Lower Gallatin 2009 Water Quality Sampling Report

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EXECUTIVE SUMMARY

This report summarizes the results of water quality monitoring on the East Gallatin Rivers and select tributary streams within the Lower Gallatin Total Maximum Daily Load (TMDL) Planning Area (LGTPA) conducted during September 2009. The LGTPA encompasses an area of approximately 997 square miles in Gallatin County in southwestern Montana, extending from below the confluence with Spanish Creek near the north end of Gallatin Canyon, downstream to its confluence with the Madison River. The goal of the 2009 sampling was to assess nutrient, *E. coli,* and algae levels during the low-flow conditions of late summer, in order to assist the Montana Department of Environmental Quality (DEQ) in the development of a TMDL Plan within the LGTPA.

Eighty-three sites were distributed across sixteen streams representing a range of land uses within the LGTPA, including urban, low-density development, agriculture, and U.S. Forest Service land. Sites were selected by DEQ staff based, in part, on results from the 2008 water quality sampling results. OASIS Environmental, Inc. conducted the sampling in September of 2009, and samples were analyzed at State-approved laboratories. Water samples from all of the sites were analyzed for nutrients (nitrogen and phosphorus compounds), while algae samples were collected from 6 sites along 3 of the streams (East Gallatin River, Bridger Creek, Thompson Creek). Samples from five of the streams (Reese Creek, Smith Creek, Sourdough/Bozeman Creek, Camp Creek, and Godfrey Creek) as well as 4 pipe outfalls on Sourdough/Bozeman Creek were analyzed for *E. coli* pathogens.

Nutrient and algae concentrations were generally higher at sites located adjacent to or downstream of urban centers and agricultural lands compared to higher elevation tributaries on forested landscapes. The highest nutrient concentrations were found at sites on the East Gallatin directly downstream from the Bozeman Wastewater Treatment Plant.

In 2008, *E. coli* concentrations exceeded the Montana water quality standards on all 5 streams sampled for *E. coli* (Reese Creek, Smith Creek, Sourdough/Bozeman Creek, Camp Creek, and Godfrey Creek). In 2009 the sampling plan was designed to further evaluate e.coli conditions, and included several sites not sampled in 2008 in order to assess source loadings and evaluate the magnitude and distribution of e.coli sources on e.coli-impaired streams: *e. coli* concentrations exceeded the 126 cfu/100 ml value at 26 of the 38 sites samples (68%) in 2009.

The algae community was sampled quantitatively at six sites using DEQ procedures for measuring chlorophyll-a. The chlorophyll-a concentration at all 6 sites was below the 150 mg/m^2 nuisance level identified by DEQ. An additional 26 sites were sampled qualitatively. These sites were estimated to have chlorophyll-a concentration less than 50 mg/m^2 and were photo documented using DEQ procedures.

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1. INTRODUCTION

The two primary water bodies within the Lower Gallatin TMDL Planning Area (LGTPA) are the Gallatin River and the East Gallatin River. The LGTPA encompasses an area of approximately 997 square miles in Gallatin County in southwestern Montana, extending from below the confluence with Spanish Creek near the north end of Gallatin Canyon, downstream to its confluence with the Madison River. Although Spanish Creek is the upstream boundary of the LGTPA on the Gallatin River, the headwaters of the Gallatin River extend into Yellowstone National Park (YNP). The river flows north from YNP through the forested Gallatin Canyon into primarily low-density residential development and agricultural lands within the Gallatin Valley.

The LGTPA encompasses the urban areas of Bozeman and Belgrade, as well as several smaller communities. The primary rural land uses within the LGTPA are agriculture, ranching, and recreational activities. A substantial portion of the tributary headwaters in the LGTPA serve as drinking water sources.

The East Gallatin River headwaters originate from several tributary streams, namely Jackson Creek, Meadow Creek and Rocky Creek. These creeks flow westward down Bozeman Pass east of Bozeman (Figure 1). A number of additional tributary streams enter the East Gallatin River, including Sourdough/Bozeman Creek (also known as Bozeman Creek), Bridger Creek, Smith Creek, and Hyalite Creek. The East Gallatin River enters the main stem of the Gallatin River north of Manhattan, at which point both rivers are of similar size.

This report summarizes the results of water quality sampling on the Gallatin and East Gallatin Rivers and select tributary streams within the LGTPA in 2009. The Montana Department of Environmental Quality (DEQ) is responsible for the assessment of Montana surface water bodies and for the development of Total Maximum Daily Load (TMDL) plans for water bodies that do not meet established water quality criteria. Such 'impaired' water bodies are placed on what is referred to as the "Montana 303d List" which is updated every two years and can be accessed at http://cwaic.mt.gov/.

The MT 303d List (2008) contains 15 stream segments within the LGTPA identified as impaired due to nutrients and/or *Escherichia coli* (*E. coli*). As part of the development of a TMDL Plan for the LGTPA, OASIS Environmental, Inc. (OASIS) conducted nutrient, *E. coli*, and algae sampling on the 15 listed stream segments, and on additional segments of interest not included on the 2008 List (Table 1). These combined segments encompassed 83 nutrient sampling sites, 32 algal sites and 38 sites for *E. coli*. Sampling occurred in September of 2009.

This report describes the field sampling methods, data analysis, and results for *E. coli,* nutrients and algae. The *Lower Gallatin TMDL Planning Area Sampling and Analysis Plan* (referred to as the LGTPA SAP) prepared by OASIS details the stream segments and impairments for each of the stream segments, sample site selection, sample collection, and analysis methods (OASIS 2009). Project deliverables including lab analysis data, field data, field data forms, representative photos of sample sites, and any changes to the SAP are reported in the *Lower Gallatin TMDL Planning Area 2009 Nutrient, E. coli, and Algae Sampling Data Submittal and Quality Review Report,* submitted to DEQ by OASIS in April, 2010 (referred to as the "SAP Addendum"). The EQWX data upload will completed in April 2010 and can be accessed at http://www.deq.state.mt.us/wqinfo/datamgmt or obtained from the Greater Gallatin Watershed Council.

1.1. Sample Sites

Stream segments sampled in this assessment, including those segments that were listed on the 2008 303d List, are tabulated in Table 1. Sample sites were distributed across 15 stream segments. The mainstem of the East Gallatin River was divided into three segments. Hyalite Creek consisted of two segments. The remaining segments were distributed among the tributary streams of both the Gallatin and the East Gallatin. The location of each site and associated field parameters sampled were mapped for the LGTPA (Figure 1). Site names are truncated to only the first four characters for ease of identification in all tables and figures for this report (i.e. site EG02-M05EGALR01 is shortened to EG02).

Nutrients were sampled at 83 sites, while *E. coli* was sampled at 38 sites and chlorophyll-a was assessed at 32 sites. Six of the chlorophyll-a sites were sampled quantitatively while algal levels at the remaining 26 sites were documented qualitatively through field notes and photographs. Streamflow was measured concurrently with each nutrient and *E. coli* sampling event in order to allow the calculation of pollutant loads.

Sampled streams varied in size, riparian environment, and adjacent land use. Several sampling sites were located on small headwater streams such as upper Bear Creek, characterized by densely forested riparian zones, cold and turbulent water as well as a cobble bottom (Figure 2). In contrast, small streams located in the valley bottom agricultural areas, such as Smith Creek, were characterized by a grass/pasture land riparian zone, slow water, meandering channels, and a fine sediment bottom (Figure 3). Larger streams such as the East Gallatin River consisted of turbulent water in its upper reaches, a densely forested riparian canopy, and a rocky bottom (Figure 4) while in its lower reaches the channel was meandering, with a more open shrub riparian zone, and a finer substrate bottom (Figure 5).

Table 1. Sample sites and parameters sampled for individual streams and segments (Sept 2009).

Watershed	Stream Name	# Sites	TMDL Required (2006 303d list)	*E. coli*	Nutrients	Chl-a	Flow
East Gallatin River	Bear Creek	4	x		4	1	4
	Ben Hart Creek	1			1		1
	Bridger Creek	5	x		5		5
	Dry Creek	4	x		4		4
	East Gallatin River Headwaters to Bridger Cr	1	x		1	1	1
	East Gallatin River Bridger Cr to Smith Cr	10	x		10	2	10
	East Gallatin River Smith Cr to Gallatin R	1	x		1	1	1
	East Gallatin River Unnamed Trib.	2			2		2
	Gibson Creek	1			1		1
	Godfrey Creek	7	x	7	7		7
	Hyalite Creek	7	x		7		7
	Jackson Creek	3	x		3		3
	Reese Creek	4	x	4	4		4
	Rocky Creek	1	x		1		1
	Smith Creek	5	x	5	5		5
	Sourdough Creek	9	x	9	9		9
	Sourdough Creek *(outflow pipe to sourdough)*	4		4	4		4
	Sourdough Creek *(unnanmed trib.)*	2		2	2		2
	Story Creek	1			1		1
	Thompson Spring Creek	4	x		4	1	4
Gallatin River	Camp Creek	7	x	7	7		7
	Total	**83**	**15**	**38**	**83**	**6**	**83**

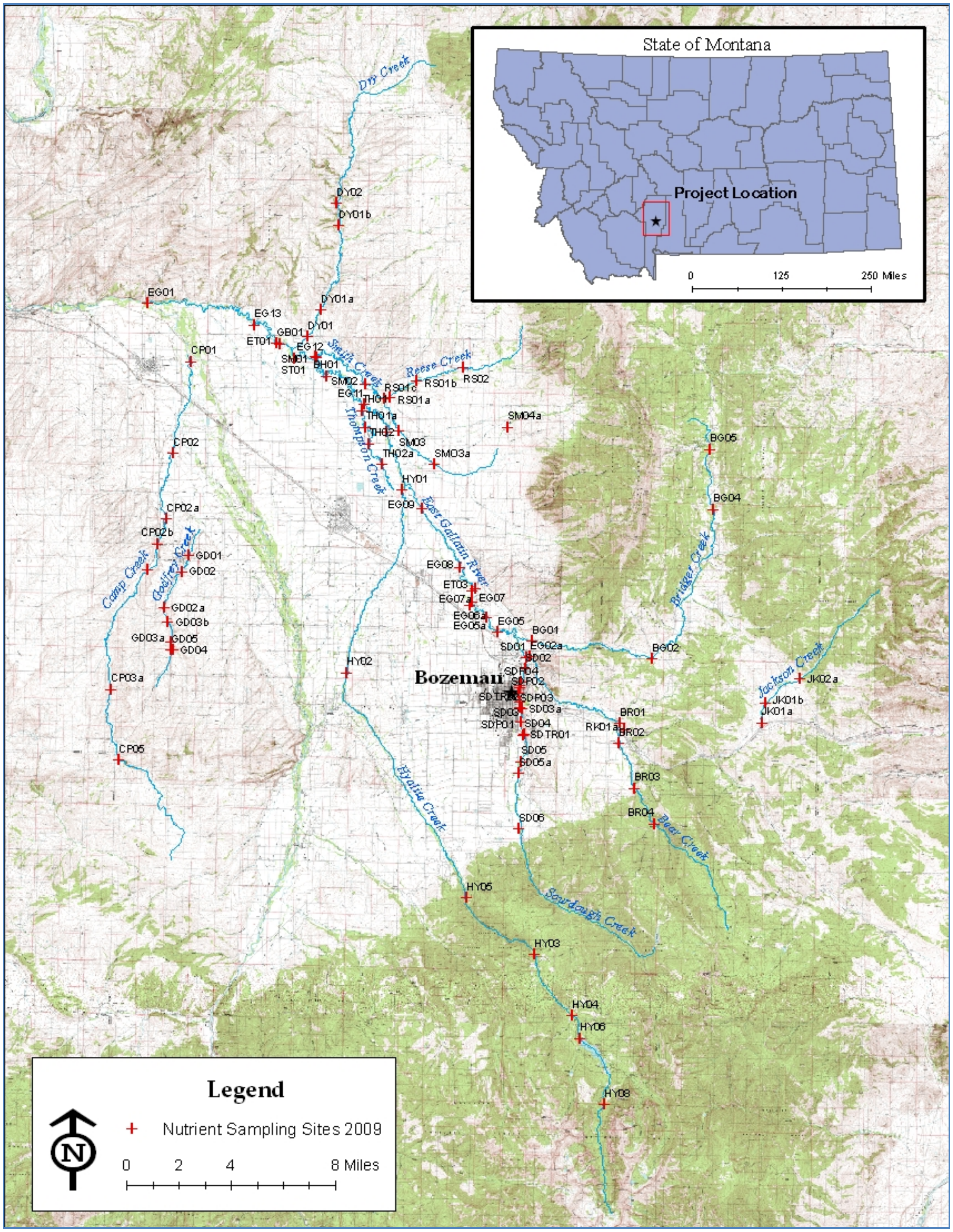

Figure 1. Sample site locations and field parameters within the LGTPA.

