Bacterial Contamination of Surface Waters in the Stanislaus National Forest, California

(Eighth Year of Study)

Summary of 2016 Results

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Recreational and management activities (e.g., commercial livestock grazing, logging, fuel treatment, mining, road management) in the Stanislaus National Forest (STF) have cumulative impacts to watershed conditions. Stream monitoring was conducted in the STF in 2016 and focused on the impacts of livestock grazing to stream water quality and observable associated impacts by livestock to riparian habitat and stream bank stability. To assess water quality in forest streams, surface waters were tested for pathogenic bacteria indicators (i.e., *Escherichia coli*, fecal coliform bacteria, and total coliform bacteria) for the eighth consecutive year within commercial cattle grazing allotments in the STF.

Background

Sample sites in 2009, 2010, and 2011 focused on comparative sampling before cattle were present at the site, followed by sampling once cattle were observed or after evidence of fresh cattle disturbance was observed at the site. The results from the first three years of sampling (2009-2011) showed that concentrations of fecal coliform bacteria in surface waters were consistently below regulatory thresholds at all sites before cattle presence or where no livestock grazed during the season. Shortly after cattle were released into the national forest to graze within allotments in the vicinity of the sampling site, fecal coliform concentrations increased and in places exceeded state standards. *E. coli* and total coliform concentrations in tested samples followed the same pattern.

Reports at the end of the 2009 and 2010 sampling seasons focused on documenting violations of state standards for fecal coliform concentrations in recreational contact waters. The 2011 report highlighted the difference in *E. coli* and fecal coliform concentrations detected in waters when cattle were not present compared to bacteria concentrations detected when cattle were present in the STF. The reports for 2012 and 2013 discussed results from sampling that specifically focused on water quality in streams within grazed areas in national forest roadless areas and wilderness areas. The potential is high in those areas for backcountry recreational users to drink the contaminated stream water.

Regional climatic variability during the course of this study (including the drought from 2012-present), led to less availability of surface waters in the central Sierra Nevada region.

During the first four of the drought water years (2011/2012 – 2014/2015), total rainfall for the central Sierra Nevada region was far below the 50-year average (40 in.) including 19 in. in 2014/2015 water year, 20.4 in. in 2013/2014, 26.5 in. in 2012/2013 water year, and 25.0 in. in 2011/2012 water year; refer to DWR's Water Conditions website (DWR 2016). During those years when there were fewer water sources available, cattle may have spent more time near streams with adequate flows which may have led to increasing fecal contaminate concentrations at sampling locations.

During the 2015/2016 water year, total precipitation (40.8 in.) exceeded the previous four water years and exceeded the 50-year total rainfall average (DWR 2016). Results of 2016 sampling detailed in this report demonstrate similar, or lower, mean concentrations of pathogenic bacteria once cattle were present compared to the prior "below normal" or drought years, though, there were still 59 violations documented for fecal coliform and *E. coli* concentrations at stream sites in 2016. These findings suggest that water year type may play a role in stream bacteria contamination levels, but regardless of fluctuations in mean concentrations that may be attributable to water year type, the pattern of increasing bacteria levels associated with cattle arriving on the allotments was observed again in 2016.

This report details the findings of the 2016 sampling season (June-October) for pathogenic bacteria concentrations (*E. coli* and fecal coliform) in five streams in the STF and will focus on more local-scale factors (cattle presence, observable recent cattle disturbance, and relative stream flow) to bacteria concentrations.

Methods

Field Site Selection for 2016

Given multiple years of limited flow, 2016 sample sites were located in streams where sampling has occurred in previous years indicated good flow that lasted well into the grazing season. Resampling stream sites provides further context given variable environmental and climatic conditions between sample years. On June 1, 2016, the central Sierra Nevada was at 24% of normal snow water equivalents for that date. The opening of roads and public access to the forest closely coincided with the release of livestock onto grazing allotments in 2016, so the ability to collect "before" livestock samples was highly limited.

Five stream sites that were exposed to commercial livestock grazing during the summer of 2016 were sampled within the STF. Bell Creek (at Middle Bell Meadow) was sampled in 2014 and 2015, tributary of Bell Creek was sampled in 2009, 2011, and 2012, Cow Creek was sampled in 2014 and 2015, and Rose Creek was sampled in 2015. The location sampled on Niagara Creek was not sampled previously. These sites are described below, and Table 1 provides location (i.e., latitude, longitude) coordinates for each site, using datum NAD 83, in addition to county, allotment, and elevation (m).

Bell Creek at Middle Bell Meadow (BC_MBM) - Samples were collected from Bell Creek in the Middle Bell Meadow area (within the Bell Meadow Allotment) in the Summit Ranger District.

The sample site is within a fenced area intended to exclude livestock from the creek, however there was observable evidence that cattle had recently been in the fenced area. Bell Creek is within the Tuolumne River watershed and flows into the Tuolumne River via the Clavey River. Twelve "before" cattle samples were collected on June 10 (n=2), June 17 (n=2), June 22 (n=2), July 14 (n=2), July 26 (n=2), and August 4, 2016 (n=2). Twelve "after" samples were collected on August 9 (n=2), September 7 (n=2), September 13 (n=2), September 19 (n=2), September 30 (n=3), and October 13, 2016 (n=3). Samples were also collected from Bell Creek in 2012, 2014, and 2015. Since only a few samples were taken in 2012, that year's limited data was not included in the report.

Bell Creek Lower at Middle Bell Meadow (BC_MBM_L) - Samples were collected from Bell Creek in the Middle Bell Meadow area (within the Bell Meadow Allotment) in the Summit Ranger District. The sample site is downstream of BC_MBM sample site and just downstream of the fence that crosses the creek. Bell Creek is within the Tuolumne River watershed and flows into the Tuolumne River via the Clavey River. No "before" cattle samples were collected, and eight "after" samples were collected on September 13 (n=3), September 19 (n=2), September 30 (n=2), and October 13, 2016 (n=1).

Trib. of Bell Creek at Lower Round Meadow (TBC_LRM) - Samples were collected from a tributary to Bell Creek (within the Bell Meadow Allotment). Bell Creek is within the Tuolumne River watershed and flows into the Tuolumne River via the Clavey River. Six "before" samples were collected on June 10 (n=2), June 17 (n=2), and June 22, 2016 (n=2). Twelve "after" cattle samples were collected on July 14 (n=2), July 26 (n=2), August 4 (n=2), August 9 (n=2). The site was moved to the mainstem Bell Creek, just downstream the confluence of the tributary of Bell Creek and Bell Creek, after the tributary was determined to have no observable flow for the September 7 (n=2), and September 13, 2016 (n=2) sampling events. Samples were collected on this tributary of Bell Creek within Lower Round Meadow in 2009, 2011, 2012, and 2013.

Cow Creek downstream of Bull Run (CC_BR) - Samples were collected from Cow Creek just downstream of Bull Run within the Herring Creek Allotment. Cow Creek is entirely within the Stanislaus River watershed and flows into the Middle Fork Stanislaus River upstream Beardsley Reservoir. Two "before" cattle samples were collected on June 30, 2016. Fourteen "after livestock" samples were collected on July 8 (n=2), July 26 (n=3), August 4 (n=3), August 9 (n=2), September 7 (n=2), September 13 (n=20), and September 19, 2016 (n=2). This location on Cow Creek was also sampled in 2011, 2012, 2014, and 2015. Since only a few samples were taken in 2011 and 2012, that data was not included in the report.

Niagara Creek at Barn Meadow (NC_BM_U) - Samples were collected from Niagara Creek adjacent to Barn Meadow within the Long Valley-Eagle Meadow Allotment. Four "before" cattle samples were collected on June 30 (n=2) and July 8, 2016 (n=2). Seven "after" cattle samples were collected on July 26 (n=2), August 4 (n=3), and August 9 (n=2). This location on Niagara Creek had not been sampled before.

