Watershed

April 2024

Root River Watershed Restoration and Protection Strategy Report Update 2024 Appendices

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Cover photo credit: Mower SWCD

Photo description: Paddlers recreating on the Middle Branch Root River near Eagle Bluff Environmental Learning Center.

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Appendix A. Cycle 1 impairments in the RRW

Waterbody Name	WID 07040008-xxx	Use Class	Year added to IWL	Use affected	Impaired water listing	TMDLs approved (Year)	Confirmed stressor(s) not yet addressed	Remaining inconclusive stressors and notes
Mill Creek	-536	2Ag	2012	AQR	*E. coli*	*E. coli* (2017)		
Willow Creek	-558	2Ag	2012	AQL	Macroinvertebrates	Nitrate (2017)	Habitat	
				DW	Nitrate			
			2010	AQR	*E. coli*	*E. coli* (2017)		
Unnamed Ck	-F46	2Bg	2012	AQL	Macroinvertebrates		Physical habitat	Nitrate & DO
Unnamed Ck	-706	2Bg	2012	AQL	Macroinvertebrates		Physical habitat	Nitrate, TSS & DO
South Fork Bear Ck	-544	2Bg	2012	AQL	Macroinvertebrates		Physical habitat	TSS & Nitrate
Middle Branch Root River	-534	2Bg	2012	AQL	Macroinvertebrates		Physical habitat	Nitrate & DO
			2010	AQR	*E. coli*	*E. coli* (2017)		
			2004	AQC	Mercury	Statewide mercury (2008)		
Rice Creek	-581	2Ag	2012	AQL	Macroinvertebrates		Physical habitat, Nitrate,	TSS, Connectivity & Temperature
					Fish			
Unnamed Ck (Wadden Valley Ck)	-605	2Bg	2012	AQL	Macroinvertebrates			Physical habitat, Nitrate & DO
Forestville Creek	-563	2Ag	2006	AQL	Turbidity			Disagreement btwn TSS & STUBE on certain days. Was a correction candidate but rejected. Additional data needed.
			2008	AQR	Fecal coliform (*E. coli*)	*E. coli* (2017)		

Waterbody Name	WID 07040008-xxx	Use Class	Year added to IWL	Use affected	Impaired water listing	TMDLs approved (Year)	Confirmed stressor(s) not yet addressed	Remaining inconclusive stressors and notes
			2010	DW	Nitrate	Nitrate (2017)		
Pine Creek	-576	2Bg	2012	AQL	Macroinvertebrates		Physical habitat	TSS, Nitrate & DO
Money Creek	-F48	2Bg	2012	AQL	Macroinvertebrates			Physical habitat, Nitrate & DO
Money Creek	-521	2Bg	2008	AQL	Turbidity			MIBI & FIBI meeting; additional info needed prior to writing TSS TMDL.
			2004	AQR	Fecal coliform	*E. coli* (2006)		
Unnamed Creek	-659	2Ag	2012	AQL	Macroinvertebrates		Physical habitat	TSS
South Fork Root River	-511	2Ag	2008	AQL	Turbidity			MIBI & FIBI meeting; additional info needed prior to writing TSS TMDL.
			2010	AQC	Mercury	Statewide mercury (2008)		
Silver Creek	-640	2Ag	2012	AQL	Macroinvertebrate		Physical habitat	Temperature, Nitrate & TSS
Trout Run Creek	-G87	2Ag	2012	AQL	Macroinvertebrate		Nitrate & Physical habitat	DO
Etna Creek	-562	2Ag	2010	DW	Nitrate	Nitrate (2017)		
Etna Creek	-597	2Ag	2012	AQL	Macroinvertebrate		Nitrate	Physical habitat
Rush Creek	-524	2Ag	2012	AQL	Macroinvertebrate		Nitrate & Physical habitat	DO
South Fork Root River	-510	2Ag	2012	AQL	Macroinvertebrate		Nitrate & Physical habitat	TSS & Temperature

Waterbody Name	WID 07040008-xxx	Use Class	Year added to IWL	Use affected	Impaired water listing	TMDLs approved (Year)	Confirmed stressor(s) not yet addressed	Remaining inconclusive stressors and notes
			2010	AQC	Mercury	Statewide mercury (2008)		
Sorenson Creek	-F52	2Bg	2012	AQL	Macroinvertebrate		Nitrate & Physical habitat	DO
Riceford Creek	-518	2Ag	2012	AQL	Macroinvertebrate	TSS (2022)	Physical habitat Nitrate*	DO
Root River	-501	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat Nitrate	
			1994		Turbidity			
			1994	AQR	Fecal coliform	*E. coli* (2006)		
			2010	AQC	Mercury	Statewide mercury (2008)		
Root River	-502	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat Nitrate	
					Turbidity			
			2010	AQC	Mercury	Statewide mercury (2008)		
Root River	-520	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat	Nitrate
			2010	AQC	Mercury	Statewide mercury (2008)		
Root River	-522	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat	Nitrate
			2010	AQC	Mercury	Statewide mercury (2008)		
Root River	-527	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat	Nitrate
			2010		Turbidity			

Waterbody Name	**WID 07040008-xxx**	**Use Class**	**Year added to IWL**	**Use affected**	**Impaired water listing**	**TMDLs approved (Year)**	**Confirmed stressor(s) not yet addressed**	**Remaining inconclusive stressors and notes**
			2010	AQC	Mercury	Statewide mercury (2008)		
Middle Branch Root River	-528	2Bg	2004	AQC	Mercury	Statewide mercury (2008)		
Middle Branch Root River	-506	2Bg	2002	AQC	Mercury	Statewide mercury (2008)		
			2012	AQR	*E. coli*	*E. coli* (2017)		
Upper Bear Creek	-540	2Ag	2012	AQL	Fish	Nitrate (2022) TSS (2022)	Physical habitat	Temperature Physical Connectivity
					Macroinvertebrate			
Bear Creek	-542	2Ag	2012	AQR	*E. coli*	*E. coli* (2017)		
Spring Valley Creek	-548	2Ag	2012	AQL	Fish	Nitrate (2022) TSS (2022)	Physical habitat Temperature	DO
					Macroinvertebrate			
				AQR	*E. coli*	*E. coli* (2017)		
North Branch Root River	-716	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat	Nitrate
			2008		Turbidity			
North Branch Root River	-717	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat DO	Nitrate
			2008		Turbidity			
South Branch Root River	-550	2Ag	2012	AQR	*E. coli*	*E. coli* (2017)		
Watson Creek	-552	2Ag	2010	DW	Nitrate	Nitrate (2017)		
			2012	AQR	*E. coli*	*E. coli* (2017)		

Waterbody Name	WID 07040008-xxx	Use Class	Year added to IWL	Use affected	Impaired water listing	TMDLs approved (Year)	Confirmed stressor(s) not yet addressed	Remaining inconclusive stressors and notes
				AQL	Fish	TSS (2017) Nitrate (2017)	Physical habitat Temperature	
					Macroinvertebrate			
South Branch Root River	-556	2Ag	2006	AQL	Turbidity	TSS (2017)		
Camp Creek	-559	2Ag	2012	AQL	Fish	TSS (2022)	Physical habitat, Nitrate, Temperature	DO
					Macroinvertebrate			
South Fork Root River	-508	2Bg	2012	AQL	Macroinvertebrate	TSS 2017	Physical habitat Nitrate	
					Turbidity			
			2010	AQC	Mercury	Statewide mercury (2008)		
			2012	AQR	*E. coli*	*E. coli* (2017)		
South Fork Root River	-509	2Bg	2012	AQL	Macroinvertebrate	TSS 2017	Physical habitat	Nitrate
			2010	AQC	Mercury	Statewide mercury (2008)		
South Fork. Root River	-573	2Bg	2012	AQL	Macroinvertebrate	TSS (2017)	Physical habitat Nitrate DO	Temperature
					Turbidity			
			2010	AQC	Mercury	Statewide mercury (2008)		
Canfield Creek	-557	2Ag	2010	DW	Nitrate	Nitrate (2017)		
Deer Creek	-546	2Bg	2012	AQR	*E. coli*	*E. coli* (2017)		

Waterbody Name	WID 07040008-xxx	Use Class	Year added to IWL	Use affected	Impaired water listing	TMDLs approved (Year)	Confirmed stressor(s) not yet addressed	Remaining inconclusive stressors and notes
Robinson Creek	-503	2Bg	1994	AQR	Fecal coliform	Fecal coliform (2006)		
Root River, Middle Branch	-530	2Bg	2004	AQC	Mercury	Statewide mercury (2008)		
Root River, Middle Branch	-532	2Bg	2004	AQC	Mercury	Statewide mercury (2008)		
Root River, Middle Branch	-B95	2Bg	2002	AQC	Mercury	Statewide mercury (2008)		
Root River, Middle Branch	-B96	2Bg	2002	AQC	Mercury	Statewide mercury (2008)		
Root River, Middle Branch (Deer Creek)	-545	2Bdg	2006	AQC	Mercury	Statewide mercury (2008)		
North Branch Root River	-535	2Bg	2012	AQR	*E. coli*	*E. coli* (2017)		
South Branch Root River	-554	2Ag	2006	AQL	Turbidity	TSS (2017)		
South Branch Root River	-555	2Ag	2004	AQL	Turbidity	TSS (2017)		
				AQR	Fecal coliform	Fecal coliform (2006)		
			2010	DW	Nitrate	Nitrate (2017)		
South Branch Root River	-H18	2Bg	2004	AQR	Fecal coliform	Fecal coliform (2006)		

Waterbody Name	WID 07040008-xxx	Use Class	Year added to IWL	Use affected	Impaired water listing	TMDLs approved (Year)	Confirmed stressor(s) not yet addressed	Remaining inconclusive stressors and notes
South Branch Root River	-H19	2Bg	2004	AQR	Fecal coliform	Fecal coliform (2006)		
South Fork Root River	-572	2Bg	2010	AQC	Mercury	Statewide mercury (2008)		
Rush Creek	-523	2Ag	2012	AQR	*E. coli*	*E. coli* (2017)		
Thompson Creek	-507	2Ag	2012	AQR	*E. coli*	*E. coli* (2017)		
Trout Run Creek	-G88	2Ag	2012	AQR	*E. coli*	*E. coli* (2017)		

Appendix B. Groundwater resources

The following groundwater technical reports, proceedings, journal articles, and databases relevant to the Root River Watershed have been recently published through collaborative efforts between state agencies and other partners:

Barry, J.D., Runkel, A.C., Alexander, E.C., (2023), Synthesizing multifaceted characterization techniques to refine a conceptual model of groundwater sources to springs in valley settings (Minnesota, USA). Hydrogeology Journal 31, 707-729.

Runkel AC, Tipping RG, Meyer JR, Steenberg JR, Retzler AJ, Parker BL, Green JA, Barry JD, Jones PM (2018) A multidisciplinary based conceptual model of a fractured sedimentary bedrock aquitard–improved prediction of aquitard integrity. Hydrogeology Journal 26(7):2133–2159.

Springshed Assessment Methods for Paleozoic Bedrock Springs of Southeastern Minnesota: Report of Methods (PDF).

16th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst (2020). Combining high resolution spring monitoring, dye tracing, watershed analysis, and outcrop and borehole observations to characterize the Galena Karst, Southeast Minnesota, USA.

15th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst (2018): Coupling Dye Tracing, Water Chemistry, and Passive Geophysics to Characterize a Siliciclastic Pseudokarst Aquifer, Southeastern Minnesota.

Runkel AC, Steenberg JR, Tipping RG, Retzler AJ (2014) Geologic controls on groundwater and surface water flow in southeastern Minnesota and its impact on nitrate concentrations in streams. Minnesota Geological Survey Open File Report 14-2, 70 pp.

Luhmann AJ (2011) Water temperature as a tracer in karst aquifers. PhD Thesis, University of Minnesota, Minneapolis, MN, 164 pp.

Databases:

MGS (Minnesota Geological Survey) and MDH (Minnesota Department of Health), 2022, County Well Index Database – Accessed through Minnesota Geospatial Commons.

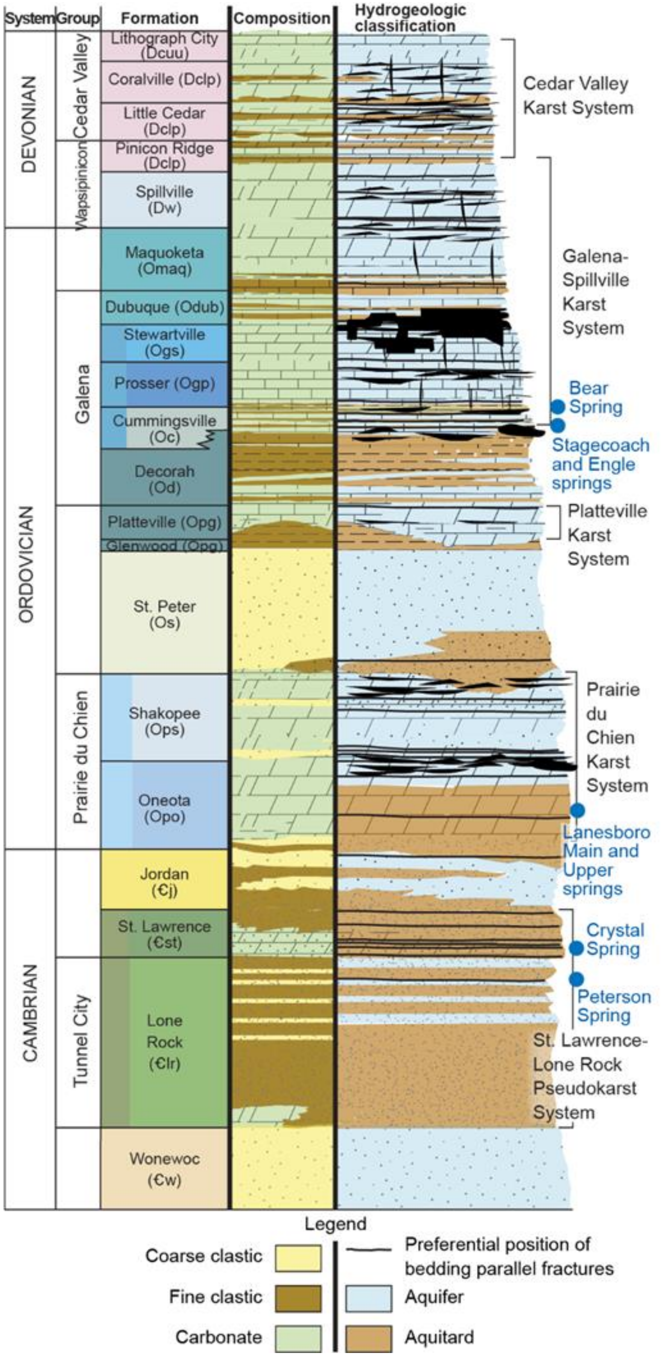
DNR (Minnesota Department of Natural Resources), 2022, Minnesota Groundwater Tracing Database: Minnesota Department of Natural Resources, Groundwater Atlas Program.

DNR (Minnesota Department of Natural Resources), 2021, County groundwater atlas water chemistry database. Available from: https://www.dnr.state.mn.us/waters/groundwater_section/mapping/chemdataaccess.html.

Appendix C. Additional Sentinel Springs Information

Springs emanating from Paleozoic aquifers in southeastern Minnesota provide perennial discharge to the many cold-water streams of the area. The position of a spring in the landscape, the aquifer it emanates from, the number of aquitards between it and the land surface, and its surrounding land use can all affect its water quality.

Figure A-1. Geologic and generalized hydrogeologic attributes of Devonian and Ordovician rocks in southeast Minnesota. Modified from Runkel et al., 2014.



A stratigraphic column for southeastern Minnesota (Figure A-1) combines lithostratigraphic and generalized hydrostratigraphic properties (modified from Runkel et al., 2014). Hydrostratigraphic attributes are generalized into aquifer or aquitard based on relative permeability, where aquifers are permeable and easily transmit water through conduits, fractures, or porous media and aquitards have lower vertical permeability that limits vertical flow. The horizontal hydraulic conductivity of the aquitards is, however, commonly comparable to that of the aquifers because of the presence of bed parallel partings and void networks that yield significant quantities of water (Runkel et al., 2018). The blue dots represent the stratigraphic positions of springs described below.

Each of the springs highlighted in this Appendix emanates from karst or pseudokarst. Karst is a terrain with distinctive landforms and hydrology created primarily from the dissolution of soluble rocks. It is characterized by sinkholes, caves, springs, and underground drainage dominated by rapid conduit flow. In karst, water dissolves fractures and joints in the bedrock forming a network of interconnected underground conduits that can carry groundwater long distances at speeds up to miles per day. Sinkholes, blind valleys, karst windows, and springs are found on the land surface above underground karst systems and are thought of as surface expressions of karst or "karst topography." Karst also occurs in areas with few or none of these land surface features and therefore the absence of these features does not imply the absence of karst.

A hydrogeologic framework that describes four prominent karst systems for southeastern Minnesota (Runkel et al., 2014) is based largely on work from Alexander and Lively (1995), Alexander et al. (1996), and Green et al. (1997, 2002). The systems described in the framework include the Devonian Cedar Valley Karst, the Upper Ordovician Galena-Spillville Karst, the Upper Ordovician Platteville Karst, and the Lower Ordovician Prairie du Chien Karst. An additional rapid conduit flow system in siliciclastic rocks of the Upper Cambrian is referred to as the St. Lawrence-Lone Rock Pseudokarst System (Barry et al. 2015; 2018b). Pseudokarst has hydrologic similarities to karst, however it is not formed through dissolution.

Flow in the shallowest part of the bedrock groundwater system is characterized by a large volume of water that moves rapidly through bedrock secondary pore networks that intimately connect surface waters to groundwater (Alexander et al., 1996; Alexander and Lively, 1995; Runkel et al., 2003; Green et al., 2002, 2012; Tipping et al., 2006; Runkel et al., 2006a, b; Luhmann et al., 2011; Barry et al., 2015, 2018a, 2019, 2020; Barry, 2021). Dye traces and water table potentiometric maps indicate that much of recharge moves laterally in variable directions, locally crosses surface water divides, and ultimately discharges as baseflow to streams in nearby incised valleys. Deeper, confined aquifers ultimately discharge to the Mississippi River and its tributaries (Delin and Woodward, 1984).

The summaries below describe the hydrostratigraphic position of springs in the Sentinel Springs network, nearby land-use, nitrate concentration variability, and additional information. Springs are arranged in hydrostratigraphic order, from springs in the Ordovician Galena Group to springs in the Cambrian section.

Bear Spring (55A0000406) is located outside of the Root River Watershed (RRW) in the Zumbro River Watershed but is included as it is an intensely monitored spring. Bear Spring is located west-southwest of Eyota, Minnesota in a rural area dominated by agriculture. Bear Spring emanates from a bedding plane parting in carbonate bedrock at the stratigraphic position of the Prosser and Cummingsville contact. A major transportation corridor, Interstate 90, is located approximately 1.5 miles to the south. Sinkholes are common in the vicinity. Dye tracing and intensive monitoring began in 2015, with additional work continuing through Spring 2023.

Table A-1. Bear Spring nitrate-N data (2018 - 2022).

	2016	2017	2018	2019	2020	2021	2022	Total
N (15-min intervals)	NA	NA	16,844	31,293	33,731	25,562	26,909	134,339
Minimum (mg/L)	NA	NA	0.94	4.76	5.81	7.67	3.81	0.94
Maximum (mg/L)	NA	NA	33.96	23.62	17.84	19.77	19.7	33.96
Average (mg/L)	NA	NA	20.70	18.62	16.06	16.04	16.08	17.23
Standard Deviation (mg/L)	NA	NA	1.93	2.30	0.99	1.67	2.17	2.49

Note: 2018 is not a full year of data.

Stagecoach Spring (23A0000004) is a perennial spring that emanates from bedding planes in the middle portion of the Cummingsville Formation of the Galena Group (Steenberg and Runkel 2018) and forms the headwaters to Watson Creek. Stagecoach Spring is located east-southeast of Wykoff, Minnesota in a rural area dominated by agriculture (in the Watson Creek HUC12). This spring has a long history of dye tracing and water quality sampling going back to the 1970's. The estimated springshed of Stagecoach is well defined, but additional work could help resolve extent and the location of groundwater divides in the area.

Table A-2. Stagecoach Spring nitrate-N data (2018 - 2021).

	2016	2017	2018	2019	2020	2021	Total
N (15-min intervals)	NA	NA	15,650	29,391	29,466	14,727	89,234
Minimum (mg/L)	NA	NA	5.9	3.3	8.8	4.65	3.3
Maximum (mg/L)	NA	NA	13.98	13.35	13.18	15.9	15.9
Average (mg/L)	NA	NA	13.09	11.93	12.36	11.26	12.16
Standard Deviation (mg/L)	NA	NA	0.97	1.43	0.75	1.36	1.29

Note: 2018 and 2021 are not full years of data.

Engle Spring (23A0000023) is a perennial spring that emanates from bedding planes in the middle portion of the Cummingsville Formation of the Galena Group (Steenberg and Runkel, 2018). Engle Spring is located west of Harmony, Minnesota in a rural area dominated by agriculture (in the Willow Creek HUC12). Dye tracing at Engle Spring began in the early 1990's and was aggressively re-started in 2018 following installation of continuous data collection of spring level, temperature, and nitrate

Table A-3. Engle Spring nitrate-N data (2016 - 2021).

	2016	2017	2018	2019	2020	2021	Total
N (15-min intervals)	NA	3,148	14,880	26,551	29,262	34,658	108,499
Minimum (mg/L)	NA	9.75	3.15	1.11	5.4	4.51	1.11
Maximum (mg/L)	NA	11.14	19.47	11.0	13.22	9.92	19.47
Average (mg/L)	NA	10.74	10.04	9.40	9.44	8.8	9.35
Standard Deviation (mg/L)	NA	0.35	1.68	1.49	0.28	0.54	1.12

Note: 2017 is not a full year of data.

