



2018 Water Quality Monitoring Report

Monitoring Team

The Rethink Runoff Stream Team (formerly known as the Chittenden County Stream Team) is a program that engages citizens across a nine-municipality region to implement projects that reduce non-point source pollution and stormwater volume at the local level. The participating towns are Burlington, Colchester, Essex, Essex Junction, Milton, Shelburne, South Burlington, Williston, and Winooski. The Water Quality Monitoring program is managed by the Chittenden County Regional Planning Commission Clean Water Advisory Committee MS4 subcommittee, coordinated by the Winooski Natural Resources Conservation District, and made possible through the support of the Vermont Department of Environmental Conservation LaRosa program. This report describes the results from the 2018 collection season; the seventh, consecutive year data was collected by this volunteer-led stream water quality monitoring effort in Chittenden County.

When, Where, and What the Stream Team Monitors

The Rethink Runoff Stream Team (RRST) has collected biweekly water quality samples at several pollutant “impaired” or “stressed” stream sites in Chittenden County since 2012. These urban or suburban streams suffer from excessive nutrient loads, sodium chloride, sedimentation, high temperatures, bacteria, and/or other pollutants. Samples were collected on six different dates in 2018: on five, scheduled bi-weekly dates and on one unscheduled “high-flow” date (i.e. during a rain event). High-flow sampling provides a snapshot of the potentially, elevated or diluted pollutant-loads moving through these systems when it rains. Samples were analyzed for turbidity, total phosphorus, and chloride at all 23 sites.

Biweekly sampling dates occurred on July 10th, July 24th, August 7th, and August 21st and September 4th, and all regular bi-weekly sampling occurred during dry/baseflow conditions. The proposed sampling dates (originally 6/26/18-8/21/18) were pushed two weeks later due to staff turnover within WNRCD to give the new Stream Team coordinator time to prepare for the volunteer training and sampling season. One rainy day sampling event occurred on August 18th at sites on Indian, Muddy, Potash, Centennial and Morehouse brooks. Table 1 indicates total rainfall in inches for the day of sampling and the day immediately preceding sampling. While baseflow sampling days all had less than 0.5 inches of rainfall, freshet sampling on August 18th had 1.65 inches.



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Table 1. Average regional rainfall, in inches, for the preceding day and day of sampling. Rainfall data for each day was gathered from several station sites across the sampling region (Burlington, Colchester, and Essex) and a daily mean was calculated. Daily means were then summed for the preceding and day-of sampling events. Rainfall data was collected from the National Oceanic and Atmospheric Administration through their daily summaries maps: <https://gis.ncdc.noaa.gov/maps/ncei/summaries/daily> The specific sampling sites and their locations are listed in Table 2. A map of the sites is shown in Figure 1.

Date	Total Rainfall (inches)
07/10/18	0.4
07/24/18	0.3
08/07/18	0.362
08/18/18	1.65 (freshet)
08/21/18	0
09/04/18	0.2

Table 2. Rethink Runoff Stream Team 2018 Water Quality Sampling Sites. Note that sites located further up a streamshed are labeled with high numbers except at Sunderland where this labeling was switched and Sunderland 20 is actually downstream of Sunderland 10. Stream Team will look into fixing this labeling anomaly with our records and those of the lab starting next field season.

Stream	Location	Site ID	Lat / Long
Centennial Brook	Grove Street in Burlington (by the parking lot for Schmanska Park)	Centennial 10	44.48453, -73.18423
	Patchen Road in South Burlington (through cemetery)	Centennial 20	44.47402, -73.17334
Indian Brook	Parking lot B of Essex High School	Indian 10	44.49668, -73.11093
	Lang Barn in Essex	Indian 20	44.50442, -73.09190
Malletts Creek	McMullen Road	Milton 10	44.60855, -73.10693
Munroe Brook	Route 7 and Bay Road (by Red Apple Motel)	Munroe 10	44.40532, -73.21735
	Spear & Webster Intersection (just south of Kwiniaska Golf Course)	Munroe 20	44.38984, -73.20103
Morehouse Brook (One new site: 20)	Landry Park Winooski (Eastern trib)	Morehouse 10	44.50035, -73.19226
	Landry Park Winooski (main branch - west of Morehouse 10)	Morehouse 20	44.50041, -73.19444



Muddy Brook (20- site changed)	River Cove Road in Williston	Muddy 10	44.47293, -73.13505
	S. Brownell Road Williston	Muddy 20	44.44196, -73.13228
	Van Sicklen Road in Williston	Muddy 30	44.42823, -73.14622
Potash Brook (40 - site changed)	Kindness Court in South Burlington near Humane Society	Potash 10	44.44572, -73.21348
	Farrell Street in South Burlington near Klinger's Bakery	Potash 20	44.44660, -73.20415
	Dorset Street in South Burlington	Potash 30	44.45150, -73.17849
	Kimball Ave South Burlington	Potash 40	44.45394, -73.14809
Engelsby Brook	Pine St in Burlington near Champlain Elementary Community Gardens	Engelsby 10	44.45627, -73.21394
	Behind UVM Redstone Campus in Burlington	Engelsby 20	44.46654, -73.19741
Alder Brook (new)	Off Chapin Road in Essex	Alder 10	44.51742, -73.06559
Bartlett Brook (new)	By Shearer Chevrolet in South Burlington	Bartlett 10	44.42596, -73.21345
Sunnyside Brook (new)	Mountain View Drive in Colchester	Sunnyside 10	44.50654, -73.17823
Sunderland Brook (new)	In Pearl Street Park in Essex Junction	Sunderland 10	44.50179, -73.12983
	Off Pine Island Road in Colchester	Sunderland 20	44.51685, -73.20421

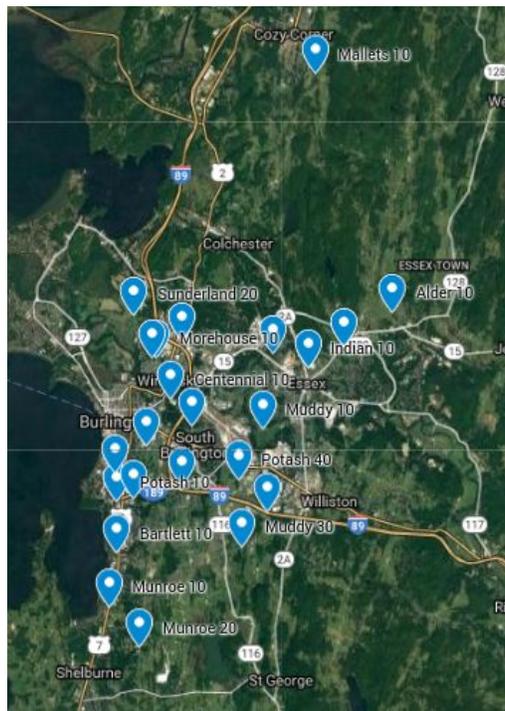


Figure 1: 2018 Rethink Runoff Stream Team Sample Sites. An interactive version of this map is available here:



Phosphorus Results

Phosphorus is an essential nutrient for plants and animals that is naturally limited in most freshwater systems. Even a modest increase can set off a chain of undesirable events, such as algal blooms, accelerated plant growth, low dissolved oxygen, and the subsequent die off of aquatic life. Although phosphorus occurs naturally in soils and rocks, additional phosphorus enters waterways through runoff from sources such as fertilized lawns and cropland, pet waste, failing septic systems, animal manure from storage areas or livestock access, wastewater treatment plants, and streambank erosion.

Phosphorus sample results continue to be high across all sampling sites. The VT 2016 water quality standard for phosphorus in Class B warm water medium-gradient streams is 27 µg/L but the mean 2018 phosphorus level for every site exceeded this standard (see Table 2).

Table 3. 2018 RRST Phosphorus Results Summary: Mean phosphorus levels in µg/L during both baseflow (dry) and high-flow (rain) sampling events in 2018. Values exceeding the Vermont chronic chloride standard of 27 µg/L are shown in red. Sites denoted with an * had at least one sampling date in which blank or dupe results were flagged. Recalculated means with this data removed resulted in very similar values such that it was decided to keep them for descriptive statistics reporting purposes. Raw data is presented in Appendix C.

