SECTION 6. BEST MANAGEMENT PRACTICES FOR NUTRIENTS AND SEDIMENT

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6.1 Introduction

6.1.1 Introduction to Phase 5.3 BMPs

The effectiveness estimates for best management practices (BMPs) that are implemented and reported by the Chesapeake Bay partners, as well as those planned for future implementation, were reviewed and refined for the Phase 5.3 Model (Simpson and Weammert 2008). The objective was to develop BMP definitions and effectiveness estimates that represent the average operational condition of the entire watershed. In the previous versions of the Watershed Model, relatively optimistic effectiveness estimates were assigned that were often based on controlled research studies that were highly managed and maintained by BMP experts. That approach failed to take into account the variability of effectiveness estimates in real-world conditions where farmers, county stormwater officials, and others who are not BMP scientists, are implementing and maintaining BMPs 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 are more closely aligned with operational, average conditions, the Phase 5.3 Model and any derivative watershed plans will better represent watershed monitoring observations.

BMP design objectives typically aim to meet three criteria of (1) minimizing off-site nutrient and sediment impacts, (2) maintaining a healthy productive soil base, and (3) meeting landowner/producer objectives. An array of nonpoint source conservation practices is available to address nutrient and sediment pollution problems. Soil, weather, slope, cropping system, tillage method, and management objectives, influence the set of practices used to reduce nutrient and sediment export and protect soil quality. The practices installed are the result of an on-site evaluation by a technical specialist. Site conditions, production system, crop rotation, owner/producer objectives, and other factors must be taken into account when developing a conservation plan, which is usually the first step in BMP installation.

Conservation practices, or BMPs, can take many forms, but essentially can be placed into one of four categories: prevention, land conversion, in-field protection, and reduced rate of load increase (Table 6.1).

The Chesapeake Bay Program (CBP) applies an adaptive management approach to BMP development that allows for forward progress in BMP implementation, management, and policy, while acknowledging uncertainty and knowledge limitations. The adaptive management approach to BMP development incorporates the best applicable science along with best current professional judgment into current effectiveness estimates, while acknowledging that going forward, the best available knowledge will improve and change.

Table 6-1. Types of conservation practices/BMPs.

Category	Definition	Result/example
Application reduction	Creating less nutrients (through feed additives) or using less fertilizer or manure for land application.	Reduces nutrient production (e.g., precision feeding, feed additives) - or - Reduces rate of nutrients applied (e.g., nutrient management plan)
Land use change	Land is converted from one type of land use to another. Often results in a less intensive use such as a grass or forest cover	Land restoration or enhancement (e.g., wetlands) - or - Land taken out of intensive agricultural use (e.g., CRP, CREP)
Efficiency change	Agronomic changes changing the amount of nutrients exported from land.	Conservation plans decrease loss
Load reduction	The amount of nutrient entering waterbodies is changed.	Erosion control structures prevent movement of sediment and nutrients to surface water.
Systems change	Existing infrastructure that has been converted to a different system.	Septic connections result in fewer septic systems and become point sources.

Other types of BMP are applied in or adjacent to the estuary. Those estuarine BMPs include, submerged aquatic vegetation plantings, offshore structures to reduce wave action, and oyster bar protection or creation among others. Such tidal Bay BMPs are outside the Phase 5.3 model domain, which stops at the tidal water's edge, but to provide a complete accounting of all management practices used by the CBP, these estuarine BMPs are described in Section 6.8.

6.1.2 Uncertainty in Assessment of BMP Effectiveness

Uncertainty in estimates of BMP effectiveness is due to factors including (1) variability in precipitation, hydrology, soils, and geology; (2) variable performance of land management practices; (3) lag time between implementing a practice and full performance and observed water quality benefits; and (4) the effects of cover, slope, and other intrinsic factors on pollutant load delivery to receiving waters. To more realistically estimate operational pollutant removals from BMPs, one must examine the factors and then use them to adjust efficiencies estimated from research plots accordingly.

A research project at the plot- or field-scale generally fails to capture the entire suite of factors that determines actual real-world efficiencies when practices are widely implemented across the watershed. For example, pollutant transport occurs through a variety of environmental pathways that include the soil surface, vadose zone, saturated zone, tile drains, and streams. The time scale of the transport varies substantially depending on the pathway followed by water from the land surface to a stream. Surface runoff to a stream can take minutes to days, whereas leaching to groundwater followed by discharge to a stream can take months to decades.

In addition, efficiencies will change from the research/demonstration scale to the watershed/basin scale because of the differences in both scale and management differences between them. On a research site, the BMP is designed, operated, and maintained in a very controlled manner. That ensures that the BMP is achieving its full potential or is near its highest efficiency. On a watershed scale, the same level of control and oversight is impossible.

The nature of plot, field, and watershed scales introduce variability in BMP effectiveness. At the plot scale, the researcher controls the land and typically carries out only one experiment at a time. Varying levels of treatment(s), including controls, are applied in a replicable experimental design. Research designs use approaches that reduce variations in natural factors such as soil, hydrology, topography, and other conditions. Meteorological conditions are more consistent from plot to plot than soil conditions, and rainfall is often simulated, providing control over amount, intensity, and drop size distribution. Data are analyzed statistically to account for variability and significance of results.

At the field scale, research becomes more difficult as replication becomes less feasible or more expensive. Different levels of treatment are still feasible, and each field receives a uniform treatment across its full extent, but heterogeneity in soils, topography, weather, and management introduce larger errors into the observations, obscuring the effects of the treatments to a greater extent than at the plot scale. Rainfall is *in situ*, resulting in heterogeneous amounts and intensity across the research site.

At the watershed scale, the researcher becomes more of an observer than a manipulator of the research site. At the watershed scale, most water quality research projects attempt to interpret the cumulative result of multiple changes in land management practices taking place at different times. Replicating experiments is rarely feasible. Implementing specific practices usually cannot be targeted to specific places in the landscape and is often limited to a small percentage of the total land area. Timing and intensity of climatic events are often the main determinant of fluctuations in water quality. For agricultural land, weather and the agricultural economy play a large role in crop choices, tillage practices, and fertilizer application. If a control watershed is available, the researcher often has little control over its management. Also, there can be lag times between land use change and a response in water quality. Given the high level of natural variability in the watershed conditions and in the water quality data, failure to detect a change between pre- and post-BMP implementation is not an indication that BMPs were unsuccessful in reducing nutrient and sediment loads, but could simply be the *noise* of natural variation being louder than the *signal* of the reduced nutrient or sediment loads from BMP application.

Also, the time it takes for an implemented practice to reach its full potential will delay its pollution reduction potential. Being able to identify possible lag times in reaching BMP pollution reductions because of phased-in implementation, or time to fully reach BMP effectiveness as in the case of riparian buffers, would improve effectiveness estimates, but it is difficult and perhaps impossible to account for lag at the watershed scale.

Watershed management conditions, including operation and maintenance of BMPs, construction supervision, and/or land use change will also affect BMP efficiencies, usually making them lower than what is observed at research plot scales. While little quantitative information exists on how BMP efficiencies should be adjusted to account for the impacts of improper maintenance on receiving waters, general adverse impacts on practice operation are understood. If maintenance is neglected, a BMP could become impaired and will fail to provide its designed functions. Proper maintenance of outlet structures, flow splitters, and clean out gates are key to achieving a stormwater BMP's designed efficiency (Koon 1995).

Sediment accumulation is one maintenance concern that if left unaddressed will adversely affect the effectiveness of some BMPs, such as dry detention ponds. As sediment accumulates, it decreases the BMP's storage volume and detention time, bypassing its intended functions and increasing discharge of nutrient and sediment-rich stormwater (Livingston et al. 1997). Increased discharge leads to decreased downstream channel stability, resulting in increased sediment loads and a reduction in available aquatic habitat. The consequences of increased stormwater discharges from sediment filled BMPs are a reduction in the BMP's pollution-removal efficiencies, and ultimately, increased ecological impairments.

High rainfall events can also influence BMP function and efficiency particularly for events above a BMP's designed maximum storm (Maule et al. 2005; Glozier et al. 2006). Conservation practices are designed to function up to a specific storm event, for example, a 10-year storm. Many continue to perform in more intense storm events. However, there is a level of storm intensity that impedes performance, and in extreme circumstances, could prevent nutrient or sediment reduction altogether. Research that estimates performance boundaries related to weather events is sparse. In addition, conservation practices can perform above literature values during low intensity storm events. To the fullest extent of the available guidance, BMP efficiencies were adjusted at rainfall events within or beyond the design maximum.

The weather adjustment links an expected loss in BMP efficiency because of storm intensity (Table 6.2). Only post-processed conservation practices receive that form of adjustment as land use change and explicit BMP simulation would already have the effect of large events directly simulated. The adjustment is additive as described in Section 6.4.4.

Table 6-2. Expected loss in efficiency from storm intensity.

Storm recurrence frequency	Efficiency level
0–15 year storm	conservation practice efficiency
5–50 year storm	70% of conservation practice efficiency
51+ year storm	30% of conservation practice efficiency

6.2 Methods Used to Determine BMP Effectiveness

6.2.1 Factors Considered in the Effectiveness Estimation

Estimating BMP efficiencies under operational conditions was guided by one key question: Is BMP efficiency recommended by the experts and/or from literature representative of what would be expected at the watershed scale? If the efficiency does not represent watershed-wide effectiveness, an adjustment was made to reflect the operational conditions of the watershed. When no quantified data on how much to adjust research values to reflect operational values exist, best professional judgment was exercised using known scientific processes to make an adjustment on the efficiency.

The BMP efficiencies were estimated primarily through literature review and professional judgment. Literature on individual BMPs were reviewed and their definitions were recommended by selected experts (Simpson and Weammert 2008). Specifically, those experts were asked to review literature that is applicable to the Chesapeake Bay watershed, with the applicable location defined as humid, temperate climates east of the Rockies. Experts were also asked to provide efficiency recommendations that should be used in the CBP's Watershed Model and associated Tributary Strategies from literature values. The expert recommendations were augmented by applying the following criteria:

- Efficiency recommendations should reflect operational conditions, defined as the average watershed-wide condition. Research scale efficiencies were adjusted to account for differences on scaling up to the watershed scale.
- Studies with negative efficiencies, i.e., the BMP acted as a source, not a sink for nutrient or sediment, were included in the efficiency development process because they reflect real world operational conditions.
- The evaluation criteria and process should be consistent among all experts involved.
- Peer-reviewed literature has been subject to stringent evaluation, and results from that literature were given more weight than literature without the same review process.
- Data from individual BMP project sites were used over median or average values calculated from multi-site analysis.

