Recreational Use Study of Pymatuning Creek, and Selected Tributaries 2017

HUC 0503010203

Ashtabula and Trumbull Counties, Ohio

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INTRODUCTION

During 2017, Eastgate Council of Governments (Eastgate) conducted a water resource assessment of 10 streams in the Pymatuning Creek watershed. This study included direct and indirect tributaries to Pymatuning Creek that are completely or mostly contained within Ohio in Ashtabula, Trumbull, and northern Mahoning counties. The boundaries of the study area were delineated through the use of USGS's hydrologic system, and thus correspond to the following 10-digit Hydrologic Unit Code (HUC): 0503010203 – Pymatuning Creek. HUC 0503010203 is the Pymatuning Creek watershed. Pymatuning Creek from its headwaters to the Ohio/Pennsylvania state line was sampled, along with its tributaries Sugar Creek and Stratton Creek.

The primary focus of the present study was to characterize the watershed with respect to attainment of the recreational designated beneficial use in the State Water Quality Standards. Field parameter data were also collected. The assessment was used to determine the current recreational use status of Pymatuning Creek and expand upon previous Ohio EPA monitoring conducted in 2008. These data were necessary precursors to the development of effective control or abatement strategies for sources of recreational use impairment in the Pymatuning Creek Watershed. A list of sampling stations used in the study can be found in Tables 1 and 2.

Specific objectives of the evaluation were to:

- Monitor and assess *E. coli* at ten sites within the Pymatuning Creek watershed (HUCs 05030102 03 01, 05030102 03 02, and 05030102 03 03).
- Evaluate the appropriateness of existing recreational use designations;
- Determine any recreational use impacts from known potential sources, including point source dischargers and unsewered communities.
- Compare present results with historical conditions.

The Pymatuning Creek watershed is located in the Erie-Ontario Lake Plain (EOLP) ecoregion. All streams in the study are designated Warmwater Habitat (WWH), Primary Contact Recreation (PCR), Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) in the Ohio Water Quality Standards (WQS).

Table 1: Sampling locations with associated sampling protocols and issues, by HUC-12, for the Pymatuning Recreational Use Study

RIVER	RIVER MILE	DRAIN. AREA	LOCATION	SAMPLE TYPE	STORET
HUC 05030102 03 01 – Headwaters Pymatuning Creek					
Pymatuning Creek	22.70	43.0	Underwood Rd.	B Grab	N04Q06
HUC 05030102 03 02 – Sugar Creek-Pymatuning Creek					
Pymatuning Creek	17.78	66.0	St. Rt. 87	B Grab	N04S26
Sugar Creek	5.72	9.0	St. Rt. 88	B Grab	N04K07
Sugar Creek	0.92	19.9	Burnett Rd.	B Grab	N04S28
HUC 05030102 03 03 – Stratton Creek-Pymatuning Creek					
Pymatuning Creek	15.80	96.0	Dst Storm Sewer #2/SR 7	B Grab	N04S23
Pymatuning Creek	15.15	97.0	Dst septic outfalls/SR 7 (south of Kinsman and SR 5)	B Grab	N04S22
Stratton Creek	4.21	9.1	Webber Rd.	B Grab	N04K08
Stratton Creek	0.70	17.1	Kinsman-Nickerson Rd.	B Grab	N04K09
HUC 05030102 03 04 –-Booth Run-Pymatuning Creek					
Pymatuning Creek	8.40	135.0	St. Rt. 88	B Grab	N04S01
Pymatuning Creek	1.94	148.0	PA state line at Orangeville	B Grab	N04S20

B – Bacteria site

Table 2: Sampling locations with geographical coordinates, by stream, for the Pymatuning Recreational Use study, 2017

RIVER	RIVER MILE	DRAIN. AREA	LOCATION	LATITUDE	LONGITUDE	USGS QUAD
Pymatuning Creek	22.70	43.0	Underwood Rd.	41.5106	-80.6344	Cherry Valley
Pymatuning Creek	17.78	66.0	St. Rt. 87	41.4553	-80.6125	Kinsman
Pymatuning Creek	15.80	96.0	Dst Storm Sewer #2/SR 7	41.4431	-80.5869	Kinsman
Pymatuning Creek	15.70	96.0	Dst Septic outfalls/SR 7	41.4430	-80.5853	Kinsman
Pymatuning Creek	15.15	96.0	Dst. Kinsman, Adj. SR 7	41.4384	-80.5884	Kinsman
Pymatuning Creek	8.40	135.0	St. Rt. 88	41.3869	-80.5575	Kinsman
Pymatuning Creek	1.94	148.0	PA state line at Orangeville	41.3400	-80.5194	Orangeville
Sugar Creek	5.72	9.0	St. Rt. 88	41.3886	-80.6318	Gustavus
Sugar Creek	0.92	19.9	Burnett Rd.	41.4375	-80.6036	Kinsman
Stratton Creek	4.21	9.1	Webber Rd.	41.4828	-80.5613	Kinsman
Stratton Creek	0.70	17.1	Kinsman-Nickerson Rd.	41.4436	-80.5779	Kinsman

STUDY AREA DESCRIPTION

Although Pymatuning Creek and its tributaries evaluated as part of this survey are contained wholly within the Erie-Ontario Lake Plain (EOLP) ecoregion, a glaciated portion of the Allegheny Plateau (Omernik and Gallant 1988), each of the principal river systems arises in, drains, and course through contrasting landforms. Influences of local and subregional topography are multifaceted and effectively establish basic elements of, or limits to, channel form and function, substrate composition, and hydrology. Of equal importance, and directly related to topography is the degree to which the landscape is or has been manipulated to suit various human uses. In modern times, the most pervasive and influential anthropogenic modifications are attendant to efforts to improve drainage, which directly affects stream power, channel form, and hydrology. These natural and artificial features in turn can have a direct effect upon the diversity, composition, and functional organization of associated fish and aquatic benthic macroinvertebrate communities.

Pymatuning Creek arises in southeast Ashtabula County and flows south for a total of 33.8 miles through northeastern Trumbull County before crossing the state line into Pennsylvania, where it joins the Shenango River. For most of its length it courses through a well-established ancient pre-glacial valley that likely drained north prior to the onset of the ice age (Shanks 1942). During the late Wisconsin epoch, the valley served as a glacial outlet, reversing stream flow southward again and thus establishing the basic form of the contemporary drainage network. The modern drainage divide between the Laurentian and Mississippian basins for the Pymatuning, as well as adjacent waters, is defined by the Cleveland end moraine, formed by the Grand River lobe of the late-Wisconsin ice sheet (Trautman 1981 and Richards et al. 1999).

