Western Virginia Water Authority
Roanoke River Impact Study

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EXECUTIVE SUMMARY

Western Virginia Water Authority (Authority) of Roanoke, Virginia retained the professional services of Biological Monitoring, Inc. (BMI) to address water quality impairments in the Roanoke River. The Virginia Department of Environmental Quality (VADEQ) classified numerous Roanoke River segments as being impaired for the Aquatic Life General Standard. Initially, DEQ believed that nitrogen discharges from the Authority WPC plant may be contributing to impairments downstream.

Total Maximum Daily Loads (TMDLs) had been previously implemented for the general standard (Aquatic Life) for sections of the river immediately upstream of WVWA. Specifically, the TMDL related to benthic impairment identified sediment as the stressor and the study prescribed reductions needed to attain the Aquatic Life use (Louis Berger 2006).

Potential sources of existing data were identified and subsequently reviewed. Sources identified for use included: American Electric Power (AEP) data, VADEQ benthic data, and VADEQ chemistry data. Relevant publications, including those generated by VADEQ, were also assessed. The study plan for this project included literature searches. In addition, ambient toxicity testing, and field sampling (benthic macroinvertebrates, physicochemical parameters, and chemistries) were conducted characterizing relevant sections of the Roanoke River.

Ambient aquatic toxicity was exhibited by samples collected both immediately upstream of WVWA (River Mile 202.20) and downstream at VADEQ's probabilistic river location (River Mile 198.08) during high flow events. This may indicate that both stations have the same stressor.

The individual metrics used to develop the Virginia Stream Condition Index (VSCI), as used to determine compliance with the Aquatic Life Designated Use, were assessed using, for example, box and whisker plots and other analytic tools. These metrics all have an expected response to perturbation (e.g., Richness metric would decrease with increased

stress). Boxplot interquartile ranges for every metric overlapped, implying that the stressor is likely the same at Stations 198.08 and 202.20.

Downstream of the WVWA discharge is a stream (Tinker Creek) that merges with the Roanoke River upstream of the station in question (River Mile 198.08) that demonstrated ambient toxicity. In addition, three of the metrics (Richness, EPT Richness, and % Mayflies) indicated that Tinker Creek is negatively influencing Station 198.08. Furthermore, Nitrogen concentration did not vary with impairment. Therefore, nitrogen is not likely the stressor at River Mile 198.08. Modeling work further studying the influence of Nitrogen is presented in a separate report and draws the same conclusion.

The Roanoke River is clearly impaired (Aquatic Life Standard) from Station 198.08 upstream to at least the Wasena Park area (Figure 1 WPU and WPD). It seems most probable that the same stressor is responsible for the impairment observed in this entire reach.

Study Conclusions:

1. The analysis of existing data and the data developed in other field studies, including the extensive study conducted by BMI found all sampling stations (both above and below the Regional WPCP) to be impaired.
2. Comparison of all available data supports the same stressor is likely causing impairment in both segments of the Roanoke River and that stressor is likely not nitrogen.
3. Any difference between station 198 and 202 likely related to the contribution from Tinker Creek.

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5.0 INTRODUCTION

Biological Monitoring, Inc. (BMI) of Blacksburg, Virginia was retained by Western Virginia Water Authority (WVWA) to conduct a supplemental TMDL study for a section of the Roanoke River. The purpose of this study was to evaluate potential stressors in a specific section of the Roanoke River.

WVWA discharges wastewater to the Roanoke River via Virginia Pollutant Discharge Elimination System (VPDES) permit # VA0025020. Sections of the Roanoke River are listed as impaired for the general standard (Aquatic Life) as measured by benthic macroinvertebrate analyses.

Total Maximum Daily Loads (TMDLs) have been implemented for the general standard (Aquatic Life) for sections of the river upstream of WVWA (DEQ 1996). These TMDLs identified sediment as the stressor responsible for impairment and prescribed reduction needed to attain the Aquatic Life use.

The study reviews DEQ's hypothesis that the section of river below the WVWA discharge (Station 4AROA198.08) has a different stressor from the section upstream of WVWA (Station 4AROA202.20). In addition to the influence of the WVWA discharge, Station 198 is likely influenced by other factors (e.g., Tinker Creek, three unlined landfills, etc.).

Tinker Creek flows into the Roanoke River between 4AROA198.08 and 4ROA202.20 and below the WVWA discharge. Tinker Creek is also listed as not attaining the aquatic life use standard. Unlined landfills, shown as points of interest in Figure 1, cannot be ruled out as potential stressors.

Potential sources of existing data were identified and subsequently reviewed. Sources that were identified for potential use included: AEP data, DEQ benthic data, and DEQ chemistry data.

The field portion of the project began with a reconnaissance visit to observe the river and the stations associated with monitoring. In addition, trips were made to the river to observe the section of the river from mile marker 198.08 (Explore Park) upstream to approximately the Cook Drive section. A sampling plan was developed from these preliminary efforts.

BMI developed a study plan consisting of a review of pertinent data, benthic macroinvertebrate sampling, and ambient toxicity testing. Data evaluations were conducted spatially and temporally to determine the extent of impairment. In addition, analyses were conducted to determine the similarity of stressors impacting the benthic community.

The2emainning portions of this document present the methods used, results obtained, and conclusions drawn from these analyses.

2.0 METHODS AND MATERIALS

5.0 General

Stations for sampling were researched prior to sampling. Stations were selected based on current DEQ data as well as the objectives of the study. Instream stations were sampled for physicochemical parameters as well as the macroinvertebrate benthic populations. Samples were collected from both Fall 2022 and Spring 2023. Each season, two samples were collected from each station. The first sample collection date was 10/24/22. Five samples were collected. Subsequently, a station was added to include Tinker Creek (TC1). The second fall sample was collected on 11/28/23. The samples collected in the spring were sampled on 3/21/23 and 5/8/23.

Grab samples were collected for physicochemical analyses. Macroinvertebrate samples were collected following BMI's Biological Monitoring Program Quality Assurance Project Plan for Wadeable Streams and Rivers as approved by the Virginia Department of Environmental Quality (BMI 2012). The Virginia Stream Condition Index (VASCI) protocol was used for these instream biological surveys (Tetra Tech 2003). The US EPA's Rapid Bioassessment Protocols for use in Wadeable Streams and Rivers (RBP) was used for sampling macroinvertebrate populations and performing habitat assessments (USEPA 1999). Qualitative habitat assessments were conducted at each bioassessment site by trained and experienced scientists.

5.0 Station Location

Six instream monitoring stations were identified for this project. Station locations were determined based on available data, reconnaissance, and the objectives of the study. Latitude and longitude coordinates were recorded at the downstream boundary of each

station using a Garmin® Global Positioning System portable unit (GPSMAP 60 CSX). Table 1 summarizes the monitoring station attributes. Figure 1 provides a map of the area and the location of the monitoring stations. Station photographs are presented as Appendix A.

Table 1. Monitoring Station Attributes.

Station ID	Location Summary	Latitude	Longitude
4AROA198.08	Roanoke River at Explore Park	37º 51.60550'	079º 51.60550'
4ATKR000.69	Tinker Creek	37º 16.47500'	079º 54.41500'
4AROA202.20	Roanoke River at 13th Street Bridge	37º 15.83352'	079º 54.90912'
WPD	Roanoke River at Downstream Wasena Park	37º 16.01262'	079º 57.40626'
WPU	Roanoke River at Upstream Wasena Park	37º 16.05918'	079º 58.03632'
CD1	Roanoke River at Cook Drive	37º 16.11100'	080º 01.49400'

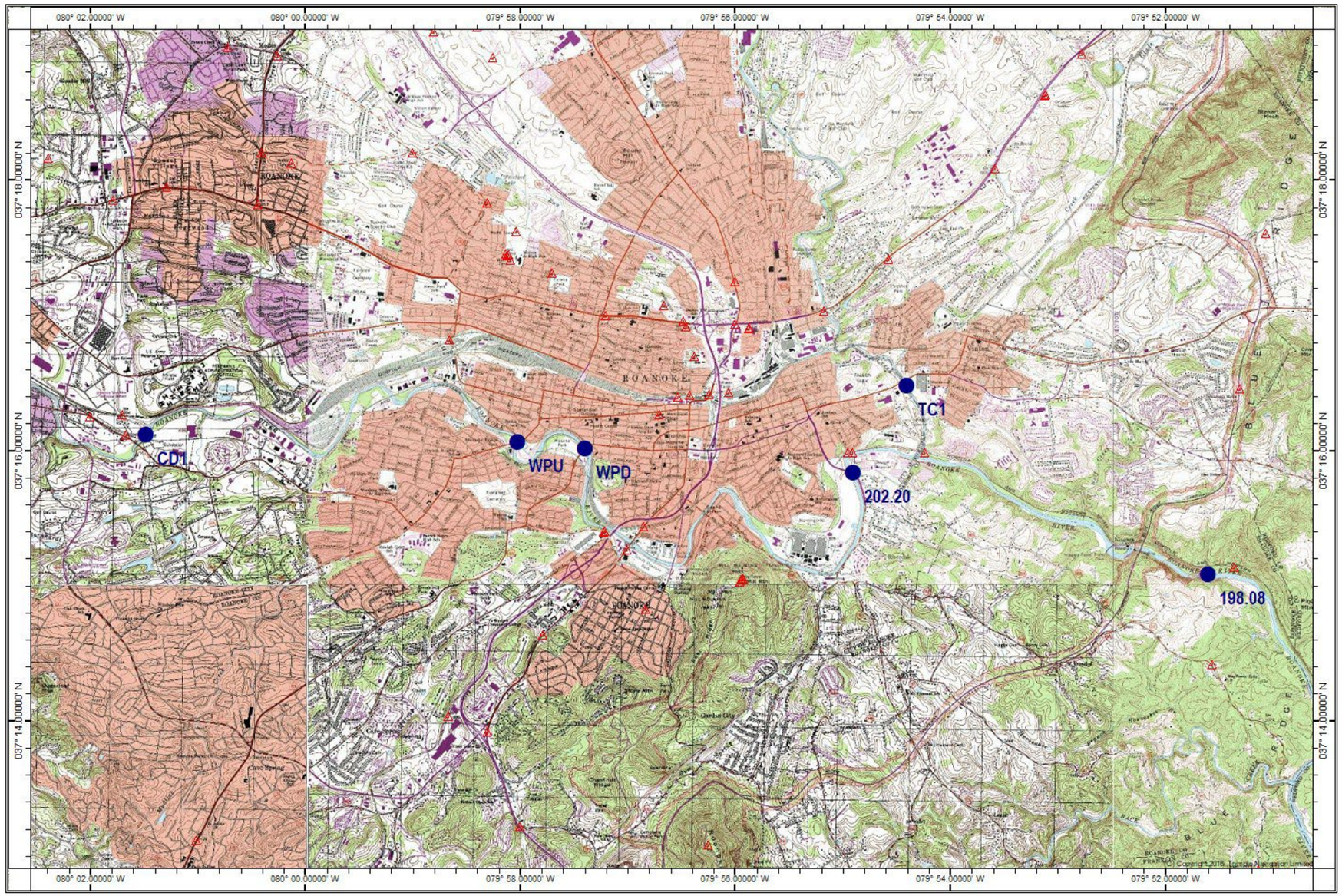

Figure 1. Map of the Monitoring Stations.

