concentrations (organic carbon, THMFP, HAAFP, UVA_{254}, ammonia, phosphorus and pathogens) were significantly lower on the San Joaquin River than they were in the city pumping stations. For all constituents, the samples taken from the San Joaquin River were less variable than those taken from the city pumping stations, and usually with lower values.

Most of the loads measured were very low compared to the load of the San Joaquin River. The largest load that was contributed was ammonia on January 20, 2011. During this event, Lathrop discharged 12.4 kg of dissolved ammonia which was approximately 7.7% of the total load.

Concentrations decreased over the course of the storm season for DOC, TOC, THMFP and pathogens. The trends were most prominent for the city pumping stations. These trends were not as apparent on the San Joaquin River. This is likely due to the difference in water source, the small sample size and because the samples taken from the San Joaquin river generally had little variation.

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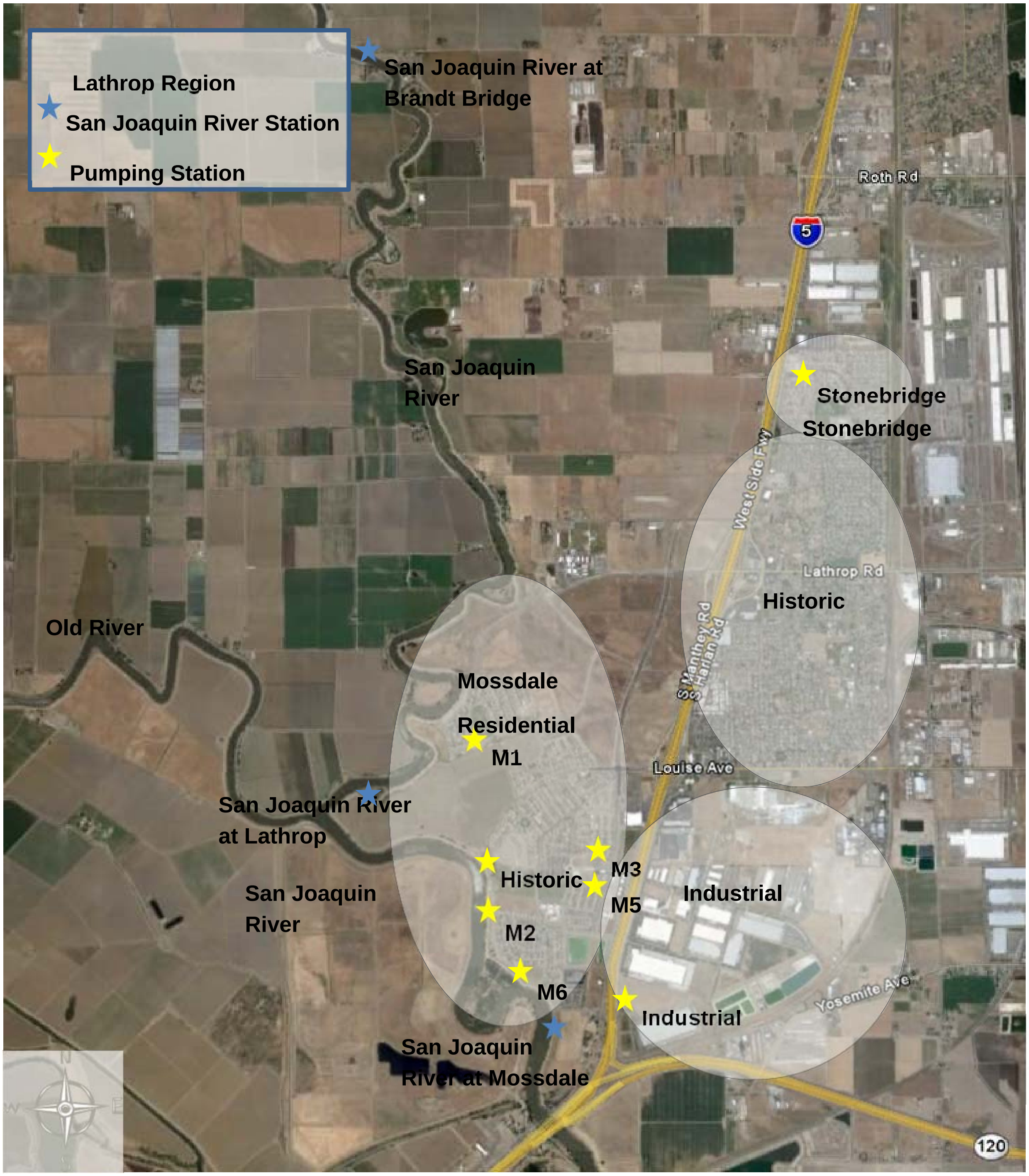
Lathrop Summary Figures

Figure A-1. Map of Lathrop Sampling Sites



Note: Although the Historic station is on the San Joaquin River, it only serves the historic region of the city.

Figure A-2. TOC Boxplots of the Combined San Joaquin River Station and Individual San Joaquin River Stations (n=3 per station)

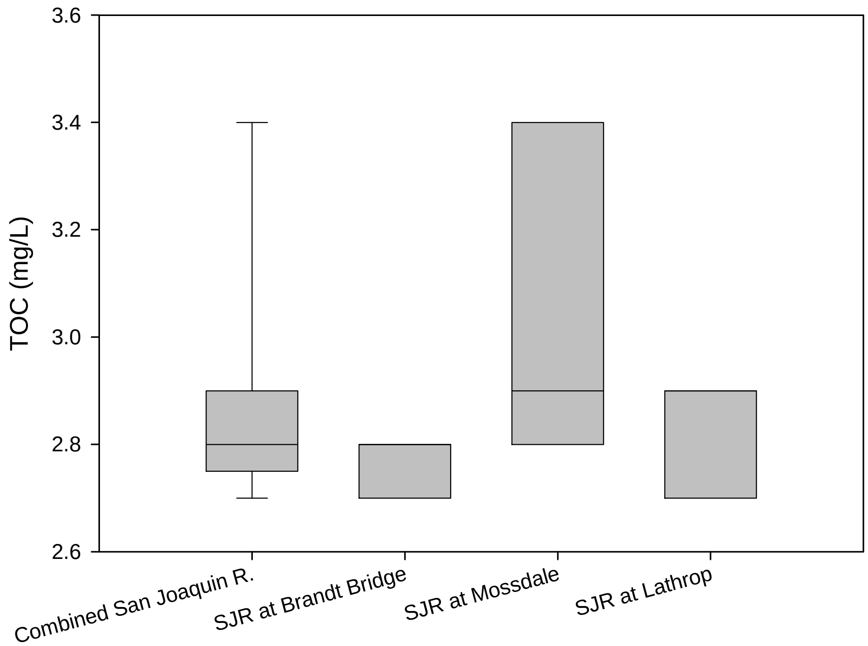


Figure A-3. TOC Boxplots of the Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

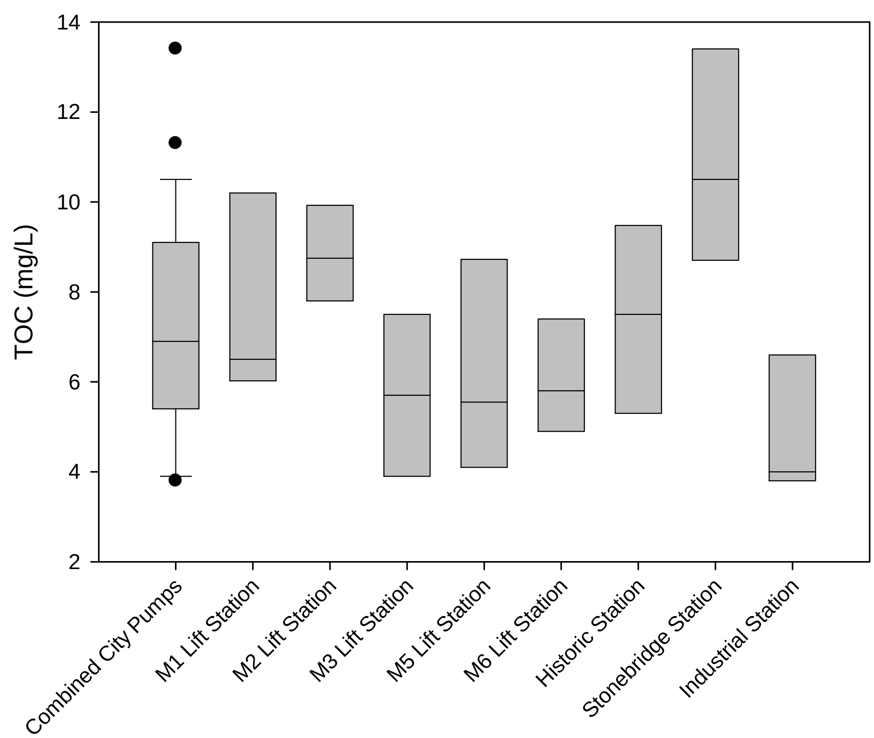
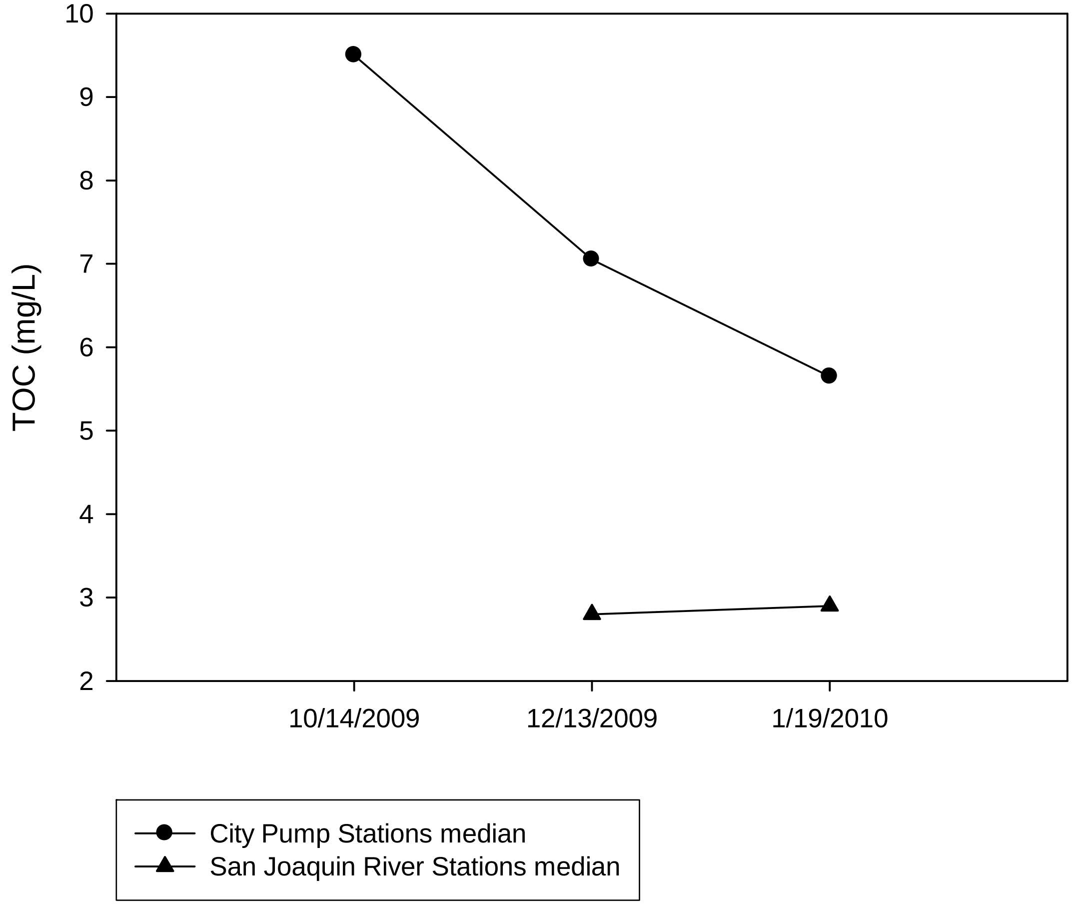


Figure A-4. TOC Trends during the Season



Note: The samples for January 19, 2010 and January 21, 2010 have been combined because these two sampling dates represent one large storm. The San Joaquin River stations were not sampled during the October 14, 2009 event.

Figure A-5. DOC Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

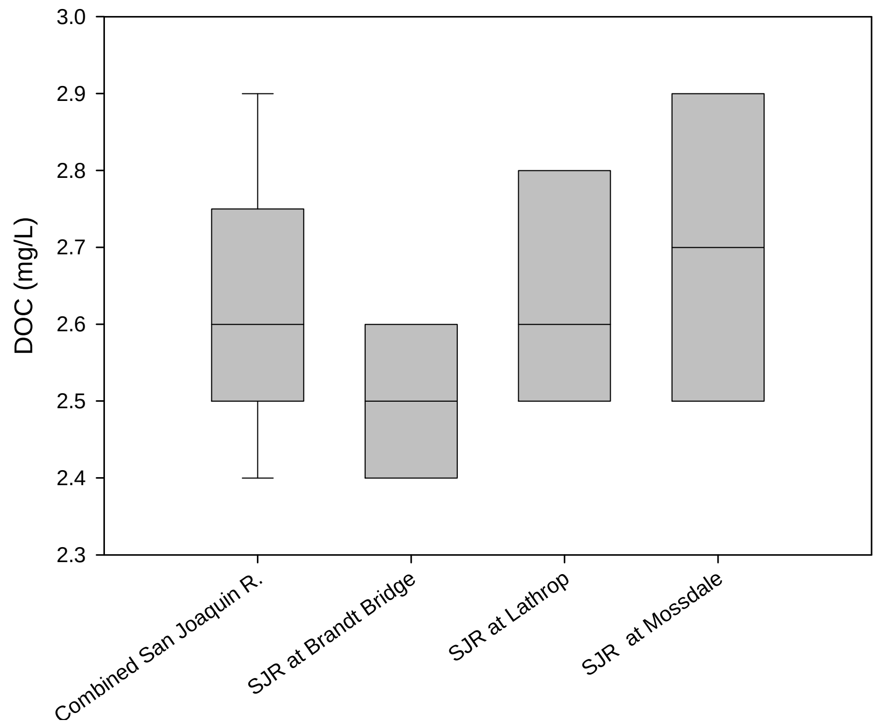


Figure A-6. DOC Boxplots of Combined City Pump Stations and Individual City Pump Stations (n= 3-4 per station)

