Cattle Creek
Stream Health Evaluation

ROARING FORK CONSERVANCY

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Definition of Terms

CDPHE: Colorado Department of Public Health and Environment

CFS: Cubic Feet per Second

CPW: Colorado Parks and Wildlife

CWA: Clean Water Act

EPA: Environmental Protection Agency

HUC: Hydrologic Unit Code

MMI: Multi-metric Index

M&E: Monitoring and Evaluation

QAQC: Quality Assurance and Quality Control

RFC: Roaring Fork Conservancy

TMDL: Total Maximum Daily Load

TVS: Table Value Standard

USFS: United States Forest Service

USGS: United States Geological Survey

WQCC: Water Quality Control Commission

WQCD: Water Quality Control Division

WQS: Water Quality Standard

WRNF: White River National Forest

Cattle Creek 2015 Stream Health Evaluation

Summary

The 14.5-mile segment of Cattle Creek between Bowers Gulch to the confluence with the Roaring Fork River is listed on Colorado's Regulation 93 *303(d) list of impaired waters* due to observed impacts to aquatic macroinvertebrate communities. Roaring Fork Conservancy (RFC) implemented water quality monitoring in 2015 with the support of Garfield County and other stakeholders in order to understand potential sources of impairment. Within a reasonable timeframe, Colorado Department of Public Health and Environment, with input from stakeholders, must make determinations on causes of stream impairments and develop a plan to address water quality issues. Monitoring in 2015 produced targeted data suitable for use in state-level regulatory proceedings.

Water chemistry sampling in Cattle Creek at 7 sites indicates increased levels of nutrients, bacteria, and total dissolved solids in the lower watershed sites. A small number of total phosphorus observations exceeded interim aquatic life standards. E. coli levels frequently exceeded recreational contact standards at multiple sites. Macroinvertebrate sampling indicates increased levels of stress and disturbance at downstream sites relative to upstream sites. Land use analysis identifies gradients of land use change that correlate with water quality findings. The upper reaches of the Cattle Creek watershed are largely undeveloped and forested, producing excellent water quality. A gradient of increasing impacts from irrigated rangeland/pasture and ranching activities occurs in the middle watershed. Increasing nutrient and bacteria levels most likely link to impacts from cattle and ranching activities. Near-stream development including light-density residential units and limited irrigation of pasture impact stream reaches in the lower watershed. Near Cattle Creek's mouth, commercial development and Highway 82 influence the creek.

Analyses of estimated septic system density at the watershed and sub-reach scales show a correlation between nitrate levels and septic tank density, indicating a potential human component to nutrient issues. However, the nested nature of sites and overall small number of data points reduces the statistical strength of these relationships.

Although riparian conditions and flow stress from significant trans-basin diversions to the Missouri Heights area are suspected to play a role in the stream health conditions of Cattle Creek, those factors were beyond the scope of monitoring. Altered or degraded riparian conditions from near-stream livestock activities or residential development may alter food webs, reduce the ability of natural vegetation to attenuate sediment and nutrient impacts from surface runoff, and overall provide less cover and habitat complexity for aquatic life.

Continued chemistry and macroinvertebrate monitoring will add depth, reliability, and increased statistical power to the dataset for Cattle Creek. Exploration of additional factors such as flow stress and fish communities may also shed additional light on stream impairments. Roaring Fork Conservancy plans to continue Cattle Creek monitoring in 2016.

1 Introduction

1.1 Purpose and Objectives

Cattle Creek, a tributary to the Roaring Fork River, is a water quality concern for Garfield County, Roaring Fork Conservancy (RFC) and other stakeholders. The 14.5-mile segment of Cattle Creek between Bowers Gulch to the confluence with the Roaring Fork River is listed on Colorado's Regulation 93 *303(d) list of impaired waters* due to observed impacts to aquatic macroinvertebrate communities. RFC implemented water quality monitoring efforts in 2015 in order to understand potential sources of impairment.

The Cattle Creek water quality monitoring program seeks to provide high-level insight into sources of water quality impairment with the following objectives:

- Collect and analyze water quality data including physical parameters, nutrients, and pathogens;
- Collect and analyze benthic macroinvertebrate samples to expand the geographic and temporal knowledge on impairment conditions;
- Compare chemistry results to applicable water quality standards;
- Collect data in a manner that meets or exceeds the state's credible data criteria; and
- Identify potential linkages between watershed land use and stream conditions.

This report details the results and initial interpretations of the first year of a multi-year data collection effort, including comparison of chemical parameters to applicable instream standards, site-by-site water quality profiles, macroinvertebrate results, and a high-level analysis of watershed land use characteristics that may impact instream conditions. Additional discussion and recommendations for ongoing monitoring are provided.

1.2 Watershed Background

Cattle Creek drains an 88 square mile watershed with elevations ranging from 11,500' in the east on Red Table Mountain to 5,940' at the mouth. The annual hydrologic cycle is snowmelt-driven, with high flows in May-June, limited high flow pulses during the summer monsoon cycle, and low base flows throughout fall and winter. USGS operated a gage at site 09084000 near Bowers Gulch from 1950 to 1972 that characterized seasonal flow patterns and basin yield for the upper half of the watershed (Figure 1). This location is near the USFS boundary, above several important tributaries like Coulter Creek. While it represents the general characteristics of the creek's annual flow regime; it does not represent typical flow conditions or full-watershed yields at the creek's outlet point. Parties interested in more detailed physical, hydrological, or biological information concerning Cattle Creek watershed are encouraged to consult additional local sources such as RFC's 2008 State of the Roaring Fork Watershed (Clarke et. al., 2008) or the Aspen-Sopris Ranger District of the White River National Forest.

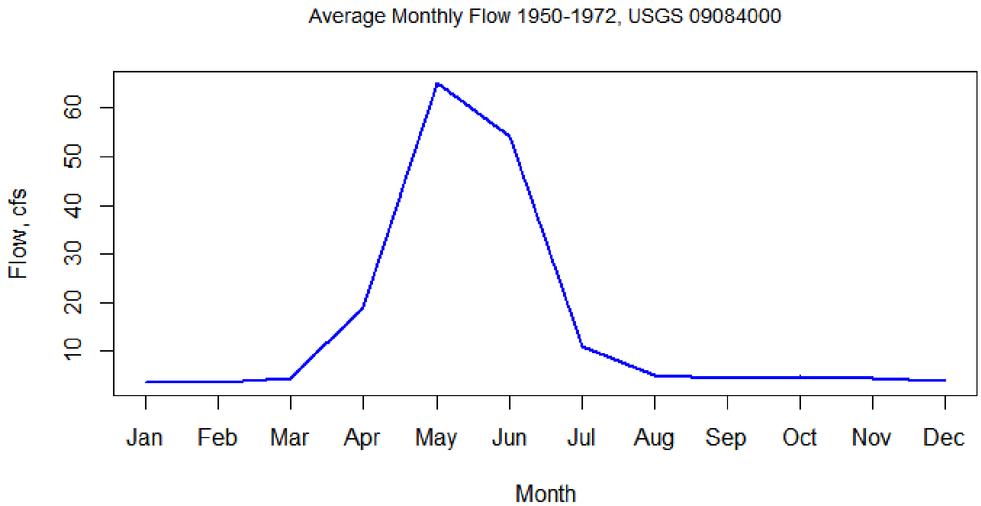


Figure 1. Annual Hydrograph

Surficial watershed geology consists of extensive coverage by sedimentary and carbonate units of the Eagle Valley Formation, the Eagle Valley Evaporite, Maroon Formation, and numerous others. Additional areal coverage by more recent basalt flows form an upland cap in portions of the basin. Quaternary landslide deposits and alluvium make up the near-stream corridor, especially in the lower canyon sections between Coulter Creek and the mouth (Kirkham and Widham, 2008). Surficial outcrops of the Eagle Valley Formation and Eagle Valley Evaporite in the area are often loosely consolidated or erosive, generating high levels of sediment and dissolved solids in the region's streams. Cattle Creek watershed is semi-arid, with precipitation levels increasing proportionately at higher elevations in the eastern watershed. Scrub forest dominating the lower western reaches, transitioning to aspen and mixed conifer forests in the higher elevations to the east.

1.2.1 Water Rights and Diversions

The Colorado Division of Water Resources Hydrobase online database reports 40 ditches and associated water rights on Cattle Creek. Five ditches with senior rights, each over 10 cfs, divert the majority of water. These diversions are transbasin to the south and feed the Spring Park reservoir or other irrigated lands in the Missouri Heights area. Return flows accrue directly to the Roaring Fork River rather than back to Cattle Creek.

Table 1. Major Water Rights

Ditch	Decreed Absolute Right, cfs	Average diversions 2009-2013, af
Mountain Meadow	53	2523
Needham	27.2	1923
Park	16.9	616
C and M	14	827
Monarch	10	174

1.2.2 Land Use and Land Cover

Land cover in the upper watershed is forested, with rangeland dominating the middle and lower portions. Below Coulter Creek, the stream steepens and enters a narrower canyon segment. A narrow alluvial valley opens in the last several miles, and scattered small ranch properties, residences, and a small commercial/industrial area occupy the bottomlands near the creek. Most of the land is unincorporated Eagle and Garfield Counties. Publicly supplied water and sewer services only occur near the mouth; most residents on Cattle Creek utilize individual septic systems. The two counties maintain little data on septic in the region, including precise location information, date of installation, type, or leach field soils. Data on riparian conditions is sparse, anecdotal evidence from site visits suggests that on many properties riparian cover is altered or compromised, especially by livestock use and residential property management.

2 Methods

2.1 Data Quality Objectives

To ensure all data is publicly available and admissible in regulatory proceedings, Cattle Creek monitoring sought to meet or exceed WQCD's Credible Evidence guidelines provided in Section III.B of the 303(d) Listing Methodology (CDPHE, 2015). Requirements include use of generally recognized collection methods to obtain representative data, metadata documentation on field and lab methods, precise geospatial information for sampling locations, and the presence and adherence to a documented sampling and analysis plan.

Field personnel measured discharge manually using the velocity-area method described in *USGS Techniques and Methods 3-A8* with a Sontek Flowtracker Handheld Acoustic Doppler velocimeter. RFC collected grab samples using methodologies based on techniques described in *USGS National Field Manual for The Collection of Water-Quality Data*. Containers were labeled with unique IDs, the date, sample location, and time of sample collection, and kept cold in an ice cooler. At the end of each collection day, RFC hand delivered samples to local labs or shipped overnight to labs in refrigerated packaging using chain of custody documentation.