Rose Creek (RC) - Samples were collected from Rose Creek in an area accessed by Forest Service Road 3N59Y, which spurs off road 4N16 (which is within the Rushing Allotment). Rose Creek is entirely within the Stanislaus River watershed and flows into the Lower Middle Fork of

the Stanislaus River. No "before" cattle water samples were collected, since cattle were already present at the site of the first visit. Ten "after" cattle samples were collected on June 13 (n=2), June 21 (n=3), July 13 (n=2), and August 8, 2016 (n=2). This location on Rose Creek was also sampled in 2015.

Table 1. List of water sample sites (latitude and longitude datum NAD 83).

Site name	County	Allotment	Latitude	Longitude	Elevation (m)
Bell Creek (BC_MBM)	Tuolumne	Bell Meadow	38.16520	-119.94111	1,991
Bell Creek low (BC_MBM_L)	Tuolumne	Bell Meadow	38.16512	-119.94153	1,991
Trib. of Bell Creek (TBC_LRM)	Tuolumne	Bell Meadow	38.15802	-119.95690	1,932
Cow Creek (CC_BR)	Tuolumne	Herring Creek	38.24919	-119.96369	2,022
Niagara Creek (NC_BM_U)	Tuolumne	Long Valley-Eagle Meadow	38.28837	-119.86011	2,303
Rose Creek (RC)	Tuolumne	Rushing	38.14169	-120.19995	1,145

Field Water Collection

A Quality Assurance Project Plan (QAPP) was prepared for this water-monitoring project and all procedures specified in the QAPP were followed.

Water samples that were collected for bacteriological testing were collected while wearing sterile gloves and collected in sterile sample bottles provided by AquaLab Water Analysis (ELAP certification). The bacteriological samples were collected before any other work was performed at the site. The sterilized Nalgene bottles hold 125 mL of liquid. They were filled to 100 mL with sample water taken directly from flowing water approximately 0.1 m below the stream's surface.

The sample containers were marked with a unique 3-digit identifying number with an indelible marker so that the markings would not "run" or otherwise become illegible when collecting the sample. The collection date, time and samplers' names were recorded on the field datasheets, which are retained at the CSERC office; they are also recorded on the Chain-of-Custody form that was transmitted to AquaLab along with each sample. No sampling bottles were contaminated during sampling or transit.

All water samples collected for bacteriological analyses were delivered to AquaLab within six hours from the time the samples were collected. The sample bottles were placed in Zip-loc plastic bags (to avoid any potential contamination from the ice water) on ice in a cooler until delivered into the custody of AquaLab.

While collecting the water samples, the presence of cattle at the sampling location, observable evidence of fresh cattle-related disturbance (e.g., cattle manure, streambank sloughing, streambed pocking), and relative flow of the stream being sampled was recorded on a field datasheet along with other observations about the sample area.

Laboratory Analyses

Water samples were delivered at Twain Harte, CA, to AquaLab, a State-certified analytical laboratory. All water samples were tested for *E. coli,* total coliform, and fecal coliform bacteria within the 6-hour holding time specified in the QAPP, using Multiple Tube Fermentation (Most Probable Number/100 mL). The detection limit using this method of analysis is two fecal coliform organisms/100 mL of water. The detection maximum using this method of analysis is 1,600 fecal coliform organism/100 mL of water, unless otherwise instructed to do.

A copy of AquaLab's Quality Assurance SOP for Multiple Tube Fermentation is on file at the CSERC office and included in appendix 5. The analytical methods utilized by this laboratory are specified in *Standard Methods For the Examination of Water and Wastewater* (19th Edition).

Data Summary and Analysis for Comparison to State and Federal Standards

Fecal coliform results were compared to the relevant water quality standards contained in the Central Valley Regional Water Quality Control Board' *Water Quality Control Plan for the Sacramento and San Joaquin River Basins* Basin Plan (CRWQCB 2016). Water contact recreation is a designated beneficial use of the receiving waters included in this study. To protect that beneficial use, the Basin Plan specifies (in part) the following numeric objectives (i.e., standards):

> *In waters designated for contact recreation (REC-1), the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 200/100 ml, nor shall more than ten percent of the total number of samples taken during any 30-day period exceed 400/100 ml. (Basin Plan at III-3)*

The Basin Plan sets the standard for all waters sampled in this study in terms of fecal coliform concentrations. However, the U.S. Environmental Protection Agency (EPA) recommended standard for recreational contact is measured in terms of *E. coli* concentrations. In addition to fecal coliform results, *E.coli* results were compared to the recommended recreational water quality criteria contained in the EPA's RWQC (USEPA 2012) for *E. coli* in freshwater in this study. EPA's recommendation, with an estimated illness rate of 36/1,000 (recommendation 1), is five or more samples for any 30-day period should not to exceed a geometric mean of 126 CFU/100 mL or ten percent of the total number of samples taken during any 30-day period should not exceed 410 CFU/100 mL.

Data were compiled for five or more samples that were collected within a 30-day period. Results were judged as a "Type 1 Violation" whenever the geometric mean of five fecal coliform samples collected over a 30-day period exceeded 200 MPN/100 mL, based on state standards, or whenever the geometric mean of five *E. coli* samples collected over a 30-day period exceeded 126 MPN/100 mL, based on EPA recommendations. Fecal coliform results were judged as a "Type 2 Violation" whenever more than ten percent of the samples collected over a 30-day

period exceeded 400 MPN/100 mL, based on State standards, or whenever more than ten percent of the *E. coli* samples collected over a 30-day period exceeded 410 MPN/100 mL, based on EPA recommendations. In effect, a Type 2 Violation exists for this study any time there are at least five samples during a 30-day period for which any single sample exceeded 400 MPN/100 mL of water for fecal coliform, or 410 MPN/100 mL for *E. coli*.

For this study, reporting periods were tabulated only when five or more samples were collected within a 30-day period. A more comprehensive analysis (i.e., tabulating all possible 30-day periods by re-starting the 30-day calendar each day) would produce additional violations.

In order to compare mean fecal coliform, and mean *E. coli* concentrations, between "before" and "after" cattle were present at the site, t-tests were performed for each bacteria type for all sites sampled in 2016. Regression (lm function) was used to test for differences in (1) fecal coliform and (2) *E. coli* concentrations (response variables) with cattle presence, fresh cattle disturbance, and/or relative flow (factor explanatory variables). All figures and statistical tests were performed in Rstudio (Version 0.99.903).

Results

Effects of Livestock Presence, Recent Livestock Disturbance, and Relative Flow on Fecal Coliform and E. coli Concentrations

Mean (and ± standard deviation) fecal coliform and *E. coli* concentrations for each site "before" cattle were present at the site and "after" cattle were present at the site are detailed in Table 3. "Before" samples were not collected at Rose Creek or at Bell Creek Lower, and are denoted with "--" (Table 3).

Mean "after" cattle fecal coliform concentration for Bell Cr. was over 8 times higher than the mean "before" cattle concentrations. Mean "after" cattle fecal coliform concentrations were over 5, 19, and 3 times higher than "before" cattle concentrations at tributary of Bell Cr., Niagara Cr., and Cow Cr., respectively. Mean "after" cattle *E. coli* concentrations for Bell Cr. were over 8 times higher than the mean "before" cattle concentrations. Mean "after" cattle *E. coli* concentrations were over 4 and 31 times higher than "before" cattle concentrations at tributary of Bell Cr. and Niagara Cr., respectively. Mean "after" cattle *E. coli* concentrations were actually lower than mean "before" cattle *E. coli* concentrations (Table 3).

Table 3.Summary of mean (± 2 standard deviation) fecal coliform and *E. coli* concentrations (MPN/100 mL) for each stream site sampled in 2016 before and after cattle arrived at the site. Sample size (n) is also included.

