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Evaluation of the Environmental Impacts of Bridge Deck Runoff – Preliminary Draft

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16. Abstract

Bridges are located in very close proximity to receiving waters, and regulatory agencies often require specific stormwater control measures for bridge deck runoff. While there is some information available on roadway runoff, few studies have focused on bridge deck runoff. Currently, there is no information available regarding the impacts of bridge deck runoff on receiving waters in Nebraska. Due to the cost, maintenance, and design issues associated with implementing structural controls for bridge deck runoff, it is important to develop a better understanding of the relationship between bridge deck runoff and potential impacts to receiving streams. The objectives of this research were to evaluate the quality of bridge deck runoff; to determine the effects of bridge deck runoff on surface water bodies in Nebraska by evaluating water and sediment chemistry; and to evaluate the effects of bridge deck runoff on aquatic life. The goal was to identify the potential environmental impacts of bridge deck runoff on receiving streams, and to determine design criteria that could be used by NDOR or regulatory agencies to identify when structural controls for bridge deck runoff may be necessary to protect in-stream water quality and aquatic life. Throughout the course of the project, we conducted in-stream dry weather sampling, sediment sampling, wet weather bridge runoff sampling, and preliminary toxicity testing. Statistical analysis of upstream and downstream in-stream samples showed that bridges did not impact the quality of the water body. Sediment sampling did not show an increase in streambed sediment concentrations from downstream to upstream. The concentrations of bridge runoff samples were higher than literature event mean concentration (EMC) values. This was mainly due to the fact that the summer of 2012 had only two rain events of significant size and there was a large antecedent dry period (ADP) between storms, making the samples much more concentrated. Two runoff events were also used in a 48-hour 5 dilution series toxicity test with fat head minnows, and no negative effects were found. These preliminary results show that there were no apparent effects of bridges on water quality and aquatic life.

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List of Abbreviations

ADP	Antecedent Dry Period
ADT	Average Daily Traffic
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CMA	Calcium Magnesium Acetate
COD	Chemical Oxygen Demand
DOT	Department of Transportation
DO	Dissolved Oxygen
EMC	Event Mean Concentration
HEM	Hexane Extractable Materials
HDPE	High Density Polyethylene
MTBE	Methyl Tert-Butyl Ether
MATC	Mid-America Transportation Center
NCHRP	National Cooperative Highway Research Program
NDOR	Nebraska Department of Roads
PAH	Polycyclic Aromatic Hydrocarbon
PVC	Polyvinyl Chloride
SFOBB	San Francisco-Oakland Bay Bridge
SVOC	Semi-volatile Organic Compound
SCMs	Stormwater Control Measures
TAC	Technical Advisory Committee
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UNL	University of Nebraska – Lincoln
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	Volatile Organic Compound

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Disclaimer

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Abstract

Bridges are located in very close proximity to receiving waters, and regulatory agencies often require specific stormwater control measures for bridge deck runoff. While there is some information available on roadway runoff, few studies have focused on bridge deck runoff. Currently, there is no information available regarding the impacts of bridge deck runoff on receiving waters in Nebraska. Due to the cost, maintenance, and design issues associated with implementing structural controls for bridge deck runoff, it is important to develop a better understanding of the relationship between bridge deck runoff and potential impacts to receiving streams. The objectives of this research were to evaluate the quality of bridge deck runoff; to determine the effects of bridge deck runoff on surface water bodies in Nebraska by evaluating water and sediment chemistry; and to evaluate the effects of bridge deck runoff on aquatic life. The goal was to identify the potential environmental impacts of bridge deck runoff on receiving streams, and to determine design criteria that could be used by NDOR or regulatory agencies to identify when structural controls for bridge deck runoff may be necessary to protect in-stream water quality and aquatic life. Throughout the course of the project, we conducted in-stream dry weather sampling, sediment sampling, wet weather bridge runoff sampling, and preliminary toxicity testing. Statistical analysis of upstream and downstream in-stream samples showed that bridges did not impact the quality of the water body. Sediment sampling did not show an increase in streambed sediment concentrations from downstream to upstream. The concentrations of bridge runoff samples were higher than literature event mean concentration (EMC) values. This was mainly due to the fact that the summer of 2012 had only two rain events of significant size and there was a large antecedent dry period (ADP) between storms, making the samples much more concentrated. Two runoff events were also used in a 48-hour 5 dilution

series toxicity test with fat head minnows, and no negative effects were found. These preliminary results show that there were no apparent effects of bridges on water quality and aquatic life.

Executive Summary

Although highways and bridge surfaces often comprise a small portion of the overall area within a watershed, they are often identified as a major contributor to stormwater runoff. In particular, bridges are located in very close proximity to receiving waters, and regulatory agencies often require specific stormwater control measures for bridge deck runoff. For example, bridges are often required to have closed decks or catchment systems that direct stormwater runoff to vegetated areas prior to discharge. While there is some information available on roadway runoff, few studies have focused on bridge deck runoff. Currently, there is no information available regarding the impacts of bridge deck runoff on receiving waters in Nebraska. Due to the cost, maintenance, and design issues associated with implementing structural controls for bridge deck runoff, it is important to develop a better understanding of the relationship between bridge deck runoff and potential impacts to receiving streams.

The objectives of this research were to evaluate the quality of bridge deck runoff, and to determine the effects of bridge deck runoff on surface water bodies in Nebraska by evaluating water and sediment chemistry as well as effects on aquatic life. The goal was to identify the potential environmental impacts of bridge deck runoff on receiving streams, and to determine design criteria that can be used by NDOR or regulatory agencies to identify when structural controls for bridge deck runoff may be necessary to protect in-stream water quality and aquatic life.

Chapter 1 Literature Review

1.1 Introduction

Since the passage of the Clean Water Act in 1972 and the Endangered Species Act in 1973, momentum has increased toward protecting native wildlife and the nation's water bodies. The mitigation of roadway and bridge deck runoff is important for the maintenance of water quality in surface water bodies. Currently, the Nebraska Department of Roads (NDOR) is interested in the effects of runoff from bridges. The following literature review was conducted to address that subject. The majority of transportation runoff studies cover highway runoff, while very few focus on bridge runoff. The current literature review focused primarily on literature pertaining to bridge runoff and water quality. Literature on highway runoff was also reviewed to compare and expand upon the results obtained from studies conducted on bridges. This review covered the types and concentrations of contaminants found in bridge runoff, as well as the effects of these contaminants on aquatic organisms, and the factors affecting the water quality attributes of bridge and highway runoff.

1.2 Bridge Runoff Studies

The number of previous studies available on highway runoff far exceeds those conducted on bridge runoff. A bridge runoff study conducted by the URS Corporation in North Carolina concluded that this was due to the fact that stormwater runoff from bridges is not significantly different than stormwater runoff from roadways, and usually occurs in much less volume than stormwater originating from large stretches of highway (URS 2010). The National Cooperative Highway Research Program (NCHRP) argued the opposite in their Report 474, pointing out that bridges are restricted in dimension and slope, decreasing the opportunity for implementing best management practices (BMPs) and safely managing those that are applicable (Dupuis 2011).

Unlike roadways, bridges cannot include BMPS along the roadway such as grass swales to filter out sediment. There is also the concern of adding gutters to bridges to divert the runoff to the stream banks where they can be filtered before reaching the stream. If the gutters are not cleaned regularly, ponding can occur, which in winter months will freeze and be a safety hazard. The divergent viewpoints expressed in these two recent reports highlight the need for additional information on bridge runoff and its effects on surface waters. A summary of the major conclusions from these two reports follows, as they were found to be the most informative resources on bridge runoff.

1.2.1 NCHRP Report 474 – Assessing the Impacts of Bridge Deck Runoff Contaminants on Receiving Waters - Volume 1: Final Report

NCHRP Report 474 consisted of three parts: an extensive literature review, a department of transportation survey, and a salt water and fresh water bridge runoff study. The literature review reported that bridges with very low traffic—specifically, average daily traffic (ADT) less than 30,000 vehicles per day—yielded no noticeable effects on their respective receiving water bodies. Bridges with very high traffic (ADT greater than 180,000 vehicles per day) had only slight effects on receiving water bodies. The investigators found an issue with the bioassays performed in previous studies in that many were conducted over long periods of time, as opposed to during the duration of a typical storm. This method causes results to be skewed toward the runoff being more toxic than it actually is, which makes it difficult to compare final toxicity findings across studies. Some toxicity was noted after exposure to 100 % bridge runoff using a toxicity testing duration equal to the duration of a typical storm. Observed toxicity increased when the exposure duration consisted of the typical seven-day chronic test used by most of the reviewed studies. It was recommended that future studies bioassay experiments should be conducted for exposure times equal to storm durations typical for the area.

In the same study, it was reported that, of the departments of transportation (DOT) in the 50 states, Washington, D. C., and the Canadian provinces that were surveyed regarding stormwater control measures (SCMs), 16 of 29 responding DOTs either already had or were proposing structural mitigation systems. These mainly consisted of diverting stormwater runoff to land for natural filtration, rather than direct discharge into the water body.

The researchers also tested bridge runoff at two locations: the San Francisco-Oakland Bay Bridge and the I-85 and Mallard Creek Bridge in North Carolina. During the testing, it was noted that runoff falling to the stream from the bridge scupper drains was quickly mixed and diluted in the receiving water. It was suggested that variable rates of dilution, as well as potentially pre-existing toxicity in upstream water, could impact test results, thus indicating that bridge runoff should be considered on a bridge-by-bridge basis. Bridges with slower rates of mixing and dilution would be more likely to display negative effects from runoff. In runoff samples, the only contaminant concentrations that exceeded acceptable limits were copper, lead, and zinc, the values of which are given in table 1.1. The lead concentration for I-85 runoff is included in the table, but it did not exceed the criteria for acceptable limits.

Table 1.1 Comparison of runoff pollutants in San Francisco-Oakland Bay Bridge (SFOBB) and I-85 and Mallard Creek (I-85) that exceeded aquatic life water quality criteria

Pollutant	SFOBB Runoff Average (μg/L)	Aquatic Life Water Quality Criteria (μg/L) – San Francisco Bay (1 hour max/4 day max)	I-85 Runoff Average (μg/L)	Aquatic Life Water Quality Criteria (μg/L) – North Carolina
Copper	195	4.9/-	57	13 (acute)/ 9.0 (chronic)[a]
Lead	103	140/5.6	*17*[c]	*25*[c]
Zinc	555	170 (max[b])/58(24 hour)	278	120 (acute)/ 120 (chronic)[a]

[a]National U.S. EPA criteria at 100 mg/L hardness (as $CaCO_3$).
[b]Instantaneous maximum.
[c]Values are included in the table, but runoff concentration did not exceed water quality criteria.

1.2.2 URS – Stormwater Runoff from Bridges: Final Report

The Bridge Stormwater Project began in November of 2008 as a result of the state government of North Carolina passing a bill requiring the North Carolina DOT to study the effects of runoff from bridges. One-hundred-fifty experts from state and federal agencies in North Carolina, along with several private companies, joined together to make the project possible. The first phase of the project involved studying the impact of bridge runoff on streams. Thirty-four bridge sites varying in characteristics such as traffic load, ecoregion, bridge deck surface material, and rural or urban usage, were selected. Each site was evaluated for bridge deck runoff quality and quantity, stream quality and quantity, streambed sediment, bioassay, biosurvey, and traffic testing. The second phase of the project involved an assessment of the capability of over 50 of the state's SCMs to control bridge runoff. The cost of installing SCMs on new or existing bridges was also estimated.

The concentrations of all pollutants from the bridge runoff were similar to that of highway runoff values. The values that exceeded a similar study of highway runoff in North

Carolina are given in table 1.2. The researchers found a minimal effect of runoff on the studied water bodies, leading to the conclusion that the state's current methods for handling stormwater on bridges was effective. These results were consistent with the literature review conducted for the Bridge Stormwater Project study, where few significant problems were identified as resulting from bridge deck runoff.

Table 1.2 Typical median event mean concentrations (EMCs) of North Carolina (NC) bridge deck runoff exceeding that of highway runoff

Parameter (units)	NC Bridge Runoff Study	NC Highway Runoff Study
Total recoverable zinc (µg/L)	65.9	30
Total suspended solids (mg/L)	39	18
Chloride (mg/L)	0.81	0.79
Orthophosphate (mg/L-P)	0.019	0.01
Total nitrogen (mg/L-N)	0.97	0.81

1.3 Pollutants in Highway and Bridge Runoff

Highway and bridge runoff can contain a number of constituents, including salts, metals, organic compounds, and bacteria. Figure 1.1 lists the sources of pollutants that are often found in stormwater runoff from highways and bridges (URS 2010). These constituents are either attached to sediment particles, suspended in the water column, or dissolved.

Parameter	Sources in the Highway Environment
Bromide	Exhaust
Cadmium	Tire wear, insecticides
Chloride	Deicing salts
Chromium	Metal plating, moving engine parts, brake lining wear
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cyanide	Anti-cake compound used to keep deicing salt granular
Fecal coliform, E. coli (indicators)	Soil, litter, bird droppings, livestock and stockyard waste hauling
Iron	Rust (automobile body and bridge structure), moving engine parts
Lead	Bearing and tire wear, oil and grease
Manganese	Moving engine parts
Nickel	Diesel fuel and gasoline (exhaust), lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Nitrogen	Atmosphere, fertilizer application
Particulates	Pavement wear, vehicles, atmosphere, maintenance
Petroleum	Spills, motor lubricants, antifreeze and hydraulic fluids, leachate from asphalt surfaces
Phosphorus	Atmosphere, fertilizer application
Polychlorinated Biphenyls (PCBs), pesticides	Applying pesticides to highway rights-of-way, background atmospheric deposition, PCB catalyst in synthetic tires
Sodium, calcium	Deicing salts, grease
Sulfate	Roadway beds, fuel, deicing salts
Zinc	Tire wear, motor oil, grease

Source: Table from URS (2010)

Figure 1.1 Sources of common highway runoff parameters

Sediments can cause two types of environmental concerns. First, if suspended solids concentrations become too high, the effect can be to inhibit the diversity of organisms that are important to a stream's ecosystem (McNeill and Olley 1998). Sediments in all types of water bodies have been found to bury fish eggs and disrupt organism diversity and the natural food chain (Buckler and Granato 1999). In a (1995) study conducted in the United Kingdom, it was found that the survival of benthic organisms consistently decreased when the organisms were in contact with sediment washed into surface water with highway stormwater. In an experiment, small crustaceans, *Gammarus pulex*, were exposed to a) sediment collected upstream and downstream of the bridge, and b) treated sediment collected downstream. Exposure to the downstream sediment resulted in an average survival rate of 90%, while exposure to the upstream sediment resulted in a 96% survival rate (Maltby et al. 1995).

The second issue with sediments is that they provide a medium of transport for other pollutants, making sediment a cause for concern in runoff. A change in total suspended solids (TSS) concentration is linked to storm characteristics. Rainfall intensity can mobilize and flush TSS from bridge decks, and can also cause bursts of higher concentrations of other contaminants throughout a storm (Han et al. 2006). Metal concentrations found to increase in sediment from highway runoff have included total zinc (Kayhanian et al. 2003; URS 2010), copper (McNeill and Olley 1998; Pontier et al. 2001), lead (Yousef et al. 1982; Patel and Drieu 2005), and chromium (Patel and Drieu 2005). Other contaminants correlated with an increase in metals in sediment include oil and grease (Kayhanian et al. 2003), TSS (Kayhanian et al. 2003; Li et al. 2008), total phosphorus (TP) (Kayhanian et al. 2003), bacteria (Kayhanian et al. 2003), and polycyclic aromatic hydrocarbons (PAHs) (Lau et al. 2009). In a study conducted in Los Angeles, it was found that BMPs that removed TSS also efficiently removed metals and PAHs

(Lau et al. 2009). Another study conducted in the UK tested the effectiveness of several natural structures at treating runoff. It was found that after runoff flowed through a silt trap and a wetland, TSS had decreased from approximately 65 mg/L to 19 mg/L. The researchers also noted that as TSS decreased, metals that were found in the solid form also decreased (Pontier et al. 2001). In a (1998) bridge runoff study conducted in Scotland, the only metal associated with suspended solids that was of concern was zinc, which reached a maximum concentration of 0.132 mg/L, most likely due to the application of road salts in the winter (McNeill and Olley 1998). In a Florida bridge runoff study with an ADT of 47,500 vehicles per day eastbound and 53,000 vehicles per day westbound, lead was found to have the highest ratio of runoff concentration to lake concentration, at 20.3:1. It was generally in solid form and settled out around the scupper drains (Yousef et al. 1982).

Other contaminants identified in runoff but not associated with sediment include dissolved metals, hardness, and total dissolved solids (TDS). These constituents have been found to be more greatly affected by the diluting properties of larger storms (Kayhanian et al. 2003). The dissolved metal fraction is the quantity of metals in a sample that are smaller than a 0.45 micrometer filter (Dupuis 2011). In the aforementioned NCHRP study, copper and zinc were the metals with the highest concentrations in undiluted runoff (Dupuis 2011). An earlier highway runoff study came to similar conclusions (Kayhanian et al. 2008). Pontier et al. (2001) found that iron and zinc were the only metals that were present in dissolved form in bridge runoff.

Bridge and road maintenance activities include the application of salts in the winter (Dupuis 2002). Studies have shown that salts are transported from roadways more slowly than expected, so they will result in effects further downstream, and in the summer months when there is more organism activity. Alternatives to salt are being studied, but most are expensive and can have negative effects on the environment, such as calcium magnesium acetate (CMA), which can increase biochemical oxygen demand (BOD). The best alternative is to use salt more efficiently while not compromising driver safety (Findlay and Kelly 2011).

Organic compounds are often split into two categories: semi-volatile organic compounds (SVOCs) and volatile organic compounds (VOCs). Some examples of SVOCs are petroleum hydrocarbons, oil, grease, PAHs, and BTEX compounds (Benzene, Toluene, Ethylbenzene, and Cylene). BTEX compounds reach streams and groundwater through petroleum spills and leaks on highways. PAHs can be formed from the incomplete combustion of fuel. One study determined that the amount of PAHs in the sampled runoff was proportional to the amount of engine exhaust in the air; it was concluded that a majority of PAHs were the result of fuel combustion in vehicles (Lau et al. 2009). PAHs have a tendency to attach to particulates in the air and in water, which has implications for their transport in the environment (Buckler and Granato 2011). VOCs consist of mono-aromatic petroleum compounds and fuel additives such as methyl tert-butyl ether (MTBE). MTBE is added to make fuel burn more cleanly. It is extremely soluble, but biodegrades very slowly, making it more commonly detected in streams and groundwater. (Buckler and Granato 2011). The biological effects of these organic constituents may be of importance due to the observed increase of their concentrations in runoff (Buckler and Granato 2011). Table 1.3 compares the average concentrations of these and previously mentioned contaminants identified in the literature review in both bridge and highway runoff.

Table 1.3 Average EMCs of bridge and highway runoff studies analyzed in the literature review

	Bridge Studies						**Highway Studies**								
	Dupuis[a] 2002 NCHRP 474	**Kim et al. 2007**	**Pontier et al. 2001[b]**	**McNeill and Olley 1998**	**Yousef et al. 1982**	**URS 2010**	**Lau et. al. 2009**	**Boisson et al. 2005**	**Li et al. 2008 College Station, TX**	**Li et al. 2008 Austin, TX**	**Kayhanian et al. 2003**	**Crabtree et al. 2006**	**Huang et al. 2005**	**Kayhanian et al. 2008**	**USEPA 1983 (NURP-Urban Runoff)**
Number of Sites (n)	n= 1/1	n= 1	n= 1	n= 11	n= 3	n= 15	n=3	n=1	n=3	n=3	n=83	n=6	n=1	n=3	n= 28
pH						6.8		7.4			13.0				
TDS (mg/L)						34					184.1		94.0		
TSS (mg/L)		155.4	65.1	32		39	67.7	16.3	137.3	138.3	148.1	114.58	8.0		100
BOD (mg/L)			2.22					8.0				6.59			
Chemical Oxygen Demand (COD) (mg/L)		137.1	29.7					41	78.7	81.7	123.8	88.62	48.0		
Dissolved Organic Carbon (DOC) (mg/L)		22.7						9.0							
Sulphate (mg/L)								6							
Chlorine (mg/L)								12							
Chloride (mg/L)						0.81						258.43			
Specific Conductance (µmhos/cm)						51									
Total Nitrogen (mg/L)		3.23				0.97									2.18
Total Kjeldahl Nitrogen (TKN) (mg/L)		2.59				0.71			1.95	1.47	2.0		2.4		1.5
TP (mg/L)		0.65				0.169		37	0.23	0.18	0.3		0.2		0.33
Orthophosphate PO_4-P (mg/L)		0.01				0.019									
Ammonium/ Ammonia (mg/L)						0.051		345			1.1	0.25			
Nitrate + Nitrite (mg/L)						0.21		954+14	0.77	0.33	1.1+0.1				0.68
Total Recoverable Arsenic (µg/L)						0.97					8.4				
Dissolved Arsenic (µg/L)						0.62					1.1				

	Bridge Studies						Highway Studies								
	Dupuis[a] 2002 NCHRP 474	**Kim et al. 2007**	**Pontier et al. 2001[b]**	**McNeill and Olley 1998**	**Yousef et al. 1982**	**URS 2010**	**Lau et. al. 2009**	**Boisson et al. 2005**	**Li et al. 2008 College Station, TX**	**Li et al. 2008 Austin ,TX**	**Kayhanian et al. 2003**	**Crabtree et al. 2006**	**Huang et al. 2005**	**Kayhanian et al. 2008**	**USEPA 1983 (NURP-Urban Runoff)**
Total Recoverable Cadmium (µg/L)	1.9/1.2					0.10	1.8				0.9	0.49			
Dissolved Cadmium (µg/L)						0.03	1.3				0.2				
Total Recoverable Chromium (µg/L)	19/12					3.9	10.1				8.8	5.98			
Dissolved Chromium (µg/L)						0.62	2.8				2.4				
Total Recoverable Copper (µg/L)	195/57		15.6			9.6	93.1		15.7	26.1	51.3	41.0			34
Dissolved Copper (µg/L)				11		2.7	66.0		6.13	5.53	13.5	20.58		51.3	
Total Recoverable Iron (µg/L)			4286		2427	1420									
Dissolved Iron (µg/L)					287	17									
Total Recoverable Nickel (µg/L)	26/17				53	2.3	20.0				10.1	5.31			
Dissolved Nickel (µg/L)					49	0.69	15.7				3.6			9.43	
Total Recoverable Lead (µg/L)	103/17				1558	5.29	33.0		7.3	12.37	79.6	23.05			144
Dissolved Lead (µg/L)					187	0.09	4.9		Below limits	Below limits	5.4			4.0	
Total Recoverable Zinc (µg/L)	555/278			29	498	65.9	507		115.7	160.7	203.4	140.3			160
Dissolved Zinc (µg/L)					336	16.8	416		45.7	52	72.7	57.49		208	
PAHs (ng/L)							360								
Phenanthrene (µg/L)	0.26/0.20											0.08			

	Bridge Studies						Highway Studies									
	Dupuis[a] 2002 NCHRP 474	**Kim et al. 2007**	**Pontier et al. 2001[b]**	**McNeill and Olley 1998**	**Yousef et al. 1982**	**URS 2010**	**Lau et. al. 2009**	**Boisson et al. 2005**	**Li et al. 2008 College Station, TX**	**Li et al. 2008 Austin ,TX**	**Kayhania n et al. 2003**	**Crabtree et al. 2006**	**Hua ng et al. 2005**	**Kayhanian et al. 2008**	**USEPA 1983 (NURP-Urban Runoff)**
Pyrene (µg/L)	0.52/0.21											0.16			
Fluoranthene (µg/L)	0.45/0.20											0.16			
Oil and Grease (mg/L)		29.42				4.8					10.6				
Total Petroleum Hydrocarbons (TPH) (mg/L)						3.1									

[a] First value is SFOBB. Second value is I-85 and Mallard Creek

[c]Concentrations before entering BMPs

1.4 Toxicity of Bridge and Highway Runoff

The general consensus of many studies is that runoff is not toxic except for in areas of direct entry into the water body (Buckler and Granato 2011). This entry point should be the focus because if a storm is of a long duration and brings little rainfall, the result is a longer exposure period for aquatic organisms but at a lower concentration. Likewise, if a storm is short with a large amount of rainfall, there occurs a shorter exposure period with a higher concentration (Dupuis 2011).

Drainage systems installed on bridges may have only a limited impact on water quality. Even extensive drainage may not be effective at containing hazardous material or oil spills (McNeill an Olley 1998). Around 2,000 spills occur each year, accompanying exponentially more accidents. The effects of normal highway runoff can be seriously overshadowed by the effect of one spill on a highway or bridge. Cleanup and documentation after a spill should be a priority, both to aid in the analysis of the effects of the spill and to prevent such spills from occurring again (Buckler and Granato 2011). One study recommended the installation of efficient oil and sedimentation BMPs near to roads and bridges of the greatest concern (Ellis et al. 1997).

1.5 Factors Influencing Runoff Quality

One of the most significant factors affecting the quantity and quality of runoff is climate. Climate and geography vary widely across the state of Nebraska, and climate must be considered when analyzing data from previously published studies (Dupuis 2011). Factors such as rainfall intensity and the lengths of antecedent dry periods (ADP) are important to consider when comparing study results (Boisson et al. 2005). A road runoff study considering storm intensity found that the concentration of pollutants became more diluted with increasing rainfall

(Kayhanian et al. 2003). This may depend on the intensity of the rain because in a road runoff study conducted by Crabtree et al. they observed an increase in pollutant contamination at higher intensities in a road runoff study (2006). The higher concentration was due to the fact that high intensity rainfall has the ability to mobilize a larger quantity and size of pollutants and sediments and carry them further into the stream. When there is an extended ADP, contaminants on the road can accumulate, resulting in a spike in the concentration of pollutants during the first rainfall event (Kayhanian et al. 2003). This was confirmed in a study by Li et al. (2008), where the length of the ADP was found to be the best indicator of high or low pollutant concentrations.

Kayhanian et a. (2003) and Crabtree et al. (2006) observed a link between season and pollutant concentrations. Metal concentrations tended to increase during the winter months due to the application of salts. Kayhanian et al. (2003) also found that when the ADP increased, so did the concentration of contaminants. Crabtree et al. (2006) did not find a link between ADP and pollutant concentrations; the researchers speculated that the lack of an observed connection was due to the low number of sites, few varying conditions between sites, and the low number of event samples taken at each site.

The “first flush”—the first amount of rain after a dry period—is an important factor in predicting the concentration of runoff contaminants (Pontier et al. 2001). In the presence of a long ADP, the volume of the receiving stream may be lower, making the effects of the first flush on water quality much higher than that of any other rainstorm (McNeill and Olley 1998). A (2001) study found that zinc, iron, and hydrocarbons were of particular concern during a first flush volume of 5-10 mm. Concentrations decreased dramatically in the first 30 minutes of rain (Pontier et al. 2001). The concentration and types of contaminants carried by the first flush can be very site-specific, depending on the size of the watershed and the characteristics of the storm

(Lau et al. 2009). When the runoff mixes with the stream, it can also lift and transport sediments and contaminants downstream, expanding the area of impact (Ellis et al. 1997). Han et al. (2006) found that the first 20% of runoff contained 30-35% of the mass of pollutants (Han et al. 2006). This implies that effectively treating the first flush would be the most efficient, cost effective, and environmentally friendly way of handling polluted runoff (Kayhanian et al. 2008). In a Korean study of runoff from bridges and parking lots, it was found that treating the first 5-10 mm of rainfall (Kim et al. 2007) was the most effective method of treating polluted runoff.

Han et al. (2006) found that total rainfall was inversely proportional to event mean concentrations (EMCs), meaning that EMCs were diluted with higher rainfall. A Texas study found that EMC and ADP were inversely proportional, and ADP was the best indicator of pollutant concentrations (Li et al. 2008).

In addition to climate factors, the design attributes of bridges and roadways can also be important in predicting impacts on water quality. Bridges can impact runoff quality depending on their size, composition, slope for drainage, and the degree to which they limit a stream's natural course (Dupuis 2002). Traffic characteristics include ADT, vehicle type, vehicle cargo, and the materials from which vehicles are made. In a study of runoff from urban roads, the U.S. Federal Highway Administration found that roads with an ADT of greater than 25,000 vehicles per day had the highest pollutant concentrations (Ellis et al. 1997). Kayhanian et al. (2003) confirmed that ADT and the amount of contaminants in sampled runoff were directly proportional. It was also determined that ADT, total storm rainfall, total seasonal rainfall, and length of the antecedent dry period could account for over 70% of the tested contaminants. However, land use could not be correlated with any increase or decrease in the concentration of pollutants in runoff (Kayhanian et al. 2003).

1.6 Final Recommendations

- In comparison to the number of highway runoff studies, there are very few bridge stormwater runoff studies available. For the purposes of this NDOR study, NCHRP Report 474 and the (2010) North Carolina URS Report will be the main bridge runoff references utilized. Highway runoff references will be used to compare results.
- When selecting bridge sites to be used in the NDOR study, characteristics such as ADT and stream size should be considered.
- When conducting bioassay experiments, an organism exposure time equal to that of a typical storm duration is recommended for use.

Chapter 2 Methods

2.1 Site Selection

A list of preliminary sites was compiled based on bridges that were within one hour of Omaha and located approximately one mile from a U.S. Geological Survey (USGS) gaging station. This list was then simplified by the TAC to four bridges based on the ADT for both directions over the bridge, stream flow, safety considerations, and accessibility for the retrieval of bridge deck runoff samples and the collection of in-stream samples. These four sites are listed in table 2.1, and include a high traffic bridge with a high stream flow, a low traffic bridge with a high stream flow, a high traffic bridge with a low stream flow, and a low traffic bridge with a low stream flow. The I-80 bridge over the Platte River site and the Highway 77 bridge over the Rock Creek site were chosen for in-stream dry weather sampling due to their differences in traffic and stream flow.

Table 2.1 Bridge sites selected and their attributes

Bridge Description	Structure Number	Average Yearly Stream Flow (cfs)	2010 ADT	2030 ADT	Wet Weather Runoff Sampling	In-stream Dry Weather Sampling
I-80 over the Platte River	S080 42729 L and R	8,060	40,830	61,452	X	X
Highway 64 over the Platte River near Leshara, NE	S064 05295	5,900	1,515	2,424	X	
I-80 over the Little Salt Creek near 27th Street exit Lincoln, NE	S080 40374 L and R	7.7	40,616	71,078	X	
Highway 77 over Rock Creek South of Ceresco, NE	S077 08081 L and R	23	8,076	12,114	X	X

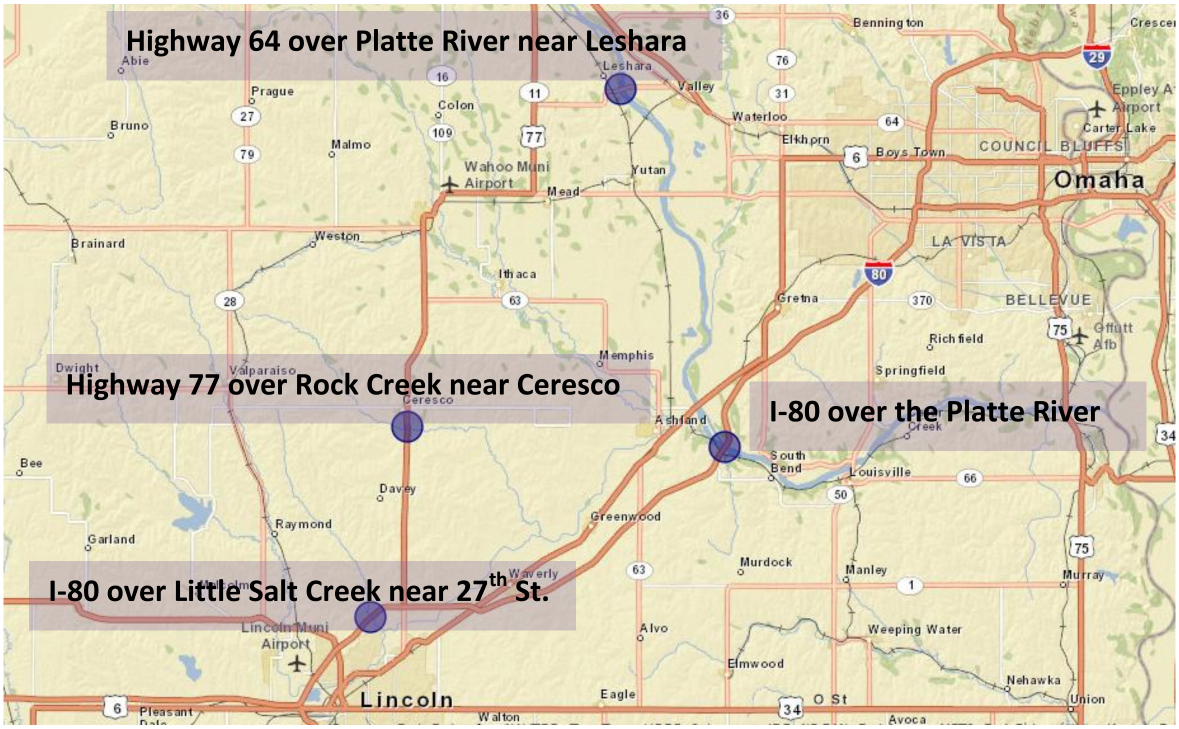


Figure 2.1 Bridge site locations

2.2 In-stream dry weather sample collection

Dry weather in-stream samples were collected at the I-80 bridge over the Platte river site and the Highway 77 bridge over Rock Creek just south of Ceresco site. Samples were collected by facing a bottle lengthwise with its opening facing downstream, submerging it in the water at half of the stream depth. At both sites, three grab samples were collected upstream and three were collected downstream of the bridge. Aerial views of each bridge are shown in figures 2.2 and 2.3, respectively.

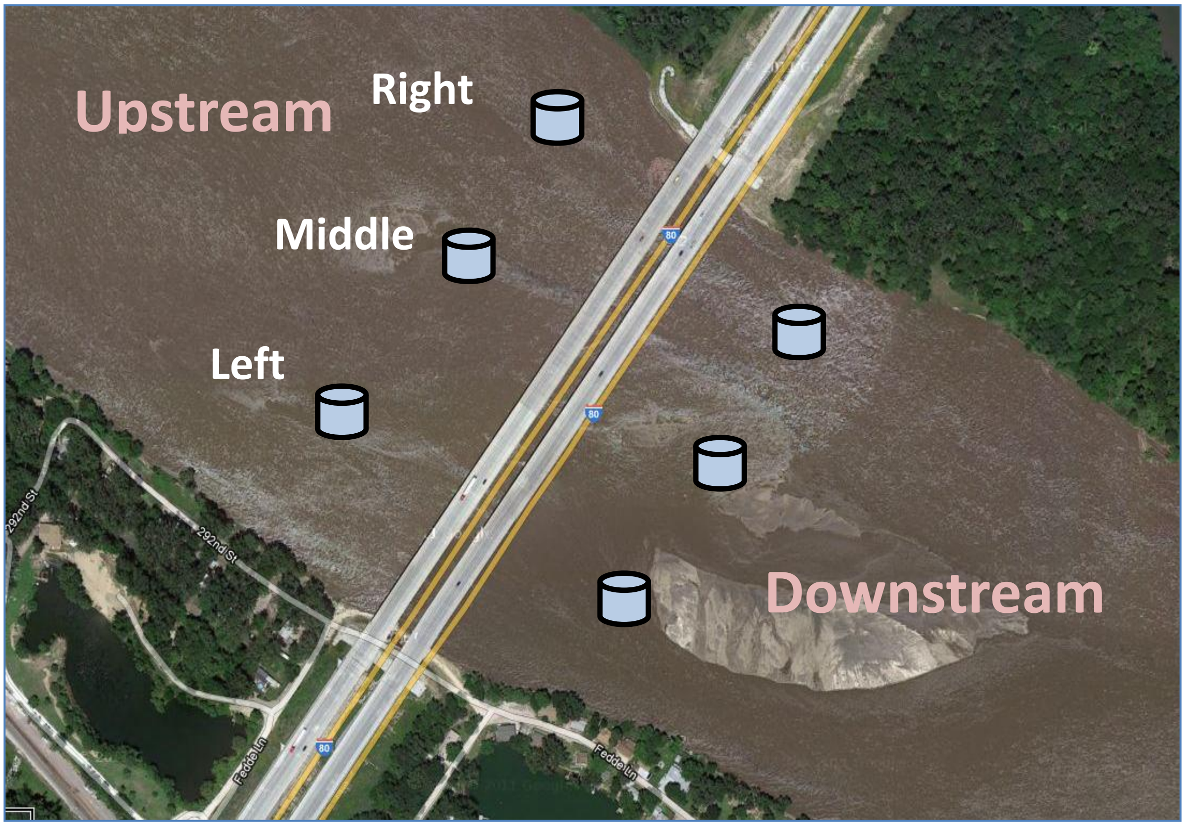


Figure 2.2 Dry weather sampling sites at the I-80 over the Platte River bridge

Figure 2.3 Dry weather sampling sites at the Highway 77 over Rock Creek bridge

2.3 Wet weather sample collection

A gutter system specific to each bridge was designed to hang under the concrete drip edge and collect runoff. A perspective drawing of the gutter is shown in figure 2.4. Each bridge was instrumented with a 20 ft length of polyvinyl chloride (PVC) gutter with a capped 90° elbow attached to the end. A hole was drilled into the cap where a plastic barb was screwed in. Then, one end of a length of ¾ in. polyethylene plastic tubing was slid onto the barb, with the other end falling into a high density polyethylene (HDPE) bucket below. Runoff was collected in the bucket to obtain composite samples for the storm event. Over the course of the project, several of the buckets went missing. Most likely they were stolen. In conjunction with the TAC, it was decided to continue using the composite sampling method instead of switching to ISCO remote samplers, due to the high cost of replacing the equipment and the low amount of rainfall received during the wet season. Lourdes Mena, a U.S. Fish and Wildlife Service (USFWS) contaminants biologist, was also consulted during this decision. She concluded this was an acceptable sampling method for a preliminary study. Figures 2.5, 2.6, and 2.7 show pictures of the bridge gutter system installed at some of the bridge sites.

