SECTION 5 – WATER QUALITY MONITORING

Water quality monitoring for Antelope Creek involves a combination of historic data and a targeted monitoring effort developed in support of this Basin Plan during 2010-2011. This section summarizes both current and historic water quality monitoring efforts to provide the most comprehensive understanding of water quality conditions in Antelope Creek.

5.1. Overview of Available Water Quality Data

This discussion is divided into two sections: 1) historic data collected by NDEQ and others, primarily over the past 5 to 10 years, and 2) targeted data collected during 2010-2011 to support development of this Basin Plan. Each of these sources is briefly summarized below, followed by a brief overview of water quality evaluation principles applied in Nebraska, and a more detailed discussion of each data source.

In 2010-2011, EA conducted in-stream sampling of four dry weather and three wet weather synoptic sampling events for approximately 11 locations on the stream.

5.1.1 Historic Data (Primarily 2002-2009)

Historic water quality data for Antelope Creek from below the Holmes Lake Dam to Salt Creek at the State Fairgrounds includes the following sources:

- NDEQ rotating basin sampling plan data for 2002-2008 collected at Antelope Creek at the State Fairgrounds. This location was included in NDEQ's water quality assessment for 2010 (NDEQ 2010) and was provided in electronic format by NDEQ. (Note: the data set forming the basis of the Antelope ammonia and *E. coli* TMDLs was limited to 2002-2004, and is discussed further in SECTION 4 – TMDL ASSESSMENT.)
- NDEQ collected additional monitoring data for Antelope Creek in 2009, also limited to the State Fairground sampling location, as provided electronically by NDEQ.
- Summer 2009, University of Nebraska–Lincoln (UNL) in-stream monitoring at five locations on Antelope Creek, as contained in a report by Mohlman et al. (2009).
- Dry weather outfall screening by UNL as part of the City's rotating NPDES illicit discharge detection and elimination monitoring program, also conducted by UNL (Mohlman et al. 2009).
- Historic wet weather flow monitoring in other Lincoln watersheds as part of NPDES monitoring in the 1990s and more recent monitoring in 2006-2007. These data sets are summarized in a thesis at UNL by Vegi (2008).

5.1.2 Recent Data (2010-2011)

In 2010-2011, EA conducted in-stream sampling of four dry weather and three wet weather synoptic sampling events for approximately 11 locations on the stream. At three of these locations, 5-week sequences of samples for fecal indicator bacteria were also collected to support calculation of geometric mean concentrations for *E. coli*. Outfalls (tributaries) to the stream were sampled for two events under dry weather conditions and investigated for signs of dry-weather pollution. In-stream sediment samples were also collected at targeted locations in the stream for two sampling events.

5.2. General Water Quality Evaluation Principles

Water quality assessment procedures used by NDEQ for Nebraska waters are defined in "Methodologies for Water body Assessments and Development of the 2010 Integrated Report for Nebraska" (NDEQ 2009). From a regulatory perspective, water quality data are compared to stream standards assigned by NDEQ to determine whether the stream attains standards. Several principles specified by NDEQ (2009) that are relevant to evaluation and interpretation of recent and historic water quality data include:

- For most constituents, streams are considered impaired if more than 10 percent of samples exceed the acute or chronic standard. A confidence interval of 90 percent is applied to the 10 percent threshold, therefore NDEQ provides a "lookup" table for these impairment thresholds, depending on number of samples collected (*e.g.,* to be identified as impaired, a sample size of 10 requires that three samples exceed the standard). A notable exception to the 10 percent rule is *E. coli*, where a seasonal geometric mean is compared to the stream standard during the recreation season of May 1 to September 30.

- NDEQ focuses water quality assessments on the most recent and representative data. Data and information collected during the past 5-year period are used to initially categorize a water body. That is, after a water body has been placed in a category, only new or newly acquired data and or information (*i.e.,* TMDLs developed) can be used to place a water body in another category. Water bodies are not shifted from category to category solely based upon the age of the data.
- As a guideline, data collected more than 5 but less than 10 years ago, are not used to identify a water body as impaired. In situations where the data is deemed representative of a water body or watershed, the data may be used to place a water body in the appropriate listing category for the Water Quality Integrated Report [NDEQ 2010]. Data older than 10 years cannot be used to determine if a stream was impaired, but that data can still be used for other analytical analysis.
- The 5-year general practice is the initial screening for data sets, however; a secondary review also considers the installation of treatment or controls, hydro-modification, diversion, impoundments or the presence of new or expanded point source discharges. Only data that has been deemed representative should be used in the assessment process.
- Rather than eliminating the "non-detects" from the assessment data, values below detection limits are calculated as 50 percent of the method detection limit.
- Generally, a 10-sample minimum per constituent is targeted for assessment purposes. For data sets with <10 samples, NDEQ follows these guidelines:
    - Assume 10 samples were "targeted" and base the assessment on n=10.
    - For data sets n=3 to n=9; if three data points exceed the applicable water quality standard or goal, the water body should be assessed as having an impaired beneficial use.
    - For data set n=8 or n=9, if no data points exceed the applicable water quality standard or goal, the water body should be assessed as fully supporting the beneficial use.
    - For all other situations with data sets n=3 to n=9, the water body should be included in Category 3, insufficient information to determine beneficial use status.
- Multiple samples collected on the same day from the same segment under static stream conditions, shall be combined and the parameter mean will be calculated and used to represent the segment's water quality condition. Exceptions to this will be when monitoring efforts are designed to evaluate diurnal or temporal impacts related to a specific pollutant source.
- In order to compare some parameter measurements to water quality criteria, additional information is often required. For example, applicable ammonia criteria are dependent upon the water's pH and temperature; many metals require measures of calcium and magnesium to derive water hardness in order to calculate their criteria. When a water quality parameter requires additional information, the guidelines for data assessment (minimum number of samples, quality assurance requirements) also apply to this data. Assessments of water quality information will not be made in the absence of simultaneously collected additional information.
- Considerations relative to natural conditions:
    - Deviations from criteria that are the result of drought or other natural phenomena are not included in the group of waters needing a TMDL.
    - "Category 4C" Water bodies: Water body is impaired, but the impairment is not the result of a "pollutant." This category also includes waters where natural causes/sources have been determined to be the cause of the impairment.
    - For nonpoint source pollutants, data collected under extreme high flows can skew the data set and force managers to establish unrealistic reduction goals to account for infrequent and often unpredictable events. When reporting beneficial use assessments, impairments due to data collected during extreme high flow events should be noted when that information is available.

The discussion of recent and historic data that follows generally follows the principles defined by NDEQ (2009).

5.3. Historic Water Quality Sampling Results

Historic water quality sampling results are available for 1) in-stream locations for Antelope Creek, 2) stormwater outfalls as part of dry weather screening, and 3) storm runoff from various land uses in other watersheds in Lincoln. These results are summarized in the subsections below.

5.3.1 In-stream Water Quality

Dry weather in-stream monitoring data available for Antelope Creek includes these sources:

- **NDEQ Monitoring Program (2002-2008) at State Fairgrounds Site**: For purposes of the 2010 Water Quality Integrated Report for Antelope Creek, the NDEQ data set includes samples collected from 2002 through 2008 referred to as: "SLP2ANTLP104", Antelope Creek at State Fair Park in Lincoln, NE. This site is located at the west entrance to the State Fairgrounds in Lincoln, approx. 0.1 mile east of 14th Street. This sampling location is identified on Figure 5-1. Table 5-1 provides a summary of NDEQ's assessment, as well as some additional descriptive statistics calculated for the purposes of this Basin Plan. The monitoring program can generally be described as monthly for most constituents, with the exception of weekly monitoring of *E. coli* during the recreational season.
- **NDEQ Monitoring Program (2009) at State Fairgrounds Site:** Since completion of the last Integrated Report, NDEQ collected additional samples at Antelope Creek during 2009, as summarized in Table 5-2. These data are generally consistent with the previously collected data summarized in Table 5-1. Constituents of concern, *E. coli*, chloride and selenium exceed stream standards, whereas ammonia does not. Table 5-2 provides data for some additional potential parameters of interest for Antelope Creek such as total phosphorus, TSS, and additional nitrogen constituents which enable a total nitrogen (TN) calculation. Because resuspension of channel sediment can be a source of *E. coli*, it is noteworthy that several of the very high *E. coli* concentrations (*i.e.,* >10,000/100 mL) appear to coincide with higher TSS concentrations; however, the data set is not adequate to draw conclusions regarding this relationship, since *E. coli* is also considerably elevated in several cases with low TSS.
- **University of Nebraska-Lincoln 2009 In-Stream Monitoring at Multiple Locations:** In 2009, UNL conducted additional in-stream sampling for the City at five locations, which were visited six times during the summer of 2009. These sites were chosen to assess whether contamination was occurring from locations such as the State Fair Grounds, the Children's Zoo and Botanical Garden, and the Holmes Park Dog Run (upstream of Holmes Lake). Figure 5-1 identifies these sampling locations, with location ANTLPSC being the same as NDEQ's location SLP2ANTLP104. Tables 5-3 and 5-4 summarize data collected as part of this sampling program.
- **Historic Fecal Coliform Data near the Children's Zoo:** Samples were collected near the Children's Zoo for fecal coliform in 1999, as summarized in Table 5-5. The historic stream standard for fecal coliform was 200/100 mL; therefore, the seasonal geometric mean of 87/100 mL met this standard, although the early summer months exceeded the standard. Overall, the concentrations observed during 1999 at the Children's Zoo were not unusually high.

Building upon data summarized in Tables 5-1 through 5-4, simple scatter plots and other graphical summaries of historic data sets were developed to evaluate water quality trends, as provided in Figures 5-2 through 5-9. Date ranges presented in these summaries vary, depending on the available data. Key observations include:

- *E. coli* was elevated in both 2004 and 2009 NDEQ sampling periods at the State Fairgrounds, with no apparent differences between the 2 years and only a few samples meeting the TMDL limit of 113/100 mL (Figure 5-2). *E. coli* concentrations span several orders of magnitude when evaluated on a monthly basis, with no apparent trend. (April concentrations appear to be lower, but there are fewer samples available for April.) Elevated *E. coli* occurs at a range of flow conditions; elevated concentrations do not appear to be dependent on flow (Figure 5-3) under ambient conditions.
- Based on 2009 sampling by Mohlman et al. at multiple locations on Antelope Creek, there is not a clear upstream to downstream trend, particularly when looking at individual synoptic sample dates. Statistical testing by Mohlman et al. showed no statistically significant differences between sample locations. All sample locations were above the stream standard (126/100 mL) and the TMDL limit (113/100 mL) for all sampling events (Figure 5-4). Nonetheless, some differences between the sites are suggested by visual inspection of the data that may be worth further exploration in future sampling efforts. For example, geometric mean *E. coli* concentrations at the Antelope Creek Park and Children's Zoo locations are more than 10 times the stream standard (Table 5-4), whereas the Fairground location is on the order of five times the stream standard. There is also greater variability (*i.e.,* wider range of values) in the sample results at the Antelope Creek Park and Children's Zoo locations (Figure 5-4). Mohlman et al. also reported that samples in the afternoon had generally higher *E. coli* concentrations than morning samples.
- Mohlman et al. (2009) analyzed samples for surfactants as a potential indicator of detergents associated with illicit discharges. Surfactants greater than 0.25 mg/L are considered an initial benchmark for the presence of

detergents associated with sewage or washwater (CWP and Pitt 2004). Compared to this benchmark, surfactants in the Antelope Creek samples are quite low, averaging 0.09 mg/L. Additionally, all samples were below this benchmark with the exception of one sample taken from Salt Creek (Fairgrounds) and one result taken from Holmes Lake (Dog Park). Surfactant results at these two sites for other sample dates were an order of magnitude lower. *E. coli* and ammonia concentrations for these two dates were not particularly elevated. Therefore, overall, the Mohlman et al. (2009) data does not suggest illicit wastewater or washwater sources based on these in-stream samples.

- Ammonia data show relatively few exceedances of water quality standards over the past 9 years (Figure 5-5), suggesting that additional controls for ammonia may not be necessary on Antelope Creek in order to meet stream standards and TMDL limits. Ammonia concentrations were highest in 2002, 10 years ago, but have been relatively low since then. These results are also confirmed by the Mohlman et al. (2009) sampling that showed attainment of ammonia criteria at all locations (Table 5-4).
- Chloride concentrations are elevated at the State Fairgrounds during all months of the year (Figure 5-6), although lower concentrations are also present during some sampling events during summer months, presumably due to conditions where higher flows are present. As would be expected, chloride and conductivity are highly correlated (Figure 5-7). Generally, conductivity is higher at low flow conditions, which suggests groundwater influence. Supplemental sampling by Mohlman et al. (2009) also suggests a groundwater influence in the lower portion of the stream segment, as evidenced by elevated chloride, selenium and conductivity at the Vine Street and Salt Creek locations (Table 5-4).
- Selenium exceeds the water quality standard and is expected to be associated with naturally occurring groundwater contributions to the stream. As shown in Table 5-4, selenium concentrations tend to be elevated in the lower reach of the stream segment, along with chloride and conductivity, further supporting this hypothesis.
- In NDEQ's 2010 Integrated Report, copper received a Category 3 determination, indicating insufficient data to determine impairment. Nonetheless, three out of nine samples exceeded the stream standard, so the stream is considered potentially impaired by copper (Table 5-1). Mohlman et al. (2009) collected additional samples on 5 days at the NDEQ monitoring location at the State Fairgrounds as well as other locations on Antelope Creek on the same date (Table 5-4). Following NDEQ procedures (NDEQ 2010) to average sampling results collected at multiple locations on the same date results in five additional copper sample events for Antelope Creek; providing a total of 14 sample events to assess impairment. However, the ancillary hardness data required to assess stream standards was not provided in the Mohlman et al. (2009) data set; therefore, NDEQ would likely exclude these data from assessment (per procedures in NDEQ 2010). Nonetheless, for general information, only two of the five additional sampling events (averaging all locations on sample dates) had detectable concentrations of copper, and none of the five events at the Antelope Creek at the Salt Creek sampling location had copper concentrations above detection limits.

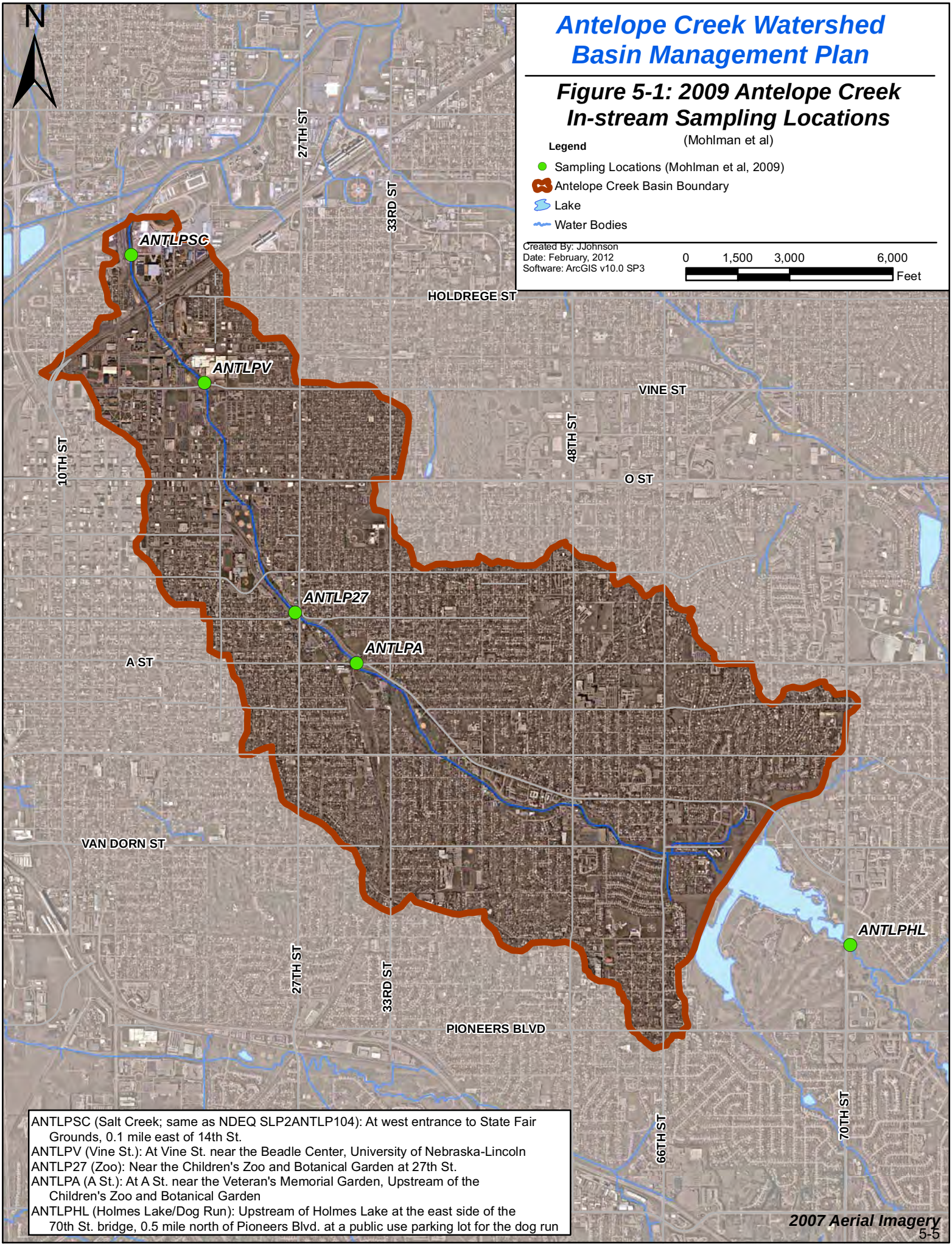

Antelope Creek Watershed
Basin Management Plan
Figure 5-1: 2009 Antelope Creek
In-stream Sampling Locations
(Mohlman et al)
Legend
Sampling Locations (Mohlman et al, 2009)
Antelope Creek Basin Boundary
Lake
Water Bodies
Created By: JJohnson
Date: February, 2012
Software: ArcGIS v10.0 SP3
0
1,500
3,000
6,000
Feet
N
ANTLPSC
ANTLPV
ANTLP27
ANTLPA
ANTLPHL
27TH ST
33RD ST
HOLDREGE ST
VINE ST
48TH ST
O ST
10TH ST
A ST
VAN DORN ST
PIONEERS BLVD
66TH ST
70TH ST
ANTLPSC (Salt Creek; same as NDEQ SLP2ANTLP104): At west entrance to State Fair Grounds, 0.1 mile east of 14th St.
ANTLPV (Vine St.): At Vine St. near the Beadle Center, University of Nebraska-Lincoln
ANTLP27 (Zoo): Near the Children's Zoo and Botanical Garden at 27th St.
ANTLPA (A St.): At A St. near the Veteran's Memorial Garden, Upstream of the Children's Zoo and Botanical Garden
ANTLPHL (Holmes Lake/Dog Run): Upstream of Holmes Lake at the east side of the 70th St. bridge, 0.5 mile north of Pioneers Blvd. at a public use parking lot for the dog run
2007 Aerial Imagery

