# Wastewater Spill into the Upper Gallatin River Watershed

## Part 2. Effects on Aquatic Life

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# REPORT SUMMARY

On March 3, 2016 there was a mechanical failure in a storage pond for tertiary treated wastewater used for golf course irrigation near Big Sky, Montana. Over the next four days approximately 30 million gallons of the treated effluent discharged into and affected downstream waterbodies (Second Yellow Mule Creek, South Fork West Fork Gallatin River, West Fork Gallatin River, and the Gallatin River). DEQ and FWP monitored water quality and surveyed fish populations in the spill-affected area between March 5th and March 12th, 2016. An acute exceedance of Montana's ammonia standards was documented on Second Yellow Mule Creek on March 5th. Further downstream, ammonia concentrations on March 5th were sequentially lower with increasing distance and dilution; there was no ammonia detected in the mainstem Gallatin River. Ammonia concentrations decreased at all tributary sites with each subsequent day of the spill and were mostly below detection by March 12th. Turbidity exceeded Montana's standards at all tributary sites for the entire study period (March 5th-12th), while in the mainstem Gallatin River turbidity exceeded the standard until March 9th. In the mainstem Gallatin River, total suspended solids (TSS) increased above background by about 17 mg/L, but TSS had largely returned to background by March 7th and completely so by March 9th. In contrast, TSS concentrations were as high as 4,560 mg/L in the affected tributaries early on in the spill and, based on those concentrations, some degree of fish mortality was to be expected. On March 10th five dead westslope cutthroat trout were found in the South Fork West Fork Gallatin River downstream from the Second Yellow Mule Creek confluence. Further, electroshocking surveys showed that the fish population in the South Fork West Fork Gallatin River, upstream of the Second Yellow Mule Creek confluence, was similar to that found in 1999, but numbers just downstream of Second Yellow Mule Creek's confluence were much lower. Another ¼ mile downstream on the South Fork West Fork Gallatin River, fish numbers were substantially higher than upstream, suggesting that many fish (especially younger fish) were displaced downstream by the spill. Looking to the future, there is uncertainty as to the spill's long-term effects on fish and aquatic life. Accumulated sediment where the spill first joins Second Yellow Mule Creek, and where Second Yellow Mule Creek joins the South Fork West Fork Gallatin River could, together, lead to additional mortality when mobilized during spring runoff, a time when westslope cutthroat trout are already stressed from spawning activities. Even without additional fish mortality, there will likely be sublethal TSS and turbidity impacts on fish and aquatic life in the affected tributaries in the coming months. If elevated turbidity lingers beyond runoff, the additional phosphorus carried by the suspended particles could induce nuisance-attached algal growth. As of this writing, weekly to biweekly monitoring is ongoing in the affected tributaries and in the Gallatin River near the West Fork confluence. This includes TSS and turbidity, and nitrogen and phosphorus at targeted locations. In July 2016 DEQ will review the results and, depending upon the findings and any remedial actions that have occurred or are planned, decide if further water quality monitoring is necessary. In addition, it is recommended that the fishery sections surveyed on March 10th (and other sections on the South Fork West Fork and West Fork Gallatin rivers) be surveyed again during summer and fall for at least three years. Macroinvertebrate samples should also be collected at locations where water sampling and/or fishery work has taken place. There are macroinvertebrate samples for these tributaries going back to the mid 1990s which can be used as points of comparison for the streams' current conditions and future recovery.

# 1.0 Introduction and Objectives

Sometime on March 3rd, 2016 there was a mechanical failure in a storage pond for tertiary treated waste water used for golf course irrigation near Big Sky, Montana. Over the next four days approximately 30 million gallons of the treated effluent discharged into and affected downstream waterbodies (Second Yellow Mule Creek, South Fork West Fork Gallatin River, West Fork Gallatin River, and the Gallatin River). DEQ and FWP monitored water quality and fisheries in the spill affected area between March 5th and March 12th, 2016.

The affected waterbodies are all classified by the state of Montana as B-1. This means their water quality is to be maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.

The objective of this report (Part 2 of a three part series) is to address the immediate effects of the spill on aquatic life. Effects were measured directly via fish population surveys, and inferred by measured impacts to aquatic life water-quality standards. FWP carried out fish surveys in the immediate aftermath of the spill. DEQ identified several aquatic-life related parameters at the onset of the spill (Water Quality Standards and Modeling Section, 2016a); ammonia, total suspended solids (TSS) and the related measurement turbidity, and the nutrients total nitrogen (TN) and total phosphorus (TP). Elevated levels of ammonia are toxic to aquatic life and salmonid fishes are particularly sensitive (Montana Department of Environmental Quality, 2012). Elevated TSS and turbidity can detrimentally affect aquatic life (Wood and Armitage, 1997), while elevated nutrients can lead to nuisance growths of attached algae and other problems. **Figure 1-1** (next page) shows the DEQ sampling locations. **Figure 1-2** shows both agencies' sites in the tributaries in and around Big Sky, Montana.

# 2.0 Methods

DEQ collected samples from March 5th to March 12th, 2016. Water samples were collected as grabs after triple rinsing the HDPE sample bottles with site water (analytes are described in **Table 2-1**, page 3). Field blanks (for evidence of inadvertent sample contamination) and duplicates (to assess repeatability) were collected. DEQ collects blanks and duplicates at the end of sampling trips; trips range from one to many days (here, the longest trip was three days). Turbidity was measured at each site immediately after sample collection using either a YSI 6600 V2-4 sonde or a Hach 2100Q Portable Turbidimeter (each calibrated by the two-point method[1]). Temperature and pH were measured using the YSI 6600 or a YSI Professional Plus hand-held meter. The pH was calibrated using the two point method and checked for calibration drift after field use.

