Analysis of Spatial Patterns in Water Quality in the First, Second and Third Branch of the White River watersheds

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Acknowledgements

This document is based on one of five templates or guidance documents generated by the VT Department of Environmental Conservation (VTDEC) to support watershed groups engaged in ambient water quality monitoring under the LaRosa Partnership Program. These templates provide examples of data reduction and visualization, as well as statistical analysis, that enable more effective communication of the data – to constituents of Partnership groups; to local, state and federal partners in project implementation; and to the VT Agency of Natural Resources for meeting a variety of needs (e.g., listing / delisting of waters, basin planning, prioritization of resources to groups for project implementation). The template was prepared by South Mountain Research & Consulting of Bristol, VT, under contract to VTDEC.

This document relies on water quality data from the White River watershed, where sampling is carried out by staff and a network of trained volunteers operating under the White River Partnership, with logistical and technical support provided by the VTDEC Monitoring, Assessment and Planning Program, South Mountain Research & Consulting Services, and Beck Pond, LLC. Analytical services are provided by the Vermont Agricultural & Environmental Laboratory (http://agriculture.vermont.gov/vael) in Burlington, VT, through an analytical services partnership grant.

For the 2018 data reported here, nutrient testing through the LaRosa Partnership program was conducted at twelve sites: 6 sites on the First Branch; 2 sites on the Second Branch; and 4 sites on the Third Branch. Eight of these sites (upstream and downstream of dams on the First, Second and Third Branches) were funded by a LaRosa Organizational Support Grant to monitor project implementation (dam removal; Third Branch site post-implementation, First and Second Branches pre-implementation). The additional four sites on the First Branch that were tested for nutrients were funded under the LaRosa 2018 Volunteer Water Quality Monitoring Analytical Services Partnerships, and nutrient data from all twelve sites are included in this document.

In addition to the nutrient testing conducted through the LaRosa program, White River Partnership (staff and volunteers) conducts in-house *E. coli,* turbidity and conductivity sampling at a network of 22 sentinel sites throughout the White River basin, funded through local foundation grants and town appropriations.

With the White River Tactical Basin Plan being updated in 2018, the White River Natural Resources Conservation District provided funding in 2018 to help analyze bacteria, turbidity and conductivity monitoring for the sites included in the LaRosa nutrient testing. The USDA Forest Service also funded bacteria, turbidity and conductivity sampling at an additional site (Bingo Brook) on the Green Mountain National Forest in 2017 and 2018. Bacteria monitoring results for all of these sites are included in this document.

Executive Summary

Through the LaRosa Partnership program, White River Partnership (WRP) undertook spatial trend analysis of nutrient levels at twelve stations in the White River watershed (6 sites on the First Branch; 2 sites on the Second Branch; and 4 sites on the Third Branch), relying on water quality data collected during eight discrete events in the summer of 2018. The nutrient data were analyzed in conjunction with data from *E. coli* bacteria, turbidity and conductivity monitoring conducted by WRP.

Objectives of this Water Quality Monitoring (WQM) effort were to: (1) help monitor project implementation (both current and prospective dam removals); (2) better define the extent and magnitude of sediment, nutrient and bacteria concentrations in the watershed; and (3) share monitoring results with the public and with partner agencies engaged in the design of restoration and conservation practices that improve water quality.

Over the years our routine WQM program has highlighted sites with chronically-elevated levels of *E. coli*. Bacteria levels along the First, Second and Third Branches of the White River have regularly exceeded the seasonal standard for E. coli, and in 2016 portions of all three 'Branches' were added to the 303(d) list of impaired streams due to consistently elevated bacteria levels.

With increasing momentum since 2013 (post-Irene; Irene caused elevated readings basin-wide in 2012), the WRP has been engaged in an adaptive WQM program in an attempt to better understand and address those high bacteria numbers. We have leveraged the data to highlight focal areas for remediation and restoration efforts and intend to document changes as cumulative impacts accrue from a growing list of projects including buffer restorations, corridor protection, dam removals and wastewater treatment facility upgrades.

The LaRosa Partnership has enhanced our WQM program with technical assistance and additional chemical analyses at both sentinel and potential source identification sites. An iterative approach has increased our interest in correlations between *E. coli* levels and nutrients in the fine grained soils along "The Branches", and how discontinuities in sediment transport at dams may contribute to elevated bacteria levels. A primary focus for our 2018 work was documenting spatial patterns and relationships of bacteria and nutrient levels as sediment continuity is restored in areas of dam removals and our long-term "hot spots" for elevated bacteria levels. Long-term monitoring has indicated the undammed White River mainstem has had relatively low bacteria levels, highlighting the high recreational value of this unique resource.

Key points in 2018 included:

- Phosphorus exceedances of VT Water Quality Standards thresholds have been intermittent on "the Branches", but typically not at exceedingly high levels. Baseline levels are higher on the Second Branch than the First and Third (consistent with differences in WQ Standards thresholds due to stream type). Exceedances in 2018 occurred at Hedding Dr (HDR, downstream of the Randolph wastewater treatment plant) and Stock Farm Rd (SFR)

- Nitrogen levels have been consistently well below VT WQ Standards thresholds on all three Branches, but also tend to be higher on the Second Branch
- *E. coli* levels on "the Branches" continue to regularly exceed VT WQ Standards thresholds
- A correlation between *E. coli* levels and Total Phosphorus readings was one of the few statistically significant patterns evident in 2017 and 2018 data; 2017 data indicated a moderate strength correlation, while the dry 2018 season showed a weak correlation
- There have been no statistically significant indications of a correlation between E. coli and Nitrogen, and regressions indicate no statistical significance to the relationship between *E. coli* and an interaction between Phosphorus and Nitrogen
- Our sample pairings in close proximity above and below dam sites have yielded inconsistent or statistically insignificant results for both bacteria and nutrients (phosphorus or nitrogen) in the past two years of sampling

From June on, summer 2018 saw abnormally dry to moderate drought conditions in much of the White River watershed, and even "wet" sampling dates had water levels below norms. As such, the 2018 season offered a window of sampling less influenced by the impacts of erosion and suspended sediments.

- Maximum transparency (minimum turbidity) readings recorded on all sampling dates
- In spite of the dry conditions, *E. coli* readings exceeded seasonal WQ thresholds (for combined "wet" and "dry" dates) at all of the First and Second Branch sites as well as the mouth of Ayers Brook. "Dry" dates exceeded thresholds on most of the First Branch sites and Ayers Brook, suggesting likely inputs from agricultural sources or failed/inadequate septic systems rather than stormwater or erosion
- It was also notable however that along the Third Branch (where the Osgood-Roundy Dam was removed in Randolph in 2016, in the same year as the 40-year-old Randolph wastewater treatment plant was upgraded), seasonal means for *E. coli* (for both "wet" and "dry" dates on the LaRosa sampling dates) at the downstream SFR (Stock Farm Rd) site along the mainstem of the Third Branch were not in exceedance of WQ Standards thresholds - in spite of the inputs from Ayers Brook

1.0 Introduction

The White River Partnership (WRP) launched a Water Quality Monitoring (WQM) Program in 2001 in an effort to identify and better understand potential threats to water quality in our watershed. Since 2001 the WRP has been monitoring water quality at locations throughout the watershed over the summer months with the help of a dedicated group of volunteers. These volunteers measure conductivity, turbidity, and sample for the presence of *E. coli*. Due in part to enhanced public engagement, our routine WQM program (effectively establishing a network of sentinel sites distributed widely through the overall White River basin) has focused on recreational sites.

Over the years our routine WQM program has highlighted sites with chronically-elevated levels of *E. coli*. Bacteria levels at sites along the First, Second and Third Branches of the White River have regularly exceeded the seasonal standard for *E. coli*, and in 2016 these three 'Branches' were added to the 303(d) list of impaired streams due to consistently elevated bacteria levels (VT DEC Water Quality Division, 2016c).

In addition to our routine (sentinel) monitoring, the WRP has been engaged in an adaptive WQM program in an attempt to better understand and address high bacteria numbers and their relationship to sediment and nutrient levels. In 2018 our more intensive adaptive monitoring was focused on the First, Second and Third Branches (based on previous results from our adaptive monitoring program). Additional stations were established to: (1) collect baseline and post-implementation monitoring data regarding dam removals; (2) better define the extent and magnitude of sediment, nutrient and bacteria concentrations in the watershed; and (3) share monitoring results with the public and with partner agencies engaged in the design of restoration and conservation practices that improve water quality.

Reporting included here examines 2018 water quality at twelve stations sampled monthly from June through September: 6 sites on the First Branch; 2 sites on the Second Branch; and 4 sites on the Third Branch.

2.0 Background

2.1 Description of Watershed

The White River watershed is a 710 square mile basin in east central Vermont encompassing portions of 30 towns in 5 counties. Originating on the Green Mountain National Forest in the town of Ripton, the 56-mile main stem of the White River eventually joins the Connecticut River at White River Junction, VT. It has 5 major tributaries: the First Branch, the Second Branch, the Third Branch, the West Branch, and the Tweed River. The mainstem White River is significant for being one of the last free-flowing rivers in the State of Vermont, and is the longest un-dammed tributary to the Connecticut River. With removal of the Sargent, Osgood, Roundy dam in Randolph in 2016, the only remaining dam on the Third Branch is the low run-of-river dam perched on a natural falls at Bethel Mills. The First and Second Branches have multiple dams still in place - both intact and breached.

The First Branch of the White drains roughly 103 square miles and flows roughly 24 miles from Washington Heights, primarily along Rte. 110, and joins the White mainstem in South Royalton near the junction of Rtes. 14 and 110. The Second Branch drains roughly 74 square miles, and the mainstem flows roughly 20 miles from the Brookfield-Williamstown Gulf, primarily along Rte. 14, and joins the White mainstem in Royalton near the junction of Rtes. 14 and 107. The Third Branch of the White drains roughly 136 square miles and flows roughly 19 miles from Roxbury and through Randolph along Rtes. 12A and 12, eventually joining the White mainstem at Peavine Park in Bethel.

The First and Second Branches are located in the Vermont Piedmont physiographic region, which comprises eastern portions of the overall White River basin (Lower White mainstem and First, Second and eastern half of Third Branches) (Stewart and MacClintock 1969; Thompson and Sorenson 2000). Conductivity readings by White River Partnership water quality monitoring volunteers over the years show values commonly ranging from 70-90 uS/cm2 in upper portions of the Third Branch and western portions of the overall White watershed, to 350-400 uS/cm along the First and Second Branches – largely due to differences in the underlying bedrock.

Calcium carbonate is a significant contributor to the higher conductivity readings in eastern portions of the White River basin. The White River is thought to be the highest pH watershed in the Connecticut River watershed with its calcareous setting (Waits River formation; VTDEC 2016). The bedrock underlying eastern portions of the White River basin tend toward calcareous, carbonate-rich formations relatively easily weathered to fertile soils (Thompson and Sorenson 2000). This has much to do with an intensive agricultural and forestry history and “few large areas of wild nature” (Thompson and Sorenson 2000). ‘The Branches’ comprise a large proportion of the agricultural land use in the White River basin, along with being more densely populated than the western portions of the overall White River basin (Appendix 1).

Land use in the First Branch watershed is estimated at 82% forested, 10.8% agricultural, and 5.1% developed. Included in the developed category are transportation corridors (no railroads) and small villages clustered along the First Branch in Chelsea, Tunbridge and South Royalton.

Land use in the Second Branch watershed is roughly 75.8% forested, 15.9% agricultural, and 5.4% developed. Included in the developed category are transportation corridors and small villages clustered along the Second Branch in Brookfield, Randolph, Bethel and Royalton.

Land use in the Third Branch watershed is roughly 84.7% forested, 8% agricultural, and 4.7% developed. Included in the developed category are the larger towns of Randolph and Bethel as well as transportation corridors and smaller villages clustered along the Third Branch.

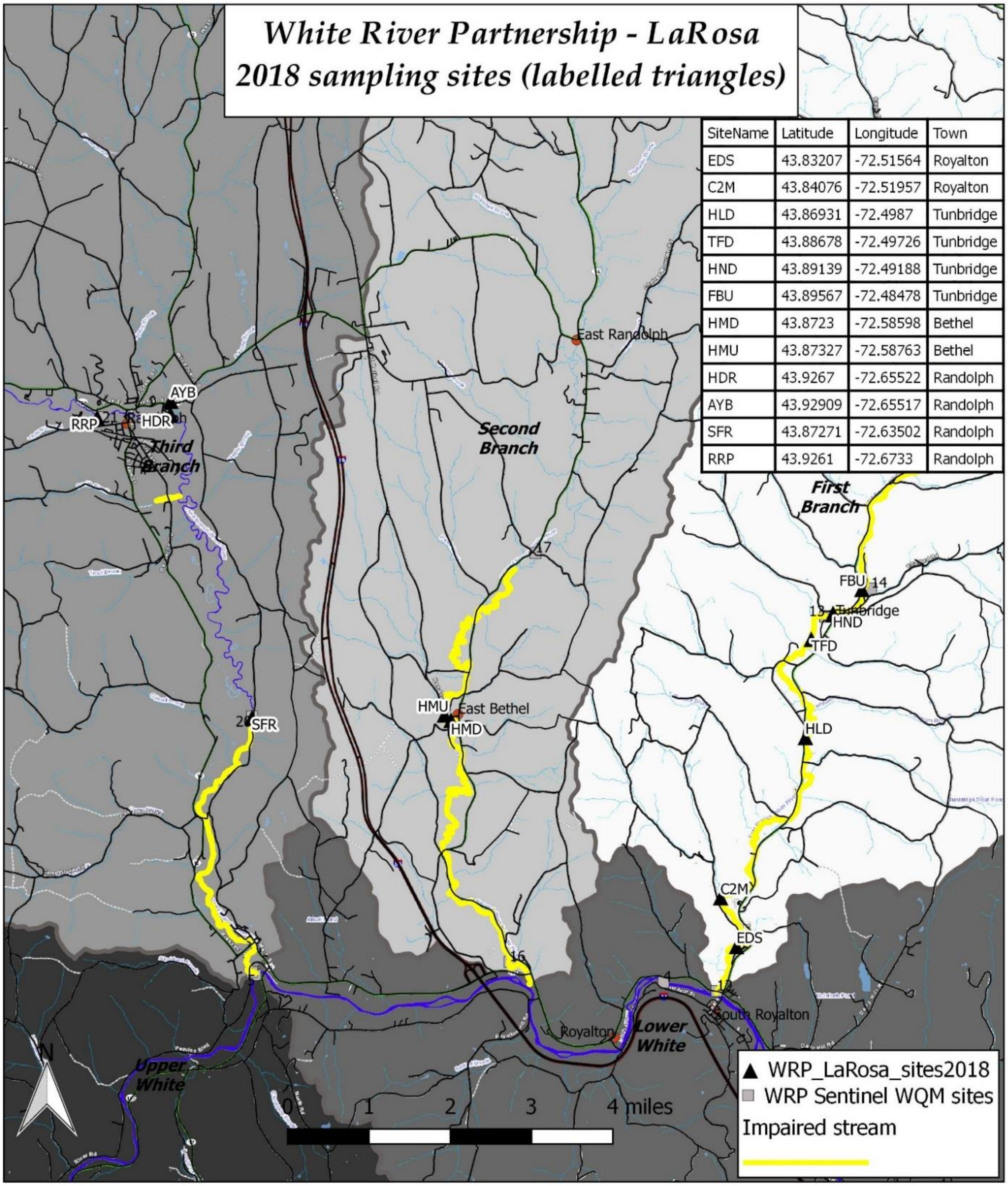
The land use estimates noted here are based on satellite imagery and likely underestimate the degree of development, in large part due to a high percentage of forest cover and diffuse settlement patterns in these basins. The Northern Vermont Piedmont biophysical region, which includes the First and Second Branch watersheds, is one of the most densely “roaded” portions of Vermont (Thompson and Sorenson 2000, p. 47), certainly a factor in water quality impacts.

The surficial sediments and soils present in the White River basin reflect a complex glacial and post-glacial history. Factors particularly affecting all three ‘Branches’, but the Second Branch in particular, are related to the heavy presence of fine sediments (clays, silts, and sands) due to the presence and subsequent draining of glacial Lake Hitchcock. Lake Hitchcock formed as an impoundment behind large volumes of glacial deposits in central Connecticut that dammed the Connecticut River valley. At its maximum extent, the lake body stretched from Rocky Hill, CT for 200 miles northward to the mouth of the Nulhegan River in Bloomfield, VT, and as far west as the Upper White mainstem in Pittsfield/Rochester and the Third Branch in Braintree. Sediments in and along the edges of the glacial Lake tend to be dominated by the stratification of fine silts, sands and gravels that settled out differentially in the still waters of the Lake as glacial streams fed into it (Appendix 2).

The finest silt loams and silty-clay components required quiet waters in the stillest portions of the Lake to settle out, and are prominent along the Second Branch as far north as the village of East Randolph, the Third Branch as far north as Randolph village, and downstream portions of the First Branch (Appendix 2). Frequently these soils have restrictive layers with low infiltration rates, leading to seasonal high water tables and generating runoff on steeper slopes. Sandier soils of greater permeability but high erodibility tend to be associated with localized deposits of glaciofluvial and alluvial origin interspersed along the river corridors of all three Branches in their present locations (Stewart, 1973; Stewart & MacClintock, 1969; USDA 2013, 2011).

2.2 Water Quality Monitoring Sites

Under White River Partnership’s routine water quality monitoring program, twenty-two sentinel stations have been established throughout the White River basin to track long-term variations in bacteria, turbidity and conductivity levels resulting from naturally fluctuating weather and vegetation, as well as human-influenced factors such as shifting land use or changes in management practices. Based in part on long-term results at these sites, portions of “the Branches” (First, Second and Third) were added to the 303(d) list of impaired streams due to consistently elevated bacteria levels (VT DEC 2016a). Coordination with the LaRosa Partnership has focused efforts in these areas over the last five years. In 2018, nutrient testing was conducted on 12 total sites, including one sentinel station on the First Branch and two sentinel stations on the Third Branch. Data from these sites are reported here.



SiteName	Latitude	Longitude	Town
EDS	43.83207	-72.51564	Royalton
C2M	43.84076	-72.51957	Royalton
HLD	43.86931	-72.4987	Tunbridge
TFD	43.88678	-72.49726	Tunbridge
HND	43.89139	-72.49188	Tunbridge
FBU	43.89567	-72.48478	Tunbridge
HMD	43.8723	-72.58598	Bethel
HMU	43.87327	-72.58763	Bethel
HDR	43.9267	-72.65522	Randolph
AYB	43.92909	-72.65517	Randolph
SFR	43.87271	-72.63502	Randolph
RRP	43.9261	-72.6733	Randolph

Figure 1. Location of sentinel and 2018 adaptive (WRP-LaRosa) stations on the First, Second, and Third Branches in the White River watershed, along with river segments considered impaired as described in the text. Flow in these watersheds is north to south or west to east.

