Forest Harvesting Practices

Definition and Nutrient and Sediment Reduction Efficiencies

For use in calibration and operation of the Chesapeake Bay Program's Phase 5.0 Watershed Model

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Summary

Forest Harvesting Practices: a suite of practices that reduce sediment and nutrient pollution to water bodies originating from forest management activities to acceptable levels.

- Effectiveness Estimate: 60% TSS, 60% TP and 50% TN

Introduction

The Mid-Atlantic Water Program (MAWP) housed at the University Of Maryland (UMD) led a project during 2006-2007 to review and refine definition and effectiveness estimates for BMPs implemented and reported by the Chesapeake Bay watershed jurisdictions prior to 2003. The objective is to develop definitions and effectiveness estimates that reflect the average operational condition representative of the entire watershed. The Chesapeake Bay Program (CBP) historically assigned effectiveness estimates based on controlled research studies that are highly managed and maintained by a BMP expert. This approach is not reflective of the variability of effectiveness estimates in real-world conditions where farmers and county stormwater officials, not BMP scientists, are implementing and maintaining a BMP across wide spatial and temporal scales with various hydrologic flow regimes, soil conditions, climates, management intensities, vegetation, and BMP designs. By assigning effectiveness estimates that more closely align with operational, average conditions modeling scenarios and watershed plans will better reflect monitored data.

One important outcome of the project is the wealth of documentation compiled on the BMPs. Previously, BMP documentation was limited and the CBP has been criticized for this in the press and in governmental reviews. To provide precise documentation the UMD/MAWP designed a robust practice development and review process utilizing literature, data, and best current professional judgment. The initial step was a literature and knowledge synthesis. Available scientific data were compiled and analyzed for quality and applicability and included in a report that summarizes all decisions on how effectiveness estimates were developed. The process for incorporating both science and best professional judgment to estimate average operational effectiveness is also well documented.

Another objective of the project was to initiate an adaptive management approach for BMP effectiveness for the CBP. An adaptive management approach allows forward progress in implementation, management and policy, while acknowledging uncertainty and limits in knowledge. The adaptive management approach to BMP development incorporates the best applicable science along with best current professional judgment into definition and effectiveness estimate recommendations. With adaptive management it is necessary to include a schedule that allows for revisions as advances knowledge and experience becomes available. UMD/MAWP recommends continued monitoring of BMPs, with revision of definitions and effectiveness estimates scheduled for every three to five years to incorporate new data and knowledge.

To review efficiencies MAWQ contracted experts, Pam Edwards and Karl Williard, and asked them to review applicable literature and propose an efficiency for model calibration based on the literature and their experience. See Appendix A for their report. The objective of this project is to estimate efficiencies that reflect operational conditions, and consequently the CBP modified the experts’ research level recommendations to reflect actual conditions. Attached to these definitions and efficiencies is a full accounting of the Chesapeake Bay Program's discussions on this BMP, who was involved, and how recommendations were developed, including data, literature, data analysis results, and discussions of how various issues were addressed. All meeting minutes are included in Appendix C.

Description/Definition

Specific, individual forestry BMPs focus primarily on controlling water quantity and energy because water movement serves as a primary mechanism for sediment and associated nutrient detachment and transport. Dissolved nutrients tend to be less impacted by typical forestry BMPs. Though, riparian BMPs, such as streamside buffer strips, may have a significant effect on dissolved nutrient loads

The definition for forest harvesting practices are a suite of practices that reduce sediment and nutrient pollution to water bodies originating from forest management activities to acceptable levels. These activities include: road, trail, and landing construction, use, and closure; harvesting and log removal activities; and site preparation or within-rotation treatments.

Practice components meet criteria standards under the USDA-NRCS National Handbook of Conservation Practices (NHCP) (http://www.nrcs.usda.gov/technical/standards/nhcp.html) and associated Field Office Technical Guides (http://www.nrcs.usda.gov/technical/efotg/) for each state. Components consisting of conservation measures included in the Forest Harvesting Practices definition include, but may not be limited to the following USDA-NRCS conservation practices:

- Forest Trails and Landings (655)
- Forest Slash Treatment (384)

Efficiency

To develop effectiveness estimates a literature review and discussions aimed at estimating the operational effectiveness with watershed wide spatial and temporal variability were conducted. These efficiencies assume they will be applied against typical forest loads. If a high loading land use is developed for disturbed forest then efficiencies should be re-evaluated and would likely be lower.

Literature Review and Data Analysis Methods

BMP efficiencies for sediment and nutrient reductions from forestry operations are based on studies in which paired watershed comparisons were made. One watershed was harvested (and also may have had site preparation) with BMPs while the second was harvested without BMPs. While many other studies in the literature compare sediment and nutrient loads between reference (undisturbed) watersheds and managed watersheds employing BMPs, BMP efficiencies cannot be determined from those types of studies. Sediment and nutrient reductions were based on in-stream water-column loadings, as there are no published studies to-date in the East that have measured to-stream or to-lake (i.e., actual hillside contributions) concentrations or loadings.

The data used to calculate sediment and nutrient reductions for this document were extracted from the papers listed in Table 1. Only data collected from regions that we deemed applicable to landscapes present in some part of the Chesapeake Bay watershed (i.e., physiography, topography, soils, hydrology and climate) are included; however, because there are so few BMP vs. no BMP comparisons, in reality few BMP vs. no BMP data have been excluded.

Data used in the calculation of BMP efficiencies for sediment are shown in Table 2. Loads for sediment from the study by Arthur et al. (1998) were presented in bar graph form, so an engineering ruler was used to measure the height of each bar and the loadings were calculated from those measurements. All other sediment and nutrient data were provided as tabular values.

Table 1. Studies from which sediment and nutrient data were obtained for forestry BMP efficiencies.

Reference	Treatment/Watershed Description	Location	Sediment Measured?	Nitrogen Measured?	Phosphorus Measured?
Kochenderfer and Hornbeck (1999)	One watershed (38.8 ha) diameter limit cut to 35.6-cm dbh with BMPs, one watershed (29.9 ha) clearcut to 12.7-cm dbh without BMPs. Hillsides averaged 40% slope in both watersheds.	Central Appalachians, north central WV	Yes	No	No
Wynn et al. (2000)	One watershed (8.5 ha) clearcut with BMPs, one watershed (7.9 ha) clearcut without BMPs. Firelines installed, herbicide applied, controlled burn and hand planting followed. Slopes average 2% over most of harvested areas except up to 30% slope along deeply incised streams.	Coastal Plain, VA	Yes	Yes	Yes
Arthur et al. (1998)	One watershed clearcut with BMPs, one watershed clearcut without BMPs. On both watersheds all stems > 35.5 cm, cut and left all stems < 5 cm dbh. Hillsides average 45% slope. Watershed sizes not given	Cumberland Plateau, eastern KY	Yes	Yes	Yes

Table 2. Efficiencies (i.e., percent reduction) for sediment loads gained from using forestry BMPs

Reference	Time Period	Sediment Load		Calculated Efficiency
		No BMPs	BMPs	
Kochenderfer and Hornbeck (1999)	1st yr after harvest 2nd yr after harvest	3227 kg/ha 323 kg/ha	123 kg/ha 77 kg/ha	96% 76%
Wynn et al. (2000)	Post harvest Post site-prep	9760 kg/ha/yr 7670 kg/ha/yr	560 kg/ha/yr 620 kg/ha/yr	94% 91%
Arthur et al. (1998)	During Harvest 1st yr post harvest 2nd yr post harvest 4th yr post harvest[1] 5th yr post harvest 6th yr post harvest	1180 kg/ha 640 kg/ha 376 kg/ha 100 kg/ha 200 kg/ha 307 kg/ha	553 kg/ha 420 kg/ha 367 kg/ha 47 kg/ha 387 kg/ha 67 kg/ha	53% 34% 2% 53% 94% 78%

[1] 3rd year post harvest figures were not collected.