Lanesboro State Fish Hatchery (springs 23A0000098 and 23A0000099) are perennial springs that emanate from the Oneota Dolomite (Steenberg and Runkel, 2018). The Lanesboro State Fish Hatchery is located west/southwest of Lanesboro, Minnesota in a rural area dominated by agriculture (in the Duschee Creek HUC12). Dye tracing and hydrogeologic investigations such as continuous temperature and nitrate monitoring in the vicinity of the Lanesboro Hatchery have been conducted since the 1990's in support of springshed mapping and water resource management. A recent report (Barry et al., 2023) combines previous investigations, the results of unpublished monitoring data, newly acquired dye tracing, and new targeted geochemical sampling to estimate residence times and to define and quantify the proportions of two different groundwater sources to the Lanesboro State Fish Hatchery.

Table A-4. Lanesboro Fish Hatchery nitrate-N data (2012 - 2018).

	2012	2013	2014	2015	2016	2017	2018	Total
N (15-min intervals)	19,126	34,528	25,275	29,246	32,765	33,735	10,301	184,976
Minimum (mg/L)	6.0	5.86	6.04	6.15	6.1	6.9	6.94	5.86
Maximum (mg/L)	6.1	6.66	6.42	6.65	7.17	7.27	7.12	7.27
Average (mg/L)	6.09	6.13	6.16	6.42	6.43	7.07	7.02	6.45
Standard Deviation (mg/L)	0.03	0.11	0.08	0.17	0.34	0.06	0.05	0.40

Note: 2012 and 2018 are not full years of data.

Peterson State Fish Hatchery Main Spring (23A0000114) is a perennial spring from that emanates from the uppermost Lone Rock Formation (Steenberg and Runkel, 2018). The Peterson State Fish Hatchery is located west/southwest of Rushford, Minnesota in a rural area of mixed wooded slopes and row crop agriculture (in the City of Peterson-Root River HUC12). Continuous nitrate monitoring equipment was deployed in 2023. Data summaries are forthcoming.

Crystal Spring Fish Hatchery (85A0000001) is located outside of the RRW in the Mississippi River-Winona Watershed but is included as it is an intensely monitored spring. Crystal Spring is a perennial spring from the lowermost St. Lawrence Formation near the contact with the underlying Tunnel City Group (Steenberg and Runkel, 2018). The Crystal State Fish Hatchery is located west of Altura, Minnesota in a rural area of mixed wooded slopes and row crop agriculture.

Table A-5. Crystal Springs Fish Hatchery nitrate-N data (2016 - 2021).

	2016	2017	2018	2019	2020	2021	Total
N (15-min intervals)	5232	28,095	34,819	34,277	33,735	34,884	171,042
Minimum (mg/L)	3.93	3.85	3.83	3.76	3.94	3.89	3.76
Maximum (mg/L)	4.67	4.94	4.66	4.75	4.93	4.48	4.94
Average (mg/L)	4.37	4.43	4.19	4.21	4.25	4.19	4.25
Standard Deviation (mg/L)	0.26	0.27	0.22	0.24	0.20	0.15	0.23

Note: 2016 is not a full year of data.

Appendix D. Subwatershed descriptions

Note – map figures referred to in this appendix are found in Appendix E.

North Fork Bear Creek

The map (Figure A-2) depicts North Fork Bear Creek Subwatershed location which is in the western headwaters of the Root River HUC-8 in the northeast corner of Mower County, Minnesota. WID 07040008-F45 is listed as impaired for macroinvertebrate index of biotic integrity. Water quality concerns related to this impairment are stream channelization and inadequate stream flow. The North Fork Bear Creek Subwatershed is 16.36 square miles and 82% of the area is under row crop (corn/soybean) agriculture. Based on Winona State University's BMP mapping project, 2% of this subwatershed is treated by structural BMPs. The map also depicts dense agricultural drainage tile, which is estimated by presence of poorly drained soils. Also depicted are altered watercourses, which are streams not reflecting natural features and function like drainage ditches. Approximately half of the streams in the North Fork Bear Creek Subwatershed are altered.

South Fork Bear Creek map description

The map (Figure A-3) depicts South Fork Bear Creek Subwatershed location, which is in the western headwaters of the Root River HUC-8 in the northeast corner of Mower County, Minnesota. This subwatershed is located just south of North Fork Bear Creek and shares a watershed boundary. The subwatershed map depicts WID 07040008-544 as listed as impaired for macroinvertebrate index of biotic integrity. Water quality concerns related to this impairment are inadequate aquatic habitat and altered watercourses. Stressors to macroinvertebrates are aquatic habitat; TSS and nitrate are inconclusive stressors. The South Fork Bear Creek Subwatershed is 20.48 square miles and 82% of the area is under row crop (corn/soybean) agriculture. Based on Winona State University's BMP mapping project, 3% of this subwatershed is treated by structural BMPs. The map also depicts dense agricultural drainage tile which is estimated by presence of poorly drained soils. Also depicted are altered watercourses which are streams not reflecting natural features and function like drainage ditches. The 11 small tributaries to the South Fork Break Creek are all identified as altered.

Spring Valley Creek

The map (Figure A-4) depicts Spring Valley Creek Subwatershed location, which is in the western headwaters of the Root River HUC-8 in east central Mower County flowing east into western Fillmore County. The subwatershed map depicts waterbody IDs 07040008-D53 and 07040008-548 as listed as impaired. 07040008-D53 is impaired for nitrate. 07040008-548 is impaired for macroinvertebrate index of biotic integrity, fishes index of biotic integrity, TSS, *E. coli* and nitrate. Water quality concerns related to these impairments are nitrate, TSS and *E. coli*. Stressors to fish and macroinvertebrates are nitrate, TSS, aquatic habitat and temperature. Dissolved oxygen is an inconclusive stressor. NPDES-permitted facilities are identified throughout the subwatershed and includes Spring Valley WWTP (Municipal Wastewater #MN0051934), Prairie Farms Dairy (Industrial stormwater permit #MNRNE387Y), and three construction stormwater sites (C00055240, C00055489, C00059242). The Spring Valley Creek Subwatershed is 30.16 square miles and 65% of the area is under row crop (corn/soybean) agriculture.

Based on Winona State University's BMP mapping project, 26% of this subwatershed is treated by structural BMPs. The map also depicts dense agricultural drainage tile which is estimated by presence of poorly drained soils. Also depicted are altered watercourses, which are streams not reflecting natural features and function like drainage ditches. There are four small tributaries to Spring Valley Creek identified as altered.

Headwaters of South Branch Root River

The map (Figure A-8) depicts Headwaters of South Branch Root River Subwatershed location, which is in the southwestern headwaters of the Root River HUC-8 in southeast Mower County flowing east into southwest Fillmore County. The subwatershed map depicts waterbody IDs 07040008-561, 07040008-H19 and 07040008-H18 as listed as impaired. 07040008-561 is impaired for macroinvertebrate index of biotic integrity. 07040008-H19 is impaired for fecal coliform bacteria. 07040008-H18 is impaired for macroinvertebrate index of biotic integrity and fecal coliform bacteria. Water quality concerns related to these impairments are nitrate, bacteria, low stream flow and lack of aquatic habitat. Stressors to macroinvertebrates are nitrate, DO, habitat and flow alteration. NPDES-permitted facilities are identified throughout the subwatershed and includes Ostrander WWTP (municipal wastewater #MN0024449) and Ironwood Sanitary Landfill (Industrial stormwater #MNRNE3BX4). The Headwaters of South Branch Root River Subwatershed is 45 square miles and 83% of the area is under row crop (corn/soybean) agriculture. Based on Winona State University's BMP mapping project, 39% of this subwatershed is treated by structural BMPs. The map also depicts dense agricultural drainage tile, which is estimated by presence of poorly drained soils. Also depicted are altered watercourses which are streams not reflecting natural features and function like drainage ditches. Six short tributaries to the South Branch Root River and the first four miles of the South Branch Root River are identified as altered.

Upper Money Creek

The map (Figure A-11) depicts Upper Money Creek Subwatershed location, which is in the northeast headwaters of the Root River HUC-8 in south central Winona County, Minnesota. The subwatershed map depicts WID 07040008-521 as listed as impaired for TSS and fecal coliform bacteria. Water quality concerns related to these impairments are TSS and bacteria. Because there are no aquatic life impairments, there are no stressors listed for fish or macroinvertebrates. The Upper Money Creek Subwatershed is 38.38 square miles and 24% of the area is under row crop (corn/soybean) agriculture. The most dominant land use in the Upper Money Creek Subwatershed is forest (43% of the total area). Based on Winona State University's BMP mapping project, 3% of this subwatershed is treated by structural BMPs. The map also depicts altered watercourses which are streams not reflecting natural features and function like drainage ditches. Six small tributaries to Upper Money Creek are identified as altered. A majority of waters in the subwatershed are natural.

Mill Creek

The map (Figure A-14) depicts Mill Creek Subwatershed location, which is in the north central headwaters of the Root River HUC-8 in southeast Olmsted County. The subwatershed map depicts WIDs 07040008-A47 and 07040008-536 listed as impaired. 07040008-A47 is impaired for nitrate. 07040008-536 is impaired for macroinvertebrate index of biotic integrity, fish index of biotic integrity, nitrate and *E. coli*. Water quality concerns related to these impairments are nitrate, TSS, *E. coli*, stream flow and aquatic habitat. Stressors to fish and macroinvertebrates are temperature, habitat, stream flow, TSS and nitrate. NPDES-permitted facilities are identified throughout the subwatershed and includes Bill Funk Trucking (Industrial stormwater #MNR053CCT), Griffin Quarry (Non-metallic mining #MNRNE3F7T) and six construction stormwater sties (C00051295, C00052846, C00055251, C00055358, C00057427, C00062255). The Mill Creek Subwatershed is 32 square miles and 46% of the area is under row crop (corn/soybean) agriculture. Based on Winona State University's BMP mapping project, 4% of this subwatershed is treated by structural BMPs. The map also depicts altered watercourses which are streams not reflecting natural features and function like drainage ditches. Judging by the map, an estimated 30% of streams are altered in the Mill Creek Subwatershed.

Carey Creek

The map (Figure A-18) depicts Carey Creek Subwatershed location, which is in the western portion of the Root River HUC-8 in northeast Mower County flowing northeast into south central Olmsted County. The subwatershed map depicts several WIDs, but none are listed as impaired. The water quality concern for Carey Creek is that protection is needed to prevent future TSS impairment and impacts from altered hydrology. The Carey Creek Subwatershed is 32 square miles and 79% of the area is under row crop (corn/soybean) agriculture. Based on Winona State University's BMP mapping project, 1.5% of this subwatershed is treated by structural BMPs. The map depicts dense agricultural drainage tile, which is estimated by presence of poorly drained soils. The map also depicts altered watercourses, which are streams not reflecting natural features and function like drainage ditches. According to the map, roughly 40% of the streams are altered in this subwatershed; mostly tributaries to Carey Creek.

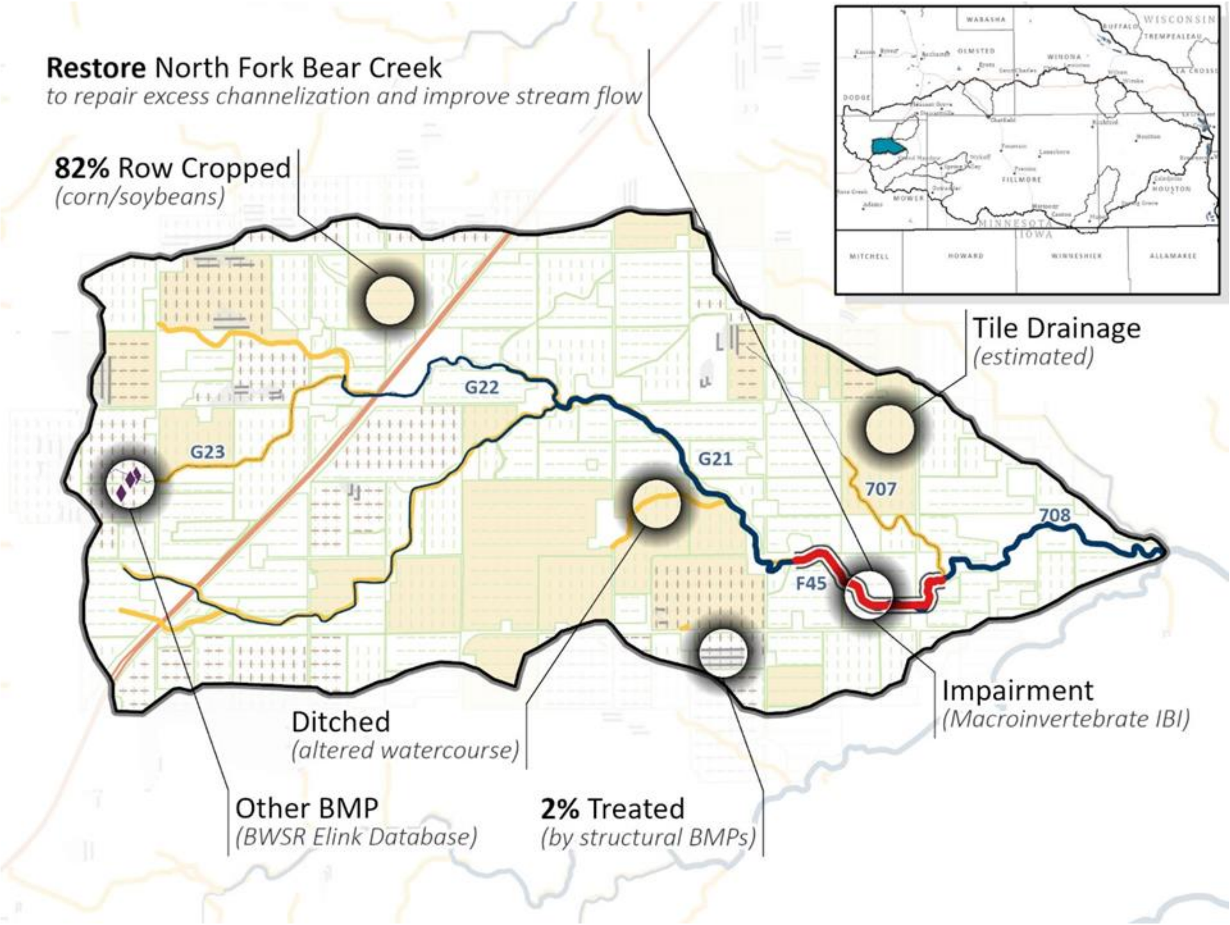
Riceford Creek

The map (Figure A-19) depicts Riceford Creek Subwatershed location, which is in the southeast headwaters of the Root River HUC-8 in southeast Fillmore County flowing northeast into southwest Houston County. The subwatershed map depicts waterbody IDs 07040008-H01 and 07040008-518 as listed as impaired. Both WIDs are impaired for macroinvertebrate index of biotic integrity. Water quality concerns related to these impairments are nitrate, TSS, habitat and flow alteration. Stressors to macroinvertebrates are nitrate, TSS, habitat and flow alteration. NPDES-permitted facilities are identified throughout the subwatershed and includes a single permitted facility Gjere Construction, Inc: (non-metallic mine #MNG490391) which is gravel quarry. The Riceford Creek Subwatershed is 21 square miles and 56% of the area is under row crop (corn/soybean) agriculture. Based on Winona State University's BMP mapping project, 10% of this subwatershed is treated by structural BMPs. The map also depicts altered watercourses which are streams not reflecting natural features and function like drainage ditches. Most of the streams in the Riceford Creek Subwatershed are natural, but altered waters exist in the most headwaters portion of this subwatershed.

Appendix E. Pollutant Source Assessment

North Fork Bear Creek

Figure A-2. Overview of North Fork Bear Creek Subwatershed.



Water quality

Streams in the North Fork Bear Creek are mostly channelized ditches and have highly altered hydrology from agricultural drainage tile. Stream section (-F45) is currently listed as impaired for macroinvertebrates. Limited habitat and very slow flows are likely impacting the macroinvertebrate community, but SID has yet to be conducted. The fish community is meeting aquatic life standards at this time.

Stressors to habitat and stream flow

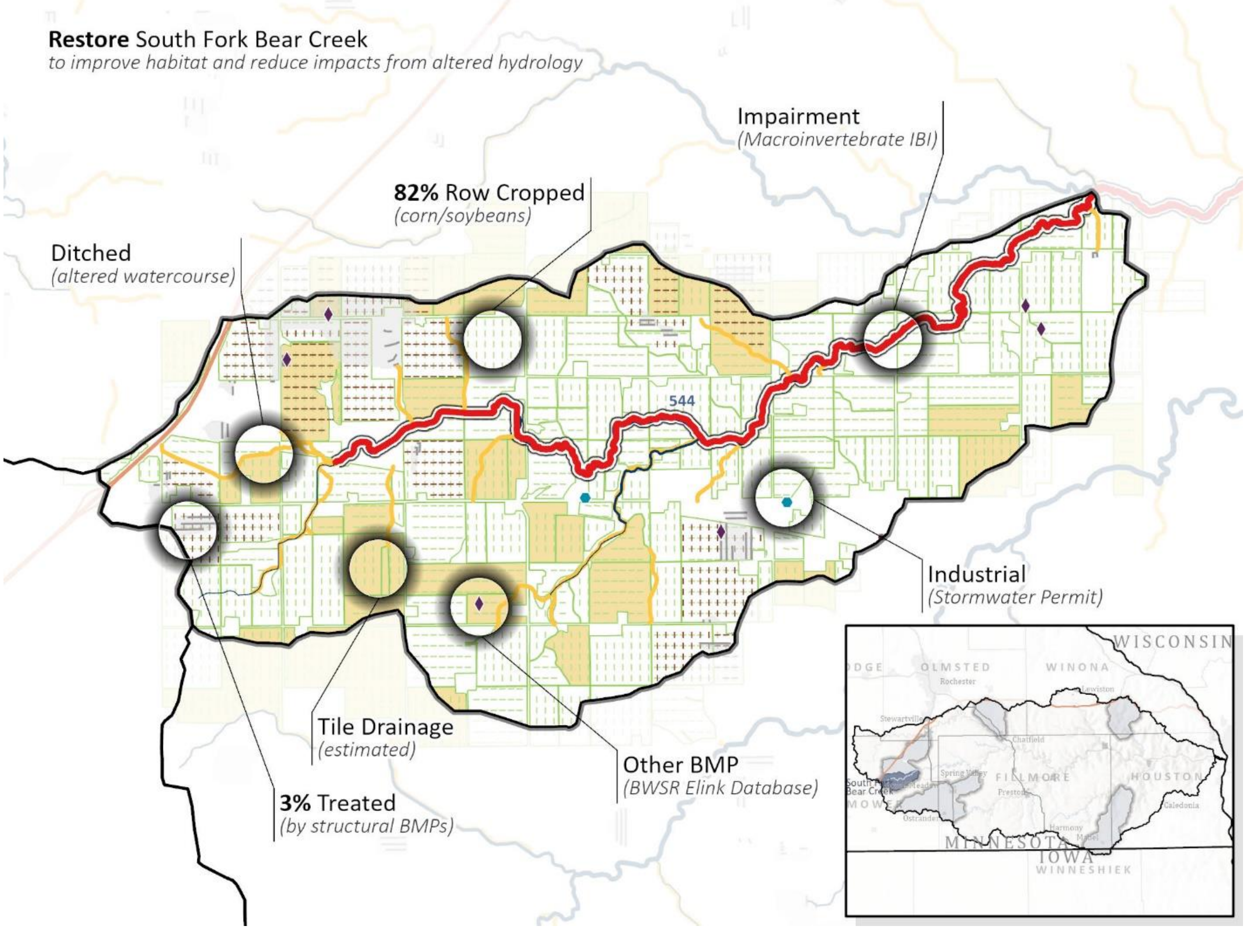
Nonpoint sources are driving water quality issues in this area since there are currently no NPDES-permitted point sources in the North Fork Bear Creek Subwatershed. While SID for macroinvertebrates has yet to be conducted, it is likely that limited aquatic habitat and lack of flow are impacting the macroinvertebrate community. There are no actively permitted groundwater users in this subwatershed, but one historic water user reported using 46.6 million gallons per year is now inactive (permit 1976-5105 for crop irrigation). Additional investigation is needed to determine the density of agricultural drainage tile and how it may be impacting the hydrology of North Fork Bear Creek. It is common for altered watercourses to have inadequate aquatic habitat because of the lack of course substrate and incised streambanks. Strategies to help address limited habitat and low stream flow are identified in Section 8 of the WRAPS Update Report.

Table A-6. Pollutant source priority summary for North Fork Bear Creek.

	Nitrate	Sediment	Habitat	Stream flow	Bacteria
Point source(s)	-	-	-	-	-
In-channel/bank	-	-	Medium	Medium	-
Cropland	-	-	Medium	Medium	-
Feedlots	-	-	-	-	-
SSTS	-	-	-	-	-
Altered hydrology (ditching, drain tile and channelization)	-	-	High	High	-

South Fork Bear Creek

Figure A-3. Overview of South Fork Bear Creek Subwatershed.



Water quality

Similar to the neighboring North Fork Bear Creek, South Fork Bear Creek Subwatershed drainage is made up of altered water channels, particularly in the headwaters. Stream section (-544) is listed as impaired for macroinvertebrates. The fish community is currently meeting but close to becoming impaired. SID conducted in Cycle 1 found that habitat is a stressor to the macroinvertebrate community. Pollutants (TSS and nitrate) have not been identified as conclusive stressors and this subwatershed was not re-visited for SID in Cycle 2.

Stressors to habitat

Permitted sources:

Three NPDES-permitted facilities exist in the subwatershed (Table A-7). Even though pollutant stressors have not been explicitly identified, it is reasonable to identify potential pollutant sources if TSS or nitrate become identified stressors in the future.

Table A-7. NPDES permitted facilities in the South Fork Bear Creek Subwatershed.

NPDES permit type	Facility Name	Permit number	Facility activity	Pollution potential
Construction stormwater	Pheasant Run Third Subdivision	C00024151	Construction over 1 acre	Low – TSS BMPs are in place during construction.
Construction stormwater	SEMA Equipment	C00049638	Construction over 1 acre	Low – TSS BMPs are in place during construction.
Industrial stormwater	Valley Transportation Service, Inc.	MNRNE3CR7	Trucking	None – no stormwater exposure

Two construction stormwater sites are permitted in the subwatershed due to their size of one or more acres. These sites are required to have structural BMPs in place to reduce sedimentation from the construction site. Because of this requirement, construction stormwater sites are not considered a significant source of TSS.