Table 5-1. Historic Water Quality Data at State Fairgrounds (2002-2008)

Parameter	N (#)	NDEQ Impairment Determination (2002-2008)						Descriptive Statistics			
		Acute Criteria	# Exced-ing Acute Std	Chronic Criteria	# Exceed-ing Chronic Std	Impairment Basis: # samples that must exceed standard	NDEQ Identified as Impaired (Y/N)	Mean	Min	Max	St Dev
Physical (mg/L, unless otherwise noted)											
Temp (C)	113	32.2	0	NA	—	16	No	17.3	3.7	30.1	7.6
DO	109	3/5	3	NA	—	16	No	11.1	4.5	22.8	3.6
pH	112	6.5-9	0	NA	—	16	No	7.58	6.81	8.59	0.35
Conductivity umhos/cm	113	2000	63	NA	—	16	Yes	5947	204	19200	5290
—Seasonal	58	2000	31	NA	—	10	Yes	4561	204	17630	4381
Chloride	113	860	73	230	73	16	Yes	2244	15	6352	1732
Calcium	25	NA	—	NA	—	NA	—	86.0	10.9	145.0	38.3
Magnesium	25	NA	—	NA	—	NA	—	28.0	1.2	48.9	14.9
Flow (cfs)	104	NA	—	NA	—	NA	—	5.2	0.0	100.4	10.9
E. coli (#/100 mL)	21	NA	—	126	NA	NA/Use Geomean	Yes	3163	164	24192	7331
Nutrients (mg/L)											
Ammonia*		—	—	—	—	—	—	—	—	—	—
—Acute	111	Calc.	1	Calc.	0	16	No	1.13	0.05	10.07	1.61
—Chronic	111	Calc.	14	Calc.	0	16	No	1.13	0.05	10.07	1.61
NO3-NO2	113	100	0	—	—	16	No	2.12	0.13	6.02	1.35
Metals (total, µg/L)											
As	30	340	0	16.7	0	6	No	<DL	<DL	<DL	<DL
Cd	11	Calc.	0	Calc.	0	3	No	<DL	<DL	<DL	<DL
Cr	8	Calc.	0	Calc.	0	3	No	<DL	<DL	<DL	<DL
Cu	9	Calc.	0	Calc.	3	3	Yes*	NC	<DL	33.89	NC
Pb	11	Calc.	0	Calc.	0	3	No	NC	<DL	<DL	NC
Hg	11	1.4	0		0	3	No	NC	<DL	<DL	NC
Ni	11	Calc.	0	Calc.	0	3	No	NC	<DL	<DL	NC
Se	22	20	0	5	8	5	Yes	6.08	<DL	13.44	2.01
Ag	11	Calc.	0	—	—	3	No	NC	<DL	1.92	NC
Zn	11	Calc.	0	Calc.	0	3	No	NC	<DL	54.89	NC
Organics (µg/L)											
Atrazine	—	—	—	—	—	—	—	—	—	—	—
—Atrazine	100	330	0	12	1	15	No	NC	<DL	14.52	NC
—Seasonal	25	330	0	12	1	5	No	NC	<DL	14.52	NC
Alachlor	40	760	0	76	0	7	No	NC	<DL	0.90	NC

Parameter	N (#)	NDEQ Impairment Determination (2002-2008)							Descriptive Statistics		
		Acute Criteria	# Exced-ing Acute Std	Chronic Criteria	# Exceed-ing Chronic Std	Impairment Basis: # samples that must exceed standard	NDEQ Identified as Impaired (Y/N)	Mean	Min	Max	St Dev
Metolachlor	100	390	0	100	0	15	No	NC	<DL	1.65	NC

Notes: N = number of samples; DL = detection limit; Calc. = standard calculated based on parameters such as hardness for metals and pH & temperature for ammonia; NR = not reported by NDEQ; NA = not applicable; NC = not calculated for purposes of this report due to large number of non-detects affecting mean and standard deviation.
* = inadequate number samples for determination of attainment.
For *E. coli*, attainment is based on comparison of the seasonal geometric mean to the standard.
Source: (Adapted from electronic data summary provided by NDEQ)

Table 5-2, NDEQ Samples Collected at State Fairgrounds in 2009

Date	NH3	NO3 / NO2	TKN	TN (calc)	TPO_4	TSS	*E. coli*	Cl	Ca	Mg	Na	As	Se
	mg/L						#/100 mL	mg/L				µg/L	
1/13/2009	0.93	3.4	0.52	4.82	0.54	<5	--	5024	168.5	62.4	3656	<5	11.9
2/3/2009	0.78	4.0	1.00	5.79	0.37	<5	--	5952	--	--	--	--	--
3/2/2009	0.66	3.1	0.86	4.66	0.29	<5	--	4924	--	--	--	--	--
4/6/2009	0.63	2.3	1.13	4.09	0.33	46	--	3202	108.5	38.8	2568	<5	6.0
5/4/2009	0.24	1.8	1.14	3.14	0.22	7.5	138	2029	--	--	--	--	--
5/11/2009	0.39	2.1	1.23	3.73	0.23	<5	285	4442	--	--	--	--	--
5/19/2009	0.19	2.2	0.73	3.15	0.51	6	517	3467	--	--	--	--	--
5/27/2009	0.44	0.5	2.11	3.05	0.55	136	> 24192	61	--	--	--	--	--
6/1/2009	0.36	1.6	1.97	3.98	0.37	6	> 24192	2404	--	--	--	--	--
6/9/2009	0.20	1.2	<0.5	1.44	0.65	8	689	2159	--	--	--	--	--
6/15/2009	0.52	1.6	1.48	3.58	0.18	<5	64	2893	--	--	--	--	--
6/22/2009	0.32	0.7	1.61	2.68	0.56	134	> 24192	627	--	--	--	--	--
6/29/2009	0.44	1.1	1.18	2.71	0.26	5	980	1507	--	--	--	--	--
7/6/2009	0.39	1.4	0.99	2.80	0.28	<5	488	2263	--	--	--	--	--
7/13/2009	0.37	2.5	0.64	3.50	0.35	<5	106	3718	--	--	--	--	--
7/20/2009	0.68	1.3	1.94	3.91	0.31	57	14136	562	34.9	7.67	388	<5	<5
7/27/2009	0.39	2.4	0.95	3.72	0.29	<5	56	3124	--	--	--	--	--
8/3/2009	0.45	2.5	0.76	3.71	0.26	<5	49	3628	--	--	--	--	--
8/10/2009	0.28	2.0	1.04	3.30	0.33	32	158	1836	--	--	--	--	--
8/17/2009	0.24	0.3	2.22	2.76	0.34	26.5	649	1038	--	--	--	--	--
8/24/2009	0.35	0.8	1.65	2.82	0.27	16	687	1214	--	--	--	--	--
8/31/2009	0.39	1.5	1.41	3.26	0.26	<5	150	2396	--	--	--	--	--
9/9/2009	0.34	1.1	1.22	2.65	0.27	8.5	192	1824	--	--	--	--	--
9/15/2009	0.19	1.9	0.68	2.76	0.30	<5	159	2675	--	--	--	--	--

Date	NH3	NO3 / NO2	TKN	TN (calc)	TPO4	TSS	*E. coli*	Cl	Ca	Mg	Na	As	Se
	mg/L						#/100 mL	mg/L				µg/L	
9/22/2009	0.46	2.5	1.21	4.15	0.27	<5	> 24192	3096	--	--	--	--	--
9/29/2009	0.44	3.0	0.59	4.06	0.22	<5	139	3966	--	--	--	--	--
10/5/2009	0.31	2.3	0.71	3.28	0.22	<5	--	2479	104.8	35.4	1788	<5	9.3
11/2/2009	0.17	0.6	1.24	1.96	0.18	9	--	695	--	--	--	--	--
12/7/2009	0.64	3.3	<0.5	3.93	0.20	14	--	4818	--	--	--	--	--
Average	0.42	1.9	1.19	3.43	0.33	18.8	619	2690	104.2	36.1	2100	<DL	7.4
Min	0.17	0.3	0.52	1.44	0.18	<DL	49	61	34.9	7.7	388	<DL	2.5
Max	0.93	4.0	2.22	5.79	0.65	136.0	24192	5952	168.5	62.4	3656	<DL	11.9
Count	29	29	27	29	29	29	22	29	4	4	4	4	4

Source: (Adapted from electronic data summary provided by NDEQ)

Table 5-3. In-stream Sampling Locations on Antelope Creek: *E. coli* Results

***E. coli* (#/100 mL)**										
Date	6/04/09 AM	6/04/09 PM	6/17/09	7/7/09	7/22/09	7/29/09	Geo. Mean	Min	Max	St. Dev
Holmes Lake (dog park)	346	358	582	1,096	978	2,094	738	346	2,094	659
A Street (Park)	1,096	732	690	844	1,160	24,200	1536	690	24,200	9512
27th Street (Zoo)	872	256	1,160	1,634	9,680	4,840	1645	256	9,680	3613
Vine Street (UNL)	226	658	358	1,734	358	1,374	597	226	1,734	623
Salt Creek (Fairground)	2,600	872	372	658	384	264	619	264	2,600	882
Geo. Mean	721	521	573	1,115	1,086	2,454				
Min	226	256	358	658	358	264				
Max	2,600	872	1,160	1,734	9,680	24,200				
St. Dev.	859	233	293	427	3645	9106				

Source: Mohlman et al. 2009

Table 5-4. In-stream Sampling Locations on Antelope Creek: Other Constituents

Location	*E. coli*	Surfactants	Ammonia	Total Copper	Chloride	Conductivity	Total Selenium
	#/100 mL	mg/L	mg/L	µg/L	mg/L	mg/L	µg/L
Holmes Lake (dog park)	738 (346-2094)	0.12 (0.02-0.45)	0.09 (<DL-0.20)	< DL	42 (23-55)	742 (652-877)	<DL
A Street (Park)	1,536 (690->24200)	0.10 (0.07-0.16)	0.07 (<DL-0.15)	17 (<DL-46)	40 (15-64)	610 (437-692)	<DL
27th Street (Zoo)	1,645 (256-9680)	0.10 (0.06-0.17)	0.09 (<DL-0.18)	14 (<DL-28)	39 (17-70)	616 (450-731)	<DL
Vine Street (UNL)	597 (226-1734)	0.06 (0.03-0.11)	0.09 (<DL-0.24)	13.9 (<DL-46)	151 (23-535)	895 (490-1272)	9.2 (2.5-16.7)
Salt Creek (Fairground)	619 (264-2600)	0.09 (0.04-0.30)	0.36 (0.13-0.60)	<DL	273 (14-532)	9483 (6050-11840)	6.0 (2.5-16.1)

Notes: Data presented include mean followed by (Minimum – Maximum)
Values below detection limits replaced with ½ of detection limit to calculate statistics
Summary includes six sampling events during the summer of 2009.
DL = detection limit
Grey-shaded cells are sample results suggest influence of groundwater.
Source: Mohlman et al. (2009)

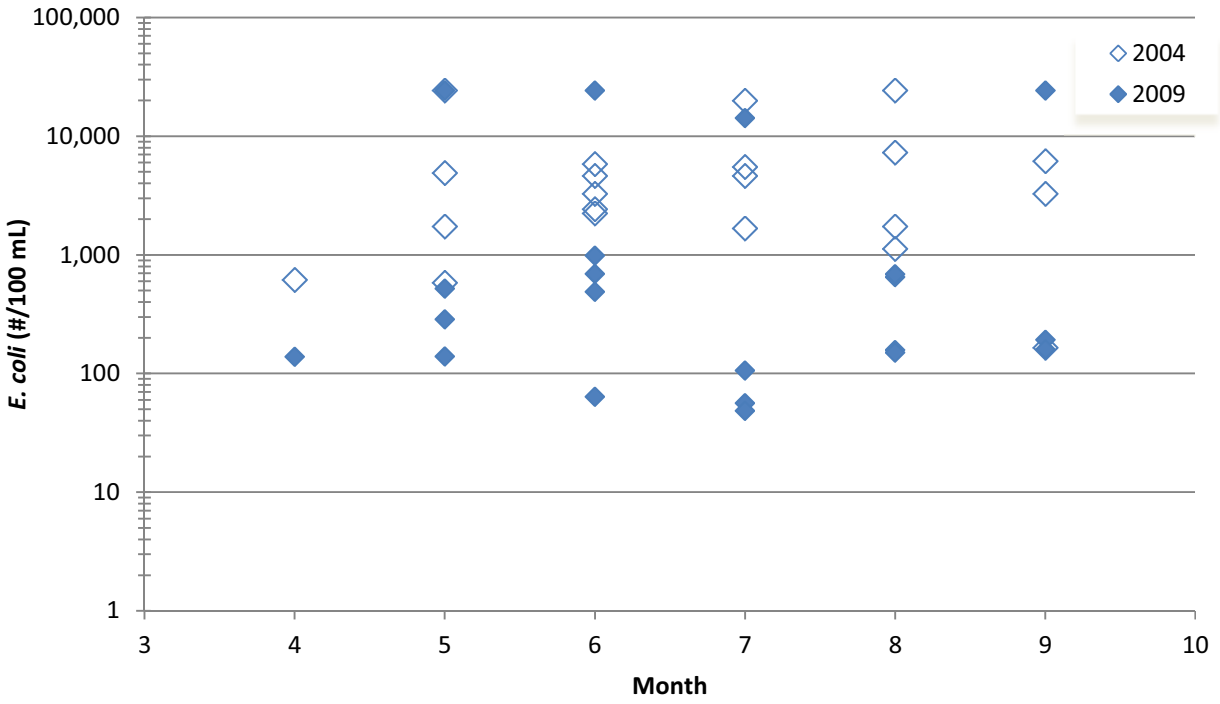
Table 5-5. Historic NDEQ Fecal Coliform Data at Antelope Creek near Children's Zoo

Collection Date	Fecal Coliform (#/100 mL)	Fecal Coliform Monthly Geometric Mean (#/100 mL
5/4/1999	50	253
5/11/1999	1020	--
5/18/1999	200	--
5/25/1999	290	--
5/27/1999	350	--
6/3/1999	670	545
6/8/1999	440	--
6/15/1999	123	--
6/22/1999	190	--
6/29/1999	7000	--
7/1/1999	240	98
7/8/1999	510	--
7/13/1999	22	--
7/20/1999	30	--
7/27/1999	110	--
8/3/1999	11	32
8/10/1999	25	--