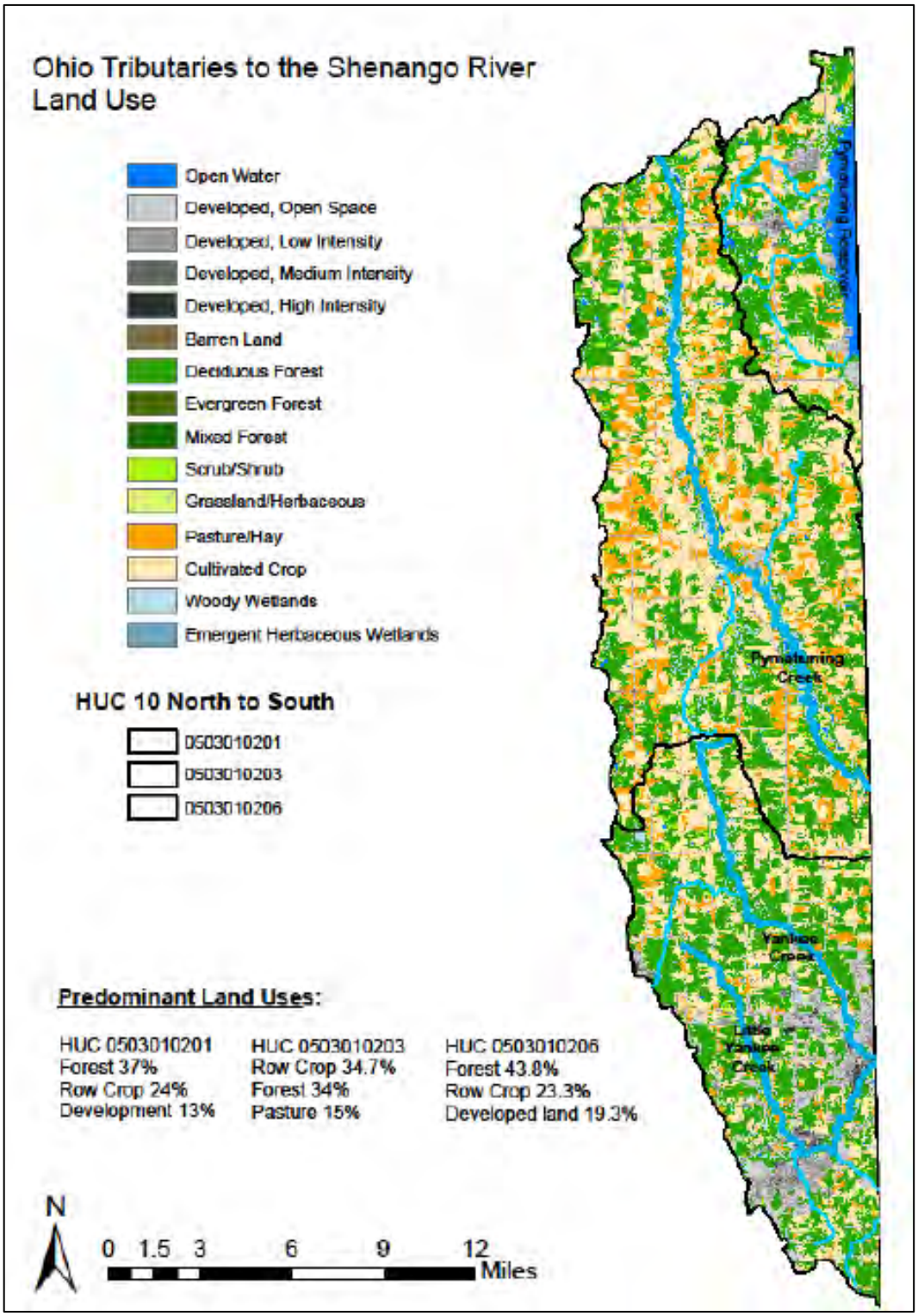
Through the northern half of the watershed, the upland topography of the Pymatuning Creek basin is derived from a combination of a high relief, hummocky end moraine, interspersed with numerous kames and kame terraces ((Richards et al. 1999). Here, glacial melt water reclaimed the old pre-glacial valley and presently the stream originates within and courses through the eastern latitudinal margin of the Cleveland end moraine. Despite the hilly, high relief, and dissected nature of the uplands, Pymatuning Creek itself is a sluggish, low gradient, rheopalustrine (flowing swamp) stream type. This apparent contradiction (high relief uplands and swampy lowlands) is a result of the great age and maturity of its pre-glacial valley. This channel form imposes strict limitations on aquatic faunal associates, as palustrine or related low gradient riverine habitats typically offer limited habitat complexity and a naturally stressful or chemically reduced environment (e.g., lower pH, low dissolved oxygen (D.O.), and high background ammonia). It must be emphasized that even under pristine conditions, streams of this type in Ohio almost universally support simple fish communities in comparison to typical riverine waters.

Moving further south, the lower half of the mainstem is still contained within the wide, pre-glacial valley, but drain level to gently rolling terrain of late-Wisconsin ground moraine. Despite this, the change in upland land forms (from end moraine in the north, to ground moraine further south) the Pymatuning still retains its low gradient, rheopalustrine channel form, hydrology and associated natural limitations. In general, the naturally poor drainage of the basin, but particularly in the lower reach through Trumbull County, necessitated much artificial surface and subsurface drainage to facilitate and support agricultural and other more intensive human land use (USDA 1986 and 2003; Office of Trumbull Co. Engineer pers.com.)

In addition to glacial geology and topography, land cover also plays a significant role in water quality and biological potential. While the underlying geological features of a watershed cannot be altered, impacts to resource quality due to land uses offer opportunities for mitigation when applicable. Figure 1 displays the land use for the Ohio Tributaries to the Shenango River watershed. As evident in the figure, forest, row crop agriculture, and developed land are the predominant land uses throughout most of the watershed. The exception is the Pymatuning Creek watershed (HUC 0503010203), where both row crop agriculture and livestock pasturage combined comprise nearly half of the watershed, and developed land is sparse.

Although not densely populated, the watershed does include a few smaller population centers that are large enough to yield a significant impact on their respective watersheds. These include Andover (population 1214) in the Wade Creek watershed, Kinsman (population 3487 including surrounding townships) in the Pymatuning Creek watershed, Brookfield (population 1288) in the Yankee Creek watershed, Masury (population 2618) in the Yankee and Little Yankee Creek watersheds, and Hubbard (population 7630) in the Little Yankee Creek watershed. According to US Census Bureau data, there has been a slight population decline in the past decade, thereby reducing the notion of imminent and rampant urbanization. However, the lack of development in this watershed has also allowed for a lack of centralized sewer systems in much of the study area, thus risking exposing local waterways to the effects of septic system failures

Figure 1: Land Use in the Ohio Tributaries to the Shenango River watershed (NLCD 2001)



RESULTS AND DISCUSSION

Water Chemistry

Surface water samples were collected from the Pymatuning Creek watershed from July through October 2017 at ten locations. Samples were analyzed for bacteria, pH, temperature, conductivity, dissolved oxygen (D.O.), and percent D.O. saturation, (Table 1). Parameters which were in exceedance of the Ohio WQS criteria are reported in Table 3. Bacteriological samples were collected from 54 locations, and the results are reported in the Recreation Use section.

Table 3: Exceedances of Ohio Water Quality Standards criteria (OAC rule 3745-1) for chemical/physical parameters measured in the Pymatuning Creek watershed Recreational Use study area, 2017. Bacteria exceedances are presented in the Recreational Use Section

RIVER	RIVER MILE	DRAIN. AREA	LOCATION	Parameter (mg/L)
HUC 05030102 03 01 – Headwaters Pymatuning Creek				
Pymatuning Creek	22.70	43.0	Underwood Rd.	None
HUC 05030102 03 02 – Sugar Creek-Pymatuning Creek				
Pymatuning Creek	17.78	66.0	St. Rt. 87	D.O. (0.5, 1.2, 1.1, 0.7, 2.0, 0.3, 0.7, 1.9 mg/L[a])
Sugar Creek	5.72	9.0	St. Rt. 88	D.O. (2.8, 2.0, 2.2, 0.3, 1.6, 1.9 mg/L[a])
Sugar Creek	0.92	19.9	Burnett Rd.	D.O. (2.9 mg/L[a])
HUC 05030102 03 03 – Stratton Creek-Pymatuning Creek				
Pymatuning Creek	15.80	96.0	Dst Storm Sewer #2/SR 7	D.O. (2.0, 3.2, 3.0, 2.6, 3.4, 1.6, 3.3, 1.0, 1.3, 2.9 mg/L[a])
Pymatuning Creek	15.15	97.0	Dst septic outfalls/SR 7 (south of Kinsman and SR 5)	D.O. (3.3, 3.8, 3.6, 3.9, 2.4, 1.7, 3.0, 3.5 mg/L[a])
Stratton Creek	4.21	9.1	Webber Rd.	None
Stratton Creek	0.70	17.1	Kinsman-Nickerson Rd.	D.O. (2.1 mg/L[a])
HUC 05030102 03 04 –-Booth Run-Pymatuning Creek				
Pymatuning Creek	8.40	135.0	St. Rt. 88	D.O. (3.5, 1.0, 2.3 mg/L[a])
Pymatuning Creek	1.94	148.0	PA state line at Orangeville	D.O. (2.3, 3.6, 3.4, 3.5, 3.7, 2.6, 2.0, 2.8 mg/L[a])

a Exceedance of the aquatic life Outside Mixing Zone Maximum water quality criterion (for D.O., below minimum).
b Exceedance of the aquatic life Outside Mixing Zone Average water quality criterion (for D.O., below 24 hour average).
c Exceedance of the statewide water quality criteria for the protection of agricultural uses.

The low gradient, wetland nature of Pymatuning Creek led to numerous WQS exceedances for dissolved oxygen in the lower reach of the stream (Table 3). All sites from RM 17.78 to RM 1.94 had at least one dissolved oxygen measurement that was below the minimum criterion of 4.0 mg/L for WWH streams. This lower reach of the stream was generally sluggish and therefore provided little turbulence that would allow for higher instream dissolved oxygen.

Channelization of the Sugar Creek headwaters at RM 5.72 resulted in a monotonous and motionless stream and allowed for general low dissolved oxygen, with one value below the WWH criterion of 4.0 mg/L.