Figure 2. Site BR03 on Bear Creek, off of Bear Canyon road.

Figure 3. Site SM01 on Smith Creek, just above the confluence with the East Gallatin River.

Figure 4. Site EG02 on the upper East Gallatin River, at Rocky Creek Farm.

Figure 5. Site EG13 on the Lower East Gallatin River, below Spaulding Bridge road.

2. *E. COLI* BACTERIA

E. coli was recently adopted as the indicator organism for pathogen pollutants in Montana water bodies. *E. coli* is a nonpathogenic bacteria often associated with fecal contamination and is assumed to indicate the presence of human pathogens. *E. coli* concentrations were measured to assess existing pathogen loads and to identify and quantify potential e.coli sources. Potential e.coli sources within the LGTPA include waste from livestock, domestic pets and wildlife, malfunctioning septic systems, and potentially untreated municipal wastewater from sewer or service line leaks or failures.

2.1. Sampling Activity

In 2008, *E. coli* sampling targeted five streams, sampled five times within a 30-day period (August 20th-September 17th, 2008), to determine if the water bodies met water quality standards for *E. coli*. The Montana e.coli standard for B-1 water bodies *[ARM 17.30.623 (2)]* specifies:

> *The geometric mean number of E. coli may not exceed **126 cfu/100mL** and 10% of the total samples may not exceed **252 cfu/100mL** during any 30-day period between April 1 through October 31. From November 1 through March 31, the geometric mean number of E. coli may not exceed 630 cfu/100mL and 10% of the samples may not exceed 1,260 cfu/100mL during any 30-day period.*

In 2009, *E. coli* samples were collected at 38 sites, distributed across five streams including four outfall pipes on Sourdough/Bozeman Creek. The sampling objective in 2009 focused on synoptic measures of *E. coli* concentrations and assessment of potential e.coli sources. Sites were sampled once in 2009 under low water conditions during September. *E. coli* was sampled longitudinally on Sourdough/Bozeman Creek in a single day to better document the influence of urban conditions on concentrations as it flows through Bozeman. This resulted in nine sample sites on the mainstem of Sourdough/Bozeman Creek plus two tributaries and four outfall pipes (Figure 6). The sample streams with the number of sites in parenthesis are listed below.

1. Camp Creek (7)
2. Godfrey Creek (7)
3. Reese Creek (4)
4. Smith Creek (5)
5. Sourdough/Bozeman Creek (9)
6. Sourdough/Bozeman Creek tribs. (2)
7. Sourdough/Bozeman outfalls (4)

2.2. Results

E. coli values on the mainstem of Sourdough/Bozeman Creek were higher in the urban portion than in the rural section (Figures 7a and 7b). Sample sites SD06, SD05a and SD05 were classified as rural relative to the downstream sites. *E. coli* concentrations in the rural sample sites were less than 50 cfu/100 ml. In the urban segment of Sourdough/Bozeman Creek, *E. coli* concentrations and loading increased substantially. All but two of the urban sample sites exceeded 126 cfu/100 ml. *E. coli* concentrations increased to 156 cfu/100 ml at SD04. An unnamed tributary entered Sourdough/Bozeman Creek adjacent to SD04. The tributary contained a concentration of 161 cfu/100 ml. An outfall pipe entered Sourdough/Bozeman Creek downstream from SD04 with an *E. coli* concentration of 365 cfu/100 ml. Mathew Bird Creek had an *E. coli* concentration of 365 cfu/100 ml at the confluence with Sourdough/Bozeman Creek. An outfall pipe, SDP03, in the vicinity of Rouse Street had the highest *E. coli* concentration longitudinally on Sourdough/Bozeman Creek, 2420 cfu/100 ml. This concentration reflects the maximum detection limit for *E. coli* colonies using these laboratory methods. *E. coli* concentrations at SDP03 may have been greater than the detection limits. *E. coli* colonies were not detected in outfall pipes SDP02 and SDP04.

On Camp Creek, *E. coli* concentrations at sites CP05 through CP02a were all greater than 126 cfu/100 ml (Figure 8a). In fact, sites CP03 and CP02b each had 687 cfu/100 ml. *E. coli* concentrations decreased at the two sites furthest downstream on Camp Creek, CP02 and CP01. Discharge increased substantially at these two sites likely diluting the *E. coli* inputs observed at the upstream sites on Camp Creek.

On Godfrey Creek, all seven sample sites had *E. coli* concentrations greater than 126 cfu/ 100 ml (Figure 9a). *E. coli* concentrations were highest at GD04, 1050 cfu/ 100 ml, and lowest at GD01, 172 cfu/ 100 ml. Discharge was nearly 2.5 times greater at GD01 likely diluting *E. coli* concentrations observed further upstream.

The three middle sites on Smith Creek, SM03a, SM03 and SM02, had *E. coli* concentrations exceeding 126 cfu/100 ml (Figure 10a). *E. coli* concentrations at the furthest upstream site, SM04a, were substantially lower than downstream sites indicating that at some point between this site and SM03a significant e.coli inputs occur. SM02 had the highest *E. coli* loading observed in the Lower Gallatin TPA in 2009, >400,000 cfu/day (Figure 10b).

Sites RS02, RS01b and RS01c on Reese Creek had *E. coli* values greater than 126 cfu/ 100 ml; 201, 411, and 154 cfu/ 100 ml respectively (Figure 11a). *E. coli* values declined at the most downstream site on Reese Creek, RS01a, to 126 cfu/100 ml.

2.3. Discussion

All of the seven streams sampled for *E. coli* within the LGTPA contained substantially high values for *E. coli*. Concentrations increased in an upstream to downstream direction with the highest values typically observed in the mid to lower third of each water body. The most downstream sites typically had lower *E. coli* values than the middle sections due to increased discharge and subsequent dilution of colonies. Four of the seven streams were rural in character. The predominant land use adjacent to these four streams was agriculture/livestock. The fifth stream, Sourdough/Bozeman Creek, flows from rural land use in the headwaters to urban in the heart of Bozeman. Two outfall pipes and two tributaries flowing into Sourdough/Bozeman Creek contributed to the *E. coli* values.

Figure 6. *E. coli* sampling at an outfall pipe on Sourdough/Bozeman Creek near Rouse Street, site SDP03.

