Section 4
Water Quality

4.1 Introduction

A water-quality assessment was conducted to evaluate the stream chemistry in the watershed with the goal of developing a watershed-management strategy that meets the requirements of the City's NPDES permit. The assessment utilized data obtained through: (1) a compilation of historic water-quality data in the watershed; and (2) limited water quality sampling at two locations in the watershed.

4.2 Methodology

Past stream-chemistry data were compiled from several sources, including the U.S. Geological Survey (USGS) National Water Information System (http://nwis.waterdata.usgs.gov/nwis), the Environmental Protection Agency STORET database (http://www.waterqualitydata.us/), the Nebraska Department of Environmental Quality (Dave Ihrie, written communication, 2014), and Kister and Mundorff (1963).

In addition, two dry-weather samples and one wet-weather sample were collected for this study along the main channel from two locations along the main channel. Though stream chemistry can be characterized a majority of the time by dry-weather sampling, a large portion of chemical loading occurs during runoff events, and thus an effort was made for at least one wet-weather sample. The two dry-weather samples occurred on May 1, 2013 and August 7, 2013 and the wet-weather sample occurred on November 5, 2013.

The two sample locations were (Figure 4-1):

- Middle Creek at SW 63rd St at Lincoln, Nebr. (USGS station number 06803170), and
- Middle Creek 0.5 miles upstream from the mouth at Lincoln, Nebr. (USGS station number 06803182).

4.2.1 Sampling Protocol

Samples were collected by the USGS using the protocols described in the USGS National Field Manual (US Geological Survey, variously dated). All samples were collected by wading to the approximate centroid of flow where grab-sampling techniques were used to triple rinse and then fill a series of polyethylene bottles. Sample bottles requiring acid preservation were acidified in the field. For dissolved constituents, some of the sample bottles were filtered from one bottle into a separate, triple-rinsed bottle using a polysulfone, pleated-membrane capsule filter having a pore size of 0.45 μm. All samples were stored on ice or refrigerated until their delivery to analytical laboratories.

For quality-assurance purposes, two replicates and one blank sample were also collected. No analytes were detected in the blank sample. With the exception of *E. coli*, all of the analytes had good reproducibility in the replicate samples. The two *E. coli* results had an average

