An assessment of Forestry Best Management Practices in North Carolina, 2018-2020

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Executive Summary

Staff with the N.C. Forest Service (NCFS) Water Resources Branch conducted detailed visual assessments of North Carolina's forestry Best Management Practices (BMPs) implemented on 216 forestland tracts across the state between December 2018 and November 2020. This report summarizes the percentages of BMP implementation and potential risks to water quality observed during these tract examinations. Additionally, this report contains recommendations for improvements by ecoregion and reviews our actions to address previous survey report recommendations. This is the second report following the 2006 amendments to the North Carolina Forestry BMP Manual, which was used to generate our survey questions.

We used standardized methodology set by the Southern Group of State Foresters (SGSF) to determine a sample size of 216 sites statewide, stratified by the four ecoregions within North Carolina: Mountains, Piedmont, Southeastern Plains, and Mid-Atlantic Coastal Plain (MACP). To identify many of the sites included in this survey, we used the Southern Forest Area Change Tools (SouthFACT), which analyzes periodic remote sensing data to locate areas of dramatic vegetation change. When SouthFACT was not practical, we identified potential sites by randomly selecting from recent NCFS records, or by assessing sites we came across while traveling. Examined tracts met the following conditions: 1) the tract was greater than five acres; 2) the tract bordered or partially contained an intermittent or perennial stream; 3) the tract contained no evidence of changing land use; and 4) tracts were operationally active or the operation had concluded within six months of our site visit.

We completed 216 surveys in 98 of North Carolina's 100 counties. When a BMP implementation opportunity was encountered, we assessed whether the BMP had been properly implemented, and whether the situation presented a risk to water quality. We surveyed some BMPs on an individual basis, aligning with the 2012-2016 BMP implementation survey report but differing from the approach used in the 2006-2008 BMP implementation survey project. For example, each waterbar was assessed by answering nine specific BMP implementation questions relative to waterbars. If there were 10 waterbars on a tract, and all BMP questions were applicable, evaluators would record 90 BMP opportunities. In total, two evaluators assessed 31,472 BMP implementation opportunities statewide, including 8,855 in the Mountains, 13,717 in the Piedmont, 4,005 in the Southeastern Plains and 4,895 in the MACP. Overall, proper BMP implementation rate was 83% statewide, 76% in the Mountains, 84% in the Piedmont, 89% in the Southeastern Plains and 87% in the MACP. Many of the surveys were collected on non-industrial private lands (69%) on an average tract size of 61 acres. Most stands (54%) were mixed hardwood and pine timber. Most of the surveyed tracts (79%) were of clearcut harvests and were identified and assessed after completion (82%).

Evaluators associated a potential water quality risk to roughly 2% of the BMP implementation opportunities. Statewide, when BMPs were not properly implemented, risks to water quality were more likely in the categories of stream crossings (38%), rehabilitation of the project site (36%) and streamside management zones (SMZs) (21%). Bridgemats were the most frequently observed crossing type (66%) followed by culvert crossings (24%). This is an encouraging observation as many efforts to promote bridgemat use have occurred over the past several years. The ratio of risks to water quality to stream crossing type show that bridgemats are a preferred crossing method, although other crossing types can also be effective in protecting water quality with proper BMP implementation. Continued education, outreach and other supporting programs that encourage the use of BMPs at stream crossings are needed to sustain high performance. Rehabilitation of project sites could be improved by proactively identifying and stabilizing critical bare soil areas away from the stream that can funnel runoff into the SMZ. Another way would be to prevent or remove logging debris from entering streams at the stream crossings. Evaluators observed many narrow SMZs that effectively shaded streams and restrained visible sediment throughout the state. However, it appears that a narrower SMZ without appropriate BMP application upslope creates a greater risk scenario compared to that of wider SMZs.

The lowest BMP implementation levels for the Mountain and Piedmont ecoregions was in the skid trail category (58 and 74%, respectively). Evaluators observed greater skid trail-to-harvest area ratios and steeper sloping skid trails in the Mountain ecoregion compared to other ecoregions. Continued preharvest assistance, education and research on selecting road, trail location (reopening legacy trails or avoiding them) and trail stabilization remains a need for both ecoregions. The lowest BMP implementation level for the Southeastern Plains ecoregion was in the rehab of the project site category (81%). Evaluators observed areas away from the stream edge in all ecoregions that could benefit from stabilization. Attention to minimizing large areas of bare soil and taking efforts to ensure that these bare soil areas are disconnected from waterways would improve implementation in this category. The lowest BMP implementation level for the MACP ecoregion was in the site preparation and reforestation category (69%). Although few site preparation sites were surveyed, evaluators observed ground disturbance between bedded rows, a lack of staggered openings for surface water to flow among bedded rows and high potential for sediment transport in some areas. A focus on BMP efforts for site preparation should be emphasized in outreach and education efforts in the coastal areas.

The highest rates of BMP implementation were found in the Chowan, White Oak, and Pasquotank river basins, while lowest were in the Little Tennessee, Watauga, and New River basins. Tracts within “Outstanding Resources Waters” and “Nutrient Sensitive Waters” had high BMP implementation rates as well.

Our findings support the conclusion that operators across the state properly BMPs to protect water quality. Continued efforts to educate operators and landowners on the importance and ease of BMP implementation should continue to be a focus. This report adds to the list of efforts to monitor and report BMP implementation in the state. Our results will be used to target training efforts, inform forestry researchers, and provide transparency on the status of BMP implementation for the forestry community and others in North Carolina.

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1: Introduction

1.1 Forestry Best Management Practices to Protect Water Quality

Protecting water quality is an integral component of forest management. Recommended forestry Best Management Practices (BMPs) help minimize water pollution by reducing soil erosion and the delivery of non-point source pollutants from silvicultural lands to streams. In North Carolina, BMPs are non-regulatory practices, or a combination of practices, that are effective in preventing or reducing nonpoint source pollution to a level that is compatible with water quality goals (02 NCAC 60C .0102(4)). The BMP recommendations are a product of experience, research and/or collaborative stakeholder efforts to identify practices that are functionally effective, economically viable, technologically feasible and institutionally allowable on silvicultural lands. The N.C. Forest Service (NCFS) publishes and leads revisions of forestry BMP recommendations with input from stakeholders having various forest management objectives. The recommended BMPs are compiled into a document titled, "North Carolina Forestry Best Management Practices Manual to Protect Water Quality". The recommendations in the 2006 edition of this manual were the basis for the survey questions used in this forestry BMP implementation monitoring project.

The NCFS actively promotes BMPs, provides technical assistance, assists with training of forest operators and inspects forestry sites to determine if operators are following applicable regulations related to water quality. In North Carolina, forestry-related, land-disturbing activities (such as logging) must comply with the standards described in the "Forest Practice Guidelines Related to Water Quality", codified in N.C. Administrative Code 02 NCAC 60C .0100 to .0209 (herein abbreviated as FPGs). Compliance with the FPG standards allows forestry activities the ability to operate in a manner that is consistent with accomplishing the objectives of protecting waterways from excessive sedimentation as required by the N.C. Sedimentation Pollution Control Act, General Statute Ch.113A. The NCFS inspects silvicultural operations for compliance with the FPGs. When a noncompliance is identified, the agency communicates with the involved parties and conducts a follow up reinspection to see if the noncompliance was resolved. Often, the agency's employees will reference the BMP manual's recommendations in their communications when offering suggested solutions for achieving FPG compliance.

Readers should recognize that the proper implementation of BMPs can lead to compliance with FPG standards; however, compliance is not automatically granted. Alternatively, improper BMP implementation does not mean the tract is out of compliance with FPG standards. Each site operation must comply with the FPGs regardless of the number, type and extent of BMPs that are or are not implemented.

1.2 Best Management Practice Implementation Survey Objectives

The purpose of this project was to assess the frequencies of properly and improperly implemented BMPs and potential visible risks to water quality in the Mountain, Piedmont, Southeastern Plains, and Mid-Atlantic Coastal Plain (MACP) ecoregions in North Carolina. The results are intended to be used for improvement recommendations, target BMP categories that could benefit from additional outreach efforts and to assess the functionality of recommended BMP specifications.

1.3 Follow up on proposed survey changes.

The NCFS considered the proposed survey changes outlined in the 2018 BMP implementation survey report. The previous recommendations are summarized in bold text and actions taken are immediately below.

- **Integrate online tools such as ArcCollector, Survey123, and the Forest Preharvest Planning Tool (FPPT) to increase information gathered at each site and improve the data collection process.**

ArcCollector and Survey123 workflows were created and used in the latest survey collection effort. Information input into ArcCollector improved the surveyor's ability to navigate around the tract and better understand site features. Survey123 and ArcCollector enabled the surveyors to collect, document and calculate soil erosion estimates at stream crossings. The workflow of Survey123 was equivalent to the digital collection system used in the previous survey. However, the ease of survey modification compared to the previous system was an improvement that can be carried forward in future surveys. The FPPT was not utilized in this survey workflow. However, the surveyors referenced similar databases used within FPPT in the ArcCollector platform.

- **Assess tracts for compliance with Forest Practice Guidelines Related to Water Quality (FPGs).**

  Surveyors assessed tracts for compliance with FPGs and shared their findings with county staff.

- **Consider the need and ability to capture more information on BMPs for site prep, wetlands and firelines since they were not well represented in the previous survey.**

  We elected not to specifically target these areas. However, we did not attempt to avoid them. Low samples in these BMP categories may, in part, be attributed to the infrequency of these practices relative to timber harvesting, or the inherent difficulty in locating these types of operations as compared with timber harvests.