Table 3. Efficiencies (i.e., percent reduction) for total nitrogen loads gained from using forestry BMPs

Reference	Time Period	Total Nitrogen Load		Calculated Efficiency
		No BMPs	BMPs	
Wynn et al. (2000)	Post harvest Post site-prep	104.7 kg/ha/yr 85.4 kg/ha/yr	41.8 kg/ha/yr 17.1 kg/ha/yr	60% 80%
Arthur et al. (1998)	1st yr post harvest	1.45 kg/ha/yr[1] a	1.27 kg/ha/yr A	12%

[1]Authur et al. (1998) measured nitrate-N loads, not total nitrogen. The authors do not state whether the nitrate analysis was conducted on filtered or unfiltered samples.

Table 4. Efficiencies (i.e., percent reduction) for total phosphorus loads gained from using forestry BMPs

Reference	Time Period	Total Phosphorus Load		Calculated Efficiency
		No BMPs	BMPs	
Wynn et al. (2000)	Post harvest Post site-prep	12.61 kg/ha/yr 10.82 kg/ha/yr	1.72 kg/ha/yr 1.60 kg/ha/yr	86% 85%
Arthur et al. (1998)	1st yr post harvest	0.36 kg/ha/yr[1]	0.20 kg/ha/yr	44%

[1]Authur et al. (1998) measured phosphate loads, not total phosphorus. The authors do not state whether the phosphate analysis was conducted on filtered or unfiltered samples.

Recommended Efficiencies for Model

Sediment

Two of the studies (Kochenderfer and Hornbeck 1999, Wynn et al. 2000) resulted in efficiencies values of 94 and 96 percent for sediment during at least the first year after treatment, even though they were in very different physiographic regions with different topographic conditions. The study by Arthur et al. (1998) had efficiencies of only 53 percent during harvesting; however, they noted that they probably would have had greater increases in sediment in the watershed with no BMPs had their logging crew not been well trained in BMPs. That is, they employed recommended logging techniques in some instances even though they were not required to. For example, the Kentucky crews never skidded logs downhill, even though this is a common practice when BMPs are ignored (e.g., Kochenderfer and Hornbeck 1999, Reinhart et al. 1963).

At a local (i.e., small watershed scale) level, the Chesapeake Bay Program (CBP) uses a more conservative efficiency sediment reduction value of **60 percent**. Research level evaluations suggest higher reductions but CBP does not think adequate operational data is available to justify increasing the efficiency.

Nutrients

Only two studies applicable to the Chesapeake Bay region directly measured percent reduction in nutrients due to BMP implementation in forested watersheds (Authur et al. 1998, Wynn et al. 2000). There is a multitude of studies in the eastern United States that examined the impacts of forest harvesting on dissolved nutrient leaching by comparing a treated (harvested) watershed to a control or reference watershed (Aubertin and Patric 1974, Hornbeck et al. 1986, Lynch and Corbett 1990, Martin et al. 2000, Swank et al. 2001). Most of these studies showed that dissolved nutrient concentrations and loads increased in the first one to three years following harvesting due to loss of biotic immobilization and increases in microbial mineralization rates. However, the studies demonstrated that nutrient concentrations and loads decreased in subsequent years following harvesting until reaching pre-harvest levels, generally after year five to ten years.

Total Nitrogen

Wynn et al. (2000) found a 60 to 80% efficiency for TN, with the higher percentage following post site-prep (herbicide and burning). Given that this is the only study specifically addressing TN efficiency, the more conservative current efficiency value of **50 percent for TN is assigned**. The research data shows an extremely high efficiency and again CBP does not feel the research is adequate to increase the efficiency.

Total Phosphorus

Total phosphorus (TP) includes all orthophosphates and condensed phosphates, both dissolved and particulate, organic and inorganic. The majority of phosphorus (P) is transported in the particulate form, bound to sediment. Thus, the efficiencies for P should approach those for sediment, which they did (44 to 86%). The Arthur et al. (1998) study (44% efficiency) stated that they analyzed phosphate on a spectrophotometer, so only the inorganic fraction of P was measured. They did not state whether their water samples were filtered or unfiltered prior to analysis. This is especially important for P analysis, since much of the P is sediment bound. Given the relatively low P loads and efficiency compared to the Wynn et al. (2000) study, one could speculate that only dissolved P from filtered samples was measured. Given the uncertainties in the Arthur et al. (1998) analysis and that adequate research does not exist to justify an increase in the efficiency, MAWQ project staff recommends an efficiency for **TP of 60% percent**. This is similar to the recommended sediment efficiency, which is logical given the similar modes of transport. Other BMPs UMD/MAWP refined during their review used a 75 to 25, particulate to dissolved P ratio to determine TP effectiveness estimates. However, in forest settings, most P is particulate so using 75 to 25, particulate to dissolved P ratio used on agricultural levels is not appropriate.

It is important to point out that nutrients that commonly travel subsurface in the dissolved phase, such as nitrate, will likely have lower efficiencies. Most forestry BMPs were developed to control energy and water movement on the surface of the landscape and may not impact subsurface processes to a large extent.

The developers, Pam Edwards and Karl Williard, proposed efficiencies substantially higher than current ones based primarily in two coastal plain studies. CBP felt that these two studies were likely to be optimistic when applied across the watershed particularly when given the variability in terrain and expertise of the harvester in BMPs application. CBP kept efficiencies close to where they are currently but reduced N slightly to account for losses through subsurface flow that do not appear to have been acknowledged in the current efficiency. For other BMPs research level efficiencies were reduced by 25% to account for variability and loss in precision/control when going from research scale to widespread application. The Forestry Workgroup felt this was too severe of a reduction because of the regulatory program governing forest harvesting practices. To accommodate limitations in the data, wide spread implementation, and the current regulatory program, forest harvesting BMPs were only discounted by 20%, relatively.

BMP Efficiency Development

Most investigations of BMP effectiveness, including those from which data have been extracted for this report, used indirect measurements of in-stream suspended sediment exports as a surrogate of actual sediment delivery to water bodies (Edwards 2003). Indirect measurements using suspended sediment measured typically at the mouth of watersheds ignore several spatial and temporal factors concerning sediment delivery. These include:

1) some eroded sediment originating from the forest operation and associated activities may still be stored on the hillside at the time the monitoring was performed;
2) delivered sediment can be stored in the channel for decades and perhaps hundreds of years before being flushed out (Reid 1982, Trimble 1981);
3) some erosion resulting from forest management operations may begin or continue after monitoring has ceased (e.g., washouts of roads constructed for the forest operation). These may be short-term inputs or they may become chronic long-term inputs, depending upon the sources;

4) bedload inputs to the water bodies are not accounted for by measurements of suspended sediment.

In the East, including the Chesapeake Bay watershed, bedload inputs are generally not considered large since the landscape is old and most bedload materials from the hillside were eroded and transported very long ago. Contemporary bedload inputs probably are associated most commonly with stream crossing construction. Thus, even though this part of the sediment budget generally is not measured, it probably is not very important, especially on a basin-wide scale.

By contrast, volumes of sediment stored in-stream can be large, especially if in-stream structures are present that serve as dams (Bill 2005). Consequently, the in-stream storage term is a very important unknown when determining BMP efficiencies because only a portion of contributions at any point in time may be measurable at a downstream monitoring site. It also adds an additional, unknown lag time to delayed hillside deliveries or new sources of sediment and associated nutrients. Thus, in-stream water-column measures of suspended sediment underestimate total suspended sediment delivery, and may therefore result in overestimations of BMP efficiencies based on simple comparisons of watershed exports.

