Swannanoa River at US 25 at Biltmore Village, Asheville, North Carolina, December 5, 2024

# Hurricane Helene Effects on Benthic Macroinvertebrates of 11 North Carolina Streams, a Preliminary Analysis

Nov. 19 – Dec. 6, 2024

North Carolina Department of Environmental Quality
Division of Water Resources
Water Sciences Section

# Biological Assessment Branch

## SUMMARY

To assess the effects of Hurricane Helene on stream macroinvertebrates and water quality, North Carolina Department of Environmental Quality Division of Water Resources (DWR) biologists visited 27 sites (Table 1, Figure 1) between Nov. 19-22 and Dec 3-6. Of these 27 sites, 11 were sampled for benthic macroinvertebrates, while 16 were only surveyed due to accessibility issues, time constraints and safety concerns. Three different river basins were targeted for sampling, including two sites sampled in the Broad, five in the Catawba and four in the French Broad River Basin. Results of the study found that water quality and benthic macroinvertebrate communities post-Hurricane Helene were moderate to good across the region, despite the destruction and degradation of in-stream and riparian habitat. Of the 11 sites sampled, four sites retained richness levels of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), or "EPT" taxa similar to pre-Helene data, while the remaining seven, or 64% of sites, suffered a general decrease in EPT richness, with four sites having significantly reduced richness (Table 2). Collected stream taxa (as well as field measured water quality parameters) were generally indicative of good surface water quality. However, despite moderate-to-good water quality overall, abundance of EPT taxa was reduced in all but one stream, with two streams containing almost no aquatic insects at all (Table 2). In addition, benthic macroinvertebrate relative abundance region-wide was reduced on average 28.5%, although one stream had no reduction at all (Table 2). In general, response of the aquatic macroinvertebrate community to Hurricane Helene was primarily characterized by the corresponding loss of riparian and in-stream habitat caused by flood scouring and impacts associated with landslides as opposed to chemical, industrial, or other anthropogenic pollutants that would typically impact surface water quality and negatively affect biological communities.

## BACKGROUND

Between Sept. 25-27, 2024, Western North Carolina experienced some of the most catastrophic flooding on record from Hurricane Helene after heavy rains fell on already saturated soils. In addition, a large number of landslides occurred in the region due to the heavy rainfall and strong winds (+74mph). Communities along river corridors were severely damaged with heavy loss of life, roads and rail lines destroyed, and riparian zones denuded of vegetation and the course of river channels altered. In addition, a total of 2,015 landslides were documented (Hurricane Helene 2024 Landslide Observations Dashboard) in the affected areas by the United States Geological Survey (USGS), with additional landslides noted by DWR biologists during sampling.

### Overview and Site Selection

Division of Water Resources biologists sampled benthic macroinvertebrates at 11 sites across Western North Carolina to assess stream and river water quality in response to Hurricane Helene's historic flooding (Table 1, Map 1). Three different river basins (Broad, Catawba and French Broad) were targeted for sampling during two different sampling events in the winter of 2024: (1) 19-21 November and (2) 3-6 December. In addition to this sampling effort, 16 sites were surveyed, but not sampled, by biologists due to accessibility issues, time constraints and safety concerns (Table 1, Figure 1). A description of sampled versus surveyed sites is found below.

### Surveyed Sites versus Sampled Sites

*Surveyed Sites*

Many benthic basinwide sites were surveyed with the possibility of subsequent macroinvertebrate sampling. However, due to the nature of the event, many streams and rivers were either inaccessible by road (e.g. roads destroyed) or unsafe to physically enter due to massive amounts of woody debris, log jams or other hazardous materials such as vehicles, residential flotsam, cables and wires, etc. Additionally, in many locations, in-stream sediments were unconsolidated, leading to dangerous walking conditions. Another reason sampling may not have occurred is whether the waterbody in question appeared to have been deleteriously affected by the high flows. In some cases, the streams and rivers appeared as if minimal flooding had taken place, in which case the stream was not sampled. Table1 lists the sites that were surveyed, but not sampled, and are denoted by a red triangle.

*Sampled Sites*

Sites that were sampled for aquatic macroinvertebrates were selected by choosing streams that had historical benthic data and that were of Good or Excellent water quality. Considering that EPT richness and abundance were the metrics used in this study, choosing sites that are already depauperate in these metrics would have made the possible effects of Hurricane Helene much more difficult to discern. Therefore, sites with Good-Fair or lower ratings were not considered. Unlike the surveyed sites, sampled sites were deemed safe for DWR personnel and access was typically good. These sites are denoted by a green circle on Table 1.

**Landslide Abundance**

The number of upstream landslides in each catchment was determined by delineating each in the USGS StreamStats Application (https://streamstats.usgs.gov/ss/) and using the catchment area map to manually count the number of documented landslides (Hurricane Helene 2024 Landslide Observations Dashboard) for each sample site (as a pour point) and their tributaries within each delineated basin.