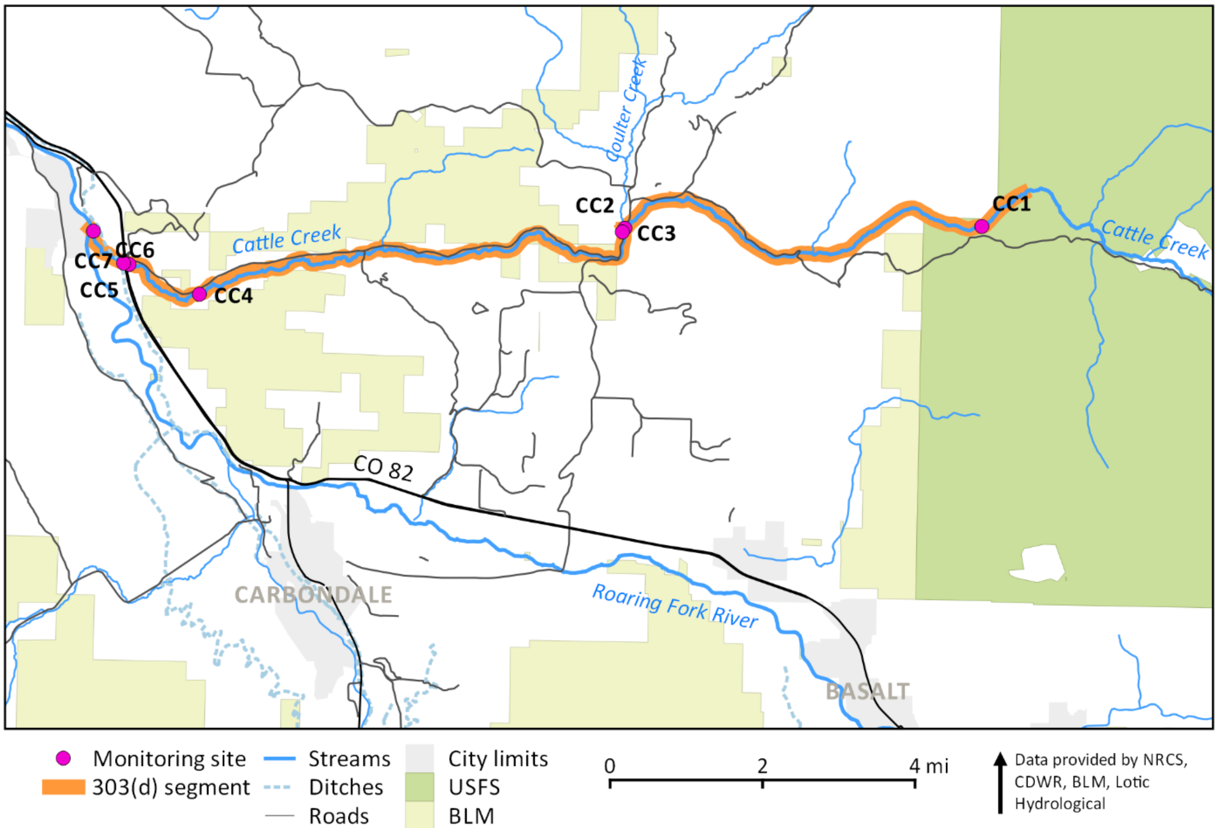
RFC Staff collects flow measurements on Cattle

2.2 Site Information

Table 2. Site Location Descriptions

Site ID	Description	Purpose	Latitude	Longitude
CC1	Cattle Creek at national forest boundary	Reference/baseline conditions	39.46637	-107.05266
CC2	Cattle Creek above confluence with Coulter Creek	Bracket Coulter Creek, capture upper watershed ranching influences	39.46484	-107.14022
CC3	Cattle Creek below confluence with Coulter Creek	Bracket Coulter Creek influence	39.46414	-107.14080
CC4	Cattle Creek at 1164 Hwy 113	Captures majority of upstream range use and agricultural properties	39.45081	-107.24426
CC5	Cattle Creek above Hwy 82	Bracket commercial/industrial land uses and major road-related impacts	39.45621	-107.26164
CC6	Cattle Creek at Rio Grande Trail Bridge	Bracket Hwy. 82	39.45644	-107.26301
CC7	Cattle Creek above confluence with Roaring Fork	Downstream integration of watershed influences	39.46240	-107.27055

Figure 2. Site location map



2.3 Field Data Collection and Sample Handling

RFC staff collected grab samples on four separate events in April, June, July, and September to coincide with hydrograph ascension, peak, recession, and base flows respectively. Single grab collection occurred at the centroid of flow. Complete mixing at each site was assumed based on Cattle Creek's narrow width and generally steep gradients, coupled with on-site verification using a field meter transect during monitoring events. For chemistry samples, staff used lab-prepared bottle kits from ACZ laboratories of Steamboat Springs and Snowmass Water and Sanitation District of Snowmass Village with pre-filled preservatives for nutrient parameters and labeled the samples with unique IDs date, location, and time of collection. Once collected, the samples were chilled and shipped to ACZ by end of field day or delivered directly to Snowmass Water and Sanitation District for pathogen analysis.

RFC collected field parameters including pH, specific conductance, temperature, and dissolved oxygen in-situ using a YSI Professional Plus multi-parameter meter that was calibrated to manufacturer recommendations prior to each field event. Field parameters were measured using methodologies based on techniques described in *USGS National Field Manual for The Collection of Water-Quality Data* and recorded for each site in the meter's internal storage then later transferred to individual site data sheets and electronic storage.

2.4 Analysis

ACZ Laboratories in Steamboat Springs analyzed chemistry samples for nutrients including nitrate, nitrite, and phosphorus. Snowmass Water and Sanitation District performed E. coli and total coliforms analysis at its wastewater treatment facility lab. Table 3 reports analytical techniques for monitoring parameters on Cattle Creek.

Table 3. Monitoring Parameter List

Parameter	Analysis	Units	Method	MDL
Discharge	Field meter	cfs		NA
pH		s.u.		0.01
Temperature		C		0.01
Dissolved Oxygen		mg/l		0.01
Specific Conductance		µS/cm		10
Nitrate (NO3) as N	ACZ Labs	mg/l	EPA 353.2 Automated Colorimetric	0.02
Nitrite (NO2) as N		mg/l	Calculation	0.01
Nitrate + Nitrite		mg/l	EPA 353.2 Automated Colorimetric	0.01
Total phosphorus		mg/l	365.1 - Auto Ascorbic Acid digest	0.01
E. coli	Snowmass WSD	Col/100ml	EPA 1605 Membrane filtration	1
Coliform		Col/100ml	EPA 1605 Membrane filtration	1

2.5 Land Use Analysis

Lotic obtained National Land Use/Land Cover datasets (NLCD) from USGS online repositories (Homer et. al, 2015, Xian et al. 2015). Limited information on septic location for Garfield and Eagle Counties was available via the county GIS or planning departments. Instead, Lotic generated a proxy dataset for septic systems from county parcel datasets. Using QGIS and ArcMap GIS software, Lotic delineated subwatershed aerial polygons above each sampling site as well as 100-foot stream buffer areas above each site on Cattle Creek and tributaries. Each subwatershed and stream buffer segment was summarized by land use categories in attempt to understand potential differences in drivers of water quality conditions at each instream site.

Individual septic/sewage disposal systems (ISDS) are common in rural and low density residential areas in Colorado, but can be sources of nutrient pollution to groundwater and streams. Nitrogen forms like nitrate and ammonia, and phosphorus forms like orthophosphate, are sometimes poorly removed even by current septic designs (Mueller and Spahr, 2006). Due to low county capacity for design and location oversight in the past, many older septic sites in Garfield and Eagle County may be constructed in either poorly- or overly-drained soils, too close to alluvial water tables, or otherwise be improperly or poorly constructed—all factors that may increase the likelihood of impacts to nearby streams.

Spatial data on septic locations and construction type are incomplete in both Garfield and Eagle County, especially for homes developed prior to recent years. Lotic used parcel datasets as a surrogate to estimate septic density in the Cattle Creek watershed, with the assumption of one ISDS per parcel. A 1:1 ratio underestimates the total number and density since larger parcels with more than one residence, or ranch facilities with ISDS systems at service buildings, are likely to have more than one ISDS. In the context of insufficient data, this represents a conservative approach to septic density estimation.

Septic density was estimated at two spatial scales: near-stream and watershed-wide. Using QGIS software, a 100-foot buffer was created around the mainstem of Cattle Creek and major perennial streams such as Coulter Creek. EPA identifies 100 feet as an important riparian zone width for attenuating non-point water quality influences including nutrients (USEPA, 2005). This analysis estimated *near-stream septic density* as the sum of parcels intersecting this buffer, a conservative approach considering that many home sites may be well-removed from near-stream zones. Similarly, *watershed-wide septic density* was estimated as the sum of parcels intersecting each of the seven subwatersheds delineated above monitoring sites.

Linear models relating septic densities to observed concentrations of nutrients and bacteria attempt to preliminarily identify what relationships may exist between development, agricultural land uses, and water quality observations. Small observation totals, the limited spatial extent of sample sites, and the 'nested' nature inherent to subwatersheds on a single stream, all contribute to limiting the statistical power of these linear models and difficulty in separating out cumulative downstream trends from individual land uses.

3 Results and Discussion

3.1 Descriptive Statistics

Monitoring results indicate Cattle Creek experiences elevated nutrients in downstream reaches during early summer, and elevated bacteria levels throughout summer. Chemistry and bacteria monitoring showed elevated total phosphorus at the lower 3 sites in June, and high bacteria levels throughout early and mid-summer at many sites (Tables 4-10, Figures 3, 4). Phosphorus exceeded interim WQCD aquatic life standards at CC5 and CC6 in June during runoff. E. coli counts exceed state standards for contact recreation at all sites in July and the 5 most-downstream sites in June. Nitrate levels increased both pre-runoff in April and post-runoff during July and September.

These results should not be construed as legal designations of stream impairment for these parameters. Standards comparison is provided as context to understanding how Cattle Creek conditions relate to regulatory benchmarks. Additional criteria regarding the number of samples and time period of results aggregation must be met for most parameters before WQCD considers one or more standard exceedances to define impairment. Due to the limited number of samples available at each site during the first year of monitoring, the maximum sample value for all parameters is compared directly to any applicable WQCD chronic standard. WQCD typically uses the 85th percentile value, or the median aggregated over designated time periods, to represent the ambient water quality for assessing standards. As more data accumulates for Cattle Creek, those approaches will become the most appropriate for standards analyses. WQCD assesses total phosphorus and total nitrogen as the annual median value not to exceed 0.110 mg/l and 1.250 mg/l respectively. Without ammonia concentrations, total nitrogen cannot be calculated. E. coli standards are calculated using a 60-day geometric mean. This could only be calculated for the June and July samples. Sites CC3-CC5 all recorded exceedances for both of these months can be assumed to exceed the regulatory benchmark. CC1 and CC2 only exceeded the standard in July. Using the 2-month geometric mean, CC2 would still exceed the standard for those summer months.

Table 4. CC1 Results

Site:	CC1	CC in National Forest									
Parameter	Units	Apr	Jun	Jul	Sep	Mean	Min	Max	Chr std	Ac std	Exceedance
Flow	cfs	17.8	111	16.4	4.5	37.4	4.5	111	--	--	--
Temperature	Celsius	4.1	10.1	11.8	7.9	8.5	4.1	11.8	17.0/9.0	21.3/13.0	
pH	s.u.	8.29	8.07	8.43	7.75	8.1	7.75	8.43	6.5-9	--	
Dissolved Oxygen	mg/l	10.2	9.3	8.4	8.8	9.2	8.4	10.2	7	--	
Specific Conductance	µS/cm	247	187	306	300	260	187	306	500	--	
Nitrate as N	mg/l	0	0	0	0	0.0	0	0.00	--	--	--
Nitrate + Nitrite	mg/l	0	0	0	0	0.0	0	0.00	--	--	--
Nitrite as N	mg/l	0	0	0	0	0.0	0	0.00	0.05	--	
Total Phosphorus	mg/l	0.01	0.04	0.02	0.02	0.02	0.01	0.04	0.11	--	
E. coli	col/100ml	1	4	145	26	44	1	145	126	--	Yes
Coliform	col/100ml	108	76	980	548	428	75.7	980	--	--	--

Table 5. CC2 Results

Site:	CC2	CC above Coulter Creek									
Parameter	Units	Apr	Jun	Jul	Sep	Mean	Min	Max	Chr std	Ac std	Exceedance
Flow	cfs	2.9	20.5	4.1	2.6	7.5	2.6	20.5	--	--	--
Temperature	Celsius	5.4	9.1	13	11.6	9.8	5.4	13.0	17.0/9.0	21.3/13.0	
pH	s.u.	8.19	8.09	7.88	8.21	8.1	7.88	8.21	6.5-9	--	
Dissolved Oxygen	mg/l	10.8	10.1	7.8	10.1	9.7	7.8	10.8	7	--	
Specific Conductance	µS/cm	519	244	439	460	416	244	519	--	--	--
Nitrate as N	mg/l	0.19	0.03	0.18	0.12	0.1	0.03	0.19	--	--	--
Nitrate + Nitrite	mg/l	0.19	0.03	0.18	0.12	0.1	0.03	0.19	--	--	--
Nitrite as N	mg/l	0	0	0	0	0.0	0	0.00	0.05	--	
Total Phosphorus	mg/l	0.02	0.05	0.04	0.03	0.04	0.02	0.05	0.11	--	
E. coli	col/100ml	15	55	345	44	114	15	345	126	--	Yes
Coliform	col/100ml	214	727	>2420	1733	1273	214	>2420	--	--	--