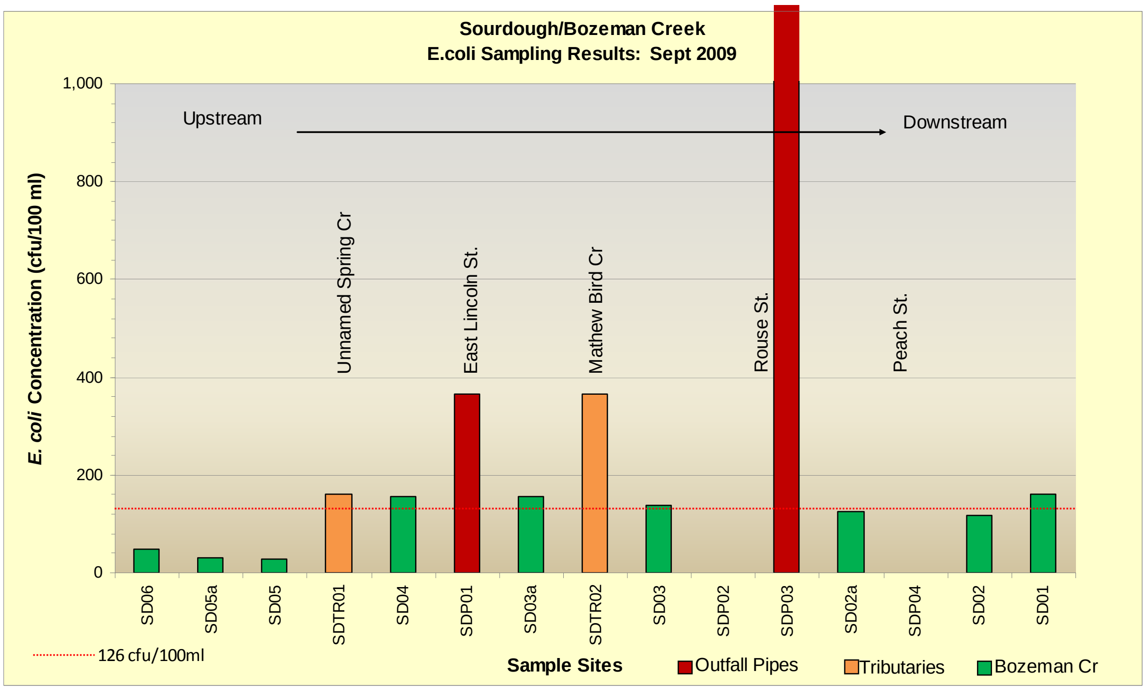

Figure 7a. *E. coli* concentrations in Sourdough/Bozeman Creek. Sept 2009

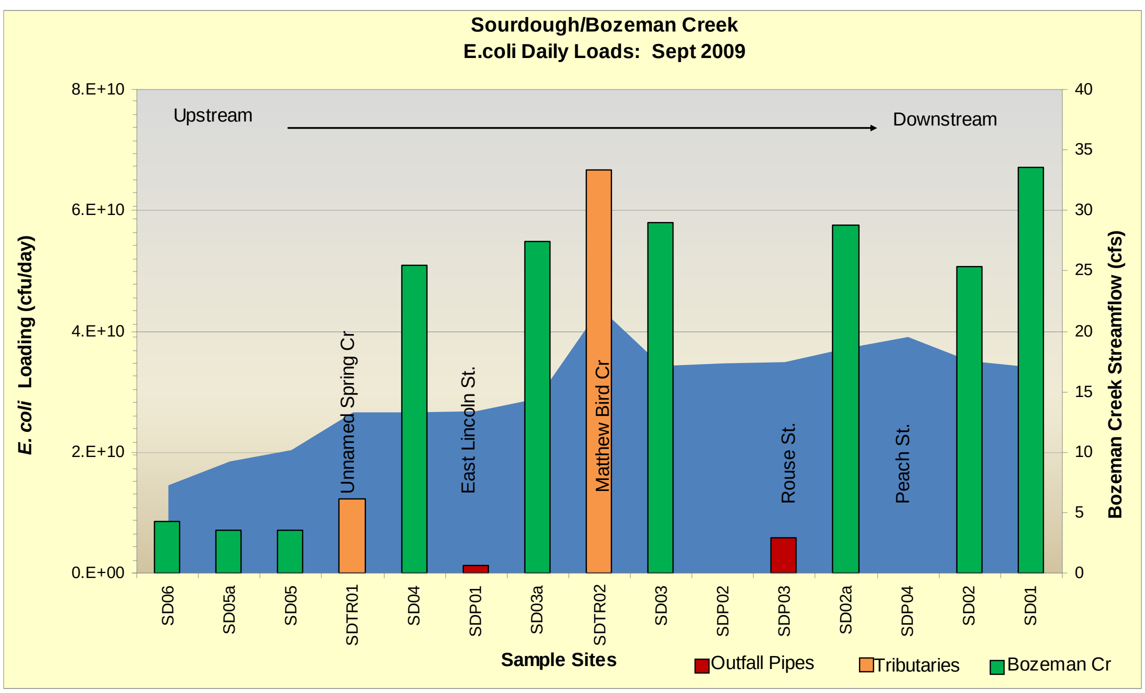

Figure 7b: *E. coli* loading in Sourdough/Bozeman Creek. Sept 2009

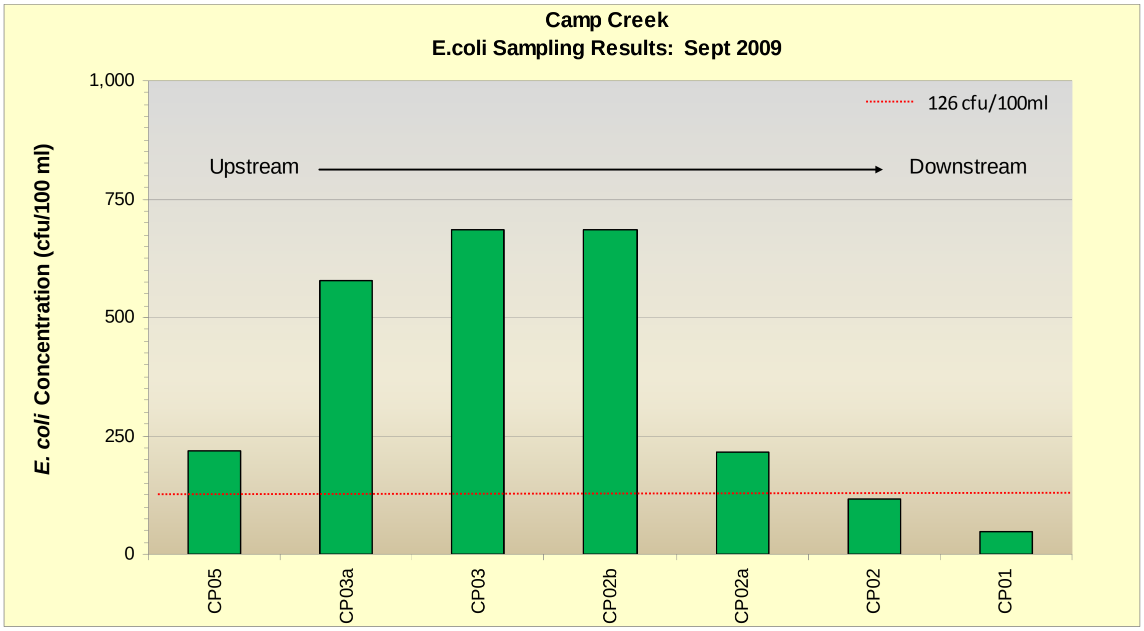

Figure 8a. *E. coli* concentrations in Camp Creek. Sept 2009

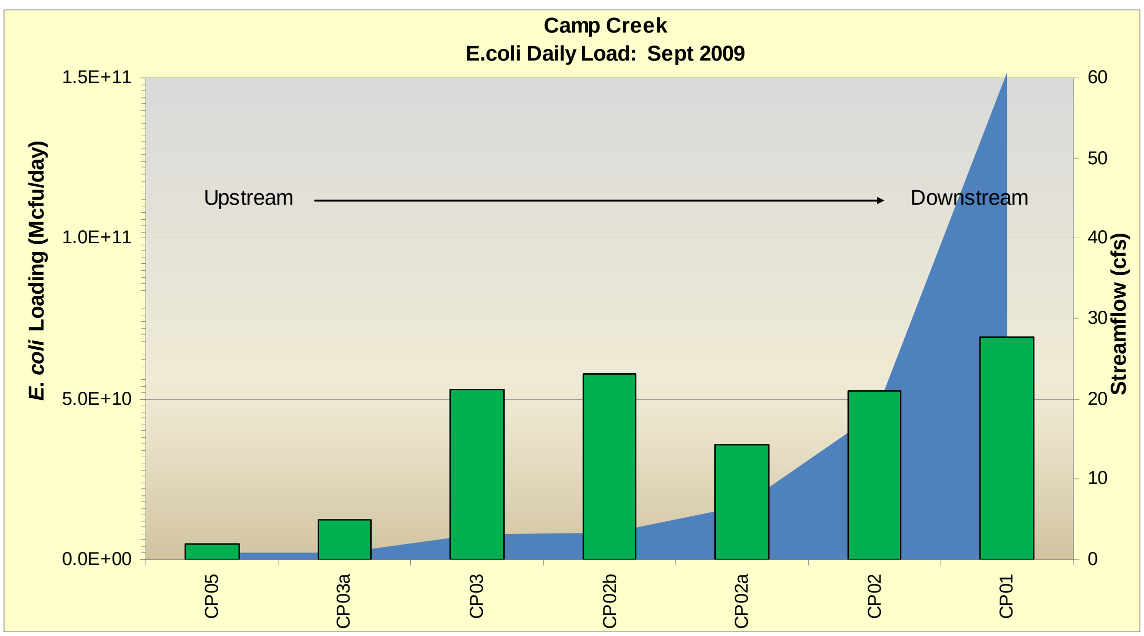

Figure 8b. *E. coli* loads in Camp Creek. Sept 2009

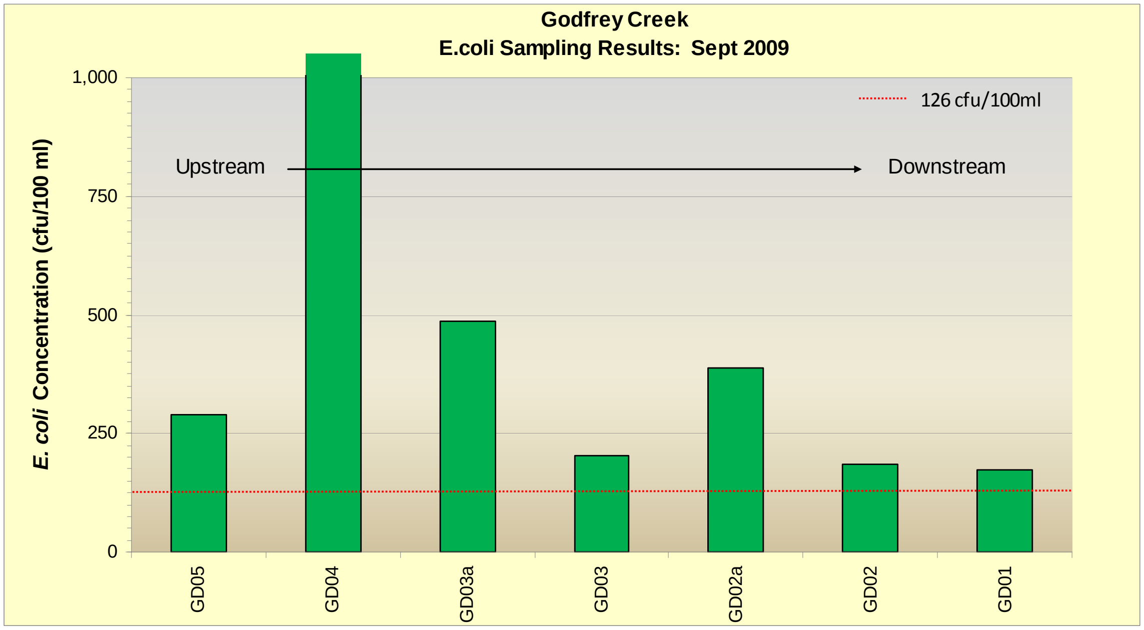

Figure 9a. *E. coli* concentrations in Godfrey Creek. Sept 2009

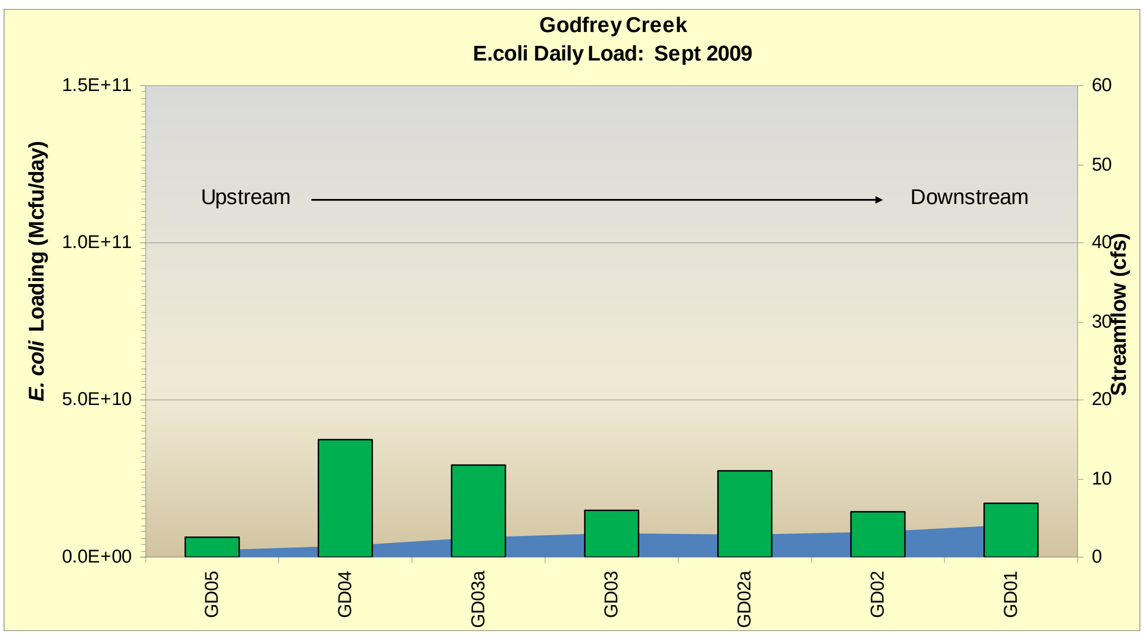

Figure 9b. *E. coli* loads in Godfrey Creek. Sept 2009

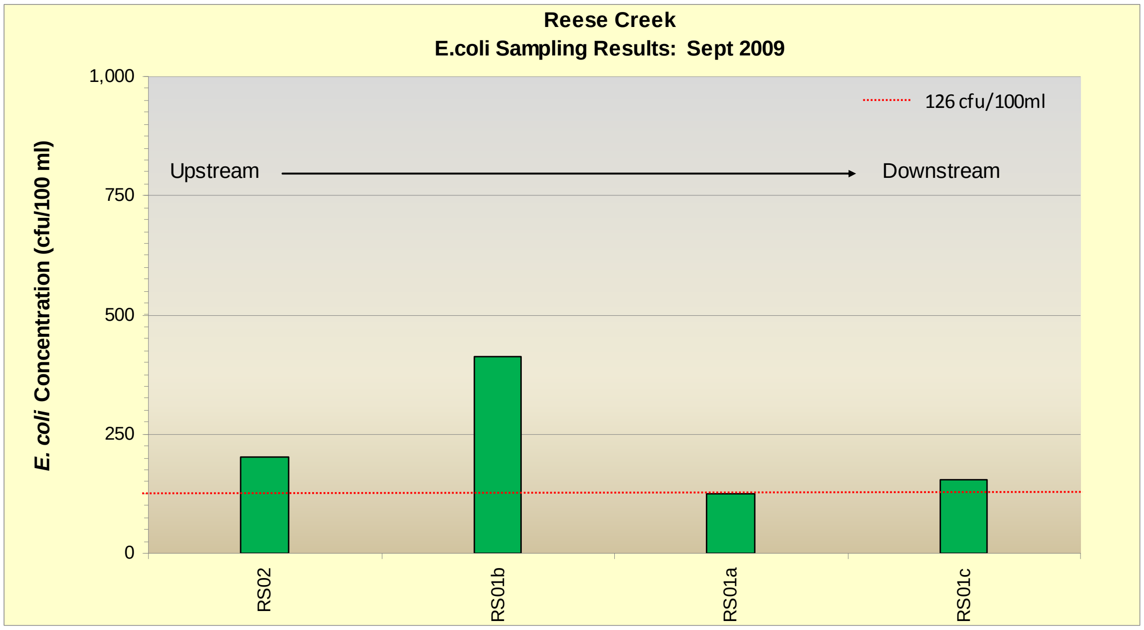

Figure 10a. *E. coli* concentrations in Reese Creek. Sept 2009

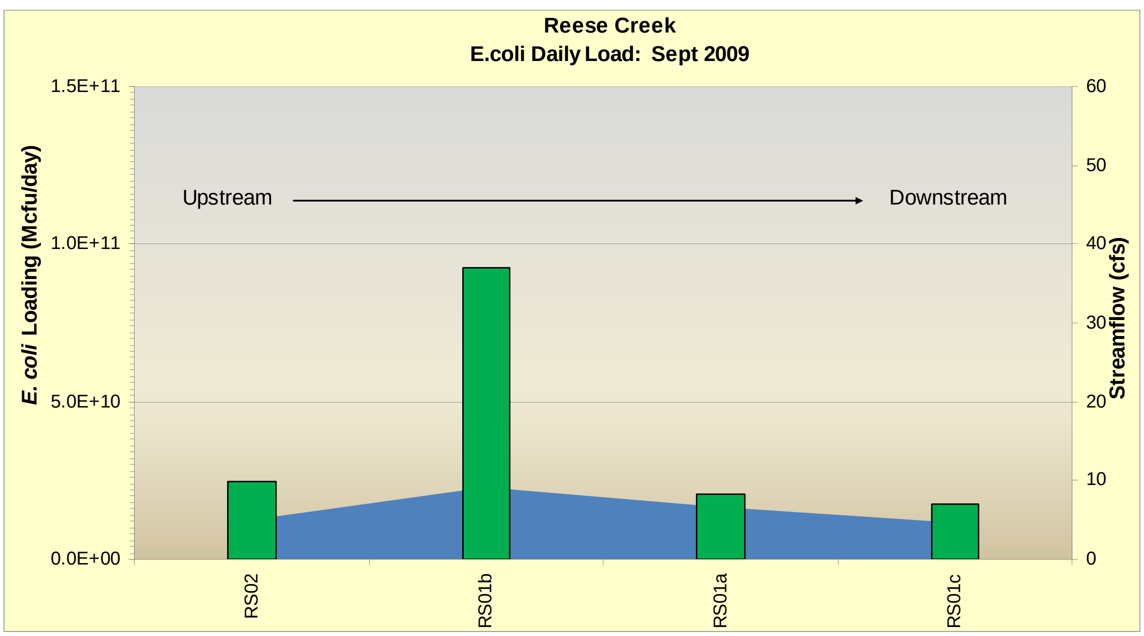

Figure 10b. *E. coli* loads in Reese Creek. Sept 2009

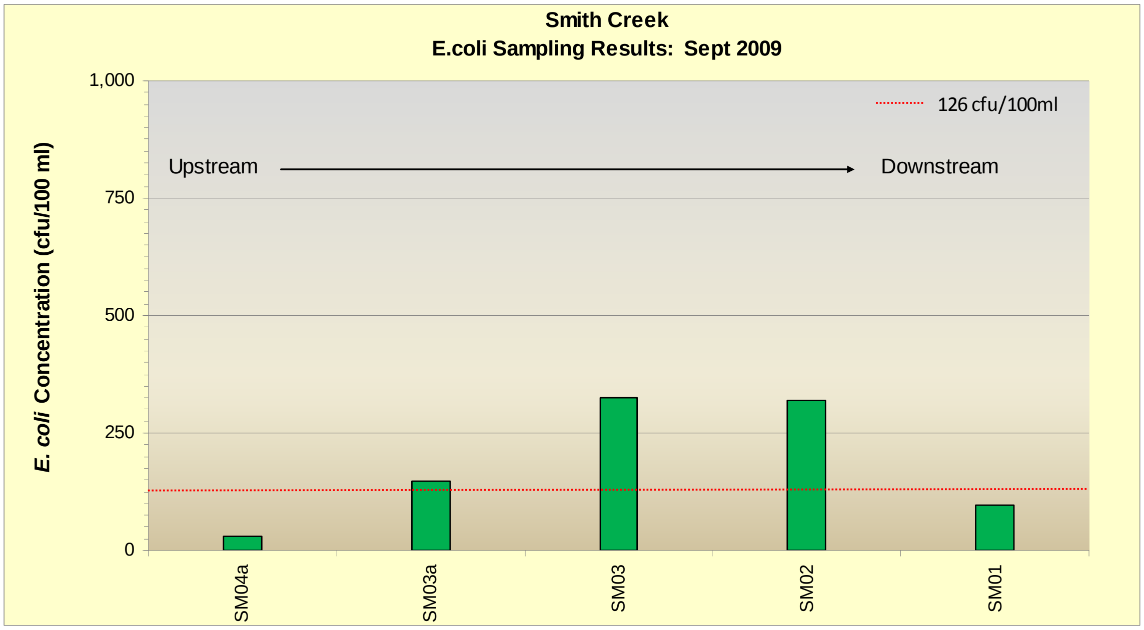

Figure 11a. *E. coli* concentrations in Smith Creek. Sept 2009

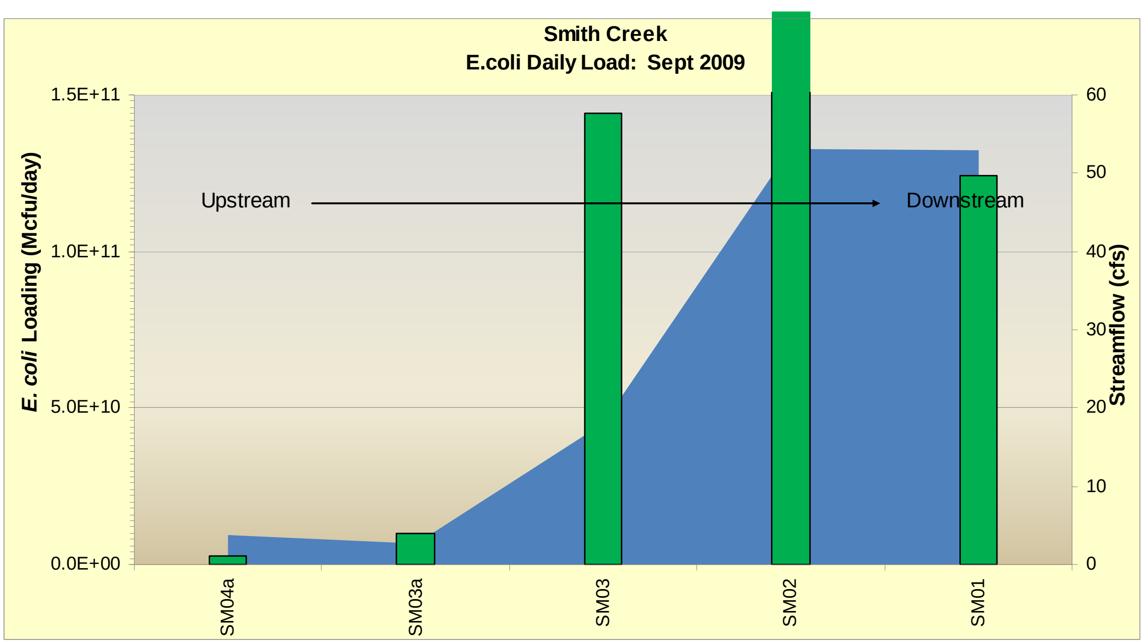

Figure 11b. *E. coli* loads in Smith Creek. Sept 2009

3. NUTRIENTS

Nutrients are required for the growth of aquatic plants and animals. In an undisturbed condition, nitrogen and phosphorus are limited in most Montana cold water streams. When nitrogen and phosphorus are introduced to streams from natural or anthropogenic sources excessive algal growth can be stimulated thereby degrading water quality. This water quality degradation can be manifested in the form of lower oxygen, increased odor, aesthetic impacts, and habitat loss. Potential sources of nitrogen and phosphorus within the LGTPA include; wildlife, livestock and pet waste, lawn and agricultural fertilizers, municipal wastewater outflows, septic systems, and phosphorus attached to sediment. A number of these sources cause nitrogen and/or phosphorus to enter streams when overland flow runs off the surrounding landscape.