**Table 1.** Site list for post Hurricane Helene benthic sampling. The symbols used match those in the following map.

| Type | Basin | Waterbody | Location | County | Latitude (DD) | Longitude (DD) |
|---|---|---|---|---|---|---|
| Sampled | BRD | Broad River | SR 2802 | Buncombe | 35.49528 | -82.27361 |
| Sampled | BRD | Hungry River | off SR 1799 | Henderson | 35.31851 | -82.34761 |
| Sampled | CTB | Buck Creek | NC 80 | McDowell | 35.73472 | -82.10138 |
| Sampled | CTB | Catawba River 2 | SR 1274 | McDowell | 35.61444 | -82.23000 |
| Sampled | CTB | Gragg Prong 2 | SR 1367 | Caldwell | 36.04636 | -81.70775 |
| Sampled | CTB | Little Buck Creek | SR 1436 | McDowell | 35.73468 | -82.08437 |
| Sampled | CTB | Wilson Creek | Off SR 1328 | Caldwell | 35.98028 | -81.76444 |
| Sampled | FRB | Ivy Creek | US 25-70 BUS | Madison | 35.77472 | -82.64528 |
| Sampled | FRB | South Toe River | SR 1167 | Yancey | 35.83111 | -82.18444 |
| Sampled | FRB | Spring Creek | NC 209, Hot Springs | Madison | 35.89278 | -82.82722 |
| Sampled | FRB | West Fork Pigeon River | SR1216 | Haywood | 35.39611 | -82.93806 |
| Surveyed | CTB | Catawba River 1 | SR 1221 | McDowell | 35.68583 | -82.06111 |
| Surveyed | CTB | Curtis Creek | SR 1227 | McDowell | 35.67306 | -82.19222 |
| Surveyed | CTB | Gragg Prong 1 | SR 1362 | Caldwell | 36.05611 | -81.71527 |
| Surveyed | CTB | Jacob Fork | SR 1924 | Burke | 35.59056 | -81.56722 |
| Surveyed | CTB | Johns River 1 | SR 1356 | Caldwell | 35.93417 | -81.69139 |
| Surveyed | CTB | Johns River 2 | SR 1438 | Burke | 35.83389 | -81.71167 |
| Surveyed | CTB | Linville River 1 | US 221 | Avery | 36.02889 | -81.89583 |
| Surveyed | CTB | Linville River 2 | NC126 | Burke | 35.79472 | -81.89028 |
| Surveyed | FRB | East Fork Pigeon River | off US 276 at SR | Haywood | 35.41806 | -82.81167 |
| Surveyed | FRB | French Broad River 1 | NC 213, nr. | Madison | 35.78611 | -82.66083 |
| Surveyed | FRB | French Broad River 2 | SR 1634 | Buncombe | 35.70833 | -82.62194 |
| Surveyed | FRB | French Broad River 3 | SR 1129 | Transylvania | 35.14861 | -82.79972 |
| Surveyed | FRB | Nolichucky River | off NC 197/SR 1321 | Mitchell | 36.07802 | -82.34755 |
| Surveyed | FRB | North Fork French Broad River | SR 1322 | Transylvania | 35.15444 | -82.84000 |
| Surveyed | FRB | Pigeon River | SR 1642 | Haywood | 35.53500 | -82.91111 |
| Surveyed | FRB | Swannanoa River | US 25 | Buncombe | 35.56833 | -82.54500 |

**Figure 1.** Map of surveyed and sampled sites.

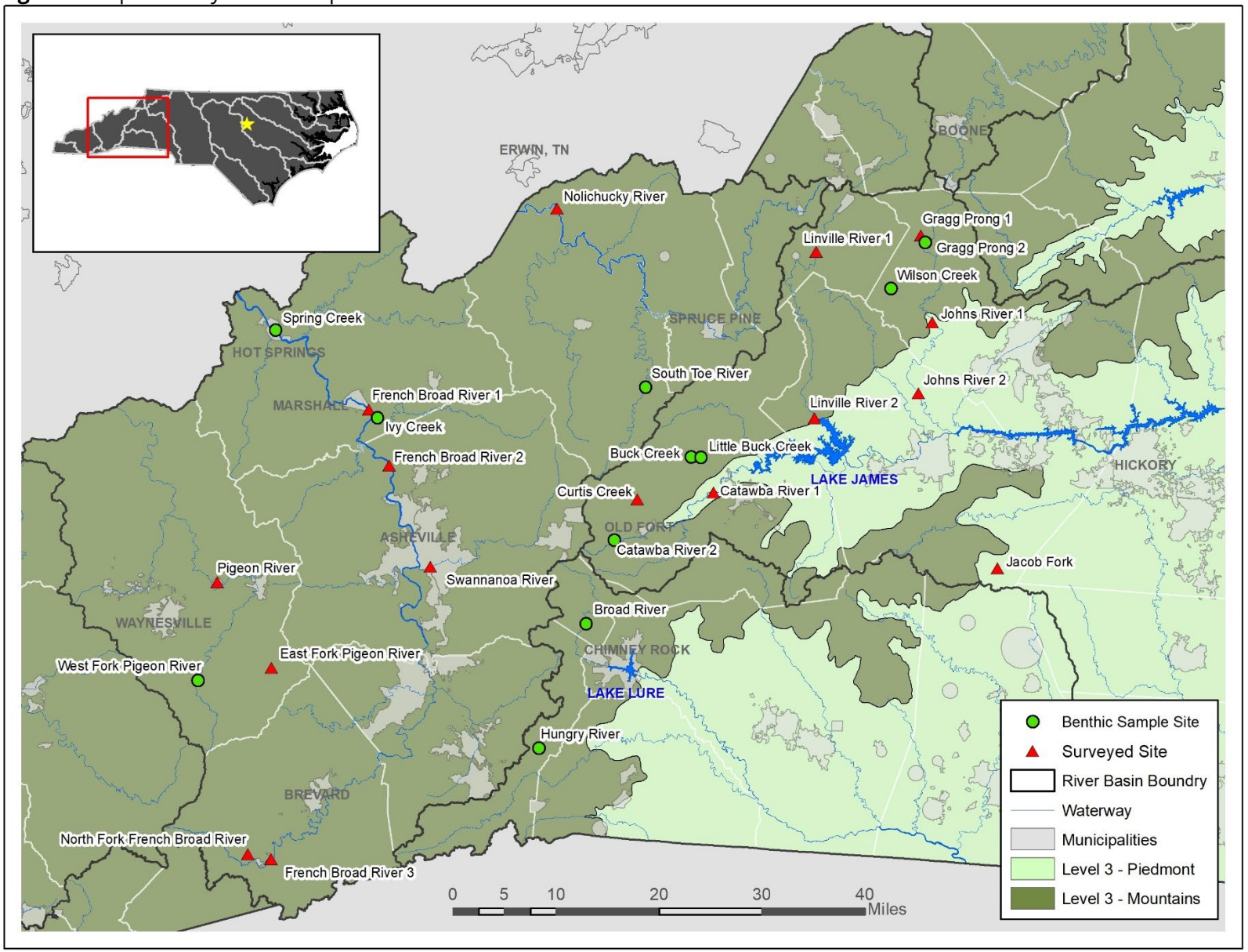

**Table 2.** Benthic EPT Richness (S) and abundance (N) for streams sampled post Hurricane Helene with historical pre-Helene data.