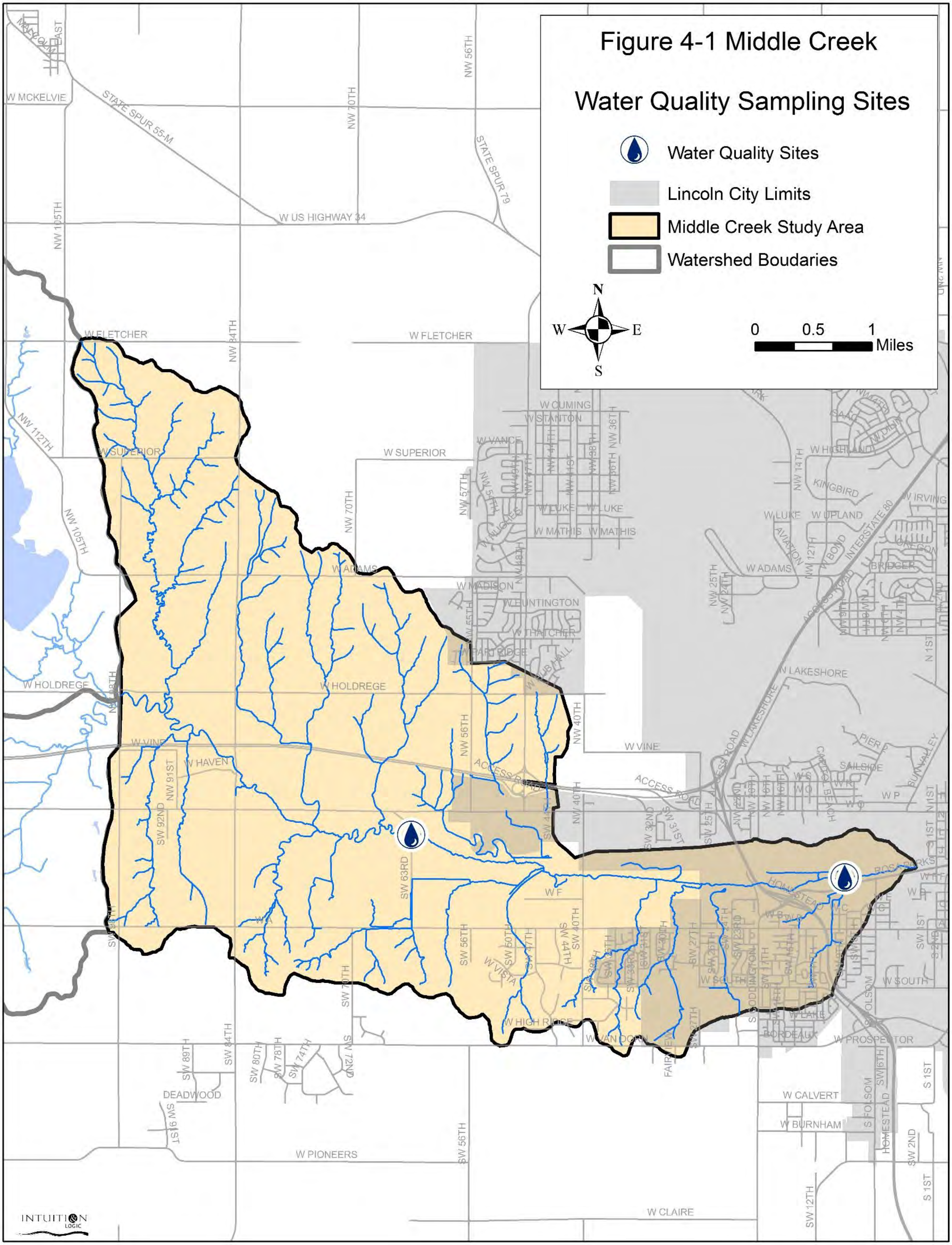

Figure 4-1 Middle Creek Water Quality Sampling Sites

relative-standard deviation of 27 percent. All *E. coli* results were analyzed using the regulatory standard known as the Quanti-Tray method (standard method 9223B) that, based on nationwide proficiency testing, is often characterized by variability of up to 40 percent.

In addition to the water samples, several ancillary data were collected. Water temperature, specific conductance, pH, dissolved oxygen, and turbidity were all measured using a multi-parameter meter calibrated on the day of collection. Velocity was estimated at the water surface using floating objects and then the mean velocity was assumed to be approximately 85% of that at the surface. Streamflow at the SW 63rd St Bridge was taken from the USGS gaging-station data there. Streamflow at the site 0.5 miles upstream of the mouth was estimated from the mean velocity and an estimate of the cross-sectional area of the stream.

4.2.2 Analytical Procedures

Analytes were selected in conjunction with the needs of the City and the respective NPDES permit. With the exception of the bacteriological results, all of the analytical chemistry was performed at the USGS National Water Quality Laboratory (NWQL):

Table 4.1 Analytes evaluated for each sample

Analyte	Laboratory	Units	Reporting Level	Reference
Dissolved calcium	NWQL	mg/L	0.022	Fishman, 1993
Dissolved magnesium	NWQL	mg/L	0.011	
Dissolved sodium	NWQL	mg/L	0.06	
Dissolved ammonia as nitrogen	NWQL	mg/L	0.010	
Dissolved copper	NWQL	µg/L	0.8	Garbarino and others, 2006
Dissolved selenium	NWQL	µg/L	0.05	
Hardness, as calcium carbonate	Calculated	mg/L	--	Fishman and Friedman, 1989
Sodium adsorption ratio	Calculated	unitless	--	
Total suspended solids	NWQL	mg/L	15	
Total phosphorus	NWQL	mg/L	0.020	Patton and Truitt, 1992
Total organic carbon	NWQL	mg/L	0.7	Standard Method 5310B
E. coli	NEHDL	MPN/100 mL	1	Standard Method 9223B
Total coliform	NEHDL	MPN/100 mL	1	
[NWQL, USGS National Water Quality Laboratory; --, not applicable; NEHDL, Nebraska Department of Health and Human Services Laboratory; mg/L, milligrams per liter; µg/L, micrograms per liter; MPN/100 mL, most-probable number of colonies per 100 milliliters.				