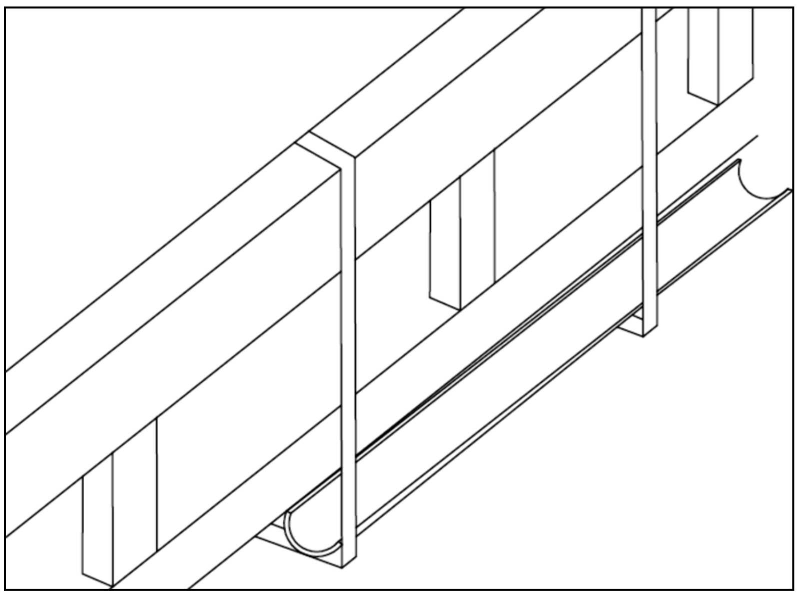


Figure 2.4 Perspective drawing of bridge gutter system

Figure 2.5 Bridge gutter installed at Highway 64 over the Platte River near Leshara, NE

Figure 2.6 Bridge gutter installed at I-80 over Platte River site

Figure 2.7 Bridge gutter installed at I-80 over Little Salt Creek site near 27th Street exit in Lincoln, NE

2.4 In-stream and bridge runoff sample analyses

The in-stream dry weather sampling dates are shown in table 2.2. Bridge runoff sampling dates are shown in table 2.3.

Table 2.2 In-stream dry weather sampling dates

Location	Sampling Dates
I-80 Bridge over the Platte River	Nov 30, 2011 April 13, 2012 July 13, 2012 Oct 18, 2012
Highway 77 Bridge over Rock Creek	Nov 30, 2011* Jan 18, 2012 April 11, 2012 Sept 12, 2012

*Only one sample was collected upstream and downstream on this day

Table 2.3 Bridge runoff sampling dates

Date Sampled	**Bridge Location**			
	I-80 Bridge over the Platte River	**Highway 64 Bridge over the Platte River**	**I-80 Bridge over Little Salt Creek**	**Highway 77 Bridge over Rock Creek**
June 15, 2012		X	X	
June 16, 2012	X	X		X
Aug 2, 2012		X		
Aug 4, 2012	X	X		X
Aug 8, 2012			X	
Aug 9, 2012	X	X		
Aug 18, 2012	X	X	X	
Aug 25, 2012	X	X	X	X
Sept 13, 2012	X	X	X	X
Sept 17, 2012	X	X		

All in-stream and bridge runoff samples were tested for total solids and TSS, and a large majority of the samples were also tested for TDS. Solids testing was conducted in the Environmental Lab at the Peter Kiewit Institute using Method 2540 as described in the 18th edition of *Standard Methods for Examination of Water and Wastewater*.

During the first half of the research project, until July 15, 2012, samples being tested for nutrients were analyzed at the University of Nebraska-Lincoln (UNL) Water Sciences Lab in Lincoln, NE under the direction of Dr. Daniel Snow. The specific nutrients being tested, and their testing methods, are listed in table 2.4. All samples were analyzed on a Seal Analytical AQ2 discrete chemistry autoanalyzer.

Table 2.4 Nutrients tested at the UNL Water Sciences Lab

Nutrient	Testing Method	Detection Limit
Nitrate – N	Automated Cd-reduction Method (nitrite subtraction) – APHA, 2005	0.0000 mg/L
Nitrite – N	Automated Colorimetric Method – APHA, 2005	0.0040 mg/L
Total Kjeldahl Nitrogen (TKN)	EPA Method 351.2 – TKN in water by Semi-Automated Colorimetry	0.10 mg/L
Total Phosphorus	EPA Method 365.1 – Phosphorus (all forms) by Semi-Automated Colorimetry	0.02 mg/L

All other contaminants (listed in table 2.5) were tested at Midwest Laboratories in Omaha, NE. See the runoff and in-stream sampling raw data tables in Appendix C and D for the varying detection limits of these methods. The first set of in-stream samples was tested for BTEX compounds (tested using method OA-1 in Table 2.5). No BTEX compounds were detected. To conserve project resources, further in-stream samples were not tested for BTEX.

Table 2.5 Analyses conducted through Midwest Laboratories

Analyses	Method
n-Hexane	OA-1
MTBE	OA-1
Benzene	OA-1
Toluene	OA-1
Ethylbenzene	OA-1
Naphthalene	OA-1
Total Xylenes	OA-1
Total Purgeable Hydrocarbons	OA-1
Arsenic (total)	EPA 200.7
Cadmium (total)	EPA 200.7
Chloride	SM 4500-CL-E
Chromium (total)	EPA 200.7
Conductance	SM 2510 B
Copper (total)	EPA 200.7
E coli	EPA 1603
Hexane Extractable Materials (HEM)	EPA 1664A-SPE
Iron (total)	EPA 200.7
Nickel (total)	EPA 200.7
Nitrate/Nitrite Nitrogen	EPA 353.2
Nitrite Nitrogen	SM 4500 NO2-B
Phosphorus (total)	SM 4500-P H
Total Kjeldahl Nitrogen (TKN)	PAI-DK 02
Zinc (total)	EPA 200.7
pH	EPA 150.1

2.5 Sediment sample collection and analyses

Three sediment samples were collected upstream and downstream of the bridge at distances of 0, 10, and 20 ft from the edge of the bridge deck, respectively. All sediment samples were collected in glass jars that were provided and tested through Midwest Laboratories in Omaha, NE for the constituents listed in table 2.6. PAH testing was also conducted at Midwest for the samples collected directly under the bridge deck; however, PAH was not detected. Information on the PAH analyses and detection limits can be found in Appendix A.

Table 2.6 Sediment sample analyses conducted through Midwest Laboratories

Analyses	Method	Detection Limit
Arsenic (total)	EPA 6010	10.0 mg/kg
Cadmium (total)	EPA 6010	0.50 mg/kg
Chromium (total)	EPA 6010	1.0 mg/kg
Copper (total)	EPA 6010	1.0 mg/kg
Iron (total)	EPA 6010	5.00 mg/kg
Lead (total)	EPA 6010	5.0 mg/kg
Nickel (total)	EPA 6010	1.0 mg/kg
Percent Solids	SM 2540 G	0.01 %
Zinc (total)	EPA 6010	1.0 mg/kg

2.6 Runoff Toxicity Testing

Due to the lack of rain during the wet season, runoff toxicity testing was conducted by Midwest Laboratories at the I-80 over the Platte River bridge and Highway 77 over Rock Creek bridge sites using a “48-hr acute with 5 dilution series” toxicity test with the fathead minnow, *P. promelas*. Both of the runoff samples were taken on September 13, 2012. The samples were analyzed for all pollutants listed in section 2.4. The rest of the sample was put into several one-gallon HDPE bottles and frozen until toxicity testing could be completed. Table 2.7 shows the analyses that were conducted immediately prior to the toxicity testing by Midwest Laboratories.

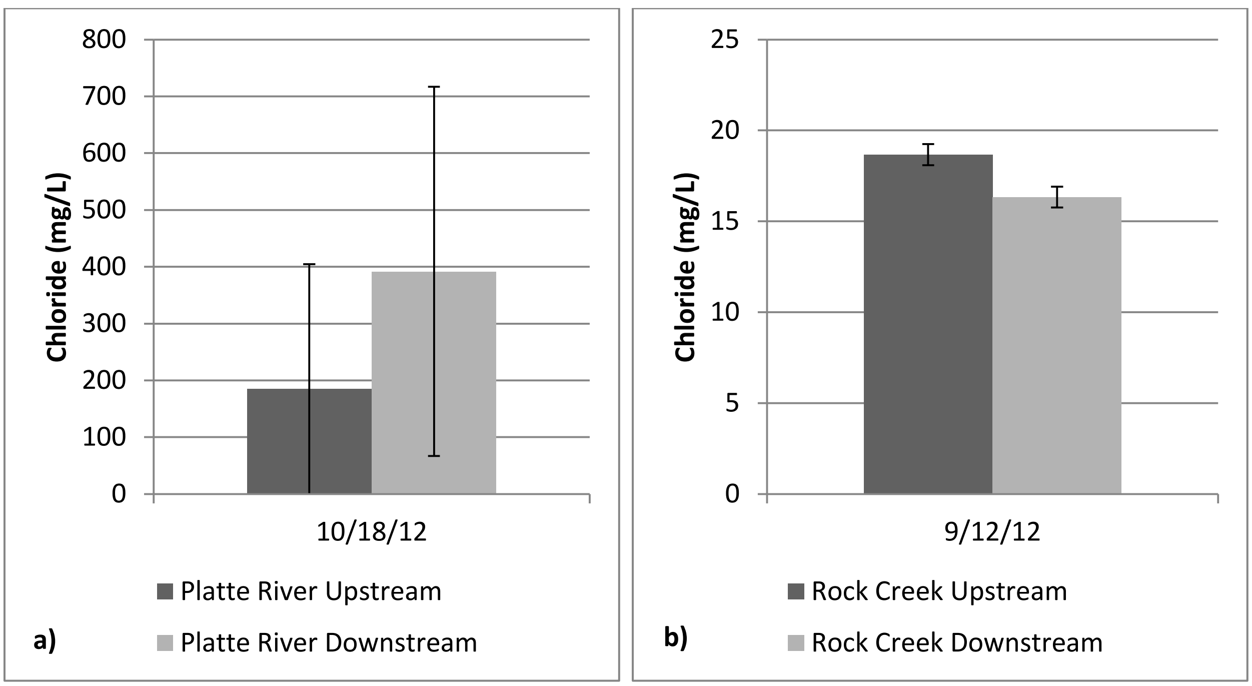
Table 2.7 Toxicity analyses conducted through Midwest Laboratories

Analyses	Method	Detection Limit
Ammoniacal Nitrogen	SM 4500-NH3 C	0.10 mg/L
Total Chlorine	SM 4500-CL D	0.001 mg/L
Conductance	SM 2510 B	2 uS/cm
Total Dissolved Solids	SM 2540 C	10 mg/L
Alkalinity (total)	SM 2320 B	10 mg CaCO3/L
Tua P. promelas	Calculated	0.50
LC50 P. promelas	Calculated	1.00

Chapter 3 Results

3.1 Dry Weather Results

The following figures show a comparison of upstream and downstream values at the I-80 over the Platte River bridge and Highway 77 over Rock Creek bridge locations. Some constituents were not detected and were not graphed in this section, including BTEX compounds, arsenic, cadmium, chromium, copper, hexane extractable materials, nickel, and zinc. See section 2.4 for the analyses and limits, and the appendix for the raw data tables.



Note differences in the magnitudes of the y-axes.

Figure 3.1 Comparison of upstream and downstream chloride values a) Platte River b) Rock Creek

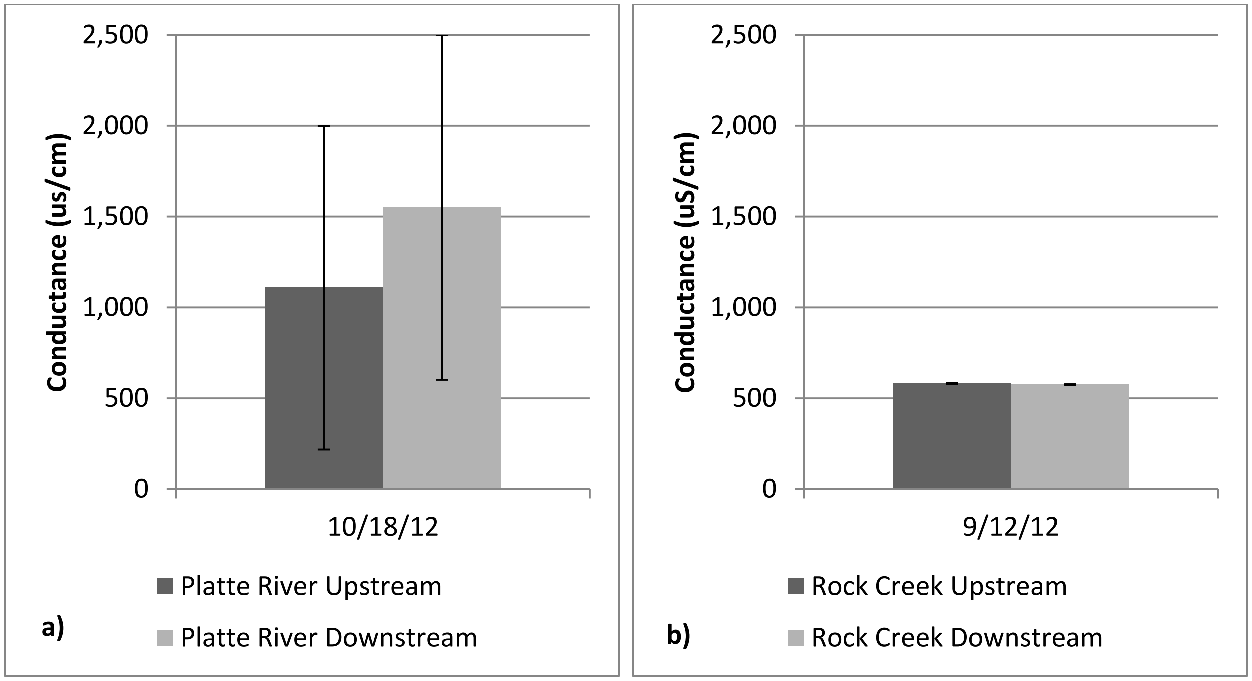


Figure 3.2 Comparison of upstream and downstream conductance a) Platte River b) Rock Creek

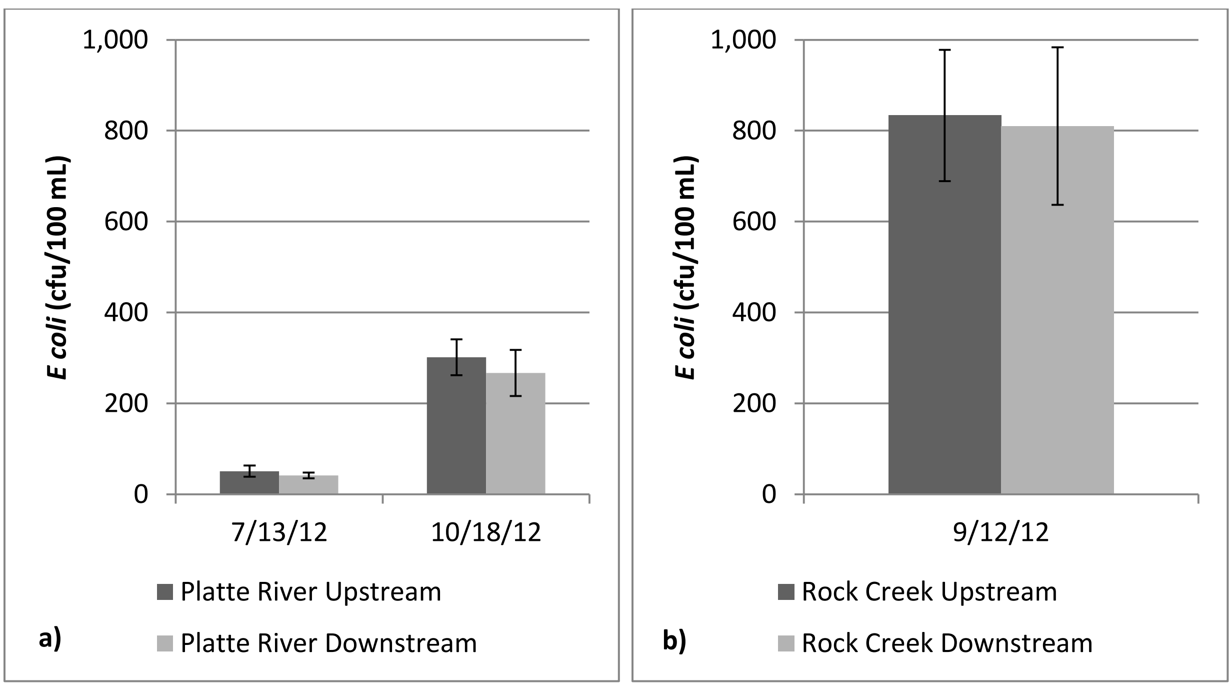


Figure 3.3 Comparison of upstream and downstream *E coli* values a) Platte River b) Rock Creek

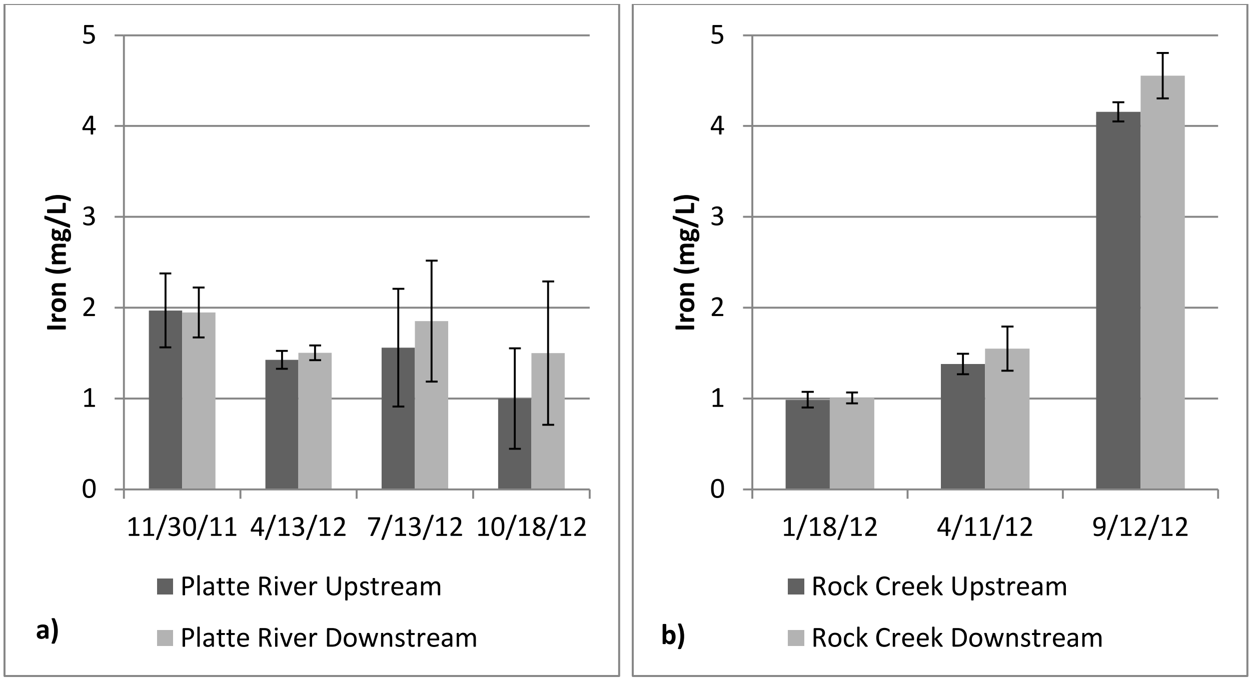


Figure 3.4 Comparison of upstream and downstream iron values a) Platte River b) Rock Creek

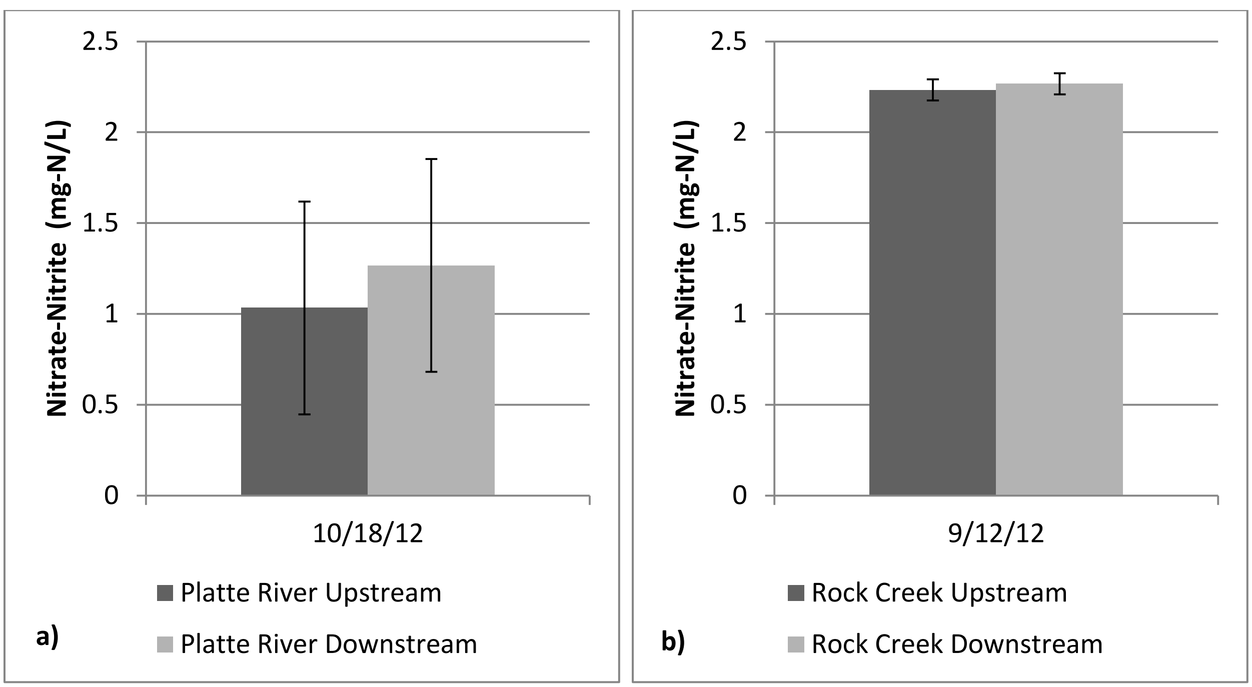


Figure 3.5 Comparison of upstream and downstream nitrate-nitrite values a) Platte River b) Rock Creek

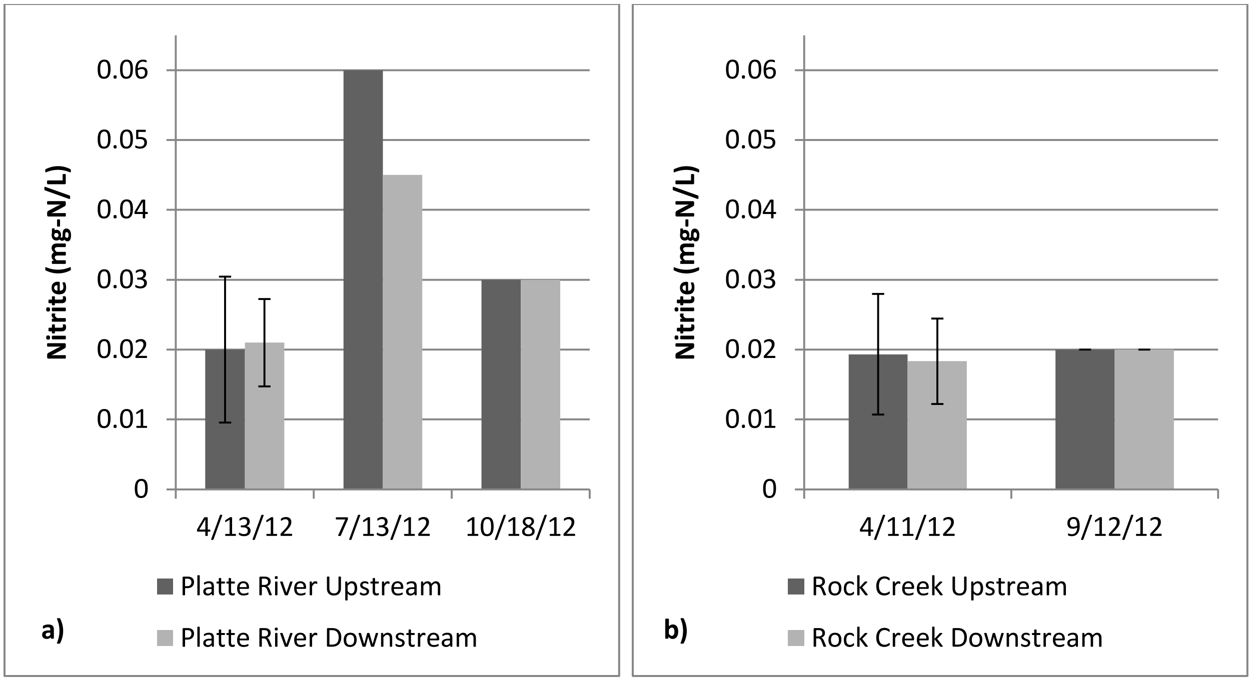


Figure 3.6 Comparison of upstream and downstream nitrite values a) Platte River b) Rock Creek

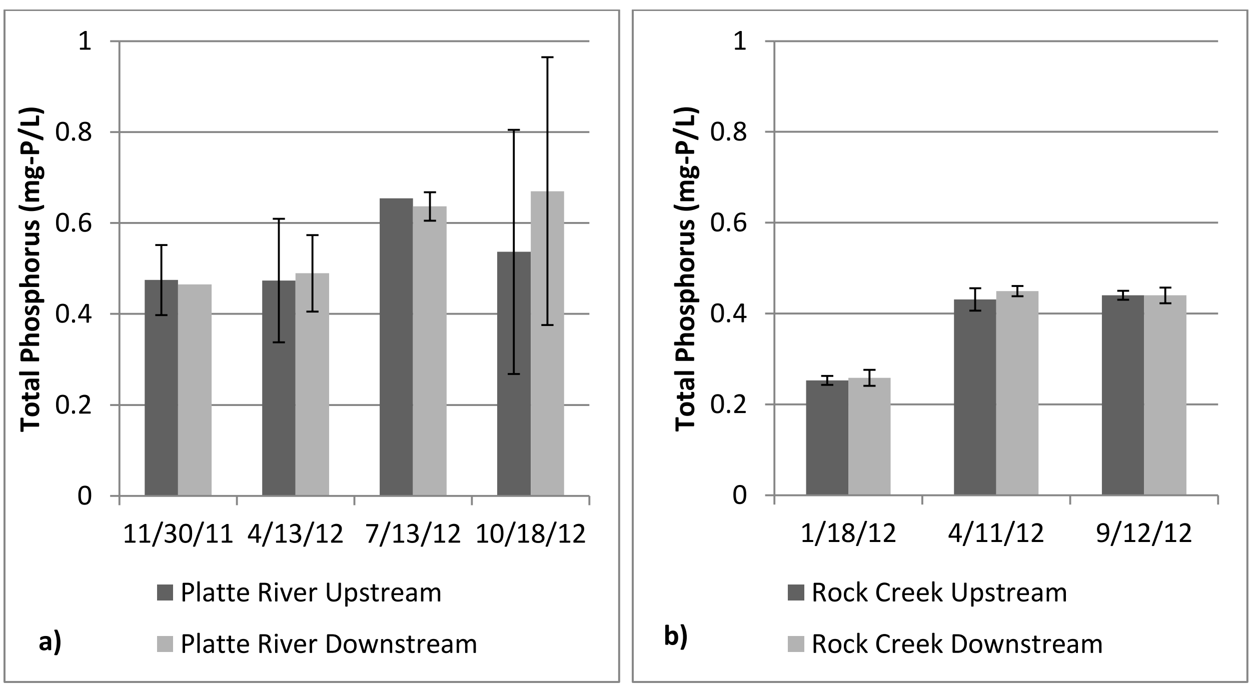
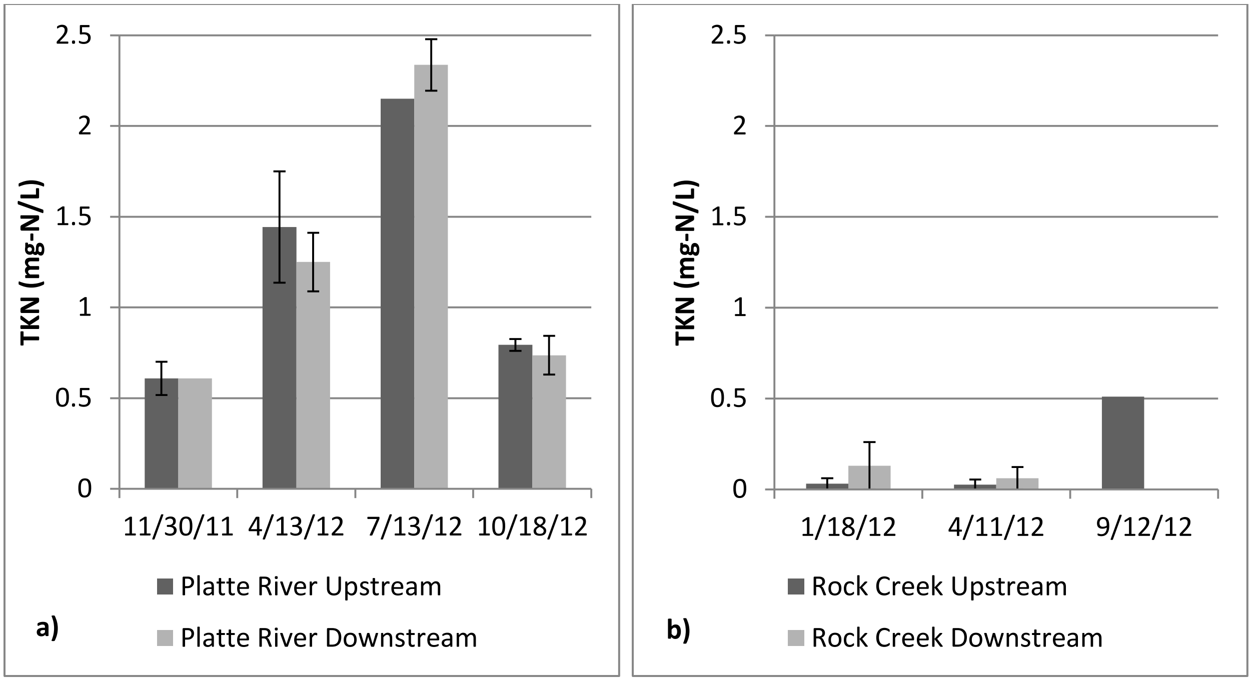


Figure 3.7 Comparison of upstream and downstream total phosphorus values a) Platte River b) Rock Creek



Note the differences in magnitudes of the y-axes. Also note that only one sample had TKN detected upstream in Rock Creek on 9/12/12, and none were detected downstream. This could be due to sampling or analysis error.