Table 1. List of Sentinel and Adaptive water quality monitoring stations sampled under LaRosa partnerships in the First, Second and Third Branch White River watersheds in 2018.

Stream	Site	Type	Location	Town
First Branch	FBU	A	upstream of breached Farnham Bros. dam, at Rec Field	Tunbridge
First Branch	HND	A	downstream of Hayward Noble Dam and Mill Bridge	Tunbridge
First Branch	TFD	S	riffle at point bar by south gate to Tunbridge Fairgrounds racetrack	Tunbridge
First Branch	HLD	A	downstream Howe Ln-Rte 110 jct (riffle at Chapman Farm swimming hole)	Tunbridge
First Branch	C2M	A	path by rugby field beyond Log Landing Ln	Royalton
First Branch	EDS	A	downstream of intact Lower Eaton Dam, river right	Royalton
Second Branch	HMU	A	upstream Hyde Mill dam, ~400 ft US of Factory Hill Rd	East Bethel
Second Branch	HMD	A	downstream Hyde Mill dam, riffle below swimming hole, river right	East Bethel
Third Branch	RRP	S	Riffle above pool recreation area and old foot bridge 20m	Randolph
Third Branch	HDR	A	Riffle DS of Randolph WWTxF and US of Ayers Brook	Randolph
Third Branch	AYB	A	Riffle US of Central St pump station	Randolph
Third Branch	SFR	S	Sample in current off ledges at pull-out	Bethel

S= Sentinel; A=Adaptive

Sites listed upstream to downstream

All twelve WRP-LaRosa 2018 stations on the First, Second and Third Branches are located on river segments classified as Class B(2) cold-water fisheries in regards to the Vermont Water Quality Standards (VWMD, 2016, App. A, F). The two stations on the Second Branch, however, are on reaches classed as Warm-water, Medium Gradient for application of Combined Nutrient Criteria for Aquatic Biota and Wildlife in Rivers and Streams (VWMD, 2016, Table 2, p. 27; pers. comm. Jim Kellogg et al., VT DEC staff, January 2017). First and Third Branch stations are on Medium High-gradient reaches regarding Combined Nutrient Criteria.

Based on results from our long-term sentinel sites and previous adaptive sampling on a number of tributaries, we surmise that fine sediments along significant portions of "the Branches" contribute to chronically high bacteria levels, primarily through dynamics connected with transport and storage of sediment and nutrients within these watersheds. We further hypothesize (based in part on preliminary adaptive sampling) that dams may contribute significantly to these dynamics. Four pairs of sites upstream and downstream of dams (two on the First Branch, one on the Second Branch, and one on the Third Branch) were thus included in our 2018 sampling plan.

On the First Branch, 2016 adaptive sampling after a series of high bacteria readings at WRP's sentinel site at the Tunbridge Fairgrounds (and expanded swimming use by numerous children at a farm downstream) bracketed the Fairgrounds by sampling at the farm downstream, and below the Hayward & Noble dam on the upstream end of the Fairgrounds. Higher bacteria readings at this dam were consistent in 2016 and somewhat surprising, sparking interest in the role that re-suspended sediments at the dams may be playing in elevated bacteria readings. The Fairgrounds site and the farm downstream were retained in the 2018 sampling plan due to their interest to the community as well as information they may provide in elucidating the relationship of bacteria levels and transport and storage of sediment and nutrients.

2.3 Discharge Measurement

The nearest continuous monitoring United States Geological Survey (USGS) streamflow gaging station is on Ayers Brook in Randolph, within roughly 4 miles of all Third Branch sites, six to seven miles of the Second Branch sites, and nine to ten miles of the First Branch sites sampled in 2018. This station (# 01142500) measures flow from an approximate drainage area of 30.5 square miles and has daily flow records dating back to 1939.

Figure 2 presents thresholds from a flow duration curve computed on daily mean flows recorded for water years 1939 through 2017. The “water year” is a standard measure of time in hydrology which begins October 1st of the previous calendar year and extends through September 30th of the indicated year. Thresholds have been categorized following VTDEC *Guidance on Streamflow Observations at time of Water Quality Sampling of Rivers and Streams*. High flows are defined as those flow conditions which are equaled or exceeded only 25% of the time, and Low flow levels are those equaled or exceeded more than 75% of the time, while those flows occurring between 25 and 75% of the time are classified as Moderate. Flood flows are those equaled or exceeded less than 5% of the time.

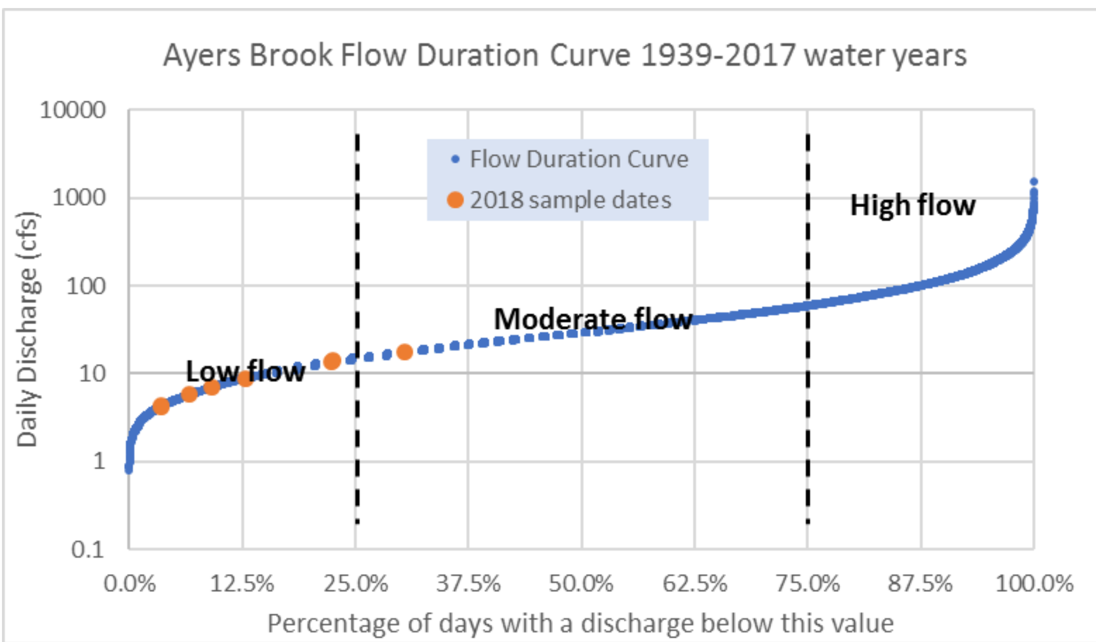


Figure 2. Flow Duration curve for Ayers Brook at Randolph, VT (USGS Stn #01142500), along with flow levels for 2018 WRP sampling dates (red points).

3.0 Methods

Sampling in the White River watershed for the LaRosa Partnership is conducted by WRP staff, with sentinel site sampling carried out by a network of volunteers trained by these staff, operating under a VTDEC- and EPA-approved Quality Assurance Project Plan (QAPP). Nutrient samples are collected in analyte-specific containers provided by the LaRosa Lab. *E. coli* samples are collected in 100 ml containers and analyzed by WRP utilizing a Colilert and Quanti-tray system, and WRP collects conductivity readings with Oakton digital pens, and turbidity samples with 120cm turbidity tubes and secchi disks.

3.1 Meteorological Conditions

To characterize meteorological conditions during sampling, WRP relies on a network of weather stations and data reported by the National Oceanic and Atmospheric Administration (NOAA). Additionally, weather conditions on the sample date, and previous day, are recorded on field sampling data sheets to capture current and antecedent weather conditions for each sample date, local to the sampling stations. Conditions for two days previous are added to digital data, as derived from the NOAA weather data (24-hour climate maps).

3.2 Sample Collection and Analysis

Monthly samples were collected on four pre-determined dates in the summer of 2018 (June 13, July 11, August 8, and September 5) on the Third Branch, on dates overlapping with our sentinel site monitoring throughout the watershed. Near-monthly samples were collected on four pre-determined dates (June 20, July 18, August 1, and August 29) on the First and Second Branches, on "off" weeks from our sentinel sites. Samples were collected as grab samples from wadeable stream reaches at a depth approximately half way between the water surface and bed of the stream. Samples were analyzed by VAEL for phosphorus (digested) and total nitrogen (persulfate). *E.coli* , turbidity (tube), and conductivity (digital submersible pen) were analyzed by WRP. Bottles were stored on ice packs in a cooler until delivery to the Vermont Agricultural & Environmental Laboratory (VAEL) in Burlington, VT.

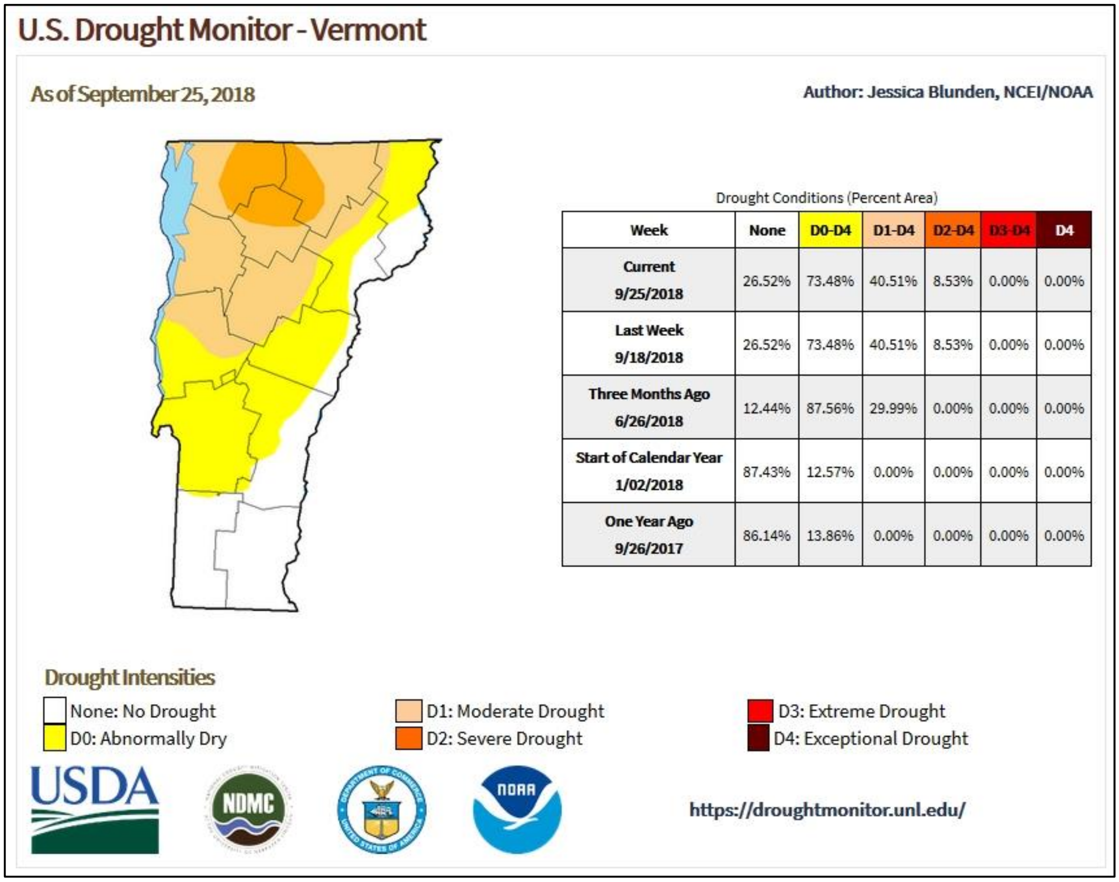
3.3 Quality Assurance / Quality Control

In accordance with the QAPP, field duplicates and field blanks were collected at a 10% frequency. The location of the field duplicate was rotated from month to month. To prepare field blanks, bottles for each scheduled analyte were filled with lab-supplied deionized water and accompanied the regular sample bottles during transport in the field and to the lab. Results of regular and field duplicate pairs from selected stations were evaluated and the average of the Relative Percent Difference (RPD) in results for each constituent was compared to a data quality goal, specified in the QAPP.

4.0 Results and Discussion

4.1 Meteorological and Hydrological Conditions

From June on, summer 2018 saw abnormally dry to moderate drought conditions in much of the White River watershed, and even "wet" sampling dates had water levels below norms (Figure 3; Figure 4).



Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current 9/25/2018	26.52%	73.48%	40.51%	8.53%	0.00%	0.00%
Last Week 9/18/2018	26.52%	73.48%	40.51%	8.53%	0.00%	0.00%
Three Months Ago 6/26/2018	12.44%	87.56%	29.99%	0.00%	0.00%	0.00%
Start of Calendar Year 1/02/2018	87.43%	12.57%	0.00%	0.00%	0.00%	0.00%
One Year Ago 9/26/2017	86.14%	13.86%	0.00%	0.00%	0.00%	0.00%

Figure 3. From June 2018 through much of the summer, the White River basin and much of Vermont to the north and west experienced abnormally dry to moderate drought conditions.

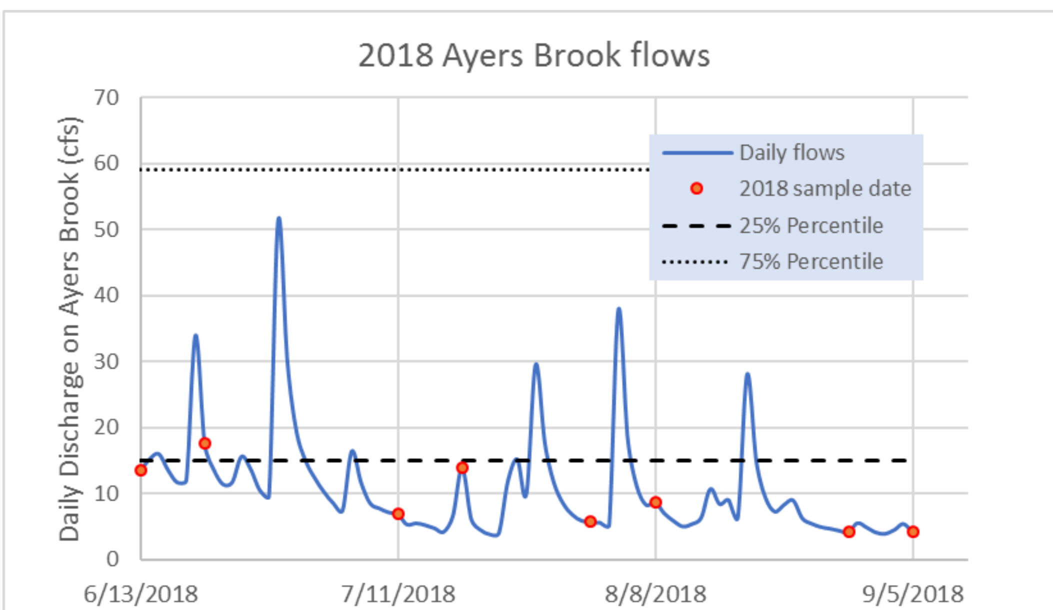


Figure 4. Daily mean and sample date discharge recorded for Ayers Brook (USGS Stn #01142500) during 2018.

Only one sampling date in 2018 (June 20) had flows classed in field observations as Moderate (based on VTDEC *Guidance on Streamflow Observations at time of Water Quality Sampling of Rivers and Streams*); all other sampling dates had Low flows. Even the June 20 flows were on the low end of the Moderate spectrum (Figure 4).

Sample dates for the Third Branch sites (6/13, 7/11, 8/8, 9/5) fell on one “wet” and three “dry” sampling dates (Figure 5). Sample dates for the First and Second Branch sites (6/20, 7/18, 8/1, 8/29) featured two “wet” and two “dry” sampling dates.

	6/13/2018	6/20/2018	7/11/2018	7/18/2018	8/1/2018	8/8/2018	8/29/2018	9/5/2018
Weather within the past 24 hrs*	Mostly Sunny	Mostly Sunny	Mostly Sunny	Rain	Partly Sunny	Scattered Rain	Mostly Sunny	Mostly Sunny
Ayers Brook USGS gauge at 9am (CFS)**	13.2	17.5	14.4	12.3	6.1	9.9	3.9	4.8
Ayers Brook USGS gauge daily mean value (CFS)**	40	33	33	22	20	20	23	13
Rain Accumulation (in) in the last 24 hrs***	0.00	0.00	0.00	0.17	0.00	0.06	0.00	0.00
Rain Accumulation (in) in the last 48 hrs***	0.00	0.43	0.00	0.19	0.00	0,06	0.00	1.44
Conditions (wet or dry)**	*dry*	*wet*	*dry*	*wet*	*dry*	*dry*	*dry*	*wet*
Flow (VT DEC Classification)	*Low-Base*	*Moderate-Freshet*	*Low-Base*	*Low-Freshet*	*Low-Base*	*Low-Base*	*Low-Base*	*Low-Freshet*

* Weather in the past 24 hrs - Descriptors include - Mostly Sunny (<49% cloud cover), Partly Sunny (50-99% cloud cover), Overcast (100% cloud cover, no rain), Scattered Rain (measurable rain <.1 but >.05 inches), Rain (>.1 inches)
**River gauge data found at: http://waterdata.usgs.gov/usa/nwis/uv?01142500
***Precip Data measured at Ayer's Brook in Randolph, found at: http://waterdata.usgs.gov/vt/nwis/uv?site_no=01142500
**** Wet - More than .1 inches in the last 24 hrs or more than .25 inches in the last 48

Figure 5. Combined meteorological conditions, flows recorded at Ayers Brook USGS gage, and field observations of flow levels for 2018 sampling dates. Ayers Brook low median monthly flow is 12.2 cfs.

4.2 Water Quality Results

Summary sample results for 2018 stations on the White River First, Second and Third Branches are listed in Appendix 3. Charts on the following pages display sites in order from upstream to downstream. Nutrient results were analyzed by the Vermont Agricultural & Environmental Laboratory, while *E. coli*, turbidity, and conductivity were analyzed by WRP.

Nutrient results (phosphorus and nitrogen) are displayed with box and whisker plots. With just four sample dates for each site, the box and whisker plots display the actual sample results at the maximum and minimum whisker ends, plus the two circles interior to the box; median is displayed with a line and mean with an ‘x’ (Fig. 6).

