Hangman Creek – Spokane River Turbidity Study, Water Year 2021

A collaborative community science project coordinated by Spokane Riverkeeper and Spokane Falls Trout Unlimited

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Abstract: During the winter and spring of 2021 community scientists collected water samples from the Spokane River to understand the impact of turbidity and sediment loading from Hangman Creek. Samples were taken in the Spokane River above and below the mouth of Hangman Creek. Results show nine turbidity violations over the course of the study in the Spokane River due to Hangman Creek. These results suggest that turbid water, even in a low flow year, is impacting the Spokane River to a degree that fish habitat and other values are degraded.

The Spokane River and mouth of Hangman Creek on March 4th, 2021

INTRODUCTION

The Spokane River flows through the traditional territories of the Spokane Tribe of Indians with historical and contemporary importance to Spokane, Coeur d'Alene, Colville, Kootenai, Nez Perce, and Palouse Tribes (Native Land Digital 2021). The River is approximately 111 miles long and is a tributary to the Columbia River (Spokane County 2021). Situated in present day Eastern Washington, the Idaho Panhandle, and into Western Montana the Spokane River Watershed (Figure 1) spans a drainage area of about 2,400 square miles (nwcouncil 2021). The region is identified by the Natural Resources Conservation Service (NRCS) as part of the Northern Rocky Mountain Valleys Region, characterized by mountain valleys with broad floodplains (NRCS 2006). Spokane River characteristics are associated with the Kootenai and Pend Oreille Rivers in NRCS Hydrologic Unit Area 1701 (NRCS 2006). Though precipitation in this region is considered adequate for some dryland farming at higher elevations, groundwater and surface water accumulation in this region are snowpack dependent (NRCS 2006). More than half of the land-use in this region is dedicated to farming and ranching (NRCS 2006).

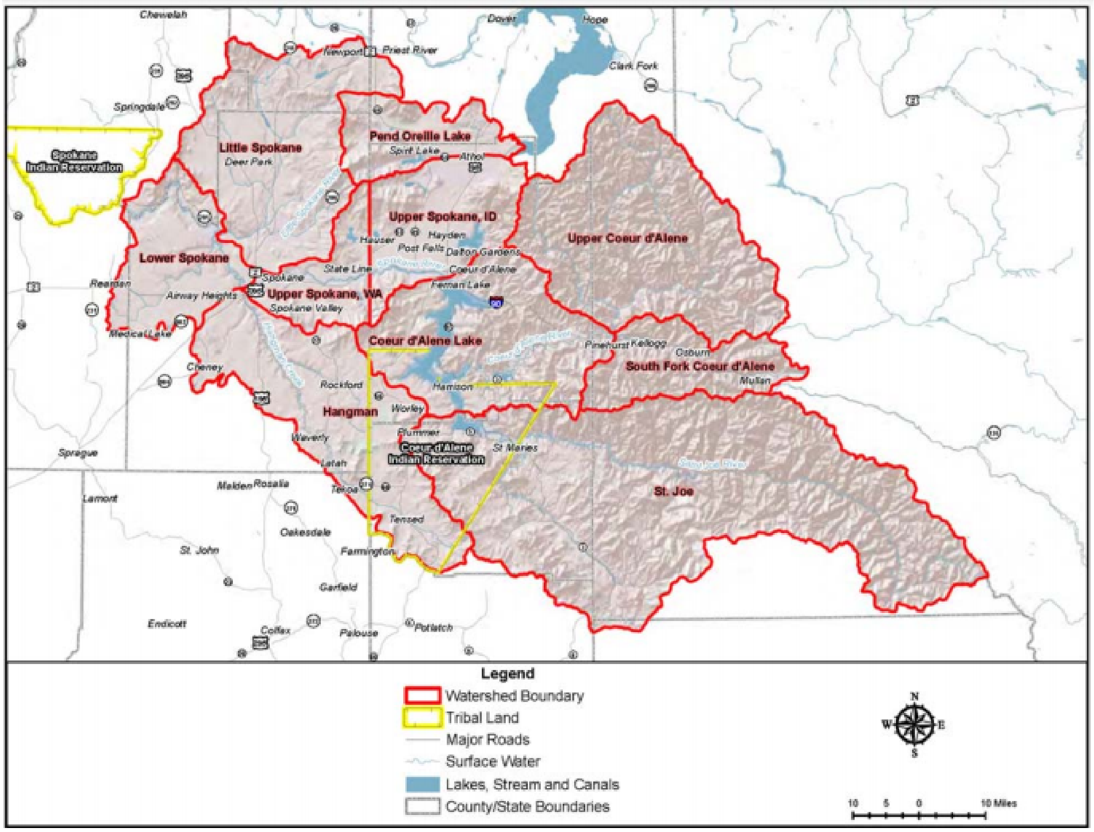


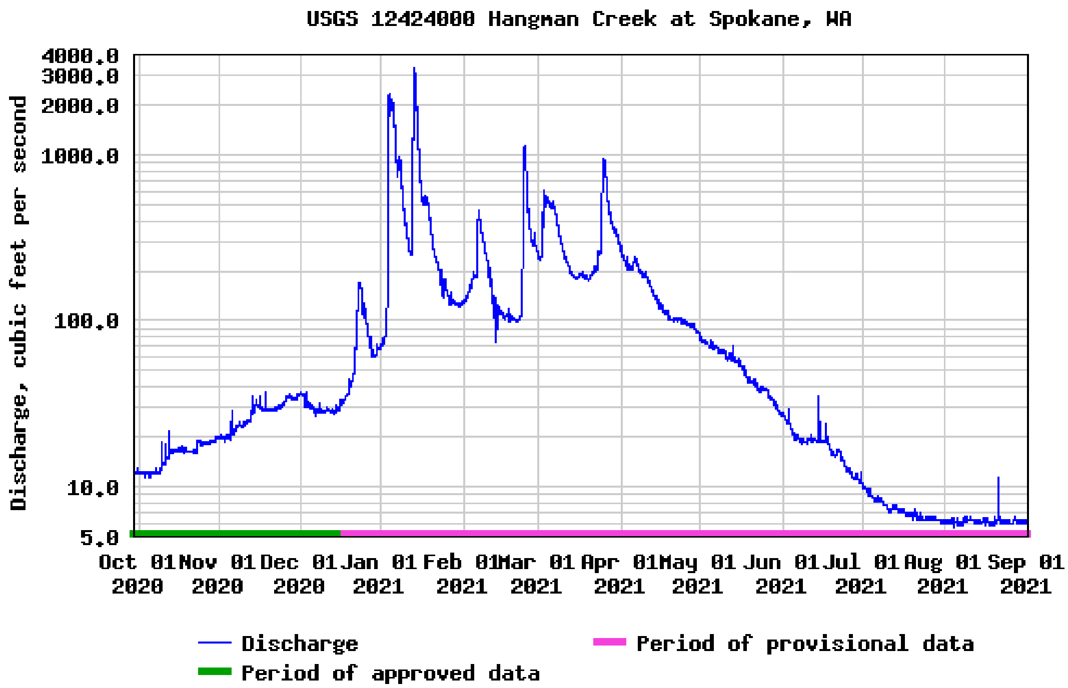
Figure 1 – Map of Spokane Watersheds (Spokane County 2011)

Hangman Creek, also referred to as Latah Creek, with a drainage area of 689 square miles, contributes approximately 10% of the Spokane River Watershed flows (SCCD 2000) and enters the Spokane River at River Mile 72.3 (SCCD 2005) at People's Park south of downtown Spokane. The watershed once teemed with anadromous salmon and trout, with over 30,000 fish caught at the mouth of Hangman Creek each year and a fishing village near the headwaters (Scholz et al. 1985).

The hydrology of Hangman Creek is 'flashy' with discharges at times ranging from less than 1 cfs to over 20,000 cfs (Joy 2009). The Hangman Creek Watershed is characterized by easily erodible material deposited by Pleistocene glacial activity over Miocene basalt flows (Joy 2009). Latah Formation silts and clays with low permeability are subject to bank slumping, wash out, and undercutting (Joy 2009). Lake Missoula Flood Deposits of silts, sands, gravel, cobbles, and boulders form steep (some over 100 ft) unstable banks where the stream can remove material at the base leading to toe failure (Joy 2009). Post Missoula Flood Alluvium of sand and gravel have formed terraces as Hangman Creek downcut through earlier flood deposits (Joy 2009).

> "The majority of the system has land uses that are generally incompatible with highly erodible soils. This combination produces an unstable system trying to regain equilibrium. Streambank erosion is symptomatic (to a degree) in most reaches. The dominance of reed canarygrass [*Phalaris arundinacea*] does not provide the necessary

root structure to stabilize the streambanks. Toe erosion perpetuates bank slumping perpetuates bank slumping and widening." (SCCD 2005)



Hangman Creek discharge graph, showing typical flashy discharge patterns.

While the Hangman Valley plant community historically included bunchgrass prairie and ponderosa pine forests with densely vegetated riparian areas of shrubs and small trees, by 1920 a significant portion of the land was cleared and cultivated for wheat, barley, pea, and lentil production (Joy 2009).

Straightening of stream channels for agricultural efficiency as well as encroachment of roads and housing development in the lower Hangman mainstem have modified the floodplain and cut off meanders reducing dissipation of the stream's energy which increases erosion and stresses the system with sediment runoff (Joy 2009). A 1939 Spokesman Review article describes the diversion of Hangman Creek as the Inland Empire Highway (Highway 195) was straightened between Marshall and the Northern Pacific viaduct in Spokane leaving an "amputated" oxbow that was expected to become stagnant if not pumped (Figure 2). The new watercourse was engineered into a hillside with the highway itself as the main barrier to the stream reconnecting with the old channel (Spokesman Review 1939). The plan, according to Clifton & Applegate, contractors with the state highway department, depended on riprap to prevent erosion, but the article noted "The creek has been objecting in its own way to this diversion" and high water continued to threaten the new construction over the historical floodplain (Spokesman Review 1939).