The primary nitrogen compounds found in streams are nitrates (NO_3^-), nitrites (NO_2^-) and ammonia (NH_3^+), in which the latter can be toxic to aquatic life at certain concentrations. Nitrates and nitrites are commonly measured together as the sum of both parameters, as nitrites rapidly oxidize to nitrate under normal stream conditions. Total nitrogen is measured for the purpose of assessing all of the different sources of nitrogen present in a stream and is the sum of all inorganic (including nitrates, nitrites and ammonia), and organic forms of nitrogen. Total phosphorus was measured in this assessment to account for all forms of phosphorus, both organic (such as phosphate, PO_4^{-3}) and inorganic.

Montana's water quality standards for nutrients (nitrogen and phosphorous forms) are narrative and are addressed via narrative criteria. These narrative criteria do not allow for "*substances attributable municipal, industrial, agricultural practices or other discharges that will...(e) create conditions which will produce undesirable aquatic life*" (ARM 17.30.637). Numeric nutrient criteria are presently under development by the Montana DEQ, and are established at levels believed to protect against the growth of 'undesirable aquatic life' (i.e algae). Draft numeric nutrient criteria DEQ provide numeric values that can be used to evaluate attainment of water quality standards for nutrients, and while not finalized at the time of this document submittal, they do provide values that allow comparison with existing nutrient conditions in the LGTPA. Table 2 shows applicable draft nutrient criteria for nutrients in the LGTPA.

