Allen Brook Water Quality Monitoring
Final Report
2007 – 2015

Background

The Williston Conservation Commission (WCC) is pleased to submit this Report to summarize the results of the 2007 to 2015 sampling seasons under the LaRosa Partnership program. The principal objectives of projects under this program are to 1) provide a perspective on the range of water quality conditions across Vermont; 2) describe water quality conditions of individual waterbodies; 3) establish a data base for waterbodies for use in documenting future changes in water quality; and, 4) educate and involve local residents in waterbody protection.

The Allen Brook is a tributary of the Winooski River that is located entirely in the Town of Williston. Its watershed is approximately 14.5 square miles in size. The mainstem of Allen Brook is approximately 11 miles long from its headwaters in the Sunset Hill area of Williston to its confluence with Muddy Brook just before Muddy Brook empties into the Winooski River. Ten small tributaries to the brook are evident on aerial photographs of the watershed, most of which are ephemeral.[i] According to the State of Vermont, the Allen Brook is a Class B waterway, and should therefore be suitable for "aquatic habitat, boating, swimming and public water supply with filtration and disinfection." Since 1992, portions of the Allen brook have been designated as "impaired" by stormwater and E.coli on the State's 303(d) Impaired Waters List.[ii] The Allen Brook and its watershed have experienced many stressors in the recent and not-so-recent past, including historic impacts from floodplain encroachment (especially in developed areas), road crossings (15 total), historic straightening to protect agricultural resources and infrastructure, and natural influences like beaver activity. The Town of Williston has also experienced rapid growth over the past two decades, both in its residential population (78% increase) and as a center of employment (135% increase in working population).[iii] Land use changes have been equally dramatic, and development has resulted in marked increases in impervious surface within the watershed. Though municipal stormwater and stream buffer regulations have been adopted to reduce future impacts from development, the Allen Brook flows directly through several areas where the Town intends to concentrate future growth (Industrial, Medium Density Residential, and Mixed Use Zoning Districts). Therefore it is important that the current E.coli and stormwater impairment of Allen Brook be accurately characterized and addressed before contamination worsens or becomes irreversible.

The Allen Brook monitoring program aims to characterize the spatial and temporal patterns of E.coli and nutrient contamination in Allen Brook. The information is used by the Williston Conservation Commission to identify potential sources of pollution, target remediation efforts, and direct public education and awareness surrounding watershed health, water quality, and stormwater contamination.

Sampling Methods and Quality Assurance

In 2015, the WCC sampled 8 locations along the Allen Brook (Figure 1, Table 1). The parameters sampled included Total Phosphorus (TP), *E. coli*, and Turbidity (NTU).