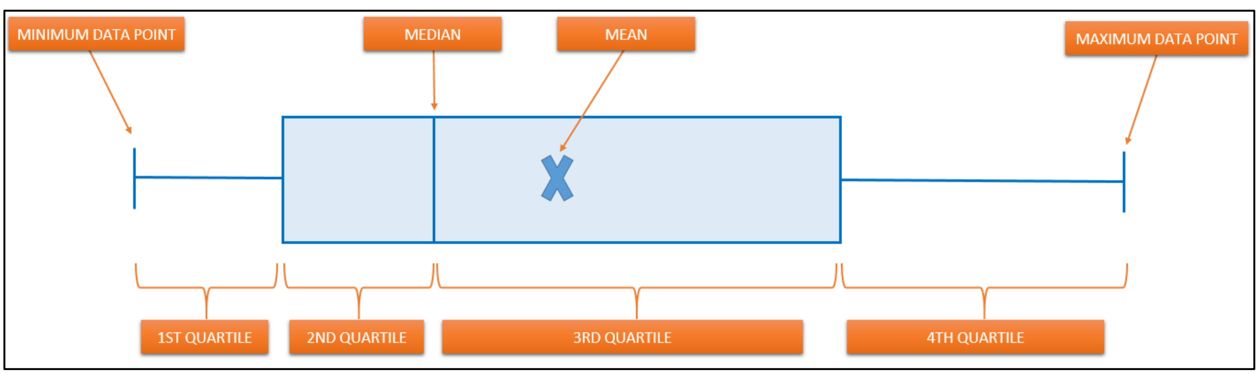


Figure 6. Key for interpreting box and whisker plots used to display nutrient results.

4.2.1 Turbidity

Summer 2018 results showing **highest transparency (lowest turbidity) readings of 120 cm or higher on all dates at all sites** indicated that nephlometric readings would have been highly unlikely to approach any thresholds specified in the Vermont WQ Standards (VWMD 2016).

With no dam removal projects currently being implemented, WRP elected to monitor and analyze turbidity using transparency tubes only at all sites on all sampling dates in 2018. These methods do not have an applicable standard under the Vermont Water Quality Standards, which instead specifies standards for nephlometric turbidity readings that are more refined at lower turbidity (higher transparency) levels. Our 2017 sampling results at two sites where both methods were used indicated the 10 NTU (Nephlometric Turbidity Units) threshold of the VT WQ Standards (for Class B waters) corresponded to transparency tube readings of roughly 85-90 cm. We recommend returning to nephlometric turbidity readings (analyzed by VAEL) in 2019 for the purposes of monitoring project implementation sites (proposed dam removals). For the purposes of general monitoring, however, results continue to support the ease and low cost of the turbidity tubes as more suitable to the purposes of our ongoing WQM program.

4.2.2 E.coli

In 2018, *E. coli* bacteria readings exceeded the single-sample VT WQ Standard threshold of 235 colonies/100 ml at most of the WRP sampling sites on the First and Second Branches on two of four dates, and at three sites along the Third Branch on three different dates (Figure 7). Out of 12 total sites sampled on all three Branches, 9 exceeded the seasonal geometric mean threshold of 126 colonies/100 ml (all 3 sites that did not exceed that threshold were along the Third Branch; Figure 8). While sites on "the Branches" have commonly exceeded seasonal standards on "wet" sampling dates, it was notable that the mouth of Ayers Brook (along the Third Branch) and most of the First Branch sites exceeded seasonal standards on "dry" dates in 2018 (Figure 8).

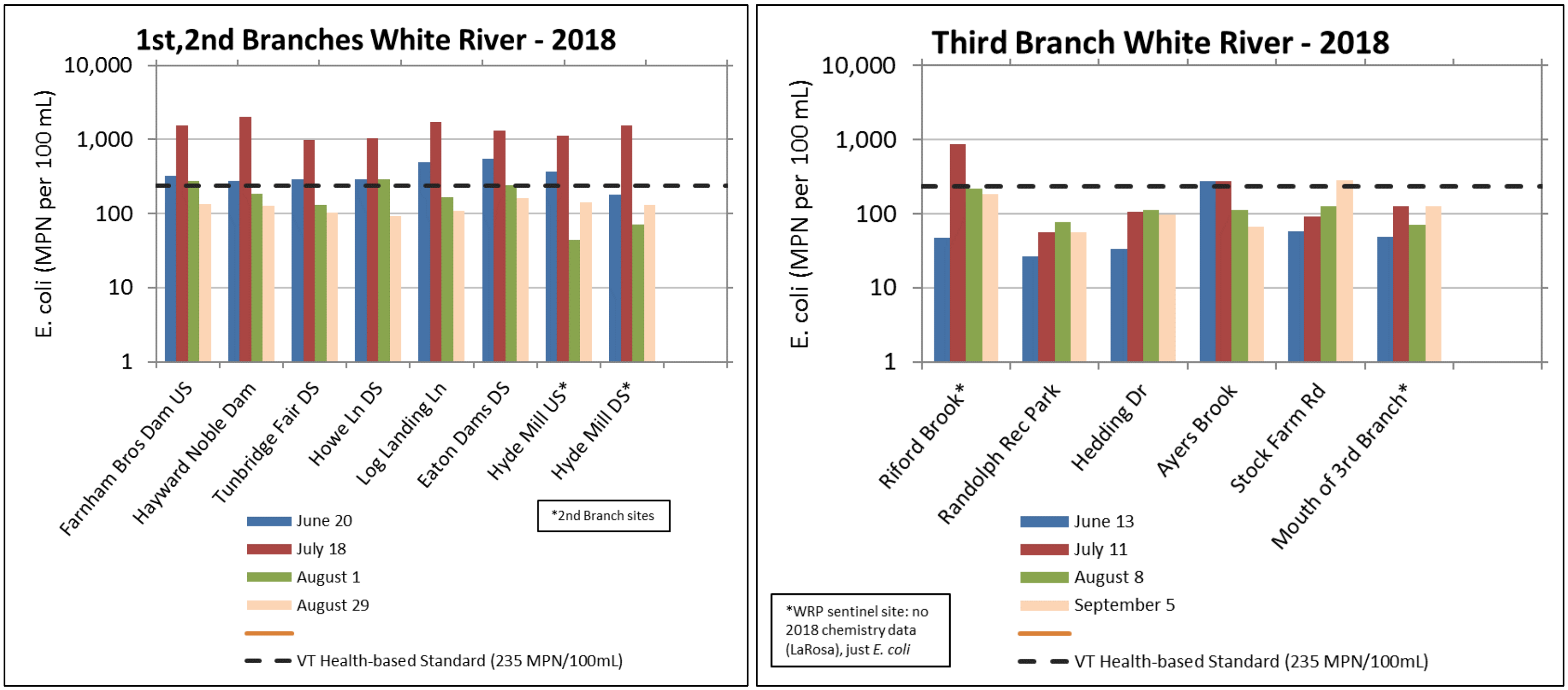


Figure 7. WRP E. coli readings on 1st, 2nd (left) and 3rd (right) Branches, 2018. The two charts are different sets of sampling dates.

VT Water Quality Standards (effective January 15, 2017):
E. coli (Class B waters): Not to exceed a geometric mean of 126 organisms /100ml obtained over a representative period of 60 days, and no more than 10% of samples above 235 organisms/100 ml.

Figure 8. E. coli, turbidity and conductivity – WRP-LaRosa 2018 results – First, Second Branches and Third Branches (sites ordered upstream to downstream)

				VRP-LaRosa 2018 Vater Quality Monitoring																		
				6/20/2018				7/18/2018				8/1/2018				8/29/2018						
	Veather within the past 24 hrs*			Mostly Sunny				Rain				Partly Sunny				Mostly Sunny						
	Ayers Brook USGS gauge at 9am (CFS)**			17.5				12.3				6.1				3.9						
	Ayers Brook USGS gauge daily mean value (CFS)**			33				22				20				23						
	Rain Accumulation (in) in the last 24 hrs***			0.00				0.17				0.00				0.00						
	Rain Accumulation (in) in the last 48 hrs***			0.43				0.19				0.00				0.00						
	*Conditions (vet or dry)*****			*wet*				*wet*				*dry*				*dry*						
				E-coli				E-coli				E-coli				E-coli						
Tributary	**Site Number**	**Town**	**Site Name**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Seasonal Mean**	*wet*	*dry*
Third Branch	RRP	Randolph	Randolph Rec Park																	49.8	55.6	48.0
Third Branch	HDR	Randolph	Hedding Dr																	78.6	95.9	73.6
Third Branch	AYB	Randolph	Ayers Brook mouth																	153.5	67.0	202.4
Third Branch	SFR	Randolph	Stock Farm Rd																	117.4	285.1	87.4
Second Branch	HMU	East Bethel	Hyde Mill US	49/21	365.4	120	310	49/40	1119.9	120	350	28/3	44.1	120	350	46/9	142.1	120	370	225.0	639.7	79.2
Second Branch	HMD	East Bethel	Hyde Mill DS	47/13	178.5	120	310	49/44	1553.1	120	350	37/4	71.2	120	350	44/11	129.6	120	370	224.9	526.5	96.1
First Branch	FBU	Tunbridge	Farnham Bros Dam US	49/19	325.5	120	320	49/44	1553.1	120	330	49/16	275.5	120	340	42/17	133.6	120	340	369.3	711.0	191.9
First Branch	HND	Tunbridge	Hayward Noble Dam	49/16	275.5	120	280	49/46	1986.3	120	330	48/11	186.0	120	340	43/13	128.1	120	350	337.9	739.7	154.4
First Branch	TFD	Tunbridge	Tunbridge Fairgrounds DS	49/17	290.9	120	290	49/38	980.4	120	330	45/9	131.4	120	340	43/5	101.9	120	350	248.6	534.0	115.7
First Branch	HLD	Tunbridge	Howe Ln DS (Chapman Farm)	49/17	290.9	120	290	49/39	1046.2	120	320	49/17	290.9	120	340	39/10	93.4	120	350	301.6	551.7	164.8
First Branch	C2M	Royalton	Log Landing Ln	49/26	488.4	120	290	49/45	1732.9	120	320	46/14	167.0	120	350	40/14	109.5	120	350	352.7	920.0	135.2
First Branch	EDS	Royalton	Eaton Dams DS	49/28	547.5	120	290	49/42	1299.7	120	330	48/17	238.2	120	350	48/7	159.7	120	350	405.6	843.6	195.0

* Weather in the past 24 hrs - Based on last 24 hrs- Descriptors include- Mostly Sunny (<49% cloud cover), Partly Sunny (50-99% cloud cover), Overcast (100% cloud cover, no rain), Scattered Rain (measurable rain <.1but >.05 inches), Rain (>.1inches)
**River gauge data found at: http://waterdata.usgs.gov/usa/nwis/uv?01142500
***Precip Data measured at Ayer's Brook in Randolph, found at: http://waterdata.usgs.gov/vt/nwis/uv?site_no=01142500
**** Wet - More than .1inches in the last 24 hrs or more than .25 inches in the last 48

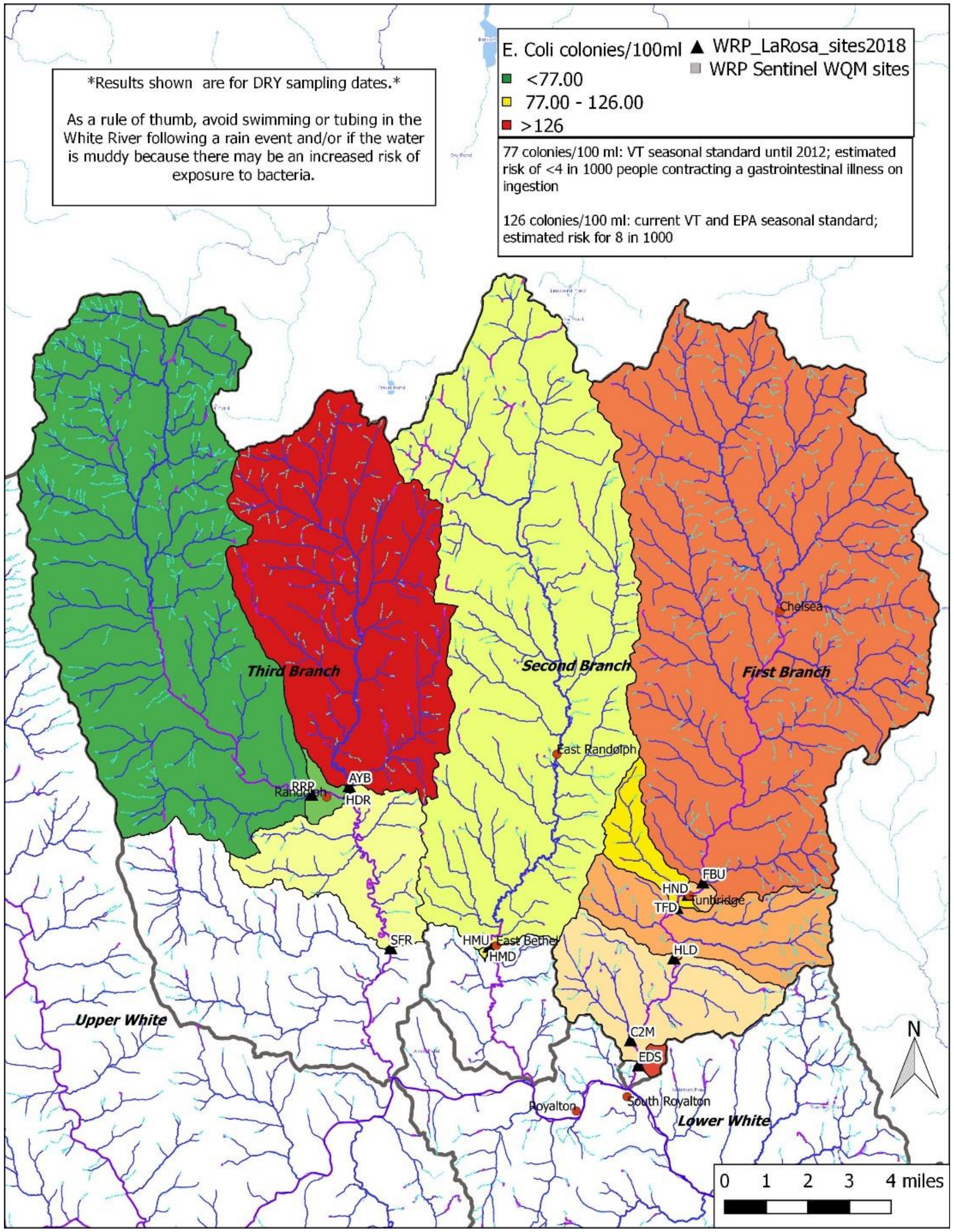
exceeds EPA daily standard (235 colonies/100mL sample)
exceeds EPA seasonal standard (126 colonies/100mL sample)

Third Branch

				VRP-LaRosa 2018 Vater Quality Monitoring																		
				6/13/2018				7/11/2018				8/8/2018				9/5/2018						
	Veather within the past 24 hrs*			Mostly Sunny				Mostly Sunny				Scattered Rain				Mostly Sunny						
	Ayers Brook USGS gauge at 9am (CFS)**			13.2				14.4				9.9				4.8						
	Ayers Brook USGS gauge daily mean value (CFS)**			40				33				20				13						
	Rain Accumulation (in) in the last 24 hrs***			0.00				0.00				0.06				0.00						
	Rain Accumulation (in) in the last 48 hrs***			0.00				0.00				0,06				1.44						
	*Conditions (vet or dry)*****			*dry*				*dry*				*dry*				*wet*						
				E-coli				E-coli				E-coli				E-coli						
Tributary	**Site Number**	**Town**	**Site Name**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Iq/ small**	**MPN**	**Turbidity**	**Conduct-ivity**	**Seasonal Mean**	*wet*	*dry*
Third Branch	RRP	Randolph	Randolph Rec Park	24/5	26.2	120	90	32/4	55.6	120	90	36/8	75.9	120	90	32/4	55.6	120	100	49.8	55.6	48.0
Third Branch	HDR	Randolph	Hedding Dr	25/0	33.6	120	120	38/17	105.9	120	140	44/6	111.9	120	140	40/9	95.9	120	140	78.6	95.9	73.6
Third Branch	AYB	Randolph	Ayers Brook mouth	49/16	275.5	120	300	48/20	272.3	120	330	42/10	110.6	120	350	34/7	67.0	120	370	153.5	67.0	202.4
Third Branch	SFR	Randolph	Stock Farm Rd	35/6	58.3	120	200	39/9	90.9	120	230	44/10	125.9	120	230	48/21	285.1	120	220	117.4	285.1	87.4
Second Branch	HMU	East Bethel	Hyde Mill US																	225.0	639.7	79.2
Second Branch	HMD	East Bethel	Hyde Mill DS																	224.9	526.5	96.1
First Branch	FBU	Tunbridge	Farnham Bros Dam US																	369.3	711.0	191.9
First Branch	HND	Tunbridge	Hayward Noble Dam																	337.9	739.7	154.4
First Branch	TFD	Tunbridge	Tunbridge Fairgrounds DS																	248.6	534.0	115.7
First Branch	HLD	Tunbridge	Howe Ln DS (Chapman Farm)																	301.6	551.7	164.8
First Branch	C2M	Royalton	Log Landing Ln																	352.7	920.0	135.2
First Branch	EDS	Royalton	Eaton Dams DS																	405.6	843.6	195.0

* Weather in the past 24 hrs - Based on last 24 hrs- Descriptors include- Mostly Sunny (<49% cloud cover), Partly Sunny (50-99% cloud cover), Overcast (100% cloud cover, no rain), Scattered Rain (measurable rain <.1but >.05 inches), Rain (>.1inches)
**River gauge data found at: http://waterdata.usgs.gov/usa/nwis/uv?01142500
***Precip Data measured at Ayer's Brook in Randolph, found at: http://waterdata.usgs.gov/vt/nwis/uv?site_no=01142500
**** Wet - More than .1inches in the last 24 hrs or more than .25 inches in the last 48

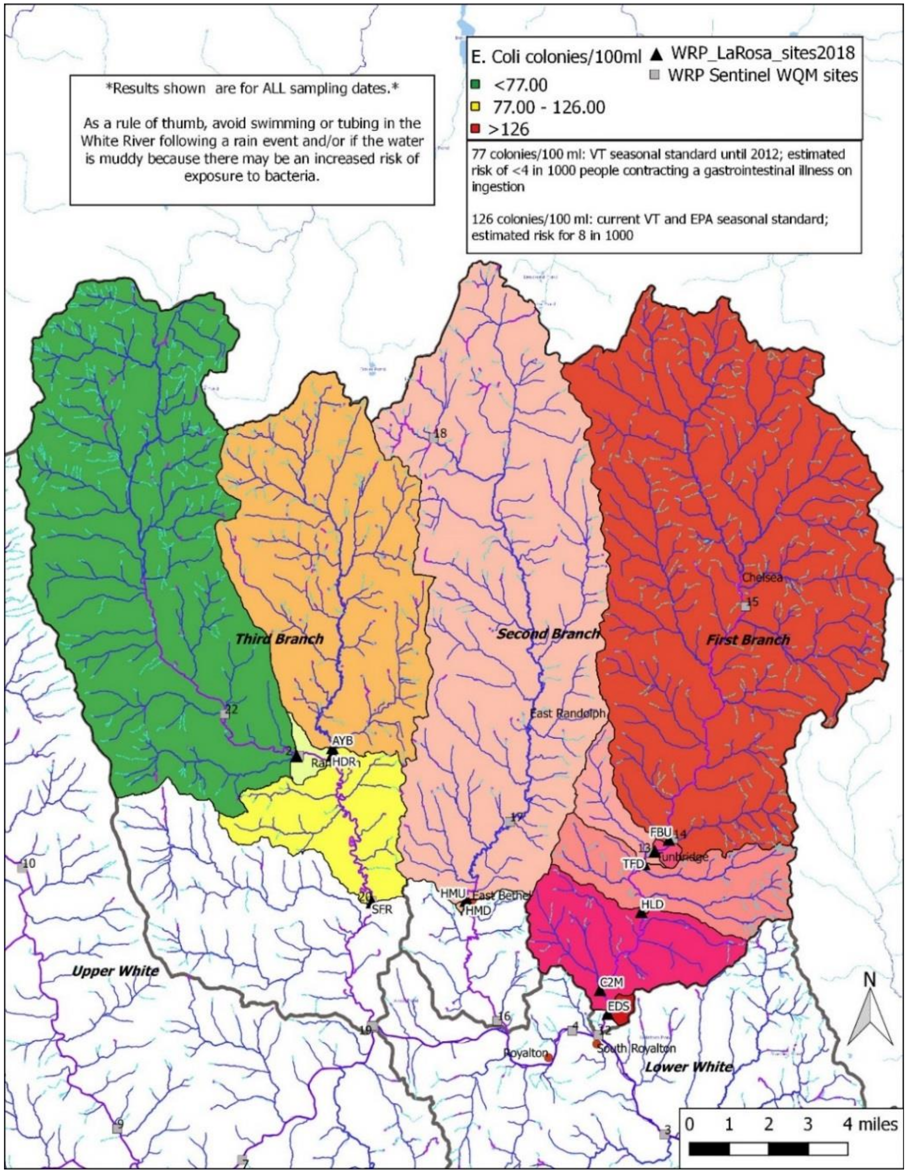
VT Water Quality Standards (effective January 15, 2017): **E. coli** (Class B): Not to exceed a geometric mean of 126 organisms /100ml obtained over a representative period of 60 days, and no more than 10% of samples above **235 organisms/100 ml**.