| | | | | Pre- Helene | | | | Post-Helene | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | winter/spring (mo/yr) | | summer (mo/yr) | | 19-21 Nov 2024, 3-6 Dec 2024 | |
| Site ID | C.C. Number | Waterbody | Drainage area ($mi^2$) | EPT S | EPT N | EPT S | EPT N | EPT S | EPT N |
| AB5 | 13162 | Broad River | 33.1 | --- | --- | 48 (8/15) | 225 | 29 | 123 |
| AB29 | 13119 | Hungry River | 18.1 | --- | --- | 50 (6/21) | 184 | 29 | 125 |
| CB321 | 13155 | Gragg Prong | 14.9 | 47 (3/89) | 207 | 46 (6/16) | 172 | 39 | 208 |
| CB104 | 13156 | Wilson Creek | 40.3 | 45 (1/24) | 155 | 48 (8/22) | 207 | 37 | 136 |
| CB6 | 13153 | Buck Creek | 14.5 | 42 (2/92) | 248 | 39 (7/17) | 171 | 15 | 30 |
| CB14 | 13157 | Catawba River | 4.5 | --- | --- | 39 (7/22) | 140 | 19 | 47 |
| CB27 | 13154 | Little Buck Creek | 5.8 | 43 (2/92) | 211 | 43 (7/22) | 191 | 42 | 142 |
| EB273 | 13163 | West Fork Pigeon River | 27.5 | 41 (12/18) | 169 | 36 (8/17) | 159 | 43 | 155 |
| EB201 | 13161 | Ivy Creek | 160.7 | --- | --- | 27 (9/22) | 121 | 21 | 75 |
| EB221 | 13118 | Spring Creek | 71.8 | --- | --- | 36 (9/22) | 116 | 26 | 107 |
| EB294 | 13158 | South Toe River * | 43.3 | 39 (12/04) | 192 | 49 (7/17) | 190 | 40 | 135 |

* Sampled about 2 km upstream of basinwide site

## METHODS

### Benthic Macroinvertebrate Sampling and Data Collection

Benthic community metrics measure the relative tolerance of a system to physical and chemical stress. Pollutants such as urban runoff, wastewater treatment plant (WWTP) discharge, sediments, or temperature variations adversely affect aquatic biological communities. Streams that are biologically degraded will usually have lower invertebrate diversity and a lower proportion of pollution sensitive species relative to streams that are pristine.

A useful metric used in assessing stream water quality is the total number, or "richness," of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) or "EPT" taxa. These three orders of aquatic insects, as a group, are more sensitive to disturbance than other orders of insects, although taxa within these groups do have differing tolerance values to pollution. A high richness of EPT (EPT S) and abundance (EPT N) generally indicates higher water quality.

EPT sampling was performed at all the study streams. The EPT collection method is composed of four samples and includes the collection of one riffle kick, one sweep, one leaf pack and visual collections. Only insects belonging to the orders Ephemeroptera, Plecoptera, and Trichoptera are sorted. Organisms are picked in the field and preserved in 95% ethanol. In the laboratory, invertebrates are identified to the lowest taxonomic unit possible and assigned values based on their relative abundance (rare, 1-2 specimens; common, 3-9 specimens; or abundant, ≥10 specimens).

The EPT S values reported are typically used to assign bioclassifications (Poor, Fair, Good-Fair, Good, and Excellent) to the streams under investigation. However, streams in this study were instead given the classification of "Not Rated." This is due to several factors. First, ratings can be affected by seasonal differences in taxonomic groups, particularly Plecoptera, many of which are considered winter taxa. As the above ratings are based on summer data, seasonal taxa need to be removed from analyses for bioassessment ratings to be comparable to those garnered during summer months (June-September). However, seasonal corrections were developed in conjunction with a different sampling method (Full Scale Method) and are not appropriate for use with EPT sampling methods. Full Scale sampling methods were considered for this study but were rejected due to the nature of the disturbance: large scale devastating floods and associated habitat effects. For example, high flows removed much of the bank habitat of the waterways and scoured or completely moved or replaced in-channel substrates. Additionally, full-scale methods require a substantial amount of time, whereas the less intensive EPT method allowed for more sites to be assessed in a shorter period. Further rationale for not rating these sites post-Helene can be found in the Results and Discussion section.

#### *Habitat Analysis*

Because streams interact with their surrounding landscape, nearby geologic conditions and riparian vegetation can affect water conditions and flows as well as habitat quality and quantity. Local conditions can sometimes negatively impact aquatic fauna either by causing the absence of one or more habitat types (e.g. root mats or coarse woody debris) or by altering the natural morphology of the channel (e.g. erosion or sedimentation). This can lead to less overall habitat for aquatic species and may ultimately lead to loss of species richness and abundances. For example, destabilized banks or lack of riparian vegetation can contribute fine sediments to the stream channel during high flow periods, resulting in embedded substrates subsequently affecting the biological communities that rely on that substrate.

In addition to benthic sampling, the stream environment is analyzed for both quality and quantity of in-stream habitat suitable for invertebrate colonization, as well as riparian integrity and bank stability. These evaluations include, but are not limited to, parameters such as depth and width, types of substrates, embeddedness, pool variety, quality of riffles, bank stability and riparian width. Habitat assessments result in a composite score between 1 and 100 with a higher score indicating a more favorable environment for stream biota.

### *Physical-Chemical Analysis*

Common physical-chemical water quality measurements such as pH, dissolved oxygen (DO), specific conductance, temperature, and turbidity (water clarity) are taken at each site to facilitate evaluation of current water conditions. These measurements often affect biological processes of many streams' biota. Changes in these parameters can signify changes to water quality and may provide additional evidence of impact to the stream. For example, higher water temperature may indicate canopy removal or increased impervious surface within the watershed. Also, increased specific conductance (water electrical conductivity, or dissolved ionic concentration, corrected for water temperature at 25° C) can signal that a discharger exists upstream. It should be noted that waters with exceedingly low ionic strength (i.e. low specific conductance) can affect pH readings and therefore pH measurements may be tenuous and unreliable at low specific conductances.

Field measurements of temperature, dissolved oxygen (DO), specific conductance and pH were taken at the time of sampling using an In-Situ Aqua TROLL 400 multimeter. Meter calibrations are performed in accordance with DWR Intensive Survey Branch Standard Operating Procedures (NCDEQ 2013). Physical-chemical measurements for the streams sampled are summarized in Table 3 in the Appendix.

See the NCDEQ Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates (2015) for a comprehensive review of all benthic macroinvertebrate sampling and analysis methods.

## RESULTS and DISCUSSION

Water quality post-Hurricane Helene was moderate to good across the region. Of the 11 sites sampled, four sites (Gragg Prong, South Toe River, Little Buck Creek and the West Fork Pigeon River) retained high EPT richness levels similar to pre-Helene data, while the remaining seven, or 64%, of sites (Broad River, Hungry River, Wilson Creek, Buck Creek, Catawba River, Ivy Creek and Spring Creek) suffered a general decrease in EPT richness, with four sites (Broad River, Hungry River, Buck Creek and the Catawba River) having significantly reduced richness (Table 2). Loss of riparian vegetation and degradation of in-stream habitat was greatest at these sites. Overall, collected stream taxa were generally indicative of good surface water quality as species intolerant of pollution were present at many sites. However, despite moderate-to-good water quality overall, the abundance of EPT taxa was reduced in all but one stream (Gragg Prong), with two streams (Buck Creek, Catawba River) containing almost no aquatic insects at all (Table 2). Benthic macroinvertebrate relative abundance region-wide was reduced on average 28.5%.