2.3 Macroinvertebrate Sampling & Assessment

2.3.1 Sampling & Identification

All biological sampling was performed in accordance with the Virginia Department of Wildlife Resources (DWR) scientific collection permit requirements. Macroinvertebrates were collected at each benthic station following the single habitat approach (riffle-run) as presented in the QAPP (BMI 2012). Samples were collected using a semi-quantitative approach.

Four samples were collected at each station using a 0.50 m wide rectangular kick-net having a 500 µm mesh size. Each sample was collected by first placing the net on the bottom downstream of the 0.50 m^2 area to be sampled. Where appropriate, large rocks and debris were brushed off into the net and removed. The area to be sampled was then vigorously kicked for approximately 30 to 90 seconds or to the Best Professional Judgment of the scientist. For each monitoring station, the four samples were rinsed, composited, placed in a labeled container, and preserved in 70% ethanol. Sample information was recorded on a BMI Sample Chain of Custody Form and returned to BMI's laboratory for enumeration and identification.

Organisms were separated from the debris in the laboratory. Subsampling was performed on each sample to a standard count of 200 ± 10%. All organisms were identified to the lowest practicable level. Organism identification utilized the appropriate taxonomic keys (Merritt, Cummins, and Berg 2019). All data analysis was performed at the family level as required by the Virginia Stream Condition Index (VASCI). All organisms from this study will be retained for a period of at least five years.

Quality control checks were made for both sorting and identification. At least 10% of samples were evaluated for sorting from each season. Likewise, at least 10% of samples were identified by a second qualified analyst.

2.3.2 Macroinvertebrate Data Assessment

Macroinvertebrate data were analyzed using *A Stream Condition Index for Virginia Non-Coastal Streams* (Tetra Tech 2003). This VASCI was developed from an analysis of data collected by the Virginia DEQ from 1994 to 1998 and 1999 to 2002. Using these data, VASCI designated statewide reference values were determined for each of the following eight metrics of community structure:

- **Total Number of Taxa** measures the total number of distinct taxa and, therefore, is representative of the diversity within a sample. High diversity is a strong indicator of stream health and ability to sustain populations. This metric value is expected to decrease in response to increased perturbation.

- **Total Number of EPT Taxa** is a measure of the total number of distinct taxa within the Orders Ephemeroptera, Plecoptera, and Trichoptera. These orders include the mayflies, stoneflies, and caddis flies, respectively. Organisms in these three orders have low tolerances to perturbation. As a result, the value of the metric is expected to decrease in response to increasing perturbation.

- **Percent Ephemeroptera** is the percentage of individual Ephemeroptera (mayflies) within a sample. This metric is calculated by dividing the number of Ephemeroptera by the total number of sample organisms. This metric indicates the relative abundance of this sensitive order within the stream community. The value of this metric is expected to decrease in response to increasing perturbation.

- **Percent P T Less Hydropsychidae** is the percentage of individuals from the orders Plecoptera and Trichoptera "less" the individuals from the family Hydropsychidae. This metric is calculated by dividing the number of organisms from the orders Plecoptera and Trichoptera (less Hydropsychidae) by the total number of sample organisms. This metric

indicates the relative abundance of these sensitive orders within the stream community. The value of this metric is expected to decrease in response to increasing perturbation.

- **Percent Scrapers** is percent abundance of individuals in the sample whose primary functional mechanism for obtaining food is to graze on substrate or periphyton, attached algae and associated material within a sample. This metric is calculated by dividing the number of organisms from the functional feeding group "scrapers" by the total number of sample organisms. The value of this metric is expected to decrease in response to increasing perturbation.

- **Percent Chironomidae** is the percent individual organisms of the Family Chironomidae within a sample. The metric is calculated by dividing the number of Chironomidae organisms by the total number of sample organisms. Family Chironomidae, the midges, are tolerant to perturbation and their relative abundance tends to increase in impacted streams. As a result, the value of this metric is expected to increase in response to increasing perturbation.

- **Percent Two Dominant Taxa** is the percentage of total individuals in the two taxa with the greatest number of organisms. The metric is calculated by adding the number of organisms present in the two largest taxa. Dividing this sum by the total number of organisms yields the relative abundance of the two dominant taxa. Samples with populations concentrated into a few taxa may be an indication of impact. This metric is expected to increase in response to increasing perturbation.

- **Hilsenhoff Biotic Index** (HBI) was originally designed to evaluate organic pollution by utilizing tolerance values to weight taxa abundance. The resulting HBI value is an estimation of overall pollution level. The metric is expected to increase in response to increasing perturbation.

The VASCI metrics and their expected response to perturbation are summarized in Table 2.

Table 2. VASCI Metrics and Expected Responses.

Metric	Expected Response
Total Number of Taxa	Decrease
Total Number of EPT Taxa	Decrease
Percent Ephemeroptera	Decrease
Percent PT Less Hydropsychidae	Decrease
Percent Scrapers	Decrease
Percent Chironomidae	Increase
Percent Two Dominant Taxa	Increase
Hilsenhoff Biotic Index	Increase

VASCI scores for each of the monitoring stations were calculated by dividing each station's metric values by the corresponding VASCI statewide reference values. This yielded a percentage score for each metric relative to the statewide reference condition. If the percentage score of any individual metric was greater than 100, the score was truncated to 100. The eight resulting values were then averaged to arrive at the VASCI score for each station.

2.4 Habitat Assessment

Habitat assessments were performed at each benthic station where macroinvertebrates were collected. Ten habitat parameters were assessed, each receiving a score of 0 – 20. These assessments include obvious physical alterations such as human land usage, vegetation degradation and removal, man-made structures such as dams, or anything that may alter the flow or ecosystem of the stream significantly. Measurements for the water quality included the temperature, amount of dissolved oxygen, conductivity, and pH. Other noted features included sediment composition, channel flow status, canopy cover and primary land use on both left and right banks. These assessments were performed as per the RBP (USEPA 1999). A description of each of the habitat parameters follows:

- **Epifaunal Substrate / Available Cover** rate the availability of structures in the stream that can be utilized as refuge, spawning, and feeding sites by macroinvertebrates. Examples of such structures would include boulders, cobble, undercut banks, roots, logs and branches. The availability of cover can be a limiting factor on stream diversity and abundance.

- **Embeddedness** rate the degree to which coarse substrate such as gravel; cobble and boulders are sunken into the sand, silt and mud substrate of the stream bottom. Embeddedness is the result of sediment movement and deposition. Increased embeddedness reduces the available refuge, feeding and spawning sites available to macroinvertebrates resulting in lower diversity and abundance.

- **Velocity / Depth Regimes** gauge the presence or absence of four velocity-depth patterns. These patterns are slow-deep, slow-shallow, fast-deep, and fast-shallow. Ideally, all four patterns should be present to best provide a stable diverse stream community.

- **Sediment Deposition** rates the degree to which new sediment has accumulated in pools, point bars and islands. Sediment deposition may be an indicator of an unstable environment and lowered diversity.

- **Channel Flow Status** rates the degree to which water fills the stream channel. Channel flow status may be affected by obstructions, diversions or widening of the stream channel. As less of the channel is filled by water, the amount of suitable substrate is also reduced.

- **Channel Alteration** rate the degree to which the shape of the stream channel has been altered. Alterations may include bridges, roads, diversion channels, channel straightening, artificial embankments, riprap, dams, weirs, and other instream structures. Channel alteration often results in scouring and loss of available habitat.

- **Frequency of Riffles (or Bends)** rates the presence of quality riffle or sinuous habitat. Riffles and sinuous streams provide quality habitat for stable, diverse communities.

- **Bank Stability** indicates the degree to which banks have eroded or may erode. Eroded banks are a sign of sediment movement and deposition, which leads to reduced epifaunal habitat. Unstable banks may also point to poor vegetative cover.

- **Bank Vegetative Protection** gauges the extent of vegetative protection at the stream bank and the nearby riparian zone. Bank vegetation plays a vital role in erosion control, nutrient uptake, stream shading, and food supply.

- **Riparian Vegetative Zone Width** measures the extent of natural vegetation from the stream through the riparian zone. Wide vegetative zones provide pollution buffering, erosion control, habitat, nutrient uptake and nutrient input. These beneficial contributions can be impaired by commercial and residential development, roads, pastures, actively worked fields, etc.

Table 3 identifies each of the ten Habitat Assessment Parameters and their range of scores. Scores for each parameter were recorded on Habitat Assessment Field Log Sheets (USEPA 1999). The habitat assessment score for each station was calculated by adding the score for each parameter

yielding a station total. The highest attainable score was 200. The actual habitat assessment process involves rating the ten parameters as optimal (>153), suboptimal (101-153), marginal (46-100), or poor (<45).

Table 3. Habitat Assessment Parameters

Parameter	Description	Scoring
1	Epifaunal Substrate / Available Cover	0-20
2	Embeddedness	0-20
3	Velocity / Depth Regime	0-20
4	Sediment Deposition	0-20
5	Channel Flow Status	0-20
6	Channel Alteration	0-20
7	Frequency of Riffles or Bends	0-20
8	Bank Stability	Left 0-10
		Right 0-10
9	Vegetative Protection	Left 0-10
		Right 0-10
10	Riparian Vegetative Zone Width	Left 0-10
		Right 0-10

2.5 Physicochemical Assessment

Prior to any field data collections, all handheld meters were calibrated. Conductivity (µS), pH (SU) and temperature (°C) were recorded at each of the sample stations. The field meter used was an OAKTON PCTS 50 combination pH/EC/TDS/Temperature Meter.

2.6 Ambient Toxicity Testing

BMI is an accredited laboratory through The NELAC Institute (TNI # VA460015). Ambient toxicity testing was performed at two of the benthic stations (198.08 and 202.20). Ambient testing included Short Term Chronic testing with *Ceriodaphnia dubia* and *Pimephales promelas*. These are the standard indicator tests used for Whole Effluent Toxicity (WET) testing required in WVWA's VPDES discharge permit.

Ambient samples were collected during high-flow events. Testing was conducted following EPA guidelines (US EPA 2002). Testing events were conducted three times. Test start dates were 11/11/22, 2/14/23, and 5/2/23.

2.7 Outside Data Sources

Benthic data collected by BMI were designed to augment data collected by the Virginia Department of Environmental Quality (DEQ). In addition, a study conducted as part of the license renewal process for American Electric Power's (AEP) Niagara Dam was also considered. AEP's Niagara Dam is located below the WVWA discharge but above Station 198.08. These data were obtained electronically by BMI and evaluated for use to evaluate the benthic impairment observed in the Roanoke River.

Nitrogen data were obtained from DEQ electronically. These data were used to evaluate Nitrogen's contribution to benthic impairment.

2.8 Data Presentation

Several methods were used to present / analyze both the collected and external data sources. These methods evaluated spatial and temporal patterns in the data. Spatial comparisons determined an estimate of the extent of impairment. Spatial and temporal evaluations were used to determine whether the source of impairment was similar amongst sites.