Valley Transportation Service, Inc. is an NPDES/SDS permitted industrial stormwater site. Industrial stormwater facilities can have industrial materials or activities that can come into contact with stormwater discharge. This site; however, has a “no exposure” certification, which means this site does not have any materials or activities that come into contact with stormwater.

No active permitted water uses are documented in the South Fork Bear Subwatershed, so it is likely that water use is not impacting the amount of water available. Additional investigation is needed to determine the presence of agricultural drainage tile because it is likely impacting the amount of water stored on the landscape and therefore available to the South Fork Bear Creek.

Unpermitted sources:

Even though pollutant stressors have not been explicitly identified, it is reasonable to identify potential pollutant sources if TSS or nitrate become identified stressors in the future. HSPF modeling is used to provide lines of evidence for potential non-point sources of TSS and nitrate loading (Table A-8 and Table A-9 respectively). Of all land uses modelled in the South Fork Bear Creek Subwatershed, agricultural/row cropped acres are estimated to provide the most nitrate and TSS loading to South Fork Bear Creek.

Table A-8. Average annual TSS contributions to South Fork Bear Creek by source (MPCA 2023).

Source		Average annual % of TSS load[a]
Permitted	None	0%
Nonpermitted	Cropland	74%
	In-channel	21%
	Pasture	2%
	Developed	4%
	Forest	<1%
	Open water, Wetland, Barren	0%

a. Percentages are rounded to nearest whole number and therefore may not add up to 100%.

Table A-9. Average annual TN contributions to South Fork Bear Creek by source (MPCA 2023).

Source		% of TN load [a]
Permitted	None	0%
Nonpermitted	Cropland - conventional acres	74%
	Cropland - conservation till acres	18%
	Cropland - manured acres	3%
	Pasture	2%
	Developed	2%
	Forest	<1%
	Open water, Wetland, Barren	<1%

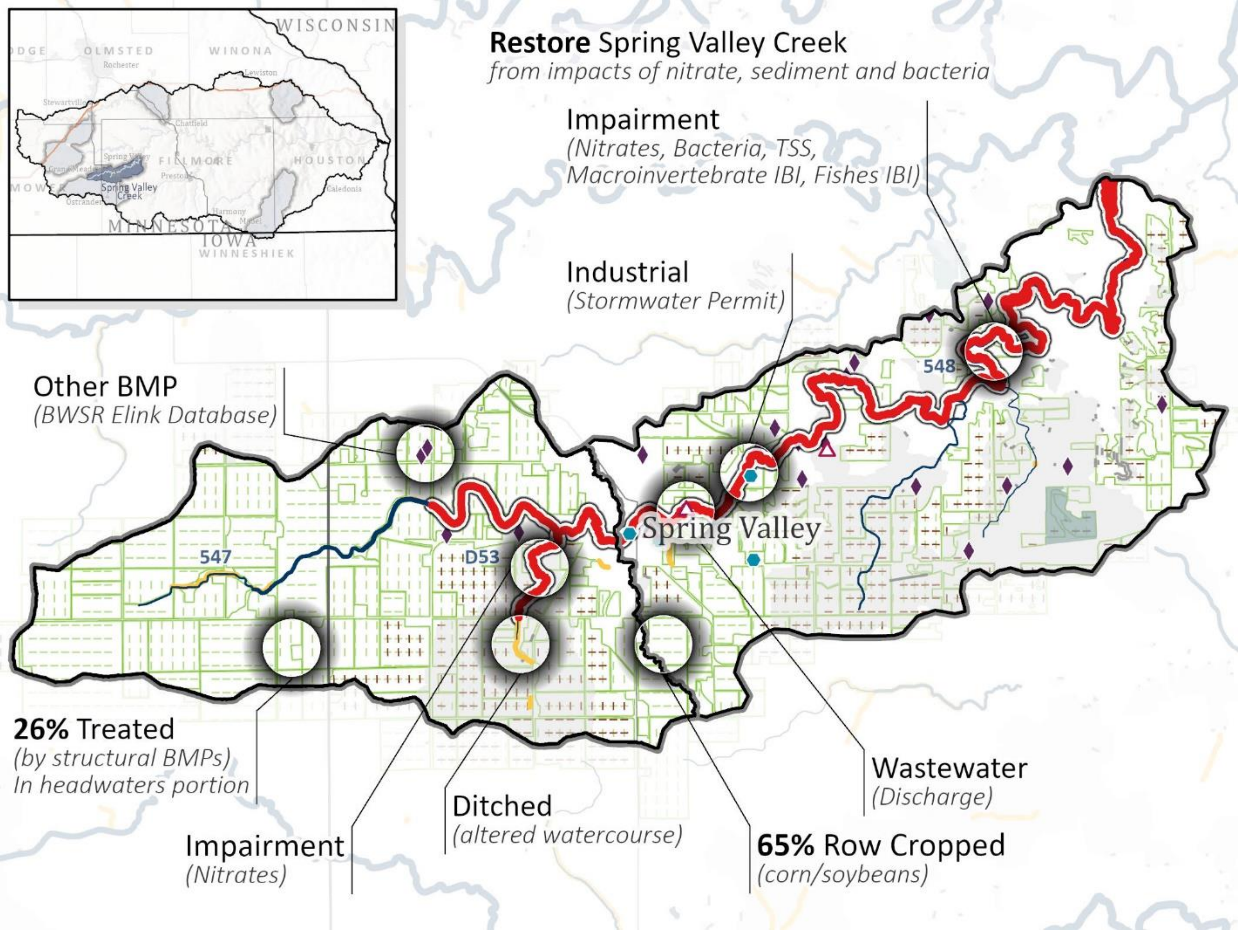
a. Percentages are rounded to nearest whole number and therefore may not add up to 100%.

Table A-10. Pollutant source priority summary for South Fork Bear Creek.

	Nitrate	Sediment	Habitat	Stream flow	Bacteria
Point source(s)	-	-	-	-	-
In-channel/bank	-	-	Medium	-	-
Cropland	-	-	Medium	-	-
Feedlots	-	-	-	-	-
SSTS	-	-	-	-	-
Altered hydrology (ditching, drain tile and channelization)	-	-	High	-	-

Spring Valley Creek

Figure A-4. Overview of Spring Valley Creek Subwatershed.



Water quality

The headwater portion of Spring Valley Creek (upstream of the town of Spring Valley) includes three WIDs: (-547), (-D53), and the upper portion of (-548). Segment (-D53) is listed as impaired for nitrate while (-548) is listed as impaired for bacteria, fish IBI, macroinvertebrate IBI, nitrate and TSS. Beyond pollutant stressors, temperature and altered hydrology are noted stressors to aquatic biology; DO/eutrophication is inconclusive (MPCA 2022).

Sediment sources

Nonpoint sources:

It has been commonly observed that the water in Spring Valley Creek becomes cloudy with sediment following a storm event and then clears in following days. This indicates that sediment inputs (as well as other pollutants not easily seen) are being mobilized from various nonpoint sources during runoff events. Two likely nonpoint sources are responsible for contributing sediment to Spring Valley Creek: row crop acreage and in-channel/stream bank erosion.

Croplands are known sources of sediment and nitrate to surface waters. The HPSF model for the Spring Valley Creek Subwatershed estimates that of all land uses in this subwatershed, agricultural acreage contributes the majority of TSS loads (Table A-11).

Table A-11. Average annual TSS contributions to Spring Valley Creek (HSFP Reach 183) by source (MPCA 2023).

Source		Average annual % of TSS load[a]
Non-permitted in-channel		37%
Permitted	Spring Valley WWTP	0.1%
Nonpermitted overland runoff	Cropland	58%
	Pasture	1%
	Developed	3%
	Forest	<1%

a. Percentages rounded to nearest whole number and therefore may not add up to 100%.

Minnesota’s Runoff Risk Advisory webpage identifies specific areas across Spring Valley Creek Subwatershed landscape as having a high stream power index (SPI). This means that there are many “conveyor belt” areas that can transport sediment (as well as nutrients/manure and pesticides) off cropland during snowmelt or storm events. Perennial vegetation in these high SPI areas (grassed waterways, prairie strips) can work to reduce pollutant transport, particularly sediment.

Sediment fingerprinting work from Belmont et al 2016 identified that streams in the North Branch HUC-10 of the RRW (including Spring Valley Creek) contribute approximately 70% of the sediment load. The MPCA field staff have noted several areas of severe bank erosion throughout Spring Valley Creek (Figure A-5).

Figure A-5. Areas of severe bank erosion on Spring Valley Creek. From left to right: (S000-769/08LM006—looking upstream, S000-769/08LM006—looking downstream and upstream of S000-772 at trail/bridge crossing).

Permitted sources:

While nonpoint sources are the dominant contributors of TSS to Spring Valley Creek, there are potential contributions coming from permitted sources (Table A-12).

Table A-12. NPDES permitted facilities in the Spring Valley Creek Subwatershed with potential TSS loading.

NPDES permit type	Facility Name	Permit number	Facility activity	Pollution potential
Industrial stormwater	Prairie Farms Dairy - Spring Valley	MNRNE387Y	Processing cheese and cheese products	None (no exposure)
Industrial stormwater (nonmetallic mining)	Croell Inc. Spring Valley (SD 008)	MNG490540	Concrete block/brick and Ready mix concrete	Low TSS – but high potential during extreme storm events.
Municipal wastewater	Spring Valley WWTP	MN0051934	Treatment of domestic waste	Low TSS

TSS loading from NPDES permitted sources is not considered significant. Spring Valley WWTP has a 30 mg/L TSS limit in effect and a weekly TSS monitoring requirement. Average effluent TSS concentrations from February 2017 to April 2022 was 4.65 mg/L. No exceedances of the 30 mg/L TSS limit have been reported within that timeframe. Croell Inc. Spring Valley quarry is required to monitor any stormwater discharge and submit monitoring information to MPCA in an annual report. The Croell Inc. Spring Valley quarry has a 65 mg/L TSS intervention limit in effect. Discharge from this facility has been reported and an exceedance of the TSS intervention limit (96 mg/L reported on November 4, 2022) was reported.

Nitrate sources

Nitrate transport in the Spring Valley Creek Subwatershed is complex. SID finds the highest nitrate concentrations (10-14 mg/L) in headwater areas of the subwatershed and decrease to 6 to 8 mg/L once downstream. It is likely that increases in downstream water inputs dilute the nitrate concentration.

Nonpoint sources:

The most common mode of nitrate transport to streams is when nitrogen inputs on cropland converts to nitrate and then vertically leaches into groundwater. This groundwater then enters surface waters through spring inflows. Nitrate can also enter surface waters through drain tiles and/or overland runoff, but those modes of transport are less significant in the Spring Valley Creek Subwatershed. The prevalence of springs and the coldwater status of Spring Valley Creek imply that groundwater is expressing a strong presence. Nitrogen inputs to cropland come in the form of commercial nitrogen fertilizer and animal manure. If these nitrogen sources convert to nitrate before plant uptake, they can easily leach through the ground and enter groundwater aquifers. Surface runoff of nitrate is also possible during a storm event, but to a lesser degree than leaching to groundwater. Springsheds outside the surface watershed may also need to be targeted for nitrogen reduction practices since springsheds can cover a much larger area than the surface area above.

The HPSF model for the Spring Valley Creek Subwatershed estimates that from all land uses agricultural acreage contributes the majority of TN loads (Table A-13).

Table A-13. Average annual TN contributions to Spring Valley Creek (HSFP Reach 183) by source (MPCA 2023).

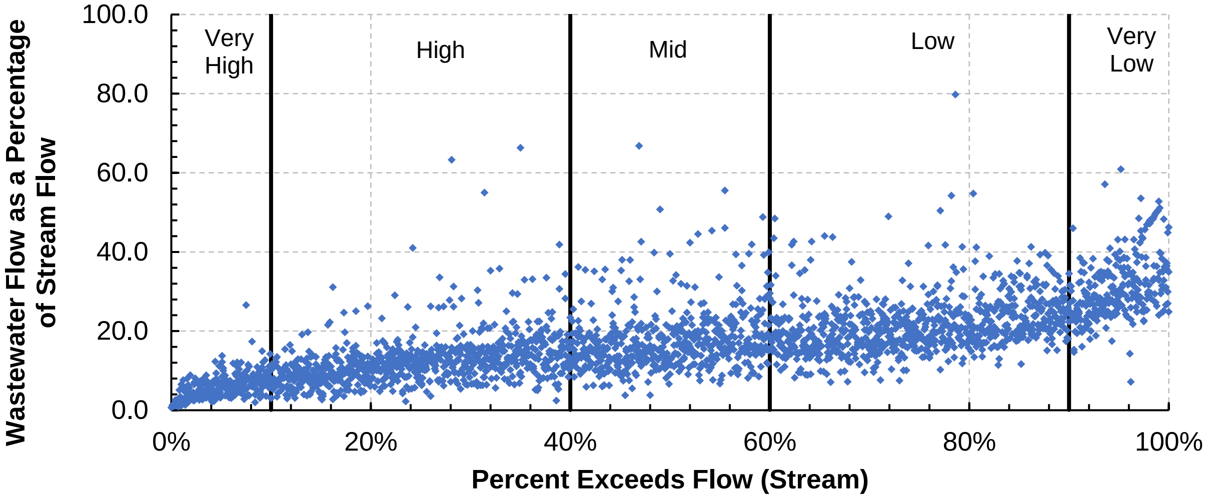
Source		Average annual TN loading (%)[a]
Permitted	Spring Valley WWTP	3%
Nonpermitted	Cropland - conventional acres	51%
	Cropland - conservation tilled acres	23%
	Cropland - manured acres	12%
	Pasture	7%
	Developed	3%
	Forest	1%
	Open Water, Wetland, Barren	<1%

a. Percentages rounded to nearest whole number and therefore may not add up to 100%.

Permitted sources:

Of all permitted sources in Spring Valley Creek Subwatershed, Spring Valley WWTP has the highest potential to contribute nitrate to Spring Valley Creek (-536). Spring Valley WWTP does not have a TN permit limit, but the next WWTP permit (expected late 2023/early 2024) will include a limit for TN. The permit will also include a schedule of compliance involving construction at the facility to address nitrate in the effluent. Average WWTP effluent nitrate concentration from March 2014 through April 2022 is 18.9 mg/L. While Spring Valley WWTP effluent has relatively high concentrations of TN, effluent typically makes up 50% or less of the stream baseflow (Figure A-6). Dilution provided by Spring Valley Creek's baseflow oftentimes buffers the in-stream concentration at the effluent discharge point to at or below the 10 mg/L nitrate drinking water standard. However, in the very rare event when stream baseflow is low and WWTP effluent makes up greater than 50% of the baseflow, the nitrogen load from the WWTP effluent pushes in-stream nitrate concentrations to exceed 10 mg/L. Because Spring Valley WWTP can be a significant source of nitrate to Spring Valley Creek, the 2023 Root River Watershed Total Maximum Daily Load (TMDL) Report includes a nitrate wasteload allocation for the WWTP. For additional discussion on Spring Valley WWTP and its pollutant potential, please see Appendix B of the TMDL (MPCA 2023a).

Figure A-6. Percentage of stream baseflow made up of Spring Valley WWTP effluent (2014 – 2022).

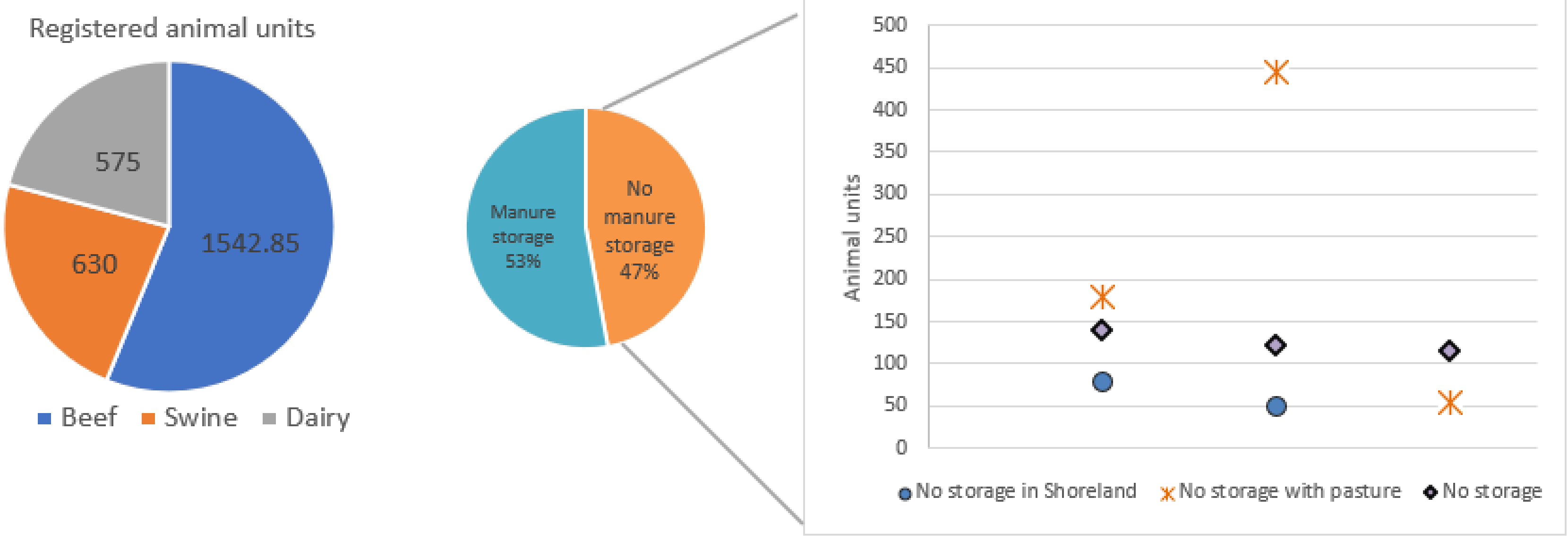


Bacteria sources

Nonpoint sources:

Similar to TSS and nitrate, nonpoint sources are largely contributing potential bacteria loads as compared to permitted sources. Animal feedlots have the potential of contributing *E. coli*, ammonia, nitrate, and phosphorus to local waters. Spring Valley Creek Subwatershed has 17 registered feedlots housing a total of 2,748 animal units (AU). This equates to 4,958 animals, primarily beef cattle. The average feedlot size is 162 AUs and no permitted CAFOs currently exist in this subwatershed. Of the 17 feedlots, about half have manure storage onsite while the other half do not. Feedlots without manure storage are primarily under 300 AUs (Figure A-7).

Figure A-7. Permitted feedlots, corresponding animal units and feedlot manure storage in Spring Valley Creek Subwatershed.



Compliance of feedlots without manure storage, particularly those in Shoreland, is needed to identify whether these facilities impacting surface waters. It is likely that most feedlots do not have chronic pollutant issues on site but could be a potential pollutant contributor when land applying manure to agricultural fields or during storm/snowmelt runoff. While pastures are components of some livestock operations, they are not considered a feedlot unless a substantial amount of the pasture cannot support perennial vegetation throughout the growing season. Winter feeding areas and cattle stream crossings are often areas needing attention to protect nearby streams from impacts of pastured livestock. In this subwatershed, the drainage area of 07040008-D51 should be targeted for improved pasture management (MPCA 2022).

The headwater areas of Spring Valley Creek span across Bennington and Frankford townships of Mower County and Spring Valley and Bloomfield townships of Fillmore County. Both counties report annual estimates of SSTS compliance to MPCA. This information is county-wide, so it is difficult to pin-point areas in the Spring Valley Creek Subwatershed that are a priority for SSTS compliance. No small communities with SSTS concerns have been reported. Because both Mower and Fillmore counties have somewhat high SSTS compliance rates (72% and 93% respectively) it is likely that SSTS is not a significant driver to the *E. coli* impairment.

Permitted sources:

While nonpoint sources are the dominant contributors of bacteria to Spring Valley Creek, there are potential contributions coming from permitted sources (Table A-14), particularly Spring Valley WWTP.

Table A-14. NPDES permitted facilities in the Spring Valley Creek Subwatershed.

NPDES permit type	Facility Name	Permit number	Facility activity	Pollution potential
Municipal wastewater	Spring Valley WWTP	MN0051934	Treatment of domestic waste	Low Fecal coliform

Sources of fecal coliform bacteria from WWTP can originate from releases or failure of treatment technology. Releases of untreated wastewater from WWTP rarely but do occur primarily due to extreme wet weather. WWTPs are required to operate and maintain their facility to minimize any releases. Releases/overflows are not approved by MPCA and the agency follows up on all overflows through investigations and, if warranted, enforcement. Spring Valley WWTP has reported two exceedances of their 200 organisms per 100 milliliter fecal coliform limit in September and October of 2016.

Temperature impacts:

Temperature is a stressor in the lower end of Spring Valley Creek (-536), near Orchard Road (monitoring station 08LM006). There are two water appropriations permitted in this subwatershed (Driftless Fish Co. LLC (2005-4105) and City of Spring Valley (1975-5069)). Combined, these users are authorized to use 430 million gallons of groundwater per year. Permitted sources are likely contributors to thermal stress observed downstream, but other factors (altered hydrology and climate) also play a significant role.

Table A-15. Pollutant source priority summary for Spring Valley Creek.