Table 6. CC3 Results

Site:	CC3	CC below Coulter Creek									
Parameter	Units	Apr	Jun	Jul	Sep	Mean	Min	Max	Chr std	Ac std	Exceedance
Flow	cfs	7.5	27.7	8.3	7.2	12.7	7.2	27.7	--	--	--
Temperature	Celsius	9.4	14.9	13.7	8.6	11.7	8.6	14.9	17.0/9.0	21.3/13.0	
pH	s.u.	8.45	8.33	7.92	7.86	8.1	7.86	8.45	6.5-9	--	
Dissolved Oxygen	mg/l	10.3	8.2	8.4	9.5	9.1	8.2	10.3	7	--	
Specific Conductance	µS/cm	419	274	439	412	386	274	439	--	--	--
Nitrate as N	mg/l	0.27	0.04	0.08	0.14	0.1	0.04	0.27	--	--	--
Nitrate + Nitrite	mg/l	0.27	0.04	0.08	0.14	0.1	0.04	0.27	--	--	--
Nitrite as N	mg/l	0	0	0	0	0.0	0	0.00	0.05	--	
Total Phosphorus	mg/l	0.05	0.07	0.08	0.04	0.06	0.04	0.08	0.11	--	
E. coli	col/100ml	1	194	345	76	154	1	344	126	--	Yes
Coliform	col/100ml	137	770	>2420	>2420	1437	137	>2419	--	--	--

Table 7. CC4 Results

Site:	CC4	CC at 1168 CR 113									
Parameter	Units	Apr	Jun	Jul	Sep	Mean	Min	Max	Chr std	Ac std	Exceedance
Flow	cfs	9.6	18.7	1.9	1.8	8.0	1.8	18.7	--	--	--
Temperature	Celsius	10.1	13.7	17.3	10.2	12.8	10.1	17.30	17.0/9.0	21.3/13.0	
pH	s.u.	8.61	8.43	8.47	8.29	8.5	8.29	8.61	6.5-9	--	
Dissolved Oxygen	mg/l	10.3	8.9	8.9	9.9	9.5	8.9	10.30	7	--	
Specific Conductance	µS/cm	450	342	526	549	467	342	549	--	--	
Nitrate as N	mg/l	0.23	0.09	0.17	0.22	0.2	0.09	0.23	--	--	--
Nitrate + Nitrite	mg/l	0.23	0.09	0.17	0.22	0.2	0.09	0.23	--	--	--
Nitrite as N	mg/l	0	0	0	0	0.0	0	0.00	0.05	--	
Total Phosphorus	mg/l	0.03	0.1	0.03	0.03	0.05	0.03	0.10	0.11	--	
E. coli	col/100ml	4	488	461	84	259	4	488	126	--	Yes
Coliform	col/100ml	64	>2420	>2420	517	1355	64	>2420	--	--	--

Table 8. CC5 Results

Site:	CC5	CC above Highway 82									
Parameter	Units	Apr	Jun	Jul	Sep	Mean	Min	Max	Chr std	Ac std	Exceedance
Flow	cfs	10.4	20.0	2.8	3.0	9.1	2.8	20.0	--	--	--
Temperature	Celsius	8.5	12.6	13.7	11.3	11.5	8.5	13.7	17.0/9.0	21.3/13.0	
pH	s.u.	8.43	8.13	7.75	7.8	8.0	7.75	8.43	6.5-9	--	
Dissolved Oxygen	mg/l	10.2	9.2	10	9.1	9.6	9.1	10.2	7	--	
Specific Conductance	µS/cm	491	400	717	705	578	400	717	--	--	
Nitrate as N	mg/l	0.24	0.13	0.26	0.24	0.2	0.13	0.26	--	--	--
Nitrate + Nitrite	mg/l	0.24	0.13	0.26	0.24	0.2	0.13	0.26	--	--	--
Nitrite as N	mg/l	0	0	0	0	0.0	0	0.00	0.05	--	
Total Phosphorus	mg/l	0.02	0.12	0.02	0.03	0.05	0.02	0.12	0.11	--	Yes
E. coli	col/100ml	4.1	387	304	117.8	203	4.1	387.30	126	--	Yes
Coliform	col/100ml	65.7	>2419	>2419	2419	1831	65.7	>2419	--	--	--

Table 9. CC6 Results

Site:	CC6	CC below Highway 82									
Parameter	Units	Apr	Jun	Jul	Sep	Mean	Min	Max	Chr std	Ac std	Exceedance
Flow	cfs	10.39	20.02	2.8	3.03	9.1	2.8	20.02	--	--	--
Temperature	Celsius	8.1	11.9	13.5	9.4	10.7	8.1	13.50	17.0/9.0	21.3/13.0	
pH	s.u.	8.36	8.13	7.72	7.64	8.0	7.64	8.36	6.5-9	--	
Dissolved Oxygen	mg/l	10.2	9.3	9.7	8.5	9.4	8.5	10.20	7	--	
Specific Conductance	µS/cm	497	404	719	698	580	404	719	--	--	
Nitrate as N	mg/l	0.26	0.14	0.26	0.25	0.2	0.14	0.26	--	--	--
Nitrate + Nitrite	mg/l	0.26	0.14	0.26	0.25	0.2	0.14	0.26	--	--	--
Nitrite as N	mg/l	0	0	0	0	0.0	0	0.00	0.05	--	
Total Phosphorus	mg/l	0.02	0.12	0.02	0.04	0.05	0.02	0.12	0.11	--	Yes
E. coli	col/100ml	8.6	488	313	139	237	8.6	488	126	--	Yes
Coliform	col/100ml	90.8	>2419	>2419	>2419	1837	90.8	>2419	--	--	--

Table 10. CC7 Results

Site:	CC7	CC at mouth									
Parameter	Units	Apr	Jun	Jul	Sep	Mean	Min	Max	Chr std	Ac std	Exceedance
Flow	cfs	9.53	23.74	3.18	9.3	11.4	3.18	23.74	--	--	--
Temperature	Celsius	7.6	10.4	13.5	11.2	10.7	7.6	13.50	17.0/9.0	21.3/13.0	
pH	s.u.	8.39	8.01	7.7	7.91	8.0	7.7	8.39	6.5-9	--	
Dissolved Oxygen	mg/l	11	9.6	10.9	9.4	10.2	9.4	11.00		--	
Specific Conductance	µS/cm	496	296	270	380	361	270	496	--	--	
Nitrate as N	mg/l	0.22	0.09	0.06	0.06	0.1	0.06	0.22	--	--	--
Nitrate + Nitrite	mg/l	0.22	0.09	0.06	0.06	0.1	0.06	0.22	--	--	--
Nitrite as N	mg/l	0	0	0	0	0.0	0	0.00	0.05	--	
Total Phosphorus	mg/l	0.02	0.08	0.02	0.02	0.04	0.02	0.08	0.11	--	
E. coli	col/100ml	3.1	410	275	48.7	184	3.1	410	126	--	Yes
Coliform	col/100ml	48.1	1986	1986	1732	1438	48.1	1986	--	--	--

3.2 Longitudinal Parameter Profiles

Longitudinal (upstream-downstream) profiles provide understanding of how parameters vary between sites and land-uses. Each profile contains four lines representing the 2016 sampling dates. In addition to geographic variations, the profiles provide an evaluation of seasonal variability in parameter levels. Although monitoring attempts to capture representative conditions, multiple factors may impact any given sampling event including daily weather, short-term variations in streamflow, and localized site influences and disturbances. Notable patterns include higher phosphorus concentrations in June, higher bacteria levels in mid-summer, and a larger increase in Specific Conductance from upstream to downstream sites (Figures 3 and 4).

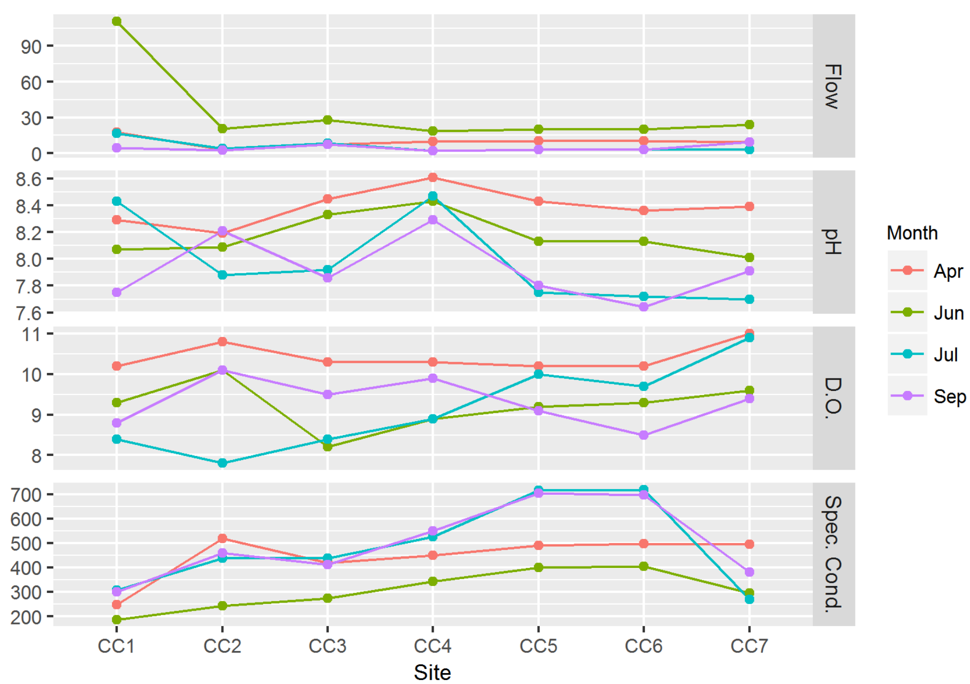


Figure 3. Field parameter profiles (flow, cfs; pH, s.u.; DO, mg/l; Specific Conductance µS/cm).

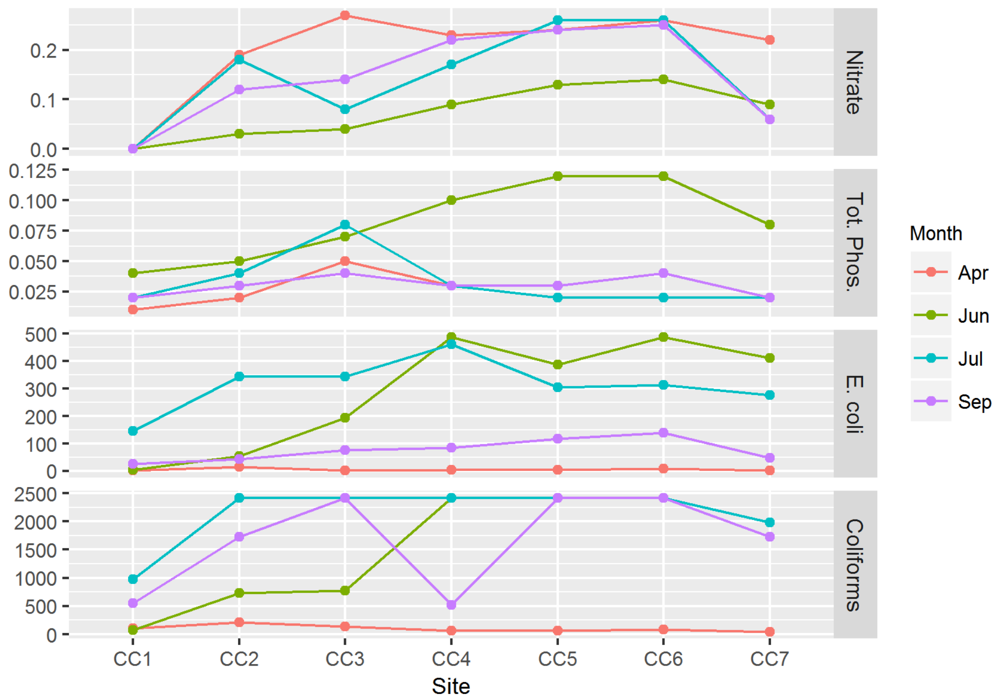


Figure 4. Nutrient and bacteria profiles (nutrients, mg/l; bacterial, colonies/100 ml)

3.3 Load

Instream load is the mass of a pollutant or natural constituent transported downstream over time. Regulators typically use load as a measure of the total amount of pollutant carried by the stream system. Load is calculated by the product of the measured concentrations and streamflow, with appropriate unit conversions; it is often reported in pounds per day for stream assessments. Figure 5 reports load for selected nutrient parameters and total dissolved solids (TDS).