	Before cattle			After cattle		
Site	**n**	**Fecal coliform**	***E. coli***	**n**	**Fecal coliform**	***E. coli***
Bell Cr. (BC_MBM)	12	41 ± 54	39 ± 55	14	355 ± 551	331 ± 555
Bell Cr. lower (BC_MBM_ L)	--	--	--	8	10,010 ± 10,299	6,331 ± 6,917
Trib. of Bell Cr. (TBC_LRM)	8	11 ± 5	11 ± 5	10	59 ± 48	46 ± 46

Cow Cr. (CC_BR)	4	52 ± 54	52 ±54	12	158 ± 178	50 ± 34
Niagara Cr. (NC_BM_U)	4	7.3 ± 7.1	2.0 ± 0	7	139 ± 176	63 ± 39
Rose Creek (RC)	--	--	--	10	349 ± 318	239 ± 254

Across all sites, mean "after" cattle fecal coliform concentrations were significantly higher than mean "before" cattle fecal coliform concentrations in 2016 (t_{62}=2.39, p = 0.02; see Figure 2 and Table 4). Mean "after" cattle *E. coli* concentrations were significantly higher than mean "before" *E. coli* concentrations across all sample sites in 2016 (t_{62}=2.33, p = 0.02; see Figure 2 and Table 4).

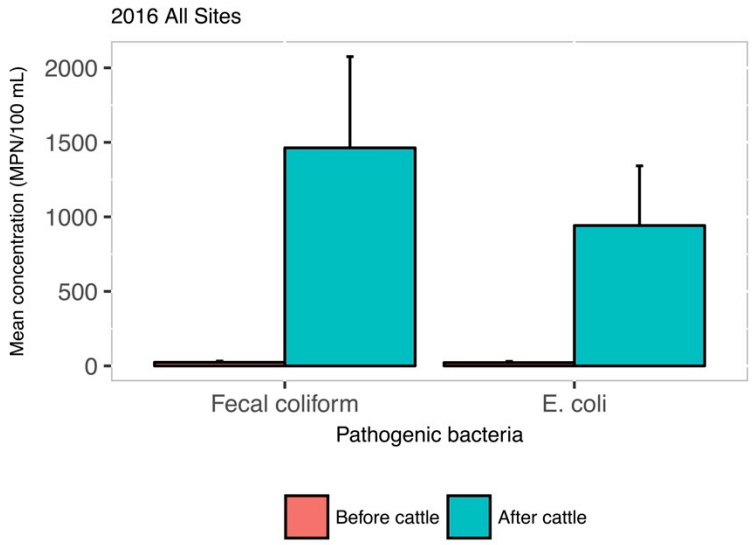

Figure 1. Mean and standard error (error bars) fecal coliform and *E. coli* concentrations (MPN/100 mL) across all 2016 sample sites for "before" (pink) and "after" (blue) cattle are present.

Across all sites, mean fecal coliform concentrations at sites with fresh cattle disturbance were over two times higher than mean fecal coliform concentrations at sites without fresh cattle disturbance, and mean *E. coli* concentrations at sites with fresh cattle disturbance were also over two times higher than mean *E. coli* concentrations at sites without fresh cattle disturbance (Table 4). Mean fecal coliform concentrations at sites when relative flows were medium-low or low were higher than concentrations at sites when flows were high, medium, and very low (Table 4). Similar results were observed for mean *E. coli* concentrations (Table 4).

Table 4. Summary of mean (± 2 standard deviation) fecal coliform and *E. coli* concentrations (MPN/100 mL) for each stream site sampled in 2016.

Factor		Fecal coliform (MPN/100 mL)	*E. coli* (MPN/100 mL)
Cattle presence	Before	25 ± 40	23 ± 40
	After	1,463 ± 4,782	942 ± 3,127
Fresh cattle disturbance	Yes	1,940 ± 6,604	1,188 ± 3,784
	No	766 ± 2,895	514 ± 2,213
Relative flow	High	2 ± 0	2 ± 0
	Medium	109 ± 266	78 ± 201
	Medium-low	2,088 ± 5,011	1,333 ± 3,888
	Low	1,510 ± 5,536	990 ± 3,175
	Very low	92 ± 127	42 ± 36

The presence of cattle ($F_1 = 79$, $p < 0.001$), relative flow ($F_4 = 7.1$, $p < 0.001$), and an interaction between relative flow and the presence of fresh disturbance ($F_3 = 14$, $p < 0.001$) are significantly related to fecal coliform concentrations across sampling sites. Specifically, there is a negative relationship between cattle absence and fecal coliform concentrations ($p < 0.001$); there is a negative relationship between medium flows and the fresh disturbance and fecal coliform concentrations ($p < 0.001$); there is a negative relationship between medium-low flows and fresh disturbance and fecal coliform concentrations ($p = 0.003$); and there is a positive relationship between low flows and fresh disturbance and fecal coliform concentrations ($p = 0.04$).

The presence of cattle ($F_1 = 58$, $p < 0.001$), relative flow ($F_4 = 7.4$, $p < 0.001$), and an interaction between relative flow and the presence of fresh disturbance ($F_3 = 13$, $p < 0.001$) are significantly related to fecal coliform concentrations across sampling sites. Specifically, there is a negative relationship between cattle absence and *E. coli* concentrations ($p = 0.001$); there is a positive relationship between the presence of fresh disturbance and *E. coli* concentrations ($p = 0.02$); there is a negative relationship between medium flows/fresh disturbance and *E. coli* concentrations ($p = 0.007$); and there is a positive relationship between medium-low flows /fresh disturbance with *E. coli* concentrations ($p < 0.001$).

These findings suggest that the presence of cattle, and also lower flows in combination with the presence of fresh cattle disturbance, are related to increasing levels of fecal coliform and *E. coli* concentrations.

Comparison of Fecal Coliform and E. coli Concentrations across Sampling Years

Across years, geometric mean concentrations for fecal coliform and *E. coli* "after" cattle were present at sampling sites were orders of magnitude higher than mean (geometric) concentrations "before" cattle arrived at Bell Creek (Figure 2), the tributary of Bell Creek (Figure 3), Rose Creek (Figure 4), and Cow Creek (Figure 5).

At Bell Creek, geometric means for "after" cattle fecal coliform concentrations were 13 and 14 times higher in 2014 and 2015 than 2016 "after" livestock were observed at sampling locations (Figure 2). Geometric means for "after" cattle *E. coli* concentrations were 17 times

higher in 2014 and in 2015 than 2016 “after” livestock were observed at sampling locations (Figure 2).

At the tributary to Bell Creek, geometric means for “after” cattle fecal coliform concentrations were 16 times higher in 2012 than 2016 “after” livestock were observed at sampling locations (Figure 3). Geometric means for “after” cattle *E. coli* concentrations were 14 times higher in 2012 than 2016 “after” livestock were observed at sampling locations (Figure 3).

Geometric means for “after” cattle fecal coliform and *E. coli* concentrations across sampling years were relatively similar at Rose Creek (Figure 4) and at Cow Creek (Figure 5).

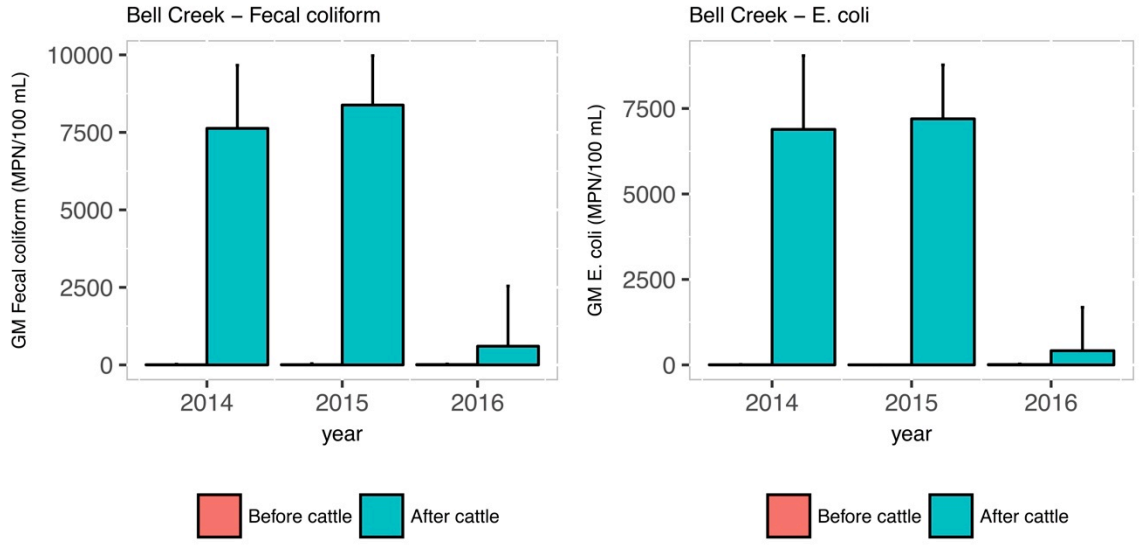

Figure 2. Geometric mean and standard error (error bars) fecal coliform (top) and *E. coli* (bottom) concentrations (MPN/100 mL) for Bell Creek (BC_MBM) “before” cattle (pink bars) and “after” cattle (blue bars) were observed at the sampling site during 2014, 2015, and 2016 sampling years.