Table 2. Draft numeric nutrient criteria for streams in the LGTPA

Nutrient Parameter	Draft Numeric Criteria
Total Nitrogen	0.300 mg/l
Nitrate/Nitrite	0.100 mg/l
Total Phosphorus	0.030 mg/l
Chlorophyll-a (algae)	129 mg/m^2

While the concentration of a substance is important for assessing compliance with MT State Water Quality Standards (DEQ 2004), water quality managers are also interested in the total amount of a substance present in a stream, or the *pollutant loading,* expressed as pounds of pollutant per day. The purpose of calculating pollutant loading is to express concentration in a sample relative to the volume of water found in the stream at the time the sample was measured. This removes the effects of dilution, allowing the comparison of pollutant levels between sites either upstream-downstream, or between streams of interest. It is also used to assess the relative impact of pollutant inputs from tributaries entering larger water bodies. Therefore, in addition to concentration, loading of nitrate-nitrites, total nitrogen and total phosphorus were also assessed within the East Gallatin and Gallatin Rivers, and in their respective tributaries in order to develop loading budgets and evaluate a stream's capacity to receive pollutant loads and still meet water quality standards and/or instream water quality criteria.

For tributary streams, the site nearest to the confluence with the East Gallatin was used for the representative nutrient concentration to calculate loading from upstream to downstream in the watershed. For example, sample site SD01 was the lowest sample site on Sourdough/Bozeman Creek, located just above its confluence with the East Gallatin River.

3.1. Sampling Activity

OASIS sampled the following nutrients in September 2009 at 83 sampling sites within the LGTPA:

- Nitrogen: nitrate-nitrite, ammonia, and total nitrogen
- Phosphorus: total phosphorus

3.2. Results and Discussion

Nutrient sampling sites on the on the East Gallatin and tributaries are illustrated in figures 12 and 13. Sample sites on Sourdough/Bozeman Creek are presented in figure 14. Nitrate-nitrite concentrations in the East Gallatin watershed ranged from 0.01 to 1.09 mg/l in September 2009 (Table 3). Nitrate-nitrite concentrations were lowest in higher elevation headwater tributaries with predominantly coniferous forest (Figure 15). Nitrate-nitrate concentrations on Sourdough/Bozeman Creek were substantially higher in the urban interface than upstream sites draining the agricultural and headwater areas of Sourdough/Bozeman Creek. Spring-fed tributary streams originating on the valley floor such as Ben Hart, Reese, Smith and Thompson Creeks had higher concentrations compared to headwater streams. In fact, Ben Hart Creek had the highest nitrate-nitrite concentration for tributaries in the LGTPA (1.09 mg/l) and was on par with concentrations observed in the mainstem East Gallatin below the wastewater treatment plan. Smith, Thompson, Reese and Story Creeks as well as an unnamed tributary also had concentrations equivalent to the mainstem East Gallatin.

On the mainstem East Gallatin, nitrate-nitrite concentrations tended to increase in a downstream direction. Site EG05 located downstream of Sourdough/Bozeman Creek confluence was two times higher than site EG02a upstream. The most substantial increase in nitrate-nitrite on the mainstem East Gallatin occurred downstream of the Bozeman wastewater treatment plant outfall. The highest concentrations on the East Gallatin were reported at sites EG07, EG07a, EG08, EG09, EG10 and EG11. Sites EG07 and EG07a were located directly downstream from the wastewater plant outfall. Nitrate-nitrite concentrations were nearly six-times higher at EG07 compared to EG06 located above the wastewater plant. Total nitrogen concentrations mirrored the patterns observed for nitrate-nitrite in the watershed (Figure 17).

Nitrate-nitrite and total nitrogen loading in the East Gallatin increased in a predictable downstream pattern (Figures 16 and 18). Nutrient concentrations in the upper reaches of the East Gallatin above sample site EG02 were very low, thus the contributions of Jackson Creek, Rocky Creek, and Bear Creek had minimal loading inputs relative to downstream sources. The loading figures incorporate discharge volume longitudinally at each of the sampling sites including the additive contribution of each tributary stream.

Nutrient loading increased substantially in the East Gallatin below the confluence of Sourdough/Bozeman Creek. Total nitrogen loading at site EG02a located on the East Gallatin upstream of the Sourdough/Bozeman Creek confluence was 27 lbs/day. In contrast, TN loading at site EG05 downstream of Sourdough/Bozeman Creek was 88 lbs/day. TN loading increased even more at site EG05a, located a short distance downstream of EG05 (130 lbs/day). EG05 was located on the upstream edge of the golf course property boundary. There was a 14 cfs increase in discharge between sites EG05 and EG05a. Flow increase in this reach may be due to a variety of factors that include surface water inputs from Mandeville Creek, the Cherry Creek pond outlet, and groundwater inputs. The increased flow resulted in the increased nutrient loading in this reach. The 2008 data also showed a similar increase in discharge through this reach (17 cfs from EG05 to EG06)

From site EG06a to EG07, nitrate/nitrite loads increased to from 61 lbs/day to approximately 476 lbs/day. The increased loading was likely due to inputs from the Bozeman Publicly Owned Treatment Works (POTW) effluent outflow: discharge monitoring data submitted Bozeman POTW during this period averaged 357 lbs/day nitrate/nitrite, and is in agreement with the loading increase between these two sites. Loads steadily increased in a downstream direction with several tributary streams entering prior to the confluence with the Gallatin River. Nitrogen load was highest at site EG01 located at the confluence with the Gallatin River.

Total phosphorus concentrations and loading were relatively low in the upper East Gallatin (Figures 19 and 20). Phosphorus levels increased from 5 to 133 lbs/day between sites EG06a to EG07 downstream of the wastewater treatment plant effluent outflow: discharge monitoring data submitted Bozeman POTW during this period averaged 125 lbs/day total phosphorus, and is in agreement with the loading increase between these two sites. Progressing downstream, total phosphorus levels decreased but remained higher than the inputs recorded upstream of the sewage treatment plant outfall. Phosphorus concentrations and associated loads decreased in the lower Gallatin River, possibly due to utilization of excess phosphorus by algae and other instream biological processes.

Table 3: Nitrate-nitrite, total nitrogen, and total phosphorus concentration and loading in the East Gallatin River and tributaries (in bold). Sept 2009

River	Chart Label	NO3-NO2 (mg/l)	NO3-NO2 Load (lbs/day)	TN (mg/l)	TN Load (lbs/day)	TP (mg/l)	TP Load (lbs/day)	TSS (mg/l)	pH	Specific Conductance (uS/cm)	DO (mg/l)
East Gallatin River and Tributaries	**Rocky Creek**	**0.01**	**0.51**	**0.19**	**9.75**	**0.012**	**0.62**	**3**	**8.5**	**376**	**8.01**
	Bear Creek	**0.03**	**0.34**	**0.17**	**1.94**	**0.016**	**0.18**	**2**	**7.54**	**333**	**10.29**
	EG02a	0.13	12.42	0.28	26.75	0.023	2.20	6	10.05	344	10.83
	Sourdough	**0.58**	**53.28**	**0.73**	**67.06**	**0.05**	**4.59**	**11**	**8.69**	**249**	**8.92**
	Bridger Creek	**0.08**	**3.76**	**0.27**	**12.70**	**0.006**	**0.28**	**4**	**8.48**	**307**	**8.82**
	EG05	0.25	48.83	0.45	87.89	0.023	4.49	3	10.81	296	11.48
	EG05a	0.29	78.41	0.48	129.79	0.022	5.95	4	10.97	312	11.23
	EG06a	0.29	61.38	0.47	99.48	0.026	5.50	8	8.6	353	9.77
	EG07	1.74	416.23	1.99	476.04	0.559	133.72	5	8.73	404	9.96
	EG07a	1.70	420.51	1.89	467.51	0.547	135.31	6	11.71	363	11.06
	East Gallatin Trib	**0.19**	**3.81**	**0.47**	**9.43**	**0.024**	**0.48**	**15**	**10.76**	**320**	**9.27**
	EG08	1.30	250.75	1.43	275.82	0.359	69.24	9	8.73	383	10.45
	EG09	1.54	162.72	1.66	175.40	0.421	44.48	6	8.98	402	13.55
	Hyalite	**0.19**	**28.56**	**1.91**	**287.12**	**0.084**	**12.63**	**19**	**8.56**	**294**	**7.90**
	EG10	0.99	374.22	1.14	430.92	0.12	45.36	7	9.06	386	11.10
	Thompson	**1.07**	**85.88**	**1.12**	**89.89**	**0.013**	**1.04**	**5**	**9.17**	**355**	**11.17**
	EG11	0.93	381.84	1.09	447.53	0.081	33.26	5	8.85	395	12.37
	Ben Hart	**1.09**	**148.86**	**1.11**	**151.59**	**0.011**	**1.50**	**8**	**7.64**	**329**	**13.61**
	EG12	0.75	392.56	0.87	455.37	0.045	23.55	1	7.93	332	13.85
	Smith	**1.00**	**285.39**	**1.12**	**319.63**	**0.031**	**8.85**	**8**	**8.07**	**314**	**12.77**
	Reese	**0.63**	**22.77**	**0.75**	**27.10**	**0.007**	**0.25**	**6**	**8.26**	**305**	**9.45**
	Story	**0.80**	**48.76**	**0.82**	**49.98**	**0.011**	**0.67**	**2**	**7.44**	**273**	**10.31**
	Dry	**0.27**	**16.06**	**0.48**	**28.56**	**0.021**	**1.25**	**28**	**8.95**	**289**	**9.14**
	East Gallatin Trib	**0.95**	**35.56**	**1.05**	**39.30**	**0.018**	**0.67**	**16**	**7.7**	**322**	**10.08**
	Gibson	**0.69**	**35.10**	**0.82**	**41.71**	**0.011**	**0.56**	**2**	**7.26**	**295**	**12.35**
	EG13	0.64	590.57	0.84	775.13	0.033	30.45	4	9.1	366	13.31
	EG01	0.45	607.22	0.65	877.09	0.016	21.59	3	8.98	365	13.79
Gallatin River Tributaries	**Camp**	0.31	101.60	0.48	157.31	0.007	2.29	5	7.15	273	10.88
	East Gallatin	0.45	607.22	0.65	877.09	0.016	21.59	3	8.98	365	13.79