Stored in-channel sediment primarily is flushed through and out of a watershed by stormflow. However, every storm behaves differently with respect to its ability to suspend and transport sediment. While the size of the storm is an important component of sediment transport potential, it is only one of several important variables (Stuart and Edwards 2006). The structure and complexity of the channel, locations and types of sediment, time since the last storm(s), antecedent flow, intensity and duration characteristics of the storm, source of stormflow (i.e., rainfall or snowmelt), rising and falling limb hysteresis, and other factors all influence the degree of in-channel sediment displacement and transport potential (Walling 1977, Rieger and Olive 1986, Beschta 1987, Goodwin and Denton 1991, Bunte and McDonald 1998, Stuart and Edwards 2006). As a result, it is impossible to predict how and when contemporary sediment additions from forestry operations will be flushed out to obtain a measure of total sediment delivery during a given time period. Likewise, while it is assumed that all of the sediment measured in the stream following a forest operation (above background or pretreatment levels) is from that operation it is impossible to ensure that is the case.

One would expect that sediment delivery would vary geographically in a catchment like the Chesapeake Bay watershed because of the extreme differences in topographic and soil conditions that exist. Generally, sediment delivery to surface waters would be higher in watersheds with one or more of the following features: steep slopes, soils with high erodibilities or lower cohesiveness (e.g., sands), high total rainfall and/or high intensity storms, high road density (especially with stream crossings), and high stream channel density (including ephemerals).

However, sediment delivery cannot be predicted well by considering each of these variables individually as they all are strongly interrelated to one another. For example, one would have interpreted incorrectly that sediment exports would be greater in the Appalachians because of steep hillslopes stream gradients compared to the flatter Coastal Plain (Table 2). The Coastal Plain soils were sandier and intense storms tend to occur somewhat more regularly throughout the Coastal Plain because of tropical storms.

The actual sediment loading from the watersheds reported in Table 2 suggest that there were clearly differences in the amount of mineral sediment delivered to the stream channels. Post harvesting sediment exports with no BMPs at the Coastal Plain site were 3 times as great from the Appalachian site, while with BMPs the Coastal Plain site was 4.5 times as great as the Appalachian site. Sediment exports with no BMPs were 2.4 times less from the Cumberland Plateau site than from the Appalachian site, while with BMPs the Cumberland Plateau site was abut 5 times as great as the Appalachian site. The pattern of these Kentucky results do suggest that the sediment losses were somewhat ameliorated on the no BMP watershed by more-careful logging practices, as Arthur et al. (1998) suspected.

Watersheds dominated by karst geology probably are some of the least likely to receive substantial inputs of sediment from forestry activities because these lands tend to be in valley segments that are dominated by other land uses and stream density is low. Unless sediment enters a pothole and goes directly into groundwater, there is little connectivity between sedimentation and groundwater. This, however, is not the case for dissolved nutrients. Relatively mobile ions such as nitrate can commonly leach to groundwater aquifers. But forests are less likely to be found on limestone geology in the Chesapeake Bay watershed than on other less fertile and upland geology.

BMP implementation lag times will vary somewhat among states because each State defines its own set of forestry BMPs (Edwards and Stuart 2002). However, typically forestry BMP implementation is required during or soon after an activity is implemented or ceases. For example, water barring and seeding of skid roads cannot be performed until after skid road use has ended, so most states require or recommend water barring and seeding soon after the road is no longer needed, or at least before the start of the wet season. Lengthy delays in implementation of forestry BMP would be unusual; instead, the total lack of BMP implementation would probably be a more common problem.

If implemented properly, forestry BMPs typically are fully functioning immediately or become so quickly. Vegetative covering of bare soil is probably the BMP that takes longest to become fully functioning simply due to the time needed for seeds or sprouts to become well established. This can occur in several weeks or in some cases can take a year or more if initial seed did not become established and native vegetation establishment becomes the fallback alternative.

Forestry BMPs are not designed specifically for extreme events, even though extreme events often are responsible for the largest additions of sediment and nutrients. For example, sediment exports from single extreme (flood) events on forested watersheds have been shown to dominate annual sediment loadings (Beasley 1979, Edwards and Owens 1991) and they can far exceed multiple years of accumulated sediment exports during more normal years (Kochenderfer and Edwards 1991). In these extreme events, the presence of BMPs to control sediment and associated nutrient losses in the watershed is overwhelmed by the energy of in-stream flows as well as concentrated overland flows in areas where subsurface flows typically only occur. The exception to planning for extreme events is that the diameter of some cross drain culverts on roads may be designed to handle estimated flows from precipitation events with given return intervals.

Possible adjustments that may improve forestry BMPs by reducing overland flow and sediment transport during these large events would be: requiring forester involvement with road and trail planning and layout and BMP implementation, reducing the allowable length between cross drain structures on roads, ensuring that all roads and trails are fully graveled (or re-vegetated), and improving cross drain outlet resistance to erosion and increasing infiltration. In some cases, increasing filter or buffer strips may help reduce sediment inputs, but in steep terrain with erodible soils, buffer strips as wide as 250 ft do not prevent overland flow originating at cross drain outlets from reaching streams; thus, more attention to reducing the amount of water passed through each cross drain may provide more sediment reduction than wider buffer strips. Also, the presence of stream crossings necessitates that buffers become progressively narrower as the road approaches the stream. In these situations, water and sediment control by other means is the best way to reduce additional sediment inputs. However, all of these recommendations involve additional costs and it is unlikely that few states will drastically change their current set of BMPs during future revisions to address large events. The very nature of nonpoint source BMPs makes it technologically difficult, if not impossible, to increase their efficiency for large events without similarly increasing implementation costs substantially.

Stream crossings by roads cut for forest harvesting are the single largest source of sediment in most watersheds. Large amounts can be mechanically pushed into the stream during crossing construction and adjacent fillslope construction. In the longer-term, crossings provide conduits for chronic inputs of sediment as water moves down the road toward the stream. Often stream crossings are at lower elevations than adjacent approaches, which exacerbate sediment delivery to streams. When possible, less invasive crossing structures, such as temporary bridges, should be used to reduce mechanical sediment deposition to streams. If crossing elevations must be lower than approaches, the road should be designed to bleed road drainage off before the crossing is reached. However, even if a road is constructed using all proper BMPs and all additional forestry BMPs are employed, if one or more crossing is included in the design, some sediment will be mechanically added to the channel during construction. Furthermore, mechanical additions can exceed that from all other sources in the watershed; thus, crossings should be avoided if possible. If crossings are used, calculated BMP efficiency based on total sediment exports will be less than that where crossings are not needed and specified bufferstrip widths can be maintained.

There is essentially no research or modeling that has been done and validated that examines BMP effectiveness for sediment and nutrients at the basin scale. Furthermore, because of cumulate downstream issues of sediment storage, flushing, and lag times in sediment routing on both the hillside and in-channel, understanding what effect forestry BMPs have at that landscape scale is probably not a task that will be solved in the foreseeable future. However, from analyses done by Edwards et al. (2004), the natural variability of in-stream suspended sediment observed for Appalachian watersheds was so great that it suggested that effectiveness of BMPs downstream would largely be unmeasurable or undetectable. It is unknown whether one or multiple forest operations done without BMPs could result in sediment increases downstream that would be large enough to influence BMP efficiency measurements, particularly as the effects of dilution, settling/storage, and various routing rates come into play. Because forestry operations in the mid-Atlantic region are usually done on fairly small parcels of land at any one time, and the number of operations in a given watershed are probably small relative to the land base and spatially dispersed, it is likely that the actual contribution that forestry BMP efficiencies has on total basin-wide efficiencies for all land uses will be negligible.