Although TDS was not directly measured, it is estimated by RFC's field meter using Specific Conductance values as a proxy variable; it is included in the raw datasets but not in the summary tables earlier in this section. TDS estimates provide context to understand what segments of the creek are carrying a relatively heavier load of dissolved solids, and thus potentially more pollutants such as nutrients. Dissolved solids levels are strongly driven by background soil and geologic sources that produce major ions and anions like calcium, magnesium, sodium, potassium, bicarbonate, chloride, and sulfate. Trace elements and other anions like nitrates may also affect levels. Land management practices that increase erosion, or apply large amounts of chemicals to the land surface, may increase the measurable signal of dissolved solids in the stream.

The highest loading to Cattle Creek for most parameters occurred in June during runoff, when large discharge volumes are capable of carrying more materials overall in solution and suspension. The significant drop between CC1 and CC2 evident in the June profiles is due to the large amount of water diverted between these two sites via the Mountain Meadow, Needham, C and M, Park, and Monarch ditches.

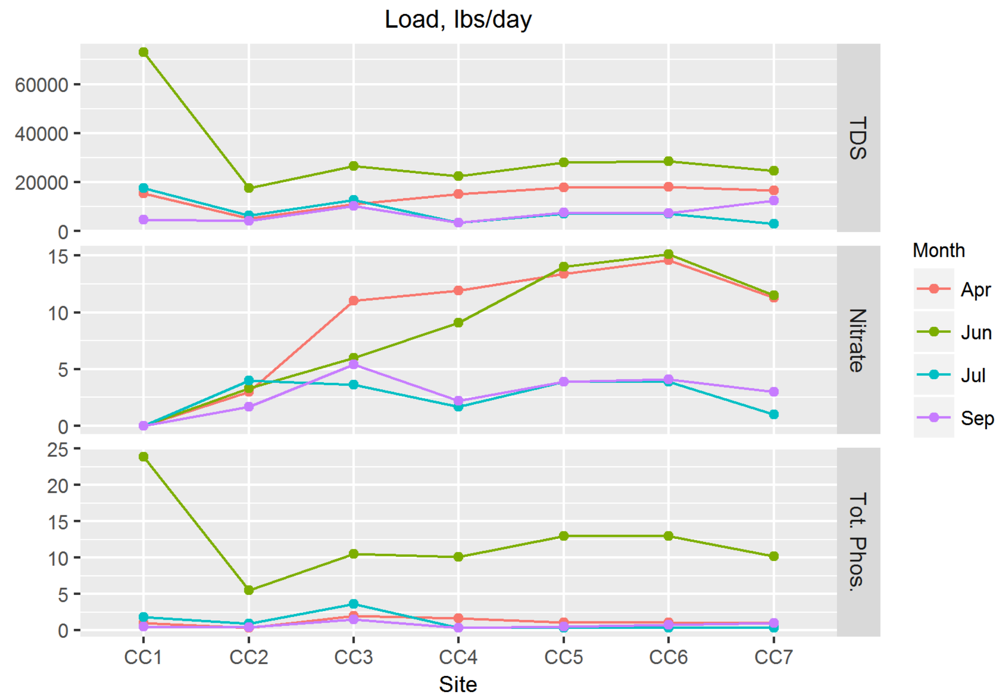


Figure 5. Load Profiles

3.4 Seasonal Boxplots

Boxplots provide a quick visual assessment to understand general relationships between sampling results for each season. The lower and upper extents of the vertical bars signify the sample minimums and maximums respectively. The top and bottom the horizontal box locate the 25th and 75th percentiles of data results, and the center line represents the median value. Due to the relatively low number of samples available at each site after one monitoring season, the quantiles are estimated by R statistical software. Outliers are determined by a software procedure and are signified by detached points. For all sites, several patterns are apparent (Figures 6 and 7). In the spring, pH is slightly more basic because runoff is likely influenced strongly by the sedimentary and carbonate soils and watershed geology. Overall conductivity levels are lowest during runoff, when increased flow dilutes dissolved concentrations of many parameters. Nutrients show variable patterns; increased total phosphorus at all sites tracks closely with runoff while nitrates are high later in the summer. Bacteria levels at all sites are also higher in mid-summer and early fall.

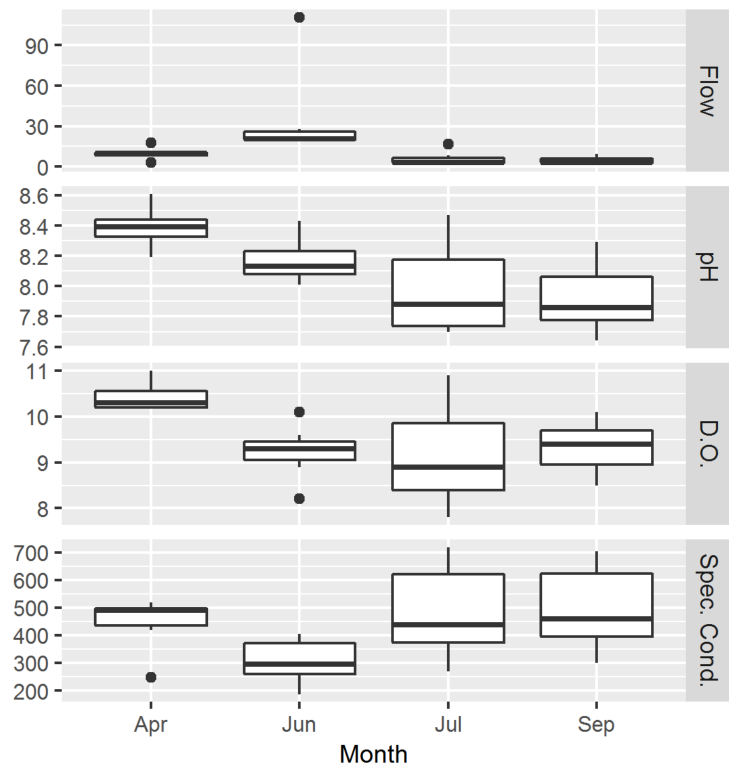


Figure 6 Seasonal Boxplots, Field Parameters (flow, cfs; pH, su; DO, mg/l; specific conductance, µs/cm)

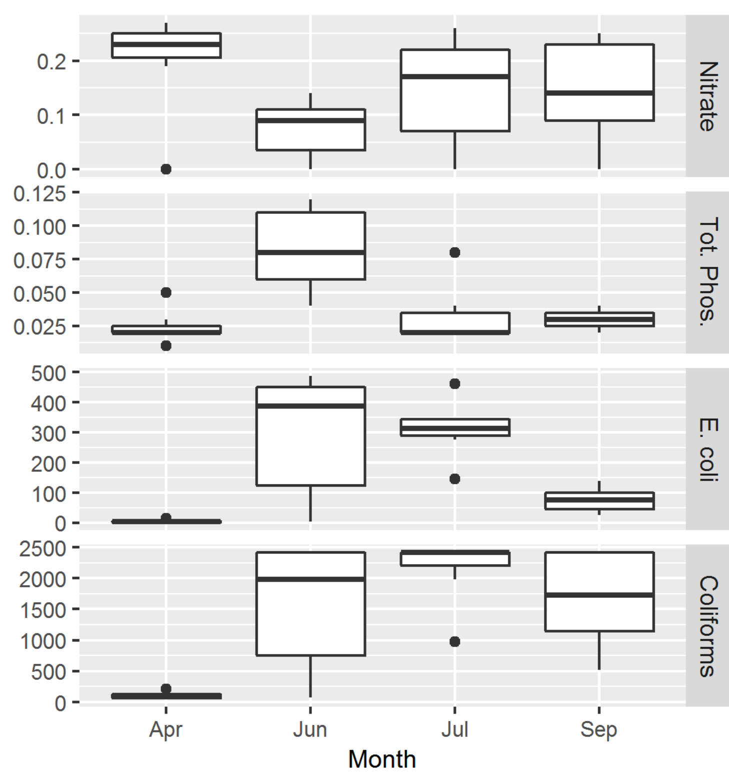


Figure 7. Seasonal Profiles, Nutrients (mg/l) and Bacteria (colonies/100ml)

3.5 Macroinvertebrate Conditions

Timberline Aquatics conducted an in-depth analysis of results including additional species metrics; results and interpretations are compiled in Appendix 1, summary information is provided here.

Biomonitoring covered an extended geographic range compared to previous data collection occurring only at CC6, downstream of the Highway 82 culvert. WQCD provides guidance for standards assessment in *Policy 10-1 Aquatic life use attainment*. Values for use-attainment status and impaired status are 52 and 42, respectively, for Biotype 1 (Transition) sites, which includes all Cattle Creek monitoring locations. Scores falling between these two thresholds are considered *grey zone* and require two auxiliary metrics to determine a final status. These metrics are the Hilsenhoff Biotic Index (HBI) and the Shannon Diversity Index (Shannon). If either the HBI > 5.4 or the Shannon < 2.4, the site is impaired.

Cattle Creek MMI scores exhibited a range of variability, with several attaining sites, several impaired, and multiple sites falling initially in the grey zone (Table 11). Scores from the reference site indicated healthy stream communities above the USFS boundary. A decline at the next site showed impacted conditions above Coulter Creek. CC2 scored initially in the grey zone and received impaired status due to the HBI metric, which was slightly above the cutoff at 5.46. Field staff noted the potential for beaver dams and backwater habitat characteristics to influence this site, and the high HBI may indicate some nutrient impacts. Scores rebound below Coulter Creek at CC3 and CC4. After initial grey zone status, auxiliary metric evaluation moved CC5 to impaired status and CC6 to attaining. CC7, at the watershed mouth, scored as impaired without any auxiliary evaluation.

Poor HBI scores are associated with potential nutrient and organic enrichment. Although Cattle Creek sites did not register on the absolute high end of HBI ranges (approaching 10), scores were still slightly but consistently higher at the lower sites. This parallels higher observations of nitrogen and phosphorus parameters in the grab samples. Chemistry samples at CC4 show a similar potential for nutrient and bacteria issues as the next three sites downstream. CC4 is also subject to potential flow impairment issues occurring between the Park Ditch and CC6. Good substrate habitat and food inputs from the more-consistently intact riparian vegetation of the sub-segment between CC3 and CC4 may account for the stronger score. Because CC7 occurs in an area observed to have reasonably good or recovering instream substrate, channel form, and riparian conditions, it is likely that water quality and/or quantity are the primary drivers of poor conditions there rather than physical or habitat factors.

Table 11. MMI Results

Site	MMI	HBI	Shannon	Status
RFC-CC1	63.9	4.87	3.70	Attain
RFC-CC1 rep	54.5	4.80	3.59	Attain
RFC-CC2	43.6	5.46	2.76	Impair
RFC-CC3	51.2	4.37	3.07	Attain
RFC-CC4	62.5	4.60	2.92	Attain
RFC-CC5	43.5	5.60	3.66	Impair
RFC-CC6	43.1	5.12	3.14	Attain
RFC-CC7	41.7	5.44	3.20	Impair

All sites in the study area show signs of aquatic life impacts, however disturbances at the lower sites were greater. An overall pattern of increasing stress in the downstream direction is present. The exception at the upper sites (CC1-CC3) is site CC2, which may have lower scores partially explained by the presence of nearby beaver dams and backwater effects. The MMI test is designed primarily to compare representative macroinvertebrate communities in similar riffle habitats. Habitat quality may be an important driver of some of the variability in MMI scores on Cattle Creek. Lower watershed site scores displayed a decrease in the prevalence of both sensitive taxa and specialized taxa (Figure 3, lower panel). Scores at the lower three sites consistently indicate increased stress and disturbance relative to the upper sites.