Benthic VSCI scores were plotted by station over time. Trend lines were added to the charts for evaluation. BMI collected benthic data VSCI scores were presented as bar graphs. Individual metrics that make up the VSCI scores were plotted on box and whisker plots. A stressor analysis (regression) was used to evaluate nitrogen's potential contribution to impairment. Chemistry data (Total Nitrogen) were plotted against VSCI scores and presented as a regression analysis.

3.0 RESULTS

3.1 BMI Station Location

Station attributes, including latitudes and longitudes are presented in Table 1 and depicted in Figure 1. Station photographs are presented in Appendix A. Flow was adequate for sampling at all stations.

5.0 BMI Macroinvertebrate Monitoring Data

3.2.1 Virginia Stream Condition Index Metrics

The raw data are summarized in Appendix B. The VASCI metric values for the monitoring stations 198.08, 202.20, and TKR0.69 are summarized in Tables 4 – 7..

Table 4. VASCI Metrics Sampled on 10/24/2022 & 11/07/2022

	198.08	TKRO.69	202.20	WPD	WPU	CD1
Total Taxa	17	15	14	12	14	15
EPT Taxa	5	7	6	4	6	7
%Ephemeroptera	12.15	2.56	5.63	2.48	6.82	8.22
%Plec+Tric less Hydropsych.	1.7	4.6	4.8	1.0	2.7	3.2
%Scrapers	33.70	27.18	50.65	90.1	75.45	59.36
%Chironomidae	10.50	29.23	31.60	1.49	2.73	7.31
% Top 2 Dominant	39.23	55.90	62.34	81.19	68.64	51.60
HBI (Family)	5.33	5.30	4.70	4.12	4.28	4.41

Table 5. VASCI Metrics Sampled on 11/28/2022

	198.08	TKRO.69	202.2	WPD	WPU	CD1
Total Taxa	13	11	11	9	13	12
EPT Taxa	4	3	4	3	6	8
%Ephemeroptera	9.36	2.45	2.09	0	9.90	7.62
%Plec+Tric less Hydropsych.	0	1.8	12.6	2.3	17.2	3.6
%Scrapers	62.13	50.92	44.50	70.59	52.60	80.72
%Chironomidae	24.68	19.63	37.70	16.74	20.31	3.59
% Top 2 Dominant	61.28	58.90	73.30	71.04	54.17	77.13
HBI (Family)	4.68	4.71	4.52	4.52	4.12	4.08

Table 6. VASCI Metrics Sampled on 3/21/2023

	198.08	TKRO.69	202.2	WPD	WPU	CD1
Total Taxa	14	8	13	14	14	11
EPT Taxa	4	2	4	4	7	4
%Ephemeroptera	1.46	1.98	3.3	12.56	18.27	13.04
%Plec+Tric less Hydropsych.	1	1	0.5	0	1.5	0
%Scrapers	58.74	42.57	77.36	61.40	48.73	65.70
%Chironomidae	23.79	41.58	13.68	11.63	17.26	10.63
% Top 2 Dominant	57.28	65.35	84.91	66.51	56.35	62.32
HBI (Family)	5.41	6.42	4.41	4.36	5.11	4.62

Table 7. VASCI Metrics18.27 Sampled on 5/10/2023

	198.08	TKRO.69	202.2	WPD	WPU	CD1
Total Taxa	148.733	11	13	15	11	17
EPT Taxa	5	4	5	8	6	7
%Ephemeroptera	8.89	6.08	9.74	3.70	10.29	14.59
%Plec+Tric less Hydropsych.	0	1.1	1.5	4.8	1.0	1.1
%Scrapers	50.56	32.60	72.31	71.96	67.16	55.68
%Chironomidae	17.78	28.73	7.18	2.65	5.88	8.65
% Top 2 Dominant	49.44	51.93	70.77	66.14	70.59	57.30
HBI (Family)	5.43	6.07	4.59	4.17	4.32	4.76

3.2.2 BMI Virginia Stream Condition Index Scores

Tables 8 through 11 present summaries of the VASCI scoring from each event. Each metric score represents a percentage of the statewide reference condition. The VASCI scores calculated for these stations ranged from 37.68 (TKR0.69, 3/21/2023) to 63.81 (WPU, 11/28/2022).

Table 8. VASCI Scoring Sampled on 10/24/2022 & 11/07/2022

	198.08	TKRO.69	202.2	WPD	WPU	CD1
Total Taxa	77.27	68.18	63.64	54.55	63.64	68.18
EPT Taxa	45.45	63.64	54.55	36.36	54.55	63.64
%Ephemeroptera	19.83	4.18	9.18	4.04	11.12	13.41
%Plec+Tric less Hydropsych.	4.66	12.96	13.38	2.78	7.66	8.98
%Scrapers	65.31	52.67	98.16	100	100	100
%Chironomidae	89.50	70.77	68.40	98.51	97.27	92.69
% Top 2 Dominant	87.82	63.73	54.43	27.18	45.32	69.94
HBI (Family)	68.63	69.18	77.89	86.54	84.16	82.17
VASCI	**57.31**	**50.66**	**54.95**	**51.25**	**57.97**	**62.38**

Table 9. VASCI Scoring Sampled on 11/28/2022

	198.08	TKRO.69	202.2	WPD	WPU	CD1
Total Taxa	59.09	50.00	50.00	40.91	59.09	54.55
EPT Taxa	36.36	27.27	36.36	27.27	54.55	72.73
%Ephemeroptera	15.27	4.00	3.42	0	16.14	12.44
%Plec+Tric less Hydropsych.	0	5.17	35.30	6.36	48.28	10.08
%Scrapers	100	98.68	86.25	100	100	100
%Chironomidae	75.32	80.37	62.30	83.26	79.69	96.41
% Top 2 Dominant	55.96	59.40	38.59	41.85	66.23	33.05
HBI (Family)	78.26	77.76	80.54	80.65	86.52	87.03
VASCI	**52.53**	**50.33**	**49.09**	**47.54**	**63.81**	**58.28**

Table 10. VASCI Scoring Sampled on 3/21/2023

	198.08	TKRO.69	202.2	WPD	WPU	CD1
Total Taxa	63.64	36.36	59.09	63.64	63.64	50.00
EPT Taxa	36.36	18.18	36.36	36.36	63.64	36.36
%Ephemeroptera	2.38	3.23	5.39	20.49	29.81	21.28
%Plec+Tric less Hydropsych.	2.73	0	1.32	0	4.28	0
%Scrapers	100	82.51	100	100	94.44	100
%Chironomidae	76.21	58.42	86.32	88.37	82.74	89.37
% Top 2 Dominant	61.73	50.08	21.81	48.39	63.09	54.45
HBI (Family)	67.46	52.68	82.20	83.00	71.98	79.10
VASCI	**51.31**	**37.68**	**49.06**	**55.03**	**59.20**	**53.82**

Table 11. VASCI Scoring Sampled on 5/10/2023

	198.08	TKRO.69	202.2	WPD	WPU	CD1
Total Taxa	59.09	50.00	59.09	68.18	50.00	77.27
EPT Taxa	45.45	36.36	45.45	72.73	54.55	63.64
%Ephemeroptera	14.50	9.91	15.89	6.04	16.79	23.81
%Plec+Tric less Hydropsych.	0	3.10	4.32	13.38	2.75	3.04
%Scrapers	97.98	63.17	100	100	100	100
%Chironomidae	82.22	71.27	92.82	97.35	94.12	91.35
% Top 2 Dominant	73.06	69.46	42.24	48.98	42.50	61.71
HBI (Family)	67.23	57.73	79.56	85.78	83.51	76.99
VASCI	**54.94**	**45.13**	**54.92**	**61.55**	**55.53**	**62.23**

3.3 BMI Habitat Assessment

Tables 12 through 15 present summaries of the habitat assessment scores for the monitoring stations. Raw data are presented in Appendix B. The habitat assessment scores calculated ranged from 113 (TKR0.69, 11/28/22) to 173 (198.08, 10/24/22).

Table 12. RBP Habitat Scoring 10/24/2022 & 11/07/2022

Parameter	198.08	TKR0.69	202.20	WPD	WPU	CD1
Subst./Cover	18	17	17	18	17	19
Embeddedness	15	9	13	10	13	12
Velocity	18	19	16	19	19	19
Sediment Dep.	13	6	19	8	11	13
Channel Flow	19	16	19	16	18	16
Channel Alt.	16	12	14	12	11	12
Freq of Riffles	18	14	17	15	14	19
Bank Stab L	9	7	10	10	10	7
Bank Stab R	9	4	10	10	9	5
Veg. Prot. L	10	9	7	9	9	6
Veg. Prot. R	9	9	9	8	8	6
Rip. Zone L	10	1	2	2	2	4
Rip. Zone R	9	2	2	1	2	1
Total	**173**	**125**	**155**	**138**	**143**	**139**

Table 13. RBP Habitat Scoring 11/28/2022

Parameter	198.08	TKR0.69	202.20	WPD	WPU	CD1
Subst./Cover	19	16	18	19	18	18
Embeddedness	16	12	13	14	14	15
Velocity	19	10	19	19	19	18
Sediment Dep.	14	9	13	9	11	12
Channel Flow	18	15	19	15	14	15
Channel Alt.	17	9	8	10	10	11
Freq of Riffles	16	16	18	17	18	19
Bank Stab L	9	5	10	7	9	8
Bank Stab R	9	5	9	7	9	8
Veg. Prot. L	10	7	9	9	9	6
Veg. Prot. R	9	7	9	8	8	7
Rip. Zone L	10	1	3	2	4	4
Rip. Zone R	4	1	2	1	1	1
Total	**170**	**113**	**150**	**137**	**144**	**142**

Table 14. RBP Habitat Scoring 3/21/2023

Parameter	198.08	TKR0.69	202.20	WPD	WPU	CD1
Subst./Cover	19	17	18	18	18	18
Embeddedness	13	12	13	13	13	12
Velocity	18	16	18	18	19	18
Sediment Dep.	15	8	10	12	10	11
Channel Flow	18	18	18	17	17	17
Channel Alt.	18	11	11	10	9	12
Freq of Riffles	18	17	18	18	18	18
Bank Stab L	9	7	9	7	9	7
Bank Stab R	7	6	9	7	8	5
Veg. Prot. L	10	6	6	8	6	4
Veg. Prot. R	8	6	7	7	6	5
Rip. Zone L	10	2	2	2	2	1
Rip. Zone R	4	2	3	2	2	2
Total	**167**	**128**	**142**	**139**	**137**	**130**

Table 15. RBP Habitat Scoring 5/8/2023

Parameter	198.08	TKR0.69	202.20	WPD	WPU	CD1
Subst./Cover	19	16	18	18	18	18
Embeddedness	13	10	12	12	13	12
Velocity	18	10	18	17	18	18
Sediment Dep.	14	10	13	12	13	14
Channel Flow	18	15	17	16	17	18
Channel Alt.	18	13	13	11	9	11
Freq of Riffles	16	16	18	15	15	18
Bank Stab L	8	7	8	6	9	8
Bank Stab R	9	5	8	5	7	6
Veg. Prot. L	8	9	7	9	8	5
Veg. Prot. R	10	9	7	7	6	6
Rip. Zone L	10	4	4	5	4	4
Rip. Zone R	5	4	4	3	4	4
Total	**166**	**128**	**147**	**136**	**141**	**142**

5.0 BMI Water Quality Assessment

Tables 16 through 19 present the water quality assessments.