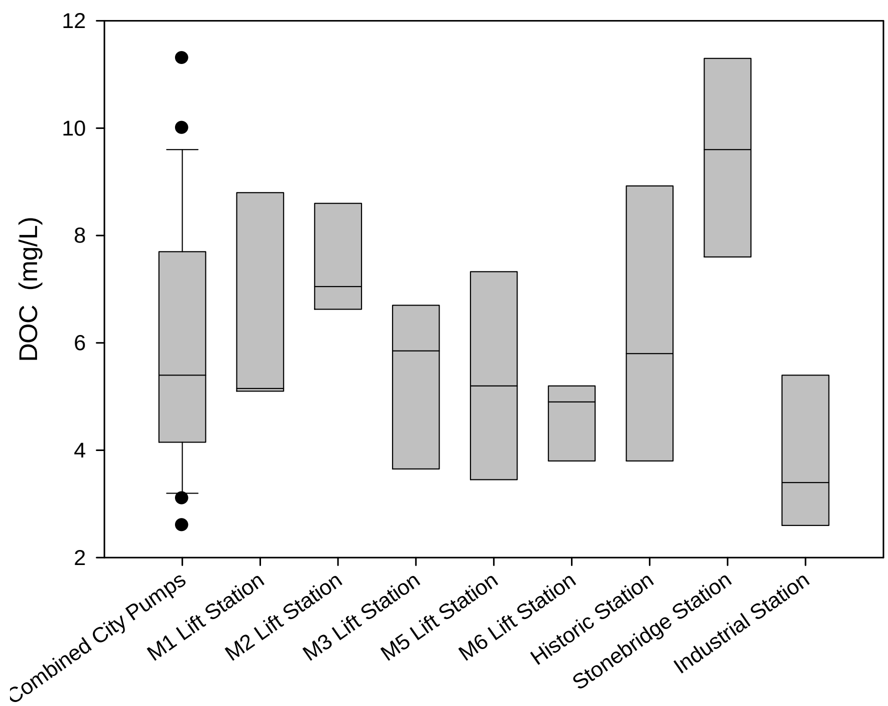
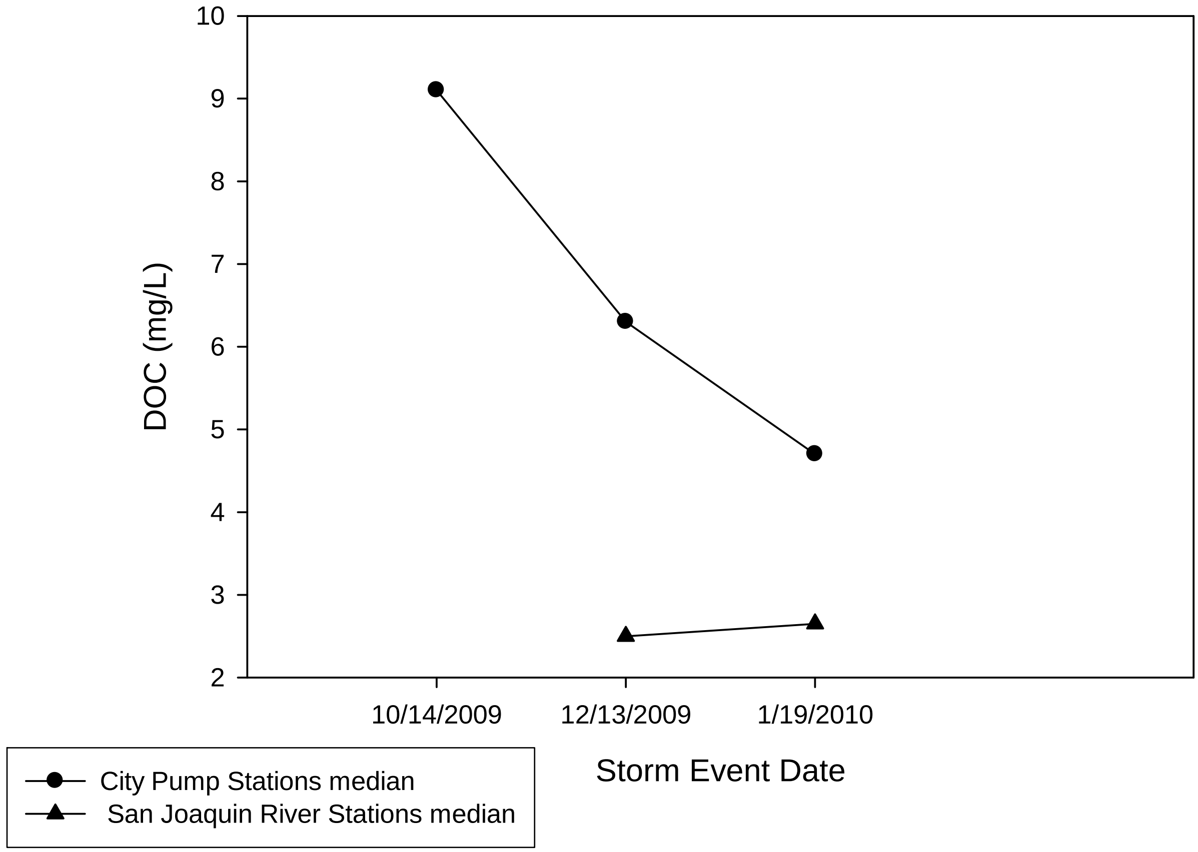


Figure A-7. DOC Trends during the Season



Note: The samples for January 19, 2010 and January 21, 2010 have been combined because these two sampling dates represent one large storm. The San Joaquin River stations were not sampled during the October 14, 2009 event.

Figure A-8. Percent DOC of TOC for all Stations

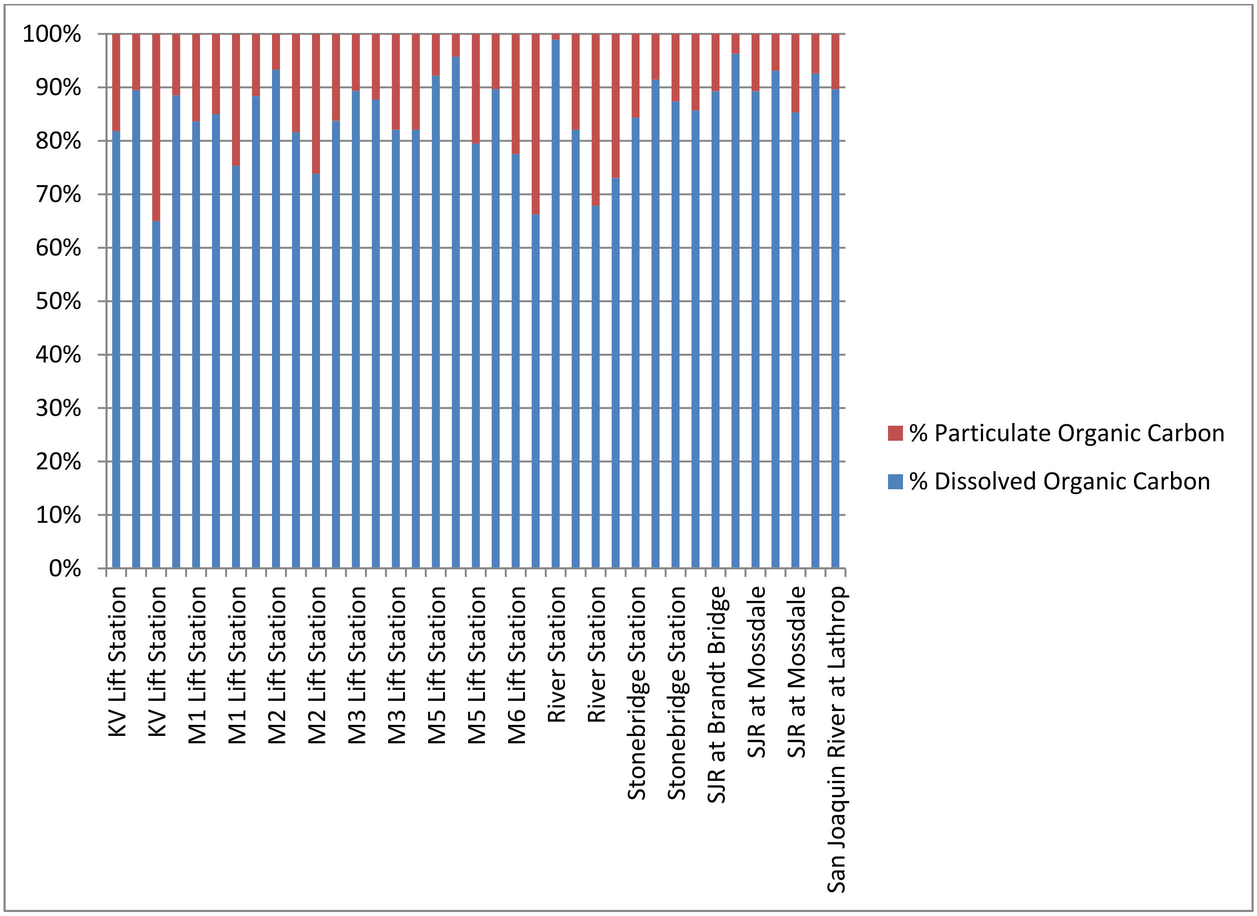


Figure A-9. THMFP Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

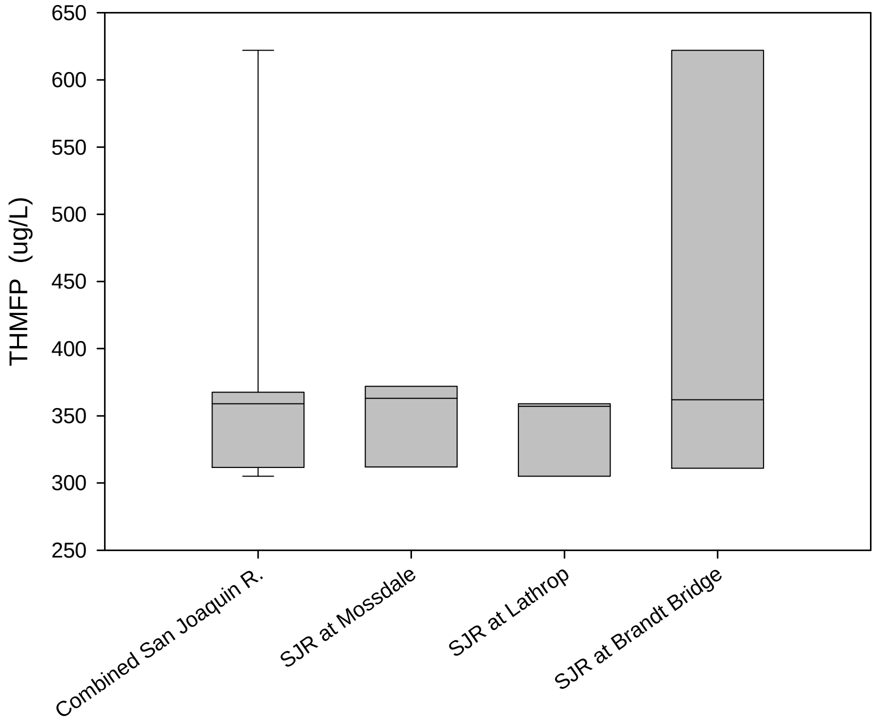


Figure A-10. THMFP Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

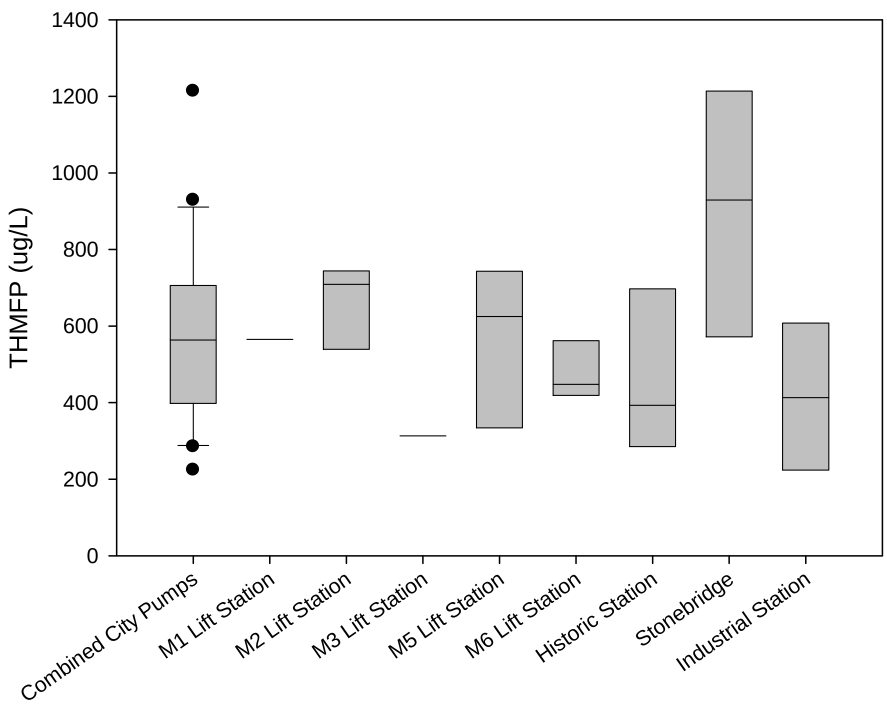
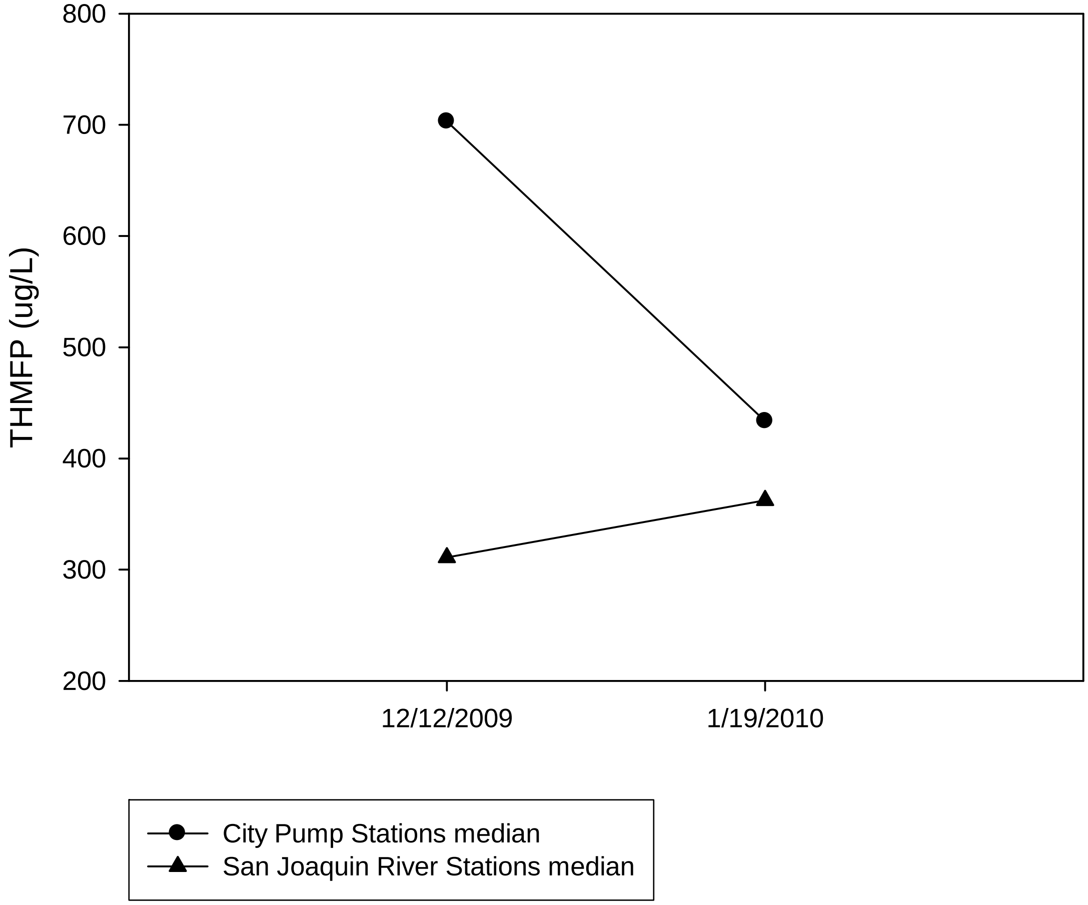


Figure A-11. THMFP Trends during the Season



Note: The samples for January 19, 2010 and January 21, 2010 have been combined because these two sampling dates represent one large storm.

