2009-2012

Careless Creek Monitoring Project Final Report

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Prepared for:

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Background

Watershed Description

Careless Creek is a tributary to the Musselshell River, located in central Montana within Golden Valley County (USGS HUC 10040201). Careless Creek has headwaters in the Big Snowy and Little Belt Mountains, and traverses approximately 100 miles to its confluence with the Musselshell River. The higher elevation portions of Careless Creek and its tributary Swimming Woman Creek are classified as B1, but the study reach of Careless Creek is classified as a C3 stream by the Montana Department of Environmental Quality (MDEQ). C3 classification means it should support non-salmonid (warm water) fisheries and is naturally of marginal quality for drinking water (MDEQ Standards). The headwaters of Careless Creek is in the Middle Rockies Ecoregion (Level III) but the study reach is located within the Northwestern Great Plains Level III Ecoregion and the Unglaciated Montana High Plains Level IV Ecoregion. Irrigated agriculture and livestock grazing are the principal land uses within the watershed. A large portion of flow within the lower portion of Careless Creek during the irrigation season comes from Deadman's Basin Reservoir because the creek is used as a conveyance for irrigation water from the reservoir to the Musselshell River. The lower 15.5 miles of Careless Creek, from the point where the canal from Deadman's Reservoir enters to the confluence with the Musselshell River, is listed as impaired on the MT 303(d) list. The 2012 MT 303(d) list indicates that the creek as partially supporting of aquatic life and warm water fishery. Probable causes of impairment noted are alteration in stream-side or littoral vegetative covers and sedimentation/siltation, while probable sources include channel erosion/incision from upstream hydro-modifications, impacts from hydro-structure flow regulation/modification, and streambank modifications/destabilization.

The Careless Creek watershed steering committee was formed in 1992 and has done much work to tackle problems within the watershed. This work has included infrastructure improvements in the water delivery system from Deadman's Reservoir, which allowed for a reduction in irrigation releases to 100 cubic feet per second (cfs) at the Careless Creek diversion and 80 cfs at the confluence of Careless Creek with the Musselshell River, designed to reduce bank erosion. Additionally, a channelized section of the stream was diverted back to its original meandering channel along with bank sloping and tree revetment projects. Agricultural BMPs (Best Management Practices) were also implemented within the watershed, including riparian fencing, prescribed grazing, and off-stream watering.

Monitoring Project Beginnings

In 2008, the Lower Musselshell Conservation District (LMCD) received a 319 grant from MDEQ, in part to monitor water quality within Careless Creek. LMCD contracted with Montana State University Extension Water Quality (MSUEWQ) to provide technical support to a citizen based monitoring team to complete this work. MSUEWQ was responsible for developing the Sampling and Analysis Plan (SAP) for Careless Creek, as well as providing technical assistance for implementation of the monitoring project, including training volunteers to carry out the field sampling.

Project Evolution

The amount and types of data collected throughout the four sampling seasons of the project have evolved due to changes in volunteer involvement, changing strategies on the best and most efficient methods, and due to extreme flooding events in 2011. In 2009 and 2010, data collection was conducted as directed by the SAP document, but data from 2011 is less complete because of record flooding in the region, during which the Musselshell River peaked at more than 5,000 CFS above its historic high (USGS, 2012). Beginning in 2011, volunteer enthusiasm for monitoring began to dwindle. This was largely due to the extensive flooding in the watershed that turned people's attention to more immediate personal and professional needs to mitigate flood damage. One volunteer became aware of a health condition in the spring of 2011 that precluded further involvement in the project. MSUEWQ continued data collection in 2011-12 to the extent possible with funding available, and continued to work with the Musselshell Watershed Coalition (MWC) on volunteer engagement to maintain some momentum surrounding citizen based monitoring. After challenges in 2011 resulted in volunteers participating in only one sample event, a decision was reached through a conversation between MSUEWQ, MWC, and MDEQ to reduce the number of sites and the parameters measured in 2012.

The citizen based monitoring efforts outlined in this project have provided valuable learning opportunities for future efforts in the Musselshell and statewide. The expectations placed on the volunteers at the outset of the project were unrealistic. Asking volunteers to donate a full day each month for 7 months over 4 years and to drive for up to an hour each direction to conduct the monitoring without mileage reimbursement was a tall order. It is also important to note that only 1 of the 4 volunteers had a personal vested interest in Careless Creek, and that the other volunteers may have been more motivated to conduct monitoring on a stream or river with which they felt a more direct connection. As MWC, MSUEWQ and MDEQ explore the future potential of citizen based monitoring in the Musselshell, it will be critical to be clear about the big picture objectives of the monitoring project and ensure that the people involved share the vision for why the monitoring is worthwhile.

Sample Sites

Per the approved SAP, six sites were chosen at the onset of monitoring efforts for sampling within the Careless Creek watershed. The selected sites were chosen because of a sampling history pre/post TMDL development, or because they were identified during a scoping trip as locations that would be helpful in defining water quality conditions within Careless Creek (Figure 1). Two sample sites were moved after the 2009 season, prior to initiating data collection in 2010. The PreOutlet site was moved upstream approximately 0.25 miles to avoid backwater from the canal confluence interfering with the stage recorder, and the Canal site was moved downstream a little over 5 miles to just above the spillway into Careless Creek (Figure 2). The new Canal site provided a better stage versus discharge relationship and also significantly reduced the travel time associated with sampling. These sites remained the same for 2011. In 2012, the number of sites was reduced from six to four by eliminating the Sterling and Hwy 238 sites. This reduction was the outcome of a decision made by MWC, MSUEWQ and MDEQ to make the most efficient use of modest remaining funds and diminished volunteer commitment. A summary of the sites used throughout the study period, including station IDs and coordinates, can be found in Table 1.

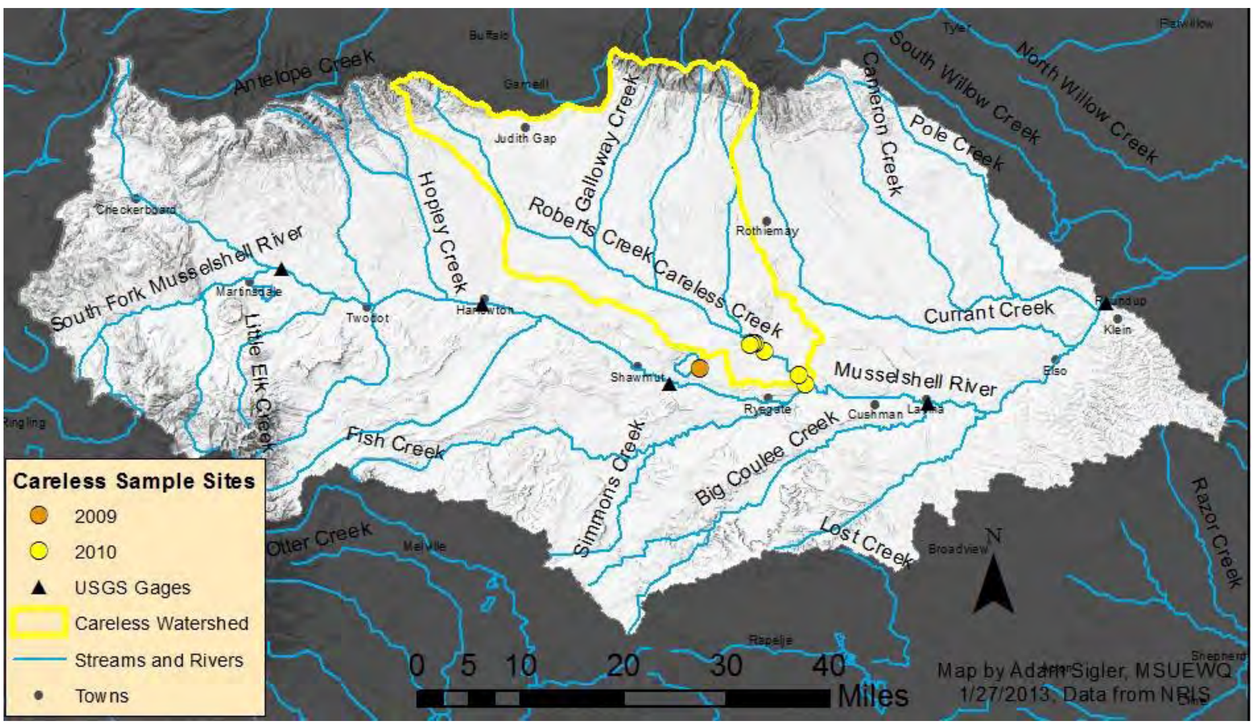

Figure 1. Careless Creek project sampling sites, 2009.

Figure 2. Careless Creek project sampling sites relocated in 2010 (Canal and PreOutlet).

Table 1. Site IDs, coordinates, and project years in which they were used.

Monitoring Station ID	Latitude	Longitude	2009 Site	2010 Site	2011 Site	2012 Site
CCHwy12W	46.3157	-109.1859	X	X	X	X
CCSterling	46.3297	-109.1982	X	X	X	
CCatHwy238	46.3631	-109.2684	X	X	X	
CCZaire	46.3736	-109.2855	X	X	X	X
CCPreOutlet	46.3729	-109.2916	X			
CCPreOutlet	46.3744	-109.2909		X	X	X
CCCanal (at headgate)	46.3394	-109.3988	X			
CCCanal (above spillway)	46.3710	-109.2966		X	X	X

Parameters Collected

Sampling was conducted in 2009, 2010, and 2011 according to the Careless Creek SAP, and included flow meter and YSI measurements, as well as grab sampling for nutrients, alkalinity, sediment, TDS, and periphyton in 2009. Collection efforts were scaled back in subsequent years, in accordance with an evolving understanding of realistic expectations for volunteer commitment. In 2010, periphyton was dropped from the sampling schedule. In 2011, nutrient samples were collected only once. In 2012, only four sites were included and only four visits were made. The parameters collected each season, as well as the sites and months for which they were collected, are summarized in Table 2.

The 2009 periphyton samples were analyzed by *Rhithron Associates* in Missoula, MT. All other samples were analyzed by Energy Laboratories in Helena, MT.

Table 2. Sampling schedule outline for project duration.

		Discharge	Temperature	SC	pH	TSS	TDS	Alk.	Tot P	Tot N	N+N	Amm as N	Periphyton
2009	Hwy12	4,5,6,8,9,10[1]	5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	4,5,6,8,9,10	4,5,6,8,9,10	8,9	8,9	8,9	8,9	8,9	8,9
	Sterling	5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	4,5,6,8,9,10	4,5,6,8,9,10						
	Hwy238	5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	4,5,6,8,9,10	4,5,6,8,9,10	8,9	8,9	8,9	8,9	8,9	8,9
	Zaire	4,5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	4,5,6,8,9,10	4,5,6,8,9,10	8,9	8,9	8,9	8,9	8,9	8,9
	PreOutlet	4,5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	5,6,8,9,10	4,5,6,8,9,10	4,5,6,8,9,10	8,9	8,9	8,9	8,9	8,9	8,9
	Canal	5,6,8,9	5,6,8,9	5,6,8,9	5,6,8,9	4,5,6,8,9,10	4,5,6,8,9,10						
2010	Hwy12	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	7,8,9	7,8,9	7,8,9	7,8,9	7,8,9	
	Sterling	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10						
	Hwy238	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	7,8,9	7,8,9	7,8,9	7,8,9	7,8,9	
	Zaire	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	7,8,9	7,8,9	7,8,9	7,8,9	7,8,9	
	PreOutlet	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	4,5,6,7,8,9,10	7,8,9	7,8,9	7,8,9	7,8,9	7,8,9	
	Canal	5,6,7,8,9	5,6,7,8,9,10	5,6,7,8,9,10	5,6,7,8,9,10	5,6,7,8,9,10	5,6,7,8,9,10						
2011	Hwy12	4,5,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	7	7	7	7	7	
	Sterling	4,5	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11						
	Hwy238	4,5	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	7	7	7	7	7	
	Zaire	4,5,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	7	7	7	7	7	
	PreOutlet	4,5	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	4,5,6,7,11	7	7	7	7	7	
	Canal	4,5,7,11	7,11	7,11	7,11	7,11	7,11						
2012	Hwy12	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10		8	8	8	8	
	Zaire	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10		8	8	8	8	
	PreOutlet	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8,10		8	8	8	8	
	Canal	6,8	5,6,8,10	5,6,8,10	5,6,8,10	5,6,8	5,6,8						

[1] = numbers listed correspond to months in which samples were taken (4 = April, etc.)