In 2018, as in previous sampling seasons, bacteria results along the Branches did not generally show consistent upstream to downstream trends even when segregating results by wet and dry sampling dates (Fig. 8). Despite 2018 "hot spot" readings at our most upstream Third Branch sentinel site (Riford Brook; fig. 7 and Appendix 3), however, Third Branch sites further downstream did otherwise indicate an increasing upstream to downstream bacteria gradient, with elevated inputs from Ayers Brook (Figs. 8-9). In addition, 2018 readings at Stock Farm Road (the most downstream 2018 WRP-LaRosa Third Branch site, with 4th-highest bacteria readings of 22 sentinel sites in our long-term monitoring), were at their lowest since Irene came through in 2012 (last table in Appendix 3).

WRP has been particularly interested in results at the Stock Farm Rd site because of its high bacteria readings historically as well as an apparent downward trend in these readings since 2016, a year featuring upstream removal of a Randolph dam plus upgrade of the 40-year old Randolph wastewater treatment plant (upstream of 2018 WRP-LaRosa sampling site HDR, downstream of RRP). Our 2018 sampling design did not include a site below the dam and above the treatment facility (which might offer data distinguishing inputs from those two areas), seems worth considering.

Figure 9. Map of geometric mean E.coli concentration for "dry" sampling dates on First, Second and Third Branches of the White River, summer 2018 sampling dates. Color coded based on current and previous Vermont Water Quality standards (as noted below legend).



Two out of four “wet” sampling dates on the First and Second Branches certainly influenced the seasonal geometric mean threshold exceedances for *E. coli* there, but half of the First Branch sites had daily threshold exceedances on “dry” dates, and 5 of the 6 stations there had geometric mean exceedances for the two dry dates (Fig. 8, Fig. 10; obviously a low sample size, to be assessed accordingly).

On the Third Branch, both Ayers Brook exceedances of daily thresholds for *E. coli* came on “dry” sampling dates.

With part of our sampling design aimed at monitoring bacteria and nutrient levels before and after dam removals, we have been interested to see no consistent results echoing initial findings in our 2016 adaptive sampling that prompted questions about the role that re-suspended sediments at the dams may be playing in elevated bacteria readings. In fact, non-parametric statistical analysis of paired sites above and below dams, as well as aggregated upstream and downstream groupings, found no significant results in 2018. That said, downward trends in the now largely undammed Third Branch watershed (and despite 2018 inputs from Ayers Brook) continue to raise questions about the role of sediment continuity in mitigating bacteria levels.

Figure 10. Map of geometric mean E.coli concentration for “all” (“wet” and “dry”) sampling dates on First, Second and Third Branches of the White River, summer 2018 sampling dates. Color coded based on current and previous Vermont Water Quality standards (as noted below legend).

4.2.3 Phosphorus

For phosphorus, VT Water Quality Standards (effective January 15, 2017) differ for the Second as opposed to the First and Third Branches of the White:

- **Phosphorus** (Class B(2), **Warm-water Medium Gradient**): Not to exceed **27 ug/L** at low median monthly flow during June through October in a section of the stream representative of well-mixed flow. **Second Branch** reaches are considered Warm-Water, Medium Gradient for Combined Nutrient Criteria for Aquatic Biota and Wildlife in Rivers and Streams even though they are considered Cold Water Fish Habitat (pers. comm., Jim Kellogg et al., VT DEC, Jan. 2017)
- **Phosphorus** (Class B(2), **Medium, High-Gradient**): Not to exceed **15 ug/L** at low median monthly flow during June through October in a section of the stream representative of well-mixed flow. **First and Third Branch** reaches are considered Medium, High-Gradient for Combined Nutrient Criteria for Aquatic Biota and Wildlife in Rivers and Streams.

Since the Water Quality Standards apply to low median monthly flow, the sampling dates in June and July 2018 were not applicable for determination of phosphorus exceedances in 2018. It should be noted, however, that exceedances did occur under applicable conditions on the Third Branch at HDR (downstream of the Randolph WWTx plant, Aug. 8) and at SFR (WRP sentinel site, Sept. 5)(Fig. 10; Appendix 3). Though no exceedingly high readings were indicated, the SFR site did show elevated phosphorus readings overall (Fig. 10).

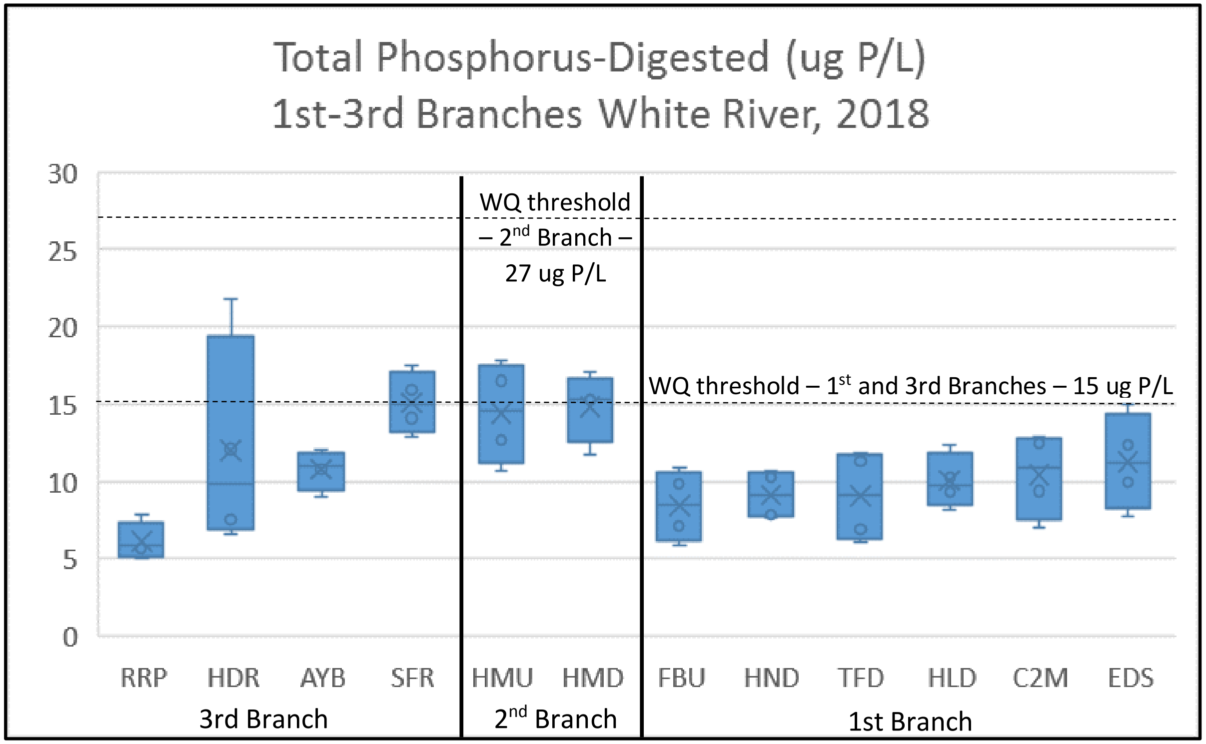


Figure 11. VAEL Phosphorus readings on First, Second and Third Branches in 2018. Exceedances of VT Water Quality Standards at two sites on Third Branch.

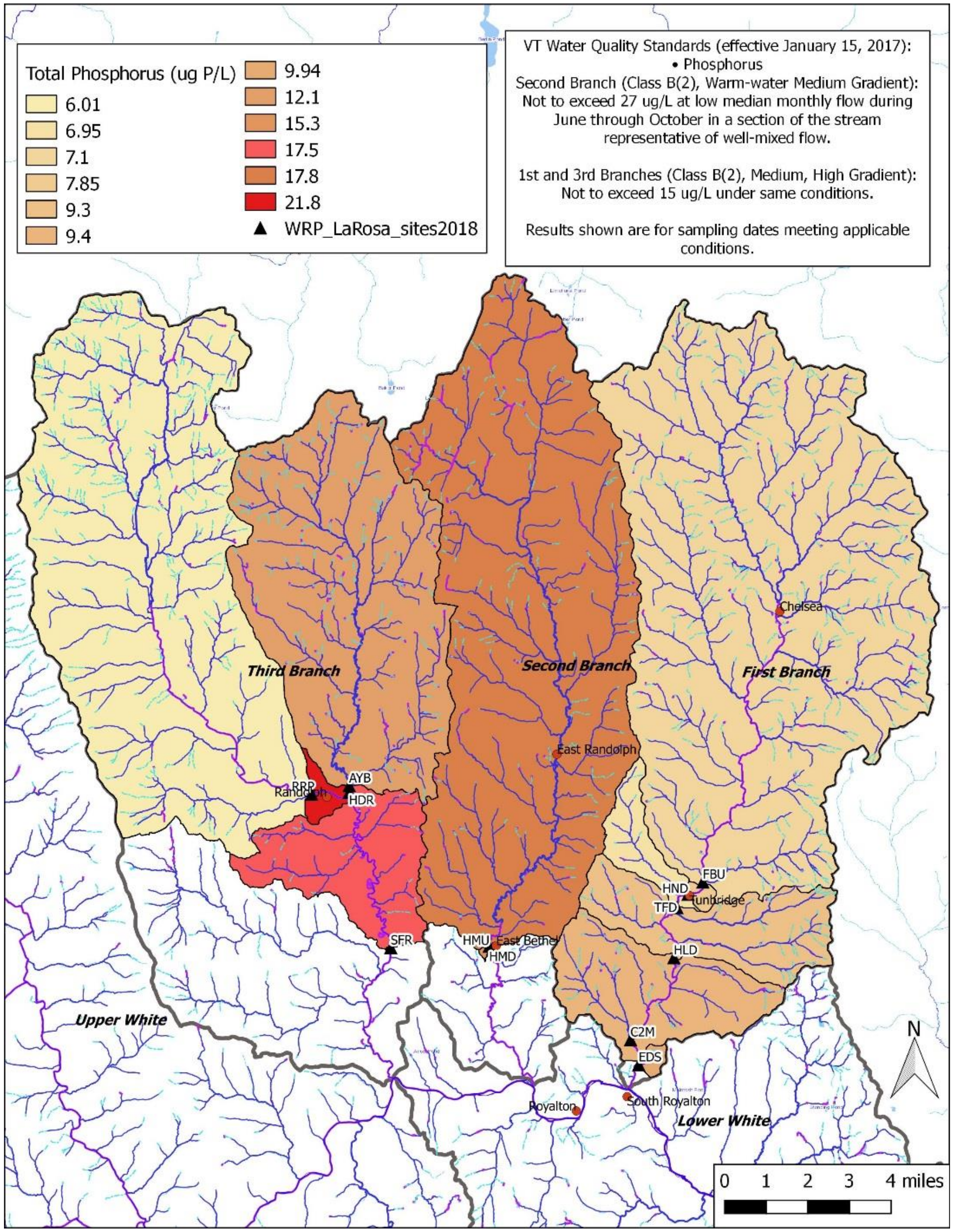


Figure 12. Map of sample station drainages showing maximum value of Total Phosphorus detected on sample dates at or below Low Median Monthly flow, 1st, 2nd and 3rd Branches White River, 2018. Exceedances of VT Water Quality Standards at two sites on Third Branch.

With the exception of one high reading downstream of the Randolph wastewater treatment plant (Fig. 11), 2018 sampling indicated generally increasing phosphorus trends from upstream to downstream stations on the First and Third Branches (Fig. 10).

Overall readings (including both "wet" and "dry" dates) were below WQ Standards thresholds at the Second Branch sites, and there was negligible difference between readings upstream and downstream of the Hyde Mill dam in East Bethel. WRP's 2018 sampling plan did not include Second Branch sites further upstream of East Bethel. Results in 2017 indicated possible phosphorus attenuation benefits in higher flows at the channel connected wetland complex upstream of Hyde Mill dam (HMU; Fig. 11). Without further upstream stations to help delineate phosphorus contributions in 2018 it was difficult to detect patterns; we would suggest adding back sites below the Gulf Road dam (base of Rte 66 in East Randolph) and at our *E. coli* long-term "hot-spot" at Dugout Rd along the Second Branch in 2019.

Readings on the First Branch indicated a general upstream to downstream increase in phosphorus levels in 2018.

Similar to results in 2017, there appeared to be a positive correlation between increasing phosphorus levels and E. coli readings (Fig. 13). Due to non-normal distribution of TP and E. coli Most Probable Number of colonies/100 ml (MPN) readings, plus overall small sample size, a Spearman's correlation was run to assess the relationship of TP for all sample dates and the bacteria levels on those dates (Fig. 13). In the relatively dry conditions of 2018 there was a weak correlation between TP and E. coli MPN, but it was statistically significant (rs = 0.328048, p = 0.02283). Results in 2017 indicated a moderately strong positive relationship for the correlation of increasing phosphorus levels and E. coli (rs = 0.67234, p = 1.66512E-07).

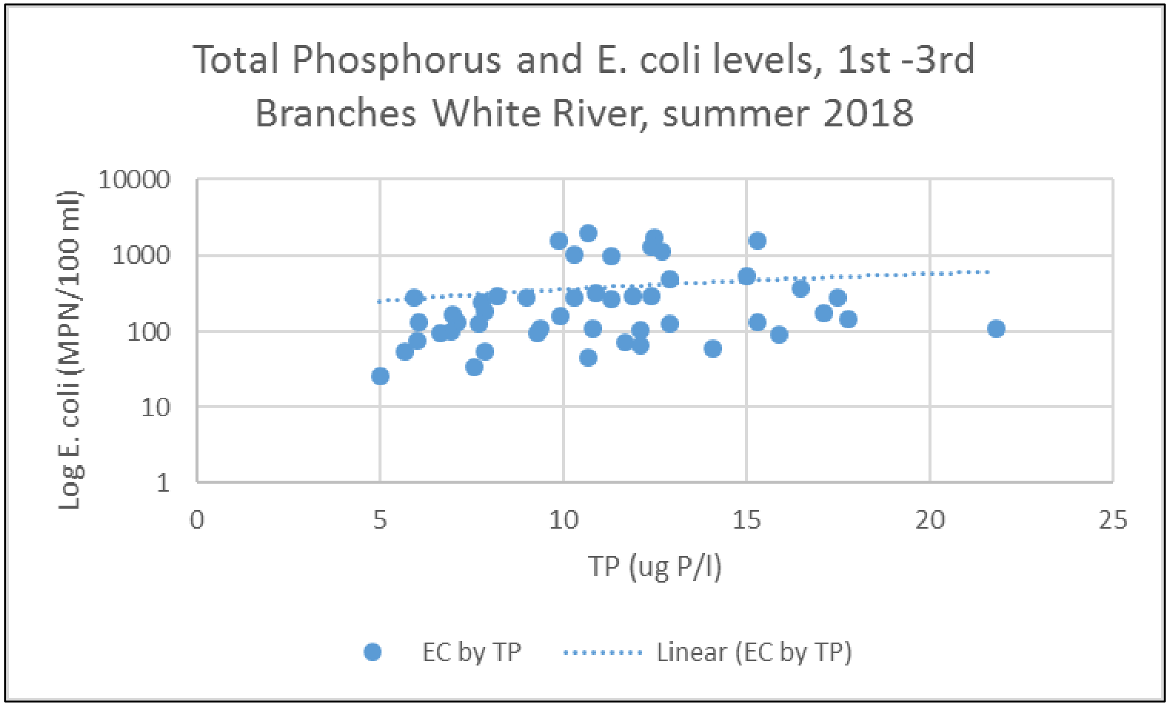


Figure 13.Scatterplot of Total Phosphorus readings against E. coli Most Probable Number (MPN) bacteria counts for First, Second and Third Branch White River sampling stations, summer 2018. Spearman's correlation indicates a weak strength, statistically significant relationship (r_s = 0.3280, p = 0.0228).

Tests for a similar relationship between nitrogen and E. coli levels in either 2017 or 2018 showed no statistical significance.

4.2.4 Nitrogen

With low water levels throughout the 2018 sampling season, even on "wet" sampling dates, Total Nitrogen (TN) was detected at low levels on all three Branches (Fig. 14). TN readings were highest on the Second Branch sites, ranging from 0.48-0.82 mg-N/l, followed by the Third Branch (range from 0.29-0.54 mg-N/l), with lowest values on the First Branch (range from 0.13-0.31 mg-N/l). These values were significantly below Vermont Water Quality Standards thresholds (5.0 mg-N/l) on all Branches under both Low and High flow conditions.