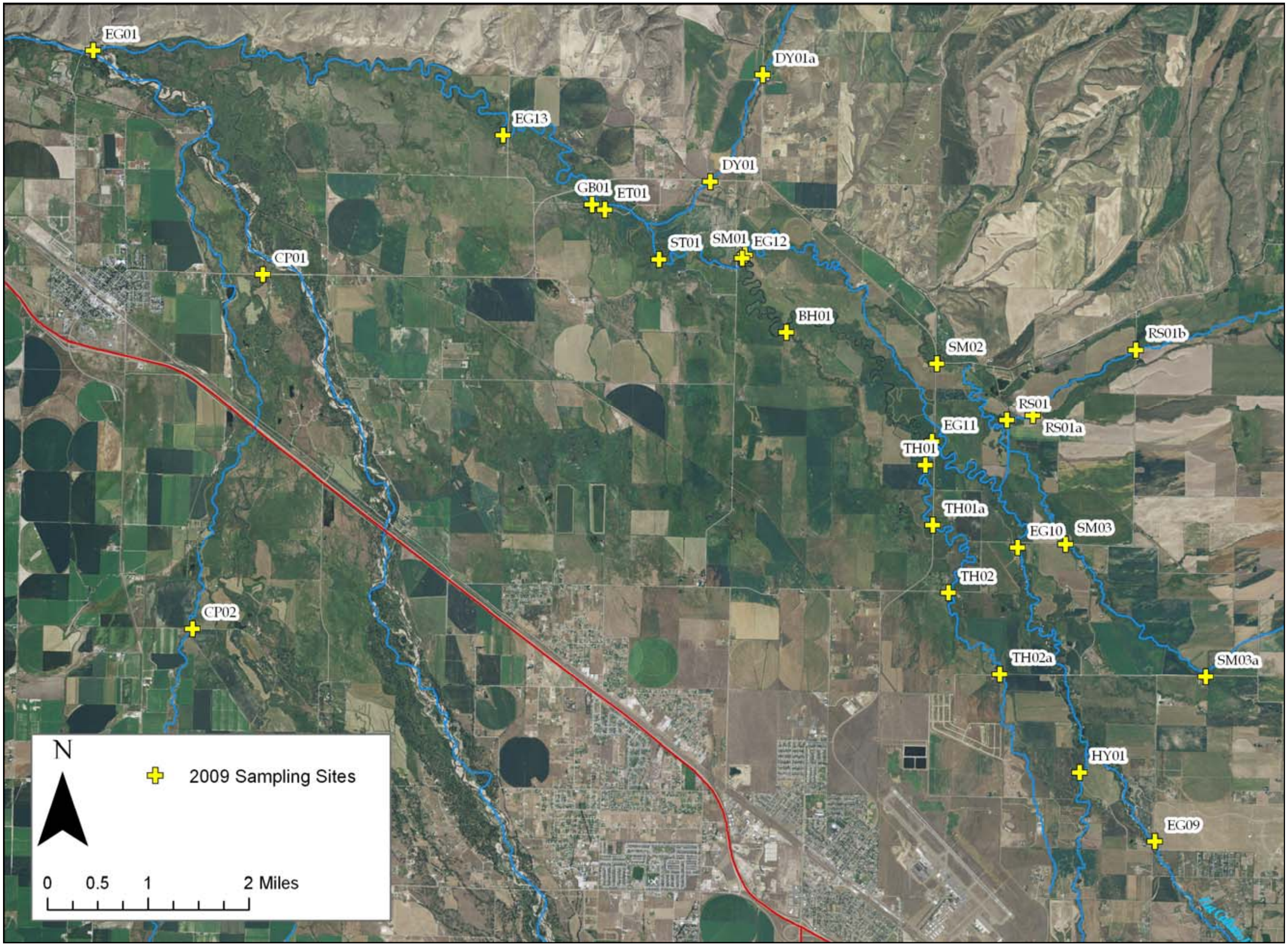

Figure 12. Sites on the lower East Gallatin River and its tributaries. Sept 2009

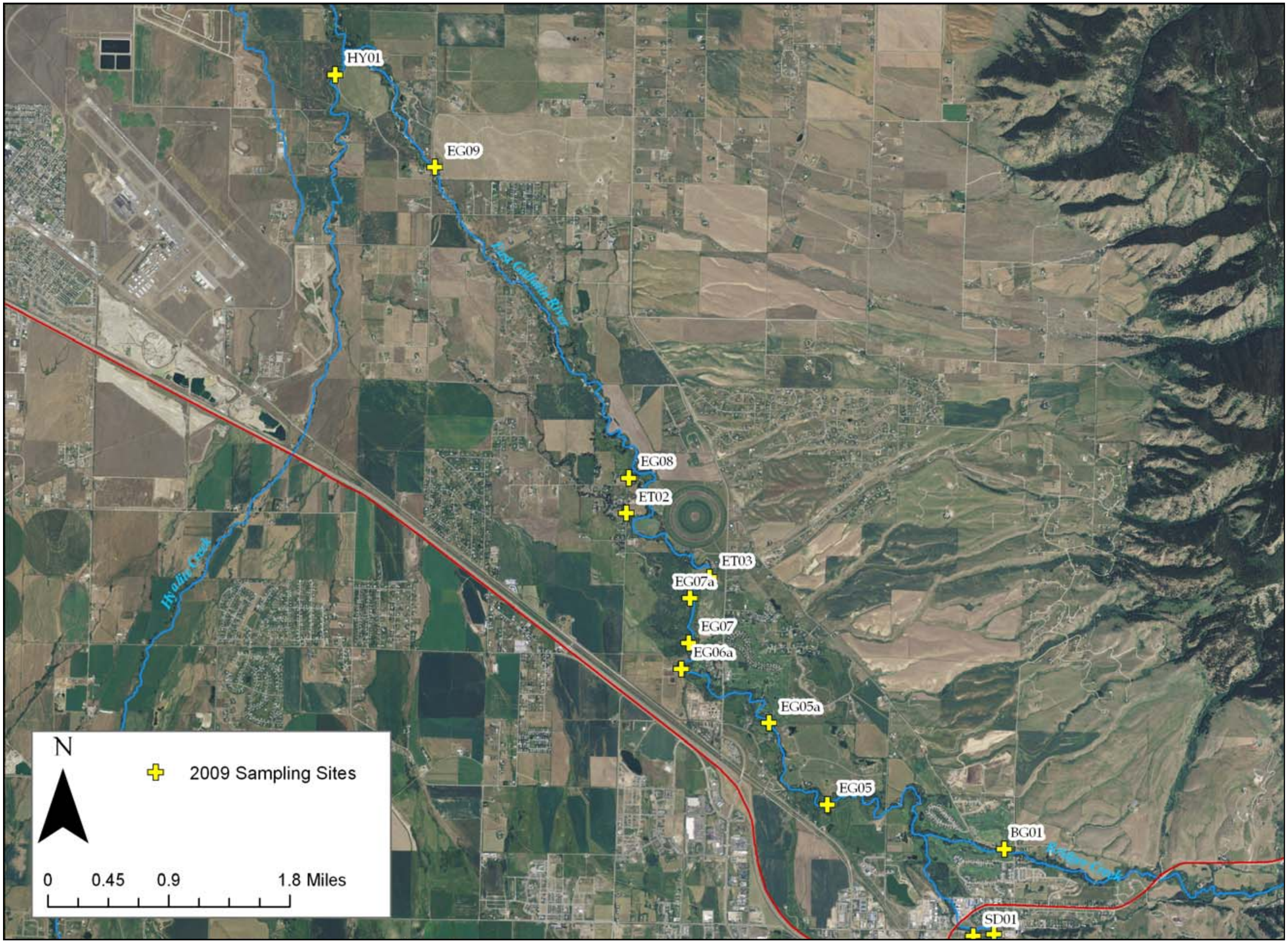

Figure 13. Sites on the upper East Gallatin River and tributaries. Sept 2009

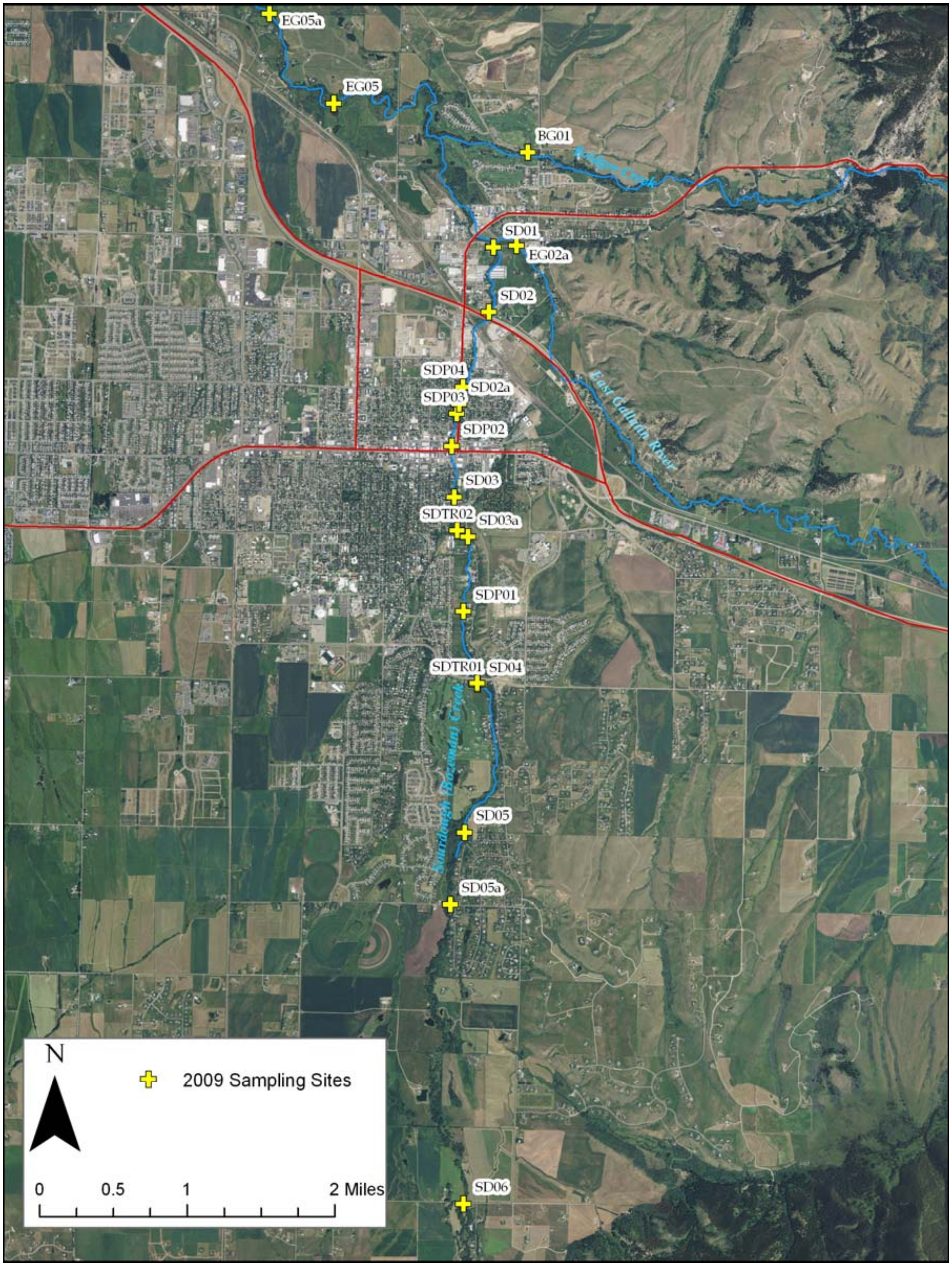

Figure 14. Sites on the upper East Gallatin River and tributaries. Sept 2009

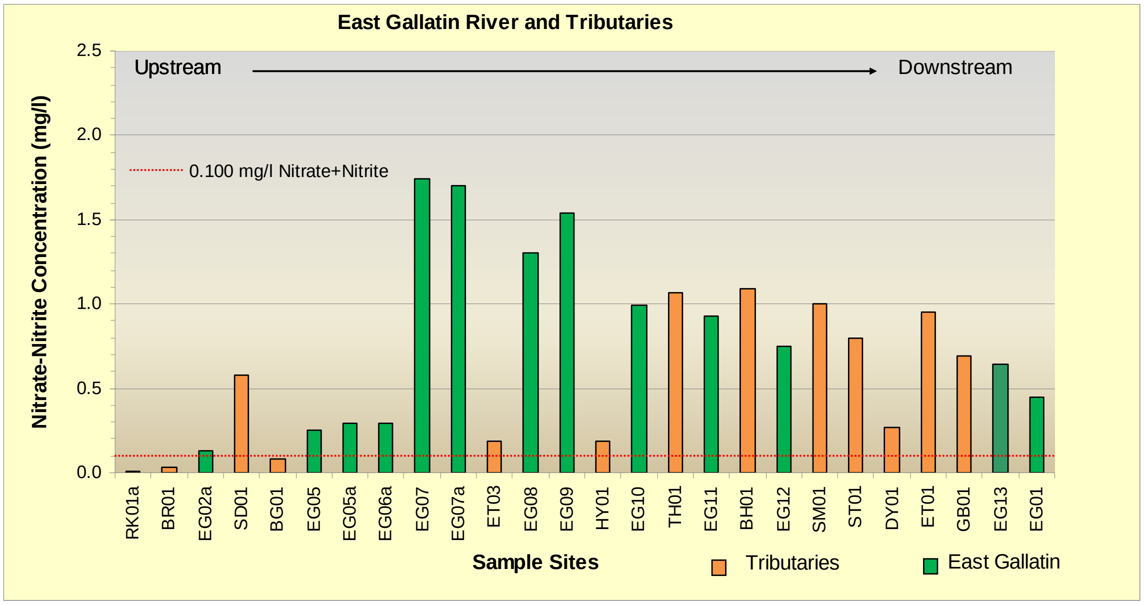

Figure 15. Nitrate-nitrite concentrations in the East Gallatin River and tributaries. Sept 2009