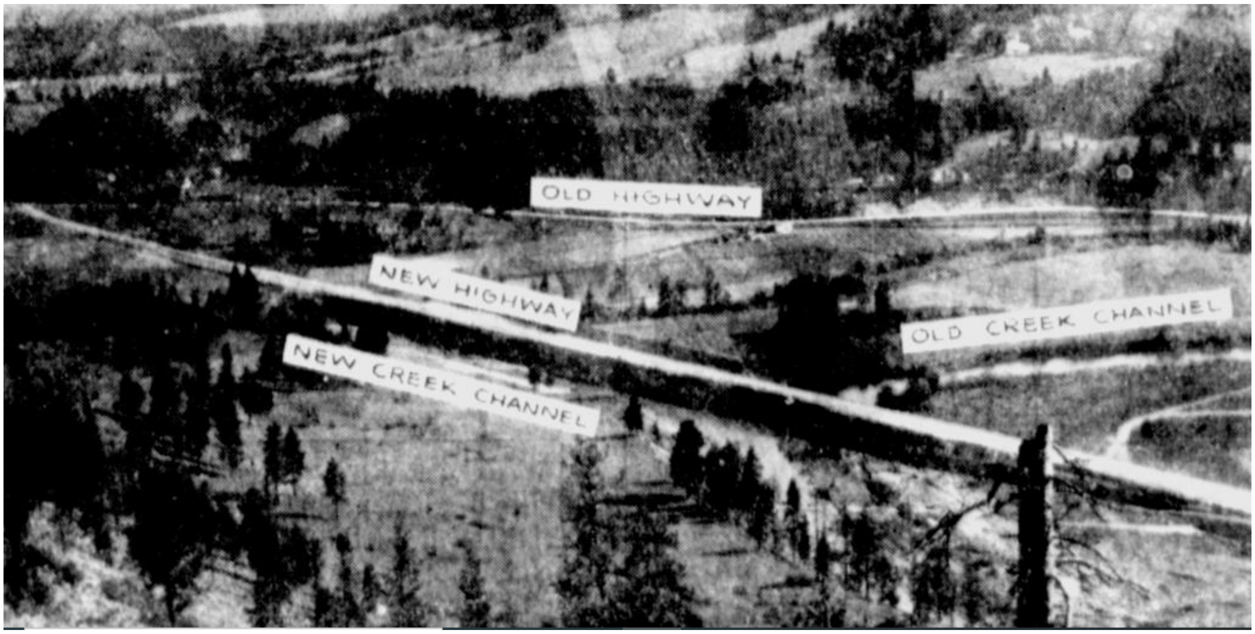


Figure 2 - 1939 diversion of Hangman Creek for Inland Empire Highway construction (Spokesman Review 1939) [south right, north left]

Erosion and the associated turbidity are a threat to aquatic habitat. The interior redband trout (*Oncorhynchus mykiss gairdneri*), a subspecies of rainbow trout (*Oncorhynchus mykiss*), is native to waters in the Columbia Basin east of the Cascade Crest (Behnke, Native Trout of Western North America 1992) and favors clear, cool streams and rivers (Behnke, Trout and Salmon of North America 2002). Once abundant native inland redband trout in the Spokane Watershed have been extirpated in the most parts of the Hangman Basin, and in remaining reaches are threatened by reductions in water quality including sedimentation (Small 2007). The historical range includes the Spokane River to Spokane Falls (Behnke, Native Trout of Western North America 1992) and a self-sustaining population of pure redband stock has been identified in California Creek, a tributary of Hangman Creek (Lee 2005). In a 2003 rainbow trout survey conducted by Parametrix for Avista Corporation's Federal Energy Regulatory Commission (FERC) Permit #2545 researchers identified 130 redds in the lower study reach below Monroe Street Dam (Figure 3) with spawning occurring between April and June. Further genetic identification could distinguish parts of this population as interior redband from introduced coastal rainbow trout.

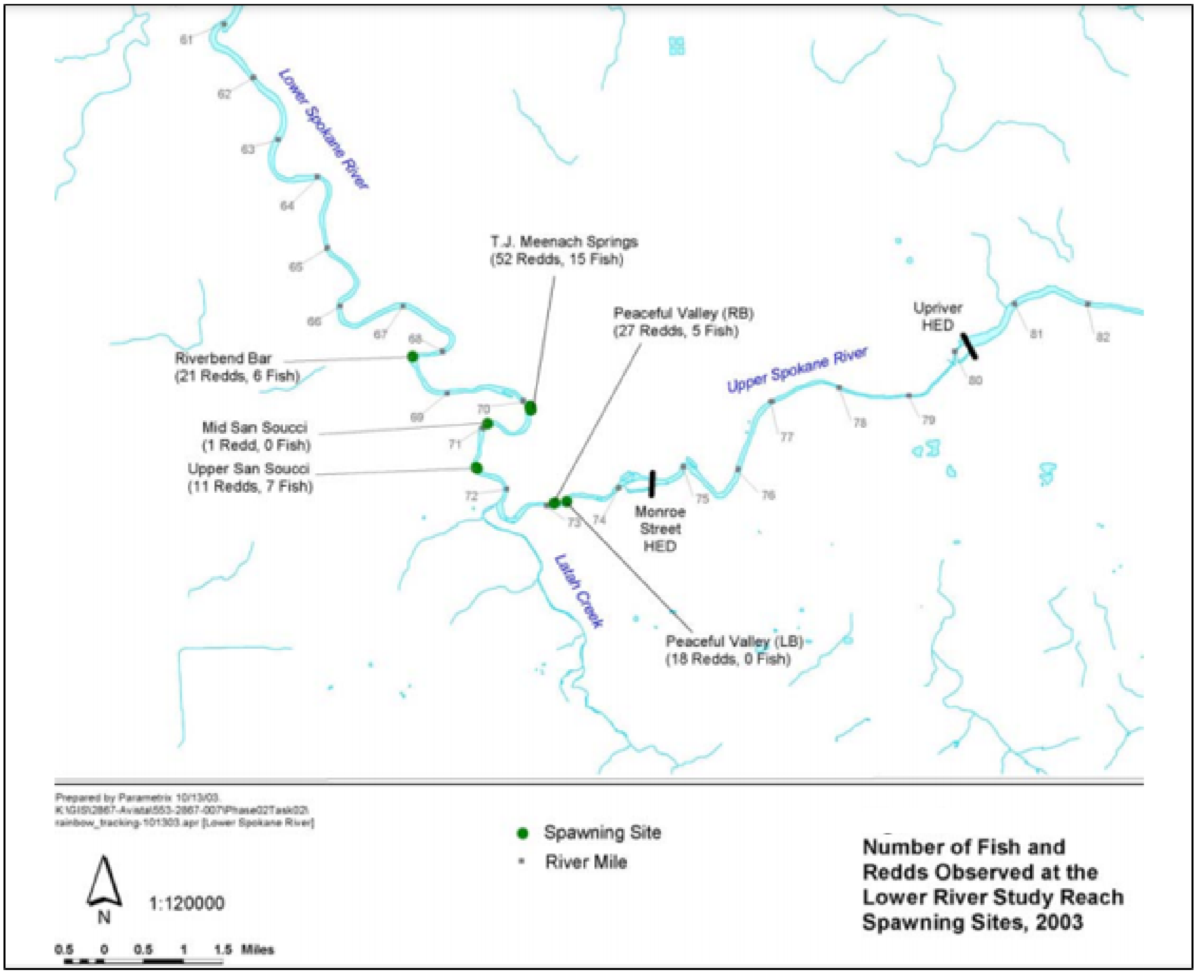


Figure 3 - Observed rainbow trout redds below Monroe Street, Spokane (Parametrix 2003)

The interior redband trout is identified as a Species of Greatest Conservation Need (SGCN) under the Washington State Wildlife Action Plan and as a Priority Species under the Washington State Department of Fish and Wildlife Priority Habitat and Species Program, requiring "protective measures for their survival due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance" (WDFW 2021). Our Washington State Administrative Code (WAC 173-201A-200 (1) Aquatic life uses (e) Aquatic life turbidity criteria) states that we have a water quality standard for Salmonid [includes salmon, trout, chars, freshwater whitefishes, and graylings] Spawning, Rearing, and Migration and specifically Non-anadromous Interior Redband Trout not to exceed 5 NTU over background when the background is 50 NTU or less. Rainbow trout, including interior redband trout, feed by sight and in turbid waters must expend more energy in predatory foraging leading to decreases in growth and limiting success of a population (Korman 2020).

As early as 1998 Hangman Creek was identified in the Environmental Protection Agency's 303 (d) list with violations of water quality standards for fecal coliform, dissolved oxygen, pH, temperature, and turbidity (Joy 2009). Sediment load does not have a water quality standard criterion (Joy 2009). Turbidity is a measure of water clarity that describes how light refracts off material in turbid (cloudy) water. Though it does not provide an exact measure of total suspended solids (TSS), turbidity is often used to indicate changes in TSS concentration in water (Fondriest 2014). In the Hangman Creek TMDL developed in 2009, the Washington State Department of Ecology noted turbidity as an impaired water quality parameter and identified sedimentation from nonpoint sources – stormwater runoff, riparian vegetation losses, streambank erosion, wetland losses, agricultural and forestry management – as major concerns in the Hangman watershed.

In Spokane County's 2011 Nonpoint Source Phosphorus Assessment, Hangman Creek is recognized as a contributing source of pollutants to the Spokane River. As phosphate is known to adhere to clay and organic matter particulates (Binkley 2013), TSS spikes indicated by a rise in turbidity from Hangman Creek may contribute to phosphorus excesses and algae blooms in the Spokane River and its Lake Spokane impoundment. To mitigate phosphorus loading from erosion the Nonpoint Source Phosphorus Assessment includes "protection of riparian zones and minimization of stream bank erosion" as well as "targeted potential reductions from agricultural areas" (Spokane County 2011). Though sedimentation problems at Nine Mile Reservoir have been traced to influences from Hangman Creek (SCCD 2000) which does have a TMDL for turbidity and the Spokane River is listed as impaired for dissolved oxygen (DO) in EPA's 303 (d) list with the main cause of the DO depletion considered to be excess algae due to phosphorus inputs from erosion (Baldwin 2018), no listing for turbidity in the Spokane River has been developed.

METHODS

In accordance with our Quality Assurance Project Plan (QAPP) the Spokane Riverkeeper Hangman Creek – Spokane River Turbidity Study for water year 2021 was conducted from December 2020 through June 2021 by community science program volunteers conducting 121 sampling sequences and collecting 411 samples from 3 locations: Hangman Creek at the 11th Street Bridge, Spokane River at Sandifur Bridge, and Spokane River below the TJ Meenach Bridge (Appendix A). Adjacent measurements downstream from the confluence at Riverside Memorial were collected for internal use, but not included in data analysis.