Methods

Discharge

Trutracks were installed each year of the Careless Creek study for continuous flow monitoring during the sampling season. Trutracks were programmed to record a water level measurement every 30 minutes. Stream stage data was downloaded from all Trutracks as a part of each sampling visit, with a few exceptions in 2011, due to high water levels. Discharge measurements were made using a Marsh-McBirney model 2000 Flo-Mate portable velocity meter and top setting rod. Discharge measurements made with the flow meter were correlated with Trutrack stage height measurements to develop rating curves for calculation of estimated flow every half hour from April through November. The 2012 rating curves can be found in Appendix B. See past reports for 2009-2011 rating curves.

Grab Samples

Water grab samples were collected for sediment and chemical analysis and were transported on ice and delivered to Energy Laboratories in Helena for analysis in accordance with holding times. One set of quality control samples (blank and duplicate) was collected on each field visit.

Quality Assurance

Quality control checks on data are critical to provide confidence that the laboratory is conducting testing in a consistent and accurate manner and that field sampling protocols are producing reliable values. In 2009, the Lower Musselshell Conservation District YSI 63 was used for measuring field parameters and was calibrated once at the beginning of the season. Starting in 2010, MSUEWQ's YSI 556, which was used for all field parameter measurements and was calibrated within 24 hours before use at each sampling event by MSUEWQ staff.

According to laboratory QA/QC reports, all analyses were completed using the method specified in the SAP. At the time of writing of this report (January 2013), quality assurance was complete for 2009 data and has been uploaded to MT-eWQX. Quality assurance was initiated for 2010, but has not been completed. The approach for completing quality assurance and uploading data for 2010-2012 to MT-eWQX is a necessary topic of conversation between MWC, MSUEWQ and MDEQ.

Results

Discharge

In 2009 it was not possible to assess the continuous discharge of the canal into Careless Creek due to poor relationships between stage and discharge at the PreOutlet and Canal sites. At the PreOutlet monitoring site, water from the canal backed up to the stilling well, which resulted in stage recordings that were influenced by canal discharge rather than by the discharge in the stream from above the confluence.

Movement of the Canal and PreOutlet sites in 2010 allowed for data collection that tells the story of how the canal influences discharge in Careless Creek (Figure 3). Discharge from the canal into Careless Creek ended around October 1st in 2010. Zaire is the sample site just downstream from where the canal enters Careless Creek, and is the site where flow alterations from the canal are most pronounced. During non-irrigation months, discharge at Zaire is controlled by discharge coming down Careless Creek at PreOutlet. In 2010, the discharge at Zaire began to rise above winter baseflow at the beginning of May as a result of increasing flow in the canal. Around the end of May, discharge from Careless Creek at PreOutlet surpassed discharge entering from the canal and the Zaire hydrograph was dominated by the flow from PreOutlet. Around July 13th, flow at PreOutlet dropped below the amount of flow from the Canal site. For the rest of the irrigation season, flow from the canal was the dominant source of flow at Zaire. While the influence of flow from the canal in Careless Creek can be seen throughout the irrigation season, the influence is most pronounced when runoff tapers off in mid-July.

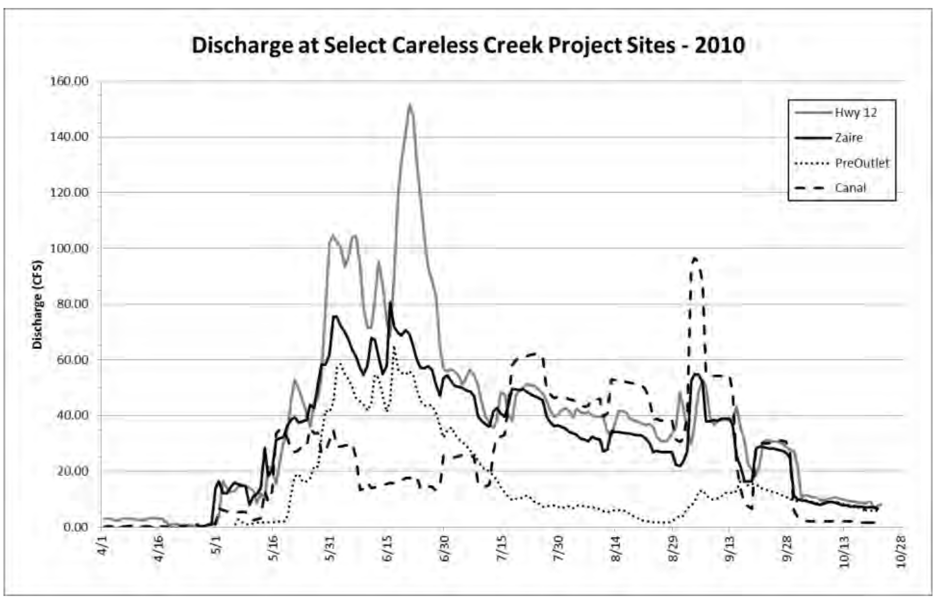

Figure 3. 2010 hydrograph from four Careless Creek project sites.

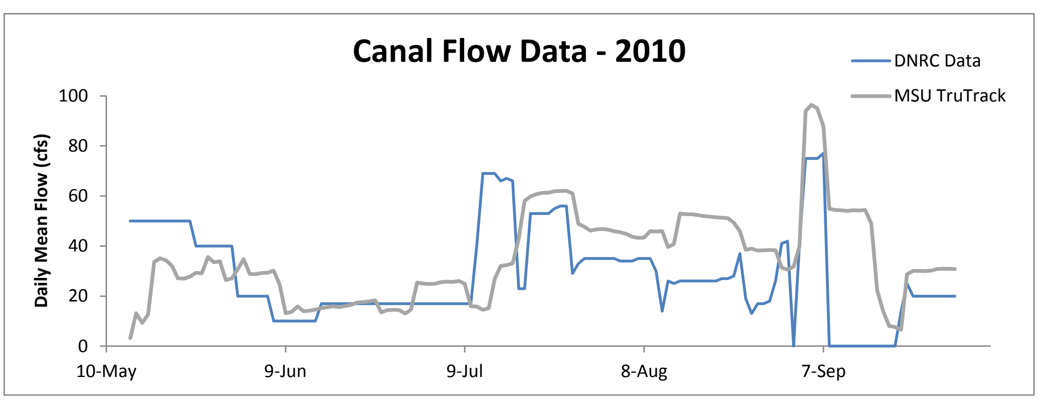

Figure 4. 2010 hydrograph for Canal site made with MSU TruTrack data and DNRC Canal release data.

In 2011, the Musselshell watershed experienced record flooding. The high water levels washed out many of the project TruTracks, resulting in missing data during flood stage flows. Figure 5 shows discharge in both the Musselshell River and in Careless Creek at its mouth, and indicates that flow in Careless Creek roughly paralleled that of the Musselshell for the periods with data. Figure 6 includes estimated data for Careless Creek during the missing data period (dashed line). The missing Careless Creek data was estimated using Musselshell data for the same period, and the average relative percent flow in Careless Creek for the two weeks before and after the missing data period. This method indicates that peak flow in Careless Creek was approximately 1200 cfs during the 2011 flooding.

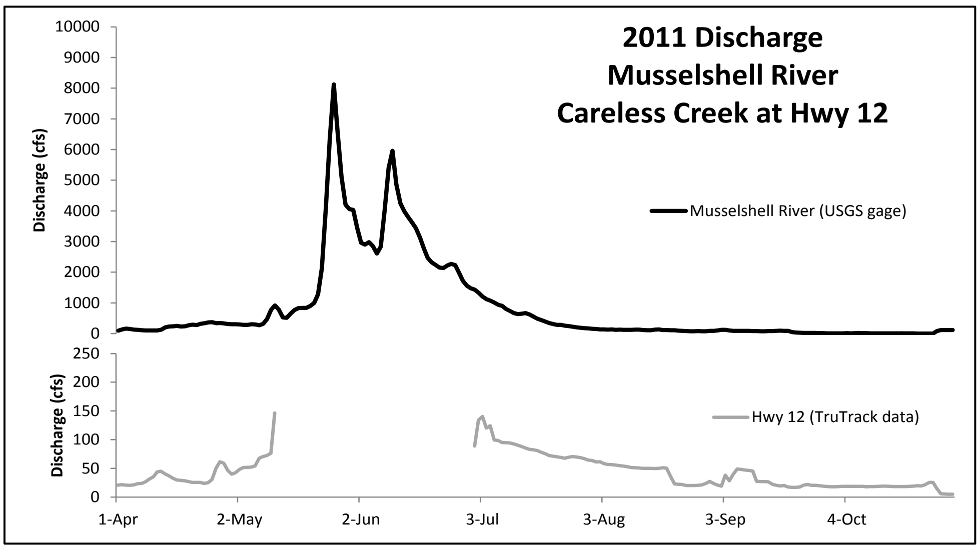

Figure 5. 2011 hydrograph from the Musselshell River and Careless Creek @ Hwy 12. Musselshell discharge peaked at 8120 cfs on May 26.

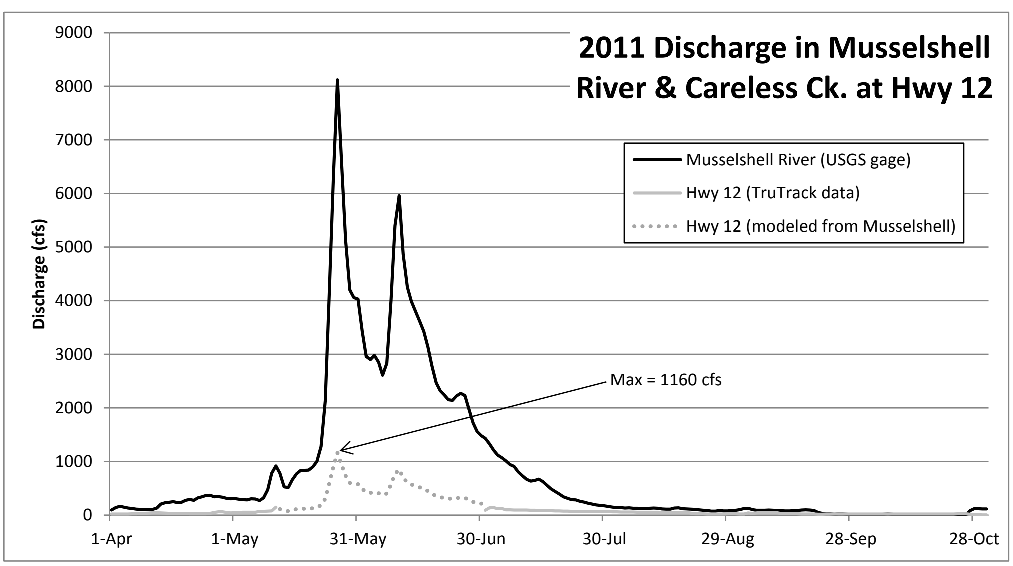

Figure 6. 2011 hydrograph from the Musselshell River and Careless Creek @ Hwy 12, including modeled flows for the period of data missing in Careless Creek (dashed line).