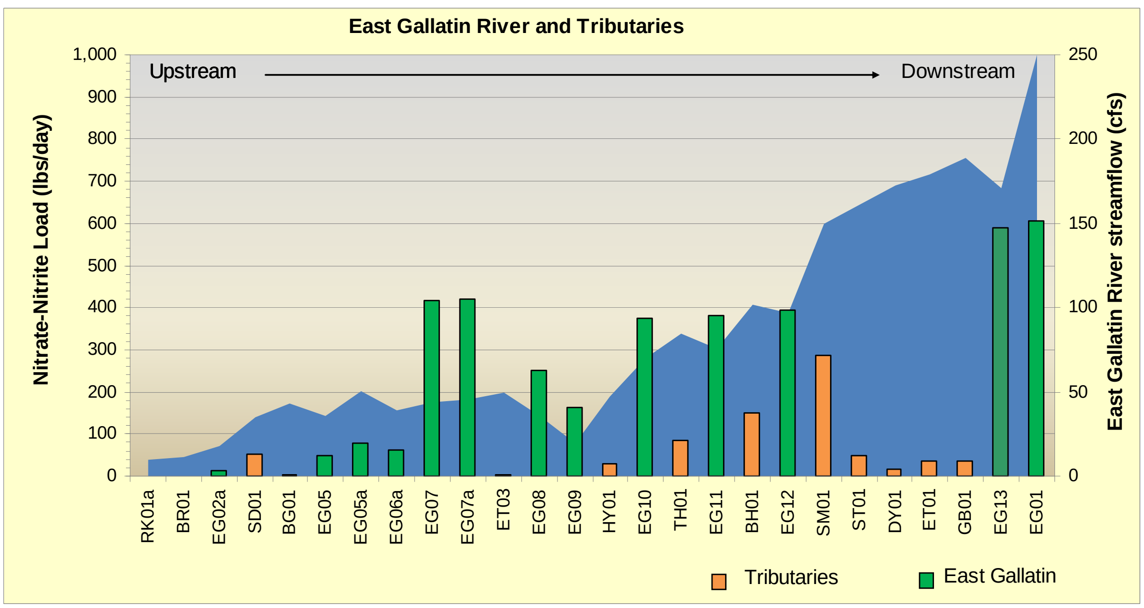

Figure 16: Nitrate-nitrite loads in the East Gallatin River and tributaries. Sept 2009

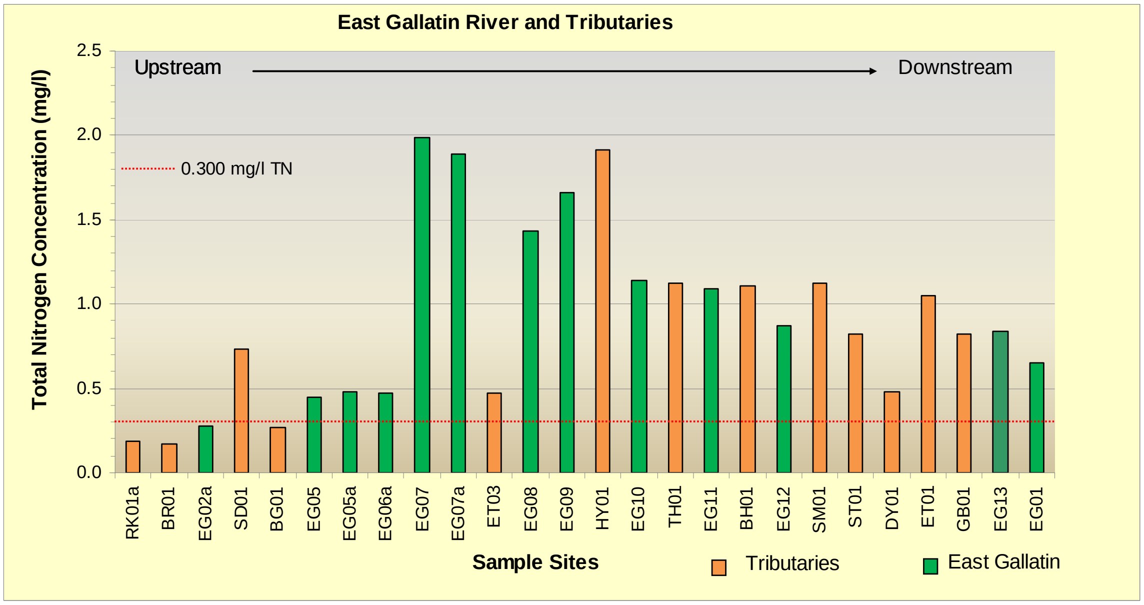

Figure 17: Total nitrogen concentrations in the East Gallatin River and tributaries. Sept 2009

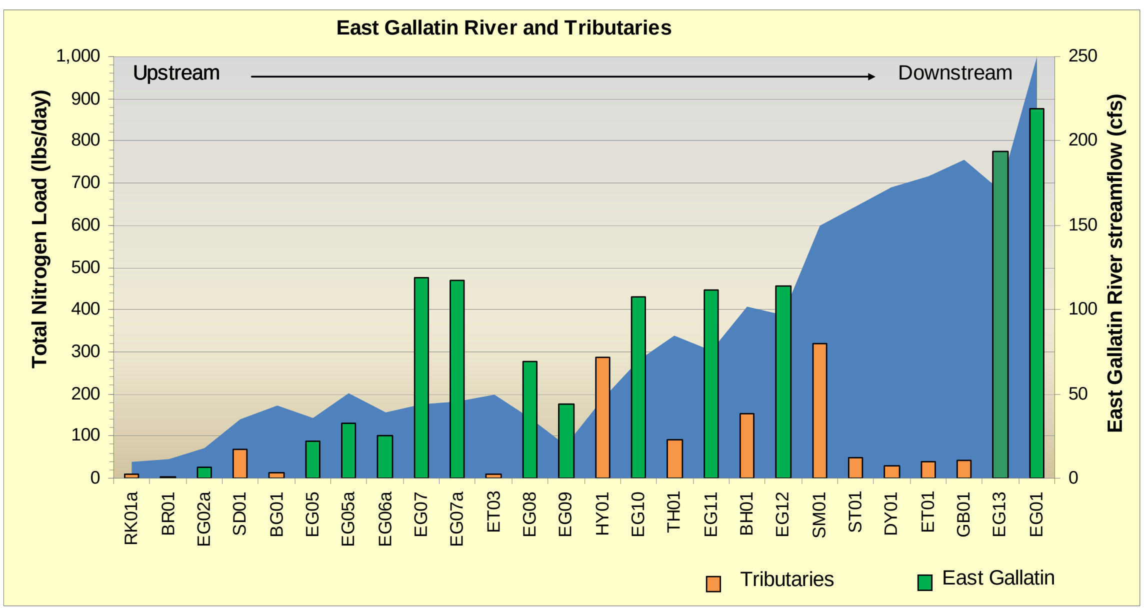

Figure 18: Total nitrogen loads in the East Gallatin River and tributaries. Sept 2009

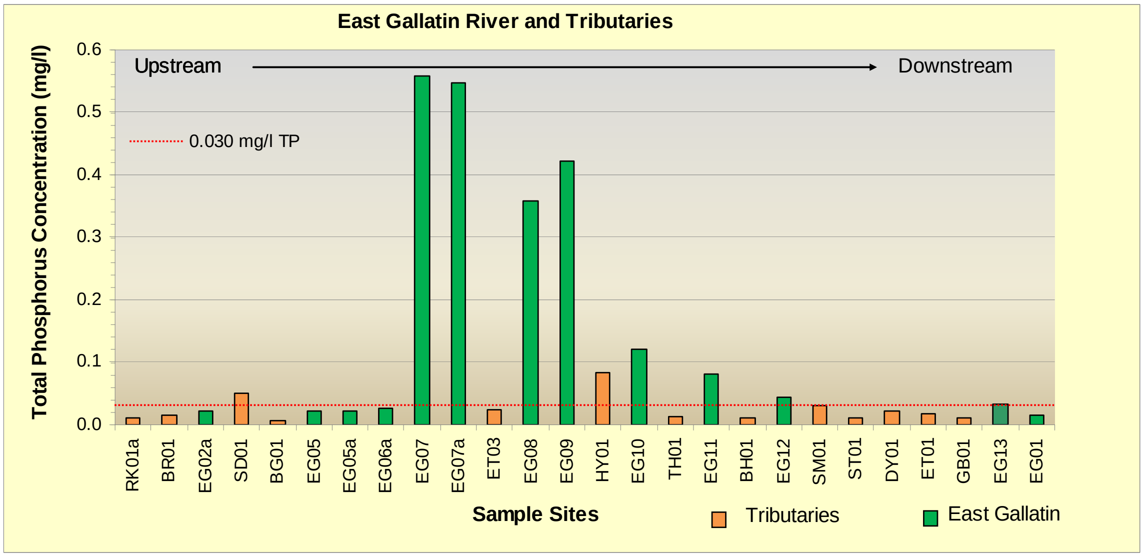

Figure 19: Total phosphorus concentrations in the East Gallatin River and tributaries. Sept 2009

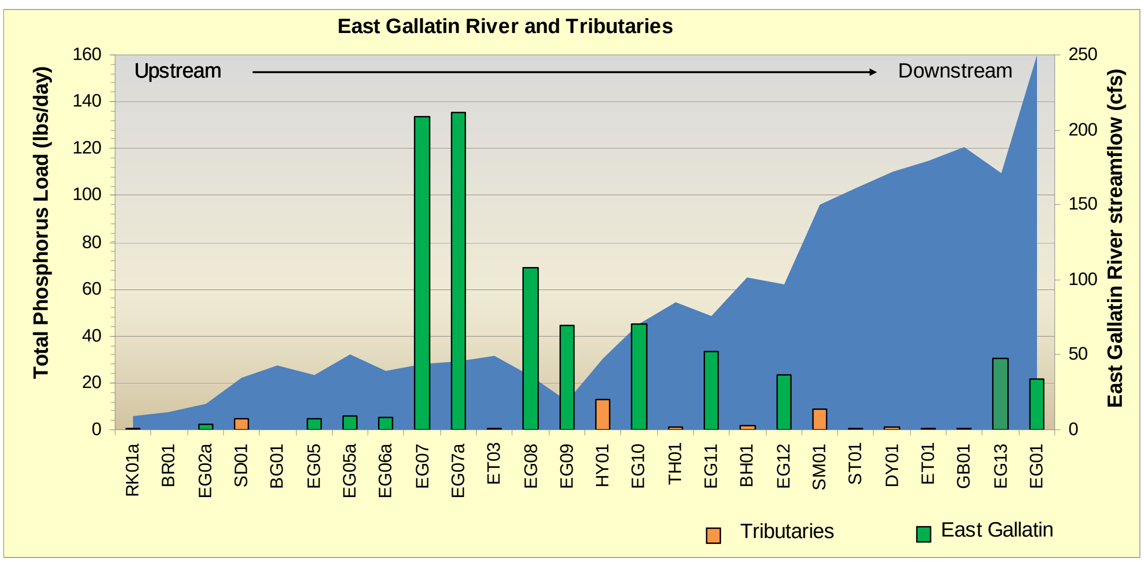

Figure 20: Total phosphorus loads in the East Gallatin River and tributaries. Sept 2009

4. ALGAE/CHLOROPHYLL-A

Chlorophyll-a is measured as a means of estimating algae biomass in a body of water. Heavy growths of algae generally indicate inferior water quality. Some streams are naturally high in nutrients and therefore have greater densities of algae present in the stream. Excess algal growth beyond natural conditions poses a threat to aquatic life as well as an aesthetic concern. High algal densities decrease the amount of habitat available for aquatic insects, in turn, impacting the fish that feed on those insects. Algal decomposition depletes oxygen concentrations resulting in impacts to aquatic life. Based on results of public perception surveys (Suplee 2009) and algae sampling and analysis, chlorophyll-a concentrations in excess of 129 mg/m^2 are classified by the DEQ as 'undesirable aquatic life'.