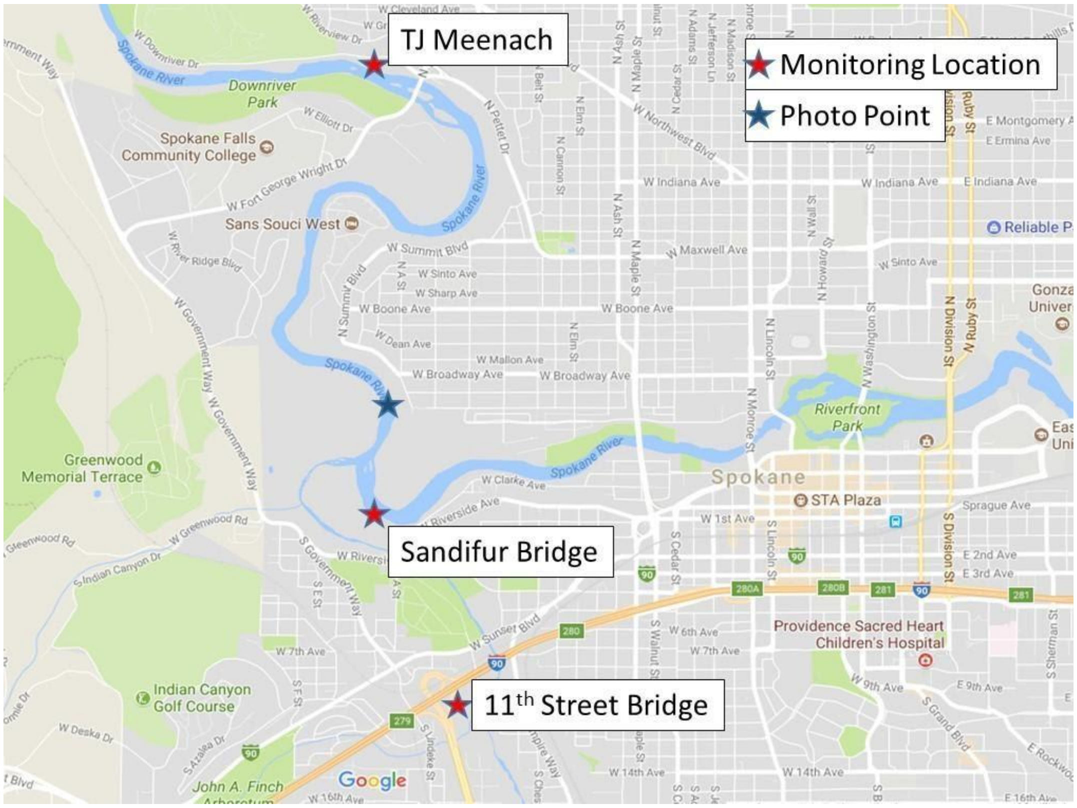


Figure 4 - Sample sites for Spokane Riverkeeper Hangman Creek -- Spokane River Turbidity Study, wy 2021

Volunteer samplers were trained in all aspects of the study, including sample collection and storage, sample location, and safety. Quality control of data was addressed through duplicate measurements, field staff training and observing samplers, and weekly review of data. Sample measurements were duplicated in the field to analyze variability in readings. Approximately 10% or 10 samples were duplicated. Any data identified as incorrectly collected, improperly stored, or held over 48 hours is discarded and not used in the analysis.

Most samples were pulled directly from the stream surface at the shoreline. The sediment in Hangman Creek tends not to settle out due to the fine nature of the particles, so pulling samples from the shoreline is assumed to be representative of the entire river. In locations where the river/creek was not accessible from the shoreline, a jar/bucket was lowered into the water from a bridge with a rope and transferred to Whirl-Pak bags for turbidity analysis. The sample site downstream from Hangman Creek in the Spokane River below TJ Meenach Bridge is located sufficiently downstream to ensure complete mixing. The sampling strategy required volunteers to sign up in advance, assuring that no storm events were targeted.

In the field, samplers determined and recorded water turbidity using a transparency tube. The transparency tube functions as a modified secchi disk, with a black and white disk located at the bottom of a clear tube. The sampler fills the 60 cm tube (marked in 0.2 cm increments) with water, looks into the opening of the tube from above, lets out water by releasing the stopcock until the disk is visible, and records the height of water remaining in the tube in centimeters to the nearest 0.2. Measurements were taken in the shade to reduce glare off the sample. Dahlgren et al. (2004) concluded that transparency significantly correlates with turbidity. No specific calibration of the transparency tube is possible. In general, bias will be held to a 3-5% acceptable error. From an upland vantage point at the corner of Summit and College ("photo point" on Figure 4), samplers photographed the mouth of Hangman Creek to record visual evidence of sediment pollution. Location, time, date, weather conditions, and USGS streamflow information was recorded for each sample on a paper field data sheet with permanent ink as well as in an online field form (https://spokanefallstu.org/spokane-river-sediment-study/).

Volunteers collected samples for Nephelometric Turbidity Units (NTU) analysis alongside the transparency tube readings. Samplers labeled Whirl-Pak bags with location, date, and time. They filled the Whirl-Pak bags with sample water from each location and dropped them off in a cooler kept below 4°C. Sundays, Tuesdays, and Fridays, Spokane Riverkeeper staff collected and processed the samples within 48 hours of sampling. Whirl-Pak samples were analyzed with the Hach 2100P and Hach 2100Q mobile turbidimeters and recorded in NTU to the nearest 0.01. The turbidimeters were calibrated once following Hach manual instructions at the beginning of the sampling period using premixed calibration solutions. The turbidimeter unit has a stated accuracy of +/- 2%.

Readings from Sandifur Bridge samples are considered a baseline reading for the Spokane River above Hangman Creek influence and compared to readings from the downstream TJ Meenach samples to determine the effect of Hangman Creek on the Spokane River.

A strong linear relationship has been established between turbidity and total suspended solids (TSS) (Dahlgren 2004). Turbidity is a measure of how light is refracted off particles in the water and does not account for bedload/settled sediments or effects of differences in refraction due to coloration of some dissolved organic matter, but turbidity can be used to estimate TSS concentration (Fondriest 2014). The Hangman Creek TMDL shows this relationship in log form on Figure 29 (Snouwert and Noll, 2011).

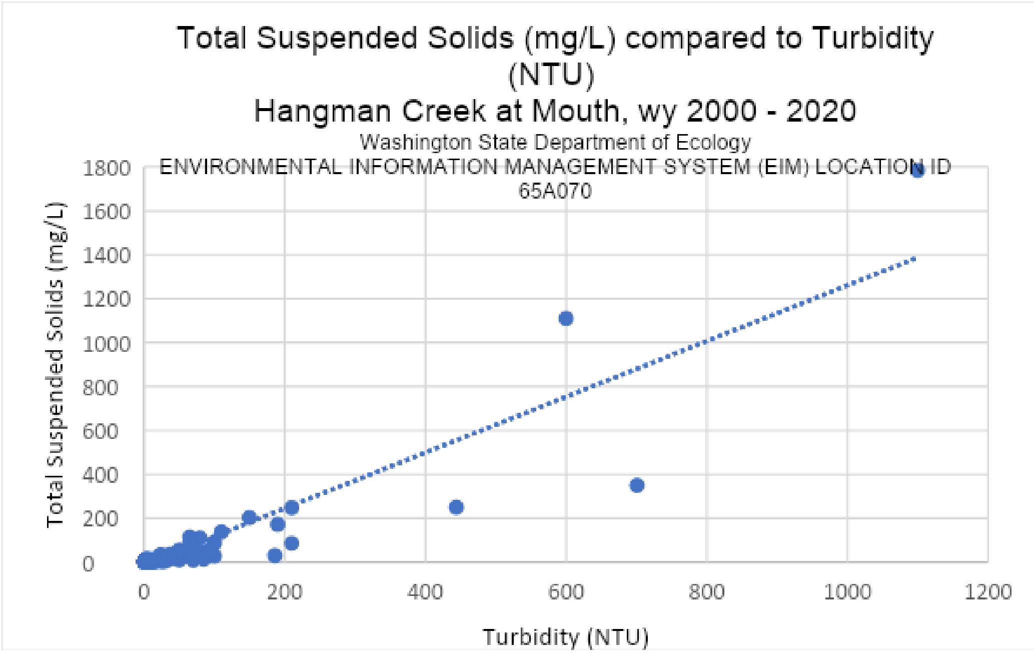


Figure 5 - Total Suspended Solids (mg/L) to Turbidity (NTU) ratio developed from wy 2000 to 2020 sampling data (ECY 2021)

To acquire an estimate of tons of suspended sediment we began with finding the ratio of TSS (mg/L) to turbidity (NTU). Based on 20 years of data, 244 incidences, from October 10th, 1999 to July 7th, 2020, recorded at the Washington State Department of Ecology Hangman Mouth Monitoring station we found the trending ratio to be 1.27 mg/L TSS to 1 NTU with a correlation R^2 value of 0.8291 (Figure 5). By applying this ratio to each replicant sample NTU of the water year 2021 Spokane Riverkeeper Turbidity Study at discharge (cfs), we found the estimated mg/L TSS per cfs at the point of sampling. Through dimensional analysis from the point of sampling we converted to tons of per day of suspended sediment. We applied this daily estimate of tons per day divided by 89 replicants to calculate a daily average and multiplied by 180 days to estimate the total tons of suspended sediment entering the Spokane River from the mouth of Hangman Creek for the duration of the study.

Turbidity data collected by Spokane Riverkeeper community science volunteers will be entered into the Washington State Department of Ecology Environmental Information Management System (EIM) database.