Outstanding issues to resolve in the future

Most states have records documenting BMP implementation for forestry operations. Those data typically are collected by the State agency responsible for BMP enforcement or compliance. Those data do not measure sediment or nutrient delivery, but they do provide specific information about percentages of sites in which BMPs were implemented and effective, and often other information that can be used to further identify where/when problems with BMP effectiveness exist. These data should be used to further refine estimates of BMP efficiencies in the Chesapeake Bay watershed.

There is a substantial need to understand how in-stream suspended sediment and dissolved nutrient values relate to actual hillside delivery of sediment and nutrients from forest operations. The relationships may be more direct and less complicated for dissolved nutrients, unless they are strongly bound to sediment (i.e., clay particles). For sediment itself and sediment-controlled nutrients, confidence in BMP efficiency values (based on in-stream measurements) will be possible only if the relationships between delivery and suspension can be estimated with some degree of certainty. While measurements of hillside deliveries of sediment and nutrients probably would be more desirable and directly applicable to determining BMP efficiencies, these types of studies are rare because they are quite expensive and labor intensive. However, they would provide data that would be a welcome addition for many uses applicable to BMP effectiveness.

There also needs to be further study of sediment routing and storage in high gradient streams in the East. To-date, most of this work has been done in Western streams that have very different sediment dynamics than the East. It is known that forest management generally does not directly or indirectly (through flow augmentation after harvesting) change stream morphology significantly (Bill 2005, Phillips 2005), but there may be subtle changes to channel erosion that are not yet understood, and this is an area of investigation that would be important to modeling sediment routing.

Applicable on-going studies

A 9-year study of hillside sediment delivery to streams in two whole watersheds in the central Appalachians in West Virginia is in its last year of data collection. One watershed has remained undisturbed, and a second has had discrete periods of pretreatment, road construction, forest harvesting, and recovery. Sample processing of the 2007 samples should be completed by late spring 2008. While the watershed is outside of the boundaries of the Chesapeake Bay watershed, the results should have application to the Bay watershed. All results from this study should be published in the next 3 to 5 years. Contact: Pam Edwards, Research Hydrologist, US Forest Service, Parsons, WV 304-478-2000 ext. 129, pjedwards@fs.fed.us.

Future Research Need

It would be useful to have discussion of impacts of potential harvesting buffers for bioenergy production. Likely two countervailing influences: a) Removal of nutrient from the buffer such that nutrient saturation becomes less likely. b) Periodic reduction in effectiveness of buffers associated with periodic disturbance.

How Modeled

The effectiveness estimate assigned to forest harvesting assumes the practice will be applied to a forested land use category that represents average, natural forests with low nutrient loading rates. Degraded land uses proposed for use in Phase 5 of WSM have increased nutrient loads compared to average forests. If the effectiveness estimates are applied to a degraded forest than estimates need to be revised to account for the higher nutrient loading rates from the degraded land use category. There may be a limit to the nutrient and hydrologic treatment capacity of the BMP that will exceed its ability to achieve the proposed effectiveness estimates on a degraded land use.

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Appendix A. Report on Forest Harvesting Practices by Pam Edwards and Karl Williard

<u>Forest Harvesting Practices</u>
Definition and Nutrient and Sediment Reduction Efficiencies

For use in calibration of the Phase 5 of the Chesapeake Bay Program Watershed Model

Recommendations for Formal Approval by the Nutrient Subcommittee's Tributary Strategy and Forestry and Tributary Strategy Workgroups

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Introduction

This document summarizes the recommended definition and nutrient and sediment reduction efficiencies for forest harvesting practices for review and final approval by the Tributary Strategy Workgroup and Forestry Workgroups.

Photograph of BMP

Forestry BMP effectiveness traditionally has been evaluated within the full set of BMPs employed on the watershed. As a result, it is impossible to evaluate the efficiency of any individual forestry BMP, so no photograph is included here.

Description/Definition

Definition: *Forestry BMPs are a suite of practices that reduce sediment and nutrient pollution to water bodies originating from forest management activities to acceptable* *levels at acceptable costs. These activities include: road, trail, and landing construction, use, and closure; harvesting and log removal activities; and site preparation or within-rotation treatments.*

Specific, individual forestry BMPs focus primarily on controlling water quantity and energy because water movement serves as a primary mechanism for sediment and associated nutrient detachment and transport. Dissolved nutrients tend to be less impacted by typical forestry BMPs. Though, riparian BMPs, such as streamside buffer strips, may have a significant effect on dissolved nutrient loads

Efficiency

Literature Review and Data Analysis Methods

BMP efficiencies for sediment and nutrient reductions from forestry operations are based on studies in which paired watershed comparisons were made. One watershed was harvested (and also may have had site preparation) with BMPs while the second was harvested without BMPs. While many other studies in the literature compare sediment and nutrient loads between reference (undisturbed) watersheds and managed watersheds employing BMPs, BMP efficiencies cannot be determined from those types of studies. Sediment and nutrient reductions were based on in-stream water-column loadings, as there are no published studies to-date in the East that have measured to-stream or to-lake (i.e., actual hillside contributions) concentrations or loadings.

The data used to calculate sediment and nutrient reductions for this document were extracted from the papers listed in Table 1. Only data collected from regions that we deemed applicable to landscapes present in some part of the Chesapeake Bay watershed (i.e., physiography, topography, soils, hydrology and climate) are included; however, because there are so few BMP vs. no BMP comparisons, in reality few BMP vs. no BMP data have been excluded.

Data used in the calculation of BMP efficiencies for sediment are shown in Table 2. Loads for sediment from the study by Arthur et al. (1998) were presented in bar graph form, so an engineering ruler was used to measure the height of each bar and the loadings were calculated from those measurements. All other sediment and nutrient data were provided as tabular values.

Percent efficiency (i.e., the % reduction in sediment or nutrients achieved by using BMPs) for each year of data were calculated from the following equation:

$$\% \text{ Efficiency} = 100\,(\textit{without BMP} - \textit{with BMP})/(\textit{without BMP}),$$

where *without BMP* represents the load measured from the watershed in which BMPs were not employed, and *with BMP* represents the load measured from the watershed in which BMPs were employed.

Table 1. Studies from which sediment and nutrient data were obtained for forestry BMP efficiencies.

Reference	Treatment/Watershed Description	Location	Sediment Measured?	Nitrogen Measured?	Phosphorus Measured?
Kochenderfer and Hornbeck (1999)	One watershed (38.8 ha) diameter limit cut to 35.6-cm dbh with BMPs, one watershed (29.9 ha) clearcut to 12.7-cm dbh without BMPs. Hillsides averaged 40% slope in both watersheds.	Central Appalachians, north central WV	Yes	No	No
Wynn et al. (2000)	One watershed (8.5 ha) clearcut with BMPs, one watershed (7.9 ha) clearcut without BMPs. Firelines installed, herbicide applied, controlled burn and hand planting followed. Slopes average 2% over most of harvested areas except up to 30% slope along deeply incised streams.	Coastal Plain, VA	Yes	Yes	Yes
Arthur et al. (1998)	One watershed clearcut with BMPs, one watershed clearcut without BMPs. On both watersheds all stems > 35.5 cm, cut and left all stems < 5 cm dbh. Hillsides average 45% slope. Watershed sizes not given	Cumberland Plateau, eastern KY	Yes	Yes	Yes

Table 2. Efficiencies (i.e., percent reduction) for sediment loads gained from using forestry BMPs

Reference	Time Period	Sediment Load		Calculated Efficiency
		No BMPs	BMPs	
Kochenderfer and Hornbeck (1999)	1st yr after harvest 2nd yr after harvest	3227 kg/ha 323 kg/ha	123 kg/ha 77 kg/ha	96% 76%
Wynn et al. (2000)	Post harvest Post site-prep	9760 kg/ha/yr 7670 kg/ha/yr	560 kg/ha/yr 620 kg/ha/yr	94% 91%
Arthur et al. (1998)	During Harvest 1st yr post harvest 2nd yr post harvest 4th yr post harvest[1] 5th yr post harvest 6th yr post harvest	1180 kg/ha 640 kg/ha 376 kg/ha 100 kg/ha 200 kg/ha 307 kg/ha	553 kg/ha 420 kg/ha 367 kg/ha 47 kg/ha 387 kg/ha 67 kg/ha	53% 34% 2% 53% 94% 78%

[1] 3rd year post harvest figures were not collected.