- **Consider collecting more detailed information at stream crossings and along streamside management zones (SMZs) to identify potential root cause issues that may contribute to lower BMP implementation scores.**

  We enhanced our data collection at stream crossings, but not along SMZs. Like the previous survey, we identified SMZ segments and measured SMZ width at multiple locations to assign each SMZ segment an average width. At stream crossings, we estimated soil erosion using the Universal Soil Loss Equation as adapted for forests (USLE-Forest) (Dissmeyer et al. 1984). These estimates help provide transparency to the potential scope of sedimentation contributed at forestry stream crossings.

- **Consider targeting tracts within specially designated river basins or watersheds to fully assess the potential benefits of using BMPs in areas where water quality concerns are already identified, or protection of good quality water is of high priority.**

  While this recommendation was not a primary focus of this round of BMP surveys, several sites were assessed in specially designated river basins or watersheds and those results are found in Table 23.

- **Link BMP usage with soil erosion estimates in an operational setting.**

  Estimates of soil erosion at 220 stream crossing approaches to intermittent or perennial streams were collected during this survey. The equations for USLE-forest factors and reference tables were integrated into Survey123. The surveyors collected and input the necessary field measurements in Survey123. The application was designed to compute an estimate of annual soil erosion. For further interpretations and information on these results, we encourage readers to view our published work (Lang et al. 2022).

2: Methods

2.1 Sample Size

The Southern Group of State Foresters (SGSF) established baseline BMP implementation survey framework for state forestry agencies to help improve regional comparisons (SGSF 2007). The SGSF formula for sample size determination is:

$$n = \frac{4p\ (100 - p)}{m^2}$$

Where n = sample size; p = estimated percent implementation of BMPs statewide (84%, based on the last survey); and m = margin of error (SGSF guidance suggests using 5%, which corresponds to a 95% confidence level). Using this formula, our total statewide sample size was 216.

The total number of survey units was stratified by ecoregion size within the state, e.g., the Piedmont ecoregion covers the most area in the state and was assigned the most survey units (Table 1). To distribute surveys across the ecoregion, at least one survey for each county was attempted. We completed surveys in 98 counties but did not complete a survey in Dare and New Hanover counties. Figure 1 illustrates the approximate survey locations in the context of North Carolina's four ecoregions. Figure 2 reveals the number of surveys conducted in each county.

Table 1. Summary of survey units by ecoregion.

Ecoregion	Timeframe	Survey Units
Blue Ridge/Mountains	06/2019 - 09/2020	37
Piedmont	12/2018 – 11/2020	80
Southeastern Plains	03/2019 – 11/2020	43
Mid-Atlantic Coastal Plain	04/2019 – 11/2020	56

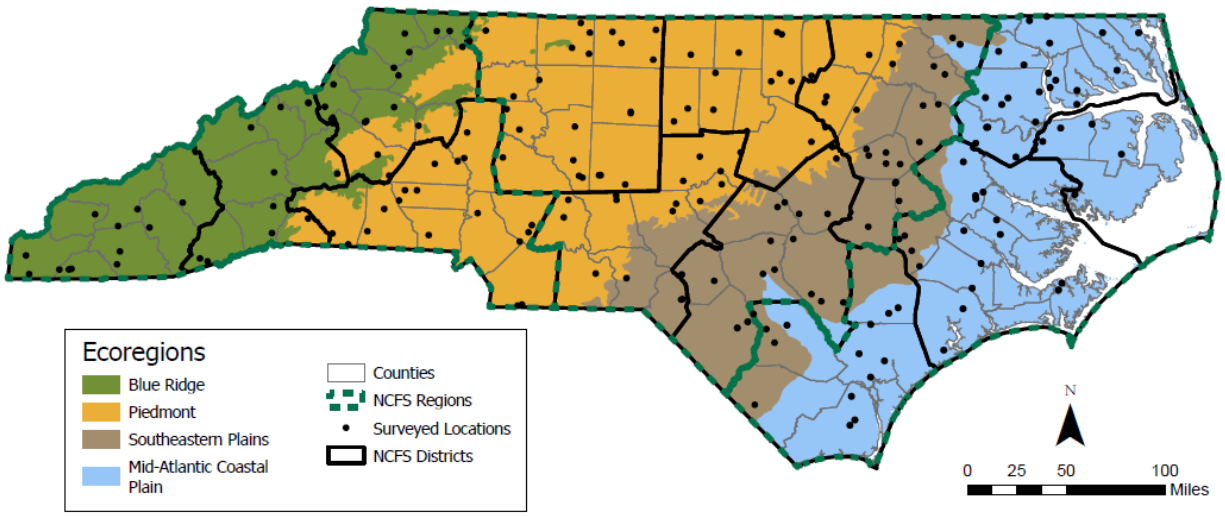


Figure 1. North Carolina ecoregions (Omernik 1987) overlaid with survey locations between 2018 and 2020, county boundaries and NCFS region and district boundaries.

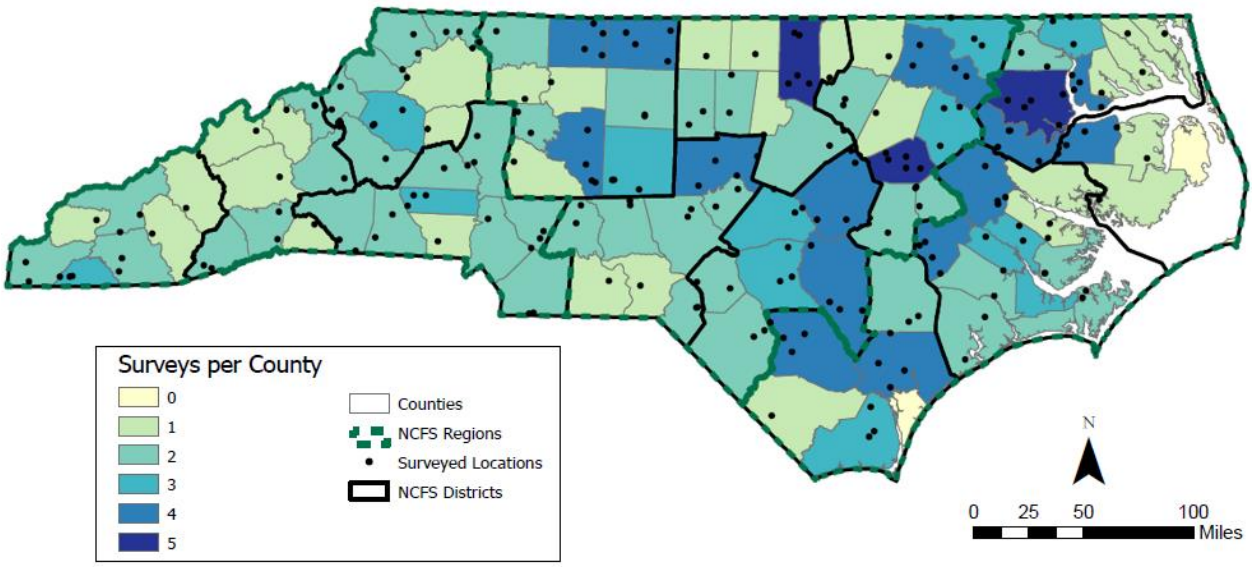


Figure 2. North Carolina counties color coded by the number of surveys collected between 2018 and 2020, overlaid with survey locations and NCFS region and district boundaries.

2.2 Survey Procedure and Implementation

Eligible tracts met the following four conditions: (1) at least 5 acres in tract size, (2) an intermittent stream, perennial stream or perennial waterbody within or adjacent to the tract boundaries, (3) operationally active or active within the past 6 months and (4) no evidence of land use conversion. An iterative process, consisting of three main methods, was used to identify survey sites. For the first method, we used Landsat satellite imagery processed through the Southern Forest Area Change Tool (SouthFACT) (www.southfact.com) and Esri™ ArcGIS software to identify areas where the imagery detected a likely change of tree canopy cover (timber harvest). The resulting list of tracts was further narrowed using Esri™ ArcGIS software by removing sites without a mapped USGS stream within 200 miles of the tract boundaries. The tract list generated from this procedure served as a starting point for discussions with NCFS county staff. These tracts could be categorized into three scenarios by NCFS county staff: (1) staff had visited the site and could confirm whether it met study criteria, (2) staff were aware of the site, but had not yet performed an inspection and could not confirm study criteria or (3) staff had no previous knowledge of the site. If ten or more tracts met situation one, they were numbered and randomly selected by the project managers who had not visited the sites, nor had any prior knowledge of the forestry operation. If less than ten tracts met scenario one, then tracts from the other two scenarios and a list of NCFS inspected sites known to meet the study criteria, but not detected by SouthFACT, were added to the random selection list. In some cases, project managers examined a site only to find that it did not qualify, in which case the next closest tract from the list was visited. For the second method, if the SouthFACT process yielded no suitable sites, project managers randomly selected from a list of NCFS inspected sites known to meet the study criteria only. The third method consisted of examining sites that were discovered opportunistically while traveling. This site selection process was repeated statewide for each county. Project managers contacted and often met with county staff prior to field visits. This interaction proved beneficial for project managers to learn about the known tract history. Project managers were also able to share the project objectives and discuss BMPs with county staff.

