Yellowstone Club Wastewater Effluent Spill Monitoring Project
Data Analysis Phase 1

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EXECUTIVE SUMMARY
Yellowstone Club Wastewater Effluent Spill Monitoring Project

Early in the morning of March 3rd, 2016, a mechanical failure of the wastewater effluent storage pond at the Yellowstone Club in Big Sky, MT caused a leak of and spilled tertiary treated wastewater into the Second Yellow Mule drainage. Second Yellow Mule is a small headwater tributary of the South Fork of the West Fork of the Gallatin River. Treated wastewater effluent from the spill cut through the hillside, where the storage pond is located, and carried sediment to Second Yellow Mule creek. Approximately 30 million gallons of wastewater spilled into Second Yellow Mule over four days until the pond stopped leaking on March 7th at 4 am.

The Gallatin River Task Force (Task Force) and Confluence Consulting Inc. began monitoring the impacts of the spill on March 4th and continued monitoring daily while the pond was actively leaking and impacting downstream surface waters. This report assesses the data collected during Phase 1 of the monitoring project from March 3rd until March 9th, when field measurements indicated that water quality concentrations resembled concentrations prior to the spill.

Data results indicate that Montana health standards were not exceeded at any of the sampling sites during the monitoring period. Aquatic life standards were exceeded for ammonia and sediment. The ammonia standard was exceeded at the most upstream sites on Second Yellow Mule (2YMASF) on March 5th and March 6th and on the South Fork, just below the confluence with Second Yellow Mule on March 5th. The turbidity standard was exceeded for all affected sites throughout Phase 1 except for the lower Gallatin site (MSGMIX), where it was exceeded on March 5th and March 6th and the upper South Fork site (SFB2YM), where the standard was exceeded March 5th through March 7th. Fish surveys conducted on March 10th documented five fish mortalities. The full extent of the aquatic life impacts will depend on how spring runoff and storm events redistribute fine sediment throughout the drainage over the upcoming months and successive years. Due to the potential cascading impacts caused by fine sediment to fish aquatic insect habitat, it may take years to fully characterize the long-term effects of the spill.

1.0 Introduction

Early in the morning of March 3rd, 2016, a mechanical failure of the wastewater effluent storage pond at the Yellowstone Club in Big Sky, MT spilled tertiary treated wastewater into the Second Yellow Mule drainage. Second Yellow Mule is a small headwater tributary of the South Fork of the West Fork of the Gallatin River. Wastewater effluent from the spill cut through the hillside, where the storage pond is located, and carried sediment from the hillside as it traveled to Second Yellow Mule creek. Approximately 30 million gallons of wastewater was delivered to Second Yellow Mule over four days until the pond stopped leaking on March 7th at 4 am.

The Task Force and Confluence Consulting began monitoring the impacts of the spill on March 4th and continued monitoring daily while the pond was actively leaking and impacting downstream surface waters. This report assesses the data collected over this initial phase of the monitoring project from March 3rd until March 9th, when field measurements indicated water concentrations resembled concentrations prior to the spill. Ongoing monitoring will continue until spring runoff has terminated to examine how fine sediment and other chemical signatures vary as higher streamflows move through the system and mobilize settled sediments. Following spring runoff, the Task Force will publish a detailed report assessing data collected during Phase 2.

2.0 Methods

The objective of this assessment is to evaluate acute impacts from the wastewater effluent spill to Second Yellow Mule Creek and affected downstream tributaries.

2.1 Sampling Locations and Frequency

A total of 10 sites were sampled to evaluate the impacts of the wastewater effluent spill. Sampling occurred daily during Phase 1 of the project. Details of the sample locations are listed in **Table 1** and are presented in **Figure 1**.

Table 1: Sample locations and rationale for site selection for the Yellowstone Club Wastewater Effluent Spill Monitoring Project

Site Name	Site Description	Rationale
BR-1	Pond breach outfall	Wastewater effluent
2YMASF	Second Yellow Mule Creek above confluence with South Fork of the West Fork of the Gallatin River	Directly affected creek
SF2YM	South Fork of the West Fork of the Gallatin River above confluence with Second Yellow Mule Creek	Above impacted tributary
SFB2YM	South Fork of the West Fork of the Gallatin River below confluence with Second Yellow Mule Creek	Downstream tributary
SFMID	Midway along the South Fork of the West Fork of the Gallatin River	Downstream tributary
SFAWF	South Fork of the West Fork of the Gallatin River above confluence with West Fork of the Gallatin River	Downstream tributary
WFASF	West Fork of the Gallatin River above confluence with South Fork of the West Fork of the Gallatin River	Above impacted tributary
WFBSF	West Fork of the Gallatin River below confluence with South Fork of the West Fork of the Gallatin River	Downstream tributary
MSGAWF	Main Stem of the Gallatin River above confluence with West Fork of the Gallatin River	Downstream tributary
MSGMIX	Main Stem of the Gallatin River well mixed with West Fork of the Gallatin River (just above Deer Creek).	Downstream tributary