Fish population sampling was conducted on the South Fork West Fork Gallatin River on March 10, 2016. Section 1 was just upstream of the Second Yellow Mule Creek confluence and was 361 ft long (**Figure 1-2**). Section 2 was just below that confluence and was 902 ft long. Section 3 was ¼ mile downstream from the Second Yellow Mule Creek confluence and was 345 ft long. Section 4 was upstream of Ousel Falls.

[1] Unlike the Hach, it is impractical to recalibrate the YSI's turbidity probe in the midst of field work. Therefore, drift from calibration was checked after returning to Helena. In a 126.0 NTU standard the YSI read 126.7 NTU (OK).

The upper three sections were blocked at the bottom end and electrofished with either a Smith-Root 12B or LR24 backpack electrofisher. Fish were netted and held in "live cars" (a net basket where fish readjust to the river and are then released) between electrofishing passes. All captured fish were measured to the nearest mm (all sites) and weighed to +/- one gram. The most downstream study section (Section 4) was sampled in one pass—turbidity precluded collection of a population estimate.

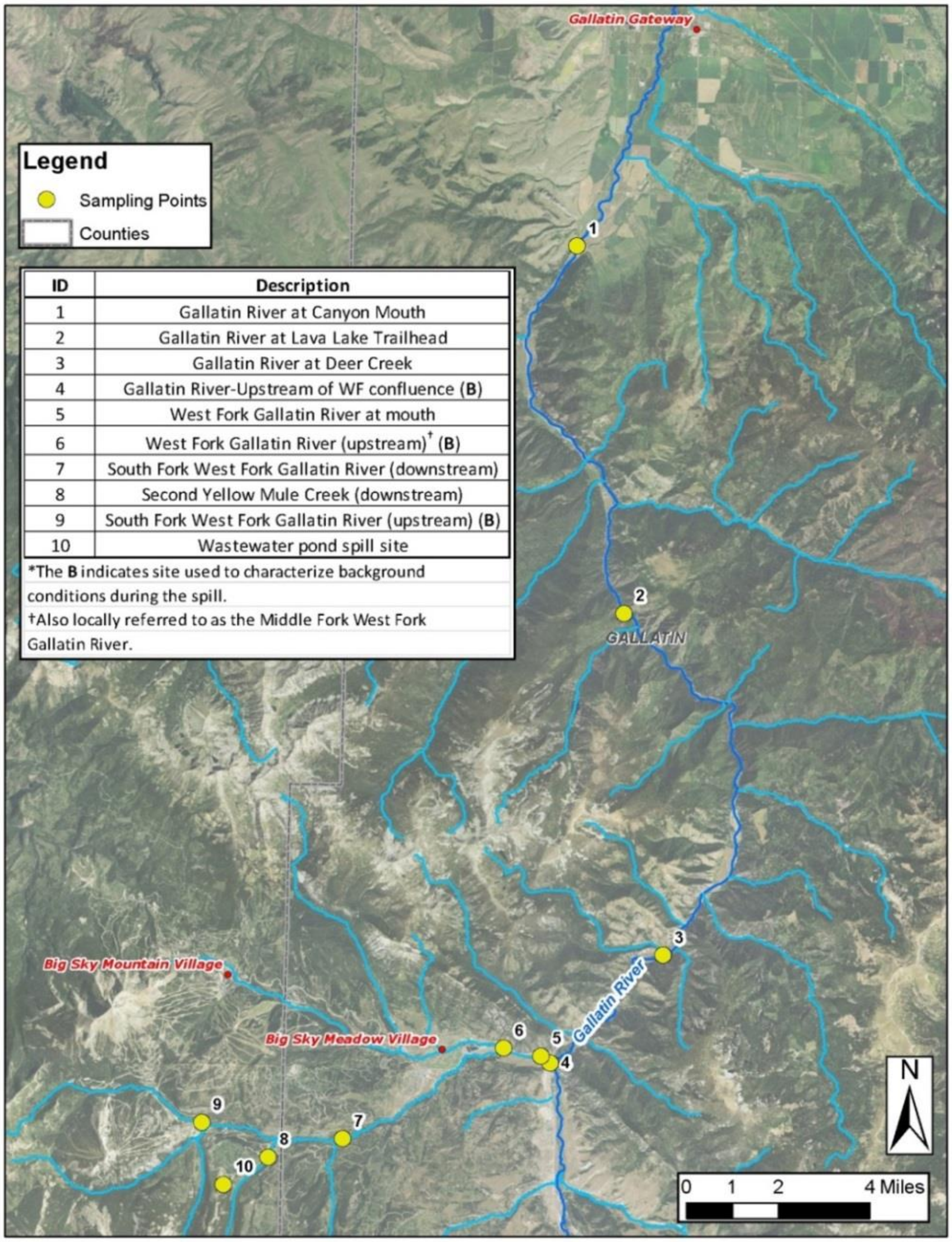


**Figure 1-1. Map showing DEQ's ten sampling locations, distributed from the spill site downstream to locations along the Gallatin River.**