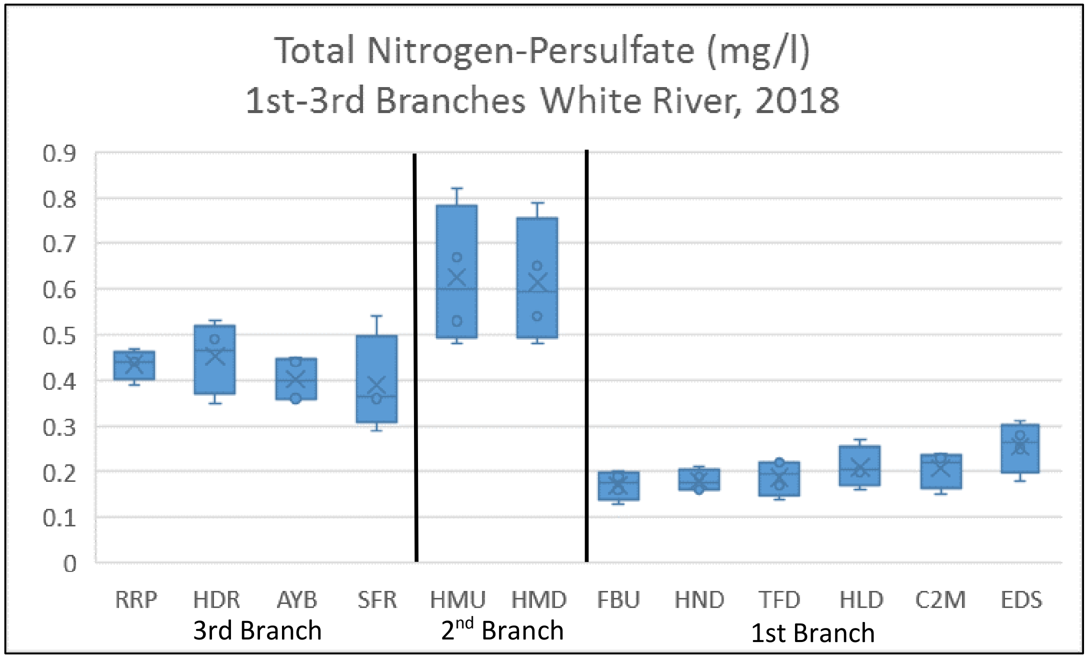
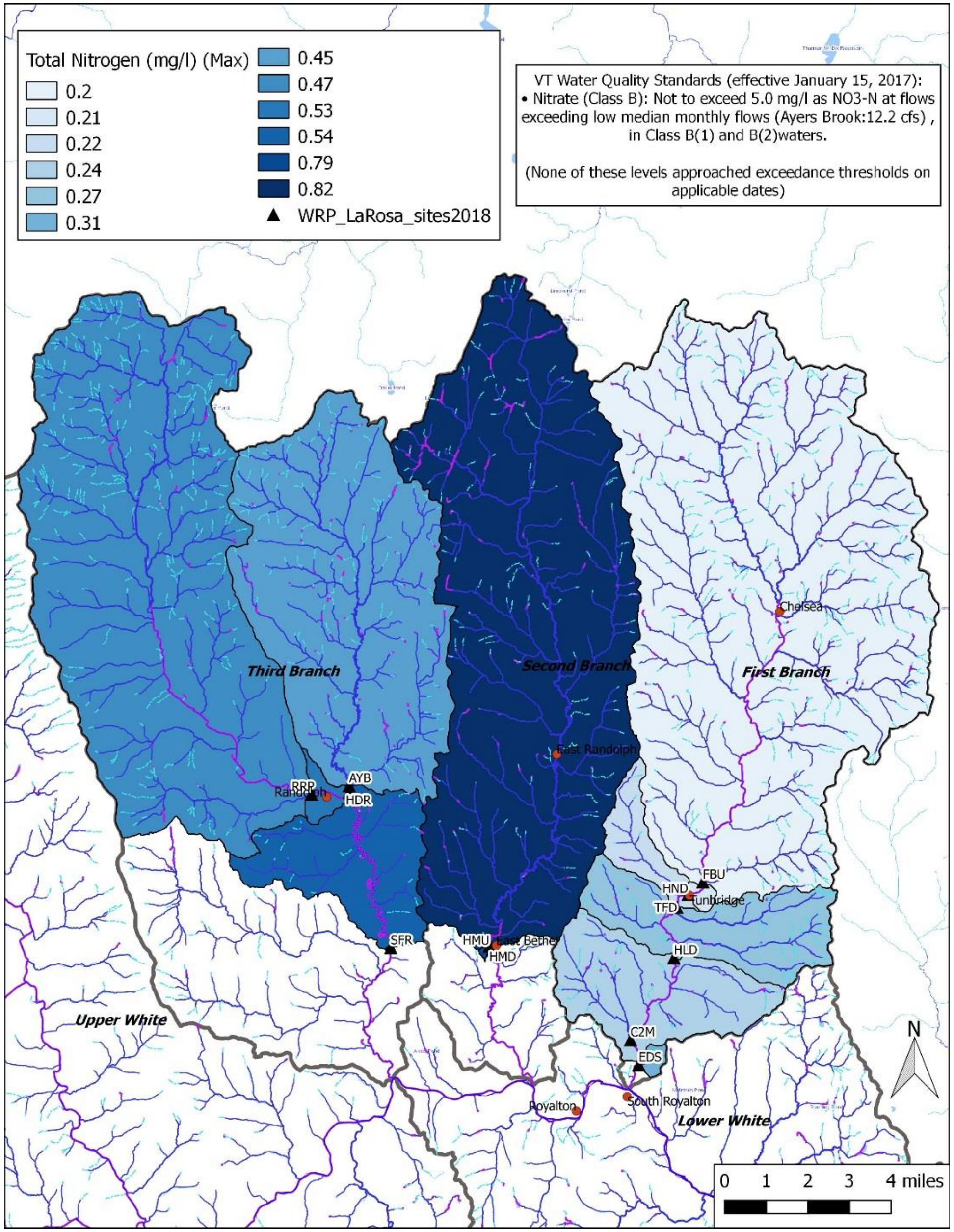


Figure 14. VAEL Total Nitrogen – Persulfate readings for all sampling dates in 2018 on the Third, Second and First Branches. VT Water Quality Standards threshold of 5.0 mg/l is well off the range of this chart.

VT Water Quality Standards (effective January 15, 2017):

- **Nitrate** (Class B): Not to exceed 5.0 mg/l as NO3-N at flows exceeding low median monthly flows, in Class B(1) and B(2)waters.

The First Branch sites showed the only relatively consistent upstream to downstream increase pattern in Total Nitrogen readings in 2018 (Fig.14).



According to Vermont Water Quality Standards (VWMD, 2016), nitrogen as nitrate (NO3-N) is not to exceed 5.0 mg/L at flows exceeding the Low Median Monthly (LMM) discharge in Class B(1) and B(2) waters. For 2018, this included the four sampling dates in June and July (Fig. 5). Figure 15 color codes the subwatersheds draining to the sampling stations by their maximum values for all eight sampling dates in 2018; all but one of these maximum readings (0.53 mg-l at HDR on Aug. 8) occurred on one of the four sampling dates exceeding LMM discharge.

Figure 15. Map of maximum value of Total Nitrogen (TN) detected on sampling dates exceeding low median monthly flows, First, Second and Third Branches White River, 2018. All readings significantly below thresholds of 5.0 mg/l as NO3-N, from the Vermont Water Quality Standards.

5.0 Conclusions

Spatial trend analysis was undertaken for 6 stations in the First Branch, 2 in the Second Branch, and 4 stations in the Third Branch White River watersheds, relying on water quality data collected during four discrete events at each station in the summer of 2018. This monitoring effort builds on previous data collection and continues to refine the spatial resolution of water quality data in these catchments to include more information about bacteria levels and potential relationships to nutrients on the three "Branches", which were listed in 2016 for impairment due to chronic high levels of *E. coli*, as well as collecting baseline data for project monitoring in the vicinity of completed and pending dam removals.

In 2001 the WRP launched the first citizen-based, water quality monitoring program in the White River watershed in response to concerns that bacteria and other pollution might be making the White River unsafe for recreation. An overarching analysis of the program and data was conducted in 2009 (Gerhardt 2009) and highlighted the high bacteria levels on "the Branches" and recommended further testing in problematic areas to include nutrient testing, particularly phosphorus and nitrogen.

With increasing momentum since 2013 (post-Irene; Irene caused elevated readings basin-wide in 2012), the WRP has been engaged in an adaptive WQM program in an attempt to better understand and address those high bacteria numbers. Previous WRP *E. coli* adaptive sampling (2013-2015) on numerous tributaries in the Second Branch catchment led us to believe that elevated *E. coli* readings were likely due to sources along the mainstem itself, and suggested that additional nutrient testing there especially might help to clarify dynamics.

- Phosphorus exceedances of VT Water Quality Standards thresholds have been intermittent on "the Branches", but typically not at exceedingly high levels. Baseline levels are higher on the Second Branch than the First and Third (consistent with differences in WQ Standards thresholds due to stream type)
- Nitrogen levels have been consistently well below VT WQ Standards thresholds on all three Branches, but also tend to be higher on the Second Branch
- *E. coli* levels on "the Branches" continue to regularly exceed VT WQ Standards thresholds
- A correlation between *E. coli* levels and Total Phosphorus readings was one of the few statistically significant patterns evident in the 2017 and 2018 data; 2017 data indicated a moderate strength correlation, while the dry 2018 season showed a weak correlation
- There have been no statistically significant indications of a correlation between E. coli and Nitrogen, and regressions indicate no statistical significance to the relationship between *E. coli* and an interaction between Phosphorus and Nitrogen

The 2018 sampling dates included two Freshet ("wet") dates on First and Second Branch sites and one Freshet date on the Third Branch sites, but due to abnormally dry or borderline drought conditions in the region through much of the summer only one sampling date had "Moderate" flows; all other dates had "Low" flows. As such, the 2018 season offered a window of sampling less influenced by the impacts of erosion and suspended sediments, and high transparency (low turbidity) readings on all sampling dates reflected this to some degree.

In spite of the dry conditions, however, *E. coli* readings still exceeded seasonal geometric means (for combined "wet" and "dry" dates) at all of the First and Second Branch sites as well as the mouth of Ayers Brook. "Dry" dates exceeded thresholds on most of the First Branch sites and Ayers Brook, suggesting likely inputs from agricultural sources or failed/inadequate septic systems rather than stormwater or erosion. There is a strong convergence of developed and agricultural land uses along all three of "the Branches" (Appendix 2), making it challenging to identify the relative contributions of these non-point sources to elevated bacteria and nutrient levels.

It was also notable however that along the Third Branch (where the Osgood-Roundy Dam was removed in Randolph in 2016), seasonal means for *E. coli* (for both "wet" and "dry" dates on the LaRosa sampling dates) at the downstream SFR (Stock Farm Rd) site along the mainstem of the Third Branch were not in exceedance of WQ Standards thresholds in spite of the inputs from Ayers Brook. (Seasonal geometric mean for *E. coli* at this site as part of our 2018 sentinel monitoring program was 130 colonies/100 ml, only slightly above the WQ exceedance threshold of 126 colonies, and the lowest levels at this site since 2012; Appendix 3). The inputs upstream of this site include developed and agricultural land uses that are among the densest in the entire watershed (Appendix 2). Of notable contrast with Second and First Branch sites, however, are significantly lower conductivity readings along the Third Branch upstream of this site (due to much less calcareous bedrock) and coarser sediments than most of the Second Branch as well as the downstream portions of the First Branch.

A USGS Scientific Investigations Report in 2005 documented some of the groundwork for new understandings about naturalized *E. coli* and stream sediments (Cinotto 2005), but much of this work is still actively evolving (Meals et al 2013; Cho et al 2016). Complex modelling is refining efforts to elucidate mechanisms and dynamics, as well as evaluate management options to address issues (Cho et al 2016). Some of these efforts delineate a role for naturalized bacteria in re-suspended sediments - especially fines in the near-surface bed sediments (Pachepsky and Shelton 2011). Some of the evolving research indicates that organic matter and elevated nutrients play a role in enchancing survivability of fecal indicator organisms - particularly phosphorus playing a role through biofilms – but results appear interrelated to other factors such as sediment size and type (Pachepsky and Shelton 2011; Cho et al 2016). Our analysis of

WRP-LaRosa sampling in 2017 and 2018 has indicated weak to moderate correlations of increasing phosphorus levels and elevated bacteria counts.

A general hypothesis developed through analysis of our long-term WQM data is that disruptions to sediment transport dynamics - not just at dams, but through other means as well (undersized structures, dredging and snagging of large woody debris) - may be playing a significant role in elevated bacteria levels, particularly where fines predominate. The White mainstem is relatively unique in its lack of dams and has registered relatively lower levels of bacteria in our long-term monitoring. Experimental measurements on a small stream have indicated, “A high concentration of streambed E. coli (“hotspot”) resuspended within the first reach caused a pulse of high E. coli concentrations that propagated along the creek without substantial attenuation…” (Cho et al 2010) Our hope is that dam removals may eliminate some “hotspots” and allow more natural sediment distribution to start to alleviate some of these issues. Pending dam removals on the First and Second Branches in 2019-2020, as well as the aforementioned 2016 dam removal at Randolph on the Third Branch, offer an exceptional opportunity to monitor changes.

Our sample pairings in close proximity above and below dam sites have yielded inconsistent or statistically insignificant results for both bacteria and nutrients (phosphorus or nitrogen) in the past two years of sampling. Yet the 2018 results along the Third Branch pique our continuing interest in possible mitigating effects of sediment transport continuity on bacteria levels as dams are removed along “the Branches”. In the long run we may recommend monitoring below selected dams (rather than both above and below), as flow conditions below the dams tend to be more comparable to the riffles at which our sentinel station monitoring is targeted. Currently, however, we recommend continuing to build this limited body of knowledge with further collection including sites both upstream and downstream of the dams, particularly given pending removals.

Mapping out the results of our testing has also clarified the importance of retaining a “critical mass” of spatial distribution to our sampling. In general indications are that phosphorus readings are elevated in high flows on all three Branches, and it is likely that significant contributions are coming from erosion and transport of particulate matter. Results from 2015-2017, however, indicated particularly elevated readings, as well as high E. coli readings, in upstream portions of the Second Branch catchment. In the dry summer of 2018, there were no phosphorus exceedances at the Hyde Mill dam sites (further downstream). Results in 2017 indicated possible phosphorus attenuation benefits in higher flows at the channel connected wetland complex upstream of Hyde Mill dam. Without further upstream stations to help delineate phosphorus contributions in 2018 it was difficult to detect patterns; we would suggest adding back sites below the Gulf Road dam (base of Rte 66 in East Randolph) and/or at our *E. coli* long-term “hot-spot” at Dugout Rd along the Second Branch in 2019. The Gulf Road dam has a lot of fine sediments backed up behind it, but based on our previous years’ results we feel that dynamics there are tied to impacts further upstream.

The primary constraint to adding more sites on the Second Branch is logistical capacity, as we will have significant time commitments in conducting a Phase 2 geomorphic analysis of the Second Branch mainstem in 2019 as well. In general, we lean toward colocating nutrient testing (thankfully made possible by the LaRosa Partnership) as much as possible with our sentinel sites in order to be able to leverage the most easily comparable data with our long-term bacteria, turbidity and conductivity sampling.

Because it drains to the Connecticut River instead of Lake Champlain, the White River watershed is not driven by the same Phosphorus TMDL as drainages entering the Lake, instead being included in a Nitrogen TMDL designed to address hypoxia in Long Island Sound. Although we have found relatively low levels of nitrogen in our testing, these results offer important information as the Long Island Sound TMDL enters new phases of implementation aimed at cost-effective management strategies (VT LIS TMDL Workgroup 2013).

Results to date and listing for *E. coli* impairment continue to focus our partnership with LaRosa on nutrient testing to give a fuller picture of water quality dynamics on "the Branches" in 2019. Similar sentinel and rotational sites will be monitored, with a particular emphasis on dam sites slated for potential removal. We will request LaRosa analysis of Total Phosphorus and Total Nitrogen for all selected sites, and turbidity (LaRosa nepholometer analysis) above and below dams slated for removal on the First and Second Branches (Based on previous results we have dropped Nitrate-Nitrite (NOx) tests.)