Figure A-12. HAAFP Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

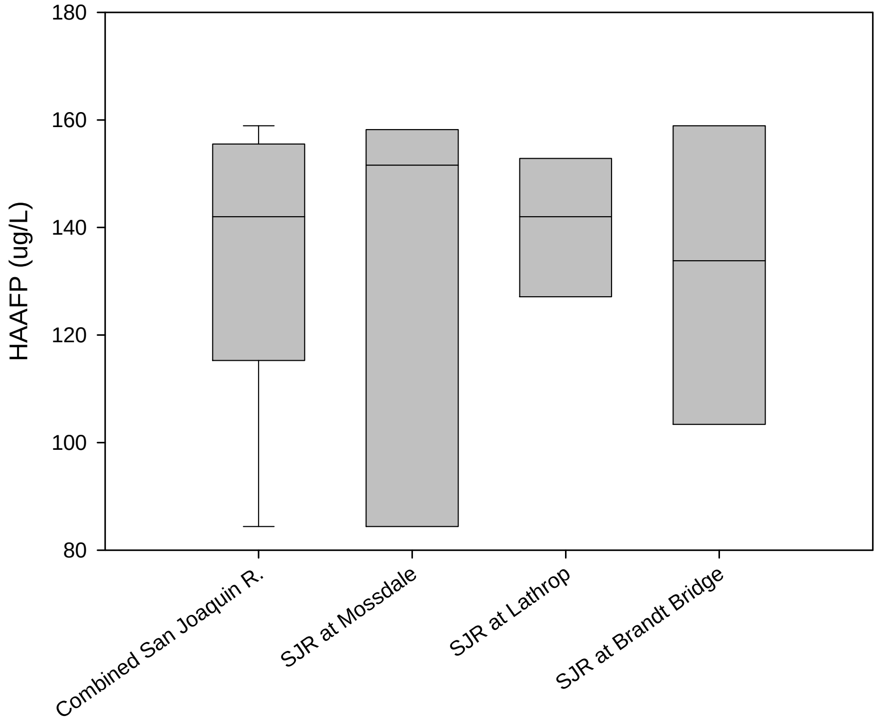


Figure A-13. HAAFP Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

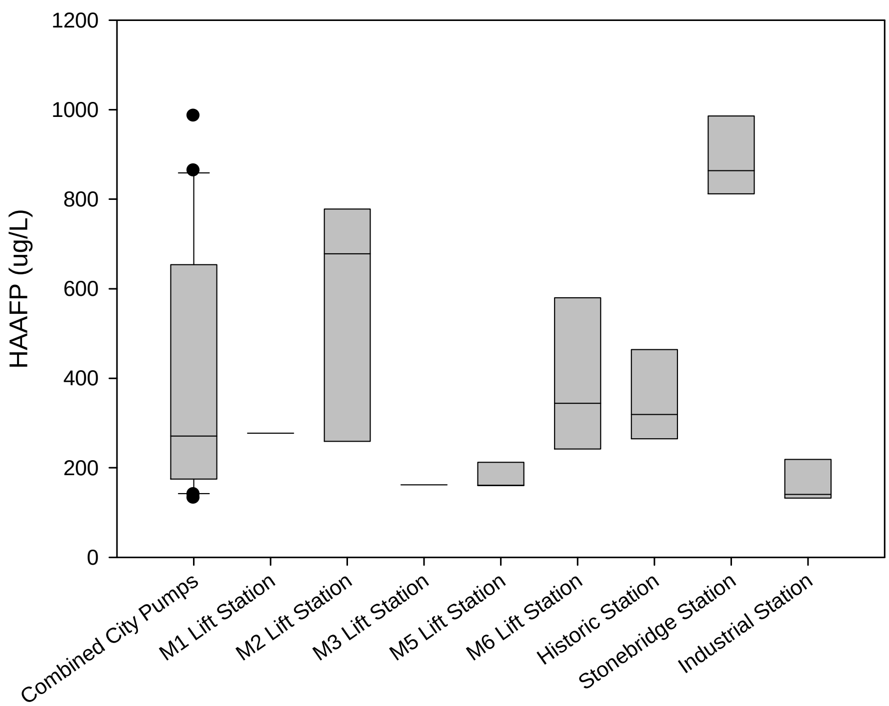


Figure A-14. Relationship between DOC and UVA_{254}

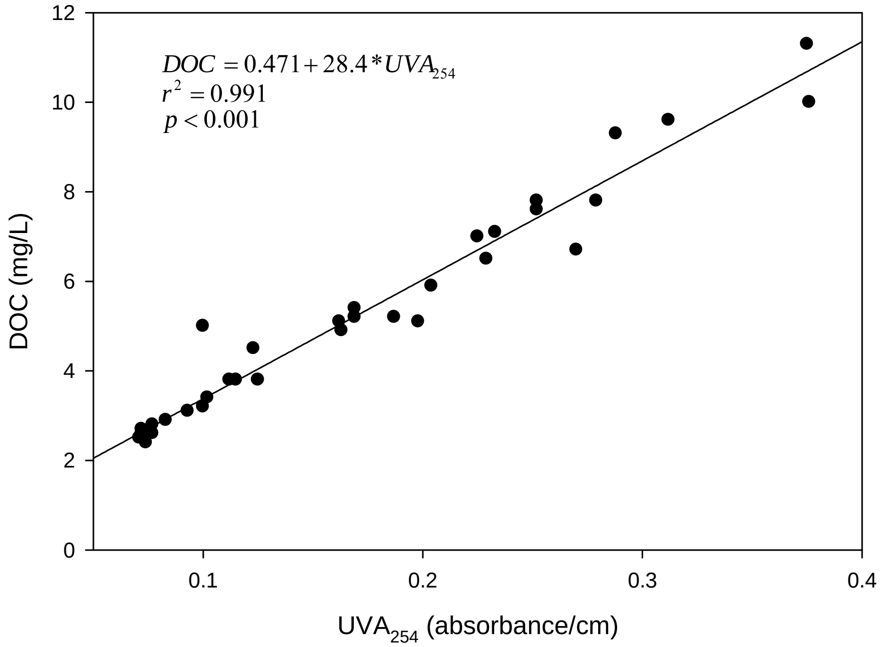


Figure A-15. Relationship between THMFP and UVA_{254}

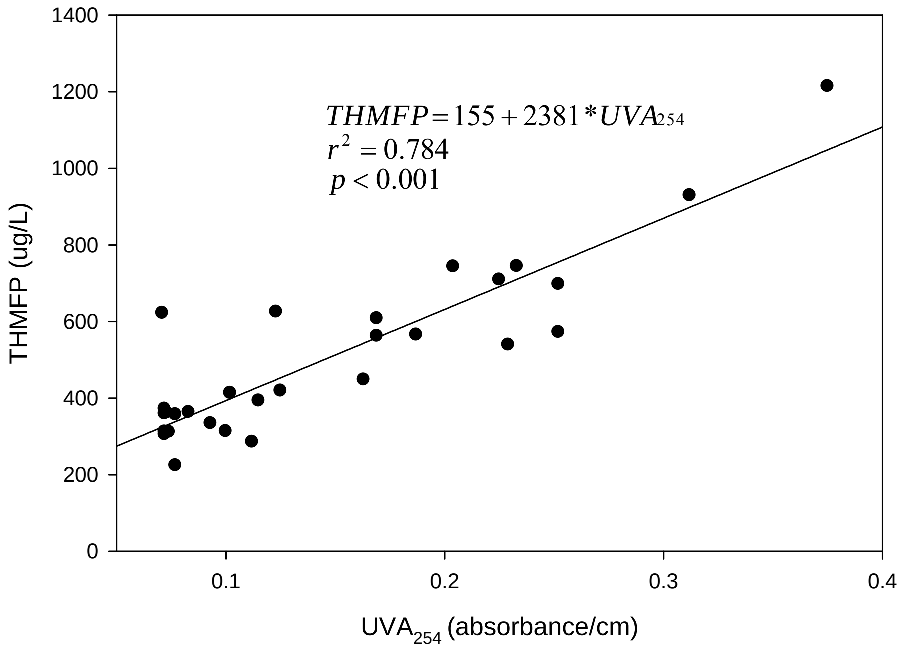


Figure A-16. SUVA Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

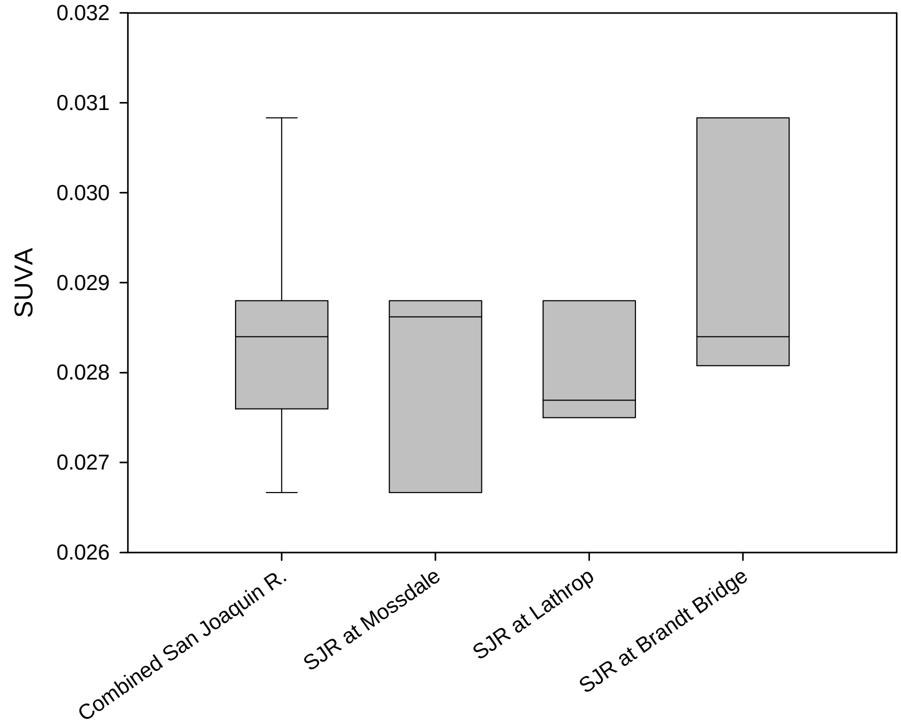


Figure A-17. SUVA Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

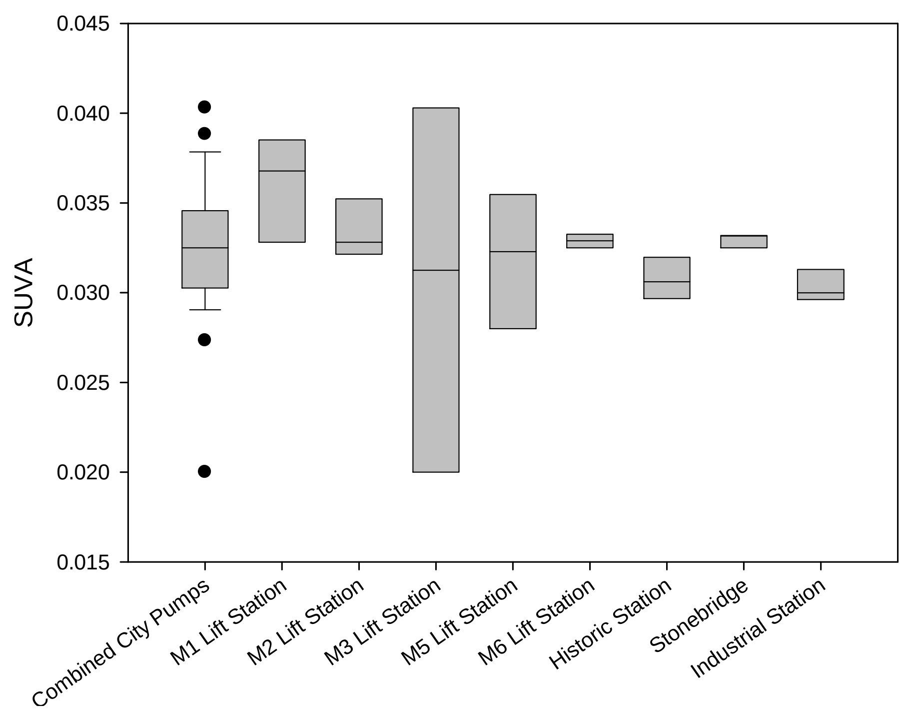


Figure A-18. EC Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

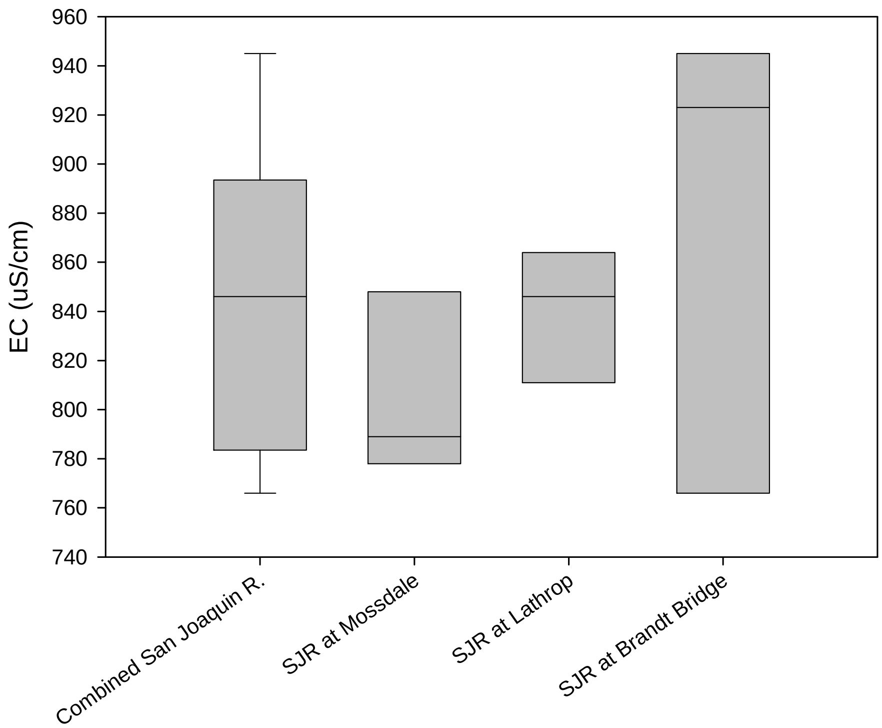


Figure A-19. EC Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

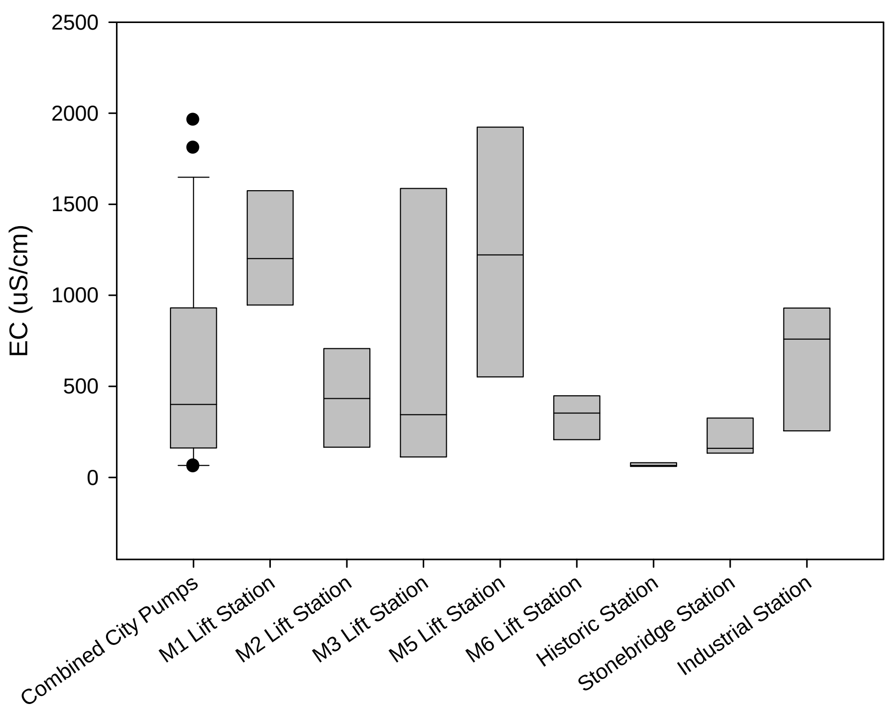


Figure A-20. TDS Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