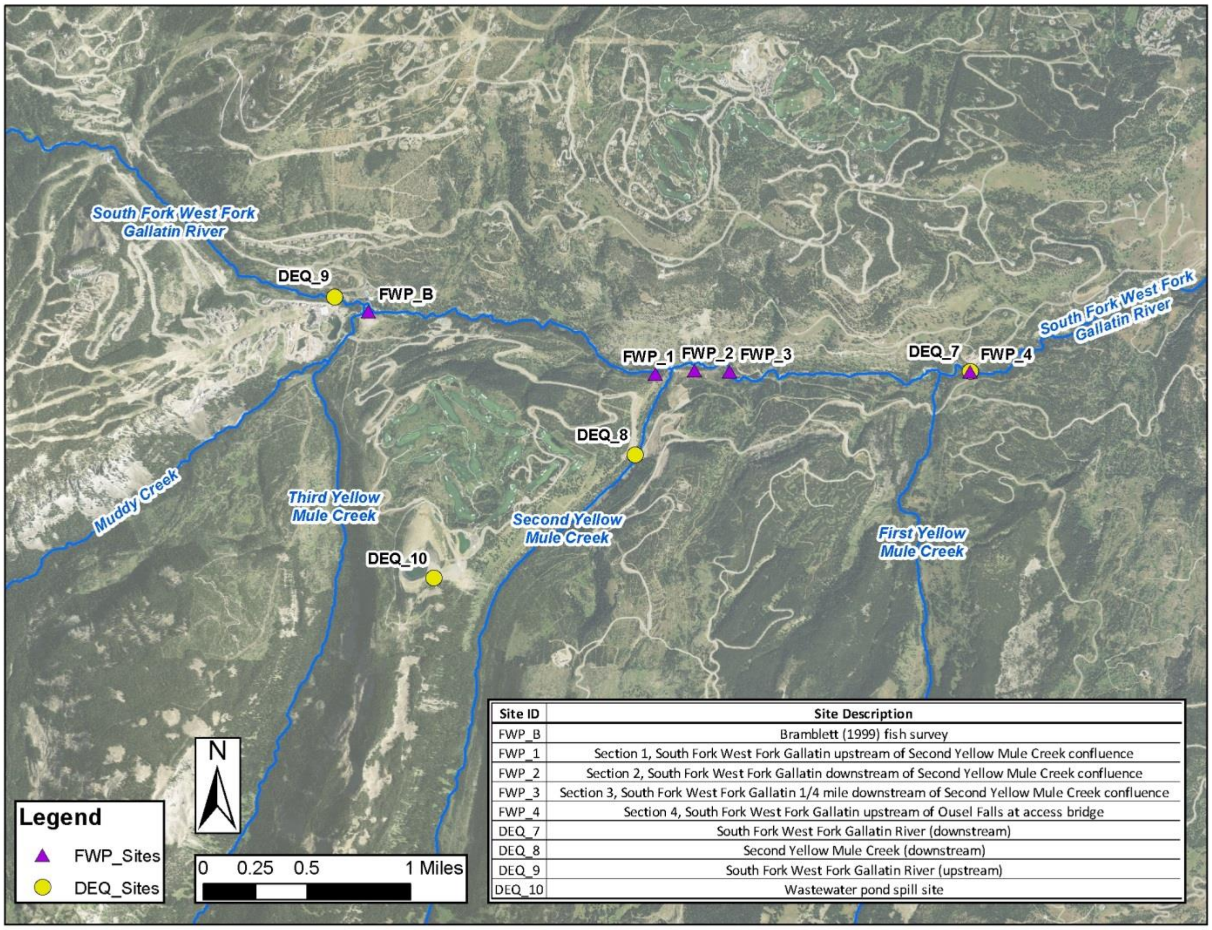


**Figure 1-2. DEQ and FWP sampling sites and sections in the tributaries. One location (FWP_B) is a fish survey site from 1999 sampled by B. Bramblett of Montana State University.**

**Table 2-1. Analytical Details for Water Quality Parameters in this Report.**

| Analyte | Preservation and Storage | Holding Time | Method | Required Reporting Limit |
|---|---|---|---|---|
| Total Ammonia ($NH_{3+4}$) | $H_2SO_4$, cool to <6°C (on ice) | 28 days | EPA 350.1 | 0.05 mg/L |
| Total Persulfate Nitrogen (TN) | Cool to <6°C (on ice) | 28 days | A4500-N-C | 0.07 mg/l |
| Total Phosphorus (TP) | $H_2SO_4$, cool to <6°C (on ice) | 28 days | EPA 365.1 | 0.003 mg/l |
| Total Suspended Solids (TSS) | Cool to <6°C (on ice) | 7 days | A2540 D | 4.0 mg/l |

# 3.0 Results

Findings for each water quality parameter and the fishery surveys are presented below.

## 3.1 Ammonia Concentrations

Ammonia concentrations spilling directly from the pond were typically 6-7 mg/L (**Table 3-1**). Concentrations were 4.7 mg/L in Second Yellow Mule Creek on March 5th. Progressing further downstream, ammonia concentrations on March 5th were sequentially lower with increasing distance and dilution; there was no ammonia detected in the mainstem Gallatin River. With each subsequent day of the spill, ammonia concentrations decreased at all tributary sites and were below detection by March 12th except for Second Yellow Mule Creek. As expected, the background sites had no detectable ammonia. Field blanks were uncontaminated and duplicates were nearly identical.