4.3 Results

Data from past sampling efforts and the sampling done as part of this study are compiled as geometric means in Table 4.2 and presented in their entirety in Appendix D. The three sample sets collected for this study range across the spring, summer, and fall seasons and include a wet-weather sample from November 2013. The addition of past sampling added 51 samples in the Middle Creek Watershed apart from that collected as part of this study. This added data for two sites beyond those sampled for this study: one near Emerald, Nebraska and another at the SW 40th St Bridge. It also added new types of data, and atrazine concentrations were included in the summaries. However, these data represent only snapshots of the true water-quality conditions. Achieving a more balanced and accurate understanding of the water quality requires repeated sampling during the full range of flow conditions, agricultural activity and seasons. All of the data associated with the USGS are also available online through the National Water Information System (http://nwis.waterdata.usgs.gov/nwis).

4.3.1 Applicability to Water-Quality Criteria

Middle Creek is classified as being used for warmwater aquatic life (class B), agricultural water supply (class A), and aesthetics (NDEQ title 117). From the context of the Nebraska 303(d) list of impaired waters in Nebraska (NDEQ, 2012), the section of Middle Creek included in the scope of this report is meeting all of those beneficial uses and is not included on that list. However, a reach of Middle Creek located upstream of Pawnee Lake is currently considered impaired because of the effect of atrazine levels on aquatic life. A total-maximum-daily load (TMDL) has been developed for that reach. Of the associated-water-quality standards that can be evaluated using the available data compiled for this report, all were met with the exception of elevated specific conductance levels at the site 0.5 miles upstream of the mouth. These levels are a product of the natural geochemistry of the watershed and are discussed in greater detail in subsequent sections.

Table 4.2 Geometric means of selected analytes in the Middle Creek Watershed

	Middle Creek near Emerald, Nebr.	**Middle Creek at SW 63rd St at Lincoln, Nebr.**	**Middle Creek at SW 40th St at Lincoln, Nebr.**	**Middle Cr 0.5 Miles Upstream from Mouth at Lincoln, Nebr.**
Number of samples	1	3	48	4
Range of years represented	1951	2013	1995-2013	1995-2013
pH, water, unfiltered, field, standard units	[A] 7.9	8	8.1	7.9
Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	[A] 920	787	566.2	3765
Dissolved oxygen, water, unfiltered, milligrams per liter	--	9.6	7.5	9.2
Suspended solids, water, unfiltered, milligrams per liter	--	40	41.4	<21
Hardness, water, milligrams per liter as calcium carbonate	[A] 357	262	[A] 249	310
Calcium, water, filtered, milligrams per liter	[A] 118	75.9	[A] 70	78.7
Magnesium, water, filtered, milligrams per liter	[A] 15	17.6	[A] 18	27.5
Sodium adsorption ratio, water, number	[A] 1.5	2	[A] 2.8	29.9
Sodium, water, filtered, milligrams per liter	[A] 65	74.2	41.4	1209
Ammonia, water, filtered, milligrams per liter as nitrogen	--	<0.06	<0.1	0.4
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	--	0.42	0.4	0.38
Escherichia coli, defined substrate test method (DSTM), water, most probable number per 100 milliliters	--	345	261.5	284
Copper, water, filtered, micrograms per liter	--	<0.95	--	<4.01
Selenium, water, filtered, micrograms per liter	--	2.7	--	1.6
Organic carbon, water, unfiltered, milligrams per liter	--	7.27	[A] 6.1	7.04
Atrazine, total, micrograms per liter	--	--	0.8	--