In general, response of the aquatic macroinvertebrate community to Hurricane Helene has been observed in loss of riparian and in-stream habitat caused by flood scouring and landslide impacts, as opposed to anthropogenic pollutants that would typically impact surface water quality and negatively affect biological communities. Due to the catastrophic, unprecedented nature of this event, the sites assessed for benthic macroinvertebrates in this study were not rated. This decision is consistent with previous studies conducted after natural, stressful climatic events (e.g., extreme drought, or as in this case, extreme flooding, scour and landslides). The benthic invertebrate metrics used to derive bioclassifications (i.e., “ratings”) are calibrated and tested primarily to detect anthropogenic stressors. As Helene was a natural stress, it was inappropriate at this time to assign ratings to these streams. However, this is only an initial survey and subsequent assessments at these locations will receive bioclassifications, as the effects of this natural stressor will likely attenuate sufficiently to allow for accurate assignment of ratings. Overall, considering the general resiliency of the benthic macroinvertebrate communities shown in this study at most sites (despite the catastrophic, unprecedented nature of the impacts), it is likely (in the absence of new stressors) these invertebrate communities will continue to improve to pre-Helene levels. Further sampling this spring or summer is recommended.

## Broad River Basin

### *Site 1: Broad River at SR 2802, Buncombe County*

Broad River at SR 2802 facing upstream prior to Hurricane Helene, August 2015.

Broad River at SR 2802 post-Helene, December 2024.

Located in extreme southeastern Buncombe County, this benthic monitoring site on the Broad River is stationed near its confluence with Flat Creek. In its upper reaches, the Broad River drains streams along the eastern flank of the Swannanoa Mountains while flowing towards the towns of Bat Cave, Chimney Rock, and ultimately Lake Lure – all of which received historic flooding and devastation from Hurricane Helene. Unfortunately, crews could not sample the Broad River downstream of this station due to road scour and destruction that isolated the above communities from recovery efforts. At the sampling site, a bridge transversing the river along Lower Flat Creek Road appeared to have been washed out, but a temporary bridge had been constructed in its place at the time of sampling. Significant bank stabilization and grading performed by heavy machinery was evident near construction of the temporary bridge. In addition, the river's confluence with Flat Creek—located approximately 10 meters upstream of the bridge—appeared to have been reworked and channelized by heavy machinery for approximately 20 meters (photo below). Benthic macroinvertebrate sampling occurred about 50 meters upstream of these stream bank and in-stream channel modifications to reduce the probability of results being biased or potentially confounded by these emergency stabilization efforts.

Confluence of Flat Creek and Broad River post-Hurricane Helene.

*Benthic Sampling Results*

A total of 29 EPT taxa were collected on Dec. 5, 2024, with an abundance of 103 (Table 2). Data from previous out-of-season sampling (winter/spring) were unavailable for this site. While taxa richness and abundance were low, the fauna present were mostly composed of pollution intolerant organisms, indicating that surface water quality at this site may not be an issue. However, it is hypothesized that scour from upstream debris flows generated by landslides degraded in-stream habitat quality, and is likely responsible for the low richness and abundance observed. To-date, USGS has documented 68 Helene-related landslides upstream of this station.

*Other Data*

Macroinvertebrate habitat scored moderate (70/100), which was significantly less than when the site was previously assessed in August 2015 (85/100). Facing upstream, riparian vegetation on the right bank appeared intact. However, left bank vegetation was sparser with deeply incised, nearly vertical straight banks. Physical-chemical parameters measured were within normal ranges for this river (Table 3). Water was clear with a turbidity of 2.01.

## *Site 2: Hungry River off SR 1799, Henderson County*

Hungry River off SR 1799 facing upstream prior to Hurricane Helene,

Hungry River off SR 1799 post-Helene, December 2024.

Located in eastern Henderson County, this benthic monitoring site on the Hungry River is situated at its confluence with the Little Hungry River at Deep Gap Road (SR 1799). Significant stabilization and re-grading of Deep Gap Road occurred near this site, as evidenced by large, quarried granite boulders and foreign material placed along the river left bank to stabilize and reduce erosion. At the time of sampling on Dec. 4, 2024, a downstream bridge at Big Hungry Road was still being repaired/replaced. Homes, cars, and large trees were noted in the river channel up and downstream (photo below) of the sampling site. The USGS reported only four landslides in the watershed upstream of the sampling site. However, one of these landslides was reported directly across from the sample site and numerous unreported, small landslides were observed by DWR biologists on

Deep Gap Road when approaching the site from the West. Of the sites sampled in the Broad River drainage, this site had the worst damage to human property observed.

*Benthic Sampling Results*

A total of 29 EPT taxa were collected with an abundance of 96 (Table 2). Data from previous out-of-season sampling (winter/spring) were unavailable for this site. While taxa richness and abundance were low, the fauna present were mostly composed of pollution intolerant organisms indicating that surface water quality at this is generally favorable. Again, it is hypothesized that extreme scour and mudslide debris flows generated by landslides degraded in-stream habitat quality and is likely responsible for the low richness and abundance observed.

Home swept off foundation, Hungry River downstream of SR 1799.

*Other Data*

Macroinvertebrate habitat scored low (52/100), but was similar to the site's previous assessment in June 2021 (57/100). However, DWR biologists noted significant new sand deposits in the channel, with 8-12-inch-high sand wrack lines in the mainstream channel. Although this site has had historical issues with sand and fine sediment deposition, percent (%) sand substrate composition increased from 30% to 50% between 2021 and 2024 pre- and post-Helene. In addition, boulder and cobble substrate decreased from 20% and 35%, respectively, to 5% and 15% during this same period, indicating significant channel filling of sand and fine sediments. Physical-chemical parameters measured were within normal ranges for a healthy river of this size in this ecoregion (Table 1). Water was clear with turbidity of 2.85 NTU despite ongoing in-stream habitat modification work continuing in the watershed.

## French Broad River Basin

### *Site 1: Ivy Creek at US 25-70 BUS, Madison County*

Ivy Creek at US25-70 BUS near Marshall facing downstream, July 2012.