The expected spatial and temporal variability for a practice was estimated on the basis of available science and knowledge of the expected geographic extent for the practice's implementation. Different reduction efficiencies were established for practice implementation across different physiographic, geomorphic, and hydrologic settings. Where possible, efficiencies were adjusted for surface water and groundwater interactions (permeability), along with geology and soil types (slope, seeps, floodplain, and such). BMPs like cover cropping are affected by age, size, time to maturity, species composition, and other site-specific conditions and this contributed to spatial and temporal variability in efficiencies.

Management conditions, including BMP operation and maintenance, design and construction supervision, or land use change will also affect efficiencies, usually making them lower than at research scales. While little quantitative information exists on how BMP efficiencies should be adjusted to account for the effects of improper maintenance on receiving waters, general adverse impacts of poor construction or maintenance are understood to occur. If maintenance is neglected a BMP can become impaired and will no longer provide its designed functions. Proper maintenance of outlet structures, flow splitters, and clean out gates is key to achieving a stormwater BMPs designed efficiency (Koon 1995). *Average* management was assumed, but it was assumed the practices were implemented and being operated and maintained. Reviews and audits of BMP implementation and performance are needed to better estimate the actual effects of reported practices.

6.2.2 Translating Research Studies to Operational-Scale Efficiencies

Using research-site and demonstration-site derived efficiencies for watershed-scale implementation efforts will fail to reflect the spatial variability of the entire watershed. Both the scale and management differences between a research plot and a BMP site will alter efficiencies. The research-based estimates of BMPs need to be adjusted to provide more realistic estimates of efficiencies for widespread adoption of the practice.

Virtually all research data are generated under controlled management conditions; meaning that studies are done on typical or representative soils (marginal land is usually excluded), agronomic management is optimal (timely planting, precise farm management, high seed emergence, and such), and other hazards (goose grazing, deer grazing, and such) are minimized or excluded. Hence, the research estimates are more representative of a best-case scenario. This optimistic scenario needs to be adjusted to lower effectiveness when the efficiencies are being applied to widespread field implementation under *average conditions* across the Chesapeake Bay watershed.

Alternatively, given the multitude of factors that influence water quality at the watershed scale of analysis, detecting a change does not lead to the conclusion that the BMPs were responsible for the change unless the other factors can be ruled out. That problem becomes more severe as watershed size increases. For those reasons, the scale of the study was taken into account and reflected in efficiency adjustment as research and demonstration site derived efficiencies for watershed scale implementation fail to reflect the spatial viability of the entire watershed. Data extrapolation to any scale is difficult, but research, field, and watershed scale estimated efficiencies will differ for the same BMP, which justifies adjusting efficiencies when comparing BMP efficiencies between scales.

Lag time in BMP implementation is a factor that needs to be considered when estimating BMP efficiencies. Many practices are reported as implemented once the plan or design has been completed. In reality, the plan could call for phased implementation over as much as 5 to 10 years. In addition, with agricultural land the farmer might not implement the practice as scheduled because of climatic, management, or economic constraints. The time it takes for an implemented practice to reach its full potential can delay pollution reduction percentages. Efforts should be made to ensure that reported implementation is close to actual, and to determine if implementation and operation is as rigorous as specified in the practice. Identifying possible lag times in reaching BMP pollution reductions because of phased-in implementation or time to maturity will more accurately estimate effectiveness.

The loss pathways and hydrologic lag time associated with each practice was examined to see if an adjustment in effectiveness should be made. Transport of pollutants occurs through a variety of environmental pathways that include the soil surface, vadose zone, saturated zone, tile drains, and streams. The time scale of this transport varies substantially depending on the pathway followed by water from the land surface to the stream. For example, surface runoff to a stream can take minutes to days, whereas leaching to groundwater followed by discharge to a stream can take months to decades.

6.2.3 Using Best Professional Judgment

While literature was reviewed and experts were recruited to suggest BMP efficiencies for annual practices in the BMP project, for several cases, it was necessary to use best professional judgment to adjust for spatial, temporal, and management variability and the estimated resulting change in practice effectiveness at widespread *average* implementation across the Chesapeake

Bay watershed (Simpson and Weammert 2008). On some occasions, it was necessary to adjust for differences in approach among the experts.

Following Simpson and Weammert (2008), EPA chose to consider the need for efficiency modification on the basis of best professional judgment on a practice-by-practice basis using availability of literature, field scale implementation data, recent revisions to BMP efficiencies, and other factors. That resulted in a variable application of best professional judgment to different practices, which was warranted on the basis of the factors above (Simpson and Weammert 2008).

It must also be recognized that the BMP efficiencies are being developed using an adaptive management approach that recognizes that our knowledge is incomplete. Adaptive management proposes a science-based and conservative approach to efficiencies. It allows BMP efficiency review and updating at recurring intervals on the basis of new research, monitoring, and experience. The conservative approach is always advisable in adaptive management and is particularly warranted here because few, if any, data suggest actual watershed-wide implementation efficiencies as high as those in the research literature. Several recent small watershed studies have indicated considerably lower reductions when groups of practices are applied in the watershed than would have been expected according to current efficiencies.

6.2.4 Accounting for Variability in Management

When scaling up BMPs from the research plot or small scales to watershed-wide implementation, it is important to account for the impact that expanded variability will have on practice performance. Several studies have shown that when BMPs are applied across even a small watershed, the resulting improvement in water quality is far less than would have been projected on the basis of research-scale data. While some part of that could be because of *legacy* nutrients or sediments, it does not explain all the difference. U.S. Geological Survey research has suggested an average nitrogen lag time of about 10 years in the Bay watershed to see the full impact of BMP changes.

Spatial and temporal variability because of soils, hydrology, geology, climate, and so on are often recognized as sources of variability. However, management and operation can also be highly variable between research watershed scales, operational watershed scales and even between different managers in an operational watershed scale. When practices are implemented across a large area on parcels managed by many different individuals, it is important to assume an *average* level of expertise, control and management in planning design, implementation, and operation of any given BMP. While data might be limited quantifying the difference between research and average planning, design, implementation, and management, it is recognized that widespread implementation rarely has the same level of oversight and control that is essential to get statistically meaningful results observed at research scale. As a result, there is a need to lower effectiveness from the research scale when widespread implementation occurs.

While the effect of average management has been considered in proposed BMP efficiencies, whether a practice is fully or partially implemented and whether it is properly maintained and revised, replaced, or upgraded as needed was not considered in these BMP effectiveness estimates. Those tend to be program management and compliance issues and should be addressed in considering the actual likely impact of implementation of a suite of BMPs as part of a watershed management plan, however, they were not considered in developing efficiencies for individual BMPs. Following Simpson and Weammert (2008), EPA assumed the BMPs were implemented and revised, upgraded, or replaced as recommended for the practice.

6.2.5 Incorporating Negative Efficiencies

Negative BMP efficiencies are reported in literature, usually because of natural processes, or issues associated with constructing and operating a BMP. Those negative efficiencies were included in the analysis because in some situations, BMPs act as a source rather than a sink (Simpson and Weammert 2008). Errors in the design, construction, and maintenance of a BMP can also create a system that is unable to provide its expected pollutant removal. In some cases, the errors can lead to flow bypassing the entire BMP, possibly resulting in negative efficiencies. Additionally, BMPs with permanent water pools often release phosphorous from saturated sediment, which can produce negative efficiencies.

6.2.6 Literature Used to Determine BMP Effectiveness Estimates

The literature cited in efficiency estimation was screened on the basis of pre-established criteria (Simpson and Weammert 2008). For existing BMP efficiencies that were developed with limited data or best professional judgment, newly available literature were consulted before refinement. Applicability and credibility of new studies were vigorously reviewed. Alternatively, for BMP efficiencies that were developed from sufficient/adequate data, a large body of consistent data was required to justify a refinement to the BMP efficiency. Among consulted literature, peer-reviewed literature was given more weight than design standards and manuals. Peer-reviewed literature has undergone a robust, critical screening before it is published; while non-peer-reviewed literature is not submitted to the same screening process. Design manuals are written to result in aspirational BMP effectiveness and often include additional components that increase the BMPs estimated median effectiveness. As such, more confidence lies in the peer-reviewed literature.

To respond to CBP workgroup concerns about the literature and data used, a task group within STAC was requested to review and assess the process whereby University of Maryland Mid Atlantic Water Program (UMD/MAWP) arrived at BMP effectiveness estimate recommendations. Specifically, the group was requested to review the logic, approach, and process used to develop BMP definitions and efficiencies. The STAC report concludes,

> The Chesapeake Bay model must be calibrated to function with operational rather than research BMP efficiencies. Hence, if reported negative efficiencies reflect operational conditions, they should be considered in an assessment of the BMP efficiency literature. Peer-reviewed literature has more credibility than do design standards/manuals that have not been subjected to independent examination.

Peer-reviewed literature was also categorized on the basis of scope of research. Studies taking place on a single site with a single BMP more accurately represent the BMP efficiency compared to single site studies with multiple BMPs, and the two previous study types were preferable to multi-site studies. Multi-site review and analysis studies generally lost the specificity of individual site characteristics. Characteristics of a site like soils, climate, and hydrology are important in evaluating the effectiveness of a BMP. Also, multi-site review and analysis studies generate a median or average of one BMP or multiple BMPs, which can enhance or diminish the value of the effectiveness estimate. Furthermore, multi-site studies tend to underreport or not publish negative efficiencies.

In addition, studies on a single site were preferred over analysis from multi-site studies because the former is a study of individual BMP projects, while the latter is a collection of BMP projects that often use design ratings for single BMPs based on multiple BMP project sites or professional judgment. Multi-site analyses are defined as a review of one BMP whose average or median performance is based on multiple sites. Therefore, the analysis can also incorporate the efficiencies reported in the single-site studies, thus counting some studies twice during statistical calculations in the cases where both single-site and multi-site results are compiled. In addition, the average or median efficiencies reported in multi-site studies represent BMPs with optimum sizing and design specifications to increase removal efficiency. The high efficiency is often not achieved at all sites and, thus, cannot be reliably used, unless the BMP definition includes the optimum sizing and design specifications. Furthermore, not only are multi-site analysis relying on design guidelines for efficiency calculations, they primarily include positive removal efficiencies only, because of a tendency to underreport or not publish negative or low performance that are inconsistent with design manuals.