Glenwood Ditch mixing with Cattle Creek below CC6 Photo: Jack Dysart

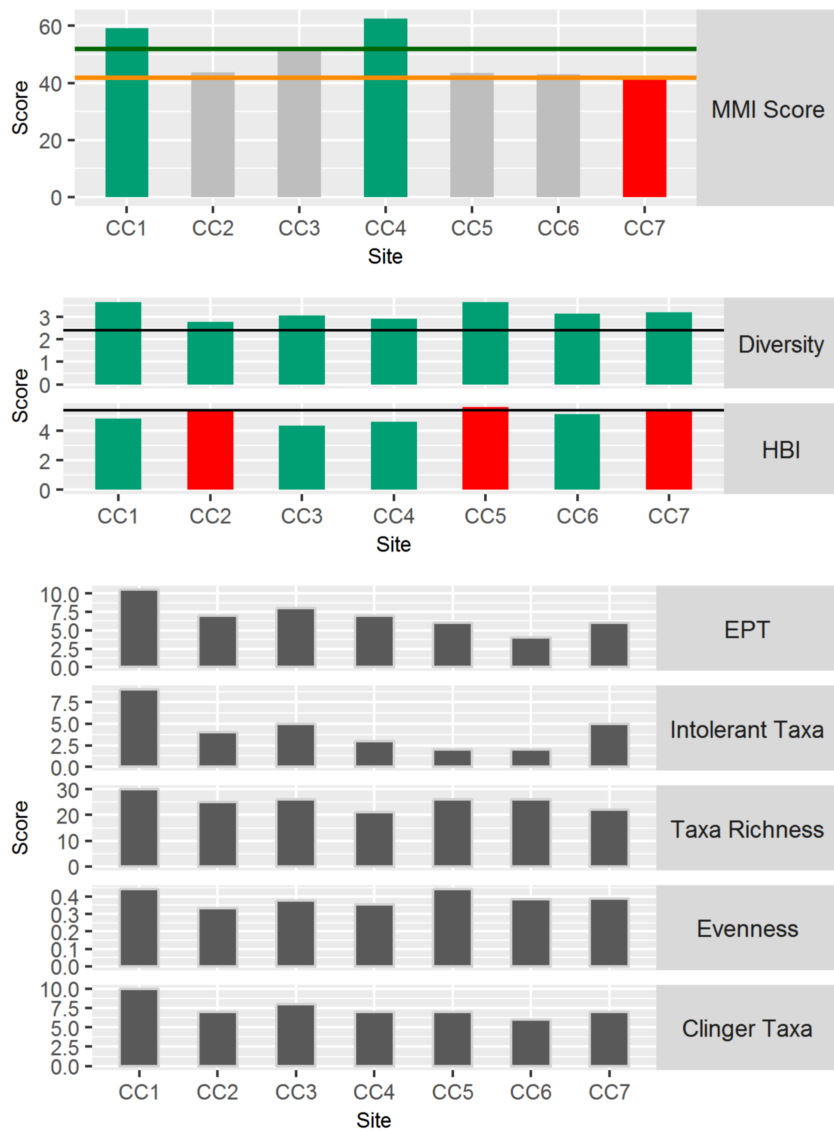


Figure 8. Macroinvertebrate Community Metrics by Site.

Top panel: MMI scores with attain/impair lines (green/orange). Middle panel: auxiliary metrics with attain/impair lines; Shannon Diversity scores must be *above* the line, HBI scores must be *below* the line. Lower panel: additional indices. For top two panels, attaining scores are *green*, impaired scores are *red.* The site CC1 score in all panels is the average score of the first sample and replicate sample, both scores attained standards prior averaging.

3.6 Land Use Analysis

3.6.1 Land Use and Land Cover Summary

Cattle Creek watershed is primarily undeveloped or lightly developed, with forest and range land comprising the dominant cover type (Figure 8, Table 12). CC1 is located near the USFS boundary, the subwatershed above this site is almost entirely evergreen and mixed deciduous forest. Although seasonal grazing is likely in this area and may provide a limited source of nutrient load or riparian degradation, the forested land cover contributes to good water quality and natural, healthy instream habitat conditions. The highest MMI score at CC1 reflect these factors.

Moving downstream, land cover shifts to scrub and rangeland, dryland ranching, and irrigated pasture/hay in the subwatersheds above CC2 and CC3. Ranching and increased residential influences are evident in water sampling at these sites, with increasing concentrations of nutrients, bacteria, and dissolved solids. Based on RFC staff field observations, riparian conditions at many of the near-stream ranch operations experience some level of alteration or degradation due to livestock use or other near-stream management practices.

As Cattle Creek steepens and enters a narrower valley below CC3, upland land cover again shifts to forest although in this case the predominant type is pinion-juniper and available precipitation and soil moisture in the uplands is likely much reduced compared to the upstream sites. A small buffer of riparian wetlands borders the stream below CC3 and alternates in the valley's bottom with small irrigated acreages and non-agricultural residential parcels. Although the grid cell resolution of the National Land Cover dataset is too coarse to identify County Route 113, this road still represents a significant amount of near-stream impervious surface that is likely to generate water quality influences including increased fine sediment and salinity from road treatments and runoff.

The lowest three sites occur in areas of increasing impervious surfaces from residential, commercial, industrial, and highway development. Although not a significant percentage of land cover, the proximity to Cattle Creek and poor riparian condition contribute combined impacts to the stream. After the relatively intact zone of riparian buffers below CC3, riparian alteration or destruction begins to increase in frequency nearing Highway 82. In the watershed overall, forested and shrub/scrub land covers comprise the largest land area, with smaller but significant amounts of grasslands and cultivated pasture (Table 12).

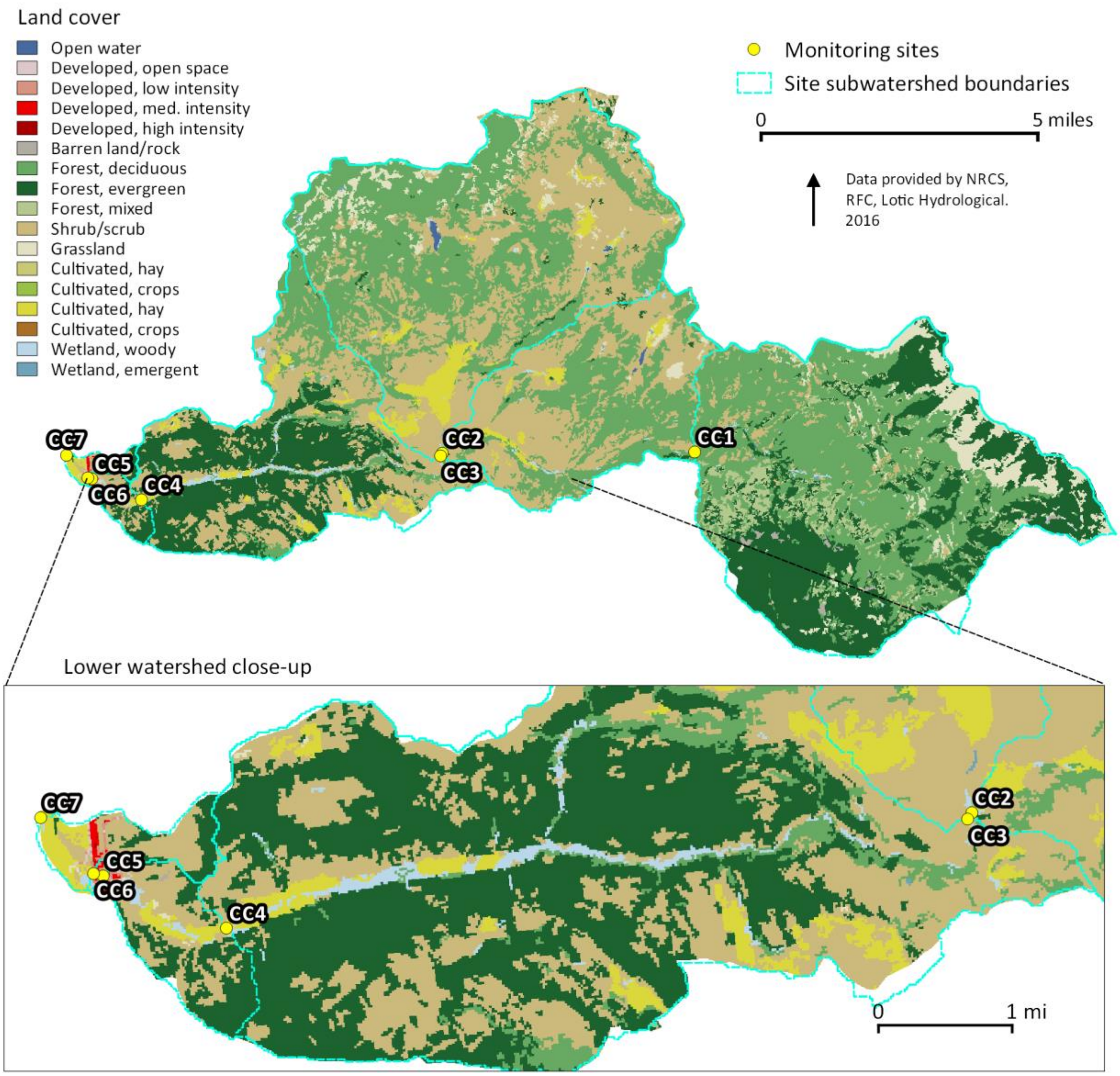


Figure 9. Land Use and Land Cover Map with Site Subwatershed Boundaries

Table 12. Land Use Summary

Type	Open water	Developed, open space	Developed, low density	Developed, med. density	Developed, high density	Barren land	Forest, deciduous	Forest, evergreen	Forest, mixed	Shrub/scrub	Herbaceous, grassland	Cultivated, hay/pasture	Cultivated, crops	Wetlands, woody	Wetlands, emergent	Cumulative square miles, subwatershed
CC1	0.00	0.00	0.00	0.00	0.00	0.18	12.7	11.1	2.40	1.01	2.77	0.00	0.00	0.07	0.01	30.4
CC2	0.02	0.00	0.00	0.00	0.00	0.18	18.0	11.2	2.41	7.42	2.95	0.43	0.00	0.16	0.02	42.9
CC3	0.09	0.00	0.00	0.00	0.00	0.18	31.4	11.4	2.45	18.1	4.42	1.69	0.00	0.23	0.05	70.1
CC4	0.09	0.00	0.00	0.00	0.00	0.18	33.8	18.1	2.46	24.1	4.44	2.47	0.00	0.56	0.05	86.4
CC5	0.09	0.01	0.01	0.00	0.00	0.18	33.8	18.5	2.46	24.4	4.45	2.53	0.00	0.59	0.05	87.2
CC6	0.09	0.01	0.02	0.01	0.00	0.18	33.8	18.5	2.46	24.4	4.45	2.53	0.00	0.59	0.05	87.3
CC7	0.09	0.02	0.03	0.03	0.00	0.18	33.8	18.6	2.46	24.7	4.46	2.64	0.00	0.60	0.05	87.8
Total square miles	0.5	0.0	0.1	0.0	0.0	1.3	198	108	17.1	124	27.9	12.3	0.0	2.8	0.3	

3.6.2 Septic Location Analysis

Linear models sought to relate septic densities to observed concentrations of nutrients and bacteria in order to identify if relationships may exist between development, agricultural land uses, and water quality observations. Both E. coli and nitrate levels had positive and statistically significant correlations with septic density at the watershed and near-stream scales. However, only in the case of nitrate was a relatively noteworthy amount of the variation (37%-39%) explained by septic density. This weakly suggests that livestock influence, ranching, and natural sources are not the only significant sources of nutrients and pathogens to Cattle Creek, but that residential sources may provide some contribution as well.

Table 13. Septic Density Data for Near-Stream Buffers
(Most near-stream homes above segments CC6 and CC7 are hooked to municipal systems.)

Site ID	Stream miles, segment	Dist. from Roaring Fork	Perennial streams above site, cumulative	Near-stream parcels, by subsegment	Near-stream parcels, cumulative	Near-stream septic density, by subsegment	Near-stream septic density, cumulative	Median E. coli	Median Total phosphorus	Median nitrate + nitrite
	mi	*mi*	*mi*	*units*	*units*	*units/mi*	*units/mi*	*n/100ml*	*mg/l*	*mg/l*
CC1	25.1	40.5	25.1	8	8	0.32	0.32	15.2	0.020	0.00
CC2	7.3	33.2	32.5	22	30	3	0.92	49.1	0.035	0.15
CC3	21.3	11.9	53.7	56	86	2.63	1.6	134.7	0.060	0.11
CC4	9.9	2.0	63.7	57	143	5.74	2.25	272.7	0.030	0.20
CC5	1.3	0.7	64.9	10	153	7.94	2.36	211.2	0.025	0.24
CC6	0.1	0.7	65.0	5	158	0	2.35	226.3	0.030	0.26
CC7	0.7	0	65.7	8	166	0	2.33	162.1	0.020	0.08

Table 14. Septic Density Data for Subwatersheds.