Collection Date	Fecal Coliform (#/100 mL)	Fecal Coliform Monthly Geometric Mean (#/100 mL
8/17/1999	4	--
8/24/1999	26	--
8/31/1999	1190	--
9/1/1999	15	11
9/9/1999	260	--
9/14/1999	1	--
9/21/1999	47	--
9/29/1999	1	--
Geometric Mean	87	

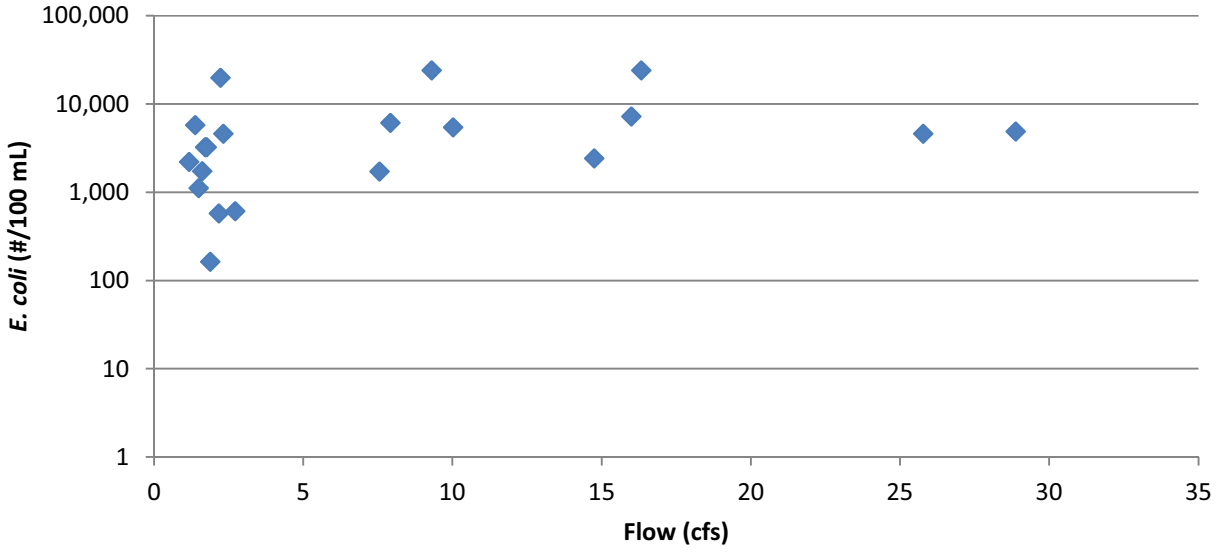
Source: NDEQ

Figure 5-2. Monthly *E. coli* at State Fairgrounds



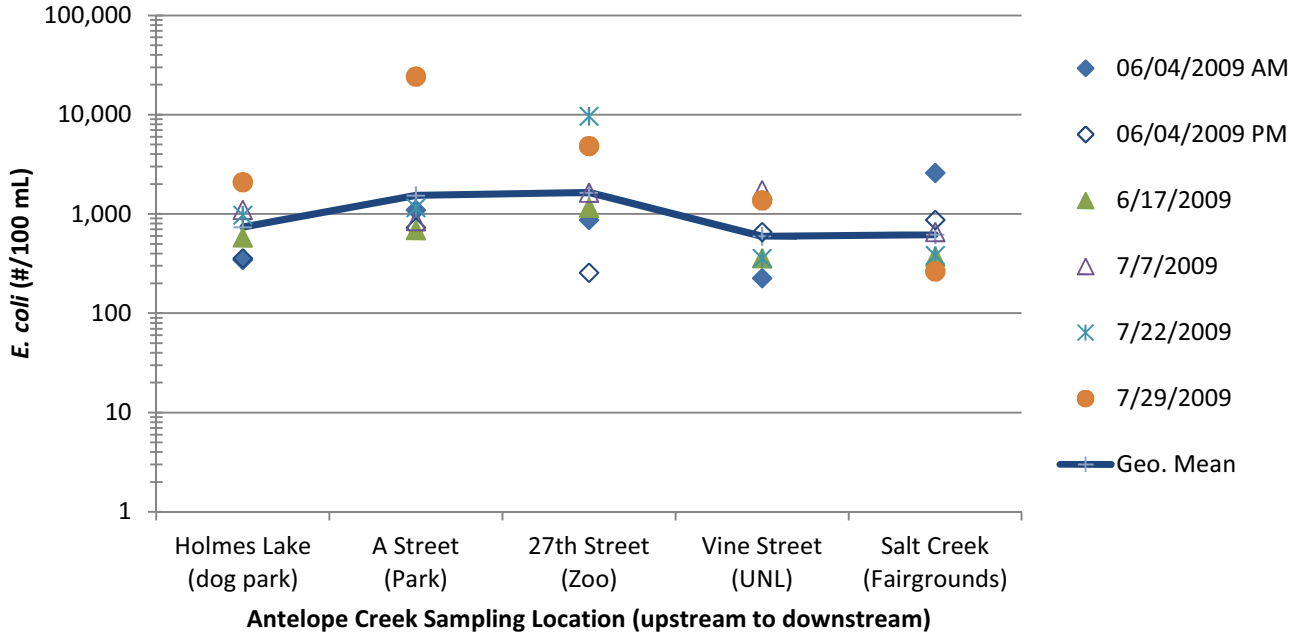
Source: NDEQ 2002-2009

Figure 5-3. *E. coli* vs. Flow Data at State Fairgrounds



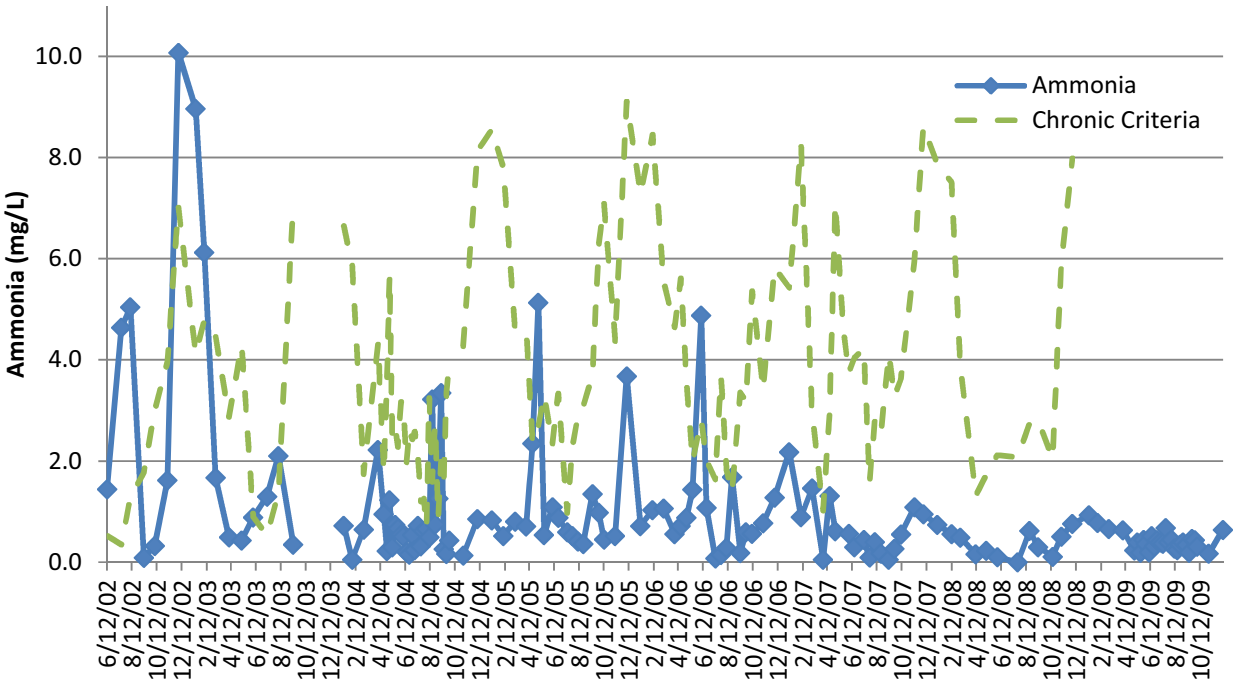
Source: NDEQ 2004

Figure 5-4. *E. coli* Sampling Results on Antelope Creek



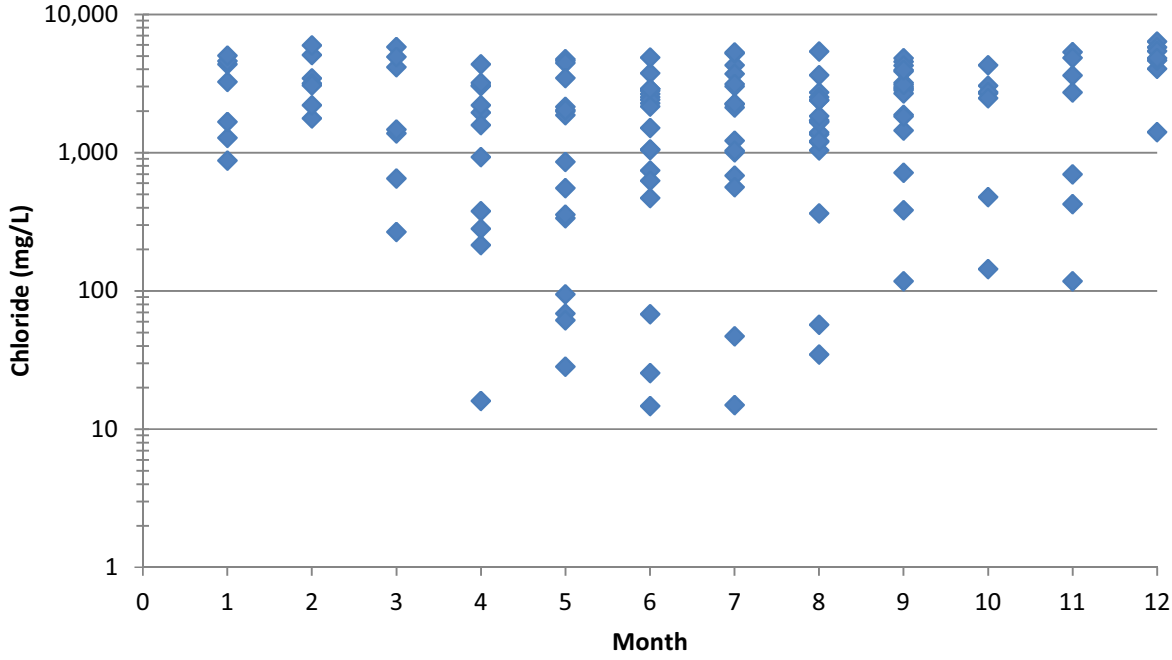
Source: (Mohlman et al., Summer 2009)

Figure 5-5. Total Ammonia at State Fairgrounds



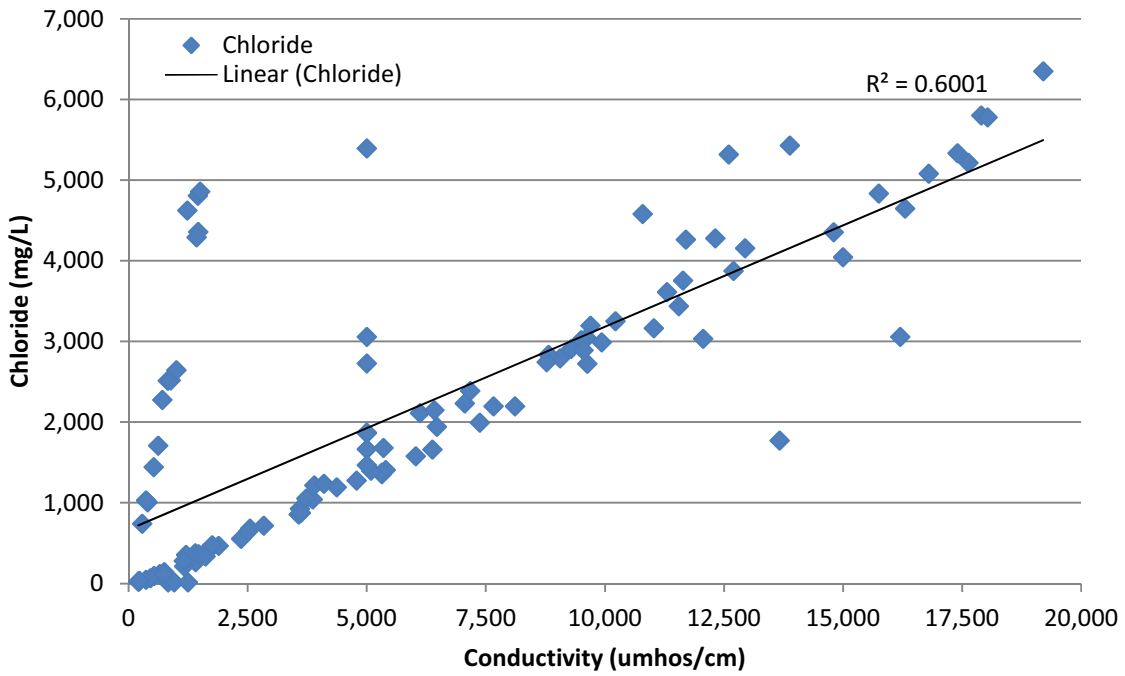
Note: field parameters needed to calculate chronic criteria not provided for 2009
Source: NDEQ 2002-2005

Figure 5-6. Chloride at State Fairgrounds



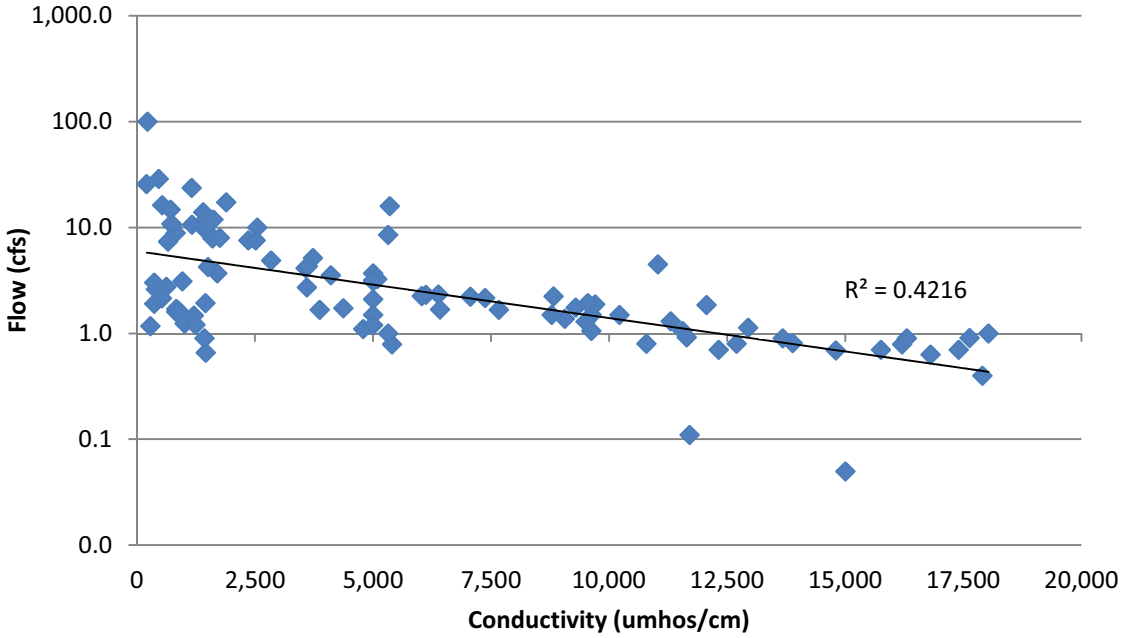
Source: NDEQ 2002-2009

Figure 5-7. Chloride vs. Conductivity at State Fairgrounds



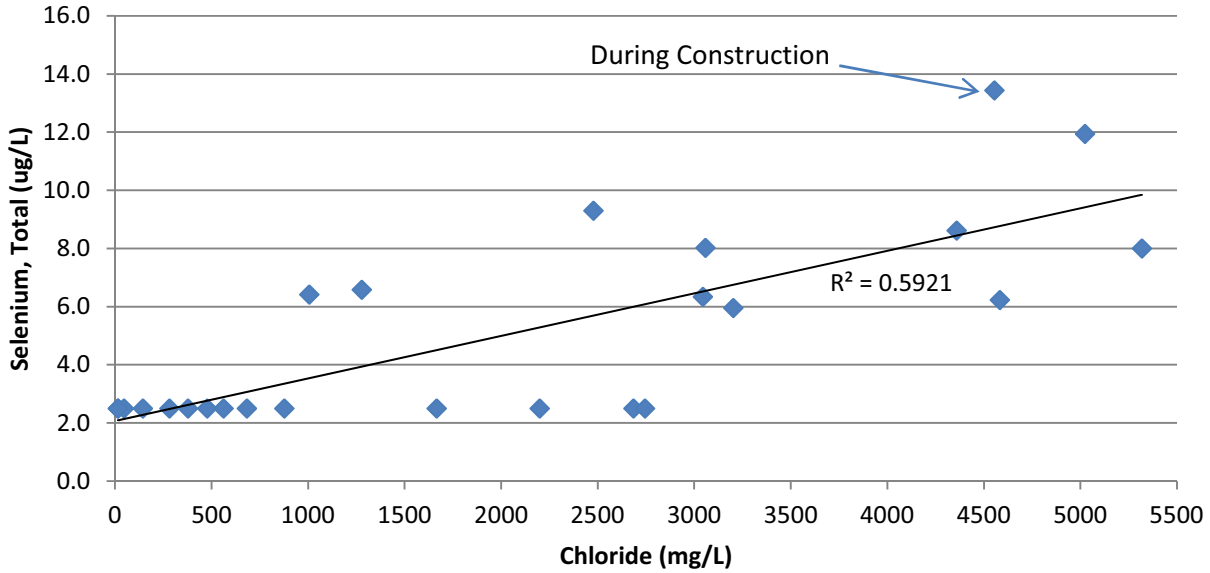
Source: NDEQ 2002-2008

Figure 5-8. Flow Versus Conductivity at State Fairgrounds



Source: NDEQ 2002-2008

Figure 5-9. Selenium vs. Chloride at State Fairgrounds



Note: Detection Limit = 5 ug/L; 1/2 of detection Limit represent non-detects in this plot.
Source: NDEQ 2002-2009