Upon arrival to subject tracts, project managers recorded basic tract characteristics such as latitude/longitude, county, ecoregion and operation type and progress. If forest operators were present at the site, an attempt was made to contact them addressing potential safety concerns for the surveyors, discuss harvest progress, identify landowners and/or timber buyers and gain insight on implemented BMPs. When evaluators believed they had

enough relevant information about the site, they observed the entire tract and examined BMP implementation opportunities. Whenever possible, the primary evaluator was accompanied by another NCFS staff member with knowledge of BMPs and water quality risks. This reduced safety risks, saved time and effort and allowed for discussion of complex situations. As they walked across the site, photographs were taken, a track of GPS points was created and notes were made for later reference.

The survey contains 12 separate BMP categories. Each category contains a series of recommended BMPs and prompts the evaluator to answer two questions for each BMP: (1) was the BMP properly implemented [yes/no] and (2) is there a risk to water quality [yes/no]. Some BMP recommendations can be assessed for the overall tract while others can be assessed on an individual basis. An example of a BMP assessed on an individual basis would be brush barriers. In the "Controlling Erosion and Runoff" category there are BMP recommendations for brush barriers. One BMP recommendation is "pile and pack down brush to achieve close contact with the ground surface". In this example, the evaluator would answer the two BMP survey (yes/no) questions for each brush barrier encountered. Additionally, the evaluator may elect to answer this question when a brush barrier is not observed, there was evidence of excessive sediment movement and/or the evaluator believed a brush barrier would have been an appropriate BMP to prevent the excessive sediment movement. There are five possible outcomes of this example BMP question each time it was evaluated:

(1) the BMP was not applicable on the tract,
(2) Yes, the BMP was properly implemented and no, it was not a risk to water quality,
(3) Yes, the BMP was properly implemented but yes, there is a risk to water quality,
(4) No, the BMP was not properly implemented, but no there is not a risk to water quality, or
(5) No, the BMP was not properly implemented and yes, there is a risk to water quality.

When assessing a risk to water quality, a "Yes" response was recorded if any of the following were observed or expected to occur:

- Visible sediment is reaching (or could potentially reach) an intermittent stream, perennial stream or perennial waterbody due to accelerated erosion (water or wind).
- Water flow and/or water quality is being inhibited or degraded by debris in an intermittent stream, perennial stream or perennial waterbody.
- Inadequate stream shading causes large fluctuations in expected stream water temperatures and/or increases expected water temperature to above water quality standards.
- Vehicle fluids, pesticides, herbicides, fertilizers or other chemicals/wastes are reaching (or could potentially reach) an intermittent stream, perennial stream, perennial waterbody or groundwater.
- Site activities (e.g., ditching, deep ripping) are extensive enough that they threaten dewatering of wetlands and create potential for converting them to non-wetlands.

There are 392 BMP recommendations in the BMP Implementation Survey. However, only a subset of these questions is applicable to any given tract. Questions not answered within the survey were treated as not applicable. To calculate BMP Implementation score, we used the following formula:

BMP Implementation Score = (Number of Implemented BMPs / Number of Applicable BMPs) x 100

A complete list of the BMP survey questions can be found online in Appendix A. If NCFS county and district staff did not accompany project managers to tracts, they were notified of the sites visited and any potential FPG compliance issues discovered. Data was analyzed using Microsoft Excel and JMP-Pro 15.2.0 (SAS Institute Inc. 2019). Most photos included in this report were taken while collecting data for this survey.

2.3 Quality Assurance/Quality Control

All improperly completed survey form data was identified and filtered out of the data analyzed in this report. Multiple copies of this data have been kept in a variety of locations on internal and external hard drives, network folders and cloud-based storage services to prevent the loss or corruption of data.

Not all BMPs listed in the manual were observed while carrying out this survey. Of the 392 BMPs included in the survey, 236 were examined at least once. We did not encounter applicable BMPs for firelines, chemical applications or handling, herbicide applications, tillage site preparation, check dams, filter areas, fill roads in wetlands or water management in wetlands. Additionally, in some ecoregions, certain BMP questions had relatively few observations. For example, though we found almost 5,000 BMPs in the "Erosion and Runoff" category, only 22 of those were found in the MACP. In some cases, these small sample sizes created wide confidence intervals. Sample sizes and confidence intervals are in Appendix B.

3: Results

3.1 Overall BMP Implementation

Evaluators assessed 31,472 BMP implementation opportunities at 216 sites across the state (Table 2).

Table 2. Counts of BMP implementation opportunities and survey sites by ecoregion.

Ecoregion	Count of BMP Implementation Opportunities	Count of Survey sites
Statewide	31,472	216
Mountain	8,855	37
Piedmont	13,717	80
Southeastern Plains	4,005	43
Mid-Atlantic Coastal Plain	4,895	56

Statewide BMP implementation was 83%. Implementation during this survey decreased slightly from the 2012-2016 survey period, which had an overall implementation rate of 84%. The Southeastern Plains had the highest overall implementation (89%) followed by MACP (87%), Piedmont (84%), and Mountains (76%). When compared to the last published survey, implementation of BMPs decreased in the Mountains and Piedmont, but increased in the Southeastern Plains and MACP.

Table 3. Overall percent implementation of BMPs by BMP category and ecoregion.

BMP Category	BMP Implementation					Properly Implemented BMP & NO RISK to Water Quality					Improperly Implemented BMP & RISK to Water Quality				
	S	M	P	SP	C	S	M	P	SP	C	S	M	P	SP	C
	--%--														
Overall	**83**	**76**	**84**	**89**	**87**	**100**	**100**	**100**	**100**	**100**	**11**	**4**	**18**	**11**	**13**
Harvesting: Capturing Sediment and Runoff	78	79	76	87	77*	100	100	100	100	100	3	2	6	0	0
Harvesting: Decks	97	94	96	99	98	100	100	100	100	100	3	9	0	0	0
Harvesting: Logging Systems	86	95	86	93	75	100	100	100	100	100	7	20	15	0	0
Harvesting: Rehabilitation of the Project Site	82	87	80	81	85	99	99	99	100	100	36	21	38	28	52
Harvesting: Skid Trails	73	58	74	85	83	100	100	100	100	100	1	0	4	1	0
Harvesting: Wetlands	81	N/A	75*	71*	86	100	N/A	100	100	100	0	N/A	0	0	0
Chemicals, Fluids and Solid Waste	29	33*	33*	N/A	0*	100	100	100	N/A	N/A	0	0	0	N/A	0
Firelines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Roads and Access	84	90	79	83	96	100	100	100	100	100	23	19	18	58	0
Site Preparation and Reforestation	69	N/A	N/A	N/A	69	100	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	0
Stream Crossings	87	86	88	89	86	100	100	100	100	100	38	21	50	7	47
Streamside Management Zones (SMZs)	91	86	91	94	90	100	100	100	100	100	21	17	28	14	12
	Higher % is Optimal					*Higher % is Optimal*					***Lower** % is Optimal*				
S: Statewide, M: Mountains, P: Piedmont, SP: Southeastern Plains, C: Mid-Atlantic Coastal Plain															
*Less than 30 applicable BMP opportunities recorded.															

When BMPs were properly implemented, there were no recorded risks to water quality in almost all cases statewide (Properly Implemented BMP & No Risk to Water Quality column in Table 3). These results demonstrate the importance of proper BMP implementation on logging sites. Stream crossings, rehabilitation of the project site and SMZ categories had the greatest frequency of risk to water quality when BMPs were improperly implemented or not implemented (Improperly Implemented BMP & No Risk to Water Quality column in table 3). These categories tend to be at or near streams. Therefore, it is not surprising that improperly implemented BMPs or lack of BMP implementation had an increased frequency of risks to water quality.

Some BMP categories were not observed throughout an entire ecoregion. Those instances are marked with "N/A" in Table 3. See Appendix B for more information on sample sizes and confidence intervals.

Key Findings:

- Overall, BMP implementation was 83% statewide, 76% in the Mountains, 84% in the Piedmont, 89% in the Southeastern Plains and 87% in the MACP (Table 2).
- A total of 31,472 applicable BMPs were assessed statewide.
    - Mountains: 8,855 total BMPs with 76% implementation and 2,125 BMPs applied incorrectly.

    - Piedmont: 13,717 total BMPs with 84% implementation and 2,195 BMPs applied incorrectly.
    - Southeastern Plains: 4,005 total BMPs with 89% implementation and 441 BMPs applied incorrectly.
    - MACP: 4,895 total BMPs with 87% implementation and 636 BMPs applied incorrectly.
- When BMPs were properly implemented, there was no risk to water quality in nearly every case.
- When BMPs were not implemented, or implemented improperly, it resulted in a risk to water quality in 13% of the BMP observations.
- Statewide, 82% of all risks to water quality were found in the rehabilitation, SMZ, and stream crossings categories.
- Several BMP survey questions were infrequently answered or not applicable for a variety of reasons. Readers should recognize that results with small sample sizes may have less statistical accuracy. Reference Appendix B.

3.2 Implementation of BMPs by Category

3.2.1: Harvesting: Controlling Runoff and Capturing Sediment

The BMPs evaluated in this category are the fundamental elements of erosion and sedimentation control that are frequently applicable on nearly every forestry operation. The key focus to reducing sedimentation into waterways is to slow down and spread out runoff, then provide cover to bare soil areas. The BMPs included in this section are those outlined in the North Carolina Forestry BMP Manual:

BMPs to Control Runoff	BMPs to Capture Sediment
Broad based dip	Filter area
Turnout	Silt fence
Cross drain	Brush barrier
Waterbar	Sediment pit/trap
Inside ditch line	Straw bale
Insloping, outsloping, crowning of road surface	Check dam

The statewide BMP implementation rate was 76% for controlling runoff and 94% for capturing sediment.