[--, No data; <, less than.]; [A] Not a true geometric mean as only one sample value was available for this analyte

4.3.2 Naturally Elevated Specific Conductance and Sodium

Perhaps most notable of the water-quality data is the sharp increase in specific conductance and dissolved sodium between the SW 40th St site and the site 0.5 miles upstream of the mouth. This phenomenon was anticipated given the locations of historical saline wetlands (as shown in Figure 4-2) in the watershed and previous literature (Kister and Mundorff, 1963; Farrar and Gersib, 1991; Verstraeten, 1997). The increase is likely attributable to the underlying Dakota aquifer that, in places, has natural geochemical characteristics that are dominated by high sodium and chloride levels (Kister and Mundorff, 1963). Towards the eastern portion of the watershed, this aquifer becomes increasingly connected to the surface water system as indicated by the presence of saline wetlands. As a result, Middle Creek streamflow, especially baseflow, is affected by this natural geochemical characteristic.

If waters with excess sodium (often characterized by the sodium-adsorption ratio) such as these were added to soil, the sodium might disrupt the soil structure by dispersing clay particles. Such dispersion would act to reduce infiltration conditions of the soil. Because all of the samples from the site near the mouth had sodium-adsorption ratios greater than 34, this water is probably unsuitable for irrigation purposes because of the potential sodium hazard to the soil (Richards, 1954). In addition, potential activities designed to reduce sodium levels in the stream for irrigation purposes would probably have a detrimental impact on the native biota of the stream ecosystem. Though Middle Creek is currently listed as a Class A agricultural water supply, Class B—where the natural background water quality limits its use for agricultural purposes—is probably more appropriate for the lower reach.

4.3.3 Runoff Characteristics

Because of persistent rainfall that occurred throughout the day on November 5, 2013, wet-weather samples were collected to represent runoff conditions. Though runoff did appear to be present during sampling, the streamflow record suggests that this was a fairly minor event. At the SW 63rd St site, the 8.9 cubic-feet-per second (cfs) measured on the day of sampling was higher than the 3.1 cfs measured a day earlier but was quite small relative to the 2013 peak of 1,100 cfs that occurred on May 31 or the 2007 peak of 4,430 cfs.

The addition of historic sampling data added a greater range of streamflows, though the highest sampled streamflow of 122 cfs was still only a small fraction of the true range that the stream experiences. Therefore, these sample data provide some information about the characteristics of runoff, but much uncertainty remains.

Given this uncertainty, general statements can still be made about Middle Creek runoff. Runoff tended to introduce and mobilize sediment in the stream, and some analytes that are typically associated with sediment (such as *E. coli*) as well as those that typically increase during runoff (total organic carbon, and atrazine) correspondingly increased. In contrast, runoff often reduces the mineral levels in a stream by introducing relatively mineral-free rainwater, and this pattern was generally seen in several of the analytes tested in this study (Specific conductance, hardness, calcium, magnesium, sodium, and sodium adsorption ratio). That some of the other analytes showed less sensitivity to runoff (ammonia, phosphorus,