Table 16. Water Quality Analyses 10/24/2022 & 11/07/2022

	198.08	TKR0.69	202.20	WPD	WPU	CD1
Conductivity (µS/cm)	510	433	447	439	434	419
pH (SU)	8.20	8.13	8.51	8.43	8.44	8.26
Temperature (°C)	12.0	17.8	12.4	12.1	12.5	17.7

Table 17. Water Quality Analyses 11/28/2022

	198.08	TKR0.69	202.20	WPD	WPU	CD1
Conductivity (µS/cm)	461	520	390	383	382	379
pH (SU)	8.10	8.13	8.25	8.24	8.21	8.36
Temperature (°C)	10.3	11.1	9.8	9.6	10.0	9.2

Table 18. Water Quality Analyses 3/22/2023

	198.08	TKR0.69	202.20	WPD	WPU	CD1
Conductivity (µS/cm)	423	488	369	363	362	368
pH (SU)	8.45	8.88	8.89	8.67	8.79	8.69
Temperature (°C)	8.7	8.4	8.2	8.1	8.5	9.5

Table 19. Water Quality Analyses 10/24/2022 & 11/07/2022

	198.08	TKR0.69	202.20	WPD	WPU	CD1
Conductivity (µS/cm)	406	741	510	342	341	344
pH (SU)	7.45	7.95	7.79	7.77	7.63	7.92
Temperature (°C)	20.7	22.1	23.0	21.2	21.3	22.1

3.5 Ambient Toxicity Testing

3.5.1 Ambient Toxicity Results 11/11/22

Ambient toxicity results from this sampling event are summarized in Table 20.
Fathead minnow (Pp) Survival ranged from 77.5% in the 100% treatment to 97.5% in the control treatment at Station 198.08. Growth at this station ranged from 0.5912 mg/organism (25% treatment) to 0.6937 mg/organism (control treatment). The 100% treatment had significantly lower survival than the control. The 25% treatment had significantly reduced growth when compared to the controls. This resulted in a No Observed Effect Concentration (NOEC) of 12.5%.

Ceriodaphnid (Cd) Survival was 100% in all treatments at Station 198.08. Reproduction at this station ranged from 30.1 offspring/organism (Control treatment) to 33.2 offspring/organism (100% treatment). No significant reductions were noted in survival or reproduction. This resulted in a NOEC of 100%.

Fathead minnow (Pp) Survival ranged from 80.0% (50% treatment) to 100% (control treatment) at Station 202.20. Growth at this station ranged from 0.5692 mg/organism (100% treatment) to 0.6530 mg/organism (12.5% treatment). The 50% treatment had significantly lower survival than the control. Growth was not significantly reduced in any treatment. This resulted in a No Observed Effect Concentration (NOEC) of 25%.

Ceriodaphnid (Cd) Survival was 100% in all treatments at Station 202.20. Reproduction at this station ranged from 31.1 offspring/organism (6.25% treatment) to 33.5 offspring/organism (100% treatment). No significant reductions were noted in survival or reproduction. This resulted in a NOEC of 100%.

Table 20. Ambient Toxicity Testing 11/11/2022

	198.08 – Pp		198.08 – Cd		202.20 – Pp		202.20 – Cd	
Treatment %	**Survival**	**Growth**	**Survival**	**Reproduction**	**Survival**	**Growth**	**Survival**	**Reproduction**
0	97.50	.6937	100.00	30.10	100.00	.6000	100.00	31.50
6.25	97.50	.6292	100.00	31.40	82.50	.5843	100.00	31.10
12.5	87.50	.6045	100.00	32.20	92.50	.6530	100.00	32.20
25	92.50	.5912*	100.00	33.00	95.00	.6305	100.00	33.00
50	92.50	.6270	100.00	31.90	80*	.5570	100.00	32.90
100	77.5*	.6187	100.00	33.20	87.50	.5692	100.00	33.50
**Denotes significant difference from control*								

3.5.2 Ambient Toxicity Results 03/07/23

Ambient toxicity results from this sampling event are summarized in Table 21.

Fathead minnow (Pp) Survival ranged from 87.5% (100% treatment) to 100% (12.5 and 50% treatments) at Station 198.08. Growth at this station ranged from 0.6475 mg/organism (12.5% treatment) to 0.7322 mg/organism (25% treatment). No significant reductions were noted for survival or growth. This resulted in a No Observed Effect Concentration (NOEC) of 100%.

Ceriodaphnid (Cd) Survival was 100% in all treatments at Station 198.08. Reproduction at this station ranged from 33.6 offspring/organism (25% treatment) to 36.8 offspring/organism (100% treatment). No significant reductions in survival or reproduction were noted. This resulted in a NOEC of 100%.

Fathead minnow (Pp) Survival ranged from 92.5% (6.25% treatment) to 100% (control treatment, 12.5, 50, and 100% treatments) at Station 202.20. Growth at this station ranged from 0.5522 mg/organism (50% treatment) to 0.6382 mg/organism (6.25% treatment). There were no significant reductions noted for survival or growth at this station. This resulted in a No Observed Effect Concentration (NOEC) of 100%.

Ceriodaphnid (Cd) Survival was 100% in all treatments at Station 202.20. Reproduction at this station ranged from 34.2 offspring/organism (25% treatment) to 37.2 offspring/organism (50% treatment). No significant reductions were noted in survival or reproduction. This resulted in a NOEC of 100%.

Table 21. Ambient Toxicity Testing 03/07/23

	198.08 – Pp		198.08 – Cd		202.02 – Pp		202.02 – Cd	
Treatment %	**Survival**	**Growth**	**Survival**	**Reproduction**	**Survival**	**Growth**	**Survival**	**Reproduction**
0	97.50	0.6807	100.00	33.90	100.00	0.5615	100.00	35.20
6.25	95.00	0.6810	100.00	35.90	92.50	0.6382	100.00	35.00
12.5	100.00	0.6475	100.00	36.50	100.00	0.5633	100.00	36.20
25	97.50	0.7322	100.00	33.60	95.00	0.5875	100.00	34.20
50	100.00	0.6655	100.00	35.10	100.00	0.5522	100.00	37.20
100	87.50	0.6885	100.00	36.80	100.00	0.6365	100.00	36.00
**Denotes significant difference from control*								

5.0.3 Ambient Toxicity Results 5/23/23

Ambient toxicity results from this sampling event are summarized in Table 22.

Fathead minnow (Pp) Survival ranged from 80.0% (25% treatment) to 100% (control treatment) at Station 198.08. Growth at this station ranged from 0.8005 mg/organism (25% treatment) to 0.9317 mg/organism (50% treatment). Survival was significantly reduced at the 25 and 100% treatments. There was no significant reduction of growth noted at any concentration. This resulted in a No Observed Effect Concentration (NOEC) of 12.5%.

Ceriodaphnid (Cd) Survival ranged from 90 (control, 25, 50, and 100%) to 100% (6.25 and 12.5% concentration) at Station 198.08. Reproduction at this station ranged from 24.8 offspring/organism (25% treatment) to 31.5 offspring/organism (control treatment). No significant reductions in survival or reproduction were noted. This resulted in a NOEC of 100%.

Fathead minnow (Pp) Survival ranged from 82.5% (100% treatment) to 100% (control and 25% treatments) at Station 202.20. Growth at this station ranged from 0.7345 mg/organism (100% treatment) to 0.8852 mg/organism (control treatment). There were no significant reductions noted for survival or growth at this station. This resulted in a No Observed Effect Concentration (NOEC) of 100%.

Ceriodaphnid (Cd) Survival ranged from 90 (control and 50% treatment) to 100% (6.25, 12.5, 25, and 100% treatments) at Station 202.20. Reproduction at this station ranged from 20.0 offspring/organism (control treatment) to 25.4 offspring/organism (25% treatment). No significant reductions were noted in survival or reproduction. This resulted in a NOEC of 100%.

Table 22. Ambient Toxicity Testing 5/23/23

	198.08 – Pp		198.08 – Cd		202.02 – Pp		202.02 – Cd	
Treatment in %	**Survival**	**Growth**	**Survival**	**Reproduction**	**Survival**	**Growth**	**Survival**	**Reproduction**
0	100.00	0.9255	90.00	31.50	100.00	0.8852	90.00	20.00
6.25	97.50	0.9123	100.00	30.60	97.50	0.8303	100.00	20.60
12.5	97.50	0.9190	100.00	30.80	90.00	0.7792	100.00	24.30
25	80.00*	0.8005	90.00	24.80	100.00	0.8508	100.00	25.40
50	97.50	0.9317	90.00	25.00	97.50	0.7675	90.00	21.40
100	85.00*	0.8365	90.00	25.78	82.50	0.7345	100.00	24.80
**Denotes significant difference from control*								

3.6 VA DEQ Benthic Data

Tables 23 – 28 present summaries of the VA DEQ Probabalistic monitoring at three stations. These data represent monitoring conducted between 2008 and 2021.

3.6.1 Station 198.08

Table 23. VSCI Metrics Station 198.08

Date	Total Taxa	EPT Taxa	%Ephem	%PT – Hydro	%Scraper	%Chiro	%2 Dom	HBI
6/8/2010	11	5	32.23	0	19.01	10.74	60.33	4.88
11/15/2010	9	5	12.5	4.17	28.33	49.17	62.5	5.12
5/12/2014	11	4	18.18	0.91	2.73	34.55	50.91	5.97
11/5/2014	9	6	18.18	2.73	38.18	40	53.64	4.87
5/13/2015	11	4	16.36	0.91	15.45	26.36	61.82	5.35
10/26/2015	17	8	29.09	3.64	64.55	7.27	52.73	4.46
4/20/2016	7	3	4.55	0.91	1.82	75.45	89.09	6.1
11/1/2016	16	7	19.09	4.55	39.09	17.27	38.18	4.97
6/8/2017	13	5	16.36	2.73	23.64	13.64	50	5.25
10/19/2017	11	6	54.55	0.91	50.91	8.18	50.91	4.04
5/13/2020	11	4	8.18	0.91	19.09	44.55	59.09	5.43
11/10/2020	9	4	3.64	0.91	46.36	5.45	80.91	5.07
4/21/2021	8	4	9.09	0.91	35.45	42.73	73.64	5.15
11/9/2021	15	8	18.18	3.64	51.82	24.55	51.82	4.73