5.3.2 Dry Weather Storm Drainage System Screening

The City conducts a dry weather sampling program of its storm drainage system to identify illicit discharges in the City storm drain system. The program is implemented on a 5 year rotating basis for three groups of sample locations at these intervals: 1) 2000/2005/2010; 2) 2001/2006/2011; 3) 2002/2007/2012, 4) 2003/2008/2013; 5) 2004/2009/2014. For purposes of this Basin Plan, the most recent sampling results were reviewed for the 2009 sampling program, conducted by the University of Nebraska-Lincoln (Mohlman et al. 2009). From June to August 2009, 51 storm drain locations were monitored throughout the City. Of these sites, 23 were located in the Antelope Creek watershed. Key information and observations based on data contained in the Mohlman et al. (2009) report include:

- Twenty-three storm drain locations were sampled, either once in the morning or in the morning and afternoon. Sample duplicates were also collected for five of these sampling events. Ten of the locations had flowing water enabling sample collection.
- Out of the 23 storm drains, five resulted in at least one sample above the *E. coli* stream standard. Follow-up sampling in the afternoon at these five locations resulted in samples below stream standards in three of the cases. The remaining two sites (F-AC-52 and F-AC-55) had *E. coli* above stream standards in both the morning and the afternoon, but other indicators of illicit connections were not present. For example, surfactants were generally low in all samples. The F-AC-52 located had one sample at 2,408/100 mL in the morning and 198/100 mL in the afternoon. At F-AC-55, the morning and afternoon samples, as well as a duplicate sample were on the order of 200/100 mL. Both of these locations are in residential areas upstream of Holmes Lake, so they do not discharge directly to the Antelope Creek segment of interest for purposes of this Basin Plan.
- Only one storm drain (monitoring location (F-AC-39) within Antelope Creek watershed was identified for follow-up sampling during the 2008 monitoring cycle. In the 2009 data set, this site appeared to have normal ranges of constituents.

In summary, available data regarding dry weather discharges from the storm drainage system do not indicate that the storm drainage system is causing the elevated *E. coli* concentrations in Antelope Creek during dry weather conditions.

5.3.3 Stormwater Quality Monitoring

The City has conducted wet weather flow monitoring periodically in support of its NPDES permit at several locations in Lincoln since 1992; however, none of the monitored outfalls are located in the portion of the Antelope Creek Basin covered in this Basin Plan. Vegi (2008) completed a thesis at UNL that summarizes the available wet weather monitoring data for the City, with Table 5-6 providing a summary for several key constituents. The data set included sampling in three watersheds representing three different land use patterns. Site #2 watershed was residential (51 ha), Site #3 was commercial (145 ha), and Site #5 was industrial (20 ha). The analysis data set included wet weather stormwater quality data for 18 events collected as a part of NPDES permit requirement from 1992 to 1999, and additional data collected during 2006 and 2007 for nine rainfall events as part of the thesis study. Although this sampling is outside of the Antelope Creek Basin, it is still useful for calibration of models, as discussed in SECTION 6 - POLLUTION SOURCES AND CONTROL STRATEGIES.

Additionally, Table 5-7 provides data for several fecal indicator bacteria parameters that show elevated bacteria in wet weather flows, consistent with experiences throughout the United States. With regard to bacteria, Vegi (2008) reported a “first-flush” effect for bacteria loads at residential sites. *E. coli* loads from residential sites were found to be higher than commercial and industrial sites

Table 5-6. Comparison of City of Lincoln Wet Weather Event Mean Concentrations (EMCs) to National Urban Runoff Program (NURP) Data Sets

Water Quality Parameter	EMC (mg/L) Value Median (Med.) and Standard Deviation (SD)											
	Residential (Site #2)				Industrial/Mixed (Site #3)				Commercial (Site #5)			
	City Med.	City SD	NURP Med.	NURP SD	City EMC	City SD	NURP EMC	NURP SD	City EMC	City SD	NURP EMC	NURP SD
COD	38	40	**73**	36	43	39	60	38	49	68	57	26
BOD_5	7.4	6.4	10	4.3	7.1	7.9	7.8	5.4	7.4	8.6	9.3	3.2
TSS	115	120	101	167	96	125	78	198	**375**	489	69	148
TKN	1.20	0.74	**1.90**	1.22	**0.95**	0.45	0.50	0.84	0.91	0.68	1.18	0.72
TN	0.71	0.59	0.74	0.69	**1.10**	0.81	0.73	0.56	**0.95**	0.78	0.57	0.40
TDP	**0.76**	0.70	0.14	0.05	0.16	0.30	0.11	0.08	**0.40**	0.43	0.08	0.07
TP	**0.97**	0.81	0.38	0.23	**0.43**	0.44	0.26	0.25	**0.76**	0.42	0.20	0.23
Cu	0.04	0.04	0.03	0.07	0.04	0.04	0.02	0.09	**0.11**	0.09	0.03	0.05
Zn	0.05	0.06	**0.14**	0.15	0.10	0.10	**0.21**	0.14	0.16	0.19	0.23	0.19

Notes: BOLD: When Student t-test showed significant statistical difference between Site Mean Concentration and National Urban Runoff Program (NURP) data. (Source: Vegi 2008)

Table 5-7. Historic Wet Weather Bacteria Data for City of Lincoln (1993)

Date	Site	Storm	Fecal Coliform #/100 mL	Total Coliform #/100 mL	Fecal Streptococcus #/100 mL	Total Streptococcus #/100 mL
7/13	1	#1	1,300,000	4,900,000	4,900,000	4,900,000
7/13	1	repl.	11,000	70,000	490,000	790,000
8/29	1	#2	14,000	130,000	230,000	330,000
9/21	1	#3	1,700	7,000	28,000	28,000
5/30	2	#1	>24,000	>24,000	-0-	-0-
6/23	2	#2	>24,000	>24,000	>24000	>24000
8/13	2	#3	46,000	94,000	>24000	>24000
5/30	3	#1	790	1,300	-0-	-0-
6/23	3	#2	>24,000	>24,000	16,000	>24000
8/19	3	#3	1,400	11,000	17,000	33,000
5/30	4	#1	790	2,400	-0-	-0-
6/23	4	#2	3,500	3,500	16,000	>24000
8/19	4	#3	1,300	3,300	800	23,000
5/30	5	#1	-0-	-0-	-0-	-0-
6/17	5	#2	>24,000	>24000	-0-	-0-
8/19	5	#3	2,000	33,000	130,000	230,000
9/13	5	#4	23,000	23,000	110,000	110,000

(Source: Vegi 2008)

5.3.4 Summary and Conclusions for Historic Monitoring Data

Review of historic data sets for Antelope Creek results in the following conclusions:

Picture 12: EA recorded stream discharge during a wet sampling event in 2011

- Historic data available for Antelope Creek suggest nonpoint sources of *E. coli* during dry weather conditions; however, conclusions regarding sources of *E. coli* based on this data set are limited since the majority of data collected are limited to one location near the State Fair Grounds (Antelope Creek confluence with Salt Creek). Limited monitoring data collected during the summer of 2009 at several additional locations show that *E. coli* was well above stream standards throughout the stream reach during the recreational season. Although there are not significant differences in *E. coli* sample results among monitoring locations, the geometric mean concentrations at A Street (Park) and 27th Street (Zoo) are more than twice the geometric means calculated for other sampling locations. The sample result variation among these sites is also greater than at the other locations.
- Elevated ammonia concentrations appear to be limited primarily to the 2002 time period. Monitoring since that time shows that the stream meets ammonia standards, without additional controls being necessary.
- Chloride, conductivity and selenium are all elevated above stream standards on Antelope Creek. Based on limited samples collected during 2009, these issues appear to be concentrated near the lower portion of the segment near Salt Creek. Groundwater inflows in this reach are expected to be the source of elevated

concentrations of these constituents. These constituents generally appear to be higher during low flow conditions, consistent with groundwater-dominated conditions. Given the guidelines described by NDEQ (2009) regarding natural sources of pollution, these constituents do not appear to warrant further controls since they are likely naturally occurring.

- The copper data set collected by NDEQ is limited to nine samples at the State Fairgrounds location. When supplemented by the sampling gathered by Mohlman et al. (2009), the total sample size at the State Fairgrounds increases to 14 events; however, lack of hardness data limits use of these data to assess attainment of the standard.
- Wet weather conditions on Antelope Creek have not been explicitly monitored. Historic NPDES monitoring in other portions of Lincoln and wet weather monitoring in other parts of the country indicate that urban stormwater would be a source of bacteria loading to streams.
- Since collection of these historic data, significant changes to the stream channel have been implemented due to the Antelope Valley Project. These changes should be considered when comparing historic and recent water quality data.

5.4. 2010-2011 Water Quality Monitoring Activities

In September 2010, the City and LPSNRD sponsored a water quality sampling program for Antelope Creek below Holmes Lake to the confluence with Salt Creek, as documented in “Work Plan: Water Quality Monitoring for Antelope Creek Watershed Basin Management Plan, City of Lincoln” (EA 2010). The purpose of the water quality sampling effort was to investigate, document, and verify potential *E. coli* and ammonia sources in the watershed, provide information needed to assess the current water quality conditions relative to the TMDL, and provide information needed to assess approaches to establishing necessary BMPs to meet the TMDL. For more information on TMDL information relating to Antelope Creek, see SECTION 4 – TMDL ASSESSMENT.

5.4.1 2010-11 Sampling Program Overview

During 2010-2011, EA conducted in-stream sampling for four dry weather and three wet weather synoptic sampling events for approximately 11 locations on the stream between September 2010 and August 2011 (Tables 5-8 and 5-9 and Figure 5-10). Dry weather sampling events were conducted following seven preceding days with no significant rainfall. Wet weather sampling events were conducted within 24 hours of a minimum of 0.5 inch rainfall. At three of these locations (AC-1, AC-4 and AC-9), 5-week sequences of samples for fecal indicator bacteria were also collected to support calculation of geometric mean concentrations for *E. coli*. In-stream sediment samples were also collected at targeted locations in the stream for two of the sampling events, as identified in Table 5-8. Outfalls (tributaries) to the stream were sampled for two events under dry weather conditions and investigated for signs of dry-weather pollution, as summarized in Table 5-10.

Table 5-8. Sampling Dates

Date	Sample Description
9/30/2010	Dry weather sampling (included tributaries)
11/12/2010	Wet weather sampling
1/17/2011	Sediment sampling
5/10/11	Dry weather and sediment sampling
5/20/11	Wet weather sampling
7/1/2011	Dry weather sampling (included tributaries)
7/22/2011	Dry weather sampling
8/8/2011	Wet weather sampling

Source: EA Field Survey 2010-2011

Table 5-9. In-stream Sampling Locations

Location ID	Location	Comment
AC-1	Holmes Lake Outfall	Initial water source for AC study reach
AC-11	Downstream of 56th and Van Dorm	Added May 10, 2011
AC-10	Downstream of 48th and Normal	Added May 10, 2011
AC-2	South Street Bridge	Downstream of AC outfalls
AC-3	"A" Street Bridge	Upstream of the Zoo
AC-4	Upstream 27th Street below sandstone outcrop	Downstream of the Zoo
AC-5	"J" Street Bridge	Flowing water above weir pool
AC-6	Union Plaza	Monitor water quality in Union Plaza
AC-7	Vine Street downstream of tunnel return	Monitor tunnel return water
AC-8	Devaney Bridge at Big "X"	Downstream of large outfalls
AC-9	NDEQ sampling location—SLP2ANTLP104	Confirmation and comparison area for TMDL data

Source: EA Sampling Plan 2010

Table 5-10. Tributary Sampling Locations

Location ID	Location	Outfall Dimension	EA August 2010 Field Comment
Trib-1	East of 48th and Normal	60 inch – round concrete	Flows present, source unknown; source believed to be groundwater infiltration; dry on 7/1/2011.
Trib-2	East of 48th and Normal	80x60 inch – concrete box culvert	Flows present, appear to be diffuse groundwater contributions; dry on 7/1/2011
Trib-3	Antelope Creek Rd. at Eden Park	80x60 inch – concrete box culvert	Flows originate from Bryan LGH Medical Center area; source believed to be air-conditioning condensate
Trib-4	Under 40th Street Bridge	36 inch – round concrete	Flows originate from Lincoln High School vicinity; source believed to be air-conditioning condensate
Trib-5	South of 38th Street	6 inch-vitrified clay	Dry on 9/30/2010 and 7/1/2011
Trib-6	SW of Normal and Sumner	48 inch – round concrete	Dry on 9/30/2010 and 7/1/2011
Trib-7	33rd and Capital Parkway	84x60 inch – concrete box culvert	Flows originate from Tabitha Health Care Services area; source believed to be air-conditioning condensate
Trib-8	South of A Street Bridge	120x60 inch – concrete box culvert	Flows originate between 28th and Arlington, and Jefferson and Arlington (water service line break); Repaired in May of 2011, flow greatly reduced during the July 2011 sampling
Trib-9	Children's Zoo upstream of sandstone outcrop	6 inch – vitrified clay pipe	Dry on 9/30/2010 and 7/1/2011
Trib-10	North of Vine Street Bridge	48x84 inch – concrete box culvert	Flows present, source unknown

Location ID	Location	Outfall Dimension	EA August 2010 Field Comment
Trib-11	17th and Y Street	42 inch – round concrete	Flow originates from Able Dormitory on UNL Campus air-conditioning unit
Trib-12	17th and Y Street	96x126 inch – concrete box culvert	Flows present, source unknown
Trib-13	North of Y Street Bridge	72-inch – round concrete	Flows present, source unknown
Trib-14	Between Big "X" and Y Street	60x72 inch concrete box culvert	50% of flow from near Jorgensen Hall on UNL campus, 50% of flow from surface drains near The Village Dormitories on UNL Campus; both sources are believed to be air-conditioning condensate
Trib-15	South of Big "X"	72 inch – round concrete	Flows present, source unknown
Trib-16	South of Big "X"	60 inch – round concrete	Some flow from Memorial Stadium
Trib-17	Devaney Bridge on Military Rd.	24 inch – round concrete	Flows present, source unknown; dry on 9/30/2010

Source: EA Sampling Plan 2010

Table 5-11. Water Quality Sampling Parameters

Water Quality Parameter Monitored	Rationale/Comment
Field Parameters: pH, conductivity, temperature, and dissolved oxygen (DO)	All sampling events for basic water quality conditions
E. coli	2007 TMDL; primary constituent of interest
Ammonia	2007 TMDL; removed from NDEQ 2010 303(d) list
Selenium	NDEQ 2008 & 2010 303(d) lists; Discontinued prior to 5/10/2011 sampling.
Copper, Dissolved (with hardness data)	NDEQ 2008 & 2010 303(d) lists; Discontinued prior to 5/10/2011 sampling.
Dissolved Organic Carbon	Added beginning 5/10/2011 to evaluate potential relationship with *E. coli.*
Total Phosphorus	Added beginning 5/10/2011 to evaluate potential relationship with *E. coli*.