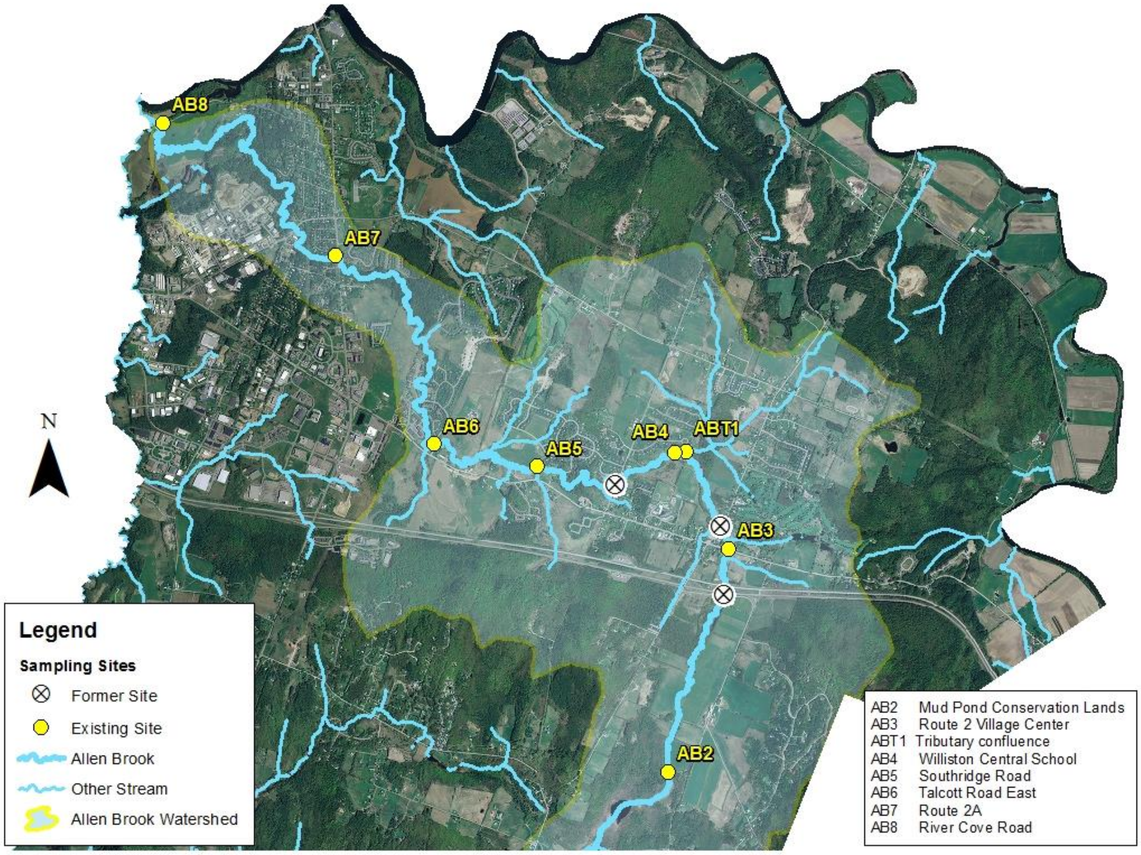

Figure 1: 2015 Allen Brook Sampling Sites

Table 1: 2015 Allen Brook Sampling Site Location Descriptions

Site	Description
AB2	Mud Pond Conservation Land, downstream of pond. Has been a sampling site for TN (2007-2013), TP (2007-Present), E.coli (2007-Present), Chloride (2010-2013), and Turbidity (2010-present)
AB3	Upstream of Route 2 crossing in Village Center. Has been a sampling site for TN (2007-2013), TP (2007-present), E.coli (2007- present), Turbidity (2010- present)
ABT1	Major tributary north of Central School ball fields, downstream of beaver lodge. Has been a sampling site for TN (2008,2010), TP (2008-present), E.coli (2010), Turbidity (2010-present)
AB4	Williston Central School- behind ball fields, south of 338 Southfield Drive (access through this yard). Has been a sampling site for TN (2007- 2010, 2013), TP (2007- present), E.coli (2007- present), Chloride (2010), Turbidity (2010- present)
AB5	Just upstream of Southridge Road crossing. Has been a sampling site for TN (2007-2010), TP (2007- present), E.coli (2007,2010), Chloride (2010), Turbidity (2007- present)

AB6	Just upstream of Talcott Road East crossing (access from Fire Station). Has been a sampling site for TN (2007-2013), TP (2007-present), *E. coli* (2007- present), Chloride (2010- 2013), Turbidity (2010- present)
AB7	Under Route 2A crossing (large culvert). Has been a sampling site for TN (2007- 2010), TP (2007- present), E.coli (2007- 2008), Chloride (2010), Turbidity (2007, present)
AB8	Just upstream of River Cove Road crossing. Has been a sampling site for TN (2007- 2013), TP (2007- present), E.coli (2007- 2010), Chloride (2010- 2013), Turbidity (2010- present)

Prior to the 2015 sampling season, the WCC developed a Quality Assurance Project Plan (QAPP)[iv], which was approved by the Vermont Department of Environmental Conservation (DEC). The QAPP specifies several objectives related to data precision, accuracy, completeness and representativeness during data collection, laboratory processing and data analysis. A detailed description of sampling methods is available in the Quality Assurance Project Plan.

The QAPP specifies that at least 80% of the anticipated number of samples will be collected, analyzed and determined to meet data quality objectives for the project to be considered successful. Unfortunately due to unforeseen staff turnover, the WCC ended the sampling program early and thus did not meet the data completeness objectives for the 2015 season (see Table 2).

Table 2: Project Completeness

Parameter	Number of Samples Anticipated	Number of Valid Samples Collected & Analyzed	Percent Complete
Total Phosphorus	8 sites, 16 weeks = 128	8 sites, 11 weeks = 88	68.75%
E. coli	4 sites, 8 weeks = 32	4 sites, 9 weeks = 36	100.13%
Turbidity	8 sites, 16 weeks = 128	8 sites, 11 weeks = 88	68.75%
Temperature	8 sites, 16 weeks = 128	0 sites, 0 weeks = 0	00.00%

At least one Field Duplicate and one Field Blank was submitted for every ten samples collected. Field Duplicate serves as a check on water quality, sampling & analysis consistency. This is a replicated sample collected at the same point in time and space so as to be considered identical. A Field Duplicate is a second sample from a second sampling event, collected immediately after the first sampling. Otherwise put, these separate samples are said to represent the same population and are carried through all steps of the sampling and analytical procedures in an identical manner. They are used to assess precision of the total method, including sampling, analysis, and site heterogeneity.

The Field Blank checks for contamination (Accuracy/Bias) in the field by processing laboratory-supplied de-ionized through the sampling train. This checks for contamination introduced from the sample container(s) or from field contamination.

The Field Duplicates and Field Blanks were subsequently analyzed for consistency and samples with values outside acceptable ranges (Table 3, Table 4) were identified.

Table 3: Acceptable Range of Values for Field Duplicate and Field Blank

Parameter	Field Duplicate – Relative Percent Difference (RPD)	Field Blank
Total phosphorus	≤ 15%	≤ 5 ug/l
E Coli	≤ 50%	≤ 1 colony/100 ml
Turbidity	≤ 15%	≤ 0.2 NTU

As shown in Table 4 below, there was one sample for which no field duplicate was submitted, and one sample for which no blank was submitted. All *E. Coli* RPDs were within the acceptable range (≤ 50%); all phosphorous RPDs were within the acceptable range (≤ 15%); and one turbidity RPD (19.65%) was outside the acceptable range (≤ 15%). Blank sample 150754-10 (AB2 – B) fell outside the acceptable range for phosphorus (6.4) and turbidity was borderline (.21). Since none of the samples were contaminated in the field by fingers or touching sediment, and there were no sample mix ups or other unresolvable issues, all sample records were kept.

Table 4: Values for Samples, Field Duplicates and Blanks

Sample Number	Site	Date	*E. Coli* (mpn/ 100 ml)	RPD Ecoli Dupe (%)	TP (ug P/L)	RPD TP Dupe (%)	Turbidit y (NTU)	RPD Turbidity Dupe (%)
150305-01	AB2	6/8/2015	91.00	30.38%	22.30	No duplicate	0.80	4.88%
150305-11	AB2 - D	6/8/2015	67.00				0.84	
150305-10	AB2 - B	6/8/2015	no blank		< 5		< 0.2	
150481-02	AB3	6/15/2015	517.21	22.57%	129.00	8.06%	12.50	4.92%
150481-10	AB3 - D	6/15/2015	648.82		119.00		11.90	
150481-09	AB3 - B	6/15/2015	< 1		< 5		< 0.2	
150516-03	ABT1	6/23/2015			212.00	14.04%	55.80	1.63%
150516-10	ABT1 - D	6/23/2015			244.00		54.90	
150516-09	ABT1 - B	6/23/2015			< 5		< 0.2	
150545-04	AB4	7/6/2015	161.62	45.53%	26.50	0.38%	1.83	3.75%
150545-10	AB4 - D	7/6/2015	101.68		26.60		1.90	
150545-09	AB4 - B	7/6/2015	< 1				1.33	
150544-05	AB5	7/13/2015			19.40	4.53%	1.21	7.17%
150544-10	AB5 - D	7/13/2015			20.30		1.30	
150544-09	AB5 - B	7/13/2015			< 5		< 0.2	
150728-06	AB6	7/20/2015	1299.65	8.40%	99.70	1.41%	16.30	1.82%
150728-09	AB6 - D	7/20/2015	1413.61		98.30		16.60	
150728-10	AB6 - B	7/20/2015	< 1		< 5		< 0.2	
150752-07	AB7	7/27/2015			24.90	5.47%	2.51	0.40%
150752-09	AB7 - D	7/27/2015			26.30		2.52	
150752-10	AB7 - B	7/27/2015			< 5		< 0.2	