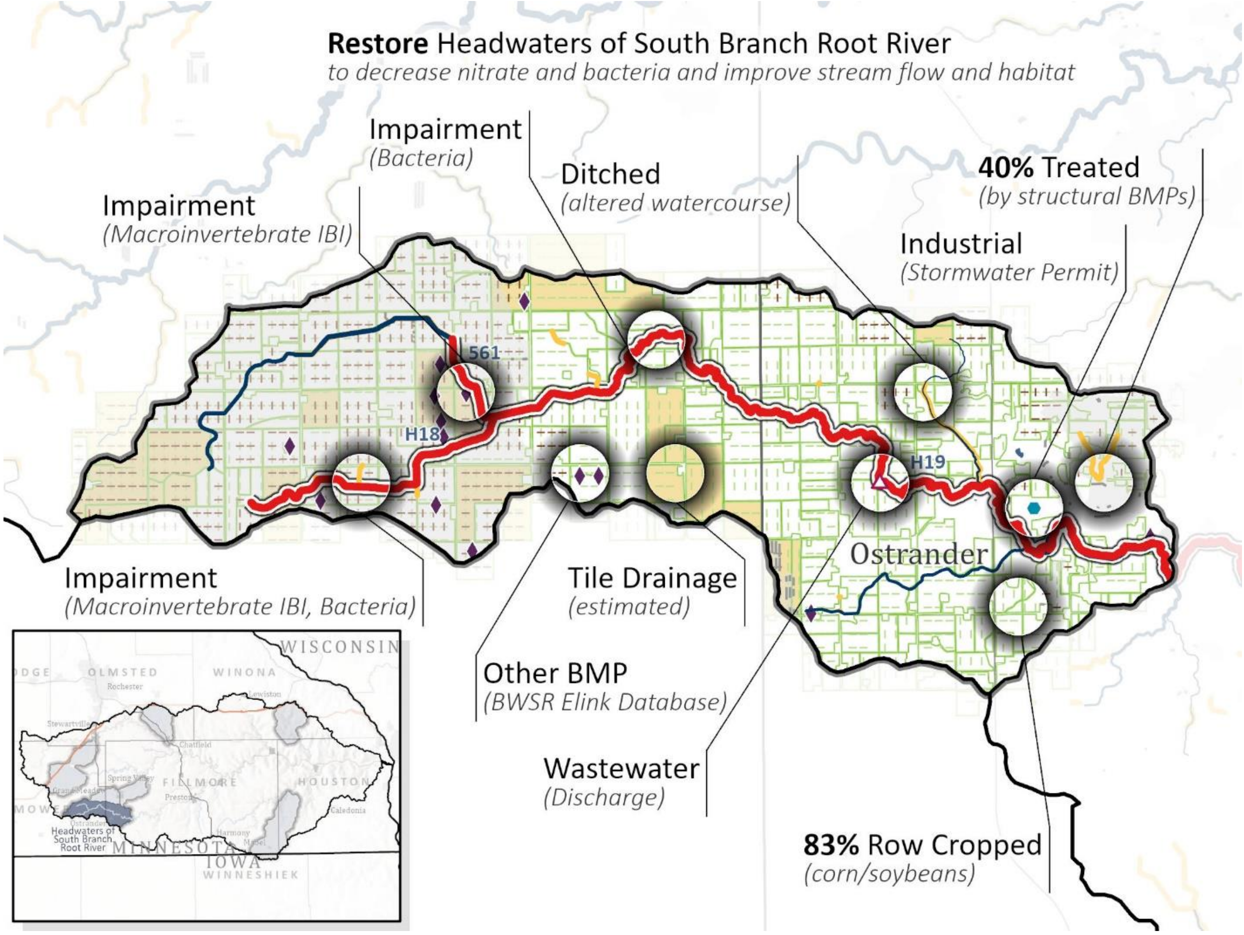
	Nitrate	Sediment	Habitat	Stream flow	Bacteria
Point source(s)	Low	-	-	-	Low
In-channel/bank	-	High	-	-	-
Cropland/manure application	High	Medium			Medium
Feedlots	-	Medium**	-	-	Low
SSTS	-	-	-	-	Low
Altered hydrology (ditching, drain tile and channelization)	-	Low	-	High*	-

*Altered hydrology is in the form of ponded springs.

** Pasture management

Headwaters of South Branch Root River

Figure A-8. Overview of Headwaters of South Branch Root River Subwatershed.



Water quality

The Headwater South Branch Root River has three assessed WIDs: (-H18), (-561) and (-H19). All WIDs have a bacteria impairment and segment (-H18) is also listed as impaired for macroinvertebrate IBI. Cycle 2 SID concluded that nitrate, DO, habitat, and flow alteration are stressors to the macroinvertebrate community. TSS is an inconclusive stressor at this time. The DO stressor is a result of the low flow conditions the South Branch Root River periodically experiences.

Nitrate sources

Nonpoint sources:

Row cropped fields are significantly contributing to the macroinvertebrate impairment of the South Branch Root River due to nitrate loading. Activities in these fields, particularly drain tile and fertilizer applications, are adding nitrogen to the river. The RRW HSPF model estimates that cropland is contributing an estimated 98% of the TN load to the subwatershed (Table A-16).

Table A-16. Average annual TN contributions to Headwater South Branch Root by source (MPCA 2023).

Source		% of TN load[a]
Permitted	Ostrander WWTP	<1%
Nonpermitted	Cropland - conventional acres	28%
	Cropland - conservation till acres	10%
	Cropland - manured acres	61%
	Pasture	1%
	Developed	1%
	Forest	<1%
	Open water, Wetland, Barren	<1%

a. Percentages rounded to nearest whole number and therefore may not add up to 100%.

The Root River Watershed SID Update Report (MPCA 2022) notes that in the South Branch Root River, nitrate is highest in late Spring (May/June) with some values greater than 20 mg/L; median ranges are between 9 to 15 mg/L. This is the time when drain tiles are flowing. RRFSP notes that at least 80% of nitrogen from agricultural fields in this subwatershed is lost through subsurface leaching and is detected as nitrate-nitrogen in tile drainage. The edge-of-field drainage tile site in South Branch Root River found that TN load at land surface was an average of 9 lbs/ac while sub-surface TN averaged 35 lbs/ac (MDA 2022).

Nitrate from permitted sources:

Due to the nature of their activity, construction and industrial stormwater facilities in this subwatershed are not considered significant sources of nitrate (Table A-17).

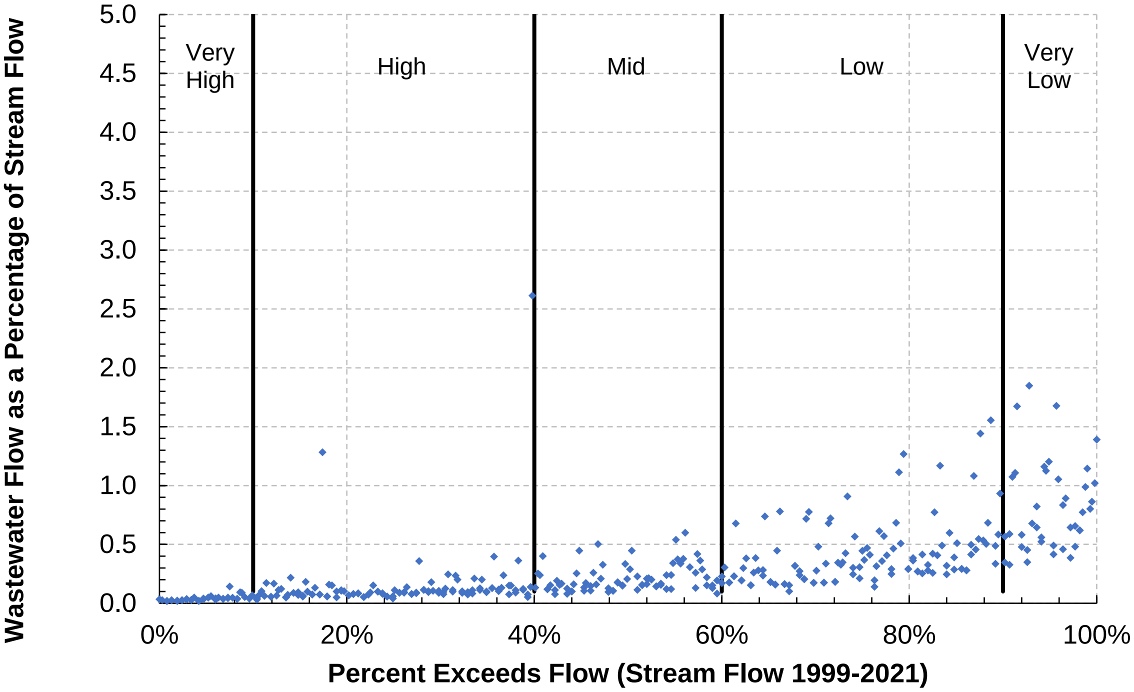
Table A-17. Permitted NPDES facilities in the Headwaters South Branch Root River Subwatershed

NPDES permit type	Facility Name	Permit number	Facility activity	Nitrate loading potential
Construction stormwater	Start Agricultural Treatment System	C00026784	Construction over 1 acre	None
Construction stormwater	Grand Meadow Substation	C00055147	Construction over 1 acre	None
Construction stormwater	Phase 2 Infrastructure Improvements	C00057786	Construction over 1 acre	None
Construction stormwater	SAP 50-599-175	C00060989	Construction over 1 acre	None
Industrial stormwater	Ironwood Sanitary Landfill	MNRNE3BX4	Solid waste landfill	None – no stormwater exposure
Municipal wastewater	Ostrander WWTP	MN0024449	Treatment of domestic waste	Low

Ostrander WWTP is designed to treat an average wet weather flow of 39,400 gallons per day and is a continuous discharger to the South Branch Root River (-H19). Since 2017, the Ostrander WWTP’s TN effluent concentrations have averaged 17.79 mg/L and ranged from 1.4 mg/L to 41 mg/L. The Ostrander WWTP permit was reissued by the MPCA on October 18, 2019, and included a TN limit of 10 mg/L. Because the Ostrander WWTP is not designed to meet the 10 mg/L limit, a compliance schedule is in effect to achieve compliance with the TN limit while being sensitive to financial constraints (pursuant to Minn. Stat §115.456).

While Ostrander WWTP effluent has high TN concentrations, the effluent nitrogen input to South Branch Root is largely diluted by the river's base flow. Even in very low stream flow conditions, WWTP effluent is estimated to make up less than 2% of the South Branch Root River's flow (Figure A-9). Because of this, Ostrander WWTP is not considered a significant source of nitrate.

Figure A-9. Ostrander WWTP effluent as a percentage of stream base flow.



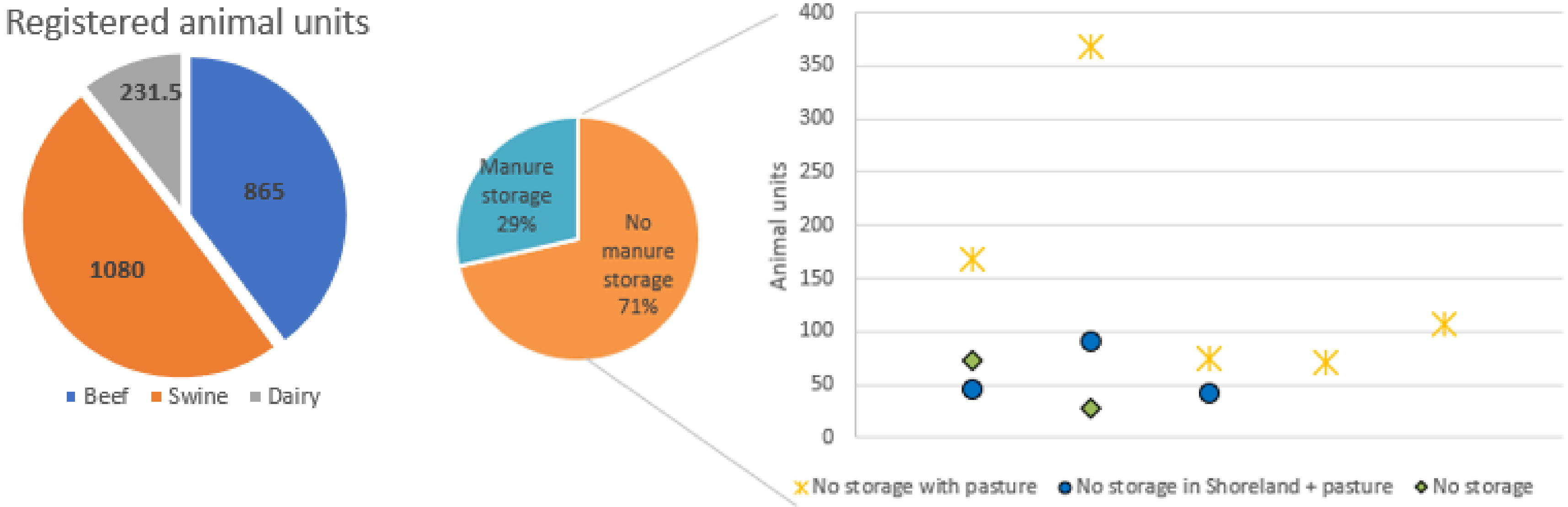
Bacteria sources

Nonpoint sources:

The headwater portion of the South Branch Root River Subwatershed lies completely within Mower County spanning over Clay and Bennington Townships. Mower County staff have prioritized SSTSs in this area that need correction either due to treatment failure, system age, or lack of SSTS system design records. Of highest priority are failing systems known as an ITPHS. Mower County staff have identified one SSTS as an ITPHS and note that the landowner is currently working on a replacement system. Three SSTSs are of great concern due to age and/or lack of records. Of medium priority are eight SSTSs over 30 years old. Of these eight, it is likely that 50% may pass compliance and the remaining may fail. No small communities in this watershed have small community SSTS concerns.

The headwaters of the South Branch Subwatershed has 14 registered feedlots housing 2,204 AU (4,941 head). Most feedlots are beef operations, but of all permitted animals, swine is the most dominant species. No CAFOs exist at this time. Most feedlots do not have manure storage on site but do have pasture as part of their operation (Figure A-10).

Figure A-10. Registered feedlots, corresponding animal units and feedlot manure storage in Headwaters South Branch Root River Subwatershed.



Permitted sources:

Ostrander WWTP is a continuous discharger to the South Branch Root River (-H19) and uses mechanical removal and ultraviolet disinfection. The WWTP's NPDES permit includes a 200 orgs/100 mL fecal coliform limit. The receiving water of Ostrander WWTP (South Branch Root River; -H19) is currently meeting AQL standards but is impaired for *E. coli.* Since 2017, Ostrander WWTP's fecal coliform concentrations have averaged 16.10 org/100 mL and ranged from 1 org/100 mL to 2,194 org/100 mL. The Ostrander WWTP has had three exceedances of their 200 org/100 mL fecal coliform limit since 2017 (October 2019, January 2022 and March 2022). Of these three exceedances, October 2019 is tied to increased discharge, likely due to a release (maximum monthly flow of 0.042 MGD). Because of these exceedances, the WWTP is listed as a low priority source for *E. coli*.

Altered hydrology/Dissolved oxygen impacts

The altered hydrology in the Headwaters South Branch Root River Subwatershed is driving stressors to the macroinvertebrate community. Altered hydrology is a consequence of farming practices such as installing field drainage tile and maintaining drainage ditches. Stream channelization is also considered altered hydrology and occurs when streambanks become so incised from high peak flow that they are cut off from their floodplain.

Row crop agriculture:

While drainage tile has agricultural benefits, primarily drying out soils for more convenient planting and harvesting conditions, it can also be consequential to available water storage. In general, tile drainage reduces long-term and short-term surface water storage. By draining historically wet landscapes (like the headwaters South Branch Root River Subwatershed) less water is available to the local rivers and streams. Drainage tile also changes the timing of surface and sub-surface runoff. Tile drainage increases annual water yield from a field or small watershed because drainage discharges more water to a waterbody during a storm event rather than storing it temporarily in shallow groundwater aquifers (MGWA 2018).

Altered/channelized streams:

Most streams in the South Branch Root Subwatershed are channelized and resemble ditches more than natural streams. The altered state of streams in this subwatershed impact the hydrology, aquatic habitat, and available oxygen of the South Branch Root River all of which are consequential to fish and macroinvertebrate communities.

Straightened and channelized channels change the timing of stream flow by increasing peak flow. This is due, for the most part, to the channel being disconnected to the floodplain. Disconnection to the floodplain not only alters peak flow but also overall available stream flow. Low stream flow conditions can occur without a connection to a floodplain. Water once being stored in the floodplain and available to the stream is now unavailable. Low water levels, a known aquatic life stressor in this subwatershed, makes streams uninhabitable for fish and macroinvertebrates.

Routine activities that occur on altered streams, such as ditch maintenance, impact stream hydrology and aquatic habitat. Channel widening from ditch maintenance can eventually lead to steeper channel slopes. Steeper channel slopes promote increased peak flow and peak flow duration; both of which can trigger increased streambank erosion. Steep, altered stream channels also lack aquatic habitat for fish and macroinvertebrates. Woody debris is often scare and steeply incised stream banks do not offer the same habitat potential as more natural stream banks.

The channelized character of South Branch Root River also impacts the availability of DO. Field staff have noted that DO is low when water flow is low. However, TP, biological oxygen demand and chlorophyll-a are also low indicating that eutrophication is not driving low DO. This supports the conclusion that low oxygen is a consequence of lack of flow. DNR flow data (2008-present) reveals that stream section 07040008-H18 has very low flow in late summer to early fall.

Biological oxygen demand from permitted sources:

While the DO stressor on aquatic life is most likely due to lack of flow, it is reasonable to assess whether permitted sources have the potential to contribute to the DO stressor. Ostrander WWTP has a carbonaceous biological oxygen demand (CBOD) limit of 25 mg/L. Since 2017, Ostrander WWTP’s CBOD concentrations have averaged 6.65 mg/L and ranged from 0.5 mg/L to 28 mg/L. Two exceedances of their CBOD limit have been reported in this timeframe (August and September 2020).

Permitted Water Users:

Four groundwater appropriations are permitted in the Headwaters of the South Branch Root River (Table A-18). Permitted withdraws range between 20 to 120 million gallons per year (MGY) with a total of 230 MGY if all appropriations are used. The DNR WHAF tool does not indicate the South Branch Root River as an area with significantly increasing water withdrawal stress, but given the low flow stressor, this may be an appropriate area for future study.

Table A-18. Permitted water uses in the South Branch Root River (provided by MNDNR).

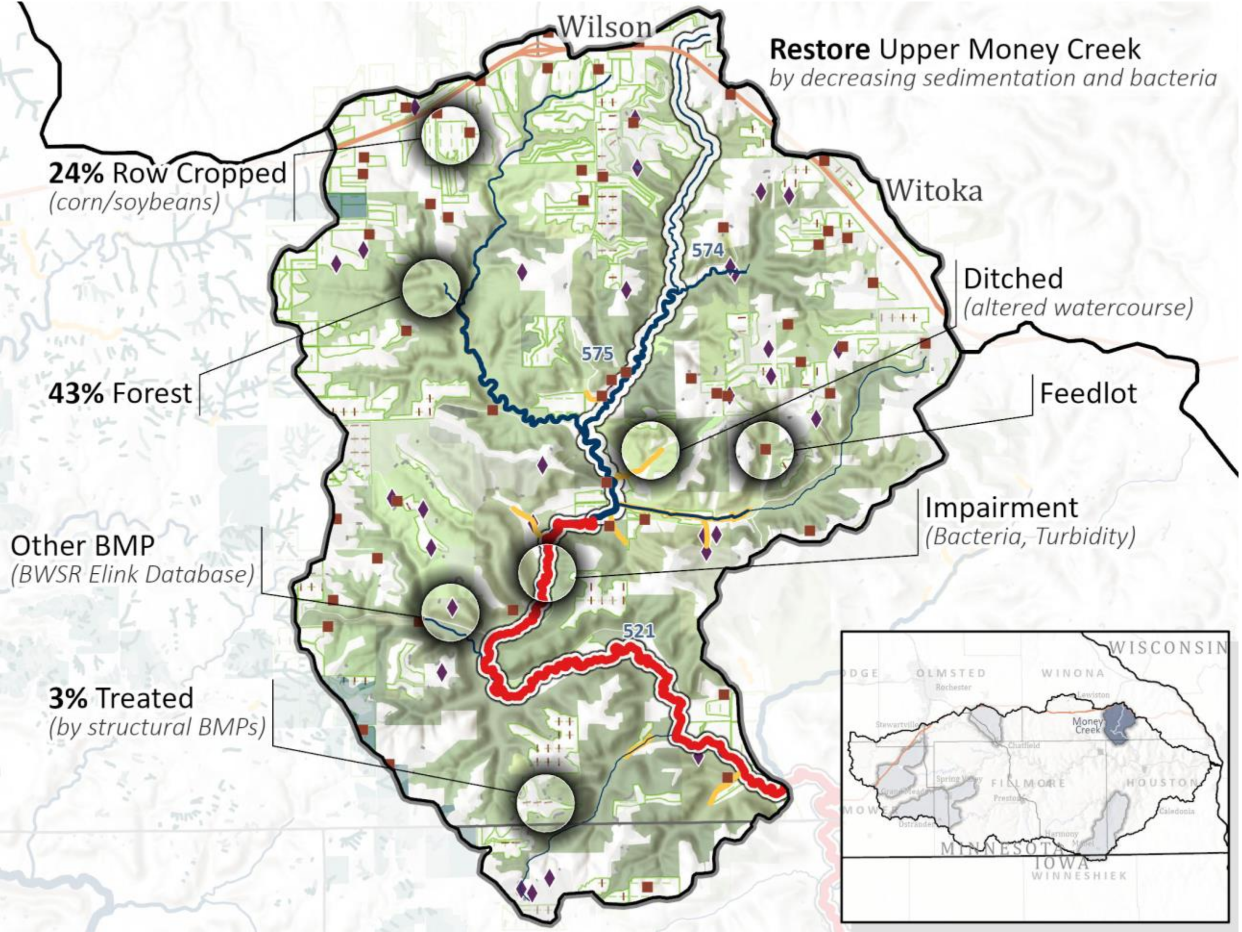
DNR Water Appropriations permit number	Permitted water use (MGY)
1986-5072	20
2015-1307	60
2014-1897	30
1982-5025	120

Table A-19. Pollutant source priority summary for Headwater South Branch Root River.

	Nitrate	Sediment	Habitat	Stream flow/Oxygen	Bacteria
Point source(s)	Low	NA	-	Low	Low
In-channel/bank	-	NA	-	-	-
Cropland	High	NA	-	High	-
Feedlots/Manure	Low	NA	-	-	Medium
SSTS	-	NA	-	-	Medium
Altered hydrology (ditching, drain tile and channelization)	-	NA	-	High	-

Upper Money Creek

Figure A-11. Overview of Upper Money Creek Subwatershed.



Water quality

The Upper Money Creek Subwatershed had three WIDs: (-574), (-575) and (-521). Only WID (-521) has been assessed for meeting water quality standards. This WID is listed as impairment for bacteria and turbidity. Currently, both fish and macroinvertebrate communities are meeting standards.

Sediment sources

Nonpoint Sources:

Because of the lack of permitted sources in the Upper Money Creek Subwatershed, nonpoint sources are playing a large role in impacting water quality.