Source: EA Sampling Plan 2010

The sampling plan was designed to help fill the following data gaps regarding *E. coli* sources on Antelope Creek:

- Provide better spatial resolution (more locations) of *E. coli* concentrations along Antelope Creek to identify trends and locations where significant *E. coli* loads are entering the creek.
- Determine whether dry-weather discharges from stormwater outfalls appear to be sources of *E. coli*, potentially suggesting illicit connections to the storm drainage system.
- Explore whether in-stream sediment appears to be a significant ongoing internal source of *E. coli* in the stream (*e.g.,* serving as a reservoir of *E. coli* that could be resuspended/remobilized).
- Conduct targeted sampling at locations suspected as potential *E. coli* sources (*e.g.,* the Children's Zoo, Holmes Lake, bridge crossings inhabited by birds, etc.).
- Complete field observations to help identify potential sources of *E. coli* such as pigeons at bridge crossings, starlings feeding on insects in exposed stream sediment at the labyrinth weir, and waterfowl in adjacent open space areas (*e.g.,* lawns, golf course).

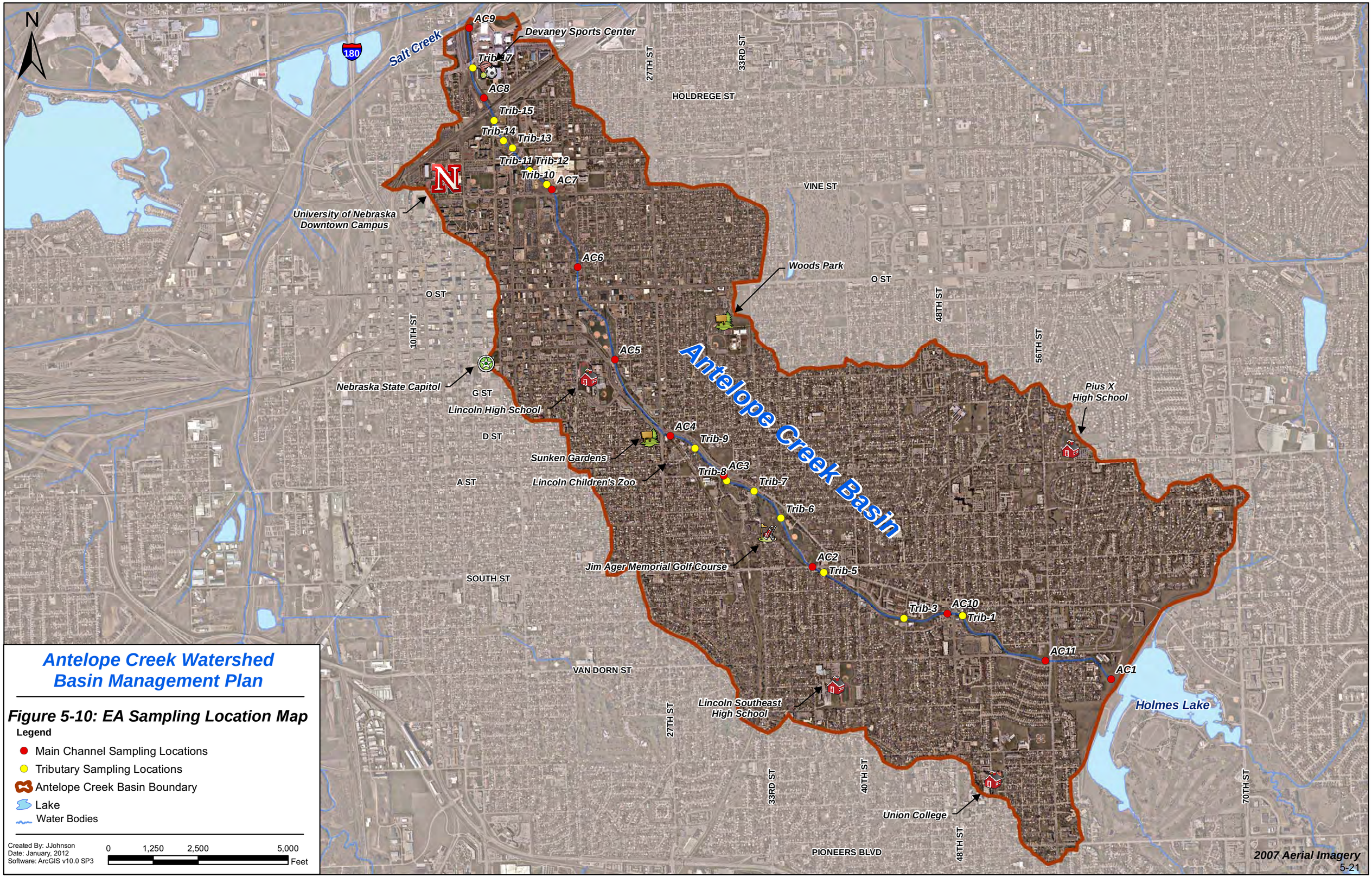
Findings from this sampling program follow for in-stream, outfall and sediment sampling, along with a narrative summary of animals observed along the creek.

5.4.2 In-Stream Sampling Results

No sample location "stands out" as being a particularly problematic source of E. coli.

Dry weather and wet weather sampling results are summarized in Tables 5-12 and 5-13, respectively, Figures 5-11 through 5-17 depict these data graphically (EA Field Data, 2010/11). (Tables and figures are provided at the end of this subsection.) Key observations include:

- Dry weather sample results vary by an order of magnitude or more at most sample locations for the four dry weather sample results. Wet weather sample results are typically an additional order of magnitude higher (*e.g.,* 10^4) and reach the upper quantitation limit of 24,200/100 mL for several samples. These results are within ranges observed in other urban communities.
- *E. coli* exceeds stream standards (126/100 mL) and the TMDL limit (113/100 mL), at all in-stream sampling locations during wet weather events, excluding the sample location below Holmes Lake (AC-1). During dry weather events, *E. coli* also exceeds standards and TMDL limits at most locations excluding the location below Holmes Lake (AC-1). Other than AC-1, rainfall events have much higher *E. coli* than dry weather events, as would be expected. Given these results, the Holmes Lake discharge does not appear to be a significant source of *E. coli* (Table 5-14 and Figure 5-12).
- For the three sites with weekly *E. coli* samples enabling calculation of geometric mean concentrations, the data show in-stream concentrations meeting stream standards below Holmes Lake (AC-1), and being elevated well above the standard for AC-4 (below zoo) and AC-9 (Fairgrounds/Salt Creek) during the recreational season. Geometric mean concentrations for the non-recreational season months (*e.g.,* Nov-Dec 2010, Sept-Oct 2010) tend to be lower, with the November-December geometric mean concentrations attaining the stream standard at all three locations.
- Dry weather *E. coli* concentrations in the stream appear to become elevated in the vicinity of the upper end of the park area upstream of the zoo and generally remain elevated for most of the reach of the stream (Figure 5-11). Although variability in the data set does not enable firm conclusions regarding statistically significant differences between sampling locations, visual inspection of the data suggest that AC-2 to AC-6 may be somewhat more elevated than the lower stream reaches for some of the sampling events (although not necessarily at a statistically significant level). This finding would be consistent with increased wildlife in green space along the creek in this area.
- Wet weather sample results generally increase in an upstream to downstream direction, which would be consistent with storm volumes being added to the creek as it flows toward Salt Creek. No sample location "stands out" as being a particularly problematic source of *E. coli*.
- At the Salt Creek (NDEQ/AC-9) location, which is the only site with a substantial number of samples enabling assessment of changes over time, data collected during 2004, 2009 and 2010/2011 do not suggest that *E. coli* conditions are worsening or improving over time. Visual inspection of the data suggests that *E. coli* concentrations were lower in the 2009 data set relative to the 2004 data set; however, the 2010-2011 data set includes a range of values representative of both 2004 and 2009. As a result, no clear trend over time is present at this sampling location.



Antelope Creek Watershed Basin Management Plan

Figure 5-10: EA Sampling Location Map

Legend

- Main Channel Sampling Locations
- Tributary Sampling Locations
- Antelope Creek Basin Boundary
- Lake
- Water Bodies

Created By: JJohnson
Date: January, 2012
Software: ArcGIS v10.0 SP3

0 1,250 2,500 5,000 Feet

Table 5-12. Antelope Creek Dry Weather Sample Results

Sample Identification	Time Sample Collected				pH				Dissolved Oxygen, mg/L			
Date	9/30/2010	5/10/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011
Trib 1	0834	--	dry	--	8.3	--	--	--	8.56	--	--	--
Trib 2	0845	--	14:45	--	8.24	--	8.37	--	8.53	--	9.51	--
Trib 3	0912	--	14:15	--	8.22	--	8.15	--	7.3	--	8.67	--
Trib 4	0930	--	14:00	--	8.26	--	8.28	--	8.14	--	9.38	--
Trib 6	--	--	--	--	--	--	--	--	--	--	--	--
Trib 7	1046	--	13:15	--	8.33	--	8.08	--	9.1	--	9.34	--
Trib 8	--	1637	12:52	--	--	--	8.50	--	--	--	10.99	--
Trib 10	1350	--	10:15	--	NR	--	8.20	--	NR	--	8.05	--
Trib 11	1412	--	9:40	--	8.24	--	8.26	--	8.14	--	8.80	--
Trib 12	1423	--	9:50	--	8.19	--	8.19	--	8.83	--	9.43	--
Trib 13	1453	--	9:19	--	7.79	--	7.66	--	7.93	--	9.59	--
Trib 14	1515	--	9:05	--	8.06	--	7.08	--	8.81	--	9.25	--
Trib 15	1543	--	8:38	--	8.18	--	8.73	--	8.36	--	8.65	--
Trib 16	1600	--	8:33	--	8.4	--	8.37	--	8.38	--	10.17	--
Trib 17	--	--	7:55	--	--	--	8.13	--	--	--	10.85	--
Trib 18*	1510	--	--	--	8.06	--	8.06	--	8.81	--	--	--
Filed Blank	1700	--	--	--	Blank	--	Blank	--	Blank	--	Blank	--
Trib 10B Rd	1200	--	--	--	8.06	--	8.06	--	9.25	--	9.25	--
AC 1	0748	14:09	9:45	9:45	7.78	7.29	9.16	9.14	8.10	8.175	8.43	4.23
AC11	--	18:15	10:05	10:05	--	8.12	9.1	8.52	--	8.19	8.26	3.89
AC 10	--	18:00	9:30	9:30	--	8.47	9.13	8.65	--	10.10	11.68	5.04
AC 2	1008	17:34	9:15	9:15	8.4	8.10	9.07	8.11	9.50	6.68	8.89	4.37
AC 3	1134	17:13	9:02	9:02	8.46	8.42	9.13	8.12	12.16	9.25	10.37	5.4
AC 4	1152	17:00	8:50	8:50	8.52	9.10	9.2	8	11.89	10.98	9.9	4.73
AC 5	1234	16:27	8:30	8:30	8.74	9.12	9.21	8.02	12.62	8.90	9.83	4.8
AC 6	1258	16:15	8:13	8:13	8.17	--	8.74	7.72	12.65	--	9.02	3.69
AC 7	1333	16:00	7:55	7:55	7.5	8.56	8.92	7.6	10.00	---	9.11	4.56
AC 8	1624	19:18	7:40	7:40	7.59	8.72	8.7	7.42	12.00	12.83	8.58	3.53
AC 9	1635	19:30	7:20	7:20	7.48	7.56	8.16	7.13	12.87	15.97	7.59	4.7
Duplicate*	1258	16:35	8:30	8:30	8.17	9.12	--	8.02	12.65	8.90	--	4.8

Sample Identification	Temperature, °C				Conductivity				Hardness, mg/L		Selenium, mg/L	
	9/30/2010	5/10/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011				
Date	17.1	--	--	--	413	--	--	--	9/30/2010	5/10/2011	9/30/2010	5/10/2011
Trib 1	18.4	--	18.9	--	463	--	686	--	236	--	< 0.150	--
Trib 2	18	--	21.9	--	902	--	1583	--	276	--	< 0.150	--
Trib 3	18.1	--	20.1	--	991	--	1179	--	356	--	< 0.150	--
Trib 4	--	--	--	--	--	--	--	--	452	--	< 0.150	--
Trib 6	17	--	25.1	--	504	--	701	--	--	--	--	--
Trib 7	--	--	19.8	--	--	--	627	--	192	216	< 0.150	< 0.0050
Trib 8	NR	--	17.8	--	NR	--	795	--	--	--	--	--
Trib 10	20.5	--	20.5	--	1176	--	1142	--	148	--	< 0.150	--
Trib 11	16.8	--	18.4	--	1286	--	1453	--	268	--	< 0.150	--
Trib 12	18.9	--	18.3	--	604	--	737	--	512	--	< 0.150	--
Trib 13	18.6	--	19.9	--	636	--	1414	--	216	--	< 0.150	--
Trib 14	18.6	--	19.5	--	1015	--	892	--	235	--	< 0.150	--
Trib 15	18.1	--	18.3	--	1190	--	1640	--	468	--	< 0.150	--
Trib 16	--	--	15.2	--	--	--	1084	--	623	--	< 0.150	--
Trib 18*	18.6	--	--	--	636	--	--	--	216	--	< 0.150	--
Field Blank	Blank	--	Blank	--	Blank	--	Blank	--	< 5.00	--	< 0.150	--
Trib 10B Rd	16.5	--	16.5	--	526	--	--	--	267	--	< 0.150	--
AC 1	18.80	22.9	27.02	28.9	343.0	595	351	289	114	304	< 0.150	< 0.0050
AC11	--	26.7	27.3	23	--	734	358	328	--	--	--	--
AC10	--	21.0	27.7	27.3	--	650	359	350	--	--	--	--
AC 2	17.90	27.4	28.65	26.7	371.0	902	365	446	141	116	< 0.150	< 0.0050
AC 3	20.00	30.0	28.86	26.3	363.0	830	368	463	141	100	< 0.150	< 0.0050
AC 4	19.90	31.7	28.67	25.9	364.0	642	365	486	145	88	< 0.150	< 0.0050
AC 5	21.40	32.9	27.49	26.1	342.0	783	370	480	137	80	< 0.150	< 0.0050
AC 6	19.40	--	26.31	27.1	308.0	--	380	469	141	52	< 0.150	< 0.0050
AC 7	18.70	23.8	25.67	27.1	380.0	824	386	501	165	64	< 0.150	< 0.0050
AC 8	21.30	23.6	24.23	26	4800.0	1006	1392	610	270	108	< 0.150	< 0.0050
AC 9	21.40	22.7	23.87	23.7	4686.0	---	1278	7510	263	104	< 0.150	< 0.0050
Duplicate*	19.4	32.9	--	26.1	308	783	--	480	137	--	--	--

Sample Identification	Ammonia, mg/L				Total Phosphorus, mg/L		Total Organic Carbon, mg/L		Copper, mg/L		E. coli, #/100ml			
Date	9/30/2010	5/10/2011	7/1/2011	7/22/2011	7/1/2011	7/22/2011	7/1/2011	7/22/2011	9/30/2010	5/10/2011	9/30/2010	5/10/2011	7/1/2011	7/22/2011
Trib 1	< 0.500	--		--	--	--	--	--	< 0.0200	--	140	--	--	--
Trib 2	< 0.500	--	<0.500	--	0.16	--	5.56	--	< 0.0200	--	<1	--	--	'--
Trib 3	< 0.500	--	<0.500	--	1.38	--	9.03	--	0.0624	--	1530	--	110	--
Trib 4	< 0.500	--	<0.500	--	0.189	--	6.34	--	< 0.0200	--	510	--	990	-
Trib 6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trib 7	< 0.450	<0.500	<0.500	--	--	--	--	--	< 0.0200	< 0.0050	<1	60	670	--
Trib 8	--	--	<0.450	--	0.283	--	5.96	--	--	--	--	--	<1	--
Trib 10	< 0.450	--	<0.500	--	0.257	--	5.73	--	0.0202	--	1860	--	220	--
Trib 11	< 0.500	--	<0.500	--	0.256	--	8.13	--	0.0263	--	<1	--	100	--
Trib 12	< 0.500	--	<0.500	--	0.479	--	3.34	--	< 0.0200	--	60	--	10	--
Trib 13	< 0.500	--	<0.500	--	0.682	--	4.53	--	< 0.0200	--	400	--	960	--
Trib 14	< 0.450	--	<0.500	--	0.299	--	3.48	--	0.0286	--	<1	--	<1	--
Trib 15	< 0.500	--	<0.450	--	0.368	--	3.72	--	< 0.0200	--	60	--	60	--
Trib 16	< 0.500	--	<0.500	--	0.264	--	4.46	--	< 0.0200	--	1610	--	290	--
Trib 18*	< 0.500	--	<0.450	--	0.332	--	4.68	--	0.0291	--	<1	--	600	--
Field Blank	< 0.500	--	--	--	0.188	--	2.61	--	< 0.0200	--	<1	--	10	--
Trib 10B Rd	< 0.500	--	--	--	0.026	--	4.41	--	0.0474	--	<1	--	140	--
AC 1	0.722	< 0.500	<0.500	<0.500	0.163	0.147	8.6	8.07	< 0.0200	< 0.0050	10	20	80	<1
AC11	--	<0.450	<0.500	<0.450	0.168	0.163	8.32	8.14	--	--	--	220	70	170
AC10	--	<0.450	<0.500	<0.500	0.178	0.149	7.44	8.01	--	--	--	<1	80	530
AC 2	< 0.500	< 0.500	<0.500	<0.500	0.187	0.183	8.4	8.25	< 0.0200	< 0.0050	910	210	290	2150
AC 3	< 0.500	< 0.500	<0.500	<0.500	0.18	0.185	8.19	8.33	< 0.0200	< 0.0050	1220	320	250	3660
AC 4	< 0.450	< 0.450	<0.500	<0.500	0.162	0.198	7.63	8.37	< 0.0200	0.00526	890	350	330	9210
AC 5	< 0.500	< 0.500	<0.500	<0.450	0.171	0.193	7.25	8.72	< 0.0200	< 0.0050	390	190	800	3880
AC 6	< 0.500	0.506	<0.450	<0.500	0.193	0.339	7.15	9.84	< 0.0200	< 0.0050	230	--	670	5800
AC 7	< 0.500	< 0.500	<0.500	<0.500	0.177	0.364	7.00	10.8	< 0.0200	< 0.0050	190	10	940	1860
AC 8	0.506	0.525	<0.500	<0.500	0.177	0.309	6.93	10.3	< 0.0200	< 0.0050	380	190	470	3260
AC 9	< 0.500	0.513	<0.500	0.637	0.193	0.265	5.26	2.57	< 0.0200	< 0.0050	250	150	740	5180
Duplicate*	<0.450	--	<0.500	<0.450	0.185	0.166	6.43	7.48	--	--	140	110	530	5800