Data from 2012 reaffirms the influences from the canal that were described for 2010, with downstream discharge at Zaire controlled by Careless Creek at PreOutlet during non-irrigation months and discharge from the canal being the dominant source of flow throughout the irrigation season (Figure 7).

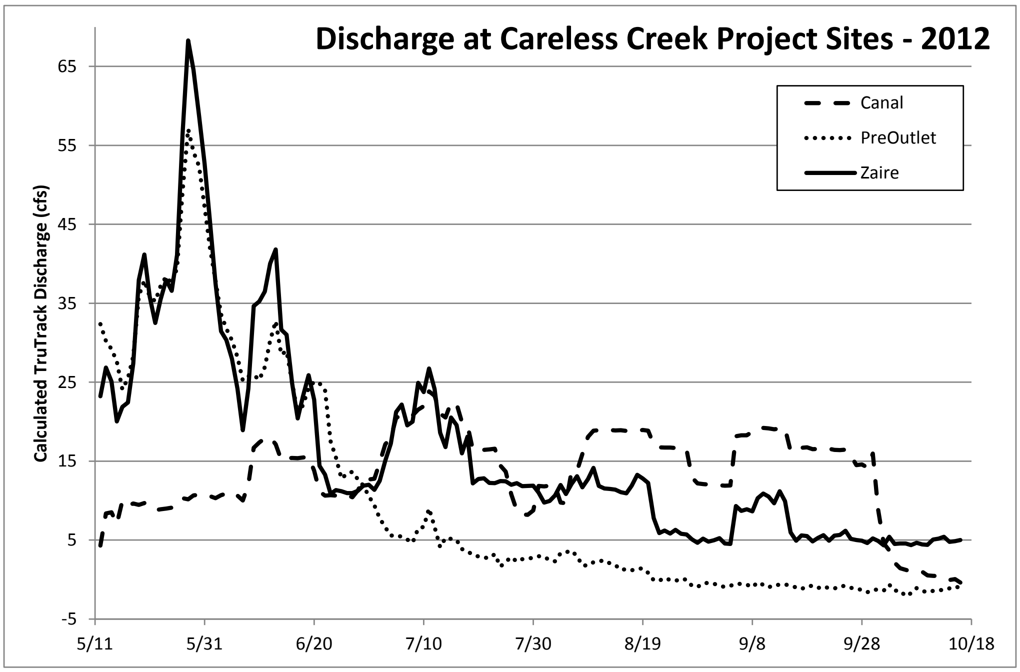

Figure 7. 2012 hydrograph from three Careless Creek project sites.

Nutrients

Excessive nitrogen levels, when in the presence of available phosphorus, can result in nuisance algae growth and eutrophication. MDEQ has established numeric nutrient criteria for Montana's Wadeable Stream and Rivers intended to control nuisance algae growth (MDEQ 2012, Suplee et al. 2008). The criteria are different based on the region of the state a stream is located in and the "ecoregions" are broken up based on geology, vegetation and climate. Careless Creek falls into the Northwestern Great Plains Ecoregion. The criteria apply during the growing season from July 1st through September 30th, which is the period when algae growth is of most concern. The total nitrogen criteria for this region is set at 1.0 mg/L (MDEQ, 2011). While the MDEQ ultimately did not include a threshold for nitrate-N in the Circular 12 nutrient criteria document, the technical guidance document that supports the standards suggested a nitrate-N threshold of 0.076 mg/L (Suplee, 2008), so this value is included to aid in interpretation of data.

Similar to nitrogen, excess levels of phosphorus in streams and lakes can stimulate growth of nuisance algae and cause eutrophication. In general, most phosphorus is tightly bound to sediment, so the pathways it takes to streams are often different than nitrogen. Important agricultural sources of phosphorus to streams include surface water runoff from agricultural fields and livestock waste. While past studies have suggested levels as low as 0.03-0.1 mg/L can contribute to eutrophication, MDEQ has set the total phosphorous (TP) criteria at 0.120 mg/L for the Northwestern Great Plains Ecoregion (MDEQ, 2011; Campbell and Wildberger, 2001; Suplee et. al, 2008).

Three forms of nitrogen [ammonia (NH_{3+4}), nitrate + nitrite (NO_{2+3}), and total persulfate nitrogen (TN)] and total phosphorous (TP) were analyzed during the study period. For detailed information on sample locations and timing, see Table 2. None of the samples collected during the study period produced a value for ammonia (detection limit of 0.05 mg/L). The sampling results for the remaining nutrient parameters (NO_{2+3}, TN, and TP), including the corresponding MDEQ criteria for that nutrient, are shown in Figures 8 through 10.

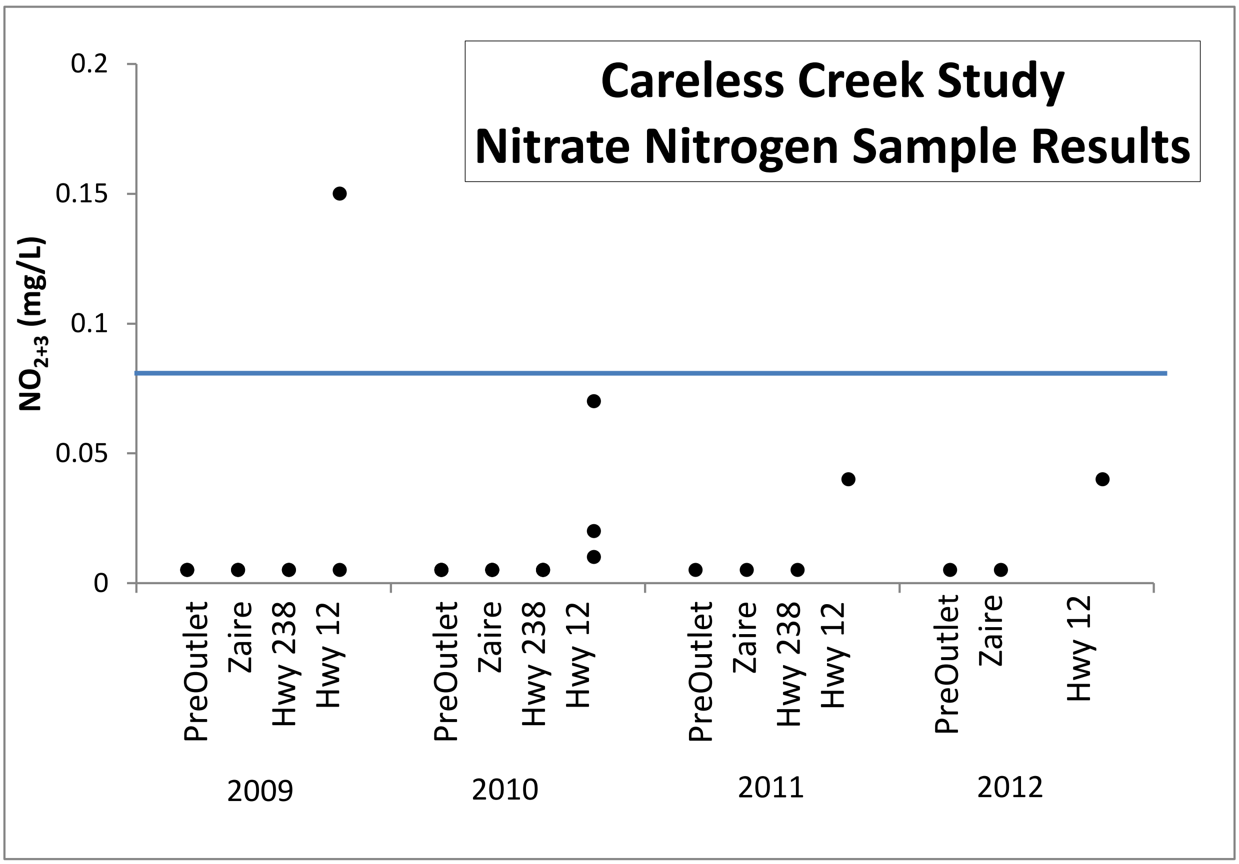

Figure 8. Nitrate levels for all samples taken during the study period. The MDEQ Technical guidance document's (Suplee 2008) suggested standard for nitrate (0.075 mg/L) shown as a blue line.

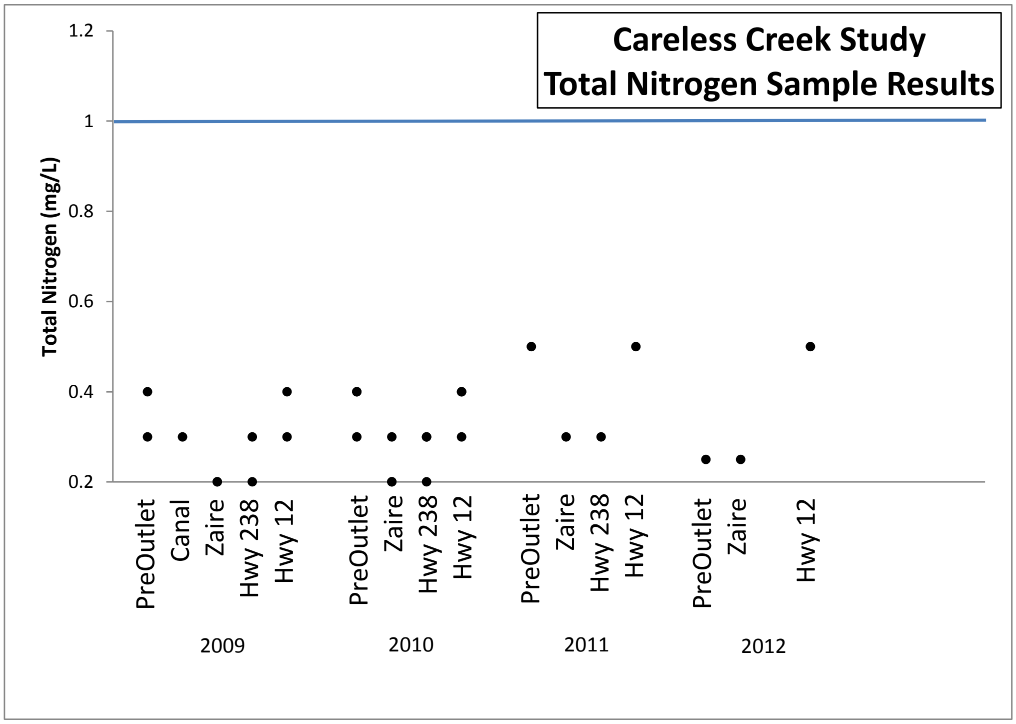

Figure 9. Total nitrogen levels for all samples taken during the study period. MDEQ Circular 12 standard for total nitrogen (1.0 mg/L) shown as a blue line.