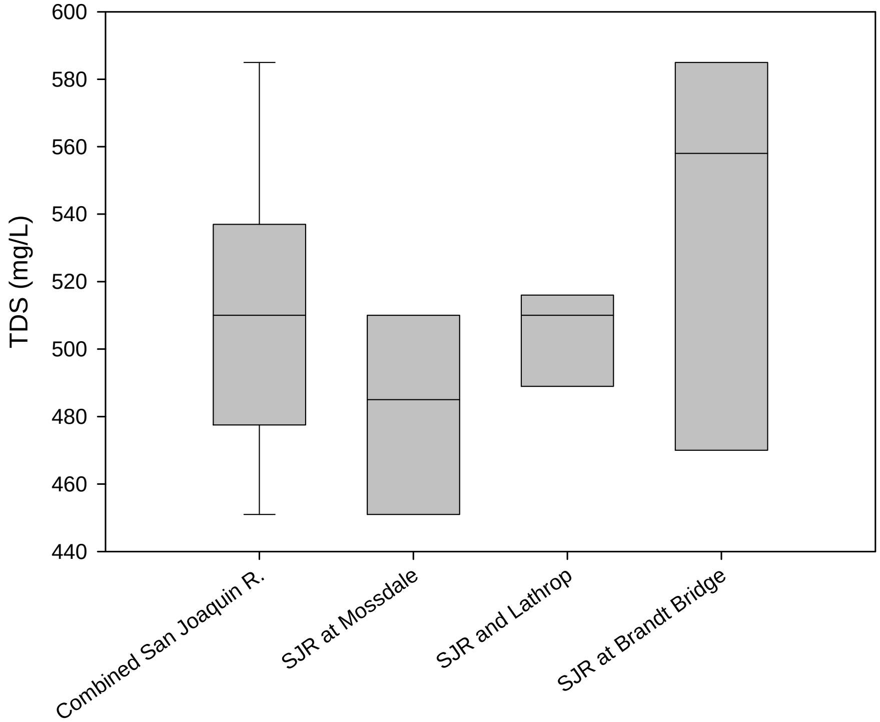


Figure A-21. TDS Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

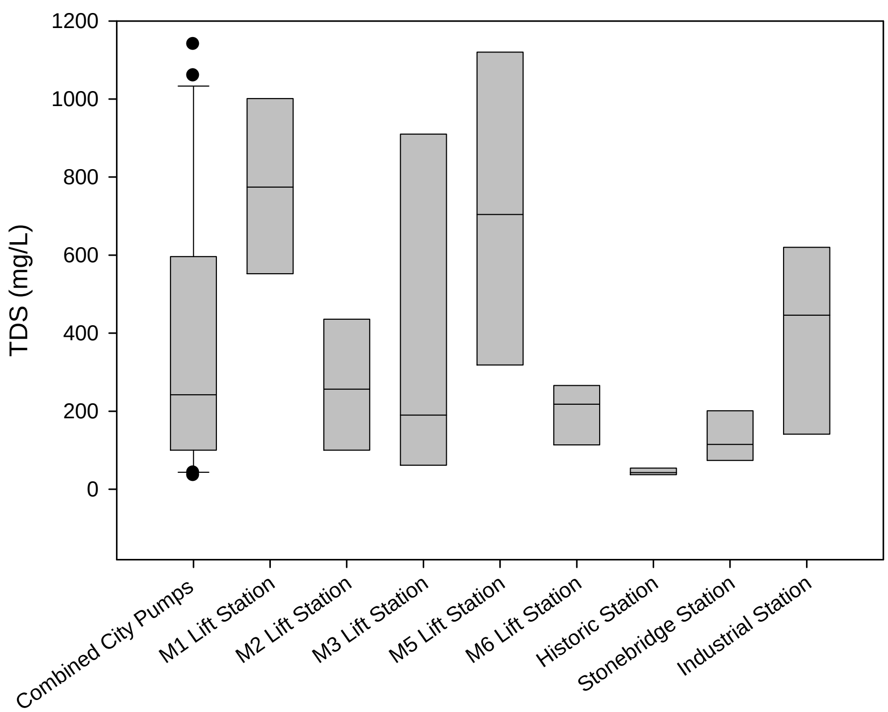


Figure A-22. Relationship between EC and TDS

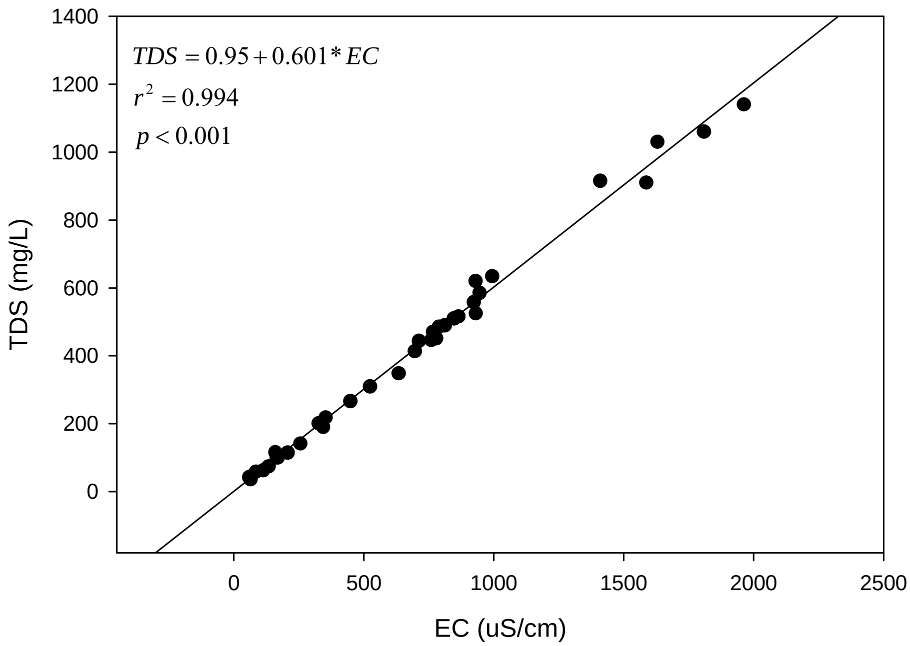


Figure A-23. Bromide Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

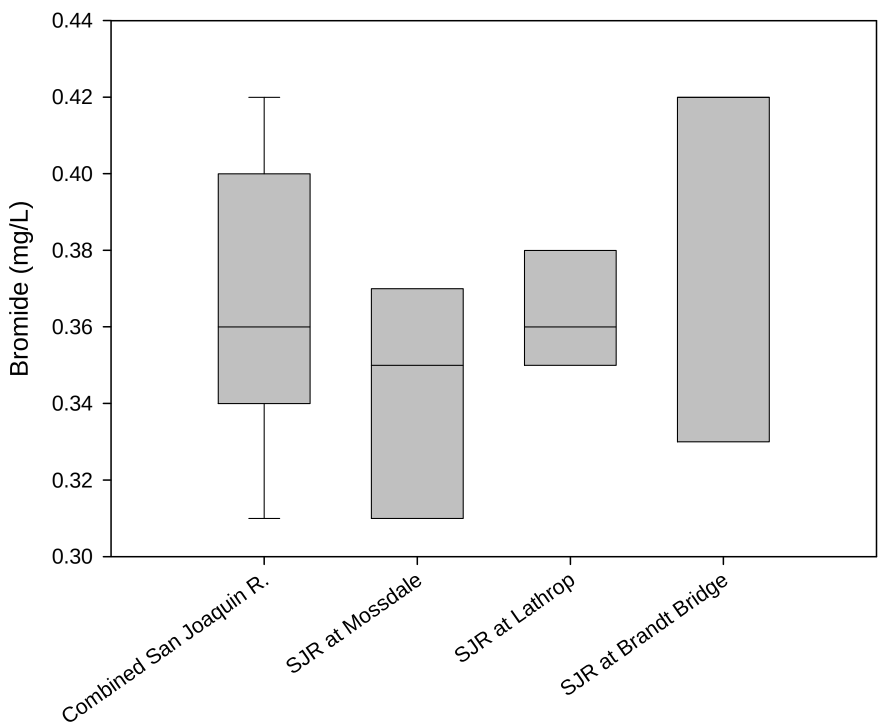


Figure A-24. Bromide Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

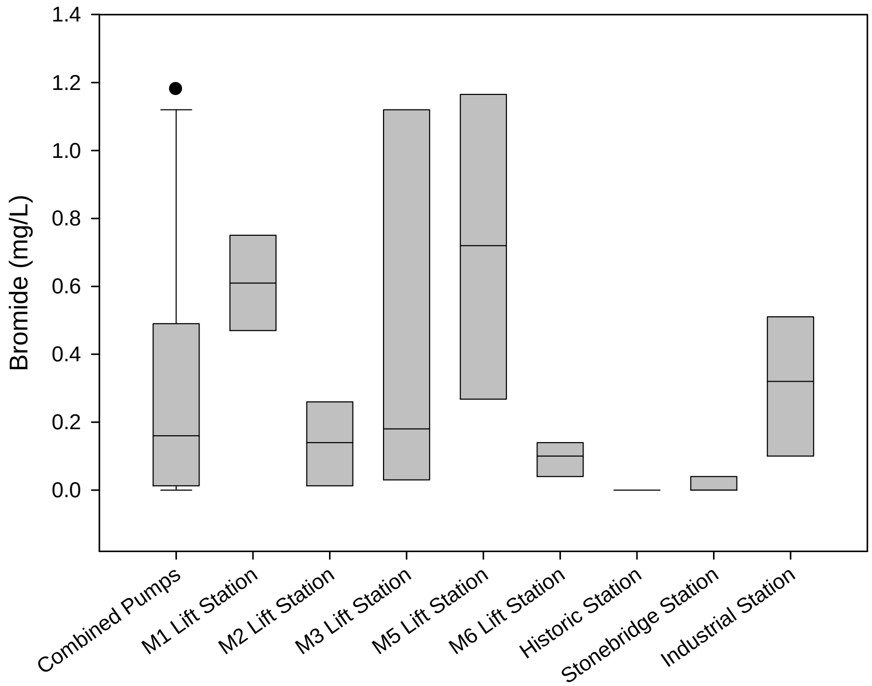


Figure A-25. Ammonia Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

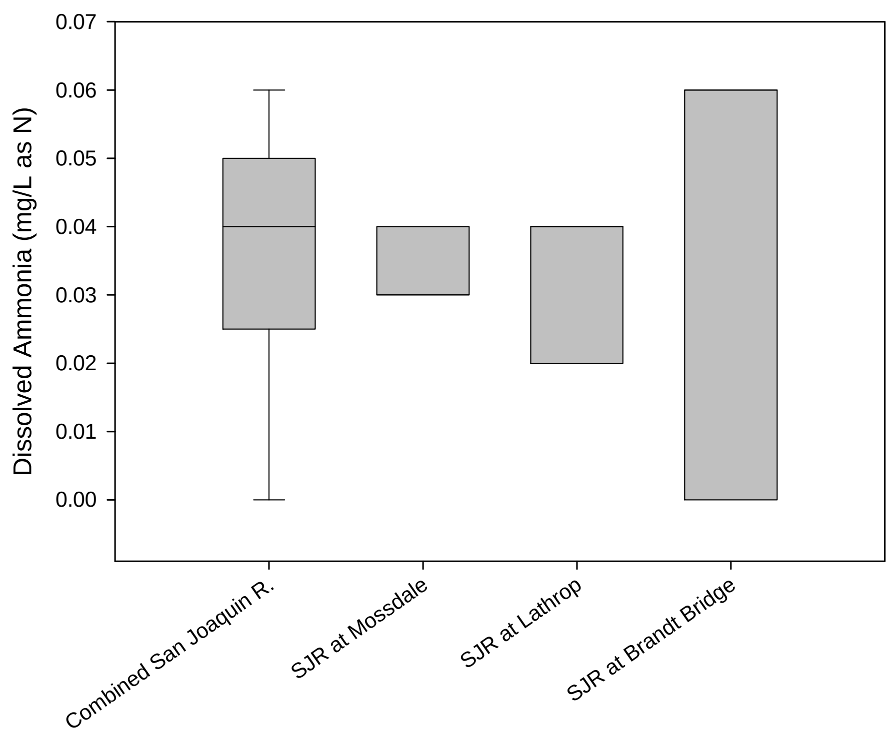


Figure A-26. Ammonia Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

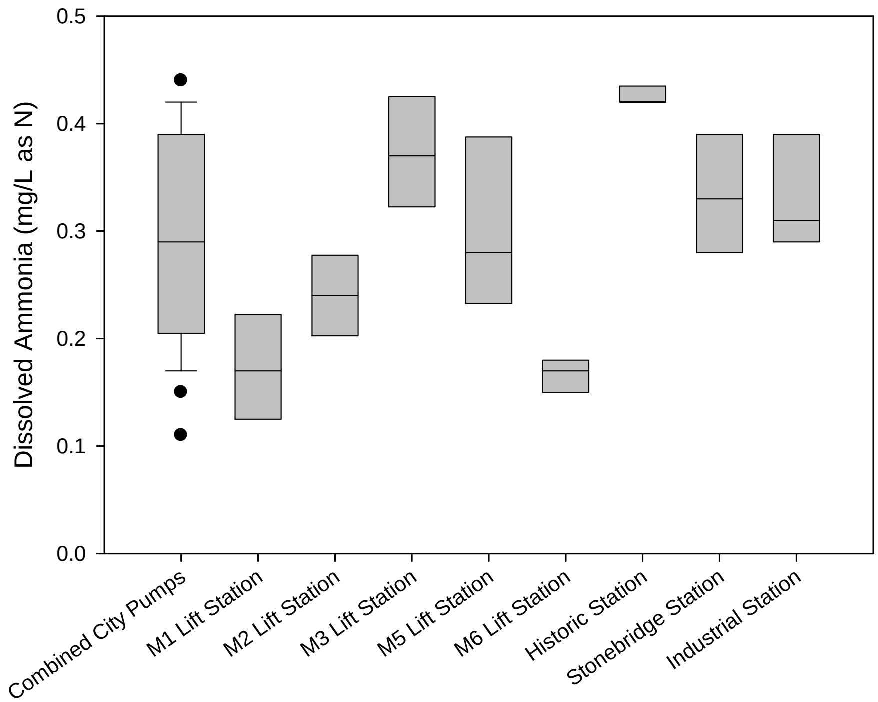


Figure A-27. Dissolved Nitrate Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

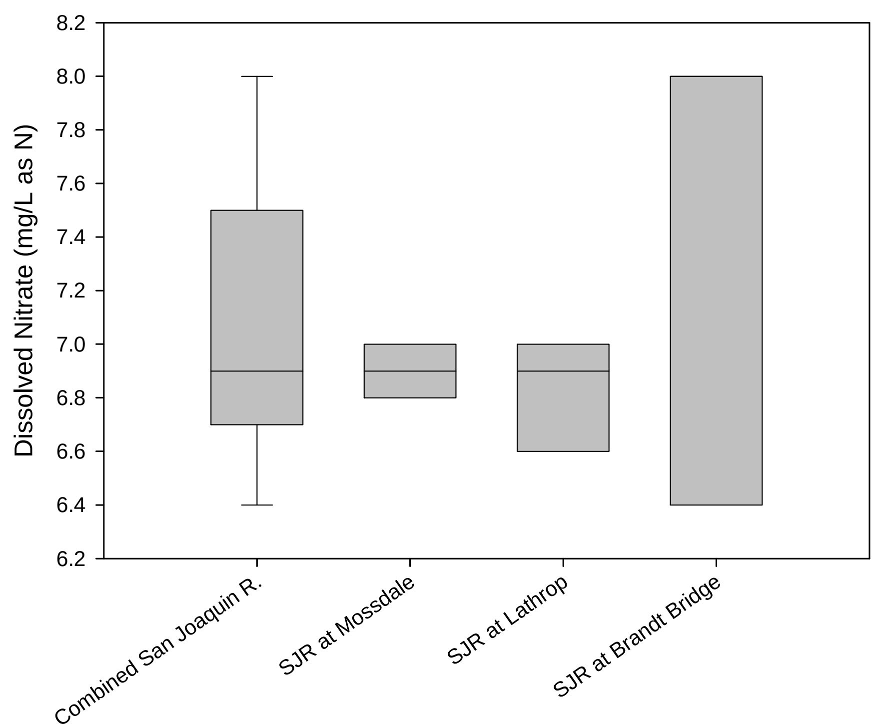


Figure A-28. Dissolved Nitrate Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