RESULTS

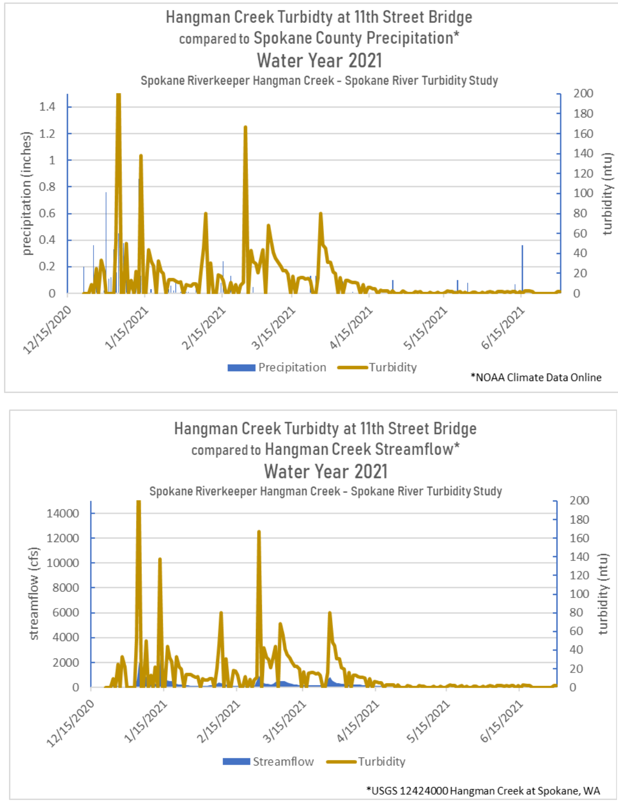


Figure 6 - Hangman Creek Turbidity at 11th Street Bridge 12/21/20 - 06/30/21

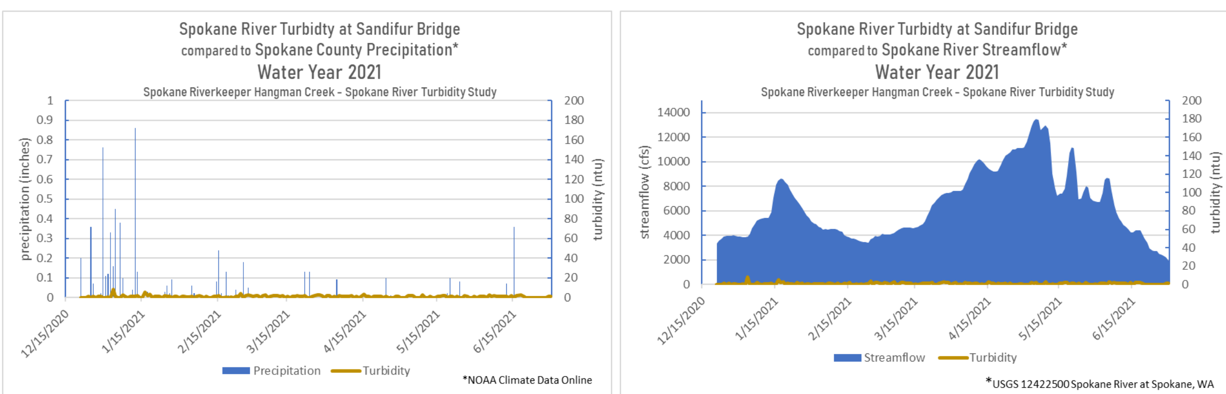
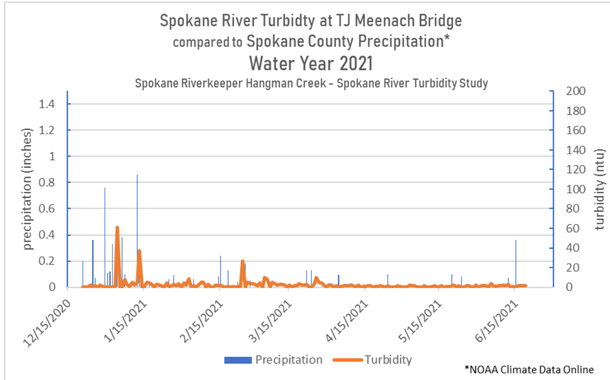


Figure 7 - Spokane River Turbidity at Sandifur Bridge 12/21/20 - 06/30/21



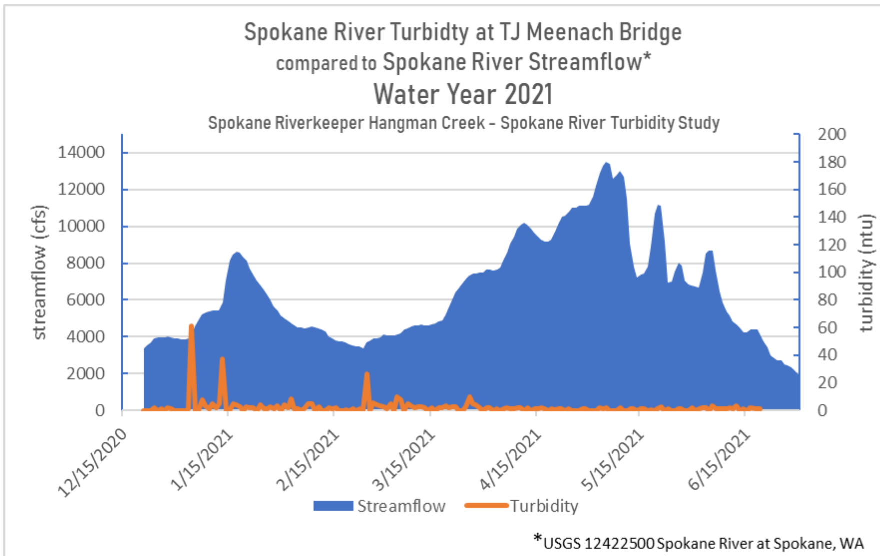


Figure 8 - Spokane River Turbidity at TJ Meenach Bridge 12/21/20 - 06/30/21

When comparing turbidity to precipitation and streamflow we find that turbidity measurements from Hangman Creek (Figure 6) are highly responsive to changes in precipitation and flow. Turbidity in Spokane River, on the other hand is stable at Sandifur Bridge (Figure 7), and spikes in turbidity at TJ Meenach Bridge (Figure 8) follow influence of Hangman Creek rather than response to precipitation or streamflow.

Table 1 - Estimated total suspended sediment based on turbidity Hangman Creek at 11th Street Bridge

73.28	average tons per day
13190.864	tons per study period (x180)
6.59	acre feet per study peiod (1 acre-foot of soil = 2,000 ton USDA)

We extrapolated estimated sediment contribution from Hangman Creek based on turbidity measurements from 11th Street Bridge samples (Appendix B). We find 13,190 tons of sediment lost from the Hangman Creek watershed during our 180-day study period (Table 1).

Interestingly this correlates well with the sediment rating curve from figure 38 of the TMDL (Joy et al, 2009), which uses flow to estimate sediment discharge. Using the yearly flow of 128 cfs the current condition or USGS model, sediment discharge is calculated at 10235 or 11472 tons, respectively.

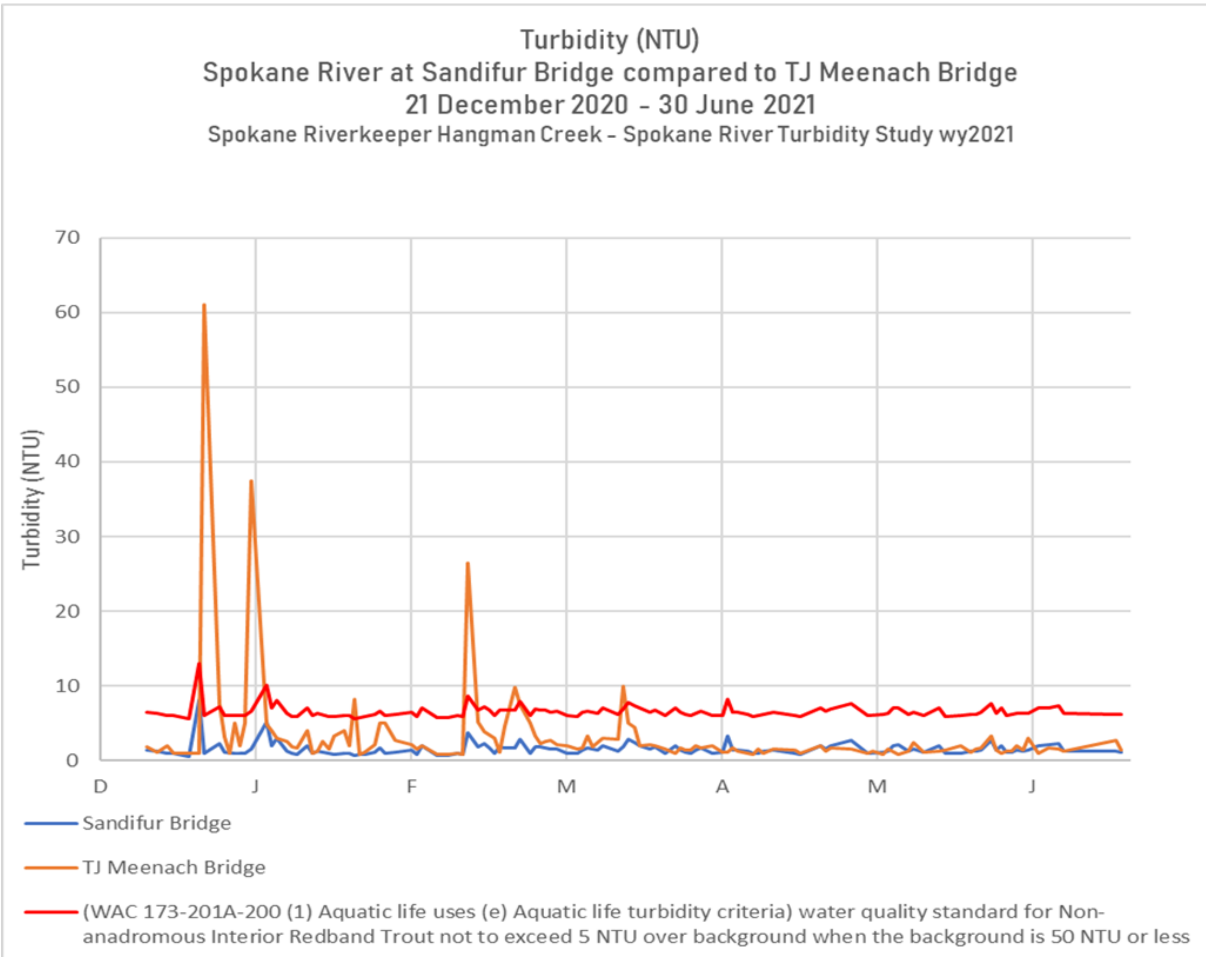


Figure 10 - chart of turbidity (NTU) comparing readings from Sandifur Bridge background samples to TJ Meenach Bridge samples with Hangman Creek sediment influence; water-quality standard violations above red line

Samples from Sandifur Bridge establish the background turbidity in Spokane River upstream from the Hangman confluence. In Figure 10, the red line shows 5 NTU above the measurements at Sandifur Bridge. The brown line, representing measurements at TJ Meenach Bridge, when above the red line, indicates measurements in excess of our Washington State Administrative Code (WAC 173-201A-200 (1) Aquatic life uses (e) Aquatic life turbidity criteria) water quality standard for Salmonid Spawning, Rearing, and Migration not to exceed 5 NTU over background when the background is 50 NTU or less.