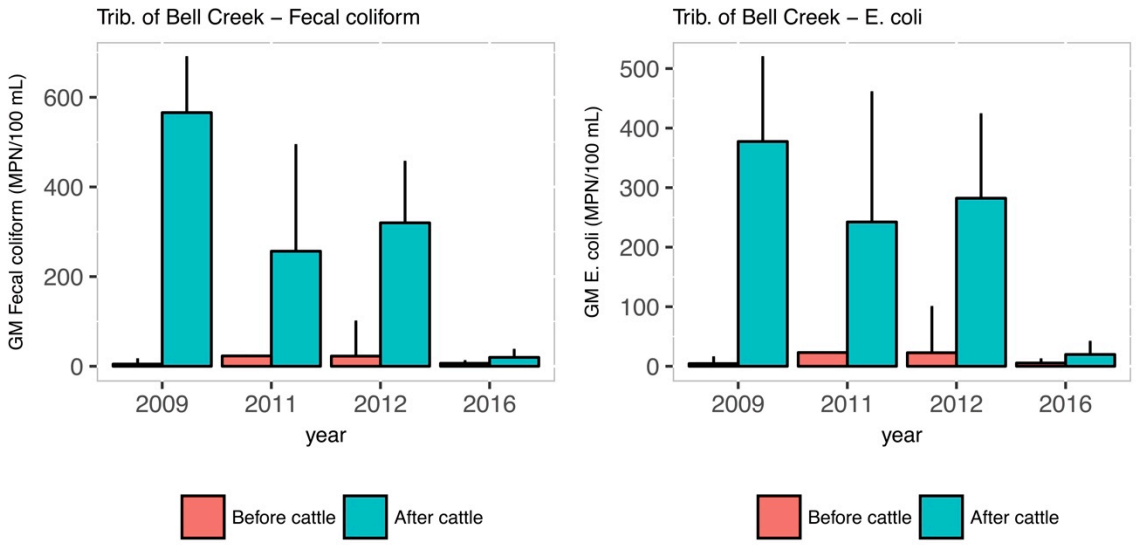

Figure 3. Geometric mean and standard error (error bars) fecal coliform (top) and *E. coli* (bottom) concentrations (MPN/100 mL) for the tributary of Bell Creek (TBC_LRM) "before" cattle (pink bars) and "after" cattle (blue bars) were observed at the sampling site during 2012 and 2016 sampling years.

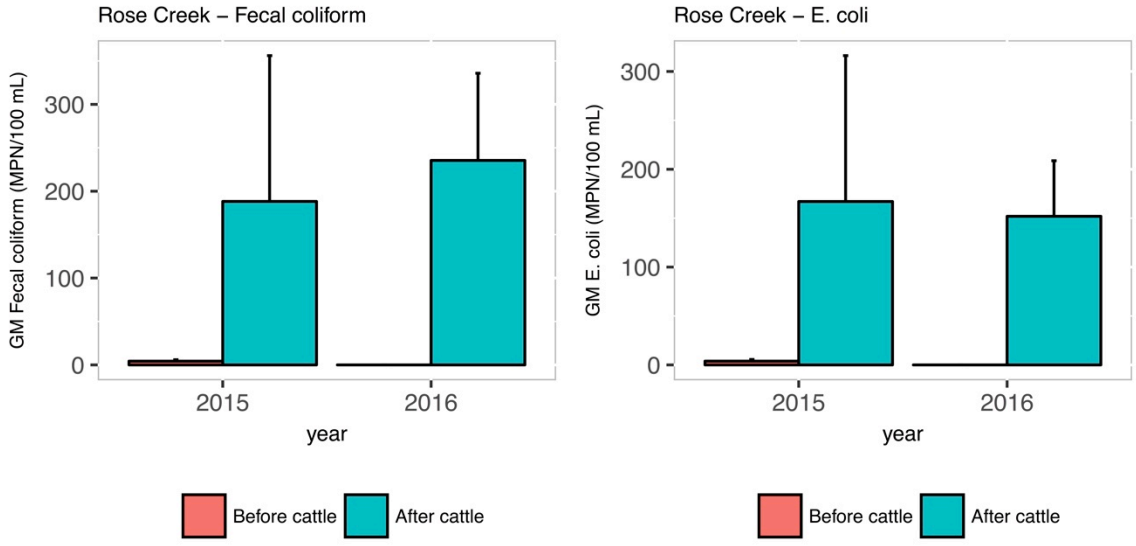

Figure 4. Geometric mean and standard error (error bars) fecal coliform (top) and *E. coli* (bottom) concentrations (MPN/100 mL) for Rose Creek (RC) "before" cattle (pink bars) and "after" cattle (blue bars) were observed at the sampling site during 2015 and 2016 sampling years.

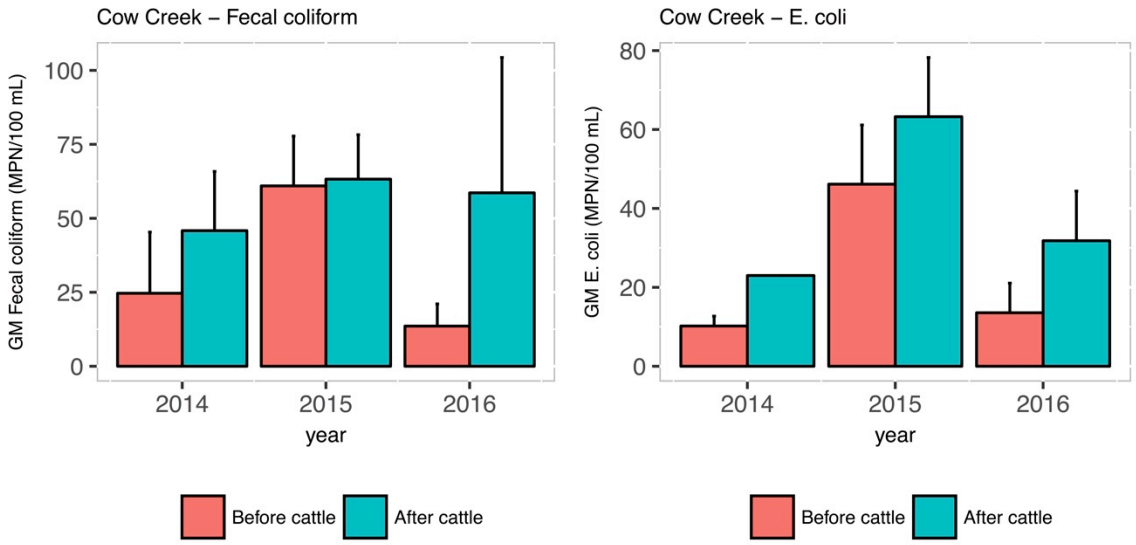

Figure 5. Geometric mean and standard error (error bars) fecal coliform concentrations (MPN/100 mL) for Cow Creek downstream of Bull Run Meadow (CC_BR) "before" cattle (pink bars) and "after" cattle (blue bars) were observed at the sampling site during 2014, 2015, and 2016 sampling years.