Table 4. Implementation of BMPs for controlling runoff by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
Statewide	4,275	76%	1,039	27
Mountains	3,206	78%	716	13
Piedmont	957	72%	299	14
Southeastern Plains	96	80%	19	0
MACP*	16	69%	5	0

*Mid-Atlantic Coastal Plain

Table 5. Implementation of BMPs for capturing sediment by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
Statewide	689	94%	43	6
Mountains	282	91%	25	0
Piedmont	354	95%	18	6
Southeastern Plains	47	100%	0	0
MACP*	6	100%	0	0

*Mid-Atlantic Coastal Plain

Key Findings and Discussion:

- When BMPs for controlling runoff and capturing sediment were properly implemented statewide, there was almost no risk to water quality. When these BMPs were improperly or not implemented, there was a risk to water quality 3% of the time. Risks to water quality appear to be relatively low when BMPs were improperly or not implemented. This may be explained by our methodology. These categories contain many BMPs assessed on an individual basis and may not be near a stream. Examples included waterbar, turnout, sediment pit, etc.
- There were 22 recorded observations for controlling runoff and capturing sediment within the MACP. Planning road and trail locations may have helped minimize the need for controlling runoff and capturing sediment in this region. Evaluators noted that when sloping land was observed in the MACP, it was most often associated with stream crossing approach ways. BMPs along approach ways were answered in the stream crossing category.
- The count of BMPs assessed for controlling runoff was nearly half of the recorded observations in the previous survey. However, the count of improperly or not implemented BMPs was similar.
- Of the 92 BMP questions, 43 were answered at least once. BMP questions associated with individual broad-based dips, road templates, check dams, cross drains and filter areas were infrequently answered or not at all. This may be due to challenges to distinguishing certain features. Many low volume roads are constructed to a minimal standard and often follow contours. However, there are naturally occurring dips in terrain that can be used to disperse runoff. These dips do not meet the definition of a broad-based dip and can create short road sections with an indistinguishable road template. Additionally, these dips in combination with other operator preferred BMPs such as turnouts, sediment pits and brush barriers can preclude the use of other BMPs requiring a material cost such as check dams and cross drains.

Photo 1. A broad area of bare soil on a surveyed site in the Piedmont ecoregion. Sediment displacement and transport is possible.

Photo 2. Ample slash and other materials are providing adequate groundcover to prevent erosion on this site in the Piedmont ecoregion.

3.2.2: Harvesting: Decks

Statewide, there were 2,005 BMPs assessed for decks including 358 in the Mountains, 785 in the Piedmont, 370 in the Southeastern Plains and 492 in the MACP.

Table 6. Implementation of BMPs for decks by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
Statewide	2,005	97%	66	2
Mountains	358	94%	23	2
Piedmont	785	96%	30	0
Southeastern Plains	370	99%	2	0
MACP*	492	98%	11	0

*Mid-Atlantic Coastal Plain

Key Findings and Discussion:

- When BMPs for decks were properly implemented statewide, there was no risk to water quality. When these BMPs were not implemented, there was a risk to water quality 3% of the time.
- Log decks were often observed on stable, flat areas and were not excessive in number or size.
- Evaluators noted varying levels of groundcover on the decks. In nearly all cases where soil cover was sparse, sedimentation potential was low and erosion often captured along the margins of the deck. There were two exceptions in the Mountain region. Both had insufficient erosion control measures to manage runoff and capture sediment on sloped deck site.

Photo 3. This logging deck in the Mountains ecoregion is on high ground away from the streamside management zones.

3.2.3: Harvesting: Logging Systems

Statewide, there were 508 BMPs assessed for logging systems including 91 in the Mountains, 161 in the Piedmont, 95 in the Southeastern Plains and 134 in the MACP.

Table 7. Implementation of BMPs for logging systems by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
Statewide	508	86%	72	5
Mountains	91	95%	5	1
Piedmont	188	86%	27	4
Southeastern Plains	95	93%	7	0
MACP*	134	75%	33	0

*Mid-Atlantic Coastal Plain

Key Findings:

- The evaluators only answered 3 of the possible 6 BMP questions for logging systems. The three not answered were associated with biomass operations.
- Statewide, BMPs for logging systems that were properly implemented had no risk to water quality in every observed case. When these BMPs were not implemented, there was a risk to water quality 7% of the time.
- Selecting a logging system is not a widespread problem based on the survey's observations. Equipment traffic can occur during wet weather with the deployment of appropriate equipment and/or tactics, or the implementation of BMPs.
- The observed risks to water quality were associated with rutting. Halting operations when machine travel creates deep rutting upon wet ground can reduce erosion potential and protect future site productivity.

Photo 4. Undesirable soil rutting in a small area on a site in the Southeastern Plains caused by timber harvesting.

3.2.4: Harvesting: Rehabilitation of Project Site

Statewide, there were 1,778 BMPs assessed for rehab including 333 in the Mountains, 984 in the Piedmont, 251 in the Southeastern Plains and 210 in the Coastal Plain. There are four subcategories within the rehab section: controlling access, runoff control and capture, stabilization and stream crossings.

Table 8. Implementation of BMPs for rehab by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
Statewide	1,778	82%	317	116
Mountains	333	87%	43	12
Piedmont	984	80%	196	75
Southeastern Plains	251	81%	47	13
MACP*	210	85%	31	16

*Mid-Atlantic Coastal Plain

Key Findings:

- When BMPs for rehab were properly implemented statewide, there was no risk to water quality 99% of the time. When these BMPs were not implemented, there was a risk to water quality 36% of the time.
- The most critical areas received appropriate rehab as evident by BMP implementation rate. However, improper implementation within the stream crossing subcategory of the rehab section had notable occurrences of risks to water quality.
- Removing debris from the channel of stream crossings appears to have the greatest room for improvement.
- Site rehabilitation is necessary to expedite site recovery. The key to future success in this category will be to (1) proactively identify and stabilize critical bare soil areas away from the stream that can funnel and outlet runoff into the SMZ, and (2) prevent or remove logging debris from entering streams at the stream crossings.

Photo 5. This stream crossing and approach way in the Piedmont ecoregion has been stabilized with straw and slash.

Photo 6. A skid trail in the Mountains ecoregion has been stabilized with grass.

3.2.5: Harvesting: Skid Trails

Statewide, there were 8,311 BMPs assessed for skid trails including 2,456 in the Mountains, 3,228 in the Piedmont, 1,130 in the Southeastern Plains and 1,497 in the MACP. Skid trail approach ways to stream crossings are not captured in this section.

Table 9. Implementation of BMPs for skid trails by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
Statewide	8,311	73%	2,283	34
Mountains	2,456	58%	1,020	3
Piedmont	3,228	74%	829	29
Southeastern Plains	1,130	85%	174	2
MACP*	1,497	83%	260	0

*Mid-Atlantic Coastal Plain

Key Findings:

- BMP implementation for skid trails was 73% statewide, 58% in the mountains, 74% in the Piedmont, 85% in the Southeastern Plains and 83% in the MACP.
- When BMPs for skid trails were properly implemented statewide, there was no risk to water quality in each case. When these BMPs were not implemented, there was a risk to water quality less than 2% of the time. Thus, despite the relatively low BMP implementation rates for this category, it would seem

that naturally occurring water infiltration into the forest soil, and sediment capturing ability on logging jobs is sufficient to prevent a risk to water quality in most cases.

- Our observations suggest that BMP implementation is lower for skid trails located away from streams compared to skid trails located near to streams.
- Seemingly unnecessary skid trails, inadequate methods to capture runoff or poorly located skid trails were noted when improper BMP implementation was identified. Proper preharvest planning can help to establish an efficient and concise skid trail network. Covering skid trails with logging debris (treetops, branches, limbs, etc.) as the operation is ongoing is a simple but effective method to prevent soil disturbance and manage runoff.

Photo 7. Erosion could be lessened along this long and steep sloping skid trail in the Mountain ecoregion by installing waterbars and turnouts to divert runoff in smaller increments onto more stable ground.

Photo 8. Skid trails in this tract in the Mountain ecoregions follows the contours and are located away from the streamside management zone, helping to minimize erosion and sedimentation potential.

3.2.6: Harvesting: Wetlands

Statewide, there were 86 BMPs assessed for wetlands including four in the Piedmont, 24 in the Southeastern Plains, and 58 in the MACP. No wetland BMPs were assessed in the Mountains ecoregion.

Table 10. Implementation of BMPs for wetlands by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
Statewide	86	81%	16	0
Mountains	0	N/A	N/A	0
Piedmont	4	75%	1	0
Southeastern Plains	24	71%	7	0
MACP*	58	86%	8	0

*Mid-Atlantic Coastal Plain

Key Findings:

- BMP implementation was 81% for wetlands statewide, 75% in the Piedmont, 71% in the Southeastern Plains and 86% in the MACP.
- No risks to water quality were identified within the wetland category whether BMPs were implemented properly or not. However, there were only 86 recorded observations statewide, making wetlands the third least observed and recorded BMP category behind chemicals, fluids and solid waste (31 recorded observations) and site preparation (39 recorded observations).

It should be noted that the recommended BMPs outlined for wetlands may not necessarily be required for complying with the silvicultural exemptions provided in Section 404 of the Clean Water Act. The 15 federally mandated BMPs for forest roads (as found in 33 CFR Part 323.4(a)(6)); and the six BMPs for mechanical site prep (as found in the US-EPA / US-ACE November 28, 1995, joint memo to the field) are the baseline requirements, and compliance with federally mandated BMPs was not assessed in this BMP survey. Those federally directed BMPs come under the authority of U.S. Army Corps of Engineers.