Location	Mean Phosphorus during Baseflow - Dry Conditions	Phosphorus during Rain Event
Alder 10*	102.06	--
Bartlett 10	57.02	--
Centennial 10	50.94	88.9
Centennial 20*	62.44	--
Englesby 10*	82.12	--
Englesby 20	98.56	--
Indian 10	41.66	180
Indian 20	97.48	--
Mallets Creek 10	39.68	--
Morehouse 10	30.9	48.8
Morehouse 20	35.86	76.5
Muddy 10	50.4	--
Muddy 20	41.6	--



Muddy 30	116.46	92.3
Munroe 10*	60.86	--
Munroe 20	88.96	--
Potash 10	44.66	--
Potash 20	35.82	--
Potash 30	89.58	--
Potash 40	318.54	--
Sunderland 10	92.94	--
Sunderland 20	55.26	--
Sunnyside 10	27.36	--

Phosphorus levels in Chittenden County Streams 2012-2018

Since the onset of this monitoring program in 2012, mean concentrations of phosphorus during baseflow have remained notably above the 27 µg/L standard at all stream sites. In fact only 7 out of the 23 sites sampled have ever exhibited phosphorus concentrations below this standard (Indian 20, Malletts 10, Morehouse 10 and 20, Potash 10 and 20, and Sunnyside 10). Out of these 7, only one site (Sunnyside 10) reports a median below the standard but the 1-yr sampling mean still falls above the standard (see Table 2 above). Sites of notable historic levels include Engelsby 20, Muddy 10, 20 and 30, Munroe 20, Potash 40, and Sunderland 10.



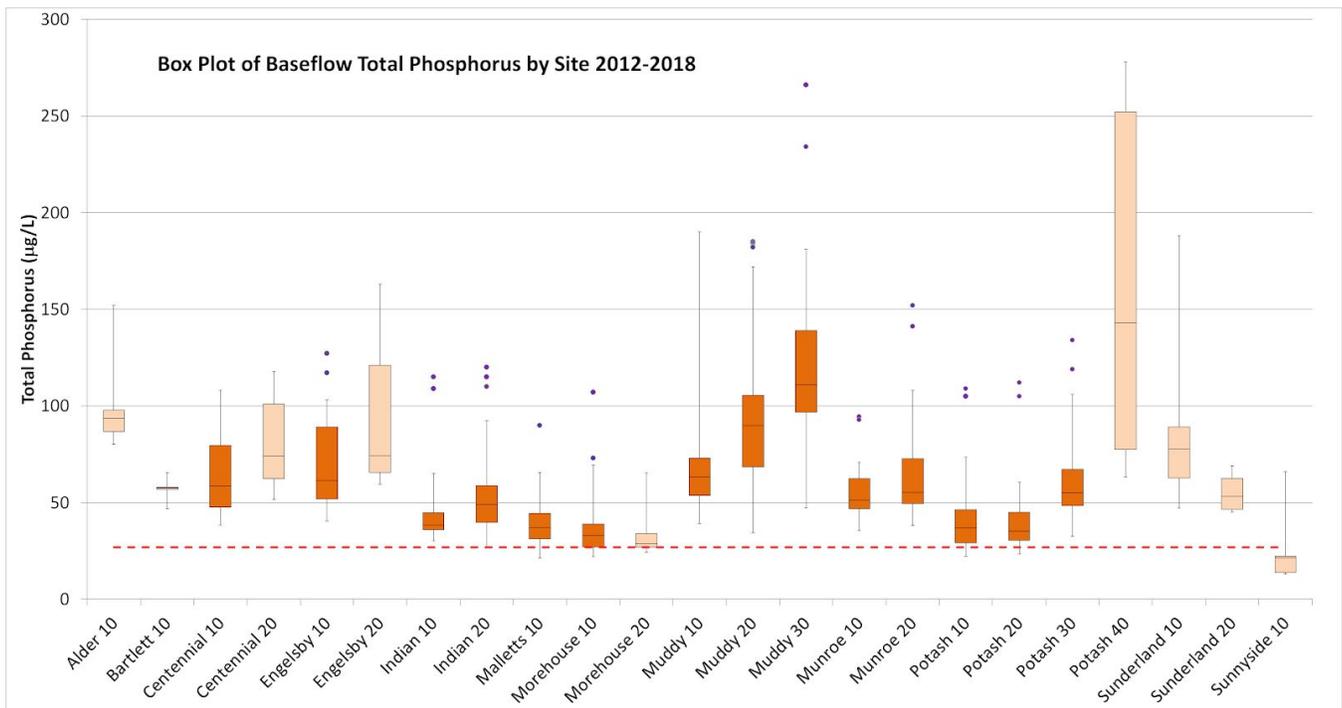


Figure 2. Comparison of total phosphorus levels across sites 2012-2018. Box plots indicate first and third quartiles and median values of total phosphorus concentrations for all sites. These values were calculated including sampling dates that may or may not have associated flagged dupe or blank samples. Lighter colored boxes indicate 1-2 years of sampling data, darker boxes indicate 6-7 years of sampling data. Dots indicate outliers which were identified as equal to or greater than 2 times the site's standard deviation. Red line indicates Vermont's 2016 Water Quality Standard of 27 micrograms/L.

Figure 2 suggests that phosphorus levels increase as sampling moves upstream. To test this hypothesis, RRST used scatter plots to graph phosphorus data over time by stream and ran statistical analyses on 8 streams that had more than one sampling site. Of the 8 streams that have more than one sampling location, 6 indicated a statistically significantly different value of phosphorus between sites, all of which presented statistically significantly higher concentrations of total phosphorus upstream. Table 4 summarizes the results of these tests. Appendix D summarizes statistics and graph visualizations. This result was somewhat surprising and merits more consideration since we assumed that total phosphorus increased in concentration as water moves downstream and more inputs are introduced.

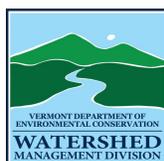


Table 4 Statistical Results of Phosphorus trends along stream lengths. Statistical tests selected because data either had too small a sample size or was not normally distributed and therefore it was not appropriate to do a Paired T-test. While Wilcoxon Signed Rank recognizes dependent samples as could be the case up and down the same stream, the Kruksal-Wallis was the best tool available to reporter but it assumes independent samples so results should be seen with caution. Location of higher concentration was estimated through graphing. Note that all values and sampling dates were included in analysis as long as they could be paired (in the case of the Wilcoxon Signed Rank), including outliers and those flagged with dupe or blank concerns.

Stream	# of Sites	Statistical Test Used	Statistically significant difference?	Location of higher concentration?
Centennial	2	Wilcoxon Signed Rank	Y	Upstream
Engelsby	2	Wilcoxon Signed Rank	N	--
Indian	2	Wilcoxon Signed Rank	Y	Upstream
Morehouse	2	Wilcoxon Signed Rank	N	--
Munroe	2	Wilcoxon Signed Rank	Y	Upstream
Sunderland	2	Wilcoxon Signed Rank	Y	Upstream
Muddy	3	Kruksal-Wallis	Y	Upstream
Potash	4	Kruksal-Wallis	Y	Upstream

Figure 2 also suggests that Muddy Brook has shown consistently high levels of Phosphorus as compared to other sites including some extremely high outliers. Interestingly, temporal data is suggesting a non-significant downward trend of Phosphorus concentrations at sites Muddy 20 and Muddy 30 with Muddy 10 holding relatively constant. This is unique to Muddy Brook and it’s not clear what land use changes or restoration efforts could have contributed to this. Figures 3 and 4 show the suggested trends for Muddy 20 and 30 respectively.