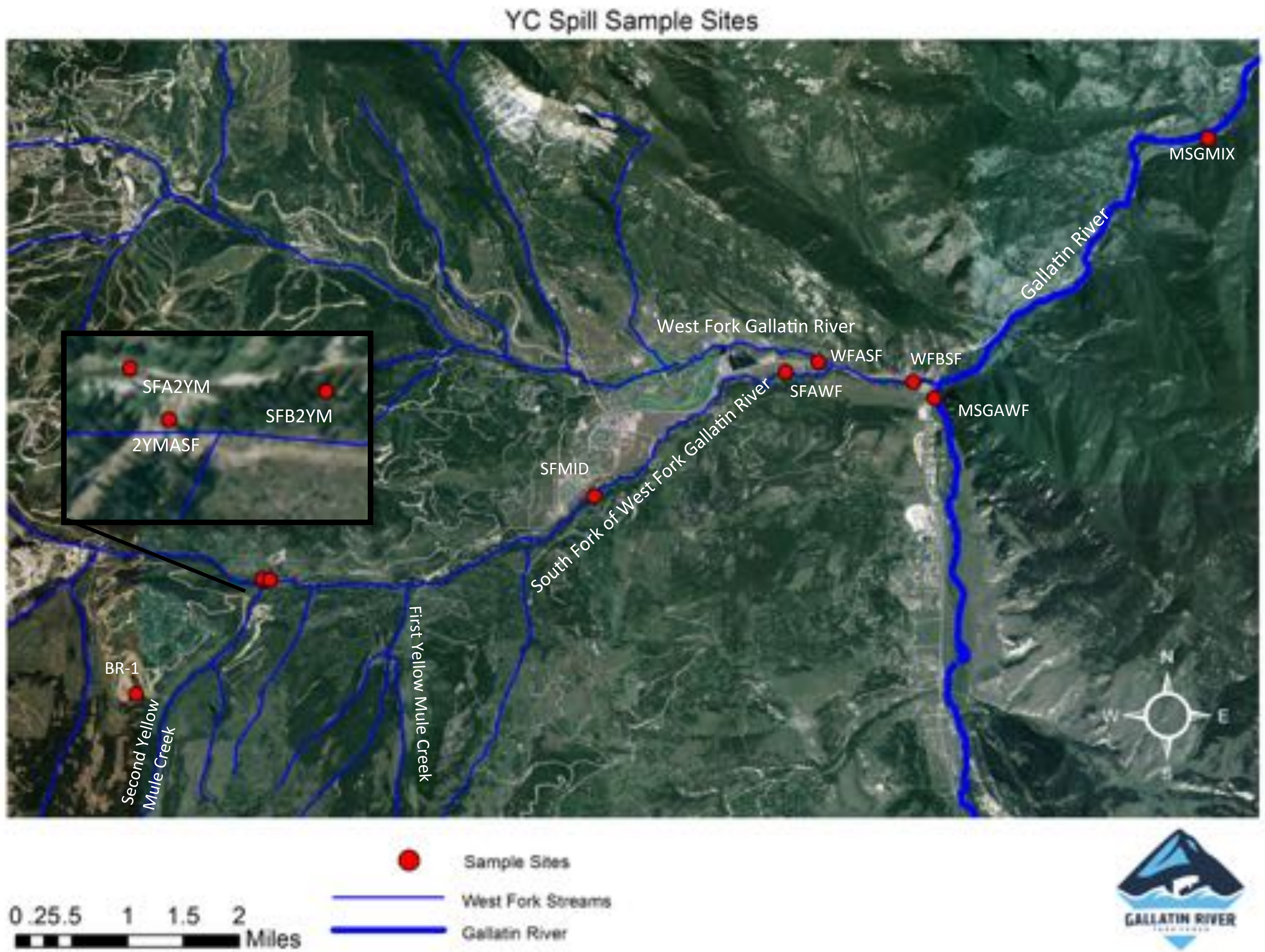

Figure 1: Yellowstone Club Wastewater Effluent Spill Monitoring Project Sampling Sites (**Table 1**)

2.2 Field Methods

2.2.1 Water Chemistry

Specific conductivity, turbidity, temperature, and pH, were measured at each site following the requirements of MT DEQ (MT DEQ, 2012) until affected streams returned to near original conditions. Water (grab) samples were collected at each site for four to six consecutive days or until affected streams returned to original conditions. Further details on methods are described in the Sampling Analysis Plan (Confluence, 2016).

2.2.2 Streamflow

Flow was measured daily above and below the confluence of Second Yellow Mule creek and the South Fork until affected streams returned to original conditions. Flow was measured using the quantitative flow meter method (MT DEQ, 2012).

2.3 Laboratory Methods

Energy Laboratories in Helena measured chloride, specific conductance, total suspended solids, pH, ammonia, nitrate + nitrite, kjeldahl nitrogen, total-nitrogen, phosphate-phosphorus, and E. coli. Lab analysis procedures are shown in **Table 2**. Further detail in the sample preparation is described in the Sampling Analysis Plan (Confluence, 2016).

Table 2: Laboratory analysis methods for samples collected for the Yellowstone Club Wastewater Effluent Spill Monitoring Project

WQ Parameter	Analysis Method	Detection Limit
Ammonia-nitrogen	350.1 Colimetry	0.05 mg/L
Chloride	300.0 Ion Chromotograph	1 mg/L
Escherichia coli	1603 Membrane Filtration	1.0 cfu/100 ml
Inorganic nitrogen (nitrate and nitrite)	353.2 Colimetry	0.01 mg/l
Kjeldahl nitrogen	351.2 Colimetry	0.5 mg/l
Total nitrogen	Calculated	0.5 mg/l
pH	4500-H Potentiometry	0.1
Phosphate-phosphorus	365.1 Colimetry	0.01 mg/l
Specific Conductance	SM 2510	1 umhos/cm
Total suspended solids	SM 2540-D	10 mg/L
Turbidity	2130-B Nephelometry	0.2 NTU

3.0 Results

3.1 Water Chemistry

Nutrient, sediment and E.coli data collected during Phase 1 of the Yellowstone Club Wastewater Effluent Spill Monitoring project are shown in in Tables 3-10.

At no point during the acute study period did concentrations of water quality constituents exceed human health standards; however, aquatic life standards were exceeded for ammonia and sediment. The ammonia standard was exceeded at the most upstream sites on Second Yellow Mule (2YMASF) on March 5th and March 6th and on the South Fork, just below the confluence with Second Yellow Mule (SFB2YM) on March 5th (**Table 4, Figures 2&3**). The turbidity standard was exceeded for all affected sites throughout the acute study period except for the lower Gallatin site (MSGMIX), where it was exceeded only on March 5th and March 6th and the upper South Fork site (SFB2YM), where the standard was exceeded March 5th through March 7th (**Table 7, Figures 4&6**).