Areas for Improvement:

Recorded observations of improperly implemented BMPs were associated with the following recommendations:

- Concentrate heavy equipment use to primary skid trails and decks. Minimize rutting, i.e., single pass produces more than 6-inch rut.
- Establish and maintain groundcover vegetation along road shoulders.
- Minimize excessive soil compaction and rutting - maintain soil physical health.
- Minimize harvesting activity in sensitive areas, i.e., wetter than normal areas or near waterbodies.
- Operate equipment during dry periods if possible. Minimize operations on saturated soils and near waterbodies.

Photo 9. A forested wetland bordering a surveyed tract in the Mid-Atlantic Coastal Plain ecoregion.

3.2.7: Forest Roads

Statewide, there were 1,040 BMPs assessed for logging roads including 161 in the Mountains, 576 in the Piedmont, 139 in the Southeastern Plains and 164 in the MACP.

Table 11. Implementation of BMPs for forest roads by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
State Total	1,040	84%	167	39
Mountains	161	90%	16	3
Piedmont	576	79%	121	22
Southeastern Plains	139	83%	24	14
MACP*	164	96%	6	0

*Mid-Atlantic Coastal Plain

Key Findings:

- BMP implementation for roads was 84% statewide, 90% in the mountains, 79% in the Piedmont, 83% in the Southeastern Plains, and 96% in the MACP.
- When BMPs for roads were properly implemented statewide, there was no risk to water quality. When these BMPs were not implemented or improperly implemented, there was risk to water quality 23% of the time.

Areas for Improvement:

- When evaluating the 32 BMPs for roads during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented:
    - Construct road to drain naturally - not into streams or waterbodies.
    - Install diversion or other structures to control and capture runoff (broad-based dips, settlement basin, etc.).
    - Maintain a road surface that provides good runoff control, water quality protection and vehicle access.
    - Minimize soil disturbance and the amount of road at any stream crossing.
    - Stabilize bare soil areas using suitable technique (seed, mulch, riprap, etc.).
    - Take prompt action to protect water quality if BMPs are not properly functioning.

Photo 10. A well maintained minimum standard forest road on a site in the Coastal Plain ecoregion. A cross drain can be seen in the foreground allowing water to freely move through the area. Additionally, the stone surface helps to reduce erosion and rutting, while also allowing for more effective vehicle traffic in wet conditions.

3.2.8: Stream Crossings

Statewide, there were 4,624 BMPs assessed for stream crossings including 1,017 in the Mountains, 2,316 in the Piedmont, 619 in the Southeastern Plains and 672 in the MACP (Table 12). There were 1,245 BMPs assessed for bridgemats, 839 BMPs assessed for culvert crossings, 217 BMPs assessed for ford crossings, 32 BMPs assessed for pole crossings and 2,291 BMPs assessed to all stream crossing types. Soil erosion was estimated from stream crossing approach ways during this assessment and published separately in a peer-reviewed journal article (Lang et al. 2022). The counts of risk to water quality in Table 12 were calculated by each BMP observation, while counts of risk to water quality in Table 14 attribute only one risk per crossing.

Table 12. Implementation of BMPs for stream crossings by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
State Total	4,624	87%	592	236
Mountains	1,017	86%	141	33
Piedmont	2,316	88%	284	151
Southeastern Plains	619	89%	71	6
MACP*	672	86%	96	46

*Mid-Atlantic Coastal Plain

Table 13. Count of stream crossing types by ecoregion.

Ecoregion	Bridgemat	Culvert	Ford	Pole	Total
State Total	153	57	14	9	233
Mountains	10	28	5	1	44
Piedmont	99	18	3	2	122
Southeastern Plains	27	4	1	1	33
MACP*	17	7	5	5	34

*Mid-Atlantic Coastal Plain

Table 14. Number of risks to water quality by stream crossing type.

Stream Crossing Type	Stream Crossings Assessed	Count of Risks to Water Quality	Frequency of Risk to Water Quality
Bridgemat	153	13	8%
Culvert	57	17	30%
Ford	14	9	64%
Pole	9	1	11%

Table 15. Stream crossing BMP metrics by river basin type (DWR buffer rule basins vs. non-buffer rule basins).

Basin Type	Survey Units	Stream Crossing BMPs Assessed	Stream Crossing BMP Implementation	Improperly Implemented BMP & RISK to Water Quality
Buffer Rule	71	1,717	86%	54%
Other	145	2,907	88%	26%

Key Findings:

- Statewide BMP implementation for stream crossings was 87%. Statewide BMP implementation was 97% for bridgemats, 78% for culverts, 68% for fords and 88% for poles.
- Bridgemat crossings were the most frequently observed stream crossing type and had the lowest frequency of risk to water quality compared to other stream crossing types.
- Culvert crossings had the greatest count of risks to water quality, but an intermediate frequency of risk to water quality compared to other stream crossing types.
- Ford crossings had the greatest frequency of risk to water quality compared to other stream crossing types. Slash on ford approach ways is uncommon partly due to the anticipated traffic (hauling vs skidding). Fords are only acceptable for road vehicle crossings and are not intended for skidding logs.
- When the 44 BMPs for stream crossings were properly implemented statewide, there was almost no risk to water quality. When these BMPs were not implemented there was a risk to water quality 37.5% of the time. This risk value is the highest of any category of BMPs.

Photos 11-14. Good examples of stream crossings throughout the ecoregions. Top left (Photo 11): A permanent ford stream crossing on a Mountain ecoregion site used for haul trucks. Top right (Photo 12): A permanent culvert stream crossing on a Piedmont ecoregion site used for haul trucks. Road mats and gravel were applied for water quality protection, and the roadway turnouts reduce the amount of eroded sediment that needs to be captured by the streamside management zone. Bottom left (Photo 13): A closed bridgemat stream crossing on a site in the Southeastern Plains ecoregion with ample slash along both approach ways. Bottom right (Photo 14): A closed bridgemat stream crossing in the MACP ecoregion with piled slash more than 10 feet from the waterway and enough ground cover to minimize erosion. Also note the waterway is free from excessive logging debris.

Areas for Improvement:

The top five improperly implemented BMPs for stream crossing included:

- Stabilize approachways using appropriate means (slash, laps, rock, etc.).
- Install crossing to allow floodwaters to flow around crossing as needed.
- Designate stream crossing location(s) using flagging, paint or other suitable marking.
- Use culvert that extends at least 12 inches beyond the edge of the fill material. If shorter, inlet/outlet headwalls adequately protected.
- Rehabilitate crossing area as soon as possible.

The top three improperly implemented BMPs with associated risk to water quality included:

- Stabilize approach ways using appropriate means (slash, laps, rock, etc.).
- Rehabilitate crossing area as soon as possible.
- Protect the inlet/outlet of the culvert/fill material with suitable stabilization measures.

Stream crossings continue to be an area of emphasis in the NCFS outreach and education programs. The findings of the survey further demonstrate that stream crossings are a critical location during a timber harvest for potential water quality impacts to occur. Much of the NCFS outreach effort has focused on promoting bridgemats. An emphasis on proper BMP implementation of other stream crossing types may improve the frequency of water quality risks. When BMPs were properly implemented for all stream crossing types, few risks to water quality were observed. The higher risks for fords observed during the survey are concerning, especially considering that in recent years the agency has emphasized the option of installing fords instead of culverts. These recommendations stemmed from repeated observations of poorly installed and failed culverts. Properly installed ford crossings offer a relatively low maintenance crossing option as compared to permanently installed culverts, which require frequent maintenance to keep them clear of debris. If this emphasis continues, this survey indicates a greater need for training on proper ford installation and use.

Photos 15-18. Examples of poor stream crossings observed during the survey. Top left (Photo 15): A permanent culvert stream crossing on a Mountain ecoregion site with ditchline turnouts feeding directly into the stream channel. Top right (Photo 16): An incised legacy road stream crossing on a Piedmont ecoregion site that's been reused and in need of additional stabilization. Ruts leading into the waterway pose a water quality sedimentation risk. Bottom left (Photo 17): A closed bridgemat stream crossing on a Southeastern Plains tract with logging slash left within the stream channel. Bottom right (Photo 18): The end wall of this MACP culvert (circled) failed and needs repair. Runoff should be better controlled along the road as well.

3.2.9: Streamside Management Zones (SMZs)

Statewide, there were 8,086 BMPs assessed for streamside management zones including 945 in the Mountains, 4,304 in the Piedmont, 1,234 in the Southeastern Plains and 1,603 in the MACP.

Table 16. Implementation of BMPs for streamside management zones by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
State Total	8,086	91%	756	160
Mountains	945	86%	132	23
Piedmont	4,304	91%	380	106
Southeastern Plains	1,234	94%	77	11
MACP*	1,603	90%	167	20

*Mid-Atlantic Coastal Plain

Key Findings:

- When BMPs for SMZs were properly implemented statewide there was no risk to water quality. When these BMPs were not implemented, there was a risk to water quality 21% of the time.
- SMZs are the last line of defense for capturing sediment and preventing sedimentation. When wider SMZs are implemented, fewer risks to water quality tend to occur. For any class of stream in any ecoregion, successful SMZs were wider on average than those SMZs where a risk to water quality was observed.
- SMZs tended to be widest along perennial streams, and the Piedmont ecoregion tended to have wider SMZs per evaluated stream segment.
- When SMZ width was less than 10 feet, risks to water quality were found 9% of the time. No risks to water quality for SMZ questions were observed with SMZ widths greater than 10 feet.