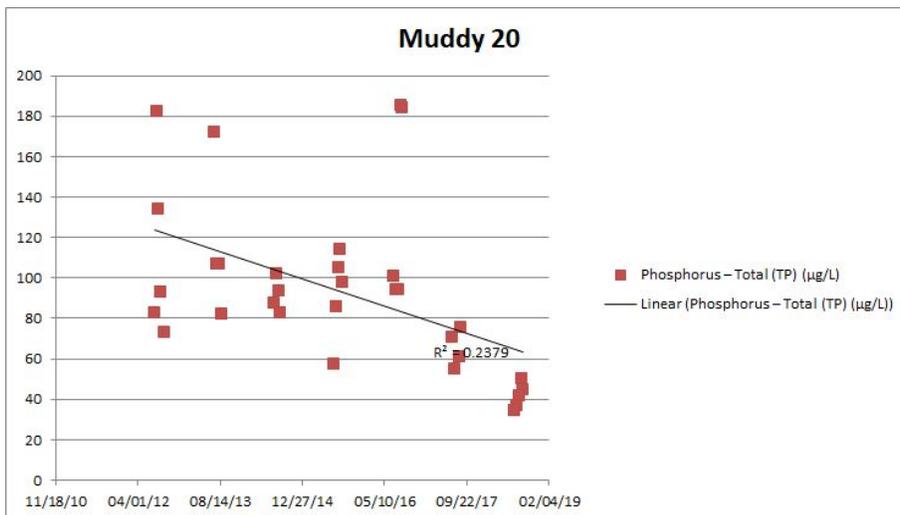


Figure 3. Total Phosphorus in Muddy 20 since 2012. Scatter plot visually suggests a downward trend but R2 of the best fit line is still only about 0.24 and not significant.

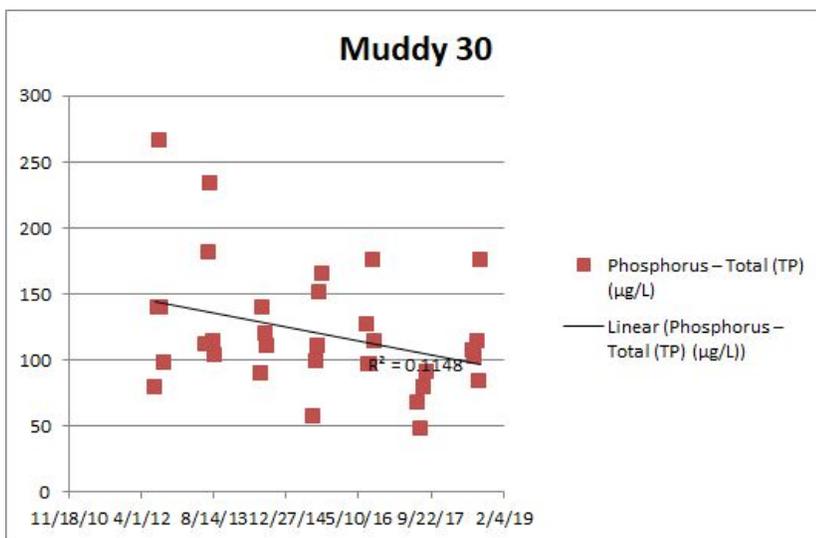
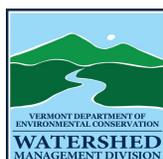


Figure 4. Total Phosphorus in Muddy 30 since 2012. Scatter plot visually suggests a downward trend but R2 of the best fit line is still only about 0.12 and not significant.

Chloride Results

Chloride is a component of salt found naturally in minerals and in oceans. While a low level of instream chloride can originate from natural sources, higher levels are generally due to the use of deicing salts. Elevated chloride levels in surface waters can negatively impact the health and reproduction of aquatic species, according to the Vermont Surface Water Management Strategy. The Stream Team took grab samples of chloride, which do not provide adequate data to label a stream impaired or acute, however, the data acts as a spot check. For reference, the Environmental Protection Agency’s (EPA) and State of Vermont’s (VT) current water quality standard for chloride is 230 mg/L (chronic criteria) and 860 mg/L (acute criteria). 230 mg/L is the highest concentration of chloride to which aquatic life can safely be



exposed for one hour once every 3 years. 860 mg/L is the highest concentration of chloride to which aquatic life can safely be exposed for four consecutive days once every 3 years.

Table 5. 2018 RRST Chloride Results Summary: This table depicts mean chloride levels in mg/L during baseflow (dry) and high-flow (rain) sampling events in 2018. Values exceeding the Vermont chronic chloride standard of 230 mg/L are shown in red. No sites had a sampling date in which blank or dupe results were flagged for chloride. Raw data is presented in Appendix C.

Location	Mean Chloride in Dry Conditions Only	Chloride during Rain Events
Alder 10	10.93	--
Bartlett 10	256	--
Centennial 10	728	248
Centennial 20	176.2	--
Englesby 10	401.8	--
Englesby 20	711.8	--
Indian 10	257.6	41.55
Indian 20	180.5	--
Mallets Creek 10	50.09	--
Morehouse 10	133.17	38.65
Morehouse 20	490.1	111
Muddy 10	231.2	--
Muddy 20	596	--
Muddy 30	34.2	35.7
Munroe 10	341.4	--
Munroe 20	169.54	--
Potash 10	570.4	--
Potash 20	600.2	--
Potash 30	330	--



Potash 40	737.1	--
Sunderland 10	187.2	--
Sunderland 20	168.2	--
Sunnyside 10	773	--

While in 2017 only three sampled brooks presented mean values above of 230 mg/L, in 2018 nine brooks presented exceedances although this increase is partially attributed to the addition of new sampling sites of concern. Similar to 2017, chloride levels were higher during baseflow conditions in the majority of cases which is suspected to be due to dilution. Chloride grab sample levels exceeded 860 mg chloride/L, in Centennial 10 and Engelsby 20 in 2018. Both streams exceeded this value on 7/10/18 and 7/24/18. This is the first time this value was surpassed in any individual sample over this seven year period. This could result in a need for more continuous monitoring at these sites to gain continuous-flow data.

Chloride levels in Chittenden County Streams 2012-2018

Since the onset of this monitoring program, mean chloride levels at Centennial 10 and Potash 10, 20 and 30 have remained notably above 230 mg/L standard. Recently added sampling sites have also presented alarmingly high data including Engelsby 20, Morehouse 20, Potash 40, and Sunnyside 10.