Ivy Creek at US25-70 BUS facing downstream post-Hurricane Helene, December 2024.

Located in southcentral Madison County, this site on Ivy Creek is stationed approximately 0.25 river mile upstream of the creek's confluence with the French Broad River near the town of Marshall, which was devasted by Hurricane Helene flooding. The Ivy Creek watershed drains the northern flank of the Great Craggy Mountains and a portion of the western edge of the Black Mountains, including the towns of Barnardsville, Mars Hill, Ivy, Jupiter and north Flat Creek. Significant erosion of riparian habitat occurred at this site. Numerous debris and log jams and eroding banks were noted at the sample site and during surveys of the watershed. At least one home near the sample site was condemned, with a high-water line nearing the roof of the home. A USGS Gage Station approximately 1.5 river miles upstream of the sample location logged a peak stream discharge of 15,400 cubic feet per second (cfs), with a gage height of 28.36 feet (major flood stage = 19ft) during the flood event (Appendix Table 2). Average discharge at the station according to USGS data is 32.8 cfs with a gage height of 2.02 feet. USGS reported 42 landslides in the watershed upstream of the sampling site with additional slides observed by DWR biologists.

Ivy Creek at US25-70 BUS facing upstream post-Helene showing riparian damage and downed transmission lines.

*Benthic Sampling Results* A total of 21 EPT taxa were collected from Ivy Creek on Dec. 5, 2024, with an abundance of 62 (Table 2). Data from previous out of season sampling (winter/spring) were unavailable for this site. While taxa richness and abundance were low, the fauna present were generally composed of pollution intolerant organisms indicating that surface water quality at this site is generally not problematic. However, as was noted at numerous sites in the region, it is hypothesized that extreme scour and mudslide debris flows associated with landslides degraded in-stream habitat quality and is likely responsible for the low EPT richness and abundance observed. Indeed, this site had the lowest EPT richness and abundance of sites sampled in the French Broad drainage.

*Other Data*

Macroinvertebrate habitat scored low (56/100), which was significantly less than when the site was previously assessed in September 2022 (73/100). Facing upstream, left bank riparian vegetation was completely removed by the extreme flows. Physical-chemical parameters measured were within normal ranges for a healthy river of this size in this ecoregion (Appendix Table 1). Water was clear, but turbidity was 8.28 NTU, indicating that active erosion and suspension of alluvial deposits of sand and fine sediments are still ongoing more than two months post-Hurricane Helene.

## *Site 2: Spring Creek at NC 209, Madison County*

Spring Creek at NC 209 near Hot Springs facing upstream, July 2012.

Spring Creek well downstream of NC 209 facing upstream post- Hurricane Helene, December 2024.

This reference site on Spring Creek in southcentral Madison County is stationed approx. 0.2 river mile upstream of the creek's confluence with the French Broad River near the town of Hot Springs, which was devasted by Hurricane Helene flooding. The Spring Creek watershed drains the eastern flank of Max Patch and surrounding mountains, including the towns of Spring Creek, Bluff and Hot Springs. Significant erosion of riparian habitat occurred at this site, and USGS reported zero landslides in the watershed upstream of the sampling site. However, DWR biologists noted several landslides along NC 212 near the community of White Rock when traveling to Hot Springs from the northeast.

Spring Creek facing downstream from NC 209 bridge in Hot Springs, December 2024. Note Spring Creek Tavern to the right.

*Benthic Sampling Results*

A total of 26 EPT taxa were collected from Spring Creek on Dec. 3, 2024, with an abundance of 92. Data from previous out of season sampling (winter/spring) were unavailable for this site. While taxa richness and abundance were low, the fauna present were generally composed of pollution intolerant organisms suggesting that surface water quality at this site remains generally favorable. Nonetheless, extreme flows and landslide induced scour and mudslide debris flows likely degraded in-stream habitat quality and could be responsible for the low richness and abundance observed.

*Other Data*

Macroinvertebrate habitat scored low (57/100), which was significantly less than when the site was previously assessed in September 2022 (77/100). Facing upstream, left bank riparian vegetation was completely removed due to scour during major flood stage. Physical-chemical parameters measured were within normal ranges for a healthy river of this size in this ecoregion (Appendix Table 1). Water was clear and turbidity was 0.71 NTU despite ongoing in-stream habitat modification work continuing in the watershed.

## *Site 3: West Fork Pigeon River at SR 1216, Haywood County*

West Fork Pigeon River at SR 1216 facing upstream, August 2017.

West Fork Pigeon River at SR 1216 facing upstream post-Hurricane Helene, December 2024.

Located in south-central Haywood County, this reference site on the West Fork Pigeon River is stationed approximately 1.0 river mile upstream of Lake Logan. The West Fork Pigeon River watershed is very well-forested and is comprised of nearly 95% forested land use. Despite significant watershed flooding, the sampling site showed minimal signs of damage, likely the result of the overwhelmingly forested nature of this catchment. A steel bridge downstream of the site remained standing and functional. A USGS Gage Station at the bridge logged a peak stream discharge of 14,800 cfs with a gage height of 11.3 feet during the flood event before it stopped recording data at 9 a.m. on Sept. 27 (Table 4). Average discharge at the station, according to USGS data, is 25.5 cfs with a gage height of 1.19 feet. A gap in the recording data extends to 12:05 p.m. on Sept. 30, when the gage appears fixed and reading a height of 2.15 feet. However, further downstream in Canton, the USGS gage on the mainstem Pigeon River recorded a peak gage height of 25.66 feet and did not stop recording data. The operational limit of the West Fork Pigeon gage is 19.36 feet. Given the water rise on the Pigeon River in Canton (operational limit 26.7 feet), it is possible that the West Fork Pigeon gage exceeded its operational limit, or was destroyed during the ensuing flood.

West Fork Pigeon River at SR 1216 facing downstream post-Hurricane Helene, December 2024.

*Benthic Sampling Results*

A total of 43 EPT taxa were collected from West Fork Pigeon River on Dec. 5, 2024, with an abundance of 140. This result is very similar to collections made at the same sampling reach in December 2018, when 41 EPT taxa were collected with an abundance of 169. Although abundance was slightly lower in 2024 versus 2018, it is clear that Helene flooding had minimal impacts to the biological community in this well-forested and conserved watershed.