Table 2 – Dates NTU measurements at TJ Meenach exceed 5 NTU over background measurements at Sandifur Bridge

date	Sandifur NTU	plus 5 Sandifur NTU	TJ Meenach NTU in excess of 5 NTU over background
1/4/2021	1	6	61
1/7/2021	2.22	7.22	7.68
1/13/2021	1.59	6.59	37.4
1/30/2021	0.82	5.82	44.6
2/2/2021	0.67	5.67	8.18
2/24/2021	3.65	8.65	26.5
3/5/2021	1.7	6.7	9.8
3/6/2021	2.85	7.85	7.48
3/26/2021	1.88	6.88	9.94

Between December 21st, 2020 and June 30th, 2021, we found turbidity measurements at TJ Meenach, with influence from Hangman Creek, to exceed more than 5 NTU over background at Sandifur Bridge in 9 incidences, by as much as 44.6 NTU on January 30th, 2021 (Table 2).

DISCUSSION

Turbidity pollution in Hangman Creek has been well documented and is included in the EPA approved 2009 TMDL developed by Washington State Department of Ecology and Spokane County Conservation District (Snouwaert 2011). In 2011 an implementation plan was developed that included expectations for adherence to best management practices (BMPs) to limit non-point source pollution into Hangman Creek by reducing erosion, reducing runoff carrying sediment, reducing livestock impacts, increasing shading of streams, and informing and educating watershed residents about water quality issues (Snouwaert 2011). "Reducing sediment and nutrients in runoff from agricultural operations will require farming with BMPs that keep soil on the production fields and reduce erosion" (Snouwaert 2011). Commitment to BMPs such as low impact direct seeding and maintenance of riparian buffers can minimize soil loss and improve water quality in Hangman Creek and subsequently in the Spokane River. Based on turbidity measurements in Hangman Creek at 11th Street Bridge we estimated 26,748 tons of soil lost to erosion into Hangman Creek in water year 2021. In this study we chose turbidity as the parameter of focus because the criterium is legally identifiable and the technology accessible to a community science endeavor. Measurement of Total Suspended Sediment (TSS) by filtered water sample is the most precise calculation for sedimentation rates (Fondriest 2014) and a follow up to the Spokane County Conservation District's *Hangman Creek Sediment Discharge Report for Water Years 1998 and 1999* could contribute to understanding the effectiveness of BMPs implemented in the Hangman Watershed in the last 20 years.

Nutrients, especially phosphorus, carried by sediment is a major driver in low dissolved oxygen levels found in Lake Spokane (Moore and Ross, 2010). The Lake Spokane DO TMDL has reduced effluent total phosphorous dramatically, yet nutrients continue to cause violations in DO standards. Much of this phosphorus entering Lake Spokane is conveyed by sediments Hangman Creek. It is becoming increasingly clear that Hangman Creek sediments are now the major driver for water quality violations in Lake Spokane.

Another recognized contributor to the excessive turbidity through Hangman Creek is channelization of the stream and floodplain encroachment by roading and development. The EPA recognizes: "Channelization and channel modification can, disturb stream equilibrium, disrupt riffle and pool habitats, create changes in stream velocities, eliminate the function of floods to control channel-forming properties, alter the base level of a stream (streambed elevation), and increase erosion and sediment load" (EPA 2007).

The Coeur d'Alene Tribe has made significant Hangman Creek restoration efforts in the upper watershed above Mission Creek with a focus on hydrogeomorphic processes in addition to healthy riparian plant communities (Kinkead 2019). In reaches severely impacted by agricultural and rail transportation activity since the 1940s, the *k'wne' 'ulchiyark'wmtsut "Make it crooked again" Relict Channel Reactivation and Floodplain Connection Project* included transformation of a 450-foot human-straightened channel to 1,400 feet of reactivated relict meander (Kinkead 2019). This meander restoration by the Coeur d'Alene Tribe decreases downstream turbidity by containing fine sediments which benefit riparian plantings such as Drummond willow (Salix drummondiana) and hardwoods that can in turn shade-out invasive reed canary grass (Kinkead 2019). Hydrogeomorphic restoration has led to raised water levels and improved groundwater conditions, creating habitat for tundra swans, painted turtles and culturally important native plants such as Camas (Camassia quamash) (Kinkead 2019).

In the lower reaches of Hangman Creek channelization resulting from housing and highway development has led to straight waterways in which high streamflow flushes turbidity through the system. In February of 2020, Washington State Department of Transportation Eastern Region administrator, Mike Gribner, administrator of WSDOT's Eastern Region, called for a development moratorium in the Latah Valley as Highway 195 (Inland Empire Highway) cannot safely support access for the growing population in the area citing "the City's failure to follow through with commitments to create an appropriate local access network and the failure to engage in responsible growth management" (McDermott 2020). The US 195 Corridor Safety Improvement program recognizes several environmental impacts under the responsibility of the Washington State Department of Transportation including impacts to Hangman Creek riparian areas, wetlands, and existing springs, as well as impairment to hydrogeomorphic features such as floodplain connectivity particularly at Hatch Road and Meadowlane (WSDOT 1999). Community members, policy makers, and environmentalists must remain vigilant to further impacts of regional development to Hangman Creek, and we may look to restoration efforts by the Coeur d'Alene Tribe in the upper watershed for potential floodplain restoration opportunities in tandem with safety improvements to Highway 195.

Our measurements for water year 2021 demonstrate influence of Hangman Creek turbidity to Spokane River turbidity as we see correlating spikes in turbidity at TJ Meenach Bridge downstream from the Hangman Creek confluence that are not present at Sandifur Bridge upstream (Figures #-#). In the 2003 count, 64 of the 130 rainbow trout redds below Monroe Street Dam were found in this impacted area (Parametrix 2003). Our Washington State Administrative Code (WAC 173-201A-200 (1) Aquatic life uses (e) Aquatic life turbidity criteria) states that we have a water quality standard for Salmonid [includes salmon, trout, chars, freshwater whitefishes, and graylings] Spawning, Rearing, and Migration and specifically Non-anadromous Interior Redband Trout (the likely subspecies in this reach) not to exceed 5 NTU over background when the background is 50 NTU or less. Turbidity measurements from TJ Meenach Bridge exceeded 5 NTU over background at Sandifur Bridge in 9 observed incidences in water year 2021 indicating a violation of water quality standards and warranting inclusion of turbidity impairment in a Spokane River Total Maximum Daily Load assessment with remediation recommendations related to turbidity inputs from Hangman Creek.

CONCLUSION

The Spokane Riverkeeper Hangman Creek – Spokane River Turbidity Study for water year 2021 demonstrates excesses of turbidity pollution in the Spokane River as influenced by previously known excesses of turbidity from Hangman Creek. Further evaluation by the Washington State Department of Ecology to establish turbidity impairment in Spokane River's 303d listing and TMDL clean-up plan is warranted. Turbidity measurements at TJ Meenach Bridge show a Washington State water quality standard violation reading above 5NTU over background measurements at Sandifur Bridge posing a threat to salmonid spawning, rearing, and migration. As stated in the Hangman Creek TMDL (2009) implementation of agricultural best management practices, reconnection of the floodplain, and the enhancement and improvement of riparian health could serve to reduce turbidity and soil loss to erosion.

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APPENDIX A

Spokane Riverkeeper Hangman Creek – Spokane River Turbidity Study Water Year 2021 DATA

Draft Report 10/12/2021

date	hangman NTU	sandifur NTU	plus 5 sandifur NTU	tj NTU		USGS TIME	Q hangman	Q spokane		PRCP Spokane Co
12/21/2020	3	2	7	4		12/21/2020 14:00 PST	45.1	3,300		0.2
12/22/2020	2	1	6	1		12/22/2020 14:00 PST	67.9	3,700		0
12/24/2020	9.03	1.4	6.4	1.8		12/24/2020 11:30 PST	165	3,850		0
12/25/2020	8.73	0.7	5.7			12/25/2020 14:00 PST	112	3,930		0.36
12/26/2020	25	1.29	6.29	1.08		12/26/2020 16:00 PST	97.6	3,970		0.07
12/27/2020	36	2	7	4		12/27/2020 14:00 PST	78.5	4,010		0
12/28/2020	33	1	6	2		12/28/2020 15:45 PST	78.5	4,010		0
12/29/2020	22	1	6	1		12/29/2020 10:45 PST	61.7	4,010		0.02
12/31/2020	17.8	1.26	6.26	3.33		12/31/2020 14:00 PST	67.9	3,870		0.11
1/1/2021		0.6	5.6			01/01/2021 14:00 PST	71.8	3,870		0.12
1/3/2021	12	8	13	1		01/03/2021 10:15 PST	119	3,870		0.16
1/3/2021	52		5			01/03/2021 15:45 PST	597	3,970		0.16
1/4/2021	222	1	6	61		01/04/2021 18:30 PST	1,790	4,180		0.45
1/4/2021	244		5			01/04/2021 18:45 PST	1,920	3,950		0.45
1/7/2021	49.8	2.22	7.22	7.68		01/07/2021 13:30 PST	787	5,340		0.1
1/7/2021	50.1		5			01/07/2021 13:45 PST	807	5,340		0.1
1/8/2021	24.4	1.05	6.05	3.11		01/08/2021 12:45 PST	833	5,320		0
1/9/2021	40.8	0.99	5.99	1		01/09/2021 14:15 PST	492	5,430		0
1/9/2021	12.8		5			01/09/2021 12:15 PST	519	5,360		0
1/10/2021		1	6	5		01/10/2021 14:00 PST	364	5,410		0
1/11/2021	24	1	6	2		01/11/2021 13:00 PST	276	5,690		0.04
1/11/2021	22		5			01/11/2021 11:30 PST	284	5,320		0.04
1/12/2021	25	1	6	5		01/12/2021 10:30 PST	254	5,360		0.86
1/12/2021	26		5			01/12/2021 14:00 PST	251	5,360		0.86
1/13/2021	187	1.59	6.59	37.4		01/13/2021 12:30 PST	2,360	5,640		0.13
1/13/2021	138		5			01/13/2021 20:30 PST	3,280	6,120		0.13
1/14/2021	534		5			01/14/2021 12:30 PST	1,910	7,170		0
1/15/2021	90.2		5			01/15/2021 12:30 PST	880	8,120		0
1/16/2021		5.13	10.13	4.94		01/16/2021 12:00 PST	563	8,490		0
1/16/2021	43.5		5			01/16/2021 12:00 PST	563	8,490		0
1/16/2021	44		5			01/16/2021 13:30 PST	546	8,460		0
1/17/2021	31	2	7	4		01/17/2021 13:30 PST	546	8,610		0.03
1/17/2021	32		5			01/17/2021 12:30 PST	530	8,610		0.03
1/18/2021	30	3	8	3		01/18/2021 13:30 PST	530	8,520		0
1/18/2021	28		5			01/18/2021 14:00 PST	524	8,520		0
1/19/2021	37.2		5			01/19/2021 12:15 PST	410	8,410		0
1/20/2021	42.4	1.32	6.32	2.63		01/20/2021 13:45 PST	292	8,150		0
1/20/2021	32.8		5			01/20/2021 09:45 PST	308	8,150		0
1/21/2021	21.7	0.94	5.94	1.82		01/21/2021 12:15 PST	243	7,820		0
1/21/2021	22.2		5			01/21/2021 11:45 PST	245	7,870		0
1/22/2021	19.8	0.83	5.83	1.68		01/22/2021 15:30 PST	214	7,270		0
1/23/2021	18	1.3	6.3	3.89		01/23/2021 11:30 PST	167	7,060		0
1/23/2021	24.7		5			01/23/2021 14:00 PST	176	7,090		0
1/24/2021	16	2	7	4		01/24/2021 13:30 PST	147	6,880		0.03
1/24/2021	14		5			01/24/2021 14:30 PST	155	6,830		0.03
1/25/2021	14	1	6	1		01/25/2021 10:30 PST	163	6,440		0.06
1/26/2021	13.5	1.26	6.26	1.32		01/26/2021 15:15 PST	141	6,250		0.02
1/27/2021	12.6		5	2.6		01/27/2021 12:45 PST	133	5,880		0.09
1/27/2021	12.1		5	1.55		01/27/2021 12:15 PST	133	5,880		0.09
1/28/2021	11.1	0.94	5.94			01/28/2021 10:00 PST	126	5,670		0
1/29/2021	9.82	0.84	5.84	3.35		01/29/2021 12:30 PST	124	5,410		0.01
1/29/2021	11.8		5			01/29/2021 12:30 PST	124	5,410		0.01
1/30/2021	12.3	0.82	5.82	44.6		01/30/2021 14:00 PST	124	5,230		0
1/31/2021	9	1	6	4		01/31/2021 12:30 PST	124	5,230		0.01
2/1/2021	8	1	6	2		02/01/2021 09:45 PST	133	4,870		0.01
2/2/2021	7.55	0.67	5.67	8.18		02/02/2021 14:00 PST	139	4,670		0
2/3/2021	9.38	0.78	5.78	0.89		02/03/2021 13:00 PST	155	4,670		0
2/4/2021	9.98	0.87	5.87	1.09		02/04/2021 12:45 PST	176	4,760		0.06
2/4/2021	9.61		5			02/04/2021 10:45 PST	169	4,560		0.06
2/6/2021	18.9	1.15	6.15	2.11		02/06/2021 12:45 PST	243	4,540		0
2/7/2021	21.2	1.66	6.66	4.97		02/07/2021 10:30 PST	401	4,580		0