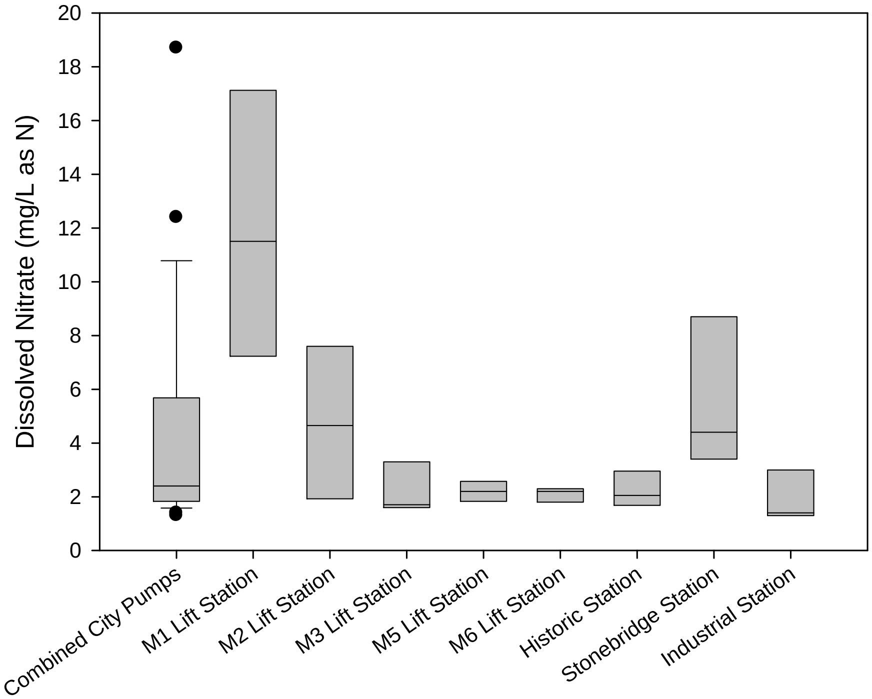


Figure A-29. Total Nitrogen Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

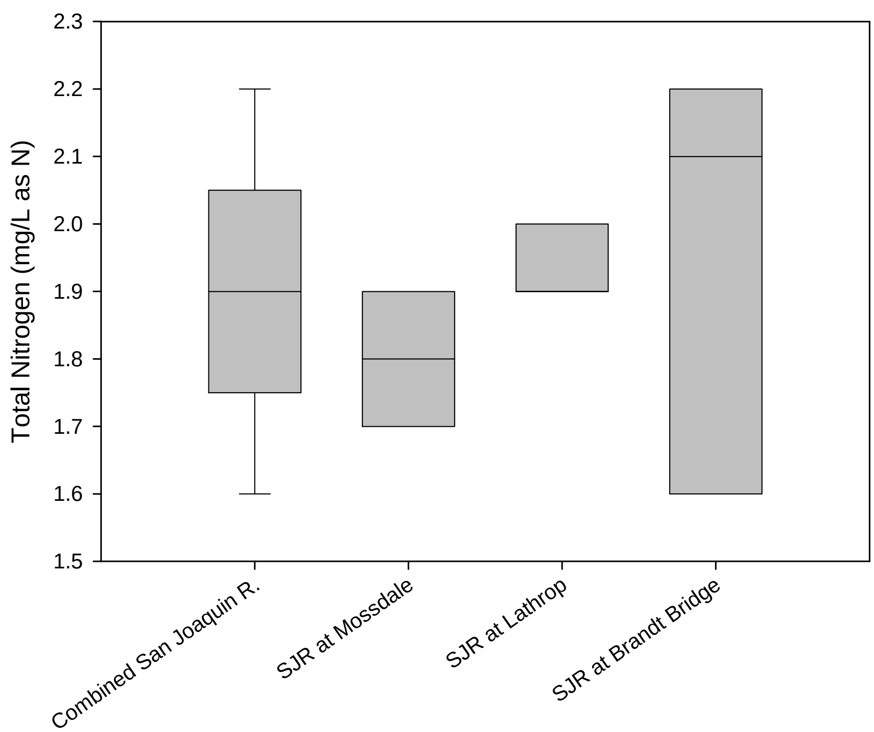


Figure A-30. Total Nitrogen Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

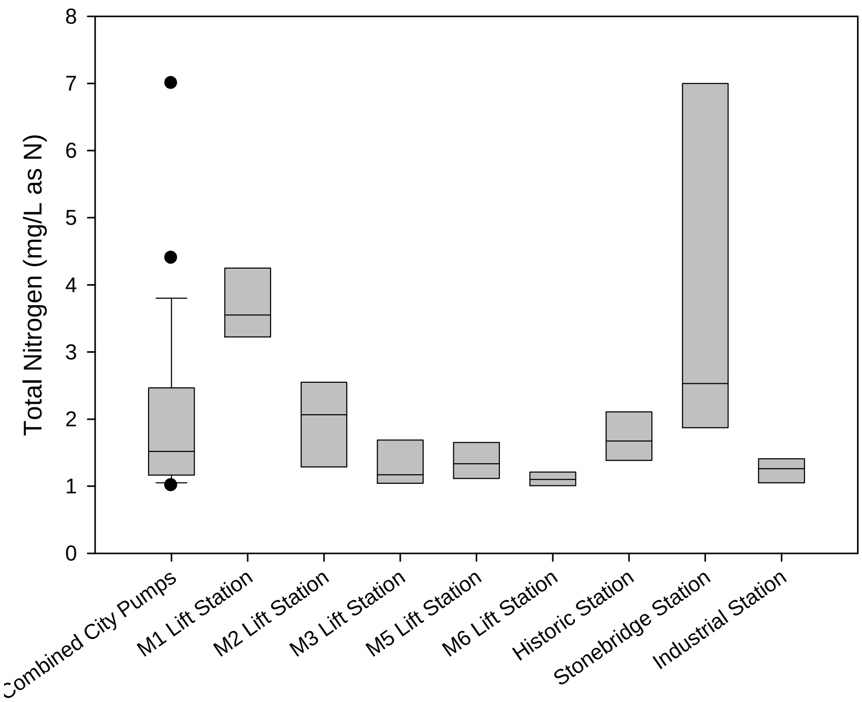


Figure A-31. Dissolved Orthophosphate Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

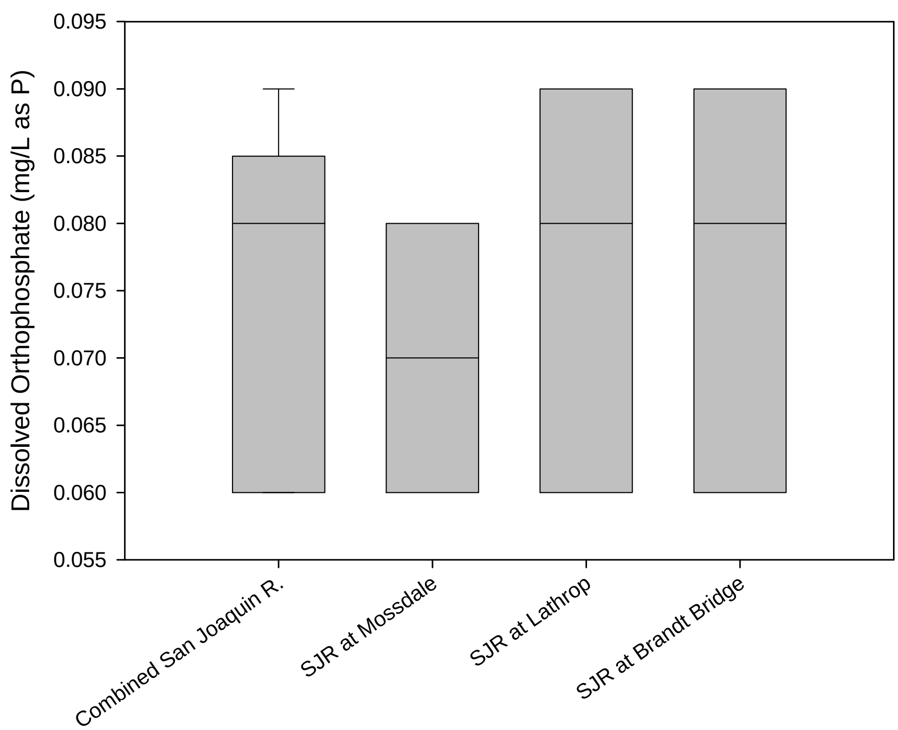


Figure A-32. Dissolved Orthophosphate Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

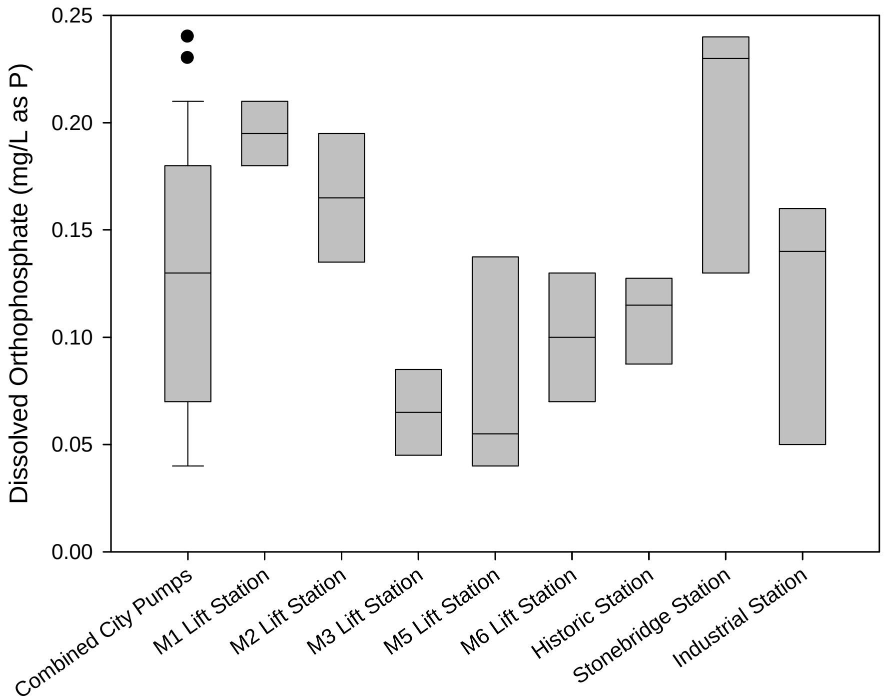


Figure A-33. Total Phosphorus Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

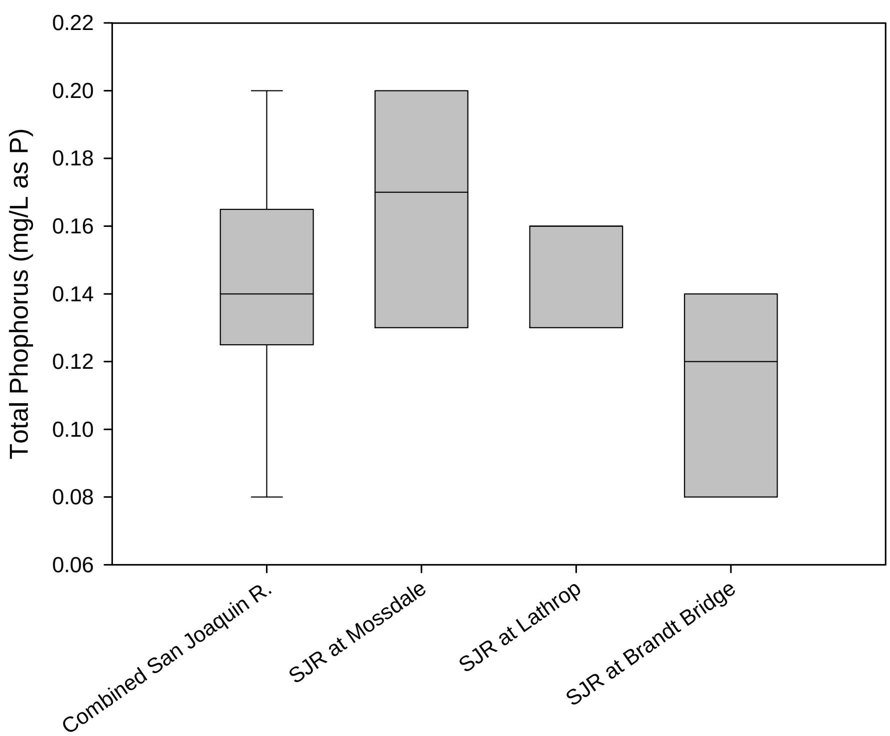


Figure A-34. Total Phosphorus Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

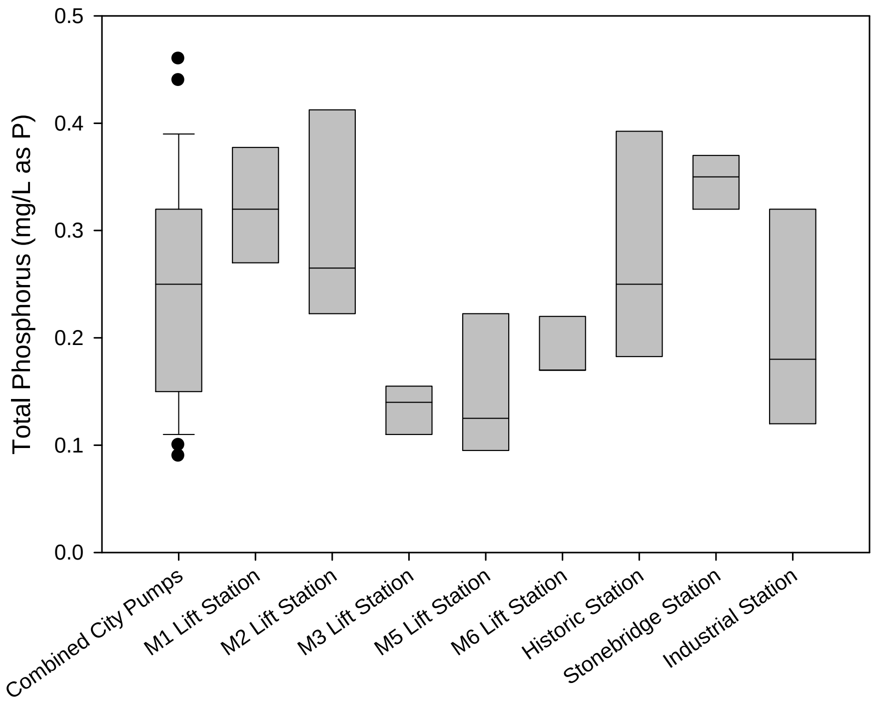


Figure A-35. Percent Orthophosphate of Total Phosphorus

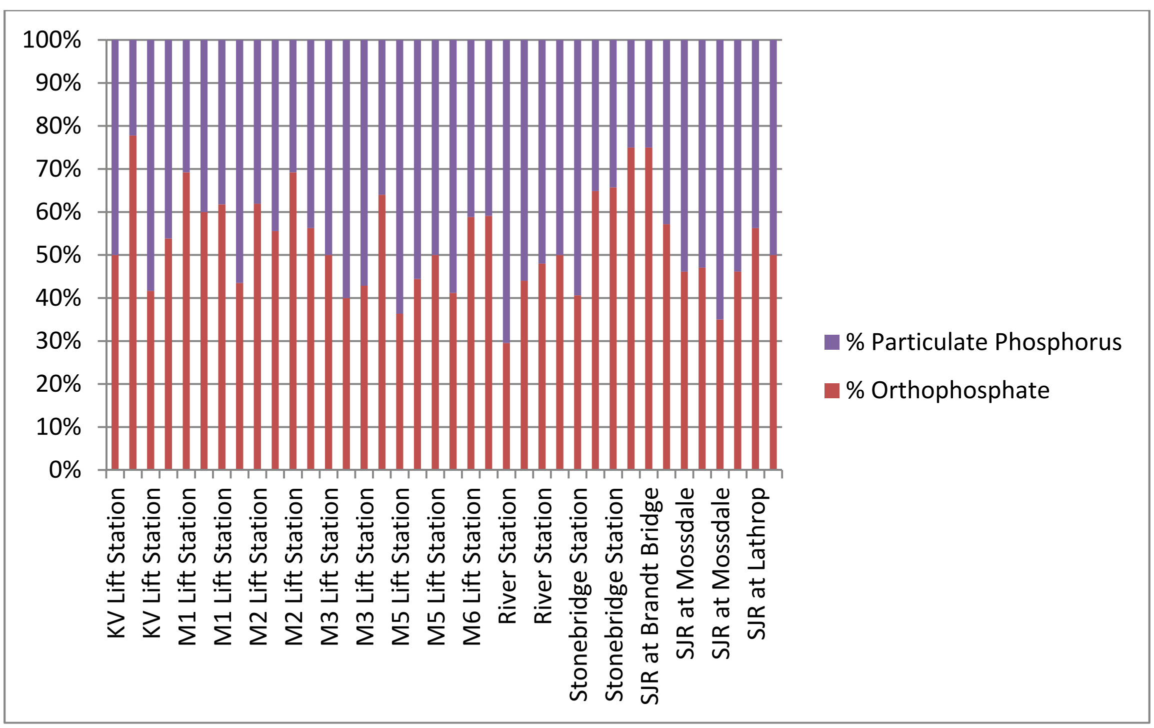


Figure A-36. Total Coliforms Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