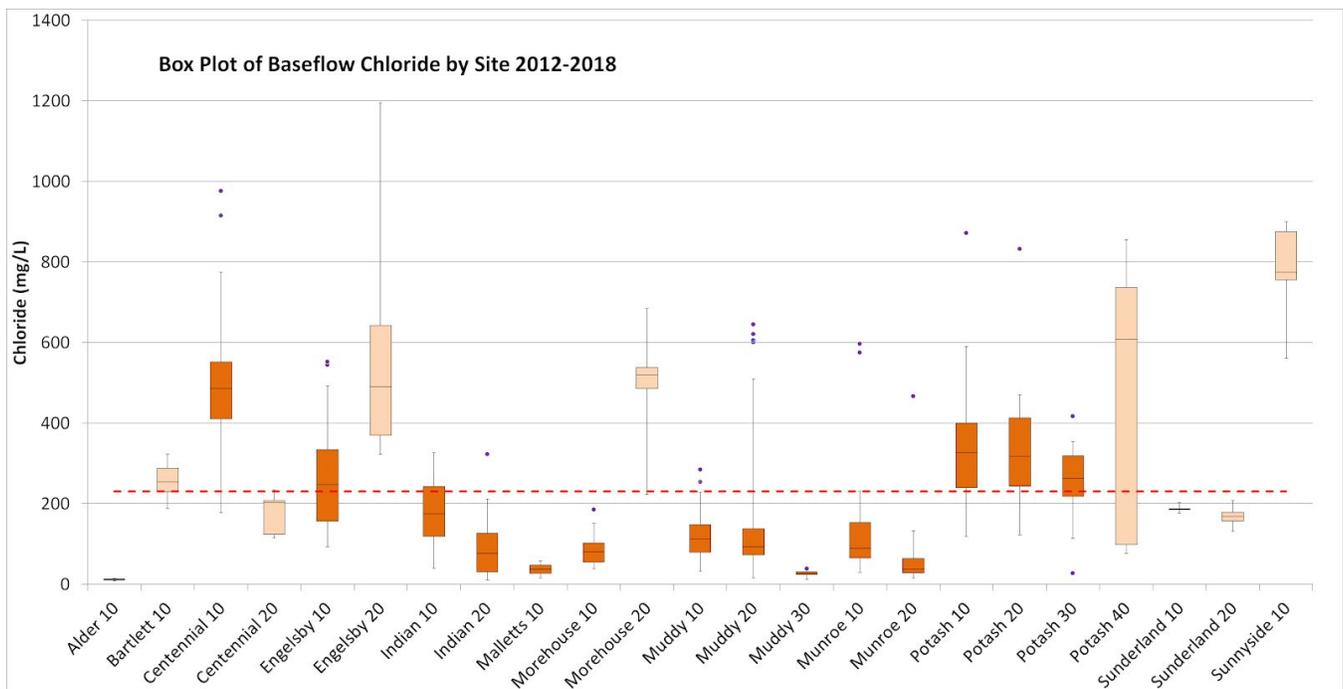


Figure 5 - Comparison of Chloride levels across sites 2012-2018. Box plots indicate first and third quartiles and median values of chloride levels (mg/L) for all sites. Lighter colored boxes indicate 1-2 years of sampling data, darker boxes indicate 6-7 years of sampling data. Dots indicate outliers which were identified as equal to or greater than 2 times the site's standard deviation. EPA's and Vermont's standard for 4-day average chloride levels (230 mg/L) is shown by the red line.



There is not as clear a link between location in the watershed and chloride levels as there is for phosphorus levels but several streams presented statistically significantly different chloride levels across sampling sites. Of the 8 streams that have more than one sampling location, 7 indicated a statistically significantly different value of Chloride between sites. This information could be useful in pin-pointing chloride pressure points along the stream length for intervention purposes. Table 6 summarizes the results of these statistical tests. Appendix E summarizes statistics and graph visualizations.

Table 6 Statistical Results of Chloride trends along stream lengths. See Table 4 note for details.

Stream	# of Sites	Statistical Test Used	Statistically significant difference?	Location of higher concentration?
Centennial	2	Wilcoxon Signed Rank	Y	Downstream
Engelsby	2	Wilcoxon Signed Rank	Y	Upstream
Indian	2	Wilcoxon Signed Rank	Y	Downstream
Morehouse	2	Wilcoxon Signed Rank	Y	Upstream
Munroe	2	Wilcoxon Signed Rank	Y	Downstream
Sunderland	2	Wilcoxon Signed Rank	N	--
Muddy	3	Kruksal-Wallis	Y	Midstream (site 20)
Potash	4	Kruksal-Wallis	Y	Unclear

Chloride data from this sampling program suggests that of the 14 sites that have been sampled for 6 or more years, chloride levels are trending upwards in 10 of them (Centennial 10, Engelsby 10, Indian 10 and 20, Malletts 10, Muddy 30, Munroe 10 and 20, and Potash 10 and 20). These trends are not statistically significant but highlight an important stressor to monitor closely. Appendix F documents graphs of these trends.

Aggregated data also suggests a general increasing trend in chloride. Figure 6 below shows that the mean, median, and standard deviation values have all increased slightly over time.



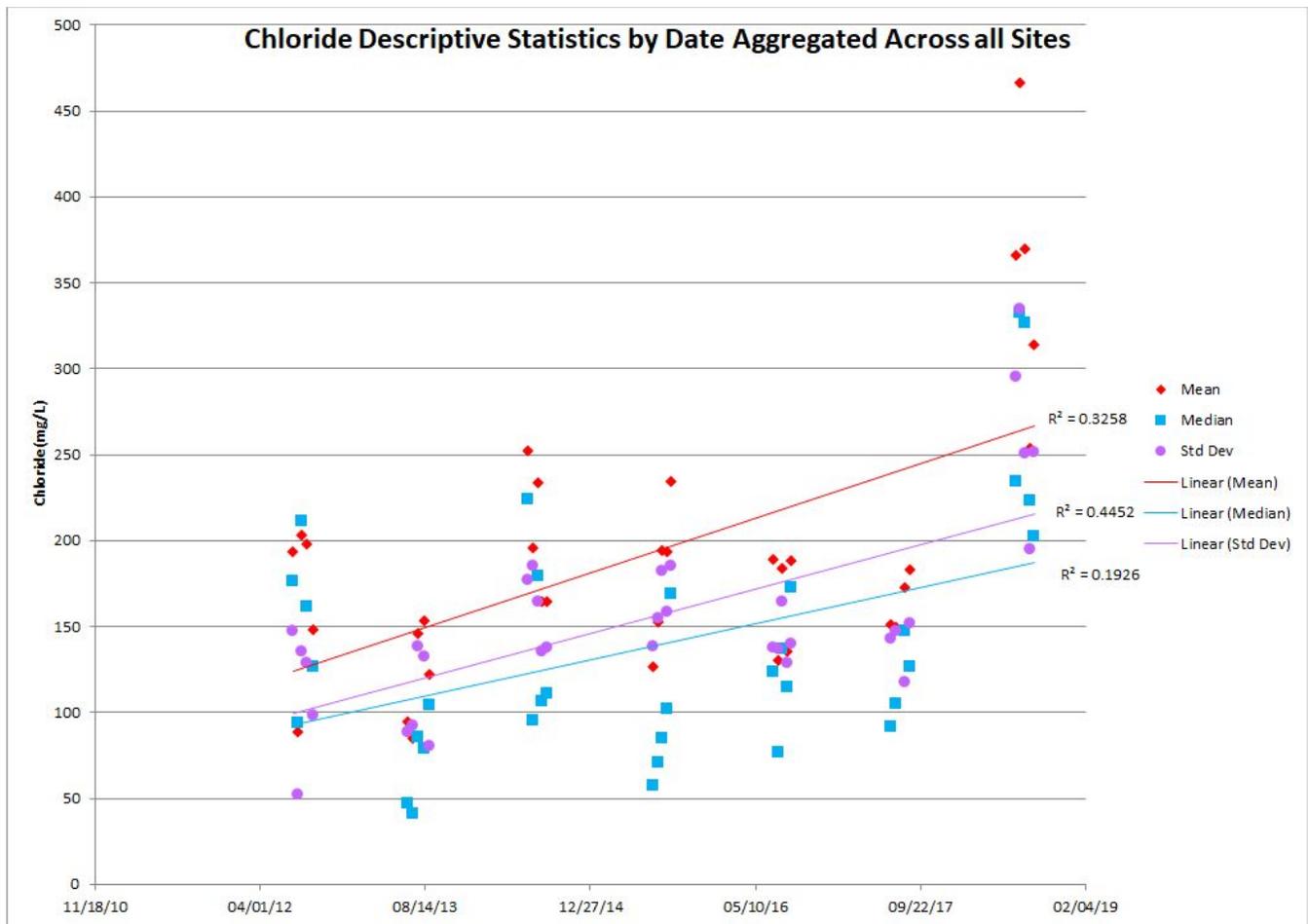


Figure 6. Descriptive Statistics for chloride data gathered across sites aggregated by date. Each sampling date since June 2016 had chloride values across sites averaged to determine mean, median, and standard deviation for the entire sampling area.

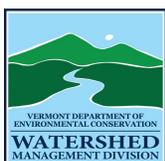
Turbidity Results

The turbidity of a water sample refers to its cloudiness. This measurement is based on the amount of algae, microbes, and sediment suspended in the water. High turbidity levels can negatively impact aquatic life by raising water temperature, decreasing forage and cover, and harming gill function, and has the potential to increase the presence and number disease-causing organisms. Turbidity measurements can also be used as an indicator for erosion and increased nutrient levels in streams. The Vermont Water Quality Standards state that turbidity should not exceed 10 NTU (nephelometric turbidity units) in cold-water fish habitat and 25 NTU in warm-water fish habitat.