Another concern regarding multi-site studies is that BMP location information is often unavailable, making it difficult to determine the applicability of a study without the critical, site-specific information on climate, soils, and hydrology. Also, the details of the methodology used in multi-site studies are often missing, and information on sampling and testing techniques and other characteristics are unavailable for review for errors or caveats.

The BMPs used in a multi-site analysis might not represent a single BMP; rather, treatment trains or multiple BMPs at the same site might have been used. As a result, a direct comparison of an individual BMP performance is impossible. Multi-site analysis could also include results that are not actually used in the site. For instance, it was found during the literature search that some urban stormwater BMP studies included results from agricultural waste treatment studies.

6.2.7 Oversight and Review

As BMP efficiencies were reviewed and recommended by multiple experts, they naturally had different approaches to efficiency development and adjustment. Additional overview and adjustment were exercised to ensure consistency of BMP evaluations among all parties involved (Simpson and Weammert 2008).

CBP workgroups with expertise on specific BMPs reviewed the BMP reports. They first determined if tracking and reporting data on BMP implementation were available in each jurisdiction to receive credit in the Watershed Model for the BMPs associated nutrient and sediment reductions. Some BMPs are subcategorized by certain design elements. If a jurisdiction did not have existing infrastructure in place to report at subcategorical level, either the jurisdictional program managers refined reporting procedures to reflect that new detail or default definition and effectiveness estimates were substituted.

The reports were further reviewed to ensure all pollution reduction mechanisms associated with a BMP were captured by the definition and effectiveness estimate. Applicable NRCS practice codes were added to the BMP definitions to assist with tracking and reporting. While the source area workgroups reviewed and modified the practice reports, the Tributary Strategy Workgroup (TSWG) analyzed the reports for their modeling components. How the practices are modeled (i.e., BMP category) needed to be agreed to. After the TSWG and source area workgroups approved the BMP definitions and effectiveness estimates, the Nutrient Subcommittee (NSC), along with UMD/MAWP conducted a ranking exercise across all the BMPs. That process was used to evaluate the logic and consistency of all the BMP effectiveness estimates. Following NSC approval of the BMP reports, the Water Quality Steering Committee approved the BMP definitions and effectiveness estimates for use in Bay policy and modeling.

6.2.8 Other Criteria Considerations

It is important to note that none of the above criteria takes into account the variability and uncertainty associated with rate of implementation, operation and maintenance, replacement, spatial variability, or tracking and reporting of a BMP. Those factors that adjust efficiencies need to be investigated and applied to future efficiency refinement procedures.

Developing efficiencies that reflect operational, real-world conditions requires a holistic view point. Certain qualities of research studies do not incorporate all the factors that will influence operational efficiencies. To account for that, research-based effectiveness estimates must be adjusted using the aforementioned guidelines.

Model output and monitoring data must be consistent and used appropriately. Better research on demonstration and monitoring of BMP, system, and small watershed conservation effects will increase confidence in BMP effectiveness. Finally, managers, policy makers, and involved citizens must be made aware of potential implications of the iterative-adaptive BMP effectiveness approach so they understand the recurring need to change effectiveness estimates as knowledge advances (Simpson and Weammert 2007).

6.3 BMP/Conservation Practice Categories

6.3.1 Nutrient Management Plans

Nutrient management BMPs are developed by certified planners across most of the Chesapeake watershed. Certified planners come from both the public and private sector. Several studies have shown that plans developed by public and the private sector planners vary in their recommendations. However, both types of nutrient management plan rates were below the *pre-plan* rates. A reliable basin-wide method is unavailable to document what landowners actually apply in a given year.

6.3.2. Maximum Implementation Level Adjustment

In the previous Phase 4.3 version of the Watershed Model, BMP implementation levels had few limits except for the land available to implement the BMPs on. There were two exceptions, in the case of the Conservation Reserve Program (CRP), limits are based on federal regulations, which call for no more than 25 percent of the total county crop acreage to be placed into the CRP. Conservation tillage limits were limited by the acres in crops that cannot use conservation tillage and allowed up to 75 percent of cropland to be in conservation tillage. All other practices were assumed to be able to be implemented at rates of 100 percent of available land.

For most *voluntary programs*, the level of participation varies according to the program's objectives; the incentives offered; and the threat, real or perceived, of regulatory action. Historically in the agricultural sector, voluntary conservation programs providing 50 to 75 percent cost sharing resulted in participation levels of between 40 to 60 percent of eligible landowners.

A voluntary conservation program incorporating focused outreach and high cost-share levels of 75 percent or more might see participation increase to as high as 80 percent. Focused outreach consists of one-on-one landowner contacts and small group meetings. In addition, the area targeted is usually a small- to medium-sized watershed. Participation does not mean full plan implementation. Variations in conservation practice implementation and practice maintenance do occur. It is unlikely that the Bay Program partners could achieve this level of success at watershed-wide scales. For those reasons, EPA limit maximum implementation levels to 90 percent for each conservation practice.

6.4 BMP Types

6.4.1 Tillage Practices

Tillage information on a county scale is obtained for the conventional and conservation tilled cropland from the Conservation Technology Information Center (CTIC 1989–2004). Those splits between conventional (high) tillage, and conservation (low) tillage are used in Phase 5.3 simulation years of 1985–2005 and are used to apportion the tilled cropland category.

6.4.2. Manure

Phase 5.3 includes manure management throughout the Chesapeake watershed irrespective of the number or location of confined animal feeding operations (CAFOs). Looking solely at CAFOs masks the more significant basin-wide problem of high animal unit (AU) density to available cropland. CAFOs normally constitute a high AU/cropland ratio, but the Chesapeake watershed has high concentrations of smaller family farms with the same problem as CAFOs, i.e., limited available cropland for manure application. This situation produces AU/cropland ratios equivalent to CAFO operations. That is why the combination of excess manure and high phosphorus levels in agricultural soils is not limited to areas adjacent to CAFOs. Soil testing has shown that the total number of fields in the high to very high range for soil phosphorus has steadily increased in animal production areas since 1985. Latest estimates place 60 percent of crop fields (basin-wide) in the high or very high range.

Phase 5.3 addresses CAFOs with the land use of *animal feeding operations*, which allows for simulating manure nutrient runoff from CAFO areas. The area of animal feeding operations is based on the population of different animal types within a land-segment and accounts for manure generated by beef cattle, dairy cows, swine, layers, broilers, and turkeys. Animal population data are obtained from the U.S. Agricultural Census for 1982, 1987, 1992, 1997, and 2002 for use in estimating both animal feeding operations and the application rates of manure nutrients to cropland and pasture. The very small areas used to represent animal feeding operations are taken from the pasture land use.

Animal feeding operations are determined by animal populations from a scenario-year. Those populations are generally projected for each animal type by state agricultural agencies or as trends from existing Agricultural Census animal populations by county. The county animal populations are distributed proportionally to land-segments according to the ratio of agricultural acres in a land-segment to agricultural acres in a county for a given scenario year. The different animal types are simplified by a conversion to animal units which calculates the necessary animal feeding operations acre. A more detailed description of the calculation of animal feeding operations can be obtained from Palace et al. (1998).

6.4.2.1. Nutrient Applications to Agricultural Land from Animal Manure

Nutrients from manure are simulated as applied to the Phase 5.3 land uses of cropland (*conventional tillage receiving manure** and *conservation tillage receiving manure)* hay land (*alfalfa and hay with nutrients)*, or simulated as directly excreted directly to *pasture*.

Model manure applications are developed with a mass balance of manure for each land-segment. The source information includes the following:

- County animal populations for each tracked animal type (beef, dairy, swine, poultry layers, broilers, and turkeys) for each model scenario-year.
- Land use acreage by land-segment as determined by methodologies described previously.
- Splits, by modeling land-segment, of the total agricultural acres in a county-segment and the total agricultural acres in a county.
- Nitrogen and phosphorus (and nutrient species within) content in manure/litter of six animal types (beef, dairy, swine, poultry layers, broilers, and turkeys).
- Splits, by land-segment, of the percent of each animal type that are confined with manure susceptible to runoff, confined with manure that is not susceptible to runoff, and pastured.
- For each animal type and model scenario-year, the percent of the total manure that is stored.
- For each animal type and for manure that is stored, not stored, and from pastured animals - proportions of total nitrogen and total phosphorus (and nutrient species within), pass-through factors.
- Volatilization rates of nitrogen.
- Relative application rates of nitrogen and phosphorous to cropland (*conventional tillage receiving manure* and *conservation tillage receiving manure)* and hay land (*alfalfa and hay with nutrients)* by land-segment.
- For each animal type and for manure that is stored, not stored, and from pastured animals - monthly proportions of the total applied/excreted manure over a year.

All the source data listed above is employed in a mass balance analysis to calculate inputs of nutrient applications to agricultural land from manure for each scenario-year. The inputs to the model are, specifically, monthly lb/acre applications of each nutrient species by land-segment to each of the agricultural land use categories.

Thorough explanations of the mass balance analysis calculations are found in Palace et al. (1998). Figure 6-1 is a flow diagram of the general process of determining nutrient applications from the source data.

* Note: Land uses simulated by the Phase 5.3 Model, such as *alfalfa* and *conventional tillage receiving manure* are in italics.

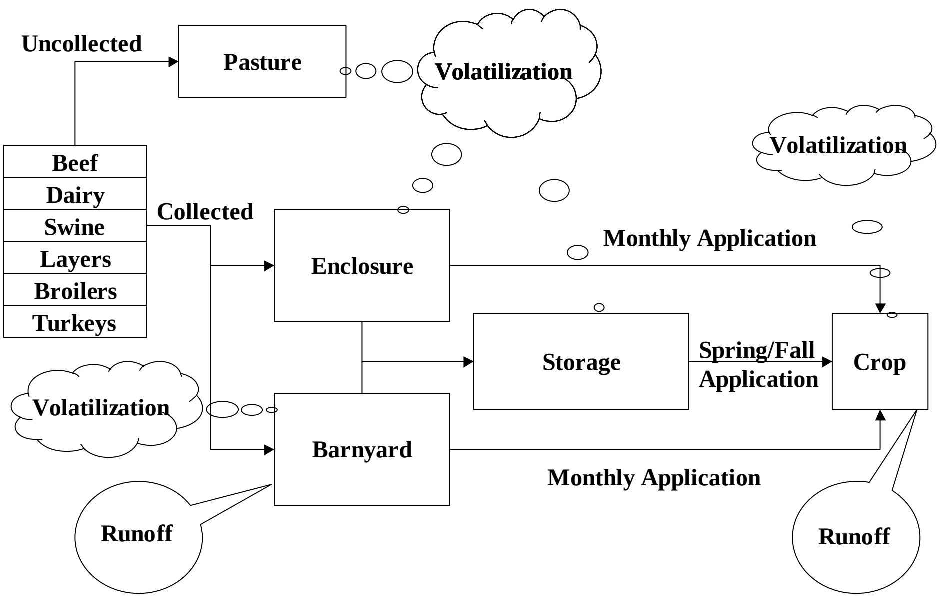


Figure 6-1. Schematic of movement and fate of manures including collection and application to agricultural land.