Several factors contribute to algae growth including lack of streamside shading, water temperature, and inputs of nitrogen and phosphorus to a stream. Therefore, while the measurement of nutrients and physical parameters provide information on conditions at the time of sampling, quantification of algal growth itself serves as an indicator of stream conditions over a longer period of time.

The concentration of chlorophyll-a per square meter serves as one of several repeatable methods for quantifying algal densities. Chlorophyll-a is one of the pigments in plants used in the photosynthetic process. The method requires collecting algae from a standard sized surface area of stream bottom. Samples are homogenized and analyzed on a spectrophotometer to quantify chlorophyll-a concentrations. The results are reported as the amount of chlorophyll-a in milligrams present per square meter, or mg/m^2. In this assessment, three field methods were used to sample algae from the stream sites; template, core and hoop methods. The actual field method used was dependent on the type of stream substrate in a given sample transect (e.g. rocky versus muddy) and algae type (e.g. short versus stringy). Example photos of algae sampling methods are presented in Figures 21, 22 and 23. Attachment G of the *LGTPA Data Upload and QAQC Report* (OASIS 2010) provides additional photos of the algae conditions present at each site sampled in 2009.

4.1. Sampling Activity

Algal density was assessed at 32 sample sites, distributed across 8 streams (Table 4). At 26 of these 32 algal sites, sampling was limited to a visual estimate only. Visual estimates were carried out at 26 of the locations where chlorophyll-a concentrations were estimated to be less than 50 mg/m^2. Sites considered less than 50 mg/m^2 were documented with field notes describing algal conditions and photos. These sites did not warrant further quantitative field sampling. This visual estimation itself provides valuable information that the site does not have excessive algae growth.

The chlorophyll-a sites quantitatively measured are highlighted in bold in Table 4. Quantitative sampling focused on 6 sample sites distributed across 3 streams; Bear

Creek (1 site), East Gallatin (4 sites) and Thompson Creek (1 site). Initially, 7 sites were targeted for quantitative field methods. Site BR03 on Bear Creek was shifted to a qualitative assessment using field photos and notes based on visual estimates of algal densities less than 50 mg/m^2 in the field (Figure 24).

4.2. Results and Discussion

Chlorophyll-a results ranged from 27.6 mg/m^2 at site BR01 on Bear Creek to 133.1 mg/m^2 on the East Gallatin at site EG10 (Figure 25). The chlorophyll-a concentration was typically higher at sites located on the mainstem of the East Gallatin in areas adjacent to or downstream of the urban population centers. Site EG13 was an exception with chlorophyll-a concentration of 54.4 mg/m^2. In contrast, chlorophyll-a concentration at EG13 during the 2008 sampling season was 1796 mg/m^2. Site TH01a located on Thompson Creek had a chlorophyll-a concentration of 89.4 mg/m^2 in 2009.

In 2008, the chlorophyll-a concentration at site EG02 on the East Gallatin located just downstream of the confluence of Bear and Jackson Creeks was 31.5 mg/m^2. In 2009, site EG02a located just upstream of the confluence with Sourdough/Bozeman Creek (~5 miles downstream from EG02) had a chlorophyll-a concentration of 103.1 mg/m^2. This marks a 3 fold increase in chlorophyll-a concentration between sites. Site EG02 was not sampled in 2009. It's uncertain if the increased algal density was the result of inter-annual variation or non-point source inputs between sites EG02 and EG02a.

Qualitative estimates of algae conducted on headwater tributary streams all met the visual criteria of less than 50 mg/m^2.

Figure 21. Template method used for scraping algae from stream substrate.

Figure 22. Filtering algae scraped from a sampled rock.

Figure 23. Sampling algae in Thompson Creek using the hoop method in 2009.

Figure 24. Site BR03 visually estimated to have less than 50 mg/m^2 of chlorophyll-a.

Table 4. Results of Chlorophyll-a analysis at the 32 sampled sites in Sept 2009. Sites quantitatively sampled are in bold.

site	stream	algae photo	Chl *a* (mg/m^2)
BG01	Bridger Creek	X	
BG02	Bridger Creek	X	
BG04	Bridger Creek	X	
BG05	Bridger Creek	X	
BR01	**Bear Creek**		**27.6**
BR03	Bear Creek	X	
EG01	East Gallatin River	X	
EG02a	**East Gallatin River**		**103.1**
EG05	**East Gallatin River**		**75.8**
EG07	East Gallatin River	X	
EG08	East Gallatin River	X	
EG09	East Gallatin River	X	
EG10	**East Gallatin River**		**133.1**
EG11	East Gallatin River	X	
EG12	East Gallatin River	X	
EG13	**East Gallatin River**		**54.4**
GD01	Godfrey Creek	X	
GD03	Godfrey Creek	X	
HY03	Hyalite Creek	X	
HY04	Hyalite Creek	X	
HY05	Hyalite Creek	X	
HY06	Hyalite Creek	X	
JK01a	Jackson Creek	X	
JK01b	Jackson Creek	X	
JK02a	Jackson Creek	X	
SD03a	Sourdough Creek	X	
SD04	Sourdough Creek	X	
SD05	Sourdough Creek	X	
TH01	Thompson Creek	X	
TH01a	**Thompson Creek**		**89.4**
TH02	Thompson Creek	X	
TH02a	Thompson Creek	X	

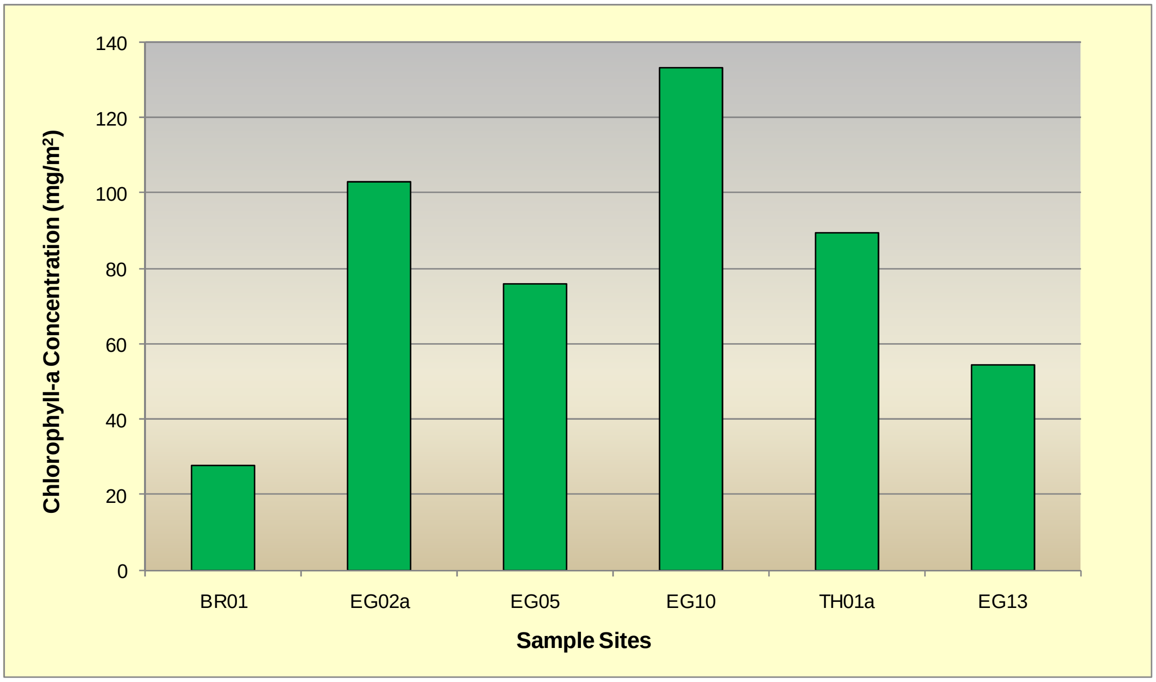

Figure 25 Chlorophyll-a concentration for sites sampled in Sept 2009 on the Lower Gallatin TPA.

5. CONCLUSIONS

Data collected during the late summer of 2009, low flow conditions in the LGTPA indicates that the East Gallatin River and its tributary streams have areas of higher nutrients, chlorophyll-a, and *E. coli,* primarily in the lower elevations of the watershed. In contrast, the forested headwater segments at higher elevations have relatively low nutrient and chlorophyll-a concentration. Similar patterns between land use and water quality were observed in the 2008 sampling effort.

The 2009 field effort on the East Gallatin and Sourdough/Bozeman Creek attempted to bracket potential source inputs with upstream and downstream sample sites. Nutrient concentrations and loading to the East Gallatin River increased substantially between sites EG06a and EG07. The Bozeman Wastewater Treatment Plant effluent outfall was located directly upstream of site EG07, and loads discharged from the WWTP outfall closely match the observed instream loading increase between these sites.

Sourdough/Bozeman Creek also caused an increase in nutrient concentrations and loading to the East Gallatin relative to observations at upstream sites. Synoptic sampling of *E. coli* on Sourdough/Bozeman Creek identified a number of locations adjacent to the urban areas that exceeded 126 cfu/100 ml. Two outfall pipes on Sourdough/Bozeman Creek, SDP01 at Lincoln Street and SDP03 at Rouse Street, had two of the highest *E. coli* values measured during the 2009 sampling effort, 365 and 2420 cfu/100 ml. The latter value was the upper reporting limit suggesting that *E. coli* concentrations could actually have been greater than the 2420 cfu/100 ml reported from the laboratory. While these e.coli concentrations were high, they did not increase instream concentrations significantly as pipe flows were low, resulting in small load contributions to Sourdough/Bozeman Creek.

6. REFERENCES

Department of Environmental Quality, DEQ. 2004. Montana Numeric Water Quality Standards, Circular WQB-7. 38 pp.

OASIS Environmental, Inc. 2009. Lower Gallatin TMDL Planning Area Nutrient, *E. coli,* and Algae Sampling and Analysis Plan. August 2009.

Suplee, M., V. Watson, M. Teply, and H. McKee. 2009. How green is too green? Public opinion of what constitutes undesirable algae levels in streams. JAWRA Vol. 45, No. 1 p. 123-140.