Site	Total parcels, subwatershed	Upstream area, subwatershed	Septic density, subwatershed	Median E. coli	Median Total phosphorus	Median nitrate + nitrite
	count	*sq mi*	*units/ sq mi*	*col/100ml*	*mg/l*	*mg/l*
CC1	15	30.4	0.49	15.2	0.020	0.00
CC2	156	42.9	3.64	49.1	0.035	0.15
CC3	315	70.1	4.49	134.7	0.060	0.11
CC4	584	86.4	6.76	272.7	0.030	0.20
CC5	605	87.2	6.94	211.2	0.025	0.24
CC6	606	87.3	6.94	226.3	0.030	0.26
CC7	625	87.8	7.12	162.1	0.020	0.08

Table 15. Linear Model Results for Nutrient and Bacteria Levels vs. Septic Density Values at Each Monitoring Site

Model	p-value	R^2
E. coli vs. near-stream septic density	0.047	0.11
E. coli vs. subwatershed septic density	0.047	0.11
Nitrate vs. near-stream septic density	<0.01	0.37
Nitrate vs. subwatershed septic density	<0.01	0.39
Total phosphorus vs. near-stream septic density	0.23	0.02
Total phosphorus vs. subwatershed septic density	0.25	0.01

4 Cattle Creek Stressors

Monitoring results from 2015 indicate that Cattle Creek experiences elevated nutrients and bacteria levels in the spring and summer. Based on analysis of watershed and near-stream land cover, the likely source is agricultural land uses, although impacts may be exacerbated by poor near-stream land management practices such as removal or destruction of woody riparian buffer zones. An analysis of riparian conditions was beyond the scope of 2015 monitoring, but empirical evidence by field staff and prior inventories conducted as part of the Stream Health Initiative suggest that significant riparian alteration and/or degradation is present in the Cattle Creek watershed. Also beyond the scope of this assessment, water diversion to the Missouri Heights area may contribute to flow stress in Cattle Creek in some years and exacerbate water quality issues by reducing the stream's capacity to dilute pollutants or chronically reducing available stream habitat and food production.

Despite low overall levels of development in the watershed, the location and impacts of the agricultural and residential activities create a clear signal of aquatic life stress in Cattle Creek. In the middle and upper watershed, grazing and pasture usage may contribute to increased sediment load, degraded riparian zones and poor filtering of nutrient or bacteria-laden agricultural runoff. In the lower watershed, low density residential development in the stream corridor has contributed to riparian alteration or degradation, and potentially to elevated nutrient or bacteria levels via aging or inappropriately situated residential septic infrastructure. Although hovering around the regulatory benchmark for impairment, it is unclear whether lackluster Cattle Creek MMI scores are merely typical of less-than-pristine conditions in other similar low-elevation watersheds of the Roaring Fork Valley dominated by ranching land uses.

The timing of high levels of total phosphorus and *E. coli* primarily suggests livestock and natural/soil sources. Since pollutant load transported from a permanent residential population would be expected to remain consistent throughout the season, with concentrations primarily affected by discharge and available dilution, the seasonal rise and fall of these parameters is more likely tied to natural hydrologic cycles, soil runoff, and grazing practices.

4.1 Nutrients

Both nitrate and total phosphorus levels in Cattle Creek are seasonally elevated. Nitrate concentration increased substantially in a downstream direction below the reference site during each sampling event; low flow periods showed the greatest increase. Concentrations were higher before and after snowmelt than during snowmelt. This suggests nitrate loading to the stream may occur at relatively consistent rates throughout the low flow periods of the year then receive dilution from high surface runoff during snowmelt. Total phosphorus concentrations followed in an opposite pattern—peaking with snowmelt then remaining consistent later in the summer and fall. Unlike nitrate, which transports readily in dissolved form, phosphorus binds strongly to sediments. Concentrations in Cattle Creek coincide with the high spring turbidity and sediment load present in snowmelt-driven streams in the area. Empirical observations of extensive algal growth and coverage at CC5 and other sites also suggest nutrient enrichment may be an issue.

4.2 Bacteria

Levels of *E. coli* exceeded contact recreation standards at all sites in July. During other sampling events, levels increased and remained consistently high at all sites below Coulter Creek (CC3). Bacteria levels issues generally begin in the upper portion of the study reach, where the stream flows through an area of frequent grazing usage but fewer stream-side homes and septic. This spatial pattern suggests, similar to nutrients, that grazing activities and streamside land management activities are likely the primary contributor to bacterial loading. Even at CC1, the least-impacted site, counts were higher in summer, potentially suggesting impacts from distributed grazing on USFS lands, beaver pond and other wildlife influences, or the presence of a natural source in sediments.

4.3 Riparian Degradation

According to the 2007 Stream Health Initiative, conditions on segments above the USFS boundary as are considered *moderately modified* and *high quality* (Malone and Emerick). Most segments below the USFS boundary received a rating of *severely degraded* with the exception of a short mileage downstream of the Coulter Creek confluence where Cattle Creek's gradient increases in a narrow canyon segment and has little streamside development before opening back up to frequent residential impacts in the lower basin. Loss of appropriate width and composition of riparian zones reduces the natural capacity to filter runoff, and attenuate nonpoint pollution such as sediment and nutrient load to Cattle Creek. Riparian loss also reduces food inputs, thermal protection, and habitat complexity in stream systems, with anticipated negative impacts to aquatic life communities.

4.4 Flow Stress

Water withdrawals in the middle and upper watershed removes significant streamflow amounts to irrigate lands out of the Cattle Creek Basin, including Missouri Heights. This may exacerbate water quality issues due to the reduced dilution and assimilation capacity available in Cattle Creek for existing stressors like agriculture and streamside development. Diversions may also contribute to elevated temperatures in lower Cattle Creek during extreme low-flow years, with associated effects to algal growth and dissolved oxygen.

4.5 Road Impacts

Prior to 2015 monitoring work, stakeholders hypothesized that road impacts specifically from Highway 82 contributed to poor water quality conditions at site CC6, the original long term indicator site for Cattle Creek. Water quality profiles from 2015 display little variation at sites CC5 and CC6, which bracket the highway, suggesting that impacts from road runoff may not be as significant as previously believed.

4.6 Glenwood Ditch

The Glenwood Ditch diverts water from the Roaring Fork River and crosses Cattle Creek just downstream of Highway 82 and the CC6 site. At this point the ditch water is added to Cattle Creek and then mixed water is either moving downstream in Cattle Creek or diverted through the continuance of the ditch. Most water quality parameters improved at the CC7 site below this mixing point, suggesting that the either the addition of Roaring Fork River water from the Glenwood Springs Ditch, the time spent flowing through undeveloped bottomlands with relatively intact riparian zones, or both, provides some chance for pollutant attenuation. However, high energy flows from the steepened ditch return chute, and backwater sediment deposition from the associated headgate, may contribute to both poor habitat and poor MMI scores this year at CC5 and in previous macroinvertebrate samples at CC6.

5 Next Steps

Monitoring work in 2015 identified potential issues with nutrients and bacteria in Cattle Creek. Annual variations climatic conditions and streamflows, as well as variations in land use activities such as grazing and irrigation, can add significant variability to monitoring results and produce atypical values in any individual year. In order to overcome this variability and generate a dataset large enough to conduct a series of statistical analyses including computation of trends, data collection is recommended for a minimum of 5 years. RFC plans to continue monitoring in 2016. Results from year 1 (2015) were used to inform and modify the 2016 plan to increase informative results as well as resource and cost efficiency.

5.1 Additional Parameters of Interest

Review of existing datasets developing new monitoring datasets for these groups may further illuminate the extent and causes of aquatic life degradation on Cattle Creek.

Fish

CPW identifies the presence of Colorado River lineage cutthroat trout, brook trout, rainbow trout, and brown trout in the Cattle Creek watershed (RFC, 2008). As recently as 2007, CPW stocked brook and rainbow trout in upper Cattle Creek and the North Fork. CPW identifies Cattle Creek as an important spawning tributary to the Roaring Fork for brown trout, which move up the stream system from the mouth during the fall to spawn. Flow stress in the lower reaches of Cattle Creek during the final months of irrigation season in September and October may negatively influence spawning success. Central compilation of existing fisheries records, as well as identification of sites and timelines for additional population surveys in the lower watershed may contribute to understanding of flow, sediment and habitat impacts to aquatic life.

Stream flow

The Roaring Fork Watershed Plan notes a 1986 instream flow right (ISF) for 4 cfs year round from Iola Creek, in the USFS-managed headwaters, to Fischer Creek, which lies between sites CC3 and CC4. An additional 2 cfs enlargement was established in 1997 on approximately 1.3 miles between Coulter Creek confluence and the Park Ditch headgates. The frequency at which these rights are met is unknown due to the absence active gauges on the stream. Comparative observations at CC3 and CC4 show the ISF was met at below Coulter Creek. At CC4, below the park ditch, flows of <2cfs in July and September indicate a very depleted stream. Continuous or seasonally-targeted streamflow monitoring may characterize whether flow stress is a chronic stressor.

Sediment

Based on empirical observations during site visits, fine sediment may be a concern at some sites. Further exploration of site substrate characteristics may also provide insight into whether habitat limitations may contribute to site scores in lower Cattle Creek watershed rather than water quality alone. While the geology of Cattle Creek is likely to produce high natural sediment loads, near-stream land use practices including riparian destruction in grazing areas may contribute to increased load. Determining sediment impacts to aquatic life and differentiating between natural and anthropogenic sources is a complex process. Additional information is provided by WQCD in Policy 98-1 *Guidance for implementation of Colorado's narrative sediment standard Regulation 31, Section 31.11(1)(a)(i)*.

Criteria for a regulatory determination of sediment impairment are complex and may require significant additions to current monitoring. If sediment monitoring is a desired goal, RFC and other stakeholders should review narrative sediment standards and identify specific objectives for monitoring (i.e. potentially pursue a 303(d) listing) prior to beginning additional work. Further exploration of site substrate characteristics may also provide insight into whether habitat limitations may contribute to site scores in lower Cattle Creek watershed rather than water quality alone.

Selenium

The 2008 State of the Roaring Fork Watershed report identified exceedance of instream standards for selenium in Cattle Creek watershed and linked its presences to natural geologic sources such as marine shale deposits (Clarke et al., 2008). If metals/trace elements are considered as a sampling parameter for Cattle Creek in the future, selenium should continue to a parameter of interest.

Total Nitrogen

Based on 2015 monitoring, nutrients are a concern in Cattle Creek. The primary indicator parameters WQCD uses for aquatic life use assessment are total nitrogen and total phosphorus. The nitrogen parameters sampled in 2015 (nitrate and nitrite) are useful to understand if nitrogen is a potential issue in the stream, but cannot be used to assess impairment. Sampling for total inorganic nitrogen, which includes ammonia rather than just nitrate/nitrate will align better with aquatic life use assessment goals.

5.2 Action alternatives

Continued sampling on Cattle Creek is recommended in multiple years to build the depth of available data across multiple seasons and climatic conditions. A variety of monitoring options are possible, with several described below, although many other combinations are viable:

Alternative 1: No change to monitoring regime
Continue monitoring in 2016 with identical sampling sites, parameters, and frequency as 2015.

Alternative 2: Water quality sampling without biomonitoring
Discontinue biomonitoring until 2017, maintain physical/chemical water sampling similar to 2015 at 7 sites and a minimum of 4 sampling events.

Alternative 3: Continue biomonitoring with reduced water quality sampling locations
Continue with approximately 7 biomonitoring sites in identical or similar locations. Reduce water quality sampling to 4-5 indicator sites in the watershed, but maintain a sampling frequency (4x per year, matching hydrographic milestones) and parameter list similar to 2015. Potential indicator sites include a range/agriculture-impacted site (CC2), a residential-impacted site (CC4 or CC5), and a full watershed integrator site that also includes highway impacts (CC7).