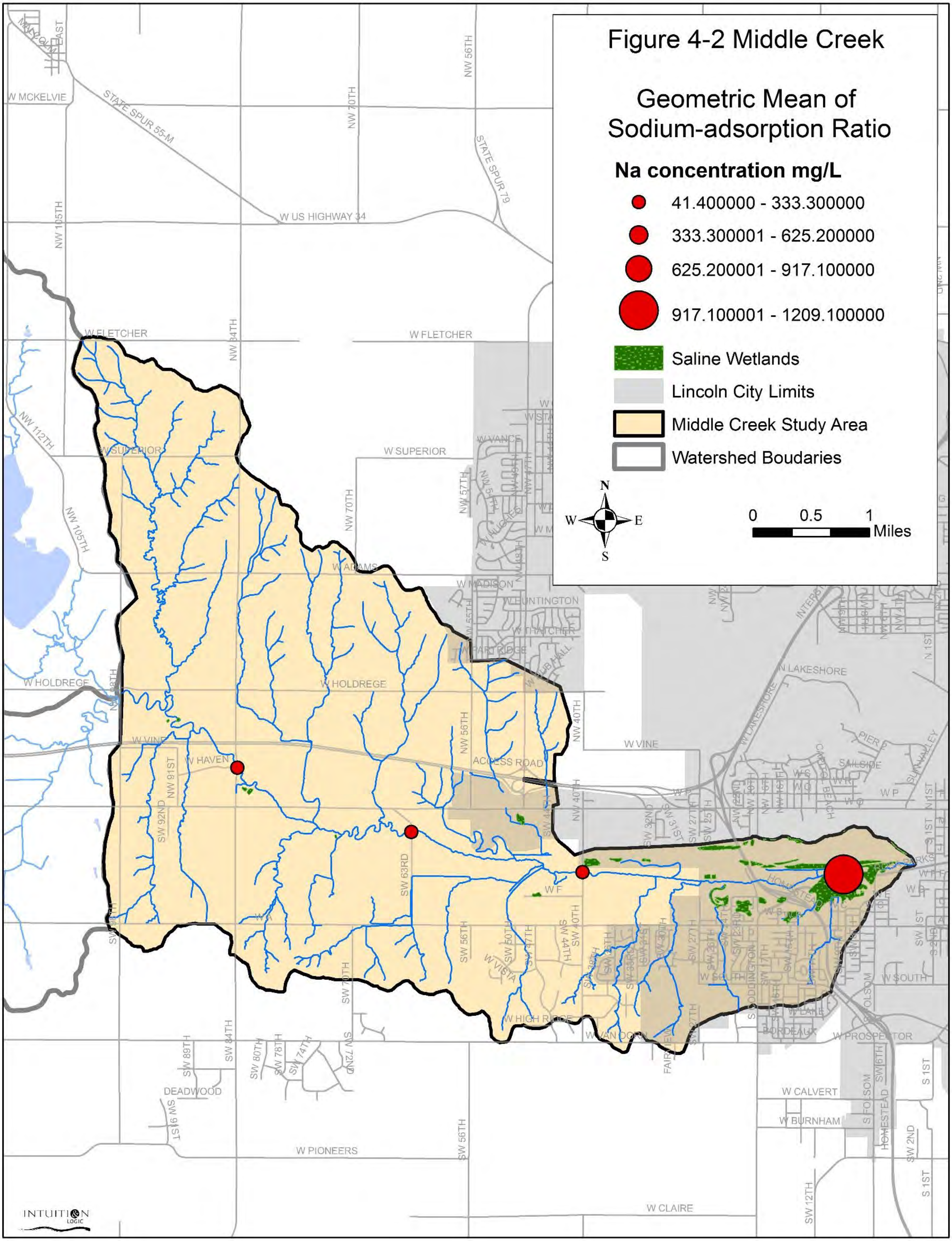

Figure 4-2 Middle Creek
Geometric Mean of Sodium-adsorption Ratio
Na concentration mg/L
41.400000 - 333.300000
333.300001 - 625.200000
625.200001 - 917.100000
917.100001 - 1209.100000
Saline Wetlands
Lincoln City Limits
Middle Creek Study Area
Watershed Boudaries
N
W
E
S
0
0.5
1
Miles
W FLETCHER
W SUPERIOR
W HOLDREGE
W VINE
W ADAMS
W US HIGHWAY 34
STATE SPUR 55-M
STATE SPUR 79
W MCKELVIE
NW 105TH
NW 112TH
NW 84TH
NW 70TH
NW 56TH
NW 40TH
W PIONEERS
W CLAIRE
W CALVERT
W BURNHAM
W PROSPECTOR
W SOUTH
DEADWOOD
INTUITION LOGIC

copper, and selenium) may suggest a relation to streamflow does not exist but may also indicate inadequate data for detecting such a relation.