In general, nutrient, sediment, and E.coli concentrations were highest at the sites closest to the spill (2YMASF & SFB2YM) and were diluted further downstream. Ammonia (**Table 4, Figures 2&3**), total nitrogen (driven by ammonia, **Table 3**), turbidity (**Table 7, Figures 4&6**), total suspended solids (**Table 8, Figures 5&7**), and phosphorus (**Table 6**) were significantly above background concentrations for winter baseflow conditions (Gallatin River Task Force, unpublished data) when the effluent pond was leaking and then quickly decreased after the pond stopped leaking on March 7th.

Water chemistry of field duplicates had reasonably similar values and field blanks were uncontaminated.

Table 3: Total nitrogen concentrations (mg/) over the acute study period

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16
BR-1	8.6	8.3	8.8			
2YMASF		13.8	6.6	1.9	2	1.8
SFA2YM		0	0	0	0.6	0
SFB2YM		11.9	3.8	0	0.7	0.5
SFMID		3.8	3.2	0.8	0.7	0.7
SFAWF		2.6	2.7	1.1	0.8	0.8
WFASF		0.6	0.6	0.6	1	0.9
WFBSF		2.2	2.2	1	0.8	0.8
MSGAWF		0	0	0	0	0
MSGMIX		0	0	0	0.5	0

Table 4: Ammonia concentrations (mg/L) over the acute study period. Values in red exceeded Montana Standards (MTDEQ, 2012)

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16
BR-1	6.9	7	6.8			
2YMASF		6.3	3.9	0.89	0.67	0.66
SFA2YM		0	0	0	0	0
SFB2YM		6.7	2.4	0.11	0	0.05
SFMID		1.85	1.71	0.26	0.07	0.08
SFAWF		1.5	1.42	0.39	0.09	0.14
WFASF		0	0	0	0	0
WFBSF		1.14	1.07	0.31	0.06	0.06
MSGAWF		0	0	0	0	0
MSGMIX		0.11	0.09	0	0	0

Table 5: Nitrate + nitrite concentrations (mg/L) over the acute study period

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16
BR-1	0.14	0.15	0.18			
2YMASF		0.25	0.25	0.53	0.69	0.71
SFA2YM		0.18	0.21	0.24	0.28	0.25
SFB2YM		0.25	0.23	0.27	0.32	0.3
SFMID		0.24	0.26	0.32	0.38	0.4
SFAWF		0.26	0.27	0.36	0.41	0.41
WFASF		0.5	0.48	0.57	0.69	0.67
WFBSF		0.31	0.33	0.43	0.52	0.52
MSGAWF		0.05	0.03	0.03	0.06	0.05

Table 6: Phosphorous concentrations (mg/L) over the acute study period

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/1	3/9/16
BR-1	2.49	2.53	2.27			
2YMASF		4.3	3.05	0.25	0.19	0.18
SFA2YM		0	0	0	0	0
SFB2YM		8.71	1.71	0.05	0.07	0.03
SFMID		2.1	1.06	0.14	0.13	0.08
SFAWF		0.77	0.8	0.17	0.09	0.06
WFASF		0.01	0.01	0.01	0.01	0.02
WFBSF		0.55	0.59	0.12	0.06	0.04
MSGAWF		0.01	0.02	0.02	0.01	0.02
MSGMIX		0.08	0.07	0.02	0.01	0.02

Table 7: Turbidity concentrations (NTU) over the acute study period. Values in red exceeded the Montana state standards.

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16
BR-1	15	2.7	2			
2YMASF		6490	1510	63.4	41.1	31.2
SFA2YM		0.8	0.8	1.1	1.7	1
SFB2YM		6250	781	8.7	5.4	4.3
SFMID		1590	570	80.5	48.7	39.2
SFAWF		607	457	148	67.3	30.3
WFASF		1	0.6	1.1	0.8	0.9
WFBSF		433	302	78.1	32.7	17
MSGAWF		4.9	4.7	3.8	2.9	1.8
MSGMIX		32.7	21	6.7	2.8	2.2

Table 8: TSS concentrations(mg/L) over the acute study period

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16
BR-1	15	14	0			
2YMASF		8440	1400	65	47	39
SFA2YM		19	0	0	0	0
SFB2YM		6470	731	18	13	0
SFMID		1100	422	104	70	52
SFAWF		327	290	147	71	29
WFASF		0	0	0	0	0
WFBSF		247	178	74	38	19
MSGAWF		0	10	12	0	0
MSGMIX		25	20	10	0	0

Table 9: Specific conductance concentrations (uS/cm) over the acute study period

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16
BR-1	773	772	776			
2YMASF		661	672	536	504	473
SFA2YM		290	289	294	288	289
SFB2YM		647	510	322	310	307
SFMID		499	499	368	358	349
SFAWF		498	493	399	391	379
WFASF		361	361	376	385	381
WFBSF		466	458	398	389	381
MSGAWF		400	393	409	471	456
MSGMIX		411	401	388	392	400

Table 10: E.coli concentrations (cfu/100 mL) over the acute study period

	3/4/16	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16
BR-1	48	24.1	18			
2YMASF		206.4	29	3	5	<1
SFA2YM		<1	4	<2	<1	1
SFB2YM		127.4	25	6	3	<1
SFMID		74.9	65	7	11	<1
SFAWF		30.5	33	8	3	3
WFASF		18.9	9	2	17	1
WFBSF		22.6	33	6	2	<1
MSGAWF		<1	<2	<2	<1	<1
MSGMIX		3.1	<2	<2	<1	<1

3.2 Streamflow Data

Stream discharge in Second Yellow Mule (2YMASF) and the South Fork (SFB2YM) significantly increased while the effluent pond was leaking on March 5th and March 6th and quickly decreased shortly after the pond stopped leaking on March 7th (**Table 11**).

Table 11: Discharge measurements (cfs) in bold font and calculations for Second Yellow Mule and the South Fork over the study period.