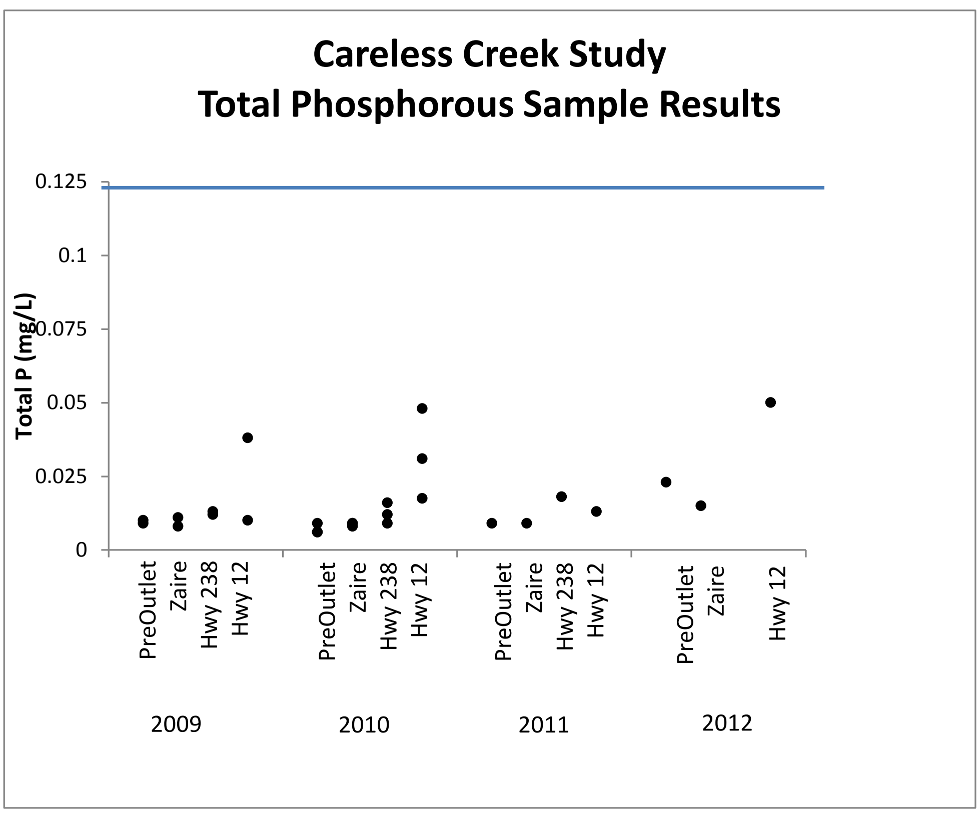

Figure 10. Total phosphorous levels for all samples taken during the study period. MDEQ Circular 12 standard for total phosphorus (0.0120 mg/L) shown as a blue line.

Total Suspended Solids (TSS)

TSS is defined as solids that will not pass through a 2 micron filter. TSS is made up of organic and mineral particles that are transported in the water column, and can be correlated to erosion of the river channel bottom and banks or erosion and sediment transport from land surfaces. High TSS levels can be detrimental to aquatic ecosystems, as high sediment concentrations and siltation can degrade habitat for fish and can limit light penetration, which limits ability of aquatic plants and algae to produce food and oxygen for other aquatic organisms. Figure 11 shows that TSS measurements tend to be higher when discharge is higher. Figure 11 also shows sediment concentrations in 2010 were more responsive to increases in discharge at the Hwy12 site than at the PreOutlet site which is upstream from the confluence of the canal.

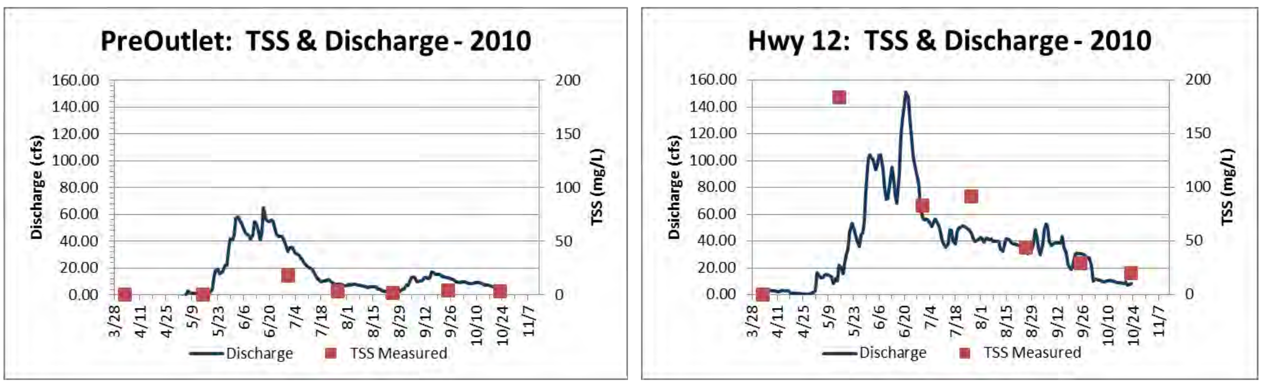

Figure 11. Discharge and TSS for the 2010 season at the PreOutlet and Hwy 12 sites.

The suggested cause of sediment impairment in Careless Creek is from hydro-modification and resulting erosion within the channel, rather than from sediment being delivered from the canal (MDEQ, 2001). The calculated 2010 sediment loads at the Canal site are not a significant portion of those calculated at Hwy 12W (Figure 12), corroborating this assumption.

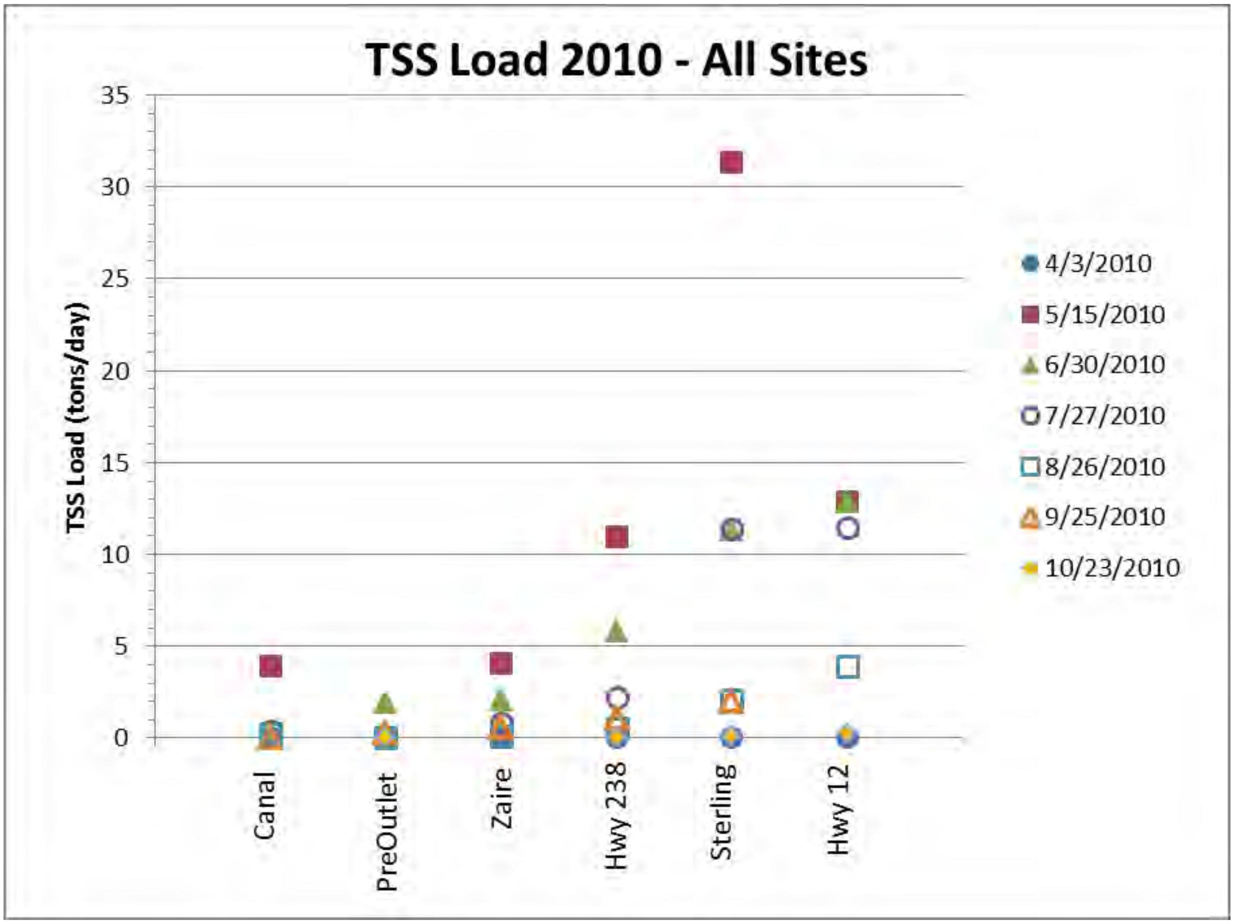

Figure 12. TSS loads for each site for each sample date in 2010.

TSS concentrations (mg/L) for each study site throughout the 4-year study period are displayed in Figure 13. Flooding and erosion in the area resulted in an abnormally high measured TSS concentration for 2011 when compared to other years.