*Other Data*

USGS reported zero landslides in the watershed upstream of the sampling site and none were observed by DWR biologists. Macroinvertebrate habitat scored high (90/100), which was very similar to when the site was previously assessed in April 2019 (92/100). Despite the flooding, riparian vegetation was almost completely intact despite some small debris- and wrack lines near pull-offs and parking along NC 215. Again, given the heavily intact forest cover in this watershed and the corresponding lack of landslides and landslide related impacts, it is unsurprising this catchment was relatively unscathed.

## Catawba River Basin

### *Site 1: Gragg Prong (2) at SR 1367, Caldwell County*

Gragg Prong looking upstream. This photo was taken in 2018 before Helene.

Gragg Prong post-Helene, 20 November 2024.

Located in northeastern Caldwell County, Gragg Prong is a small reference stream that drains the Pisgah Game Lands south of Blowing Rock. This site was selected as a reference control to Wilson Creek, a larger river site to the southwest of Gragg Prong. Aside from a damaged bridge, the immediate environs of Gragg Prong show signs of high flows. However, riparian vegetation, while bent downstream by high flows, remained completely intact. Overbank deposits of sand were present, but no erosion or washed-out banks were noted, and no landslides were recorded in this watershed.

*Benthic Sampling Results*

A total of 39 EPT taxa were collected (Table 2), a 17% decrease from the last out-of-season sample taken at this site in March 1989. However, EPT abundance (208) was the same as that recorded in 1989 (207), indicating little to no scour of the benthos. This was further evidenced by the presence of scraping taxa on the benthic substrate such as *Glossosoma nigrior*, a turtle-case caddis easily impacted by high scour flows. The macroinvertebrates collected indicated a healthy thriving benthic community.

Gragg Prong looking downstream. This photo was taken after Hurricane Helene.

*Other Data*

Colonizable macroinvertebrate habitat was present and in good condition. A thin layer of periphyton was observed on the instream habitat, suggesting scour was minimal. Physical-chemical parameters measured were within normal ranges for a healthy stream of this size in this ecoregion (Table 3). Water was clear with a turbidity measure of 1.2 NTU. Overall, Gragg Prong appears little affected by Hurricane Helene.

## *Site 2: Wilson Creek off SR1328, Caldwell County*

Wilson Creek, pre-Helene, July 2017.

Wilson Creek post-Helene, 20 November 2024.

Wilson Creek lies in western Caldwell County, and drains much of Pisgah National Forest, originating on the southern slope of Grandfather Mountain. It is considered by BAB biologists to be one of the best reference streams in North Carolina, as it has the highest EPT richness ever recorded (69 taxa, summer sample) from any waterbody in this state. In addition, Wilson Creek contains many rare aquatic species, including new species discovered by DWR biologists (*Stenonema wudigeum, Isoperla arcana*). Wilson Creek was sampled below Mortimer, just above the bridge that spans Harpers Creek, a tributary to Wilson Creek. The bridge was washed out and access to the basinwide site was only available via NC 90 (Edgemont Road). Upstream communities fared poorly during Helene with at least four landslides reported above Edgemont, although many small landslides were noted along Brown Mountain Road by DWR biologists. New river channels were noted below Edgemont and near Mortimer. Riparian vegetation, including large trees, were swept away and transported downriver, forming large

debris dams in many places along Brown Mountain Road. However, the river channel at the basinwide site was relatively intact although riparian vegetation was thinned.

Wilson Creek with new stream channels post-Helene (foreground).

*Benthic Sampling Results*

A total of 37 EPT taxa were collected with an abundance of 136, a 17.8 % and 12.3% decrease, respectively, from the last out-of-season sample taken in January 2024 (Table 2). In-stream fauna was primarily composed of pollution intolerant taxa, although some were low in relative abundance.

*Other Data*

Macroinvertebrate habitat was excellent (89/100) but was slightly affected by scour as little evidence of periphyton was noted on the rocks. Physical-chemical parameters measured were within normal ranges for a healthy stream of this size in this ecoregion (Table 3). Water was clear with a turbidity measure of 0.9 NTU.

## *Site 3: Buck Creek at NC 80, McDowell County*

Buck Creek pre-Helene, July 2017.

Buck Creek, same reach, post-Helene, 19 November 2024.

Buck Creek lies in western McDowell County and drains the slopes of the Blue Ridge Escarpment. The sampling site on Buck Creek is approximately 1 kilometer upstream of Lake Tahoma. The Buck Creek watershed upstream of the sampling site was devastated by 66 reported landslides, which both scoured the river channel and

completely denuded the banks of riparian vegetation, up to the level of the roadway in some reaches. DWR biologists also observed some small hillside slumps within the sampling reach. Additionally, upstream communities were devasted by historical flooding, which included loss of life. In some reaches, vehicles and houses were deposited in the river channel and in one instance, a house was nearly buried by sediment.

*Benthic Sampling Results*

A total of 15 EPT taxa were collected on Nov. 19, 2024, a reduction of 64.3 % from previous winter taxa levels (Table 2). In addition, most taxa collected were represented by only a single individual for a total abundance of 30, in contrast to the winter sample in 1992, where an abundance of 248 was recorded, an 87.9% reduction. Unlike most of the other sites sampled in this study, the macroinvertebrate community at this location was decimated by Hurricane Helene.

Buck Creek denuded banks, post-Helene, 19 November 2024.

*Other Data*

Macroinvertebrate habitat was severely affected (75/100) by the flooding and scour, with the edge habitat almost completely gone. Periphyton was notably absent, and the channel was scoured down to bedrock in places. In some areas the stream was a small, wetted channel amidst a large, dry boulder and cobble field. While physical-chemical parameters measured were within normal ranges, the water was only relatively clear, with a turbidity measure of 3.0 NTU, likely due to ongoing in-stream construction work occurring in the upstream catchment. Buck Creek has historically rated Excellent or Good based on the macroinvertebrate fauna present. If rated for this study, Buck Creek would have received a Fair rating, or three bioclassifications below Excellent.

## *Site 4: Catawba River (2) at SR 1274, McDowell County*

Catawba River at SR 1274, July 2022.

Catawba River, same reach post-Helene, 21 November 2024.

The Catawba River at SR 1274 is the uppermost reach of the river sampled by BAB biologists and is situated just below Catawba Falls parking area and trailhead near Old Fort. The nearby trails are a popular destination for hikers and waterfall seekers from across the state. At this location, the river has a drainage area of 4.5 square miles and is about 4-5 meters wide. The catchment above the sampling site is known by BAB biologists to be historically prone to landslides, which have been observed via Google Earth. As confirmed by DWR staff, numerous small landslides were noted along the road during the drive to the site. A small landslide was observed just 50 meters upstream of the site, with the hillside trees forming a large debris dam across the stream channel. A further four landslides were reported by the USGS to be upstream of the sampling site.