The physical characteristics of upper Money Creek are likely contributing to sediment loading to Money Creek. The high gradient of the headwater tributaries can exacerbate bank channel and bank scouring particularly during times of increased peak stream flow. Even though most of the riparian area in the headwaters appears to be well vegetated, major incision and increased peak flows continue to erode streambank areas (Figure A-12).

Figure A-12. Stream incision and bank erosion near 08LM016. Photo credit: MPCA staff.

Row crop agriculture is not the dominant land use in the Upper Money Creek Subwatershed. Belmont 2016 notes that 25% to 30% of sediment in this area of the RRW comes from agricultural fields while the remaining comes from the floodplain (legacy sediment). The Root River HSPF model estimates that a majority of TSS loading is coming from the dominant land use: pastures. Closely behind pastureland is cropland acres (Table A-20). It is likely that cropland is contributing less to the water quality concerns than other subwatersheds in the RRW. There may be specific locations contributing to TSS and should be addressed if and when observed.

Table A-20. Average annual TSS contributions to Upper Money Creek by source (MPCA 2023).

Source		Average annual % of TSS load[a]
Permitted	None	0%
Nonpermitted	Cropland	20%
	In-channel	51%
	Pasture	23%
	Developed	4%
	Forest	2%
	Open water, Wetland, Barren	<1%

a. Percentages rounded to nearest whole number and therefore may not add up to 100%.

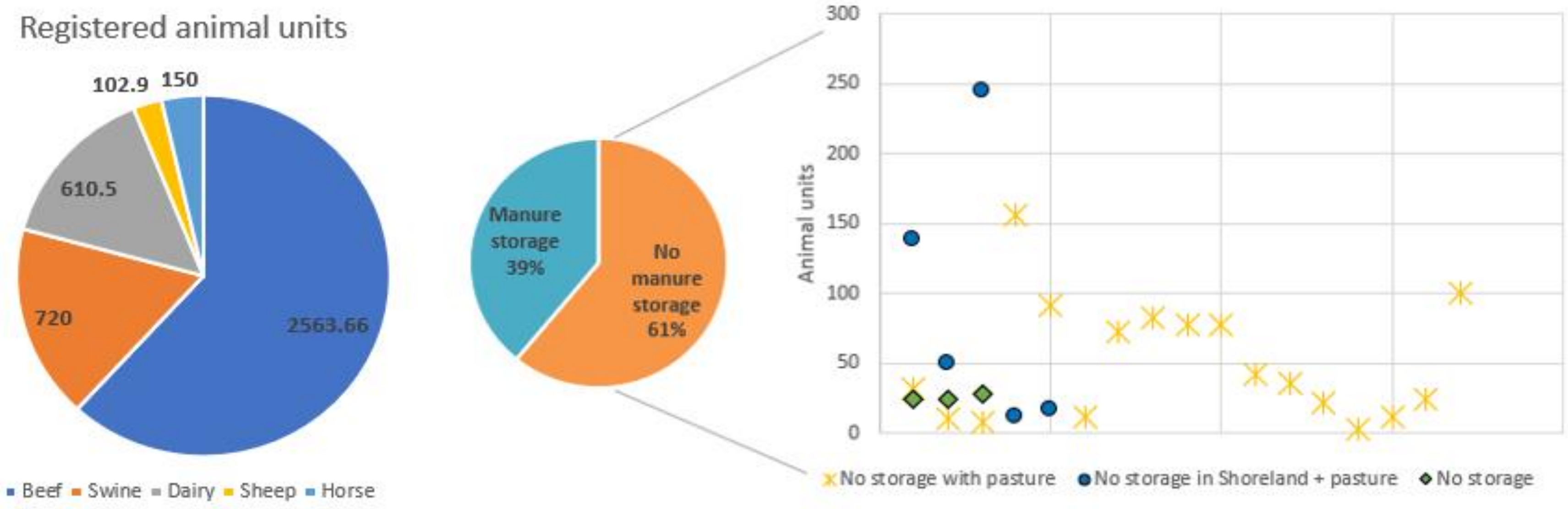
Bacteria sources

Nonpoint Sources:

The village of Witoka sits on the headwater area of Upper Money Creek. This community is a low priority for small community SSTS concerns. Witoka has largely been upgraded over the past 20 years, so it is likely this community is not a significant *E. coli* contributor. Winona County reports 17 SSTS in the Wiscoy Township that are located in shoreland and floodplain. Seven of these SSTS are newer than the year 2000. It is likely that some, particularly those over 30 years old, may not be in compliance and could be contributing pollutants to surface waters.

Upper Money Creek Subwatershed has 42 registered feedlots housing 4,147 AU (7,782 head); primarily beef operations. No permitted CAFOs exist, and most do not have manure storage on site (Figure A-13). Many of the registered feedlots in Upper Money Creek have pastures as part of their operation. Feedlots with pastures with sections of Upper Money Creek flowing through them are potential *E. coli* and sediment sources. Cattle traffic in and around streams may increase sedimentation and livestock defecation in streams contributes *E. coli*.

Figure A-13. Registered feedlots, corresponding animal units and feedlot manure storage in Upper Money Creek Subwatershed.



Permitted sources:

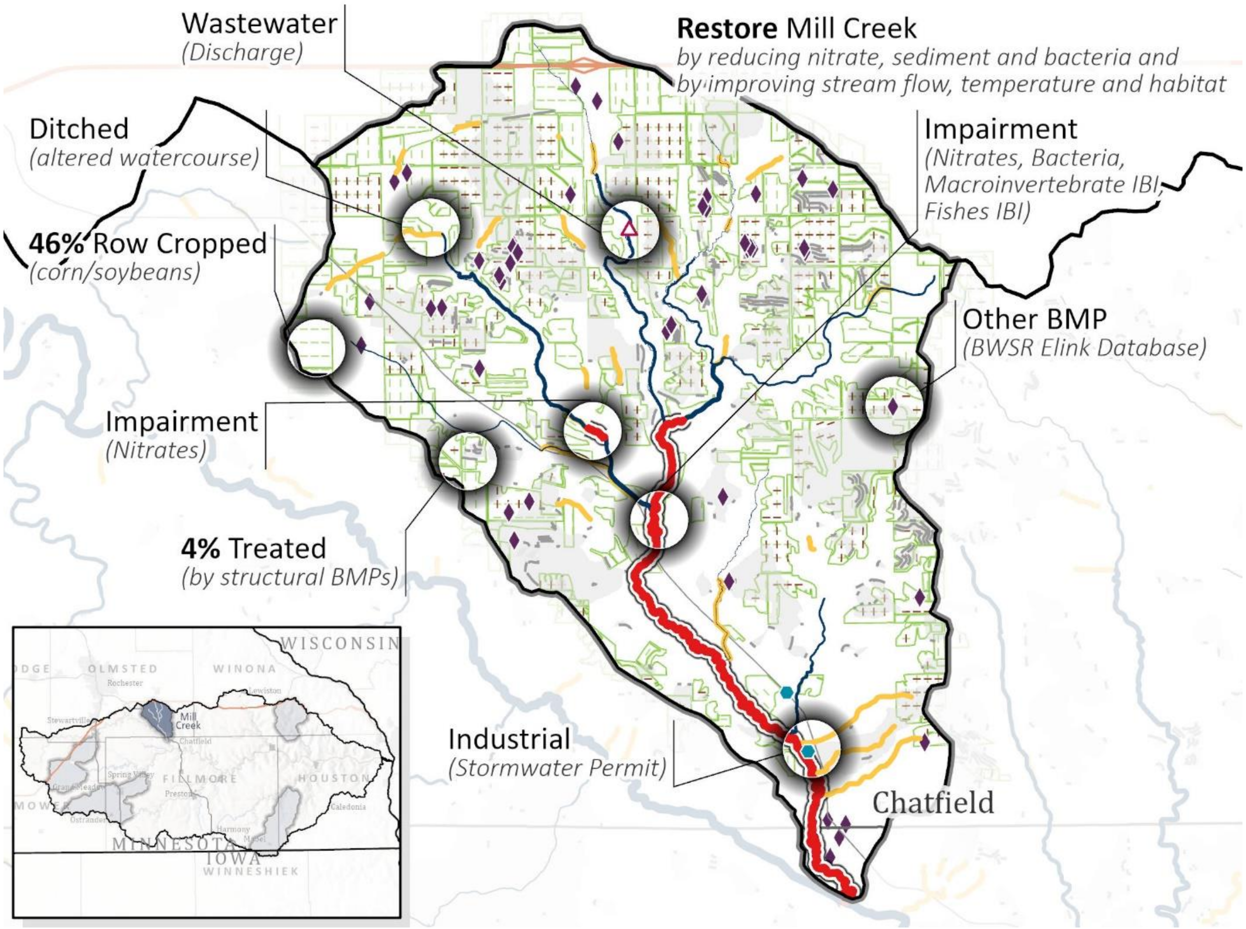
The current permitted source in this subwatershed is a construction stormwater site and is not a source of bacteria.

Table A-21. Pollutant source priority summary for Upper Money Creek.

	Nitrate	Sediment	Habitat	Stream flow	Bacteria
Point source(s)	-	-	-	-	-
In-channel/bank	-	High	-	-	-
Cropland	-	Medium	-	-	-
Feedlots/Manure/Pastures	-	Medium	-	-	Medium
SSTS	-	-	-	-	Low
Altered hydrology (ditching, drain tile and channelization)	-	Low	-	-	-

Mill Creek

Figure A-14. Overview of Mill Creek Subwatershed.



Water quality

Mill Creek Subwatershed has several headwater WIDs that combine to make (-536) Mill Creek. Headwater WID (-A47) is impaired for nitrate and Mill Creek (-536) is impaired for nitrate, bacteria, macroinvertebrate index of biotic integrity (MIBI) and fish index of biotic integrity (FIBI). Stressors to macroinvertebrates and fish include nitrate, TSS, habitat and flow alteration. The town of Chatfield has a DWSMA that is currently a level one vulnerable DWSMA. See Section 2.3 of the WRAPS Update Report for additional discussion on Chatfield DWSMA nitrate monitoring.

Sediment sources

Permitted sources:

All permitted facilities in this subwatershed have a low potential to contribute TSS to Mill Creek. Construction stormwater sites are required to have structural BMPs in place during active construction so that minimal sediment leaves the construction site. Because of this permit condition, construction stormwater sites are not considered a significant source of TSS but may be during extreme storm events.

The industrial stormwater facilities identified in Table A-22 below are required to monitor stormwater discharge on a quarterly basis. A benchmark TSS concentration of 100 mg/L is in effect for both facilities. Since 2017, Bill Funk Trucking has not reported any monitored discharge. Griffin Quarry has not had any monitored discharge reported since 2017, as well.

Table A-22. Permitted NPDES facilities in the Mill Creek Subwatershed.

NPDES permit type	Facility Name	Permit number	Facility activity	Pollution potential
Industrial stormwater	Bill Funk Trucking	MNR053CCT	Trucking	Low TSS.
Industrial stormwater	Griffin Quarry	MNR053BMN	Sand and gravel mining	Low TSS – but high potential during extreme storm events.
Nonmetallic mining	Mathy Construction - Engrav Quarry #521 (SD104)	MNG490081	Construction sand/gravel and crushed/broken limestone	Low TSS – but high potential during extreme storm events.

Nonpoint sources:

The overall lack of significant pollutants from permitted sources points to nonpoint sources as the more significant sources of TSS. For Mill Creek Subwatershed, the top two nonpoint sources of sediment are from in-channel/streambank sources or upland agricultural fields.

The Belmont study (Belmont 2016) found that Mill Creek's (and other streams in the North Branch Root River HUC10) sediment load is primarily coming from within the channel and streambank. Field staff have noted areas of instability and bank erosion in stream reaches upstream of Chatfield.

The RRW HSPF model estimates that of all land uses, cropland contributes the most sediment to the subwatershed (Table A-23).

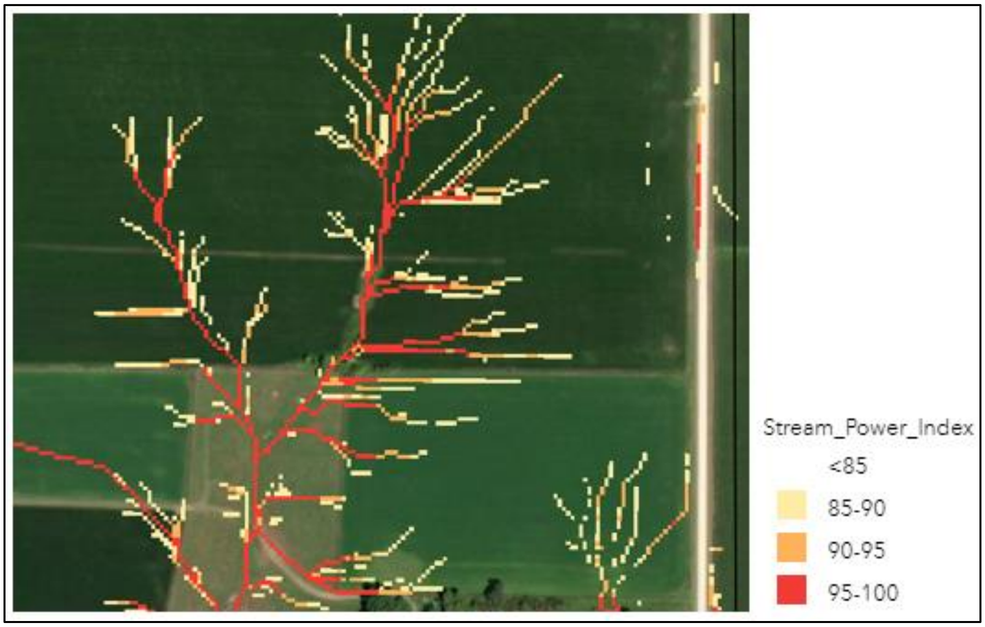
Table A-23. Average annual TSS contributions to Mill Creek by source (MPCA 2023).

Source		Average annual % of TSS load[a]
In-channel		17%
Overland runoff	Cropland	53%
	Pasture	22%
	Developed	7%
	Forest, open water, wetland, and barren	2%

b. Percentages are rounded to nearest whole number and therefore may not add up to 100%.

Sediment loading from agriculture fields may be most significant in the headwater areas of the subwatershed. SID work has found that headwater monitoring sites had significantly higher TSS concentrations and lower transparency measurements as compared to the main channel of Mill Creek (-536). The Minnesota Runoff Risk Advisory Forecast identifies many areas across the headwaters of Mill Creek Subwatershed as having a high SPI (Figure A-15). This means that there are many "conveyor belt" areas that can transport sediment (as well as nutrients/manure and pesticides) off cropland during snowmelt or storm events. Perennial vegetation in these high SPI areas (grassed waterways, prairie strips) can work to reduce pollutant transport, particularly sediment. In several of these areas, there are no structural BMPs preventing sediment from entering a stream during runoff events. Practices such as prairie strips, filter strips, field borders, conservation cover, contour grass strips no-till or cover crops would be ideal in these areas.

Figure A-15. High stream power index areas in the headwaters of Mill Creek Subwatershed.



Nitrate sources

Permitted sources:

The nature of the permitted facilities in the Mill Creek Subwatershed are not conducive to producing nitrogen inputs into the environment (Table A-22). Because of this, permitted facilities are not considered significant sources of nitrate.

Nonpoint sources:

The most prominent source of nitrogen in the Mill Creek Subwatershed is from agricultural fields. This is supported by the RRW HSPF model (Table A-24).

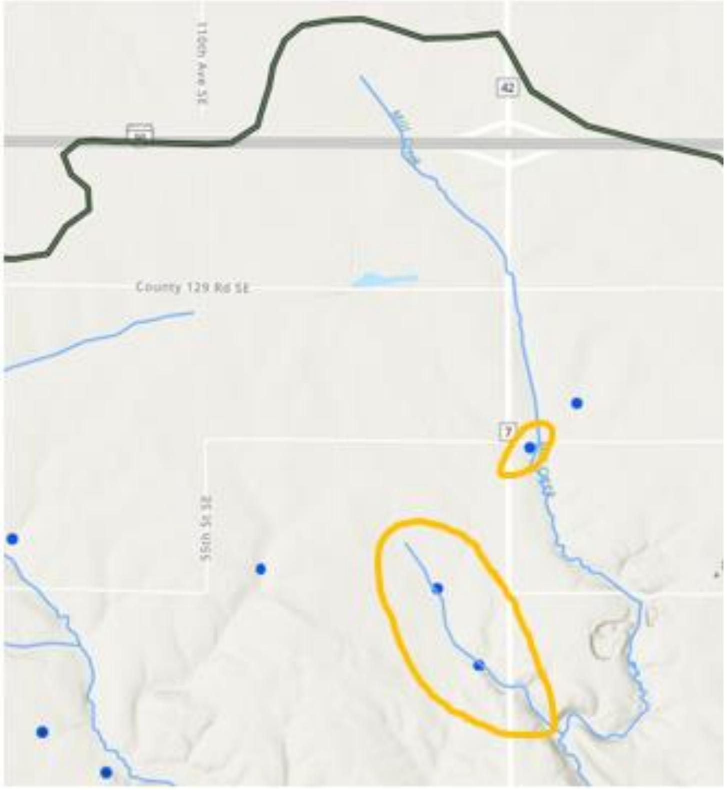
Table A-24. Average annual TN contributions to Mill Creek by source (MPCA 2023).

Source		Average annual TN loading (%)[a]
Nonpermitted	Cropland - conventional acres	25%
	Cropland - manured acres	36%
	Cropland - conservation tilled acres	5%
	Pasture	28%
	Developed	3%
	Forest	3%
	Open Water, Wetland, Barren	<1%

a. Percentages are rounded to nearest whole number and therefore may not add up to 100%.

Nitrogen inputs (commercial nitrogen fertilizer and animal manure) on cropland are very likely leaching into groundwater and then entering Mill Creek through springs and other groundwater inputs. Nitrogen loading from row crop agriculture is most significant in the headwater areas of the subwatershed as the northwest portion of the upper headwater area has average nitrate concentrations over 10 mg/L. This may be due to the higher influence of springs in this area (Figure A-16). Groundwater from these springs may be driving the elevated stream nitrate concentrations. It is important to note the springs displayed in Figure A-16 are likely an under-representation of all springs present.

Figure A-16. Location of mapped springs in close proximity to Mill Creek headwaters (DNR's Karst Features Database).



While no spring monitoring for nitrate is currently underway in the Upper Mill Creek Subwatershed, neighboring Bear Spring springshed has a long history of nitrate spring monitoring. Bear Spring nitrate concentrations are some of the highest observed in southeast Minnesota spring monitoring. It is reasonable to assume the springshed underlying Mill Creek has a very similar condition to the Bear Spring springshed as they have similar land use, geology, and proximity to each other. Nitrogen reduction both within the Mill Creek Subwatershed and the greater spring shed would be beneficial for nitrate reduction to address both groundwater inputs and overland runoff.

Bacteria sources

Permitted sources:

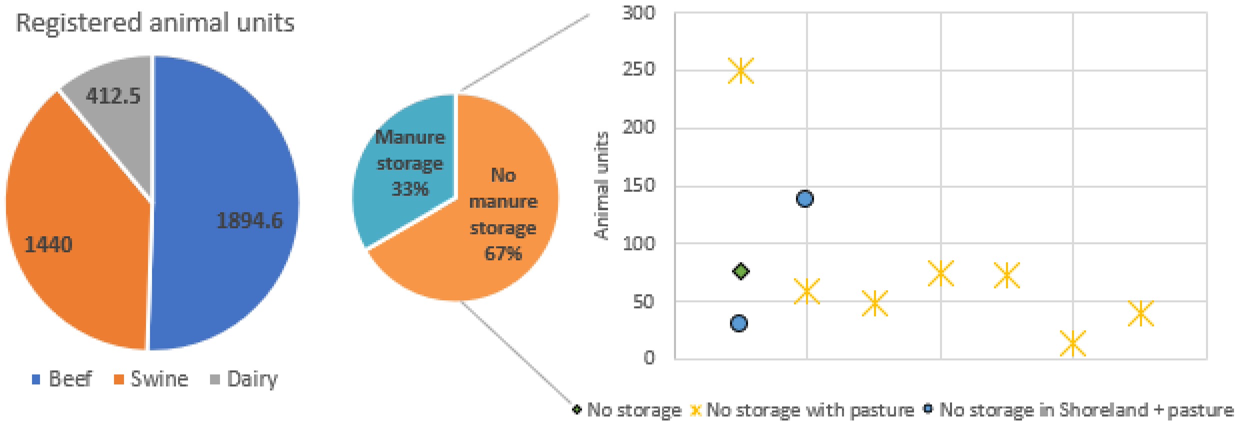
The nature of the permitted facilities in the Mill Creek Subwatershed (Table A-22) are not conducive to producing *E. coli*. Because of this, permitted facilities are not considered significant sources of *E. coli*.

Nonpoint sources:

The Town of Cummingsville has been identified as a potential small community of SSTS concern in Olmsted County and is near the watershed boundary of Mill Creek. Cummingsville is a potential small community of concern because of one or more factors including poor soils, small lots, presences of karst and/or well contamination. G-Cubed, the contracted administrator of the SSTS program for the Town of Cummingsville, verified that SSTS have either been updated or the property has transferred hands in the last 15 years. A property transfer requires that SSTS must either be compliant or brought into compliance by replacement. SSTS is not considered a priority *E. coli* source for Mill Creek at this time.

Mill Creek Subwatershed has 14 registered feedlots housing 2,558 AU (6,033 head); primarily beef operations, but most animals are swine. No CAFOs currently exist and a majority of the feedlots do not have manure storage on site (Figure A-17).

Figure A-17. Registered feedlots, corresponding animal units and feedlot manure storage in Mill Creek Subwatershed.



Feedlot facilities with no manure storage, with pastures and located in Shoreland have a higher probability of contributing *E. coli* bacteria to surface waters. This is due to lack of containment or treatment of stockpiled manure, close proximity of the facility to a surface and/or livestock's direct contact with surface water.

