Re-evaluating Forest Harvesting BMP efficiencies for the Chesapeake Bay Program's Watershed Model

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Summary:

The Timber Harvest Task Force was convened by the Forestry Workgroup and Land Use Workgroup to improve the modeling of the water quality impacts of forest harvesting in the Phase 7 Watershed Model. We conducted an initial evaluation of the literature and consulted experts to determine if there was a need to re-evaluate: 1. The loading rates of harvested forests, 2. The nutrient and sediment removal efficiencies of forest harvesting BMPs, and 3. The credit duration of forest harvesting BMPs. Based on our research, we determined that there is insufficient research to support modifying the loading rates of harvested forests, but **we recommend changes to the nitrogen efficiency rate and credit duration for the Forest Harvesting Practices BMP.**

Introduction:

The Chesapeake Bay Program is currently updating its modeling and analysis tools, including the Chesapeake Assessment Scenario Tool (CAST), which is a publicly available model of the Chesapeake Bay watershed used to estimate changes in long-term nutrient and sediment loads due to changes in point sources, land use, and land management. Harvested forest is one land use type modeled in CAST. With the implementation of forest harvesting BMPs, harvest managers can prevent significant soil erosion, reducing the total sediment and nutrient loads in waterways that could otherwise result from an unsustainable harvest. These BMPs include practices that are implemented to minimize impacts during forest harvest, as well as practices to minimize water quality impacts following the harvest. These BMPs are described in the USDA-NRCS National Handbook of Conservation Practices and include, but are not limited to, Forest Trails and Landings (655) and Forest Slash Treatment (384). The Bay Program uses BMP "efficiencies" to quantify the percentage of a pollutant load that is removed when a BMP is applied.

The Bay Program's Forestry Workgroup (FWG) provides expertise to the partnership on forestry-related issues, including timber harvesting. To best advise the Forestry Workgroup on their recommendations for Phase 7 of the watershed model, we conducted a literature review of materials related to the water quality impacts of forest harvesting and timber harvest BMPs and consulted forest harvest experts. During this literature review, we searched for information relevant to the base loading rates of harvested forests, the efficiency rate for timber harvest BMPs, as well as the credit duration for forest harvesting BMPs.

Current Base Loads and Efficiencies:

When the Bay Program was doing the last major update to CAST (for the Phase 6 model), Maryland Forest Service conducted a review to establish loading rates for harvested forest. Based on this review, loading rate ratios were established to determine the relative loads of harvested forest to true forest.

Table 1: Loading rate ratios for harvested forest based on data review by Justin Hynicka, MD DNR (2015)

	TN Loading Rate Ratio	TP Loading Rate Ratio	TSS Loading Rate Ratio
True Forest	1	1	1
Harvested Forest	7.03	3.12	3.05

However, when the Phase 6 loading rates were established, a slightly different loading rate ratio was established for TN and a much different loading rate ratio was established for TSS (Chesapeake Bay Program Phase 6 Watershed Model Documentation- Section 2). These modified loading rates appear to be erroneous in the Phase 6 model based on consultation with the modeling team.

Table 2: Loading rates and loading rate ratios for harvested forest in CAST documentation

	TN Loading Rate Ratio	TN Loading Rate (lbs/acre/yr)	TP Loading Rate Ratio	TP Loading Rate (lbs/acre/yr)	TSS Loading Rate Ratio	TSS Loading Rate (tons/acre/yr)
True Forest	1	1.68	1	.08	1	.07
Harvested Forest	7.07	11.88	3.12	.24	10	.6

For Forest Harvesting BMP efficiencies, between 2006-2007, the University of Maryland led a project to review and refine effectiveness estimates for forest harvesting BMPs implemented and reported within the Chesapeake Bay Watershed. As a part of this project, Pamela Edwards (USDA Forest Service) and Karl Williard (Southern Illinois University) were asked to review applicable literature and propose an efficiency for model calibration based on the literature and their experience. Edwards and Williard examined three studies that contained data of timber harvest with and without BMPs from comparable plots to calculate an efficiency rate of the BMPs. Edwards and Williard averaged the efficiency rates from these studies to form a recommended efficiency rate for CAST. These rates were discounted by 20% to develop a conservative estimate, with the estimate for TN being discounted further, as there was only one study that specifically addressed TN efficiency.

They recommended that the efficiency be set to a conservative **60% for total suspended solids (TSS), 50% for total nitrogen (TN), and 60% for total phosphorus (TP).** These recommendations were formally adopted in the 2009 report "Developing Best Management Practice Definitions and Effectiveness Estimates for Nitrogen, Phosphorus and Sediment in the Chesapeake Bay Watershed (Page 300 – 342)", by Dr. Thomas Simpson and Sarah Weammert. Forest harvesting BMPs were assigned a credit duration of one year, so these efficiencies are applied to loading rates for a duration of one year. This information can also be found in the Chesapeake Bay Program's Quick Reference Guide for Best Management Practices (Page 162 – 163).