Figure 3.8 Comparison of upstream and downstream TKN values a) Platte River b) Rock Creek

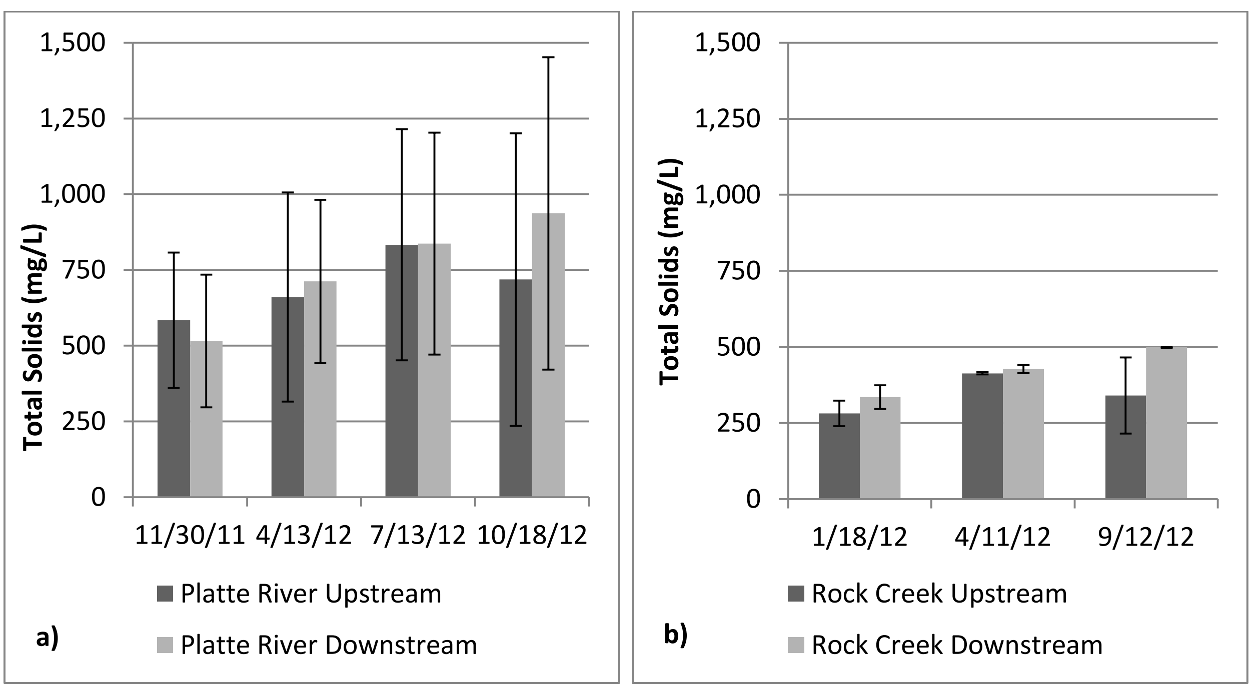


Figure 3.9 Comparison of upstream and downstream total solids values a) Platte River b) Rock Creek

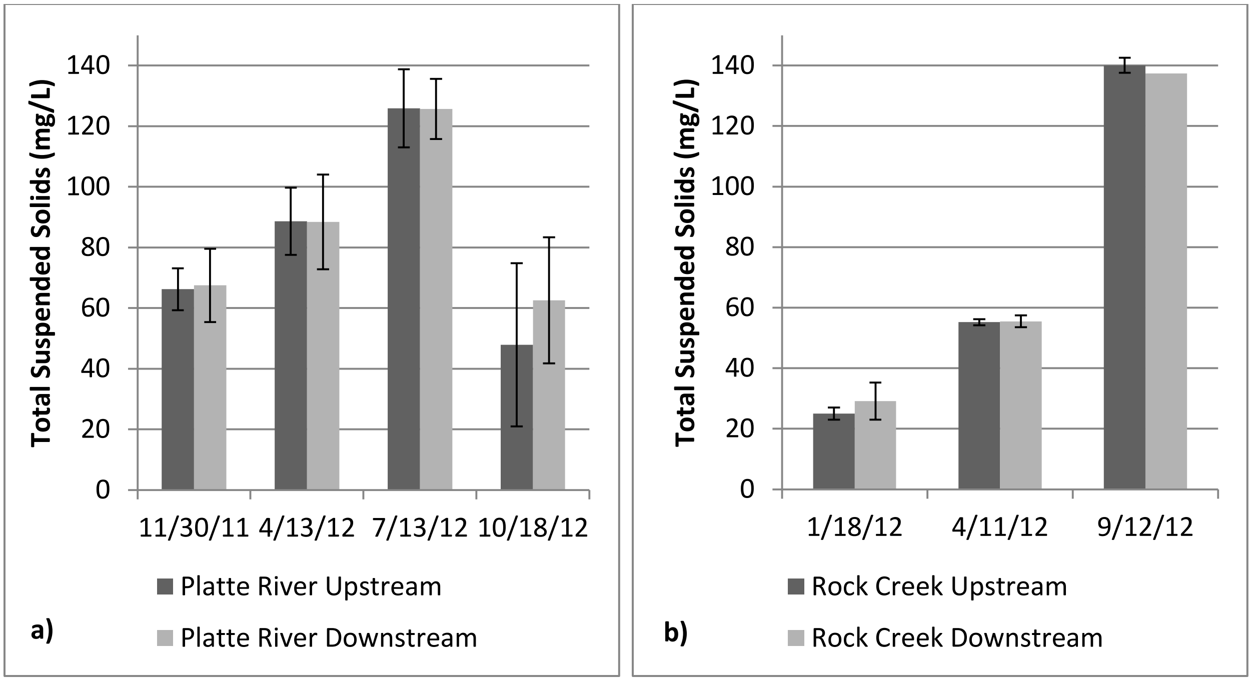


Figure 3.10 Comparison of upstream and downstream total suspended solids values a) Platte River b) Rock Creek

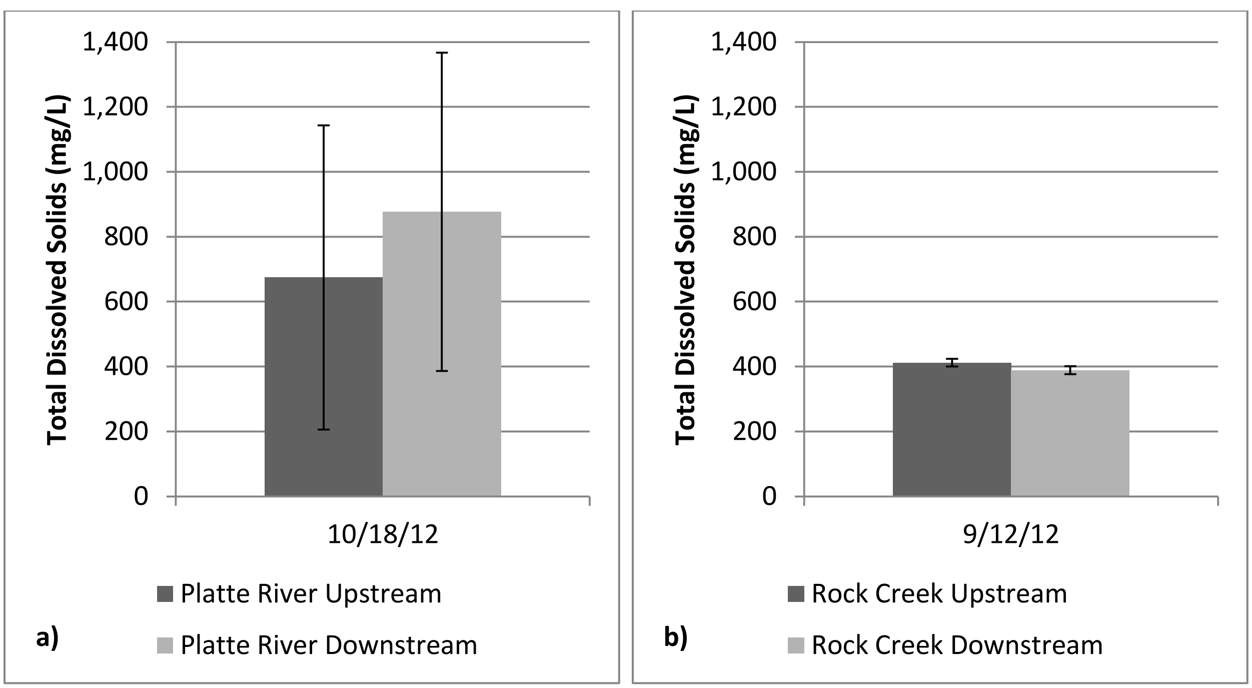


Figure 3.11 Comparison of upstream and downstream total dissolved solids values a) Platte River b) Rock Creek

3.2 Wet Weather Runoff Results

3.2.1 Precipitation

The following figures show the amount of rainfall throughout the summer and the corresponding sampled rain events. Weather stations selected were as close to bridge locations as possible, however rain events must still be considered approximate in regards to the exact locations of the bridges. The black square dots on the graph signify the storm events that were sampled.

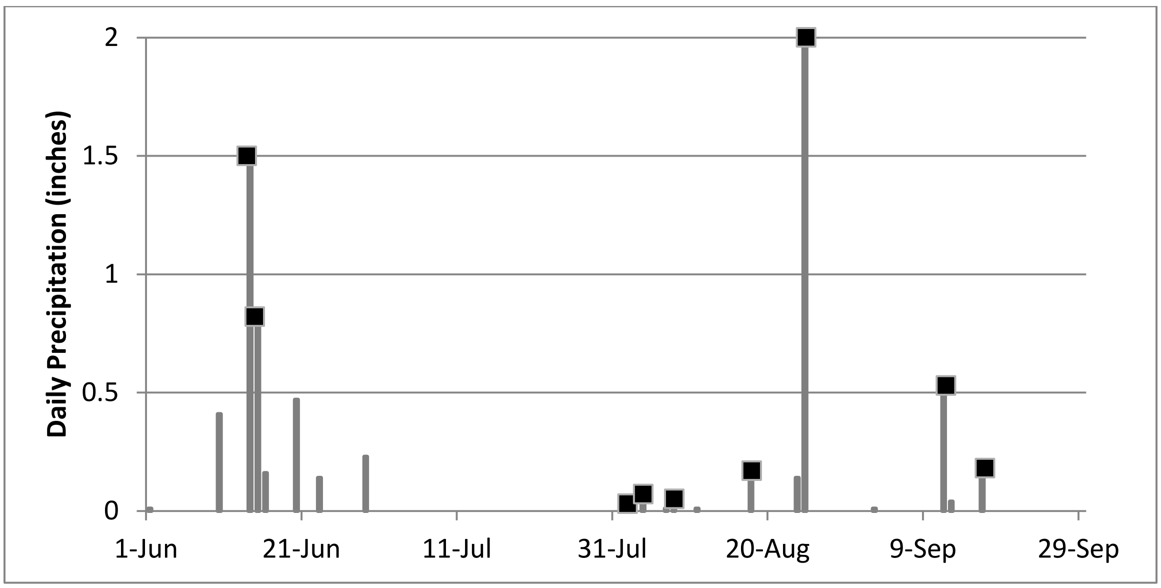


Figure 3.12 Rainfall for the Highway 64 bridge over the Platte River taken from a Valley, NE weather station

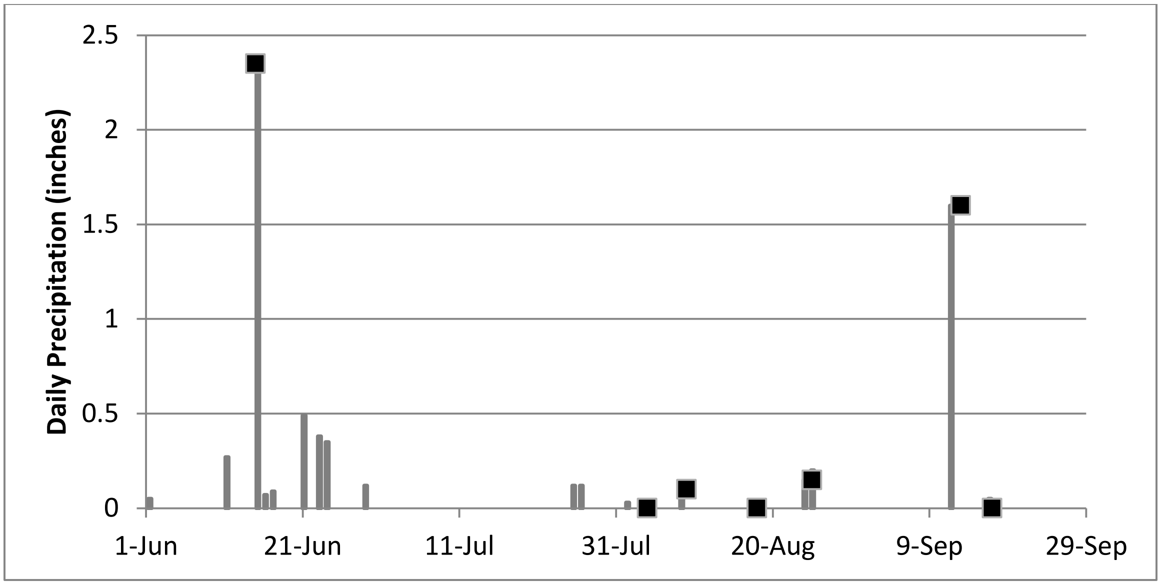


Figure 3.13 Rainfall for the I-80 bridge over the Platte River taken from a nearby Ashland, NE weather station

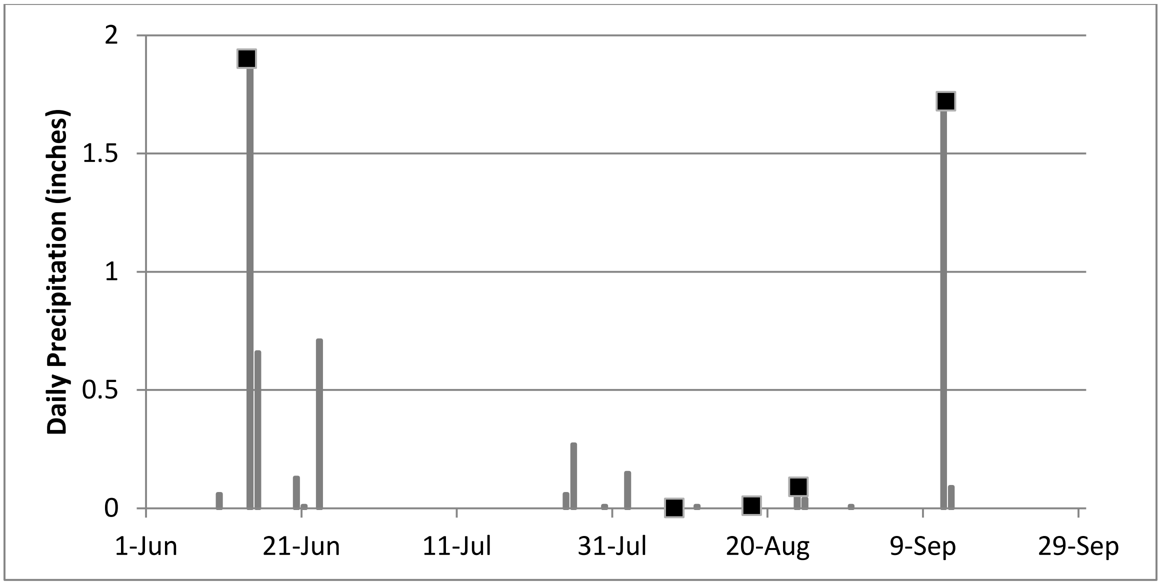


Figure 3.14 Rainfall for the I-80 bridge over the Little Salt Creek taken from a nearby Lincoln, NE weather station

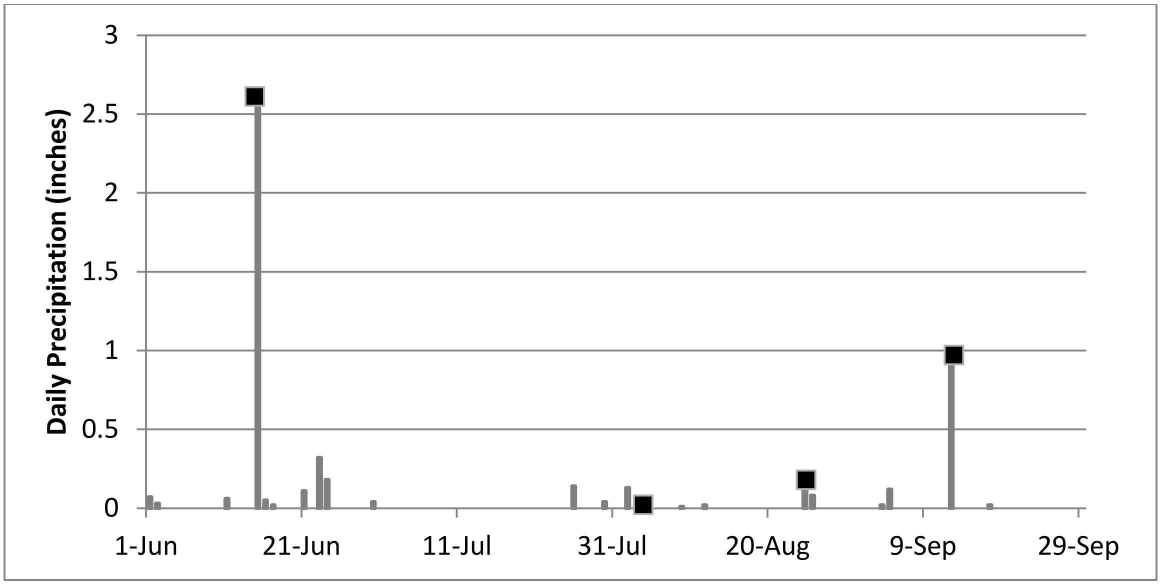


Figure 3.15 Rainfall for the Highway 77 bridge over the Rock Creek taken from a nearby Raymond, NE weather station

3.2.2 Bridge Runoff Contaminant Results

The following pages contain figures showing the concentration of different contaminants over time at each bridge. An “X” on the graph along the x-axis signifies that the contaminant was not detected. Some of the contaminants were not detected in all or most of the sampling events, and were not included in these figures. Naphthalene was only detected once, at 2 μg/L, on August 2, 2012 at the Highway 64 over Platte River bridge site. The contaminants that were not detected at any time were MTBE, toluene, ethylbenzene, total xylenes, arsenic, and cadmium.

3.2.2.1Benzene

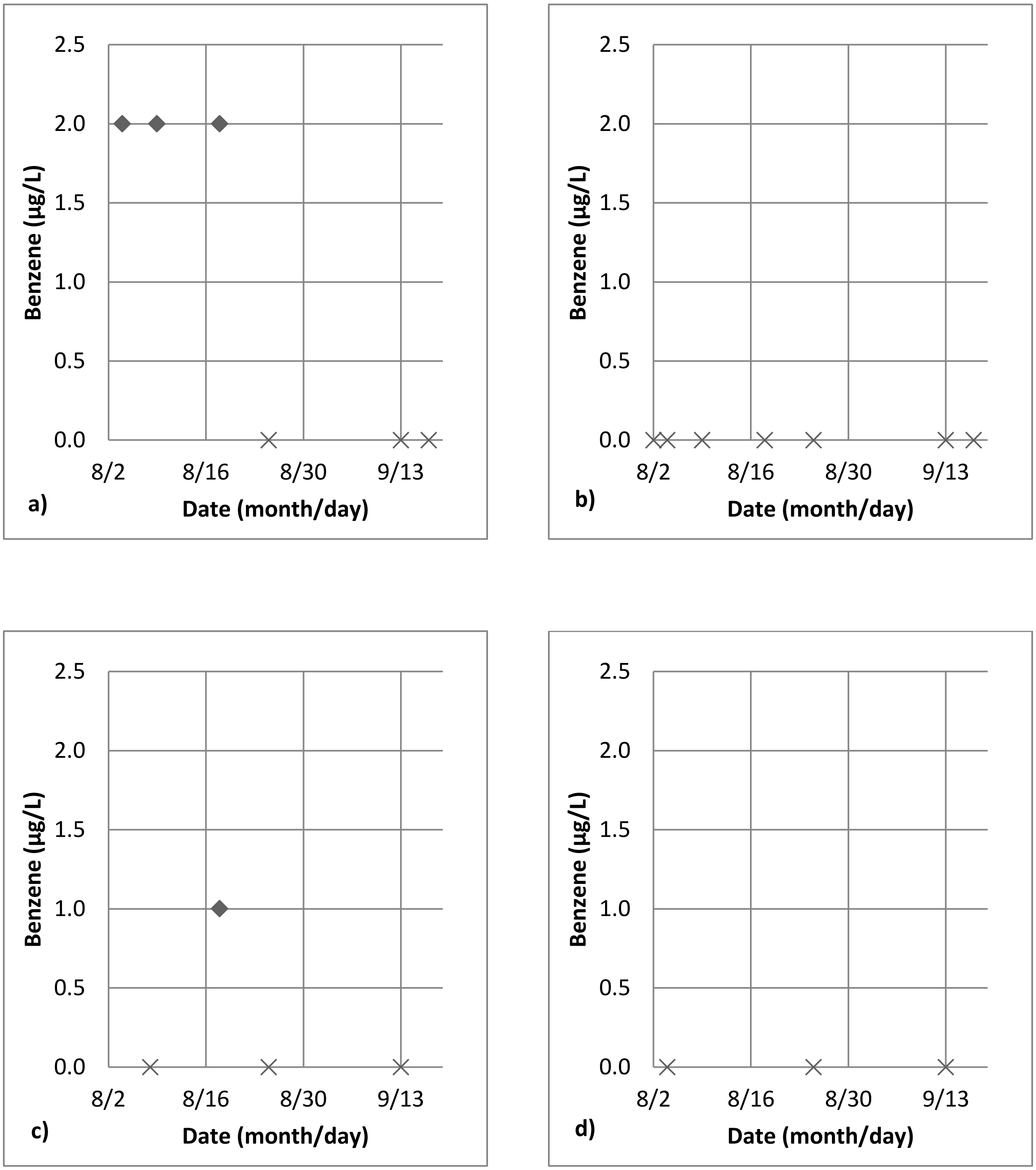


Figure 3.16 Benzene concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.2 Chloride

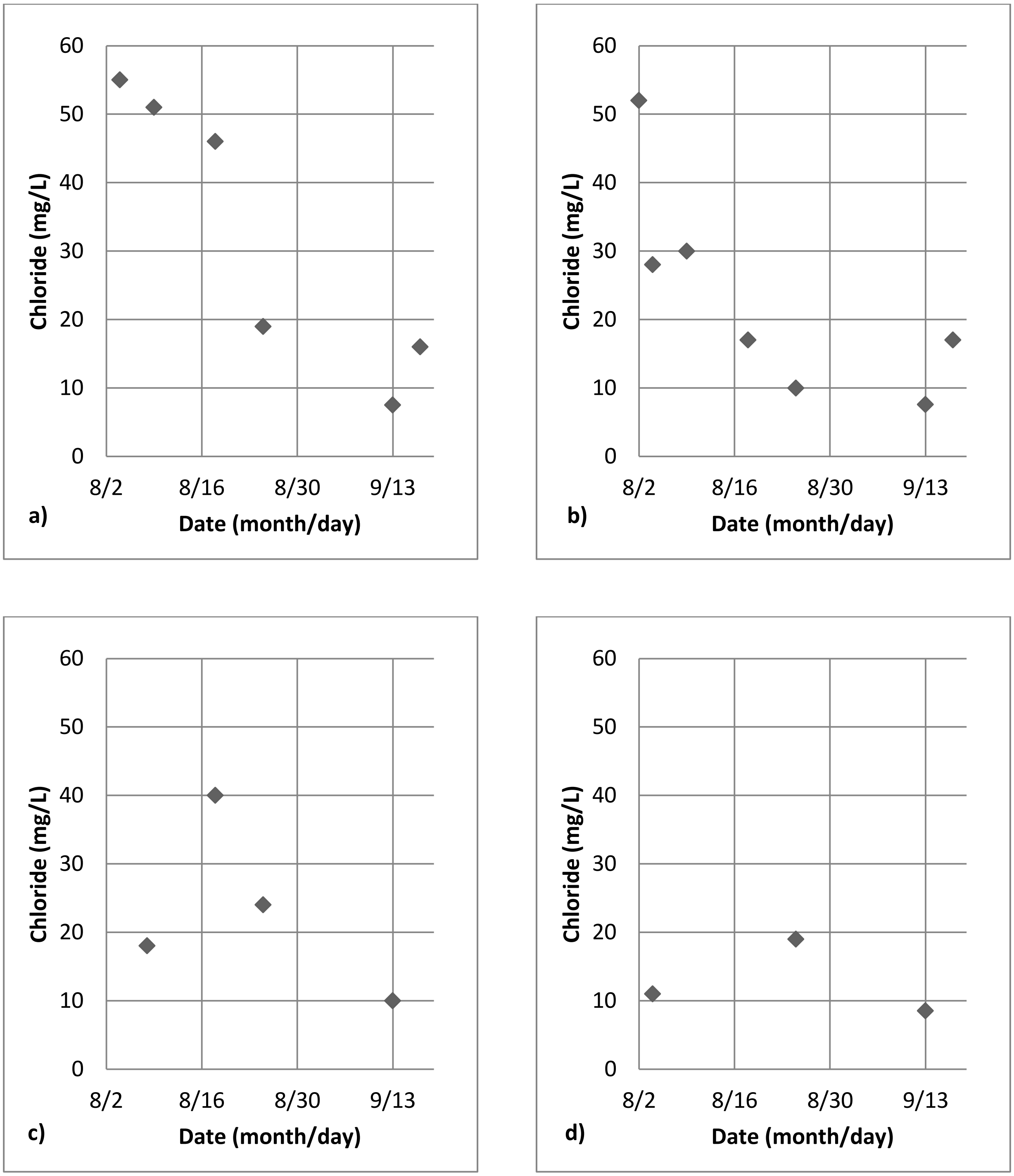


Figure 3.17 Chloride concentration in Runoff from **a**) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.3 Chromium

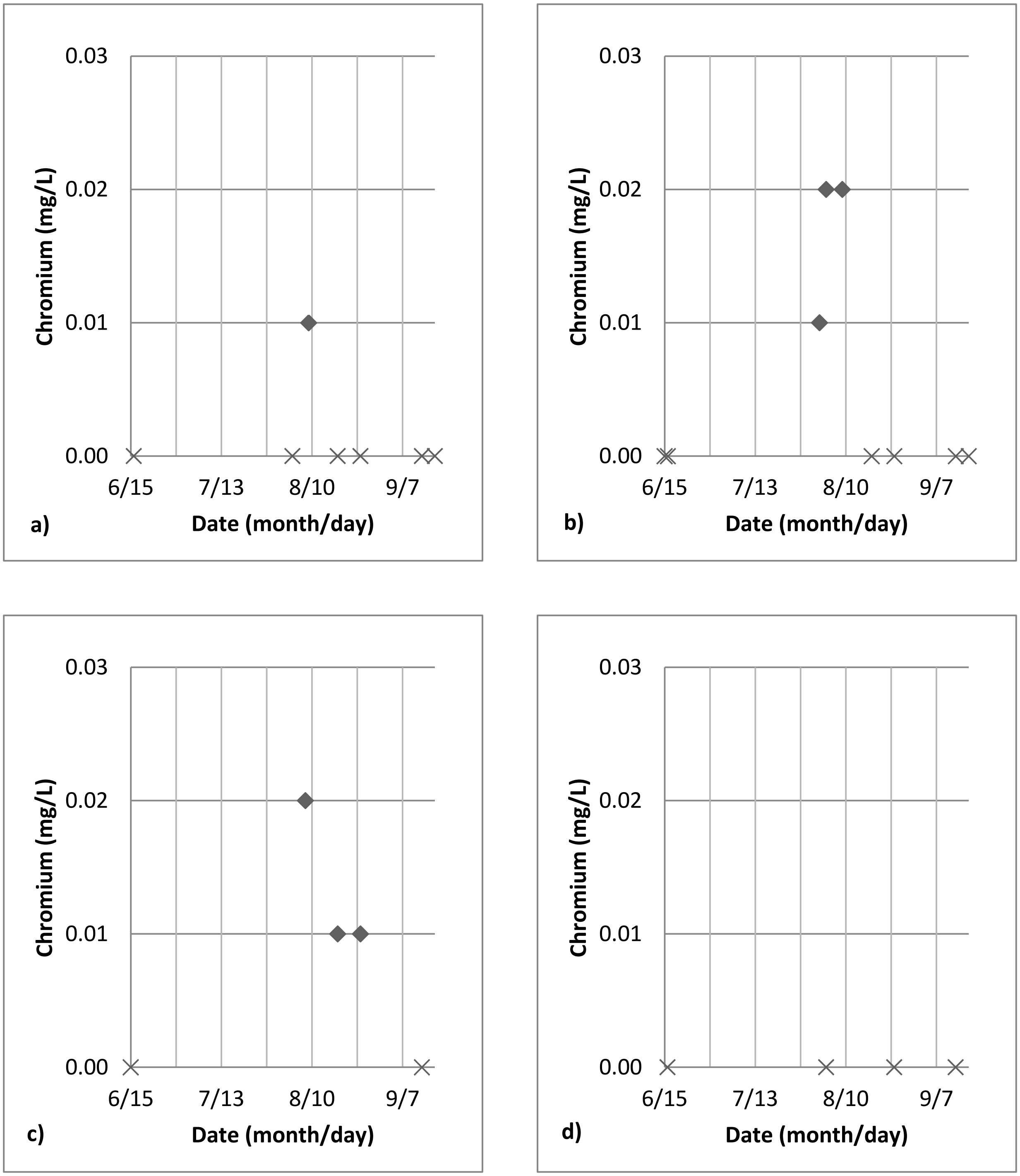


Figure 3.18 Chromium concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.4 Conductance

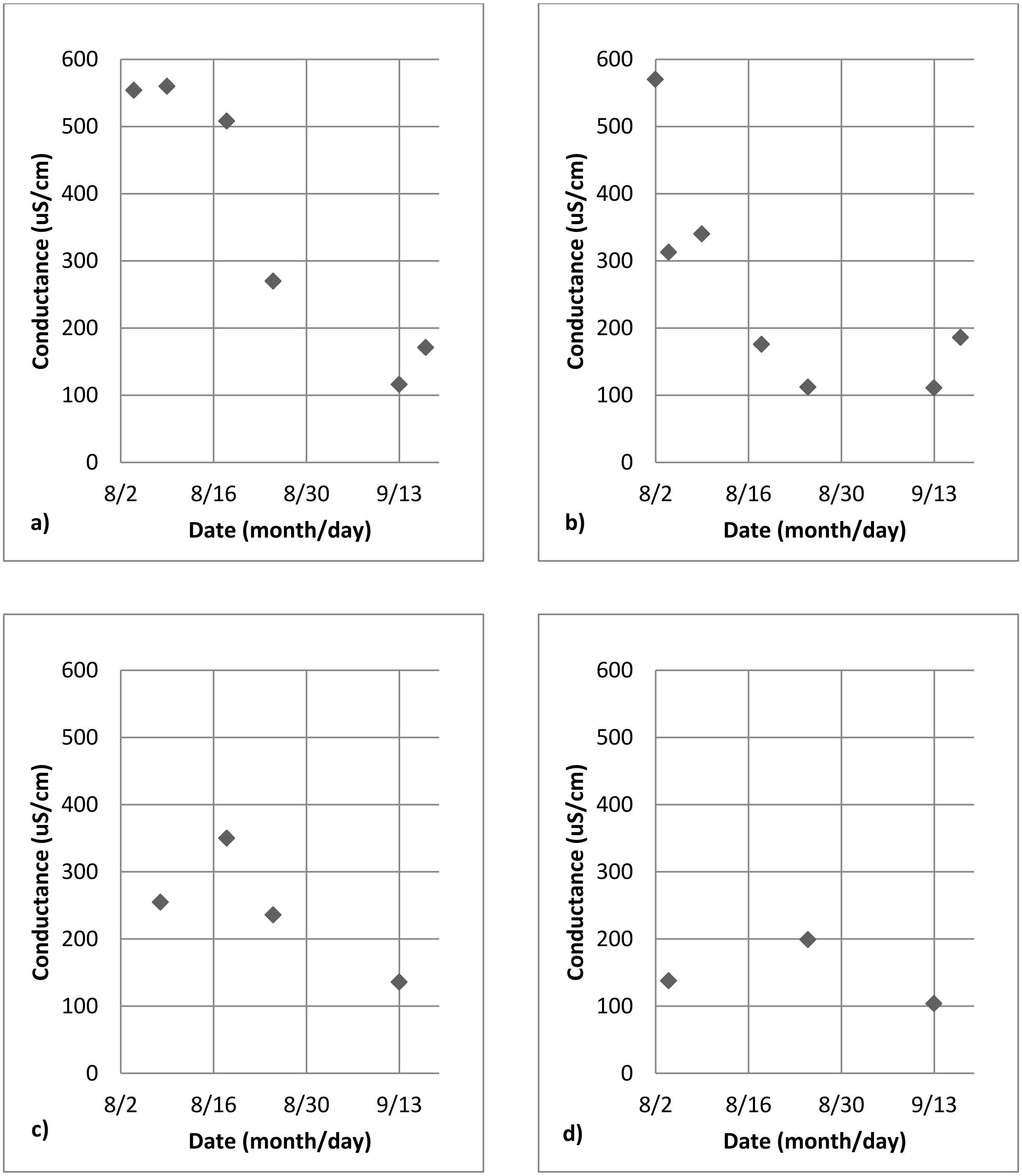


Figure 3.19 Conductance of runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.5 Copper

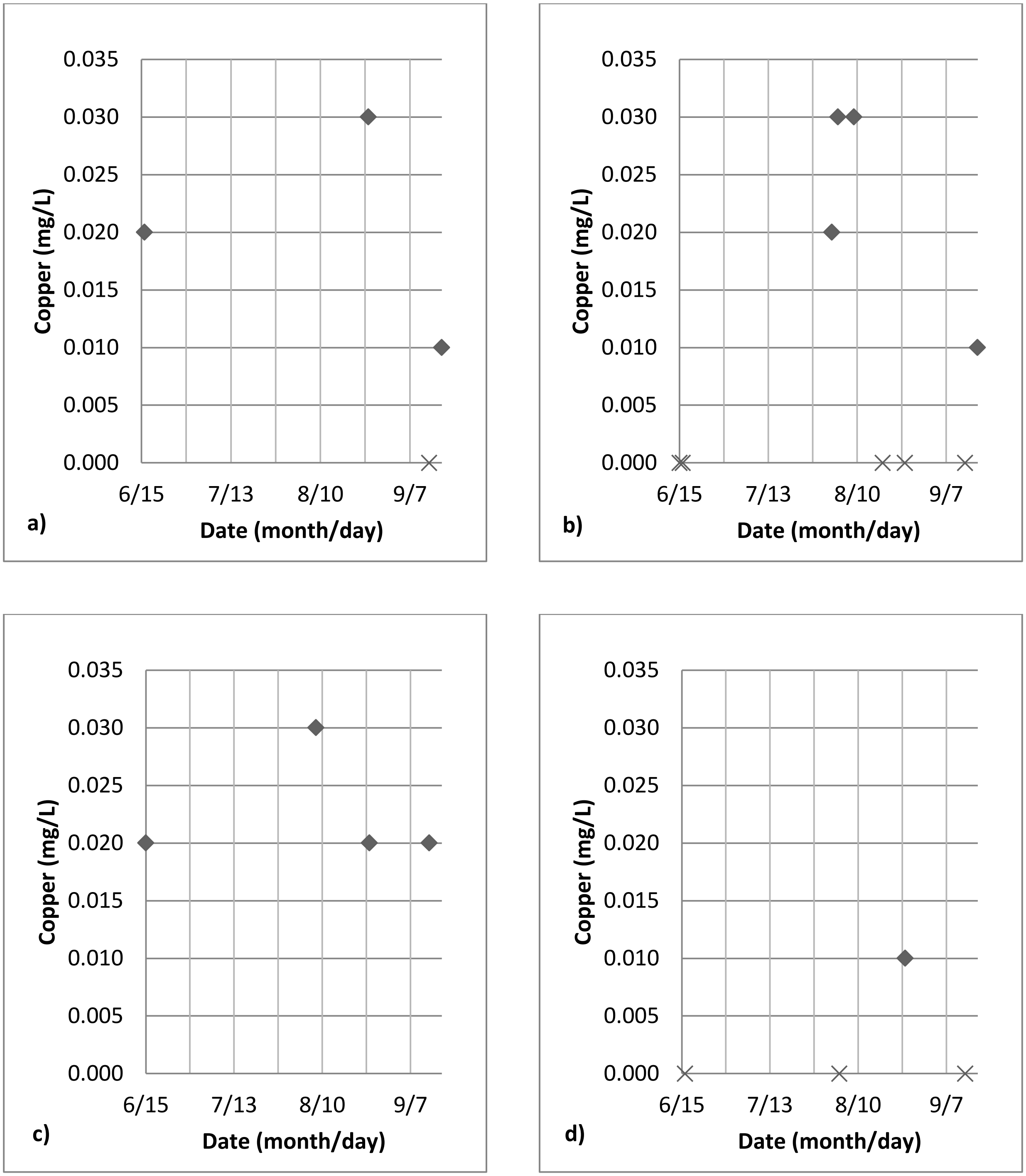


Figure 3.20 Copper concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.6 *E coli*

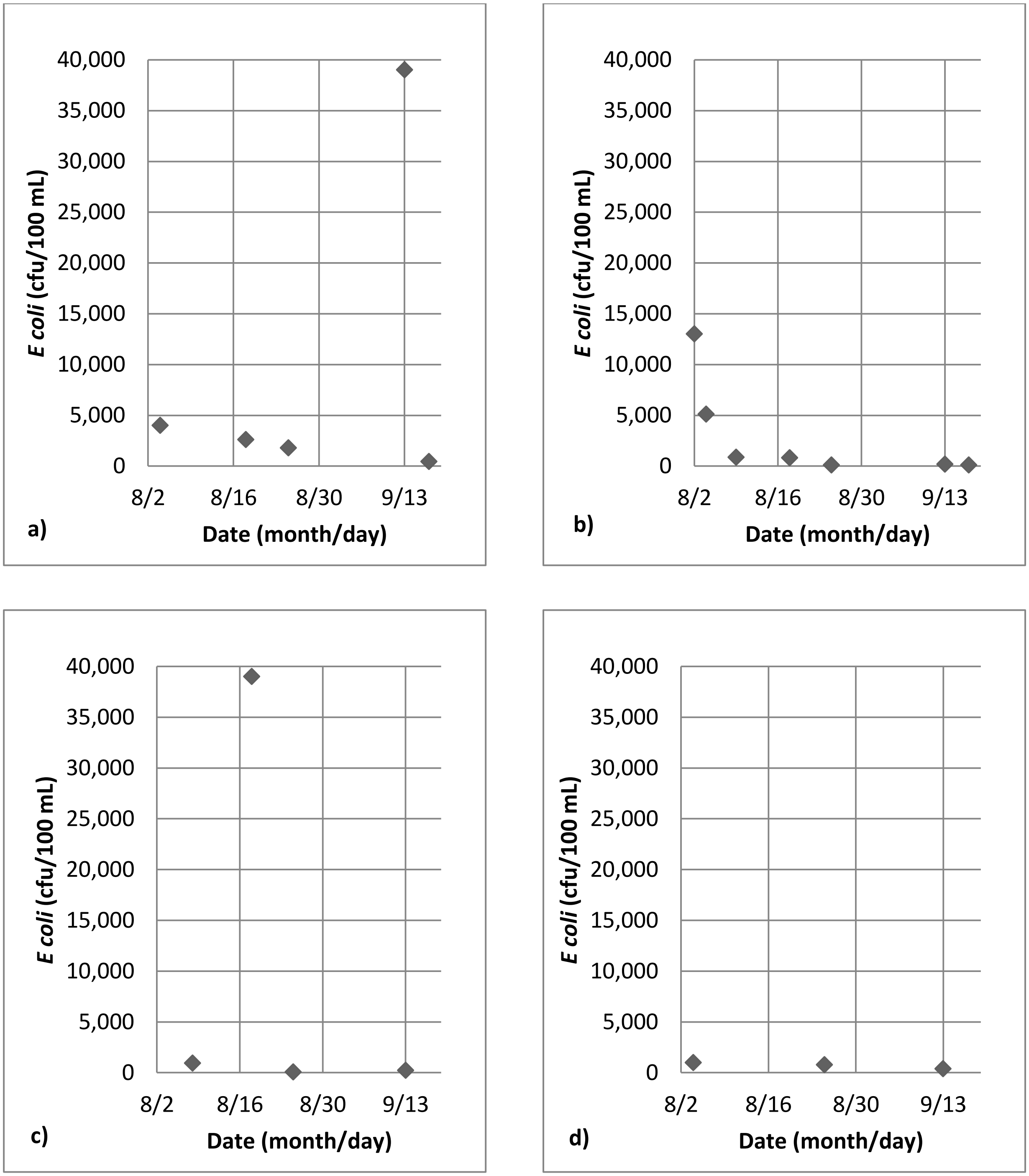


Figure 3.21 *E coli* concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.7 HEM