Recreation Use

Water quality criteria for determining attainment of recreation uses are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977), but there is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more practicable. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly. Fecal indicator bacteria by themselves, including *E. coli*, are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high fecal coliform or *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

Streams in the Pymatuning Creek watershed are designated as primary contact recreation (PCR) use in OAC Rule 3745-1-25. Water bodies with a designated recreation use of PCR —...are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking, and scuba diving‖ [OAC 3745-1-07 (B)(4)(b)]. There are three classes of PCR use to reflect

differences in the potential frequency and intensity of use. Streams designated PCR Class A support, or potentially support, frequent primary contact recreation activities. Streams designated PCR Class B support, or potentially support, occasional primary contact recreation activities. Streams designated as PCR Class C support, or potentially support, infrequent primary contact recreation activities. The Pymatuning Creek mainstem is designated PCR Class B from the headwaters to RM 15.8 in Kinsman; from RM 15.87 to the Pennsylvania state line, Pymatuning Creek is classified as PCR Class A. All other streams assessed in the survey are designated Class B PCR waters.

The *E. coli* criteria that apply to PCR Class A and B streams include a seasonal geometric mean of 126 and 161 cfu/100 ml, respectively, and maximum values of 298 and 523 cfu/100 ml, respectively. The geometric mean is based on two or more samples and is used as the basis for determining attainment status when more than one sample is collected.

Ten locations in the Pymatuning Creek watershed were sampled 12 times between July 31st and October 18th, 2017 and twice between May 1st and June 30th, 2018. Evaluation of *E. coli* results revealed that 10 of the 12 locations sampled failed to attain the applicable recreation use criterion (Table 4).

Because of the rural nature of most of the study area, centralized sewer systems are rare and therefore most homes located outside of the major population centers treat their sanitary waste via home sewage treatment systems (HSTS). Therefore, failing HSTS are suspected as a source of *E. coli* in the Pymatuning Creek mainstem, Stratton Creek and Sugar Creek.

The large percentage of land dedicated to row crop agriculture and livestock pasturage may also contribute to the excessive levels of bacteria in the watershed. As indicated in Figure 1, roughly half of the land in the Pymatuning Creek watershed is dedicated to row crop agriculture and livestock pasturage. As a result, these activities, manure-laden runoff from farm fields or pasture, animal feedlots, and/or unrestricted livestock access to stream channels could also contribute *E. coli* bacteria to many of the streams that are located within or downstream from agricultural operations.

When comparing the *E. coli* geometric mean values of samples after a rain event to those samples that were collected with no rain with 72 hours, one can see that runoff contributes a significant source of bacteria in the watershed (Figure 2). At three locations that were in non-attainment, the *E. coli* results fell below the recreation use criterion when no rain was recorded within 72-hours of sampling. At 7 of the 10 locations in the study, the geometric mean values of *E. coli* were below those recorded in the 2008 study. At baseflow, the geometric mean values of *E. coli*, were below those recorded in 2008.

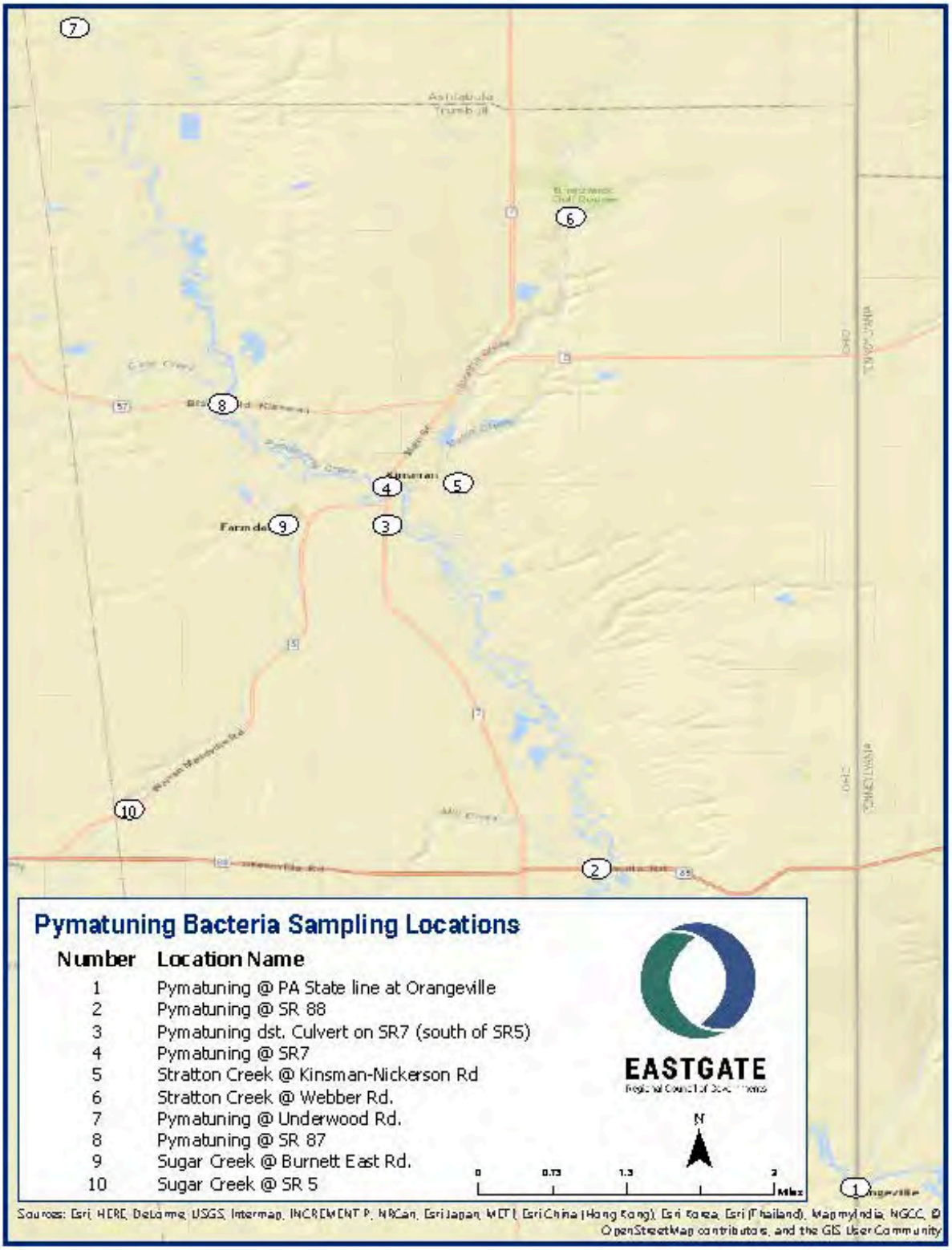
*Table 4: Recreation beneficial use attainment table for 10 locations in the Pymatuning Creek watershed, July 31 through October 18, 2017 and May 1 through June 30, 2018. Note: All E.coli values are expressed as colony forming units (cfu) per 100 ml of water. Bold **red** values exceed applicable criteria (OAC 3745-1-05, Table 5-1).*

Location	River Mile	Rec Class*	Number of Samples	Geometric Mean† (rain within 72 hours/no rain)	Attainment Status	Potential Source(s) of Bacteria
HUC 050301020301 – Headwaters Pymatuning Creek						
Pymatuning Creek @ Underwood Rd	22.70	B	12	**245/179**	**NON**	Livestock/agriculture
HUC 050301020302 – Sugar Creek-Pymatuning Creek						
Pymatuning Creek @ SR 87	17.78	B	12	146/154	FULL	
Sugar Creek @ SR 88	5.72	B	12	**276/201**	**NON**	Livestock/agriculture; failing home septic systems
Sugar Creek @ Burnett Road	0.92	B	12	**169**/151	**NON**	Livestock/agriculture; failing home septic systems
HUC 050301020303 – Stratton Creek-Pymatuning Creek						
Pymatuning Creek @ SR 7	15.80	B	12	**201**/138	**NON**	Failing home septic systems; illicit sewage discharges
Pymatuning dst. Culvert on SR7 (south of SR5)	15.15		12	**220/192**		Livestock/agriculture; failing home septic systems
Stratton Creek @ Weber Road	4.21	B	12	**214**/147	**NON**	Failing home septic systems
Stratton Creek @ Kinsman-Nickerson Road	0.70	B	12	143/124	FULL	
HUC 050301020304 – Booth Run-Pymatuning Creek						
Pymatuning Creek @ SR 88	8.40	B	12	**351/286**	**NON**	Livestock/agriculture; Failing home sewage treatment systems
Pymatuning Creek @ PA state line at Orangeville	1.94	B	12	109/65	FULL	