Photo 19. In this example of an improperly implemented SMZ, a significant number of trees have been harvested all the way up to the stream banks, resulting in increased sunlight exposure to the stream. Groundcover is lacking in portions of the SMZ, reducing its function in preventing accelerated erosion. Sediment that appears to be freshly deposited can be seen in the channel.

Areas for Improvement:

There were 19 BMP questions recorded for SMZs during this survey. Risk to water quality was scarcely observed. In the few instances of documented risks, the following BMPs were not implemented properly:

- Minimize disturbance to the soil and groundcover within the ephemeral stream area.
- Maintain approximately half of the preharvest vegetative canopy cover within the SMZ.
- Avoid roads, skid trails, decks and portable sawmills inside the SMZ.

Photo 20. This is a good example of a SMZ. It was marked with flagging and maintained during harvest.

Table 17. Average streamside management zone width by ecoregion, stream type and risk to water quality.

Ecoregion	Perennial Streams		Intermittent Streams	
	No Risk	**Risk**	**No Risk**	Risk
	--feet--			
Statewide	29	2	25	1
Mountains	23	n/a	33	n/a
Piedmont	30	2	24	2
Southeastern Plains	27	n/a	22	0
MACP*	30	n/a	20	0

*Mid-Atlantic Coastal Plain

Table 18. SMZ width by the count of SMZ segments and risks to water quality.

SMZ Width (ft.)	SMZs Segments	Risk to Water Quality	Frequency of Risk to Water Quality
0-10	85	8	9%
11-30	320	0	0%
31-50	97	0	0%
>50	42	0	0%

Table 19. SMZ segments by buffer rule applicability.

Buffer Rule Applicability	Survey Units	Count of BMPs for SMZs Assessed	SMZ BMP Implementation (Percent)	Improperly Implemented BMP & RISK to Water Quality (Percent)	Avg. SMZ width (ft.): NO RISK to Water Quality	Avg. SMZ width (ft.): RISK to Water Quality
Yes	71	3,157	93%	27%	27	2
No	145	4,929	89%	19%	28	1

3.2.10: Site Preparation and Reforestation

While this survey primarily focused on timber harvesting operations, some BMPs were assessed for site preparation as the opportunities arose. The majority of BMPs in this category focus on 'mechanical' site prep practices, which involve the movement and consolidation of leftover logging debris and/or the tillage of soil to prepare it for reforestation. All 39 BMP observations were assessed in the MACP.

Table 20. Implementation of BMPs for site preparation by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent of Properly Implemented BMPs	Count of Improperly or Not Implemented BMPs	Count of Risk to Water Quality
State Total	39	69%	12	0
Mountains	0	N/A	N/A	N/A
Piedmont	0	N/A	N/A	N/A
Southeastern Plains	0	N/A	N/A	N/A
MACP*	39	69%	12	0

*Mid-Atlantic Coastal Plain

Key Findings:

- BMP implementation for site preparation and reforestation was 69% in the Coastal Plain. No BMPs for site preparation and reforestation were observed in the Mountains, Piedmont or Southeastern Plains.
- The BMPs implemented improperly were as follows:
    - Stagger bed openings from one bed row to the next when gap openings are used within rows.
    - Avoid creating large contiguous areas of exposed bare soil.
    - Conduct bedding when soil moisture conditions are appropriate to avoid impacts to soil structure and infiltration.
    - Minimize intensive soil disturbance and reduce the risk of erosion and sediment transport.

Photo 21. Bedding was used on this site to keep seedlings from being inundated with water. However, the soil appears to have mounded when wet, creating less than ideal soil structure for seedling growth.

3.2.11: Chemical Application, Handling, Mixing, and Sorting

Statewide there were 31 BMPs assessed for chemicals, fluids and solid waste, including six in the mountains, 21 in the Piedmont and four in the MACP.

Table 21. Implementation of BMPs for chemical application by ecoregion.

Ecoregion	Count of BMPs Assessed	Percent BMP Implementation	Count of Improperly Implemented BMPs	**Count of Risk to Water Quality**
Statewide	31	29%	22	0
Mountains	6	33%	4	0
Piedmont	21	33%	14	0
Southeastern Plains	0	N/A	N/A	N/A
MACP*	4	0%	4	0

*Mid-Atlantic Coastal Plain

Key Findings:

- No risks to water quality were identified because of chemical application, handling, mixing and/or sorting whether BMPs were properly implemented or not.
- Low counts of recorded observations in this category may be attributed to survey methodology. Many of the visited sites were evaluated after the logger had moved off-site. When a logging deck had oil buckets, hoses or other trash, the BMP survey questions could be answered as improperly implemented. However, if no trash was observed, the evaluator recorded 'not applicable'. An alternative methodology should be considered for the next round of surveys.

Areas for Improvement:
The BMPs implemented improperly were as follows:

- Keep fluids secure in labeled containers that control or minimize leakage or spillage.
- Do not burn or bury garbage and trash on-site.
- Store garbage and waste in a container (or bag), empty/replace as needed and store to prevent spill or vandalism.

3.3: Implementation by River Basin

Table 22 displays the results for each of the 17 major river basins in North Carolina. A map of the major river basins is shown in Figure 3. The Cape Fear River basin contained 36 surveys (the most of any river basin) which correlates with the fact that this is the largest basin by area in North Carolina. Forestry management occurs frequently within this basin. The most frequent risk to water quality when BMPs were not implemented or improperly implemented was in the Neuse and Catawba River basins at 28% and 24% of observations respectively.

Table 22. BMP implementation and risk to water quality by river basin.

River Basin	Area ($mi.^2$)	Surveys	BMPs Assessed	BMP Implementation with 95% Confidence Interval	Properly Implemented & NO RISK to Water Quality	Improperly Implemented BMP & RISK to Water Quality
Cape Fear	9,164	36	4591	88% ± 1%	100%	12%
Yadkin-Pee Dee	7,221	29	5010	80% ± 1%	100%	15%
Neuse	6,148	30	3537	88% ± 1%	100%	28%
Tar-Pamlico	6,062	19	2744	88% ± 1%	100%	13%
Roanoke	3,493	22	2970	85% ± 1%	100%	14%
Pasquotank	3,366	8	505	89% ± 3%	100%	0%
Lumber	3,329	9	509	88% ± 3%	100%	0%
Catawba	3,285	14	2184	80% ± 2%	100%	24%
French Broad	2,829	8	2120	76% ± 2%	100%	4%
Little Tennessee	1,797	6	1548	71% ± 2%	100%	0%
Broad	1,514	7	1300	77% ± 2%	100%	6%
White Oak	1,382	3	258	89% ± 4%	100%	0%
Chowan	1,298	12	1185	90% ± 2%	100%	8%
New	754	5	971	75% ± 3%	100%	0%
Hiwassee	644	5	1149	77% ± 2%	100%	2%
Watauga	205	1	312	72% ± 5%	100%	8%
Savannah	171	2	579	81% ± 3%	100%	0%
				Higher % is Optimal	*Higher % is Optimal*	***Lower** % is Optimal*

"N/A" indicates that no survey sites were found in that river basin during the survey.

Table 23 displays results for harvests within specially designated watersheds or rivers. When the designation applied to the reach of a river, BMP survey sites were included if they were in the same 12-digit hydrologic unit code (*HUC) and upstream of the designated reach. This was done because nonpoint source pollution in the watershed could potentially affect the designated body of water. While BMP implementation was highest in Outstanding Resource Waters (ORW) and lowest in trout watersheds, the implementation percentages were in the 80's for most waterbodies with low overall variability and a water quality risk observed less than 25% of the time.

**HUC – The U.S. is divided and sub-divided into successively smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units. The hydrologic units are arranged or nested within each other, from the largest geographic area (regions) to the smallest geographic area (cataloging units). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system (U.S. Geological Survey). https://water.usgs.gov/GIS/huc.html*

Table 23. BMP implementation and risk to water quality by special water designations.

Designation	Surveys	BMPs Assessed	BMP Implementation with 95% CI	Properly Implemented & NO RISK to Water Quality	Improperly Implemented BMP & RISK to Water Quality
303(d)*	35	5,419	82% ± 1%	100%	6%
Buffer Rule	71	9,908	87% ± 1%	100%	22%
Coastal Shellfish	60	3,303	86% ± 1%	100%	14%
HQW**	12	1,531	78% ± 2%	100%	8%
Nutrient Sensitive	69	8,868	89% ± 1%	100%	19%
ORW***	3	171	94% ± 4%	100%	0%
Trout	25	6,253	76% ± 1%	100%	2%
Water Supply	45	8,459	82% ± 1%	100%	14%
Wild and Scenic	2	306	85% ± 4%	100%	0%
			Higher % is Optimal	*Higher % is Optimal*	***Lower** % is Optimal*

"N/A" indicates that no survey sites were found in a watershed with that designation during the survey
* Classified as an impaired water under the Federal Clean Water Act Section 303(d)
** Classified as a High Quality Water by the N.C. Department of Environmental Quality
*** Classified as an Outstanding Resource Water by the N.C. Department of Environmental Quality

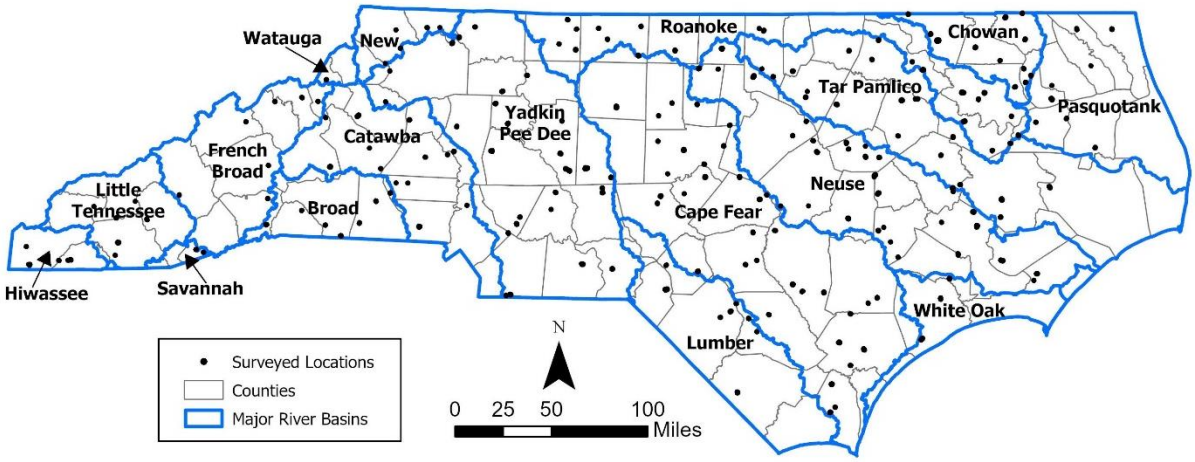


Figure 3. Major river basins of North Carolina overlaid with county boundaries and survey locations between 2018 and 2020.