4.3.3.1 Total Suspended Solids

Total-suspended solids (TSS) showed a direct relation with streamflow (Figure 4-3). The maximum-sampled TSS concentration was 636 mg/L (which, on the day of sampling, was equivalent to 209 tons of sediment transport), but the trend of the data implies that those concentrations are probably higher during larger runoff events. Given that the channel is incised and actively widening, these solids are likely originating both from overland and in-channel erosional processes.

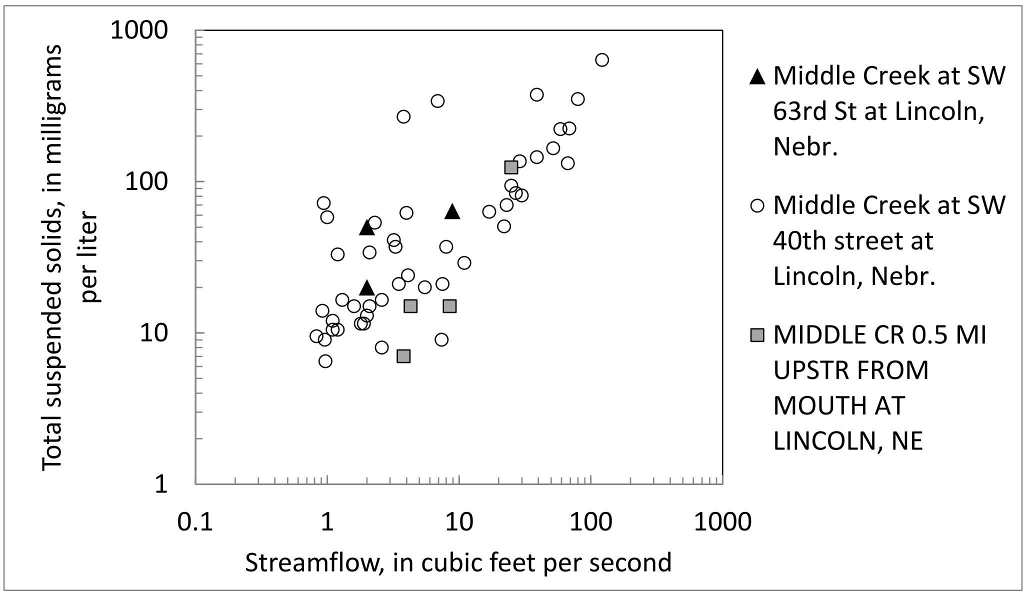

Figure 4-3. Total-suspended solid concentrations increase as streamflows increase in Middle Creek.

4.3.3.2 Bacteria

Bacteria levels appear to increase during runoff conditions (Figure 4-4). The maximum-sampled *E. coli* concentration was almost 20,000 colonies per 100 mL, but—as with TSS—the trend of the data imply that those concentrations may be considerably higher during larger runoff events. Though not specific to Middle Creek, sampling data from Salt Creek near Ashland, Nebraska (USGS station number 06805000), show *E. coli* levels going as high as 120,000 colonies per 100 mL (http://nwis.waterdata.usgs.gov/nwis).