Habitat and flow alteration

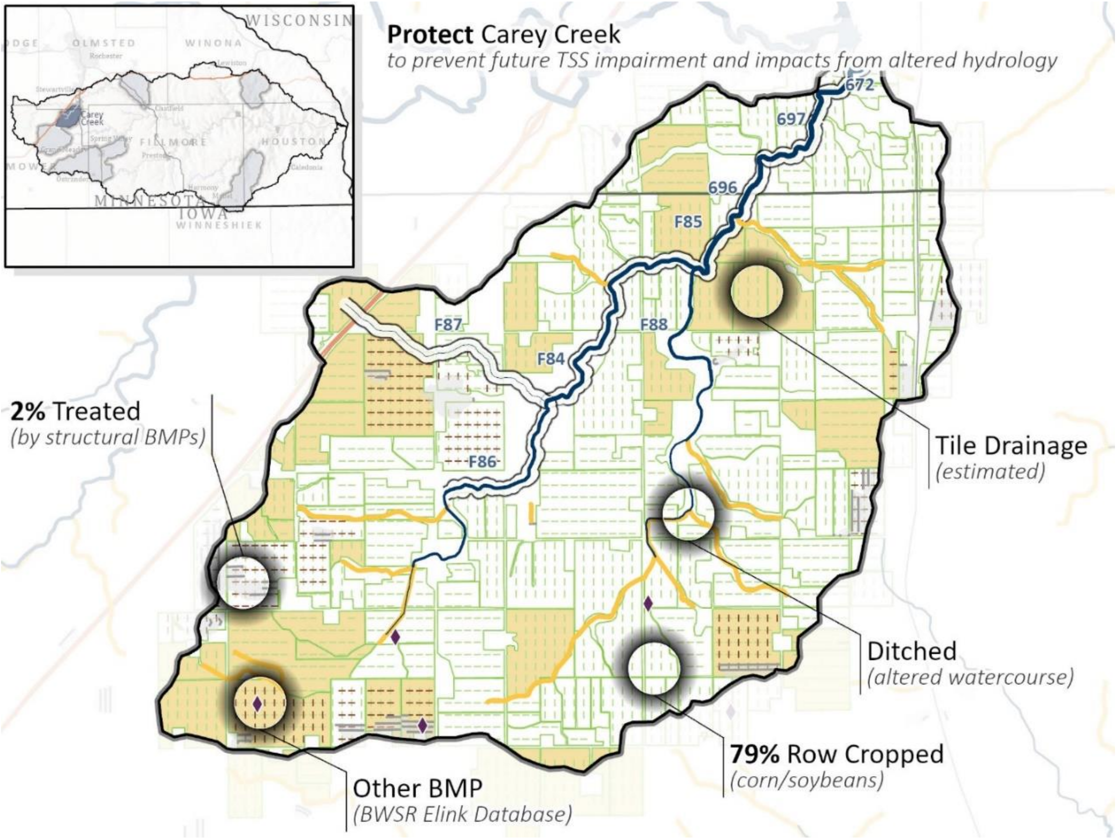
Habitat and flow alteration stressors for Mill Creek are connected. The habitat stress for aquatic life is driven by the influx of sediment, which covers aquatic habitat and clouds the water column. Altered hydrology is a consequence of land use due to less water storage on the landscape. Upland sedimentation and streambank erosion are being driven by altered hydrology. Practices that encourage water storage and infiltration will lessen the impact of altered hydrology and improve habitat conditions. In addition to land use, karst is impacting available flow in the upstream section of Mill Creek. It is noted in the RRW SID Report that the most upstream section of Mill Creek periodically loses all flow in certain times of year. This is likely due to karst-related phenomena which makes the stream lose all its flow to underground aquifers then resurfaces downstream. This condition will vary depending on the time of year, underlying water table elevation and soil moisture conditions.

Table A-25. Pollutant source priority summary for Mill Creek.

	Nitrate	Sediment	Habitat	Stream flow	Bacteria
Point source(s)	Low	Low	-	-	Low
In-channel/bank	-	High	-	-	-
Cropland	High	High	-	-	-
Feedlots/Manure	Medium	-	-	-	Medium
SSTS	-	-	-	-	-
Altered hydrology (ditching, drain tile and channelization)	-	-	Medium	Medium	-

Carey Creek

Figure A-18. Overview of Carey Creek Subwatershed.



Water quality

There are currently no water quality impairments in the Carey Creek Subwatershed. WID (-696) is the only WID that has been assessed in this subwatershed. Currently, this stream section is meeting both fish and macroinvertebrate IBI thresholds. Sediment impacts have the highest potential to degrade this subwatershed. Protection is needed to prevent future degradation of aquatic life.

Sediment sources

Permitted Sources:

No NPDES permitted sites are in Carey Creek Subwater at the writing of this report.

Nonpoint Sources:

Like the other waters in the North Branch Root HUC-10, it is likely that most of the sediment is coming from within the channel itself. Little work has been done in this subwatershed that would identify specific locations of major incision or erosion.

Because it is the dominant landscape, it is likely that row crop fields are contributing to the sediment load, particularly in the headwater areas. This is supported by the Root River HSPF model which estimates the majority of TSS loading originates from agricultural/row cropped acres (Table A-26). Additional field visits are needed to better understand if overland runoff or sediment from agricultural drain tiles are contributing the most sediment.

Table A-26. Average annual TSS contributions to Mill Creek by source (MPCA 2023).

Source		Average annual % of TSS load[a]
Permitted	None	0%
Nonpermitted	Cropland	69%
	In-channel	20%
	Pasture	7%
	Developed	4%
	Forest	<1%
	Open water, Wetland, Barren	0%

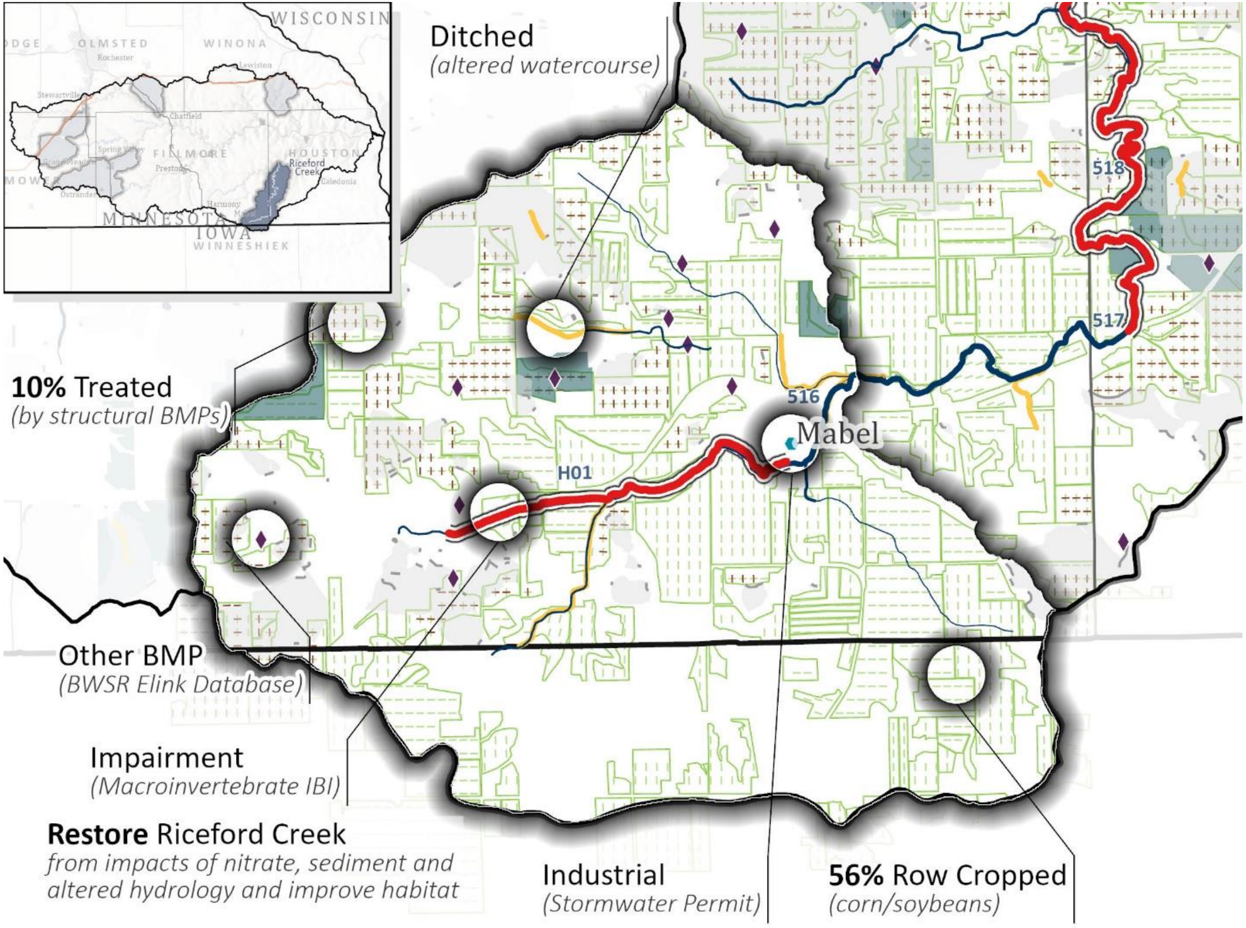
Percentages are rounded to nearest whole number and therefore may not add up to 100%.

Table A-27. Protection priorities for Carey Creek.

	Nitrate	Sediment	Habitat	Stream flow	Bacteria
Point source(s)	-	-	-	-	-
In-channel/bank	-	High	-	-	-
Cropland	-	High	-	-	-
Feedlots/Manure	-	-	-	-	-
SSTS	-	-	-	-	-
Altered hydrology (ditching, drain tile and channelization)	-	High	High	High	-

Riceford Creek

Figure A-19. Overview of Riceford Creek Subwatershed.



Water quality

The headwater portion of Riceford Creek (upstream of the town of Mabel) includes a single WID (-H01). (-H01) is currently listed as impaired for MIBI. Stressors to macroinvertebrates include nitrate, TSS, habitat and flow alteration. For additional information about the water quality of the entire Riceford Creek Subwatershed, see the Root River TMDL (MPCA 2023a).

Sediment sources

Permitted sources:

Permitted facilities in the headwaters of Riceford Creek are found in Table A-28.

Table A-28. Permitted NPDES facility in Upper Riceford Creek Subwatershed.

NPDES permit type	Facility Name	Permit number	Facility activity	Pollutant potential
Industrial stormwater (nonmetallic mining)	Gjere Construction – Gjere Quarry (SD 001)	MNG490391	Sand and gravel mining	Low TSS – but high potential during extreme storm events.

Gjere Quarry has an outflow located within a ¼ mile of the warmwater (2Bg) section of Riceford Creek (-H01). This site is required to monitor for TSS on a semi-annual basis and has a TSS intervention limit of 100 mg/L. According to reporting records, the quarry has not had any reportable discharges in 2019, 2020, or 2021.

Nonpoint sources:

The headwaters of Riceford Creek have been seeing a decline in stream transparency due to TSS since 2008. SID work found that in-stream transparency of (-H01) was worse in the headwater section and improved moving downstream. This could be due to natural settling from stream gradient or an influx of spring inflow (dilution). The headwater area of the Riceford Creek Subwatershed has about 750 acres treated by structural BMPs, about 6% of the area.

Belmont 2016 notes that 71% of the sediment for the tributaries in the South Fork Root River (including Riceford Creek) comes from floodplain/riparian areas. Field staff have noted areas above Mabel with severe bank erosion. Water transparency has been steadily declining in this area since 2008. This headwater area of Riceford Creek is also heavily modified, and channelization is likely exacerbating influx of sediment, particularly during times of peak flow. Refer to the Headwaters of South Branch Root River for discussion of channelization's impact to hydrology and streambank erosion.

Because of the high presence of cropland in the Riceford Creek headwater area, sediment is likely coming from agricultural land in the headwaters area. The Root River HSPF model supports this conclusion by estimating that the majority of TSS loading originates from agricultural/row cropped acres compare to all other land uses (Table A-29).

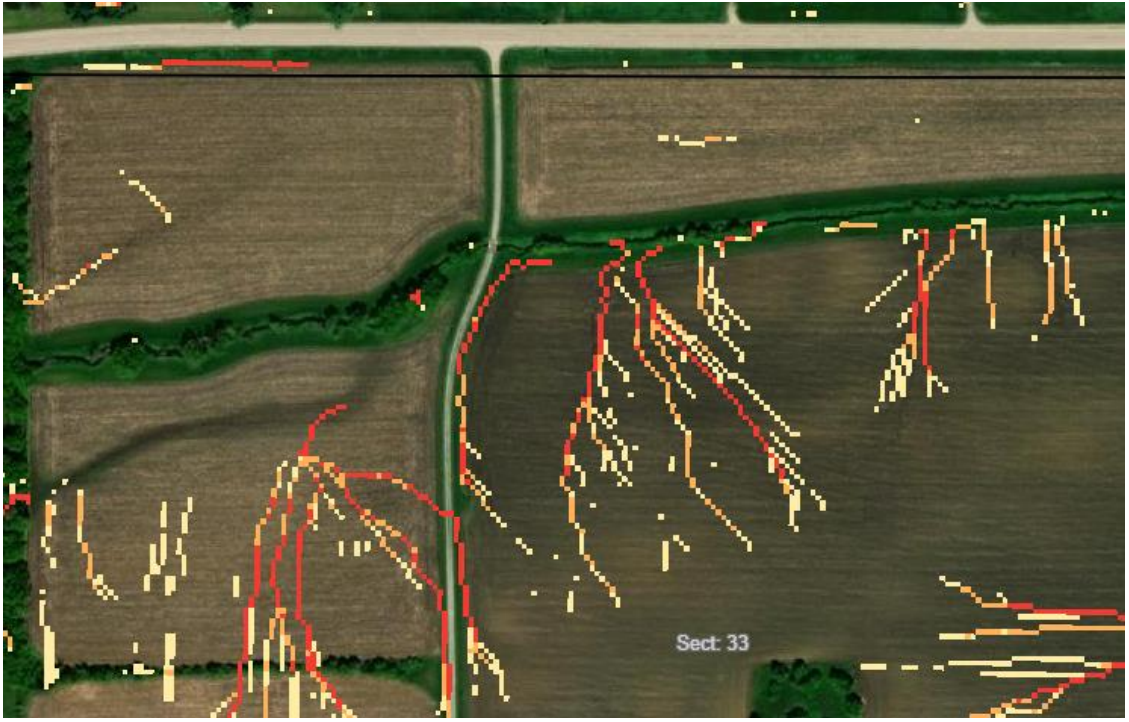
Table A-29. Average annual TSS contributions to Upper Riceford Creek (HSPF Reach 110) by source (MPCA 2023).

Source		Average annual % of TSS load[a]
Permitted	None	0%
Nonpermitted	Cropland	25%
	In-channel	65%
	Pasture	8%
	Developed	2%
	Forest	<1%
	Open water, Wetland, Barren	<1%

a. Percentages are rounded to nearest whole number and therefore may not add up to 100%.

TSS loading likely depends on the time of year. There is likely a high sediment load in the spring months when there is a lack of vegetative cover to treat runoff. Minnesota's Runoff Risk Advisory webpage indicates many high SPI areas in fields adjacent to Riceford Creek (Figure A-20). The many SPI areas are indicative of concentrated flows that can carry pollutants to surface waters. Structural practices targeting the high SPI areas will help to reduce TSS loads during times of runoff.

Figure A-20. High SPI areas in Upper Riceford Creek.



Nitrate sources

Permitted sources:

The nature of the permitted facilities in the Riceford Creek Subwatershed are not conducive to producing nitrogen inputs into the environment. Because of this, permitted facilities are not considered significant sources of nitrate.

Nonpoint sources:

The RRW HSPF model estimates that the majority of the nitrogen load to Riceford Creek is coming from cropland (Table A-30).

Table A-30. Estimated TN loading from various land uses in Mill Creek Subwatershed.

Source		Average annual TN loading (%)[a]
Permitted	None	0%
Nonpermitted	Cropland - conventional acres	27%
	Cropland - conservation till acres	15%
	Cropland - manured acres	25%
	Pasture	26%
	Developed	2%
	Forest	4%
	Open water, Wetland, Barren	<1%

a. Percentages are rounded to nearest whole number and therefore may not add up to 100%.

Even though nitrate is a stressor to macroinvertebrates located in (-H01), nitrate concentrations are highest in the middle section of Riceford Creek (-518) downstream of this focus area. It is likely that these nitrate loads are predominately coming from spring inputs as the most common pathway for nitrate to enter surface water is leaching from agricultural fields into groundwater aquifers. Of note, an unnamed tributary entering Riceford creek near 140th Street (near Fillmore/Houston County line) has four mapped springs near Riceford Creek. A better understanding of nitrogen applications in the upper and middle drainage areas is needed as well as springshed mapping.

Habitat and stream flow

The headwaters of Riceford Creek are heavily channelized which impacts sediment transport and TSS concentrations. Sediment from streambank erosion settles onto the streambed and smothers available aquatic habitat. Large storm events and increases in stream flow produce high sediment from scouring of streambanks (Table A-31). Practices that slow stormwater runoff and increase upland water storage along with targeted streambank stabilizations will promote improvement to aquatic habitat.

Table A-31. Pollutant source priority summary for headwaters of Riceford Creek.

	Nitrate	Sediment	Habitat	Stream flow	Bacteria
Point source(s)	-	-	-	-	-
In-channel/bank	-	High	-	-	-
Cropland	High	Medium	-	-	-
Feedlots/Manure	Low	-	-	-	-
SSTS	-	-	-	-	-
Altered hydrology (ditching, drain tile and channelization)	-	Medium	Medium	Medium	-

Appendix F. Additional priorities for targeting

Waters with more than one impairment (from MPCA's 2022 Impaired Waters List):

All WIDs on the same waterbody have been combined. Only waterbodies with more than one different impairment are identified (e.g. if a waterbody had two impaired WIDs and both were impaired for the same parameter, they were not counted).

Waterbody name	WID	Number of total impairments	Impairments
Bear Creek (Lost Creek)	07040008-A18	3	Macroinvertebrates, Fish and TSS
Camp Creek	07040008-559	2	Macroinvertebrates and Fish
Forestville Creek	07040008-563	3	Turbidity, Fecal coliform and NO3-N
Mill Creek	07040008-536	4	Macroinvertebrates, Fish, *E. coli* and NO3-N
Middle Branch Root River	07040008-506 07040008-528 07040008-530 07040008-532 07040008-534 07040008-B96 07040008-B95	12	Mercury, *E. coli*, TSS and Macroinvertebrates
Money Creek	07040008-521 and 07040008-F48	3	Turbidity, Macroinvertebrates and Fecal coliform
North Branch Root River	07040008-535 07040008-716 07040008-717	5	*E. coli*, Macroinvertebrates and Turbidity
Rice Creek	07040008-581	2	Macroinvertebrates and Fish
Root River (mainstem)	07040008-501 07040008-502 07040008-520 07040008-522 07040008-527	15	Mercury, Macroinvertebrates, Turbidity/TSS and Fecal coliform
Rush Creek	07040008-523 07040008-524	2	Macroinvertebrates and *E. coli*
South Branch Root River	07040008-550 07040008-554 07040008-555 07040008-556 07040008-H18 07040008-H19	10	TSS/Turbidity, *E. coli*/Fecal coliform and NO3-N
South Fork Root River	07040008-508 07040008-509 07040008-510 07040008-511 07040008-572 07040008-573	15	Mercury, Macroinvertebrates, Turbidity and *E. coli*
Spring Valley Creek	07040008-548	5	Macroinvertebrates, Fish, TSS, *E. coli* and NO3-N
Trout Run Creek	07040008-G87 07040008-F88	2	Macroinvertebrates and *E. coli*

Waterbody name	**WID**	**Number of total impairments**	**Impairments**
Unnamed Creek (Bloody Run Creek)	07040008-F08	3	Macroinvertebrates, Fish and NO3-N
Unnamed Creek (Wadden Valley Creek)	07040008-605	2	Macroinvertebrates and Fish
Upper Bear Creek	07040008-540	2	Macroinvertebrates and Fish
Watson Creek	07040008-552	5	Macroinvertebrates, Fish, TSS, *E. coli* and NO3-N
Willow Creek	07040008-558	3	Macroinvertebrates, *E. coli* and NO3-N

WIDs with High/Medium altered hydrology influence (based on Cycle 2 SID and Pollutant Source Assessment)

All waters in the RRW are impacted by altered hydrology in some capacity. The following waters have been identified in Cycle 2 has having a medium/high impacts from altered hydrology:

Waterbody name	WID
North Fork Bear Creek	07040008-F45
South Fork Bear Creek	07040008-544
Spring Valley Creek	07040008-548
Headwaters South Branch Root River	07040008-H18
Mill Creek	07040008-536
Carey Creek	07040008-696
Riceford Creek	07040008-H01 and 07040008-518
Upper Bear Creek/Bear Creek (Lost Creek)	07040008-540 and 07040008-A18