Table 3. Efficiencies (i.e., percent reduction) for total nitrogen loads gained from using forestry BMPs

Reference	Time Period	Total Nitrogen Load		Calculated Efficiency
		No BMPs	BMPs	
Wynn et al. (2000)	Post harvest Post site-prep	104.7 kg/ha/yr 85.4 kg/ha/yr	41.8 kg/ha/yr 17.1 kg/ha/yr	60% 80%
Arthur et al. (1998)	1st yr post harvest	1.45 kg/ha/yr[1] a	1.27 kg/ha/yr a	12%

[1]Authur et al. (1998) measured nitrate-N loads, not total nitrogen. The authors do not state whether the nitrate analysis was conducted on filtered or unfiltered samples.

Table 4. Efficiencies (i.e., percent reduction) for total phosphorus loads gained from using forestry BMPs

Reference	Time Period	Total Phosphorus Load		Calculated Efficiency
		No BMPs	BMPs	
Wynn et al. (2000)	Post harvest Post site-prep	12.61 kg/ha/yr 10.82 kg/ha/yr	1.72 kg/ha/yr 1.60 kg/ha/yr	86% 85%
Arthur et al. (1998)	1st yr post harvest	0.36 kg/ha/yr[1]	0.20 kg/ha/yr	44%

[1]Authur et al. (1998) measured phosphate loads, not total phosphorus. The authors do not state whether the phosphate analysis was conducted on filtered or unfiltered samples.

Sediment

Two of the studies (Kochenderfer and Hornbeck 1999, Wynn et al. 2000) resulted in efficiencies values of 94 and 96 percent for sediment during at least the first year after treatment, even though they were in very different physiographic regions with different topographic conditions. The study by Arthur et al. (1998) had efficiencies of only 53 percent during harvesting; however, they noted that they probably would have had greater increases in sediment in the watershed with no BMPs had their logging crew not been well trained in BMPs. That is, they employed recommended logging techniques in some instances even though they were not required to. For example, the Kentucky crews never skidded logs downhill, even though this is a common practice when BMPs are ignored (e.g., Kochenderfer and Hornbeck 1999, Reinhart et al. 1963).

While the two studies that had true “no BMP” operations showed efficiencies of approximately 95 percent, this is probably too high to recommend because of the limitations associated with using only suspended sediment values and the small number of studies. So at a local (i.e., small watershed scale) level, I would recommend using a more conservative efficiency value of **75 percent**.

Statement of Conservatism

Because of all of the unknowns related to sediment delivery, storage, and routing, the estimate of 75 percent is really a best guess based on professional judgment. Research studies clearly show that sediment inputs to surface waters can be reduced by using BMPs, and in many cases in-stream sediment levels reported from undisturbed watersheds are much higher than from well managed forests. Worst case studies, such as Reinhart et al. (1963) used in the analysis by Kochenderfer and Hornbeck (1999) indicate that poor management can lead to substantial sediment delivery, even if it is measured indirectly by in-stream surrogates. Thus, the expectation of generally high BMP efficiencies is realistic, and we would not consider the value of 75 percent to be overreaching.

Nutrients

Only two studies applicable to the Chesapeake Bay region directly measured percent reduction in nutrients due to BMP implementation in forested watersheds (Authur et al. 1998, Wynn et al. 2000). There is a multitude of studies in the eastern United States that examined the impacts of forest harvesting on dissolved nutrient leaching by comparing a treated (harvested) watershed to a control or reference watershed (Aubertin and Patric 1974, Hornbeck et al. 1986, Lynch and Corbett 1990, Martin et al. 2000, Swank et al. 2001). Most of these studies showed that dissolved nutrient concentrations and loads increased in the first one to three years following harvesting due to loss of biotic immobilization and increases in microbial mineralization rates. However, the studies demonstrated that nutrient concentrations and loads decreased in subsequent years following harvesting until reaching pre-harvest levels, generally around year five to ten.

Total Nitrogen

Wynn et al. (2000) defines total nitrogen (TN) as the sum of total Kjedahl nitrogen (TKN) and ammonium. TKN is a measure of organic nitrogen compounds and ammonium. In forested watersheds that have been harvested, the majority of organic nitrogen in water is found in the particulate form.

Wynn et al. (2000)found a 60 to 80% efficiency for TN, with the higher percentage following post site-prep (herbicide and burning). Given that this is the only study specifically addressing TN efficiency, I would recommend the more conservative efficiency value of **60% for TN**.

Nitrate-N
Of the inorganic nitrogen species (ammonium, nitrite, and nitrate), nitrate is the dominant form that leaches to receiving waters. It is considered a mobile anion, because of its exclusive non-specific adsorption characteristics. Authur et al. (1998) showed that nitrate loads were reduced by 12%, when BMPs were implemented during the harvesting operation. Since the Authur et al. (1998) study may not have had a true "no BMP" application, I would expect that the efficiency for nitrate-N could be greater than their results. Therefore, I would recommend an efficiency of **20% for nitrate-N**.

Total Phosphorus and Phosphate
Total phosphorus (TP) includes all orthophosphates and condensed phosphates, both dissolved and particulate, organic and inorganic. The majority of phosphorus (P) is transported in the particulate form, bound to sediment. Thus, the efficiencies for P should approach those for sediment, which they did (44 to 86%). The Arthur et al. (1998) study (44% efficiency) stated that they analyzed phosphate on a spectrophotometer, so only the inorganic fraction of P was measured. They did not state whether their water samples were filtered or unfiltered prior to analysis. This is especially important for P analysis, since much of the P is sediment bound. Given the relatively low P loads and efficiency compared to the Wynn et al. (2000) study, one could speculate that only dissolved P from filtered samples was measured. Given the uncertainties in the Arthur et al. (1998) analysis, I would recommend an efficiency for **TP of 75%**, which is more in line with the Wynn et al. (2000) study. This is similar to the recommended sediment efficiency, which is logical given the similar modes of transport.

It is important to point out that nutrients that commonly travel subsurface in the dissolved phase, such as nitrate, will likely have lower efficiencies. Most forestry BMPs were developed to control energy and water movement on the surface of the landscape and may not impact subsurface processes to a large extent. The primary exception would be streamside buffer strips, which can significantly impact nitrate concentrations and loads through processes such as plant uptake and denitrification.