2016 Sample Violations of State and Federal Water Quality Standards

Below are tables that describe individual violations of state water quality standards for fecal coliform and violations of EPA recommendations for *E. coli* for each site sampled in 2016. The tables detail the corresponding samples used to calculate the geometric mean that represent a Type 1 Violation (fecal coliform- 200 MPN/100 mL; *E. coli*- 126 MPN/100 mL), or the corresponding samples used to determine a 10% total sample exceedance of 400 MPN/100 mL for fecal coliform or 410 MPN/100 mL for *E.coli* leading to a Type 2 Violation. Across all sites, there were 37 Type 1 and Type 2 violations of California's regulatory water quality standards for fecal coliform, and 22 Type 1 and Type 2 violations of the USEPA's recommended water quality standards for *E. coli*. Tables are organized by bacteria type and then site.

i. Fecal Coliform

Bell Creek (Middle Bell Meadow)

There were three Type 1 violations for fecal coliform documented for Bell Creek adjacent to Middle Bell Meadow during the following 30-day sampling periods: 8/19-9/19, 9/7-10/7, and 9/13-10/13. There were six Type 2 violations for fecal coliform including samples BC_MBM091316_01 and BC_MBM091316_02, and also sample BC_MBM091916_01 and sample BC_MBM093016_02 during two different 30-day sampling periods (9/13-10/13 and 9/19-10/19).

Violation #1: Fecal coliform (FC) Type 1 Violation
Site: Bell Creek (BC_MBM)
30-day sampling period: Aug. 19 - Sept. 19, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM090716_01	9/7/16	50
BC_MBM090716_02	9/7/16	50
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
Geo Mean		**286**

Violation #2: Fecal coliform (FC) Type 1 Violation
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 7 - Oct. 7, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM090716_01	9/7/16	50
BC_MBM090716_02	9/7/16	50
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	500
Geo Mean		**271**

Violation #3: Fecal coliform (FC) Type 1 Violation
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 - Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	500
BC_MBM101316_01	10/13/16	30
BC_MBM101316_01a	10/13/16	30
BC_MBM101316_02	10/13/16	80
Geo Mean		**217**

Violation #4: Fecal coliform (FC) Type 2 Violation - BC_MBM091316_01 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 – Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM**091316_01**	**9/13/16**	**1600***
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	500
BC_MBM101316_01	10/13/16	30

BC_MBM101316_01a	10/13/16	30
BC_MBM101316_02	10/13/16	80

Violation #5: Fecal coliform (FC) Type 2 Violation - BC_MBM091316_02 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 – Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	**9/13/16**	**>1600***
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	500
BC_MBM101316_01	10/13/16	30
BC_MBM101316_01a	10/13/16	30
BC_MBM101316_02	10/13/16	80

Violation #6: Fecal coliform (FC) Type 2 Violation - BC_MBM091916_01 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 – Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	**9/19/16**	**500***
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	500
BC_MBM101316_01	10/13/16	30
BC_MBM101316_01a	10/13/16	30
BC_MBM101316_02	10/13/16	80

Violation #7: Fecal coliform (FC) Type 2 Violation - BC_MBM093016_02 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 – Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	**9/30/16**	**500***
BC_MBM101316_01	10/13/16	30
BC_MBM101316_01a	10/13/16	30
BC_MBM101316_02	10/13/16	80

Violation #8: Fecal coliform (FC) Type 2 Violation - BC_MBM091916_01 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 19 – Oct. 19, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM091916_01	**9/19/16**	**500***
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170

BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	500
BC_MBM101316_01	10/13/16	30
BC_MBM101316_01a	10/13/16	30
BC_MBM101316_02	10/13/16	80

Violation #9: Fecal coliform (FC) Type 2 Violation – BC_MBM093016_02 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 19 – Oct. 19, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	170
BC_MBMB093016_01a	9/30/16	170
BC_MBM093016_02	**9/30/16**	**500***
BC_MBM101316_01	10/13/16	30
BC_MBM101316_01a	10/13/16	30
BC_MBM101316_02	10/13/16	80

Bell Creek Lower downstream of exclosure fence (Middle Bell Meadow)

There were four Type 1 violations for fecal coliform documented for Bell Creek Lower downstream of the fence adjacent to Middle Bell Meadow during the following 30-day sampling periods: 8/19-9/19, 8/30-9/30, 9/13-10/13, and 9/19-10/19. There were also seven Type 2 violations for fecal coliform including seven samples within the same 30-day period (9/13-10/13) including BC_MBM_L091316_01, BC_MBM_L091316_02, BC_MBM_L 091316_03, BC_MBM_L 091916_01, BC_MBM_L091916_02, BC_MBM_L093016_01, and BC_MBM_L093016_02.

Violation #10: Fecal coliform (FC) Type 1 Violation
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
Sampling dates: Aug. 19 - Sept. 19, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
	Geo Mean	**13,707**

Violation #11: Fecal coliform (FC) Type 1 Violation
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: **Aug. 30 – Sept. 30, 2016**

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
	Geo Mean	**6,479**

Violation #12: Fecal coliform (FC) Type 1 Violation

Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: **Sept. 13 - Oct. 13, 2016**

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80
	Geo Mean	**3,741**

Violation #13: Fecal coliform (FC) Type 1 Violation
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: **Sept. 19 - Oct. 19, 2016**

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80
	Geo Mean	**1,755**

Violation #14: Fecal coliform (FC) Type 2 Violation - BC_MBM_L091316_01 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	**9/13/16**	**>16,000***
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80

Violation #15: Fecal coliform (FC) Type 2 Violation - BC_MBM_L091316_02 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	**9/13/16**	**9,000***
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80

Violation #16: Fecal coliform (FC) Type 2 Violation - BC_MBM_L091316_03 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000

BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L**091316_03**	**9/13/16**	**>16,000***
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80

Violation #17: Fecal coliform (FC) Type 2 Violation - BC_MBM_L 091916_01 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	**9/19/16**	**7,000***
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80

Violation #18: Fecal coliform (FC) Type 2 Violation - BC_MBM_L 091916_02 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	**9/19/16**	**30,000***
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80

Violation #19: Fecal coliform (FC) Type 2 Violation - BC_MBM_L 093016_01 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000
BC_MBM_L093016_01	**9/30/16**	**1,100***
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	80

Violation #20: Fecal coliform (FC) Type 2 Violation - BC_MBM_L 093016_02 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	FC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	7,000
BC_MBM_L091916_02	9/19/16	30,000

BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	**9/30/16**	**900***
BC_MBM_L101316_01	10/13/16	80

Tributary of Bell Creek (Lower Round Meadow)

There were no Type 1 or Type 2 Violations for fecal coliform during the sampling period (6/10 – 8/9) at the tributary of Bell Creek. Once the site was moved into the mainstem Bell Creek, just downstream the confluence of the tributary of Bell Creek and Bell Creek, after the tributary was determined to have no observable flow, we still found no Type 1 or Type 2 Violations in the mainstem Bell Creek on 9/7 or 9/13.

Niagara Creek (Upper Barn Meadow)

There were no Type 1 violations found at Niagara Creek for fecal coliform. There were three Type 2 violations for fecal coliform including sample ID NC_BM_U080416_02 during three different 30-day sampling periods including 7/4-8/4, 7/26-8/26, and 8/4-9/4.