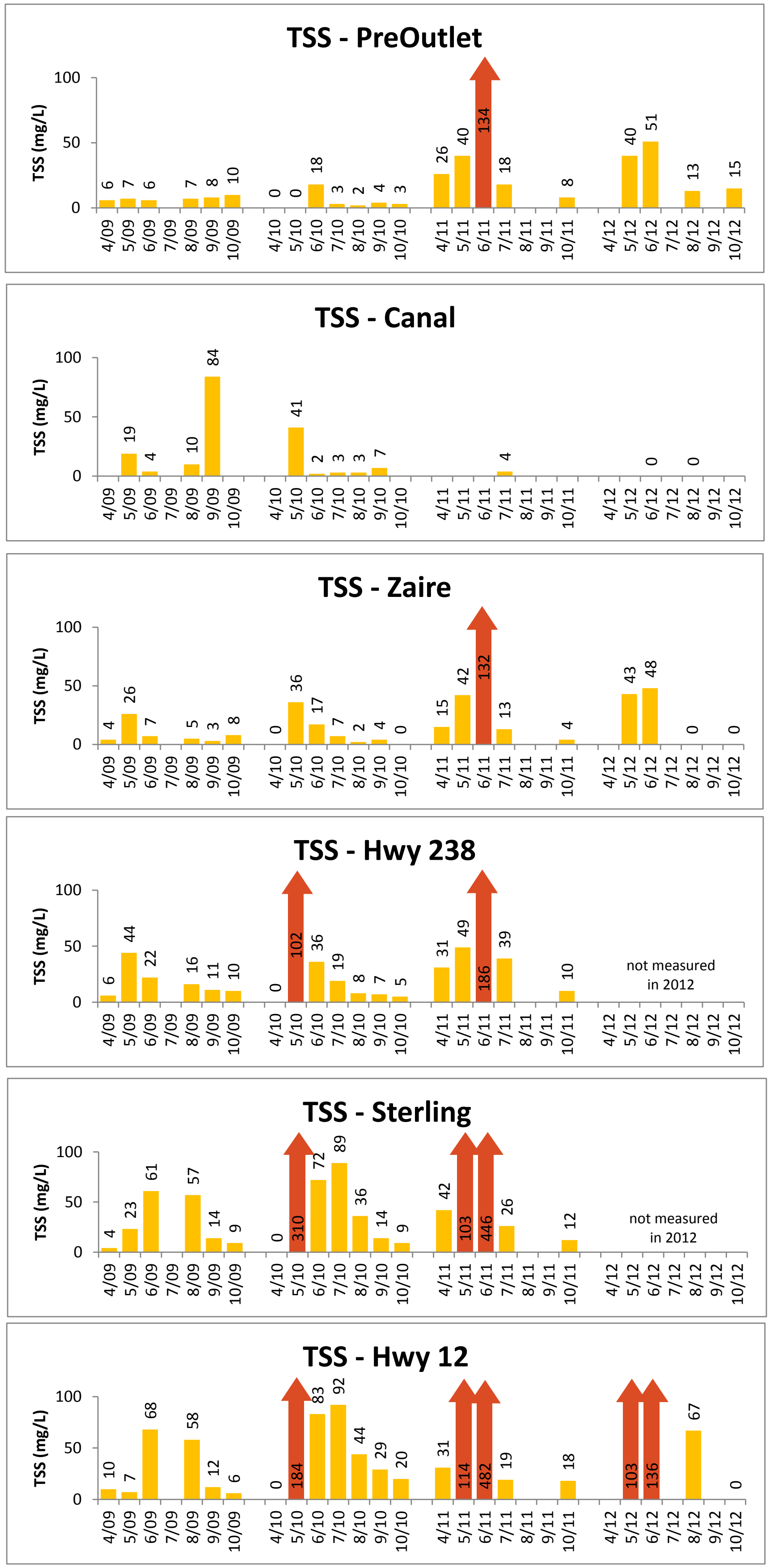

Figure 13. TSS concentrations (mg/L) for each study site, shown upstream to downstream, throughout the study period (2009 – 2012). A printed value of 0 = no detect.

Total Dissolved Solids (TDS)

TDS are the solid matter in water that will pass through a 2 micron filter. Dissolved materials include calcium, bicarbonate, nitrogen, phosphorus, iron, sulfur and other ions (Mitchell and Stapp, 2000). Rainwater usually has less than 10 mg/L TDS and hence TDS is typically lower in streams during spring runoff, when snow is feeding the stream with low TDS water. This spring snowmelt dilution effect can be seen in data for Careless Creek in Figure 14, which shows that TDS measurements tend to be lower when discharge is higher.

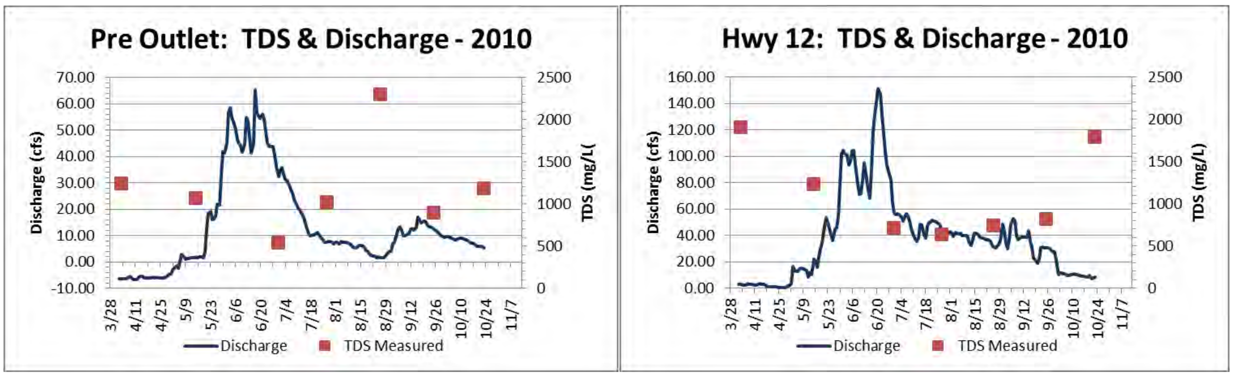

Figure 14. Discharge and TDS for Careless Creek Monitoring Project, 2010.

The Environmental Protection Agency (EPA) has set a guideline of 500 mg/L for TDS in drinking water which primarily related to the aesthetic quality of drinking water. TDS is a concern in irrigation water due to potential for accumulation of salt in the root zone, leading to drought stress on crops. Irrigation management and crop sensitivity factor into what TDS levels are of concern, but 2000 mg/L is a general threshold for suitability for irrigation. In Montana's surface water systems (rivers, lakes, streams, etc.), the TDS varies from less than 100 mg/L in many mountain areas to much greater than 2500 mg/L during low flow in some smaller prairie streams.

TDS concentrations (mg/L) for each study site throughout the 4-year study period are displayed in Figure 15. Orange bars highlight the instances where grab sample results exceeded the 2000 mg/L threshold for irrigation suitability. These instances were rarely during the irrigation season and most frequently occurred at the PreOutlet site, upstream of the confluence with the Canal. Grab samples from the Canal never approached the irrigation threshold during the study period.

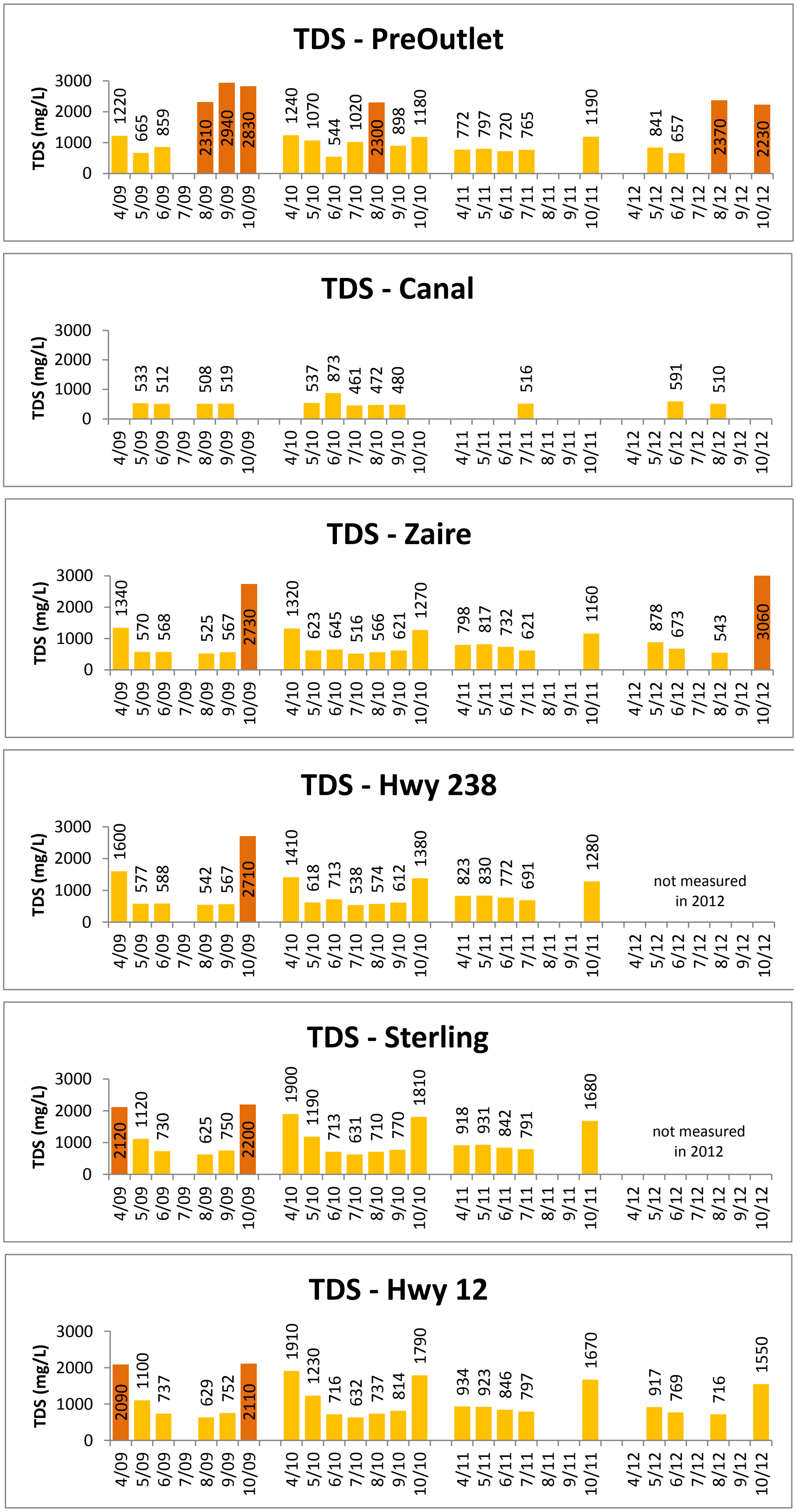

Figure 15. TDS concentrations for each study site throughout the study period (2009 – 2012).

Salt Load Calculations

Figure 16 shows instantaneous loads calculated by multiplying discharge by TDS for the 2010 sample events. For April through August, the canal is the source of a notable portion of the salinity load to Careless Creek, but this is not surprising as it is the dominant source of flow during this period (see Figure 3). It is important to note that TDS grab samples from the Canal never exceeded 873 mg/L during the study period (Figure 15).

Other significant increases in load occur between Zaire and Sterling, but it is again important to note that there are no exceedances of the 2000 mg/L suggested irrigation threshold during irrigation season (May through September) during the study period (Figure 15).

If the MWC wanted to explore salinity loading along Careless Creek in more detail, load calculations similar to those for 2010 (Figure 16) could be made for other years of the study.

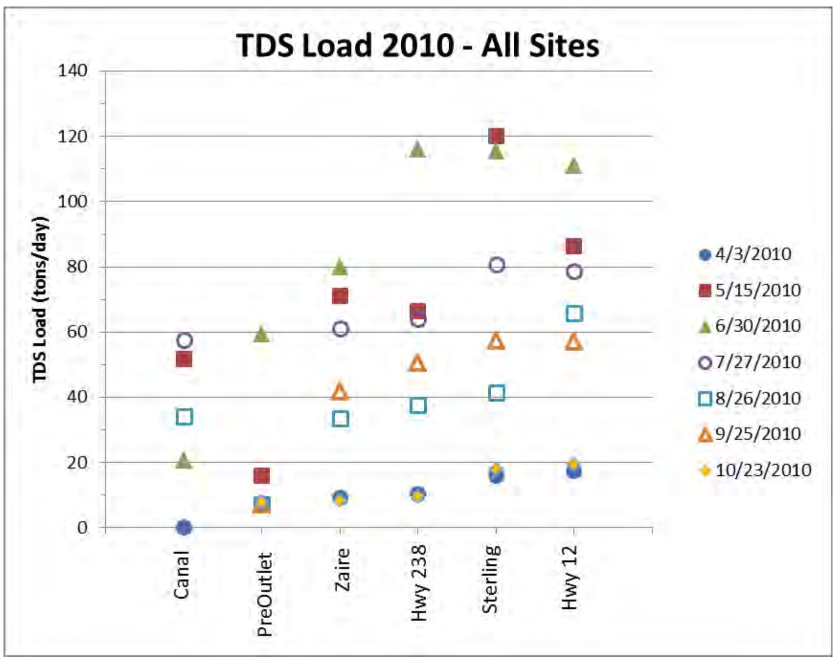

Figure 16. Discharge and TDS for Careless Creek Monitoring Project, 2010.