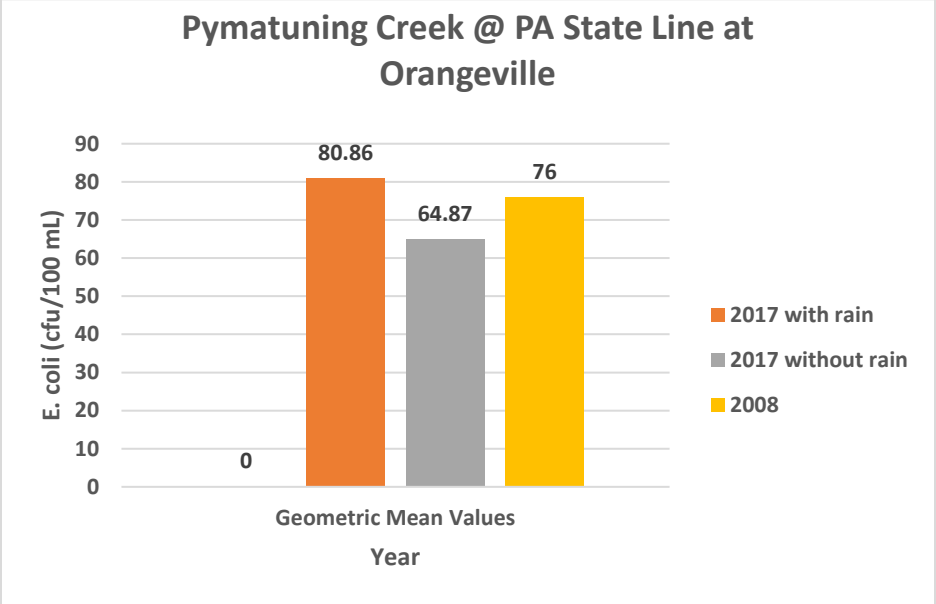
*Recreation class may include primary contact recreation classes (A, B or C); bathing waters (BW); or secondary contact recreation (SCR).

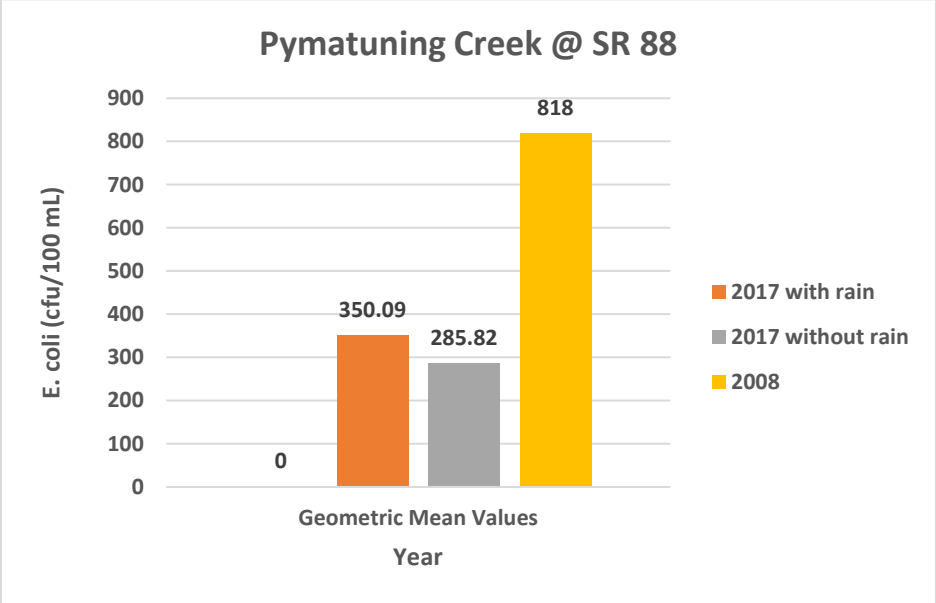
†Attainment status is determined based on the seasonal geometric mean of 126/100ml. The status cannot be determined at locations where fewer than two samples were collected during the recreation season.

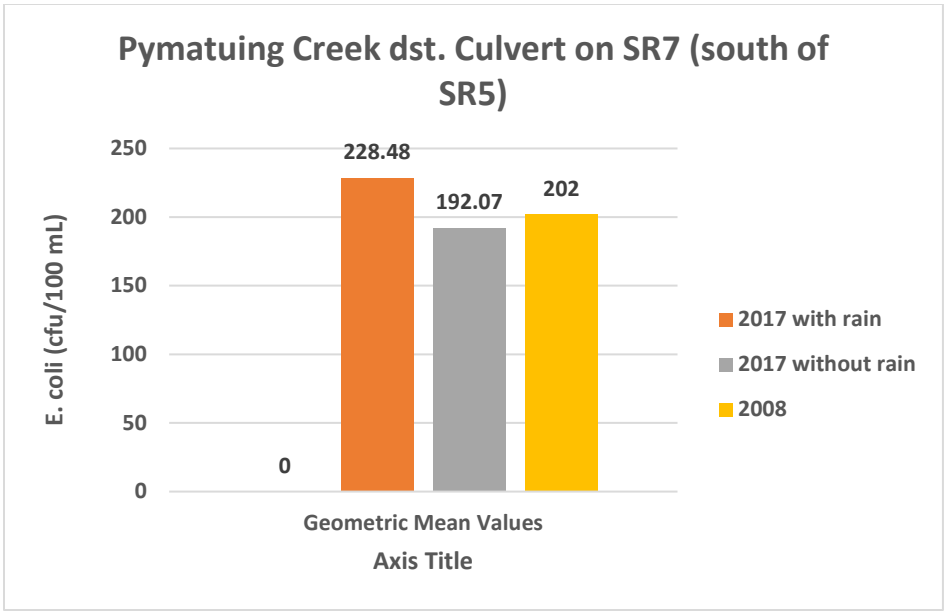
Figure 2: Pymatuning Bacteria Sampling Locations