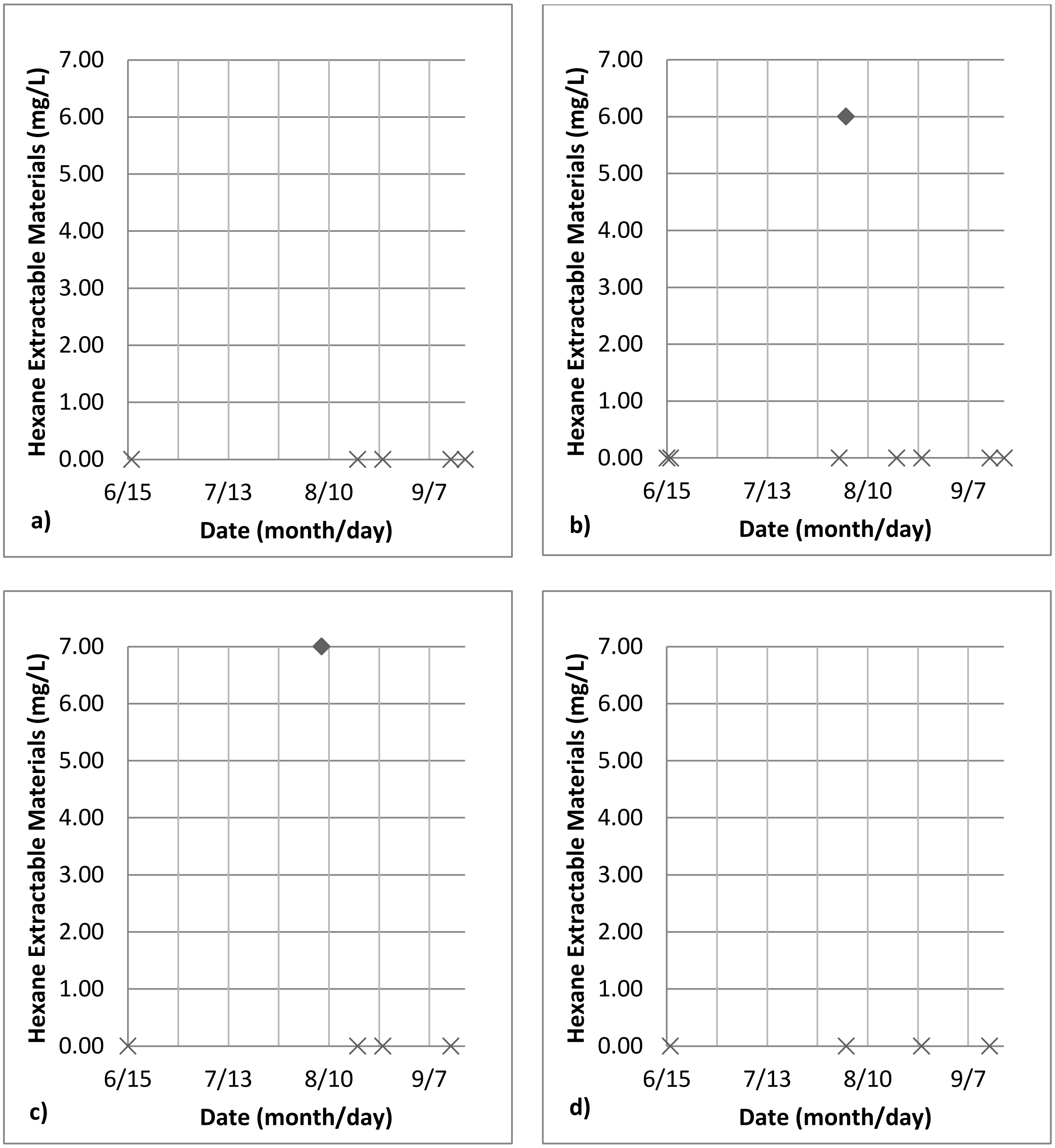


Figure 3.22 Hexane Extractable Materials concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.8 n-Hexane

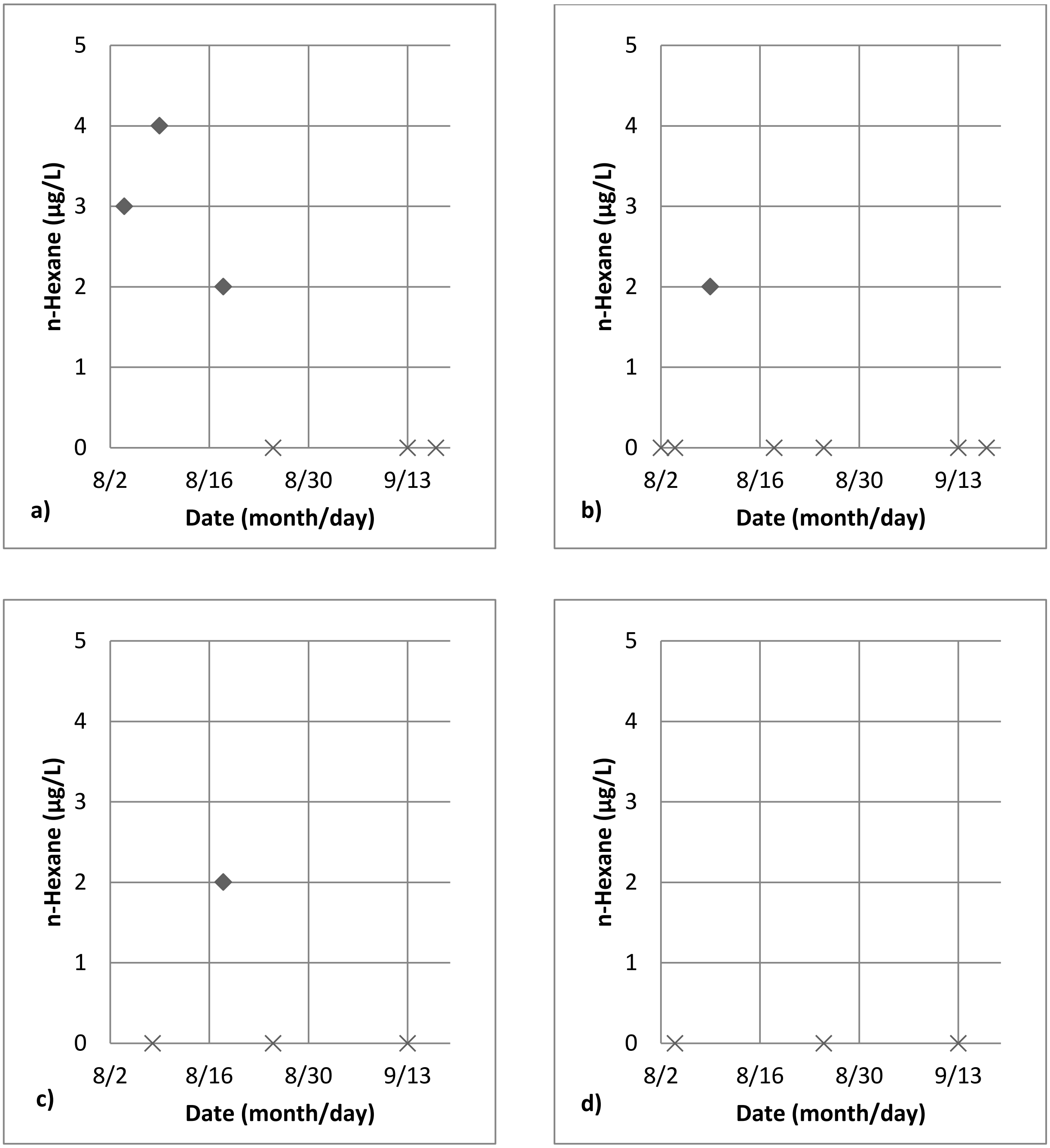


Figure 3.23 n-Hexane concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.9 Iron

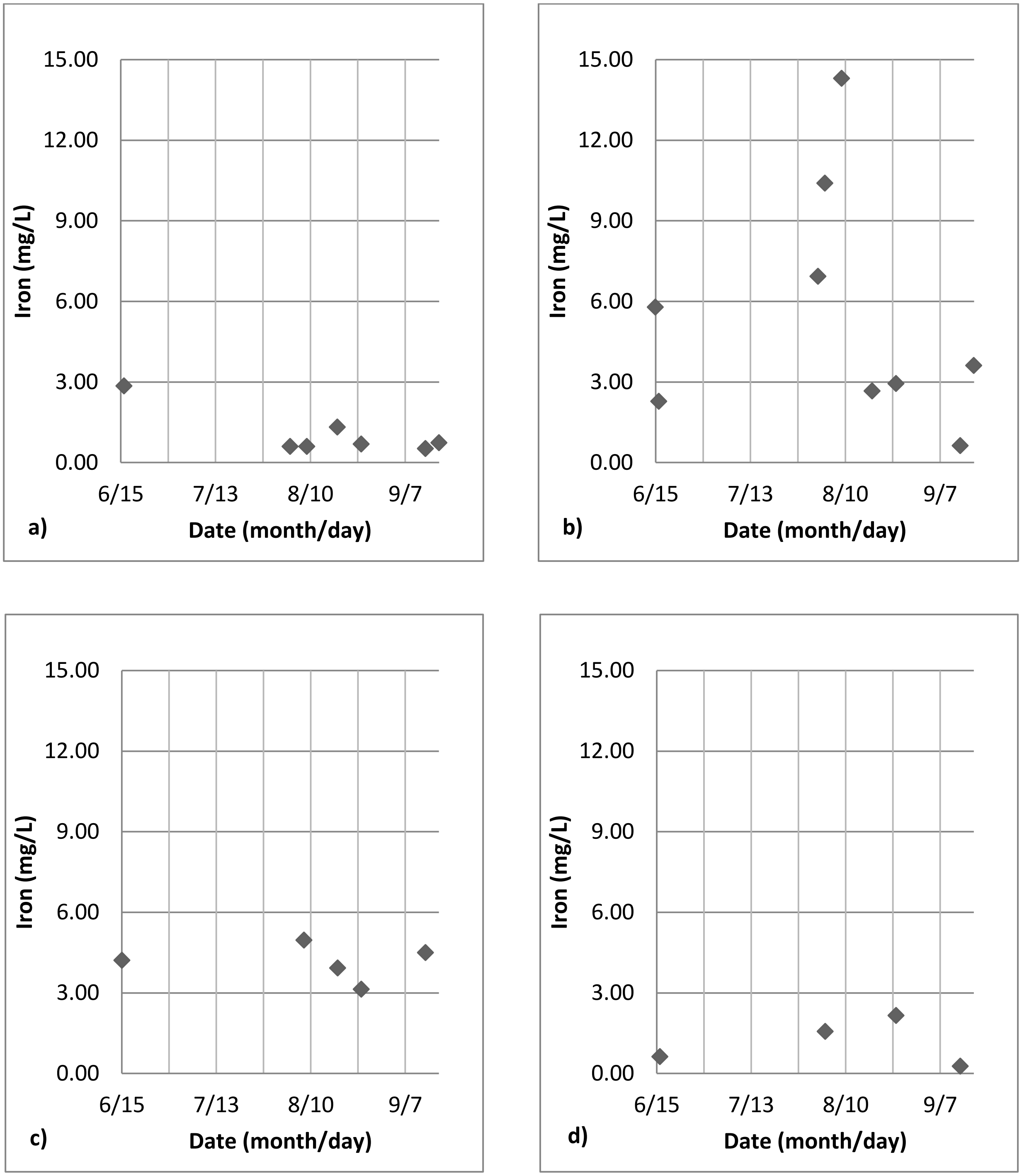


Figure 3.24 Iron concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.10 Nickel

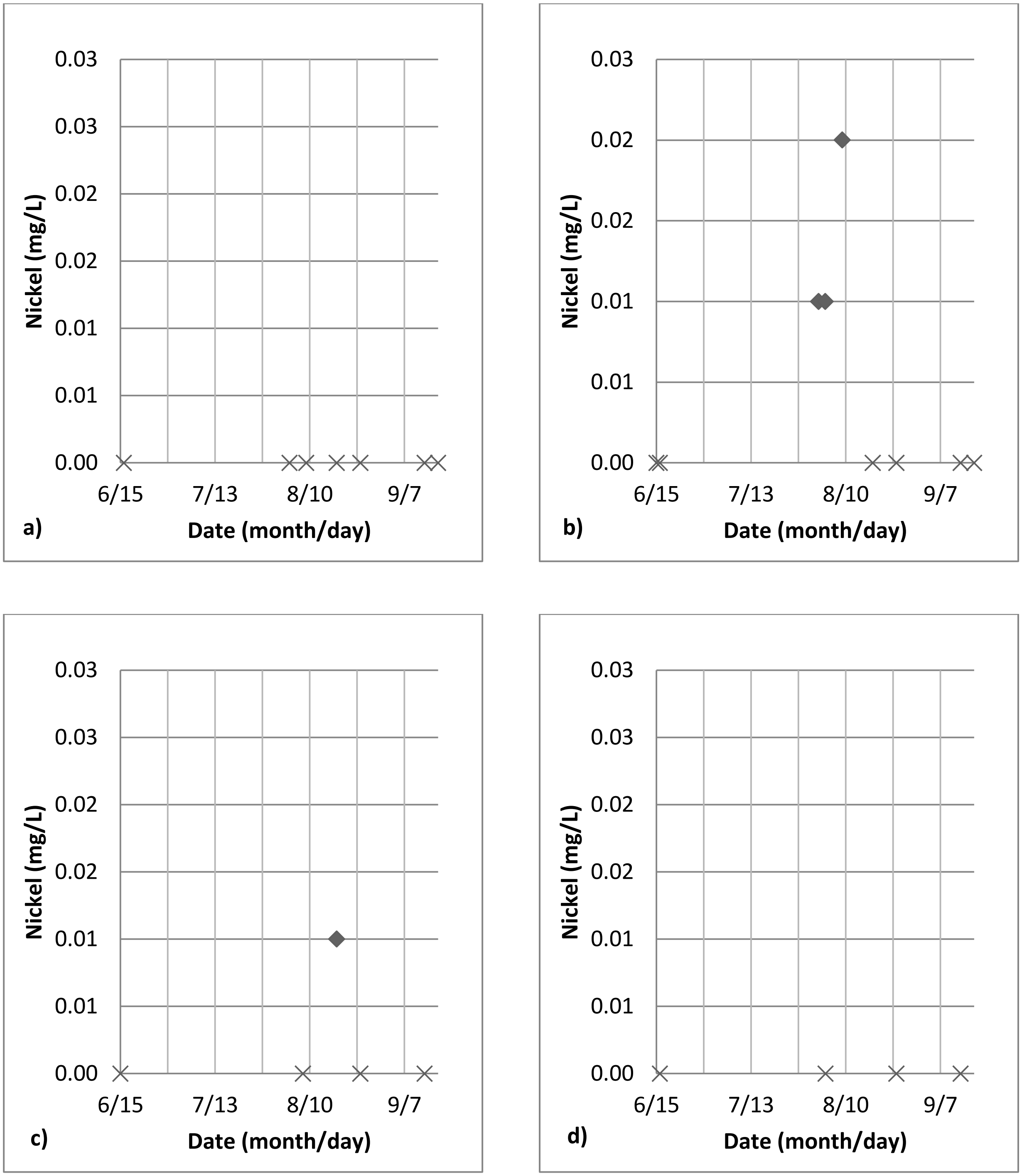


Figure 3.25 Nickel concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.11 Nitrate/Nitrite

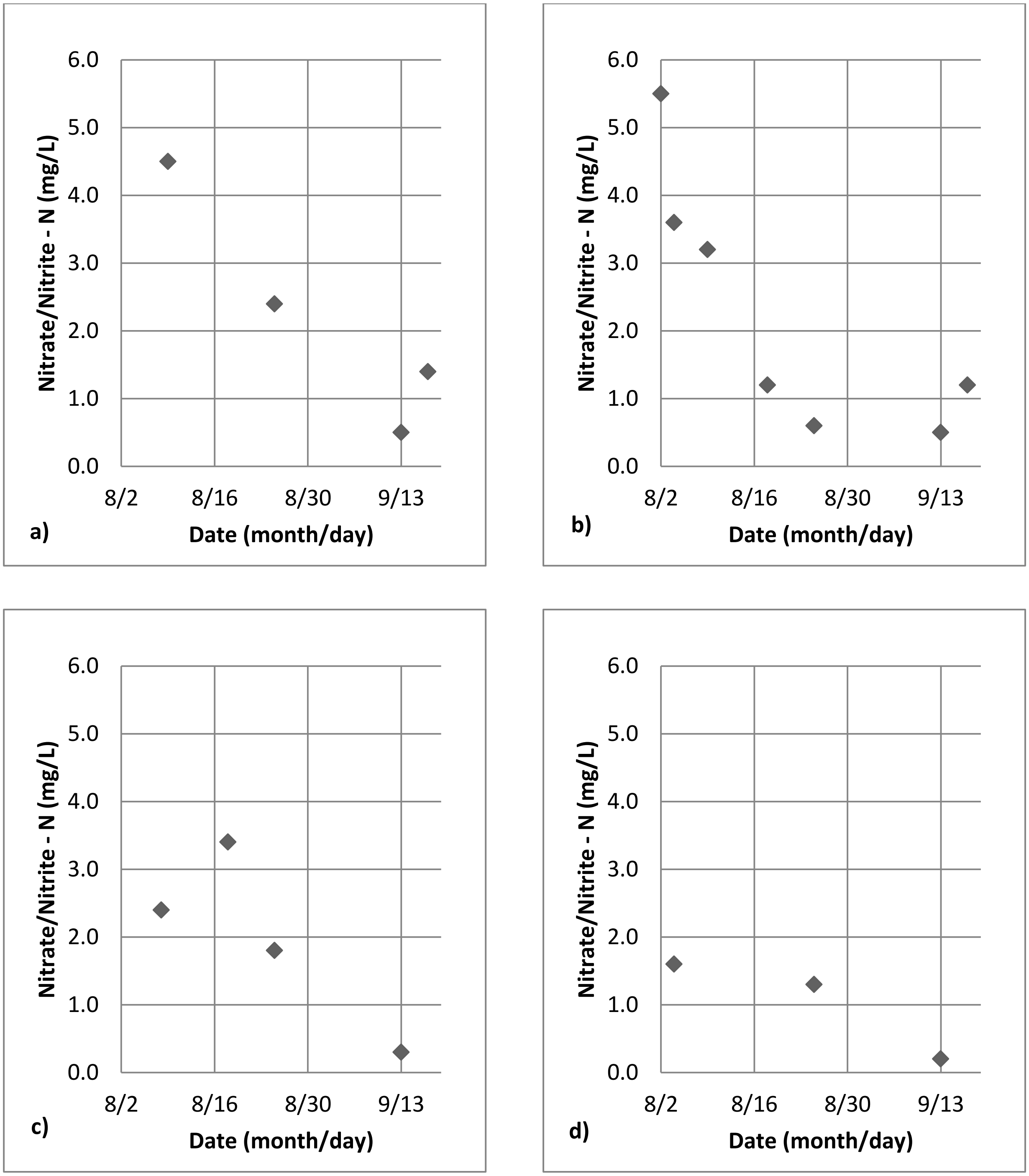


Figure 3.26 Nitrate/Nitrite concentration in runoff from **a**) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.12 Nitrite

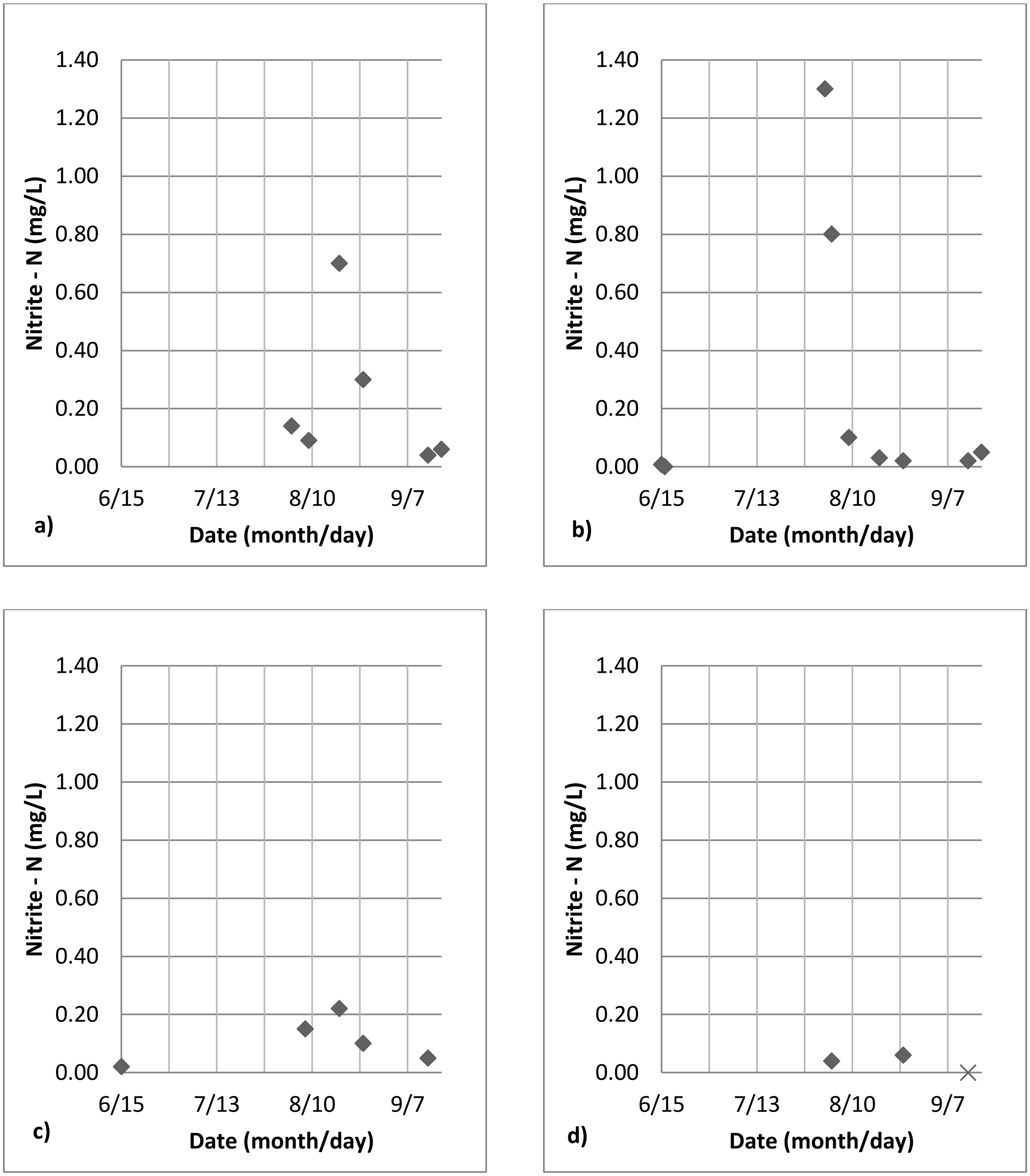


Figure 3.27 Nitrite concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.13 TP

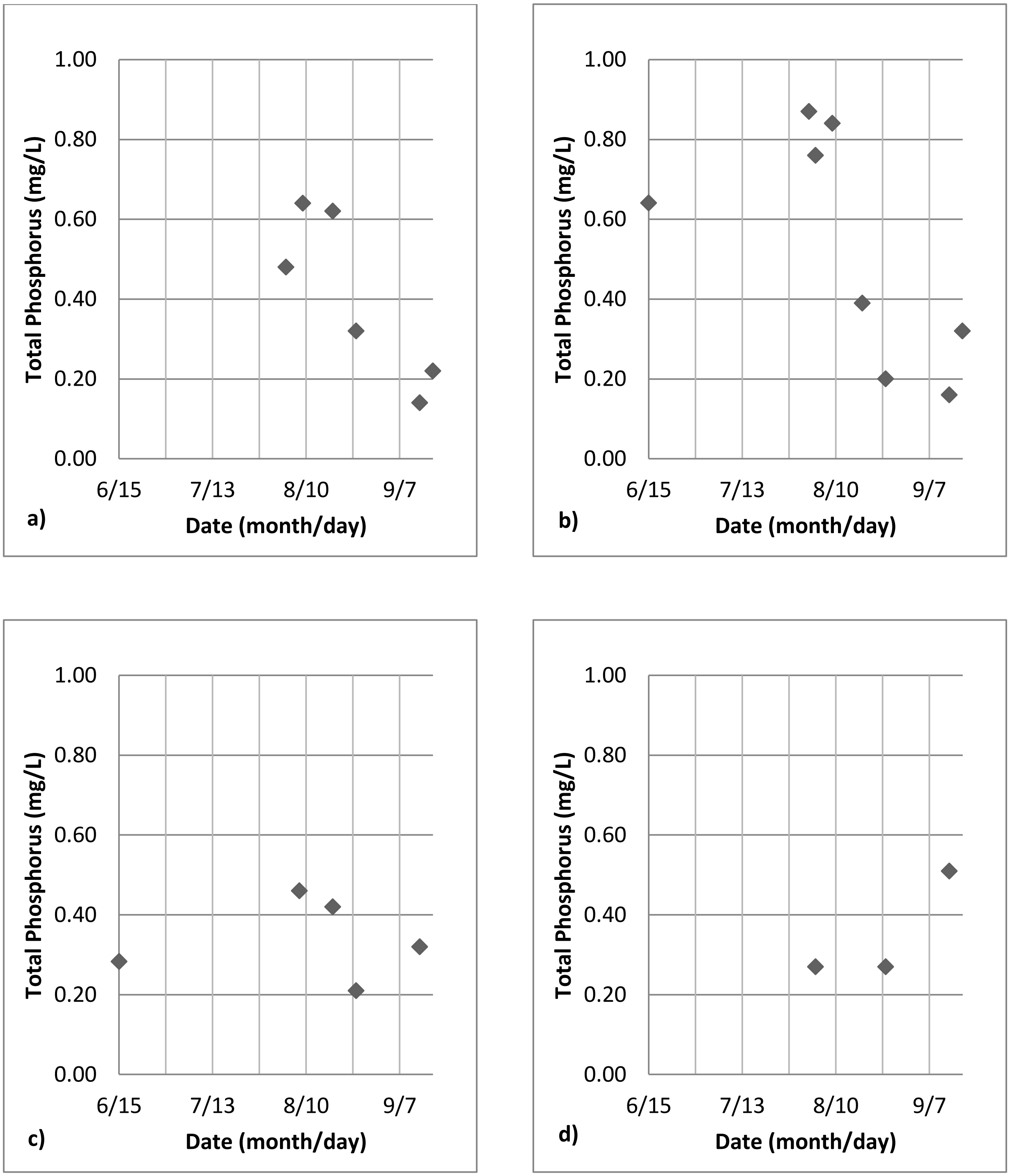


Figure 3.28 Total phosphorus concentration in runoff from a) I-80 Bridge over Platte River b) Highway 64 Bridge over Platte River c) I-80 Bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.14 TKN

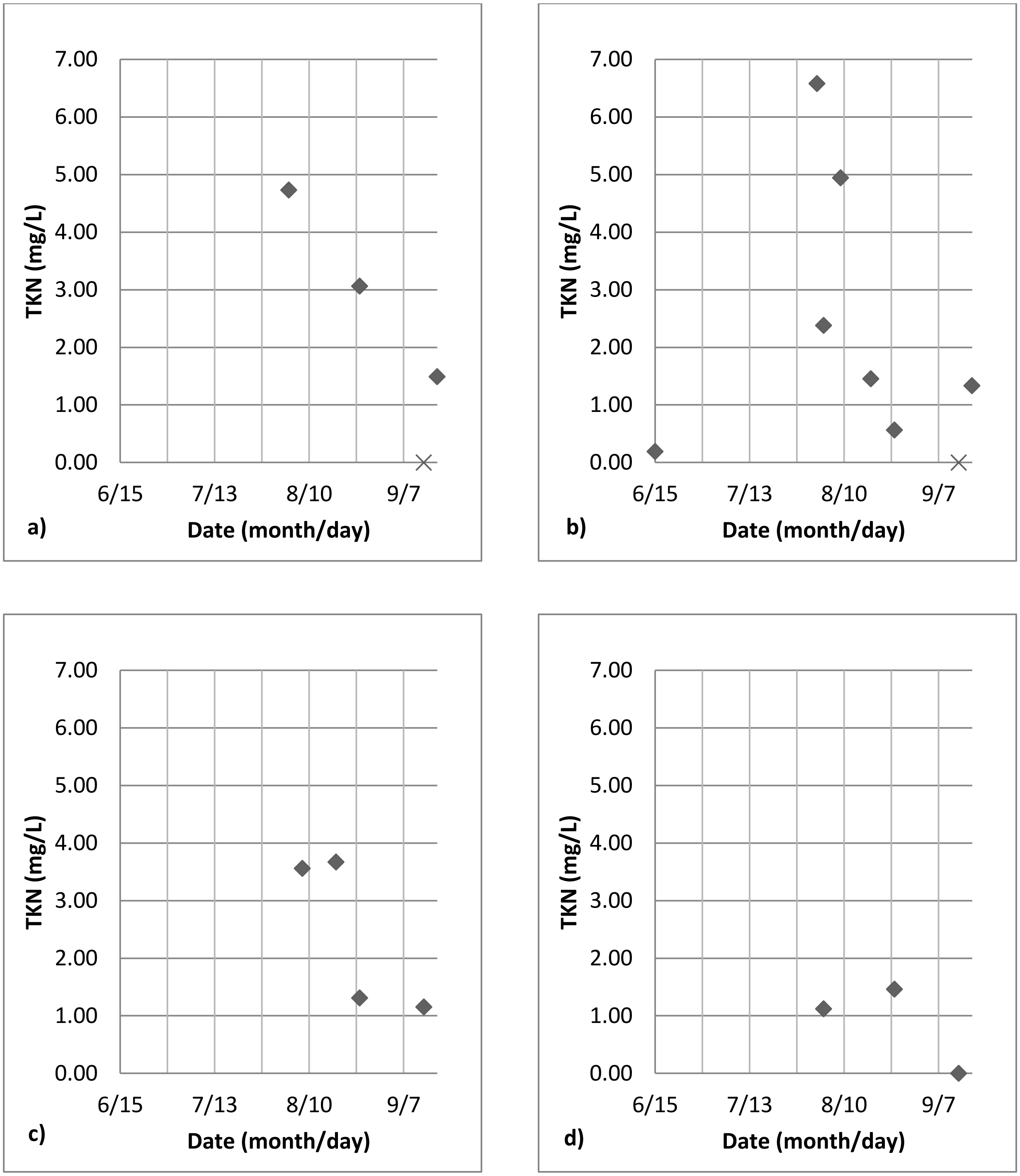


Figure 3.29 TKN concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 Bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.15 Total Purgeable Hydrocarbons

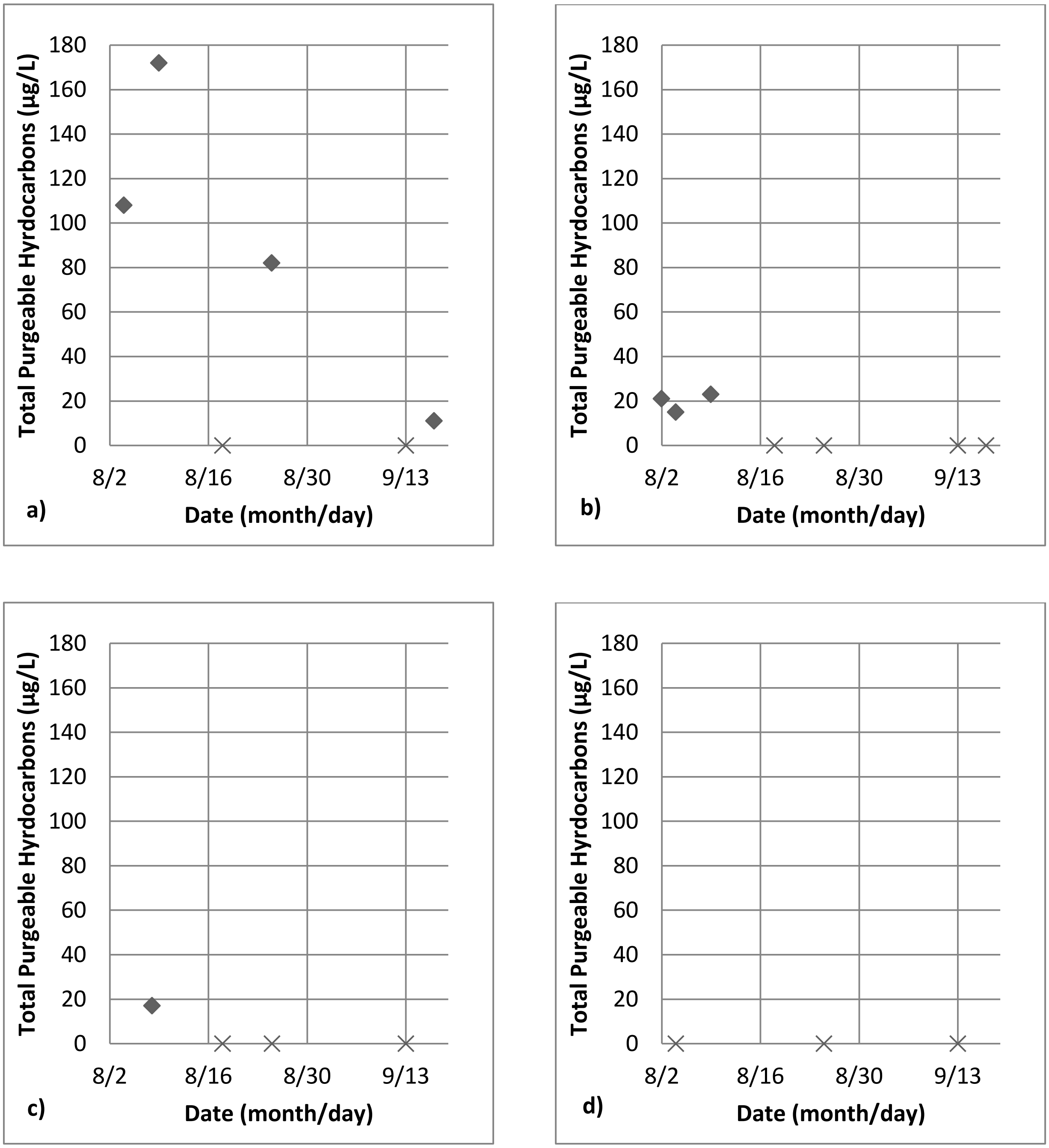


Figure 3.30 Total purgeable hydrocarbons concentration in runoff from a) I-80 Bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.16 Zinc