To estimate the amount of nutrients in manure excreted in a land-segment, animal populations are converted to animal units (1 AU = 1,000 lbs animal weight), and the nutrient content per animal unit is applied. The calculations assume average nutrient levels in voided manure for each animal type.

Different animal species create varied volumes of manure with distinct nutrient concentrations. The animal types accounted for in the mass balance include beef, dairy, swine, poultry layers, broilers, and turkeys. As already described for the animal feeding operations land use category, animal population data are obtained from the U.S. Agricultural Census (1982, 1987, 1992, and 1997). Generally, animal populations for a model scenario-year are interpolated from Agricultural Census animal populations by county or projected for future years for each animal type by state agricultural agencies. The county animal populations are distributed proportionally to land-segments according to the scenario-year ratio of agricultural acres in a land-segment to agricultural acres in a county.

The mass balance analysis distributes voided manure nutrients into three groups: confined/never susceptible to runoff, confined/susceptible to runoff, and pasture. It is assumed that dairy cows are in confined areas all the time, and all dairy manure is susceptible to runoff if livestock waste management systems are not used. Beef are assumed to be in pasture 100 percent of the time except for regions of the Bay basin where snow covers the ground a large portion of the winter when beef cattle are housed in feed lots or confined areas. Within these northern model land-segments, it is assumed that beef are pastured 80 percent of the time.

Manure produced in confined areas can be properly or improperly stored before land applications. Adequate storage allows farm operators to apply manure to their land when crops can use the nutrients and when the soil and weather conditions are appropriate. Animal waste management systems not only provide significant nutrient reduction benefits, but also greatly reduce a farmer’s need for chemical fertilizers. Non-pastured livestock manure must be stockpiled or spread daily if no storage system is available, resulting in a high potential for nutrient pollution to reach ground and surface waters. On the other hand, poultry manure remains in the production house for a majority of the time and is relatively dry so if it is properly stacked outside, the potential for nutrient loss is less than that of livestock waste.

For a given model scenario-year, the manure mass balance calculates the total nutrient mass generated from manure that is both stored and not stored. Losses of ammonia from volatilization from the period between manure generation to land application is taken out of the total. Volatilization over a period of several months, represents about a 50 percent loss of total nitrogen from freshly excreted manure (Loomis and Conner 1992). Nutrient losses from runoff are also subtracted according to defined percentages for stored and un-stored manure for each animal type. The remaining yearly nutrient mass is applied to cropland and hay acreage according to designated relative application rates and in predetermined monthly proportions. Most notably, un-stored manure is applied to cropland and hay uniformly over a 12-month period. That mostly addresses manure from non-pastured livestock where there is no storage system. The stored manure is applied in four individual spring and fall months in one-quarter allotments for livestock and greater spring proportions for poultry.

Alternatively for pasture manure, the mass balance calculates the total yearly nutrient mass voided by pastured animals, takes out ammonia losses from volatilization, and puts the remaining mass on pasture acres uniformly over a 12-month period. The product of the relational database mass-balance is, again, monthly nutrient applications in lbs/acre by species and by modeling state-segment to each of the agricultural land use categories.

In combination with land use acreage, also derived from Agricultural Census information, reasonable estimates of trends in manure nutrient applications, on a lb/acre basis, can be calculated. That is an important diagnostic number to be considered in developing tributary strategies with the worst-case scenario being a significant loss of agricultural land over time with nutrients from animal manure increasing while little of the remaining cropland and hay are following nutrient management plans. Overall, the large-scale, county-based, and repeatable Agricultural Census data are best for the two decade simulation period of the Phase 5.3 Model.

While the source data for animal populations is acceptable as a whole, inadequacies still exist, mostly from errors associated with survey information. Many assumptions or estimates are applied to the manure mass balance to derive lb/acre nutrient applications, including those mentioned previously for land use determinations.

In the case of nutrient content in manure/litter for individual animal types, concentrations are rooted in literature sources but are applied universally across the entire watershed according to animal class. In reality, different animal feeds would yield various nutrient concentrations in voided manure, but that information is not available to the nonpoint source project on a scale of the 40-million-acre watershed.

Last, assumptions are made as to the splits of each animal type that are confined with manure susceptible to runoff, confined with manure that is not susceptible to runoff, and pastured; the percent of the total manure that is stored; the proportions of nutrients that run off barnyards and the amount of ammonia volatilized; the relative application rates of nutrients to cropland and hay; and the monthly proportions of total applied and excreted manure over a year.

Most of the above mentioned estimates are rooted in knowledge from Bay-state agricultural or environmental agency personnel or, in some cases, come from literature. As with land use assumptions and methodologies, the estimates were reviewed by Bay Program participants in the Tributary Strategy Workgroup and the Agricultural Nutrient Reduction Workgroup before employment in the manure mass balance.

In the past, the Tributary Strategy Workgroup determined means for filling data gaps in the Agricultural Census animal populations where certain numbers are not reported so that farm-specific information is not divulged. State representatives in the group, often collaborating with their agricultural agency, also defined extrapolation methodologies from Census data or forecasted trends to project watershed animal numbers that are defensible.

At a minimum, the following information is required for each BMP: BMP name, location by land-segment, amount, units of acres treated or planted or animal waste systems installed. Animal waste systems include animal type and animal numbers or units.

6.4.3 Categories and Types of Conservation Practices (BMPs)

There are four ways to incorporate BMPs into the Phase 5.3 Watershed Model. They are (1) land use change, (2) post-processed after model run efficiency factors, (3) a combination land use change and efficiency factors, and (4) explicit simulation of the BMP. The different BMPs simulated by any of those methods are listed in Table 6-3.

Table 6-3. Types of conservation practices.

Agriculture
Nutrient Management
Forest Buffers trp
Forest Buffers
Wetland Restoration
Land Retirement to hyo
Land Retirement to pas
Grass Buffers
Tree Planting
Carbon Sequestration / Alternative Crops
Conservation Tillage
Continuous No Till
Enhanced Nutrient Management
Decision Agriculture
Conservation Plans
Cover Crop Early Other Wheat
Cover Crop Standard Other Wheat
Commodity Cover Crop Early Other Wheat
Commodity Cover Crop Standard Other Wheat
Cover Crop Early Drilled Rye
Cover Crop Standard Drilled Rye
Cover Crop Standard Drilled Barley
Cover Crop Standard Drilled Wheat
Cover Crop Standard Other Barley
Cover Crop Standard Other Rye
Off Stream Watering with Fencing
Off Stream Watering Without Fencing
Off Stream Watering With Fencing and Prescribed Grazing

Upland Prescribed Grazing
Upland Precision Intensive Rotational Grazing
Horse Pasture Management
Animal Waste Management - Livestock
Animal Waste Management - Poultry
Barnyard Runoff Control
Loafing Lot Management
Mortality Composters
Water Control Structures
Poultry Phytase
Swine Phytase
Dairy Feed Management

Developed: Urban/Suburban

Forest Conservation
Urban Growth Reduction
Impervious Urban Surface Reduction
Urban Forest Buffers
Urban Grass Buffers
Tree Planting Urban
Abandoned Mine Reclamation
Wet Ponds and Wetlands
Dry Detention Ponds and Hydrodynamic Structures
Dry Extended Detention Ponds
Urban Infiltration Practices - no sand\veg_no underdrain
Urban Infiltration Practices - with sandveg_no underdrain
Urban Filtering Practices
Erosion and Sediment Control
Urban Nutrient Management
Street Sweeping Mechanical Monthly
Street Sweeping (In Units of Feet)
Street Sweeping (In Units of Pounds)
Urban Stream Restoration
Non Urban Stream Restoration
Septic Connections
Septic Denitrification
Septic Pumping

Resource

Forest Harvesting Practices
Dirt & Gravel Road Erosion & Sediment Control - Driving Surface Aggregate + Raising the Roadbed
Dirt & Gravel Road Erosion & Sediment Control - with Outlets
Dirt & Gravel Road Erosion & Sediment Control - Outlets only

6.4.4 BMP Effectiveness Applied in the Phase 5.3 Model

In the Phase 5.3 Model the BMP reduction efficiencies are applied universally, across the entire Bay watershed. In the model, the simulation of a land use within a land-segment is not a representation of all the different types of that land use in the segment. The land use is modeled as a single representative average land use, therefore, the assumption of a representative nutrient and sediment reduction capacity is reasonable. Table 6.3 lists the BMPs in the model.

The BMP effectiveness inputs to the Phase 5.3 model are calculated with: 1) the source information of the land use data after integrating BMPs that involve land use changes; 2) the BMP implementation levels from CBP jurisdictions after compilation and computations for formatting and quality assurance; and 3) the BMP reduction efficiency file. Those three sources are used to compute, by land-segment and by land use, the model input inputs according to the following equation:

$$\text{Fraction Reduction} = \frac{\text{acres treated by BMP}}{\text{total segment acres}} \times \text{BMP efficiency}$$

Built into the program are assignments for each BMP as to whether the practice is considered *additive* or *multiplicative*. BMPs that cannot be applied to the same land use are mutually exclusive and are considered additive in nutrient reduction capabilities. An example of additive BMPs would be streambank protection with fencing and without fencing where the pasture land has either type of protection, but never both.

The other type of BMP, which applies to most controls, is considered to be multiplicative and several BMPs are applied on the same land use. Those practices are considered to behave as consecutive BMPs because one BMP reduces the nutrients available for subsequent BMPs to reduce. Multiplicative functions are applied to that class of BMP. An example of multiplicative BMPs would be a land use of *conservation tillage receiving manure* where cover crops, a farm plan, and a riparian forest buffer down-gradient from the cropland were are applied.