Table 7. 2018 RRST Turbidity Results Summary. Mean turbidity levels in NTU baseflow (dry) and high-flow (rain) sampling events in 2018. Overall mean values exceeding the Vermont standard of 25 NTU are shown in red. Raw data is presented in Appendix C.

Location	Mean Turbidity in Dry Conditions Only	Turbidity during Rain Event
Alder 10	30.9	--
Bartlett 10	11.402	--
Centennial 10	5.198	18.2
Centennial 20	3.462	--
Englesby 10	6.92	--
Englesby 20	2.242	--
Indian 10	7.738	64.9
Indian 20	9.104	--
Mallets Creek 10	4.772	--
Morehouse 10	5.938	8.52
Morehouse 20	2.816	21.3
Muddy 10	6.252	--
Muddy 20	5.928	--
Muddy 30	17.68	11.5
Munroe 10	6.724	--
Munroe 20	18.9	--
Potash 10	4.868	--
Potash 20	1.488	--
Potash 30	10.782	--
Potash 40	39.32	--
Sunderland 10	8.032	--



Sunderland 20	10.106	--
Sunnyside 10	11.044	--

Mean baseflow turbidity levels did not exceed the VT Water Quality standard for turbidity of 25 nephelometric units (NTU) for warm-water fish habitat in 2018 except at Potash 40 and Alder 10. This represents an increase of two sites as compared to 2017 but one of these sites was newly added in 2018. As suspected, turbidity concentrations were mostly higher during rain events, and surpassed standards on Indian Brook alone.

Turbidity Levels in Chittenden County Streams 2012-2018

Mean, baseflow turbidity values have only rarely exceeded the VT standard for warm-water streams of 25 NTU over the seven year sampling period. Of note, however, is the high turbidity recorded for new sampling sites Alder 10 and Potash 40. Higher turbidity in Alder 10 is not surprising because the site is comparatively more agricultural with a couple farms and potential field runoff nearby. Turbidity has not been included in sampling support requests for the 2019 field season but will be revisited in 2020.

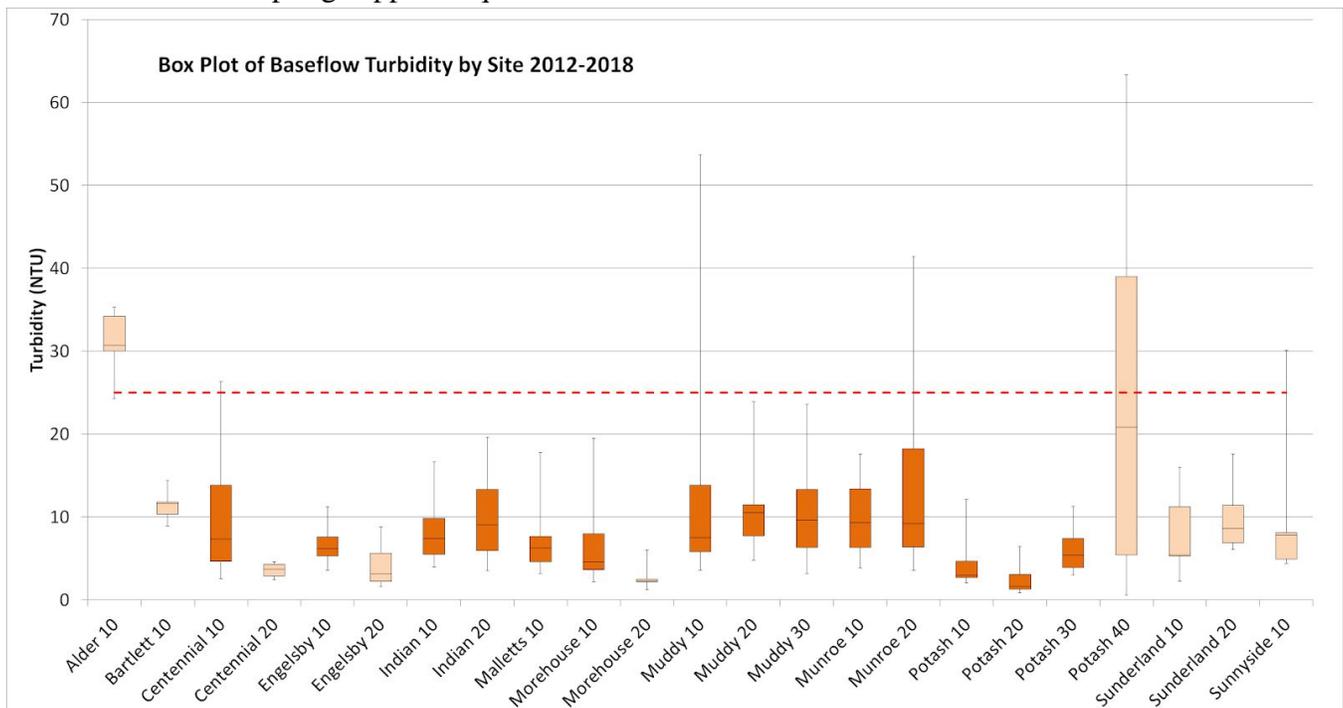


Figure 7 - Comparison of turbidity levels 2012-2018 during baseflow (dry) conditions. The standard proposed by the State of Vermont for mean turbidity at baseflow in medium gradient, warm water streams (25 NTU) is indicated by the red line. These values were calculated including sampling dates that may or may not have associated flagged dupe or blank samples.

Importantly, it was challenging to secure valid turbidity data for the 2018 sampling season. Appendix A will reveal a mean relative percent difference between duplicate and actual samples above the acceptable 15%. Some but not all of this was due to having very low sample values in relation to test sensitivity.



This adds to the Stream Team’s resolve to remove this parameter from future sampling activities for the time being.

Turbidity was statistically significantly different along only two streams (Morehouse and Potash). The Morehouse site results, while significant, both fell under the water quality standards such that the difference is of less interest to the research team. In contrast, Potash 40 presented turbidity levels which both exceeded water quality standards and were significantly different from other sites along that brook. The sampling team suspects this could be due to the unique hydrology of Potash 40 which is located among a complex of artificial wetlands within an industrial park. The water has no noticeable flow rate or direction and presents less as a stream and more as a marsh. It is suspected that in-stream sampling practices might disturb a lot of bottom sediment in such a setting thereby leading to higher turbidity readings. Considering this, Potash 40 has been removed from the 2019 sampling program.

Visualization revealed no notable trends in turbidity data over time and it is therefore not currently recognized as a high priority threat.

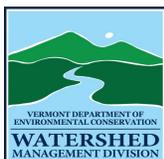
Conclusion

The Rethink Runoff Stream Team has monitored chloride, phosphorus, and turbidity in various, stormwater impaired streams in Chittenden County for the past seven consecutive years (2012-2018). The 2018 season’s results are similar to those obtained over the past six years, and indicate that all stream sites have sustained phosphorus levels well above the Vermont standard and that chloride is becoming a prevalent and growing concern.

Phosphorus levels in almost all sampled streams have remained two to four times the Vermont water quality standard of 27 µg/L. Muddy Brook continues to maintain high levels of phosphorus although values are potentially trending downwards. Six streams sampled also showed statistically significantly higher concentrations of total phosphorus upstream as opposed to downstream which presents an opportunity to explore localized stressors. It’s important to consider that while phosphorus levels are presenting high in many sites, turbidity levels are low. This provides some clues as to sources of phosphorus and should inform phosphorus reduction efforts. For example, it is possible these high phosphorus values can be attributed to more urban-like runoff such as car wash detergents, liquid lawn fertilizers, and pet waste.