**Table 3-1. Concentrations of ammonia measured from March 5th to March 12th, 2016.**

| | Ammonia concentration (mg/L as N) | | | | |
|---|---|---|---|---|---|
| **Site Number and Name*** | **March 5th (Sat)** | **March 6th (Sun)** | **March 7th (Mon)** | **March 9th (Wed)** | **March 12th (Sat)** |
| (10) Wastewater pond spill site | 6.5 | 6.6 | 7.5 | no flow | no flow |
| (9) South Fork West Fork Gallatin River (upstream)(**B**) | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| (8) Second Yellow Mule Creek (downstream) | 4.7 | 3.9 | 0.77 | 0.72 | 0.45 |
| (7) South Fork West Fork Gallatin River (downstream) | 1.91 | 1.77 | 0.09 | <0.05 | <0.05 |
| (6) West Fork Gallatin River (upstream)† (**B**) | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| (5) West Fork Gallatin River at mouth | 0.98 | 0.95 | 0.13 | 0.06 | <0.05 |
| (5) West Fork Gallatin River at mouth (*field duplicate*) | *see March 7th result* | | 0.11 | 0.05 | <0.05 |
| (4) Gallatin River-Upstream of WF confluence (**B**) | <0.05 | <0.05 | <0.05 | <0.05 | not collected |
| (3) Gallatin River at Deer Creek | <0.05 | <0.05 | <0.05 | <0.05 | not collected |
| (2) Gallatin River at Lava Lake Trailhead | <0.05 | <0.05 | <0.05 | <0.05 | not collected |
| (1) Gallatin River at Canyon Mouth | <0.05 | <0.05 | <0.05 | <0.05 | not collected |
| *Field blank* | *see March 7th result* | | <0.05 | <0.05 | <0.05 |

* The **B** indicates site used to characterize background conditions during the spill.
† Also locally referred to as the Middle Fork West Fork Gallatin River.

Ammonia concentrations in the tributaries were greatly elevated as a result of the spill, and Montana's ammonia standard (Montana Department of Environmental Quality, 2012) was exceeded in Second Yellow Mule Creek on March 5th. Based on the pH measured during sampling[2], the acute ammonia standard for Second Yellow Mule Creek on March 5th was 4.13 mg/L. No other acute ammonia standards were exceeded at any site or time. Montana also has two longer-term (chronic) ammonia standards (a 4-

[2] Adjusting for the pH probe's drift from calibration, pH in Second Yellow Mule Creek on March 5th was 8.16.

day and a 30-day average)(Montana Department of Environmental Quality, 2012). Based on the concurrent pH and temperature data, no sites exceeded these chronic ammonia standards.

## 3.2 Turbidity and Total Suspended Solids

The applicable turbidity standard is quasi-numeric, while the TSS standard is narrative; both provide that no person may violate the standards (i.e., natural exceedences are excluded). The turbidity standard states "*The maximum allowable increase above naturally occurring turbidity is five nephelometric turbidity units except as permitted in 75-5-318, MCA*." The narrative standard states "*No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to 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*[3]."

Focus in this section will be on acute effects; longer-term chronic effects have greater uncertainty, and will be addressed in the **Discussion**.

Results for turbidity (as nephelometric turbidity units, or NTU) and TSS (mg/L) are in **Table 3-2** (next page). Turbidity was as high as 1,686 NTU (Second Yellow Mule Creek). DEQ's background sites (**Figure 1-1**) provide for interpretation of the turbidity standard (i.e., an allowable 5 NTU above naturally occurring). The background turbidity ranged from 0.6-1.8 NTU; thus, in the impacted tributaries, the standard was exceeded at all sites all days of the study. Even on DEQ's last sampling day (March 12$^{th}$) turbidity was still >25 NTU above background in the tributaries. In the mainstem Gallatin River, turbidity exceeded the standard until March 9$^{th}$.

In the tributaries, TSS were extremely high during the first days of the spill. TSS in water leaking from the pond were fairly low (5-108 mg/L), but in Second Yellow Mule Creek reached 4,560 mg/L (March 5$^{th}$; **Table 3-2**) and were probably higher the day before, on March 4$^{th}$. The large TSS increase between the pond and the stream resulted from erosion as the spill discharge cut into the hillside as it flowed to Second Yellow Mule Creek. In the mainstem Gallatin River, TSS increased above background by about 17 mg/L, but TSS largely returned to background concentrations by March 7$^{th}$ and completely so by March 9$^{th}$.

DEQ uses scientific studies to interpret the narrative sediment standard. Fish and aquatic life are impacted by TSS concentrations and the duration of exposure. In Second Yellow Mule Creek and the South Fork West Fork Gallatin River, the TSS concentrations DEQ measured would be expected to induce some mortality on juvenile and adult salmonids, potentially as much as 20% mortality (Newcombe and Jensen, 1996). During later phases of the spill on those streams, and at other affected tributaries on all dates, the continued high TSS concentrations could cause sublethal effects (e.g. physiological stress, impaired homing, reduced feeding)(Newcombe and Jensen, 1996).

Short-term acute effects of TSS on macroinvertebrates include increased downstream drift and effects on respiration due to silt deposition on respiration structures (Wood and Armitage, 1997). Water ouzels (or dippers, *Cinclus mexicanus*) are birds which site feed on aquatic macroinvertebrates and were

[3] Found at Administrative Rules of Montana 17.30.623. Also, Montana law (at 75-5-318, MCA) allows for short-term turbidity increases by activities that have been reviewed in advance by DEQ or FWP.

unquestionably displaced from the affected tributaries during the spill (some were observed at the background sites during sampling). Elevated sediments can also impact mussels (Henley, et al., 2000), but past population surveys have never revealed mussels to occur in the affected tributaries (Stagliano and Montana Natural Heritage Program, 2010).