Violation #21: Fecal coliform (FC) Type 2 Violation – NC_BM_U080416_02 (* in table)
Site: Niagara Creek at Upper Barn Meadow (NC_BM_U)
30-day sampling period: July 4 – Aug. 4, 2016

Unique ID	Date	FC (MPN/100mL)
NC_BM_U070816_01	7/8/16	17
NC_BM_U070816_02	7/8/16	8
NC_BM_U072616_01	7/26/16	30
NC_BM_U072616_02	7/26/16	30
NC_BM_U080416_01	8/4/2016	240
NC_BM_U080416_02	**8/4/2016**	**500***
NC_BM_U080416_03	8/4/2016	80

Violation #22: Fecal coliform (FC) Type 2 Violation - NC_BM_U080416_02 (* in table)
Site: Niagara Creek at Upper Barn Meadow (NC_BM_U)
30-day sampling period: July 26 – Aug. 26, 2016

Unique ID	Date	FC (MPN/100mL)
NC_BM_U072616_01	7/26/16	30
NC_BM_U072616_02	7/26/16	30
NC_BM_U080416_01	8/4/2016	240
NC_BM_U080416_02	**8/4/2016**	**500***
NC_BM_U080416_03	8/4/2016	80
NC_BM_U080916_01	8/9/2016	23
NC_BM_U080916_02	8/9/2016	70

Violation #23: Fecal coliform (FC) Type 2 Violation - NC_BM_U080416_02 (* in table)
Site: Niagara Creek at Upper Barn Meadow (NC_BM_U)
30-day sampling period: Aug. 4 – Sept. 4, 2016

Unique ID	Date	FC (MPN/100mL)
NC_BM_U080416_01	8/4/2016	240
NC_BM_U080416_02	**8/4/2016**	**500***
NC_BM_U080416_03	8/4/2016	80
NC_BM_U080916_01	8/9/2016	23
NC_BM_U080916_02	8/9/2016	70

Cow Creek (Bull Run)

There was one Type 1 violation for fecal coliform at the Cow Creek site in 2016 during the following 30-day sampling period: 8/4-9/4. There were also six Type 2 violations for fecal coliform at Cow Creek including two samples CC_BR080416_01 and CC_BR080416_02 within three different 30-day sampling periods: 7/8-8/8, 7/26-8/26, and 8/4-9/4.

Violation #24: Fecal coliform (FC) Type 1 Violation
Site: Cow Creek downstream of Bull Run Meadow (CC_BR)
30-day sampling period: Aug. 4 – Sept. 4, 2016

Unique ID	Date	FC (MPN/100mL)
CC_BR080416_01	8/4/2016	500
CC_BR080416_02	8/4/2016	500
CC_BR080416_02a	8/4/2016	300
CC_BR080916_01	8/9/2016	80
CC_BR080916_02	8/9/2016	130
	Geo Mean	**239**

Violation #25: Fecal coliform (FC) Type 2 Violation – CC_BR080416_01 (* in table)
Site: Cow Creek downstream of Bull Run Meadow (CC_BR)
30-day sampling period: **July 8 – Aug. 8, 2016**

Unique ID	Date	FC (MPN/100mL)
CC_BR070816_01	7/8/16	50
CC_BR070816_02	7/8/16	130
CC_BR072616_01	7/26/16	23
CC_BR072616_02	7/26/16	50
CC_BR072616_02a	7/26/16	130
CC_BR080416_01	**8/4/2016**	**500***
CC_BR080416_02	8/4/2016	500
CC_BR080416_02a	8/4/2016	300

Violation #26: Fecal coliform (FC) Type 2 Violation – CC_BR080416_02 (* in table)
Site: Cow Creek downstream of Bull Run Meadow (CC_BR)
30-day sampling period: **July 8 – Aug. 8, 2016**

Unique ID	Date	FC (MPN/100mL)
CC_BR070816_01	7/8/16	50
CC_BR070816_02	7/8/16	130
CC_BR072616_01	7/26/16	23
CC_BR072616_02	7/26/16	50
CC_BR072616_02a	7/26/16	130
CC_BR080416_01	8/4/2016	500
CC_BR080416_02	**8/4/2016**	**500***
CC_BR080416_02a	8/4/2016	300

Violation #27: Fecal coliform (FC) Type 2 Violation – CC_BR080416_01 (* in table)
Site: Cow Creek downstream of Bull Run Meadow (CC_BR)
30-day sampling period: **July 26 – Aug. 26, 2016**

Unique ID	Date	FC (MPN/100mL)
CC_BR072616_01	7/26/16	23
CC_BR072616_02	7/26/16	50
CC_BR072616_02a	7/26/16	130
CC_BR080416_01	**8/4/2016**	**500***

CC_BR080416_02	8/4/2016	500
CC_BR080416_02a	8/4/2016	300
CC_BR080916_01	8/9/2016	80
CC_BR080916_02	8/9/2016	130

Violation #28: Fecal coliform (FC) Type 2 Violation – CC_BR080416_02 (* in table)
Site: Cow Creek downstream of Bull Run Meadow (CC_BR)
30-day sampling period: **July 26 – Aug. 26, 2016**

Unique ID	Date	FC (MPN/100mL)
CC_BR072616_01	7/26/16	23
CC_BR072616_02	7/26/16	50
CC_BR072616_02a	7/26/16	130
CC_BR080416_01	8/4/2016	500
CC_BR080416_02	**8/4/2016**	**500***
CC_BR080416_02a	8/4/2016	300
CC_BR080916_01	8/9/2016	80
CC_BR080916_02	8/9/2016	130

Violation #29: Fecal coliform (FC) Type 2 Violation – CC_BR080416_01 (* in table)
Site: Cow Creek downstream of Bull Run Meadow (CC_BR)
30-day sampling period: **Aug. 4 – Sept. 4, 2016**

Unique ID	Date	FC (MPN/100mL)
CC_BR080416_01	**8/4/2016**	**500***
CC_BR 080416_02	8/4/2016	500
CC_BR080416_02a	8/4/2016	300
CC_BR080916_01	8/9/2016	80
CC_BR080916_02	8/9/2016	130

Violation #30: Fecal coliform (FC) Type 2 Violation – CC_BR080416_02 (* in table)
Site: Cow Creek downstream of Bull Run Meadow (CC_BR)
30-day sampling period: **Aug. 4 – Sept. 4, 2016**

Unique ID	Date	FC (MPN/100mL)
CC_BR080416_01	8/4/2016	500
CC_BR080416_02	**8/4/2016**	**500***
CC_BR080416_02a	8/4/2016	300
CC_BR080916_01	8/9/2016	80
CC_BR080916_02	8/9/2016	130

Rose Creek

There were two Type 1 violations for fecal coliform documented for Rose Creek during the following 30-day sampling periods: 5/21-6/21 and 6/13-7/13. There were five Type 2 violations for fecal coliform including the three samples RC061316_01, RC061316_02, and RC071316_02 during the following 30-day sampling periods: 5/21-6/21 and 6/13-7/13.

Violation #31: Fecal coliform (FC) Type 1 Violation
Site: Rose Creek (RC)
30-day sampling period: May 21 – June 21, 2016

Unique ID	Date	FC (MPN/100mL)
RC061316_01	6/13/2016	900
RC061316_02	6/13/2016	900
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170

RC062116_03	6/21/2016	300
	Geo Mean	**397**

Violation #32: Fecal coliform (FC) Type 1 Violation
Site: Rose Creek (RC)
30-day sampling period: June 13 – July 13, 2016

Unique ID	Date	FC (MPN/100mL)
RC061316_01	6/13/2016	900
RC061316_02	6/13/2016	900
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	300
RC071316_01	7/13/2016	240
RC071316_02	7/13/2016	500
	Geo Mean	**382**

Violation #33: Fecal coliform (FC) Type 2 Violation – RC061316_01 (* in table)
Site: Rose Creek (RC)
30-day sampling period: **May 21 – June 21, 2016**

Unique ID	Date	FC (MPN/100mL)
RC061316_01	**6/13/2016**	**900***
RC061316_02	6/13/2016	900
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	300

Violation #34: Fecal coliform (FC) Type 2 Violation – RC061316_02 (* in table)
Site: Rose Creek (RC)
30-day sampling period: **May 21 – June 21, 2016**

Unique ID	Date	FC (MPN/100mL)
RC061316_01	6/13/2016	900
RC061316_02	**6/13/2016**	**900***
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	300

Violation #35: Fecal coliform (FC) Type 2 Violation – RC061316_01 (* in table)
Site: Rose Creek (RC)
30-day sampling period: June 13 – July 13, 2016

Unique ID	Date	FC (MPN/100mL)
RC061316_01	**6/13/2016**	**900***
RC061316_02	6/13/2016	900
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	300
RC071316_01	7/13/2016	240
RC071316_02	7/13/2016	500

Violation #36: Fecal coliform (FC) Type 2 Violation – RC061316_02 (* in table)
Site: Rose Creek (RC)
30-day sampling period: June 13 – July 13, 2016