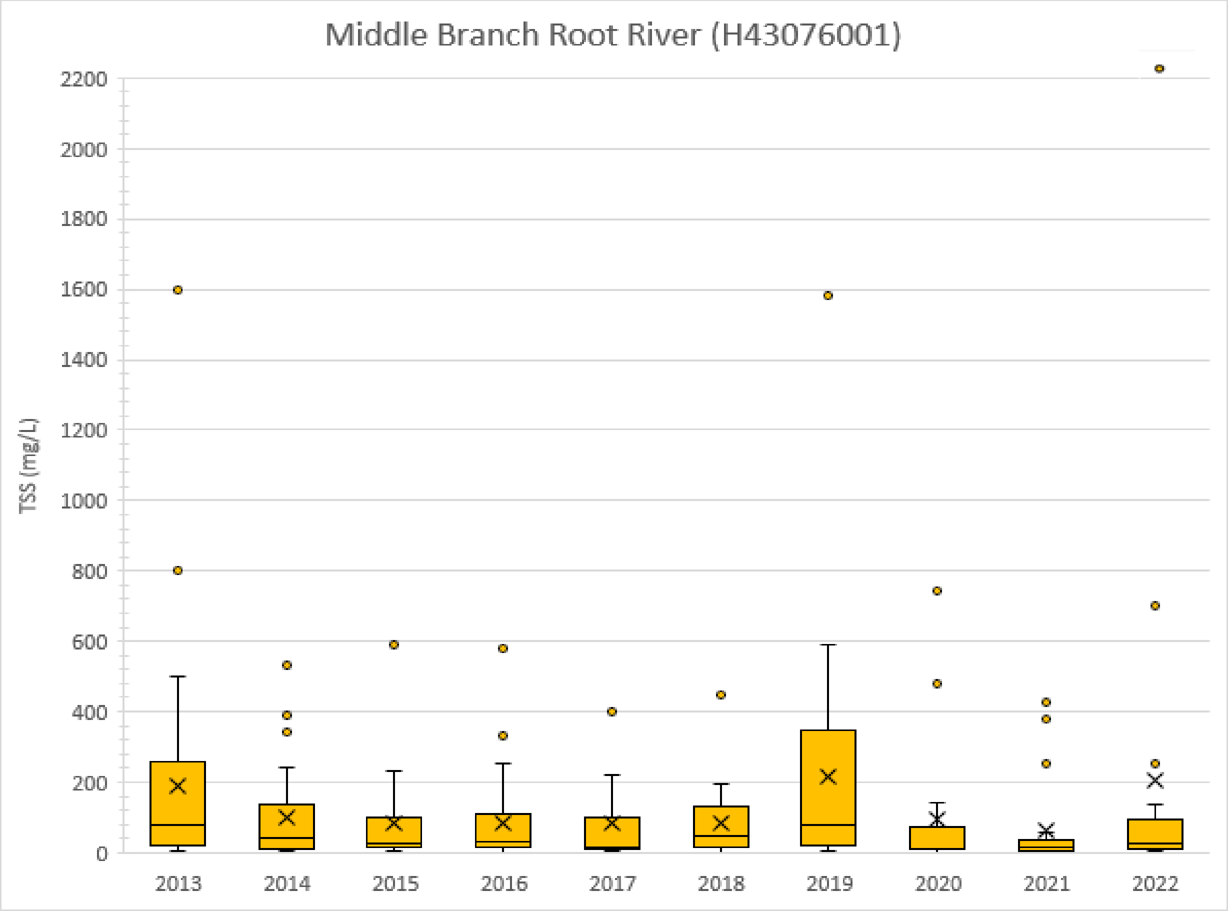
Appendix G. Recommendations from Cycle 2 SID

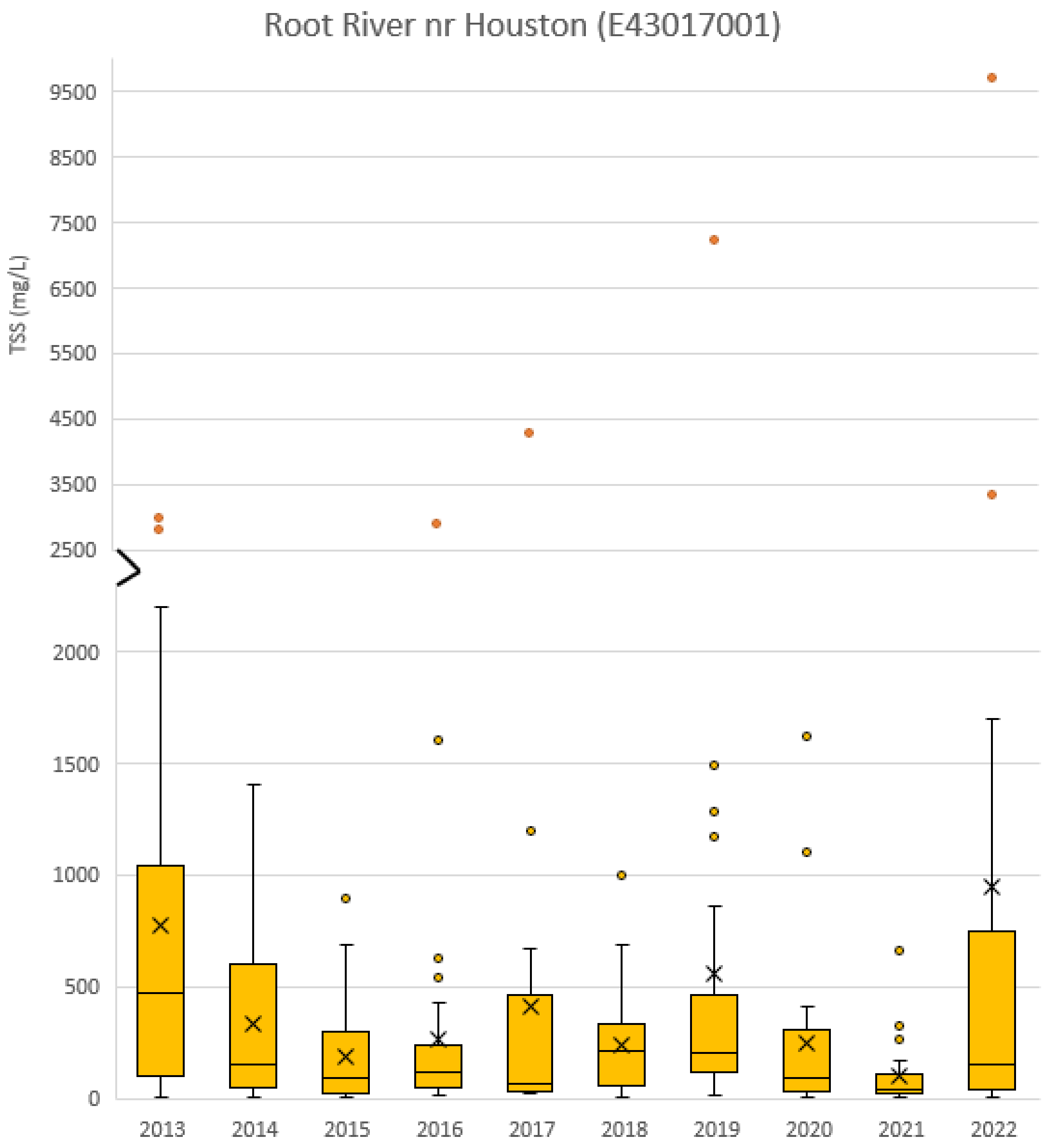
HUC10	HUC12	Waterbody (WID)	Issue	Suggested Strategy
North Branch Root River	Mill Creek	Unnamed Creek / “Mill Ck trib” (07040008-A47)	Nitrate	**Implementation:** Focus N reduction practices in headwaters area.
			Sediment	Monitoring/Investigation: identify primary TSS sources (could be springs or habitat improvement practices). TSS highest in HW area then levels at main stem Mill Creek.
Middle Branch Root River	Bear Creek	• Upper Bear Creek (07040008-540) • Bear Creek / “Lost Ck” (07040008-A18)	Sediment	**Implementation:** Floodplain restoration and other TSS reduction practices. Turbidity long lasting after storm events.
	Spring Valley Creek	Spring Valley Creek (07040008-548)	Nitrate	**Implementation**: Focus N reduction practices in headwater drainage areas of 07040008-D53 and 07040008-F98.
			Sediment	**Implementation:** TSS reduction practices needed in headwaters area, specifically southwest of city of Spring Valley).
South Branch Root River	Camp Creek	Camp Creek (07040008-559)	Temperature	Monitoring/Investigation: Additional investigation needed on impacts from quarry and/or density of sinkholes.
			Sediment	Compliance: MPCA/LGUs to verify compliance of Big Springs Quarry.
	Watson Creek	Watson Creek (07040008-552)	Temperature	**Implementation:** Address lack of shade and increased sediment in middle and lower areas of WID.
			Nitrate	**Implementation**: Target N reduction efforts in headwaters of Watson; particularly Thunderhead Springshed.
			Sediment	**Implementation:** Streambank restoration to fix unstable banks; increased TSS between CR 117 and CR 11.
	Willow Creek	Crystal Creek (07040008-601)	Nitrate	**Protection:** Vulnerable fish and macroinvertebrates need protection from elevated NO3-N (still below 10 mg/L).
			Sediment	**Protection:** Vulnerable fish and macroinvertebrates need protection from elevated TSS.
	South Branch Root River Headwaters	South Branch Root River (07040008-H18)	Nitrate	Monitoring/Investigation: Monitoring N contributions from ag field tile may help identify priority restoration areas.

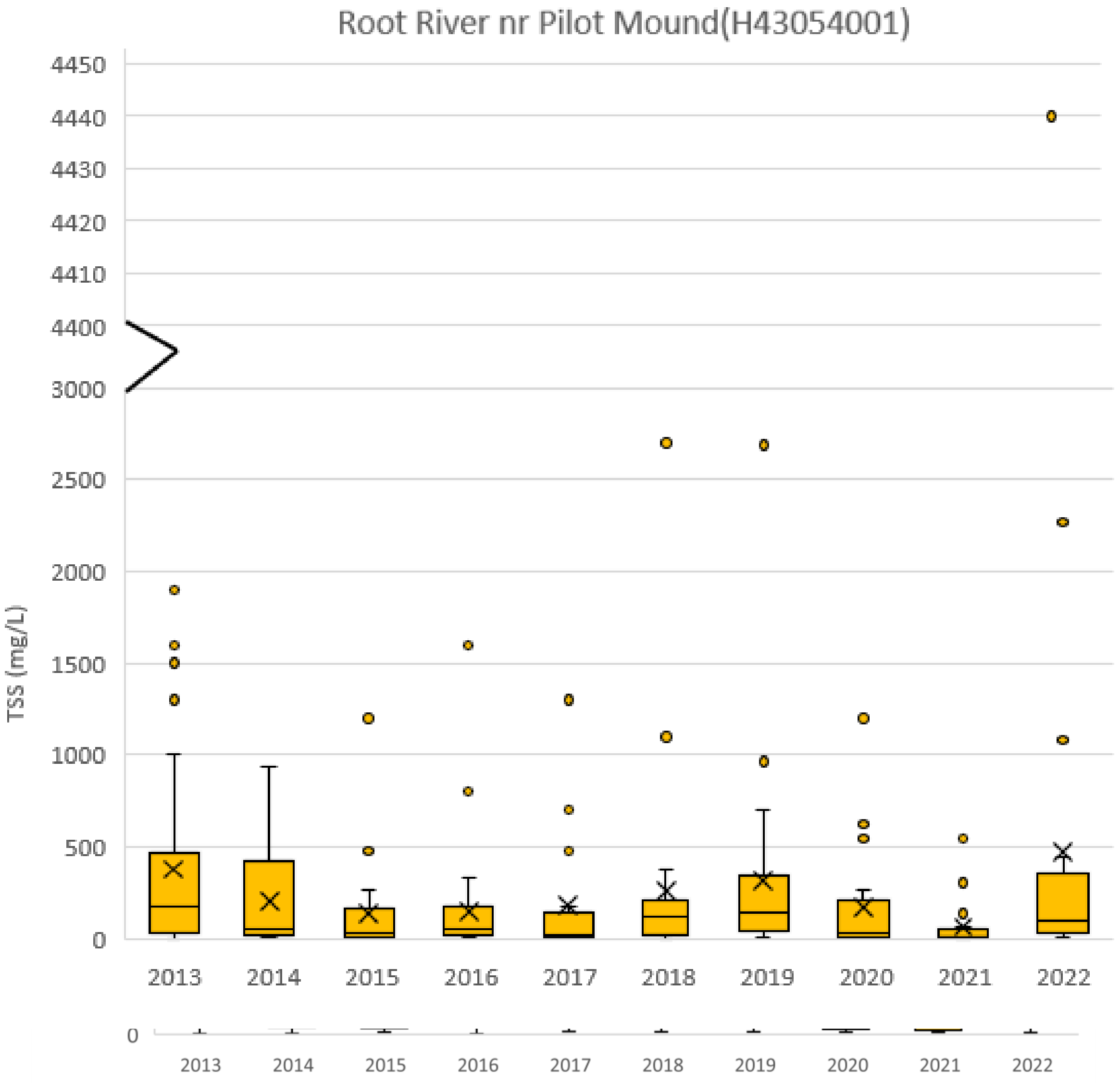
HUC10	HUC12	Waterbody (WID)	Issue	Suggested Strategy
			Habitat	**Implementation:** Low summer base flow and ditch clean outs significantly impact habitat. Work with landowners and drainage authority.
South Fork Root River	Upper South Fork Root River	South Fork Root River (07040008-511)	Habitat	**Implementation:** Suffers from lack of flow during certain times of year (tied to drain tile density?).
	Riceford Creek	Riceford Creek (07040008-518)	Nitrate	Monitoring/Investigation: Better understand land use variability and N applications in this coldwater reach.
		Riceford Creek (07040008-H01)	Sediment	**Implementation:** Runoff control practices, managed pastures and address gullies and steep ravines needed in headwaters area.
	Bridge Creek	Bridge Creek (07040008-G92)	Habitat	**Protection:** Stabilization of habitat, additional coarse substrate and increased riffle habitat.
Rush-Pine	Pine Creek	Pine Creek (07040008-526)	Habitat	**Protection:** Habitat protection for continued support of macroinvertebrates.
Root River (lower main stem)	Silver Creek	Silver Creek (07040008-640)	Habitat	**Implementation:** Additional stream stability practices may accelerate natural stream habitat improvement from 2007 flood.

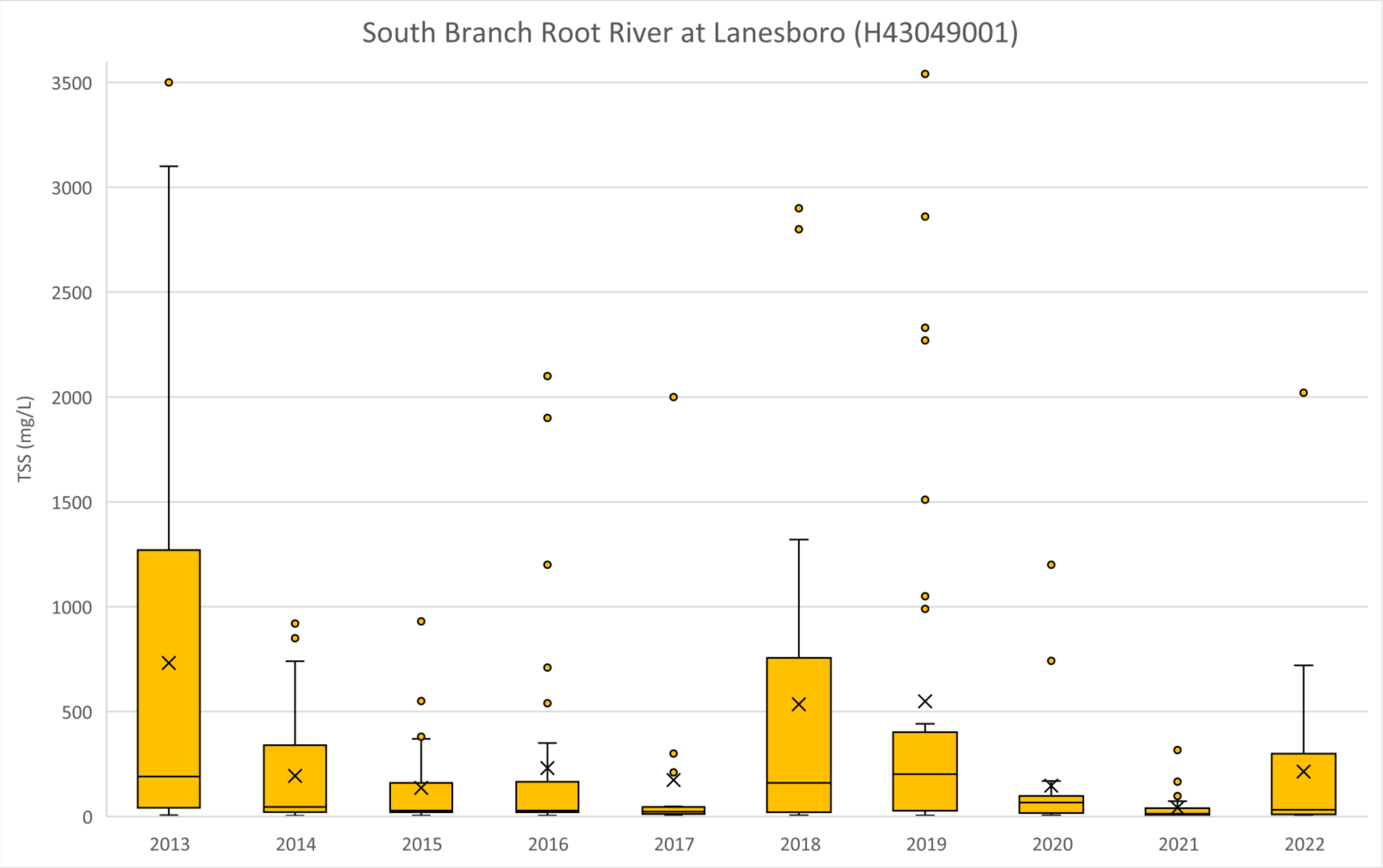
Appendix H. Annual concentrations from WPLMN stations

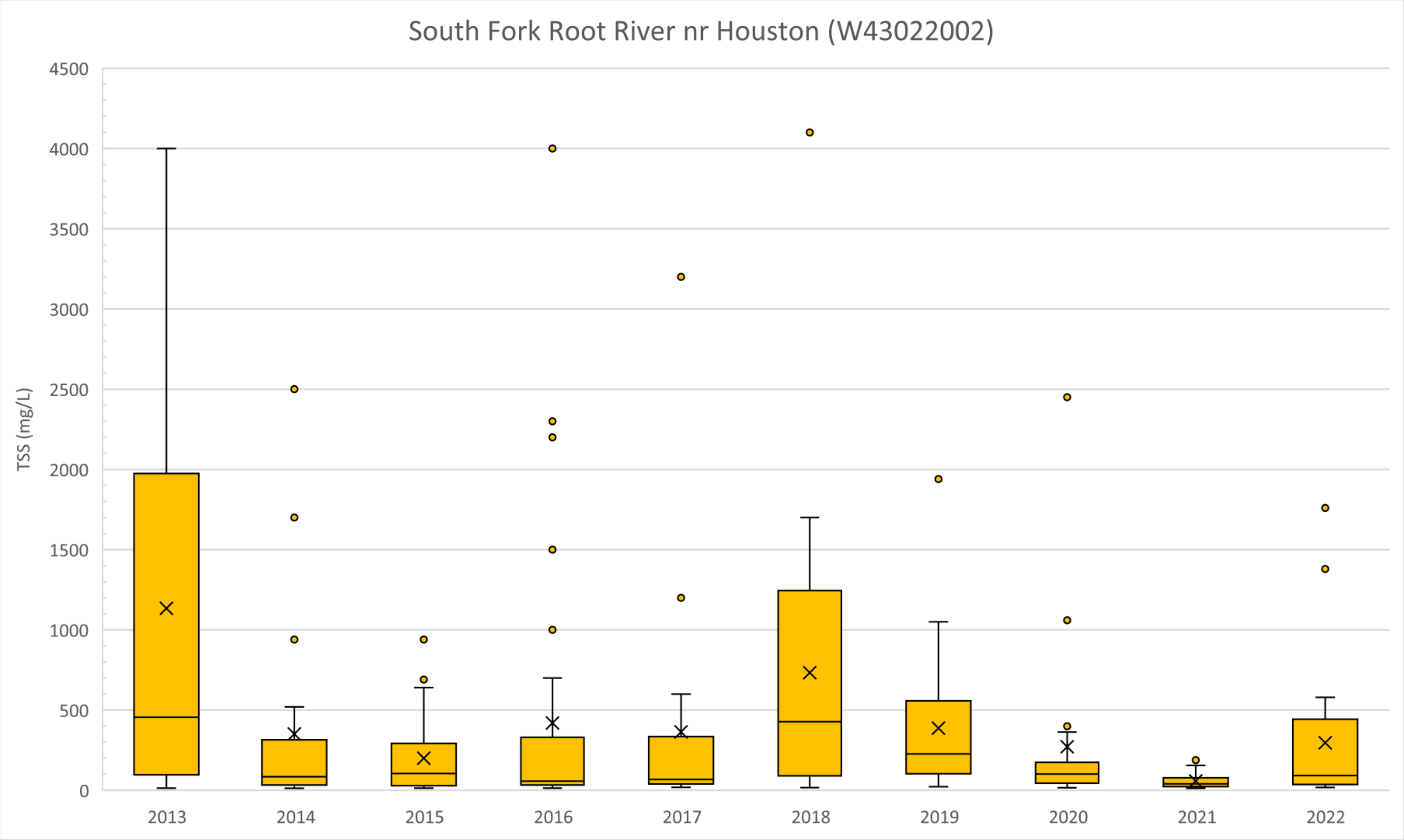
Annual concentrations for total suspended solids (TSS):