When these efficiencies are applied to the recommended base loading rate ratios in Table 1, harvested forests with BMPs would yield the following loading rate ratios and efficiencies over true forest loads:

Table 3: Impact of current BMP efficiencies on harvested forest loads relative to true forest

	Original recommended loading rate ratio	**Current forest harvesting BMP efficiency**	**Loading rate ratio after BMP application**	**% of additional loads over True Forest removed by BMPs**
TN	7.03	50%	3.52	58%
TP	3.12	60%	1.25	88%
TSS	3.05	60%	1.22	89%

Research Methodology:

We surveyed literature related to forest harvesting and sediment, nitrogen, and phosphorus loads (full list of literature surveyed included in the bibliography). However, given that forest harvesting BMPs are already highly efficient for TP and TSS removal relative to True Forest (Table 3), we focused our evaluation of forest harvesting BMP efficiencies on TN. We focused on relevant studies published within the last 15 years (since the previous BMP efficiency study was conducted), between 2009 - 2024. We examined studies that took place either in full or partially within the Chesapeake Bay Watershed and neighboring states, as well as eastern mixed deciduous and pine forests. In addition, we consulted with several experts, who assisted in guiding our research. These include Dr. C. Rhett Jackson from the University of Georgia, Dr. Michael Aust from the University of Virginia Tech, and Moriah Van Voorhis from the North Carolina Forest Service, who we want to thank for their assistance. Rodney Newlin from the Virginia Department of Forestry and Andrew Vinson from the Virginia Department of Forestry were also consulted and assisted in the drafting of this report.

Results: Literature Review Summary

Nitrogen:

There was insufficient literature to reevaluate base TN loading rates of harvested forests in the absence of BMPs. In most cases, studies evaluated the overall effects of forest harvesting with BMPs on water quality as compared with a reference (unharvested) site or a modeled "no harvest" scenario.

Four studies were identified that evaluated the impacts of harvests with BMPs on nitrogen; however only two of these quantified TN loads, which is how the Bay Program quantifies the impacts of BMPs on water quality. Only one of these two could be used to clearly quantify the impacts of harvesting on TN loads (Boggs et al. 2015), as the other had many confounding factors complicating the analysis (Marchman et al. 2013). Studies noted even if TN *concentrations* did not significantly increase, there were measured increases in TN *loads* due to increased streamflow resulting from reduced evapotranspiration after harvest.

Table 4: Summary of literature reviewed to evaluate the effects of forest harvesting BMPs on TN

Reference	**Study Overview**	**Key Findings**
DaSilva et al., 2012	Study from north-central Louisiana. Evaluated the effectiveness of LA's voluntary BMPs at preventing water quality degradation by comparing water quality of tracts harvested with BMPs to a tract harvested without BMPs. Note study was not published in a peer-reviewed journal (included in conference proceedings), and they did not quantify nutrient loading (only concentrations)	Results "showed no significant increase in TN from the two BMP-implemented harvests, though there were spikes in TN from the non-BMP implemented tract"
Marchman et al., 2013	Study from Upper Coastal Plain in GA. Compared loads from harvested forests with BMPs with reference watersheds. Treatment watersheds also had additional ag loads coming in and there was high inter-annual variability in N concentrations for both treatment and reference watersheds.	"Although changes in NOx and TN concentrations were small, and the other nutrient concentrations did not show apparent silvicultural effects**, all nutrient loads and yields increased following silvicultural treatments because of the increase in streamflows**. With the application of modern BMPs, changes in nutrient concentrations due to timber harvest and planting were modest

		or statistically insignificant in this study." "However, because forest harvest necessarily reduces evapotranspiration and thus increases streamflows, forest harvest will increase nutrient and sediment loads even if concentrations remain unchanged." Note given the high variability in TN loads between years and between sites and upstream agricultural influences in the treatment watersheds, we were unable to quantify the effects of harvest on TN loads relative to the control watersheds.
Boggs et al., 2015	Study from North Carolina Piedmont. Compared measured nutrient loads from harvest sites with vegetated buffer strip BMPs with modeled no treatment loads for all treatment watersheds	Mean annual measured TN from harvest sites (with BMPs) were higher than the mean annual modeled (no harvest) values across all treatment watersheds. An analysis using their data showed an average 37% increase in TN concentrations and **a 198% increase in TN loads from harvest sites** with BMPs over modeled no harvest loads.
Witt et al., 2016	Study from Cumberland Plateau, Kentucky. Evaluated the impacts of varying Streamside Management Zone (SMZ) configurations on water quality. Treatment watersheds were compared with unharvested control watersheds. Evaluated a variety of water quality parameters, but for Nitrogen only evaluated nitrate and Ammonium concentrations (not TN loads).	"Nitrate concentrations were higher in harvested watersheds at both the perennial and intermittent monitoring locations". "Comparisons of ammonium nitrate concentrations from treatment watersheds and unharvested control watersheds did not result in statistical differences"
Literature reviewed by Edwards and Williard (2009)		
Wynn et al., 2000	Study from the coastal plain, VA included in the original 2009 BMP evaluation. One watershed was clearcut with BMPs and one watershed was clearcut without BMPs.	Found a **60 to 80% efficiency for TN loads**, with the higher percentage following post site-prep (herbicide and burning).