Unique ID	Date	FC (MPN/100mL)
RC061316_01	6/13/2016	900
RC061316_02	**6/13/2016**	**900***

RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	300
RC071316_01	7/13/2016	240
RC071316_02	7/13/2016	500

Violation #37: Fecal coliform (FC) Type 2 Violation – RC071316_02 (* in table)
Site: Rose Creek (RC)
30-day sampling period: June 13 – July 13, 2016

Unique ID	Date	FC (MPN/100mL)
RC061316_01	6/13/2016	900
RC061316_02	6/13/2016	900
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	300
RC071316_01	7/13/2016	240
RC071316_02	**7/13/2016**	**500***

ii. *E. coli* Violations

Bell Creek (Middle Bell Meadow)

There were three Type 1 violations for *E. coli* documented for Bell Creek adjacent to Middle Bell Meadow during the following 30-day sampling periods: 8/19-9/19, 9/7-10/7, and 9/13-10/13. There were four Type 2 violations for *E. coli* including two samples: BC_MBM091316_01 and BC_MBM091316_02 during the 30-day sampling period 9/13-10/13, and sample BC_MBM091916_01 during two different 30-day sampling periods (9/13-10/13 and 9/19-10/19).

Violation #1: *E. coli* (EC) Type 1 Violation
Site: Bell Creek (BC_MBM)
30-day sampling period: Aug. 19 - Sept. 19, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM090716_01	9/7/16	30
BC_MBM090716_02	9/7/16	50
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
Geo Mean		**262**

Violation #2: *E. coli* (EC) Type 1 Violation
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 7 - Oct. 7, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM090716_01	9/7/16	30
BC_MBM090716_02	9/7/16	50
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	110
BC_MBM093016_01a	9/30/16	170

BC_MBM093016_02	9/30/16	300
	Geo Mean	**230**

Violation #3: *E. coli* (EC) Type 1 Violation
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 - Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	110
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	300
BC_MBM101316_01	10/13/16	17
BC_MBM101316_01a	10/13/16	23
BC_MBM101316_02	10/13/16	50
	Geo Mean	**173**

Violation #4: *E. coli* (EC) Type 2 Violation - BC_MBM091316_01 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 – Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM**091316_01**	**9/13/16**	**1600***
BC_MBM091316_02	9/13/16	>1600
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	110
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	300
BC_MBM101316_01	10/13/16	17
BC_MBM101316_01a	10/13/16	23
BC_MBM101316_02	10/13/16	50

Violation #5: *E. coli* (EC) Type 2 Violation - BC_MBM091316_02 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 – Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	**9/13/16**	**>1600***
BC_MBM091916_01	9/19/16	500
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	110
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	300
BC_MBM101316_01	10/13/16	17
BC_MBM101316_01a	10/13/16	23
BC_MBM101316_02	10/13/16	50

Violation #6: *E. coli* (EC) Type 2 Violation - BC_MBM091916_01 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 13 – Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM091316_01	9/13/16	1600
BC_MBM091316_02	9/13/16	>1600

BC_MBM091916_01	**9/19/16**	**500***
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	110
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	300
BC_MBM101316_01	10/13/16	17
BC_MBM101316_01a	10/13/16	23
BC_MBM101316_02	10/13/16	50

Violation #7: *E. coli* (EC) Type 2 Violation - BC_MBM091916_01 (* in table)
Site: Bell Creek (BC_MBM)
30-day sampling period: Sept. 19 – Oct. 19, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM091916_01	**9/19/16**	**500***
BC_MBM091916_02	9/19/16	170
BC_MBM093016_01	9/30/16	110
BC_MBM093016_01a	9/30/16	170
BC_MBM093016_02	9/30/16	300
BC_MBM101316_01	10/13/16	17
BC_MBM101316_01a	10/13/16	23
BC_MBM101316_02	10/13/16	50

Bell Creek Lower downstream of exclosure fence (Middle Bell Meadow)

There were four Type 1 violations for *E. coli* documented for Bell Creek Lower downstream of the fence adjacent to Middle Bell Meadow during the following 30-day sampling periods: 8/19-9/19, 8/30-9/30, 9/13-10/13, and 9/19-10/19. There were also seven Type 2 violations for *E. coli* including seven samples within the same 30-day period (9/13-10/13): BC_MBM_L091316_01, BC_MBM_L091316_02, BC_MBM_L 091316_03, BC_MBM_L 091916_01, BC_MBM_L091916_02, BC_MBM_L093016_01, and BC_MBM_L093016_02.

Violation #8: *E. coli* (EC) Type 1 Violation
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
Sampling dates: Aug. 19 - Sept. 19, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
	Geo Mean	**11,438**

Violation #9: *E. coli* (EC) Type 1 Violation
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: **Aug. 30 – Sept. 30, 2016**

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
	Geo Mean	**5,693**

Violation #10: *E. coli* (EC) Type 1 Violation
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: **Sept. 13 - Oct. 13, 2016**

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50
	Geo Mean	**3,150**

Violation #11: *E. coli* (EC) Type 1 Violation
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: **Sept. 19 - Oct. 19, 2016**

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50
	Geo Mean	**1,333**

Violation #12: *E. coli* (EC) Type 2 Violation - BC_MBM_L091316_01 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	**9/13/16**	**>16,000***
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50

Violation #13: *E. coli* (EC) Type 2 Violation - BC_MBM_L091316_02 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	**9/13/16**	**9,000***
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50

Violation #14: *E. coli* (EC) Type 2 Violation - BC_MBM_L091316_03 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L**091316_03**	**9/13/16**	**>16,000***
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50

Violation #15: *E. coli* (EC) Type 2 Violation - BC_MBM_L 091916_01 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	**9/19/16**	**5,000***
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50

Violation #16: *E. coli* (EC) Type 2 Violation - BC_MBM_L 091916_02 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	**9/19/16**	**17,000***
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50

Violation #17: *E. coli* (EC) Type 2 Violation - BC_MBM_L 093016_01 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000
BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	**9/30/16**	**1,100***
BC_MBM_L093016_02	9/30/16	900
BC_MBM_L101316_01	10/13/16	50

Violation #18: *E. coli* (EC) Type 2 Violation - BC_MBM_L 093016_02 (* in table)
Site: Bell Creek downstream of exclosure fence (BC_MBM_L)
30-day sampling period: Sept. 13-Oct. 13, 2016

Unique ID	Date	EC (MPN/100mL)
BC_MBM_L091316_01	9/13/16	>16,000
BC_MBM_L091316_02	9/13/16	9,000
BC_MBM_L091316_03	9/13/16	>16,000

BC_MBM_L091916_01	9/19/16	5,000
BC_MBM_L091916_02	9/19/16	17,000
BC_MBM_L093016_01	9/30/16	1,100
BC_MBM_L093016_02	**9/30/16**	**900***
BC_MBM_L101316_01	10/13/16	50

Tributary of Bell Creek (Lower Round Meadow)

There were no Type 1 or Type 2 Violations for *E. coli* at the tributary of Bell Creek during the 2016 sampling period (6/10 – 8/9). Once we moved the site into the mainstem Bell Creek, just downstream the confluence of Trib. of Bell Creek and Bell Creek, after the tributary was determined to have no observable flow we still found no Type 1 or Type 2 Violations in the mainstem Bell Creek on 9/7 or 9/13.

Niagara Creek (Upper Barn Meadow)

There were no Type 1 or Type 2 violations for *E. coli* at the sampling site on Niagara Creek for the 2016 sampling season (6/30-8/9).

Cow Creek (Bull Run Meadow)

There were no Type 1 or Type 2 violations for *E. coli* at the sampling site on Cow Creek for the 2016 sampling season (6/30-8/9).

Rose Creek

There were two Type 1 violations for *E. coli* documented for Rose Creek during the following 30-day sampling periods: 5/21-6/21 and 6/13-7/13. There were two Type 2 violations for *E. coli* from the sample RC061316_01 during the two 30-day sampling periods: 5/21-6/21 and 6/13-7/13.