	3/5/16	3/6/16	3/7/16	3/8/16	3/9/16	3/16/16
2YMASF	10.44	6.2	**0.68**	**0.46**	**0.52**	**0.27**
SFA2YM	**4.87**	**6.48**	**6.48**	**7.56**	**6.5**	**7.04**
SFB2YM	**15.31**	**12.68**	7.16	8.02	7.02	7.31

4.0 Discussion

4.1 Human Health Effects

Two water quality constituents monitored after the spill are regulated for human health risks by the MT DEQ. The MTDEQ has set a human health standard for nitrate + nitrite of 10 mg/L because of risks to infants, particularly those under six months of age. Nitrate+nitrite concentrations at all sites were well below 10 mg/L with the highest concentration in Second Yellow Mule of 0.71 mg/L on March 9th (**Table 5**).

E.coli is an indicator of fecal contamination and some strains of E.coli can cause severe illness in humans. MT DEQ has developed E.coli standards for surface water that vary depending on the time of year. E. coli standards are less stringent in the colder months when human water contact is less likely. All samples were well below the MTDEQ standard of 1,290 cfu/100 mL, with the highest concentration of 206.4 cfu/100 mL occurring in Second Yellow Mule on March 5th (MTDEQ, 2012, **Table 10**).

Table 12: MTDEQ human health standards for E.coli and nitrate+nitrite (MTDEQ, 2012)

Parameter	Value	Units
Nitrate + Nitrite	10	mg/L
E.coli	1,260	cfu/100 mL

4.2 Aquatic Life Effects

The primary water quality constituents of concern to aquatic life from the treated wastewater effluent spill are nutrients and sediment. Direct evidence of aquatic life impacts was documented by a fish survey conducted on March 10th (MTDEQ, 2016b). These included five fish mortalities of Westslope Cutthroat trout hybrids and extensive damage to sculpin fins. Additional fish and habitat surveys will occur after spring runoff. The full extent of the aquatic life impacts will depend on how spring runoff and storm events redistribute fine sediment throughout the drainage over the upcoming months and in successive years. The full extent of the impact on aquatic life may take years to fully characterize due to the potential cascading impacts of fine sediment on fish and aquatic insect habitat.

4.2.1 Nutrient Standards

Montana water quality standards help protect the beneficial uses of state surface waters, such as drinking water, fisheries, wildlife, and agriculture. Comparison of measured water chemistry data to the MTDEQ aquatic life standards can be useful to make inference to aquatic life impacts or help guide additional research questions; however, these comparisons do not provide decisive conclusions of aquatic life impacts associated with the spill.

The Montana nutrient standards for total nitrogen and phosphorous only pertain to summer baseflow because the primary concern is excess algal growth, which can deplete oxygen levels and degrade fish and aquatic insect habitat. Total nitrogen and phosphorous values after the spill were significantly higher than historical values collected by the Gallatin River Task Force since 2001 (Gallatin River Task Force, unpublished data). Total nitrogen concentrations were elevated due to the ammonia component (**Tables 3&4**). Nitrate + nitrite values were within the range of expected values and historical observations (Gallatin River Task Force, unpublished data, **Table 5**). Phosphate levels were an order or two of magnitude higher in Second Yellow Mule and the South Fork as compared to historical observations (Gallatin River Task Force, unpublished data) and concentrations in the pond effluent (**Table 6**). Phosphorous was likely released with soil erosion as the effluent cut through the hillside on its way from the pond to Second Yellow Mule.

The MTDEQ has set yearlong standards for acute and chronic ammonia concentrations in surface waters. Ammonia can be toxic to fish by affecting the central nervous system, causing convulsions and death (Randall et al. 2002). Acute standards are applicable for a single ammonia measurement; while, chronic standards consider concentrations over a longer time period, typically 30 days. The ammonia standard is a calculation of ammonia concentration, pH and temperature because it's toxicity is principally due to the un-ionized form, NH_3 (Arthur et al. 1987), which varies with pH and temperature. As pH increases, the relative proportion of unionized ammonia increases, making ammonia more toxic to aquatic life (Brinkman et al. 2009; Paley et al. 1993; EPA 1999). Other factors that affect ammonia toxicity to fish are the length of exposure and the life stage of the exposed fish.

Ammonia concentrations are typically very low (<0.1) in streams because this form of nitrogen is unstable and readily available for plant consumption. Ammonia concentrations of the treated wastewater effluent varied between 6 and 7 mg/L (**Table 4, Figures 2&3**), which are within the range of typically observed values. Because this large load of ammonia was released during the winter when biological activity is limited, it was not readily consumed in the terrestrial or aquatic environments as it traveled to Second Yellow Mule and downstream to the Gallatin. The acute aquatic standard was exceeded in Second Yellow Mule on March 5th and Mach 6th and in the South Fork on March 5th (**Table 13**). Ammonia levels were elevated for all impacted sites while the pond was leaking and then rapidly decreased once the pond stopped leaking on March 7th.

Table 13: Acute ammonia criteria calculations. Values in red are above the Montana acute ammonia standards.

	3/5/16	**3/6/16**	**3/7/16**	**3/8/16**	**3/9/16**
2YMASF	5.62	3.83	3.83	3.83	3.83
SFA2YM	ND	ND	ND	ND	ND
SFB2YM	4.64	3.83	0.11	ND	0.05
SFMID	3.83	3.83	0.26	0.07	0.08
SFAWF	4.64	4.64	3.83	3.83	3.83
WFASF	ND	ND	ND	ND	ND
WFBSF	3.83	3.83	3.15	3.15	3.15
MSGAWF	ND	ND	ND	ND	ND
MSGMIX	3.83	2.59	ND	ND	ND