*Benthic Sampling Results*

A total of 19 EPT taxa were collected on Nov. 21, 2024, (Table 2), with a very low abundance of 47. Data from previous out-of-season sampling (winter/spring) were not available for this site. While taxa richness and abundance are low, the fauna present is composed of highly pollution intolerant organisms that would not normally be present in an urban setting, indicating that water quality at this site is not be why the organisms are lacking. Instead, it is suggested that extreme scour and debris flows associated with upstream landslides are responsible for the low richness and abundance observed.

A small landslide and debris dam just upstream of the sampling site.

*Other Data*

Macroinvertebrate habitat was not overtly affected (89/100) by the flooding and scour. It is likely that the very small drainage area simply could not provide enough water to enable major flooding. It was noted that the very low bridge over the stream was not overtopped by the flood and lacked a debris wrack line. Additional photo evidence shows that the high water was sufficient to expose the root systems of bank vegetation only up to 2-3 feet of the bank. Physical-chemical parameters measured were within normal ranges for a healthy stream of this size (Table 3).

## *Site 5: Little Buck Creek at SR 1436, McDowell County*

Little Buck Creek pre-Helene, July 2022.

Little Buck Creek lies in western McDowell County and is a tributary to Lake Tahoma. The benthic sampling site is located a few hundred meters upstream of the lake. There is little development in the watershed and no landslides were reported in the watershed (USGS) or observed by DWR biologists. This site was selected due to its proximity to Buck Creek and as a small stream control reach.

*Benthic Sampling Results*

A total of 42 EPT taxa were collected on Nov. 19, 2024, very similar to previous winter taxa levels, when 43 EPT taxa were collected in February 1992 (Table 2). However, abundance values were lower during this sampling event (142) compared to the previous winter sampling event in 1992 (211), suggesting some scour occurred during Hurricane Helene flooding. Despite the lower numbers, the benthic community was diverse and composed of numerous pollution intolerant taxa indicating a healthy community.

*Other Data*

Macroinvertebrate habitat on Little Buck Creek was unaffected by Hurricane Helene flooding scoring an excellent 89/100, with both riffles and (streambank) edge habitats intact. Periphyton was present on the surface of instream rocks. Riparian vegetation was present, with the only evidence of flooding some significant overbank deposits of sand. A large tree had fallen into the stream channel at the site and acted as a debris dam, but the vast majority of the riparian was intact. Physical-chemical parameters measured were within normal ranges for a healthy stream of this size in this ecoregion (Table 3). Water was clear with a turbidity of 1.9 NTU. Little Buck Creek was largely unaffected by Hurricane Helene and harbored a diverse and healthy macroinvertebrate fauna.

## *Site 6: South Toe River at SR 1167, Yancey County*

South Toe River near Celo, pre-Helene, July 2021.

South Toe River, post-Helene, 21 November 2024.

Located in eastern Yancey County, the South Toe River drains the eastern portion of the Black Mountains, including Mount Mitchell. The benthic basinwide site at Celo was not sampled for this study due to access issues, but a suitable reach was sampled about 2 km downstream where the river could be safely accessed. A low bridge at the sample site was washed out. The USGS reported 40 landslides upstream of this site, while numerous additional, but small, landslides were noted by DWR staff when approaching and surveying the river. The upper catchment of the South Toe received heavy damage to the river corridor and riparian landscape with trees, residences, and roads severely damaged or completely washed away. This site has historically maintained an Excellent bioclassification.

*Benthic Sampling Results*

Forty EPT taxa were collected on Nov. 21, 2024, similar to a sampling event in December 2004. Like almost all streams in this study, the abundance value of EPT taxa (135) was lower than the previous winter data (192). Most taxa were common with only a few taxa abundant and, in fact, many taxa had only a single specimen collected. The benthic macroinvertebrate community was mostly composed of highly pollution sensitive taxa, although taxa abundances were lowered due to scour. Nonetheless, 40 EPT taxa is notable considering the destructive force of water and debris that traversed this reach.

South Toe River bank, 21 Nov. 2024. The red house on the left was moved off its foundation, but stopped from hitting the white house only by a large tree.

*Other Data*

Macroinvertebrate habitat was moderate scoring 80/100, with the frequent loose riffles and stream edge root mats partly intact. Periphyton biomass on submerged substrate was low. Facing upstream, riparian vegetation was mostly present on the left bank although large areas of scoured bedrock were visible in some areas. Physical-chemical parameters measured were normal for a large stream in this ecoregion (Table 3). Water was clear with a turbidity measure of 1.3 NTU. Overall, the benthos of the South Toe River was largely unaffected by Hurricane Helene.

**Table 3.** Habitat and Physical-Chemical data for streams sampled for benthos after Hurricane Helene, 27 September 2024.