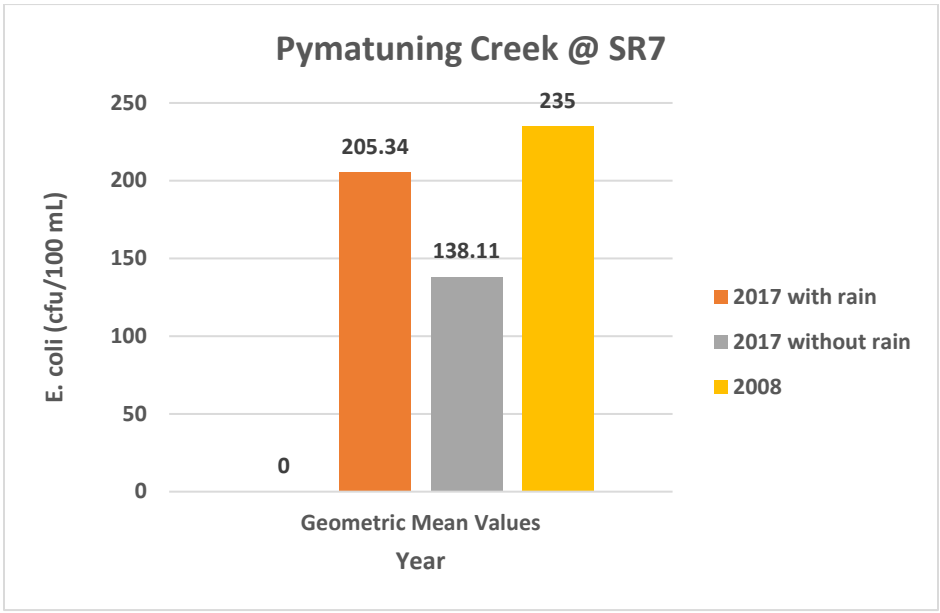


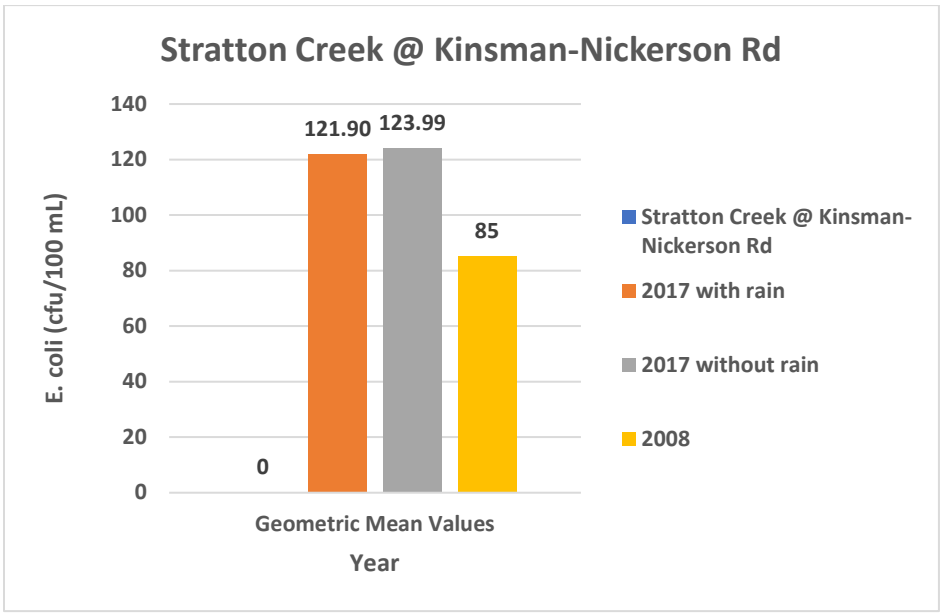
The following bar graph charts were developed to show comparisons of geometric mean values of *E. coli* in 2017, with and without rainfall), during the sampling period of July 1, 2017 through October 31st, 2017. The data was then compared to Ohio EPA's 2008 OEPA survey results.

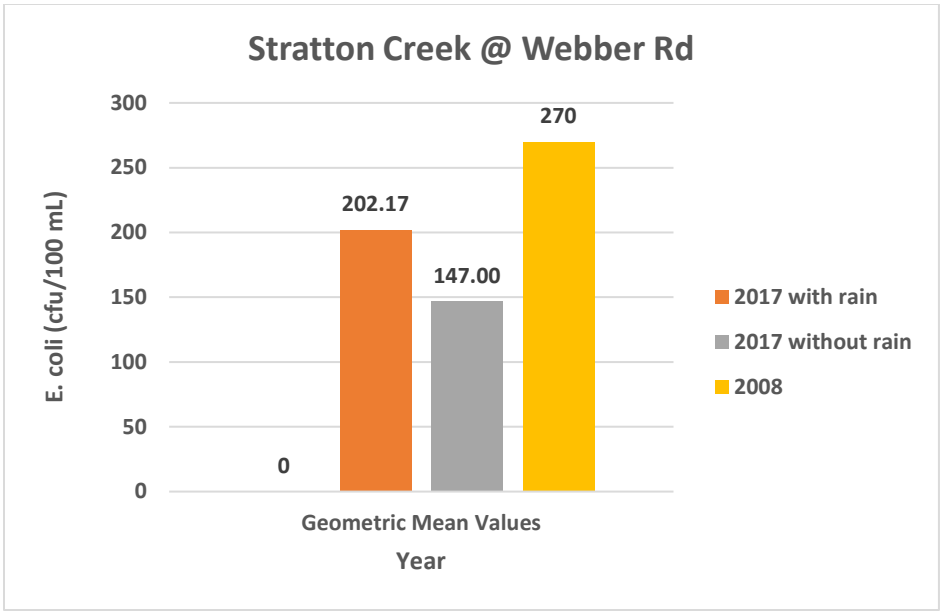


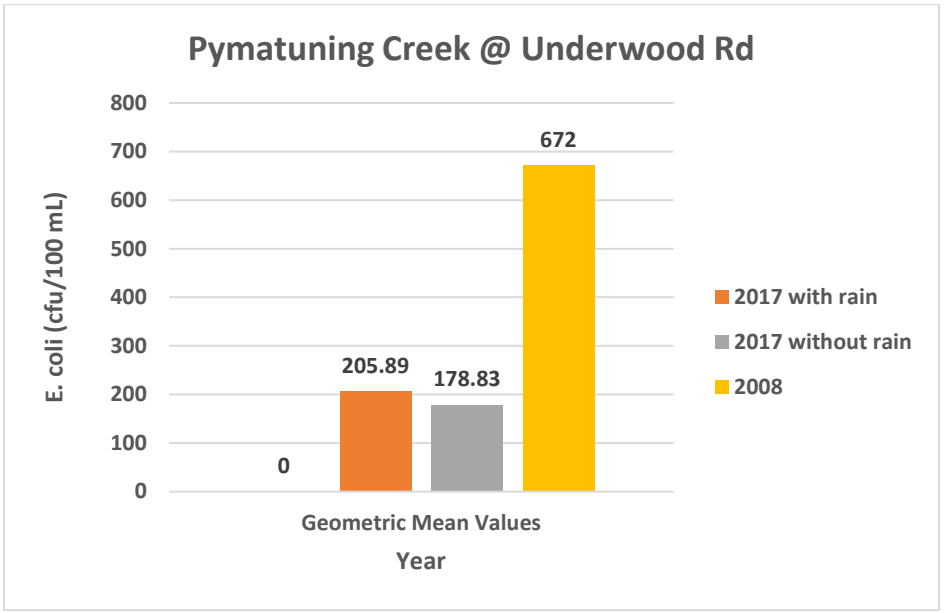


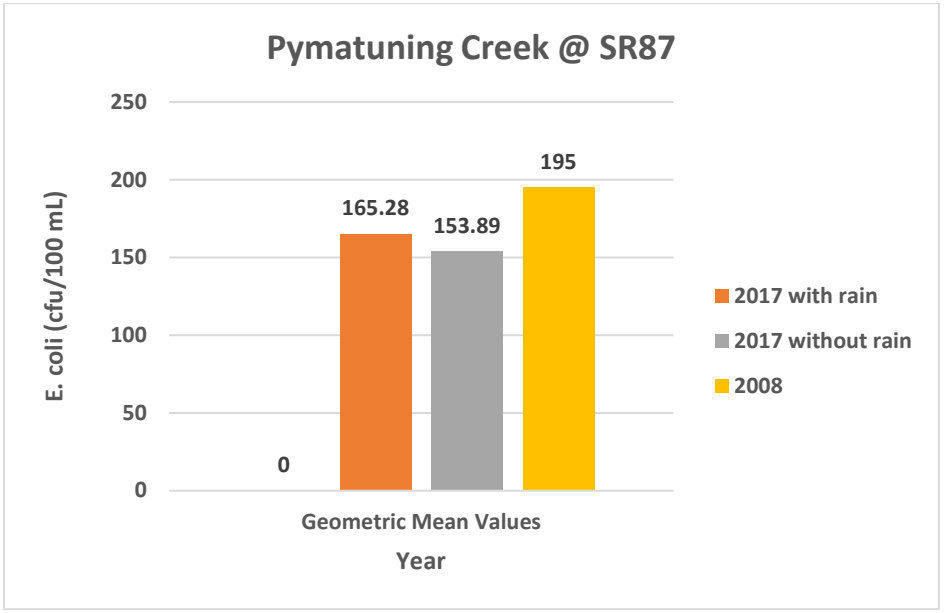

Pymatuing Creek dst. Culvert on SR7 (south of SR5)
E. coli (cfu/100 mL)
250
200
150
100
50
0
228.48
192.07
202
0
Geometric Mean Values
Axis Title
2017 with rain
2017 without rain
2008