The product of the BMP relational database is, again, a spreadsheet file of pass-through factors for each land use and for total nitrogen, total phosphorus, and sediment by model land-segment. The Phase 5.3 Model *passes through* the fraction of the nutrient and sediment load resulting from the combined impact of BMPs. Pollutant reductions because of BMP land use changes are accounted for through the simulation of a lower-yielding land use. For details on how each of the BMP effectiveness estimates were assigned, see www.mawaterquality.org/bmp_reports.htm.

For nutrient management plan implementation the Phase 5.3 Model calculates the impact of that BMP through an explicit simulation of nutrient management land uses rather than through the use of the BMP efficiencies. The input of nutrient management implementation acres by land-segment are determined from jurisdictional submissions.

6.5 Agricultural Best Management Practices

6.5.1 Animal Waste Management Livestock

Animal waste management systems are practices designed for proper handling, storage, and use of wastes generated from AFOs and include a means of collecting, scraping, or washing wastes and contaminated runoff from confinement areas into appropriate waste storage structures. Lagoons, ponds, or steel or concrete tanks are used for treating or storing liquid wastes. Storage sheds or pits are common storage structures for solid wastes. Controlling runoff from roofs, feedlots and loafing areas are an integral part of such systems.

Definition:	Practices designed for proper handling, storage, and use of wastes generated from animal feeding operations.
Land use:	*Animal feeding operation (afo)* for livestock and poultry
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 80%, TP: 80%
Reference:	Appendix H, BMP Basics

6.5.2 Barnyard Runoff Control

Definition:	This practices includes the installation of practices to control runoff from barnyard areas. This includes practices such as roof runoff control, diversion of clean water from entering the barnyard and control of runoff from barnyard areas. Use the first percent efficiency if controls are installed on an operation with manure storage; and the second percent if the controls are installed on a loafing lot without manure storage. The sediment efficiency has not been incorporated into the current watershed model but will be included in the updated model that is under development at this time.
Land use:	*animal feeding operations (afo)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 20%, TP: 20%, TSS: 40%
Reference:	Tributary Strategies document

6.5.3 Loafing Lot Management

Definition:	The stabilization of areas frequently and intensively used by people, animals or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures. This does not include poultry pad installation.
Land use:	*Animal feeding operation (afo)* for livestock
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 20%, TP: 20%, TSS: 40%
Reference:	NRCS Practice 561: Heavy Use Area Protection NRCS Guide

6.5.4 Mortality Composters (Poultry)

BMP Definition

Mortality composters involve composting routine mortality in a designed, on-farm facility, with subsequent land application of the compost. That prevents the necessity to bury dead animals that could result in nutrient leachate, or rendering of dead animals for processing into animal feeds or incineration. Mortality composting can be, and is, applied to various species including poultry, swine, and dairy calves.

While there are many objectives to mortality composting, Section 6 evaluates only its water quality benefit compared to burial. Mortality composting reduces the risk of disease transmission; prevents nuisances such as flies, vermin, and scavenging animals; and combats odor resulting from the anaerobic breakdown of proteins. In addition to water quality benefits, mortality composting benefits both human and animal health.

BMP Subcategories

Mortality composting effectiveness is categorized by broilers, layers, hens, turkeys, swine, and dairy calves.

Applicable NRCS Code

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. Cultural components consisting of shorter term conservation measures included in the Mortality Composting definition include the USDA-NRCS conservation practices listed below.

<u>Animal Mortality Facility (316)</u> An on-farm facility for the treatment or disposal of livestock and poultry carcasses.

Purpose

This practice can be applied as part of a conservation management system to support one or more of the following purposes:

- Decrease nonpoint source pollution of surface and groundwater resources
- Reduce the effect of odors that result from improperly handled animal mortality
- Decrease the likelihood of the spread of disease or other pathogens that result from the interaction of animal mortality and predators
- To provide contingencies for normal and catastrophic mortality events

Conditions where practice applies

This practice applies where animal carcass treatment or disposal must be considered as a component of a waste management system for livestock or poultry operations. It applies where on-farm carcass treatment and disposal are permitted by federal, state, and local laws, rules, and regulations. It also applies where a waste management system plan as described in the National Engineering Handbook (NEH), Part 651, Agricultural Waste Management Field Handbook (AWMFH) has been developed that accounts for the end use of the product from the mortality facility. The practice includes disposal of both normal and catastrophic animal mortality; however, it does not apply to catastrophic mortality resulting from disease.

Effectiveness estimate

The pollution reductions associated with mortality composting is calculated using a set of equations incorporating the average mortality weight, nitrogen and phosphorus composition, percent mortality, the number of animals each year, and an effectiveness estimate. Mortality is not consistent, it increases with animal weight. To account for that, average mortality weight is within the 70th weight percentile. The average nutrient composition, percent mortality, and number of animals each year are dependent on each animal type. The effectiveness estimate remains the same regardless of species with 40 percent reduction for nitrogen and a 10 percent reduction for phosphorus when compared to burial.

Definition:	A physical structure and process for disposing of dead poultry. Composed material is combined with poultry litter and land applied using nutrient management plan recommendations.
Land use:	*animal feeding operations (afo)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 40%, TP: 10%
Reference:	UMD/MAWP

Application in the Phase 5.3 Model

The CBP Agricultural Workgroup decided to not include mortality compositing in the Phase 5.3 Model because of the nutrient tradeoffs between a live animal generating manure over it's life cycle and the nutrients reduced by carcass composting were seen as difficult to calculate and probably trivial.   This is because the Agricultural Census animal units of poultry for example, are numbers of animals housed, not numbers of animals finished. Using the Agricultural Census estimates of animal units in effect counts both the finished to market poultry and the associated mortality in the houses. In this case, counting the poultry mortalities as both producing manures, and as producing nutrient loads from composters, would double count the nutrient load from these animals. For this reason mortality composing was not a BMP used in the Phase 5.3 simulation.

6.5.5 Dairy Precision Feeding and Forage Management

After adopting feed management practices, manure testing can result in an elevated manure nutrient content. For example, a switch to a more digestible forage, an encouraged feed management practice, could result in elevated manure phosphorus content. That improves net farm income by feeding nutrients more efficiently, one intent of feed management. The other purpose of feed management is to reduce the quantity of nutrients excreted in manure by minimizing the over-feeding of nutrients. It is that purpose, decreased manure nutrient content for improved water quality, that is able to receive credit for dairy precision feeding as a water quality BMP. Decreased manure nutrient content must be demonstrated for this credit.

Dairy precision feeding reduces the quantity of phosphorous and nitrogen fed to livestock by formulating diets within 110 percent of NRC recommended level to minimize the excretion of nutrients without negatively affecting milk production.

There is one applicable NRCS code: Feed Management (592)—Managing the quantity of available nutrients fed to livestock and poultry for their intended purpose.

Purpose

- Supply the quantity of available nutrients required by livestock and poultry for maintenance, production, performance, and reproduction while reducing the quantity of nutrients, especially nitrogen and phosphorus, excreted in manure by minimizing the over-feeding of those and other nutrients.
- Improve net farm income by feeding nutrients more efficiently

Conditions where practice applies

- Confined livestock and poultry operations with a whole farm nutrient imbalance, with more nutrients imported to the farm than are exported or used by cropping programs.
- Confined livestock and poultry operations that have a significant buildup of nutrients in the soil because of manure land application.
- Confined livestock and poultry operations that land apply manure and do not have a land base large enough to allow nutrients to be applied at rates recommended by soil test and used by crops in the rotation.
- Livestock and poultry operations seeking to enhance nutrient efficiencies.

Definition:	Reduces the quantity of phosphorous and nitrogen fed to livestock by formulating diets within 110% of NRC recommended level to minimize the excretion of nutrients without negatively affecting milk production.
Land use:	*animal feeding operations (afo)*
Efficiency Credited:	Application reduction
Effectiveness estimate:	TN: 24%; TP: 25%, or as reported by States
Reference:	UMD/MAWP

6.5.6 Nutrient Management Applications

Definition:	Nutrient management plan (NMP) implementation (crop) is a comprehensive plan that describes the optimum use of nutrients to minimize nutrient loss while maintaining yield. An NMP details the type, rate, timing, and placement of nutrients for each crop. Soil, plant tissue, manure, or sludge tests are used to assure optimal application rates. Plans should be revised every 2 to 3 years.
Land use:	*conventional tillage with manure (hwm), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw), alfalfa (alf),* and *pasture(pas)*
Efficiency credited:	Landuse change to *nutrient management conventional tillage with manure (nhi), nutrient management conventional tillage without manure (nho), nutrient management conservation tillage with manure*

	(nlo), nutrient management hay (nhy), nutrient management alfalfa (nal), and *nutrient management pasture (npa),* respectively
Effectiveness estimate:	N/A
Reference:	BMP Basics

6.5.7 Agricultural Forest Buffers

Mature stands of trees with well-developed root systems, an organic surface layer, and understory vegetation adjacent to open water. Such areas provide multiple benefits, including wildlife habitat, water quality improvement, and temperature control. The wider the buffer is, the greater the variety and the higher the quality of those benefits. The recommended minimum width is 100 feet. Areas along streams receiving forest buffers are assumed to provide multiple benefits regardless of the state of the land uses adjacent to them. The type and frequency of forest buffer maintenance to ensure full use of the buffer's filtering/interception capabilities is not widely practiced.

Definition:	Agricultural riparian forest buffers are linear wooded areas along rivers, stream and shorelines. Forest buffers help filter nutrients, sediments and other pollutants from runoff as well as remove nutrients from groundwater. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with 35 feet minimum width required.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw), alfalfa (alf), pasture (pas), nutrient management conventional tillage without manure (nho), nutrient management conservation tillage with manure (nlo), nutrient management hay (nhy), nutrient management alfalfa (nal), nutrient management pasture (npa), degraded riparian pasture (trp),* and *hay without nutrients (hyo)*
Efficiency credited:	Landuse change to *forest, woodland, and wooded (for)* and a reduction efficiency for upland areas.
Effectiveness estimate:	Varies geographically TN: 19-65% (4x acres); TP: 30-45% (2x acres); TSS: 40-60% (2x acres). See table below.
Reference:	Forest buffer white paper

Riparian Forest Buffers - Nutrient Reduction Effectiveness Estimates			
	TN	TP	TSS
Inner Coastal Plain	65%	42%	56%
Outer Coastal Plain Well Drained	31%	45%	60%
Outer Coastal Plain Poorly Drained	56%	39%	52%
Tidal Influenced	19%	45%	60%
Piedmont Schist/Gneiss	46%	36%	48%
Piedmont Sandstone	56%	42%	56%
Valley and Ridge - marble/limestone	34%	30%	40%

Valley and Ridge - sandstone/shale	46%	39%	52%
Appalachian Plateau	54%	42%	56%

6.5.8 Agricultural Grass Buffers

An agricultural grass buffer is an area of grasses that is at least 35 feet wide on one side of a stream. The riparian area is managed to maintain the integrity of stream channels and shorelines, and to reduce the effects of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals.