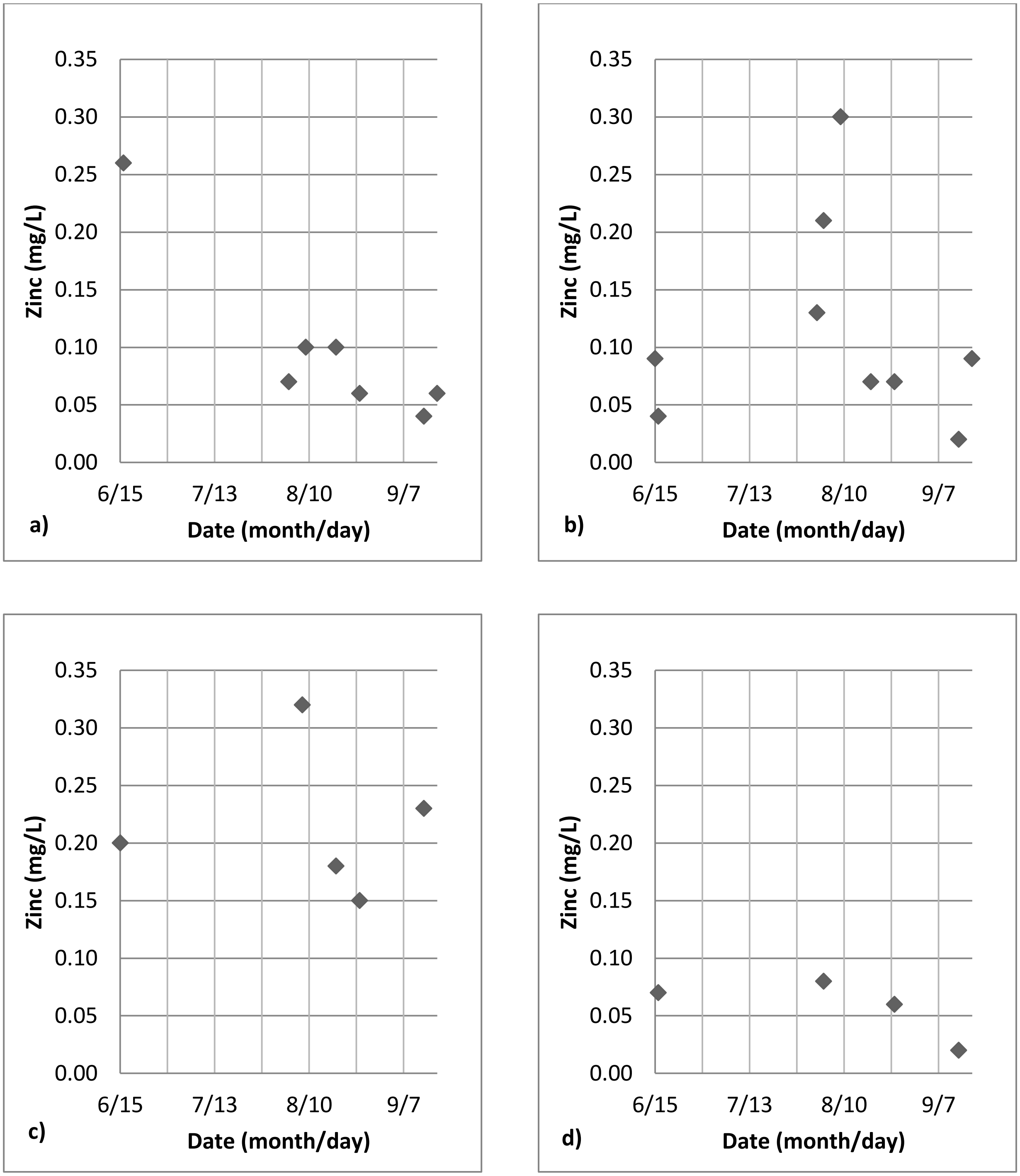


Figure 3.31 Zinc concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.17 pH

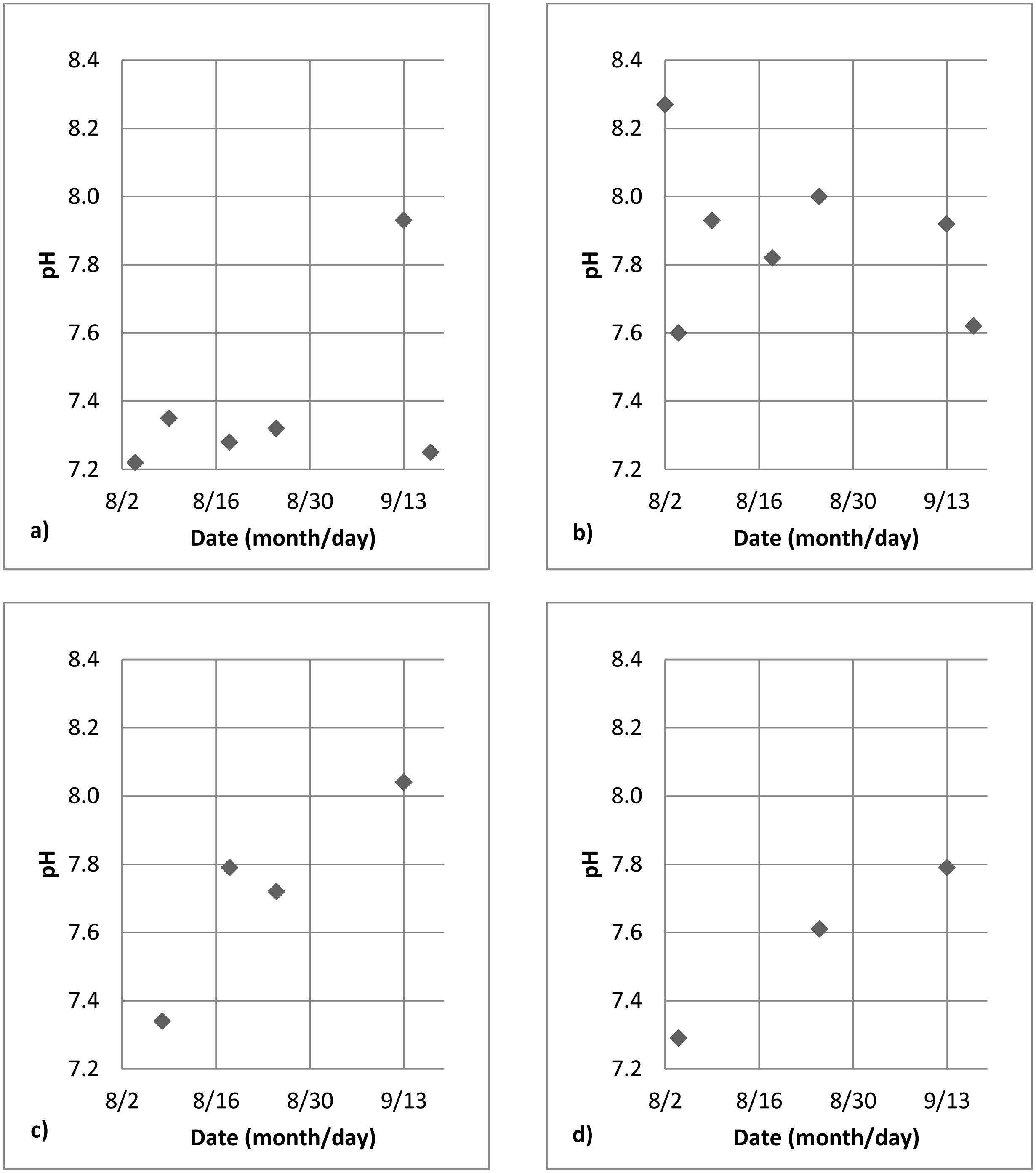


Figure 3.32 pH of Runoff from a) I-80 bridge over Platte River b) Highway 64 Bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.18 Total Solids

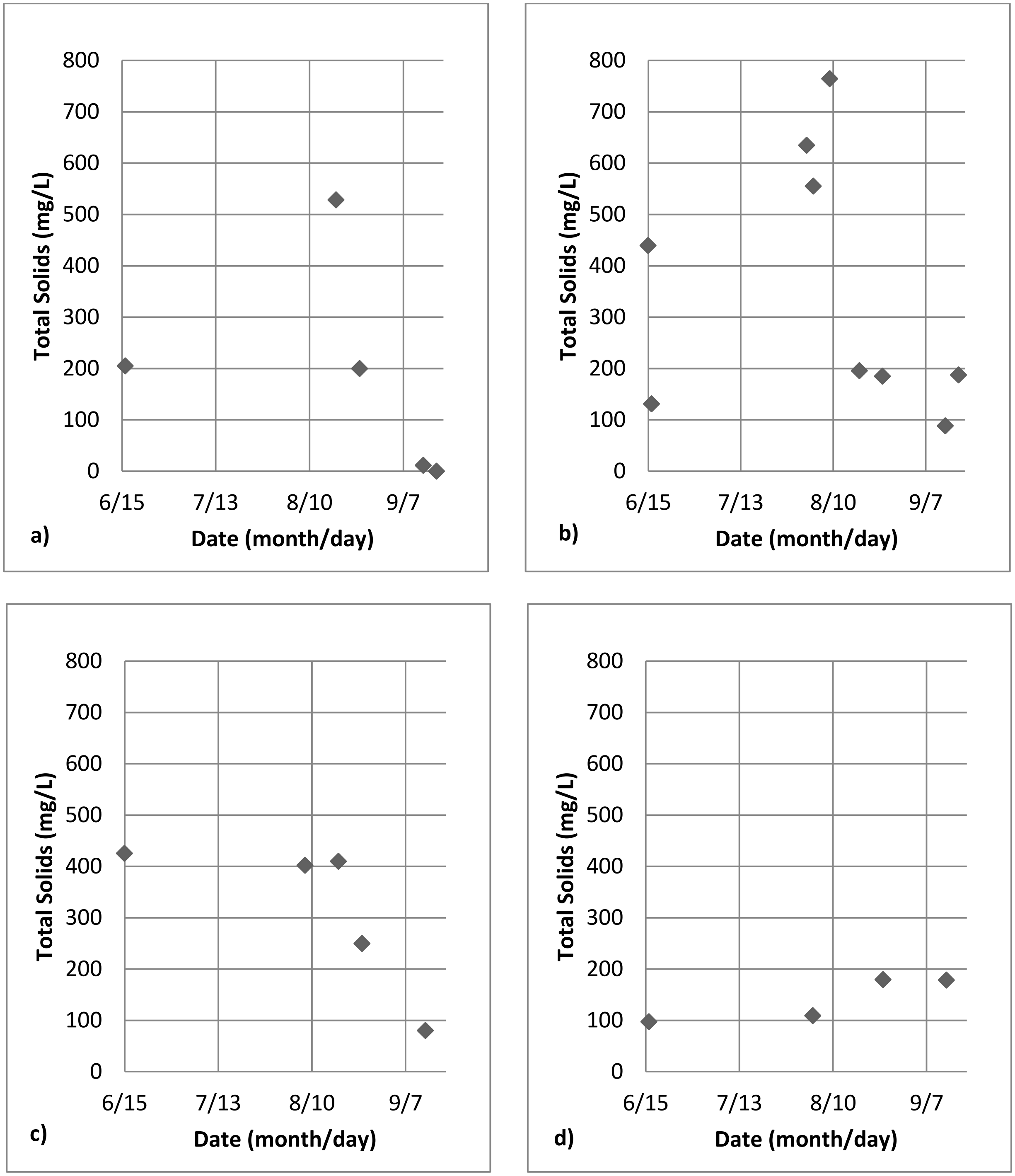


Figure 3.33 Total solids concentration in runoff from **a**) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.19 TSS

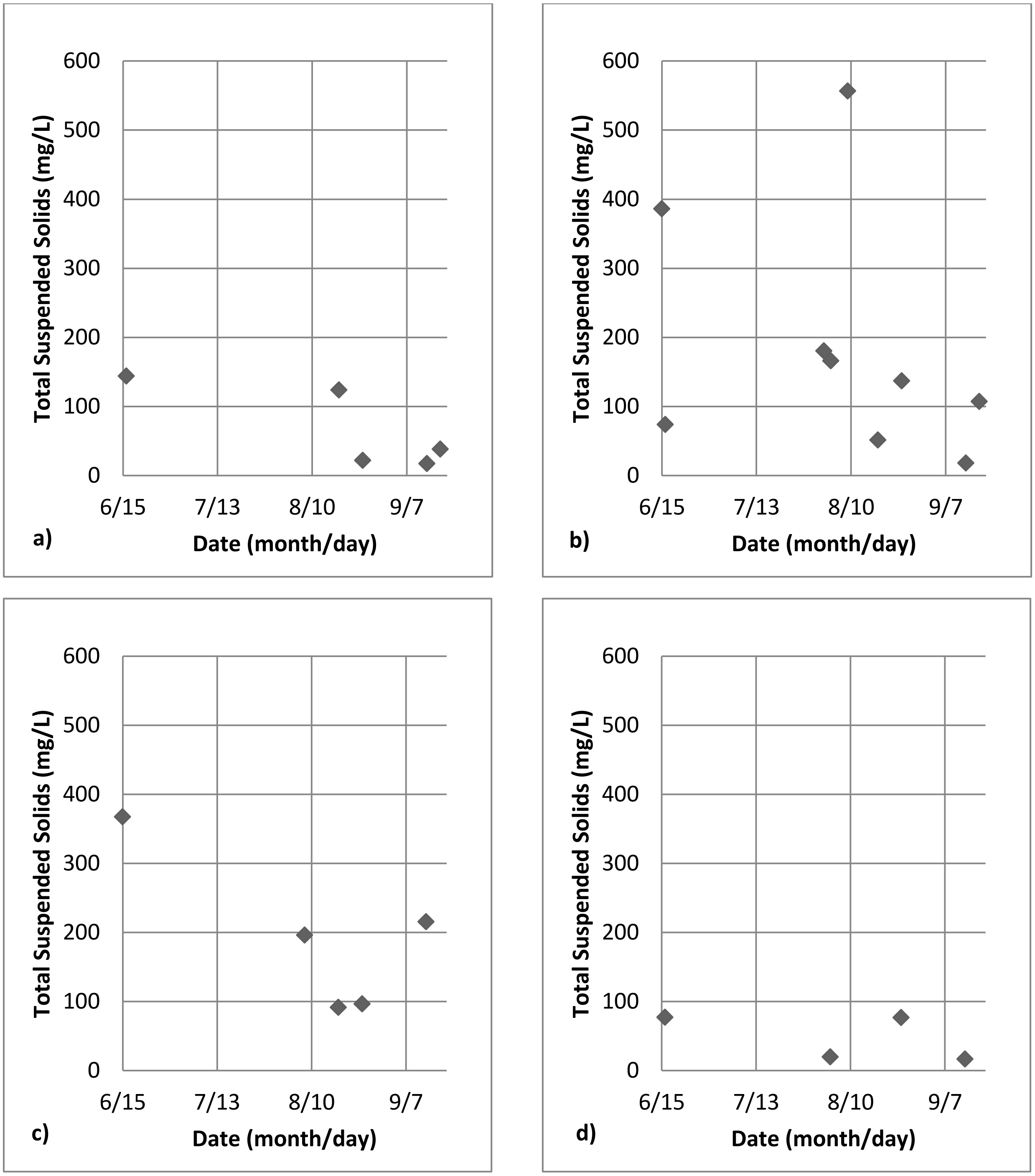


Figure 3.34 TSS concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.2.20 TDS

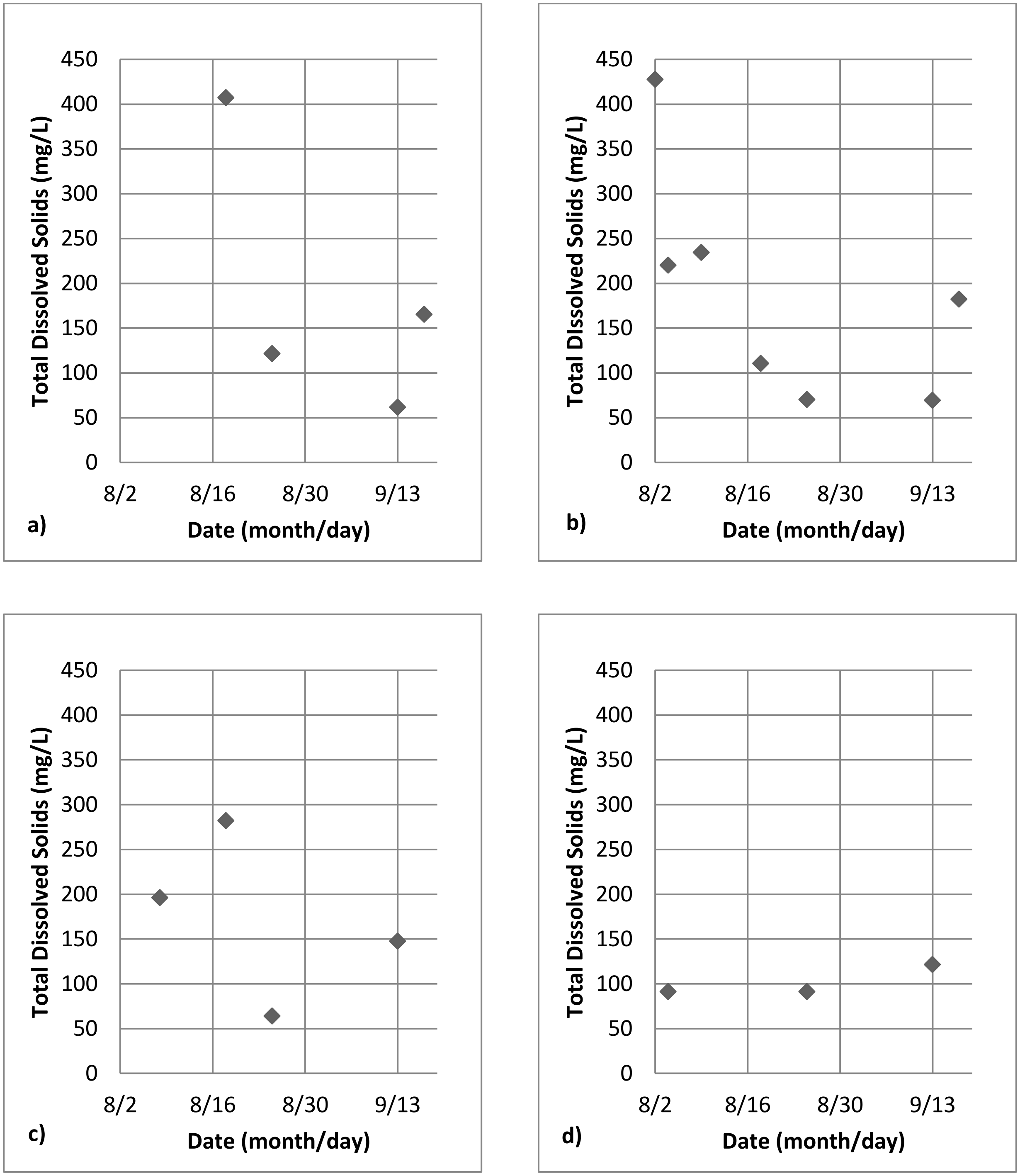


Figure 3.35 TDS concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

3.2.3 Sediment Sampling Results

Sediment sampling was conducted at the Highway 77 over Rock Creek bridge on September 12th, 2012, along with dry weather in-stream sampling. Table 3.1 shows the results for the metals and solids that were tested. Arsenic and cadmium were not included in the table because they were not detected at their respective detection limits of 10 mg/kg and 0.50 mg/kg.

Table 3.1 Sediment sampling results

Distance from bridge (ft)	Chromium (total) (mg/kg)	Copper (total) (mg/kg)	Iron (total) (mg/kg)	Lead (total) (mg/kg)	Nickel (total) (mg/kg)	Percent Solids (%)	Zinc (total) (mg/kg)
20 upstream	8.0	6.3	8,255	5.5	8.1	61.5	26.3
10 upstream	8.0	6.0	7,978	n.d.[a]	7.6	49.3	24.7
0 upstream	8.0	6.7	8,608	6.2	8.9	51.1	26.6
0 downstream	4.3	3.9	4,562	n.d.[a]	4.8	50.3	14.5
10 downstream	5.5	3.8	7,881	5.3	6.6	57.3	19.6
20 downstream	4.8	2.4	10,479	n.d.[a]	7.9	41.7	12.7

[a] Detection limit for Lead = 5.0 mg/kg

3.2.4 Toxicity Testing Results

Due to the cost of toxicity testing, only two runoff samples were tested for toxicity. One sample from the I-80 over the Platte River bridge was tested, as was one sample from the Highway 77 over Rock Creek bridge site. Both were collected during the sampling event on September 13, 2012. These two locations were chosen because they were the same locations as the in-stream dry weather sampling. Test results showed that all of the fathead minnows survived the 48-hour 5-dilution series test. Tables 3.2 and 3.3 show the dissolved oxygen (DO), pH, and survival rates of the fathead minnows at different dilutions for both sites. Table 3.4 shows the constituents that were tested, in addition to the toxicity tests.

Table 3.2 pH and survival rates of the fathead minnows at different dilutions during the 48-hour toxicity test for I-80 over Platte River 9-13-12 runoff sample

	Initial		**Final**		**# alive/20 tested**	
Dilution	**DO**	**pH**	**DO**	**pH**	**24 hr.**	**48 hr.**
100%	7.7	7.8	7.1	8.6	20	20
50%	7.8	7.9	7.1	8.5	20	20
25%	8.0	8.0	7.1	8.4	20	20
12.5%	8.0	8.1	7.3	8.2	20	20
6.25%	8.0	8.1	7.3	8.1	20	20
Control	8.0	8.2	7.2	7.8	20	20

Table 3.3 pH and survival rates of the fathead minnows at different dilutions during the 48-hour toxicity test for Highway 77 Rock Creek 9-13-12 runoff sample

	Initial		**Final**		**# alive/20 tested**	
Dilution	**DO**	**pH**	**DO**	**pH**	**24 hr.**	**48 hr.**
100%	8.1	7.8	7.0	7.6	20	20
50%	7.8	7.7	7.2	7.8	20	20
25%	7.8	7.7	7.3	7.9	20	20
12.5%	7.8	7.7	7.6	7.9	20	20
6.25%	7.6	7.7	7.5	8.0	20	20
Control	7.4	7.6	7.6	7.9	20	20

Table 3.4 Constituents measured before toxicity testing

Constituent	**I-80 over the Platte River**	**Highway 77 over Rock Creek**
Ammoniacal Nitrogen	n.d.	0.43
Ammoniacal Nitrogen	0.14 mg/L	0.21
Total chlorine	n.d.	n.d.
Conductance	104 uS/cm	119 uS/cm
Total Dissolved Solids	44 mg/L	70 mg/L
Alkalinity (total)	33 mg CaCO3/L	38 mg CaCO3/L
Tua P. promelas	< 1.00	< 1.00
LC50 P. promelas	> 100%	> 100%

Chapter 4 Data Analysis and Discussion of Results

4.1 Dry Weather Statistical Analysis

Using the statistical analysis software GraphPad Prism, the upstream and downstream values of contaminants were compared. The comparisons of the dates and locations that were found to be significantly different are shown in table 4.1 below, along with their P-values. However, these few instances do not change the general conclusion that the bridges did not affect downstream contaminant concentrations.

Table 4.1 Statistical analysis P-value results

Bridge	Contaminant	Date	P Value
I-80 over Platte River	Iron	July 13, 2012	0.01674
	TKN	July 13, 2012	0.03029
	Total Solids	Nov 30, 2011	0.04368
Highway 77 over Rock Creek	Iron	Sept 12, 2012	0.04179
	Nitrite – N	Sept 12, 2012	0

4.2 Temporal Trends in Runoff

Refer to section 3.2.2 for figures showing the concentration of contaminants found during the sampling period. Many contaminant concentrations in runoff decreased throughout the summer period for most of the bridges, including concentrations of chloride, conductance, nitrate/nitrite, TP, TKN, and total purgeable hydrocarbons. This is to be expected due to the accumulation of contaminants during the winter months and a decrease in contaminants throughout the wet season, as there were less pollutants to be washed away.

Other contaminants showed a spike in concentration after having low to undetectable values, including benzene, chromium, copper, *E. coli*, HEM, n-hexane, and nickel. In general, these spikes in concentration occurred during the first half of August. Some of these contaminants were not included in the testing until August, so it is difficult to make generalizations regarding their periods of concentration. The remainder, including chromium, copper, HEM, and nickel, had been included in the testing since the start of the summer. Upon examining the contaminants tested over the entire summer coupled with the precipitation figures presented in section 3.2.1, it is suggested that this peak may have occurred due to the lack of rainfall in the month of July. The rainfall in the first half of August was likely just enough to carry pollutants over the bridge deck without a large degree of dilution.

4.3 Correlation between Antecedent Dry Period (ADP) and Pollutant Concentration

The following figures compare the concentrations of contaminants in the bridge runoff with the ADP in days. Also included in the graphs are trend lines to better represent general increases or decreases in the data. Upon examining the first two graphs, it is difficult to see any correlation between ADP and the concentration of pollutants in bridge runoff. Since this is the case across all types of pollutants (showing similar or no results), only the first few sets of figures are shown in this section. The remaining sets of figures can be found in Appendix B of the current report.

4.3.1 Chloride Concentration versus ADP

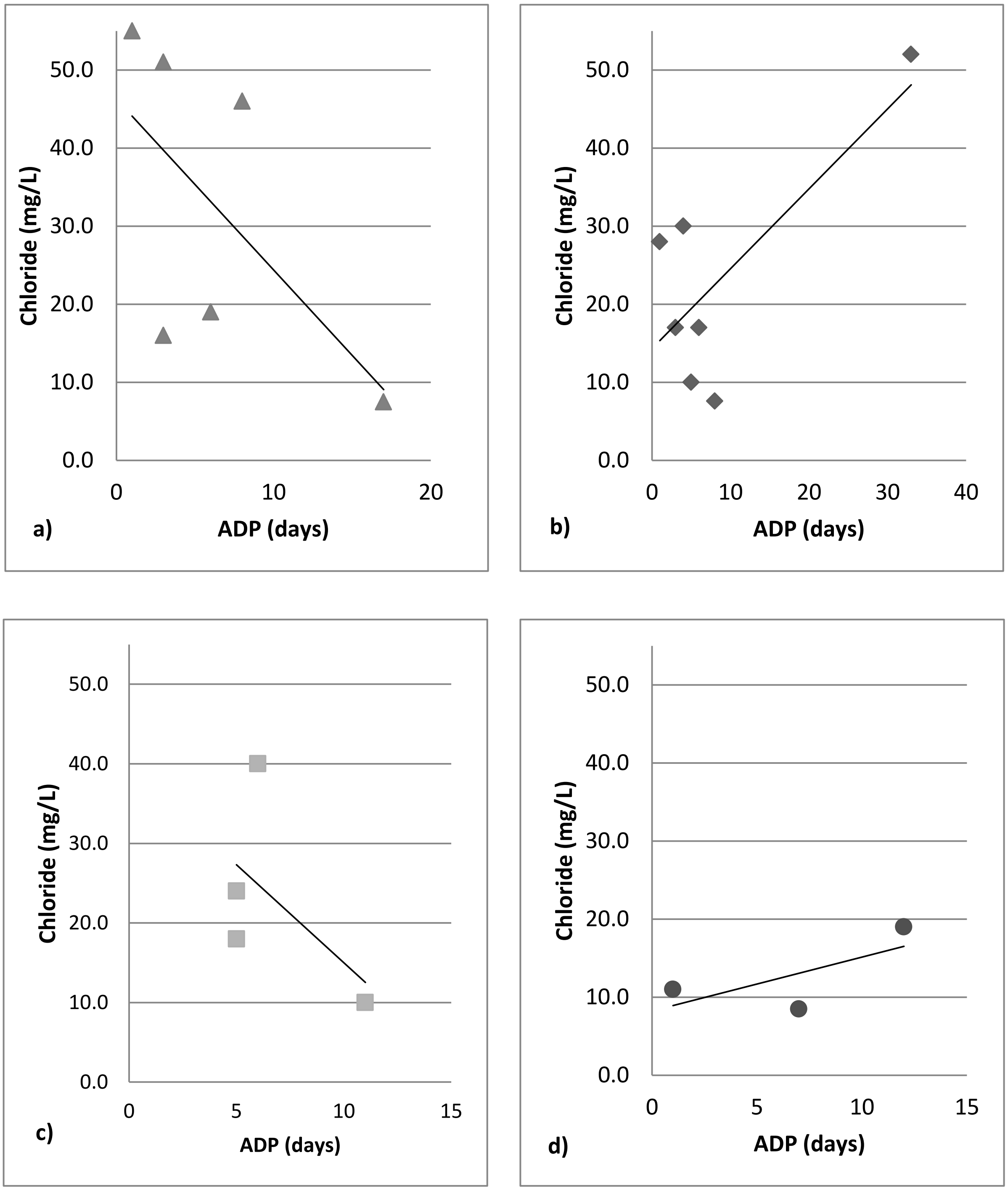


Figure 4.1 Chloride concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

4.3.2 Conductivity versus ADP

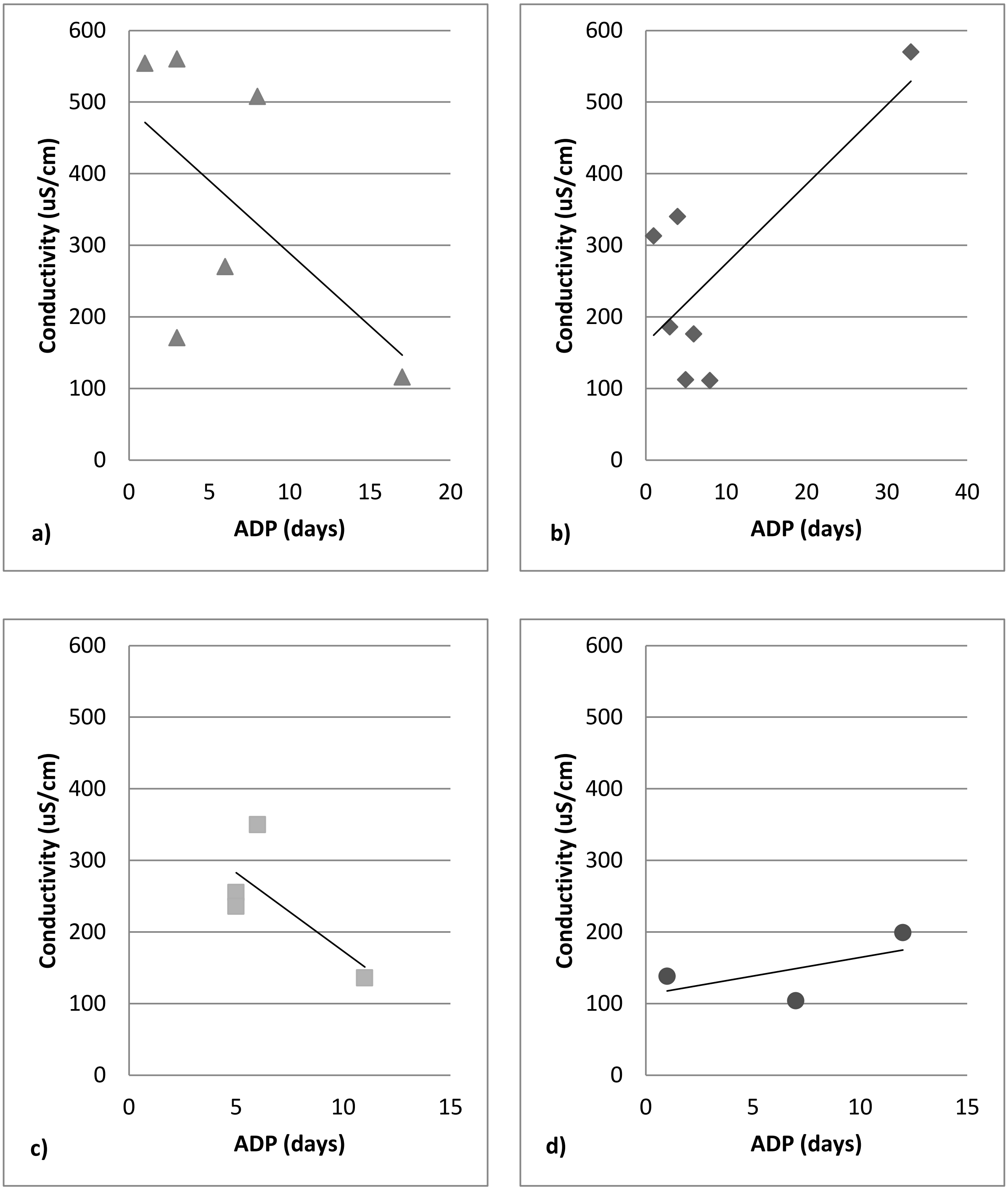


Figure 4.2 Conductivity of Runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

4.3.3 Copper Concentration versus ADP

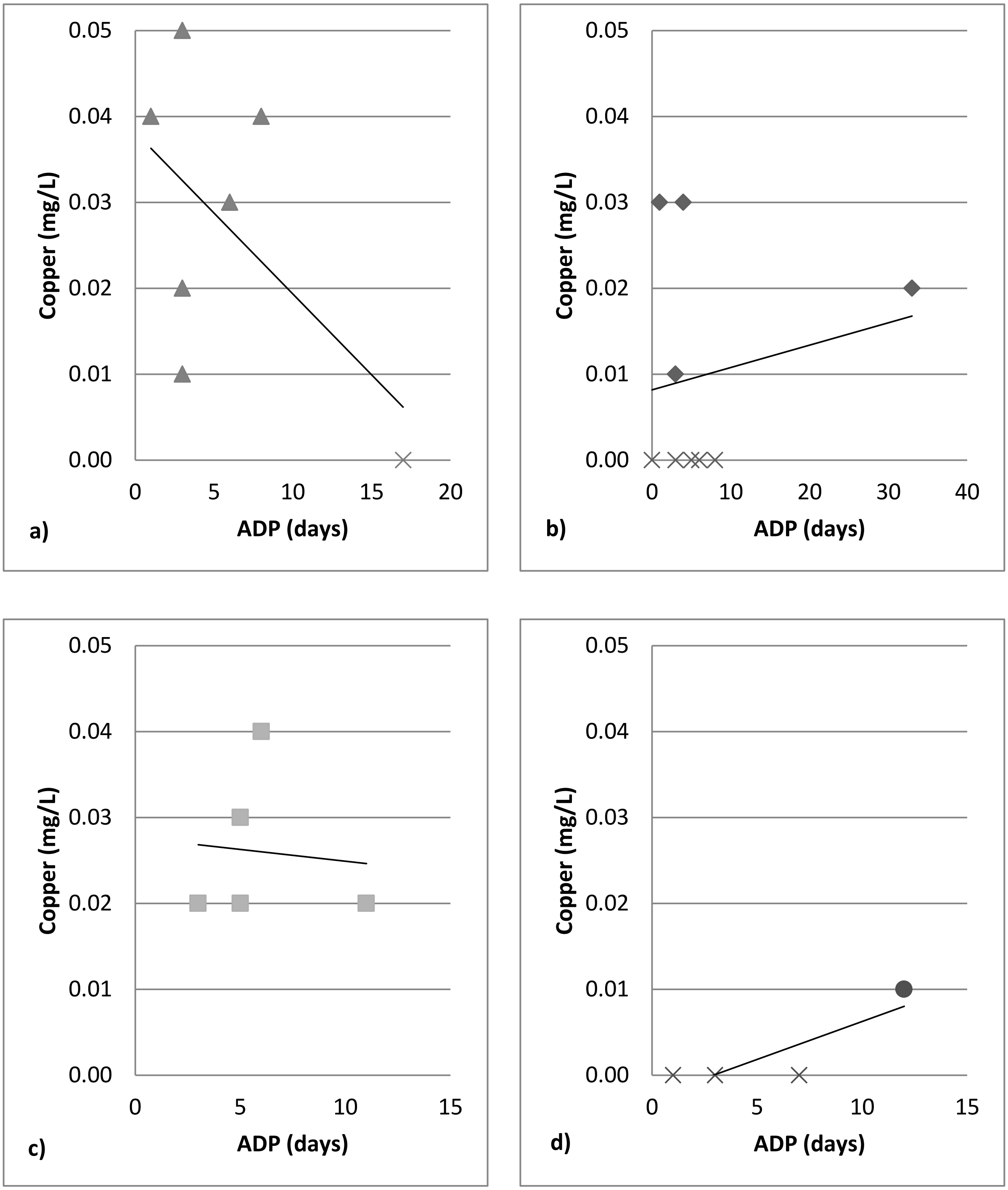


Figure 4.3 Copper concentration in runoff from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

4.4 Correlation between ADT and Pollutant Concentration

The following sets of figures show the average and standard deviation of pollutants for each bridge based on their respective ADT. The ADT is the amount of traffic per day on the bridge in both directions. There was little to no correlation between the amount of traffic and the concentration of the pollutants in the bridge runoff.