Sample Number	Site	Date	*E. Coli* (mpn/ 100 ml)	RPD Ecoli Dupe (%)	TP (ug P/L)	RPD TP Dupe (%)	Turbidity (NTU)	RPD Turbidity Dupe (%)
150753-08	AB8	8/3/2015			21.40	6.33%	7.12	0.42%
150753-09	AB8 - D	8/3/2015			22.80		7.09	
150753-10	AB8 - B	8/3/2015			< 5		< 0.2	
150754-01	AB2	8/10/2015	166.40	0.00%	30.60	2.26%	1.96	3.64%
150754-09	AB2 - D	8/10/2015	166.40		31.30		1.89	
150754-10	AB2 - B	8/10/2015	< 1		6.40		0.21	
150755-02	AB3	8/18/2015			27.80	3.19%	0.95	19.65%
150755-01	AB3 - D	8/18/2015			28.70		0.78	
150755-03	AB3 - B	8/18/2015			< 5		< 0.2	
150756-03	ABT1	8/25/2015			27.10	1.86%	2.90	
150756-09	ABT1 - D	8/25/2015			26.60			
150756-10	ABT1 - B	8/25/2015			< 5		< 0.2	

Results

Relationship to Stream Discharge/Flow

Flow (discharge magnitude) can dramatically affect certain water quality parameters, thus it is important to record flow observations during data collection. A quantitative discharge measurement in a gaged stream is the most precise method, and WCC intended to calculate estimated discharge using field recorded measurements of a USGS staff gage in Allen Brook. However, due to a very dry July and August, the water level was below the gage height 6 out of 11 sampling days (Table 5). This stream gage was no longer being monitored by USGS, thus records of stream discharge were not available for the 2015 sampling season.

Table 5: Measured Height at Allen Brook USGS Stream Gage

Date	Height at Stream Gage (ft)
6/8/2015	1.44
6/15/2015	1.24
6/23/2012	1.8
7/6/2012	0.26
7/13/2012	below gage
7/20/2012	1.1
7/27/2012	below gage
8/3/2012	below gage
8/10/2012	below gage
8/18/2012	below gage
8/25/2012	below gage

Thus, actual estimated discharge magnitudes could not be used to estimate nutrient loads. However, a nearby stream gage located on the Laplatte River at Shelburne Falls[v] was used as a proxy for flow conditions on the Allen Brook. Figures 3-5 plot the discharges of 2 stream gages, the Laplatte River gage and the Winooski River gage located near the intersection of Route 2A in Essex Junction (Figure 2). These two streams show a remarkably similar flow pattern even though they are different orders and are located in different watersheds. Since the Winooski's flow is altered by upstream dams, we decided to use the Laplatte River discharge as a proxy for the flow on the Allen Brook.

Figure 2: USGS Stream Gage Locations

In early June, streamflows were high but declining (Figure 3). From June 8-10, streamflows rapidly rose and peaked at 14,200 for the Winooski and 814 for the Laplatte. This was the highest flow observed all summer. During the rest of June and early July, streamflows rose and fell, while overall gradually diminishing. The flows in the Winooski had sharper peaks than on the Laplatte. Flows on the Laplatte were generally low during most of July, while the Winooski flow experienced a sharp rise and fall around July 20 (Figure 4). This may be attributed to a dam release. In August, flows were very low on both streams, with the exception of a small peak around August 12-13 (Figure 5).