Grass buffers have been assumed to be 70 percent as efficient at reducing total nitrogen (TN) as forest buffers. The efficiency derived for TP is assumed to be 75 percent of the TSS efficiency. Emerging literature is raising questions about this, which suggests that it be re-evaluated as new data becomes available.

Practice components meet criteria standards under the USDA-NRCS 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 included in the Riparian Forest Buffer Practices include the following USDA-NRCS conservation practices:

- Channel Bank Vegetation (322)
- Tree/Shrub Establishment (612)
- Tree/Shrub Site Preparation (490)

Areas along streams receiving forest buffers are assumed to provide multiple benefits regardless of the state of the land uses adjacent to them. The type and frequency of buffer maintenance to ensure full use of the buffer's filtering/interception capabilities is not widely practiced.

Definition:	Agricultural riparian grass buffers are linear strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers or tidal waters that help filter nutrients, sediment, and other pollutants from runoff. The recommended buffer width for riparian grass buffers (agriculture) is 100 feet, with 35 feet minimum width required.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw), alfalfa (alf), pasture (pas), nutrient management conventional tillage without manure (nho), nutrient management conservation tillage with manure (nlo), nutrient management hay (nhy), nutrient management alfalfa (nal), nutrient management pasture (npa), degraded riparian pasture (trp),* and *hay without nutrients (hyo)*
Efficiency credited:	Landuse change to *hay without nutrients (hyo)* and reduction efficiency for upland areas.
Effectiveness estimate:	Varies geographically. TN: 13-46%(4x acres); TP: 30-45%(2x acres); TSS: 40-60%(2x acres). See table below.
Reference:	UMD/MAWP

Riparian Grass Buffers - Nutrient Reduction Effectiveness Estimates			
	TN	TP	TSS
Inner Coastal Plain	46%	42%	56%
Outer Coastal Plain Well Drained	21%	45%	60%
Outer Coastal Plain Poorly Drained	39%	39%	52%
Tidal Influenced	13%	45%	60%
Piedmont Schist/Gneiss	32%	36%	48%
Piedmont Sandstone	39%	42%	56%
Valley and Ridge - marble/limestone	24%	30%	40%
Valley and Ridge - sandstone/shale	32%	39%	52%
Appalachian Plateau	38%	42%	56%

6.5.9 Agricultural Wetland Restoration

The CBP uses the following definitions to classify wetland restoration on agricultural land and wetland creation:

Reestablishment (restore)—Manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a *former* wetland. Results in a gain in wetland acres.

Establishment (create)—Manipulation of the physical, chemical, or biological characteristics present to develop a wetland that did not previously exists on an upland or deepwater site. Results in a gain in wetland acres.

The literature search for this practice focuses only the water quality benefits that wetlands provide and literature on the wildlife, mitigation wetlands, and natural wetlands are not considered.

These wetland treatment system designs have an even flow distribution and adequate retention time. The temporal variability of water flow through wetlands also results in variability of water detention times, which in turn affects the removal efficiencies. The longer water is detained within a wetland the more material could be removed from the water within the wetland. As flow variability increases the effective water detention time decreases and therefore the removal efficiency decreases (Jordan et al. 2003). It is intuitively clear that a wetland with steady water flow is likely to have higher removal rate than a wetland with the same amount of annual flow concentrated during a few days of high flow. Understanding these temporal flow conditions is necessary to provide estimated effectiveness.

Practice components meet criteria standards under the USDA-NRCS 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 included in the Wetland Restoration Practices on Agricultural Land, and Wetland Creation include the following USDA-NRCS conservation practices:

- Constructed Wetland (656)
- Wetland Creation (658)
- Wetland Restoration (657)

Restored versus created wetlands

Agricultural wetland restoration activities re-establish the natural hydraulic condition in a field that existed before the installation of subsurface or surface drainage. In contrast, *wetland creation* establishes a wetland in a place where none previously existed. Created wetlands can use artificial or highly engineered hydrology. Often created wetlands have regulated water inputs, with water being pumped or fed in at steady controlled rates. In contrast, restored wetlands generally have natural or unregulated water inputs, with water entering through surface or subsurface flows at variable uncontrolled rates.

Wetlands that are created (new location), restored (re-establishing prior hydrology) or enhanced (changing wetland type) have the ability to filter nutrients and sediment from water before its release into an open water system. The reduction efficiency of a wetland as a filtering agent varies with season, vegetation, and water retention time.

The CBP uses drainage area to predict wetland creation and restoration effectiveness. Removal of total nitrogen and phosphorus by restored wetlands can be predicted from the relationship between the percentage of nitrogen or phosphorus removed and the percentage of the watershed occupied by wetland receiving discharge from the entire watershed. Following Simpson and Weammert (2007), CBP assumes that removal proceeds exponentially with detention time, as expected with first order kinetics, and also assumes that detention time (wetland volume divided by water flow rate) is proportional to the percentage of watershed occupied by wetland. This follows if water discharge is proportional to watershed area and if different wetlands have similar average depths. Finally, CBP assumes that there is no removal if there is no wetland area (i.e., the curve must go through the origin). Based on these assumptions:

$$\text{Removal} = 1 - e^{-k\,(\text{area})}$$

Where *removal* is the proportion (not percentage) of the input removed by the wetland, *area* is the proportion watershed area occupied by wetland, and *k* is a fitted parameter. A non-linear regression was used to fit this equation to data from studies reported in the literature.

When wetland area or drainage area is unreported CBP recommends the following.

Definition:	Agricultural wetland restoration activities reestablish the natural hydraulic condition in a field that existed before the installation of subsurface or surface drainage. Projects can include restoration, creation and enhancement acreage. Restored wetlands can be any wetland classification including forested, scrub-shrub or emergent marsh.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw), alfalfa (alf), pasture (pas), nutrient management conventional tillage without manure (nho), nutrient management conservation tillage with manure (nlo), nutrient management hay (nhy), nutrient management alfalfa (nal), nutrient management pasture (npa), degraded riparian pasture (trp),* and *hay without nutrients (hyo)*

Efficiency credited:	Efficiency
Effectiveness estimate:	Varies geographically. See table below.
Reference:	UMD/MAWP

TN and TP removal effectiveness estimates for wetlands broken down by geomorphic region.

Geomorphic Province	Area of wetland as % of watershed area	TN Removal Effectiveness Estimate	TP Removal Effectiveness Estimate	TSS Removal Effectiveness Estimate
Appalachian	1%	7%	12%	15%
Piedmont and Valley	2%	14%	26%	15%
Coastal Plain	4%	25%	50%	15%

The assigned percents for each geomorphic area are based on scientific understanding of the natural hydrology and geology found in each region and are used to determine the drainage area. The area of wetland as a percent of watershed area is then compared to the graph provided from the equation to determine TN removal and TP removal.

6.5.10 Conservation Tillage

Conservation tillage involves planting, growing, and harvesting crops with minimal disturbance to the soil surface. Conservation tillage is designed to reduce erosion and maintain or improve soil health properties. Conservation tillage increases infiltration by reducing surface sealing and enhancing macropore connectivity and flow. Conservation tillage techniques include minimum tillage, mulch tillage, ridge tillage, and no-till. No-till farming is a form of conservation tillage in which the crop is planted directly into vegetative cover or crop residue with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface. The Chesapeake Bay Watershed Model uses annual reports of conservation tillage acres (CTIC) and conservation tillage is explicitly modeled as a separate land use.

Conservation tillage systems have traditionally required two standard components: (a) a minimum of 30 percent of the soil surface covered by crop residue and/or organic residues immediately following the planting operation; and (b) a non-inversion tillage method. Direct field measurements are relied on to determine the percent residue covering the soil surface.

Conservation tillage is limited on slopes that are too steep for row crops because of potential for erosion and unsafe equipment operations. No-till poses a management problem on fields with poor drainage in heavy soils because of low soil temperature in the spring. Finally, the benefits of no-till will increase incrementally during the transition period from conventional to conservation tillage systems with the improvement of soil physical properties.

NRCS Practice Standards

Practice components meet criteria standards under the USDA-NRCS 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. Cultural components consisting of shorter term conservation measures included in the Conservation Tillage Practices definition include the following USDA-NRCS conservation practices:

- Residue and Tillage Management, Mulch Till (345)
- Residue and Tillage Management, No-Till/Strip Till/Direct Seed (329)
- Residue and Tillage Management, Ridge Till (346)

Traditional tillage methods included some form of inversion tillage equipment, loose soil surface and no crop residue. Those conditions result in nutrient and sediment loss during moderate to severe storm events. In addition, soil surface temperatures are high and moisture levels low.

A sufficient crop residue on the soil surface and the use of a non-inversion tillage practices, reduces the amount of loose surface soil and provides some protection against evaporation and high temperatures. The residue also acts as a barrier to storm event sheet flow reducing water velocity and improving infiltration. As a result, nutrient and sediment edge-of-field loss is substantially lower than under a conventional tillage system.