Chloride levels continue to surpass standards in several streams, most notably at Centennial 10, Engelsby 20, Morehouse 20, Potash 40, and Sunnyside 10. For the first time in Stream Team’s sampling history, chloride levels exceeded the EPA’s and VT’s acute standard of 860 mg chloride/L on the same two sampling dates at both Centennial 10 and Engelsby 20. As mentioned in prior year reports it is suspected that Engelsby’s high levels are due to a nearby parking lots on the UVM campus but further assessments should consider rising stressors across the sampling region at all sites of concern.

Low turbidity values in most sites reveal this does not appear to be a significant stressor in the Chittenden County area although research team should consider potential sediment inputs upstream of



Alder 10 for remediation. After seven years of showing minimal concern, turbidity will be abandoned at most locations in the 2019 season.

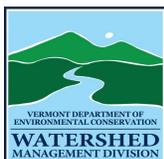
There will be a few sampling adjustments made to the 2019 sampling effort. Potash 40 will be removed because of its unique and confounding hydrological conditions that complicates data analysis. Munroe 10 seems to be located physically too close to Munroe 20 to be giving any valuable information on landscape impacts so it will similarly be abandoned. Munroe 20 will be kept, however as a valuable data point because a housing development is planned and will be implemented upstream soon. Finally, Bartlett 10 will be removed because it is already sampled by a team from UVM.

It became clear this year that, moving forward, the Stream Team needs explicit guidance and documented practices in the QAPP for dealing with outliers and data points whose duplicates or blanks were flagged. For 2018 analysis all data points were included because those whose duplicates or blanks were flagged, still had values less than two standard deviations from the mean. Outliers, similarly, only presented when multi-year data was assessed such that for 2018-specific descriptive statistics, all data points were included. Given the small sampling sizes, however, (5 - 6 data points per site per year) this may not be a reliable practice for future analysis and consultation will be sought from the La Rosa Partnership for technical guidance on this practice.

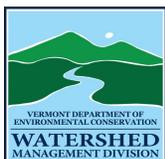
Finally, it is the goal of this team to improve outward reporting of these data such that each stream could eventually receive some type of scorecard and summary sheet across the multiple parameters evaluated. We expect that scoring, and then ranking streams holistically is one step towards simplifying where to direct remediation efforts. This may be attempted in the 2019 report.



Appendix A. Quality Assurance Measures for phosphorus, chloride, and turbidity sampling in 2018.



RPD Analysis			
Date	Location	Test	RPD (%)
07/10/18	Munroe 20	Chloride (mg/L)	0.00
		TP(ug P/L)	17.52
		Turbidity (NTU)	7.92
	Muddy 10	Chloride (mg/L)	0.59
		TP(ug P/L)	4.96
		Turbidity (NTU)	3.79
	Engelsby 10	Chloride (mg/L)	1.61
		TP(ug P/L)	71.28
		Turbidity (NTU)	1.00
07/24/18	Potash 20	Chloride (mg/L)	0.48
		TP(ug P/L)	0.00
		Turbidity (NTU)	18.62
	Muddy 30	Chloride (mg/L)	1.20
		TP(ug P/L)	0.98
		Turbidity (NTU)	2.96
	Indian 10	Chloride (mg/L)	3.28
		TP(ug P/L)	0.78
		Turbidity (NTU)	2.57
08/07/18	Potash 30	Chloride (mg/L)	0.00
		TP(ug P/L)	0.91
		Turbidity (NTU)	7.76
	Munroe 10	Chloride (mg/L)	0.87
		TP(ug P/L)	10.23
		Turbidity (NTU)	20.16
	Indian 20	Chloride (mg/L)	0.49
		TP(ug P/L)	4.08
		Turbidity (NTU)	20.61
08/21/18	Potash 40	Chloride (mg/L)	0.70
		TP(ug P/L)	2.81
		Turbidity (NTU)	52.12
	Malletts 10	Chloride (mg/L)	1.94
		TP(ug P/L)	0.60
		Turbidity (NTU)	4.62
	Bartlett 10	Chloride (mg/L)	0.78
		TP(ug P/L)	1.69
		Turbidity (NTU)	5.22
09/04/18	Sunderland 10	Chloride (mg/L)	1.00
		TP(ug P/L)	9.52
		Turbidity (NTU)	33.93
	Morehouse 10	Chloride (mg/L)	2.80
		TP(ug P/L)	12.66
		Turbidity (NTU)	89.69
	Centennial 20	Chloride (mg/L)	0.81
		TP(ug P/L)	24.39
		Turbidity (NTU)	38.43
Mean RPD	Parameter	Actual	Target
	Chloride (mg/L)	1.10	≤5
	TP(ug P/L)	10.83	≤30
	Turbidity (NTU)	20.63	≤15



Appendix B. Project Completeness

Project proposal anticipated 5 dates for baseflow sampling across 23 sites (115 samples per parameter) as well as 2 rain dates sampling across 5 sites (10 samples per parameter). This is a total of 125 samples per parameter not including duplicates and blanks.

Parameter	Number of Samples Anticipated (not including blanks and Dupes) = 23 sites*5 sampling dates	Number of Valid Samples* Collected and Analyzed	Percent Complete
Chloride	125	121	97%
Total Phosphorus	125	116	93%
Turbidity	125	117	94%

*“Valid sample” includes all samples not flagged by issues that arose from blank or dupe results

Appendix C. Individual Sample Results. Boxes highlighted in yellow indicate issue flagged by inconsistent blank result. Boxes highlighted in red indicate sample whose duplicate is notably different in value. All values included in graphing and statistical analyses of 2018 report.

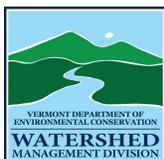
Sample Number	Location	Date	Chloride (mg/L)	TP(ug P/L)	Turbidity (NTU)
181280-01	Alder 10	7/10/2018	12	152	35.3
181398-01	Alder 10	7/24/2018	13.4	97.8	24.3
181538-01	Alder 10	8/7/2018	9.73	86.7	30
181652-01	Alder 10	8/21/2018	7.82	80.1	34.2
181809-01	Alder 10	9/4/2018	11.7	93.7	30.7
181280-02	Alder 10 Blank	7/10/2018	< 2	5.48	< 0.2
181280-03	Bartlett 10	7/10/2018	229	57.8	11.6
181398-02	Bartlett 10	7/24/2018	322	56.8	10.3
181538-02	Bartlett 10	8/7/2018	288	65.7	14.4



181652-02	Bartlett 10	8/21/2018	254	46.9	11.8
181809-02	Bartlett 10	9/4/2018	187	57.9	8.91
181652-03	Bartlett 10 Field Dup	8/21/2018	256	47.7	11.2
181398-04	Centennial 10 Blank	7/24/2018	< 2	< 5	< 0.2
181280-04	Centennial 10	7/10/2018	915	46.4	3.79
181398-03	Centennial 10	7/24/2018	976	57.7	7.39
181538-03	Centennial 10	8/7/2018	775	40.9	3.2
181629-01	Centennial 10	8/18/2018	248	88.9	18.2
181652-04	Centennial 10	8/21/2018	430	47.7	6.08
181809-03	Centennial 10	9/4/2018	544	62	5.53
181280-05	Centennial 10 Blank	7/10/2018	< 2	< 5	< 0.2
181280-06	Centennial 20	7/10/2018	234	74.1	2.88
181398-05	Centennial 20	7/24/2018	202	62.3	3.7
181538-04	Centennial 20	8/7/2018	207	51.6	2.43
181652-05	Centennial 20	8/21/2018	114	66.6	3.74
181809-05	Centennial 20	9/4/2018	124	57.6	4.56
181538-05	Centennial 20 Blank	8/7/2018	< 2	9.17	0.5
181809-04	Centennial 20 Dup	9/4/2018	123	73.6	3.09
181280-07	Engelsby 10	7/10/2018	492	102	6.05
181398-06	Engelsby 10	7/24/2018	544	44.4	5.94
181538-06	Engelsby 10	8/7/2018	480	51.9	4.36
181652-06	Engelsby 10	8/21/2018	296	117	14.1