**Table 3-2. Concentrations of TSS (mg/L) and turbidity (NTU) measured from March 5th to March 12th, 2016.**

| Site Number and Name* | TSS (mg/L) and Turbidity (NTU) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | March 5th (Sat) | | March 6th (Sun) | | March 7th (Mon) | | March 9th (Wed) | | March 12th (Sat) | |
| | TSS | Turb | TSS | Turb | TSS | Turb | TSS | Turb | TSS | Turb |
| (10) Wastewater pond spill site | 8 | 17.1 | 5 | 19.9 | 108 | 56.0 | no flow | | no flow | |
| (9) South Fork West Fork Gallatin River (upstream)(**B**) | <4 | 0.8 | <4 | 1.8 | <4 | 0.6 | <4 | 0.6 | <4 | 0.7 |
| (8) Second Yellow Mule Creek (downstream) | 4560 | 1686 | 1240 | 739.6 | 67 | 57 | 33 | 29.5 | 31 | 25.8 |
| (7) South Fork West Fork Gallatin River (downstream) | 2450 | 1678 | 1870 | 1020 | 115 | 73 | 79 | 48 | 85 | 56 |
| (6) West Fork Gallatin River (upstream)† (**B**) | <4 | 0.7 | <4 | 1.0 | <4 | 0.9 | <4 | 1.1 | <4 | 1.0 |
| (5) West Fork Gallatin River at mouth | 248 | 471 | 190 | 327 | 86 | 102 | 47 | 42 | 31 | 31.5 |
| (5) West Fork Gallatin River at mouth (*field duplicate*) | *see March 7th result* | | | | 79 | n/a | 47 | n/a | 31 | n/a |
| (4) Gallatin River-Upstream of WF confluence (**B**) | 6 | 2.3 | 9 | 4.9 | 13 | 8.2 | 6 | 3.2 | not collected | |
| (3) Gallatin River at Deer Creek | 28 | 40.9 | 24 | 33.1 | 10 | 9.6 | <4 | 3.3 | not collected | |
| (2) Gallatin River at Lava Lake Trailhead | 27 | 36.7 | 36 | 53.8 | 14 | 20.8 | <4 | 5.2 | not collected | |
| (1) Gallatin River at Canyon Mouth | 14 | 21.2 | 16 | 22.0 | 12 | 14.0 | 4 | 4.1 | not collected | |
| *Field blank* | *see March 7th result* | | | | <4 | n/a | <4 | n/a | <4 | n/a |

* The **B** indicates site used to characterize background conditions during the spill.

† Also locally referred to as the Middle Fork West Fork Gallatin River.

## 3.3 FISH POPULATION SURVEYS

Two species of fish occupy habitat upstream of Ousel Falls on the South Fork West Fork Gallatin River—westslope cutthroat trout hybrids (hybrids of *Oncorhynchus clarki lewisi* and rainbow trout, *Oncorhynchus mykiss*), and sculpin (*Cottus spp.*). Five mortalities of westslope cutthroat (ranging in length from 146-231 mm) were found immediately downstream from the confluence with Second Yellow Mule Creek.

Electroshocking population estimates on the South Fork West Fork Gallatin River are shown in **Figure 3-1.** Compared to a 1999 population estimate, trout numbers were similar upstream of Second Yellow Mule Creek but suppressed below it. (About 100 feet of Second Yellow Mule Creek were also electrofished, and two sub-adult trout were found.) The South Fork West Fork Gallatin's normally coarse substrate (cobble and boulder) was completely embedded by 1-2 feet of silt and sand just below the Second Yellow Mule Creek confluence, and continued but reduced embeddedness was observed for another ¼ mile downstream. Substrate smothering and high levels of suspended sediment may have displaced many fish downstream, as evidenced by the rise in fish numbers surveyed downstream (**Figure 3-1**). Length-frequency histograms for both species of fish and for all surveyed sections are in **Figure 3-2**. It appears that younger fish (particuarly younger sculpin) were disproportionally displaced downstream from the area of greatest sediment impact. Immediately downstream of Second Yellow Mule Creek, many sculpin showed evidence of fin erosion, related to high levels of suspended sediment. Aside from obvious fin erosion on sculpin, gill lamellae of captured trout and sculpin did not show any signs of erosion or damage.