Pollution reduction mechanisms for conservation tillage are as follow (Dinnes 2004):

- Reduced erosion and transport of nutrient enriched sediment and particulate
- Improved water infiltration and nutrient (phosphorous) adsorption to soil matrix
- Improved stabilization of soil surface to impede wind and water erosion detachment and transport of nutrient enriched sediment and particulates
- Reduced volume of runoff water reaching surface waters
- Temporary nutrient sequestration in soil organic matter

The secondary benefits of conservation tillage are as follow (Dinnes 2004):

- Decreased evaporation/increased moisture retention
- Reduced production costs; Reduced equipment requirements with no-till
- Carbon sequestration
- Yield increases in slight to moderate drought years
- Reduced loss of sediment-bound pesticides and chemicals

Definition:	Conservation tillage involves planting and growing crops with minimal disturbance of the surface soil. Conservation tillage requires two components, (a) a minimum 30% residue coverage at the time of planting and (b) a non-inversion tillage method. No-till farming is a form of conservation tillage in which the crop is seeded directly into vegetative cover or crop residue with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without*

	manure (hom), and nutrient management conventional tillage without manure (nho)
Efficiency credited:	Land use change to *conservation tillage with manure (lwm)* and *nutrient management conservation tillage with manure (nlo)*
Effectiveness estimate:	N/A, directly simulated as a land use. Possible recommendation of: TN: 8%, TP: 22%, TSS: 30%
Reference:	UMD/MAWP

6.5.11 Carbon Sequestration and Alternative Crops

Definition:	Carbon Sequestration refers to the conversion of cropland to hay land (warm season grasses). The hay land is managed as a permanent hay land providing a mechanism for sequestering carbon within the soil. (Note: this practice has not be incorporating into the watershed model nor has specifications been developed for its use as an approved BMP)
Land use:	Row crops of *conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), nutrient management conventional tillage without manure (nho), conservation tillage with manure (lwm), and nutrient management conservation tillage with manure(nlo)*
Efficiency credited:	Landuse change to *hay without nutrients (hyo)*
Effectiveness estimate:	N/A, simulated as land use change.
Reference:	BMP Basics

6.5.12 Conservation Plans

Conservation Planning: Field and Pasture Erosion Control Practices are a combination of practices, other than conservation tillage or no-till, that reduces soil loss to or below tolerance. Practice components meet criteria standards under the USDA-NRCS 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. The practices help to control erosion and nutrient runoff by modifying cultural or structural practices. Cultural practices can change from year to year and include changes to crop rotations. The practices do not include reduction credits to certain cultural practice changes on crop or hay land, such as conservation tillage or cover crop practices which are credited as individual BMPs. However, cultural practice changes are reflected in pastureland reduction efficiencies. Structural components consisting of longer term conservation measures included in the *Field and Pasture Erosion Control Practices* include the following USDA-NRCS conservation practices. Note that credit cannot be taken for each practice implemented under a farm erosion and sediment plan or an NRCS Conservation Plan; the suite of practices listed in the plan are prescribed to meet a USDA-NRCS RUSLE2 prediction of soil losses at or below the soil loss tolerance value (T) for the accredited land acreage.

Applicable NRCS codes

- Access Road (560)
- Alley Cropping (311)
- Animal Trails and Walkways (575)
- Conservation Cover (327)
- Conservation Crop Rotation (328)
- Contour Buffer Strips (332)
- Contour Farming (330)
- Critical Area Planting (342)
- Diversion (362)
- Field Border (386)
- Filter Strip (393)
- Grade Stabilization Structure (410)
- Grassed Waterway (312)
- Lined Waterway or Outlet (468)
- Residue Management, Seasonal (344)
- Rock Barrier (555)
- Row Arrangement (557)
- Sediment Basin (350)
- Strip cropping (585)
- Structure for Water Control (587)
- Terrace (600)
- Underground Outlet (620)
- Water and Sediment Control Basin (638)
- Windbreak/Shelterbelt Establishment (380)

Many conservation practices are available to address soil movement, transport, and loss from agricultural fields. The practices used are site-specific based on site conditions, landowner operation, and land use. This situation makes it difficult to know the effect of any one conservation practice. Because conservation practices can be combined in any way to meet the individual field situation, it is not practical to establish practice efficiencies for individual field practices or combination of practices.

The one item all conservation plans have in common is their objective of reaching and maintaining an average soil loss level of *T*.

Definition:	Farm conservation plans are a combination of agronomic, management and engineered practices that protect and improve soil productivity and water quality, and to prevent deterioration of natural resources on all or part of a farm. Plans can be prepared by staff working in conservation districts, natural resource conservation field offices or a certified private consultant. In all cases, the plan must meet technical standards.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw), alfalfa (alf), pasture (pas), nutrient management conventional tillage without manure (nho), nutrient management conservation*

	tillage with manure (nlo), nutrient management hay (nhy), nutrient management alfalfa (nal), nutrient management pasture (npa), degraded riparian pasture (trp), and hay without nutrients (hyw)			
Efficiency credited:	Efficiency varies by land use			
Effectiveness estimate:	Land use	TN	TP	TSS
	conventional till	8	15	25
	conservation till	3	5	8
	hay	3	5	8
	pasture	5	10	14
Reference:	UMD/MAWP			

6.5.13 Land Retirement

Agricultural land retirement takes marginal and highly erosive cropland out of production by planting permanent vegetative cover such as shrubs, grasses, or trees. Agricultural agencies have a program to assist farmers in land retirement procedures. Land retired and planted to trees is reported under *Tree Planting*.

Definition:	Agricultural land retirement takes marginal and highly erosive cropland out of production by planting permanent vegetative cover such as shrubs, grasses, and/or trees. Agricultural agencies have a program to assist farmers in land retirement procedures.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw), alfalfa (alf), pasture (pas), nutrient management conventional tillage without manure (nho), nutrient management conservation tillage with manure (nlo), nutrient management hay (nhy), nutrient management alfalfa (nal), nutrient management pasture (npa), degraded riparian pasture (trp), and hay without nutrients (hyo)*
Efficiency credited:	Landuse change to either *hay without nutrients (hyo)* or *pasture (pas)* depending on the management practice applied.
Effectiveness estimate:	N/A, directly simulated as a land use change.
Reference:	BMP Basics

6.5.14 Poultry and Swine Phytase

Phytase can be injected into poultry feeds by the integrator or other feed suppliers. Manure phosphorous reductions occur because less phosphorous needs to be blended into feed rations, resulting in a phosphorous source reduction. A reduction up to approximately 30 percent in manure phosphorus might be possible under optimum conditions.

Definition:	Phytase can be injected into poultry feeds by the integrator or other feed suppliers. Manure phosphorous reductions occur because less phosphorous needs to be blended into feed rations, resulting in a

	phosphorous source reduction.
Land use/Animal type:	*Animal feeding operations (afo)* of broilers, pullets, layers, turkeys, sows, hogs for breeding, and hogs for slaughter.
Efficiency credited:	Application reduction
Effectiveness estimate:	Default: Broilers 16%; Layers 21%; Pullets 21%; Turkeys 16%; Sows and hogs 0%
Reference:	BMP Basics

6.5.15 Agricultural Water Control Structure

The Water Control Structure BMP consists of installing and managing boarded gate systems in agricultural land that contains surface drainage ditches. The ditch systems are often necessary in coastal plain regions to create agricultural land suitable for cultivation on flat topography. Load reduction occurs as the result of both volume reduction and nutrient concentration reduction. By desig, these drainage water control structures reduce the total volume of water flow. Also, the inorganic nitrogen concentrations in the drainage waters are reduced through denitrification or recycled for plant growth. As runoff occurs beyond the agronomic growing season, nitrogen continues to be reduced by denitrification. For application of this practice to the Chesapeake Bay region's coastal soils, a nitrogen reduction efficiency of 33 percent is provided for each managed and drained acre.

Proper installation and management of the boarded gate structures is critical to achieve the stated nitrogen reductions. Installation can be according to NRCS code number 537 and must include an operation and maintenance plan using the following methods: (1) maintain flashboard settings to retain storm runoff water levels within 30 inches of the ground surface along at least 50 percent of the upstream ditch reach all year; and (2) maintain flashboard settings to retain storm runoff water levels within 12–18 inches of the ground surface in winter if no small grain crop is present.

Definition:	Installing and managing boarded gate systems in agricultural land that contains surface drainage ditches.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw), alfalfa (alf), nutrient management conventional tillage without manure (nho), nutrient management conservation tillage with manure (nlo), nutrient management hay (nhy), nutrient management alfalfa (nal), and hay without nutrients (hyo)*
Efficiency credited:	Efficiency
Effectiveness estimate	TN: 33%
Reference:	WCS Reccs

6.5.16 Manure Transport

Alternative uses of manure/manure transport is the practice of reducing or eliminating excess nutrient applications within the Chesapeake Bay by either transporting the manure outside of the

Chesapeake Bay watershed or finding an alternative use for the excess manure. Excess manure is defined as manure nutrients produced within an area that exceeds the recommended application rates associated with the crops grown.

Definition:	Manure is transported by truck from the county of origin to another or out of the watershed. Manure transported to another county in the watershed results in increased manure mass in the receiving county
Land use/Animal type:	*Animal feeding operations (afo)* of beef heifers, dairy heifers, other cattle, hogs and pigs for breeding, hogs for slaughter, horses, broilers, layers, pullets, turkeys, sheep and lambs, milk goats, and angora goats.
Efficiency credited:	Application reduction
Effectiveness estimate:	N/A
Reference:	BMP Basics

6.5.17 Cover Crops (Early/Late/Standard)

This BMP refers to (non-harvested) cereal cover crops specifically designed for nutrient removal. This BMP is more prevalent in the lower Chesapeake Bay basin because of the longer growing season. The crops capable of nutrient removal include rye, wheat, barley, and to a lesser extent, oats. There is no BMP reduction credit for legume cover crops such as clover and vetch that fix their own nitrogen from the atmosphere.

Significant amounts of nitrogen can remain in the soil after harvest of summer annual crops such as corn, soybeans, and vegetables. Nitrate nitrogen is particularly subject to leaching toward groundwater if substantial nitrogen remains in the soil as crop uptake of the summer annual crop ceases. Fall nitrate nitrogen levels in soils are more pronounced following years of less crop nutrient uptake because of drought conditions. The cereal cover crops trap nitrogen in their tissues as they grow, provided root growth is sufficient to reach the available soil nitrogen.

This BMP also provides some benefit for sediment erosion control, particularly when established after low residue crops. The BMP is less effective in reducing phosphorus than sediment losses because some phosphorous is transported in water soluble forms in addition to particulate forms. Because corn does not sufficiently uptake nitrogen, cover crops are essential following moderate drought conditions. However, droughts can leave more nitrogen than the cover crop can trap. In years when rainfall has allowed excellent summer annual crop yields, cover crops are warranted because abundant soil nitrogen is available. Effectiveness is reduced when cover crops are established on very sandy soils where residual nitrate might have already migrated below the early rooting depth of a cover crop.

Small Grain Enhancement/Commodity Cover Crop

Commodity cereal cover crops differ from cereal cover crops because they can be harvested for grain, hay, or silage and can receive nutrient applications but only on or after March 1 of the spring following their establishment. The intent of the practice is to modify normal small grain production practices by eliminating fall and winter fertilization so that the crops scavenge available soil nitrogen similarly to cover crops for part of their production cycle. That can encourage planting of more acreage of cereal grains by providing farmers with the flexibility of planting an inexpensive crop in the fall and delaying the decision to either kill or harvest the crop according to crop prices, silage needs, weather conditions, and such, in the spring.