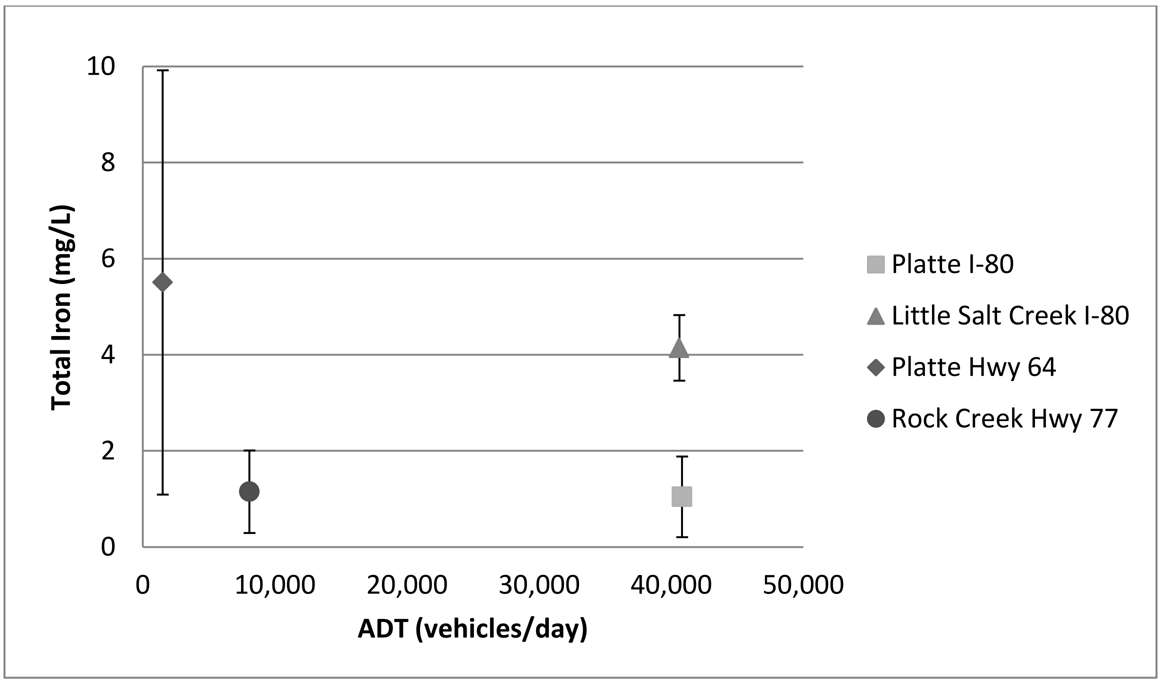


Figure 4.4 Iron concentration of bridge deck runoff versus ADT

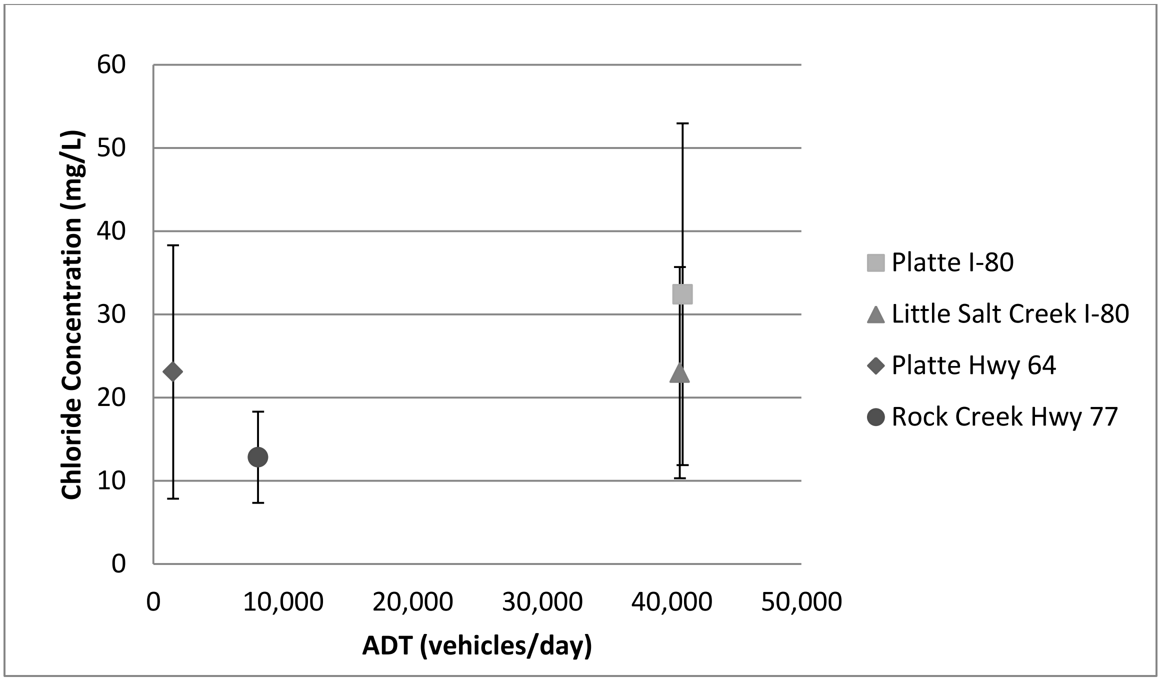


Figure 4.5 Chloride concentration of bridge deck runoff versus ADT

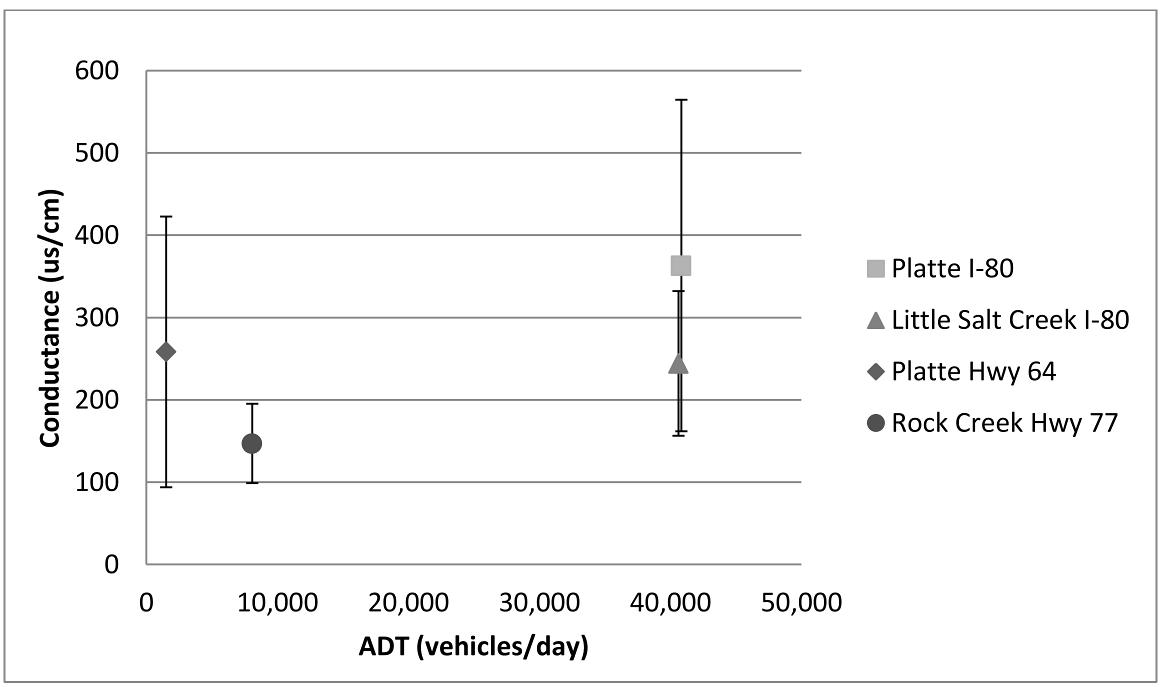


Figure 4.6 Conductance of bridge deck runoff versus ADT

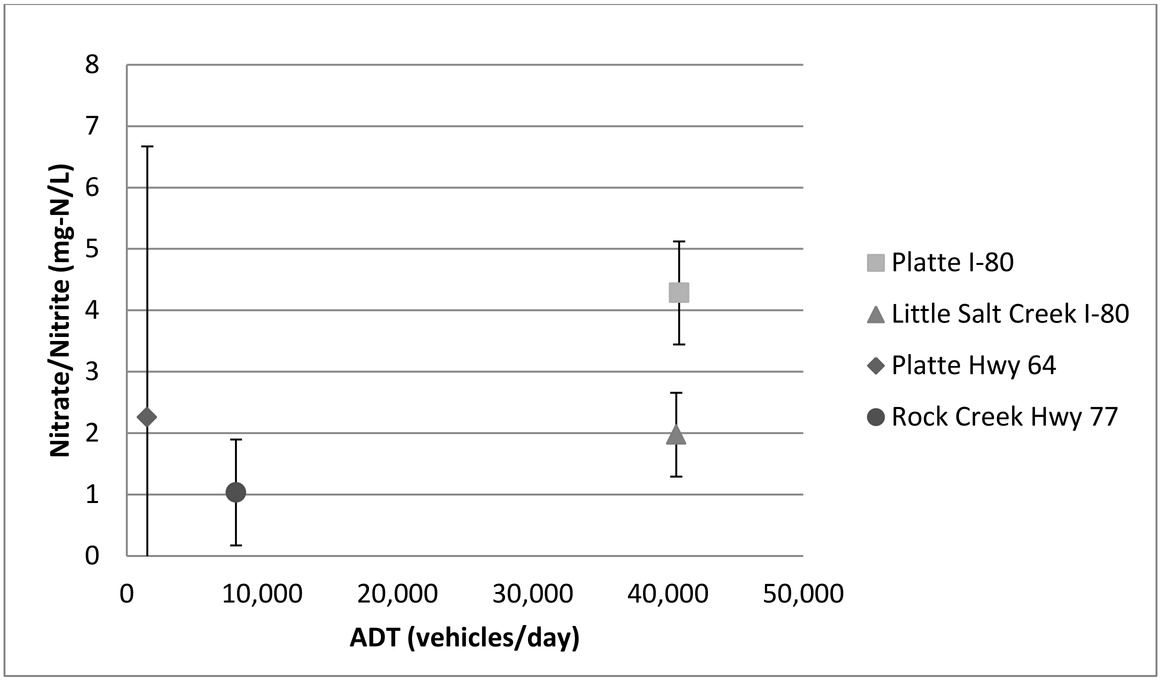


Figure 4.7 Nitrate/Nitrite in bridge deck runoff versus ADT

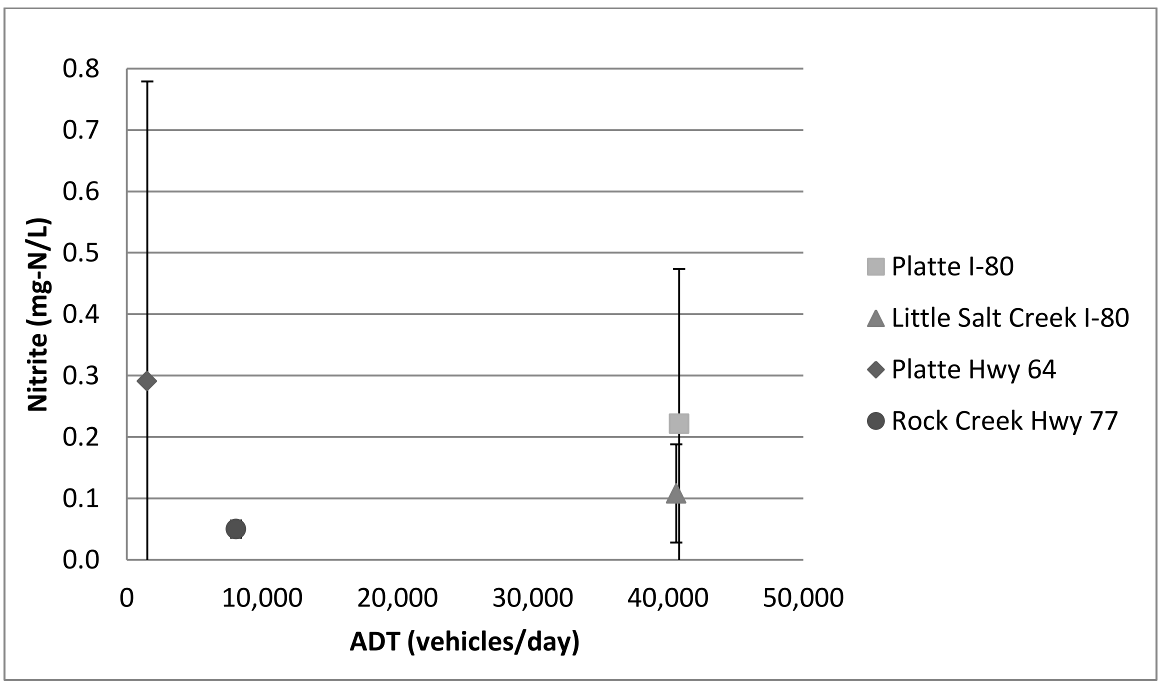


Figure 4.8 Nitrite in bridge deck runoff versus ADT

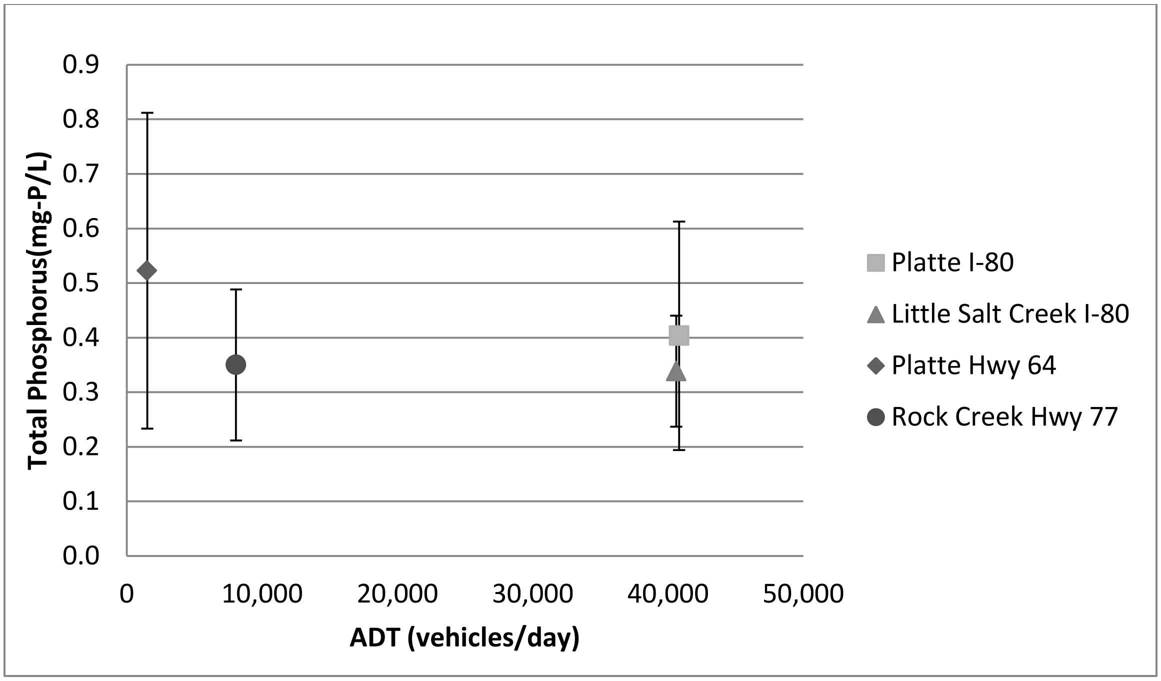


Figure 4.9 TP in bridge deck runoff versus ADT

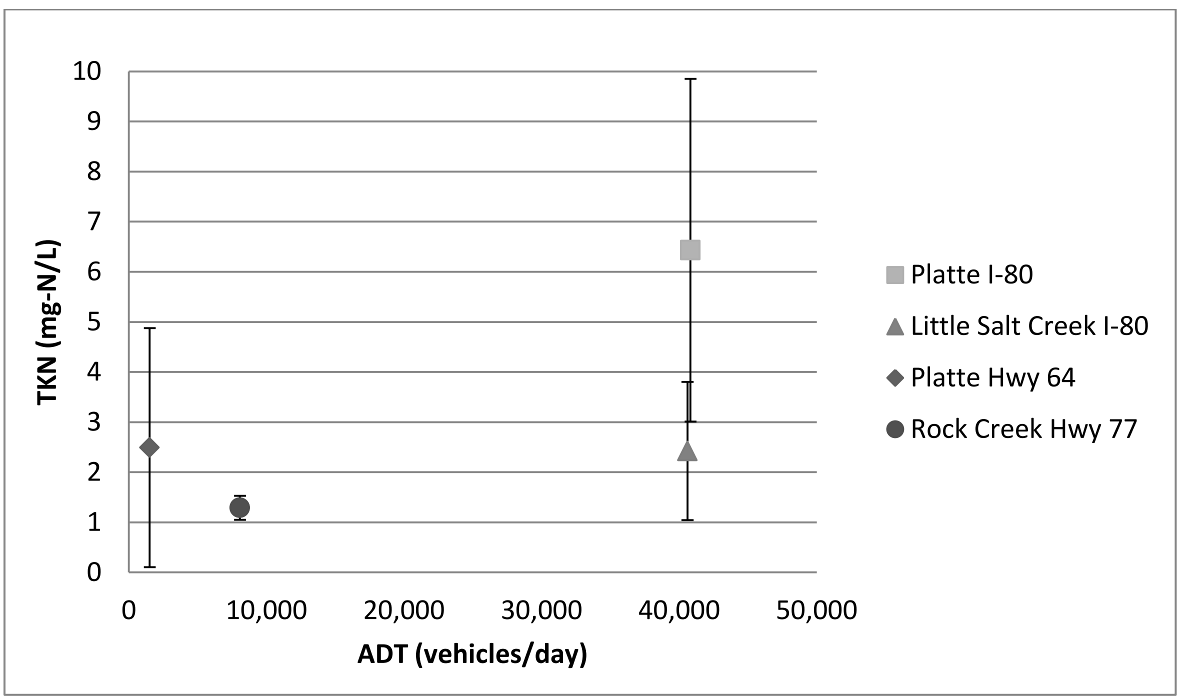


Figure 4.10 TKN in bridge deck runoff versus ADT

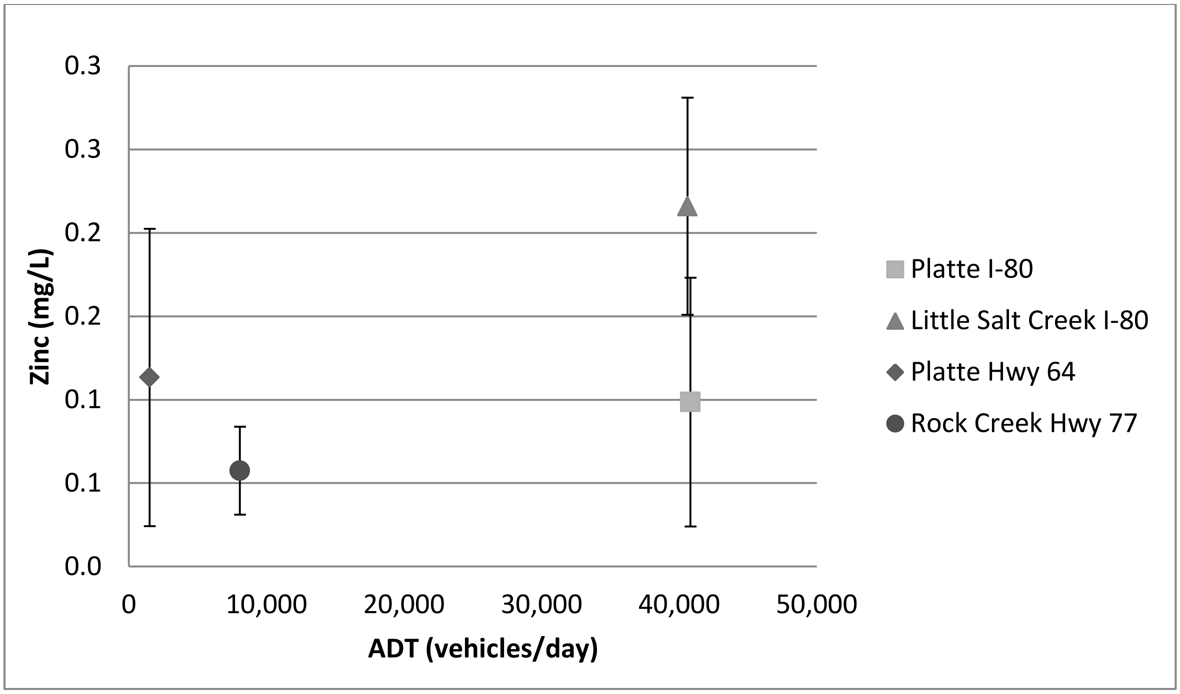


Figure 4.11 Zinc in bridge deck runoff versus ADT

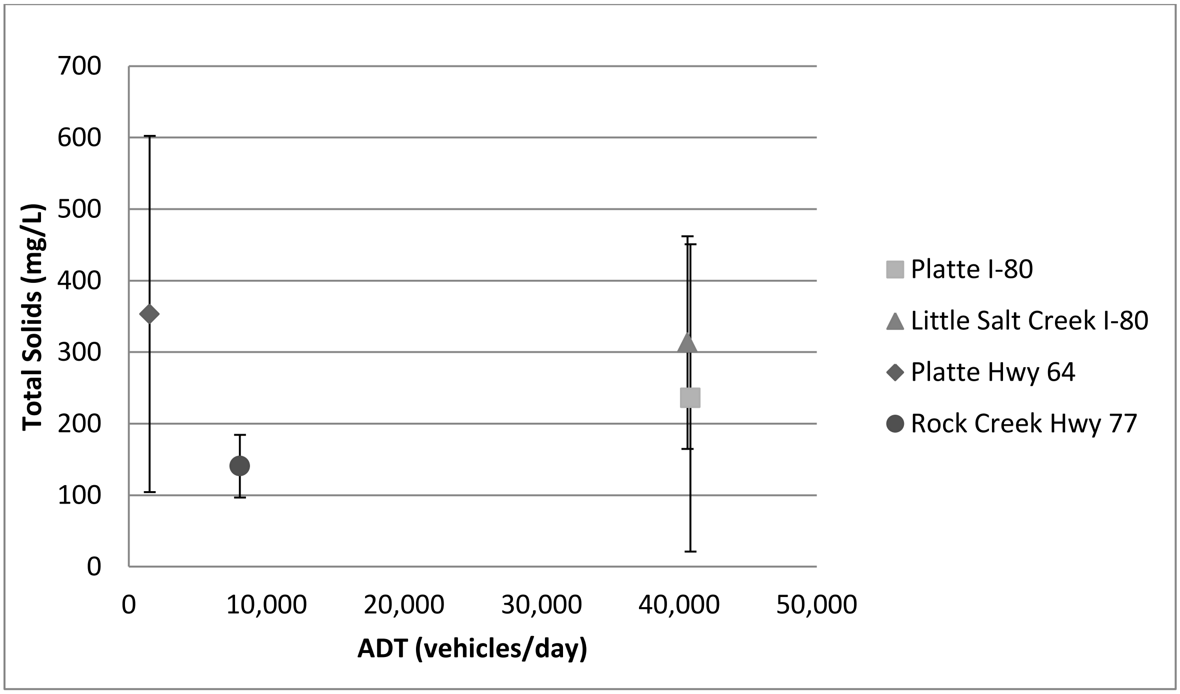


Figure 4.12 Total solids in bridge deck runoff versus ADT

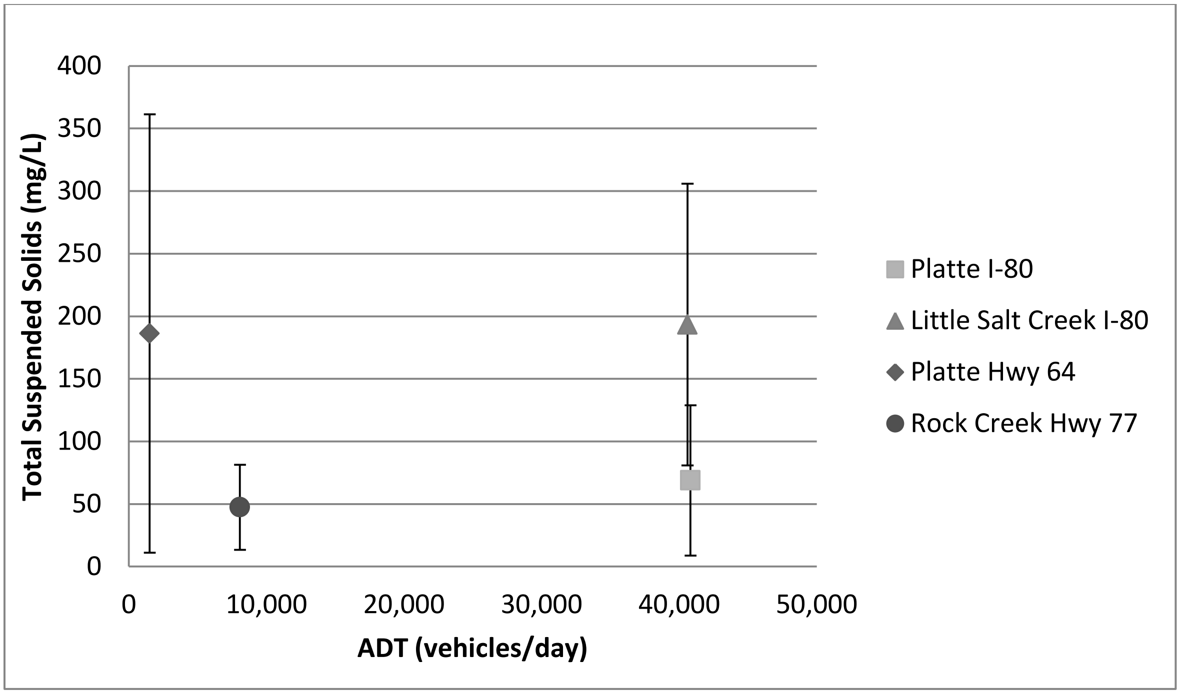


Figure 4.13 TSS in bridge deck runoff versus ADT

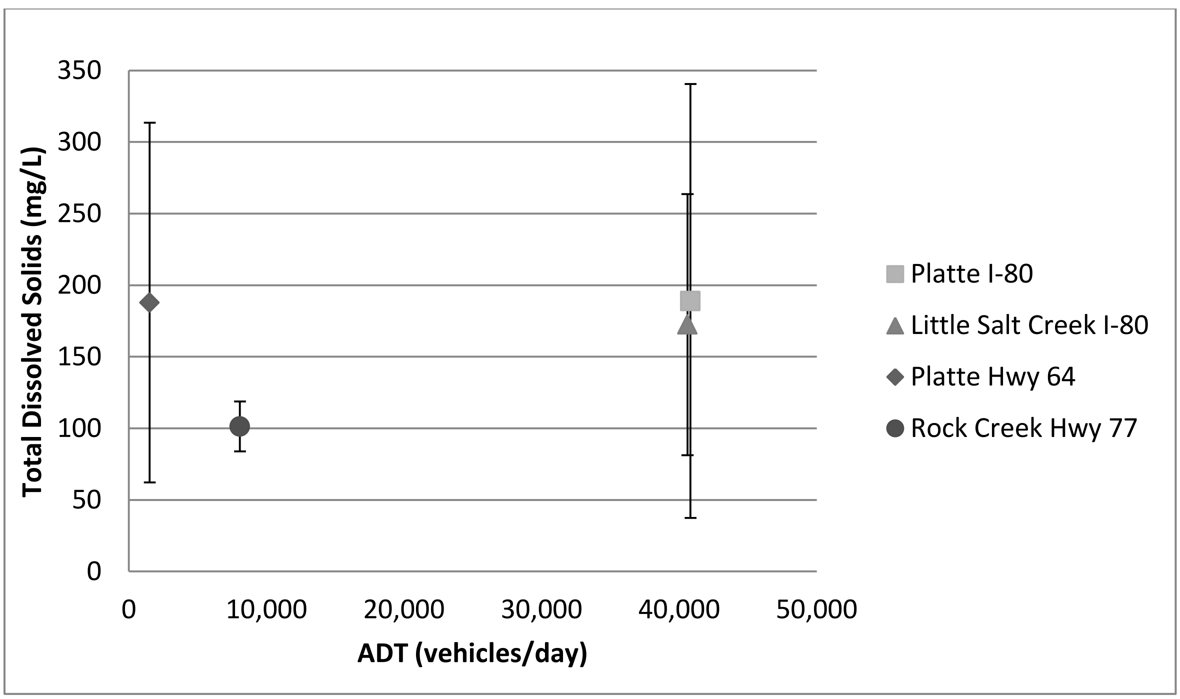


Figure 4.14 TDS in bridge deck runoff versus ADT

4.5 Literature Comparison

Table 4.2 shows a comparison of the values found in this study as compared to other recent studies. The URS 2010 study in North Carolina was an extensive analysis of bridge runoff across the state, the final conclusion of which was that the concentration of contaminants from bridge decks was sufficiently diluted and dispersed so as to not affect river and stream wildlife. Further information regarding this and other studies shown in table 4.2 is explained in the literature review in section 1.2.2. The NDOR highway runoff study was conducted by a fellow UNL graduate student, who measured concentrations of highway runoff in Nebraska. The study provides good insight into differences between highway and bridge runoff that are specific to Nebraska.

Table 4.2 Comparison of contaminant values with literature values

	Bridge Runoff Studies			NDOR Constructed Wetlands Highway Runoff Study 2012		
Contaminants	**NDOR 2012 Average Values**	**NDOR 2012 Max Values**	**URS 2010**	**West Pipe Mean EMCs**	**East Pipe Mean EMCs**	**USEPA 1983 (NURP-Urban Runoff)**
Number of Sites (n)	4	4	n= 15	1	1	n= 28
pH	7.65	8.27	6.8			
TDS (mg/L)	170.22	427.72	34	509	332	
TSS (mg/L)	138.12	556.64	39	240	120	100
Chloride (mg/L)	24.33	55.00	0.81	207.3	139	
Specific Conductance (µmhos/cm)	270.25	570.00	51			
Total Kjeldahl Nitrogen (TKN) (mg/L)	3.16	9.23	0.71	2.40	1.71	1.5
Total Phosphorus (mg/L)	0.42	0.87	0.169	0.248	0.215	0.33
Nitrate + Nitrite (mg/L)	2.63	9.20	0.21	0.8	0.63	0.68
Total Recoverable Arsenic (µg/L)	n.d.	n.d.	0.97			
Total Recoverable Cadmium (µg/L)	n.d.	n.d.	0.10			
Total Recoverable Chromium (µg/L)	10	20	3.9	0.040	0.027	
Total Recoverable Copper (µg/L)	30	50	9.6	0.048	0.026	34
Total Recoverable Iron (µg/L)	3,290	14,300	1,420	50	4.5	
Total Recoverable Nickel (µg/L)	10	20	2.3	0.0010	0.009	
Total Recoverable Zinc (µg/L)	120	320	65.9	0.0273	0.0235	160
Total Petroleum Hydrocarbons (TPH) (mg/L)	56.13	172.00	3.1			

Chapter 5 Conclusion

Although highways and bridge surfaces often comprise a small portion of the overall area within a watershed, they are often identified as a contributor to stormwater runoff. In particular, bridges are located in very close proximity to receiving waters. While there is some information available on roadway runoff, few studies have focused on bridge deck runoff, and there is no information available regarding the impacts of bridge deck runoff on receiving waters in Nebraska. Due to the cost, maintenance, and design issues associated with implementing structural controls for bridge deck runoff, the objective of this research was to evaluate the quality of bridge deck runoff, and to determine the effects of bridge deck runoff on surface water bodies in Nebraska by evaluating water and sediment chemistry, as well as effects on aquatic life.

First, four bridge locations were chosen for their close proximity to USGS gauging stations, safe access points, and varying ADT and stream flow. Two of these locations were selected for dry weather in-stream sampling. Several sampling events were conducted for both locations, and statistical analysis software was used to determine whether a difference existed between contaminant concentrations upstream and downstream of the bridges. It was determined that the selected bridges did not significantly impact the water quality of the sampled streams. Sediment sampling was also conducted at the Rock Creek site, but the concentration of metals did not appear to increase downstream of the bridge.

Gutters were designed and constructed to catch and collect runoff from the bridge deck. Despite the dry summer, at least three runoff events were collected and sampled from each of the four bridge locations. The concentrations of contaminants in the runoff samples were analyzed based on ADT, ADP, temporal trends, and literature values. No definite relationship could be pinpointed between the average concentration of contaminants at each site and its daily traffic. It was also difficult to observe a direct relationship between contaminant concentration and the amount of time since the last rain. While some of the sampled runoff values were slightly higher than literature EMC values, the contaminants are diluted once they reach the stream. A toxicity test using fat head minnows was conducted using two different bridge runoff samples. No effects were found.

This research project sought to identify the potential environmental impacts of bridge deck runoff on receiving streams, and to determine design criteria that could be used by NDOR or regulatory agencies to identify when structural controls for bridge deck runoff may be necessary to protect in-stream water quality and aquatic life. According to the data thus far, there were no significant impacts of bridge deck runoff on the stream. However, further sampling and testing is recommended to ensure definitive results. Additional recommendations for future research are listed below:

- Due to low rainfall occurring during the study period, it was difficult to justify setting up an ISCO automated sampler to collect runoff.   and better calculate EMCs. Utilization of this sampling method would make it possible to obtain first flush values and EMCs, as well as comparing to literature and regulations values.
- Weather stations closest to the bridge locations may not have been an accurate representation of actual rainfall occurring at the sites. For future research, it may be beneficial to set up small weather stations at the bridge locations, or even to install rain gauges to manually measure rainfall before comparing to nearby weather stations.
- Previous studies in other states have conducted street sweeping of bridges, then tested the collected sediment for contaminants such as metals. This would be beneficial after

all runoff sampling is completed, in order to determine what is left on the bridges following rain events.

- Additional toxicity testing using samples from varying rainfall amounts would be helpful to firmly establish that runoff does not affect stream wildlife.
- Additional in-stream sediment sampling at more bridge locations and at greater distances upstream and downstream of the bridge and across the cross section of the stream would also help to determine whether metals found in the sediment increase downstream of the bridge.
- A final recommendation is to potentially focus on only two of the four bridges from this study in order to facilitate less drive time to bridge sites to check for runoff. This would help to conserve project resources (i.e., money for fuel) as well as provide better quality data, since runoff samples could be picked up in a more timely fashion.

Chapter 6 Implementation Plan

Data and findings from this research project will be used to develop and implement a decision making tool to determine the need for stormwater collection and treatment systems on future new bridge structures over streams and rivers in Nebraska. The findings will be used to identify specific parameters such as ADT, bridge deck surface area, and receiving stream characteristics that will be used to determine the potential need for stormwater collection and treatment for new bridge structures over impaired streams and/or those with known endangered species use or habitation. The decision making tool will be used during the early development phases of project design, allowing for stormwater treatment assessment and coordination with the Federal Highway Administration and Nebraska Resource and Regulatory Agencies, leading to an efficient and streamlined project delivery by the scheduled PS&E turn-in date.

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Appendix A

The sediment samples that were tested for PAHs all were analyzed using the EPA 8270C method.