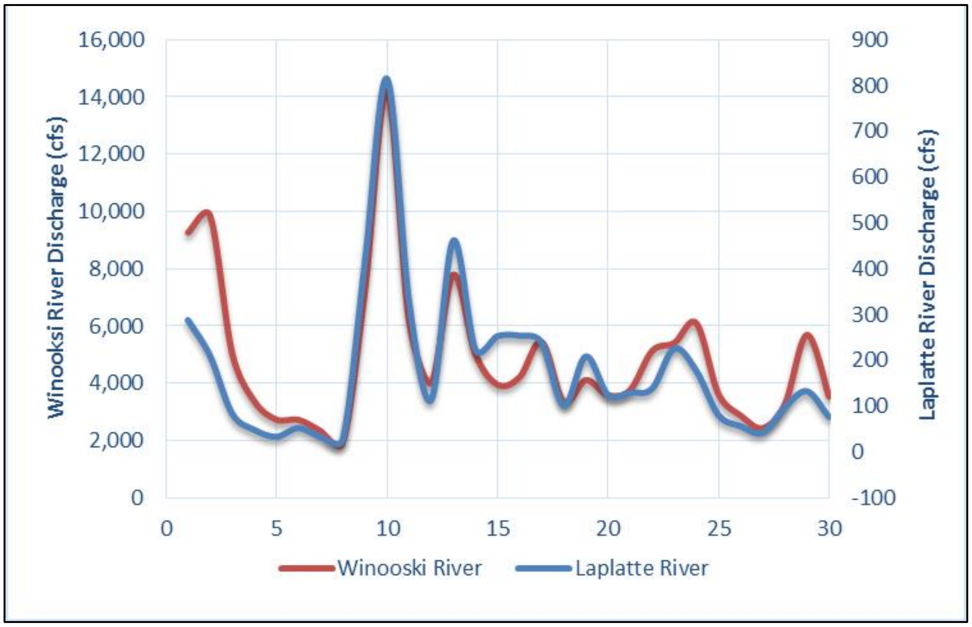

Figure 3: June 2015 Daily Mean Discharge of Two Gaged Streams

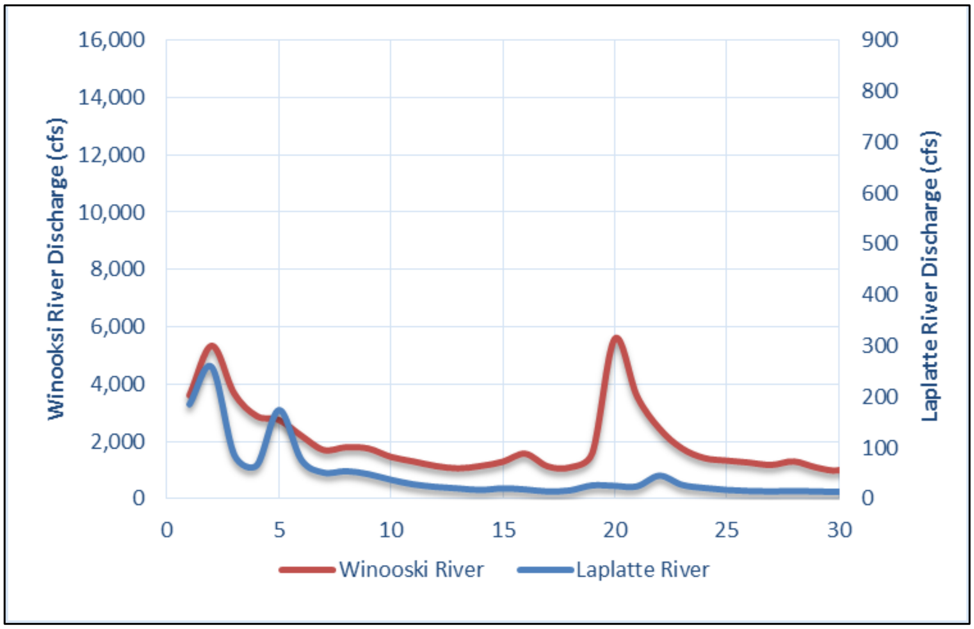

Figure 4: July 2015 Daily Mean Discharge of Two Gaged Streams

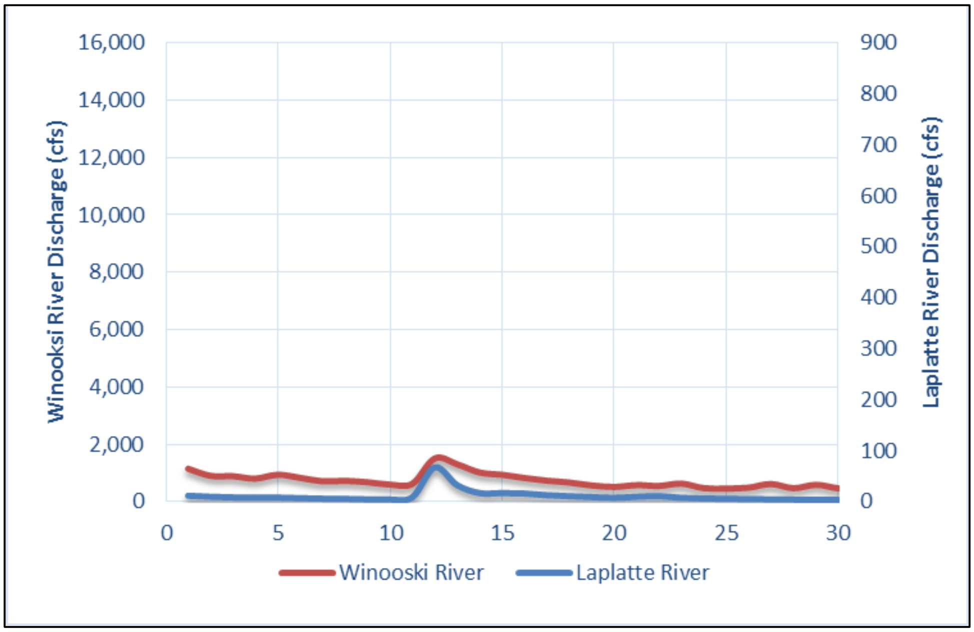

Figure 5: August 2015 Daily Mean Discharge of Two Gaged Streams

As shown in Figures 6-8, streamflow had a marked effect on nutrient and E coli concentrations. Phosphorus, Turbidity and *E. coli* levels rose following and proportional to streamflow peaks, albeit with a significant lag period. The sites further downstream in the Allen Brook watershed were much more sensitive to streamflow fluctuations than those further upstream in the watershed.