3.4: Implementation According to Ownership and Forest Management

3.4.1: Ownership

Survey units were located on a diversity of forest owner types. We determined ownership category through communications with NCFS staff and parcel data to develop Table 24. Most surveys occurred on tracts owned by non-industrial private forest (NIPF) landowners.

Table 24. Ownership type by survey and assessed BMP counts and percent BMP implementation and risks to water quality.

Owner Type	Count of Surveys	Percent of Surveys	Percent BMP Implementation	Count of BMPs Assessed	Count of Risks to Water Quality
Federal	4	2%	89%	335	0
Forest Industry	17	8%	88%	1,015	12
NIPF*	150	69%	81%	24,157	549
Other Private	18	8%	91%	2,111	10
Other Public	1	< 1%	78%	50	0
State	7	3%	82%	1,015	0
TIMO/REIT**	19	9%	88%	2,583	61

* Non-Industrial Private Forestland

**Timber Investment Management Organization/Real Estate Investment Trust

3.4.2: Timber Type Category

Evaluators categorized dominant timber type for each survey unit (Table 25).

Table 25. Timber type by survey and assessed BMP counts and percent BMP implementation and risks to water quality.

Timber Type	Count of Surveys	Percent of Surveys	Percent BMP Implementation	Count of BMPs Assessed	Count of Risks to Water Quality
Eastern White Pine	2	< 1	70%	647	0
Loblolly Pine	35	16	89%	2,862	75
Mixed Hardwood	47	22	79%	7,861	190
Mixed Pine	15	7	86%	1,684	29
Mixed Hardwood & Pine	117	54	84%	18,418	338

3.4.3: Harvest Progress

Evaluators estimated the progress of each harvest at the time the survey was carried out (Table 26).

Table 26. Harvest or operational progress by survey and assessed BMP counts and percent BMP implementation and risks to water quality.

Progress	Count of Surveys	Percent of Surveys	Percent BMP Implementation	Count of BMPs Assessed	Count of Risks to Water Quality
0-25%	1	< 1%	94%	31	0
26-50%	3	1%	86%	332	0
51-75%	10	4%	75%	2,139	85
76-100%	24	11%	81%	3,466	115
Completed	178	82%	84%	25,504	432

3.4.4: Harvest Method

Survey units were categorized using one of the following timber harvest methods: clearcut, selection (e.g., diameter limit), thinning, seed tree/shelterwood or salvage (Table 27).

Table 27. Harvest method by survey and assessed BMP counts and percent BMP implementation and risks to water quality.

Harvest Method	Count of Surveys	Percent of Surveys	Percent BMP Implementation	Count of BMPs Assessed	Count of Risks to Water Quality
Clearcut	171	79%	84%	23,983	557
Selection	21	10%	77%	5,003	53
Thinning	14	6%	90%	1,217	22
Seed Tree/Shelterwood	9	4%	86%	1,127	0
Salvage	1	< 1%	67%	142	0

3.4.5: Acreage Class

Survey units covered a wide range of areas and evaluators categorized each unit in terms of acreage ranges (Table 28). The average survey unit size was 61 acres.

Table 28. Tract acreage by survey and assessed BMP counts, and percent BMP implementation and risks to water quality.

Tract Acreage	Count of Surveys	Percent of Surveys	Percent BMP Implementation	Count of BMPs Assessed	Count of Risks to Water Quality
5-20	28	13%	84%	2,682	14
21-40	60	28%	81%	9,016	138
41-60	44	20%	82%	6,436	160
61-80	29	13%	86%	4,124	60
81-100	20	9%	84%	2,477	63
>100	35	16%	84%	6,737	197

4: Conclusions

4.1 Statewide Summary

Overall BMP implementation for the state was 83% during this survey cycle. Categories with scores above 90% and more than 30 observations were decks and SMZs. Categories scoring below 80% and having more than 30 observations were capturing sediment and runoff and skid trails. Several categories had fewer than 30 observations and should be interpreted carefully. A minimum of 30 observations is often thought to provide enough samples to conduct significant statistics. Readers should recognize that results with small sample sizes may have less statistical accuracy. Readers should reference Appendix B for sample sizes and confidence intervals.

There is room for improvement for BMP implementation, however observed risks to water quality were relatively infrequent (about 2% in this cycle). The survey site criteria targeted silvicultural operations containing or bordering waterbodies, and during a period where the land is most susceptible to having a water quality risk. Few observations of risks demonstrate exceptional efforts by operators and supporting land managers.

This survey identifies how the appropriate implementation of non-regulatory BMPs can avoid or minimize visible risks to water quality attributes. Listed below are some notable observations from the survey:

1. Forestry operations that expose mineral soil near streams are more likely to cause a risk to water quality and therefore, demand higher rates of BMP usage.
2. Bare soil areas away from streams can still be of concern if runoff cannot be slowed and dispersed prior to it entering the SMZ. The SMZ should not be the only BMP implemented.

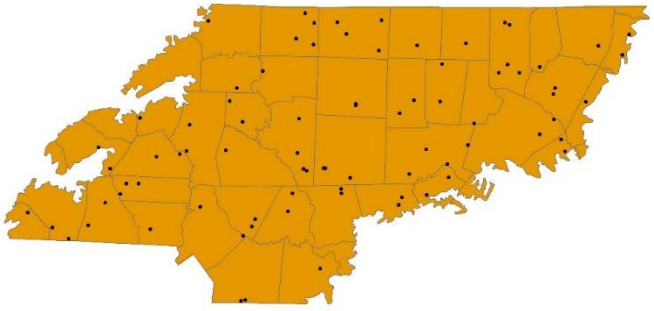
3. Water quality risks were frequently observed with poor road location and stabilization, operating heavy machinery near streams and unstable stream crossing approach ways.
4. The use of water control structures such as waterbars, turnouts or broad-based dips to incrementally direct runoff along roads and skid trails is key for protecting water quality.
5. Preharvest plan development, effectively communicating to operators and seeking technical assistance from a forester or ranger likely improve the implementation of BMPs.

4.2 Regional Summaries

4.2.1 Mountains

There were 37 survey units and 8,855 BMP opportunities recorded in the Mountains ecoregion. About 76% of BMP observations were categorized as properly implemented. About 1% of BMP observations were associated with a water quality risk. Most BMP categories had proper implementation scores above 85%. The skid trail category scored the lowest (58%) of categories with more than 30 observations. The low proper implementation score can be partially explained by the type of skid trails (bladed), lack of cover and poor locations or excessive number of skid trails. Bladed trails are often necessary to safely traverse steep terrain with wheeled logging equipment. However, these trails are known to be more prone to erosion and subsequently present more challenges for erosion control BMPs when compared to overland skid trails. It is our observation that slash on skid trails is less often placed and driven over when compared to other regions. Additionally, some tracts also had seemingly unnecessary trails, or trails that were too close together, which resulted in more skid trails per harvest area compared to other regions. Emphasis on minimizing the extent of skid trails, locating them in the least impactful areas and installing measures to slow and disperse runoff should be the focus of outreach and education in this region.