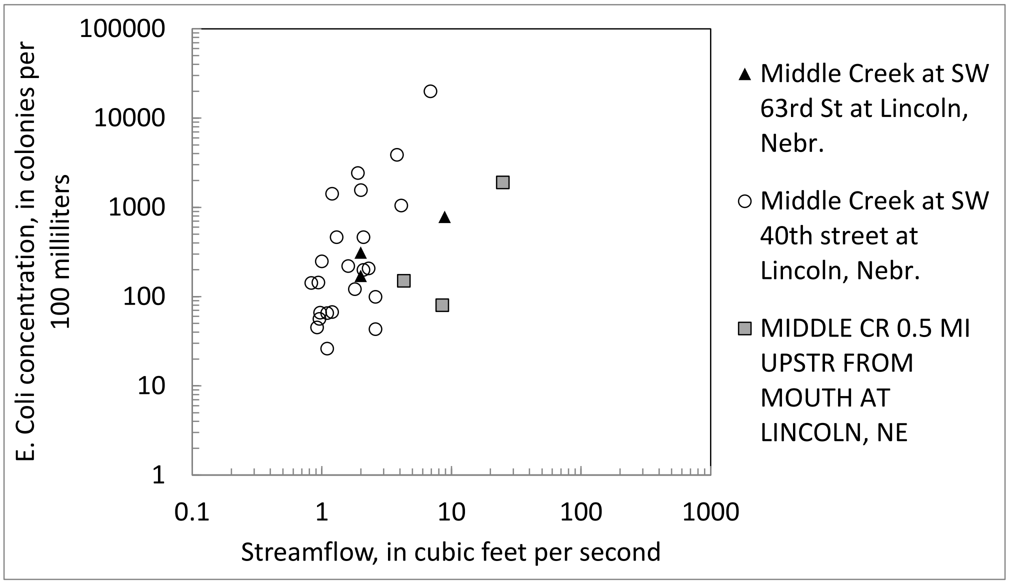

Figure 4-4. *E. coli*. concentrations increase as streamflows increase in Middle Creek.

4.3.3.3 Total Phosphorus

Unlike TSS and *E. coli*, total phosphorus (TP) data did not show a strong relation to streamflow (Figure 4-5). This is somewhat surprising given that most phosphorus typically occurs in particulate-organic form or is bound to sediment particles, both of which would be expected to be mobilized during runoff conditions. Though this may be a result of inadequate data to fully define TP characteristics in Middle Creek, it may also suggest that phosphorus levels are less sensitive to variations in runoff.

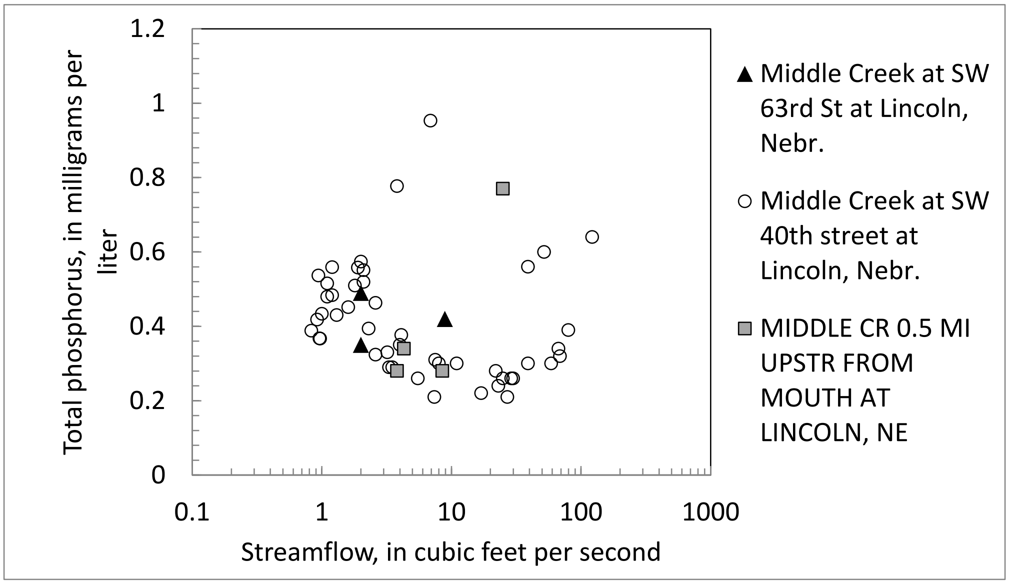

Figure 4-5. Total phosphorus concentrations show no strong relation to streamflows in Middle Creek.

4.3.3.4 Atrazine

Though atrazine was not sampled for this study, historic atrazine data showed a strong increasing relation to streamflow (Figure 4-6). Because atrazine is typically applied to cropland, this suggests that at least some of the stormwater is currently affected by agricultural runoff rather than urban runoff.