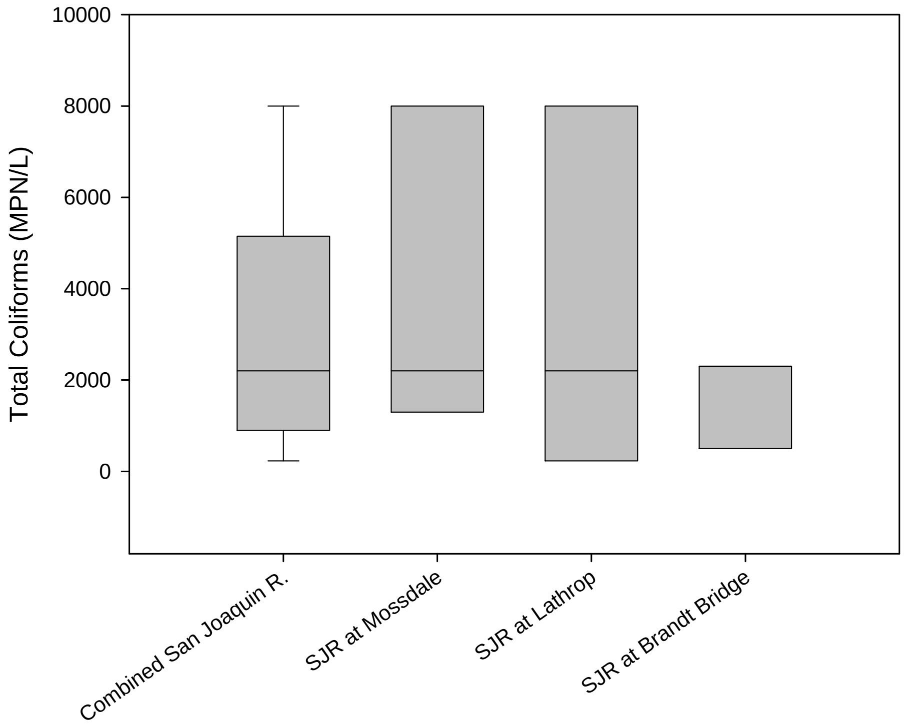


Figure A-37. Total Coliforms Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

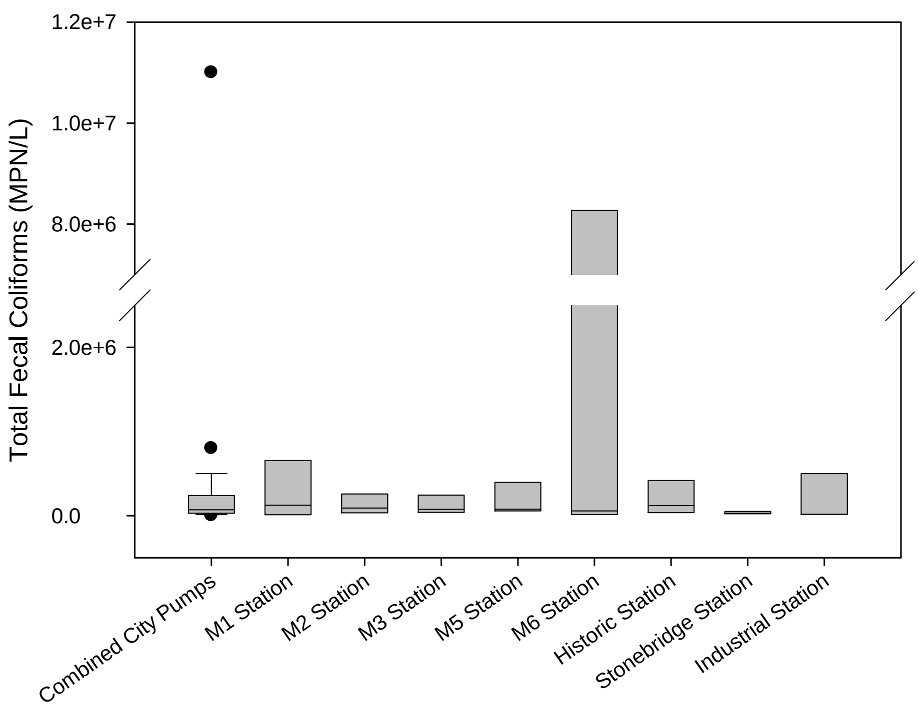
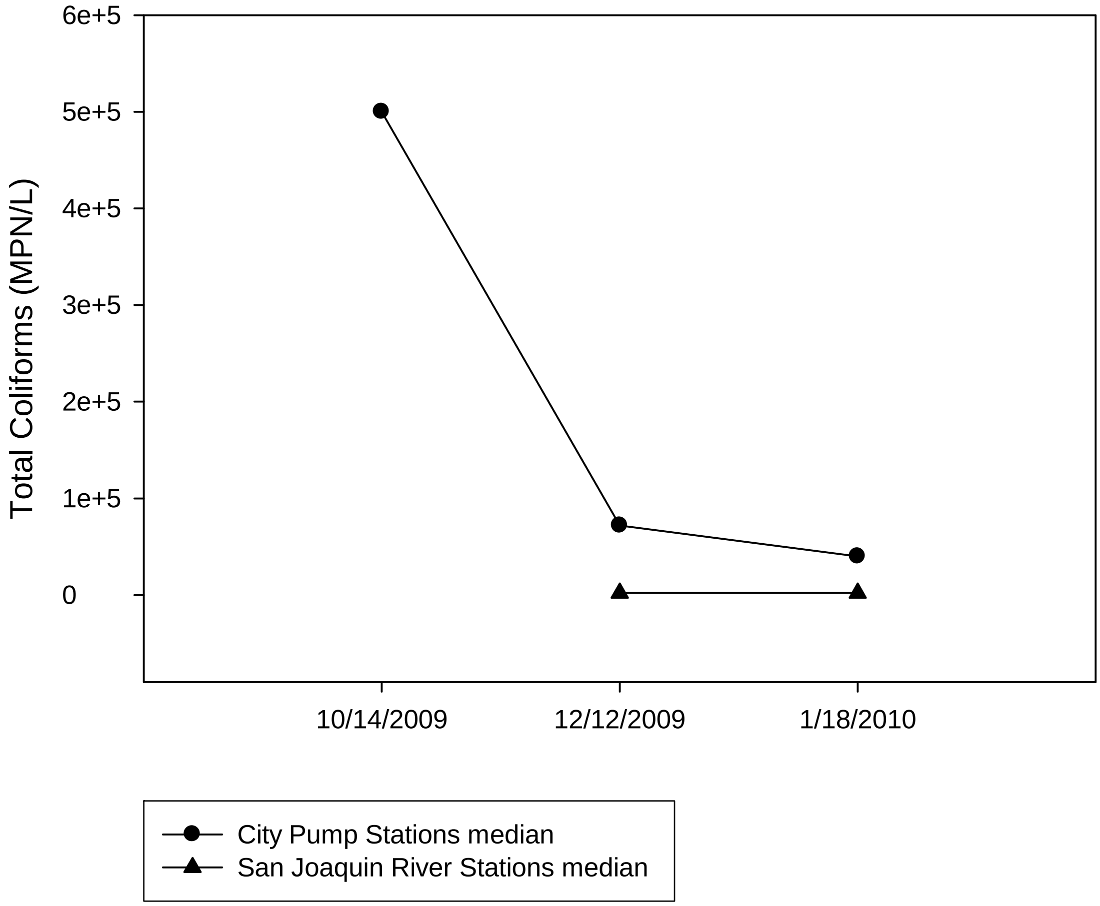


Figure A-38. Total Coliforms Trends during the Season



Note: The samples for January 18, 2010 and January 20, 2010 have been combined because these two sampling dates represent one large storm. The San Joaquin River stations were not sampled during the October 14, 2009 event.

Figure A-39. Fecal Coliforms Boxplots of Combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3 per station)

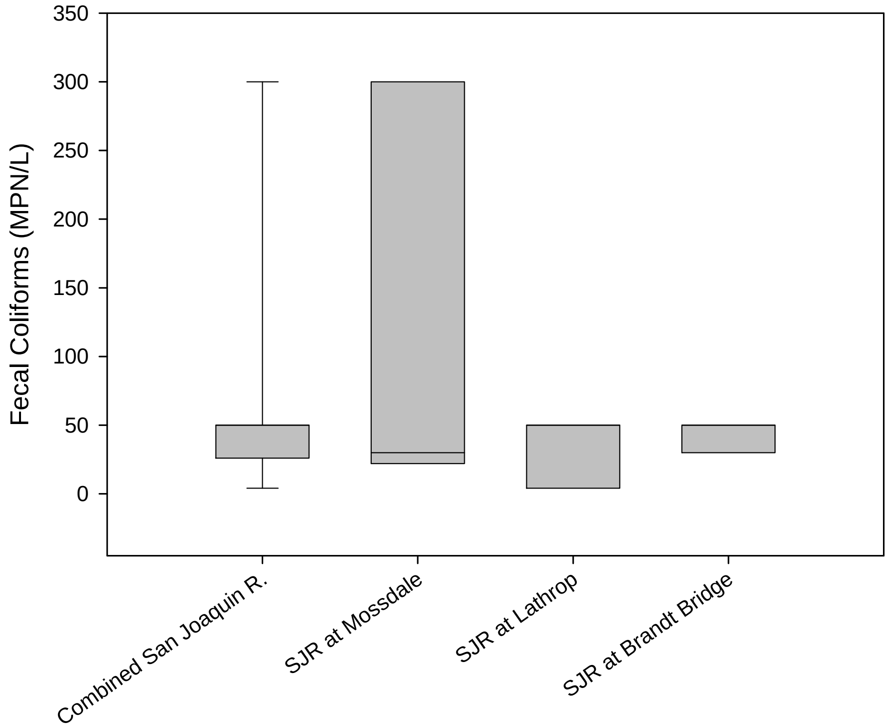


Figure A-40. Fecal Coliforms of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)

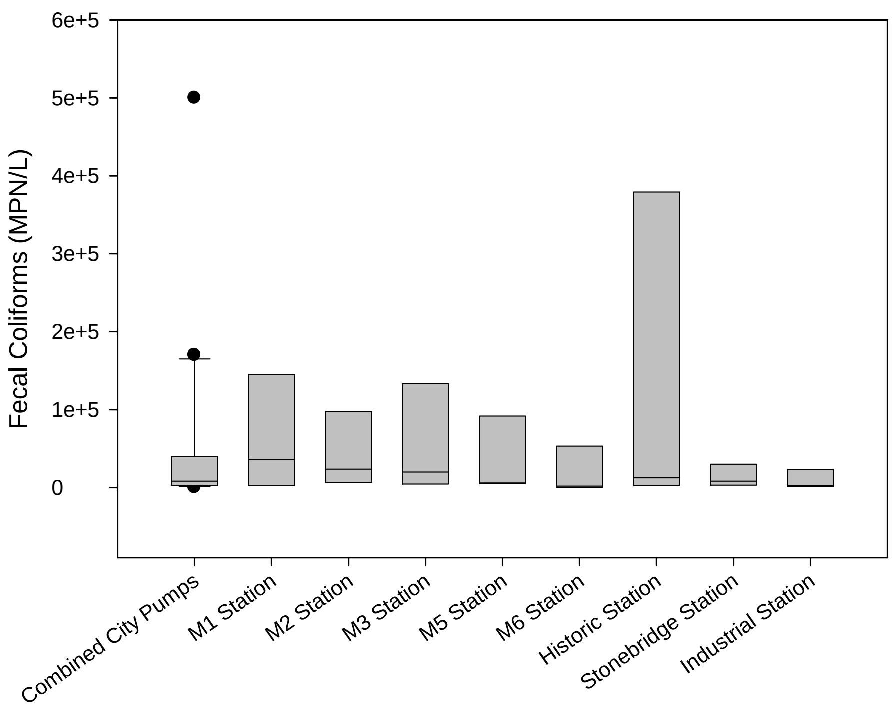
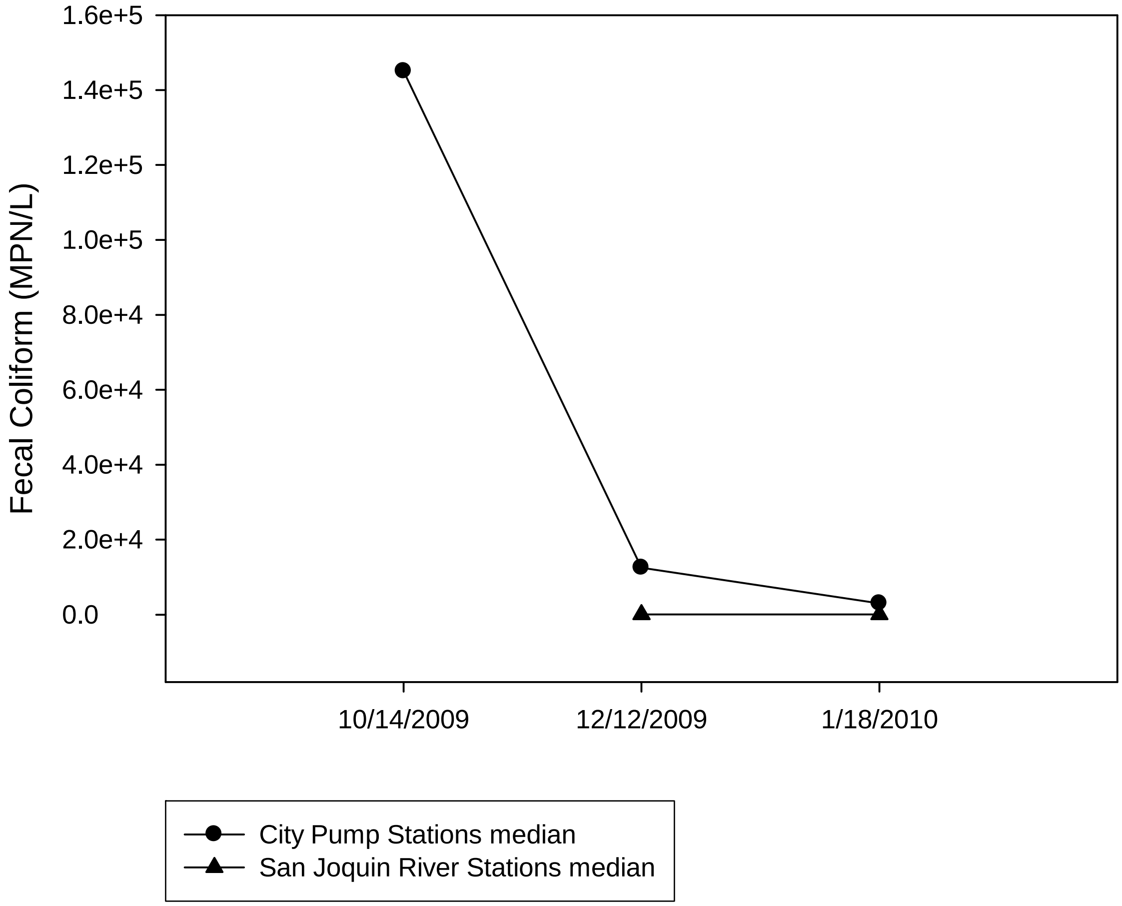


Figure A-41. Fecal Coliform Trends during the Season



Note: The samples for January 18, 2010 and January 20, 2010 have been combined because these two sampling dates represent one large storm. The San Joaquin River stations were not sampled during the October 14, 2009 event.