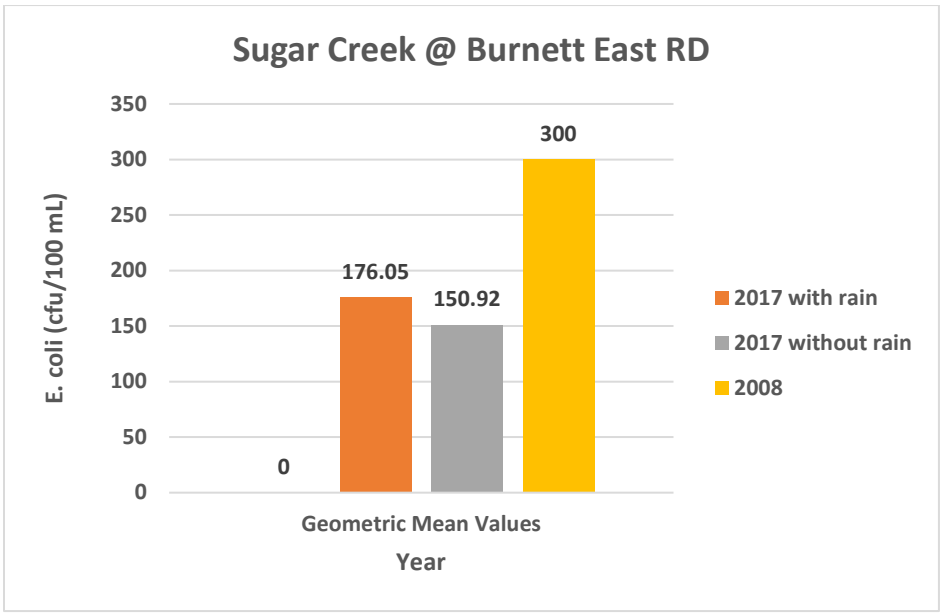

Pymatuning Creek @ SR7
E. coli (cfu/100 mL)
250
200
150
100
50
0
205.34
138.11
235
0
Geometric Mean Values
Year
2017 with rain
2017 without rain
2008

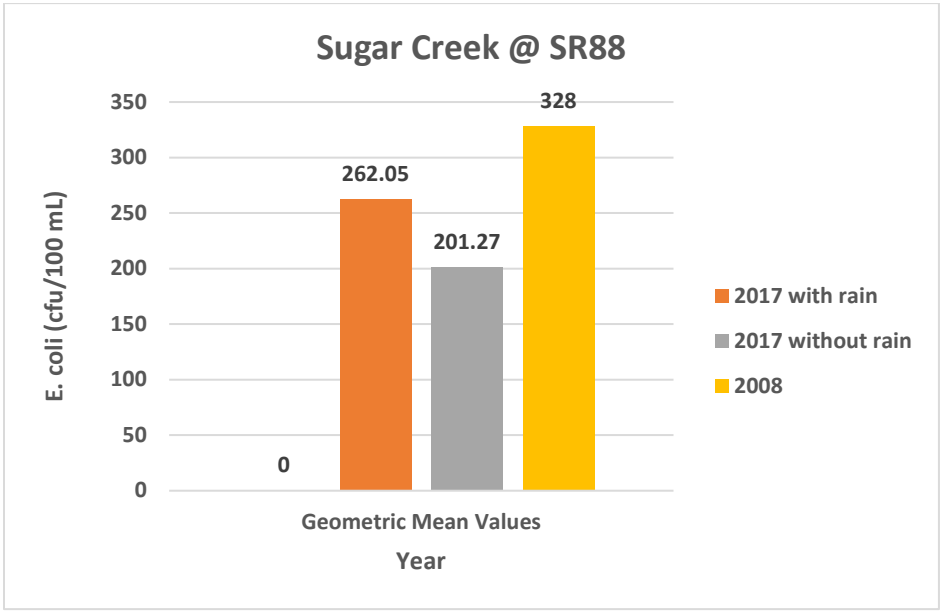

Stratton Creek @ Kinsman-Nickerson Rd
E. coli (cfu/100 mL)
140
120
100
80
60
40
20
0
121.90
123.99
85
0
Geometric Mean Values
Year
Stratton Creek @ Kinsman-Nickerson Rd
2017 with rain
2017 without rain
2008


Stratton Creek @ Webber Rd
E. coli (cfu/100 mL)
300
250
200
150
100
50
0
202.17
147.00
270
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year

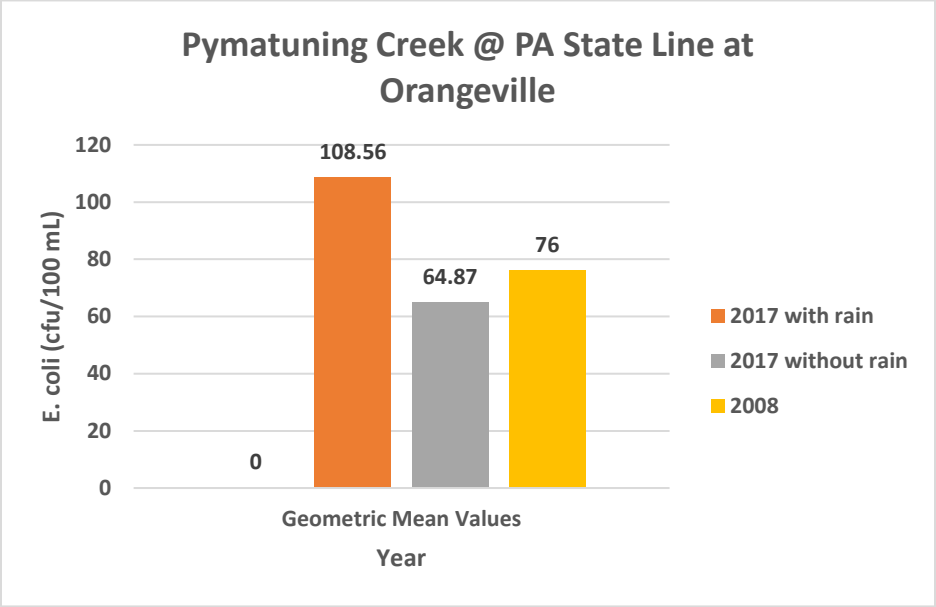

Pymatuning Creek @ Underwood Rd
E. coli (cfu/100 mL)
800
700
600
500
400
300
200
100
0
205.89
178.83
672
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year

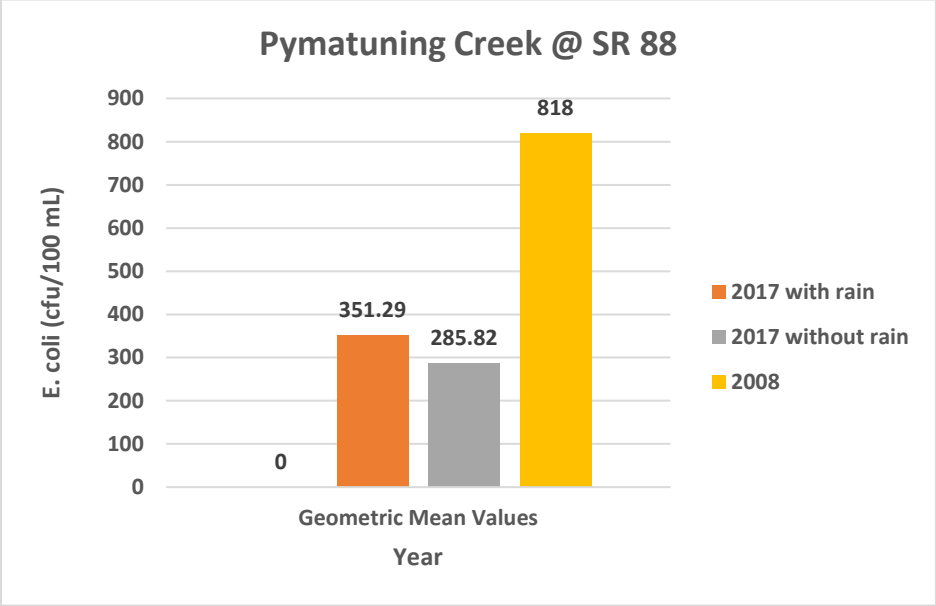

Pymatuning Creek @ SR87
E. coli (cfu/100 mL)
250
200
150
100
50
0
165.28
153.89
195
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year