181809-06	Engelsby 10	9/4/2018	197	95.3	4.15
181398-07	Engelsby 10 Blank	7/24/2018	< 2	< 5	< 0.2
181280-08	Engelsby 10 Field Dup	7/10/2018	500	48.4	5.99
181280-09	Engelsby 20	7/10/2018	1030	103	3.12
181398-08	Engelsby 20	7/24/2018	1195	121	2.56
181538-07	Engelsby 20	8/7/2018	642	129	1.58
181652-07	Engelsby 20	8/21/2018	370	74.2	2.25
181809-07	Engelsby 20	9/4/2018	322	65.6	1.7
181538-08	Engelsby 20 Blank	8/7/2018	< 2	< 5	< 0.2
181280-10	Indian 10	7/10/2018	288	38.9	14.5
181398-09	Indian 10	7/24/2018	300	38.5	3.94
181538-09	Indian 10	8/7/2018	326	37.8	5.46
181629-02	Indian 10	8/18/2018	41.55	180	64.9
181652-08	Indian 10	8/21/2018	140	43.2	4.96
181809-08	Indian 10	9/4/2018	234	49.9	9.83
181652-09	Indian 10 Blank	8/21/2018	< 2	< 5	< 0.2
181398-10	Indian 10 Field Dup	7/24/2018	310	38.8	3.84
181280-11	Indian 20	7/10/2018	131	115	13.6
181398-11	Indian 20	7/24/2018	322	110	6.63
181538-10	Indian 20	8/7/2018	206	120	5.92
181652-10	Indian 20	8/21/2018	55.5	68.3	11.8
181809-09	Indian 20	9/4/2018	188	74.1	7.57



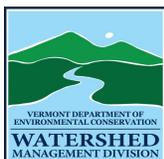
181809-10	Indian 20 Blank	9/4/2018	< 2	< 5	0.23
181538-11	Indian 20 Field Dup	8/7/2018	205	125	7.28
181809-11	Malletts 10	9/4/2018	54.5	44.4	4.61
181280-12	Malletts 10	7/10/2018	48.15	41.2	6.25
181398-12	Malletts 10	7/24/2018	57	36.7	3.22
181538-12	Malletts 10	8/7/2018	47.35	42.6	4.28
181652-11	Malletts 10	8/21/2018	43.45	33.5	5.5
181652-12	Malletts 10 Field Dup	8/21/2018	44.3	33.7	5.76
181280-13	Morehouse 10	7/10/2018	136	32.9	10.2
181398-13	Morehouse 10	7/24/2018	185	26.2	6.18
181538-13	Morehouse 10	8/7/2018	150	26	2.18
181629-03	Morehouse 10	8/18/2018	38.65	48.8	8.52
181652-13	Morehouse 10	8/21/2018	49.85	32.4	3.59
181809-12	Morehouse 10	9/4/2018	145	37	7.54
181280-14	Morehouse 10 Blank	7/10/2018	< 2	< 5	< 0.2
181809-13	Morehouse 10 Dup	9/4/2018	141	42	19.8
181280-15	Morehouse 20	7/10/2018	537.5	27.1	5.99
181398-14	Morehouse 20	7/24/2018	684	24.4	1.23
181538-14	Morehouse 20	8/7/2018	486	65.3	2.48
181629-04	Morehouse 20	8/18/2018	111	76.5	21.3
181652-14	Morehouse 20	8/21/2018	223	28.5	2.18
181809-14	Morehouse 20	9/4/2018	520	34	2.2



181629-05	Morehouse 20 Blank	8/18/2018	< 2	< 5	0.22
181280-16	Muddy 10	7/10/2018	170	55.1	7.5
181398-15	Muddy 10	7/24/2018	220	51.8	6.87
181538-15	Muddy 10	8/7/2018	228	43.1	4.11
181652-15	Muddy 10	8/21/2018	254	49.8	6.31
181809-15	Muddy 10	9/4/2018	284	52.2	6.47
181398-16	Muddy 10 Blank	7/24/2018	< 2	< 5	0.23
181280-17	Muddy 10 Field Dup	7/10/2018	171	57.9	7.79
181280-18	Muddy 20	7/10/2018	645	34.5	4.97
181398-17	Muddy 20	7/24/2018	620	36.9	4.77
181538-16	Muddy 20	8/7/2018	600	41.8	5.9
181652-16	Muddy 20	8/21/2018	510	50.2	7.72
181809-16	Muddy 20	9/4/2018	605	44.6	6.28
181538-17	Muddy 20 Blank	8/7/2018	< 2	< 5	< 0.2
181280-19	Muddy 30	7/10/2018	31.2	107	21.1
181398-18	Muddy 30	7/24/2018	33.4	102	13.3
181538-18	Muddy 30	8/7/2018	34	114	13.9
181629-06	Muddy 30	8/18/2018	35.7	92.3	11.5
181652-17	Muddy 30	8/21/2018	38.25	84.3	16.5
181809-17	Muddy 30	9/4/2018	34.15	175	23.6
181652-18	Muddy 30 Blank	8/21/2018	< 2	< 5	< 0.2
181398-19	Muddy 30 Field Dup	7/24/2018	33	103	13.7



181280-20	Munroe 10	7/10/2018	230	54.4	5.25
181398-20	Munroe 10	7/24/2018	596	69.5	8.69
181538-19	Munroe 10	8/7/2018	575	64.9	8.25
181652-19	Munroe 10	8/21/2018	152	52.6	5.28
181809-18	Munroe 10	9/4/2018	154	62.9	6.15
181809-19	Munroe 10 Blank	9/4/2018	< 2	7.58	< 0.2
181538-20	Munroe 10 Field Dup	8/7/2018	570	71.9	10.1
181280-21	Munroe 20	7/10/2018	92.9	108	30.2
181398-21	Munroe 20	7/24/2018	466	88.8	33.9
181538-21	Munroe 20	8/7/2018	132	116	9.2
181652-20	Munroe 20	8/21/2018	63	55.2	6.7
181809-20	Munroe 20	9/4/2018	93.8	76.8	14.5
181280-22	Munroe 20 Field Dup	7/10/2018	92.9	90.6	27.9
181280-23	Potash 10	7/10/2018	490	32	2.84
181398-22	Potash 10	7/24/2018	872	31.6	2.39
181538-22	Potash 10	8/7/2018	484	41.4	4.09
181652-21	Potash 10	8/21/2018	416	74.3	12.1
181809-21	Potash 10	9/4/2018	590	44	2.92
181280-24	Potash 20	7/10/2018	470	31.7	0.98
181398-23	Potash 20	7/24/2018	832	30.3	1.12
181538-23	Potash 20	8/7/2018	416	33.8	1.02
181629-07	Potash 20	8/18/2018	187	74	8.71



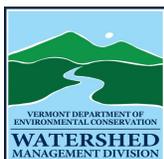
181652-22	Potash 20	8/21/2018	460	37.8	1.39
181809-22	Potash 20	9/4/2018	823	45.5	2.93
181398-24	Potash 20 Field Dup	7/24/2018	828	30.3	1.35
181280-25	Potash 30	7/10/2018	338	104	3.13
181398-25	Potash 30	7/24/2018	332	98	3.39
181538-24	Potash 30	8/7/2018	416	55.1	4.09
181652-23	Potash 30	8/21/2018	348	71.8	32
181809-23	Potash 30	9/4/2018	216	119	11.3
181538-25	Potash 30 Field Dup	8/7/2018	416	54.6	4.42
181280-26	Potash 40	7/10/2018	607.5	252	50.2
181398-26	Potash 40	7/24/2018	736	277.8	39
181538-26	Potash 40	8/7/2018	855	847.8	23.3
181652-24	Potash 40	8/21/2018	720	72.1	20.8
181809-24	Potash 40	9/4/2018	767	143	63.3
181652-25	Potash 40 Field Dup	8/21/2018	715	70.1	12.2
181280-27	Sunderland 10	7/10/2018	176	77.8	11.2
181398-27	Sunderland 10	7/24/2018	185	62.7	5.41
181538-27	Sunderland 10	8/7/2018	186	188	16
181652-26	Sunderland 10	8/21/2018	187	89.2	2.24
181809-25	Sunderland 10	9/4/2018	202	47	5.31
181652-27	Sunderland 10 Blank	8/21/2018	< 2	< 5	< 0.2
181809-26	Sunderland 10 Dup	9/4/2018	200	51.7	7.48