Table 24. VSCI Metric Scoring Station 198.08

Date	Fam Richness	Fam EPT	%Ephem	%PT-H	Fam %Scraper	%Chironomidae	Fam %2Dom	Fam %MFBI	VSCI
6/8/2010	50	45.45	52.58	0	36.84	89.26	57.33	75.23	**50.84**
11/15/2010	40.91	45.45	20.39	11.7	54.91	50.83	54.19	71.69	**43.76**
5/12/2014	50	36.36	29.66	2.55	5.29	65.45	70.94	59.22	**39.94**
11/5/2014	40.91	54.55	29.66	7.66	74	60	67	75.4	**51.15**
5/13/2015	50	36.36	26.69	2.55	29.95	73.64	55.18	68.32	**42.84**
10/26/2015	77.27	72.73	47.46	10.21	100	92.73	68.31	81.49	**68.78**
4/20/2016	31.82	27.27	7.42	2.55	3.52	24.55	15.76	57.35	**21.28**
11/1/2016	72.73	63.64	31.14	12.77	75.76	82.73	89.33	73.93	**62.75**
6/8/2017	59.09	45.45	26.69	7.66	45.81	86.36	72.25	69.92	**51.66**
10/19/2017	50	54.55	88.98	2.55	98.66	91.82	70.94	87.7	**68.15**
5/13/2020	50	36.36	13.35	2.55	37	55.45	59.12	67.25	**40.14**
11/10/2020	40.91	36.36	5.93	2.55	89.85	94.55	27.59	72.46	**46.28**
4/21/2021	36.36	36.36	14.83	2.55	68.71	57.27	38.1	71.39	**40.7**
11/9/2021	68.18	72.73	29.66	10.21	100	75.45	69.63	77.54	**62.93**

3.6.2 Station TKR0.69

Table 25. VSCI Metrics Station TKR0.69

Date	Total Taxa	EPT Taxa	%Ephem	%PT – Hydro	%Scraper	%Chiro	%2 Dom	HBI	SCI Score
9/23/2008	13	5	13.33	2.5	24.17	19.17	47.5	5.22	50.89
5/6/2015	12	4	10.91	0.91	23.64	49.09	70.91	5.24	40.01
11/17/2015	16	6	16.36	1.82	38.18	20.91	44.55	4.78	58.63
5/19/2016	15	4	14.55	1.82	22.73	26.36	48.18	5	49.93
11/8/2016	9	6	3.64	34.55	5.45	52.73	82.73	4.23	45.77
6/8/2017	13	4	3.64	2.73	34.55	30	59.09	5.22	46.93
11/2/2017	12	4	4.55	0	12.73	5.45	80	5.65	38.79

Table 26. VSCI Metric Scoring Station TKR0.69

Date	Fam Richness	FAM EPT	%Ephem	%PT-H	%Scraper	%Chir	Fam %2Dom	%MFBI	VSCI
9/23/2008	59.09	45.45	21.75	7.02	46.83	80.83	75.87	70.23	**50.89**
5/6/2015	54.55	36.36	17.8	2.55	45.81	50.91	42.04	70.05	**40.01**
11/17/2015	72.73	54.55	26.69	5.11	74	79.09	80.14	76.74	**58.63**
5/19/2016	68.18	36.36	23.73	5.11	44.05	73.64	74.88	73.53	**49.93**
11/8/2016	40.91	54.55	5.93	97.04	10.57	47.27	24.96	84.91	**45.77**
6/8/2017	59.09	36.36	5.93	7.66	66.95	70	59.12	70.32	**46.93**
11/2/2017	54.55	36.36	7.42	0	24.67	94.55	28.9	63.9	**38.79**

3.6.3 Station 202.20

Table 27. VSCI Metrics Station 202.20

Date	Total Taxa	EPT Taxa	%Ephem	%PT – Hydro	%Scraper	%Chiro	%2 Dom	SCI Score
12/1/2009	9	32.11	6.42	30.28	5.5	44.95	4.64	17
6/8/2010	6	42.15	2.48	24.79	4.13	52.89	4.37	13
4/17/2012	6	22.73	1.82	19.09	31.82	46.36	5.19	13
10/10/2012	6	32.73	1.82	45.45	20	42.73	4.61	12
5/12/2014	5	45.45	1.82	14.55	12.73	52.73	4.91	16
11/10/2014	7	7.27	4.55	47.27	19.09	45.45	4.82	14
5/13/2015	6	26.36	5.45	18.18	30	50.91	5.16	12
10/26/2015	9	24.55	12.73	58.18	9.09	39.09	4.11	14
5/14/2020	5	15.45	0.91	15.45	53.64	66.36	5.43	11
11/10/2020	8	3.64	7.27	61.82	3.64	57.27	4.51	19
4/21/2021	1	3.64	0	58.18	17.27	75.45	4.76	5
11/8/2021	7	14.55	18.18	35.45	24.55	38.18	4.45	13

Table 28. VSCI Metric Scoring Station 202.20

Date	Richness	EPT	%Ephem	%PT-H	%Scraper	%Chiro	%2Dom	%MFBI	SCI
12/1/2009	77.27	81.82	52.38	18.04	58.67	94.5	79.55	78.89	67.64
6/8/2010	59.09	54.55	68.76	6.96	48.05	95.87	68.07	82.84	60.52
4/17/2012	59.09	54.55	37.08	5.11	37	68.18	77.51	70.7	51.15
10/10/2012	54.55	54.55	53.39	5.11	88.09	80	82.76	79.2	62.2
5/12/2014	72.73	45.45	74.15	5.11	28.19	87.27	68.31	74.88	57.01
11/10/2014	63.64	63.64	11.86	12.77	91.61	80.91	78.82	76.23	59.93
5/13/2015	54.55	54.55	43.01	15.32	35.24	70	70.94	71.17	51.85
10/26/2015	63.64	81.82	40.04	35.75	100	90.91	88.02	86.63	73.35
5/14/2020	50	45.45	25.21	2.55	29.95	46.36	48.61	67.25	39.42
11/10/2020	86.36	72.73	5.93	20.43	100	96.36	61.74	80.75	65.54
4/21/2021	22.73	9.09	5.93	0	100	82.73	35.47	77.01	41.62
11/8/2021	59.09	63.64	23.73	51.07	68.71	75.45	89.33	81.68	64.09

3.7 AEP Benthic Data

Tables 29 – 34 present summaries of the AEP collected benthic data.

3.7.1 Station 198 (NFQT10)

Table 29. VSCI Metrics Station 198.08

Date	Total Taxa	EPT Taxa	%Ephem	%PT – Hydro	%Scraper	%Chiro	%2 Dom	HBI
10/5/2020	12	2	5.41	0	6.31	71.17	18.02	5.43
6/4/2021	16	6	18.18	3.64	32.73	48.18	10.91	4.71

Table 30. VSCI Metric Scoring Station 198.08

Date	Richness	EPT	%Ephem	%PT-H	%Scraper	%Chiro	%2Dom	%MFBI	SCI
9/15/2020	54.55	18.18	8.82	0.00	12.22	81.98	41.66	67.17	35.57
6/4/2021	72.73	54.55	29.66	10.21	63.42	89.09	74.88	77.81	59.04

3.7.2 Station 202.2 (NFQT2)

Table 31. VSCI Metrics Station 202.2

Date	Total Taxa	EPT Taxa	%Ephem	%PT – Hydro	%Scraper	%Chiro	%2 Dom	HBI
9/15/2020	11	5	5.31	1.77	61.06	60.18	6.19	4.74
6/3/2021	12	6	18.97	1.72	23.28	43.97	28.45	4.98

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Table 32. VSCI Metric Scoring Station 202.2

Date	Richness	EPT	%Ephem	%PT-H	%Scraper	%Chiro	%2Dom	%MFBI	SCI
9/15/2020	50.00	45.45	8.66	4.97	100.00	93.81	57.55	77.30	54.72
6/4/2021	54.55	54.55	30.94	4.84	45.11	71.55	80.97	73.78	52.04

3.7.3 Station TKRO.69 (NFQT1)

Table 33. VSCI Metrics Station TKRO.69

Date	Total Taxa	EPT Taxa	%Ephem	%PT – Hydro	%Scraper	%Chiro	%2 Dom	HBI
9/15/2020	16	4	4.17	4.17	22.5	69.17	55	5.21
6/4/2021	14	3	10.53	0.88	7.89	65.79	55.26	5.27

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Table 34. VSCI Metric Scoring Station TKRO.69

Date	Richness	EPT	%Ephem	%PT-H	%Scraper	%Chiro	%2Dom	%MFBI	SCI
9/15/2020	72.73	36.36	6.80	11.70	43.60	45.00	44.56	70.47	41.40
6/4/2021	63.64	27.27	17.17	2.46	15.30	44.74	49.44	69.53	36.19

5.0 Total Nitrogen Data

Table 35. Station 198.08 Total Nitrogen Data

Date	Total N (mg/L)
5/13/2015	1.69
10/26/2015	3.48
4/20/2016	2.12
11/1/2016	3.11
2/27/2017	2.45
4/18/2017	2.25
6/7/2017	1.58
6/8/2017	2.08
8/24/2017	2.82
10/19/2017	3.01
10/19/2017	3.04
12/19/2017	3.87
1/7/2021	1.19
3/10/2021	0.43
5/27/2021	2.36
7/7/2021	1.87
9/8/2021	2.48
11/29/2021	3.25
2/10/2022	1.6
4/14/2022	1.56
4/14/2022	1.52
6/13/2022	1.7
8/11/2022	1.42
10/19/2022	2.82
11/1/2022	3.75
12/5/2022	2.32

Table 36. Station TKR0.69 Total Nitrogen Data

Date	Total N (mg/L)
1/16/2008	1.29
3/5/2008	0.96
5/1/2008	1.33
7/7/2008	1.36
9/8/2008	1.45
9/23/2008	1.34
11/6/2008	1.22
2/10/2009	1.24
4/6/2009	1.3
6/16/2009	1.55
8/13/2009	1.6
10/14/2009	1.55
12/15/2009	1.33
2/18/2010	1.78
4/15/2010	1.69
6/10/2010	1.62
8/31/2010	1.81
10/13/2010	1.72
12/21/2010	1.71
2/9/2011	1.57
4/6/2011	1.44
6/15/2011	1.67
8/1/2011	1.59
10/4/2011	1.56
12/14/2011	1.86
2/9/2012	1.5
3/7/2012	1.22
5/2/2012	1.53
7/5/2012	1.95
9/24/2012	1.49
1/7/2013	1.44
3/5/2013	1.27
5/30/2013	1.44
7/18/2013	1.62
9/12/2013	1.67
11/21/2013	1.39
2/24/2014	1.31
4/24/2014	1.39

Table 36 (Continued). Station TKR0.69 Total Nitrogen Data

6/16/2014	1.53
8/7/2014	1.39
10/29/2014	1.34
12/3/2014	1.31
1/26/2015	1.38
3/12/2015	1.31
5/21/2015	1.81
7/7/2015	1.34
9/9/2015	1.45
11/16/2015	1.66
2/29/2016	1.55
4/7/2016	1.68
5/19/2016	1.3
6/20/2016	1.68
8/4/2016	1.39
10/17/2016	2.08
11/8/2016	1.59
12/14/2016	1.6
1/30/2017	1.54
3/23/2017	1.33
5/15/2017	1.2
6/8/2017	1.61
7/20/2017	1.61
9/25/2017	1.4
11/2/2017	1.27
11/14/2017	1.21
2/14/2018	1.78
4/25/2018	0.92
6/14/2018	1.72
8/8/2018	1.5
10/3/2018	1.6
12/6/2018	1.61
1/22/2019	1.35
¾/2019	1.12
5/9/2019	1.62
7/2/2019	1.7
9/10/2019	1.52
11/13/2019	1.53
6/4/2020	1.76
8/19/2020	1.49