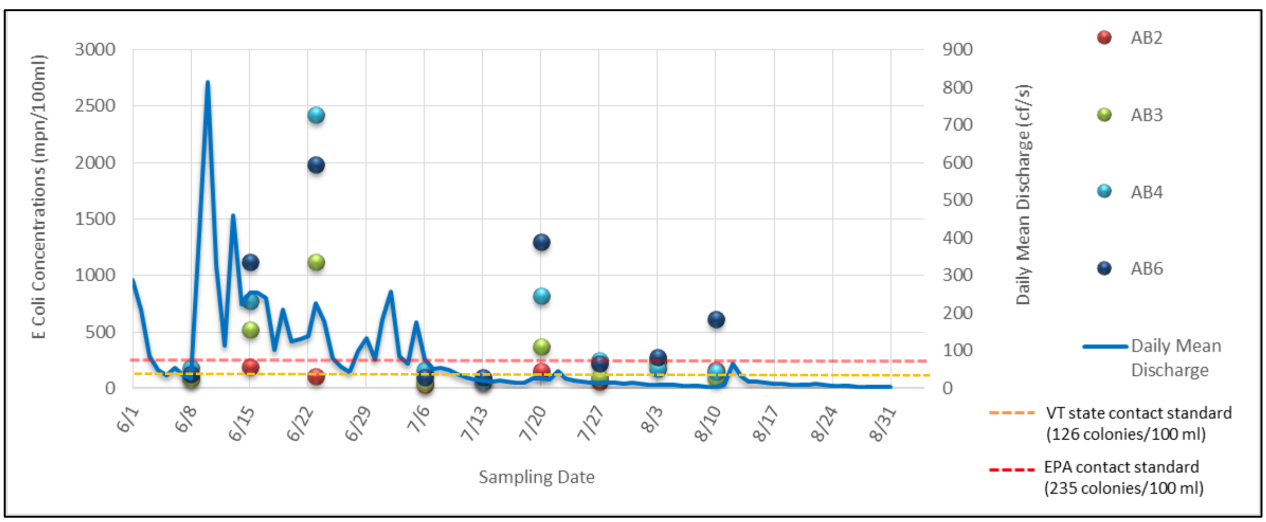

Figure 6: E coli concentrations along the Allen Brook in relationship to daily mean discharge. USGS 04282795 LAPLATTE RIVER AT SHELBURNE FALLS, VT stream gage discharge data was used as a proxy for Allen Brook streamflow to estimate timing of individual storm events.

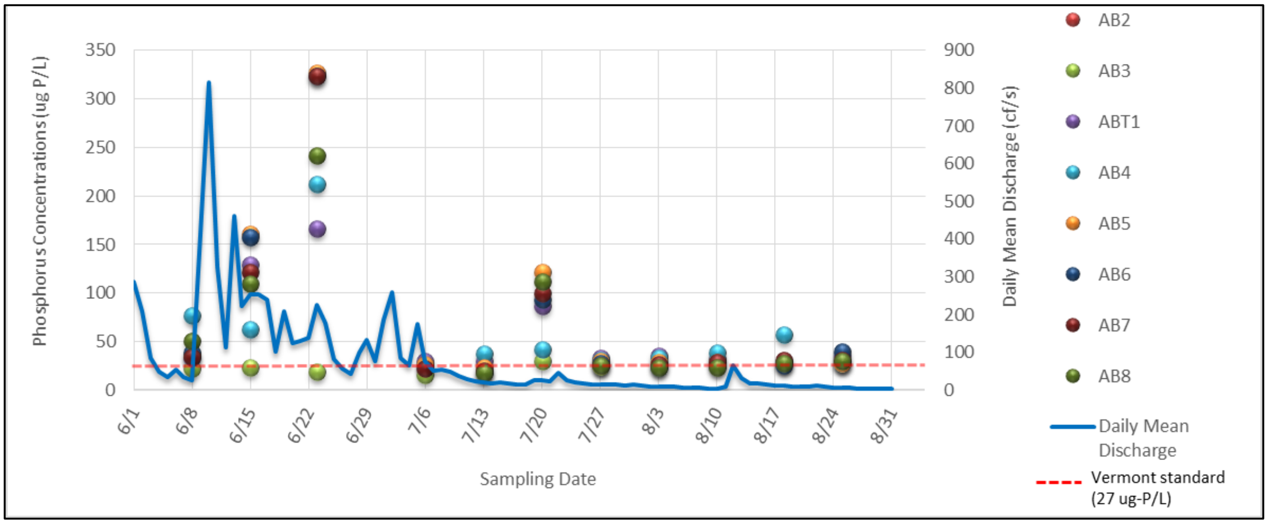

Figure 7: Phosphorous concentrations along the Allen Brook in relationship to daily mean discharge. USGS 04282795 LAPLATTE RIVER AT SHELBURNE FALLS, VT stream gage discharge data was used as a proxy for Allen Brook streamflow to estimate timing of individual storm events.

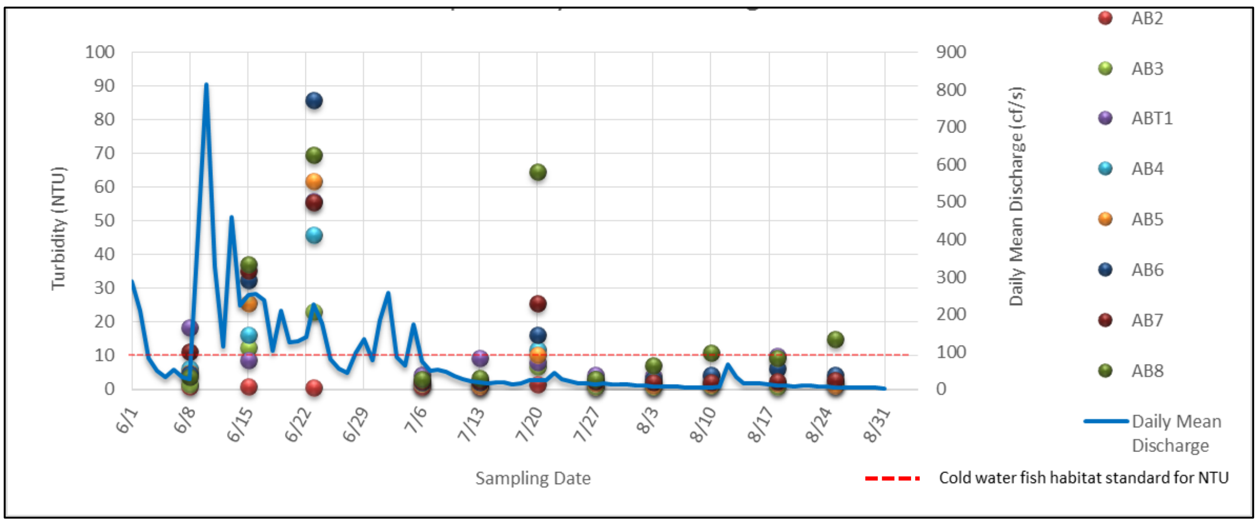

Figure 8: Turbidity levels along the Allen Brook in relationship to daily mean discharge. USGS 04282795 LAPLATTE RIVER AT SHELBURNE FALLS, VT stream gage discharge data was used as a proxy for Allen Brook streamflow to estimate timing of individual storm events.