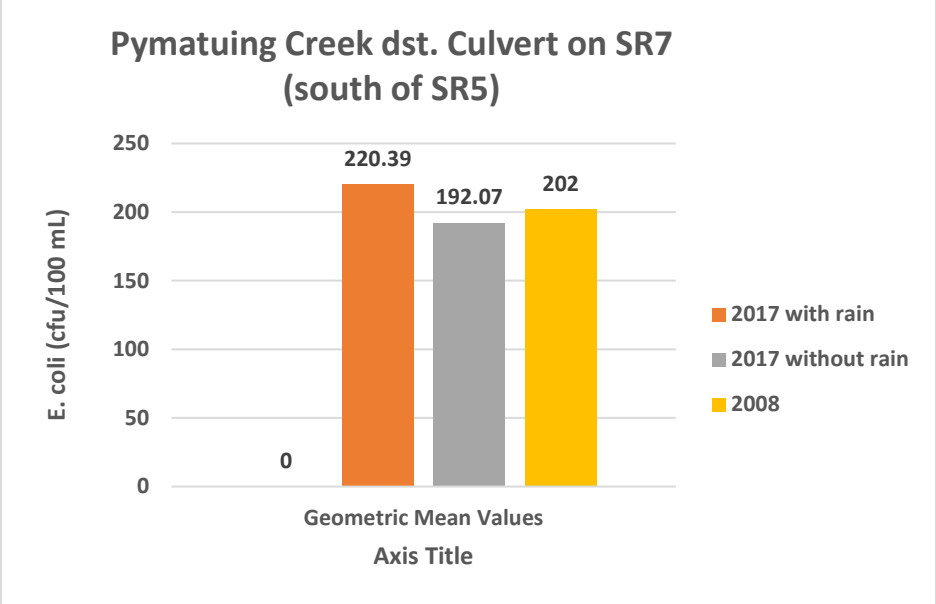

Sugar Creek @ Burnett East RD
E. coli (cfu/100 mL)
350
300
250
200
150
100
50
0
176.05
150.92
300
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year

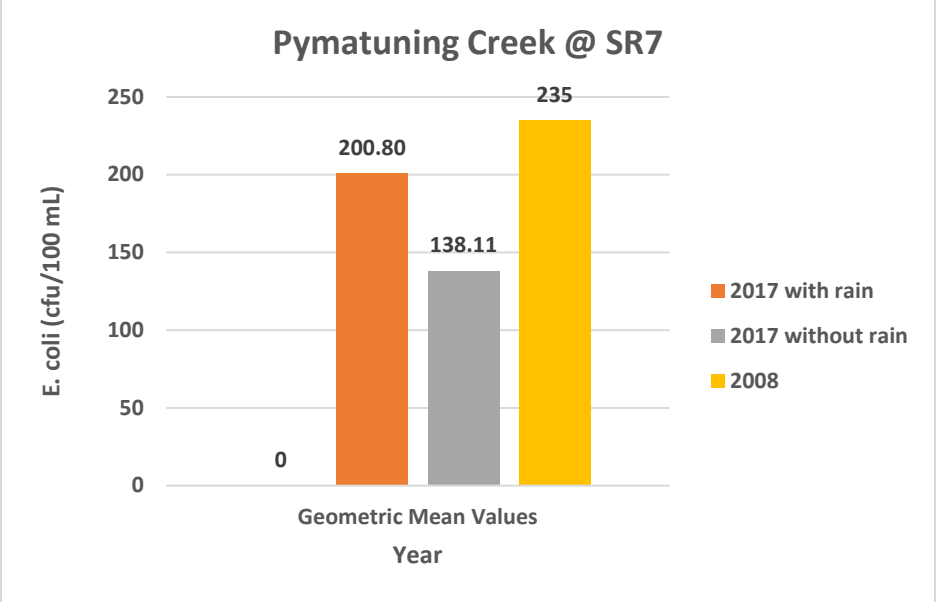

Sugar Creek @ SR88
E. coli (cfu/100 mL)
350
300
250
200
150
100
50
0
262.05
201.27
328
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year

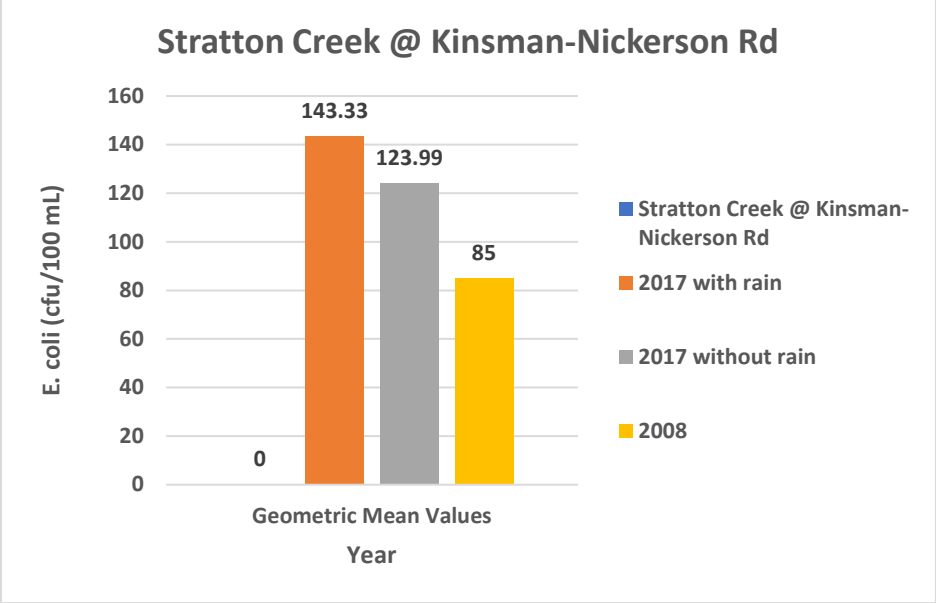
The following bar graph charts take the data from the 2017 sampling events and incorporate the new data from sampling performed in May and June 2018. The results show the geometric mean values of *E. coli*, with and without rainfall) and are compared to Ohio EPA's 2008 OEPA survey results.