Results: Expert Consultation

When reaching out to experts, they acknowledged that there have not been many new timber harvest BMP research and studies published, and that most BMPs are comparable to BMPs done pre-2000. They also expressed that the current BMP efficiencies in CAST were likely conservative. They suggested that BMPs captured over 95% of sediments, that phosphorus loads were highly associated with sediment loads and thus similar, and that very little nitrogen was entering waterways with proper BMP usage. This supports the findings from the literature showing that harvests do not generate significant increases in nutrient loads when BMPs are utilized.

We also consulted Rodney Newlin and Andrew Vinson from the Virginia Department of Forestry. They reported that they perform a BMP audit on 240 randomly selected harvests each year. These audits report when there is a significant risk (SR), which is defined as a harvest where the lack of a BMP is causing or likely to cause pollution, and when there is active sedimentation (AS) occurring. Looking at the last 10 years of their BMP audit reports (2013 – 2023), there was an average of no SR for 98.3% of their audits, and no AS for 99.3% of their audits. Given this high percentage and the high sample size, they supported that BMPs capture >95% of sediments. In addition, Newlin and Vinson reported that BMPs are designed to handle 10-year storm events if they are properly installed and not altered by someone.

Recommendations:

There was insufficient literature looking at base loads of harvested forests without forest harvest BMPs. However, given the likely errors uncovered in the current base loads for harvested forest for TN and TSS, **we recommend correcting the loading rate ratios of harvested forests for TN and TSS to align with the original recommendations from the Forestry Workgroup for Phase 6 (TN= 7.03, TSS= 3.05, Table 3)**

The literature and expert consultation suggest that **the current efficiency rates for TSS and TP should be maintained**, but the efficiency rate TN from forest harvesting BMPs could be increased, while still remaining conservative. Although the literature review had mixed results regarding the impacts of forest harvesting with BMPs on TN loads, experts advised that very little nitrogen enters waterways with BMP implementation. Boggs et al. 2015 showed an average 199% increase in TN loads from harvest sites with BMPs over modeled no harvest loads (see Appendix for TN loading data). Achieving this loading would require a 57.6% efficiency rate for harvesting BMPs (Table 5). This is closely aligned with the low end of the original efficiency estimates identified by Simpson & Weammert in their 2009 report, which found a 60-80% efficiency for harvesting BMPs.

Table 5: Revised efficiency rate calculations

	Loading Rate Ratio
True Forest	1
Harvested Forest with BMPs (based on Boggs et al. 2015)	2.98
Previous harvested forest ratio (without BMPs)	7.03
Efficiency rate required to achieve loading rate ratio from Boggs et al. 2015	**57.6%**

Currently, CAST reports a 50% efficiency rate for TN. Given the results of our literature review and Simpson and Weammert's findings, **we recommend changing the efficiency rate for TN to 60%.** This would also bring the efficiency rate of TN into alignment with that of TP and TSS.

There was evidence that efficiencies are maintained throughout multiple years after BMP implementation, both from the literature and from experts. **We recommend changing the credit duration to three years** to align with the full post-harvest time period for which the land loads as a harvested forest in the model**.**

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Appendix- Summary of Boggs et al. 2015

- HF1 and HFW1 were 35 year old mixed-pine hardwood stands
- UF1 was a 70 year old mixed-pine hardwood stand
- For HF1 and UF1, the entire watershed area was clearcut harvested.
  - A 15.2 M riparian buffer was retained on each side, with some harvesting of high-value trees from the buffer as allowed by local regulations.
  - Additional BMPs were used to prevent sedimentation and other water quality issues in accordance with the North Carolina Forest Practices Guidelines Related to Water Quality
  - Additional BMPs included skidding trees without crossing stream channels and redistributing slash to limit soil disturbance
- For HFW1, there was a partial harvest where 1/3 of the total watershed area was clearcut
- Monitoring was conducted for three years post-harvest
- Modeled concentrations are mean values from the linear model that was developed during the calibration period to determine what load would be if the clearcut had not occurred

TN loads (kg/ha/yr)				
Site	**Measured**	**Modeled**		**% increase in loads from harvest over modeled no-harvest baseline**
HF1	2.62	0.72		2.64
HFW1	1.28	0.71		0.80
UF1	3.13	0.89		2.52
Average				1.99