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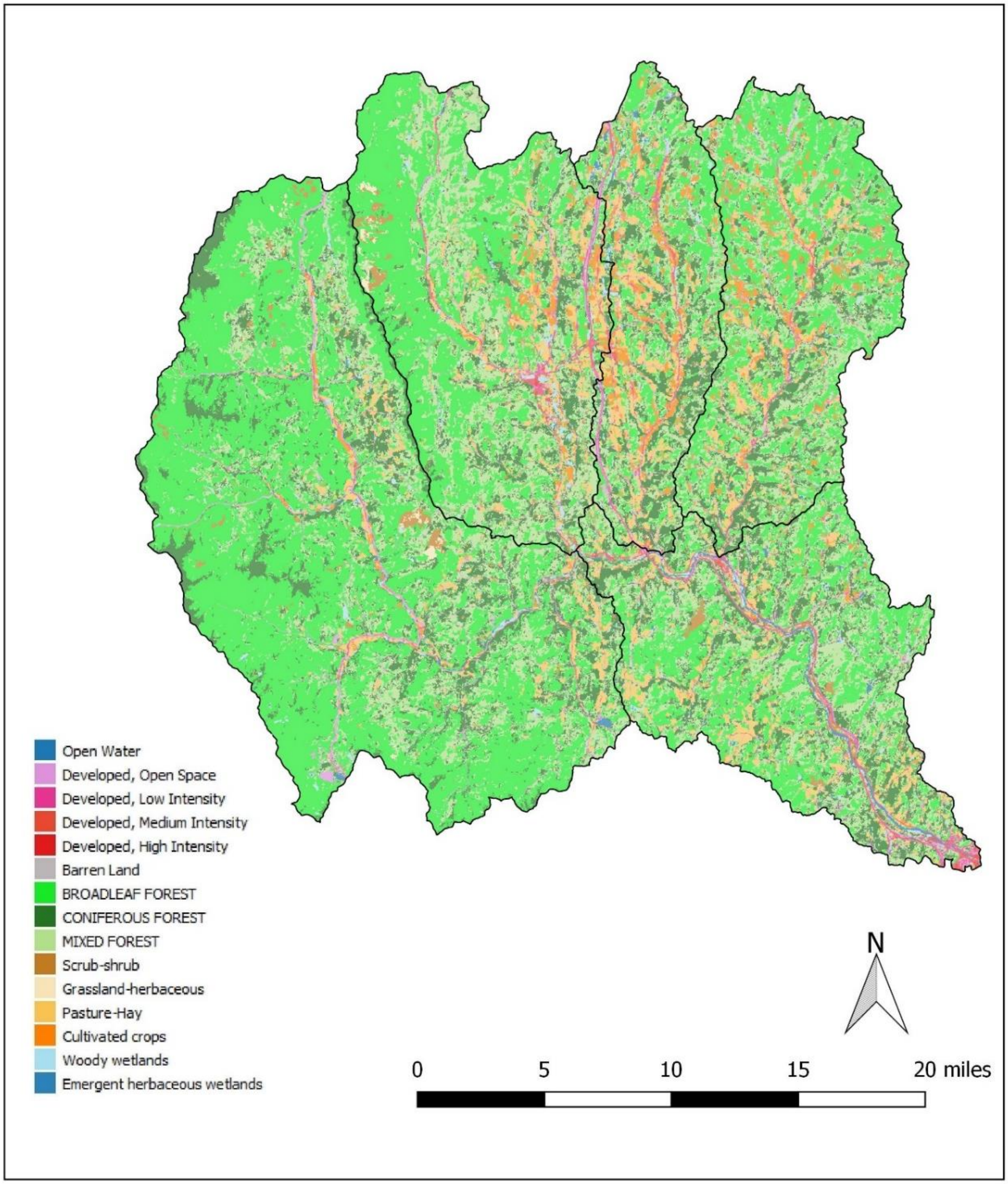
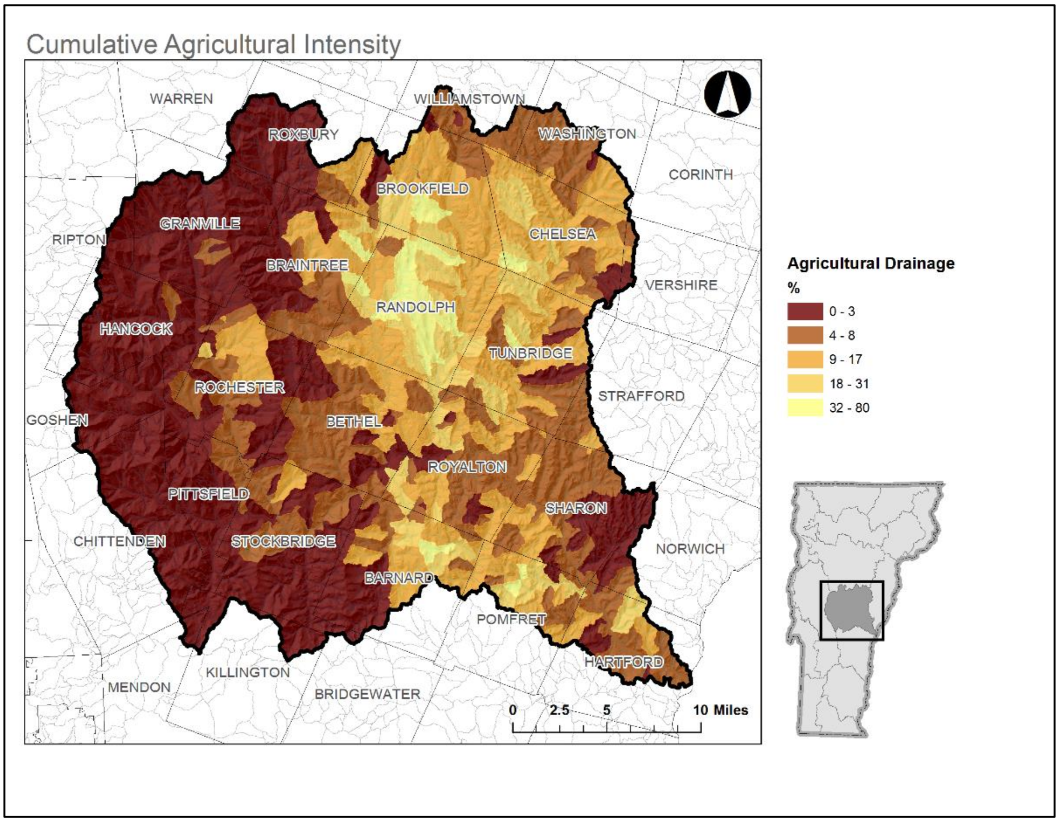
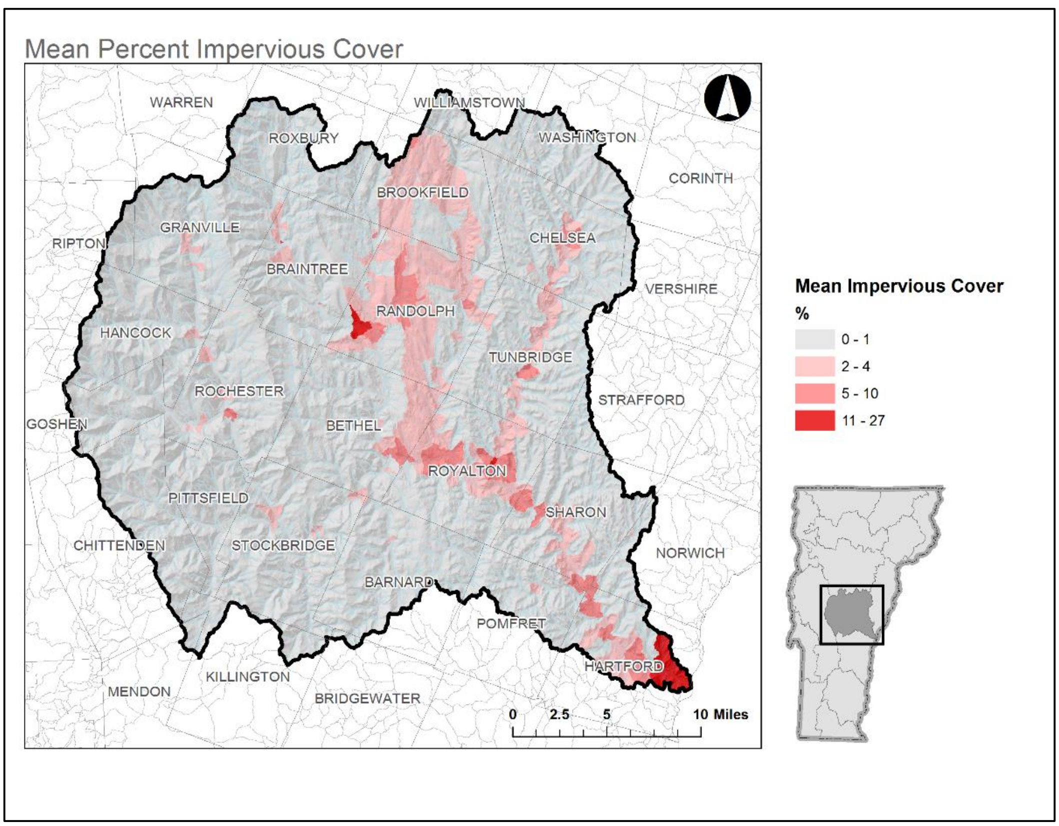
Appendix 1 - Land Cover / Land Use White River watershed



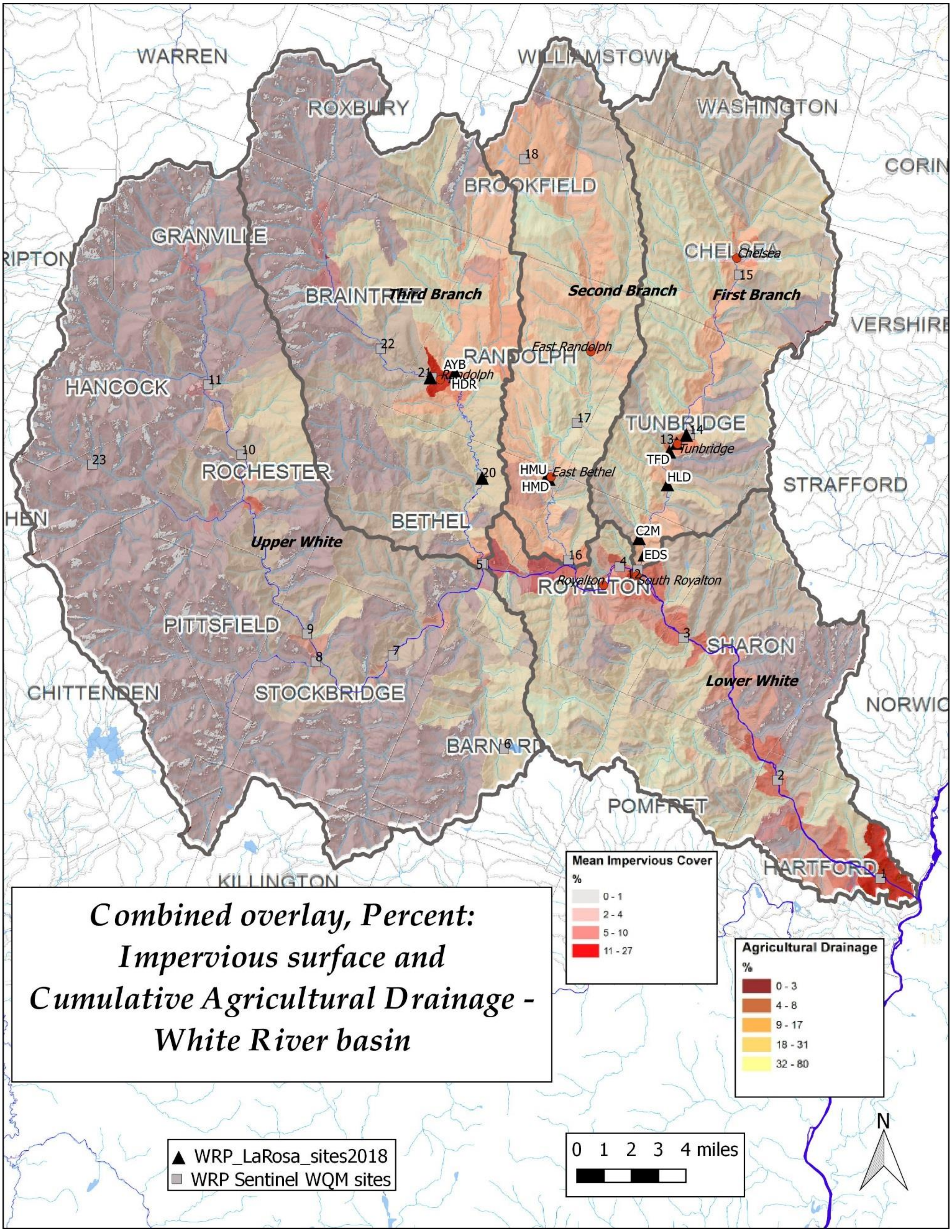
Land Cover - Land Use
White River basin

Although predominantly forested and diffusely settled overall, the White River basin has a preponderance of agricultural uses and more densely settled areas in eastern portions of the basin, particularly the northeastern subwatersheds occupied by "The Branches".
(2011 National Land Cover Dataset (30m))



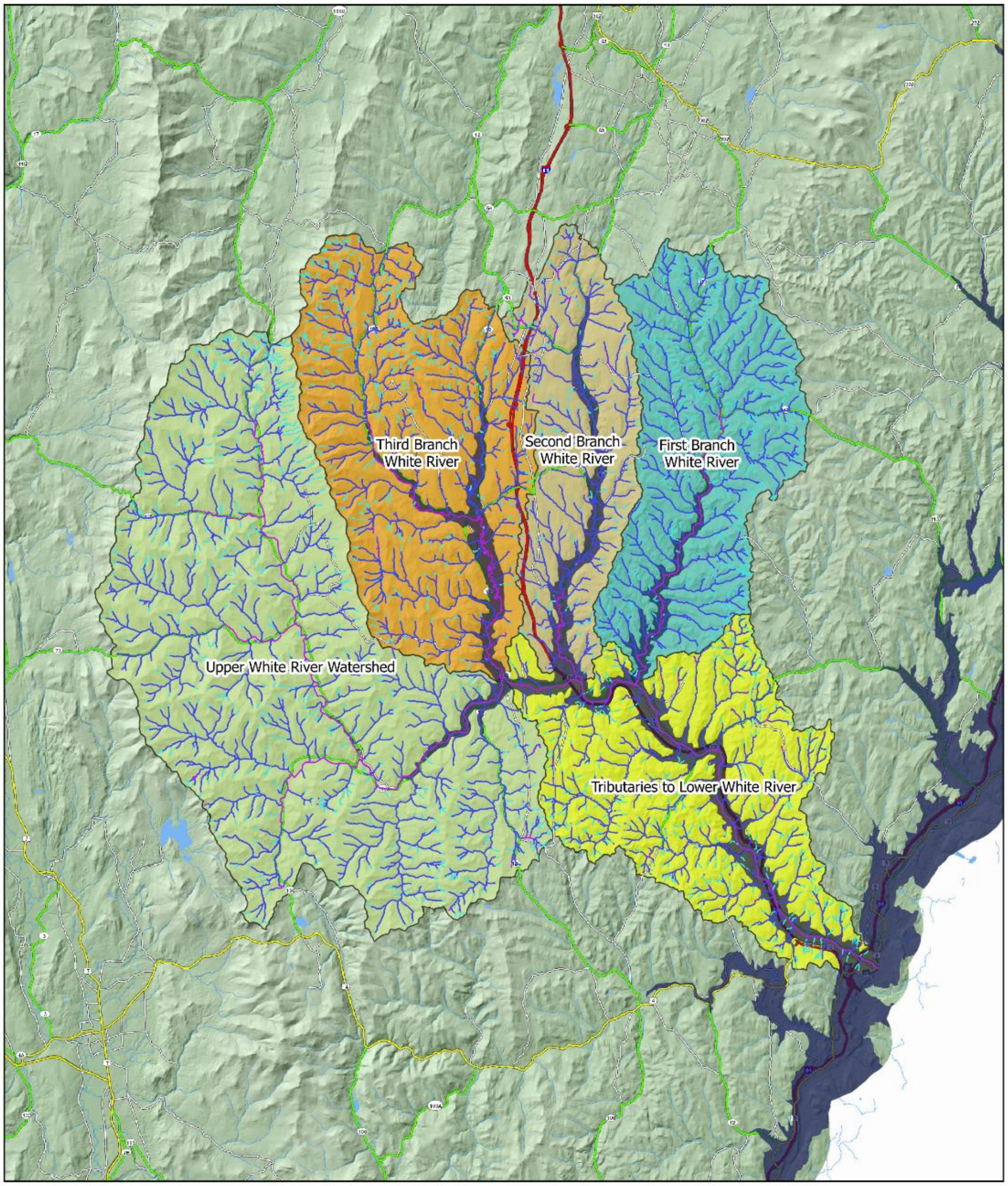


Cumulative Agricultural Intensity and Mean Percent Impervious cover are indicative of preponderance of agricultural uses and more densely settled areas in eastern portions of the White River basin, particularly the northeastern subwatersheds occupied by "The Branches". Analysis and maps courtesy of VT DEC Watershed Management Division.

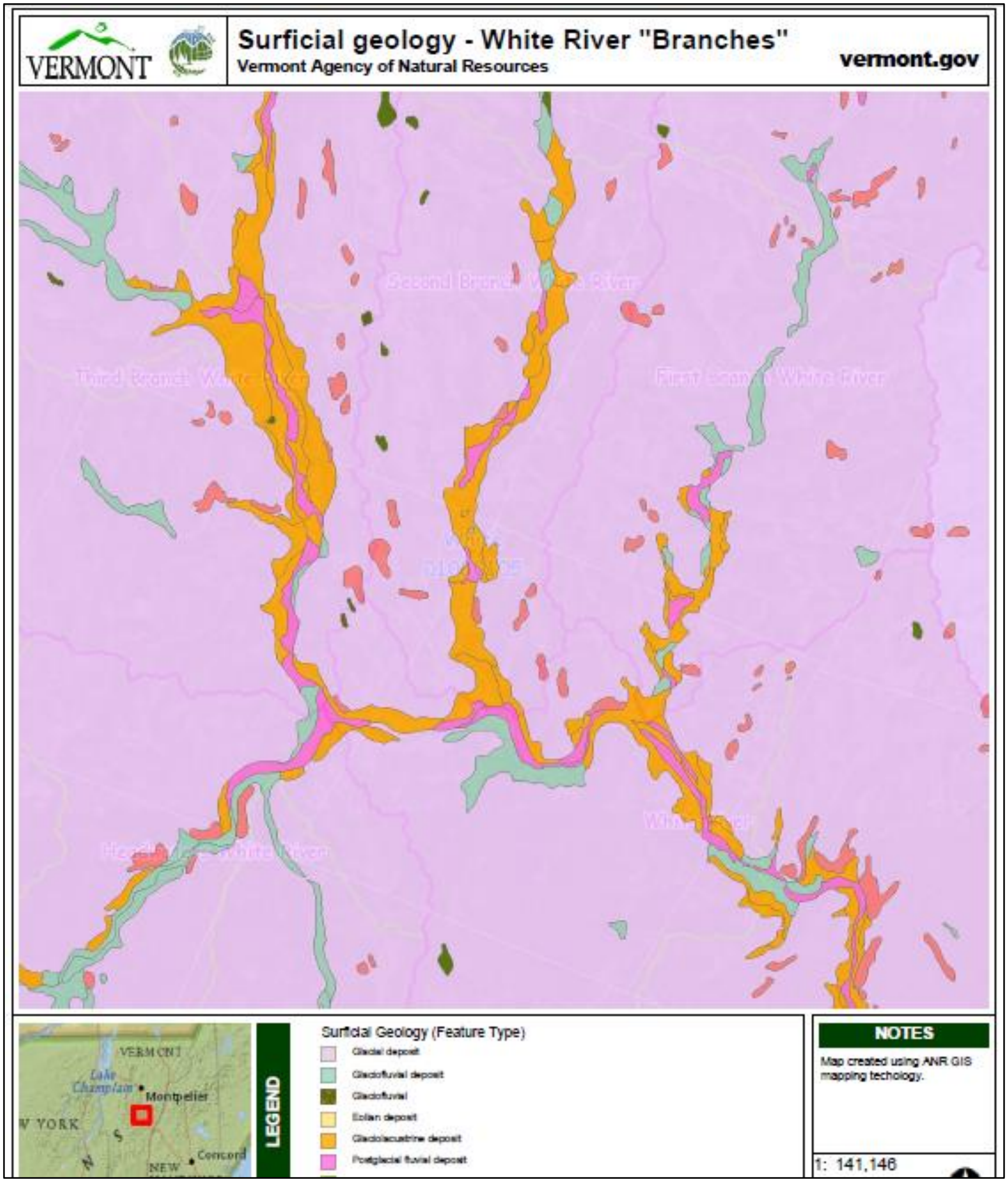


Combined overlay of percent Impervious and Cumulative Agricultural Drainage in relation to WRP sentinel and LaRosa 2018 sampling stations.