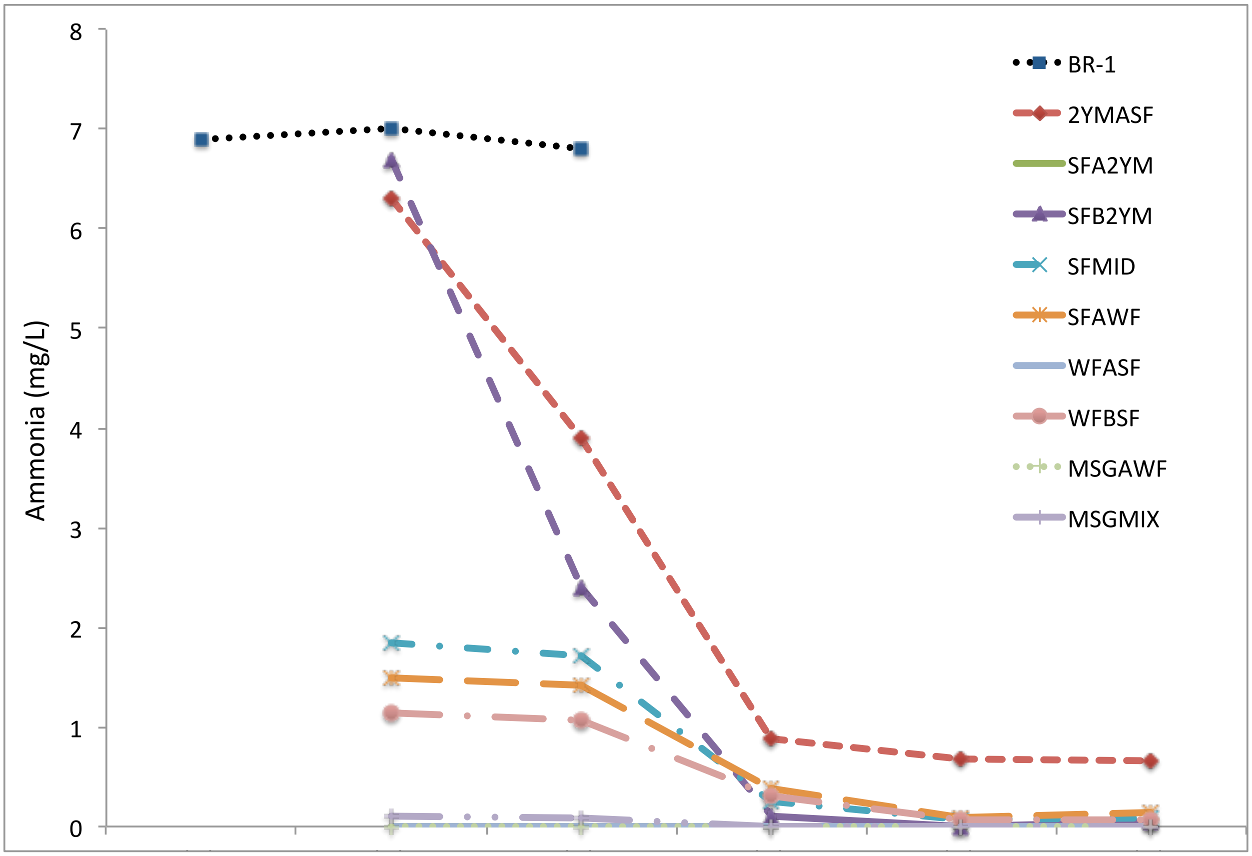

Figure 2: Ammonia concentrations in streams affected by the Yellowstone Club Wastewater Effluent Spill.