Sediment

I reiterate the comments made above in the sediment section. The recommended efficiencies for nutrients are really a best guesstimate based on professional judgement, given the lack of studies that directly measure the abilities of BMP's to reduce nutrient delivery to receiving waters at the watershed scale. Since TP is so similar in its mode of transport to sediment, I am relatively comfortable with the TP efficiency of 75%. I would expect that the TN and nitrate-N efficiencies would be lower than TP, given that nitrogen is more commonly transported subsurface in the dissolved phase. Most applied

BMPs are expected to have less of an impact on subsurface modes of transport. Also, the TN efficiency of 60% compared to the nitrate efficiency of 20% follows this reasoning, as TN has a greater likelihood to be transported on the surface in the particulate phase. Thus, I am comfortable that the nitrogen efficiencies are lower than the TP, but I feel there is a wider range of possible efficiencies for nitrogen, given its variable modes of transport.

BMP Efficiency Development

Most investigations of BMP effectiveness, including those from which data have been extracted for this report, used indirect measurements of in-stream suspended sediment exports as a surrogate of actual sediment delivery to water bodies (Edwards 2003). Indirect measurements using suspended sediment measured typically at the mouth of watersheds ignore several spatial and temporal factors concerning sediment delivery. These include:

1) some eroded sediment originating from the forest operation and associated activities may still be stored on the hillside at the time the monitoring was performed;
2) delivered sediment can be stored in the channel for decades and perhaps hundreds of years before being flushed out (Reid 1982, Trimble 1981);
3) some erosion resulting from forest management operations may begin or continue after monitoring has ceased (e.g., washouts of roads constructed for the forest operation). These may be short-term inputs or they may become chronic long-term inputs, depending upon the sources;
4) bedload inputs to the water bodies are not accounted for by measurements of suspended sediment.

In the East, including the Chesapeake Bay watershed, bedload inputs are generally not considered large since the landscape is old and most bedload materials from the hillside were eroded and transported very long ago. Contemporary bedload inputs probably are associated most commonly with stream crossing construction. Thus, even though this part of the sediment budget generally is not measured, it probably is not very important, especially on a basin-wide scale.

By contrast, volumes of sediment stored in-stream can be large, especially if in-stream structures are present that serve as dams (Bill 2005). Consequently, the in-stream storage term is a very important unknown when determining BMP efficiencies because only a portion of contributions at any point in time may be measurable at a downstream monitoring site. It also adds an additional, unknown lag time to delayed hillside deliveries or new sources of sediment and associated nutrients. Thus, in-stream water-column measures of suspended sediment underestimate total suspended sediment delivery, and may therefore result in overestimations of BMP efficiencies based on simple comparisons of watershed exports.

Stored in-channel sediment primarily is flushed through and out of a watershed by stormflow. However, every storm behaves differently with respect to its ability to suspend and transport sediment. While the size of the storm is an important component of sediment transport potential, it is only one of several important variables (Stuart and Edwards 2006). The structure and complexity of the channel, locations and types of sediment, time since the last storm(s), antecedent flow, intensity and duration characteristics of the storm, source of stormflow (i.e., rainfall or snowmelt), rising and falling limb hysteresis, and other factors all influence the degree of in-channel sediment displacement and transport potential (Walling 1977, Rieger and Olive 1986, Beschta 1987, Goodwin and Denton 1991, Bunte and McDonald 1998, Stuart and Edwards 2006). As a result, it is impossible to predict how and when contemporary sediment additions from forestry operations will be flushed out to obtain a measure of total sediment delivery during a given time period. Likewise, while it is assumed that all of the sediment measured in the stream following a forest operation (above background or pretreatment levels) is from that operation it is impossible to ensure that is the case.

One would expect that sediment delivery would vary geographically in a catchment like the Chesapeake Bay watershed because of the extreme differences in topographic and soil conditions that exist. Generally, sediment delivery to surface waters would be higher in watersheds with one or more of the following features: steep slopes, soils with high erodibilities or lower cohesiveness (e.g., sands), high total rainfall and/or high intensity storms, high road density (especially with stream crossings), and high stream channel density (including ephemerals).

However, sediment delivery cannot be predicted well by considering each of these variables individually as they all are strongly interrelated to one another. For example, one would have interpreted incorrectly that sediment exports would be greater in the Appalachians because of steep hillslopes stream gradients compared to the flatter Coastal Plain (Table 2). The Coastal Plain soils were sandier and intense storms tend to occur somewhat more regularly throughout the Coastal Plain because of tropical storms.

The actual sediment loading from the watersheds reported in Table 2 suggest that there were clearly differences in the amount of mineral sediment delivered to the stream channels. Post harvesting sediment exports with no BMPs at the Coastal Plain site were 3 times as great from the Appalachian site, while with BMPs the Coastal Plain site was 4.5 times as great as the Appalachian site. Sediment exports with no BMPs were 2.4 times less from the Cumberland Plateau site than from the Appalachian site, while with BMPs the Cumberland Plateau site was abut 5 times as great as the Appalachian site. The pattern of these Kentucky results do suggest that the sediment losses were somewhat ameliorated on the no BMP watershed by more-careful logging practices, as Arthur et al. (1998) suspected.

Watersheds dominated by karst geology probably are some of the least likely to receive substantial inputs of sediment from forestry activities because these lands tend to be in valley segments that are dominated by other land uses and stream density is low. Unless sediment enters a pothole and goes directly into groundwater, there is little connectivity between sedimentation and groundwater. This, however, is not the case for dissolved nutrients. Relatively mobile ions such as nitrate can commonly leach to groundwater aquifers. But forests are less likely to be found on limestone geology in the Chesapeake Bay watershed than on other less fertile and upland geology.

BMP implementation lag times will vary somewhat among states because each State defines its own set of forestry BMPs (Edwards and Stuart 2002). However, typically forestry BMP implementation is required during or soon after an activity is implemented or ceases. For example, water barring and seeding of skid roads cannot be performed until after skid road use has ended, so most states require or recommend water barring and seeding soon after the road is no longer needed, or at least before the start of the wet season. Lengthy delays in implementation of forestry BMP would be unusual; instead, the total lack of BMP implementation would probably be a more common problem.

If implemented properly, forestry BMPs typically are fully functioning immediately or become so quickly. Vegetative covering of bare soil is probably the BMP that takes longest to become fully functioning simply due to the time needed for seeds or sprouts to become well established. This can occur in several weeks or in some cases can take a year or more if initial seed did not become established and native vegetation establishment becomes the fallback alternative.

Forestry BMPs are not designed specifically for extreme events, even though extreme events often are responsible for the largest additions of sediment and nutrients. For example, sediment exports from single extreme (flood) events on forested watersheds have been shown to dominate annual sediment loadings (Beasley 1979, Edwards and Owens 1991) and they can far exceed multiple years of accumulated sediment exports during more normal years (Kochenderfer and Edwards 1991). In these extreme events, the presence of BMPs to control sediment and associated nutrient losses in the watershed is overwhelmed by the energy of in-stream flows as well as concentrated overland flows in areas where subsurface flows typically only occur. The exception to planning for extreme events is that the diameter of some cross drain culverts on roads may be designed to handle estimated flows from precipitation events with given return intervals.

Possible adjustments that may improve forestry BMPs by reducing overland flow and sediment transport during these large events would be: requiring forester involvement with road and trail planning and layout and BMP implementation, reducing the allowable length between cross drain structures on roads, ensuring that all roads and trails are fully graveled (or re-vegetated), and improving cross drain outlet resistance to erosion and increasing infiltration. In some cases, increasing filter or buffer strips may help reduce sediment inputs, but in steep terrain with erodible soils, buffer strips as wide as 250 ft do not prevent overland flow originating at cross drain outlets from reaching streams; thus, more attention to reducing the amount of water passed through each cross drain may provide more sediment reduction than wider buffer strips. Also, the presence of stream crossings necessitates that buffers become progressively narrower as the road approaches the stream. In these situations, water and sediment control by other means is the best way to reduce additional sediment inputs. However, all of these recommendations involve additional costs and it is unlikely that few states will drastically change their current set of BMPs during future revisions to address large events. The very nature of nonpoint source BMPs makes it technologically difficult, if not impossible, to increase their efficiency for large events without similarly increasing implementation costs substantially.