*Notes Regarding Duplicates
30 Sept 2010 Trib 18 is a duplicate of Trib 14
30 Sept 2010 Duplicate provided for AC 6
10 May 2011 Duplicate provided for AC 5
1 July 2011 Duplicate provided for AC 6
22 July 2011 Duplicate provided for AC 5

Table 5-13. Antelope Creek Wet Weather Sample Results

Sample Identification	Time Sample Collected			pH			Dissolved Oxygen, mg/L			Temperature, °C			Conductivity		
Date	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011
AC 1	1305	8:20	10:30	6.63	8.49	8.99	9.86	9.90	9.05	8.6	16.6	27.7	668	509	279
AC 11	--	8:48	10:50	--	8.36	8.84	--	9.56	9.22	--	16.4	27.3	--	487	887
AC 10	--	8:58	11:10	--	8.37	8.83	--	9.61	10.65	--	16.3	28.0	--	418	307
AC 2	1227	8:27	11:30	6.81	8.27	8.34	10.60	9.25	8.87	7.2	16.2	28.2	317	464	462
AC 3	1210	9:36	11:45	6.76	8.29	8.50	11.65	9.82	11.23	7.2	16.2	28.7	275	446	465
AC 4	1148	9:51	12:05	6.58	8.30	8.48	12.10	9.77	11.10	7.0	16.3	28.7	261	449	471
AC 5	1123	10:10	12:25	6.67	8.32	8.54	12.50	9.80	11.29	7.1	16.5	29.0	210	442	464
AC 6	1050	10:35	12:40	6.75	7.74	7.68	11.48	9.12	8.19	6.8	17.4	27.8	160	188	235
AC 7	1030	10:55	12:50	6.78	8.10	7.88	11.84	9.49	10.16	7.6	16.5	27.2	186	368	258
AC 8	955	11:12	13:05	6.91	7.97	7.89	11.00	9.15	10.40	7.9	16.5	27.8	1760	353	390
AC 9	925	11:22	13:30	7.12	7.73	7.48	11.78	7.61	12.40	7.8	16.1	27.9	1516	306	2746
Duplicate*	1055	11:05	11:10	--	8.10	8.83	--	9.49	10.65	--	16.5	28.0	--	368	307

Sample Identification	Ammonia, mg/L			Hardness, mg/L	Selenium, mg/L	Copper, mg/L	Phosphorus-Total, mg/L		Total Organic Carbon, mg/L		E. coli, #/100ml		
Date	11/12/2010	5/20/2011	8/8/2011	11/12/2010	11/12/2010	11/12/2010	5/20/2011	8/8/2011	5/20/2011	8/8/2011	11/12/2010	5/20/2011	8/8/2011
AC 1	< 0.500	<0.50	<0.50	304	< 0.0050	< 0.0050	<0.100	0.184	6.10	8.13	230	80	80
AC 11	--	<0.50	<0.45	--	--	--	<0.100	0.192	13.40	7.94	--	2490	630
AC 10	--	<0.50	<0.50	--	--	--	0.111	0.174	8.86	7.41	--	10120	840
AC 2	< 0.500	<0.50	<0.50	116	< 0.0050	< 0.0050	0.106	0.816	7.47	7.96	6020	4110	1360
AC 3	< 0.500	<0.45	<0.50	100	< 0.0050	< 0.0050	0.113	0.709	7.74	8.18	13000	9810	1280
AC 4	< 0.450	<0.50	<0.50	88	< 0.0050	0.0053	0.114	0.742	7.73	8.07	13000	10470	1560
AC 5	< 0.500	<0.50	<0.45	80	< 0.0050	< 0.0050	0.112	0.655	15.40	8.13	7560	14140	4620
AC 6	0.506	<0.50	<0.45	52	< 0.0050	< 0.0050	1.454	0.200	7.47	9.45	24200	260	17330
AC 7	< 0.500	<0.50	<0.45	64	< 0.0050	< 0.0050	0.163	0.211	8.24	8.72	15540	8670	15540
AC 8	0.525	<0.50	<0.50	108	< 0.0050	< 0.0050	0.192	0.211	8.49	7.4	13000	15540	17330
AC 9	0.513	<0.45	<0.45	104	< 0.0050	< 0.0050	0.208	0.177	6.83	3.91	24200	19870	8170
Duplicate*	<0.500	<0.50	<0.45	56	< 0.0050	0.0095	0.152	0.161	7.51	7.78	24200	17330	890

*Notes for Duplicates:

12 Nov 2010 Duplicate provided for AC 6

20 May 2011 Duplicate provided for AC 5

8 Aug 2011 Duplicate provided for AC 10

- Evaluation of seasonal trends was not an objective of the sampling program, since the stream standard applies during the summer time period (May – Sept), and the majority of the sample events focused on this timeframe. Nonetheless, the November-December sampling events show lower concentrations of *E. coli*, as would be expected during the winter
- Findings for 2010-2011 sample results for *E. coli* are generally consistent with previous work by NDEQ (2004, 2009) and Mohlman et al. (2009).

In summary, available data show both wet weather and dry weather *E. coli* issues; therefore, both wet weather and dry weather management strategies are needed to reduce *E. coli* loading to the stream. Elevated in-stream concentrations generally begin in the AC-2 area at the upper end of the park/greenbelt area and remain generally elevated for most of the stream reach, even though the downstream (AC-9 at the Fairgrounds/Salt Creek) is somewhat lower than the central portion of the stream in the park/greenbelt area.

Findings for ammonia, selenium and copper include:

- Ammonia: Out of 31 wet weather samples only three ammonia results were above detection limits and were in the vicinity of the 0.5 mg/L detection limit. Out of 40 dry weather sample results, only six results were above detection limits, with all but one of these values below chronic (30-day) calculated stream standards and no values above acute stream standards. These results confirm that additional ammonia controls are not necessary to achieve stream standards, consistent with recent NDEQ monitoring in 2009.
- Selenium: All wet and dry weather sample results were below detection limits. (Note the September 30, 2010 sampling event has a relatively high detection limit (0.15 mg/L), but a lower detection limit of 0.005 mg/L was in place beginning in May 2011.)
- Copper: Out of 18 dry weather samples collected during two sampling events, only one sample (5.2 µg/L) was above the detection limit of 5 µg/L. Out of nine wet weather samples collected during one sampling event, only one sample (5.2 µg/L) was above detection limits. Ancillary hardness data was collected along with the copper samples, with samples collected following a Quality Assurance Project Plan (EA 2010). Following NDEQ's procedures to average multiple samples collected on the same date, all three sampling events show copper below the detection limit of 0.005 mg/L. Adding these three events to the nine NDEQ events results in a total of 12 events with three copper exceedances; which demonstrates attainment of the copper standard based on NDEQ procedures (NDEQ 2010). Specifically, the 10 sample minimum for assessment is now met, and for a 12-sample data set, four out of 12 samples would need to exceed the standard for the stream to be identified as impaired. These results remove uncertainty regarding potential impairment due to elevated copper concentrations on Antelope Creek, and attainment of the copper standard is now demonstrated.

Table 5-14. *E. coli* Summary Table (2010-2011)

Date	EA Note	Flow Notes	AC1	AC 11	AC10	AC2	AC3	AC4	AC5	AC6	AC7	AC8	AC9
9/30/2010	Dry #1	--	10	--	--	910	1220	890	390	230	190	380	250
10/8/2010	--	--	20	--	--	--	--	430	--	--	--	--	240
10/15/2010	--	--	50	--	--	--	--	110	--	--	--	--	160
10/22/2010	--	--	10	--	--	--	--	200	--	--	--	--	200
10/29/2010	--	--	540	--	--	--	--	5800	--	--	--	--	180
11/12/2010	Wet #1	Follows 1.72 inch rain	230	--	--	6020	13000	13000	7560	24200	15540	13000	24200
11/19/2010	--	--	1	--	--	--	--	1	--	--	--	--	1
11/22/2010	--	--	1	--	--	--	--	1	--	--	--	--	1
12/3/2010	--	--	20	--	--	--	--	470	--	--	--	--	70
12/10/2010	--	--	--	--	--	--	--	--	--	--	--	--	690
5/10/2011	Dry #2	--	20	220	1	210	320	350	190	NS	10	190	150
5/20/2011	Wet #2	Follows 1.87 inch rain; Salt Creek backwater	80	2490	10120	4110	9810	10470	14140	260	8670	15540	19870
5/27/2011	--	--	140	--	--	--	--	3880	--	--	--	--	650
6/3/2011	--	--	1	--	--	--	--	119	--	--	--	--	84
6/10/2011	--	--	60	--	--	--	--	5480	--	--	--	--	5840
6/17/2011	--	--	60	--	--	--	--	4620	--	--	--	--	2490
7/1/2011	Dry #3	Holmes Lake Flow	80	70	80	290	250	330	800	670	940	470	740
7/8/2011	--	Follows heavy rain est. (2 inch+); Salt Creek backwater	10	--	--	--	--	280	--	--	--	--	2150
7/15/2011	--		130	--	--	--	--	1340	--	--	--	--	280
7/22/2011	Dry #4	Follows light rain (<0.3 inch)	1	170	530	2150	3660	9210	3880	5800	1860	3260	5180
7/29/2011	--	Follows light rain	30	--	--	--	--	6140	--	--	--	--	510
8/5/2011	--	Follows rain (0.45 inch)	4890	--	--	--	--	24200	--	--	--	--	24200

Date	EA Note	Flow Notes	AC1	AC 11	AC10	AC2	AC3	AC4	AC5	AC6	AC7	AC8	AC9
8/8/2011	Wet #3	Follows rain over several days (1.16 inch)	80	630	840	1360	1280	1560	4620	17330	15540	17330	8170
8/12/2011	--	Follows heavy rain	160	--	--	--	--	12040	--	--	--	--	10470
8/19/2011	--	Follows heavy rain (est. 1 inch)	1	--	--	--	--	1400	--	--	--	--	3300
8/26/2011	--	--	10	--	--	--	--	3880	--	--	--	--	1470
9/2/2011	--	--	40	--	--	--	--	1520	--	--	--	--	240
Geometric Mean (all samples)*			27	333	205	1219	1788	959	1966	2145	1319	2343	622
# of Samples (all samples)			26	5	5	7	7	26	7	6	7	7	27
Geometric Mean (May-Sept only)			31	333	205	935	1284	2155	1571	1321	875	1761	1511
# of Samples (May-Sept)			18	5	5	6	6	18	6	5	6	6	18

Note: It is not appropriate to compare differences between sites with substantially differing numbers of samples. Be aware that sites AC1, AC4 and AC9 have more than three times as many samples as other sites in this table.
Source: EA Field Data 2010-2011