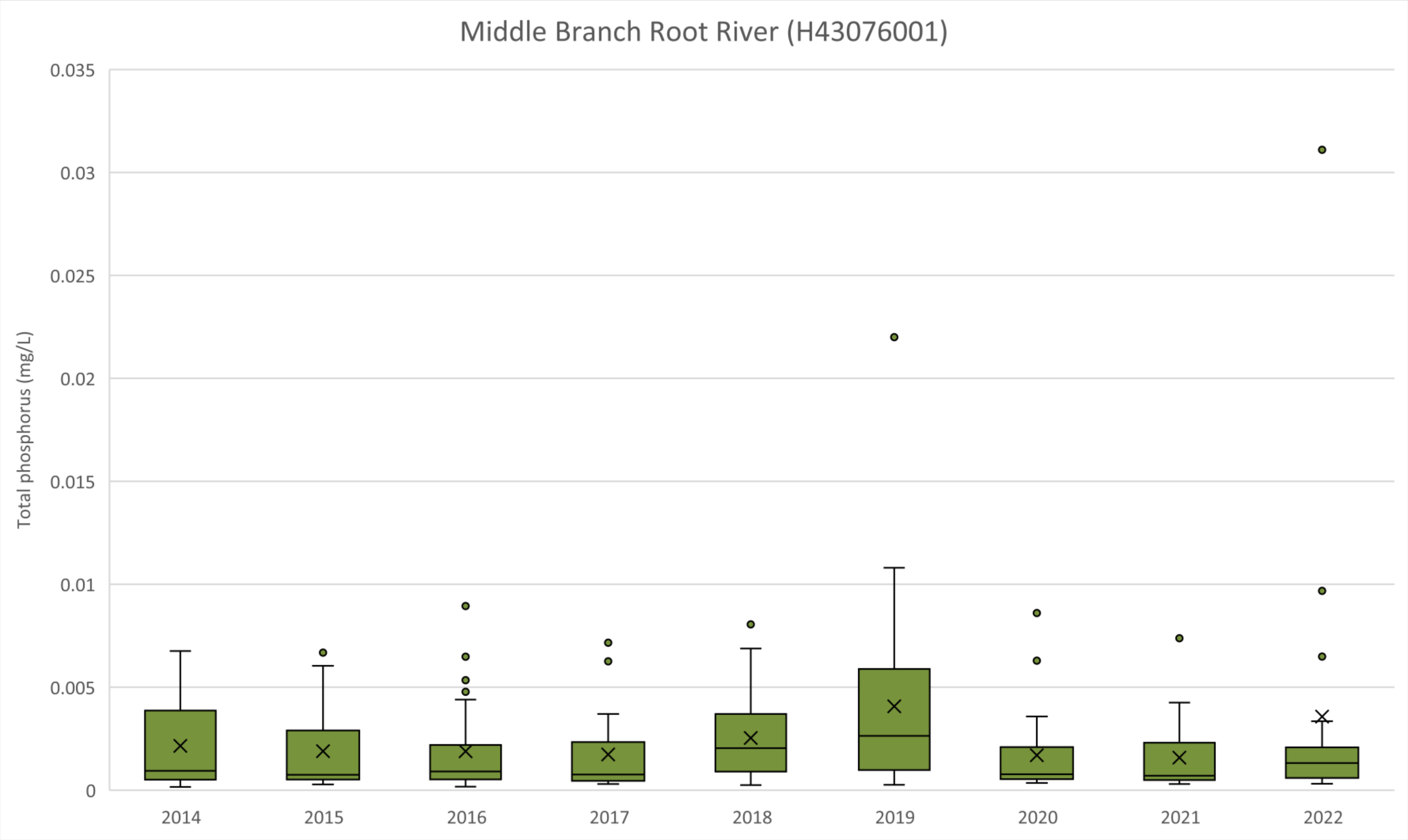

Root River nr Houston (E43017001)
TSS (mg/L)
9500
8500
7500
6500
5500
4500
3500
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

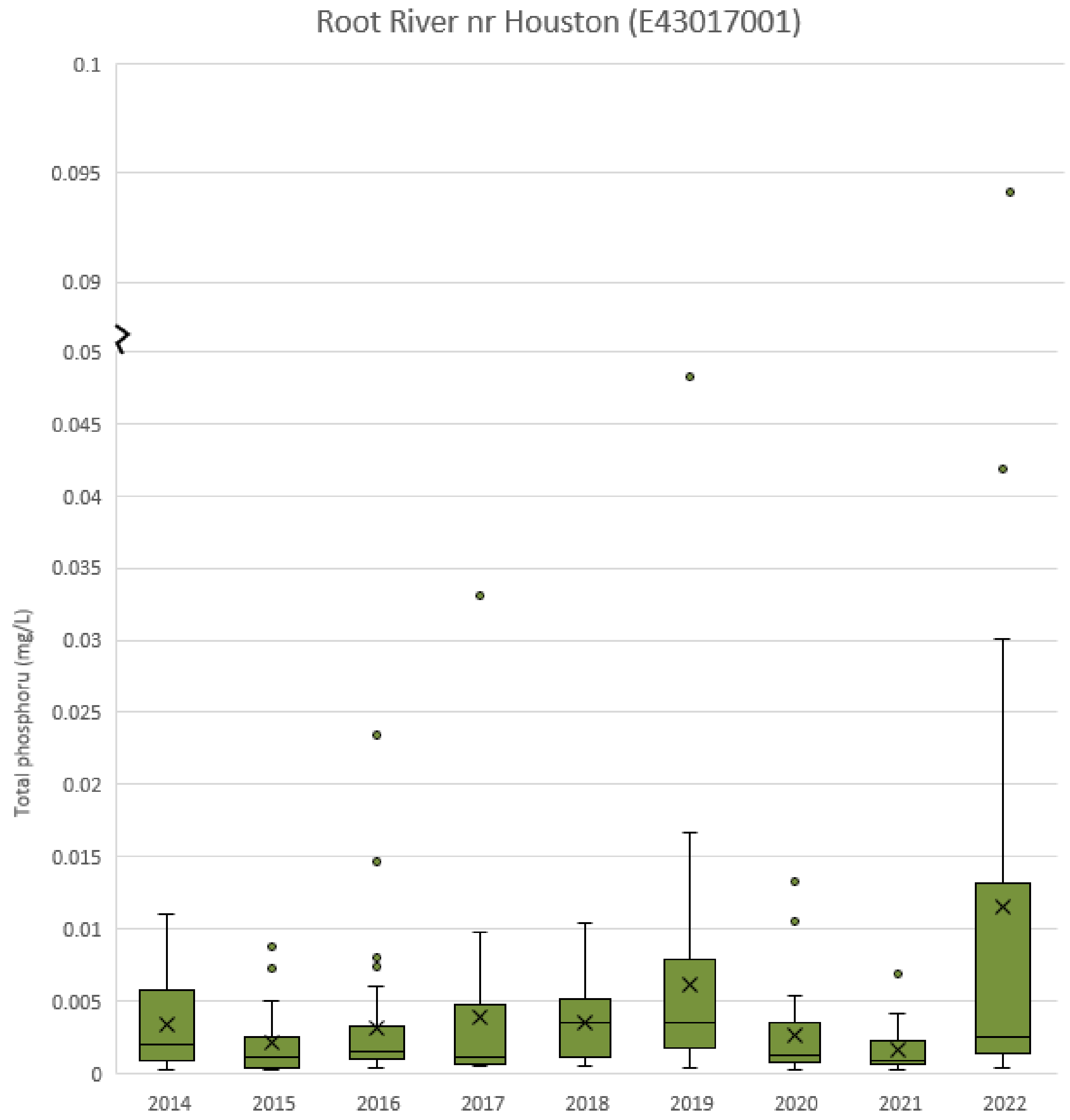

Root River nr Pilot Mound(H43054001)
TSS (mg/L)
4450
4440
4430
4420
4410
4400
3000
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

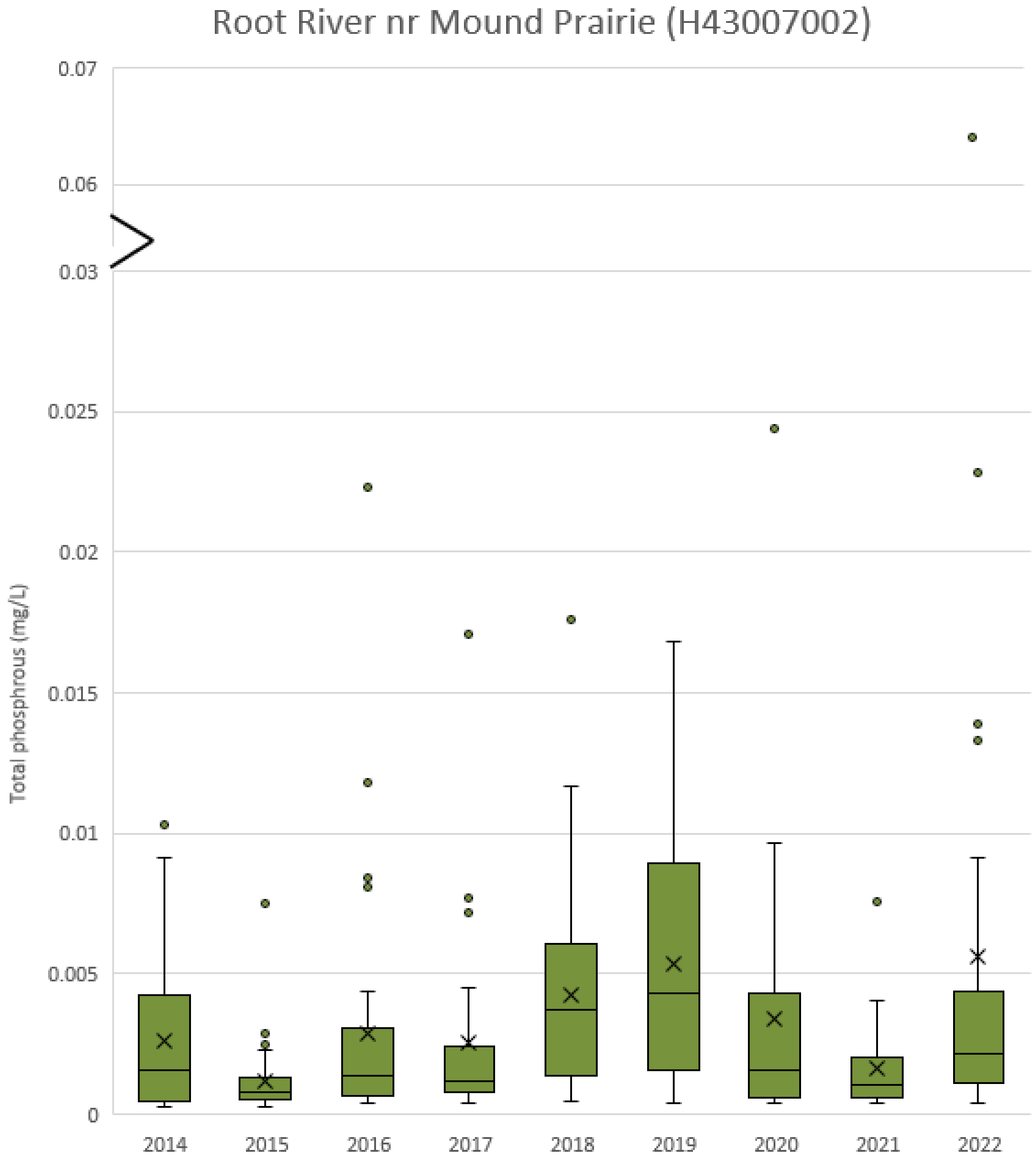

South Branch Root River at Lanesboro (H43049001)
TSS (mg/L)
3500
3000
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

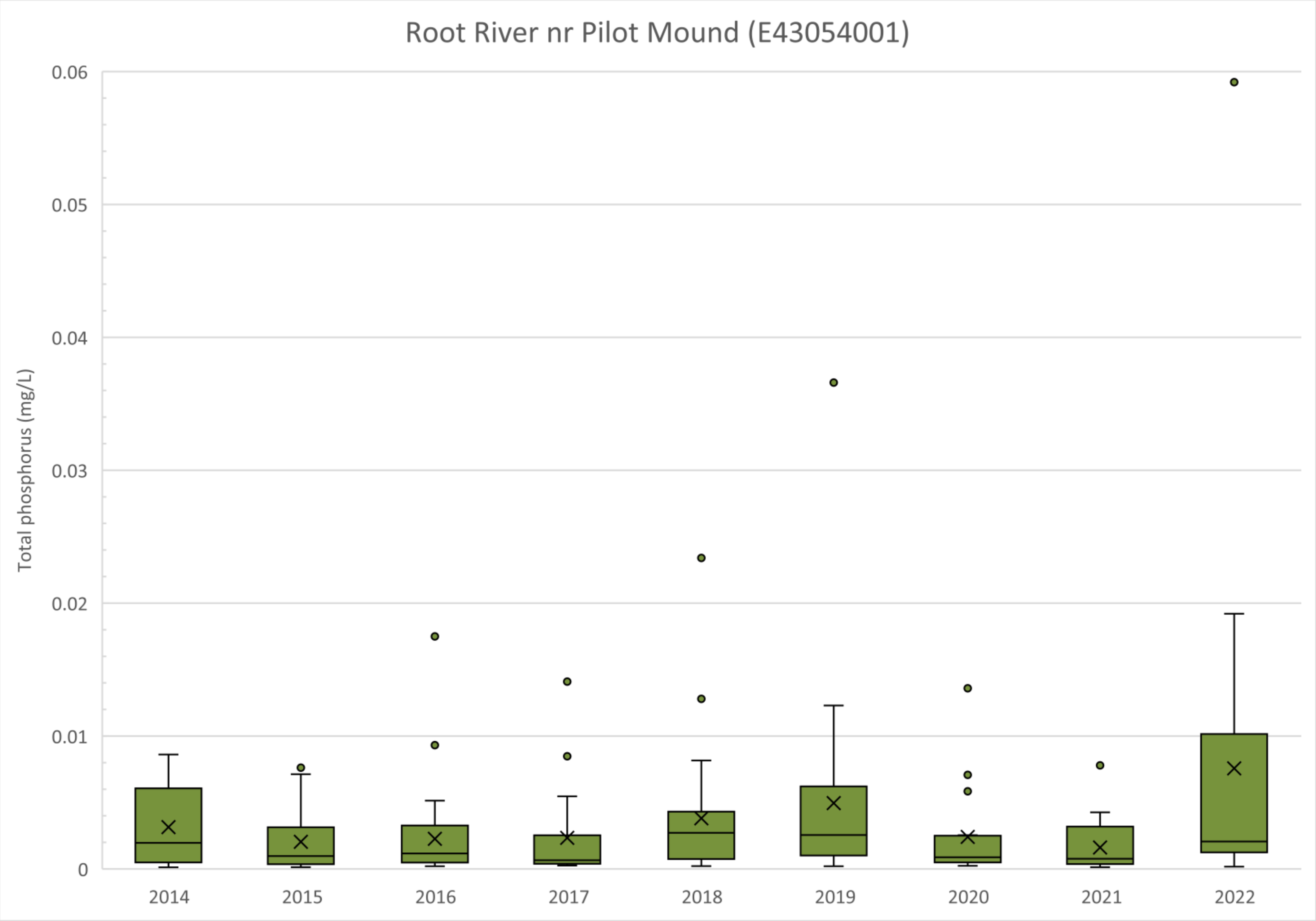

South Fork Root River nr Houston (W43022002)
TSS (mg/L)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

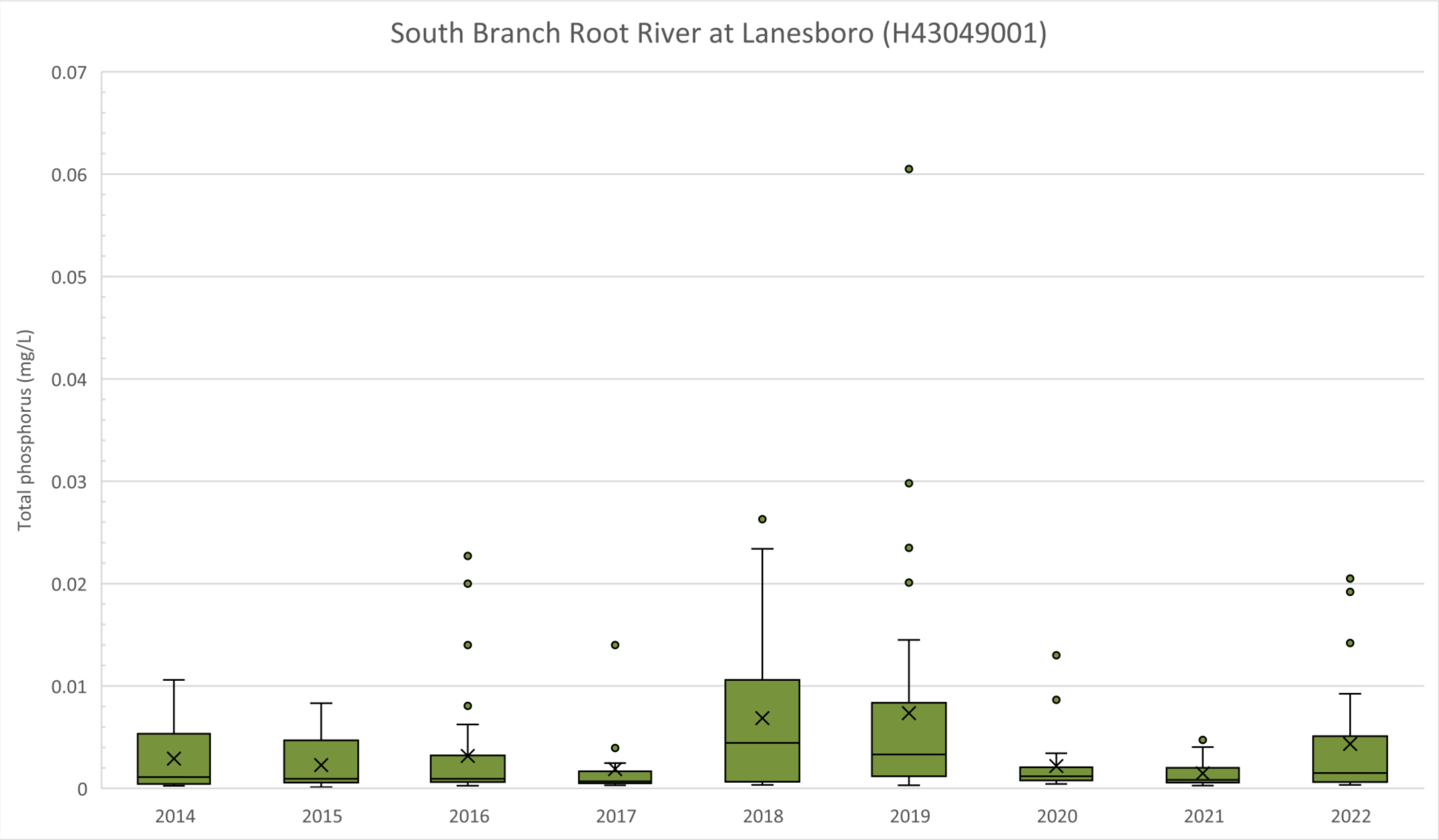
Annual concentrations for total phosphorus (TP):

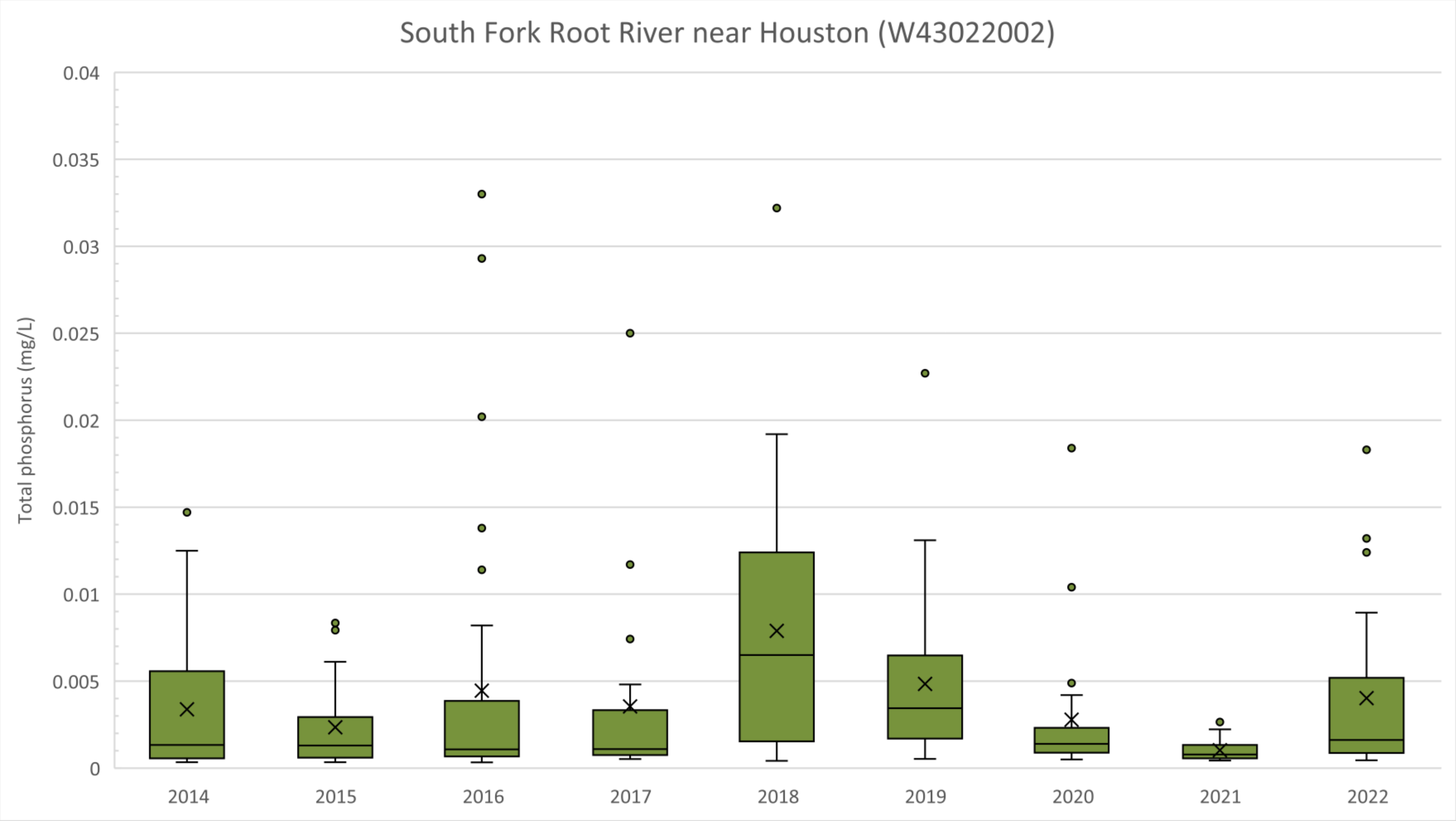



Root River nr Houston (E43017001)
Total phosphoru (mg/L)
0.1
0.095
0.09
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
2014
2015
2016
2017
2018
2019
2020
2021
2022


Root River nr Mound Prairie (H43007002)
Total phosphrous (mg/L)
0.07
0.06
0.03
0.025
0.02
0.015
0.01
0.005
0
2014
2015
2016
2017
2018
2019
2020
2021
2022


Root River nr Pilot Mound (E43054001)
Total phosphorus (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
2014
2015
2016
2017
2018
2019
2020
2021
2022


South Branch Root River at Lanesboro (H43049001)
Total phosphorus (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2014
2015
2016
2017
2018
2019
2020
2021
2022


South Fork Root River near Houston (W43022002)
Total phosphorus (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
2014
2015
2016
2017
2018
2019
2020
2021
2022