Specific Conductance

Specific conductance (SC) is a measurement of water's capacity to conduct an electric current (standardized to 25^{o} C). SC is closely correlated with TDS because the salt in water is what conducts electricity. The close correlation between SC and TDS is illustrated in Figure 17, making it redundant to discuss results for SC. SC values for the project period are presented in Appendix A. This relationship reiterates the fact that SC is a useful surrogate variable for cheaply and easily estimating total dissolved solids in a water body.

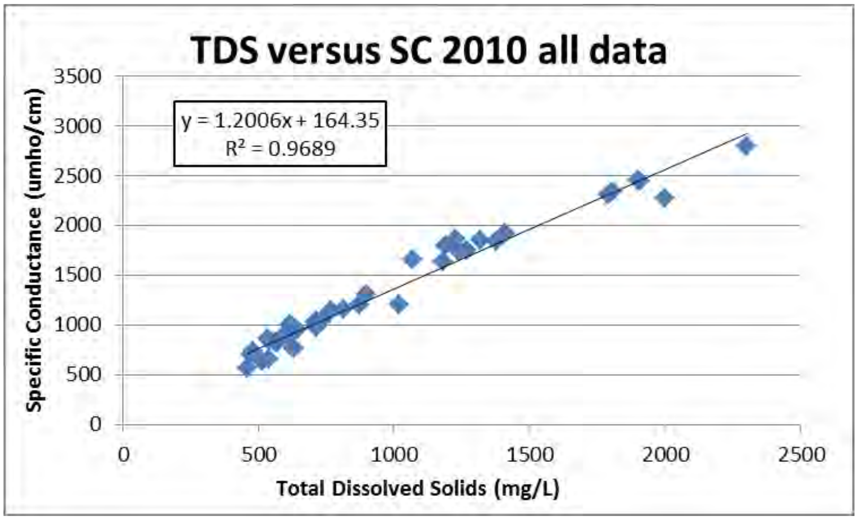

Figure 17. TDS versus Specific Conductance, Careless Creek Monitoring Project, 2010.

pH

The pH of water is an indicator of acidity and alkalinity of water and affects biological availability and solubility of chemical constituents in water. Geology controls baseline pH in a stream, but water temperature and changes in photosynthesis also cause seasonal and daily variations. Photosynthesis in streams is carried out by vegetation such as algae and macrophytes and affects pH by taking CO_2 out of the water which reduces acidity. The acceptable range for pH in surface water, according to MDEQ criteria is 6.5 to 8.5.

pH measurements for the study period are included in Appendix A. Values in 2009 ranged from 7.43 to 9.67, values in 2010 ranged from 7.85 to 8.92, values in 2011 ranged from 6.72 to 8.41, and values in 2012 ranged from 7.54 to 8.63. The highest pH measurements in 2009 were attributed to a likely instrument calibration issue. In 2011 there were three values above the 8.5 threshold (both at 8.51), two at Sterling on April 15th and May 16th, and one at Hwy 12 on May 16th. In 2012, the only value above the threshold was measured at 8.63 in late May at the Canal site.

Water Temperature

Water temperature impacts many of the physical, biological and chemical characteristics of a stream. Examples include the amount of oxygen water can hold, the photosynthesis rate of algae and aquatic plants, the metabolic rates of aquatic organisms and the sensitivity of organisms to pollution (Mitchell and Stapp, 2000).

Water temperature measurements for the study period are included in Appendix A. Measured temperatures ranged from 5.5^{o} C to 21.6^{o} C in 2009 and from 5.48^{o} C to 23.01^{o} C in 2010, and from -0.3^{o}C (in November) to 22.98^{o}C in 2011. Values in 2012 ranged from 8.75^{o}C to 20.68^{o}C. Temperatures were relatively stable throughout the stream for each sample date and followed typical patterns of cool spring temperatures, warm summer temperatures and cold temperatures moving into November.

Dissolved Oxygen (DO)

Dissolved oxygen in streams is critical for the survival of fish and macroinvertebrates. In streams where algae or other aquatic vegetation is present, DO concentrations can fluctuate dramatically over a 24-hour period. The lowest concentrations are just before sunrise, when plants in the stream begin to photosynthesize and create oxygen, raising DO levels. For this reason, the MDEQ is most interested in DO concentrations between 6:00 and 8:00 AM when they are lowest. MT water quality standards for streams which support cold water fisheries say DO concentrations should never drop below 4 mg/L and should not drop below 8.0 mg/L for the protection of early life stages of fish (MDEQ-7).

Although DO was not included in the SAP, it was measured once on July 27th 2010, before 8:00 AM and then again during regular sampling after 8:00 AM. Results presented in Table 4 show that DO levels for all sites were below the 8.0 mg/L threshold for the protection of early life stages and the DO at the PreOutlet site was approaching the threshold for stress on adult fish. Sites resampled after 10:40 all produced DO values above the 8.0 mg/L threshold.

Table 4. Dissolved oxygen at Careless Creek sites on July 27th 2010 before 8:00 AM and then during the regular sampling event after 8:00 AM.

	Before 8:00 AM		After 8:00 AM	
Site	**Time**	**DO (mg/L)**	**Time**	**DO (mg/L)**
CCCanal	7:23	7.5	13:03	9.2
CCPreOutlet	7:05	4.66	12:30	9.61
CCZaire	6:55	7.57	11:30	9.4
CCHwy 238	6:43	6.81	10:40	8.27
CCSterling	6:26	7.3	9:52	7.65
CCHwy12	6:15	7.35	8:40	7.43

Periphyton

Periphyton (benthic algae) samples were collected twice during the 2009 sampling season. Rhithron Associates analyzed the samples and a report on the results is housed with MDEQ.

Conclusions

The Careless Creek Restoration Plan (2001) determined sedimentation was the primary source of impairment to Careless Creek and outlined a restoration goal with three objectives designed to reduce sediment in Careless Creek. These are summarized in Table 5.

Table 5. Summary of the 2001 Careless Creek Restoration Plan, including source of impairment and recommended solutions.

Nature of Impairment	Sediment	
Determined Source of Impairment	Erosive discharge from canal during irrigation season.	
Restoration Goal	Reduce maximum measured sediment concentrations of 130-180 mg/L by 25%.	
Associated Restoration Objectives	1.	Reduce irrigation water releases to 100 cfs at the canal diversion and 80 cfs at confluence with Musselshell.
	2.	Restore vegetation to 54% of the currently eroding banks.
	3.	Increase channel length by 4% by restoring oxbow.

Discharge

While 2009 site placement and 2011 flooding left holes in the data for the study period, TruTrack data indicates that the first objective set forth in the water quality restoration plan are being met. Discharge from Deadman's Reservoir to Careless Creek via the canal did not exceed 100 cfs during the study period, and while discharge regularly exceed 80 cfs at the confluence of Careless Creek and the Musselshell River during the study period, these events were all associated with natural peaks in the hydrograph (late May to late July) and do not correlate with canal releases (Figure 3).

TSS

The goal of the Careless Creek Restoration Plan states that sediment (TSS) delivered to the Musselshell River by Careless Creek was as high as 130–180 mg/L during the irrigation season and set a TMDL target to reduce sediment by 25%. Although a specific target threshold TSS values were not defined in the Restoration Plan, it is presumed that the reference to a 25% reduction in sediment is applied to cumulative sediment loads during the irrigation season or annually. However, sediment-related measurements referenced in the Restoration Plan include a "background measurement of total suspended solids (TSS) delivered by Careless Canal between 14-16 milligrams per liter (mg/l) at both high and low flows" in addition to "TSS delivered to the Musselshell River measured as high as 130–180 mg/l during the irrigation season." The lack of inclusion of discharge or load information in this target makes the goal ambiguous and difficult to quantify. It is noteworthy that the vast majority of sediment concentrations measured during this study were far below the 130-180 mg/l range noted in the restoration plan. Furthermore, the largest TSS concentrations were measured in 2011 during a significant flood event which begs the larger question of how restoration plans fit in the context of natural disturbance events.

Eroding Banks

The reduction of sediment by 25 percent was to be "accomplished by stabilizing and restoring vegetation to a minimum of 54 percent of eroding streambanks. NRCS assessed streambank condition along the study reach in both 1995 and 2008. The report offers percent change (in linear feet) of streambank features along five study reaches. However, "eroding bank" may have been reclassified as "vulnerable bank", "vegetated bank", or "stable bank" under NRCS criteria, making direct correlations with the changes called for in the Restoration Plan difficult.

Considerations for Moving Forward (discussed at 1/28/2013 MWC meeting)

- MWC is interested in pursuing salinity monitoring along the mainstem of the Musselshell and will move forward with procurement of meters and collaboration with MSUEWQ on preparation of a monitoring plan. David Stout who is a Big Sky Watershed Corp member with LMCD will take the lead on the ground in getting these efforts initiated.
- Photo points monitoring will be pursued and David Stout will work with MSUEWQ and others on development of a plan for the monitoring.

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Appendix A. Project Data

Ammonia as N Sample Results (mg/L) - Careless Creek						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/28/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/27/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/2009	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
8/22/2009	**ND**	NM(a)	**ND**	**ND**	NM(a)	**ND**
9/29/2009	**ND**	NM(a)	**ND**	**ND**	NM(a)	**ND**
10/17/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/3/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/15/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/30/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2010	**ND**	NM(a)	**ND**	**ND**	NM(a)	**ND**
8/26/2010	**ND**	NM(a)	**ND**	**ND**	NM(a)	**ND**
9/25/2010	**ND**	NM(a)	**ND**	**ND**	NM(a)	**ND**
10/23/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/16/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2011	**ND**	NM(a)	**ND**	**ND**	NM(a)	**ND**
8/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
9/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
11/10/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/29/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
7/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
8/21/2012	**ND**	NM(a)	**ND**	NM (c)	NM(a)	**ND**
9/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
10/16/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)

(a) = per 2009 SAP

(b) = not flowing

(c) = cancelled per DEQ

(d) = not visited/sampling event not conducted

Nitrate Nitrogen Sample Results (mg/L) - Careless Creek						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/28/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/27/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/2009	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
8/22/2009	**ND**	NM(a)	**ND**	**ND**	NM(a)	**ND**
9/29/2009	**ND**	NM(a)	**ND**	**ND**	NM(a)	**0.15**
10/17/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/3/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/15/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/30/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2010	**ND**	NM(a)	**ND**	**ND**	NM(a)	**0.02**
8/26/2010	**ND**	NM(a)	**ND**	**ND**	NM(a)	**0.01**
9/25/2010	**ND**	NM(a)	**ND**	**ND**	NM(a)	**0.07**
10/23/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/16/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2011	**ND**	NM(a)	**ND**	**ND**	NM(a)	**0.04**
8/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
9/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
11/10/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/29/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
7/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
8/21/2012	**ND**	NM(a)	**ND**	NM (c)	NM(a)	**0.04**
9/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
10/16/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)

(a) = per 2009 SAP

(b) = not flowing

(c) = cancelled per DEQ

(d) = not visited/sampling event not conducted

Total N Sample Results (mg/L) - Careless Creek						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/28/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/27/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/2009	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
8/22/2009	**0.3**	NM(a)	**0.2**	**0.2**	NM(a)	**0.3**
9/29/2009	**0.4**	**0.3**	**0.2**	**0.3**	**0.4**	**0.4**
10/17/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/3/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/15/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/30/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2010	**0.4**	NM(a)	**0.3**	**0.3**	NM(a)	**0.4**
8/26/2010	**0.4**	NM(a)	**0.2**	**0.2**	NM(a)	**0.3**
9/25/2010	**0.3**	NM(a)	**0.2**	**0.3**	NM(a)	**0.4**
10/23/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/16/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2011	**0.5**	NM(a)	**0.3**	**0.3**	NM(a)	**0.5**
8/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
9/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
11/10/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/29/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
7/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
8/21/2012	**ND**	NM(a)	**ND**	NM (c)	NM(a)	**0.5**
9/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
10/16/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)