| Stream | BROAD R | HUNGRY R | GRAGG PR | WILSON CR | BUCK CR | CATAWBA R | L BUCK CR | S TOE R | IVY CR | SPRING CR | W FK PIGEON R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Habitat Scores** | | | | | | | | | | | |
| Channel modification (5) | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| In-stream habitat (20) | 15 | 14 | 18 | 18 | 16 | 18 | 18 | 18 | 12 | 16 | 19 |
| Bottom substrate (15) | 12 | 8 | 13 | 15 | 10 | 12 | 14 | 14 | 8 | 14 | 13 |
| Pool variety (10) | 8 | 2 | 8 | 10 | 10 | 10 | 8 | 10 | 7 | 3 | 10 |
| Riffle habitats (16) | 7 | 12 | 16 | 15 | 15 | 14 | 16 | 14 | 10 | 10 | 16 |
| Bank erosion (7) | 2 | 2 | 6 | 5 | 2 | 4 | 6 | 4 | 2 | 3 | 6 |
| Bank vegetation (7) | 7 | 5 | 6 | 6 | 4 | 6 | 6 | 6 | 5 | 4 | 7 |
| Light penetration (10) | 7 | 2 | 4 | 5 | 5 | 9 | 7 | 3 | 5 | 2 | 9 |
| Left riparian (5) | 4 | 0 | 4 | 5 | 5 | 4 | 5 | 5 | 0 | 0 | 2 |
| Right riparian (5) | 4 | 3 | 3 | 5 | 3 | 4 | 4 | 2 | 3 | 1 | 3 |
| Total Habitat (100) | **70** | **52** | **83** | **86** | **75** | **86** | **89** | **81** | **56** | **57** | **90** |
| **Other Habitat** | | | | | | | | | | | |
| Average stream width (m) | 5.3 | 5.3 | 8 | 12 | 8 | 5 | 4 | 26 | 6.1 | 6.1 | 3.5 |
| Average stream depth (m) | 0.28 | 0.23 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.5 | 0.3 | 0.2 |
| Canopy (%) | 50 | 15 | 40 | 10 | 40 | 70 | 60 | 10 | 30 | 20 | 80 |
| Substrate (%) | | | | | | | | | | | |
| Boulder | 20 | 5 | 30 | 20 | 25 | 25 | 25 | 10 | 10 | 20 | 30 |
| Cobble | 30 | 15 | 30 | 30 | 25 | 25 | 35 | 30 | 20 | 20 | 40 |
| Gravel | 30 | 15 | 20 | 20 | 25 | 15 | 20 | 20 | 20 | 20 | 20 |
| Sand | 10 | 50 | 10 | 20 | 10 | 20 | 15 | 20 | 40 | 30 | 10 |
| Silt | 10 | 10 | 0 | 0 | 15 | 5 | 0 | 0 | 5 | 10 | 0 |
| Other | 0 | 5 | 10 | 10 | 10 | 5 | 5 | 20 | 5 | 0 | 0 |
| description | --- | woody debris | bedrock | bedrock | bedrock | bedrock | bedrock | bedrock | woody debris | --- | --- |
| **Physicochemical** | | | | | | | | | | | |
| Temperature (ºC) | 5.56 | 4.9 | 12.6 | 12.4 | 11.5 | 9.4 | 11.9 | 8.3 | 2.98 | 3.9 | 5.19 |
| Dissolved oxygen (mg/L) | 11.75 | 11.8 | 10.3 | 10.1 | 10.4 | 10.5 | 10.1 | 10.5 | 12.34 | 12.64 | 11.3 |
| Specific conductance (µmhos/cm) | 31.77 | 30.7 | 35.5 | 17.8 | 33.3 | 41.7 | 20.5 | 12.3 | 92.21 | 52.71 | 11.52 |
| pH | 6.47 | 6.5 | 6.7 | 6.4 | 7 | 6.5 | 6.5 | 5.6 | 6.82 | 6.41 | 6.15 |
| Turbidity (NTU) | 2 | 2.9 | 1.2 | 0.9 | 3 | 1.5 | 1.9 | 1.3 | 8.3 | 0.7 | 0.3 |

**Table 4 .** Available stream flow data for surveyed and sampled sites post-Hurricane Helene. Data compiled from https://waterdata.usgs.gov/nc/nwis/rt, https://water.noaa.gov/, and https://fiman.nc.gov/.

| Basin | Waterbody | Location | Stream Guage Height Peak Flow (ft) | Stream Guage Height Median Flow (ft) | Discharge (ft3/s) | Median Discharge (ft3/s) | Moderate Flood Stage (ft) | Major Flood Stage (ft) |
|---|---|---|---|---|---|---|---|---|
| BRD | BROAD RIVER | SR 2802 | | | | | | |
| BRD | HUNGRY RIVER | OFF SR 1799 | | | | | | |
| CTB | BUCK CREEK | NC 80 | | | | | | |
| CTB | CATAWBA RIVER | SR 1274 | | | | | | |
| CTB | GRAGG PRONG 2 | SR 1367 | | | | | | |
| CTB | LITTLE BUCK CREEK | SR 1436 | | | | | | |
| CTB | WILSON CREEK | OFF SR 1328 | | | | | | |
| FRB | IVY CREEK | US 25-70 BUS | 28.36 | 2.02 | 15400 | 32.8 | 17.5 | 19 |
| FRB | SOUTH TOE RIVER | SR 1167 | 26.06 | 0.8 | 26100 | 62.7 | 15 | 23 |
| FRB | SPRING CREEK | NC 209, HOT SPRINGS | | | | | | |
| FRB | WEST FORK PIGEON RIVER | SR1216 | 11.3 | 1.19 | 14800 | 25.5 | 14 | 18 |
| CTB | CATAWBA RIVER | SR 1221 | 21.82 | 1.65 | 41800 | 140 | 16 | 18 |
| CTB | CURTIS CREEK | SR 1227 BE TANTROUGH | | | | | | |
| CTB | GRAGG PRONG | SR 1362 | | | | | | |
| CTB | JACOB FORK | SR 1924 | 17.92 | 1.68 | 5910 | 18.4 | 22 | 24 |
| CTB | JOHNS RIVER 1 | SR 1356 | | | | | | |
| CTB | JOHNS RIVER 2 | SR 1438 | 30.48 | 2.25 | 45200 | 315 | 18 | 24 |
| CTB | LINVILLE RIVER 1 | US 221 | | | | | | |
| CTB | LINVILLE RIVER 2 | NC126 | 13.11 | 50.3 | 28300 | 1.16 | 14 | 16 |
| FRB | EAST FORK PIGEON RIVER | OFF US 276 AT SR 1887 | | | | | | |
| FRB | FRENCH BROAD RIVER 1 | NC 213, NR. MARSHALL | 20.08 | 1.75 | 54100 * | 1220 | 10 | 13 |
| FRB | FRENCH BROAD RIVER 2 | SR 1634 | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| FRB | FRENCH BROAD RIVER 3 | SR 1129 | | | | | | |
| FRB | NOLICHUCKY RIVER | OFF NC 197/SR 1321 | | | | | | |
| FRB | NORTH FK FRENCH BROAD R | SR 1322 | | | | | | |
| FRB | PIGEON RIVER | SR 1642 | 25.67 | 1.5 | 67300 | 72 | 15 | 19 |
| FRB | SWANNANOA RIVER | US 25 | 27.33 | 1.44 | 13200 | 49.4 | 14.5 | 16.5 |

* max value not displayed on graph

## REFERENCES

North Carolina Department of Environmental Quality (NCDEQ). 2013.Standard Operating Procedures Manual: Physical and Chemical Monitoring Version 2.1. Division of Water Resources. Intensive Survey Branch. Raleigh, North Carolina. December 2013.

North Carolina Department of Environmental Quality (NCDEQ). 2015. Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates. Division of Water Resources. Raleigh, North Carolina. November 2015.

U.S. Geological Survey, 2024, Hurricane Helene 2024 Landslide Observations Dashboard, accessed January 15, 2025 at URL https://www.arcgis.com/apps/dashboards/01b4f51fc0b64002bf7722a9acfc181d