Data Trends over Time

To characterize and compare the sampling data gathered from 2007-2015 (no samples were taken in 2009). The median concentration of each parameter was calculated for each monitoring site for each year. Comparing the data in this way brought some interesting trends to light. Below is a summary of the findings for each parameter.

Total Phosphorous:

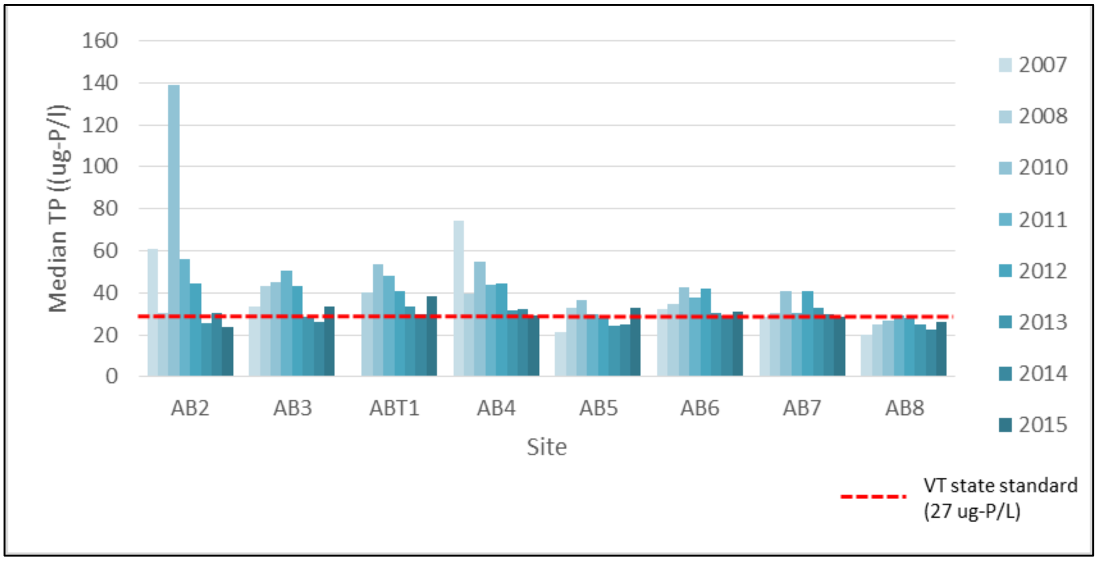

Figure 9: Allen Brook phosphorous (TP) concentrations from 2007-2015.

Over the eight year sampling span, 76% of the samples are above the Vermont Standard (27 ug-P/L).[vi] Total Phosphorous (TP) concentrations tend to be slightly higher at upstream sampling sites (AB2, AB3, AB4 and ABT1), and are the lowest at AB8. We would expect to see these results because agricultural land is concentrated in the upstream reach. AB8 was the only site at which TP concentrations were consistently under the Vermont water quality standard of 27 ug-P/L for a warm water, median gradient stream. From 2011 on, phosphorus concentrations appear to decrease across all sites, although with a slight rise in 2015. The decrease is most noticeable in the upstream sampling sites. The decrease in phosphorus concentrations may be related to the implementation of stormwater BMPs, agricultural BMPs, or the completion of a series of riparian buffer improvement projects from 2012-2014, all of which reduce the amount of sediment and phosphorus entering the Allen Brook. If this is indeed the case, we would expect to see continued future decreases in phosphorus concentrations over time.

E. coli:

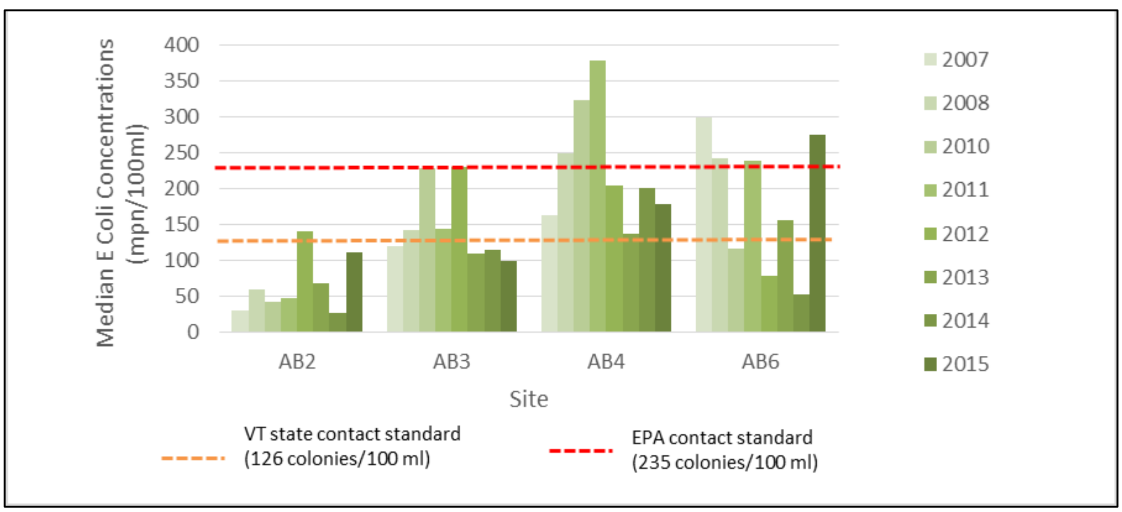

Figure 10: Allen Brook E. coli concentrations from 2007-2015.