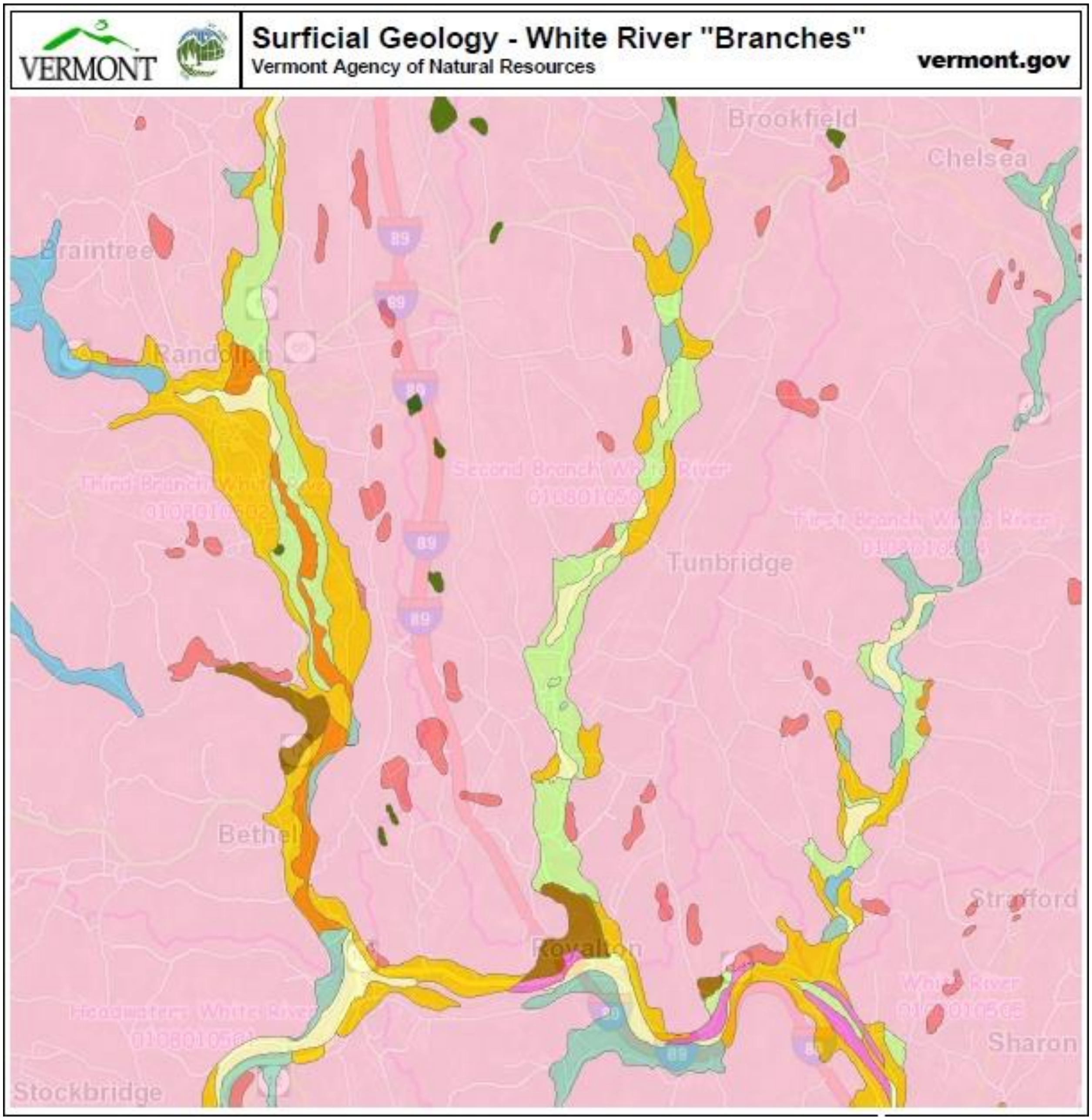
Appendix 2- Approximate Extent of Glacial Lake Hitchcock in the White River Basin and Resulting Surficial Geologic Features



Approximate extent of glacial Lake Hitchcock (dark blue) in the White River basin



Surficial geology of the White River 'Branches' indicating preponderance of glaciolacustrine, glaciofluvial and postglacial fluvial deposits (frequently featuring sands, silts and clays; see following page also) along significant portions of the Second and Third Branches and downstream portions of the First Branch – areas formerly occupied by glacial Lake Hitchcock.



Surficial Geology (Lithology)

- till
- terminal moraine
- moraine
- isolated kame
- kame terrace
- swamp, peat and/or muck
- outwash
- silt, silty clay, and clay
- bedrock exposure
- alluvium
- lake gravel
- fluvial gravel
- fluvial sand
- lake sand
- pebbly sand

Lithology of the White River 'Branches' indicating preponderance of glaciolacustrine, glaciofluvial and postglacial fluvial soils including silt, clay, sands and fine gravels along significant portions of the Second and Third Branches and downstream portions of the First Branch – areas formerly occupied by glacial Lake Hitchcock.

Appendix 3 - 2018 Summary Water Quality Results, Summary WRP *E. coli* data 2012-2018

Abbreviations:

mg/L = milligrams per liter
ug/ L = micrograms per liter
MPN/100 mL = organisms per 100 milliliters
uS = microSiemens

Nutrient testing – WRP-LaRosa 2018 results – First, Second and Third Branches White River (sites ordered upstream to downstream)

	Nitrogen, Total - Persulfate (mg/L)	13-Jun	20-Jun	11-Jul	18-Jul	1-Aug	8-Aug	29-Aug	5-Sep	Average
3rd Branch	RRP	0.44		0.47			0.44		0.39	**0.44**
	HDR	0.44		0.49			0.53		0.35	**0.45**
	AYB	0.44		0.45			0.36		0.36	**0.40**
	SFR	0.54		0.37			0.36		0.29	**0.39**
2nd Branch	HMU		0.67		0.82	0.48		0.53		**0.63**
	HMD		0.65		0.79	0.48		0.54		**0.62**
1st Branch	FBU		0.20		0.19	0.13		0.16		**0.17**
	HND		0.21		0.19	0.16		0.16		**0.18**
	TFD		0.22		0.22	0.14		0.17		**0.19**
	HLD		0.21		0.27	0.16		0.20		**0.21**
	C2M		0.23		0.24	0.15		0.21		**0.21**
	EDS		0.31		0.28	0.18		0.25		**0.26**
	Phosphorus - Digested (ug P/L)	**13-Jun**	**20-Jun**	**11-Jul**	**18-Jul**	**1-Aug**	**8-Aug**	**29-Aug**	**5-Sep**	**Average**
3rd Branch	RRP	5.00		7.85			6.01		5.69	**6.14**
	HDR	7.56		12.10			21.80		6.65	**12.03**
	AYB	9.02		11.30			10.80		12.10	**10.81**
	SFR	14.10		15.90			12.90		17.50	**15.10**
2nd Branch	HMU		16.50		12.70	10.70		17.80		**14.43**
	HMD		17.10		15.30	11.70		15.30		**14.85**
1st Branch	FBU		10.90		9.88	5.93		7.10		**8.45**
	HND		10.30		10.70	7.85		7.70		**9.14**
	TFD		11.90		11.30	6.08		6.95		**9.06**
	HLD		12.40		10.30	8.22		9.30		**10.06**
	C2M		12.90		12.50	6.99		9.40		**10.45**
	EDS		15.00		12.40	7.80		9.94		**11.29**

VT Water Quality Standards (effective January 15, 2017):

- **Nitrate** (Class B): Not to exceed 5.0 mg/l as NO3-N at flows exceeding low median monthly flows (*Ayers Brook:12.2 cfs*) , in Class B(1) and B(2)waters.
- **Phosphorus**

Second Branch: (Class B(2), Warm-water Medium Gradient): Not to exceed **27 ug/L** at low median monthly flow during June through October in a section of the stream representative of well-mixed flow. Second Branch reaches are considered Warm-Water, Medium Gradient for Combined Nutrient Criteria for Aquatic Biota and Wildlife in Rivers and Streams even though they are considered Cold Water Fish Habitat (pers. comm., Jim Kellogg et al., VT DEC, Jan. 2017)

1st and 3rd Branches: (Class B(2), Medium, High Gradient): Not to exceed **15 ug/L** at low median monthly flow during June through October in a section of the stream representative of well-mixed flow.

E. coli, turbidity and conductivity – WRP-LaRosa 2018 results – First and Second Branches (sites ordered upstream to downstream)

				VRP-LaRosa 2018 Vater Quality Monitoring																		
				6/20/2018				7/18/2018				8/1/2018				8/29/2018						
	Veather within the past 24 hrs*			Mostly Sunny				Rain				Partly Sunny				Mostly Sunny						
	Ayers Brook USGS gauge at 9am (CFS)**			17.5				12.3				6.1				3.9						
	Ayers Brook USGS gauge daily mean value (CFS)**			33				22				20				23						
	Rain Accumulation (in) in the last 24 hrs***			0.00				0.17				0.00				0.00						
	Rain Accumulation (in) in the last 48 hrs***			0.43				0.19				0.00				0.00						
	*Conditions (wet or dry)*****			*wet*				*wet*				*dry*				*dry*						
				E-coli				E-coli				E-coli				E-coli						
Tributary	Site Number	Town	Site Name	Iq/ small	MPN	Turbidity	Conduct-ivity	Iq/ small	MPN	Turbidity	Conduct-ivity	Iq/ small	MPN	Turbidity	Conduct-ivity	Iq/ small	MPN	Turbidity	Conduct-ivity	Seasonal Mean	*wet*	*dry*
Third Branch	RRP	Randolph	Randolph Rec Park																	49.8	55.6	48.0
Third Branch	HDR	Randolph	Hedding Dr																	78.6	95.9	73.6
Third Branch	AYB	Randolph	Ayers Brook mouth																	153.5	67.0	202.4
Third Branch	SFR	Randolph	Stock Farm Rd																	117.4	285.1	87.4
Second Branch	HMU	East Bethel	Hyde Mill US	49/21	365.4	120	310	49/40	1119.9	120	350	28/3	44.1	120	350	46/9	142.1	120	370	225.0	639.7	79.2
Second Branch	HMD	East Bethel	Hyde Mill DS	47/13	178.5	120	310	49/44	1553.1	120	350	37/4	71.2	120	350	44/11	129.6	120	370	224.9	526.5	96.1
First Branch	FBU	Tunbridge	Farnham Bros Dam US	49/19	325.5	120	320	49/44	1553.1	120	330	49/16	275.5	120	340	42/17	133.6	120	340	369.3	711.0	191.9
First Branch	HND	Tunbridge	Hayward Noble Dam	49/16	275.5	120	280	49/46	1986.3	120	330	48/11	186.0	120	340	43/13	128.1	120	350	337.9	739.7	154.4
First Branch	TFD	Tunbridge	Tunbridge Fairgrounds DS	49/17	290.9	120	290	49/38	980.4	120	330	45/9	131.4	120	340	43/5	101.9	120	350	248.6	534.0	115.7
First Branch	HLD	Tunbridge	Howe Ln DS (Chapman Farm)	49/17	290.9	120	290	49/39	1046.2	120	320	49/17	290.9	120	340	39/10	93.4	120	350	301.6	551.7	164.8
First Branch	C2M	Royalton	Log Landing Ln	49/26	488.4	120	290	49/45	1732.9	120	320	46/14	167.0	120	350	40/14	109.5	120	350	352.7	920.0	135.2
First Branch	EDS	Royalton	Eaton Dams DS	49/28	547.5	120	290	49/42	1299.7	120	330	48/17	238.2	120	350	48/7	159.7	120	350	405.6	843.6	195.0

* Weather in the past 24 hrs - Based on last 24 hrs- Descriptors include- Mostly Sunny (<49% cloud cover), Partly Sunny (50-99% cloud cover), Overcast (100% cloud cover, no rain), Scattered Rain (measurable rain <.1 but >.05 inches), Rain (>.1 inches)
**River gauge data found at: http://waterdata.usgs.gov/usa/nwis/uv?01142500
***Precip Data measured at Ayer's Brook in Randolph, found at: http://waterdata.usgs.gov/vt/nwis/uv?site_no=01142500
**** Wet - More than .1 inches in the last 24 hrs or more than .25 inches in the last 48

exceeds EPA daily standard (235 colonies/100mL sample)
exceeds EPA seasonal standard (126 colonies/100mL sample)

Third Branch

				VRP-LaRosa 2018 Vater Quality Monitoring																		
				6/13/2018				7/11/2018				8/8/2018				9/5/2018						
	Veather within the past 24 hrs*			Mostly Sunny				Mostly Sunny				Scattered Rain				Mostly Sunny						
	Ayers Brook USGS gauge at 9am (CFS)**			13.2				14.4				9.9				4.8						
	Ayers Brook USGS gauge daily mean value (CFS)**			40				33				20				13						
	Rain Accumulation (in) in the last 24 hrs***			0.00				0.00				0.06				0.00						
	Rain Accumulation (in) in the last 48 hrs***			0.00				0.00				0,06				1.44						
	*Conditions (wet or dry)*****			*dry*				*dry*				*dry*				*wet*						
				E-coli				E-coli				E-coli				E-coli						
Tributary	Site Number	Town	Site Name	Iq/ small	MPN	Turbidity	Conduct-ivity	Iq/ small	MPN	Turbidity	Conduct-ivity	Iq/ small	MPN	Turbidity	Conduct-ivity	Iq/ small	MPN	Turbidity	Conduct-ivity	Seasonal Mean	*wet*	*dry*
Third Branch	RRP	Randolph	Randolph Rec Park	24/5	26.2	120	90	32/4	55.6	120	90	36/8	75.9	120	90	32/4	55.6	120	100	49.8	55.6	48.0
Third Branch	HDR	Randolph	Hedding Dr	25/0	33.6	120	120	38/17	105.9	120	140	44/6	111.9	120	140	40/9	95.9	120	140	78.6	95.9	73.6
Third Branch	AYB	Randolph	Ayers Brook mouth	49/16	275.5	120	300	48/20	272.3	120	330	42/10	110.6	120	350	34/7	67.0	120	370	153.5	67.0	202.4
Third Branch	SFR	Randolph	Stock Farm Rd	35/6	58.3	120	200	39/9	90.9	120	230	44/10	125.9	120	230	48/21	285.1	120	220	117.4	285.1	87.4
Second Branch	HMU	East Bethel	Hyde Mill US																	225.0	639.7	79.2
Second Branch	HMD	East Bethel	Hyde Mill DS																	224.9	526.5	96.1
First Branch	FBU	Tunbridge	Farnham Bros Dam US																	369.3	711.0	191.9
First Branch	HND	Tunbridge	Hayward Noble Dam																	337.9	739.7	154.4
First Branch	TFD	Tunbridge	Tunbridge Fairgrounds DS																	248.6	534.0	115.7
First Branch	HLD	Tunbridge	Howe Ln DS (Chapman Farm)																	301.6	551.7	164.8
First Branch	C2M	Royalton	Log Landing Ln																	352.7	920.0	135.2
First Branch	EDS	Royalton	Eaton Dams DS																	405.6	843.6	195.0

* Weather in the past 24 hrs - Based on last 24 hrs- Descriptors include- Mostly Sunny (<49% cloud cover), Partly Sunny (50-99% cloud cover), Overcast (100% cloud cover, no rain), Scattered Rain (measurable rain <.1 but >.05 inches), Rain (>.1 inches)
**River gauge data found at: http://waterdata.usgs.gov/usa/nwis/uv?01142500
***Precip Data measured at Ayer's Brook in Randolph, found at: http://waterdata.usgs.gov/vt/nwis/uv?site_no=01142500
**** Wet - More than .1 inches in the last 24 hrs or more than .25 inches in the last 48

VT Water Quality Standards (effective January 15, 2017): **E. coli** (Class B): Not to exceed a geometric mean of 126 organisms /100ml obtained over a representative period of 60 days, and no more than 10% of samples above **235 organisms/100 ml**. In waters receiving combined sewer overflows, the representative period shall be 30 days

***E. coli* seasonal geometric means 2018 – Sentinel sites plus WRP-LaRosa Third Branch sites sampled on same dates (AYB, HDR) (downstream to upstream)**

2018 White River Partnership Bacteria Data																		
				5/30/2018	6/13/2018	6/27/2018	7/11/2018	7/25/2018	8/8/2018	8/22/2018	9/5/2018	9/19/2018						
	Weather within the past 24 hrs*			Mostly Sunny	Mostly Sunny	Mostly Sunny	Mostly Sunny	Overcast	Scattered Rain	Rain	Mostly Sunny	Scattered Rain						
	West Hartford USGS gauge at 9am (CFS)**			631	329	256	205	381	422	256	256	256						
	W. Hartford USGS gauge daily mean value (CFS)**			1400	982	967	654	542	473	414	325	405						
	ain Accumulation (in) max in the last 24 hrs-NWS COOP**			0.00	0.00	0.00	0.18	1.20	0.06	0.16	0.00	0.1						
	ain Accumulation (in) max in the last 48 hrs-NWS COOP**			0.02	0.00	0.04	0.18	1.20	0.06	0.16	1.47	0.18	GeoMean			# times daily std was exceeded		
	Conditions (wet or dry)****			dry	dry	dry	dry	wet	dry	wet	wet	wet	all	wet	dry	all	wet	dry
				E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli	E-coli
Tributary	Site Number	Town	Site Name	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN	MPN
Lower Main Stem	1	Hartford	Old River Rd	36.4		22.6	40.8	91.0	81.6	86.0	140.8	9.8	48.3	57.3	40.7	0	0	0
	2	W. Hartford	West Hartford Bridge	21.1	17.3	17.5	22.3	84.2	65.0	61.6	71.7	32.3	36.4	58.9	27.0	0	0	0
	3	Sharon	The Sharon Academy	52.9	38.9	62.0	46.5	121.1	387.3	63.7	131.7	78.0	82.8	94.3	87.7	1	0	1
	4	Royalton	Pinch Rock	58.3	38.8	54.6	35.5	149.7	272.3	41.4	22.3	35.5	56.5	47.1	74.5	1	0	1
Upper Main Stem	5	Bethel	Peavine Park-Bethel	21.3	13.2	10.8	125.9	71.7	122.3	17.3	79.9	32.7	37.6	42.4	43.4	0	0	0
	6	Barnard	Silver Lake	1.0	3.0	56.3	146.7	27.5	17.3	11.9	4.1		12.4	11.0	19.4	0	0	0
	7	Stockbridge	Gaysville Bridge	4.1	7.5	15.8	238.2	95.8	139.6	13.5	35.0	44.1	31.7	37.6	38.3	1	0	1
	8	Stockbridge	Mouth of Tweed	5.2	18.9	32.3	111.2	37.9	38.8	93.2	40.4	29.5	33.8	45.3	29.2	0	0	0
	9	Stockbridge	Peavine Park-Stockbridge	17.5	43.5	79.8	184.2	145.0	272.3	110.6	152.9	66.3	92.5	112.9	91.5	1	0	1
	23	Rochester	Bingo Brook	3.1	7.3	14.6	18.7	27.9	43.2	73.3	13.5		17.1	30.2	13.8	0	0	0
	10	Rochester	Lion's Club Park	74.4	27.5	95.9	88.4	90.8	113.0	79.8	156.5	64.4	80.6	92.4	91.9	0	0	0
	11	Hancock	Taylor Meadow Rd	9.7	34.1	133.3	172.6	139.6	95.9	86.2	73.3	17.5	60.7	62.7	68.0	0	0	0
First Branch	12	Royalton	Mouth of First Branch	93.3	261.3	344.8	225.4	435.2	2419.6	435.2	139.6	108.1	286.7	231.2	363.9	5	2	3
	13	Tunbridge	Tunbridge Fairgrounds	51.2	76.2	159.7	167.0	272.3	307.5	151.5	95.9	275.5	148.4	181.7	143.1	3	1	2
	14	Tunbridge	Town Pool Tributary	67.7	1.0	3.1	14.8	65.0	547.5	108.6	13.5	12.1	23.2	32.8	36.1	1	0	1
	15	Chelsea	Chelsea Rec Park	62.4	123.4	83.3	228.2	547.5	344.8	344.8	165.8	218.7	191.4	287.6	142.2	3	2	1
Second Branch	16	Royalton	Mouth of Second Branch	143.9	146.7	185.0	116.2	198.9	146.7	248.1	222.4	135.4	166.6	196.3	146.0	1	1	0
	17	Randolph	Dugout Road	111.2	155.3	222.4	125.9	461.1	119.1	156.5	125.9	214.2	168.9	210.0	138.8	1	1	0
	18	Brookfield	Sunset Lake		1.0	26.2	3.1	41.4	6.3	21.1	4.1		7.8	15.3	8.0	0	0	0
Third Branch	19	Bethel	Mouth of Third Branch	56.3	48.7	115.3	125.9	90.6	69.7	56.5	126.7	32.7	73.0	67.9	86.9	0	0	0
	20	Bethel	Stock Farm Road	59.4	58.3	90.8	90.9	214.3	125.9	142.1	325.5	307.6	130.5	235.0	88.6	2	1	1
	AYB	Randolph	Ayers Brook mouth		275.5		272.3		110.6		67.0		153.5	67.0	173.5	2	0	2
	HDR	Randolph	Hedding Dr		33.6		105.9		111.9		95.9		78.6	95.9	108.9	0	0	0
	21	Randolph	Randolph Rec Park	43.5	26.2	42.0	55.6	93.3	75.9	365.4	55.6	23.8	59.3	82.0	52.7	1	1	0
	22	Braintree	Riford Brook Road	42.8	47.3	31.3	866.4	172.3	218.7	488.4	185.0	74.3	134.0	184.4	126.2	2	1	1
exceeds EPA daily standard (235 colonies/100mL sample)						Most Probable Number (statistical)						210				25	10	15
exceeds EPA seasonal standard (126 colonies/100mL sample)													total samples			12%		
* Weather in the past 24 hrs - Based on last 24 hrs- Descriptors include- Mostly Sunny (<49% cloud cover), Partly Sunny (50-99% cloud cover), Overcast (100% cloud cover, no rain), Scattered Rain (measurable rain <.1 but >.05 inches), Rain (>.1 inches)																210		
**River gauge data found at: http://waterdata.usgs.gov/usa/nwis/uv?01144000																		
***Weather Data found at: https://www.weather.gov/btv/climatemaps																		
**** Wet - More than .1 inches in the last 24 hrs or more than .25 inches in the last 48																		