Figure 5-11. 2010-2011 Dry Weather Sampling Results for Antelope Creek

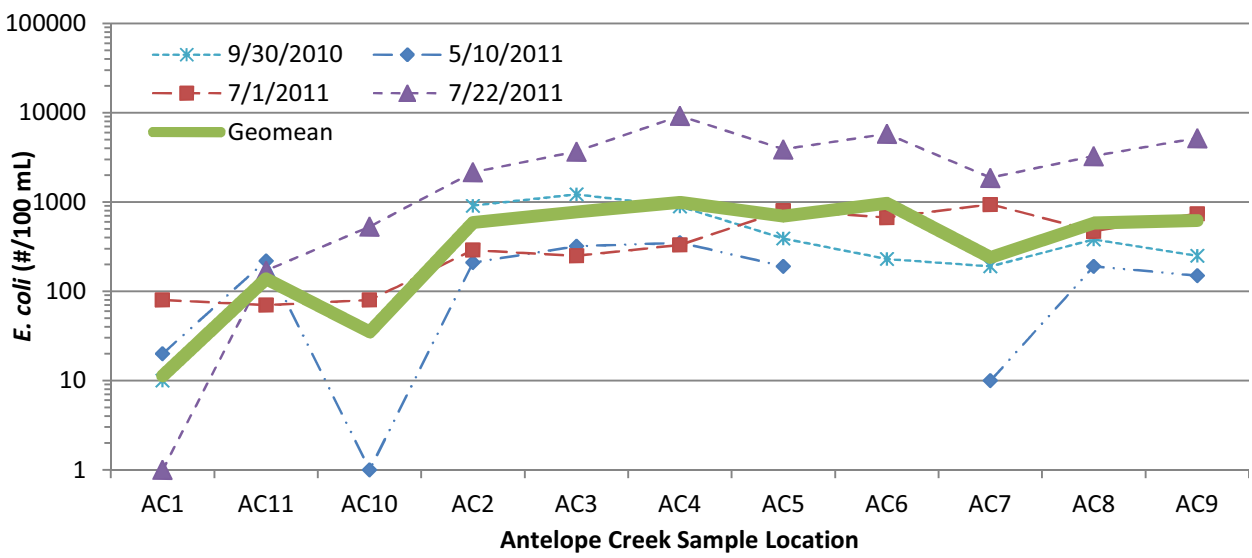


Figure 5-12. 2010-2011 Wet Weather Sampling Results for Antelope Creek

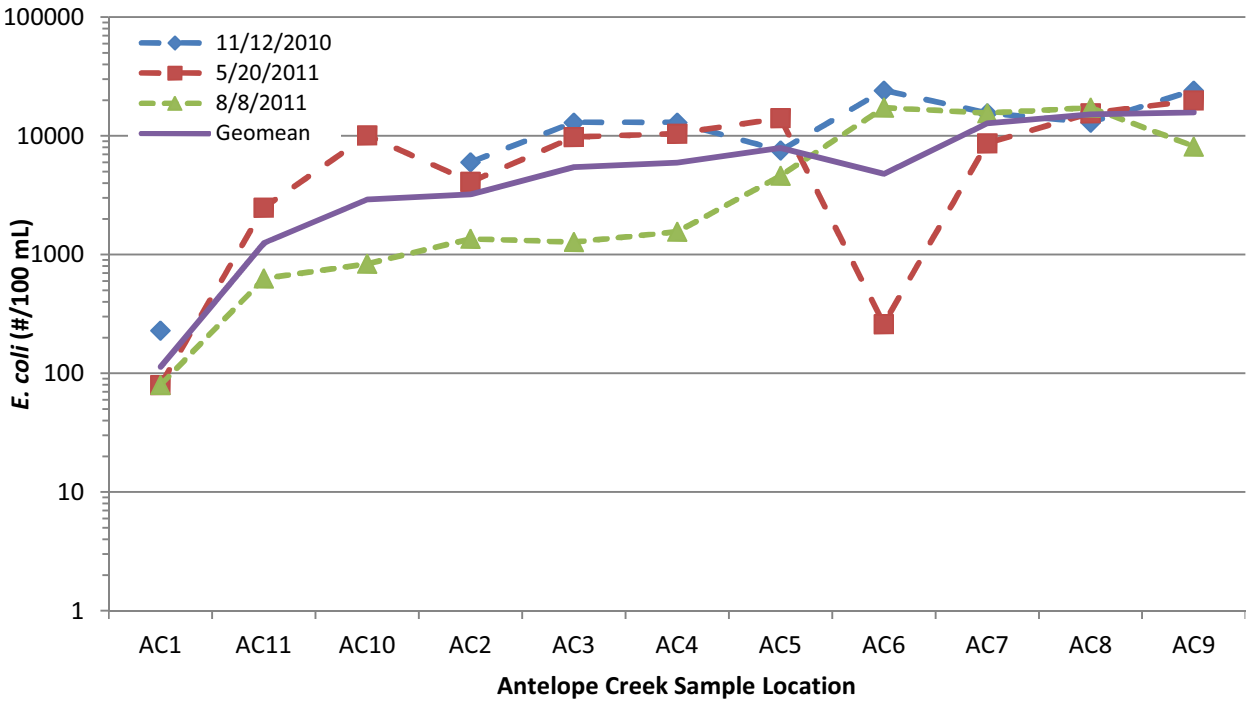
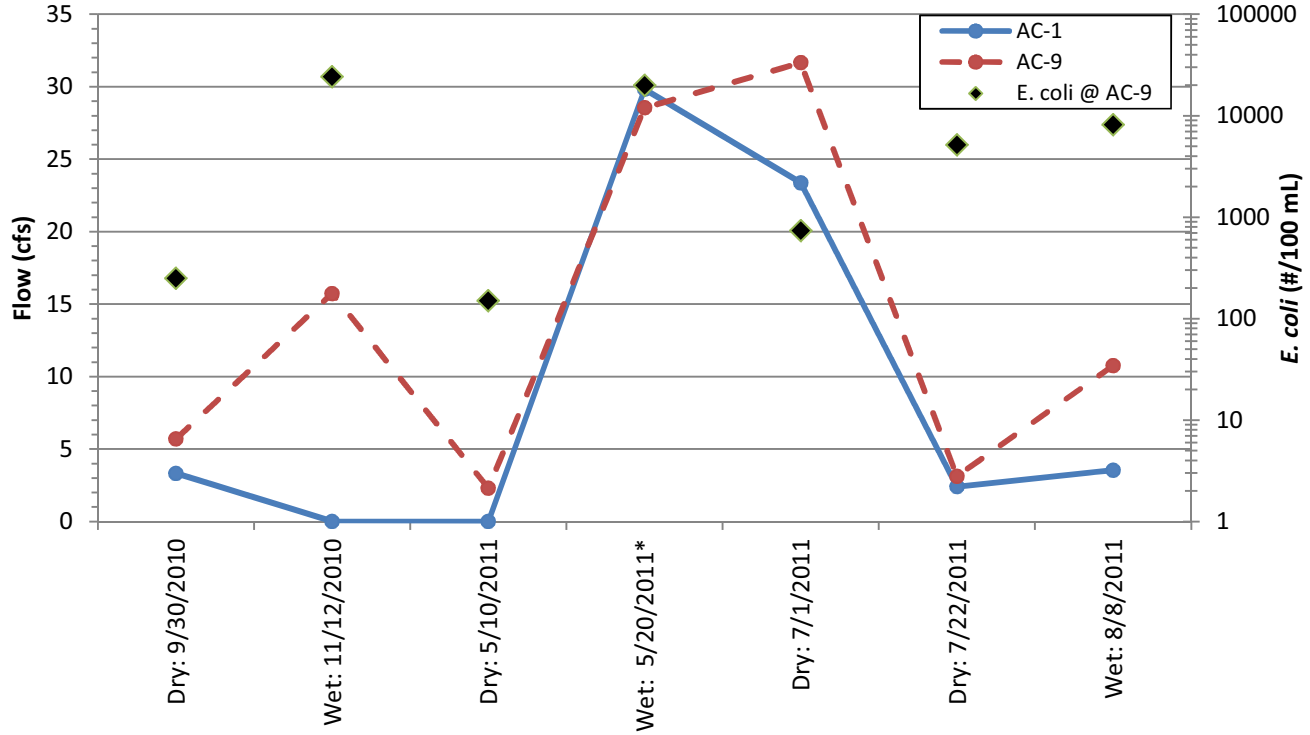


Figure 5-13. Flow Conditions During 2010-2011 Sampling Events

(with *E. coli* @ AC-9 shown on secondary Y-axis)



Note: Wet weather event rainfall amounts include: 11/10/10 = 1.72 inch; 5/20/11 = 1.87 inch; 08/08/11 = 1.16 inch over several days.
* = Wet weather flows on 5/20/11 at AC-9 affected by Salt Creek backwater.

Figure 5-14. Comparison of 2010-2011 Flow Estimates to Other Flow Data Collected on Antelope Creek

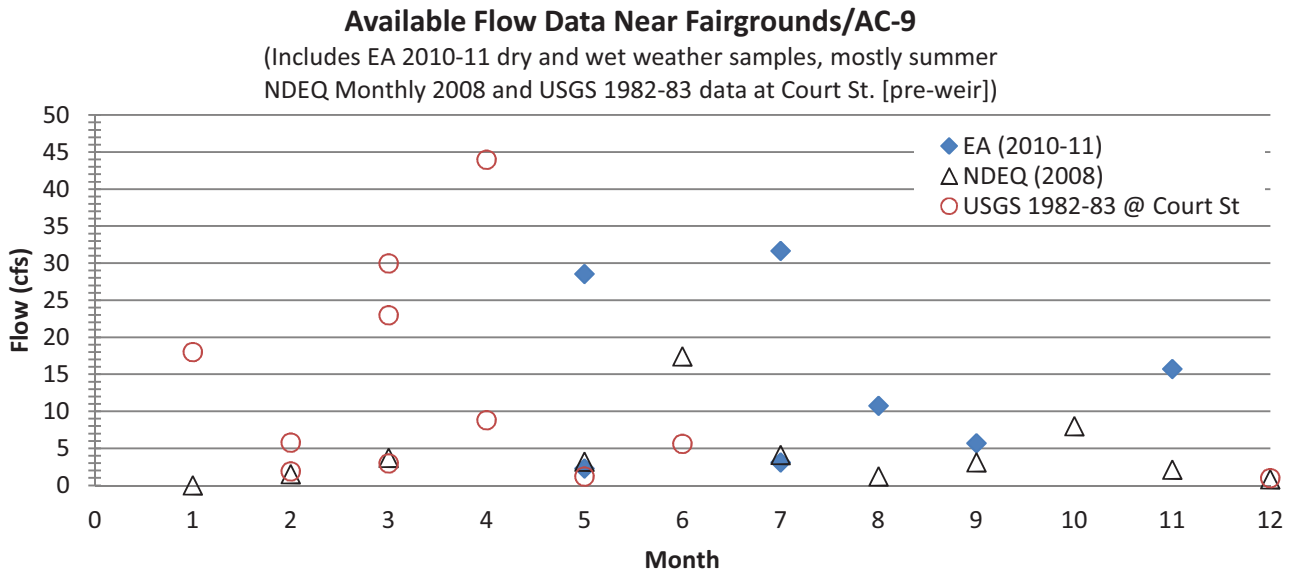
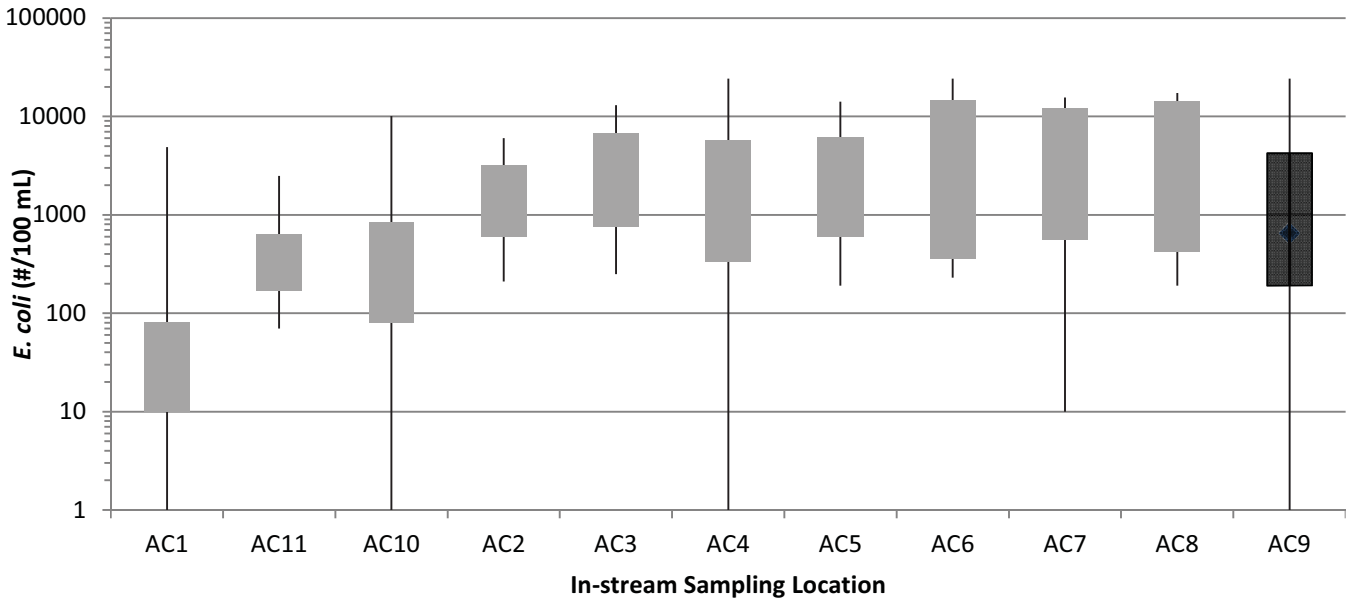


Figure 5-15. 2010-2011 Boxplots of All 2010-2011 Sampling Results for Antelope Creek



Box Plot Key: Diamond = median, Box = 25th-75th percentiles, "whiskers" = minimum and maximum values.
Important Note: Numbers of sampling events are significantly different between monitoring locations, with AC-1, AC-4 and AC-9 have approx. 27 events, whereas most other locations have only 5-7 events.

Figure 5-16. Boxplots of Annual Sampling Results for Antelope Creek at the State Fairgrounds (AC-9)

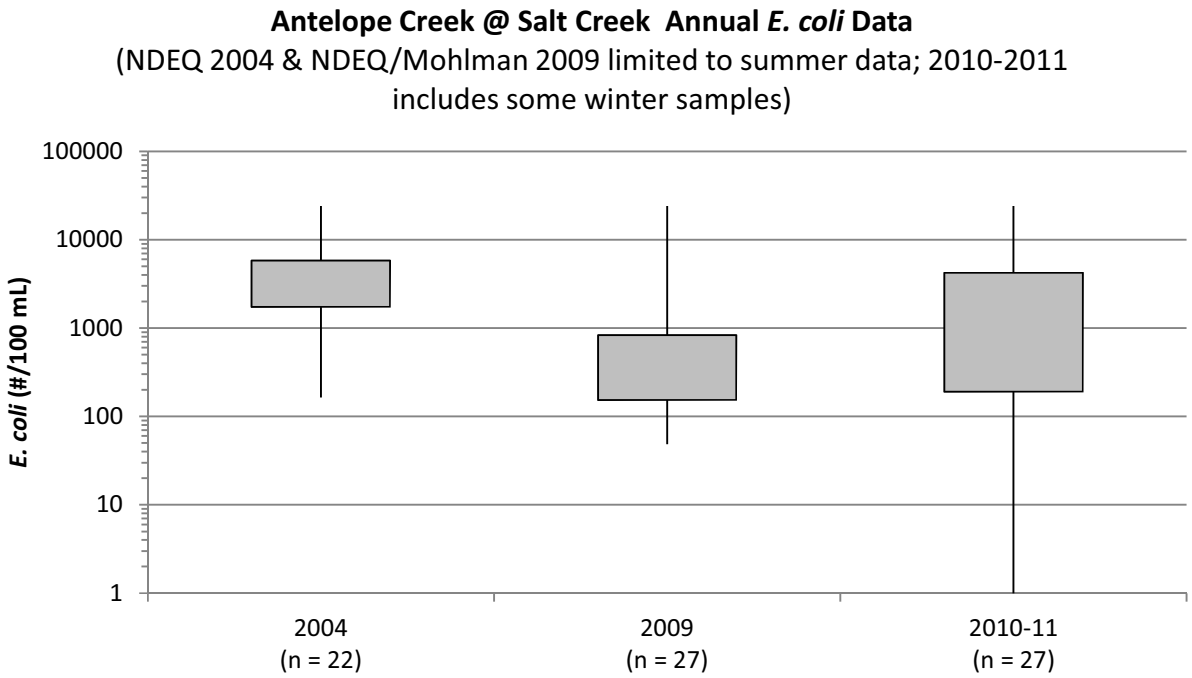
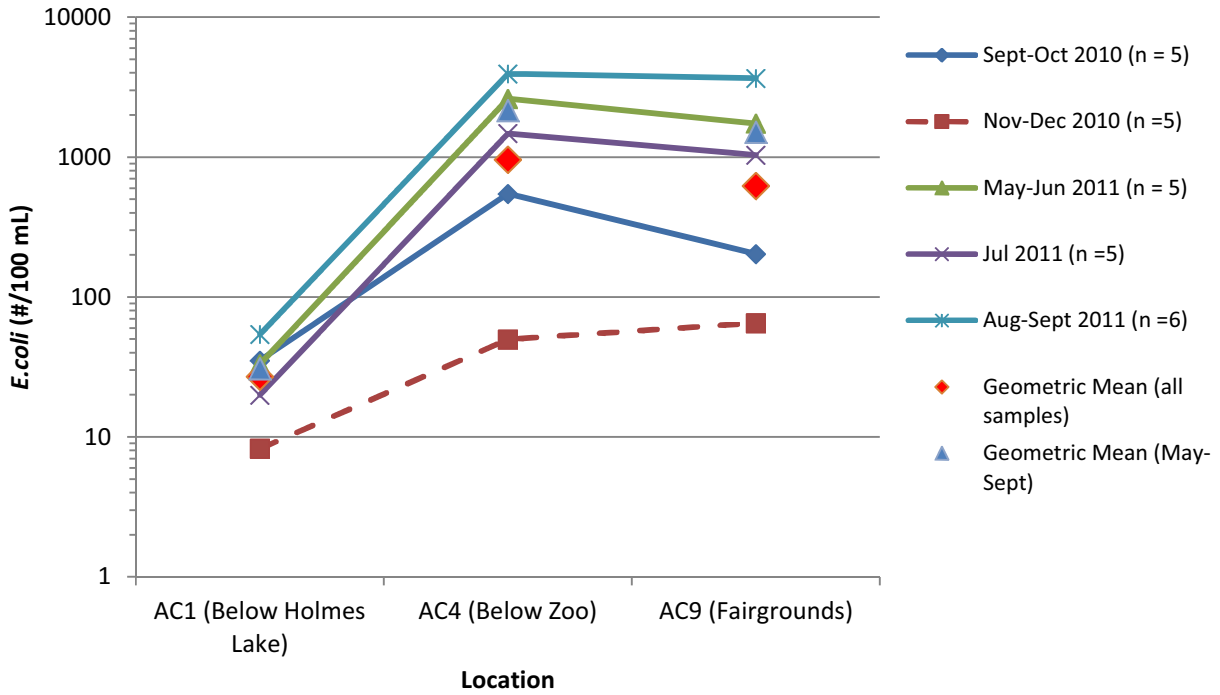


Table 5-15. Geometric Mean Values Calculated for Locations with Weekly Sampling

Date	Geometric Mean Values		
	AC-1 (Below Holmes Lake)	AC-4 (Below Zoo)	AC-9 (Fairgrounds)
Sept-Oct 2010 (n = 5)	35	547	203
Nov-Dec 2010 (n =5)	8	50	65
May-Jun 2011 (n = 5)	33	2615	1736
Jul 2011 (n =5)	20	1476	1033
Aug-Sept 2011 (n =6)	54	3942	3662
Geometric Mean (all samples)	27	959	622
Geometric Mean (May-Sept)	31	2155	1511

Source: EA Field Data 2010-2011

Figure 5-17. 2010-2011 Geometric Mean *E. coli* Concentrations at AC-1, AC-4 and AC-9



Note: Each Value is a Geometric Mean of Weekly Samples Collected over a 30-day Period
Source: EA Field Data 2010-2011