Figure A-42. ***E. coli*** **Boxplots of combined San Joaquin River Stations and Individual San Joaquin River Stations (n=3)**

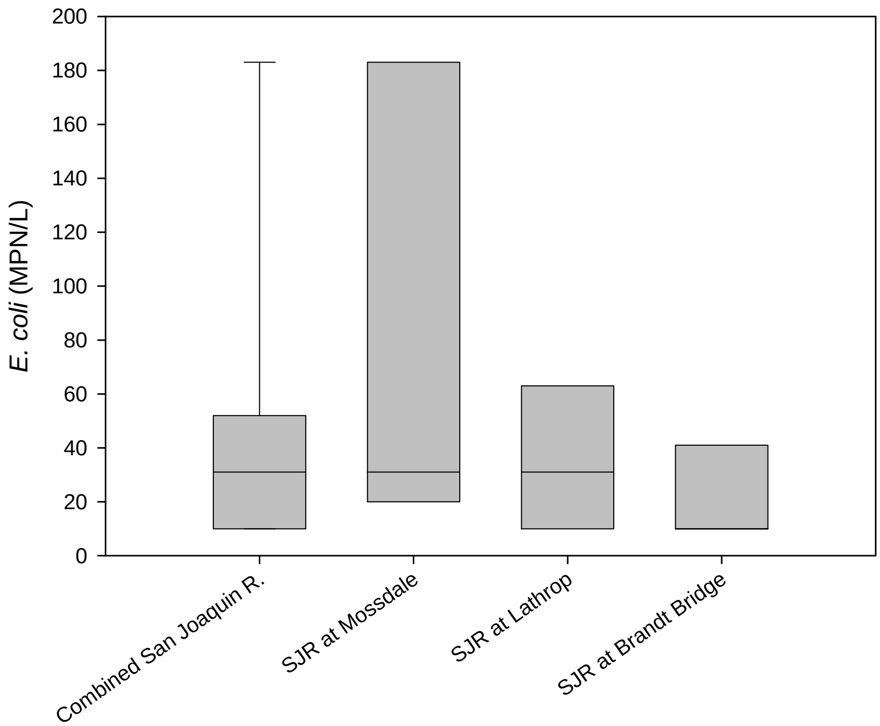


Figure A-43. ***E.coli*** **Boxplots of Combined City Pump Stations and Individual City Pump Stations (n=3-4 per station)**

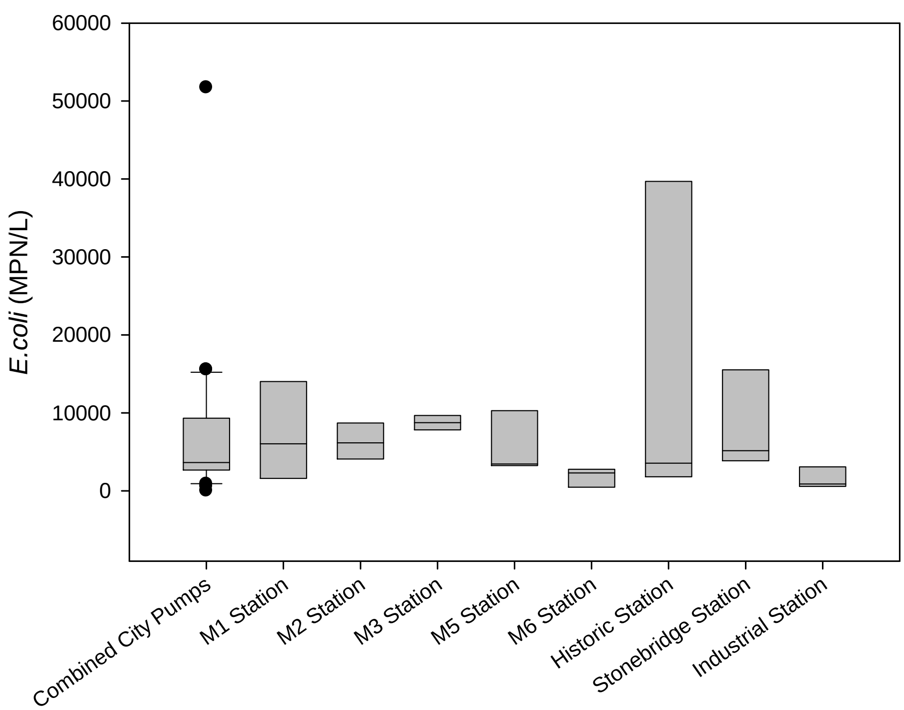
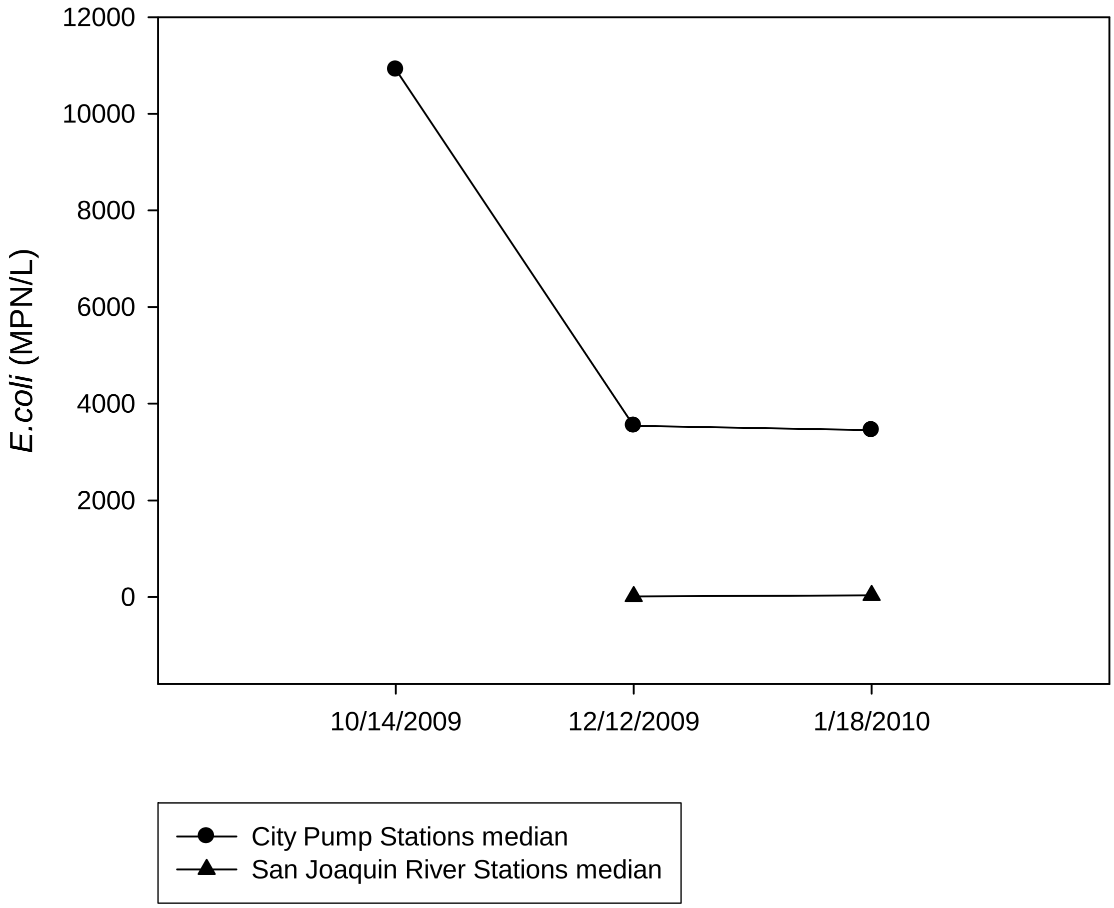


Figure A-44. *E.coli* Seasonal Trends during the Season



Note: The samples for January 18, 2010 and January 20, 2010 have been combined because these two sampling dates represent one large storm. The San Joaquin River stations were not sampled during the October 14, 2009 event.

Lathrop Summary Tables

Table A-1. Precipitation and Flows during Sampling Events

Date of Storm	Stonebridge Rain Gauge (in.)*	Historic Rain Gauge (in.)*	Range of San Joaquin River Flows at Mossdale (cfs)	Range of San Joaquin River Flows at Brandt Bridge (cfs)
10/13/-10/14/10	1.75	1.96	12 to 2111	-1202 to 2574
12/12-12/13/10	0.79	0.87	-515 to 2555	-1860 to 2330
1/17-1/20/10	1.73	1.82	-484 to 3894	-2300 to 2500

* Rain gauges located at the sampling sites are shown in Figure A-1

Table A-2. TOC Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L)	Median (mg/L)	Minimum (mg/L)	Maximum (mg/L)
SJR at Mossdale	3	3.0	2.9	2.8	3.4
SJR at Lathrop	3	2.8	2.9	2.7	2.9
SJR at Brandt Bridge	3	2.8	2.8	2.7	2.8
M1	4	7.6	6.5	6.0	11.3
M2	4	8.8	8.7	7.5	10.3
M3	4	6.3	6.6	3.9	8.0
M5	4	6.1	5.5	3.9	9.5
M6	3	6.0	5.8	4.9	7.4
Historic	4	7.4	7.5	5.2	9.5
Stonebridge	3	10.9	10.5	8.7	13.4
Industrial	3	4.8	4.0	3.8	6.6

Table A-3. DOC Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L)	Median (mg/L)	Minimum (mg/L)	Maximum (mg/L)
SJR at Mossdale	3	2.7	2.7	2.5	2.9
SJR at Lathrop	3	2.6	2.6	2.5	2.8
SJR at Brandt Bridge	3	2.5	2.5	2.4	2.6
M1	4	6.3	5.1	5.1	10
M2	4	7.4	7.0	6.5	9.1
M3	4	5.4	5.8	3.2	6.7
M5	4	5.3	5.2	3.1	7.8
M6	3	4.6	4.9	3.8	5.2
Historic	4	6.2	5.8	3.8	9.3
Stonebridge	3	9.5	9.6	7.6	11.3
Industrial	3	3.8	3.4	2.6	5.4

Table A-4. TOC Load

Station	Date of Storm Event			
	October 13, 2009	December 12, 2009	January 18, 2010	January 20, 2010
SJR at Mossdale	N/A	8838 kg/d	9011 kg/d	13144 kg/d
M1	N/A	2	N/A	N/A
M2	N/A	N/A	3	68
M3	N/A	18	30	15
M5	N/A	N/A	28	23
M6	N/A	N/A	4	11
Historic	76	86	79	95
Stonebridge	N/A	N/A	N/A	N/A
Industrial	N/A	N/A	N/A	N/A

Note: Some load data is not available due to unavailable pump data. Load from the pump stations is listed as total kilograms discharged. Pumping is not continuous, therefore showing kg/d of load is not an accurate representation of load. Load at the Mossdale station is an instantaneous load.

Table A-5. THMFP Summary Statistics for all Stations

Station	Sample Number (n)	Mean (ug/L)	Median (ug/L)	Minimum (ug/L)	Maximum (ug/L)
SJR at Mossdale	3	349.0	363.0	312.0	372.0
SJR at Lathrop	3	340.3	357.0	305.0	359.0
SJR at Brandt Bridge	3	431.7	362.0	311.0	622.0
M1	1	565.0	565.0	565.0	565.0
M2	3	664.0	709.0	539.0	744.0
M3	1	313.0	313.0	313.0	313.0
M5	3	567.3	625.0	334.0	743.0
M6	3	476.3	448.0	419.0	562.0
Historic	3	458.3	393.0	285.0	697.0
Stonebridge	3	905.0	929.0	572.0	1214.0
Industrial	3	415.0	413.0	224.0	608.0

Table A-6. HAAFP Summary Statistics for all Stations

Station	Sample Number (n)	Mean (ug/L)	Median (ug/L)	Minimum (ug/L)	Maximum (ug/L)
SJR at Mossdale	3	131.4	151.6	84.4	158.2
SJR at Lathrop	3	140.6	142.0	127.1	152.8
SJR at Brandt Bridge	3	132.0	133.8	103.4	158.9
M1	1	277.2	277.2	277.2	277.2
M2	3	571.6	678.0	259.0	778.0
M3	1	162.1	162.1	162.1	162.1
M5	3	177.9	160.8	160.5	212.5
M6	3	388.7	344.0	242.0	580.0
Historic	3	349.3	319.0	265.0	464.0
Stonebridge	3	887.3	864.0	812.0	986.0
Industrial	3	163.8	140.5	132.1	218.9

Table A-7. Regression Statistics for UVA_{254} with THMFP and DOC

	All Sites	San Joaquin River Stations	City Pump Stations
UVA_{254} and THMFP	$r^2=0.784$ $p<0.001$	$r^2<0.001$ $p=0.614$	$r^2=0.832$ $p<0.001$
UVA_{254} and DOC	$r^2=0.991$ $p<0.001$	$r^2=0.538$ $p=0.015$	$r^2=0.987$ $p<0.001$

Table A-8. SUVA Summary Statistics for all Stations

Station	Sample Number (n)	Mean	Median	Minimum	Maximum
SJR at Mossdale	3	0.0280	0.0286	0.0267	0.0288
SJR at Lathrop	3	0.0280	0.0277	0.0275	0.0288
SJR at Brandt Bridge	3	0.0291	0.0284	0.0281	0.0308
M1	4	0.0361	0.0368	0.0318	0.0388
M2	3	0.0334	0.0328	0.0321	0.0352
M3	3	0.0305	0.0313	0.0200	0.0403
M5	4	0.0319	0.0323	0.0273	0.0358
M6	3	0.0329	0.0329	0.0325	0.0333
Historic	4	0.0308	0.0307	0.0295	0.0323
Stonebridge	3	0.0330	0.0332	0.0325	0.0332
Industrial	3	0.0303	0.0300	0.0296	0.0313

Table A-9. EC Summary Statistics for all Stations

Station	Sample Number (n)	Mean (uS/cm)	Median (uS/cm)	Minimum (uS/cm)	Maximum (uS/cm)
SJR at Mossdale	3	805.0	789.0	778.0	848.0
SJR at Lathrop	3	840.3	846.0	811.0	864.0
SJR at Brandt Bridge	3	878.0	923.0	766.0	945.0
M1	4	1241.3	1202.0	931.0	1630.0
M2	4	435.5	432.5	165.0	712.0
M3	3	681.3	344.0	113.0	1587.0
M5	4	1232.3	1221.5	524.0	1962.0
M6	3	336.0	353.0	207.0	448.0
Historic	4	68.5	65.0	59.0	85.0
Stonebridge	3	206.7	160.0	134.0	326.0
Industrial	3	648.3	759.0	256.0	930.0

Table A-10. Total Dissolved Solids Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L)	Median (mg/L)	Minimum (mg/L)	Maximum (mg/L)
SJR at Mossdale	3	482.0	485.0	451.0	510.0
SJR at Lathrop	3	505.0	510.0	489.0	516.0
SJR at Brandt Bridge	3	537.7	558.0	470.0	585.0
M1	4	776.0	774.5	525.0	1030.0
M2	4	264.0	256.5	100.0	443.0
M3	3	387.3	190.0	62.0	910.0
M5	4	714.3	704.0	309.0	1140.0
M6	3	199.3	218.0	114.0	266.0
Historic	4	45.0	43.0	36.0	58.0
Stonebridge	3	130.0	115.0	74.0	201.0
Industrial	3	402.3	446.0	141.0	620.0

Table A-11. Bromide Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L)	Median (mg/L)	Minimum (mg/L)	Maximum (mg/L)
SJR at Mossdale	3	0.343	0.350	0.310	0.370
SJR at Lathrop	3	0.363	0.360	0.350	0.380
SJR at Brandt Bridge	3	0.390	0.420	0.330	0.420
M1	3	0.610	0.610	0.460	0.760
M2	3	0.138	0.140	0.010	0.260
M3	3	0.443	0.180	0.030	1.120
M5	3	0.718	0.720	0.250	1.180
M6	3	0.093	0.100	0.040	0.140
Historic	3	0.000	0.000	0.000	0.000
Stonebridge	3	0.013	0.000	0.000	0.040
Industrial	3	0.310	0.320	0.100	0.510

Table A-12. Bromide Loads

Station	Date of Storm Event			
	October 13, 2009	**December 12, 2009**	**January 18, 2010**	**January 20, 2010**
SJR at Mossdale	N/A	1167 kg/d	1087 kg/d	1198 kg/d
M1	N/A	<1	N/A	N/A
M2	N/A	N/A	<1	<1
M3	N/A	3	N/A	<1
M5	N/A	N/A	6	2
M6	N/A	N/A	<1	<1
Historic	<1	<1	<1	<1
Stonebridge	N/A	N/A	N/A	N/A
Industrial	N/A	N/A	N/A	N/A

Note: Some load data is not available due to unavailable pump data. Load from the pump stations is listed as total kilograms discharged. Pumping is not continuous, therefore showing kg/d of load is not an accurate representation of load. Load at the Mossdale station is an instantaneous load.