Table 36 (Continued). Station TKR0.69 Total Nitrogen Data

10/5/2020	1.54
12/14/2020	1.02
1/7/2021	1.22
3/10/2021	1.44
5/27/2021	1.55
7/7/2021	1.4
9/8/2021	1.45
11/29/2021	1.43
2/10/2022	1.4
4/14/2022	1.02
5/11/2022	1.31
6/13/2022	1.49
8/11/2022	1.35
10/19/2022	1.31
10/20/2022	1.41

Table 37. Station 202.20 Total Nitrogen Data

Date	Total N (mg/L)
3/5/2008	0.67
5/1/2008	0.64
7/7/2008	0.65
9/8/2008	0.66
11/6/2008	0.44
2/10/2009	0.6
4/6/2009	0.56
6/16/2009	0.98
8/13/2009	0.83
10/14/2009	0.58
12/15/2009	0.87
2/18/2010	0.87
4/15/2010	0.62
6/10/2010	0.77
8/31/2010	0.95
10/13/2010	0.72
12/21/2010	0.96
2/9/2011	0.79
4/6/2011	0.69
6/15/2011	0.8
8/1/2011	0.69
10/4/2011	0.56
12/14/2011	1.01
2/9/2012	0.64
3/7/2012	0.76
5/2/2012	0.6
7/5/2012	0.74
9/24/2012	0.69
11/6/2012	0.37
1/7/2013	0.63
3/5/2013	0.61
5/30/2013	0.56
7/18/2013	0.7
9/12/2013	0.77
11/21/2013	0.49
2/24/2014	0.83
4/24/2014	0.52
6/16/2014	0.66

Table 37 (Continued). Station 202.20 Total Nitrogen Data

8/7/2014	0.67
10/29/2014	0.64
12/3/2014	0.75
1/26/2015	0.62
3/12/2015	1.14
5/21/2015	0.69
7/7/2015	0.78
9/9/2015	0.76
11/16/2015	0.56
2/29/2016	0.82
4/7/2016	0.67
6/20/2016	0.78
8/4/2016	0.93
10/17/2016	0.88
12/14/2016	0.64
1/30/2017	0.9
3/23/2017	0.56
5/15/2017	0.55
7/20/2017	0.8
9/25/2017	0.6
11/14/2017	0.56
2/14/2018	0.87
4/25/2018	0.92
6/14/2018	0.92
8/8/2018	0.85
10/3/2018	0.97
12/6/2018	0.66
1/22/2019	0.74
¾/2019	0.71
5/9/2019	0.58
7/2/2019	0.68
9/10/2019	0.75
11/13/2019	0.8
2/27/2020	0.79
6/4/2020	0.77
8/19/2020	0.73
10/5/2020	0.6
12/14/2020	0.72
1/7/2021	0.6

Table 37 (Continued). Station 202.20 Total Nitrogen Data

3/10/2021	0.72
5/27/2021	0.8
7/7/2021	0.61
9/8/2021	0.7
11/29/2021	0.54
2/10/2022	0.76
4/14/2022	0.4
4/14/2022	0.41
6/13/2022	0.64
8/11/2022	0.8
10/19/2022	0.49
11/1/2022	0.52
12/5/2022	0.57

4.0 DATA PRESENTATION / INTERPRETATION

4.1 Impairment

The study results show that the Roanoke River is impaired (VSCI < 60) from station 198.08 continuing upstream through at least the Wasena Park area (Figure 1, WPU). Upstream from that point, the VSCI scores are higher and did attain scores > 60. It is therefore not likely that station 198.08 has a different stressor than Station 202.20. In addition, aquatic toxicity was exhibited by samples collected at both 198.08 and 202.20 during high flow events. This alone may indicate that both stations have the same stressor.

Figures 2 and 3 present charts of the benthic scores (VSCI). Figure 2 is the DEQ collected data alone. Figure 3 is the DEQ data along with the AEP and BMI data. The figures show that VSCI scores are trending downward at both Stations 202.20 and TKR0.69. The trend at Station 198 is positive over the same period.

Figure 2. DEQ Benthic Scores

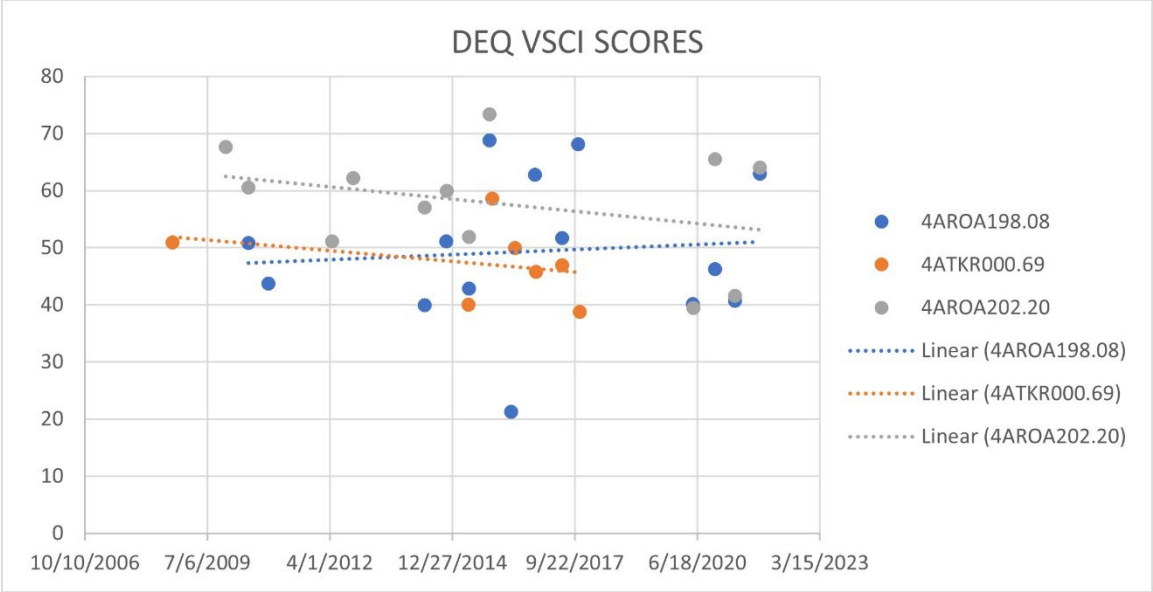
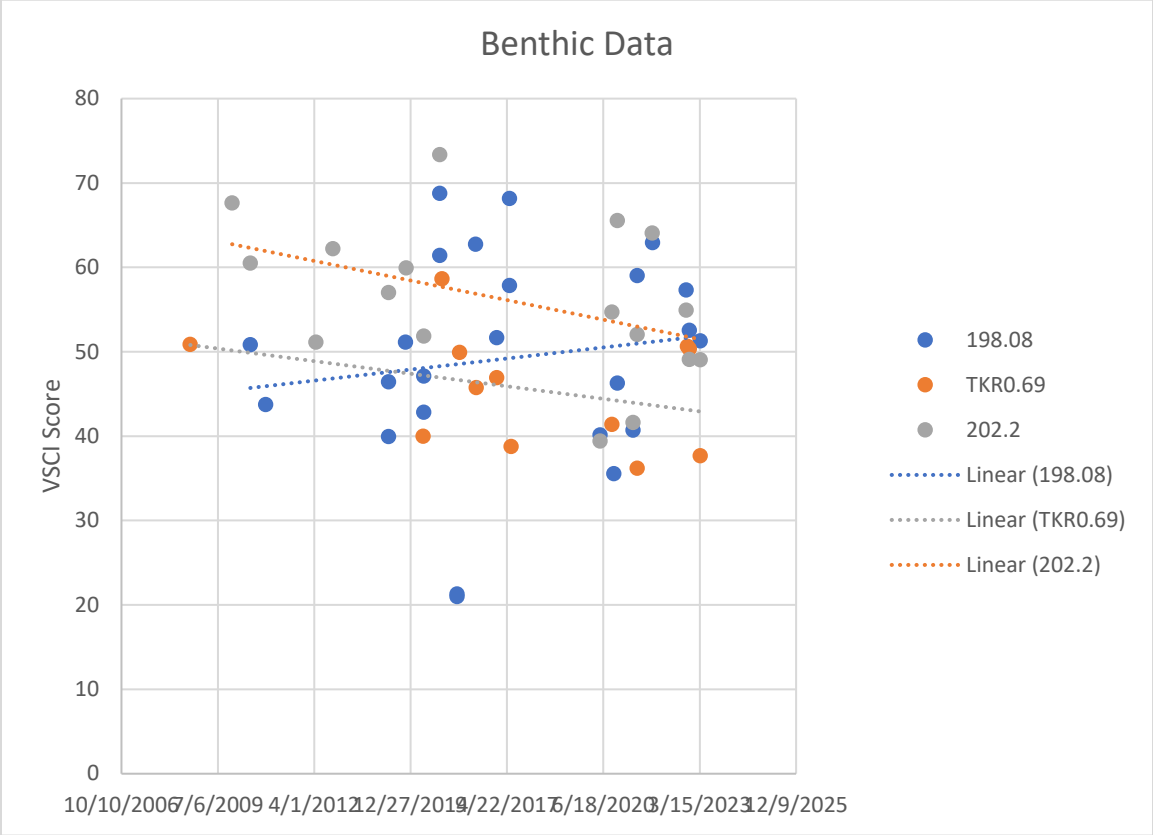


Figure 3. DEQ, AEP, and BMI Benthic Data



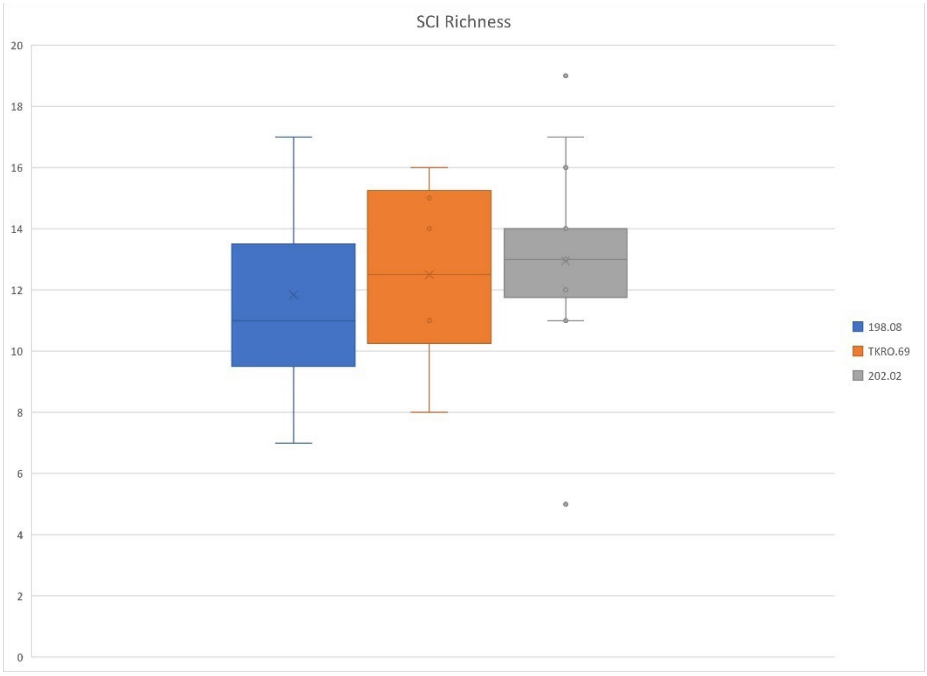
4.2 Individual Metrics

By examining the individual metrics that constitute the VSCI score, we may be able to indicate whether both stations have the same stressor. Figures 4 – 11 are box and whisker plots depicting each metric for three stations that were examined (198.08, TKR0.69, and 202.20).