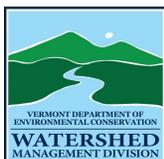
181280-28	Sunderland 20	7/10/2018	208	45.1	6.07
181398-28	Sunderland 20	7/24/2018	156	62.4	11.4
181538-28	Sunderland 20	8/7/2018	178	53.3	8.57
181652-28	Sunderland 20	8/21/2018	131	68.9	17.6
181809-27	Sunderland 20	9/4/2018	168	46.6	6.89
181809-28	Sunderland 20 Blank	9/4/2018	< 2	< 5	< 0.2
181280-29	Sunnyside 10	7/10/2018	900	21.5	4.91
181398-29	Sunnyside 10	7/24/2018	875	22.3	8.07
181538-29	Sunnyside 10	8/7/2018	775	13	4.37
181652-29	Sunnyside 10	8/21/2018	560	13.9	7.77
181809-29	Sunnyside 10	9/4/2018	755	66.1	30.1

Appendix D. Statistically Different Phosphorus Up and Downstream

Stream	Test statistic, Critical Value, Two-tailed Alpha Value	Visualization
Centennial	0,6,0.05	<p>Phosphorus Up and Downstream Centennial</p> <p>The chart displays phosphorus concentration (P in µg/L) on the y-axis (0.00 to 180.00) against dates on the x-axis (06/27/17, 10/27/17, 02/27/18, 06/27/18). A horizontal green line represents the P Limit at approximately 25 µg/L. Blue diamonds represent Centennial 10 data points, and red squares represent Centennial 20 data points. Centennial 20 values are consistently higher than Centennial 10 values, with several points exceeding 100 µg/L. Both data series are generally above the P Limit.</p>



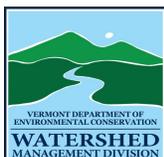
<p>Indian</p> <p>159, 187, 0.05</p>		<h3 style="text-align: center;">Phosphorous Up and Downstream Indian</h3> <p style="text-align: center;">Date</p>
<p>Munroe</p> <p>90,127,0.05</p>		<h3 style="text-align: center;">Phosphorus Up and Downstream Munroe</h3> <p style="text-align: center;">Date</p>
<p>Sunderland</p> <p>0,1, 0.1</p>		<h3 style="text-align: center;">Phosphorus Up and Downstream Sunderland</h3> <p style="text-align: center;">Date</p>

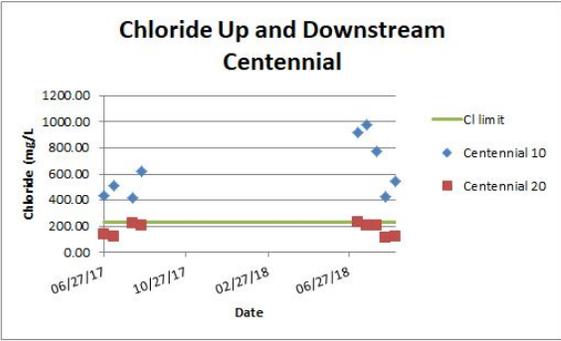
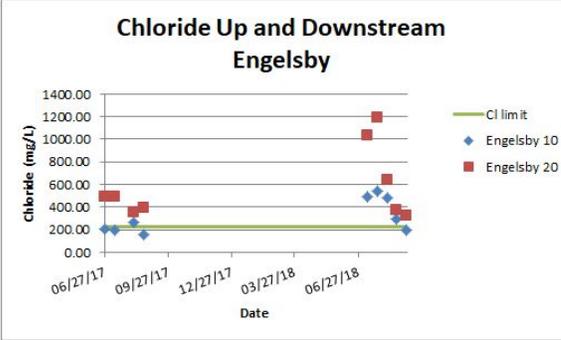
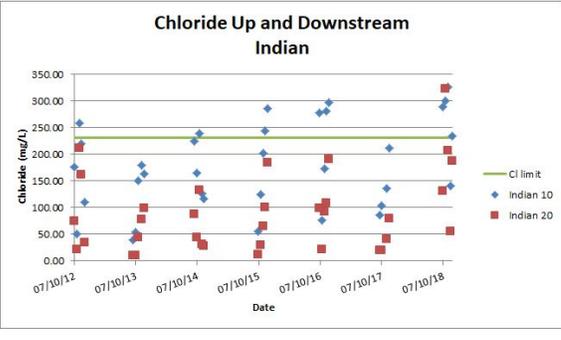
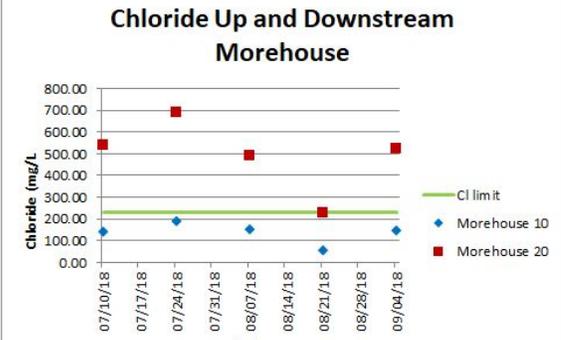


Site	K, Critical Value, Two tailed Alpha Value	Visualization
Muddy	26.85, 5.99, 0.05	
Potash	43.94, 7.81, 0.05	

Appendix E. Statistically Different Chloride Up and Downstream

Stream	Test statistic, Critical Value, Two-tailed Alpha Value	Visualization



Centennial	0, 6, 0.05	 <p>Chloride Up and Downstream Centennial</p> <p>This scatter plot shows chloride levels (mg/L) from 06/27/17 to 06/27/18. The y-axis ranges from 0.00 to 1200.00. A green horizontal line represents the 'Cl limit' at approximately 200 mg/L. Blue diamonds represent 'Centennial 10' and red squares represent 'Centennial 20'. Most data points are below the limit, with a notable spike for Centennial 10 in early 2018.</p>
Engelsby	0, 6, 0.05	 <p>Chloride Up and Downstream Engelsby</p> <p>This scatter plot shows chloride levels (mg/L) from 06/27/17 to 06/27/18. The y-axis ranges from 0.00 to 1400.00. A green horizontal line represents the 'Cl limit' at approximately 200 mg/L. Blue diamonds represent 'Engelsby 10' and red squares represent 'Engelsby 20'. There is a significant spike for Engelsby 20 in early 2018, reaching over 1000 mg/L.</p>
Indian	1, 187, 0.05	 <p>Chloride Up and Downstream Indian</p> <p>This scatter plot shows chloride levels (mg/L) from 07/10/12 to 07/10/18. The y-axis ranges from 0.00 to 350.00. A green horizontal line represents the 'Cl limit' at approximately 250 mg/L. Blue diamonds represent 'Indian 10' and red squares represent 'Indian 20'. Data points fluctuate around the limit, with several points for Indian 10 exceeding it.</p>
Morehouse	0, 1, 0.1	 <p>Chloride Up and Downstream Morehouse</p> <p>This scatter plot shows chloride levels (mg/L) from 07/10/18 to 09/04/18. The y-axis ranges from 0.00 to 800.00. A green horizontal line represents the 'Cl limit' at approximately 200 mg/L. Blue diamonds represent 'Morehouse 10' and red squares represent 'Morehouse 20'. There are several spikes for Morehouse 20, with one reaching nearly 700 mg/L.</p>



Munroe	9, 117, 0.05	
Site	K, Critical Value, Two tailed Alpha Value	Visualization
Muddy	57.23, 5.99, 0.05	
Potash	8.33, 7.81, 0.05	

Appendix F. Notable Trends in Chloride Increases Over Time By Site. Sorted in descending order by R2 values.