(a) = per 2009 SAP

(b) = not flowing

(c) = cancelled per DEQ

(d) = not visited/sampling event not conducted

Total P Sample Results (mg/L) - Careless Creek						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/28/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/27/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/2009	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
8/22/2009	**0.01**	NM(a)	**0.011**	**0.013**	NM(a)	**0.038**
9/29/2009	**0.009**	NM(a)	**0.008**	**0.012**	NM(a)	**0.01**
10/17/2009	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/3/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/15/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/30/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2010	**0.006**	NM(a)	**0.009**	**0.016**	NM(a)	**0.048**
8/26/2010	**0.009**	NM(a)	**0.008**	**0.009**	NM(a)	**0.031**
9/25/2010	**0.006**	NM(a)	**0.009**	**0.012**	NM(a)	**0.0175**
10/23/2010	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
5/16/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
6/15/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
7/27/2011	**0.009**	NM(a)	**0.009**	**0.018**	NM(a)	**0.013**
8/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
9/2011	NM(d)	NM(a)	NM(d)	NM(d)	NM(a)	NM(d)
11/10/2011	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)	NM(a)
4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/4/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
5/29/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)
7/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
8/21/2012	**0.023**	NM(a)	**0.015**	NM (c)	NM(a)	**0.05**
9/2012	NM(d)	NM(a)	NM(d)	NM (c)	NM(a)	NM(d)
10/16/2012	NM(a)	NM(a)	NM(a)	NM (c)	NM(a)	NM(a)

(a) = per 2009 SAP

(b) = not flowing

(c) = cancelled per DEQ

(d) = not visited/sampling event not conducted

TDS Sample Results (mg/L) - Careless Creek						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009	**1220**	NM(b)	**1340**	**1600**	**2120**	**2090**
5/28/2009	**665**	**533**	**570**	**577**	**1120**	**1100**
6/27/2009	**859**	**512**	**568**	**588**	**730**	**737**
7/2009	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)
8/22/2009	**2310**	**508**	**525**	**542**	**625**	**629**
9/29/2009	**2940**	**519**	**567**	**567**	**750**	**752**
10/17/2009	**2830**	NM(b)	**2730**	**2710**	**2200**	**2110**
4/3/2010	**1240**	NM(b)	**1320**	**1410**	**1900**	**1910**
5/15/2010	**1070**	**537**	**623**	**618**	**1190**	**1230**
6/30/2010	**544**	**873**	**645**	**713**	**713**	**716**
7/27/2010	**1020**	**461**	**516**	**538**	**631**	**632**
8/26/2010	**2300**	**472**	**566**	**574**	**710**	**737**
9/25/2010	**898**	**480**	**621**	**612**	**770**	**814**
10/23/2010	**1180**	**2000**	**1270**	**1380**	**1810**	**1790**
4/15/2011	**772**	NM(b)	**798**	**823**	**918**	**934**
5/16/2011	**797**	NM(b)	**817**	**830**	**931**	**923**
6/15/2011	**720**	NM(b)	**732**	**772**	**842**	**846**
7/27/2011	**765**	**516**	**621**	**691**	**791**	**797**
8/2011	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)
9/2011	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)
11/10/2011	**1190**	**1900**	**1160**	**1280**	**1680**	**1670**
4/2012	NM(d)	NM(d)	NM(d)	NM (c)	NM (c)	NM(d)
5/4/2012	**841**	NM(b)	**878**	NM (c)	NM (c)	**917**
5/29/2012	**657**	**591**	**673**	NM (c)	NM (c)	**769**
7/2012	NM(d)	NM(d)	NM(d)	NM (c)	NM (c)	NM(d)
8/21/2012	**2370**	**510**	**543**	NM (c)	NM (c)	**716**
9/2012	NM(d)	NM(d)	NM(d)	NM (c)	NM (c)	NM(d)
10/16/2012	**2230**	NM(b)	**3060**	NM (c)	NM (c)	**1550**

(a) = per 2009 SAP

(b) = not flowing

(c) = cancelled per DEQ

(d) = not visited/sampling event not conducted

TSS Sample Results (mg/L) - Careless Creek						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009	**6**	NM(b)	**4**	**6**	**4**	**10**
5/28/2009	**7**	**19**	**26**	**44**	**23**	**7**
6/27/2009	**6**	**4**	**7**	**22**	**61**	**68**
7/2009	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)
8/22/2009	**7**	**10**	**5**	**16**	**57**	**58**
9/29/2009	**8**	**84**	**3**	**11**	**14**	**12**
10/17/2009	**10**	NM(b)	**8**	**10**	**9**	**6**
4/3/2010	**ND**	NM(b)	**ND**	**ND**	**ND**	**ND**
5/15/2010	**ND**	**41**	**36**	**102**	**310**	**184**
6/30/2010	**18**	**2**	**17**	**36**	**72**	**83**
7/27/2010	**3**	**3**	**7**	**19**	**89**	**92**
8/26/2010	**2**	**3**	**2**	**8**	**36**	**44**
9/25/2010	**4**	**7**	**4**	**7**	**14**	**29**
10/23/2010	**3**	**50**	**ND**	**5**	**9**	**20**
4/15/2011	**26**	NM(b)	**15**	**31**	**42**	**31**
5/16/2011	**40**	NM(b)	**42**	**49**	**103**	**114**
6/15/2011	**134**	NM(b)	**132**	**186**	**446**	**482**
7/27/2011	**18**	**4**	**13**	**39**	**26**	**19**
8/2011	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)
9/2011	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)	NM(d)
11/10/2011	**8**	**6**	**4**	**10**	**12**	**18**
4/2012	NM(d)	NM(d)	NM(d)	NM (c)	NM (c)	NM(d)
5/4/2012	**40**	NM(b)	**43**	NM (c)	NM (c)	**103**
5/29/2012	**51**	**ND**	**48**	NM (c)	NM (c)	**136**
7/2012	NM(d)	NM(d)	NM(d)	NM (c)	NM (c)	NM(d)
8/21/2012	**13**	**ND**	**ND**	NM (c)	NM (c)	**67**
9/2012	NM(d)	NM(d)	NM(d)	NM (c)	NM (c)	NM(d)
10/16/2012	**15**	NM(b)	**ND**	NM (c)	NM (c)	**ND**

(a) = per 2009 SAP

(b) = not flowing

(c) = cancelled per DEQ

(d) = not visited/sampling event not conducted

Measured Discharge Data (in cfs) for Study Period						
	PreOutlet	Canal	Zaire	Hwy 238	Sterling	Hwy 12
4/23/2009	2.09	NO FLOW	2.55	NM	NM	3.05
5/28/2009	8.00	36.70	38.38	30.98	23.11	NM
6/27/2009	3.20	20.72	27.38	26.79	29.43	26.01
7/2009	NM	NM	NM	NM	NM	NM
8/22/2009	0.18	NM	49.21	50.94	51.84	47.64
9/29/2009	NM	31.44	52.75	54.02	45.02	44.40
10/17/2009	NM	NO FLOW	0.57	1.59	2.27	2.07
4/3/2010	2.24	NO FLOW	2.62	2.75	3.10	3.40
5/15/2010	5.57	35.73	42.23	39.86	37.43	25.98
6/30/2010	40.46	8.83	45.97	60.36	60.04	57.45
7/27/2010	2.70	46.32	43.86	44.21	47.50	46.24
8/26/2010	1.17	26.72	22.04	24.41	21.66	33.17
9/25/2010	2.91	NM	25.01	30.60	27.55	25.99
10/23/2010	2.44	NO FLOW	2.42	2.55	3.62	4.04
4/15/2011	33.93	NO FLOW	33.92	35.26	37.71	32.55
5/16/2011	63.76	NM	62.88	60.92	64.36	62.86
6/15/2011	NM	NM	NM	NM	NM	NM
7/27/2011	22.12	27.35	50.97	NM		85.57
8/2011	NM	NM	NM	NM	NM	NM
9/2011	NM	NM	NM	NM	NM	NM
11/10/2011	2.13	NO FLOW	2.27	NM	3.84	0.78
4/2012	NM	NM	NM	NM	NM	NM
5/4/2012	52.51	NO FLOW	49.04	NM	NM	53.00
5/29/2012	47.18	12.73	57.81	NM	NM	76.08
7/2012	NM	NM	NM	NM	NM	NM
8/21/2012	1.08	14.96	16.10	NM	NM	18.83
9/2012	NM	NM	NM	NM	NM	NM
10/16/2012	0.03	NO FLOW	0.11	NM	NM	0.96

Temperature (in C) for Study Period						
	PreOutlet	Canal	Zaire	Hwy 238	Sterling	Hwy 12
4/23/2009	NM	NM	NM	NM	NM	NM
5/28/2009	21.00	14.10	20.70	19.30	20.60	15.30
6/27/2009	20.00	18.10	16.40	16.60	18.10	16.90
7/2009	NM	NM	NM	NM	NM	NM
8/22/2009	21.60	19.10	20.20	19.50	19.80	18.80
9/29/2009	16.70	16.80	14.50	12.80	10.40	9.60
10/17/2009	8.60	NO FLOW	7.10	6.20	6.10	5.50
4/3/2010	6.38	NO FLOW	5.48	4.63	4.78	4.60
5/15/2010	15.17	12.93	11.87	10.38	12.80	10.80
6/30/2010	21.92	23.01	21.42	20.68	20.97	20.39
7/27/2010	19.24	19.40	19.10	19.14	19.45	19.39
8/26/2010	21.78	20.77	18.98	19.70	18.77	18.18
9/25/2010	12.06	13.50	11.95	11.75	11.34	11.04
10/23/2010	8.67	NO FLOW	8.25	7.99	7.64	7.26
4/15/2011	6.72	NM	5.91	5.71	5.64	5.23
5/16/2011	12.39	NM	11.87	11.27	11.47	10.99
6/15/2011	NM	NM	NM	NM	NM	NM
7/27/2011	19.48	19.98	21.09	22.04	22.67	22.98
8/2011	NM	NM	NM	NM	NM	NM
9/2011	NM	NM	NM	NM	NM	NM
11/10/2011	1.31	0.60	1.28	0.18	-0.03	0.40
4/2012	NM	NM	NM	NM	NM	NM
5/4/2012	11.97	NO FLOW	11.41	NM	NM	11.20
5/29/2012	13.41	15.33	13.60	NM	NM	13.29
7/2012	NM	NM	NM	NM	NM	NM
8/21/2012	16.61	20.68	19.44	NM	NM	17.36
9/2012	NM	NM	NM	NM	NM	NM
10/16/2012	8.75	NO FLOW	10.14	NM	NM	10.71