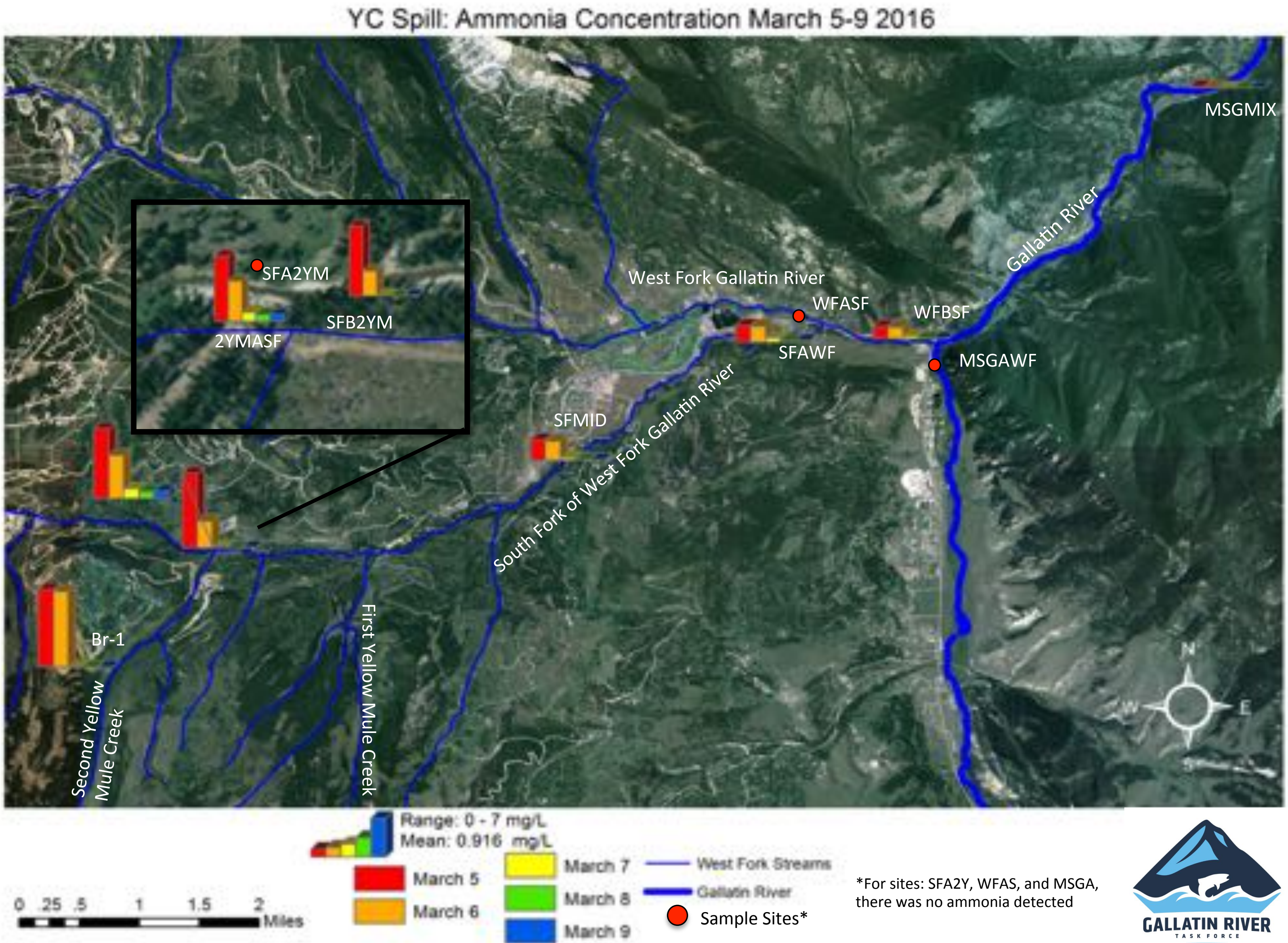

Figure 3: Ammonia concentrations in streams affected by the Yellowstone Club Wastewater Effluent Spill

4.2.1 Sediment Standards

The MTDEQ has set standards for turbidity and total suspended solids (TSS) to protect for sediment impacts on aquatic life. Fine sediment can impact aquatic life by: 1) accumulating on the streambed and reducing oxygen availability for fish eggs and macroinvertebrates, 2) reducing visibility required for fish to find food, 3) lessening light penetration used for aquatic plant photosynthesis, 4) clogging fish/ aquatic insect gills, and 5) damaging fins and other parts of fish aquatic insect anatomy. Turbidity and TSS concentrations were significantly elevated in the affected streams and are attributed to the severe erosion on the hillside between the effluent storage pond and Second Yellow Mule. Turbidity and TSS levels were low in the pond effluent, $\leq$15 NTU and mg/L, (**Tables 7&8, Figures 4,5,6&7**).

The Montana turbidity standard is exceeded when values are 5 NTU (nephelometric turbidity units) above naturally occurring conditions. Naturally occurring conditions for winter baseflow were estimated by measuring turbidity at similar sites not affected by the spill. The turbidity standard was exceeded for all affected sites throughout the acute study period except for the lower Gallatin site (MSGMIX), where exceedance occurred on March 5th and March 6th and the upper South Fork site (SFB2YM), where exceedance occurred March 5th through March 7th (**Table 7, Figures 4&6**). Turbidity levels in Second Yellow Mule, the South Fork and the West Fork were an order of magnitude or more higher than typically observed levels at spring runoff on March 5th and 6th (Gallatin River Task Force, unpublished data). Throughout the study period, turbidity levels in the mainstem Gallatin were comparable to historically observed levels during spring runoff. In general, the turbidity concentrations decreased going downstream.

The Montana TSS standard is narrative and states that TSS concentrations should not *create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife*. The MTDEQ uses scientific studies to interpret the narrative sediment standard and their evaluation of the data from the initial study period can be found in their technical report (MTDEQ, 2016b). Similar to turbidity, TSS levels decreased over time and as going downstream.

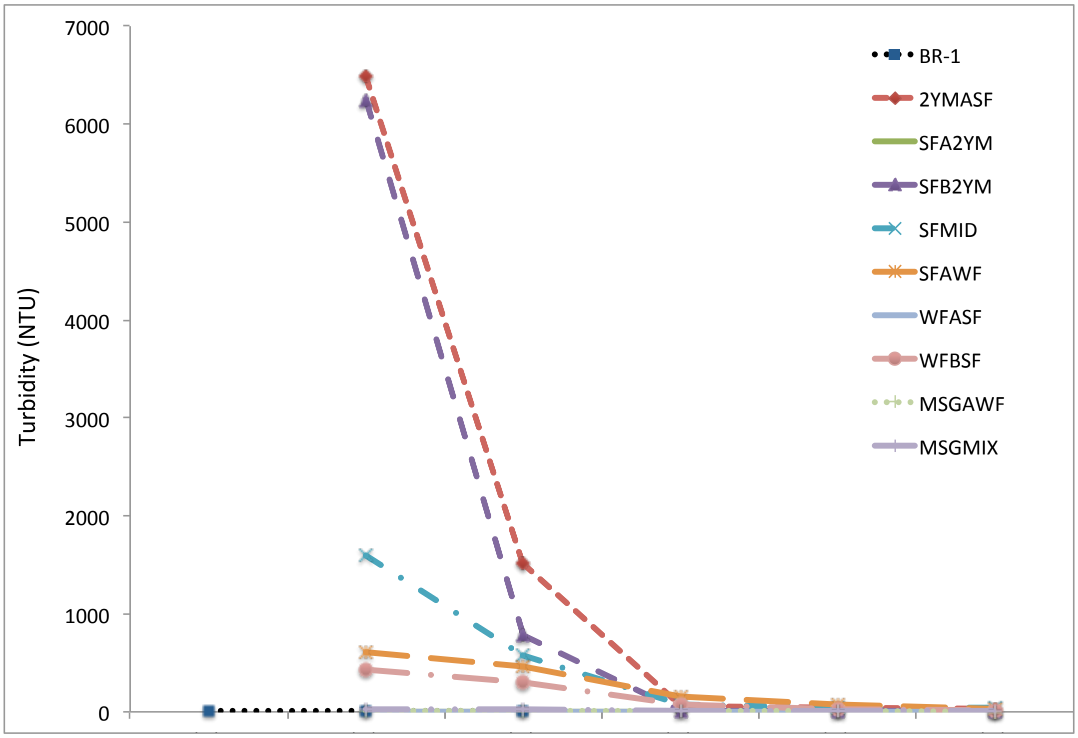

Figure 4: Turbidity concentrations in streams affected by the Yellowstone Club Wastewater Effluent Spill