5.4.3 Dry Weather Outfall Investigations and Sampling Results

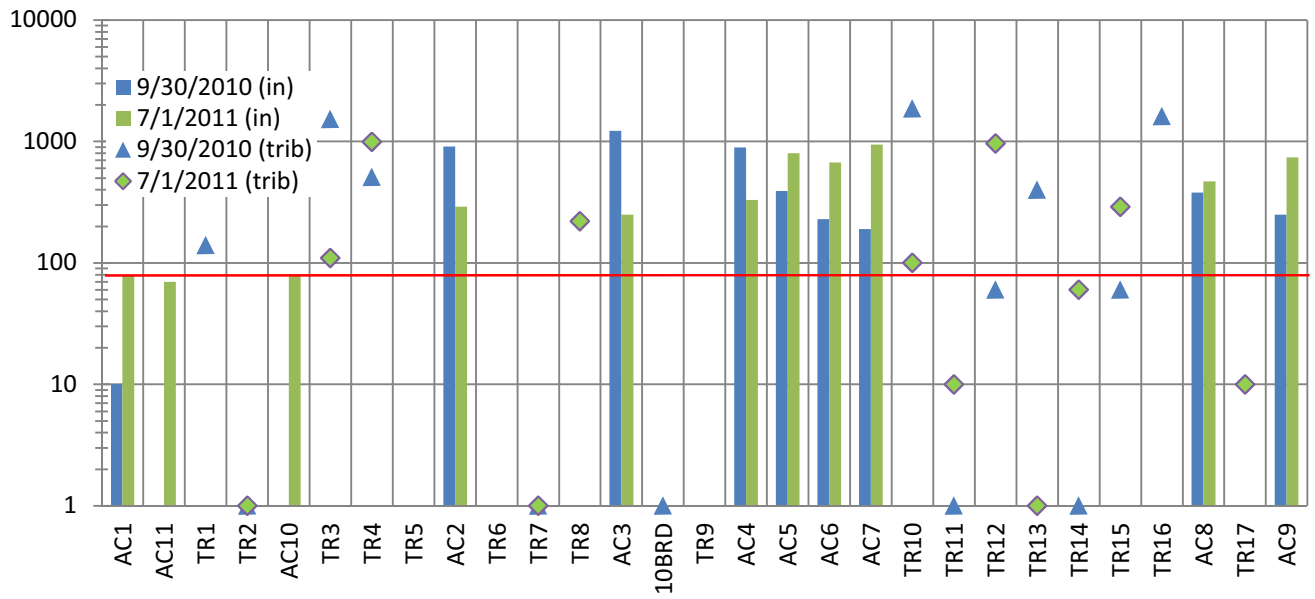
In August 2010, EA completed a dry weather survey of storm drainage system outfalls to the creek. An inventory of these outfalls included basic descriptive information such as size and location, as well as documentation of factors that could suggest potential illicit discharges such as flow, odor, algae and sediment characteristics. Potential natural sources of *E. coli* such as birds and other urban wildlife were also documented, where relevant. Outfalls with dry weather flows were documented during the initial outfall inventory then re-visited one week later (no rain during that time) to re-check for flows. Sites with discharges occurring during both field visits were selected for sampling and further exploration of the origin of the flows. Table 5-10 (in Section 5.1) identifies the outfalls sampled during dry weather conditions on September 30, 2010 and July 1, 2011. Figure 5-18 shows the sampling results for outfall and in-stream locations on these sample dates. (Outfalls are shown as individual markers and in-stream samples are shown as bars.) Key findings include:

- Dry weather flows from most outfalls were relatively minimal, generally below 0.2 cfs (or less than 5% of the flow at AC-1). On September 30, outfall T-2 had flows estimated at 0.4 cfs; however, *E. coli* was not detected at this outfall.
- There are 13 primary outfalls that discharge into the closed conduit adjacent to Union Plaza. The inlet to this conduit is located at the labyrinth weir, with the outlet to the stream located north of Vine Street. EA conducted sampling upstream of the labyrinth weir and downstream of the confluence north of Vine Street. There were no obvious spikes of *E. coli* from the outlet of the closed conduit, which did not merit further investigation. Other general water quality parameters changed due to influences from groundwater. During dry weather conditions, little to no discharge was seen from the closed conduit.
- Visual inspection of outfall for signs of illicit connections generally resulted in observations with low likelihood of illicit connection. Examples of signs of illicit connections could be odor, staining, excessive algae growth, toilet paper, etc. Several outfalls had some algae growth and staining, but not at a level raising suspicion of illicit connections. Evidence of animal presence in several outfalls was also noted.
- For the two dry weather sampling events, the only outfall with *E. coli* above the stream standard for both sampling events was T-4 at 510 and 990/100 mL. Flows at T-4 were very low, less than 0.02 cfs. For all other outfalls, results varied, such as 1) one sample exceeded the standard, but the second sample did not; 2) both sample results were below detection limits, or 3) at least one of the sampling events had no flow. For

locations with *E. coli* above stream standards, the highest concentrations observed were in the range of 1,500-1,800/100 mL. Although these concentrations are an order of magnitude above the stream standard, they are not outside of the range of concentrations associated with transient urban wildlife sources and are lower than concentrations expected to be associated with illicit connections (*e.g.,* 7,000-10,000/100 mL or higher). Combined with field observations that did not show signs of illicit connections, these results suggest that dry-weather discharges from the storm drainage system are not likely to be significant sources of elevated in-stream *E. coli*. Additionally, wildlife, such as raccoons and swallows, was documented to be present in some of the outfalls.

- All outfall samples were below detection limits for ammonia and selenium. Most copper values were below detection limits or in the vicinity of the detection limit (0.02 mg/L). Detected values of copper ranged from 0.0202 to 0.0624 mg/L; however, in-stream concentrations on those dates were below detection limits.

Figure 5-18. 2010-2011 Dry Weather Synoptic Sampling Results for Antelope Creek and Flowing Outfalls



Source: EA Field Data 2010-2011

In-stream Sediment

Recent literature has suggested that fecal indicator bacteria can persist for relatively long periods of time in water body sediments. For this reason, two sediment sampling events were completed and analyzed for fecal indicator bacteria, nutrients (Total Kjeldahl Nitrogen (TKN) and Total Phosphorous (TP)) and Chemical Oxygen Demand (COD) to explore whether sediment may be a potentially significant source of *E. coli* to the stream and to see whether nutrient conditions in the sediment appeared to be potentially related to *E. coli* concentrations. As would be expected, the January samples had low concentrations of bacteria, making it difficult to draw conclusions from this data set (Figure 5-19). The May sediment samples also had generally low concentrations of bacteria, with the exceptions of AC-2 (430 mpn/kg), which is at the South Street bridge, and AC-4 (240 mpn/kg), which is downstream of the zoo. Relationships between nutrients and *E. coli* concentrations in the sediment were not apparent, based on this limited data set.

Based on these results, it is possible that *E. coli* in-stream sediments is contributing to elevated concentration of *E. coli* in the water column, particularly during storms when sediment is resuspended; however, the available data do not suggest that this is a leading or primary cause of elevated *E. coli* in the stream.

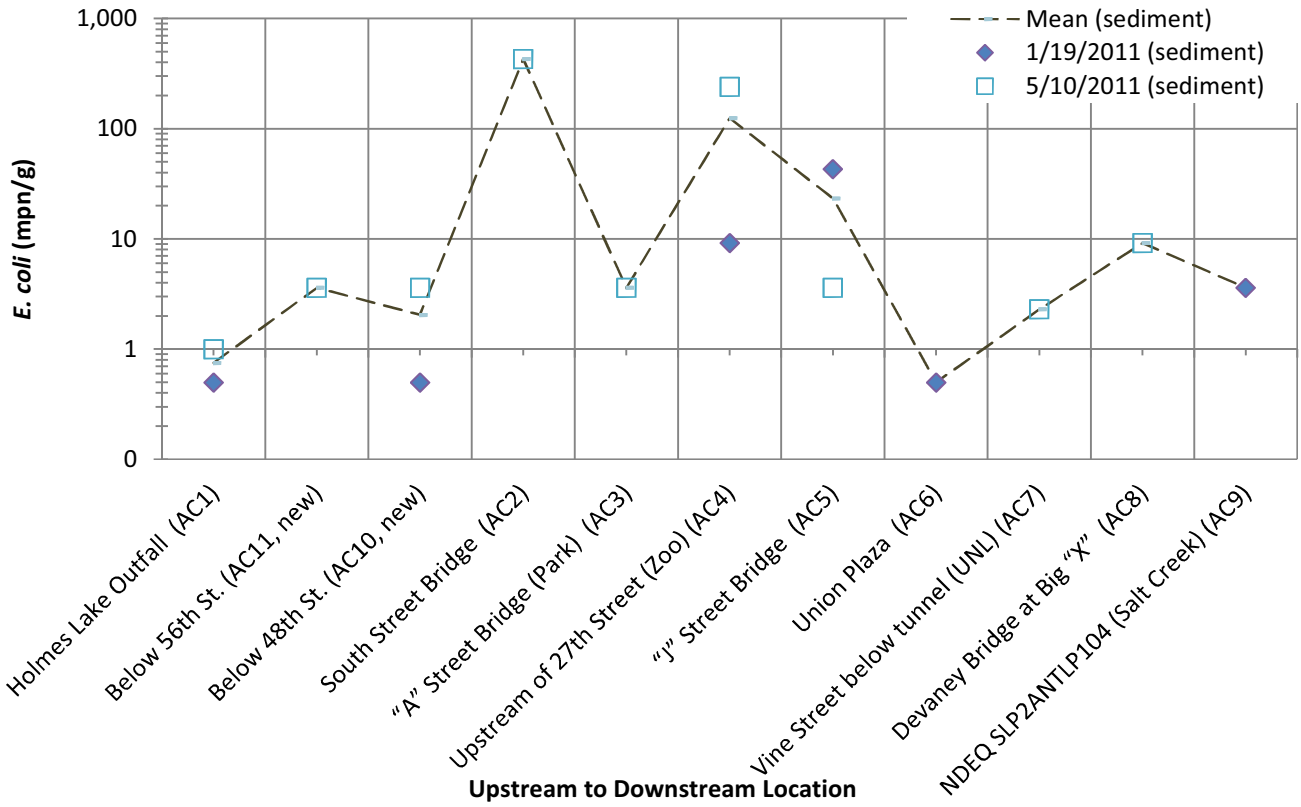
Copper and lead values in sediment samples collected from AC were generally below the levels reported to have observable effects on benthic populations based on data reported in NOAA Technical Memorandum NOS OMA 52, except at AC-4. Concentration for copper and lead at AC-4 are elevated to levels shown to have adverse effects on benthic organisms. Additional data is needed to confirm the value and to evaluate the toxicity.

Table 5-16. 2011 Summary of In-stream Sediment Samples for Antelope Creek

Sample Location	TKN, mg/kg		Phosphorus-Total, mg/kg		COD, mg/kg		Cu mg/kg	Lead, mg/kg	*E. coli*, mpn/g		Entero-bacteriaceae cfu/g		Fecal Coliform, mpn/g	
Date	1/17/2011	5/10/2011	1/17/2011	5/10/2011	1/17/2011	5/10/2011	1/17/2011	1/17/2011	1/17/2011	5/10/2011	1/17/2011	5/10/2011	1/17/2011	5/10/2011
AC 1	48.9	158	82.2	70.5	755	1193	1.3	<5	nd	nd	70	1160	nd	nd
AC 11	—	440	—	177	—	264	—	—	—	3.6	—	610	—	13
AC 10/ 48th Street Bridge	324	109	113	93.6	4092	1280	3.2	9.4	nd	3.6	170	520	2	13
AC 2	—	135	—	156	—	433	—	—	—	430	—	610	—	350
AC 3	—	77	—	79.9	—	713	—	—	—	3.6	—	400	—	8
AC 4	71.8	58	80.2	78.5	305	912	38.8	347	9.2	240	130	930	49	280
AC 5/Weir	1142	166	243	106	11234	476	12	30.2	43	3.6	50	1120	350	2
AC 6/ Union Plaza	931	x	313	x	13883	x	4	6.9	nd	x	30	x	nd	x
AC 7	—	268	—	103	—	1058	—	—	—	nd	—	nd	—	2
AC 8	—	81	—	137	—	1050	—	—	—	9.2	—	40	—	8
AC 9/State Fair Park	652	x	160	x	2906	x	15.3	7.2	3.6	x	nd	x	33	x

Notes: X = no sediment to sample; nd = non-detect; — = not sampled for this event
mg/kg = milligram per kilogram; mpn/g = most probable number per gram; cfu/g = colony forming unit per gram
Source: EA Field Data 2011

Figure 5-19. 2010-2011 Sediment Sampling Results for Antelope Creek



Source: EA Field Data 2010-2011

Animal Sources Observed

Fecal deposition from birds and animals of all sizes can contribute to elevated bacteria concentrations in Antelope Creek. These contributions occur not only from areas immediately adjacent to the creek, but also from the broader watershed, particularly during runoff events. During water quality sampling events, EA staff recorded field observations related to potential animal sources along the creek. Table 5-17 provides a summary of these comments, which document the presence of pigeons, ducks, swallows and raccoons at various times. In particular, locations AC-4 and AC-5 appear to be influenced by pigeons and ducks, respectively. Surveys of animals and birds in other parts of the watershed were not recorded.

Table 5-17. Animals Observed During Sampling Events (2010-2011)

Date	Location	Animal Observations
5/27/2011	AC1	5 turkey vultures on dam
8/26/2011	AC1	Raccoon feces downstream of sampling
5/20/2011	AC2	Starlings sitting on edge of stream (~6)
5/20/2011	AC3	A few swallows nesting under bridge
5/20/2011	AC4	Pigeons downstream of sampling point (many under bridge)
8/19/2011	AC4	20 pigeons flew out from under bridge
9/2/2011	AC4	40 pigeons flew out from under bridge
11/12/2010	AC5	15-20 ducks 200 feet upstream in the stream
5/20/2011	AC5	Mallards swimming upstream (3 families) ~20
7/1/2011	AC5	Birds upstream (6-8), many birds downstream ~20 ducks
5/20/2011	AC8	Pigeons roosting on bridge downstream of sampling point (~6)
5/27/2011	AC9	Several horses east of site training area of former state fairgrounds
6/17/2011	AC9	Washing horse pens at former state fairgrounds
Tributaries/Outfalls		
7/1/2011	T12	A few barn swallow nests with feces piled beneath; raccoon tracks in outfall
7/1/2011	T7	Barn swallows inside (3) + turtle dove

Source: EA Field Survey 2010-2011

5.5. Overall Summary and Conclusions

Both historic and recent water quality and sediment data for Antelope Creek in Lincoln, Nebraska have been summarized and evaluated to support this Basin Plan. Based on sampling by NDEQ (2004, 2009), UNL/Mohlman et al. (2009) and EA (2010/2011), the following observations are provided to support recommendations to improve water quality in the main stem of Antelope Creek.

- Available data for Antelope Creek suggest diffuse sources of *E. coli* under dry weather conditions. Based on available information, it appears that the likely sources of bacteria are urban wildlife such as pigeons under bridges and other birds and wildlife, particularly in the park land and undeveloped areas of the riparian corridor where concentrated animal populations appear more common than other locations in the watershed.
- Although *E. coli* is elevated above stream standards in some dry weather outfall samples, the results do not suggest on-going illicit discharges such as failing sanitary sewer lines or illicit sanitary connections.
- Under wet weather conditions, *E. coli* concentrations are approximately an order of magnitude (10x) higher than dry weather conditions.
- Wet weather *E. coli* concentrations generally increase in a downstream direction, but no particular stream segment appears to be an *E. coli* “hot spot.”
- Sediment samples show that *E. coli* can reside in channel sediments, particularly in the AC-2 and AC-4 sample locations; however, concentrations are not particularly high in the sediments. For this reason, sediment does not appear to be a key source of *E. coli*, although *E. coli* present in sediments may contribute to elevated *E. coli*, particularly under runoff conditions when sediments are scoured and resuspended in the water column.
- Recent sampling data is generally within the range of sample results collected by NDEQ and others for this reach of stream.
- Overall, results suggest that the upper central portion of the stream segment (AC-2 to AC-6) may be an appropriate starting point to focus on non-structural and structural strategies to reduce *E. coli*.
- Based on the cumulative data sets now available, Antelope Creek attains water quality standards for ammonia and copper.
- Selenium, chloride and conductivity appear to be most elevated in the lower portion of the stream segment, with concentrations believed to be influenced by geologic conditions and groundwater contributions to the

stream in this area. Because sources of these constituents are expected to be naturally occurring, they have not been addressed in detail in this analysis.

- Based on the cumulative data set now available, Holmes Lake discharges to Antelope Creek generally attain stream standards for *E. coli*.
- The State Fairgrounds have been moved to another city, and all animal operations, including horse racing, will cease after 2013. The site is now being redeveloped into a private/public sector research campus associated with the University of Nebraska at Lincoln (Innovation Campus). As a result, the State Fairgrounds area is not expected to warrant additional investigation with regard to *E. coli.*

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