E. coli seasonal geometric means – all WRP Sentinel sites – 2012-2018

WRP Bacteria data - Seasonal Geometric means (number of dates used in calculation)

				2018			2017			2016			2015			2014			2013			2012						
Tributary	Site Number	Town	Site Name	All	Wet	Dry	All	Wet	Dry	All	Wet	Dry	All	Wet	Dry	All	Wet	Dry	All	Wet	Dry	All	Wet	Dry	avg All	rank	avg Dry	rank Dry
Lower Main Stem	1	Hartford	Old River Rd	48 (8)	57 (4)	41 (4)	90 (9)	265 (4)	38 (5)	32 (9)	46 (2)	29 (7)	129 (9)	381 (5)	33 (4)	37 (9)	133 (3)	20 (6)	140 (8)	316 (6)	12 (2)	120 (9)	318 (6)	17 (3)	85	14	27	19
	2	W. Hartford	West Hartford Bridge	36 (9)	59 (4)	27 (5)	83 (9)	156 (4)	50 (5)	34 (9)	74 (2)	27 (7)	119 (9)	301 (5)	38 (4)	62 (9)	188 (3)	36 (6)	130 (9)	355 (6)	18 (3)	156 (9)	520 (6)	14 (3)	89	13	30	18
	3	Sharon	The Sharon Academy	83 (9)	94 (4)	88 (5)	142 (9)	283 (4)	82 (5)	83 (9)	548 (2)	48 (7)	225 (9)	487 (5)	86 (4)	125 (9)	585 (3)	58 (6)	158 (9)	295 (6)	45 (3)	285 (9)	740 (6)	42 (3)	157	8	64	10
	4	Royalton	Pinch Rock	56 (9)	47 (4)	74 (5)	84 (9)	163 (4)	50 (5)	91 (9)	256 (2)	68 (7)	143 (9)	259 (5)	68 (4)	124 (9)	328 (3)	77 (6)	131 (8)	332 (5)	28 (3)	336 (9)	893 (6)	48 (3)	138	10	59	11
Upper Main Stem	5	Bethel	Peavine Park-Bethel	38 (9)	42 (4)	43 (5)	28 (9)	74 (4)	13 (5)	52 (9)	477 (2)	28 (7)	64 (9)	120 (5)	29 (4)	40 (8)	122 (2)	27 (6)	84 (9)	112 (6)	47 (3)	133 (8)	305 (5)	33 (3)	63	18	31	16
	6	Barnard	Silver Lake	12 (8)	11 (3)	19 (5)	13 (9)	23 (4)	8 (5)	13 (6)	NA NA	13 (6)	9 (9)	25 (5)	3 (4)	3 (9)	13 (3)	2 (6)	14 (8)	23 (6)	3 (2)	4 (7)	8 (4)	2 (3)	10	22	7	21
	7	Stockbridge	Gaysville Bridge	32 (9)	38 (4)	38 (5)	44 (8)	205 (3)	17 (5)	49 (9)	116 (2)	39 (7)	62 (9)	101 (5)	33 (4)	102 (8)	593 (3)	36 (5)	78 (9)	127 (6)	29 (3)	178 (9)	322 (6)	54 (3)	78	16	35	15
	8	Stockbridge	Mouth of Tweed	34 (9)	45 (4)	29 (5)	26 (9)	48 (4)	16 (5)	39 (9)	276 (2)	22 (7)	34 (9)	37 (5)	31 (4)	38 (9)	89 (3)	25 (6)	43 (9)	71 (6)	16 (3)	106 (9)	131 (6)	70 (3)	46	20	30	17
	9	Stockbridge	Peavine Park-Stockbridg	92 (9)	113 (4)	91 (5)	115 (9)	302 (4)	53 (5)	88 (9)	227 (2)	67 (7)	88 (9)	119 (5)	60 (4)	82 (9)	188 (3)	54 (6)	52 (9)	79 (6)	23 (3)	189 (9)	415 (6)	39 (3)	101	11	55	12
	10	Rochester	Lion's Club Park	81 (9)	92 (4)	92 (5)	57 (9)	98 (4)	37 (5)	123 (9)	581 (2)	79 (7)	82 (9)	91 (5)	72 (4)	99 (9)	174 (3)	74 (6)	63 (9)	69 (6)	53 (3)	186 (9)	330 (6)	59 (3)	99	12	66	9
	11	Hancock	Taylor Meadow Rd	61 (9)	63 (4)	68 (5)	39 (9)	69 (4)	24 (5)	56 (9)	335 (2)	34 (7)	34 (9)	28 (5)	44 (4)	59 (9)	73 (3)	54 (6)	22 (9)	32 (6)	10 (3)	81 (9)	111 (6)	44 (3)	50	19	40	14
First Branch	12	Royalton	Mouth of First Branch	287 (9)	231 (4)	364 (5)	241 (9)	431 (4)	151 (5)	231 (9)	1365 (2)	139 (7)	446 (9)	949 (5)	174 (4)	248 (9)	387 (3)	199 (6)	197 (9)	366 (6)	57 (3)	445 (9)	884 (6)	113 (3)	299	3	171	2
	13	Tunbridge	Tunbridge Fairgrounds	148 (9)	182 (4)	143 (5)	237 (9)	456 (4)	140 (5)	276 (9)	1646 (2)	165 (7)	228 (9)	449 (5)	98 (4)	213 (9)	253 (3)	195 (6)	117 (9)	164 (6)	59 (3)	282 (9)	625 (6)	57 (3)	214	5	123	5
	14	Tunbridge	Town Pool Tributary	23 (9)	33 (4)	36 (5)	58 (9)	77 (4)	47 (5)	30 (9)	331 (2)	15 (7)	108 (9)	321 (5)	28 (4)	23 (9)	242 (3)	7 (6)	88 (9)	158 (6)	27 (3)	168 (9)	603 (6)	13 (3)	71	17	25	20
	15	Chelsea	Chelsea Rec Park	191 (9)	288 (4)	142 (5)	271 (9)	591 (4)	145 (5)	113 (9)	375 (2)	80 (7)	266 (9)	471 (5)	130 (4)	165 (9)	237 (3)	137 (6)	80 (9)	117 (6)	37 (3)	321 (9)	451 (6)	163 (3)	201	6	119	6
Second Branch	16	Royalton	Mouth of Second Branch	167 (9)	196 (4)	146 (5)	240 (9)	409 (4)	157 (5)	281 (9)	1591 (2)	171 (7)	383 (9)	712 (5)	177 (4)	309 (9)	482 (3)	248 (6)	390 (9)	715 (6)	116 (3)	691 (9)	1350 (6)	181 (3)	352	2	171	3
	17	Randolph	Dugout Road	169 (9)	210 (4)	139 (5)	309 (9)	766 (4)	149 (5)	300 (9)	947 (2)	216 (7)	496 (9)	1376 (5)	139 (4)	213 (9)	500 (3)	139 (6)	365 (9)	662 (6)	111 (3)	1086 (8)	1502 (6)	410 (2)	420	1	186	1
	18	Brookfield	Sunset Lake	8 (7)	15 (3)	8 (4)	25 (7)	41 (4)	13 (3)	7 (9)	40 (2)	4 (7)	15 (9)	23 (5)	8 (4)	8 (8)	28 (3)	4 (5)	17 (6)	106 (3)	3 (3)	17 (6)	49 (4)	2 (2)	14	21	6	22
Third Branch	19	Bethel	Mouth of Third Branch	73 (9)	68 (4)	87 (5)	103 (9)	177 (4)	67 (5)	98 (9)	650 (2)	57 (7)	202 (9)	383 (5)	91 (4)	231 (9)	735 (3)	130 (6)	148 (9)	350 (6)	26 (3)	398 (8)	957 (5)	92 (3)	179	7	79	8
	20	Bethel	Stock Farm Road	130 (9)	235 (4)	89 (5)	172 (9)	315 (4)	105 (5)	194 (9)	652 (2)	137 (7)	312 (9)	484 (5)	180 (4)	359 (9)	738 (3)	251 (6)	177 (8)	453 (5)	37 (3)	300 (9)	674 (6)	60 (3)	235	4	123	4
	21	Randolph	Randolph Rec Park	59 (9)	82 (4)	53 (5)	81 (9)	126 (4)	57 (5)	94 (9)	591 (2)	56 (7)	52 (9)	56 (5)	48 (4)	66 (9)	109 (3)	51 (6)	78 (9)	138 (6)	25 (3)	134 (9)	318 (6)	24 (3)	81	15	45	13
	22	Braintree	Riford Brook Road	134 (9)	184 (4)	126 (5)	233 (9)	410 (4)	148 (5)	327 (9)	1218 (2)	225 (7)	74 (9)	52 (5)	115 (4)	62 (9)	72 (3)	58 (6)	61 (9)	89 (6)	28 (3)	171 (9)	304 (6)	54 (3)	152	9	108	7

Rank is based on relationship to 22 long-term monitoring sites spread throughout the White River basin

Appendix 4- 2018 QA/QC - LaRosa Partnership Final Report

This appendix summarizes QA/QC measures conducted to satisfy provisions of the 2018 QAPP for LaRosa Partnership Volunteer Monitoring Analytical Services and Organizational Support Grant sampling conducted by the White River Partnership in 2018 on the First, Second and Third Branches of the White River. The final report was submitted under separate cover according to the Spatial Trend Template introduced by VTDEC in 2017 as part of a suite of templates for more standardized reporting (WRP-LaRosa_SpatialTrend2018_1st-3rdBr).

Table 7c – Project Completeness

Parameter	Number of Samples Anticipated**	Number of Valid Samples Collected & Analyzed	Percent Complete *
Chlorophyll-*a*			
Chloride			
Total and Dissolved Phosphorus	58	58	100%
E. coli			
Total Suspended Solids			
Transparency			
Alkalinity			
pH			
Turbidity			
Total nitrogen (persulfate digestion)	58	58	100%
Total NOx			
Si, dissolved			
Dissolved Oxygen			
Conductivity			
Temperature			

* Percent Complete = # of Valid Samples Collected and Analyzed / # of Samples Anticipated

** Includes field duplicates and blanks; 5 of each (48 samples x 10% = 4.8)

Quality Assurance Results

For quality assurance we collected 5 blanks for each of 2 parameters, for a total of 10 blanks (48 total samples: 48 samples x 2 parameters = 96 samples; 10 blanks = 10.4%).

The quality of the data collected can be calculated using the average blank concentration, by parameter (should be close to Reporting Limit for each parameter). The results are listed below.[1]

Average Blank Concentration by Parameter

Parameter	Average Blank Samples	Parameter Reporting Limit
Total Nitrogen (TN)	<0.1 mg/L	0.1 mg/L
Total Phosphorus (TP)	<5 µg/L	5 µg/L

Sample	Location	Date	Test	Sym-bol	Results	Units	Remark
181108-05	TFD-BLANK	6/20/2018	Nitrogen,Total-Persulfate	<	0.1	mg/L	
181305-05	AYB-BLANK	7/11/2018	Nitrogen,Total-Persulfate	<	0.1	mg/L	
181348-07	C2M-BLANK	7/18/2018	Nitrogen,Total-Persulfate	<	0.1	mg/L	
181492-03	FBU-BLANK	8/1/2018	Nitrogen,Total-Persulfate	<	0.1	mg/L	
181492-11	HMU-BLANK	8/1/2018	Nitrogen,Total-Persulfate	<	0.1	mg/L	
Average			Nitrogen,Total-Persulfate	<	0.1	mg/L	

181108-05	TFD-BLANK	6/20/2018	Phosphorus - Digested	<	5	ug P/L	
181305-05	AYB-BLANK	7/11/2018	Phosphorus - Digested	<	5	ug P/L	
181348-07	C2M-BLANK	7/18/2018	Phosphorus - Digested	<	5	ug P/L	
181492-11	HMU-BLANK	8/1/2018	Phosphorus - Digested	<	5	ug P/L	
181492-03	FBU-BLANK	8/1/2018	Phosphorus - Digested	<	5	ug P/L	
Average			Phosphorus - Digested	<	5	ug P/L	

[1] Parameter Reporting Limits and Estimated Precision for Field Duplicates are from Table 7B – Primary Laboratory Analysis Protocols for Water Samples of the Vermont General Quality Assurance Project Plan (QAPP) for Volunteer, Educational and Local Community Monitoring and Reporting Activities (VT Department of Environmental Conservation). Table 7B is included at end of this QA/QC appendix).

To assess the precision of results for duplicate samples, the "Mean Relative Percent Difference" between field duplicate samples was calculated. The average RPD should be less than or equal to the Estimated Precision listed in Table 7b of the project QAPP[1]. This simple measure is calculated as follows:

RPD field duplicate pair 1 = absolute value (sample1-sample2) / average (sample1 and sample2);

and,

The Mean RPD for "n" duplicate pair = average (RPD pair 1 + RPD pair 2 + ... + RPD pair n)

Mean Relative Percent Difference (RPD) by Parameter

Parameter	Mean RPD	Estimated Precision for Field Duplicates
Total Nitrogen (TN)	3.0%	≤20%
Total Phosphorus (TP)	5.7%	≤30%

Sample Number	Location	Date	Test	Result	Unit	REG	RPD
181108-04	TFD-DUP	6/20/2018	Nitrogen, Total - Persulfate	0.21	mg/L	0.22	4.7%
181305-04	AYB-DUP	7/11/2018	Nitrogen, Total - Persulfate	0.46	mg/L	0.45	2.2%
181348-06	C2M-DUP	7/18/2018	Nitrogen, Total - Persulfate	0.26	mg/L	0.24	8.0%
181492-02	FBU-DUP	8/1/2018	Nitrogen, Total - Persulfate	0.13	mg/L	0.13	0.0%
181492-10	HMU-DUP	8/1/2018	Nitrogen, Total - Persulfate	0.48	mg/L	0.48	0.0%
Average							3.0%

181108-04	TFD-DUP	6/20/2018	Phosphorus - Digested	13.7	ug P/L	11.9	14.1%
181305-04	AYB-DUP	7/11/2018	Phosphorus - Digested	11.4	ug P/L	11.3	0.9%
181348-06	C2M-DUP	7/18/2018	Phosphorus - Digested	11.9	ug P/L	12.5	4.9%
181492-02	FBU-DUP	8/1/2018	Phosphorus - Digested	6.39	ug P/L	5.93	7.5%
181492-10	HMU-DUP	8/1/2018	Phosphorus - Digested	10.8	ug P/L	10.7	0.9%
Average							5.7%

Table 7b – Primary Laboratory Analysis Protocols for Water Samples:

Parameter	Reporting Limit [A]	Accuracy [B] (% Recovery)	Estimated Precision for Field Duplicates [C] (RPD)	Laboratory Precision (RPD)	Analytical Method Reference [B]
Chlorophyll-*a*	0.5 ug/l	--	≤15%	10%	EPA 445.0
Total and dissolved phosphorus	5 μg/l	85-115%	≤30%	15% [B]	*Std. Methods* (21st ed.) 4500-P H
E. coli [D, E]	1 MPN /100ml	N/A	125% (<25cfu) 50% (>25 mpn)	125% (<25cfu) 75% (>25 mpn)	*Std. Methods* (21st ed.) 9223 (Colilert)
Chloride (Cl)	2 mg/l	85-110%	≤ 5%	≤ 5%	*Std. Methods* (21st ed.) 4500-Cl G
Total Suspended Solids (TSS)	1 mg/l	80-120%	≤15%	≤ 15%	*Std. Methods* (21st ed.) 2540D
Turbidity	0.2 NTU	N/A	≤ 15%	≤15%	EPA 180.1
Alkalinity	1 mg/l	N/A	≤5% (>20 mg/l) <15% (<20 mg/l)	≤5% (>20 mg/l) <15% (<20 mg/l)	*Std. Method*s (21st ed.) 2320B
Total nitrogen (TN) (persulfate digestion)	0.1 mg/l	85%-115%	≤20%	≤10%	*Std. Methods* (21st ed.) 4500-N C
Total NOx	0.05 mg/l	85%-110%	≤10%	≤5%	EPA 353.2

(A) - Reporting Limit is the minimum reported value (lowest standard in calibration curve or MDLx3)

(B) - Section 5.0, Vermont Dept. of Conservation Laboratory QA Plan, 2008

(C) - Generated by the analysis of field duplicates

(D) - EPA's New England Regional Laboratory recommends that all samples resulting in Too Numerous to Count (TNTC) growth, defined as greater than 200 colonies on the membrane filter, be recorded as "TNTC."

(E) -As a quality control check on bacteria counts, if two or more analysts are available, each should count colonies on the same membrane plate for about 10% of the samples, and agree on the # of colonies within 10%.