These metrics all have an expected response to perturbation (e.g. Richness metric would decrease with increased stress). As may be seen from the boxplots, interquartile ranges for every metric overlap. This would indicate that the stressor is likely the same at Stations 198.08 and 202.20.

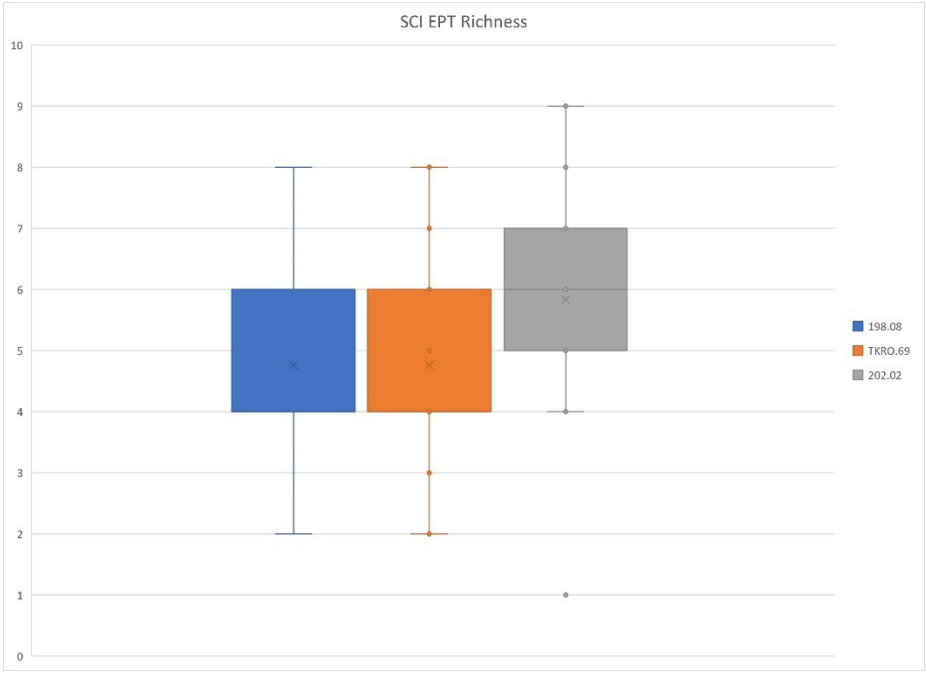
By adding the Tinker Creek station, there is more information to be gleaned. Three of the metrics (Richness, EPT Richness, and % Mayflies) indicate that Tinker Creek is negatively influencing Station 198.08.

Figure 4. Box and Whisker Plot for Richness



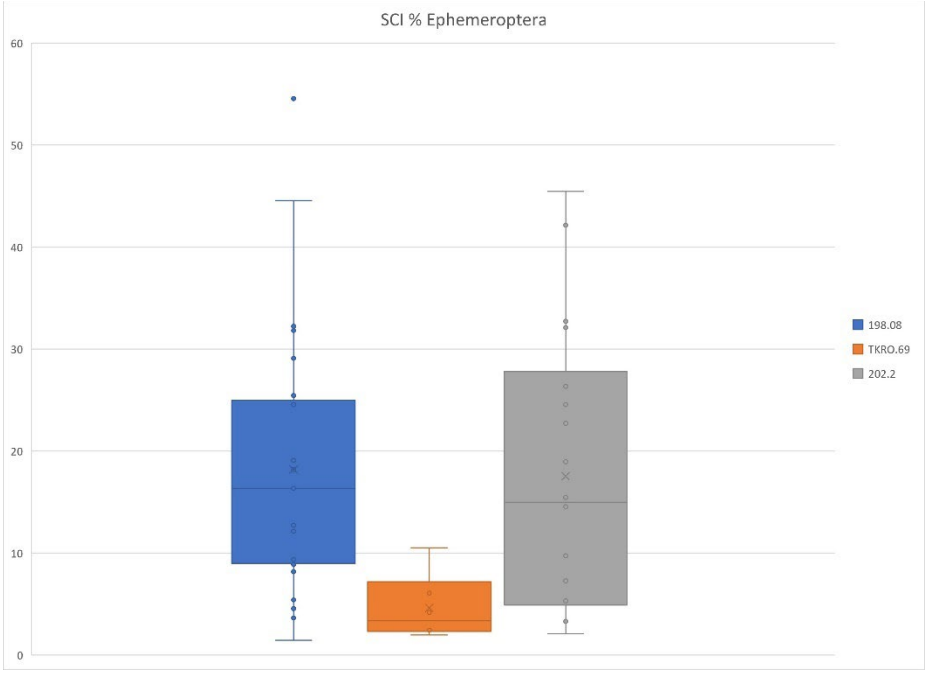
Note: Expected response to perturbation is a decrease in Richness. Medians overlap interquartile ranges; therefore stressors are likely the same.

Figure 5. Box and Whisker Plot for EPT Richness



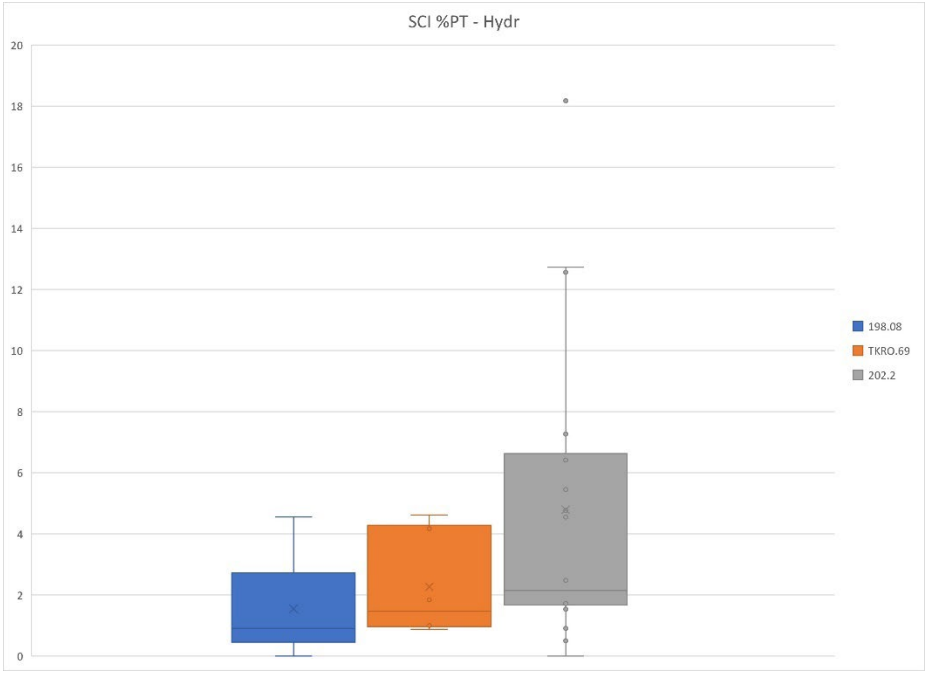
Note: Expected response to perturbation is a decrease in EPT Richness. Medians overlap interquartile ranges; therefore, stressors are likely the same.

Figure 6. Box and Whisker Plot for % Mayflies



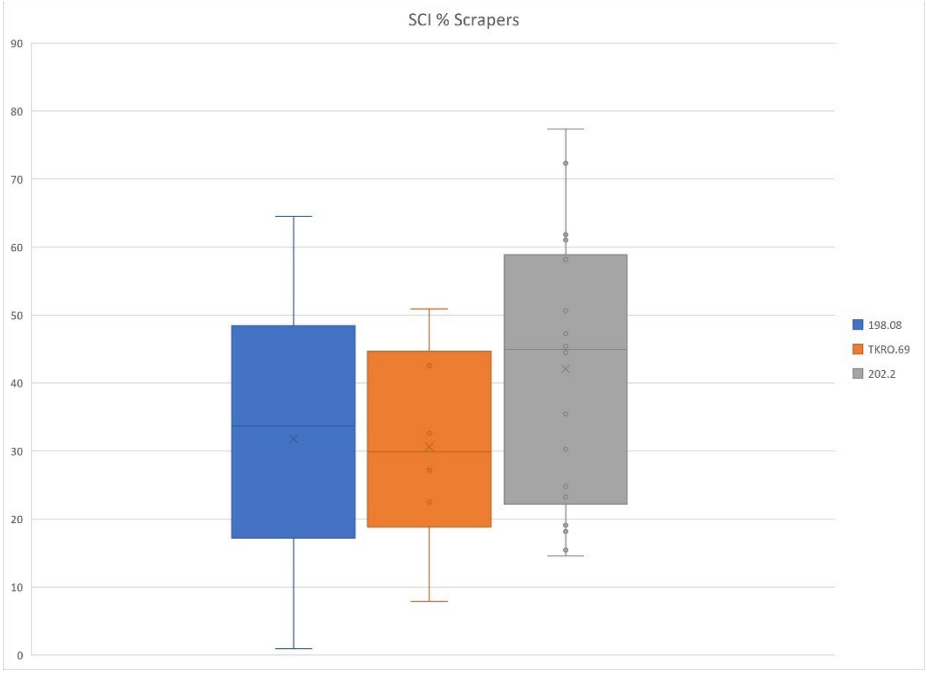
Note: Expected response to perturbation is a decrease in % Mayflies. Medians overlap interquartile ranges (198.08 and 202.20); therefore, stressors are likely the same.