Concentrations of E. *coli* are quite variable across sites and over time. Site AB2 is the furthest upstream site, located within a protected wetland area. Sites AB4 and AB6 are both located downstream of residential development. Site AB 3 is located downstream from agricultural uses.

Site AB2 was the only sampling location to consistently remain under 126 mpn/100ml (VT state contact standard), except for 2012. This trend makes sense as AB2 is situated in a conservation area where the only inputs would be wildlife related. Over the 8 year sampling period, site AB4, located behind the Allen Brook elementary school, averaged the highest *E. coli* concentrations. On 7/7/2011 the sample at AB4 showed a very large spike in *E. coli*. When cross referencing this date with the flow data there was an increase in flow from 3.1 cf/s on June 30th to 23cf/s on July 7th. The high *E. coli* concentrations in 2011 are also likely reflective of the high flow events associated with Tropical Storm Irene in August of that year and other significant runoff events that occurred in June.

All sites exceeded the EPA standard and Vermont standard on four or more sampling events in 2015 (see Table 6). All sampling sites exceeded Federal (235 colonies/100mL) and State (126 colonies/100mL) standards for E. coli at least once if not multiple times during each sampling season except in 2013 when site AB2 did not exceed the EPA standard. Over the eight year sampling span, 55% of the samples were above the Vermont Standard and 34% were above the EPA standard.

Table 6: 2015 E. coli Data – Allen Brook Sites

Date	Sampling Site			
	AB2	AB3	AB4	AB6
6/8/2015	91	84	179	126
6/15/2015	191.79	517.21	770.1	1119.87
6/23/2015	110.61	1119.87	2419.6	1986.29
7/6/2015	32.67	52.04	161.62	93.31
7/13/2015	61.27	73.8	71.73	95.86
7/20/2015	156.48	365.4	816.41	1299.65
7/27/2015	59.4	98.81	248.9	218.72
8/3/2015	235.93	238.22	172.16	275.51
8/10/2015	166.4	90.86	142.09	613.14
(yellow)	Above Vermont standard (126 mpn/100ml)			
(pink)	Above EPA standard (235 mpn/100ml)			

Source sampling (DNA testing) at sites AB3, AB4 and AB6 could be valuable for determining the origin (human, bovine, etc.) of these *E. coli* concentrations, and the Conservation Commission is looking into sources of funding for this effort. If the *E. coli* at AB3 was determined to be bovine in origin, the farmland bordering the Allen Brook between sites AB2 and AB3 should be checked to ensure that there is an appropriate sized buffer between the fields and the stream. Also, it might be worthwhile to try and raise awareness amongst the farmers to try and not spread manure during or before significant rain events. This phenomenon may improve with the new proposed Required Agricultural Practices that prohibit manure spreading when field conditions are conducive to runoff or if runoff events are anticipated.

Turbidity: (Figure 11)

As opposed to TP, the Turbidity was generally greater downstream than upstream. This trend makes sense as the level of turbidity tends to be cumulative in the water and there is a greater amount of impervious surface and developed areas located in the downstream stretch of the Allen Brook, which could cause excess sediment to be washed into the stream during a storm event.

Overall, Site AB8 had the highest turbidity. Notably, AB8 is downstream from an area of industrial development which may be responsible for some illicit discharge or stream buffer encroachment. Also, the Allen Brook travels through an area of severely eroded farmland along River Cove Road immediately upstream from site AB8. This site, the Griswold Farm, was the site of a 4 acre streambank restoration project in 2012-2013 which is being managed by Friends of the Winooski River. From 2012 - 2014 stream buffer restoration projects were implemented along other stretches of the Allen Brook in the vicinity of sampling points AB4, AB5 and AB6 with the intention of reducing stream bank erosion. It may take additional time for stabilization to occur along this corridor and to be reflected in the sampling results.

2014 was a relatively low turbidity year across all the sampling points. In 2015 Turbidity increased sharply at sites AB8 and ABT1. The cold water fish habitat standard (10 NTU) for Turbidity was exceeded at all sites except AB2 at different times during the 2015 sampling season (Table 7). Looking at the median values for every site over the 8 year period shows that only site AB8 has a median over 10 NTU. Over the eight year sampling span, only 11% of the samples exceeded the Vermont cold water fish habitat standard of 10 NTU.

Table 7: 2015 Turbidity Data – Allen Brook Sites

Date	AB2	AB3	ABT1	AB4	AB5	AB6	AB7	AB8
6/8/2015	0.8	1.59	18.2	6.33	5.07	4.51	11.3	3.78
6/15/2015	0.98	12.5	8.83	16.2	25.5	32.5	35.2	37.1
6/23/2015	0.63	23	55.8	45.7	61.8	85.8	55.5	69.5
7/6/2015	0.9	1.86	4.21	1.83	1.73	2.21	2.39	2.93
7/13/2015	0.95	1.12	9.43	2.08	1.21	2.27	2.36	3.23
7/20/2015	1.55	6.7	8.2	11.8	10.2	16.3	25.4	64.4
7/27/2015	0.92	0.94	4.36	1.68	1.94	2.93	2.51	3.03
8/3/2015	1.05	0.93	3.89	2.02	1.04	3.06	1.99	7.12
8/10/2015	1.96	1.21	3.85	2.07	1.57	4.33	2.27	10.8
8/18/2015	1.45	0.95	9.87		1.74	6.3	2.33	9.16
8/25/2015	1.96	1.49	2.9	1.68	1.29	4.42	2.66	14.8
	>10 NTU							