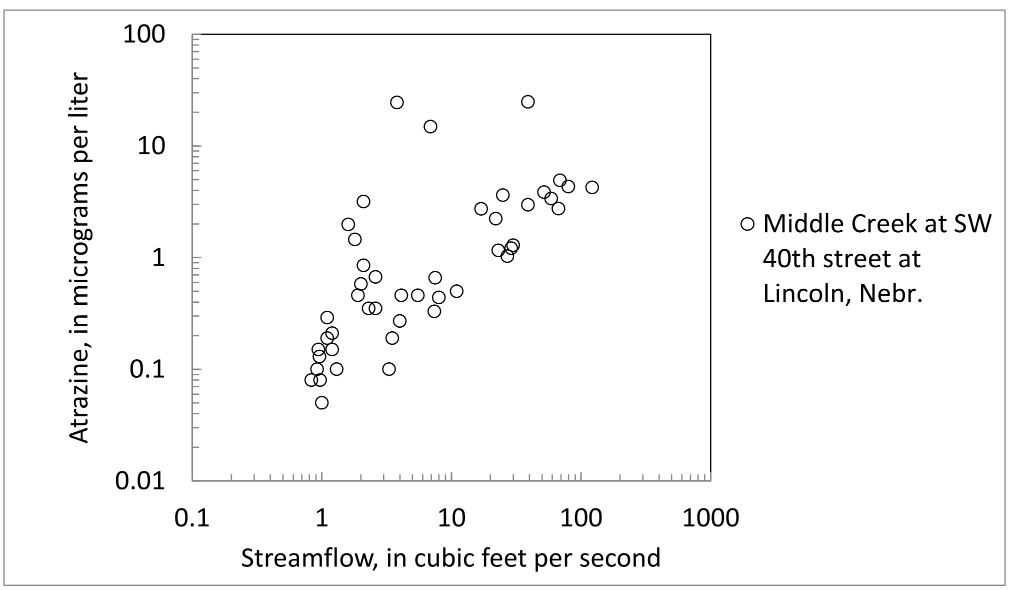

Figure 4-6. Atrazine concentrations increase as streamflows increase in Middle Creek.

4.4 Managing Stormwater Quality

The Clean Water Act, and specifically the National Pollutant Discharge Elimination System (NPDES) regulates surface-water quality in Lincoln. As part of the NPDES program, the City must apply stormwater best-management practices (BMPs) designed to preserve the quality of its streams and reservoirs. BMPs can be both structural and nonstructural and typically strive to reduce the impacts of stormwater runoff on the receiving water bodies.

The results confirm that stormwater runoff affects the physical and chemical characteristics of the stream. Some of those characteristics may be following natural processes associated with the hydrologic cycle, such as the dilution of minerals during rainfall-runoff. Some of those characteristics may be exacerbated by anthropogenic processes such as erosion, pesticide application, or nutrient enrichment. Consequently, a stormwater management program should consider these processes. A focus on urban BMPs will provide benefits, but will neglect the contributions of agricultural runoff to the water quality. A focus on in-channel processes may neglect the contribution of overland processes.

In this context, a comprehensive program employing multiple types of stormwater BMPs may be most effective at managing the stormwater quality in the Middle Creek Watershed. Non-structural BMPs such as education, land planning, and enforcement of sediment control provisions will be important for preventing pollution and coordinating BMP implementation in a basin affected by both urban and agricultural runoff. Structural BMPs such as those listed in the City's Drainage Criteria Manual will serve to reduce pollutant loading from overland processes. Capital-improvement projects associated with channel stabilization (and listed in other sections of this report) will likely reduce the amount of sediments (and associated constituents) being mobilized. On their own, each of these BMPs may not provide a measureable benefit to the water quality. However, as more of these BMPs are applied, their cumulative effect may improve the water quality in the Middle Creek Watershed.

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