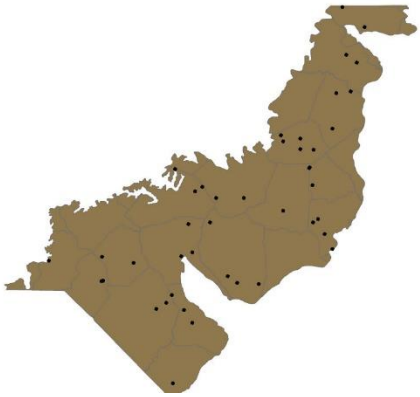
4.2.2 Piedmont



There were 80 survey units and 13,717 BMP opportunities recorded in the Piedmont ecoregion. Roughly 84% of BMP observations were categorized as properly implemented and about 3% of BMP observations were associated with a water quality risk. Several BMP categories had proper implementation scores above 85%. The skid trail (74%) and road access (79%) categories scored lowest of the categories with more than 30 observations. The low proper implementation score of the skid trail and haul roads can be partially explained by lack of erosion control measures used, poor or excessive skid trail locations and lack of BMP improvements or maintenance for legacy skid trails and roads. It was our observation that operators reopen historic/legacy roads and trails without applying necessary erosion control measures or other upgrades to minimize erosion potential at locations away from streams. However, near streams we observed a higher usage rate of BMPs for erosion control. The lack of erosion control measures away from the stream can result in a water quality risk if runoff is allowed to concentrate and flow

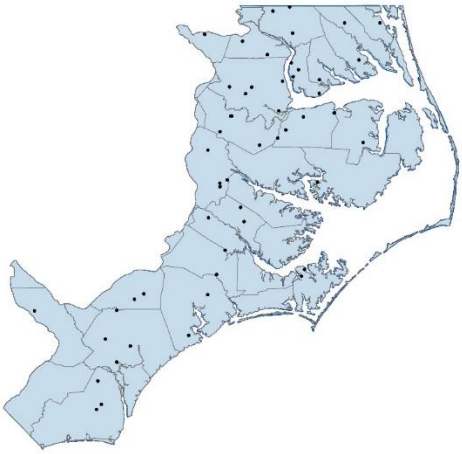
downhill uncontrolled. Emphasis on keeping roads and trails away from legacy gullies and ephemeral streams, and implementing BMPs in these areas should be the focus of outreach and education in this region.

4.2.3 Southeastern Plains



There were 43 survey units and 4,005 BMP opportunities recorded in the Southeastern Plains ecoregion. Approximately 89% of BMP observations were categorized as properly implemented. Roughly 1% of BMP observations were associated with a water quality risk. All but two BMP categories had proper implementation scores above 85%. The rehabilitation of the project site (81%) category scored lowest of the categories with more than 30 observations. The low proper implementation score of this category can be partially explained by debris observed in channels at stream and ditch crossings. In many cases, water could percolate through blockages and there were no observations of water backing up onto an adjacent landowner's property. Fine sand and silt soils common in this region can be problematic when used as a road base. A lack of road base compaction lends these roads susceptible to scour and increased erosion potential. Emphasis on using curb logs at bridgemat crossings to reduce debris falling in channels, removal of excessive logging debris from waterways, and identifying opportunities to improve road base structure should be the focus of outreach and education in this region.

4.2.4 Mid-Atlantic Coastal Plain



There were 56 survey units and 4,895 BMP opportunities that we recorded in the MACP ecoregion. Roughly 87% of our BMP observations were categorized as properly implemented BMPs. Most BMP categories had scores above 85%. The site preparation (69%) and logging systems (75%) categories scored lowest of the categories with more than 30 observations. Risks to water quality were only associated with about 2% of BMP observations. Only three tracts assessed had mechanical site preparation. Our observations of those tracts revealed some water ponding on areas of the tract where there were no gaps within bed rows and there were large contiguous areas of bare soil. The slight deficiencies in logging system selection BMPs were associated with rutting. Rutting can be avoided or reduced by ceasing operations when machine travel creates deep rutting, deploying special logging tactics (such as 'shovel trails'), or low ground pressure equipment (such as tracks or dual tires). Emphasis on identifying wet ground areas, and strategic planning of when and how to access them should be the focus of outreach and education for harvesting in this region. Emphasis on when and where to leave gaps in bedding rows that prevent water impounding, while minimizing contiguous bare soil areas near waterways should be the focus of outreach and education for mechanical site preparation in this region.

5: Proposed Changes to the Next Assessment

The NCFS released an updated version of the BMP Manual in December 2021. The next BMP survey cycle will assess the BMPs from the revised edition. The majority of the BMPs were edited for brevity and clarity while remaining functionally equivalent to the 2006 manual's recommendations. However, some notable changes were made to the BMPs for SMZs, waterway crossings and forest harvesting in wetlands. The next survey will attempt to assess those changes. The next cycle of statewide BMP surveys will begin as soon as January 2023, allowing the forestry community time to adapt its operations to the revisions published in the December 2021 edition of the BMP Manual.

The survey collection platform should be improved by including filter questions, which if answered in the affirmative, will direct the surveyor to another set of questions. If not, the surveyor will progress to the next section. Such improvement should help make surveyors more efficient in collecting data.

Two additional answer choices should be included in the next survey, "not present" and "unknown". These categories would provide further information and clarity around BMPs that would have otherwise been unanswered. In the current survey, questions were left blank if surveyors were unable to determine an answer while onsite, especially on tracts that are no longer active. For example, to answer whether equipment was checked regularly for oil leaks on a tract that was closed out, the current survey would leave the question blank whereas the new survey would answer "unknown". This will provide greater clarity during data analysis and potentially highlight BMPs, or categories of BMPs, that we are often unable to observe.

In keeping with current technology, the geospatial data collection platform should be migrated from ESRI's Collector to FieldMaps. FieldMaps is a new ESRI product that combines functionality from Collector and a handful of other apps. ESRI's Collector platform may no longer be supported by the end of the next survey cycle. Survey123 should still be used to capture responses to questions.

6: References

Lang, A.J., W.A. Coats, T.A. Gerow Jr., and W.A. Swartley. 2022. Estimates of soil erosion and best management practice effectiveness at forestry stream crossings in North Carolina. Journal of Soil and Water Conservation. 77(3):292-304. doi:10.2489/jswc.2022.00110.

Omernik, James M. "Ecoregions of the conterminous United States." Annals of the Association of American geographers 77.1 (1987): 118-125

SAS Institute Inc., 2019. Using JMP Pro 16.0.0. SAS Institute, Cary, NC.

SGSF, 2007. Silviculture best management practices implementation monitoring: a framework for state forestry agencies. Southern Group of State Foresters Water Resources Committee, 24p.

Appendix A: List of BMP Implementation Questions

Online Only

Appendix B: Sample Size and Confidence Intervals for BMP Implementation Data

All tables available online.

Sample size and confidence intervals for overall implementation of best management practices (BMPs) by category and region.

BMP Category	Sample Size					BMP Implementation Rate & 95% Confidence Interval				
	Statewide	Mountains	Piedmont	Southeastern Plains	MACP*	S	M	P	SP	C
Overall	**31,472**	**8,855**	**13,717**	**4,005**	**4,895**	83 ± 0.4	76 ± 1	84 ± 1	89 ± 1	87 ± 1
Harvesting: Capturing Sediment	31	6	21	0	4	75 ± 15	68 ± 30	72 ± 18	N/A	64 ± 34
Harvesting: Controlling Runoff	2,005	358	785	370	492	29 ± 2	34 ± 5	33 ± 3	N/A	0 ± 0
Harvesting: Decks	4,964	3,488	1,311	143	22	97 ± 0	94 ± 1	96 ± 1	98 ± 3	91 ± 13
Harvesting: Logging Systems	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
Harvesting: Rehabilitation of the Project Site	508	91	188	95	134	86 ± 3	93 ± 5	85 ± 5	91 ± 6	75 ± 7
Harvesting: Skid Trails	1,778	333	984	251	210	82 ± 2	87 ± 4	80 ± 2	81 ± 5	85 ± 5
Harvesting: Wetlands	1,040	161	576	139	164	84 ± 2	89 ± 5	79 ± 3	82 ± 6	95 ± 3
Chemicals, Fluids, and Solid Waste	39	0	0	0	39	69 ± 14	N/A	N/A	N/A	69 ± 14
Firelines	8,311	2,456	3,228	1,130	1,497	73 ± 1	58 ± 2	74 ± 2	84 ± 2	83 ± 2
Roads and Access	8,086	945	4,304	1,234	1,603	91 ± 1	86 ± 2	91 ± 1	94 ± 1	89 ± 2
Site Preparation and Reforestation	4,624	1,017	2,316	619	672	87 ± 1	86 ± 2	88 ± 1	88 ± 3	86 ± 3
Stream Crossings	86	0	4	24	58	80 ± 8	N/A	63 ± 34	68 ± 18	84 ± 9
Streamside Management Zones (SMZs)	**31,472**	**8,855**	**13,717**	**4,005**	**4,895**	83 ± 0.4	76 ± 1	84 ± 1	89 ± 1	87 ± 1

*Mid-Atlantic Coastal Plain

Appendix C: List of Supplemental Resources

An Assessment of Forestry Best Management Practices in North Carolina, 2018-2020: Map Journal
https://storymaps.arcgis.com/stories/d9cc331a12284aad8aa432f0f8ffd8f0

Implementation of Forestry Best Management Practices: 2018 Southern Region Report.
https://southernforests.org/water/SGSF%20Water%20BMP%20Report%20FINAL.pdf

Protecting the Nation's Water: State Forestry Agencies and Best Management Practices. 2019. National Association of State Foresters.
https://www.stateforesters.org/newsroom/protecting-the-nations-water-state-forestry-agencies-and-best-management-practices/

NCFS Glossary
http://ncforestservice.gov/publications/Forestry%20Leaflets/FM01.pdf

North Carolina Forestry Best Management Practices Manual and Published Research Appendix, Dec.2021 Edition.
https://www.ncforestservice.gov/water_quality/bmp_manual.htm

Omernik, James M. "Ecoregions of the conterminous United States." Annals of the Association of American geographers 77.1 (1987): 118-125

Previous NCFS BMP Surveys
http://ncforestservice.gov/water_quality/wq_bmp_studies.htm

USDA-USFS Forest Inventory and Analysis: Forests of North Carolina, 2020.
https://www.ncforestservice.gov/Managing_your_forest/pdf/NC_2020_FIA_Factsheet.pdf

USEPA National Management Measures to Control Nonpoint Source Pollution from Forestry
https://www.epa.gov/nps/national-management-measures-control-nonpoint-source-pollution-forestry