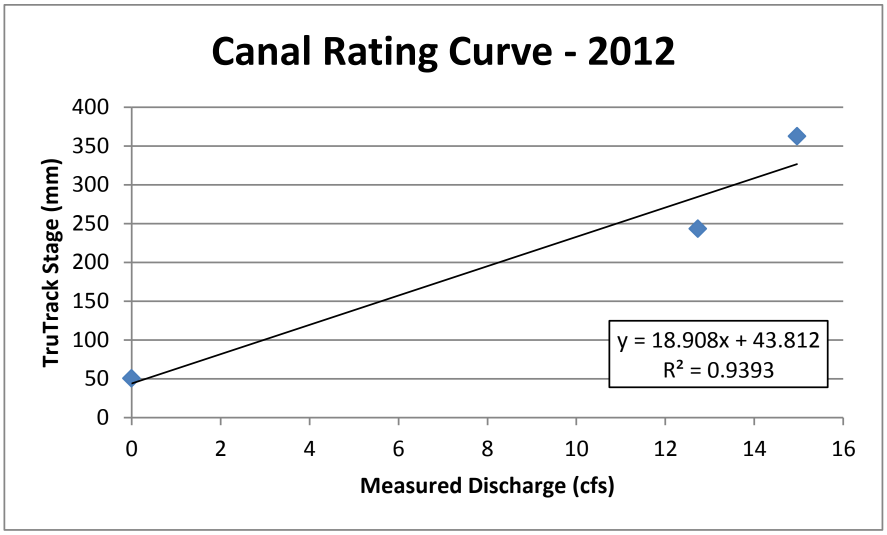
pH for Study Period						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009		**NO FLOW**		NM	NM	
5/28/2009	**8.32**	**8.30**	**8.34**	**8.31**	**8.14**	**8.31**
6/27/2009	**9.26**	**8.98**	**9.67**	**9.66**	**9.40**	**8.85**
7/2009	NM	NM	NM	NM	NM	NM
8/22/2009	**7.74**	**7.51**	**7.75**	**7.71**	**7.43**	**7.70**
9/29/2009	**7.90**	**8.25**	**8.06**	**8.02**	**7.94**	**7.85**
10/17/2009	**7.72**	**NO FLOW**	**7.86**	**7.88**	**7.88**	**7.99**
4/3/2010	**8.19**	**NO FLOW**	**8.29**	**8.61**	**8.39**	**8.49**
5/15/2010	**8.29**	**8.36**	**8.39**	**8.33**	**8.22**	**8.13**
6/30/2010	**8.36**	**8.92**	**8.42**	**8.28**	**8.19**	**8.22**
7/27/2010	**8.12**	**8.41**	**8.26**	**8.13**	**8.25**	**8.24**
8/26/2010	**8.06**	**8.51**	**8.45**	**8.25**	**8.27**	**8.20**
9/25/2010	**8.24**	**8.48**	**8.34**	**8.23**	**8.19**	**8.01**
10/23/2010	**8.41**	**NO FLOW**	**8.11**	**8.12**	**8.03**	**8.02**
4/15/2011	**6.72**	**NO FLOW**	**8.39**	**8.43**	**8.51**	**8.44**
5/16/2011	**8.43**	NM	**8.42**	**8.40**	**8.54**	**8.51**
6/15/2011	NM	NM	NM	NM	NM	NM
7/27/2011	**8.19**	**8.43**	**8.38**	**8.32**	**8.42**	**8.39**
8/2011	NM	NM	NM	NM	NM	NM
9/2011	NM	NM	NM	NM	NM	NM
11/10/2011	**8.13**	**7.98**	**8.09**	**7.92**	**8.11**	**7.57**
4/2012	NM	NM	NM	NM	NM	NM
5/4/2012	**7.95**	**NO FLOW**	**8.06**	NM	NM	**7.55**
5/29/2012	**8.45**	**8.63**	**8.40**	NM	NM	**8.46**
7/2012	NM	NM	NM	NM	NM	NM
8/21/2012	**7.54**	**8.40**	**7.99**	NM	NM	**7.55**
9/2012	NM	NM	NM	NM	NM	NM
10/16/2012	**8.09**	**NO FLOW**	**7.83**	NM	NM	**8.25**

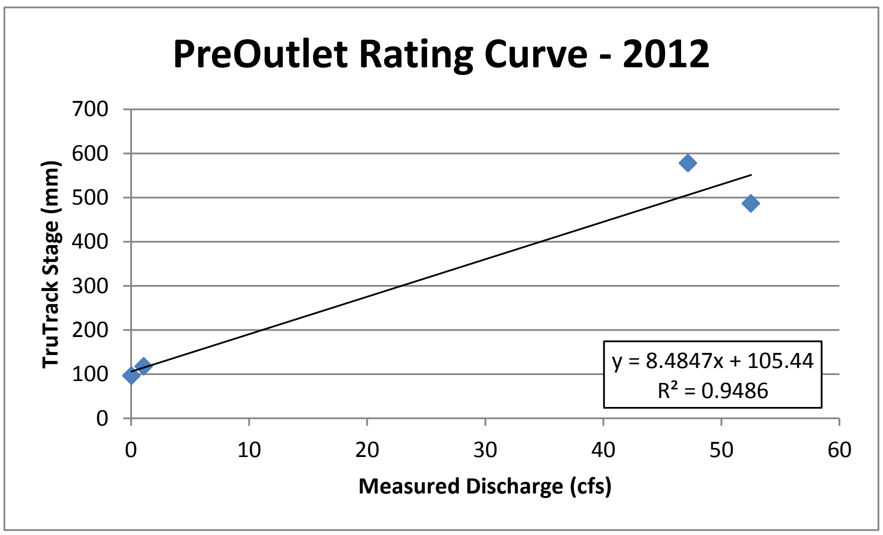
SC (in uhmo/cm) for Study Period						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy 12**
4/23/2009	NM	NM	NM	NM	NM	NM
5/28/2009	**1035**	**785**	**867**	**878**	**1462**	**1284**
6/27/2009	**1292**	**772**	**852**	**885**	**1081**	**329**
7/2009	NM	NM	NM	NM	NM	NM
8/22/2009	**2988**	**777**	**806**	**783**	**946**	**979**
9/29/2009	**3638**	**806**	**837**	**860**	**1127**	**1142**
10/17/2009	**3686**	**NO FLOW**	**3315**	**3566**	**2155**	**2920**
4/3/2010	**1742**	**NO FLOW**	**1857**	**1918**	**2457**	**2442**
5/15/2010	**1661**	**868**	**974**	**1007**	**1801**	**1869**
6/30/2010	**836**	**1202**	**952**	**978**	**1043**	**1035**
7/27/2010	**1207**	**571**	**631**	**663**	**760**	**768**
8/26/2010	**2800**	**704**	**826**	**830**	**1019**	**1045**
9/25/2010	**1306**	**736**	**903**	**934**	**1146**	**1160**
10/23/2010	**1636**	**NO FLOW**	**1745**	**1844**	**2345**	**2311**
4/15/2011	**1239**	NM	**1252**	**1295**	**1400**	**1414**
5/16/2011	**1183**	NM	**1198**	**1226**	**1358**	**1380**
6/15/2011	NM	NM	NM	NM	NM	NM
7/27/2011	**1144**	**764**	**931**	**1020**	**1141**	**1113**
8/2011	NM	NM	NM	NM	NM	NM
9/2011	NM	NM	NM	NM	NM	NM
11/10/2011	**957**	**2404**	**1706**	**1883**	**2276**	**2310**
4/2012	NM	NM	NM	NM	NM	NM
5/4/2012	**1285**	**NO FLOW**	**1295**	NM	NM	**1397**
5/29/2012	**1120**	**900**	**1075**	NM	NM	**1204**
7/2012	NM	NM	NM	NM	NM	NM
8/21/2012	**3000**	**808**	**840**	NM	NM	**1082**
9/2012	NM	NM	NM	NM	NM	NM
10/16/2012	**2894**	**NO FLOW**	**3522**	NM	NM	**2085**

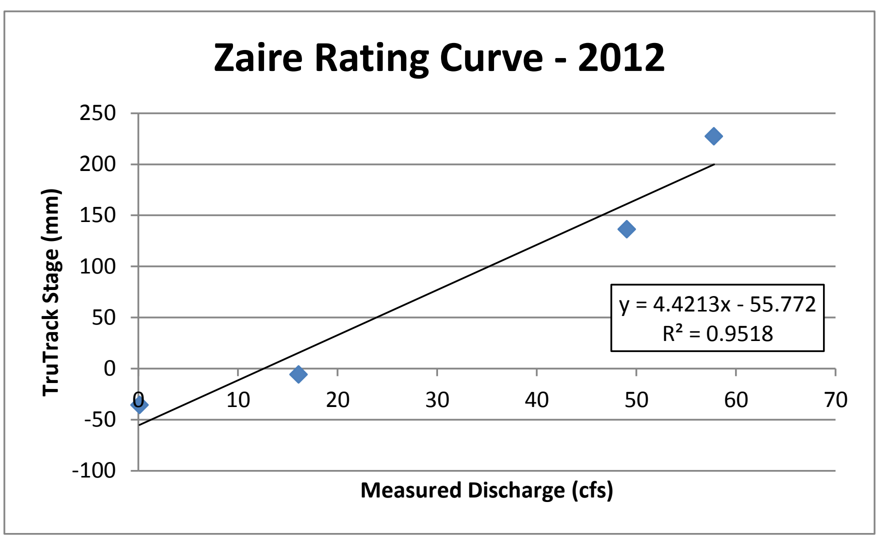
Summary Statistics 2009 - 2012						
	PreOutlet	**Canal**	**Zaire**	**Hwy 238**	**Sterling**	**Hwy12**
	Min = ND	Min = n/a	Min = ND	Min = ND	Min = n/a	Min = ND
Nitrate N	Max = ND	Max = n/a	Max = ND	Max = ND	Max = n/a	Max = 0.15
(mg/L)	Mean = ND	Mean = n/a	Mean = ND	Mean = ND	Mean = n/a	Mean = 0.05
	n = 7	n = 0	n = 7	n = 7	n = 0	n = 7
	Min = ND	Min = 0.3	Min = ND	Min = 0.2	Min = 0.4	Min = 0.04
Total N	Max = 0.5	Max = 0.3	Max = 0.3	Max = 0.3	Max = 0.4	Max = 0.5
(mg/L)	Mean = 0.33	Mean = 0.3	Mean = 0.20	Mean = 0.27	Mean = 0.4	Mean = 0.33
	n = 7	n = 1	n = 7	n = 6	n = 1	n = 7
	Min = 0.006	Min = n/a	Min = 0.008	Min = 0.009	Min = n/a	Min = 0.010
Total P	Max = 0.023	Max = n/a	Max = 0.015	Max = 0.018	Max = n/a	Max = 0.050
(mg/L)	Mean = 0.0103	Mean = n/a	Mean = 0.0099	Mean = 0.0133	Mean = n/a	Mean = 0.0296
	n = 7	n = 0	n = 7	n = 6	n = 0	n = 7
	Min = 544	Min = 461	Min = 516	Min = 542	Min = 625	Min = 629
TDS	Max = 2940	Max = 2000	Max = 3060	Max = 2710	Max = 2200	Max = 2090
	Mean = 1337.2	Mean = 743.7	Mean = 961.0	Mean = 934.7	Mean = 1135.1	Mean = 1107.7
	n = 22	n = 14	n = 22	n = 18	n = 18	n = 22
	Min = ND	Min = ND	Min = ND	Min = ND	Min = ND	Min = ND
TSS	Max = 134	Max = 84	Max = 132	Max = 186	Max = 446	Max = 482
	Mean = 19.0	Mean = 16.6	Mean = 18.9	Mean = 33.4	Mean = 73.7	Mean = 72.0
	n = 22	n = 14	n = 22	n = 18	n = 18	n = 22

***Ammonia as N not included because all data points were Non Detect.**

Appendix B: 2012 Rating Curves







*See previous reports for rating curves for prior years.