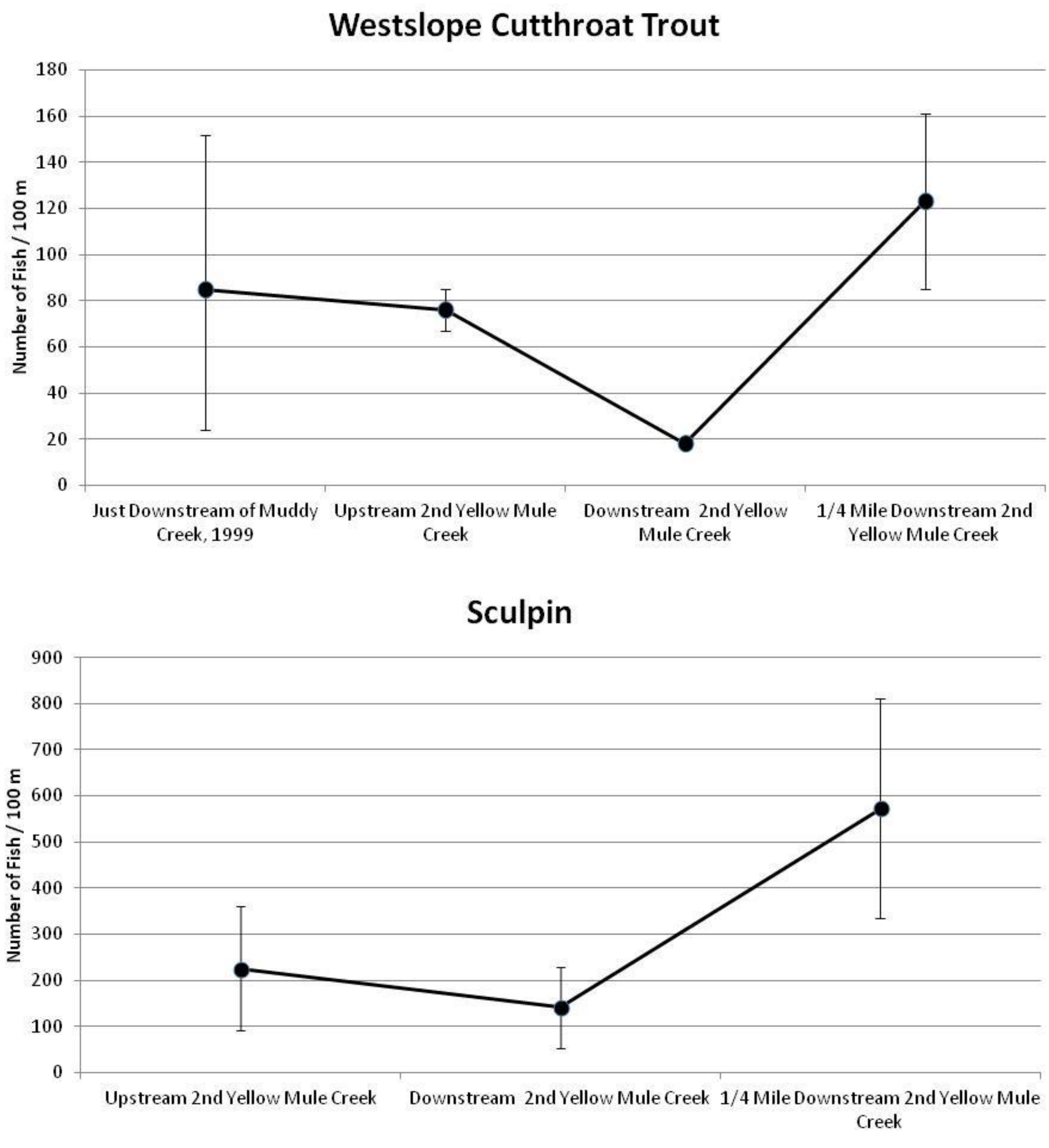


**Figure 3-1. Population estimates on the South Fork West Fork Gallatin River. Estimates are standardized to number of fish per 100 m and include (for cutthroat trout) comparison data from a 1999 survey. Error bars are 95% confidence intervals.**