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date	hangman NTU	sandifur NTU	plus 5 sandifur NTU	tj NTU		USGS TIME	Q hangman	Q spokane		PRCP Spokane Co
2/8/2021	45.9	1	6	5		02/08/2021 08:00 PST	325	4,490		0
2/8/2021	78		5			02/08/2021 09:45 PST	316	4,470		0
2/8/2021	80		5			02/08/2021 14:00 PST	304	4,540		0
2/9/2021	38.8		5			02/09/2021 10:45 PST	257	4,450		0
2/10/2021	30.6	1.14	6.14	2.68		02/10/2021 09:00 PST	214	4,490		0
2/10/2021	27.8		5			02/10/2021 13:30 PST	203	4,520		0
2/13/2021	18.3	1.47	6.47	2.11		02/13/2021 11:30 PST	85.6	4,180		0
2/14/2021	17.3	0.85	5.85	1.52		02/14/2021 14:00 PST	119	3,910		0.08
2/15/2021	13	2	7	2		02/15/2021 10:30 PST	112	3,770		0.24
2/18/2021	11.2	0.71	5.71	0.78		02/18/2021 10:15 PST	116	3,660		0.13
2/20/2021	8.86	0.75	5.75	0.87		02/20/2021 09:45 PST	102	3,470		0
2/22/2021	8	1	6	1		02/22/2021 10:30 PST	107	3,450		0.04
2/22/2021	8	1	6	1		02/22/2021 10:45 PST	107	3,450		0.04
2/23/2021	14.4	0.83	5.83	0.8		02/23/2021 18:45 PST	1,100	3,990		0
2/23/2021	11		5			02/23/2021 14:00 PST	346	3,450		0
2/24/2021	176	3.65	8.65	26.5		02/24/2021 12:15 PST	1,030	3,520		0
2/24/2021	167		5			02/24/2021 12:15 PST	1,030	3,520		0
2/25/2021	69.4		5			02/25/2021 12:30 PST	460	3,770		0.18
2/26/2021	45.6	1.81	6.81	5.23		02/26/2021 14:15 PST	300	3,970		0
2/26/2021	42.8		5			02/26/2021 16:15 PST	296	4,010		0
2/27/2021	32.1	2.25	7.25	3.81		02/27/2021 12:00 PST	288	4,030		0.05
2/28/2021	29.7	1.71	6.71	3.46		02/28/2021 11:30 PST	276	3,990		0
3/1/2021	22	1	6	3		03/01/2021 12:15 PST	240	4,620		0
3/1/2021	21		5			03/01/2021 11:00 PST	240	4,070		0
3/2/2021	30.9	1.82	6.82	1.15		03/02/2021 14:00 PST	251	4,030		0
3/2/2021	33.9		5			03/02/2021 12:30 PST	245	4,050		0
3/3/2021	38.6	1.71	6.71	4.52		03/03/2021 12:30 PST	471	4,030		0
3/3/2021	43.7		5			03/03/2021 12:45 PST	492	4,030		0
3/4/2021	96.1		5			03/04/2021 12:00 PST	519	4,090		0
3/5/2021	73.1	1.7	6.7	9.8		03/05/2021 12:30 PST	503	4,070		0
3/5/2021	68.2		5			03/05/2021 14:00 PST	503	4,140		0
3/6/2021	55.6	2.85	7.85	7.48		03/06/2021 11:30 PST	492	4,160		0
3/6/2021	55.6		5			03/06/2021 16:00 PST	487	4,220		0
3/7/2021	40.7		5			03/07/2021 12:30 PST	481	4,520		0
3/8/2021	37	1	6	5		03/08/2021 07:30 PST	405	4,490		0
3/8/2021	35		5			03/08/2021 10:45 PST	396	4,470		0
3/9/2021	28.6	1.89	6.89	3.33		03/09/2021 12:30 PST	316	4,560		0
3/9/2021	31.2		5			03/09/2021 14:00 PST	316	4,600		0
3/10/2021	27.3	1.81	6.81	2.28		03/10/2021 15:15 PST	268	4,670		0
3/11/2021	22.7	1.71	6.71	2.6		03/11/2021 12:15 PST	240	4,670		0
3/11/2021	22.7		5			03/11/2021 12:30 PST	240	4,670		0
3/12/2021	22.8	1.51	6.51	2.73		03/12/2021 09:15 PST	224	4,620		0
3/13/2021	19.5	1.57	6.57	2.18		03/13/2021 15:30 PST	194	4,670		0
3/14/2021	15		5			03/14/2021 11:00 PDT	189	4,580		0
3/15/2021	17	1	6	2		03/15/2021 10:30 PDT	182	4,580		0
3/17/2021	15.4	0.93	5.93	1.59		03/17/2021 13:45 PDT	189	4,820		0
3/17/2021	15.4		5			03/17/2021 13:30 PDT	189	4,800		0
3/18/2021	16.8	1.45	6.45	1.72		03/18/2021 13:00 PDT	184	4,910		0
3/18/2021	15.6		5			03/18/2021 10:45 PDT	184	4,840		0
3/19/2021	16	1.63	6.63	3.35		03/19/2021 14:00 PDT	180	5,360		0
3/20/2021	14.4	1.48	6.48	1.89		03/20/2021 11:30 PDT	174	5,480		0
3/21/2021	15	1.36	6.36	2.46		03/21/2021 12:30 PDT	189	6,120		0
3/22/2021	13	2	7	3		03/22/2021 14:00 PDT	201	6,520		0.13