Violation #19: *E. coli* (EC) Type 1 Violation
Site: Rose Creek (RC)
30-day sampling period: May 21 – June 21, 2016

Unique ID	Date	EC (MPN/100mL)
RC061316_01	6/13/2016	900
RC061316_02	6/13/2016	300
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	110
	Geo Mean	**261**

Violation #20: *E. coli* (EC) Type 1 Violation
Site: Rose Creek (RC)
30-day sampling period: June 13 – July 13, 2016

Unique ID	Date	EC (MPN/100mL)
RC061316_01	6/13/2016	900
RC061316_02	6/13/2016	300
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170

RC062116_03	6/21/2016	110
RC071316_01	7/13/2016	240
RC071316_02	7/13/2016	300
	Geo Mean	**257**

Violation #21: *E. coli* (EC) Type 2 Violation – RC061316_01 (* in table)
Site: Rose Creek (RC)
30-day sampling period: **May 21 – June 21, 2016**

Unique ID	Date	EC (MPN/100mL)
RC061316_01	**6/13/2016**	**900***
RC061316_02	6/13/2016	300
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	110

Violation #22: *E. coli* (EC) Type 2 Violation – RC061316_01 (* in table)
Site: Rose Creek (RC)
30-day sampling period: June 13 – July 13, 2016

Unique ID	Date	EC (MPN/100mL)
RC061316_01	**6/13/2016**	**900***
RC061316_02	6/13/2016	300
RC062116_01	6/21/2016	240
RC062116_02	6/21/2016	170
RC062116_03	6/21/2016	110
RC071316_01	7/13/2016	240
RC071316_02	7/13/2016	300

Conclusion

The results of the 2016 stream water sampling for indicator bacteria (*E. coli* and fecal coliform) demonstrate instances of continued pollution of surface waters in sampled forest streams. The overlap of cattle presence with increased levels of contamination of indicator bacteria in test samples suggests that the presence of cattle (as currently permitted and regulated on National Forest System lands for summer grazing) may be a significant contributor to instream pollution. **After eight years of collecting stream water samples throughout the Stanislaus Forest, the results remain consistent. Concentrations of fecal coliform and *E. coli* in streams within national forest lands test consistently far below state and federal exceedance levels when cattle are absent from sampling locations. Once cattle are present at sampling sites, the test results show that fecal coliform and *E. coli* concentrations often increase and remain elevated during the time period that cattle are present in the sampling area.**

Across all sites sampled in 2016, average fecal coliform and *E. coli* concentrations were determined to be orders of magnitude higher once cattle arrived, compared to average concentrations before cattle arrived. In addition, test results also revealed a relationship between increasing fecal coliform and *E. coli* concentrations with the presence of fresh livestock disturbance (e.g., fresh cattle manure, sloughing, pocking) and relative flow in the sampled streams.

Although there were violations, comparing bacteria concentrations across sampling years did demonstrate that mean (geometric) fecal coliform and *E. coli* concentrations were lower at some sites in 2016 compared to previous sampling years, specifically at Bell Creek (BC_MBM) and at the tributary of Bell Creek (TBC_LRM). Relative flows were similar among sampling years at these sites at similar times of sampling (relative flow was low from Aug.-Oct. in 2014, 2015, and 2016 at Bell Creek, and was low from mid July on at tributary to Bell Creek). Therefore relative flows do not explain the differences in bacteria concentrations during the "after" cattle periods between sampling years. However, since the study was not able to quantify cattle densities at the sites during the sampling seasons it is difficult to determine if the variation in bacterial concentrations across years was due to changes in livestock management or if variation was due other environmental factors (e.g., water year type, seasonal rainfall events, etc.) that may have varied across the sampling years.

The results for the 2016 summer season include 10 Type 1 and 27 Type 2 violations of California's regulatory water quality standards for fecal coliform bacteria, and 9 Type 1 and 13 Type 2 violations of the USEPA's recommended water quality standards for *E. coli* in Bell Creek, Cow Creek, Niagara Creek, and Rose Creek. If the previous EPA (1986) standards for *E. coli* of 235 CFU/100 mL were used in this report, there would have been 8 additional *E. coli* violations in Bell Creek and Rose Creek that are not shown in the violation tables in the Results section of this report.

The 59 combined state and federal violations in 2016, in addition to CSERC's previous water quality sampling efforts conducted in the summers of 2009-2015, provide persistent evidence of the failure of Best Management Practices (BMPs) to consistently produce results that comply with state water quality standards. This most recent sampling year further documents that BMPs as currently applied by the Stanislaus Forest range managers are not meeting water quality objectives in some livestock-affected streams in a manner consistent with state water quality standards. This study also documents that, even with implementation of BMPs, concentrations of fecal coliform and *E. coli* are still in violation of state and/or recommended federal standards in sampled streams, and may be at least in part due to the presence of livestock as currently regulated and permitted on National Forest System lands.

Livestock grazing in the sampled areas are not unlike practices throughout the STF and other public lands where livestock grazing occurs in the Sierra Nevada. Previous studies have demonstrated that livestock grazing is related to elevated concentrations of stream pathogenic bacterial concentrations on Sierra Nevada forest lands and national parks (Derlet et al. 2006, 2008, 2012; Myers and coauthors 2011, 2012). The findings from the 2016 sampling period, findings from CSERC's previous years of sampling, and peer-reviewed literature (see above) demonstrate the need for consideration of: (1) appropriate changes in permitted livestock grazing management policies in order to eliminate or reduce contamination of surface waters; (2) increased water quality monitoring of high-use livestock sites where prolonged or concentrated presence of cattle increases the potential for violations of water quality standards; and (3) removal of livestock from known areas where current livestock management techniques (such as fencing and herding) have not resulted in compliance with water quality standards (Derlet et al. 2008).

This is the eighth year of detecting elevated fecal coliform and *E. coli* concentrations in streams within national forest grazing allotment areas that are also used by varying numbers of recreational visitors. One consideration for reducing the risk of exposing those recreational visitors (swimmers, hikers, campers, backpackers) to pathogens or indicators of pathogens in national forest water is to evaluate where the areas with the highest levels of recreational use occur within each national forest. Keeping livestock out of those high-use recreational areas would appear to be one effective strategy to avoid, in those specific areas, exposure by recreational visitors to stream water that fails to meet State and federal standards for recreational contact and public health.

References

California Department of Water Resources (DWR). 2016. Water Conditions. http://www.water.ca.gov/waterconditions/waterconditions.cfm

California Regional Water Quality Control Board (CRWQCB). 2016. Water Quality Control Plan for the Sacramento and San Joaquin River Basins. 4th edition. California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA.

Derlet, R.W. and J.R. Carlson. 2006. Coliform bacteria in Sierra Nevada wilderness lakes and streams: What is the impact of backpackers, pack animals, and cattle? Wilderness and Environmental Medicine, 17: 15-20.

Derlet, R.W., K.A. Ger, J.R. Richards, and J.R. Carlson. 2008. Risk Factors for Coliform Bacteria in Backcountry Lakes and Streams in the Sierra Nevada Mountains: A 5-Year Study. Wilderness and Environmental Medicine, 19:82-90.

Derlet, R. W., J. R. Richards, L. L. Tanaka, C. Hayden, K. A. Ger, and C. R. Goldman. 2012. Impact of summer cattle grazing on the Sierra Nevada watershed: Aquatic algae and bacteria. Journal of Environmental and Public Health, 2012: 1-7.

Myers, L. and J. Kane. 2011. The impact of summer cattle grazing on surface water quality in high elevation mountain meadows. Water Quality Exposure and Health, 3: 51-62.

Myers, L. and B. Whited. 2012. The impact of cattle grazing in high elevation Sierra Nevada mountain meadows over widely variable annual climatic conditions. Journal of Environmental Protection, 3:823-837.

United States Environmental Protection Agency (USEPA). 1986. Quality criteria for water: 1986. Washington, D.C.: US Environmental Protection Agency Office of Water Regulations and Standards. 477 p.

United States Environmental Protection Agency (USEPA). 2012. Recreational Water Quality Criteria. Office of Water EPA 820-F-12-058.