Stream crossings by roads are the single largest source of sediment in most watersheds. Large amounts can be mechanically pushed into the stream during crossing construction and adjacent fillslope construction. In the longer-term, crossings provide conduits for chronic inputs of sediment as water moves down the road toward the stream. Often stream crossings are at lower elevations than adjacent approaches, which exacerbate sediment delivery to streams. When possible, less invasive crossing structures, such as temporary bridges, should be used to reduce mechanical sediment deposition to streams. If crossing elevations must be lower than approaches, the road should be designed to bleed road drainage off before the crossing is reached. However, even if a road is constructed using all proper BMPs and all additional forestry BMPs are employed, if one or more crossing is included in the design, some sediment will be mechanically added to the channel during construction. Furthermore, mechanical additions can exceed that from all other sources in the watershed; thus, crossings should be avoided if possible. If crossings are used, calculated BMP efficiency based on total sediment exports will be less than that where crossings are not needed and specified bufferstrip widths can be maintained.

There is essentially no research or modeling that has been done and validated that examines BMP effectiveness for sediment and nutrients at the basin scale. Furthermore, because of cumulate downstream issues of sediment storage, flushing, and lag times in sediment routing on both the hillside and in-channel, understanding what effect forestry BMPs have at that landscape scale is probably not a task that will be solved in the foreseeable future. However, from analyses done by Edwards et al. (2004), the natural variability of in-stream suspended sediment observed for Appalachian watersheds was so great that it suggested that effectiveness of BMPs downstream would largely be unmeasurable or undetectable. It is unknown whether one or multiple forest operations done without BMPs could result in sediment increases downstream that would be large enough to influence BMP efficiency measurements, particularly as the effects of dilution, settling/storage, and various routing rates come into play. Because forestry operations in the mid-Atlantic region are usually done on fairly small parcels of land at any one time, and the number of operations in a given watershed are probably small relative to the land base and spatially dispersed, it is likely that the actual contribution that forestry BMP efficiencies has on total basin-wide efficiencies for all land uses will be negligible.

Outstanding issues to resolve in the future

Most states have records documenting BMP implementation and effectiveness for forestry operations. Those data typically are collected by the State agency responsible for BMP enforcement or compliance. Those data do not measure sediment or nutrient delivery, but they do provide specific information about percentages of sites in which BMPs were implemented and effective, and often other information that can be used to further identify where/when problems with BMP effectiveness exist. These data could be used to further refine estimates of BMP efficiencies in the Chesapeake Bay watershed.

There is a substantial need to understand how in-stream suspended sediment and dissolved nutrient values relate to actual hillside delivery of sediment and nutrients from forest operations. The relationships may be more direct and less complicated for dissolved nutrients, unless they are strongly bound to sediment (i.e., clay particles). For sediment itself and sediment-controlled nutrients, confidence in BMP efficiency values (based on in-stream measurements) will be possible only if the relationships between delivery and suspension can be estimated with some degree of certainty. While measurements of hillside deliveries of sediment and nutrients probably would be more desirable and directly applicable to determining BMP efficiencies, these types of studies are rare because they are quite expensive and labor intensive. However, they would provide data that would be a welcome addition for many uses applicable to BMP effectiveness.

Of course, there also needs to be further study of sediment routing and storage in high gradient streams in the East. To-date, most of this work has been done in Western streams that have very different sediment dynamics than the East. It is known that forest management generally does not directly or indirectly (through flow augmentation after harvesting) change stream morphology significantly (Bill 2005, Phillips 2005), but there may be subtle changes to channel erosion that are not yet understood, and this is an area of investigation that would be important to modeling sediment routing.

Applicable on-going studies

A 9-year study of hillside sediment delivery to streams in two whole watersheds in the central Appalachians in West Virginia is in its last year of data collection. One watershed has remained undisturbed, and a second has had discrete periods of pretreatment, road construction, forest harvesting, and recovery. Sample processing of the 2007 samples should be completed by late spring 2008. While the watershed is outside of the boundaries of the Chesapeake Bay watershed, the results should have application to the Bay watershed. All results from this study should be published in the next 3 to 5 years. Contact: Pam Edwards, Research Hydrologist, US Forest Service, Parsons, WV 304-478-2000 ext. 129, pjedwards@fs.fed.us.

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Appendix B. Comments from STAC Reviewers

I. Bob Shaffer. Email correspondence follows:

Sarah: I believe 70% for sediment and 60% for TN and TP are reasonable from an observed operational viewpoint, as well as being supported by the relevant studies. Also, please note that the Wynn et al. study was conducted in the coastal plain of Virginia, not NC.

Bob Shaffer

-----Original Message-----
From: Sarah Weammert [mailto:sweammer@umd.edu]
Sent: Monday, April 23, 2007 3:13 PM
To: Shaffer, Robert
Subject: RE:

Thank you Bob for your comments! Can you recommend an efficiency that you feel is not conservative but is also reflective of effectiveness found on operational lands (versus research plots)?

Sarah

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Sarah Weammert
Faculty Extension Assistant
BMP Project Leader
1434 Animal Science/Ag Engineering Bldg
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Fax: (301)-314-9023
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From: Shaffer, Robert [mailto:rshaffer@vt.edu]
Sent: Monday, April 23, 2007 1:42 PM
To: Sarah Weammert
Subject: RE:

Sarah: I have reviewed your proposed efficiencies for forest harvesting BMPs. My comments are:
1. definition is accurate
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2. proposed efficiencies are overly conservative based on results from the studies cited as well as my best professional judgment.

Sincerely,

Bob Shaffer

-----Original Message-----
From: Sarah Weammert [mailto:sweammer@umd.edu]
Sent: Monday, April 23, 2007 10:23 AM
To: Shaffer, Robert
Subject:

Good morning,

My name is Sarah Weammert and I'm working with Tom Simpson at the University of Maryland on a review of definitions and efficiencies for a select list of BMPs. This project is being funded by the Chesapeake Bay Program and proposed efficiencies will be used for calibration of Phase 5 of the Watershed Model. To review efficiencies UMD contracted an expert and asked them to review applicable literature and propose an efficiency for model calibration based on the literature and their experience. The objective of this project is to estimate efficiencies that reflect operational conditions. We are not looking for the efficiency one would expect at a research plot.

All BMP efficiencies are going through a robust review process. The next step is to ask scientists to review the proposed efficiencies. Jim Pease recommended I ask you to review the proposal for forest harvesting. We ask that you read the attached review with particular attention to the definition and determine if the definition reflects how the BMP is implemented in practice. Please also review the proposed efficiency and based on your best professional judgment state if you feel the efficiency is a reasonable estimate. While doing this keep in mind the following constraints. We must have one efficiency for bay-wide application. However, this efficiency will be applied to individual county land segments that have a specific load based on its soil, climate, amount of impervious surface, etc. Any additional editorial comments are welcome. We guess the review taking one to two hours.

If you see any major problems with the proposal please contact me ASAP. We need reviews back so they can be submitted to the Bay Program's source area workgroups for review. Please send me your review by COB May 1st. I really appreciate your time and energy, thank you for your help!

II. Daniel Rider. Email correspondence follows:

Good Afternoon,

I am pleased to provide you with my professional opinion regarding the suitability of the proposed Forestry BMP efficiencies to be used in the Bay Model. I will be brief in my comments.