Table A.1 Sediment testing for PAHs

Analyses	Detection Limit (µg/kg)	Analyses	Detection Limit (µg/kg)
Phenol	330	2,4-Dinitrophenol	800
bis(2-Chloroethyl) Ether	330	4-Nitrophenol	800
2-Chlorophenol	330	Dibenzofuran	330
1,3-Dichlorobenzene	330	2,4-Dinitrotoluene	330
1,4-Dichlorobenzene	330	2,6-Dinitrotoluene	330
1,2-Dichlorobenzene	330	Diethyl Phthalate	330
2-Methylphenol	330	4-Chlorophenyl Phenyl Ether	330
bis(2-Chloroisopropyl) Ether	330	Fluorene	330
4-Methylphenol	330	4-Nitroaniline	800
N-Nitroso-di-n-propylamine	330	4,6-Dinitro-2-methylphenol	800
Hexachloroethane	330	N-Nitrosodiphenylamine	330
Nitrobenzene	330	4-Bromophenyl Phenyl Ether	330
Isophorone	330	Hexachlorobenzene	330
2-Nitrophenol	800	Pentachlorophenol	800
2,4-Dimethylphenol	330	Phenanthrene	330
bis(2-Chloroethoxy) Methane	330	Carbazole	330
2,4-Dichlorophenol	330	Anthracene	330
1,2,4-Trichlorobenzene	330	Di-n-butyl Phthalate	330
Naphthalene	330	Fluoranthene	330
4-Chloroaniline	330	Pyrene	330
Hexachlorobutadiene	330	Butyl Benzyl Phthalate	330
4-Chloro-3-methylphenol	330	3,3’-Dichlorobenzidine	330
2-Methylnaphthalene	330	Benzo (a) Anthracene	330
Hexachlorocyclopentadiene	330	Bis(2-ethylhexyl) Phthalate	330
2,4,6-Trichlorophenol	330	Chrysene	330
2,4,5-Trichlorophenol	800	Di-n-octyl Phthalate	330
2-Chloronaphthalene	330	Benzo (b) Fluoranthene	330
2-Nitroaniline	800	Benzo (k) Fluoranthene	330
Dimethyl Phthalate	330	Benzo (a) pyrene	330
Acenaphthylene	330	Indeno(1,2,3-cd) Pyrene	330
3-Nitroaniline	800	Dibenz (a,h) Athracene	330
Acenaphthene	330	Benzo(g,h,i) Perylene	330

B.1 *E coli* concentration versus ADP

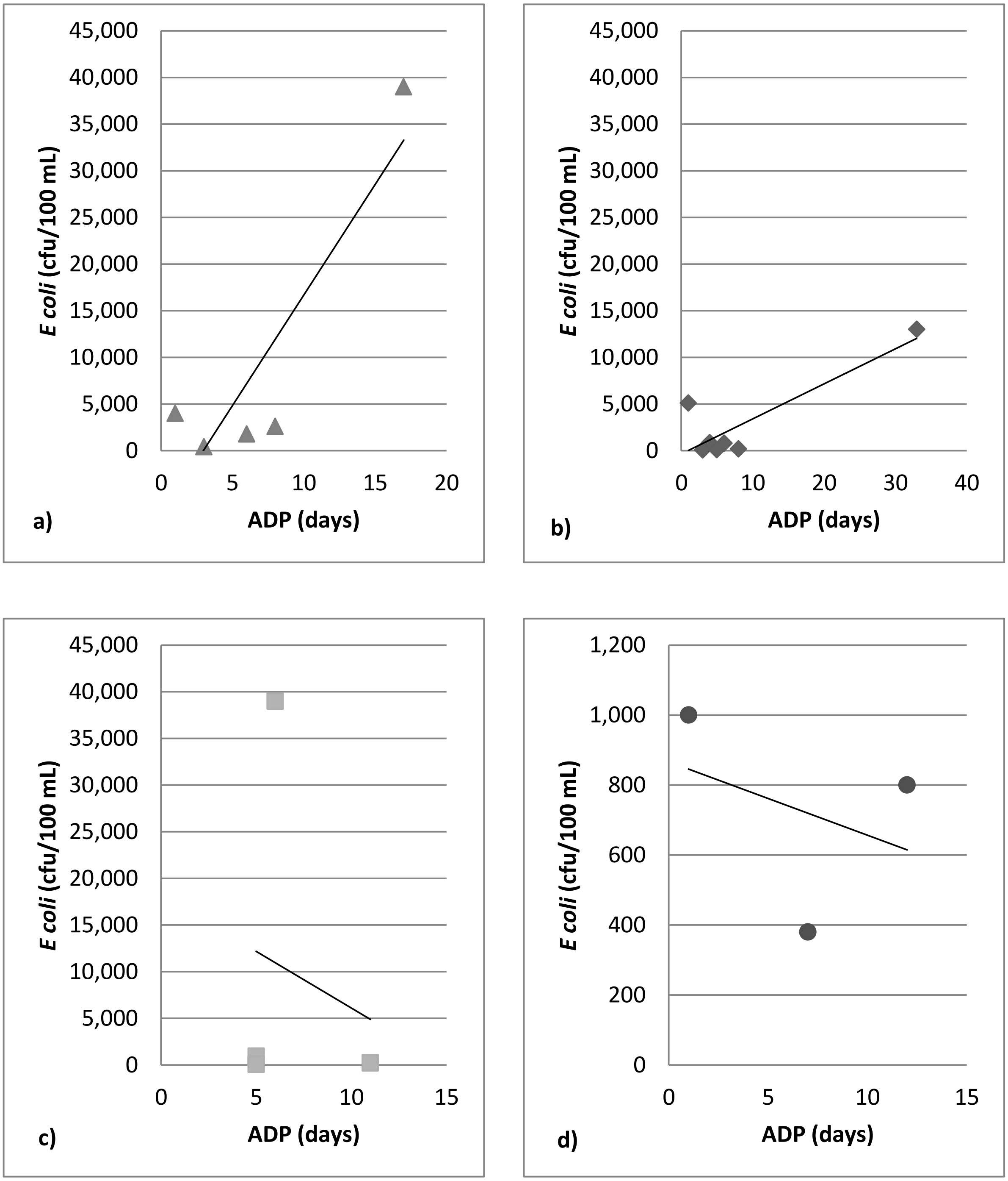

Figure B.1 *E coli* concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.2 Iron Concentration versus ADP

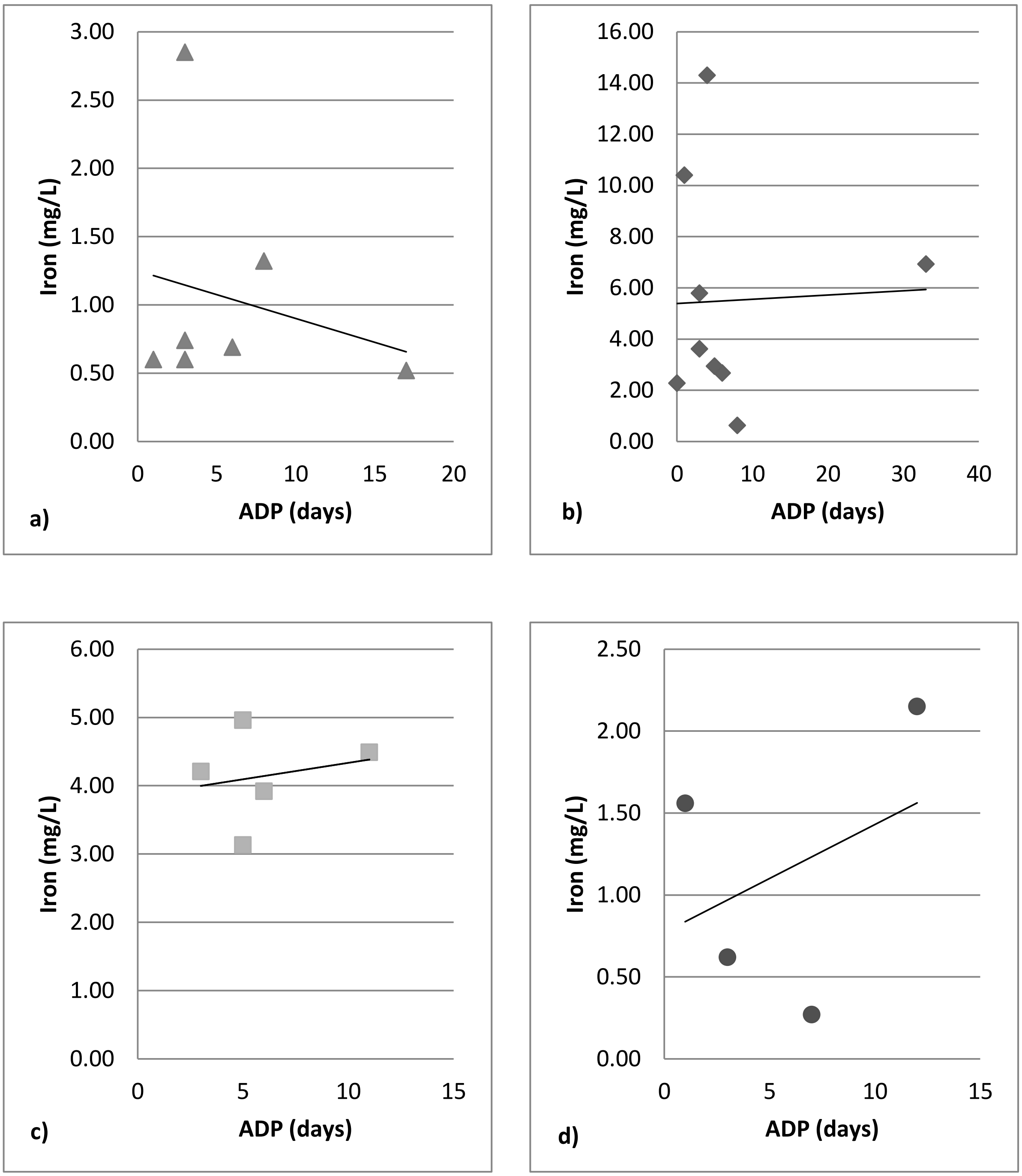

Figure B.2 Iron concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.3 Nitrate/Nitrite Concentration versus ADP

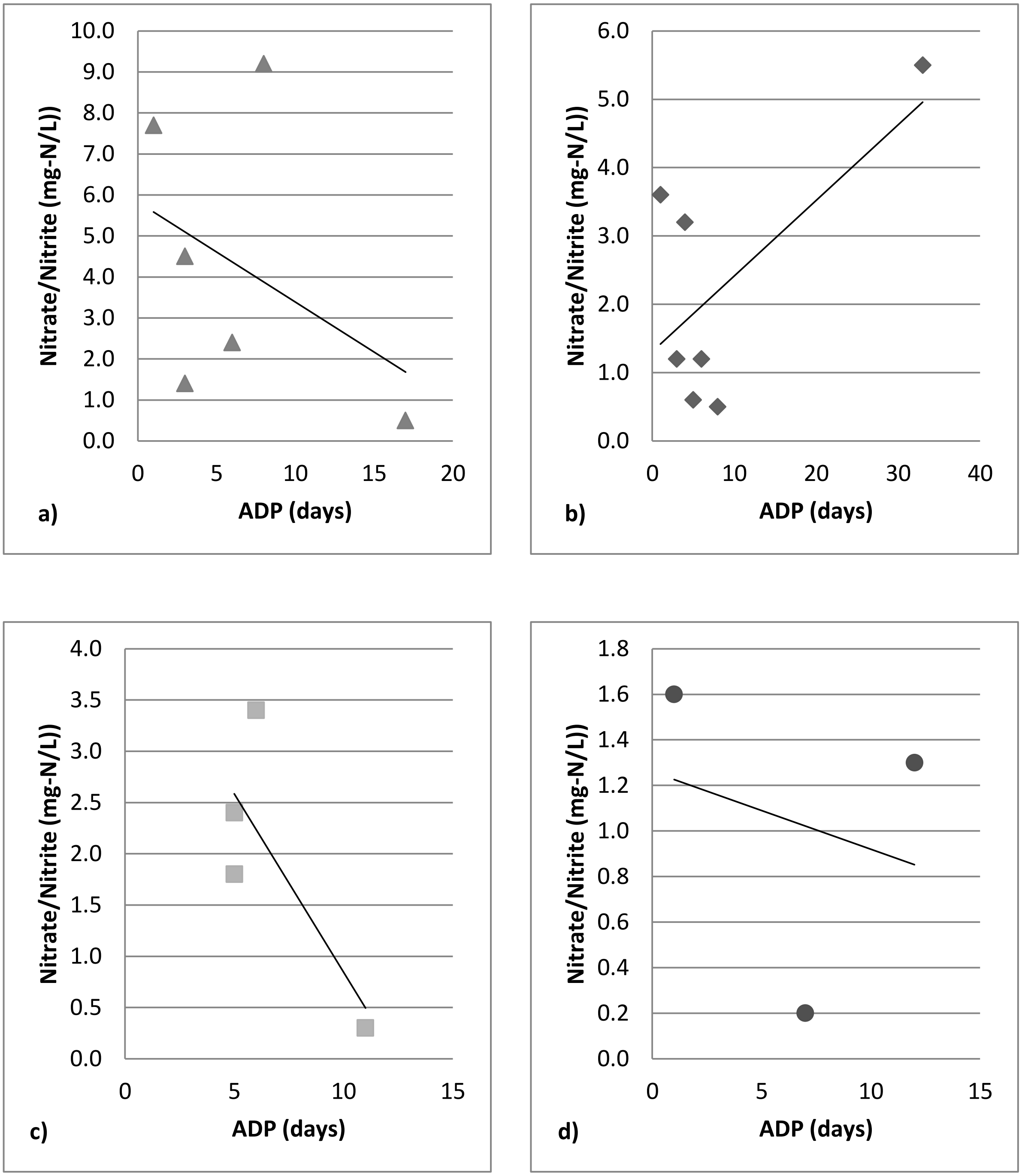

Figure B.3 Nitrate/Nitrite concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.4 Nitrite Concentration versus ADP

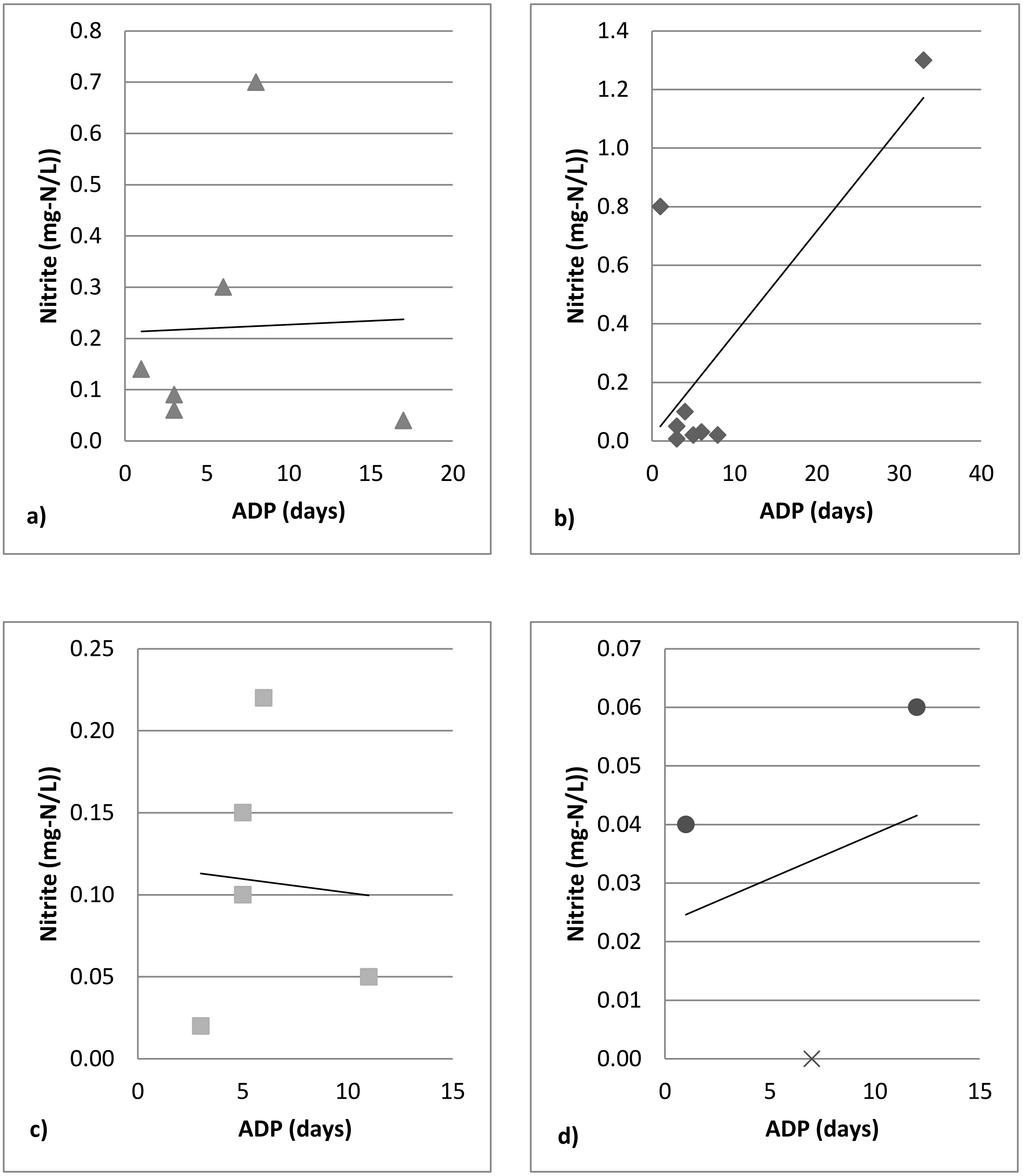

Figure B.4 Nitrite concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.5 Total Phosphorus Concentration versus ADP

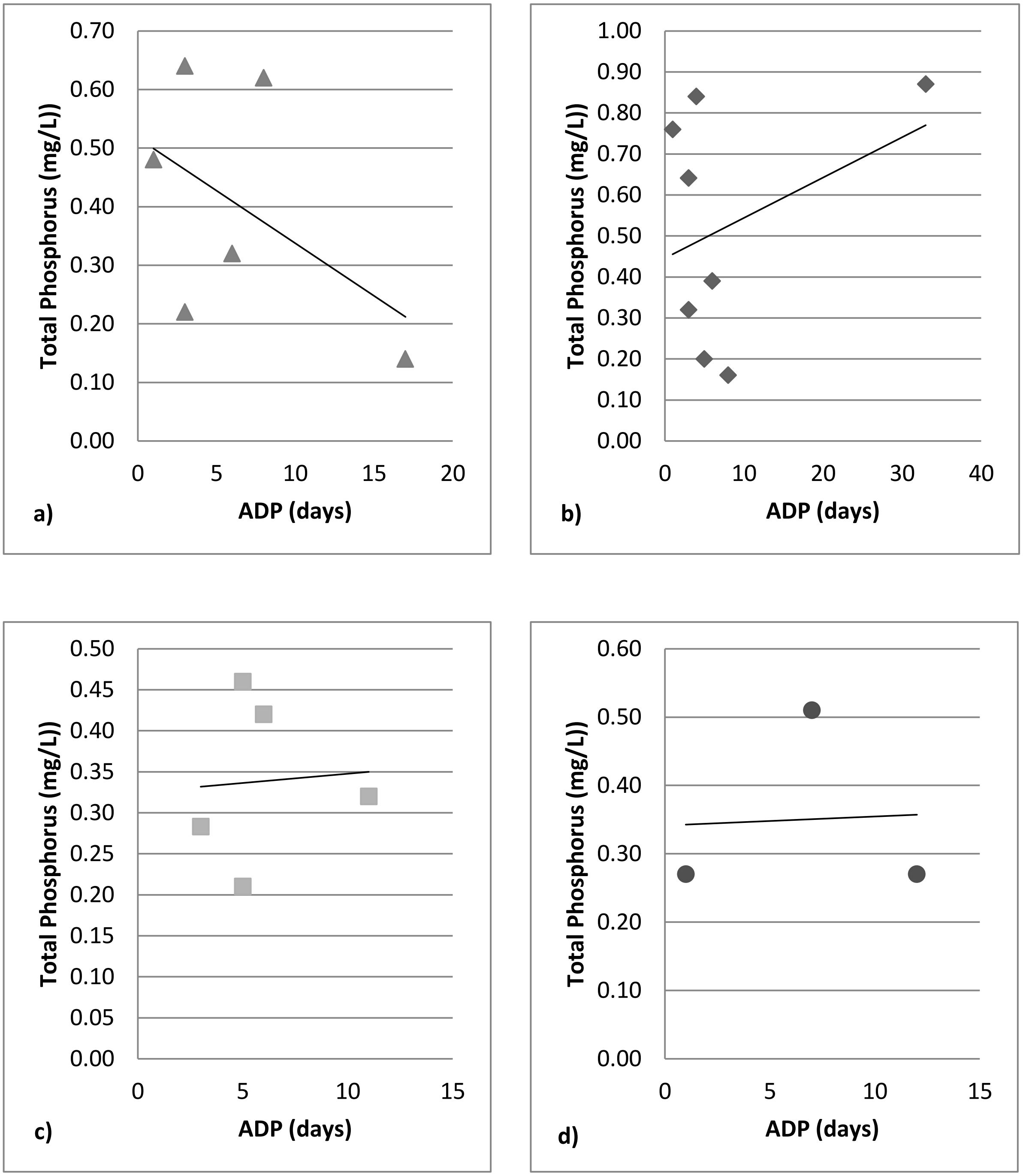

Figure B.5 Total phosphorus concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.6 TKN Concentration versus ADP

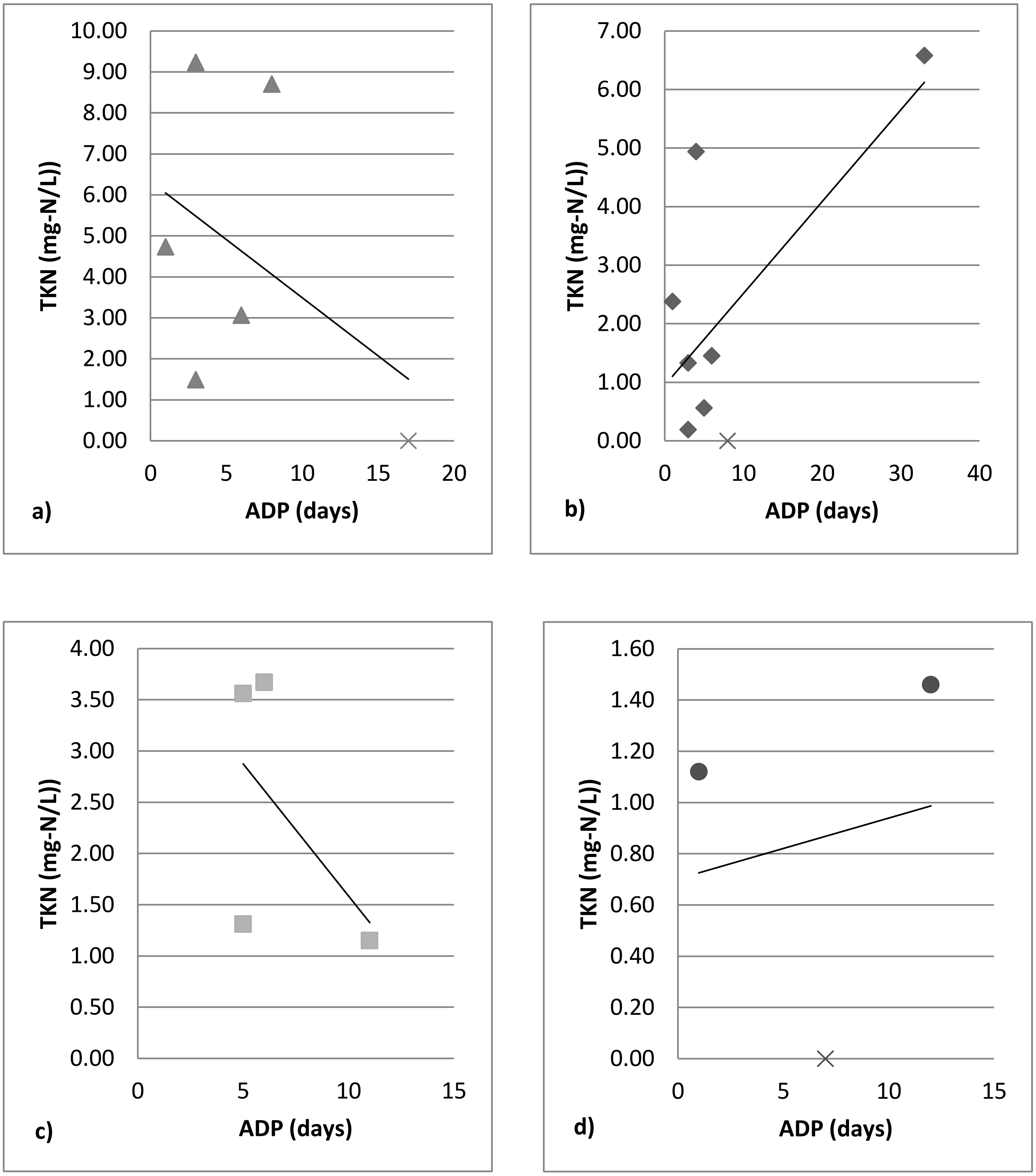

Figure B.6 TKN concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.7 Zinc Concentration versus ADP

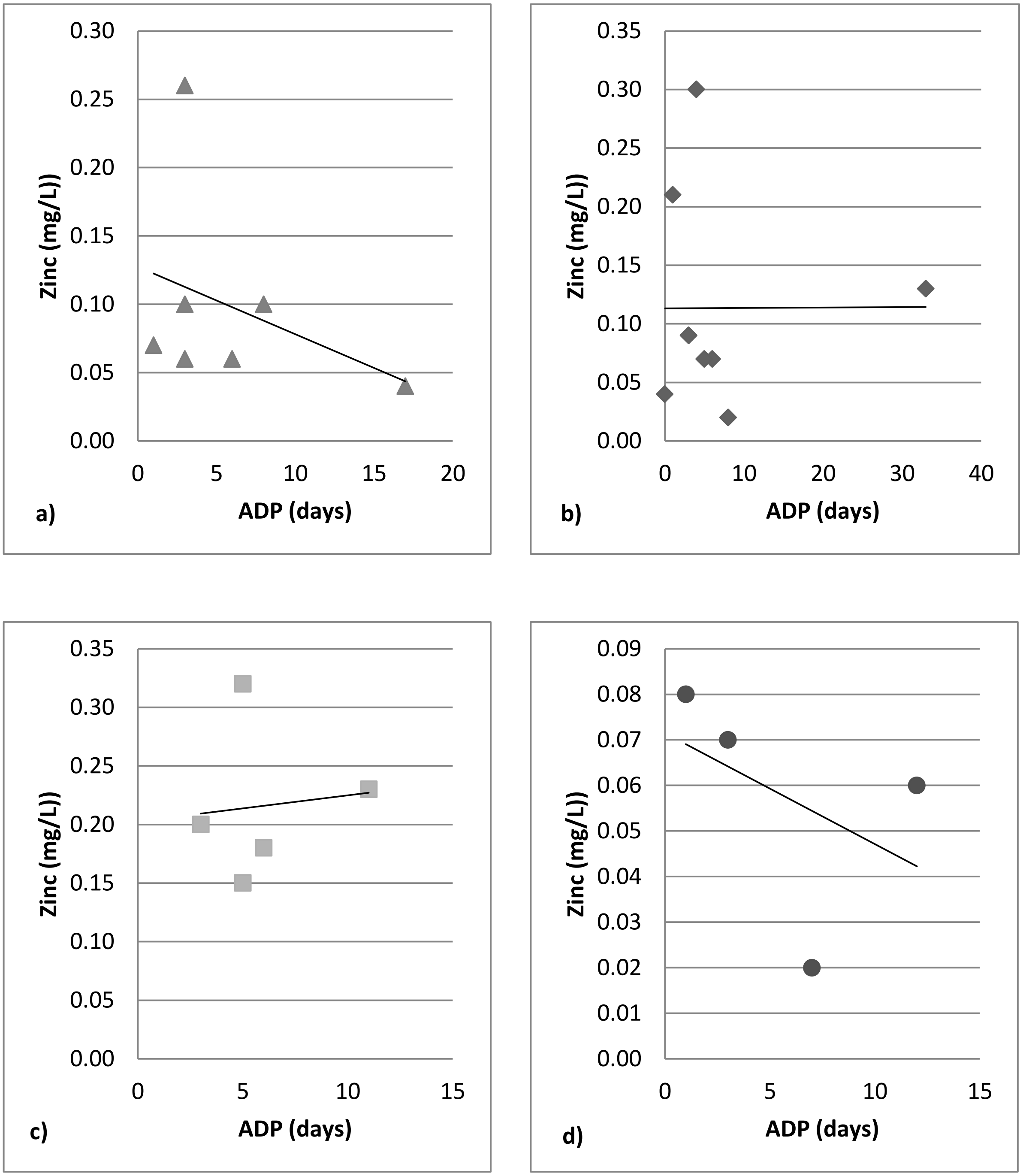

Figure B.7 Zinc concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.8 Total Solids Concentration versus ADP

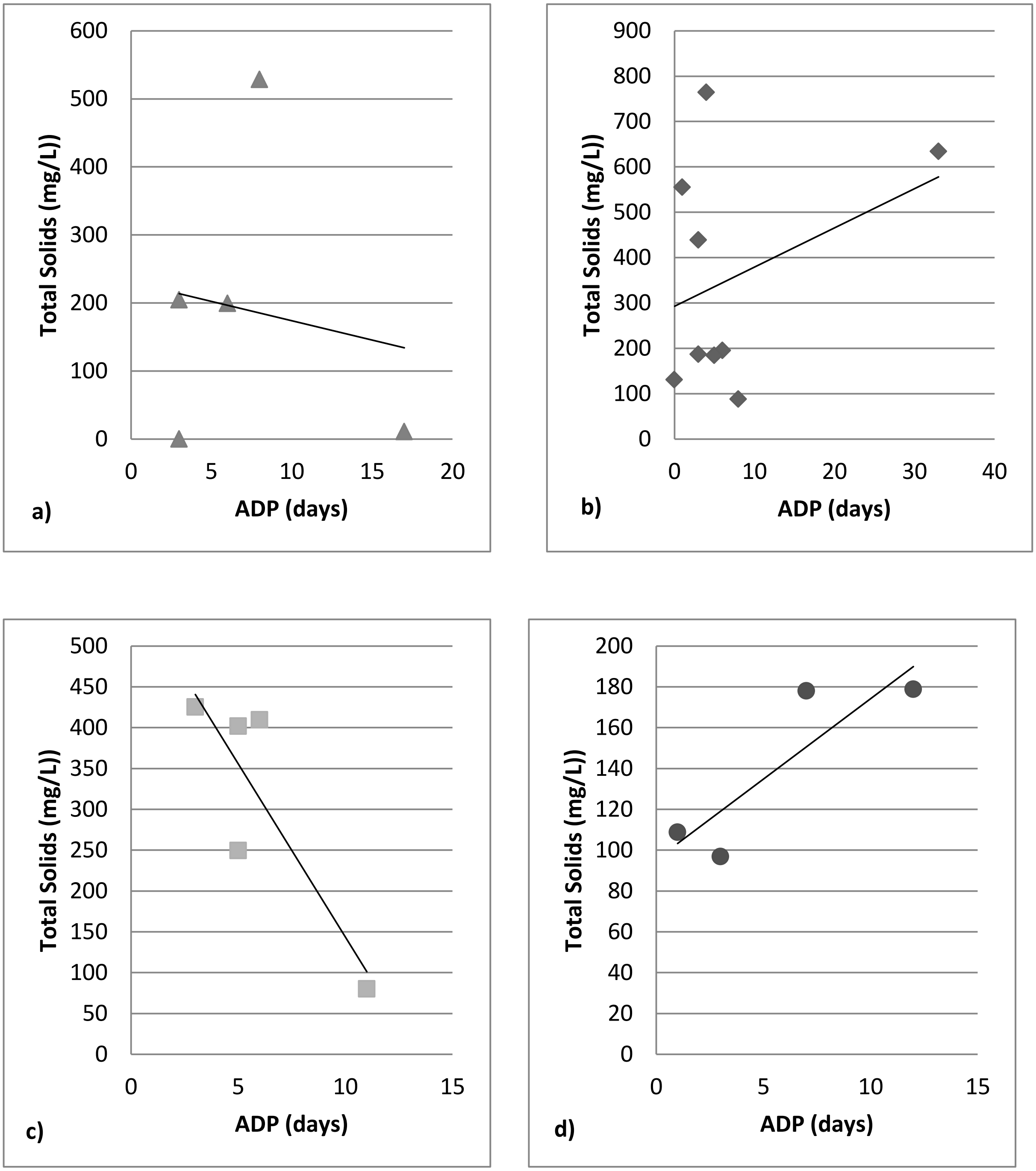

Figure B.8 Total solids concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.9 TSS Concentration versus ADP

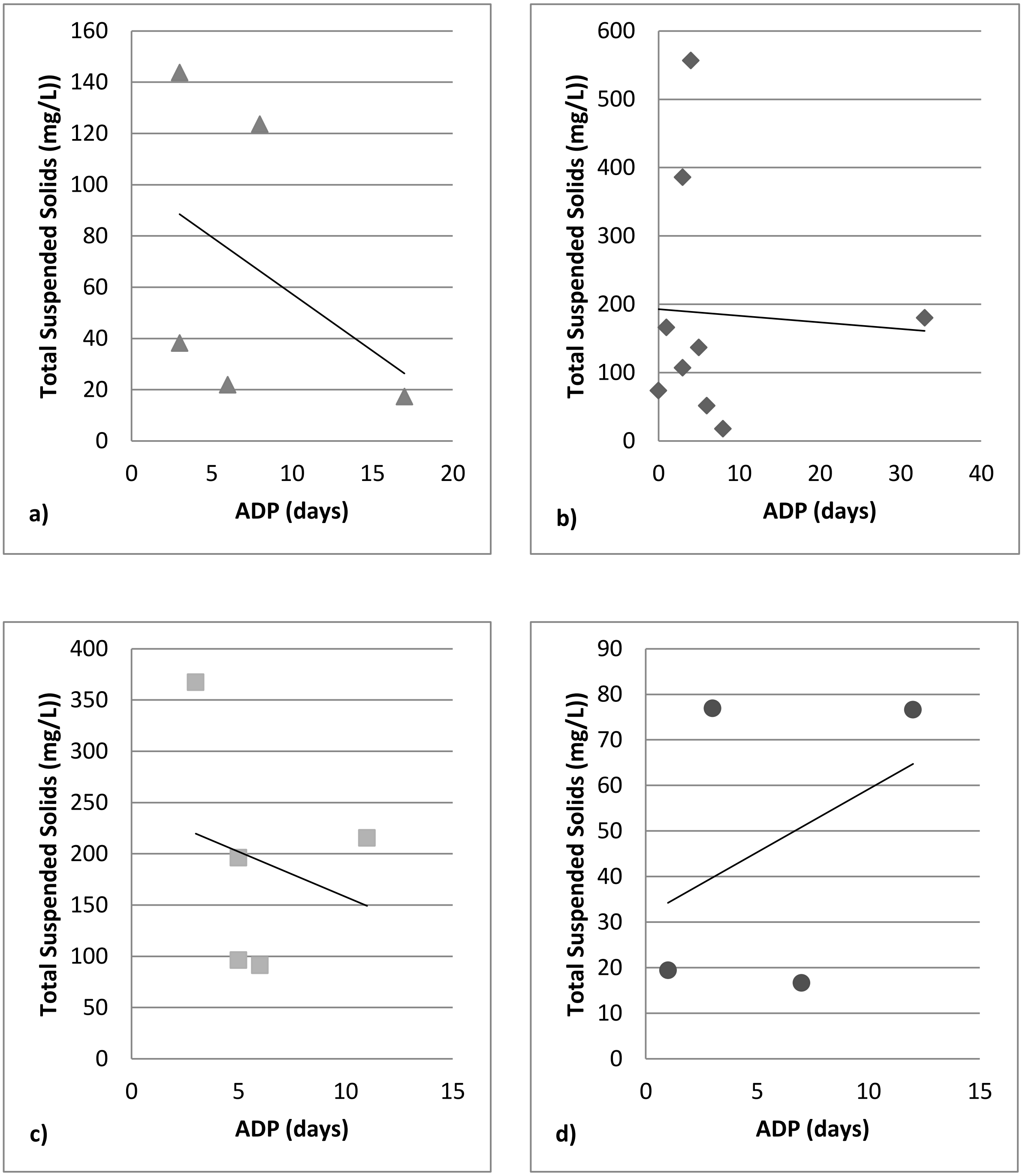

Figure B.9 TSS concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

B.10 TDS Concentration versus ADP

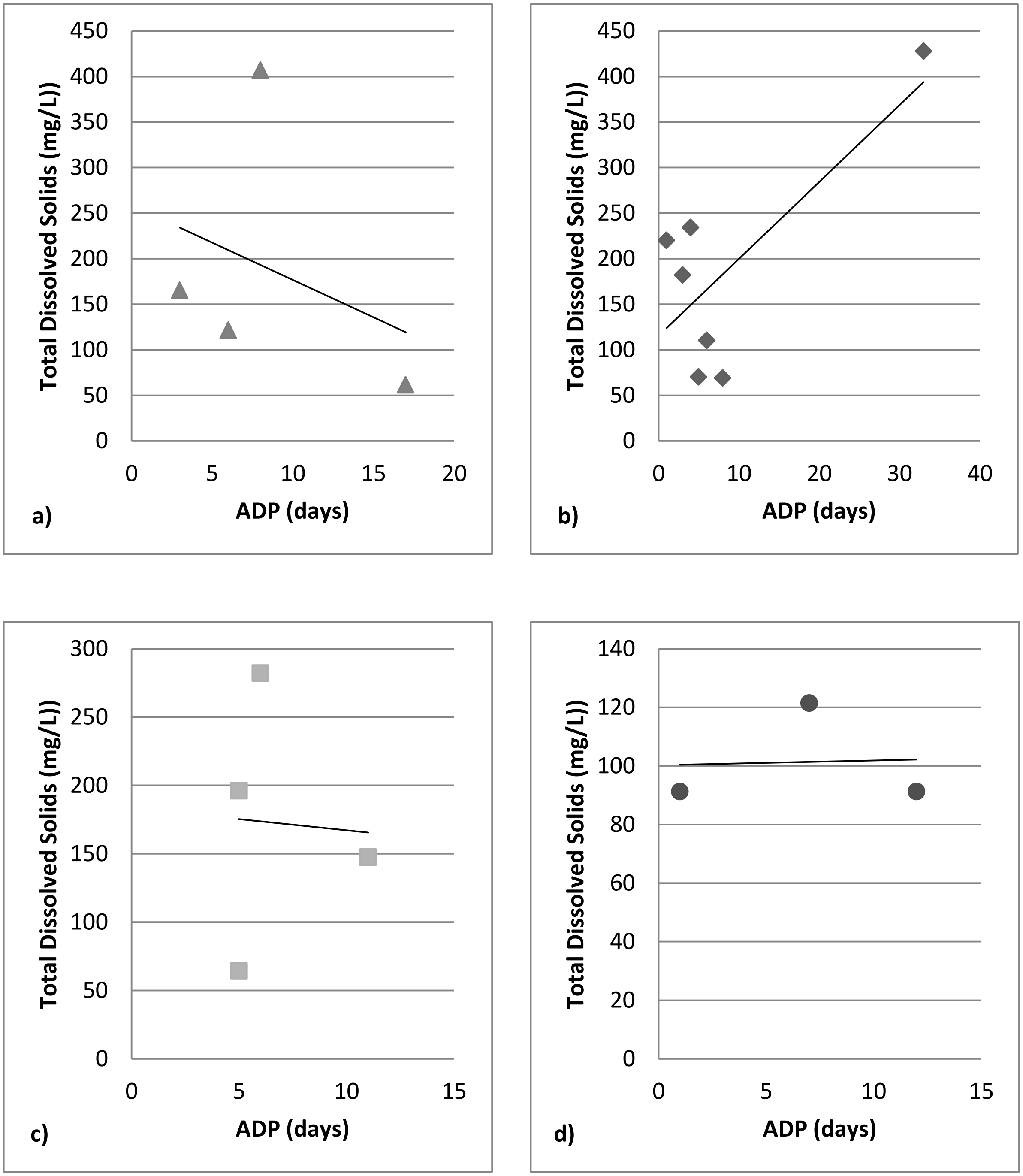

Figure B.10 TDS concentration in runoff versus ADP from a) I-80 bridge over Platte River b) Highway 64 bridge over Platte River c) I-80 bridge over Little Salt Creek d) Highway 77 bridge over Rock Creek