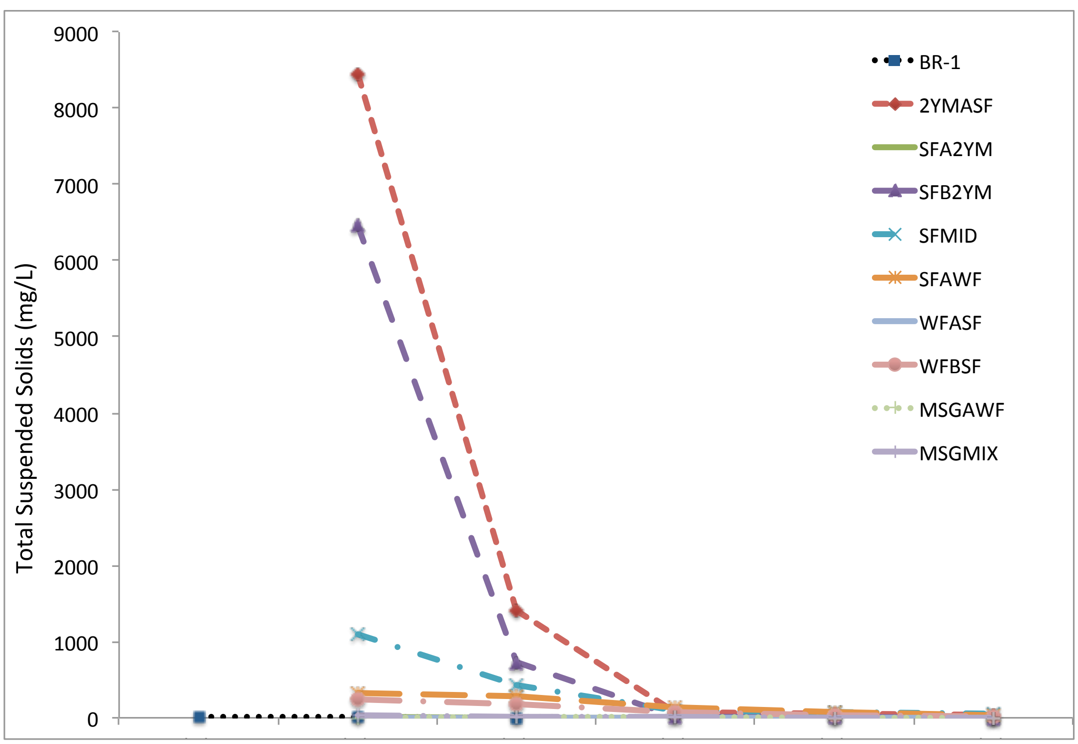

Figure 5: Total suspended solid concentrations in streams affected by the Yellowstone Club Wastewater Effluent Spill