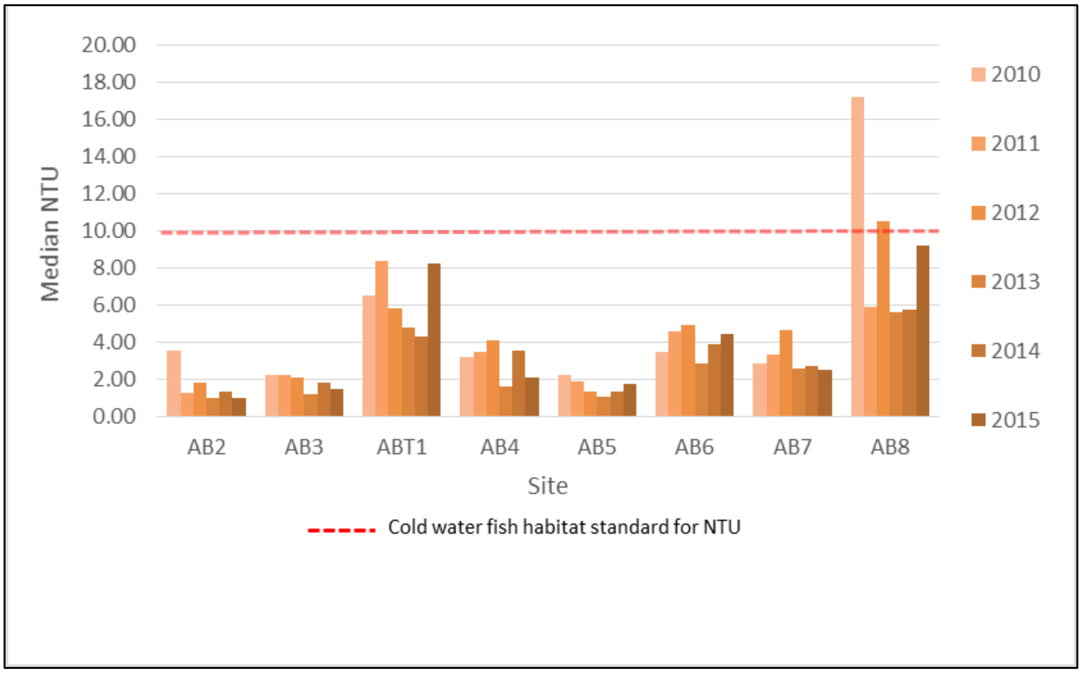

Figure 11: Allen Brook turbidity concentrations from 2007-2015.

Conclusion/Lessons Learned

Eight years of data collection and analysis is revealing some trends, while other parameters remain variable across sites and over time. Streamflow measurements from nearby watersheds appear correlated to nutrient and *E. coli* concentrations, with higher concentrations following peak streamflows. Downstream sites are highly sensitive to changes in stream flow. For future sampling, it would be helpful to re-establish a reliable mechanism for measuring flow on the Allen Brook, even during low flows.

Since 2011, median phosphorous concentrations have been steadily decreasing (except for 2015), most notably in upstream sites. This decrease may be related to improvement of stormwater management and or/agricultural practices, riparian buffer plantings and floodplain restoration, or other land use changes. Continuing to track phosphorus over time along a gradient of land uses will help determine the effectiveness of these management practices.

Concentrations of *E. coli* are quite variable across sites and over time. Site AB2, the furthest upstream site and located within a protected wetland area, was the only sampling location to consistently remain below 126 mpn/100ml (VT state contact standard). The evidence to date suggests that overland stormwater runoff is a major factor in Allen Brook's bacteria and nutrient impairment, although other contributory sources may also exist. Sites where E.coli concentrations were most elevated are located along a section of Allen Brook that flows through medium density suburban developments. The biological source (human vs. other animal) of *E. coli* contamination should be identified so that remediation efforts can be planned for and implemented.

With the exception of AB8, all sites' median values for turbidity are well below the Vermont cold water fish habitat standard of 10 NTU. Over the eight year sampling span, only 11% of the samples exceeded this standard. The industrial complex in the vicinity of AB8 should be checked to ensure that there is no illicit discharge contributing to turbidity concentrations at AB8. Continuing to test turbidity levels will help determine if BMP implementation projects designed to reduce peak flows and stream bank erosion positively impact the stream.

It is a primary objective of the WCC to ensure that the Allen Brook provides high-quality habitat for aquatic and riparian organisms, as well as opportunities for safe public recreation, including swimming, wading, and fishing. Meeting these objectives will involve addressing the E.coli and nutrient problems which have placed the brook on the State's 303(d) list. Continued water quality monitoring is an important step in this process and will complement the State's efforts to develop and implement a sediment TMDL for Allen Brook.

As a clearer picture of bacteria and/or nutrient contamination in Allen Brook emerges, the Town and WCC are developing strategies for improvement of water quality. Watershed-wide strategies include stringent and thorough review of development projects to ensure they meet current State stormwater standards, working with property owners to bring old stormwater infrastructure up to current standards, maintaining the Town's existing riparian buffer restoration projects, supporting efforts to implement additional buffer planting projects, and working to conserve and protect floodplains and upland forests.

References

[i] Dolan, K., L. Barg, C. Hession, C. Cianfrani, B. Kort and C. Cook. 2001. Progress Report: Allen Brook Water Quality Improvement Plan and TMDL. Prepared for VT Agency of Natural Resources.

[ii] Vermont Department of Environmental Conservation, September 2008. *A Total Maximum Daily Load (TMDL) to Address Biological Impairment in the Allen Brook.* Prepared for the U.S. Environmental Protection Agency-Region 1.

[iii] Town of Williston, 2006. *2006-2011 Town of Williston Comprehensive Plan.*

[iv] Williston Conservation Commission, 2015. *Vermont General Quality Assurance Project Plan for Volunteer, Educational and Local Community Monitoring and Reporting*. Prepared for the Vermont Department of Environmental Conservation.

[v] US Geological Survey, 2016. *Stream Stats, Version 3*. Accessed February 24, 2016 at http://water.usgs.gov/osw/streamstats/.

[vi] State of Vermont Agency of Natural Resources Department of Environmental Conservation, 2014. *Vermont Water Quality Standards Environmental Protection Rule Chapter 29(a)*. Accessed February 24, 2016 at http://www.anr.state.vt.us/dec/rulessum.htm.