1. The definition accurately reflects the purpose and applicability of forestry BMPs.

2. I suggest that the efficiencies of 50%, 40%, and 50% for sediment, total nitrogen and total phosphorus (respectively) are set too low. The UMD staff cited a lack of scientific evidence to warrant assigning higher efficiencies. However, the body of science available clearly indicated much higher efficiencies realized. Therefore, I fail to understand how the staff concluded that efficiencies lower than those reported is justifiable. While I am not familiar with the Arthur study, I am familiar with both the Kochenderfer and Wynn studies: both of these studies utilized harvesting protocols just as they would be implemented in a practical setting. I suspect that these two studies reflect the actual impacts of BMPs as they are implemented on the ground.

Thank you for the opportunity to respond and I hope my comments are viewed as constructive review. Please feel free to contact me should you have any questions.

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III. Mary Beth Adams. Email correspondence follows:

It still looks pretty good to me, after a mroe thorough read through. i think we can progress with it. MBa Mary Beth Adams USDA Forest Service Timber and Watershed Laboratory Parsons, WV 26287 304-478-2000, X-130 mbadams@fs.fed.us

Appendix C. Meeting Minutes

Minutes: Tributary Strategy Workgroup Meeting
June 4, 2007
10:00 AM to 3:00 PM
NRCS MD State Office, Annapolis

- The MARWP recommended more conservative efficiencies than the experts. It was a concern that the efficiencies would not be achieved when applied to future disturbed forest land uses.
- ACTION: In order for the MARWP to determine if the efficiencies apply to the degraded forest land uses in the model, Jeff Sweeney will provide Tom with explanations of what degraded land uses are and how much loading is associated with them in the model.
- Judy Okay suggested that the MARWP look at state audits because states audit BMPs and have a certain percentage of compliance. They also have an idea on what goes on outside of the audits.
- Next Steps: The MARWP will factor in state audits and the model's definition and loads from degraded forest land use. The Forestry Workgroup will be reviewing this practice on June 12th.

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Minutes: Nutrient Subcommittee Meeting
June 6, 2007
10:00 AM to 3:00 PM
Fish Shack—Chesapeake Bay Program Office

- The Forest Harvesting numbers were suggested based on limited studies and are generally not believed to be reflective of widespread implementation conditions by the average harvester.

- MAWP reduced the developer's recommendations. Mary Beth Adams, a reviewer, supported MAWP's recommendations.
- There is an issue with applying these numbers to disturbed forests that must be addressed.

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Forestry Workgroup Meeting
Chesapeake Bay Program Office; Annapolis, MD
June 12, 2007

- The BMP proposal for forest harvesting was developed by Pam Edwards and Karl Williard and it was reviewed by Mary Beth Adams, Dan Rider and Bob Scaffer.

- The current efficiencies are a 50% TN reduction, 50% TP reduction, and 50% TSS reduction. Edwards and Williard proposed raising these efficiencies to 60% TN, 75% TP, and 75% TSS. UMD is proposing efficiencies that are lower than Edwards and Williard's efficiencies: 40% TN, 50% TP, and 50% TSS.
- UMD recommends more conservative efficiencies than the experts for the following reasons:
  - Authors note that loggers with BMP implementation experience may have biased results
  - Limited number of studies
  - Research scale vs. operational conditions
- Sarah did not provide the developers with the current efficiencies, however she does not know if they looked at them on their own.
- It is important to note that these efficiencies must only be applied to typical forest loads, not to any future "disturbed forest" land use. Before application to a disturbed forest land use, efficiencies must be adjusted.
- This practice is only applied to 1% of forest acreage.
- ACTION: Email comments on the proposed efficiencies for forest harvesting to Gene Odato (godato@state.pa.us) and comments on the proposed efficiencies for forest buffers to Judy Okay (jokay@chesapeakebay.net) during the next two weeks (June 26 deadline). These comments will summarize the FWG's recommendations for these efficiencies to the Tributary Strategy Workgroup and may override the contractor's (UMD) recommendations.

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- The FWG believes the BMPs are put in place for subsurface flow so the efficiencies should reflect that.
- The FWG recommends a margin of safety between 20% and 30% and supported by scientific literature.
- MARWP recommends 40% reduction for TN, 50% for TP, and 50% for TSS.
- The FWG recommends a 60% reduction for TN, 75% for TP, and 75% for TSS.
- Judy mentioned that forest harvesting is regulated which provides more confidence in the efficiencies. Therefore, the margin of safety reduction should be on the lower side.
- Tom added that giving regulated BMPs a higher efficiency would be making the assumption that just because they are regulated they are performing effectively.
- If a 20% margin of safety is applied to the FWG recommendations, they would closely reflect MARWP's recommendations.
- Helen mentioned that the loading rate for forest harvesting is very high and may need to be readdressed. The TSWG should look into if the entire harvested forest area is considered a disturbed forest land use.
    - ACTION: The TSWG will work with the modelers to determine how forest harvesting and disturbed forests are applied in the model.
- The FWG would like the numbers to go back to the developers for their opinion on the appropriate margin of safety reduction.
- DECISION: The TSWG agreed to support the FWG recommendation with a 20% relative reduction, making the efficiencies 50% for TN, 60% for TP, and 60% for TSS.
    - ACTION: MARWP will work with the developers to review the proposed 20% margin of safety and get their opinion.

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Nutrient Subcommittee Meeting
Chesapeake Bay Program Office; Annapolis, MD
August 15, 2007

- The TSWG asked the Forestry Workgroup and MAWP to work together to develop a consensus final recommendation for consideration by the NSC. The FWG and MAWP were able to accomplish this task and presented the final recommendation to the NSC for its approval.
- Two issues were raised during the course of this discussion that warranted significant consideration:
    1.) There is concern about how the BMP efficiency was developed regarding uniform flow versus concentrated flow. After reviewing the research, this is an emerging issue and there is not consensus within the research community about how to address this in BMP efficiencies. However, the FWG considered this issue and addressed it as best they could in developing the efficiencies.
    2.) There is concern over how land conversion reductions are handled in the model and if they are already accounted for the BMP efficiencies. After lengthy discussion it was decided that the efficiencies are correct with regards to this concern but the way the efficiencies are calculated in the model needs to be clarified.
- The FWG considered the above issues at length during the development of the forestry efficiencies and built them into the recommendations presented at today's meeting. Improvements can be made in the future to refine these efficiencies further as new information becomes available.
- The recommended forestry BMPs were approved, with the understanding that the values will be rounded to the nearest 5 or 0.
- TN 50%, TP 60%, TSS 60%

Participants

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Chesapeake Bay Program
Water Quality Steering Committee
Conference Call
August 27, 2007

SUMMARY OF DECISIONS, ACTIONS AND ISSUES

Water Quality Steering Committee Approval of Year 1 MAWP BMP Efficiencies

Issue: At the Water Quality Steering Committee's June 20-21, 2007 meeting, the Steering Committee agreed that they would conduct the final review all of the Nutrient Subcommittee's recommended BMP definitions and efficiencies and take action on any BMPs that the Nutrient Subcommittee (NSC) could not agree on an efficiency for. Definitions and efficiencies for twelve of the thirteen Year 1 BMPs were approved by the Nutrient Subcommittee and determined to be consistent with the available data by the MAWP. The Cover Crop BMP was not resolved. The Steering Committee was asked by the Nutrient Subcommittee to approve the package of the 12 consensus-supported BMP efficiencies and make the final decision on the cover crop BMP efficiencies based on three options.

DECISION: The Water Quality Steering Committee approved the 12 BMP definitions and efficiencies, described in the advance briefing papers, as recommended by the Nutrient Subcommittee and its workgroups for use in Phase 5 Chesapeake Bay Watershed Model.

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