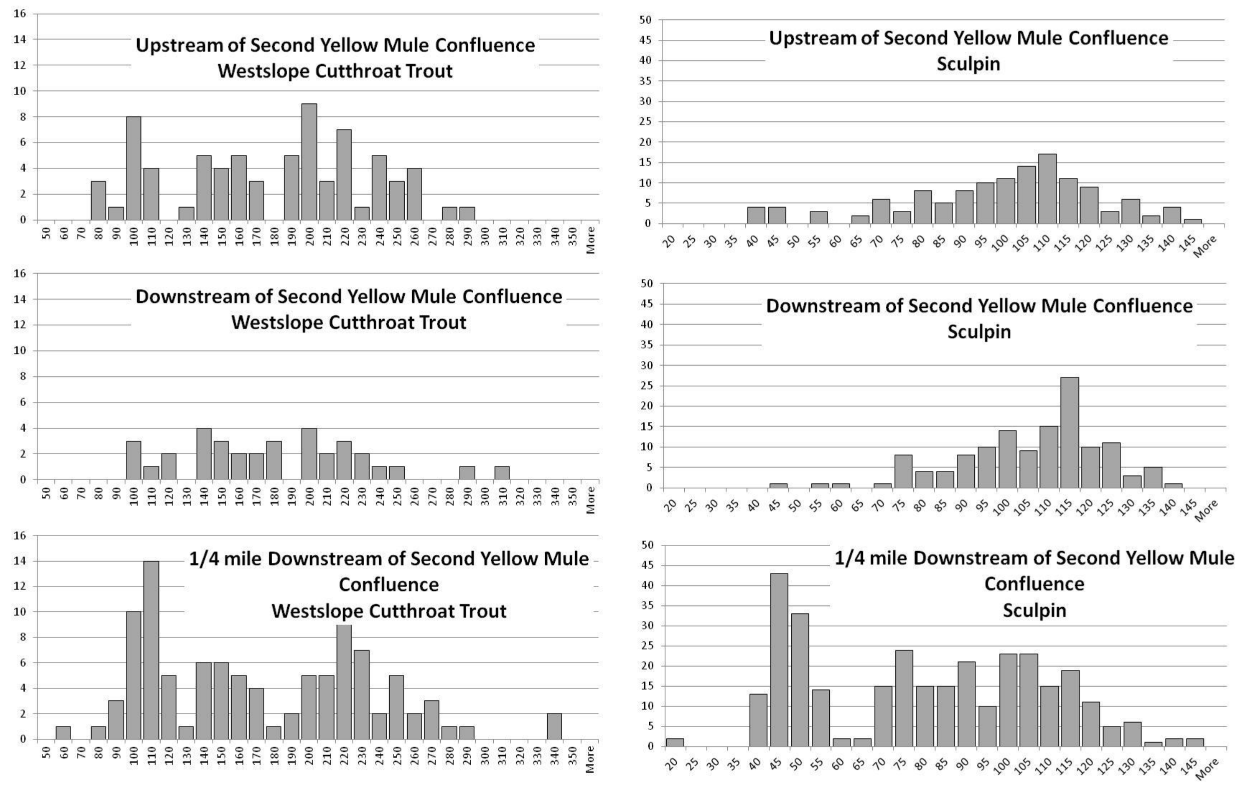


**Figure 3-2. Length frequency histograms for westslope cutthroat trout and sculpin in sections along the South Fork West Fork Gallatin River. Length units (x-axis) are in mm.**

## 3.4 Nitrogen and Phosphorus (Nutrient) Concentrations

Nutrient concentration results are in **Table 3-3** (next page). Compared to background sites, concentrations of TP were fairly high coming from the pond itself, but were then greatly increased by the erosion; this is explained by the fact that phosphorus is commonly bound to soil particles and clays (Froelich, 1988). In contrast, TN concentrations showed a decreasing trend with distance from the spill. Field blanks were uncontaminated and duplicate values were very similar.

Montana has standards for concentrations of nitrogen and phosphorus in surface waters (Montana Department of Environmental Quality, 2014). The standards are intended to prevent nuisance growths of algae (eutrophication), and to protect aquatic life from secondary effects of elevated nutrients such as low dissolved oxygen. An important aspect of these standards is that they apply seasonally, from early July (after runoff) to the end of September. The spill occurred in winter when very low water temperatures (near 0˚C, all sites) greatly diminish the potential for nuisance algal growth. Further, cold water holds more dissolved oxygen than warm water. DEQ did not expect there to be any short-term effect from the spill's highly elevated nutrients because it occurred in winter, and no evidence suggests that any eutrophication occurred. The potential for longer-term nutrient effects after runoff will be touched upon in the **Discussion**.

**Table 3-3. Concentrations of total phosphorus (TP) and total nitrogen (TN) March 5-12, 2016.**

| Site Number and Name | Total Phosphorus (TP) and Total Nitrogen (TN) as mg/L | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | March 5th (Sat) | | March 6th (Sun) | | March 7th (Mon) | | March 9th (Wed) | | March 12th (Sat) | |
| | TP | TN | TP | TN | TP | TN | TP | TN | TP | TN |
| (10) Wastewater pond spill site | 2.51 | 8.7 | 2.64 | 8.9 | 2.03 | 13.5 | no flow | | no flow | |
| (9) South Fork West Fork Gallatin River (upstream)(**B**) | 0.009 | 0.23 | 0.010 | 0.24 | 0.007 | 0.20 | 0.006 | 0.19 | <0.003 | 0.21 |
| (8) Second Yellow Mule Cr (downstream) | 7.38 | 5.6 | 3.14 | 5.7 | 0.259 | 1.58 | 0.184 | 1.47 | 0.132 | 1.20 |
| (7) South Fork West Fork Gallatin River (downstream) | 3.61 | 2.86 | 2.84 | 2.89 | 0.134 | 0.55 | 0.109 | 0.46 | 0.096 | 0.42 |
| (6) West Fork Gallatin River (upstream)(**B**) | 0.015 | 0.55 | 0.016 | 0.54 | 0.014 | 0.48 | 0.012 | 0.45 | 0.010 | 0.54 |
| (5) West Fork Gallatin River at mouth | 0.814 | 1.68 | 0.639 | 1.97 | 0.165 | 0.71 | 0.085 | 0.61 | 0.036 | 0.49 |
| (5) West Fork Gallatin River at mouth (*field duplicate*) | *see March 7th result* | | | | 0.157 | 0.71 | 0.078 | 0.62 | 0.041 | 0.47 |
| (4) Gallatin River-Upstream of WF confluence (**B**) | 0.022 | 0.09 | 0.028 | 0.14 | 0.029 | 0.10 | 0.017 | 0.10 | Not collected | |
| (3) Gallatin River at Deer Creek | 0.101 | 0.23 | 0.077 | 0.25 | 0.034 | 0.15 | 0.014 | 0.11 | Not collected | |
| (2) Gallatin River at Lava Lake Trailhead | 0.037 | 0.15 | 0.097 | 0.27 | 0.050 | 0.11 | 0.026 | 0.08 | Not collected | |
| (1) Gallatin River at Canyon Mouth | 0.361 | 0.15 | 0.051 | 0.23 | 0.050 | 0.17 | 0.020 | 0.10 | Not collected | |
| *Field blank* | *see March 7th result* | | | | <0.003 | <0.04 | <0.003 | <0.04 | <0.003 | <0.04 |

# 4.0 DISCUSSION

## 4.1 FORMS OF NITROGEN IN THE STORAGE POND

At the onset of the spill DEQ and others estimated (based on existing data) that the water spilling from the pond would have about 7-8 mg/L TN, much of which would be nitrate, and around 1-3 mg/L ammonia. Although the initial TN estimate was close (**Table 3-3**), nearly 75% of the TN was in the form of ammonia, with only low levels (<1 mg/L) of nitrate in the treated effluent (Water Quality Standards and Modeling Section, 2016b). During wastewater treatment, ammonia is usually converted to nitrate, but this biologically-mediated process is not as efficient during cold weather. Thus, treated effluent that was pumped to the pond had much higher levels of ammonia than initially expected.