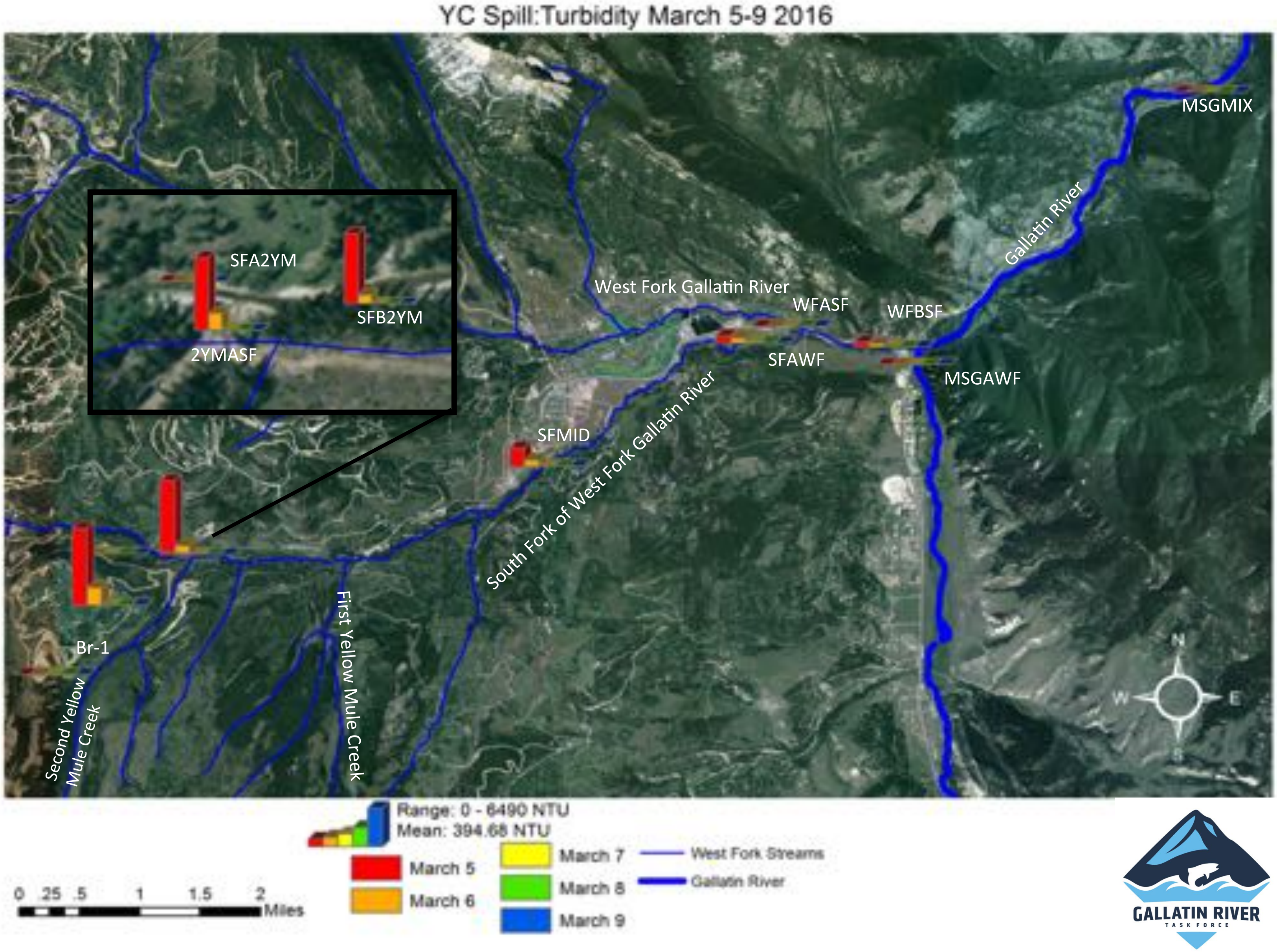

Figure 6: Turbidity concentrations in streams affected by the Yellowstone Club Wastewater Effluent Spill

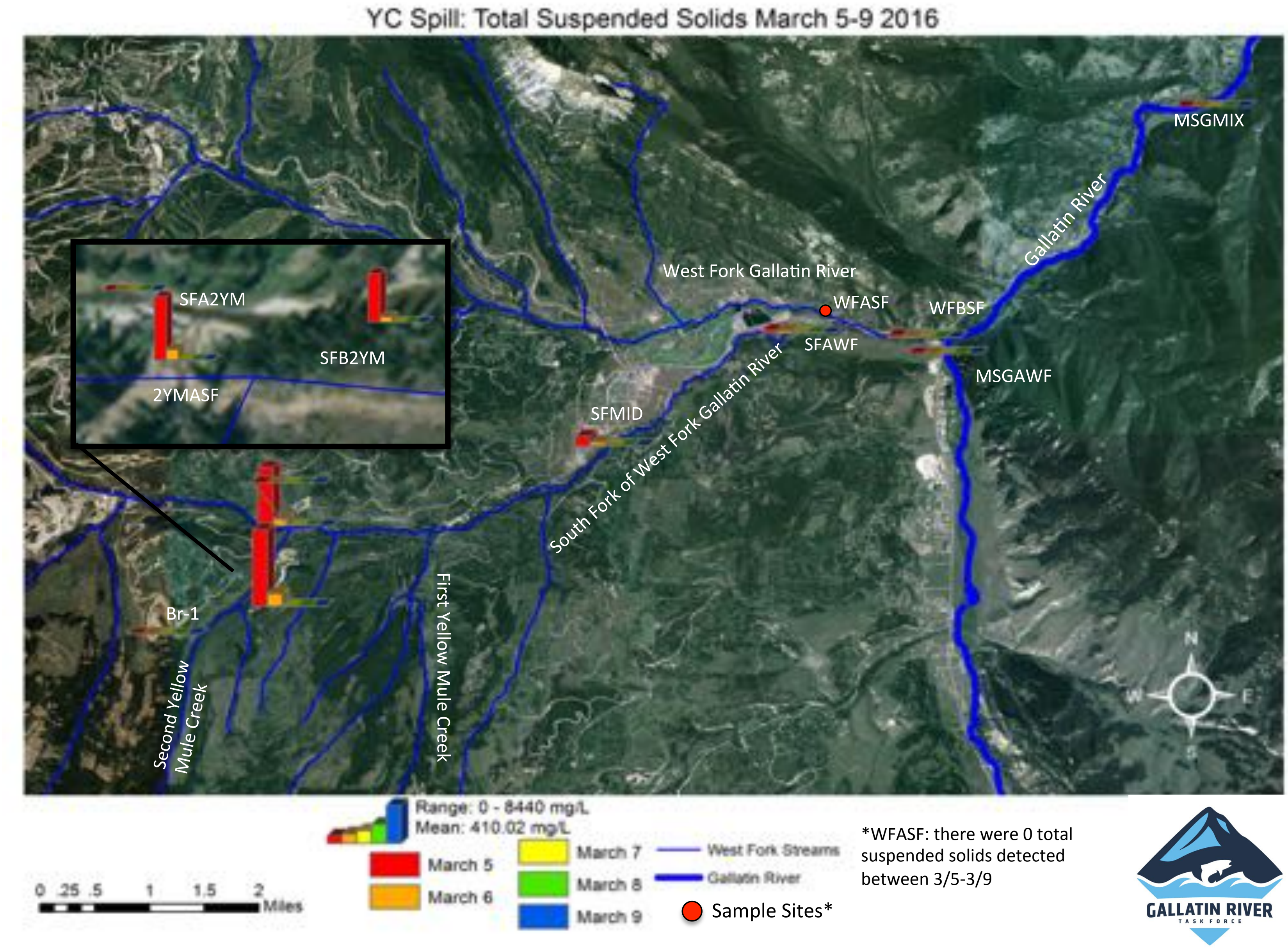

Figure 7: TSS concentrations in streams affected by the Yellowstone Club Wastewater Effluent Spill

5.0 Conclusions

Data results indicate that Montana health standards were not exceeded at any of the sampling sites throughout the monitoring period. Aquatic life standards were exceeded for ammonia and sediment. The ammonia standard was exceeded at the most upstream sites on Second Yellow Mule (2YMASF) on March 5th and March 6th and on the South Fork, just below the confluence with Second Yellow Mule on March 5th. The turbidity standard was exceeded for all affected sites throughout the acute study period except for the lower Gallatin site (MSGMIX), where it was exceeded on March 5th and March 6th and the upper South Fork site (SFB2YM), where the standard was exceeded March 5th through March 7th. Fish surveys conducted on March 10th documented five fish mortalities. The full extent of the aquatic life impacts will depend on how spring runoff and storm events redistribute fine sediment throughout the drainage over the upcoming months and successive years. Therefore, assessing the impacts on aquatic life may take years to fully characterize due to the potential cascading impacts of fine sediment on fish and aquatic insect habitat.

6.0 References

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