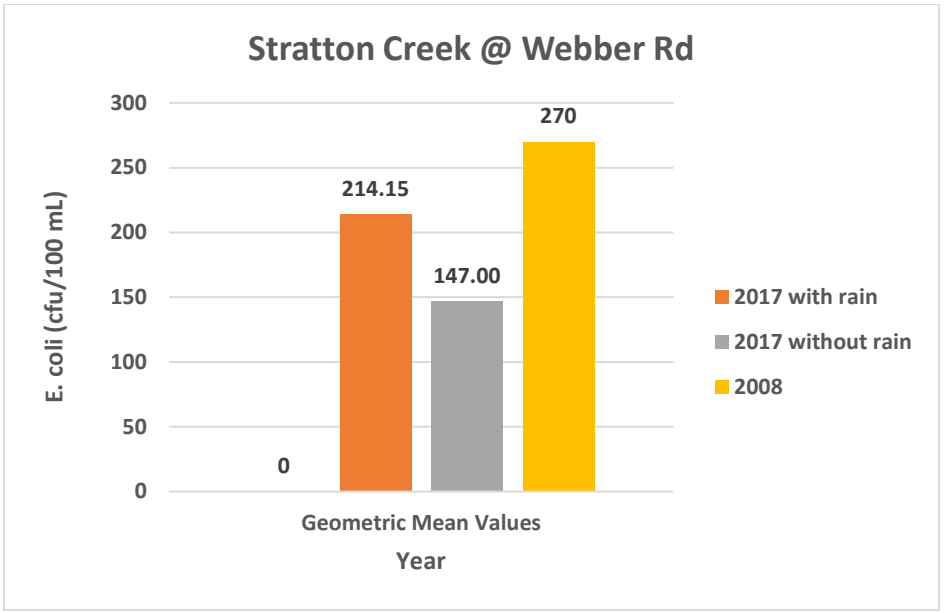


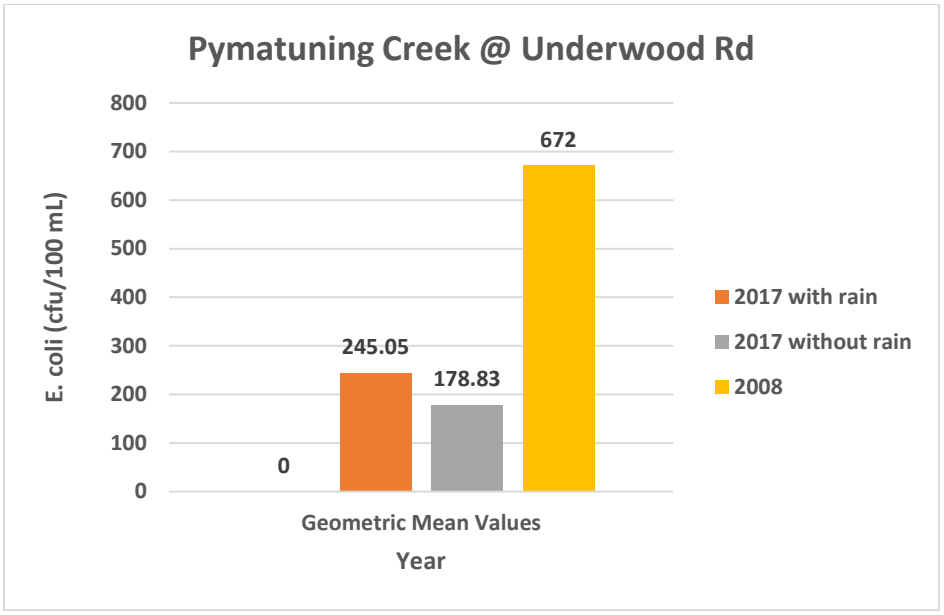


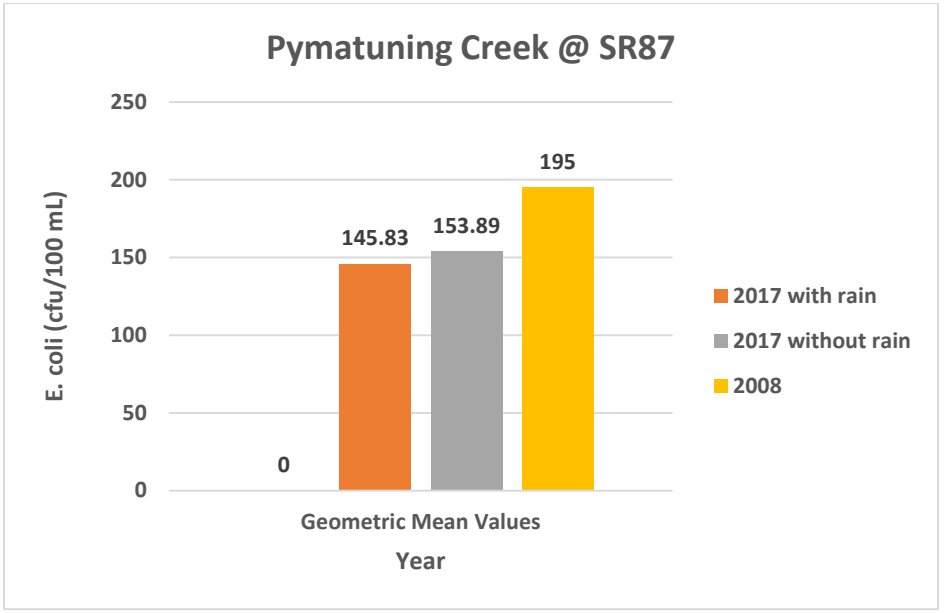

Pymatuing Creek dst. Culvert on SR7 (south of SR5)
E. coli (cfu/100 mL)
250
200
150
100
50
0
220.39
192.07
202
0
Geometric Mean Values
Axis Title
2017 with rain
2017 without rain
2008

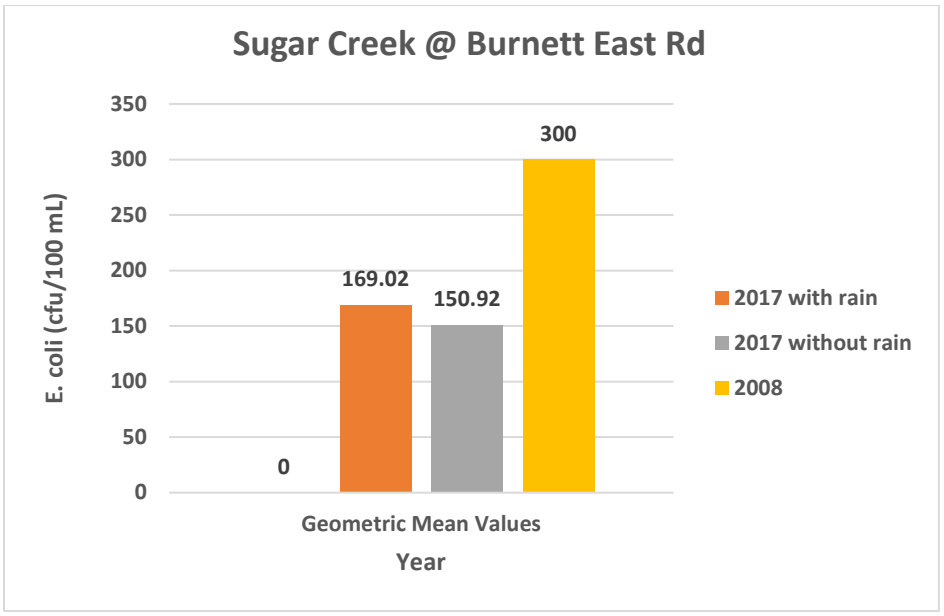

Pymatuning Creek @ SR7
E. coli (cfu/100 mL)
250
200
150
100
50
0
200.80
138.11
235
0
Geometric Mean Values
Year
2017 with rain
2017 without rain
2008

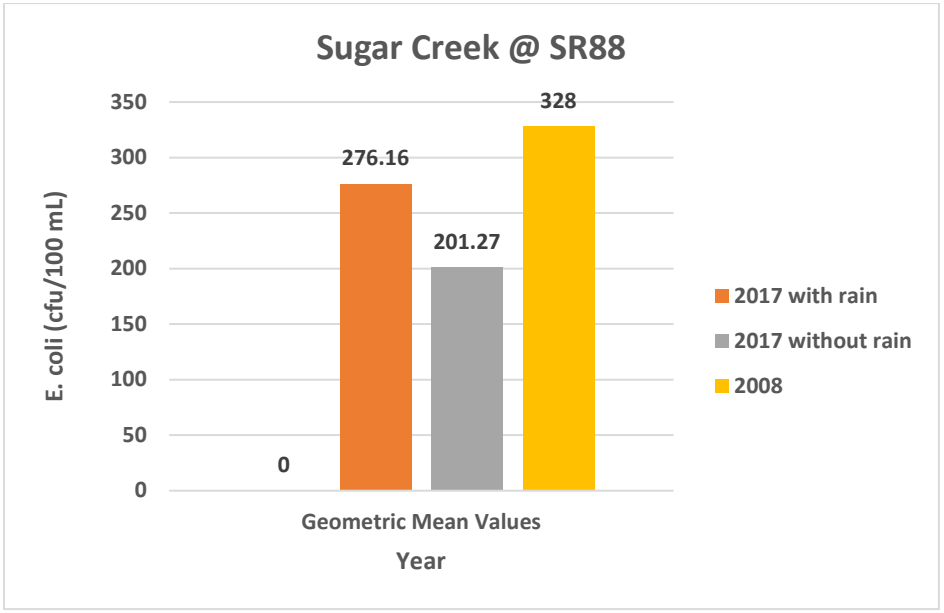

Stratton Creek @ Kinsman-Nickerson Rd
E. coli (cfu/100 mL)
160
140
120
100
80
60
40
20
0
143.33
123.99
85
0
Geometric Mean Values
Year
Stratton Creek @ Kinsman-Nickerson Rd
2017 with rain
2017 without rain
2008


Stratton Creek @ Webber Rd
E. coli (cfu/100 mL)
300
250
200
150
100
50
0
214.15
147.00
270
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year


Pymatuning Creek @ Underwood Rd
E. coli (cfu/100 mL)
800
700
600
500
400
300
200
100
0
245.05
178.83
672
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year


Pymatuning Creek @ SR87
E. coli (cfu/100 mL)
250
200
150
100
50
0
145.83
153.89
195
0
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year


Sugar Creek @ Burnett East Rd
E. coli (cfu/100 mL)
350
300
250
200
150
100
50
0
0
169.02
150.92
300
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year


Sugar Creek @ SR88
E. coli (cfu/100 mL)
350
300
250
200
150
100
50
0
0
276.16
201.27
328
2017 with rain
2017 without rain
2008
Geometric Mean Values
Year

REFERENCES

Dufour, A.P. (1977). *Escherichia coli*: The fecal coliform. Am. Soc. Test. Mater. Spec.Publ. 635: 45-58.

National Land Cover Data (NLCD 2001)

Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of the upper midwest states.

EPA/600/3-88/037. U. S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon. 56 pp.

Shanks, R. E. 1942. Vegetation of Trumbull County. Ohio Journal of Science, Vol. 42, pp 220- 236.

Trautman, M.B. 1981. The Fishes of Ohio. Ohio State University Press, Columbus, OH.

United States Department of Agriculture, 2003. Soils Survey of Ashtabula County Ohio. Natural Resource Conservation Service, Ohio Department of Natural Resources, Division of Soil and Water Conservation, 443 pp.

—1986. Soil Survey of Trumbull County Ohio. Soil Conservation Service, Ohio Department of Natural Resources, Division of Soil and Water Conservation, 156 pp.