## 4.2 EFFECTS ON AQUATIC LIFE

Ammonia and TSS concentrations both reached levels in the upper tributaries that would be expected to impact aquatic life and cause some limited degree of fish mortality. Those findings are consistent with the observation of dead trout in the South Fork West Fork Gallatin River downstream of Second Yellow Mule Creek.

Less certain are the effects going forward. Although elevated turbidity and TSS are a natural part of spring runoff, the event is normally time-limited. Due to the spill, elevated sediment effects may persist from late winter through early spring, runoff, and perhaps even into summer baseflow. Even modestly elevated turbidity, when extended over long periods, is known to reduce macroinvertebrate numbers and impede site feeders like trout (Wagener and LaPerriere, 1985; Quinn, et al., 1992; Wood and Armitage, 1997). In an Alaskan stream, long-term increases in turbidity (from an average of 3 NTU to 56 NTU) caused by placer mining led to significant declines in macroinvertebrate density and biomass; even relatively short durations (weeks) of similar NTU changes caused a decline in macroinvertebrate density, and seemed to specifically affect stoneflies (Wagener and LaPerriere, 1985). This degree of turbidity increase is similar to the increases DEQ observed at the end of its sampling (**Table 3-2**).

The most pertinent question is whether multiple stressors—sediment and flushing flows before cutthroat trout spawning—will have an impact on late winter and spring mortality. The accumulated sediment in the reaches below Second Yellow Mule Creek will very likely be mobilized during spring run-off, at a time when westslope cutthroat are stressed due to spawning activities. Questions regarding delayed mortality from a second sediment flush, reduced recruitment because of poor oxygenation of redds, and oxygen starvation of brown trout and/or brook trout redds downstream of Ousel Falls remain. And if elevated turbidity was to persist into summer baseflow, the increased phosphorus load carried by the sediment could lead to nuisance algal growth throughout the affected tributaries, and possibly even in the Gallatin River.

# 5.0 CONCLUSIONS AND RECOMMENDATIONS

One exceedance of Montana's acute ammonia standards was documented on Second Yellow Mule Creek on March 5$^{th}$. At downstream sites, ammonia concentrations on March 5$^{th}$ were sequentially lower with increasing distance and dilution; there was no ammonia detected in the mainstem Gallatin River. Ammonia concentrations decreased at all tributary sites with each subsequent day of the spill.

Turbidity exceeded Montana's standards at all tributary sites for the entire study period (March 5th-12th), while in the mainstem Gallatin River turbidity exceeded the standard until March 9th. In the mainstem Gallatin River, TSS increased above background by about 17 mg/L, but TSS had largely returned to background concentrations by March 7th and completely so by March 9th. In contrast, TSS concentrations were as high as 4,560 mg/L in the affected tributaries and, based on those concentrations, some degree of fish mortality was to be expected. Corroborating this is the fact that five dead westslope cutthroat trout were found in the South Fork West Fork Gallatin River downstream from the Second Yellow Mule Creek confluence. Further, electroshocking surveys showed that the fish population upstream of the Second Yellow Mule Creek confluence was similar to that found in 1999, but numbers just downstream of Second Yellow Mule Creek's confluence were much lower. Another ¼ mile downstream on the South Fork West Fork Gallatin River, fish numbers were substantially higher than upstream, suggesting that many fish (especially younger fish) were displaced downstream by the spill.

Looking to the future, there is a good deal of uncertainty as to the long-term effects on fish and aquatic life. Accumulated sediment where the spill first joins Second Yellow Mule Creek, and where Second Yellow Mule Creek joins the South Fork West Fork Gallatin River could, together, lead to additional mortality (or delayed mortality) when mobilized during spring runoff. Even if no additional mortality occurs, there are likely to be sublethal TSS and turbidity effects which will impact fish and aquatic life in the affected tributaries in the coming months. If elevated turbidity lingers beyond runoff, the additional phosphorus carried by the suspended particles could induce nuisance attached algal growth.

As of this writing, the Yellowstone Club has committed to support weekly to biweekly monitoring sampling in the affected tributaries, and in the Gallatin River near the West Fork confluence. This ongoing work includes TSS and turbidity, and nutrients at targeted locations. In July 2016 DEQ will review the results and, depending upon findings and any remedial actions that have occurred or are planned, decide if further water quality monitoring is necessary. Additional recommendations are:

- The fishery sections surveyed on March 10th (as well as other sections on the South Fork West Fork and West Fork Gallatin rivers) should be surveyed again during summer and fall for at least three years. Stratified random sampling of fish populations in Second Yellow Mule Creek, First Yellow Mule Creek, the South Fork West Fork and the West for Gallatin rivers should occur in summer/fall of 2016 – 2018. Repeated sampling will provide information on population recovery in the event the spill had impacts on individual fish or recruitment.

- An assessment of the impacts from high levels of suspended and bedload sediment through core sampling or other methods should be undertaken to determine short and long-term impacts to salmonid populations. High levels of suspended and bedload sediment, especially smaller size fractions, have a great potential to negatively impact recruitment of salmonids through clogging/filling of redds.

- Macroinvertebrate samples should be collected at locations where water sampling and/or fishery work has taken place. There are good records of macroinvertebrates for these tributaries going back to the mid-1990s (and earlier) which can be used as points of comparison for the streams' current conditions and future recovery.

# 6.0 References


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