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date	hangman NTU	sandifur NTU	plus 5 sandifur NTU	tj NTU		USGS TIME	Q hangman	Q spokane		PRCP Spokane Co
3/25/2021	16.9	1.22	6.22	2.87		03/25/2021 12:15 PDT	530	6,980		0
3/25/2021	15.8		5			03/25/2021 14:00 PDT	674	7,090		0
3/26/2021	67.7	1.88	6.88	9.94		03/26/2021 18:00 PDT	787	7,300		0
3/26/2021	80		5			03/26/2021 10:30 PDT	907	7,410		0
3/27/2021	50.1	2.78	7.78	5.02		03/27/2021 19:00 PDT	497	7,410		0
3/27/2021	48.3		5			03/27/2021 14:00 PDT	519	7,460		0
3/28/2021	44.8	2.4	7.4	4.41		03/28/2021 10:15 PDT	440	7,410		0
3/29/2021	31	2	7	2		03/29/2021 14:00 PDT	373	7,540		0
3/29/2021	27		5			03/29/2021 15:15 PDT	364	7,570		0
3/30/2021	22.2		5			03/30/2021 12:15 PDT	346	7,600		0
3/30/2021	31		5			03/30/2021 14:00 PDT	346	7,760		0
3/31/2021	19.7	1.54	6.54	2.15		03/31/2021 22:45 PDT	284	7,760		0
3/31/2021	21.2		5			03/31/2021 11:00 PDT	308	7,760		0
4/1/2021	19.1	1.81	6.81	1.98		04/01/2021 12:30 PDT	261	7,600		0
4/1/2021	19.7		5			04/01/2021 12:45 PDT	265	7,600		0
4/2/2021	17.2		5			04/02/2021 12:15 PDT	240	7,570		0
4/3/2021	15.8	1	6	1.57		04/03/2021 12:30 PDT	219	7,620		0
4/5/2021	13	2	7	1		04/05/2021 10:15 PDT	206	8,290		0
4/6/2021	13.1	1.46	6.46	1.64		04/06/2021 14:00 PDT	229	8,700		0
4/7/2021	11.4	1.13	6.13	1.34		04/07/2021 13:45 PDT	224	9,110		0
4/8/2021	10.8	0.98	5.98	1.37		04/08/2021 13:30 PDT	203	9,530		0.01
4/9/2021	10.6	1.38	6.38	1.97		04/09/2021 16:00 PDT	189	9,870		0
4/10/2021	10.1	1.65	6.65	1.66		04/10/2021 14:00 PDT	194	10,100		0
4/12/2021	9	1	6	2		04/12/2021 14:00 PDT	163	10,200		0
4/14/2021	6.05	1.05	6.05	1.06		04/14/2021 12:15 PDT	135	9,690		0
4/15/2021	5.77	3.22	8.22	1.07		04/15/2021 14:00 PDT	128	9,530		0
4/16/2021	4.78	1.45	6.45	1.76		04/16/2021 17:00 PDT	121	9,320		0
4/17/2021	4.81	1.44	6.44	1.26		04/17/2021 15:15 PDT	112	9,230		0
4/19/2021	2.98	1.24	6.24	1		04/19/2021 11:15 PDT	107	9,320		0
4/20/2021	2.51	0.94	5.94	0.85		04/20/2021 16:00 PDT	101	9,780		0
4/21/2021	2.68	0.97	5.97	1.55		04/21/2021 11:30 PDT	101	10,200		0
4/22/2021	2.39	1.2	6.2	0.9		04/22/2021 14:00 PDT	104	10,500		0
4/24/2021	2.7	1.47	6.47	1.48		04/24/2021 13:30 PDT	97.6	10,800		0.1
4/28/2021	2.24	1.03	6.03	1.39		04/28/2021 11:00 PDT	93.0	11,100		0
4/29/2021	1.43	0.88	5.88	1.04		04/29/2021 14:00 PDT	88.5	11,100		0
5/3/2021	2	2	7	2		05/03/2021 15:00 PDT	73.1	12,900		0
5/4/2021	1.38	1.59	6.59	1.3		05/04/2021 14:00 PDT	71.8	13,400		0
5/5/2021	1.52	1.93	6.93	1.66		05/05/2021 12:45 PDT	71.8	13,500		0
5/9/2021	1.38	2.66	7.66	1.59		05/09/2021 12:00 PDT	66.7	12,900		0
5/12/2021	1.17	1.02	6.02	0.96		05/12/2021 13:15 PDT	61.7	8,960		0
5/13/2021			5	1.22		05/13/2021 14:00 PDT	60.5	8,070		0
5/15/2021	1.38	1.17	6.17	0.88		05/15/2021 11:00 PDT	58.2	7,430		0
5/16/2021	2.51	1.28	6.28	1.48		05/16/2021 13:15 PDT	55.9	7,490		0
5/17/2021	2	2	7			05/17/2021 09:30 PDT	52.5	7,430		0
5/18/2021	1.66	2.07	7.07	0.85		05/18/2021 14:00 PDT	49.3	9,050		0
5/20/2021	1.44	1.23	6.23	1.23		05/20/2021 14:00 PDT	44.1	11,200		0.1
5/21/2021	1.94	1.51	6.51	2.47		05/21/2021 12:30 PDT	43.1	11,300		0
5/23/2021	1.09	1.08	6.08	1.1		05/23/2021 12:00 PDT	38.4	6,930		0
6/7/2021	2	2	7	1		06/07/2021 14:00 PDT	21.0	6,520		0
6/8/2021	1.36	1.08	6.08	1.24		06/08/2021 14:00 PDT	18.5	5,950		0
6/9/2021	1.78	1.14	6.14	1.24		06/09/2021 08:45 PDT	19.7	5,410		0
6/10/2021	1.33	1.35	6.35	1.93		06/10/2021 14:00 PDT	18.5	5,270		0
6/11/2021	1.98	1.33	6.33	1.36		06/11/2021 14:00 PDT	19.1	4,890		0
6/12/2021	1.91	1.37	6.37	3.04		06/12/2021 14:00 PDT	18.5	4,520		0.07
6/14/2021	2	2	7	1		06/14/2021 16:00 PDT	18.5	4,470		0
6/16/2021	2.54	2.08	7.08	1.65		06/16/2021 14:15 PDT	18.5	4,430		0
6/18/2021	2.19	2.28	7.28	1.54		06/18/2021 14:00 PDT	17.9	3,990		0
6/19/2021	1.63	1.28	6.28	1.33		06/19/2021 11:15 PDT	17.3	3,810		0
6/29/2021	1.63	1.23	6.23	2.68		06/29/2021 16:45 PDT	11	1,950		0
6/30/2021	2.1	1.17	6.17	1.35		06/30/2021 13:30 PDT	11	1,720		0

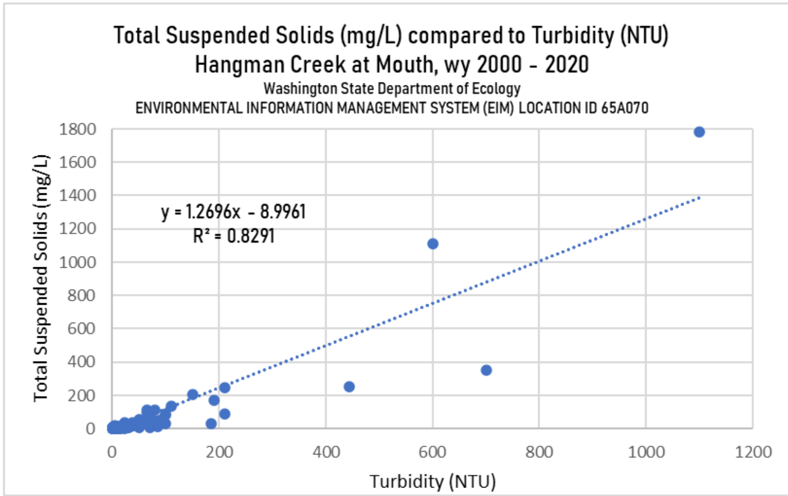
PRCP Spokane Co (NOAA Climate Data Online USW00024157 SPOKANE INTERNATIONAL AIRPORT, WA US)

USGS TIME Q hangman (USGS 12424000 Hangman Creek at Spokane, WA)

USGS TIME Q spokane (USGS 12422500 Spokane River at Spokane, WA)

APPENDIX B

Spokane Riverkeeper Hangman Creek – Spokane River Turbidity Study Water Year 2021
NTU to TSS Conversion



Sample Date	Sample turbidity(NTU)	TSS (mg/L) by (1.27mg/L per NTU -hangman TSS to NTU ratio)	(1mg/L = 4.1727e-9tons/gal)	cfs	gal per sec (1cfs to 7.4805gal)	tons per gallon per second	tons per day (1 day to 86400 seconds)
12/21/20	3	3.81	1.5898E-08	67.9	507.92595	8.075E-06	0.697680013
12/22	2	2.54	1.05987E-08	165	1234.2825	1.30817E-05	1.130262171
12/24	9.03	11.4681	4.78529E-08	112	837.816	4.0092E-05	3.463945301
12/25	8.73	11.0871	4.62631E-08	97.6	730.0968	3.37766E-05	2.918295826
12/26	25	31.75	1.32483E-07	78.5	587.21925	7.77967E-05	6.721634882
12/27/20	36	45.72	1.90776E-07	78.5	587.21925	0.000112027	9.67915423
12/28/20	33	41.91	1.74878E-07	61.7	461.54685	8.07143E-05	6.973717596
12/29/20	22	27.94	1.16585E-07	67.9	507.92595	5.92167E-05	5.116320095
12/31	17.8	22.606	9.43281E-08	71.8	537.0999	5.06636E-05	4.377334137
1/3/21	12	15.24	6.35919E-08	1790	13390.095	0.000851502	73.56979224
1/4/21	222	281.94	1.17645E-06	807	6036.7635	0.007101957	613.6090576
1/7/21	49.8	63.246	2.63907E-07	519	3882.3795	0.001024586	88.52418827
1/8/21	24.4	30.988	1.29304E-07	251	1877.6055	0.000242781	20.97629588
1/9/21	40.8	51.816	2.16213E-07	3280	24536.04	0.005305002	458.3521358
1/11/21	24	30.48	1.27184E-07	546	4084.353	0.000519464	44.88168331
1/12/21	25	31.75	1.32483E-07	254	1900.047	0.000251724	21.7489842
1/13/21	187	237.49	9.90975E-07	2360	17653.98	0.017494644	1511.537277
1/14/21	534	678.18	2.82984E-06	1910	14287.755	0.040432085	3493.332118
1/15/21	90.2	114.554	4.77999E-07	880	6582.84	0.003146594	271.8657276
1/16/21	44	55.88	2.3317E-07	546	4084.353	0.000952351	82.28308607
1/17/21	31	39.37	1.64279E-07	546	4084.353	0.000670974	57.97217427
1/18/21	30	38.1	1.5898E-07	530	3964.665	0.000630302	54.45808643
1/19/21	37.2	47.244	1.97135E-07	410	3067.005	0.000604614	52.23866253
1/20/21	42.4	53.848	2.24692E-07	292	2184.306	0.000490795	42.40469663
1/21/21	21.7	27.559	1.14995E-07	243	1817.7615	0.000209034	18.06056199
1/22/21	19.8	25.146	1.04927E-07	214	1600.827	0.00016797	14.51256628
1/23/21	18	22.86	9.53879E-08	167	1249.2435	0.000119163	10.29566087
1/24/21	16	20.32	8.47893E-08	147	1099.6335	9.32371E-05	8.055686748
1/25/21	14	17.78	7.41906E-08	163	1219.3215	9.04622E-05	7.815934166
1/26/21	13.5	17.145	7.15409E-08	141	1054.7505	7.54578E-05	6.519557706
1/27/21	12.6	16.002	6.67715E-08	133	994.9065	6.64314E-05	5.739676808
1/28/21	11.1	14.097	5.88226E-08	126	942.543	5.54428E-05	4.790256584
1/29/21	9.82	12.4714	5.20394E-08	124	927.582	4.82708E-05	4.170598911
1/30/21	12.3	15.621	6.51817E-08	124	927.582	6.04614E-05	5.223866253
1/31/21	9	11.43	4.7694E-08	124	927.582	4.42401E-05	3.822341161
2/1/21	8	10.16	4.23946E-08	133	994.9065	4.21787E-05	3.644239243
2/2/21	7.55	9.5885	4.00099E-08	139	1039.7895	4.16019E-05	3.594404956
2/3/21	9.38	11.9126	4.97077E-08	155	1159.4775	5.7635E-05	4.979661123
2/4/21	9.98	12.6746	5.28873E-08	176	1316.568	6.96297E-05	6.016008783
2/6/21	18.9	24.003	1.00157E-07	243	1817.7615	0.000182062	15.73016689
2/7/21	21.2	26.924	1.12346E-07	401	2999.6805	0.000337001	29.11692355
2/8/21	78	99.06	4.13348E-07	316	2363.838	0.000977087	84.42030908
2/9/21	38.8	49.276	2.05614E-07	257	1922.4885	0.00039529	34.15309778
2/10/21	30.6	38.862	1.62159E-07	214	1600.827	0.000259589	22.42851152
2/13/21	18.3	23.241	9.69777E-08	85.6	640.3308	6.20978E-05	5.365251776
2/14/21	17.3	21.971	9.16784E-08	119	890.1795	8.16102E-05	7.05112343
2/15/21	13	16.51	6.88913E-08	112	837.816	5.77182E-05	4.986853701
2/18/21	11.2	14.224	5.93525E-08	116	867.738	5.15024E-05	4.449807918
2/20/21	8.86	11.2522	4.69521E-08	102	763.011	3.58249E-05	3.095274331
2/22/21	8	10.16	4.23946E-08	107	800.4135	3.39332E-05	2.931831571
2/23/21	14.4	18.288	7.63103E-08	110	822.855	6.27923E-05	5.425258422
2/24/21	176	223.52	9.32682E-07	1030	7704.915	0.007186235	620.8906861
2/25/21	69.4	88.138	3.67773E-07	460	3441.03	0.001265519	109.3408774
2/26/21	45.6	57.912	2.41649E-07	300	2244.15	0.000542298	46.85450455
2/27/21	32.1	40.767	1.70108E-07	288	2154.384	0.000366479	31.66378097
2/28/21	29.7	37.719	1.5739E-07	276	2064.618	0.00032495	28.07571233