Table A-13. Ammonia Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L as N)	Median (mg/L as N)	Minimum (mg/L as N)	Maximum (mg/L as N)
SJR at Mossdale	3	0.033	0.030	0.030	0.040
SJR at Lathrop	3	0.033	0.040	0.020	0.040
SJR at Brandt Bridge	3	0.040	0.060	0.000	0.060
M1	4	0.173	0.170	0.110	0.240
M2	4	0.240	0.240	0.200	0.280
M3	4	0.373	0.370	0.310	0.440
M5	4	0.300	0.280	0.230	0.410
M6	3	0.167	0.170	0.150	0.180
Historic	4	0.425	0.420	0.420	0.440
Stonebridge	3	0.333	0.330	0.280	0.390
Industrial	3	0.330	0.310	0.290	0.390

Table A-14. Ammonia Loads

Station	Date of Storm Event			
	October 13, 2009	**December 12, 2009**	**January 18, 2010**	**January 20, 2010**
SJR at Mossdale	N/A	94 kg/d	93 kg/d	154 kg/d
M1	N/A	0.06	N/A	N/A
M2	N/A	N/A	0.07	1.6
M3	N/A	1	N/A	1.2
M5	N/A	N/A	1.1	1.7
M6	N/A	N/A	0.1	0.3
Historic	3	4.0	5.9	7.6
Stonebridge	N/A	N/A	N/A	N/A
Industrial	N/A	N/A	N/A	N/A

Note: some load data is not available due to unavailable pump data. Load from the pump stations is listed as kg/d, but pumping is not continuous. Load at the Mossdale station is an instantaneous load.

Table A-15. Dissolved Nitrate Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L as N)	Median (mg/L as N)	Minimum (mg/L as N)	Maximum (mg/L as N)
SJR at Mossdale	3	6.90	6.90	6.90	6.90
SJR at Lathrop	3	6.83	6.90	6.83	6.83
SJR at Brandt Bridge	3	7.47	8.00	7.47	7.47
M1	4	11.95	11.50	6.10	18.70
M2	4	4.73	4.65	1.90	7.70
M3	3	2.20	1.70	2.20	2.20
M5	4	2.20	2.20	2.20	2.20
M6	3	2.10	2.20	2.10	2.10
Historic	4	2.23	2.05	2.23	2.23
Stonebridge	3	5.50	4.40	5.50	5.50
Industrial	3	1.90	1.40	1.30	3.00

Table A-16. Total Nitrogen Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L as N)	Median (mg/L as N)	Minimum (mg/L as N)	Maximum (mg/L as N)
SJR at Mossdale	3	1.80	1.80	1.70	1.90
SJR at Lathrop	3	1.93	1.90	1.90	2.00
SJR at Brandt Bridge	3	1.97	2.10	1.60	2.20
M1	4	3.69	3.55	3.20	4.40
M2	4	1.97	2.07	1.14	2.60
M3	4	1.30	1.17	1.01	1.85
M5	4	1.37	1.34	1.09	1.71
M6	3	1.11	1.10	1.01	1.21
Historic	4	1.72	1.68	1.34	2.20
Stonebridge	3	3.80	2.53	1.87	7.00
Industrial	3	1.24	1.26	1.05	1.41

Table A-17. Total Nitrogen Loads

Station	Date of Storm Event			
	October 13, 2009	**December 12, 2009**	**January 18, 2010**	**January 20, 2010**
SJR at Mossdale	N/A	5365 kg/d	5593 kg/d	7345 kg/d
M1	N/A	2	N/A	N/A
M2	N/A	N/A	<1	9
M3	N/A	4	N/A	4
M5	N/A	N/A	6	8
M6	N/A	N/A	<1	2
Historic	18	16	21	24
Stonebridge	N/A	N/A	N/A	N/A
Industrial	N/A	N/A	N/A	N/A

Note: Some load data is not available due to unavailable pump data. Load from the pump stations is listed as total kilograms discharged. Pumping is not continuous, therefore showing kg/d of load is not an accurate representation of load. Load at the Mossdale station is an instantaneous load.

Table A-18. Dissolved Orthophosphate Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L as P)	Median (mg/L as P)	Minimum (mg/L as P)	Maximum (mg/L as P)
SJR at Mossdale	3	0.070	0.070	0.060	0.080
SJR at Lathrop	3	0.077	0.080	0.060	0.090
SJR at Brandt Bridge	3	0.077	0.080	0.060	0.090
M1	4	0.195	0.195	0.180	0.210
M2	4	0.165	0.165	0.130	0.200
M3	4	0.065	0.065	0.040	0.090
M5	4	0.078	0.055	0.040	0.160
M6	3	0.100	0.100	0.070	0.130
Historic	4	0.110	0.115	0.080	0.130
Stonebridge	3	0.200	0.230	0.130	0.240
Industrial	3	0.117	0.140	0.050	0.160

Table A-19. Total Phosphorus Summary Statistics for all Stations

Station	Sample Number (n)	Mean (mg/L as P)	Median (mg/L as P)	Minimum (mg/L as P)	Maximum (mg/L as P)
SJR at Mossdale	3	0.167	0.170	0.130	0.200
SJR at Lathrop	3	0.150	0.160	0.130	0.160
SJR at Brandt Bridge	3	0.113	0.120	0.080	0.140
M1	4	0.323	0.320	0.260	0.390
M2	4	0.300	0.265	0.210	0.460
M3	4	0.135	0.140	0.100	0.160
M5	4	0.148	0.125	0.090	0.250
M6	3	0.187	0.170	0.170	0.220
Historic	4	0.275	0.250	0.160	0.440
Stonebridge	3	0.347	0.350	0.320	0.370
Industrial	3	0.207	0.180	0.120	0.320

Table A-20. Total Phosphorus

Station	Date of Storm Event			
	October 13, 2009	**December 12, 2009**	**January 18, 2010**	**January 20, 2010**
SJR at Mossdale	N/A	410 kg/d	528 kg/d	773 kg/d
M1	N/A	<1	N/A	N/A
M2	N/A	N/A	<1	2
M3	N/A	<1	N/A	<1
M5	N/A	N/A	<1	1
M6	N/A	N/A	<1	<1
Historic	3	2	4	4
Stonebridge	N/A	N/A	N/A	N/A
Industrial	N/A	N/A	N/A	N/A

Note: Some load data is not available due to unavailable pump data. Load from the pump stations is listed as kg/d, but pumping is not continuous. In parentheses are kilograms of TOC discharged during the storm. Load at the Mossdale station is an instantaneous load.

Table A-21. Total Coliforms

Station	Sample Number (n)	Mean	Median	Minimum	Maximum
SJR at Mossdale	3	3.83E+03	2.20E+03	1.30E+03	8.00E+03
SJR at Lathrop	3	3.48E+03	2.20E+03	2.30E+02	8.00E+03
SJR at Brandt Bridge	3	1.70E+03	2.30E+03	5.00E+02	2.30E+03
M1	4	2.63E+05	1.25E+05	2.30E+03	8.00E+05
M2	4	1.27E+05	9.00E+04	2.80E+04	3.00E+05
M3	4	1.20E+05	7.50E+04	3.00E+04	3.00E+05
M5	4	1.76E+05	7.70E+04	5.00E+04	5.00E+05
M6	4	2.78E+06	5.50E+04	5.00E+03	1.10E+07
Historic	4	1.91E+04	1.20E+05	2.30E+04	5.00E+05
Stonebridge	3	3.43E+04	3.00E+04	2.30E+04	5.00E+04
Industrial	3	1.77E+05	1.70E+04	1.40E+04	5.00E+05

Table A-22. Fecal Coliforms

Station	Sample Number (n)	Mean	Median	Minimum	Maximum
SJR at Mossdale	3	117	30	22	300
SJR at Lathrop	3	34	50	4	50
SJR at Brandt Bridge	3	43	50	30	50
M1	4	61150	36150	2300	170000
M2	4	42500	23500	3000	120000
M3	4	52535	20000	140	170000
M5	4	34250	6000	5000	120000
M6	4	18371	1705	75	70000
Historic	4	131525	12500	1100	500000
Stonebridge	3	13666	8000	3000	30000
Industrial	3	8800	2300	1100	23000

Table A-23. *E.coli*

Station	Sample Number (n)	Mean	Median	Minimum	Maximum
SJR at Mossdale	3	78	31	20	183
SJR at Lathrop	3	34	31	10	63
SJR at Brandt Bridge	3	20	10	10	41
M1	4	7223	6035	1291	15531
M2	4	6331	6171	3654	9330
M3	4	8749	8747	7701	9804
M5	4	5666	3454	3255	12500
M6	4	1851	2302	20	2780
Historic	4	15022	3543	1281	51720
Stonebridge	3	8192	5172	3873	15531
Industrial	3	1507	882	565	3076

Appendix B

Data Quality Control

This data quality review covers the sample dates listed in Table B-1 from November 2010 through March 2012. Data from 6 stations were collected through the Municipal Water Quality Investigation Program during this reporting period. The data review was performed using the available quality control data stored in the California Department of Water Resources' Bryte Laboratory - Field and Laboratory Information Management System database. This database was used to retrieve data from Bryte Laboratory and Wech Chemical Laboratory that was outside the established control limits. Both labs are certified by the U.S. Environmental Protection Agency and the Department of Public Health's Environmental Laboratory Accreditation Program. The data quality review indicated that the Lathrop study data from 2010 through 2012 was in acceptable quality overall. A few analyses were outside the control limits, but they were not considered to have a significant impact on the overall data quality of the project. The results of the review are presented in Table B-2 and Table B-3.

Table B-1. Sample Dates

	Sample Date	Run	Submittal ID
Season 2	11/7/2010	Lathrop Urban Runoff Boat	CI1010B0039
	11/8/2010	Lathrop Urban Runoff East	CI1010B0040
	11/8/2010	Lathrop Urban Runoff West	CI1010B0041
	11/20/2010	Lathrop Urban Runoff Boat	CD1110B0266
	11/21/2010	Lathrop Urban Rnoff East	CB1110B0001
	11/21/2010	Lathrop Urban Runoff West	CB1110B0002
	12/18/2010	Lathrop Urban runoff Boat	CB1210B0003
	12/19/2010	Lathrop Urban Runoff East	CD1210B0277
	12/19/2010	Lathrop Urban Runoff West	CD1210B0278
	3/19/2011	Lathrop Urban Runoff Boat	CD0311B0023
	3/21/2011	Lathrop Urban Runoff East	CD0311B0024
	3/21/2011	Lathrop Urban Runoff West	CD0311B0027
	3/24/2011	Lathrop Urban Runoff Boat	CA0311B0015
	3/25/2011	Lathrop Urban Runoff East	CA0211B0010
	3/25/2011	Lathrop Urban Runoff West	CA0211B0012
	6/4/2011	Lathrop Urban Runoff Boat	CD0611B0028
	6/5/2011	Lathrop Urban Runoff East	CD0611B0030
	6/5/2011	Lathrop Urban Runoff West	CD0611B0031
Season 3	10/5/2011	Lathrop Urban Runoff Boat	CR1011B0001
	10/6/2011	Lathrop Urban Runoff East	CR1011B0007
	10/6/2011	Lathrop Urban Runoff West	CR1011B0008
	1/20/2012	Lathrop Urban Runoff Shore	CR0112B0006
	1/21/2012	Lathrop Urban Runoff	CR0112B0005
	3/14/2012	Lathrop Urban Runoff Shore	CR0312B0077
	3/16/2012	Lathrop Urban Runoff	CR0312B0078

Table B-2. Total Internal Quality Control Batches

Analyte	Method	LCS Recovery	RPD-LCS Duplicate	Matrix Spike	RPD- Matrix spike duplicate	Method Blank
2-Bromo-1-chloropropane	DWR THMFP (Buffered)					6
Azinphos methyl (Guthion)	EPA 614					27
Benfluralin	EPA 614					27
BHC-alpha	EPA 608					27
BHC-beta	EPA 608					27
BHC-delta	EPA 608					27
Bromacil	EPA 614					27
Captan	EPA 608					27
Chlordane	EPA 608					27
Chlorothalonil	EPA 608					27
	EPA 614					27
Conductance (EC)	Std Method 2510-B					25
	EPA 608					27
Cyfluthrin	Pyrethroids - GC/MS NCI-SIM					8
Dacthal (DCPA)	EPA 608					27
Demeton (Demeton O + Demeton S)	EPA 614					27
Diazinon	EPA 614					27
	EPA 608					27
Dicofol	EPA 608					27
Dimethoate	EPA 614					27
Diuron	EPA 608					27
Endosulfan sulfate	EPA 608					27
Endosulfan-I	EPA 608					27
Endosulfan-II	EPA 608					27
Endrin	EPA 608					27
Endrin aldehyde	EPA 608					27
	EPA 614					27
Ethion	EPA 614					27
Heptachlor epoxide	EPA 608					27
Malathion	EPA 614					27
Methidathion	EPA 614					27
Methoxychlor	EPA 608					27
Mevinphos	EPA 614					27
	DWR HAAFP (Buffered)					13
Naled	EPA 614					27

Analyte	Method	LCS Recovery	RPD-LCS Duplicate	Matrix Spike	RPD- Matrix spike duplicate	Method Blank
Napropamide	EPA 614					27
o,p'-DDE	EPA 608					27
Oxyfluorfen	EPA 608					27
p,p'-DDD	EPA 608					27
p,p'-DDE	EPA 608					27
p,p'-DDT	EPA 608					27
PCB-1016	EPA 608					27
PCB-1221	EPA 608					27
PCB-1232	EPA 608					27
PCB-1242	EPA 608					27
PCB-1248	EPA 608					27
PCB-1254	EPA 608					27
PCB-1260	EPA 608					27
	EPA 614					27
Pentachloronitrobenzene (PCNB)	EPA 608					27
	EPA 608					27
pH	Std Method 2320 B					25
Phosalone	EPA 614					27
Phosmet	EPA 614					27
Profenofos	EPA 614					27
Prometryn	EPA 614					27
Propetamphos	EPA 614					27
s,s,s-Tributyl Phosphorotrithioate (DEF)	EPA 614					27
Simazine	EPA 608					27
Solids	EPA 160.2					25
	Std Method 2540 C					25
Thiobencarb	EPA 608					27
	EPA 614					27
Toxaphene	EPA 608					27
Yttrium	EPA 200.7 (D)					12

Table B-3. Matrix Spike and LCS Recovery Exceedance

Quality Control Measure Name	Analyte	Method	Total Batches	Method Out of Limit	Recovery (%)	Control Limits (%)	Units
Matrix spike	Kjeldahl Nitrogen	EPA 351.2	52	3	136.3	70-130	mg/L as N
Matrix spike	Kjeldahl Nitrogen	EPA 351.2	52	3	136.3	70-130	mg/L as N
Matrix spike	Kjeldahl Nitrogen	EPA 351.2	52	3	136.3	70-130	mg/L as N
Matrix spike	Calcium	EPA 200.7 (D)	80	2	21.93	80-120	mg/L
Matrix spike	Calcium	EPA 200.7 (D)	80	2	18.93	80-120	mg/L
LCS - Recovery	Deltamethrin/ Tralomethrin	Pyrethroids - GC/MS NCI-SIM	13	6	16.42	35-137	ng/L
LCS - Recovery	Deltamethrin/ Tralomethrin	Pyrethroids - GC/MS NCI-SIM	13	6	14.94	35-137	ng/L
LCS - Recovery	Deltamethrin/ Tralomethrin	Pyrethroids - GC/MS NCI-SIM	13	6	16.42	35-137	ng/L
LCS - Recovery	Deltamethrin/ Tralomethrin	Pyrethroids - GC/MS NCI-SIM	13	6	14.94	35-137	ng/L
LCS - Recovery	Deltamethrin/ Tralomethrin	Pyrethroids - GC/MS NCI-SIM	13	6	16.42	35-137	ng/L
LCS - Recovery	Deltamethrin/ Tralomethrin	Pyrethroids - GC/MS NCI-SIM	13	6	14.94	35-137	ng/L
LCS - Recovery	Dibromochloro methane	Std Method 5710B/EPA 524.2	58	6	67.33	70-130	µg/L
LCS - Recovery	Dibromochloro methane	Std Method 5710B/EPA 524.2	58	6	64.17	70-130	µg/L
LCS - Recovery	Dibromochloro methane	Std Method 5710B/EPA 524.2	58	6	67.33	70-130	µg/L
LCS - Recovery	Dibromochloro methane	Std Method 5710B/EPA 524.2	58	6	64.17	70-130	µg/L
LCS - Recovery	Dibromochloro methane	Std Method 5710B/EPA 524.2	58	6	64.17	70-130	µg/L
LCS - Recovery	Dibromochloro methane	Std Method 5710B/EPA 524.2	58	6	67.33	70-130	µg/L