Alternative 4: Biomonitoring only
Continue with approximately 4-7 biomonitoring sites in identical or similar locations. Discontinue instream chemistry grab samples.

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Appendix 1: Timberline Aquatics detailed macroinvertebrate report

A Review of Aquatic Life and Stream Health in the Cattle Creek Drainage

Introduction

In September 2015, Roaring Fork Conservancy (RFC) conducted benthic macroinvertebrate sampling at seven locations on Cattle Creek, a tributary of the Roaring Fork River, to assess existing aquatic conditions and evaluate potential anthropogenic stress in this system. Samples were collected by RFC and then sent to the Colorado Department of Public Health and Environment (CDPHE) for identification and enumeration. A replicate sample was taken at one of the study locations (RFC-CC1) to ensure consistency. This study included a portion of Cattle Creek that has been included on Colorado's 303(d) list of impaired waters. Results from the fall of 2015 benthic macroinvertebrate sampling are provided in this report.

6 Background

Aquatic conditions in rivers and streams are often influenced by the physical, chemical, and biological components of the surrounding ecosystem. Several recent studies have emphasized the need for biological monitoring (biomonitoring) in order to assist in the evaluation of aquatic conditions in streams (Plafkin et al. 1989, Barbour et al. 1999, Paul et al. 2005, Bonada et al. 2006). Benthic macroinvertebrates are the most frequently used organisms for biomonitoring studies because evolution and ecological processes have produced macroinvertebrate communities with taxa-specific adaptations to the natural environment. Detailed information regarding species-specific sensitivity provides an opportunity for monitoring environmental disturbances or pollution using macroinvertebrate assemblages. Therefore, benthic macroinvertebrate communities represent a valuable tool as biological indicators of water quality and aquatic conditions. Biomonitoring programs that utilize benthic macroinvertebrate assemblages have advantages that are not realized by physical or chemical water quality monitoring alone (Ward et al. 2002).

Results provided by consistent sampling practices and accurate identifications can produce valuable information regarding aquatic conditions. Sustained biological monitoring is essential to understanding the effects of long-term influences such as population growth, urban development, and changes in land-use practices (Likens and Lambert 1998, Voelz et al. 2005). Certain taxa can survive or even thrive in the presence of various contaminants so it is often necessary to employ several biotic indices (metrics) in the analysis of macroinvertebrate data. Bonada et al. (2006) found that the problems associated with individual biomonitoring tools (metrics) can be improved upon by using a multiple metric index. In this study, individual metrics and a multi-metric index (MMI) were used to evaluate aquatic conditions among sampling sites and provide information regarding areas with the greatest impacts to aquatic life within the study area.

Selected Macroinvertebrate Metrics

Multi-Metric Index (MMI)

In the fall of 2010, the CDPHE published specific guidelines for benthic macroinvertebrate sampling and analysis to assist in the evaluation of aquatic life in streams in the State of Colorado (Colorado Department of Public Health and Environment 2010). These guidelines described specific protocols for the analysis of benthic macroinvertebrate data using a Multi-Metric Index (MMI).

The MMI provides a single index score based on five or six equally weighted metrics. The group of metrics used in MMI calculations depends on the location of the sampling site and corresponding Biotype (Mountains, Transitional, or Plains). Each of the metrics used in the MMI produces a score that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites" in the state of Colorado.

In this study, all sites on Cattle Creek were contained within Biotype 1. Biotype 1 includes streams in the Transitional Zone between high elevation and low elevation habitats in Colorado. Metrics currently used for Biotype 1 include: Percent Non-insect Taxa, EP Taxa, Percent Chironomidae, Percent Sensitive Plains Families, Predator-Shredder Taxa, and Clinger Taxa. These metrics were employed at each study site to assist in data analysis during the fall of 2015. The thresholds for MMI scores that determine impairment or attainment for aquatic life use in Biotype 1 are as follows:

Biotype	Attainment Threshold	Impairment Threshold
Transition (Biotype 1)	52	42

Metric scores that fall between the thresholds for attainment and impairment require further evaluation using two auxiliary metrics, the Shannon Diversity (Diversity) and Hilsenhoff Biotic Index (HBI), in order to determine if the site is in attainment or impaired for aquatic life use. Thresholds for these individual metrics are as follows:

Biotype	HBI	Diversity
Transition (Biotype 1)	5.4	2.4

If a study site produces an MMI score in the 'grey zone' (between the attainment and impairment thresholds) the auxiliary metric scores must be less than the HBI threshold and greater than the Diversity threshold to achieve an 'attainment' designation.

Additional Individual Metrics

In order to assist in the evaluation of aquatic life in the study area, additional individual metrics were applied and compared among sites. These metrics were selected because they are widely used in western streams and should provide additional value to this study. A description of each of these metrics has been provided below:

Ephemeroptera Plecoptera Trichoptera (EPT): The design of this metric is based on the assumption that the Orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are generally more sensitive to pollution and environmental stress than other benthic macroinvertebrate Orders (Lenat 1988). The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

Intolerant Taxa: The intolerant taxa metric provides a measure of all macroinvertebrate taxa (at each study site) that are known to be sensitive to a variety of perturbations. A decline in this metric value is an indication of increased pollution or stressed environmental conditions.

Clinger Taxa: Clingers are benthic macroinvertebrates having behavioral and/or morphological adaptations that allow them to attach or "cling" to substrate surfaces, often in riffle habitat (Merritt et al. 2008). Excessive sedimentation, rapid changes in discharge, or substantial algal growth can cause a reduction in this metric value (Hughes and Brossett 2009).

Taxa Richness: Taxa Richness is a metric often used to provide an indication of habitat adequacy and water quality. Taxa Richness, or the total spectrum of taxonomic groups present at a given site, will generally decrease when exposed to decreasing water quality or habitat degradation (Resh and Jackson 1993). The Taxa Richness measurement is reported as the total number of identifiable taxa collected from each sampling location.

Shannon Evenness (Evenness): Shannon-Weaver evenness (Evenness) values were used to detect changes in macroinvertebrate community balance and structure. The Evenness value ranges between 0.0 and 1.0. Values lower than 0.3 are generally considered indicative of organic pollution (Ward et al. 2002).

Shannon Diversity (Diversity): Diversity values are used to detect changes in macroinvertebrate community structure. In unpolluted waters, Diversity values typically range from near 3.0 to 4.0. In polluted waters this value is generally less than 1.0.

Hilsenhoff Biotic Index (HBI): Most of this metric's value lies in detection of organic pollution, but it has also been used to evaluate aquatic conditions in a variety of other circumstances. The HBI was originally developed using macroinvertebrate taxa from streams in Wisconsin; therefore, it may require regional modifications (Hilsenhoff 1988). Although the value indicating a certain water quality rating may vary among regions, comparison of the values produced within the same system should provide information regarding sites with impacts from a variety of stressors including nutrient enrichment. Values for the HBI range from 0.0 to 10.0, and <u>increase</u> as water quality decreases.

Results

In order to evaluate the biological integrity of Cattle Creek, a tributary of the Roaring Fork River, seven study sites were sampled for benthic macroinvertebrates during September 2015. A Multi-Metric Index (MMI) score was calculated for each site (based on protocols designed by the CDPHE), and several individual metrics were also used as part of this assessment. All sites in this study area were located within Biotype 1, the Transitional Zone. Results from the fall of 2015 provided evidence of disturbances throughout much of the study area; however, impacts to aquatic life were most prevalent in the downstream portions of Cattle Creek (Table 1). The lowest MMI score in the study area was found at site RFC-CC7, and this score indicated 'impairment' for aquatic life use, regardless of auxiliary metric scores. Four of the seven study sites produced MMI scores that fell within the 'grey zone' and required further analysis using auxiliary metrics (HBI and Diversity) to determine if aquatic conditions were in 'attainment' or 'impaired' for aquatic life use. Two of the four sites that produced scores in the 'grey zone' (sites RFC-CC2 and RFC-CC5) were considered 'impaired', while the other two study sites (sites RFC-CC3 and RFC-CC6) were in attainment for aquatic life use. The remaining two sites (RFC-CC1 and RFC-CC4) produced MMI scores above the attainment threshold (Table 1).

In general, individual metrics detected an increase in stress in a downstream direction with some of the best metric values occurring at site RFC-CC1 (Table 2). An overall decrease in community balance and a decline in the richness of sensitive macroinvertebrate taxa could be observed at most of the remaining six study sites. A variety of stressors and/or alterations to the aquatic environment (including sedimentation and land development in the watershed) could potentially be influencing Cattle Creek in this study area. It is likely that benthic macroinvertebrate communities in the downstream portion of the study area were influenced by some of these anthropogenic stressors during the fall of 2015.

Results from data analysis using the MMI (and other individual metrics) exhibited some variability within the study area that may not have been entirely related to anthropogenic activities. At site RFC-CC1, two replicate samples were collected in order to evaluate consistency in the sampling methodology. Results from the replicate (QA) sample detected nearly a 10% change in several metric values including MMI scores (Tables 1 and 2). Based on these results it is likely that some of the variability among metric values within this study area might be attributed to sampling methodology and habitat quality. For example, the relatively low MMI scores found at site RFC-CC2 followed by an improvement in MMI scores at sites RFC-CC3 and RFC-CC4 could probably be attributed to beaver activity that altered habitat at site RFC-CC2 , and likely caused the low MMI score (Table 1). Sites RFC-CC3 and RFC-CC4 produced MMI scores that were similar to the most upstream site (RFC-CC1), indicating that there were probably only minor changes in the level of stress to macroinvertebrate communities in this portion of Cattle Creek. The three remaining sites (RFC-CC5, RFC-CC6, and RFC-CC7) produced consistently low MMI scores, and other metrics detected a decrease in sensitive and specialized taxa at these locations (Tables 1 and 2). The consistency in MMI scores (and other individual metric values) generated for these three downstream sites suggested that anthropogenic stress was most prevalent in the downstream portion of study area. Future biomonitoring studies on Cattle Creek will provide valuable information regarding the consistency of impacts occurring within this study area.

Table 1. MMI scores (and individual MMI component scores) for macroinvertebrate samples collected from Cattle Creek in September 2015.

Metric	RFC-CC1	RFC-CC1 QA	RFC-CC2	RFC-CC3	RFC-CC4	RFC-CC5	RFC-CC6	RFC-CC7
EP Taxa	50.1	39.4	7.5	29.0	47.8	49.4	28.1	39.7
% Non-Insect Taxa	56.9	34.1	0.0	4.2	49.1	0.0	0.0	0.0
% Chironomidae	74.2	77.8	100	96.5	84.1	66.1	71.7	69.6
% Sensitive Families	66.7	64.4	92.1	100.0	100.0	49.7	71.5	72.8
Predator/Shredder Taxa	78.6	71.4	28.6	35.7	42.9	42.9	42.9	14.3
Clinger Taxa	57.1	40.1	33.3	41.9	51.2	52.7	44.3	53.7
MMI Score	**63.9**	**54.5**	**43.6**	**51.2**	**62.5**	**43.5**	**43.1**	**41.7**

Table 2. Individual metric values for macroinvertebrate samples collected from Cattle Creek in September 2015.

Metric	RFC-CC1	RFC-CC1 QA	RFC-CC2	RFC-CC3	RFC-CC4	RFC-CC5	RFC-CC6	RFC-CC7
EPT	11	10	7	8	7	6	4	6
Intolerant Taxa	10	8	4	5	3	2	2	5
Clinger Taxa	11	9	7	8	7	7	6	7
Taxa Richness	33	27	25	26	21	26	26	22
Evenness	0.4508	0.4337	0.3341	0.3778	0.3551	0.4438	0.3831	0.3869
Diversity	3.70	3.59	2.76	3.07	2.92	3.66	3.14	3.20
HBI	4.87	4.80	5.46	4.37	4.60	5.60	5.12	5.44

Individual site discussion

River/Stream: Cattle Creek
Site ID: Cattle Creek at National Forest Boundary
Location: Boundary of White River National Forest above Gauging Station
River Watch Site Name and (Number): N/A
WQCD Site ID: RFC-CC1
Coordinates (NAD 83): N 39.28’06.27” W 107.03’59.95”

Site Description:

Site RFC-CC1 represented the farthest upstream site within the Cattle Creek study area and was accessible via a dirt road. This site was established near the headwaters of Cattle Creek (located within the White River National Forest) and was upstream from all water diversions and urbanized development associated with portions of Garfield and Eagle counties.