Figure 7. Box and Whisker Plot for %PT Less Hydropsychidae



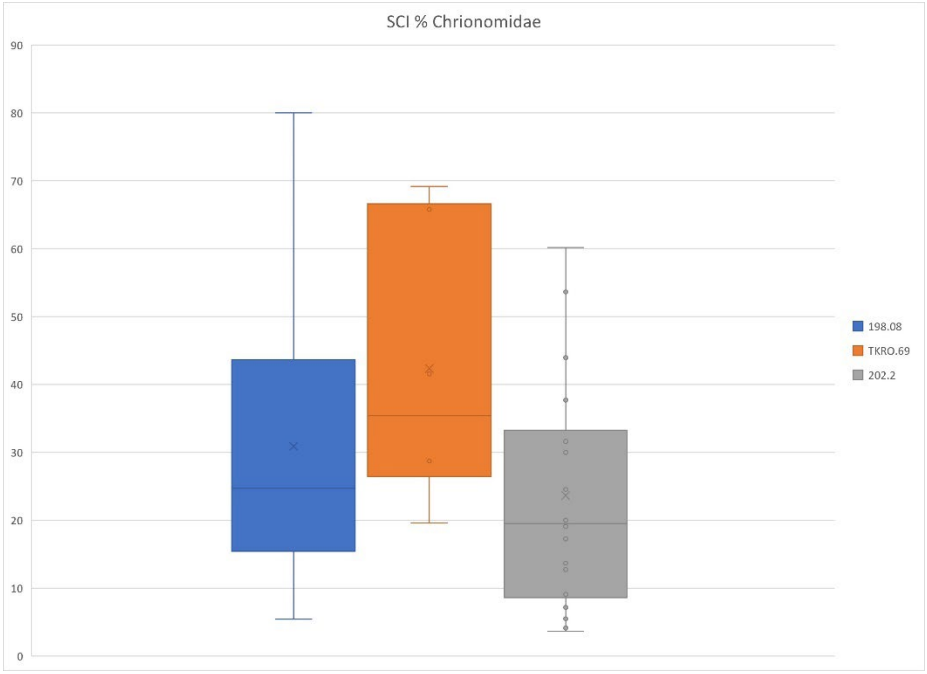
Note: Expected response to perturbation is a decrease in %PT Less Hydropsychidae. Medians overlap interquartile ranges; therefore, stressors are likely the same.

Figure 8. Box and Whisker Plot for % Scrapers



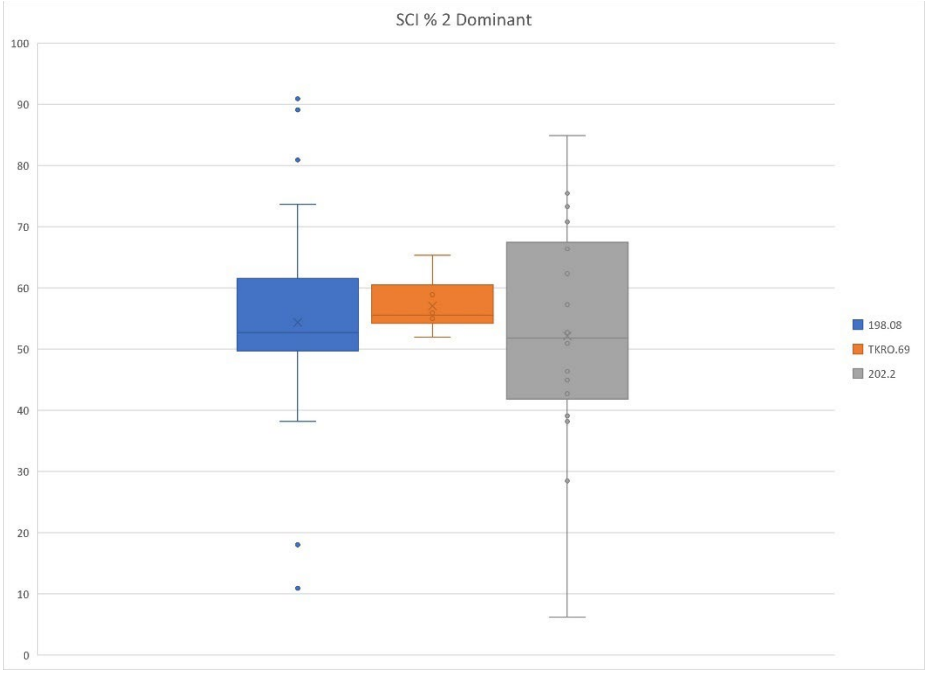
Note: Expected response to perturbation is a decrease in % Scrapers. Medians overlap interquartile ranges; therefore, stressors are likely the same.

Figure 9. Box and Whisker Plot for % Chironomidae



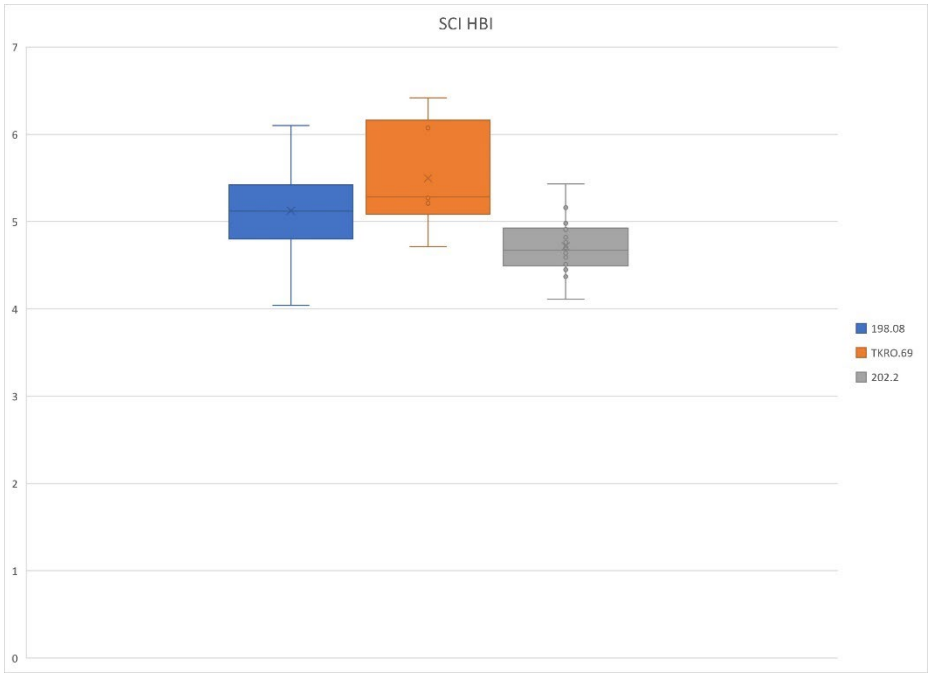
Note: Expected response to perturbation is an increase in % Chironomidae. Medians overlap interquartile ranges; therefore, stressors are likely the same.

Figure 10. Box and Whisker Plot for % 2 Dominant Taxon



Note: Expected response to perturbation is an increase in % 2 Dominant Taxon. Medians overlap interquartile ranges; therefore, stressors are likely the same.

Figure 11. Box and Whisker Plot for Hilsenhoff Biotic Index



Note: Expected response to perturbation is an increase in Hilsenhoff Biotic Index. Medians overlap interquartile ranges (198.08 and 202.20); therefore, stressors are likely the same.

4.3 Nitrogen

Since nitrogen has been observed at Station 198.08, BMI regressed Nitrogen versus benthic scores. However, the nitrogen data did not coincide with the benthic data. Therefore, the nitrogen data from the six months prior to benthic sampling were averaged and used to evaluate its role in impairment.

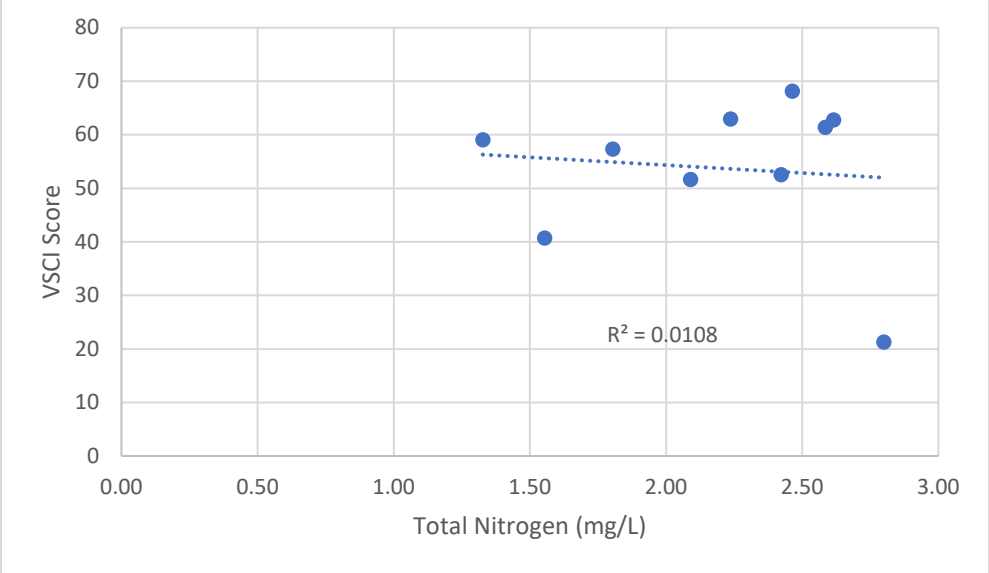
Table 38 presents a summary of the nitrogen data collected from 2017 to present for station 198.08.

Table 38. Summary of Nitrogen Measurements at 198.08

Total # Measurements	# > 2.0mg/L	# > 3.0mg/L	# > 4.0 mg/L
22	13	5	0

Figure 12 presents a regression of the averaged nitrogen data (see above) and the VSCI score. The resultant R^2 value (0.0108) would indicate that nitrogen is not responsible for the observed impairment.

Figure 12. Regression of Nitrogen and VSCI at 198.08



4.4 Discussion and Conclusion

Impairment exists in the Roanoke River from Station 198.08 upstream to at least the Wasena Park area. Based on professional judgement, this impairment is typical for urbanized streams. There is reduced richness of the intolerant orders (Ephemeroptera, Plecoptera, and Trichoptera). Furthermore, there is an abundance of tolerant organisms as indicated by the higher HBI scores. The VSCI scores are trending downward at both Stations 202.20 and TKR0.69. The trend at Station 198.08 is positive over the same period.

Aquatic toxicity was observed instream at both Stations 198.08 and 202.20 during high flow events. This observed toxicity may play a role in the impairment.

The source of the impairment was not discovered from the data collected thus far. Additional work is therefore needed to identify the exact stressor(s). However, nitrogen is not likely causing impairment based on the data collected to date.

Study Conclusions

1. The analysis of existing data and the data developed in other field studies, including the extensive study conducted by BMI found extensive impairment (extending from station 198.08 upstream to at least the Wasena Park area and well above the WVWA plant).
2. Comparison of all available data supports that the same stressor is likely causing impairment both above and below the WVWA plant (Stations 198.08 and 202.20) and that stressor is likely not nitrogen.
3. Any differences observed between stations 198.08 and 202.20 likely related to the contribution from Tinker Creek.

5.0 LITERATURE CITED

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7.

Appendix A: Station Photographs

Roanoke River (198.08)

Tinker Creek (TKR0.69)

Roanoke River (202.20)

Roanoke River (WPD)

Roanoke River (WPU)

Roanoke River (CD1)

Appendix B. BMI Raw Benthic Data