Appendix C Raw Data – Bridge Runoff Sampling

	n-Hexane (µg/L) (limit=1)	Methyl t-Butyl Ether (µg/L) (limit=1)	Benzene (µg/L) (limit=1)	Toluene (µg/L) (limit=1)	Ethylbenzene (µg/L) (limit=1)	Naphthalene (µg/L) (limit=1)
	Conducted by Midwest Laboratories					
Hwy 64 Platte River						
15-Jun-12	-	-	-	-	-	-
16-Jun-12	-	-	-	-	-	-
2-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	2.00
4-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
9-Aug-12	2.00	n.d.	n.d.	n.d.	n.d.	n.d.
18-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
25-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-Sep-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
17-Sep-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Average	2.00					2.00
Std Dev	-	-	-	-	-	-
I-80 Little Salt Creek						
15-Jun-12	-	-	-	-	-	-
8-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
18-Aug-12	2.00	n.d.	1.00	n.d.	n.d.	n.d.
25-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-Sep-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Average	2.00		1.00			
Std Dev	-	-	-	-	-	-
I-80 Platte River						
16-Jun-12	-	-	-	-	-	-
4-Aug-12	3.00	n.d.	2.00	n.d.	n.d.	n.d.
9-Aug-12	4.00	n.d.	2.00	n.d.	n.d.	n.d.
18-Aug-12	2.00	n.d.	2.00	n.d.	n.d.	n.d.
25-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-Sep-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
17-Sep-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Average	3.00		2.00			
Std Dev	1.00	-	0.00	-	-	-
Hwy 77 Rock Creek						
16-Jun-12	-	-	-	-	-	-
4-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
25-Aug-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-Sep-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Average						
Std Dev	-	-	-	-	-	-
Total Average	2.60	-	1.75	-	-	2.00
Total Std Dev	0.89	-	0.50	-	-	-
Total Max Value	4.00	-	2.00	-	-	2.00
Total Min Value	2.00	-	1.00	-	-	2.00

"-" means test was not conducted, "n.d." means not detected

	Total Xylenes (µg/L) (limit=1)	Total Purgeable Hydrocarbons (µg/L) (limit=10)	Arsenic (total) (mg/L) (limit=0.10)	Cadmium (total) (mg/L) (limit=0.002)	Chloride (mg/L) (limit=1.0)	Chromium (total) (mg/L) (limit=0.01)
	Conducted by Midwest Laboratories					
Hwy 64 Platte River						
15-Jun-12	-	-	n.d.	n.d.	-	n.d.
16-Jun-12	-	-	n.d.	n.d.	-	n.d.
2-Aug-12	n.d.	21.00	n.d.	n.d.	52.0[a]	0.01
4-Aug-12	n.d.	15.00	n.d.	n.d.	28.0[b]	0.02
9-Aug-12	n.d.	23.00	n.d.	n.d.	30.0	0.02
18-Aug-12	n.d.	n.d.	n.d.	n.d.	17.0	n.d.
25-Aug-12	n.d.	n.d.	n.d.	n.d.	10.0	n.d.
13-Sep-12	n.d.	n.d.	n.d.	n.d.	7.6	n.d.
17-Sep-12	n.d.	n.d.	n.d.	n.d.	17.0	n.d.
Average		19.67			23.1	0.02
Std Dev	-	4.16	-	-	15.24	0.01
I-80 Little Salt Creek						
15-Jun-12	-	-	n.d.	n.d.	-	n.d.
8-Aug-12	n.d.	17.00	n.d.	n.d.	18.0	0.02
18-Aug-12	n.d.	n.d.	n.d.	n.d.	40.0[b]	0.01
25-Aug-12	n.d.	n.d.	n.d.	n.d.	24.0	0.01
13-Sep-12	n.d.	n.d.	n.d.	n.d.	10.0	n.d.
Average		17.00			23.0	0.01
Std Dev	-	-	-	-	12.70	0.01
I-80 Platte River						
16-Jun-12	-	-	n.d.	n.d.	-	n.d.
4-Aug-12	n.d.	108.00	n.d.	n.d.	55.0[b]	n.d.
9-Aug-12	n.d.	172.00	n.d.	n.d.	51.0[b]	0.01
18-Aug-12	n.d.	n.d.	n.d.	n.d.	46.0[b]	n.d.
25-Aug-12	n.d.	82.00	n.d.	n.d.	19.0	n.d.
13-Sep-12	n.d.	n.d.	n.d.	n.d.	7.5	n.d.
17-Sep-12	n.d.	11	n.d.	n.d.	16.0	n.d.
Average		120.67			32.4	0.01
Std Dev	-	66.61	-	-	20.54	-
Hwy 77 Rock Creek						
16-Jun-12	-	-	n.d.	n.d.	-	n.d.
4-Aug-12	n.d.	n.d.	n.d.	n.d.	11.0[b]	n.d.
25-Aug-12	n.d.	n.d.	n.d.	n.d.	19.0	n.d.
13-Sep-12	n.d.	n.d.	n.d.	n.d.	8.5	n.d.
Average					12.8	
Std Dev	-	-	-	-	5.48482756	-
Total Average	-	56.13	-	-	24.33	0.01
Total Std Dev	-	59.01	-	-	15.98	0.01
Total Max Value	-	172.00	-	-	55.00	0.02
Total Min Value	-	11.00	-	-	7.50	0.01

"-" means test was not conducted, "n.d." means not detected

[a] Detection Limit = 10 mg/L, [b] Detection Limit = 2.0 mg/L

	Conductance (uS/cm) (limit=2)	Copper (total) (mg/L) (limit=0.01)	E coli (cfu/100 mL) (limit=1)	HEM (mg/L) (limit=5)	Iron (total) (mg/L) (limit=0.01)	Nickel (total) (mg/L) (limit=0.01)
	Conducted by Midwest Laboratories					
Hwy 64 Platte River						
15-Jun-12	-	n.d.	-	n.d.	5.79	n.d.
16-Jun-12	-	n.d.	-	n.d.	2.28	n.d.
2-Aug-12	570	0.02	13,000	n.d.	6.93	0.01
4-Aug-12	313	0.03	5,100	6	10.40	0.01
9-Aug-12	340	0.03	870	-	14.30	0.02
18-Aug-12	176	n.d.	810	n.d.	2.67	n.d.
25-Aug-12	112	n.d.	100	n.d.	2.94	n.d.
13-Sep-12	111	n.d.	190	n.d.	0.63	n.d.
17-Sep-12	186	0.01	90	n.d.	3.61	n.d.
Average	258	0.02	2,880	6	5.51	0.01
Std Dev	164.28	0.01	4803.06	-	4.41	0.01
I-80 Little Salt Creek						
15-Jun-12	-	0.02	-	n.d.	4.21	n.d.
8-Aug-12	255	0.03	950	7	4.96	n.d.
18-Aug-12	350	0.04	39,000	n.d.	3.92	0.01
25-Aug-12	236	0.02	70	n.d.	3.13	n.d.
13-Sep-12	136	0.02	230	n.d.	4.49	n.d.
Average	244	0.03	10,063	7	4.14	0.01
Std Dev	87.72	0.01	19295.46	-	0.68	-
I-80 Platte River						
16-Jun-12	-	0.02	-	n.d.	2.85	n.d.
4-Aug-12	554	0.04	4,000	-	0.60	n.d.
9-Aug-12	560	0.05	-	-	0.60	n.d.
18-Aug-12	508	0.04	2,600	n.d.	1.32	n.d.
25-Aug-12	270	0.03	1,800	n.d.	0.69	n.d.
13-Sep-12	116	n.d.	39,000	n.d.	0.52	n.d.
17-Sep-12	171	0.01	440	n.d.	0.74	n.d.
Average	363	0.04	9,568		1.05	
Std Dev	201.41	0.01	16503.49	-	0.84	-
Hwy 77 Rock Creek						
16-Jun-12	-	n.d.	-	n.d.	0.62	n.d.
4-Aug-12	138	n.d.	1,000	n.d.	1.56	n.d.
25-Aug-12	199	0.01	800	n.d.	2.15	n.d.
13-Sep-12	104	n.d.	380	n.d.	0.27	n.d.
Average	147	0.01	727		1.15	
Std Dev	48.1352262	-	316.438514	-	0.86089101	-
Total Average	270.25	0.03	5812.11	6.50	3.29	0.01
Total Std Dev	161.17	0.01	12077.49	0.71	3.33	0.01
Total Max Value	570.00	0.05	39000.00	7.00	14.30	0.02
Total Min Value	104.00	0.01	70.00	6.00	0.27	0.01

"-" means test was not conducted, "n.d." means not detected

	Nitrate/Nitrite Nitrogen (mg/L) (limit=0.2)	Nitrite Nitrogen (mg/L) (limit=0.02)	Phosphorus (total) (mg/L) (limit=0.05)	TKN (mg/L) (limit=0.50)	Zinc (total) (mg/L) (limit=0.50)	pH
	Conducted by Midwest Laboratories					
Hwy 64 Platte River						
15-Jun-12	-	0.007* [h]	0.64* [i]	0.19* [j]	0.09	-
16-Jun-12	-	-	-	-	0.04	-
2-Aug-12	5.5	1.30 [d]	0.87 [c]	6.58 [a]	0.13	8.27
4-Aug-12	3.6	0.80 [e]	0.76	2.38	0.21	7.60
9-Aug-12	3.2	0.10	0.84	4.94	0.30	7.93
18-Aug-12	1.2	0.03	0.39	1.45 [a]	0.07	7.82
25-Aug-12	0.6	0.02	0.20 [b]	0.56	0.07	8.00
13-Sep-12	0.5	0.02	0.16	n.d.	0.02	7.92
17-Sep-12	1.2	0.05	0.32	1.33	0.09	7.62
Average	2.3	0.29	0.52	2.49	0.11	7.88
Std Dev	1.88	0.49	0.29	2.39	0.09	0.23
I-80 Little Salt Creek						
15-Jun-12	-	0.020* [h]	0.283* [i]	-	0.20	-
8-Aug-12	2.4	0.15	0.46	3.56	0.32	7.34
18-Aug-12	3.4	0.22	0.42	3.67 [a]	0.18	7.79
25-Aug-12	1.8	0.10	0.21 [b]	1.31 [a]	0.15	7.72
13-Sep-12	0.3	0.05	0.32	1.15	0.23	8.04
Average	2.0	0.11	0.34	2.42	0.22	7.72
Std Dev	1.30	0.08	0.10	1.38	0.07	0.29
I-80 Platte River						
16-Jun-12	-	-	-	-	0.26	-
4-Aug-12	7.7 [f]	0.14	0.48	4.73	0.07	7.22
9-Aug-12	4.5 [f]	0.09	0.64	9.23	0.10	7.35
18-Aug-12	9.2 [g]	0.70 [e]	0.62	8.70 [a]	0.10	7.28
25-Aug-12	2.4	0.30	0.32 [b]	3.06	0.06	7.32
13-Sep-12	0.5	0.04	0.14	n.d.	0.04	7.93
17-Sep-12	1.4	0.06	0.22	1.49	0.06	7.25
Average	4.3	0.22	0.40	6.43	0.10	7.39
Std Dev	3.52	0.25	0.21	3.42	0.07	0.27
Hwy 77 Rock Creek						
16-Jun-12	-	-	-	-	0.07	-
4-Aug-12	1.6	0.04	0.27	1.12	0.08	7.29
25-Aug-12	1.3	0.06	0.27 [b]	1.46 [a]	0.06	7.61
13-Sep-12	0.2	n.d.	0.51	n.d.	0.02	7.79
Average	1.0	0.05	0.35	1.29	0.06	7.56
Std Dev	0.73711148	-	0.13856406	-	0.0262996	0.253246
Total Average	2.63	0.20	0.42	3.16	0.12	7.65
Total Std Dev	2.47	0.33	0.22	2.71	0.09	0.31
Total Max Value	9.20	1.30	0.87	9.23	0.32	8.27
Total Min Value	0.20	0.01	0.14	0.19	0.02	7.22

*Conducted at UNL Water Sciences Lab,
"-" means test was not conducted, "n.d." means not detected,
[a] Detection Limit = 1.00 mg/L, [b] Detection Limit = 0.10 mg/L, [c] Detection Limit = 0.25 mg/L,
[d] Detection Limit = 0.5 mg/L, [e] Detection Limit = 0.2 mg/L, [f] Detection Limit = 0.4 mg/L,
[g] Detection Limit = 1 mg/L, [h] Detection Limit = 0.0040, [I] Detection Limit = 0.02 mg/L,
[j] Detection Limit = 0.10 mg/L

	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)	Rainfall from nearest weather station (in)	Antecedent Dry Period (ADP)
	Conducted by Lauren Swadener				
Hwy 64 Platte River					
15-Jun-12	439.13	386.00	-	1.5	3
16-Jun-12	131.15	73.68	-	0.82	0
2-Aug-12	634.5	180.20	427.72	0.03	33
4-Aug-12	555.09	166.06	220.22	0.07	1
9-Aug-12	764.36	556.64	234.38	0.05	4
18-Aug-12	195.79	51.43	110.48	0.17	6
25-Aug-12	184.62	136.94	70.27	2	5
13-Sep-12	88.24	17.86	69.20	0.53	8
17-Sep-12	187.37	107.06	182.23	0.18	3
Average	353.36	186.21	187.79		
Std Dev	249.13	175.16	125.61		
I-80 Little Salt Creek					
15-Jun-12	425.27	367.41	-	1.9	3
8-Aug-12	401.92	196.08	196.08	0	5
18-Aug-12	409.8	91.29	282.16	0.01	6
25-Aug-12	249.52	96.19	64.13	0.09	5
13-Sep-12	80	215.46	147.54	1.72	11
Average	313.30	193.29	172.48		
Std Dev	148.49	112.53	91.19		
I-80 Platte River					
16-Jun-12	204.63	143.76	-	2.35	3
4-Aug-12	-	-	-	0	1
9-Aug-12	-	-	-	0.1	3
18-Aug-12	528.42	123.64	407.06	0	8
25-Aug-12	199.59	21.91	121.51	0.15	6
13-Sep-12	10.94	17.24	61.58	1.6	17
17-Sep-12	-	38.17	165.39	0	3
Average	235.90	68.94	188.89		
Std Dev	214.84	60.04	151.55		
Hwy 77 Rock Creek					
16-Jun-12	96.83	76.92	-	2.61	3
4-Aug-12	108.78	19.42	91.26	0.02	1
25-Aug-12	178.91	76.64	91.24	0.18	12
13-Sep-12	178.05	16.67	121.43	0.97	7
Average	140.64	47.41	101.31		
Std Dev	43.96	33.93	17.42		
Total Average	284.22	138.12	170.22	0.68	6.28
Total Std Dev	203.31	135.99	110.33	0.87	6.77
Total Max Value	764.36	556.64	427.72	2.61	33.00
Total Min Value	10.94	16.67	61.58	0.00	0.00

“-“ means test was not conducted, “n.d.” means not detected

Appendix D Raw Data – In-stream Dry Weather Sampling

	n-Hexane (µg/L) (limit=1)	Methyl t-Butyl Ether (µg/L) (limit=1)	Benzene (µg/L) (limit=1)	Toluene (µg/L) (limit=1)	Ethylbenzene (µg/L) (limit=1)	Naphthalene (µg/L) (limit=1)	Total Xylenes (µg/L) (limit=1)	Total Purgeable Hydrocarbons (µg/L) (limit=10)	Arsenic (total) (mg/L) (limit=0.10)
	Tested by Midwest Laboratories								
Platte River Upstream									
L 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
M 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
R 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
L 13-Apr-12	-	-	-	-	-	-	-	-	n.d.
M 13-Apr-12	-	-	-	-	-	-	-	-	n.d.
R 13-Apr-12	-	-	-	-	-	-	-	-	n.d.
L 13-Jul-12	-	-	-	-	-	-	-	-	n.d.
M 13-Jul-12	-	-	-	-	-	-	-	-	n.d.
R 13-Jul-12	-	-	-	-	-	-	-	-	n.d.
L 18-Oct-12	-	-	-	-	-	-	-	-	n.d.
M 18-Oct-12	-	-	-	-	-	-	-	-	n.d.
R 18-Oct-12	-	-	-	-	-	-	-	-	n.d.
Average	-	-	-	-	-	-	-	-	-
Std Dev	-	-	-	-	-	-	-	-	-
Platte River Downstream									
L 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
M 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
R 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
L 13-Apr-12	-	-	-	-	-	-	-	-	n.d.
M 13-Apr-12	-	-	-	-	-	-	-	-	n.d.
R 13-Apr-12	-	-	-	-	-	-	-	-	n.d.
L 13-Jul-12	-	-	-	-	-	-	-	-	n.d.
M 13-Jul-12	-	-	-	-	-	-	-	-	n.d.
R 13-Jul-12	-	-	-	-	-	-	-	-	n.d.
L 18-Oct-12	-	-	-	-	-	-	-	-	n.d.
M 18-Oct-12	-	-	-	-	-	-	-	-	n.d.
R 18-Oct-12	-	-	-	-	-	-	-	-	n.d.
Average	-	-	-	-	-	-	-	-	-
Std Dev	-	-	-	-	-	-	-	-	-

“-“ means the test was not conducted, “n.d.” means not detected

	Cadmium (total) (mg/L) (limit=0.002)	Chloride (mg/L) (limit=1.0)	Chromium (total) (mg/L) (limit=0.01)	Conductance (uS/cm) (limit=2)	Copper (total) (mg/L) (limit=0.01)	E coli (cfu/100 mL) (limit=1)	HEM (mg/L) (limit=5)	Iron (total) (mg/L) (limit=0.01)	Nickel (total) (mg/L) (limit=0.01)
	Tested by Midwest Laboratories								
Platte River Upstream									
L 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	1.5	n.d.
M 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	2.21	n.d.
R 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	2.2	n.d.
L 13-Apr-12	0.002	-	0.01	-	n.d.	-	n.d.	1.38	n.d.
M 13-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.36	n.d.
R 13-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.54	n.d.
L 13-Jul-12	n.d.	-	n.d.	-	n.d.	64	n.d.	2.16	n.d.
M 13-Jul-12	n.d.	-	n.d.	-	n.d.	40	n.d.	1.65	n.d.
R 13-Jul-12	n.d.	-	n.d.	-	n.d.	48	n.d.	0.87	n.d.
L 18-Oct-12	n.d.	433[a]	n.d.	2126	n.d.	260	n.d.	1.6	n.d.
M 18-Oct-12	n.d.	107[b]	n.d.	731	n.d.	306	n.d.	0.89	n.d.
R 18-Oct-12	n.d.	15	n.d.	469	n.d.	338	n.d.	0.51	n.d.
Average	0.002	185	0.01	1108.666667	-	176	-	1.48916667	-
Std Dev	-	219.6452	-	890.722366	-	139.7312	-	0.54318017	-
Platte River Downstream									
L 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	1.63	n.d.
M 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	2.1	n.d.
R 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	2.11	n.d.
L 13-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.49	n.d.
M 13-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.59	n.d.
R 13-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.43	n.d.
L 13-Jul-12	n.d.	-	n.d.	-	n.d.	48	n.d.	2.42	n.d.
M 13-Jul-12	n.d.	-	n.d.	-	n.d.	40	n.d.	2.02	n.d.
R 13-Jul-12	n.d.	-	n.d.	-	n.d.	36	n.d.	1.12	n.d.
L 18-Oct-12	n.d.	598[c]	n.d.	2158	n.d.	276	n.d.	1.83	n.d.
M 18-Oct-12	n.d.	560[c]	n.d.	2040	n.d.	212	n.d.	2.07	n.d.
R 18-Oct-12	n.d.	17	n.d.	457	n.d.	312	n.d.	0.6	n.d.
Average	-	391.67	-	1551.67	-	154.00	-	1.70	-
Std Dev	-	325.03	-	949.84	-	127.57	-	0.50	-

"-" means the test was not conducted, "n.d." means not detected, [a] Detection Limit = 250 mg/L, [b] Detection Limit = 5.0 mg/L, [c] Detection Limit = 50 mg/L

	Nitrate/Nitrite Nitrogen (mg/L) (limit=0.2)	Nitrite Nitrogen (mg/L) (limit=0.02)	Phosphorus (total) (mg/L) (limit=0.05)	TKN (mg/L) (limit=0.50)	Zinc (total) (mg/L) (limit=0.01)	pH
	Tested by Midwest Laboratories					
Platte River Upstream						
L 30-Nov-11	-	-	0.563* [b]	0.586* [c]	n.d.	-
M 30-Nov-11	-	-	0.421* [b]	0.71* [c]	0.01	-
R 30-Nov-11	-	-	0.44* [b]	0.531* [c]	n.d.	-
L 13-Apr-12	-	0.027* [a]	0.63* [b]	1.12* [c]	n.d.	-
M 13-Apr-12	-	0.008* [a]	0.4* [b]	1.73* [c]	n.d.	-
R 13-Apr-12	-	0.025* [a]	0.39* [b]	1.48* [c]	n.d.	-
L 13-Jul-12	-	0.082* [a]	0.672* [b]	2.16* [c]	0.01	-
M 13-Jul-12	-	0.038* [a]	0.637* [b]	2.14* [c]	0.01	-
R 13-Jul-12	-	-	-	-	n.d.	-
L 18-Oct-12	0.6	0.03	0.33	0.77	0.01	8.33
M 18-Oct-12	0.8	n.d.	0.44 [d]	0.78	0.01	8.5
R 18-Oct-12	1.7	n.d.	0.84	0.83	0.01	8.56
Average	1.033333333	0.035	0.52390909	1.167	0.01	8.463333
Std Dev	0.585946528	0.025044	0.15587652	0.61006377	0	0.119304
Platte River Downstream						
L 30-Nov-11	-	-	-	-	n.d.	-
M 30-Nov-11	-	-	0.459* [b]	0.494* [c]	0.01	-
R 30-Nov-11	-	-	0.471* [b]	0.722* [c]	n.d.	-
L 13-Apr-12	-	0.028* [a]	0.58* [b]	1.1* [c]	n.d.	-
M 13-Apr-12	-	0.016* [a]	0.474* [b]	1.23* [c]	0.01	-
R 13-Apr-12	-	0.019* [a]	0.414* [b]	1.42* [c]	n.d.	-
L 13-Jul-12	-	0.063* [a]	0.672* [b]	2.26* [c]	0.01	-
M 13-Jul-12	-	0.027* [a]	0.624* [b]	2.25* [c]	0.01	-
R 13-Jul-12	-	n.d.* [a]	0.613* [b]	2.5* [c]	n.d.	-
L 18-Oct-12	1.7	0.03	0.84	0.83	0.01	8.32
M 18-Oct-12	1.5	0.03	0.84	0.76	0.02	8.34
R 18-Oct-12	0.6	n.d.	0.33	0.62	0.01	8.56
Average	1.27	0.03	0.57	1.29	0.01	8.41
Std Dev	0.59	0.02	0.17	0.73	0.00	0.13

*Conducted at UNL Water Sciences Lab, "-" means test was not conducted, "n.d." means not detected,
[a] Detection Limit = 0.0040 mg/L, [b] Detection Limit = 0.02 mg/L , [c] Detection Limit = 0.10 mg/L, [d] Detection Limit = 0.10 mg/L

	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)
Platte River Upstream			
L 30-Nov-11	841.03	58.25	-
M 30-Nov-11	439.32	69.94	-
R 30-Nov-11	472.12	70.55	-
L 13-Apr-12	1054.05	76.22	-
M 13-Apr-12	518.87	97.51	-
R 13-Apr-12	409.26	92.26	-
L 13-Jul-12	1116.58	132.45	-
M 13-Jul-12	983.58	134.20	-
R 13-Jul-12	398.95	111.11	-
L 18-Oct-12	1261.73	67.57	1208.11
M 18-Oct-12	554.50	58.98	487.94
R 18-Oct-12	338.67	17.24	327.59
Average	699.05	82.19	674.54
Std Dev	329.50	33.40	468.98
Platte River Downstream			
L 30-Nov-11	763.30	54.26	-
M 30-Nov-11	349.51	77.86	-
R 30-Nov-11	432.00	70.36	-
L 13-Apr-12	1001.90	72.49	-
M 13-Apr-12	665.38	89.15	-
R 13-Apr-12	468.81	103.67	-
L 13-Jul-12	1138.63	135.76	-
M 13-Jul-12	942.55	125.46	-
R 13-Jul-12	428.84	115.83	-
L 18-Oct-12	1295.87	64.61	1233.15
M 18-Oct-12	1167.88	82.23	1079.58
R 18-Oct-12	346.34	40.82	317.46
Average	750.09	86.04	876.73
Std Dev	348.79	29.01	490.39

"-" means test was not conducted, "n.d." means not detected

	n-Hexane (µg/L) (limit=1)	Methyl t-Butyl Ether (µg/L) (limit=1)	Benzene (µg/L) (limit=1)	Toluene (µg/L) (limit=1)	Ethylbenzene (µg/L) (limit=1)	Naphthalene (µg/L) (limit=1)	Total Xylenes (µg/L) (limit=1)	Total Purgeable Hydrocarbons (µg/L) (limit=10)	Arsenic (total) (mg/L) (limit=0.10)
	Tested by Midwest Laboratories								
Rock Creek Upstream									
1 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1 18-Jan-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2 18-Jan-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3 18-Jan-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1 11-Apr-12	-	-	-	-	-	-	-	-	n.d.
2 11-Apr-12	-	-	-	-	-	-	-	-	n.d.
3 11-Apr-12	-	-	-	-	-	-	-	-	n.d.
1 12-Sept-12	-	-	-	-	-	-	-	-	n.d.
2 12-Sept-12	-	-	-	-	-	-	-	-	n.d.
3 12-Sept-12	-	-	-	-	-	-	-	-	n.d.
Average	-	-	-	-	-	-	-	-	-
Std Dev	-	-	-	-	-	-	-	-	-
Rock Creek Downstream									
1 30-Nov-11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1 18-Jan-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2 18-Jan-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3 18-Jan-12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1 11-Apr-12	-	-	-	-	-	-	-	-	n.d.
2 11-Apr-12	-	-	-	-	-	-	-	-	n.d.
3 11-Apr-12	-	-	-	-	-	-	-	-	n.d.
1 12-Sept-12	-	-	-	-	-	-	-	-	n.d.
2 12-Sept-12	-	-	-	-	-	-	-	-	n.d.
3 12-Sept-12	-	-	-	-	-	-	-	-	n.d.
Average	-	-	-	-	-	-	-	-	-
Std Dev	-	-	-	-	-	-	-	-	-

"-" means test was not conducted, "n.d." means not detected

	Cadmium (total) (mg/L) (limit=0.002)	Chloride (mg/L) (limit=1.0)	Chromium (total) (mg/L) (limit=0.01)	Conductance (uS/cm) (limit=2)	Copper (total) (mg/L) (limit=0.01)	E coli (cfu/100 mL) (limit=1)	HEM (mg/L) (limit=5)	Iron (total) (mg/L) (limit=0.01)	Nickel (total) (mg/L) (limit=0.01)
	Tested by Midwest Laboratories								
Rock Creek Upstream									
1 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	0.76	n.d.
1 18-Jan-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.07	n.d.
2 18-Jan-12	n.d.	-	n.d.	-	n.d.	-	n.d.	0.9	n.d.
3 18-Jan-12	n.d.	-	n.d.	-	n.d.	-	n.d.	0.99	n.d.
1 11-Apr-12	n.d.	-	n.d.	-	0.44	-	n.d.	1.31	1.65
2 11-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.51	n.d.
3 11-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.32	n.d.
1 12-Sept-12	n.d.	19	n.d.	584	n.d.	740	n.d.	4.14	n.d.
2 12-Sept-12	n.d.	19	n.d.	579	n.d.	1000	n.d.	4.06	n.d.
3 12-Sept-12	n.d.	18	n.d.	578	n.d.	760	n.d.	4.27	n.d.
Average	-	18.67	-	580.33	0.44	833.33	-	2.03	1.65
Std Dev	-	0.58	-	3.21	-	144.68	-	1.48	-
Rock Creek Downstream									
1 30-Nov-11	n.d.	-	n.d.	-	n.d.	-	-	0.75	n.d.
1 18-Jan-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.03	n.d.
2 18-Jan-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.05	n.d.
3 18-Jan-12	n.d.	-	n.d.	-	n.d.	-	n.d.	0.94	n.d.
1 11-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.27	n.d.
2 11-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.[a]	1.7	n.d.
3 11-Apr-12	n.d.	-	n.d.	-	n.d.	-	n.d.	1.68	n.d.
1 12-Sept-12	n.d.	16	n.d.	577	n.d.	660	n.d.	4.54	n.d.
2 12-Sept-12	n.d.	16	n.d.	574	n.d.	1000	n.d.	4.31	n.d.
3 12-Sept-12	n.d.	17	n.d.	576	n.d.	770	n.d.	4.81	n.d.
Average	-	16.33	-	575.67	-	810.00	-	2.21	-
Std Dev	-	0.58	-	1.53	-	173.49	-	1.65	-

"-" means test was not conducted, "n.d." means not detected

[a] : Detection limit of 20 mg/L

	Nitrate/Nitrite Nitrogen (mg/L) (limit=0.2)	Nitrite Nitrogen (mg/L) (limit=0.02)	Phosphorus (total) (mg/L) (limit=0.05)	TKN (mg/L) (limit=0.50)	Zinc (total) (mg/L) (limit=0.01)	pH
	Tested by Midwest Laboratories					
Rock Creek Upstream						
1 30-Nov-11	-	-	0.462*[b]	0.345*[c]	n.d.	-
1 18-Jan-12	-	n.d.*[a]	0.264*[b]	0.403*[c]	n.d.	-
2 18-Jan-12	-	n.d.*[a]	0.248*[b]	0.36*[c]	n.d.	-
3 18-Jan-12	-	n.d.*[a]	0.246*[b]	0.419*[c]	n.d.	-
1 11-Apr-12	-	0.021*[a]	0.455*[b]	0.539*[c]	1.1	-
2 11-Apr-12	-	0.01*[a]	0.406*[b]	0.486*[c]	0.02	-
3 11-Apr-12	-	0.027*[a]	0.432*[b]	0.516*[c]	n.d.	-
1 12-Sept-12	2.3	0.02	0.44	0.51	0.02	8.22
2 12-Sept-12	2.2	0.02	0.43	n.d.	0.02	8.22
3 12-Sept-12	2.2	0.02	0.45	n.d.	0.02	8.22
Average	2.233333333	0.019667	0.3833	0.44725	0.236	8.22
Std Dev	0.06	0.01	0.09	0.08	0.48	0.00
Rock Creek Downstream						
1 30-Nov-11	-	-	0.471*[b]	0.194*[c]	n.d.	-
1 18-Jan-12	-	n.d.*[a]	0.258*[b]	0.329*[c]	n.d.	-
2 18-Jan-12	-	n.d.*[a]	0.241*[b]	0.14*[c]	n.d.	-
3 18-Jan-12	-	n.d.*[a]	0.276*[b]	0.39*[c]	n.d.	-
1 11-Apr-12	-	0.013*[a]	0.455*[b]	0.553*[c]	0.01	-
2 11-Apr-12	-	0.017*[a]	0.457*[b]	0.599*[c]	0.01	-
3 11-Apr-12	-	0.025*[a]	0.436*[b]	0.675*[c]	0.01	-
1 12-Sept-12	2.3	0.02	0.42	n.d.	0.02	8.01
2 12-Sept-12	2.2	0.02	0.45	n.d.	0.02	8.13
3 12-Sept-12	2.3	0.02	0.45	n.d.	0.02	8.12
Average	2.27	0.02	0.39	0.41	0.015	8.086667
Std Dev	0.06	0.00	0.09	0.21	0.01	0.07

*Conducted at UNL Water Sciences Lab, "-" means test was not conducted, "n.d." means not detected,
[a] Detection Limit = 0.0040 mg/L, [b] Detection Limit = 0.02 mg/L, [c] Detection Limit = 0.10 mg/L

	Total Solids (mg/L)	Total Suspended Solids (mg/L)	Total Dissolved Solids (mg/L)
	Tested by Lauren Swadener		
Rock Creek Upstream			
1 30-Nov-11	367.27	17.99	-
1 18-Jan-12	328.06	27.26	-
2 18-Jan-12	270.48	24.19	-
3 18-Jan-12	245.65	23.56	-
1 11-Apr-12	409.26	54.62	-
2 11-Apr-12	414.45	54.64	-
3 11-Apr-12	415.91	56.33	-
1 12-Sept-12	426.78	138.11	406.65
2 12-Sept-12	397.32	139.24	425.32
3 12-Sept-12	197.56	142.86	403.06
Average	347.27	67.88	411.68
Std Dev	82.53	51.79	11.95
Rock Creek Downstream			
1 30-Nov-11	374.29	14.36	-
1 18-Jan-12	345.45	28.57	-
2 18-Jan-12	292.59	35.52	-
3 18-Jan-12	368.53	23.35	-
1 11-Apr-12	413.31	53.70	-
2 11-Apr-12	429.64	57.63	-
3 11-Apr-12	439.78	55.20	-
1 12-Sept-12	497.74	132.21	379.81
2 12-Sept-12	500.00	142.50	397.50
3 12-Sept-12	-	-	-
Average	406.81	60.34	388.65
Std Dev	68.86	46.23	12.51

"-" means test was not conducted, "n.d." means not detected

Appendix E Raw Data – In-stream Sediment Sampling

9-12-12 Rock Creek	Arsenic (total) (mg/kg) (limit = 10)	Cadmium (total) (mg/kg) (limit = 0.50)	Chromium (total) (mg/kg) (limit = 1.0)	Copper (total) (mg/kg) (limit = 1.0)	Iron (total) (mg/kg) (limit = 5.00)	Lead (total) (mg/kg) (limit = 5.0)	Nickel (total) (mg/kg) (limit = 1.0)	Percent Solids (%) (limit = 0.01)	Zinc (total) (mg/kg) (limit = 1.0)
	Tested by Midwest Laboratories								
20 ft upstream	n.d.	n.d.	8.0	6.3	8,255	5.5	8.1	61.5	26.3
10 ft upstream	n.d.	n.d.	8.0	6.0	7,978	n.d.	7.6	49.3	24.7
0 ft upstream	n.d.	n.d.	8.0	6.7	8,608	6.2	8.9	51.1	26.6
Average Upstream			8.0	6.3	8,280	5.9	8.2	53.9	25.9
Std Dev. Upstream			0.0	0.3	258	0.4	0.5	5.4	0.8
0 ft downstream	n.d.	n.d.	4.3	3.9	4,562	n.d.	4.8	50.3	14.5
10 ft downstream	n.d.	n.d.	5.5	3.8	7,881	5.3	6.6	57.3	19.6
20 ft downstream	n.d.	n.d.	4.8	2.4	10,479	n.d.	7.9	41.7	12.7
Average Downstream			4.9	3.4	7,641	5.3	6.4	49.7	15.6
Std Dev. Downstream			0.5	0.7	2,422	0.0	1.3	6.4	2.9