Sample Date	Sample turbidity(NTU)	TSS (mg/L) by (1.27 mg/L per NTU- hangman TSS to NTU ratio)	(1mg/L = 4.1727e-9 tons/gal)	cfs	gal per sec (1cfs to 7.4805gal)	tons per gallon per second	tons per day (1 day to 86400 seconds)
3/1/21	22	27.94	1.16585E-07	240	1795.32	0.000209308	18.08419474
3/2/21	30.9	39.243	1.63749E-07	251	1877.6055	0.000307457	26.56424856
3/3/21	38.6	49.022	2.04554E-07	471	3523.3155	0.000720709	62.26922555
3/4/21	96.1	122.047	5.09266E-07	519	3882.3795	0.001977162	170.826797
3/5/21	73.1	92.837	3.87381E-07	503	3762.6915	0.001457595	125.9362086
3/6/21	55.6	70.612	2.94643E-07	492	3680.406	0.001084405	93.69256893
3/7/21	40.7	51.689	2.15683E-07	481	3598.1205	0.000776052	67.05091954
3/8/21	37	46.99	1.96075E-07	405	3029.6025	0.000594038	51.32417768
3/9/21	28.6	36.322	1.51561E-07	316	2363.838	0.000358265	30.95411333
3/10/21	27.3	34.671	1.44672E-07	268	2004.774	0.000290034	25.05893985
3/11/21	22.7	28.829	1.20295E-07	240	1795.32	0.000215968	18.65960094
3/12/21	22.8	28.956	1.20825E-07	224	1675.632	0.000202458	17.49234837
3/13/21	19.5	24.765	1.03337E-07	194	1451.217	0.000149964	12.95691453
3/14/21	15	19.05	7.94899E-08	189	1413.8145	0.000112384	9.709979562
3/15/21	17	21.59	9.00886E-08	182	1361.451	0.000122651	10.59706411
3/17	15.4	19.558	8.16097E-08	189	1413.8145	0.000115381	9.96891235
3/18	16.8	21.336	8.90287E-08	184	1376.412	0.00012254	10.58747401
3/19	16	20.32	8.47893E-08	180	1346.49	0.000114168	9.864106222
3/20	14.4	18.288	7.63103E-08	174	1301.607	9.93261E-05	8.581772413
3/21/21	15	19.05	7.94899E-08	189	1413.8145	0.000112384	9.709979562
3/22/21	13	16.51	6.88913E-08	201	1503.5805	0.000103584	8.949621374
3/25/21	16.9	21.463	8.95587E-08	530	3964.665	0.00035507	30.67805536
3/26/21	67.7	85.979	3.58765E-07	787	5887.1535	0.002112102	182.4856226
3/27/21	50.1	63.627	2.65496E-07	497	3717.8085	0.000987065	85.28239086
3/28/21	44.8	56.896	2.3741E-07	440	3291.42	0.000781416	67.51432703
3/29/21	27	34.29	1.43082E-07	364	2722.902	0.000389598	33.66126248
3/30/21	22.2	28.194	1.17645E-07	346	2588.253	0.000304495	26.3083933
3/31/21	19.7	25.019	1.04397E-07	284	2124.462	0.000221787	19.16239635
4/1/21	19.1	24.257	1.01217E-07	261	1952.4105	0.000197617	17.07415136
4/2/21	17.2	21.844	9.11485E-08	240	1795.32	0.000163641	14.13855225
4/3/21	15.8	20.066	8.37294E-08	219	1638.2295	0.000137168	11.85131262
4/5/21	13	16.51	6.88913E-08	206	1540.983	0.00010616	9.172248771
4/6/21	13.1	16.637	6.94212E-08	229	1713.0845	0.000118921	10.27476814
4/7/21	11.4	14.478	6.04124E-08	224	1675.632	0.000101229	8.746174183
4/8/21	10.8	13.716	5.72328E-08	203	1518.5415	8.69103E-05	7.509050861
4/9/21	10.6	13.462	5.61729E-08	189	1413.8145	7.9418E-05	6.86171889
4/10/21	10.1	12.827	5.35232E-08	194	1451.217	7.76738E-05	6.711017268
4/12/21	9	11.43	4.76994E-08	163	1219.3215	5.81543E-05	5.024529107
4/14/21	6.05	7.6835	3.20609E-08	135	1009.8675	3.23773E-05	2.797398874
4/15/21	5.77	7.3279	3.05771E-08	128	957.504	2.92777E-05	2.52959524
4/16/21	4.78	6.0706	2.53308E-08	121	905.1405	2.29279E-05	1.980972632
4/17/21	4.81	6.1087	2.54898E-08	112	837.816	2.13557E-05	1.845135869
4/19/21	2.98	3.7846	1.57922E-08	107	800.4135	1.26401E-05	1.09210726
4/20/21	2.51	3.1877	1.33013E-08	101	755.5305	1.00495E-05	0.86827811
4/21/21	2.68	3.4036	1.42022E-08	101	755.5305	1.07302E-05	0.927088963
4/22/21	2.39	3.0353	1.26654E-08	104	777.972	9.85332E-06	0.851327168
4/24/21	2.7	3.429	1.43082E-08	97.6	730.0968	1.04464E-05	0.902565719
4/28/21	2.24	2.8448	1.18705E-08	93	695.6865	8.25814E-06	0.713503683
4/29/21	1.43	1.8161	7.57804E-09	88.5	662.02425	5.01685E-06	0.433455543
5/3/21	2	2.54	1.05987E-08	73.1	546.82455	5.79561E-06	0.500740892
5/4/21	1.38	1.7526	7.31307E-09	71.8	537.0999	3.92785E-06	0.339366354
5/6/21	1.52	1.9304	8.05498E-09	71.8	537.0999	4.32633E-06	0.373794825
5/9/21	1.38	1.7526	7.31307E-09	66.7	498.94935	3.64885E-06	0.315260945
5/12/21	1.17	1.4859	6.20021E-09	61.7	461.54685	2.86169E-06	0.247249988
5/15/21	1.38	1.7526	7.31307E-09	58.2	435.3651	3.18386E-06	0.275085262
5/16/21	2.51	3.1877	1.33013E-08	55.9	418.15995	5.56208E-06	0.48056335
5/17/21	2	2.54	1.05987E-08	52.5	392.72625	4.16237E-06	0.359628873
5/18/21	1.66	2.1082	8.79689E-09	49.3	368.78865	3.24419E-06	0.280298168
5/20/21	1.44	1.8288	7.63103E-09	44.1	329.89005	2.5174E-06	0.217503542
5/21/21	1.94	2.4638	1.02807E-08	43.1	322.40955	3.3146E-06	0.286381084
5/23/21	1.09	1.3843	5.77627E-09	38.4	287.2512	1.65924E-06	0.143358344
6/7/21	2	2.54	1.05987E-08	21	157.0905	1.66495E-06	0.143851549
6/8/21	1.36	1.7272	7.20709E-09	18.5	138.38925	9.97383E-07	0.086173928
6/9/21	1.78	2.2606	9.43281E-09	19.7	147.36585	1.39007E-06	0.120102343
6/10/21	1.33	1.6891	7.04811E-09	18.5	138.38925	9.75382E-07	0.084273082
6/11/21	1.98	2.5146	1.04927E-08	19.1	142.87755	1.49917E-06	0.129528045
6/12/21	1.91	2.4257	1.01217E-08	18.5	138.38925	1.40074E-06	0.121023678
6/14/21	2	2.54	1.05987E-08	18.5	138.38925	1.46674E-06	0.126726365
6/16/21	2.54	3.2258	1.34603E-08	18.5	138.38925	1.86276E-06	0.160942483
6/18/21	2.19	2.7813	1.16055E-08	17.9	133.90095	1.55399E-06	0.134264871
6/19/21	1.63	2.0701	8.63791E-09	17.3	129.41265	1.11785E-06	0.096582615
6/29/21	1.63	2.0701	8.63791E-09	11	82.2855	7.10774E-07	0.061410911
6/30/21	2.1	2.667	1.11286E-08	11	82.2855	9.15722E-07	0.079118352
average	26.90472868	34.16900543	1.42577E-07	279.9976744	2094.522603	0.000848178	73.28258216
SD	55.44627655	72.93422416	3.04333E-07	436.3860252	3264.385661	0.004121466	356.0946904
CI	8.029801111	11.0437768	4.60824E-08	66.0780301	494.2967042	0.000624077	53.92023189

73.28258216	average tons per day
13190.86479	tons per study period (x180)
26748.14249	ANNUAL tons (x365)
6.595432394	acre feet study period (1acre-foot of soil = 2,000 tons USDA)
13.37407124	ANNUAL ACRE FEET (1acre-foot of soil = 2,000 tons USDA)