The immediate riparian vegetation surrounding this site mostly consisted of shrubs and bushes with minimal trees. Various riffle areas were observed at this site with a cobble substrate; however, substantial algae growth covered much of the stream bed. Macroinvertebrate data collected at this site may have been partially influenced by the large beaver dam located upstream from site RFC-CC1.

In 2011, this site achieved a ‘good’ MMI score by the WQCD, and more recently, portions of Cattle Creek located upstream from the USFS border have obtained an ‘Outstanding Waters’ designation from the WQCD.

Benthic Macroinvertebrate Review:

Two replicate samples were taken at site RFC-CC1 as a means of quality assurance (QA) and to evaluate the variability in the samples collected using the proposed methodology. The results from these duplicate samples suggested that the sampling technique used in this study may have introduced up to 10% variability in MMI scores, and similar levels of inconsistencies in some of the individual metric values (Tables 1 and 2). Results from the original sample at RFC-CC1 indicated that disturbances were relatively minor based on an MMI score of 63.9; however, a lower MMI score (54.5) and a loss of sensitive taxa was demonstrated by the replicate (QA) sample. Assuming that the macroinvertebrate community was most rigorously structured by water quality parameters, it is likely that the QA sample may have been negatively biased due to sampling in a disturbed area or insufficient habitat.

The MMI score from the original sample at site RFC-CC1 was the highest in the study area, although both samples produced scores indicating that aquatic conditions were in attainment for aquatic life use. The original sample also indicated that sensitive and specialized taxa were well-represented at this location, and metrics used to measure macroinvertebrate community structure (Diversity and Evenness) produced values (3.70 and 0.4508, respectively) suggesting that the community was well-balanced at site RFC-CC1 in September of 2015 (Table 2). Most metrics were in agreement that this site supported the heathiest macroinvertebrate community in the study area.

River/Stream: Cattle Creek
Site ID: Cattle Creek above Confluence with Coulter Creek
Location: above the confluence of Cattle Creek and Coulter Creek
River Watch Site Name and (Number): N/A
WQCD Site ID: RFC-CC2
Coordinates (NAD 83): N 39.27'52.96" W 107.08'26.32"
Site Description:

Located just above the confluence with Coulter Creek, site RFC-CC2 was established to evaluate existing aquatic conditions in Cattle Creek before its convergence with Coulter Creek. This site may have been affected by runoff associated with some modified land use activities such as ranching.

The surrounding riparian vegetation mainly consisted of tall grasses and a few shrubs. This site was established between two beaver dams which resulted in a benthic macroinvertebrate sample that was not taken from typical riffle habitat. The unusual habitat at this site may have resulted in biased data.

Benthic Macroinvertebrate Review:

Aquatic communities demonstrated a decline in sensitive taxa and community balance from site RFC-CC1 to RFC-CC2 based on the MMI scores and other individual metric values. An MMI score of 43.6 was produced at site RFC-CC2 which fell into the 'grey zone' on the MMI scale, and ultimately this site was determined to be 'impaired' for aquatic life use based on an elevated HBI value (Tables 1 and 2). Other individual metrics (EPT Taxa, Intolerant Taxa, and Clinger Taxa) also suggested that this location could not support as many sensitive and specialized taxa when compared to site RFC-CC1 (Table 2). A slight increase in the proportion of nutrient-tolerant taxa was also found at site RFC-CC2, based on the relatively high HBI value. The lowest Diversity and Evenness values in the study area were detected at site RFC-CC2 suggesting that stress at this site was negatively affecting macroinvertebrate community structure and balance. The decreased MMI score and reduction in sensitive and specialized taxa observed at this location were possibly influenced by the altered habitat due to beaver activity; however, modified land use practices in the area may have also contributed to detectable impacts. Future biomonitoring at this site should be conducted in a manner that avoids unusual or recently modified habitats. This will help to validate the level of anthropogenic impacts that actually occur at this location.

River/Stream: Cattle Creek
Site ID: Cattle Creek below Confluence with Coulter Creek
Location: below the confluence of Cattle Creek and Coulter Creek
River Watch Site Name and (Number): N/A
WQCD Site ID: RFC-CC3
Coordinates (NAD 83): N 39.57’51.10” W 107.08’26.49”
Site Description:

Site RFC-CC3 was established downstream from the confluence of Cattle Creek and Coulter Creek in order to assess potential pollutants that may enter Cattle Creek upstream of this location. Occasionally, water is removed from this site by the local fire department which may inhibit macroinvertebrate community densities.

This site was surrounded by tall grasses with minimal shrubs and trees. Substantial amounts of algae were observed on the stream bed at this site which may have had some affect benthic macroinvertebrate communities.

Benthic Macroinvertebrate Review:

The MMI and other individual metric values generally detected an improvement in aquatic conditions at site RFC-CC3 when compared to site RFC-CC2. An MMI score of 51.2 was calculated for site RFC-CC3 which fell into the ‘grey zone’, but results from the auxiliary metrics (Diversity and HBI) indicated that aquatic conditions remained in attainment for aquatic life use (Table 2). The lowest HBI value (4.37) was observed at site RFC-CC3 suggesting lower proportions of nutrient-tolerant taxa were found at this site when compared to the other six Cattle Creek study sites (Table 2). The Diversity and Evenness values (3.07 and 0.3778, respectively) produced at this site increased slightly from site RFC-CC2, indicating an improvement in community balance, while the EPT, Intolerant Taxa, and Percent Sensitive Families metrics detected a slight improvement in the number and relative abundance of sensitive macroinvertebrate taxa at site RFC-CC3.

River/Stream: Cattle Creek
Site ID: Cattle Creek at 1164 Hwy 113
Location: above Highway 113
River Watch Site Name and (Number): N/A
WQCD Site ID: RFC-CC4
Coordinates (NAD 83): N 39.27’02.62” W 107.14’40.12”

Site Description:

Site RFC-CC4 was located downstream from the majority of agricultural areas surrounding Cattle Creek. This site was also immediately upstream from Highway 113 and its associated runoff.

The riparian vegetation at site RFC-CC4 mainly consisted of tall grass with several surrounding trees that provided ample shading. Surrounding ranches and developed areas may have influenced aquatic conditions at this site.

Benthic Macroinvertebrate Review:

Results from the MMI analysis at site RFC-CC4 indicated that aquatic conditions had improved at this location; however, several of the individual metric values decreased at this site when compared to site RFC-CC3. The MMI score produced at site RFC-CC4 (62.5) was one of the highest scores within the study area and well-above the attainment threshold (Table 1). Despite this relatively high MMI score, several individual metrics used to evaluate sensitive and specialized taxa (EPT, Intolerant Taxa, and Clinger Taxa) detected slight impacts to the benthic macroinvertebrate community at this location (Table 2). This disagreement among metrics was caused by an increase in the relative abundance of sensitive taxa, while the richness and diversity of these taxa declined. One of the lowest Intolerant Taxa values (3) was produced at site RFC-CC4 along with the lowest Taxa Richness value (21) suggesting this site could not maintain the variety of taxa found at other study locations.

River/Stream: Cattle Creek
Site ID: Cattle Creek above Hwy 82
Location: above Highway 82 above Glenwood Ditch
River Watch Site Name and (Number): N/A
WQCD Site ID: RFC-CC5
Coordinates (NAD 83): N 39.27'21.95" W 107.15'39.13"
Site Description:

Site RFC-CC5 was established above the crossing of Cattle Creek and Highway 82 in order to evaluate stream conditions upstream from this major road. In between study sites RFC-CC4 and RFC-CC5, various businesses (including a junk yard and auto-repair shop) within Garfield County are located in close proximity to Cattle Creek. Runoff from these developments may enter Cattle Creek upstream from site RFC-CC5. Downstream from this site, Cattle Creek mixes with water from Glenwood Ditch which has caused buildups of sediment and substantial backwatering to occur.

The riparian vegetation at this site mainly consisted of shrubs with several trees and tall grass. Substantial amounts of algae were observed at site RFC-CC5 in 2015.

Benthic Macroinvertebrate Review:

Most analysis tools (including the MMI score and individual metric values) detected a decline in aquatic conditions at site RFC-CC5 (Tables 1 and 2). This site was designated as impaired for aquatic life use due to a relatively low MMI score (43.5) and a high HBI value (5.60). Some of the highest Diversity and Evenness values (3.66 and 0.4438, respectively) were observed at this location suggesting that the macroinvertebrate community was well-balanced; however, sensitive and specialized taxa decreased at this site (determined by the EPT, Intolerant Taxa, and Clinger Taxa metrics) compared to upstream sites in the study area. The low Intolerant Taxa value (2) found at site RFC-CC5 suggested the majority of macroinvertebrate taxa collected at this location could survive in a stressed environment. The relatively high HBI value of 5.60 found at site RFC-CC5 was the highest in the study area and indicated that the proportions of nutrient-tolerant taxa had increased.

River/Stream: Cattle Creek
Site ID: Cattle Creek at Rio Grande Trail Bridge
Location: below Highway 82 above Glenwood Ditch
River Watch Site Name and (Number): N/A
WQCD Site ID: RFC-CC6
Coordinates (NAD 83): N 39.27’23.43” W 107.15’46.99”
Site Description:

This site was located downstream from Highway 82 and it is potentially impacted from sediment erosion and runoff from the highway that includes de-icing agents and petroleum products. Backwatering occurring downstream from site RFC-CC6 at Glenwood Ditch may have also affected benthic macroinvertebrate communities at site RFC-CC6. This site has been placed on Colorado’s 303(d) list of impaired waters based on previously collected macroinvertebrate data.

The absence of trees at this site resulted in minimal shading from the surrounding shrubs and grasses. Increased algal growth was observed at this site which may have been influenced by the lack of shade or the downstream ditch infrastructure.

Benthic Macroinvertebrate Review:

The MMI score and most individual metric values continued to decrease at site RFC-CC6 compared to site RFC-CC5 (Table 1 and 2). The MMI score of 43.1 fell within the ‘grey zone’ between ‘attainment’ and ‘impairment’; however, this site still achieved an ‘attainment’ designation based on results produced by the auxiliary metrics (Diversity and HBI). The lowest EPT, Intolerant Taxa, and Clinger Taxa values were detected at this site suggesting that sensitive and specialized taxa were severely reduced at this location during the fall of 2015. The macroinvertebrate community at this location may have been influenced by runoff from Highway 85 or the mixing of waters from Cattle Creek and Glenwood Ditch that caused an influx of sediments at sites RFC-CC5 and RFC-CC6.

River/Stream: Cattle Creek
Site ID: Cattle Creek above Confluence with the Roaring Fork River
Location: 100 yds above confluence with the Roaring Fork River
River Watch Site Name and (Number): N/A
WQCD Site ID: RFC-CC7
Coordinates (NAD 83): N 39.27'46.49" W 107.16'14.46"
Site Description:

Located at the farthest downstream boundary of the Cattle Creek study area, site RFC-CC7 was located approximately 100 yards upstream from the Roaring Fork River. This site was included in the Cattle Creek study area in order to evaluate cumulative impacts in Cattle Creek before it enters the Roaring Fork River.

This site received minimal shading from surrounding riparian vegetation which may have altered the temperature of the water and the amount of algae growing at this site. Site RFC-CC7 was also located downstream from Glenwood Ditch.

Benthic Macroinvertebrate Review:

Although several metrics (particularly those that measure the richness of sensitive taxa) detected improvements at site RFC-CC7, the lowest MMI score within the study area (41.7) was also generated at this location (Table 1). These results indicated that site RFC-CC7 was impaired for aquatic life use; although the EPT, Intolerant Taxa, and Clinger Taxa metrics all detected slight improvements. The conflicting results in metric values were caused by a slight increase in the number (richness) of sensitive taxa while the relative abundance of these taxa decreased. The Diversity value (3.20) suggested healthy community balance at this site; however the Taxa Richness value (22) was one of the lowest in the study area. The HBI value also remained relatively high at site RFC-CC7 suggesting there was a high proportion of nutrient tolerant taxa in September 2015.

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