Planting Date Categories

Original planting dates established by the CBP were refined and a new category added. Revised planting dates better reflect breakouts associated with jurisdictional cover crop programs. Early planting of a fall established cereal cover crop is critical in achieving substantial uptake of nitrogen in the fall. Research indicates that nitrogen uptake and trapping ability diminished rapidly when planting dates extend beyond optimum planting dates. To be eligible for level 1 reduction credit, referred to as early planting, the cover crop must be planted earlier than 14 days before the long-term published average date of the first killing frost in the fall. To be eligible for level 2 reduction credit, called standard planting, the cover crop must be planted 14 days before the average frost date up to the published long-term average date of the first killing frost in the fall.

There are benefits of planting cover crops later than the first frost that become evident in the spring. To capture the limited benefit, a third planting date category, called late planting, that explores a cover crop BMP with a much discounted efficiency for planting from the first frost date and up to 3 weeks after is added. The BMP provides a highly discounted efficiency to either late planted wheat or rye, according to that crop’s benefit during spring growth. The BMP would need to be incorporated with a no-till drill system to receive any reduction credit.

To illustrate the different planting dates, on the Eastern Shore of the average first frost date is October 15, thus, early planting occurs up to October 1, standard planting occurs from October 1 to October 15, and late planting occurs October 16 to November 5.

The planting dates were revised from the late and early planting dates used for reporting by the jurisdictions. Original planting dates were defined as up to 7 days before published first frost date for early planted cover crops, and late planted cover crops were planted up to 7 days after the published first frost date. Previous and future cover crop acres reported will need to be categorized into the new early, standard, and late planting dates.

Planting date time frames are

Level One Early: Anything before 2 weeks before average frost date.

Level Two Standard: From 2 weeks before average frost date up to average frost date.

Level Three Late: From average frost date plus 3 weeks.

The pollutant reduction mechanisms of cover crops are (Dinnes 2004):

- Improved stabilization of soil surface to impede wind and water erosion detachment and transport of nutrient enriched sediment and particulates
- Improved water infiltration and nutrient adsorption to soil matrix
- Increased crop growing season for greater use of available nutrients
- Reduced in-field volume of runoff water
- Reduced erosion and transport of nutrient enriched sediments and particulates
- Temporary nutrient sequestration in soil organic matter

- Trapping and retention of transported nutrient enriched sediments and particulates
- Vegetative assimilation

Definition:	Cereal cover crops reduce erosion and the leaching of nutrients to groundwater by maintaining a vegetative cover on cropland and holding nutrients within the root zone. This practice involves the planting and growing of cereal crops (non-harvested) with minimal disturbance of the surface soil. The crop is seeded directly into vegetative cover or crop residue with little disturbance of the surface soil. These crops capture or “trap” nitrogen in their tissues as they grow. By timing the cover crop burn or plow-down in spring, the trapped nitrogen can be released and used by the following crop. Different species are accepted as well as, different times of planting (early, late and standard), and fertilizer application restrictions. Manure application on cover crops is not modeled and acres of cover crops that receive manure are not eligible. There is a sliding scale of efficiencies based on crop type and time of planting. Commodity cover crops differ from cereal cover crops in that they can be harvested for grain, hay, or silage and they might receive nutrient applications, but only after March 1 of the spring following their establishment. The intent of the practice is to modify normal small grain production practices by eliminating fall and winter fertilization so that crops function similarly to cover crops by scavenging available soil nitrogen for part of their production cycle.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure (nhi), conventional tillage without manure (hom), conservation tillage with manure (lwm), nutrient management conventional tillage without manure (nho)*, and *nutrient management conservation tillage with manure (nlo)*
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies greatly, see Simpson and Weammert (2008).
Reference:	UMD/MAWP

6.5.18 Continuous No-Till

The Continuous No-Till (CNT) BMP is a crop planting and management practice in which soil disturbance by plows, disk, or other tillage equipment is eliminated. In most cases, large amounts of crop residue are left on the surface to protect the soil from storm events. CNT involves no-till methods on all crops in a multi-crop, multi-year rotation. Also included with the CNT BMP will be other practices such as cover crops, nutrient management, and aspects of carbon sequestration. CNT is mutually exclusive of all other BMPs. Therefore, when an acre is reported under CNT, it will not be eligible for additional reductions from implementing other practices, such as cover crops or nutrient management planning. Implementing the CNT BMP system will result in the reduction of nonpoint source pollution to waters from nutrients and sediments. The purpose of the CNT BMP is to improve soil organic matter content and soil quality and reduce sediment and runoff with the use of no-till planting, and to use nutrient management indicators to manage the movement of nitrogen, and phosphorus.

Multi-crop, multi-year rotations on cropland are eligible. Crop residue should remain on the field. Planting a cover crop might be needed to maintain residue levels. Producers must have and follow a current nutrient management plan. The system must be maintained for a minimum of 5 years. All crops must be planted using no-till methods.

The Chesapeake Bay Watershed Model has conventional tillage crop land-uses and conservation tillage land-uses (30 percent crop residue or conservation tillage), but it does not have an explicit land use that defines the properties of continuous no-till. Since continuous no-till is considered a subset of conservation tillage it is necessary to calculate the effects of CNT as a reduction efficiency relative to the efficiency already achieved by the conservation tillage land use.

Definition:	The Continuous No-Till (CNT) BMP is a crop planting and management practice in which soil disturbance by plows, disk or other tillage equipment is eliminated. CNT involves no-till methods on all crops in a multi-crop, multi-year rotation. When an acre is reported under CNT, it will not be eligible for additional reductions from the implementation of other practices such as cover crops or nutrient management planning. Multi-crop, multi-year rotations on cropland are eligible. Crop residue should remain on the field. Planting of a cover crop might be needed to maintain residue levels. Producers must have and follow a current nutrient management plan. The system must be maintained for a minimum of five years. All crops must be planted using no-till methods.
Land use:	*conservation tillage with manure (hwm) and nutrient management conservation tillage with manure (nhi)*
Efficiency credited:	Efficiency
Effectiveness estimate:	Varied by geography within the following ranges; TN: 10-15%; TP: 20-40%; TSS: 70%
Reference:	CNT Report

6.5.19 Ammonia Emissions Reduction

Biofilters are composed of housing ventilation systems that pass air through a biofilter media that incorporates a layer of organic material, typically a mixture of compost and wood chips or shreds that supports a microbial population and reduces ammonia emissions by oxidizing volatile organic compounds into carbon dioxide, water, and inorganic salts. A biofilter system can be, and is, applied to various species including poultry, swine, and dairy.

Treatment effectiveness depends on many factors such as, moisture levels, filter median type/pore size, and detention time. Nicolai and Janni (1998) showed to achieve successful treatment, biofilters must have a sufficient detention time and fans that can accommodate pressure loss through the biofilter; moisture content of the filter media must remain between 40–70 percent; and biofilters must be composed of a media mixture range from 30:70 to 50:50 ratio by weight of compost and wood chips or other inert fill materials. Their research showed no difference between 4-second and 6-second detention times, or 4 seconds and 8 seconds, but detention times of less than 4 seconds will affect performance.

In addition to the nutrient benefits, biofilters also have the potential to provide other co-benefits including

- Filters also retain or trap particles
- Reduce odor, microbial bioaerosol and hydrogen sulfide emissions

Covers: There are two categories of covers, permeable and impermeable, each composed of various materials. Permeable covers include straw, geotextile, clay balls, perlite, rigid foam, oil, natural crust, and organic materials (corn stalks, sawdust, wood shavings, rice hulls, ground corncobs, and grass clippings). Impermeable covers include inflatable plastic (positively pressurized), floating plastic (negatively pressurized), floating plastic, suspended plastic, concrete, and wood/steel. A cover can be, and is, applied to various species including swine and dairy. This report focuses on permeable plastics that cover liquid lagoons, in particular geotextiles, because they are most widely implemented throughout the Chesapeake Bay watershed.

Using permeable plastics composed of nonwoven fabric, thermally bonded, continuous polypropylene filaments, covers create a physical barrier to prevent mass transfer of volatile chemical compounds from the liquid by covering manure storage facilities to decrease wind velocity (decrease surface area), and reduce radiation onto the manure storage surface (lower temperature). Permeable covers act as biofilters at the manure/air interface by physically limiting the emissions of ammonia and other gases from the surface of storage lagoons and create a biologically active zone where the emitted ammonia and other gases will be aerobically decomposed by microorganisms.

There are many advantages to geotextiles. They have low costs, are relatively effective at odor and gas reductions and are resistant to rot, moisture, and chemical attack. Their disadvantages include a short life time, decreases in performance over time, costly disposal, can become submerged, and safety is a main issue during agitation and pumping.

Straw covers are not recommended because they cannot be managed in a way that does not result in the release of ammonia when land applied. Future development of straw covers should include application methods to overcome that barrier. Note that while there are active management systems that draw and trap greenhouse gases (methane), this practice uses static covers that do not trap methane.

In addition to the water and air quality benefits, covers also have the potential to provide other co-benefits, such as reducing the transfer of hydrogen sulfide and other odorous compounds.

Vegetative Filter: Vegetative barrier planted near poultry houses in the direct path of fan discharge. Intercepts high ammonia concentrations leaving the production facility, prevents or minimizes local deposition.

Litter treatment: a surface application of an acidifier to poultry litter to acidify poultry litter and maintain ammonia in the non-volatile ionized form (ammonium). One approach is to incorporate acidifying agents such as aluminum sulfate (alum), sodium bisulfate, acidified clay, calcium chloride, calcium sulfate, magnesium chloride, and magnesium sulfate. Litter treatments create an acidic environment resulting in more ammonium forming and less ammonia volatilizing. Alum also reduces phosphorus runoff by precipitating soluble phosphorus. To receive ammonia emission reduction credit alum must be applied at a rate of 250 lbs/1,000 square feet.

In addition to the nutrient benefits, litter treatment also has the potential to provide other co-benefits including

- Improved air quality for poultry living and humans working in confined spaces leading to improved poultry health and performance as some amendments suppress bacterial pathogens and pests (darkling beetles) and expose to ammonia levels can damage the bird's respiratory system, and also result in poor body weight, feed efficiency, and condemnation rate
- Reduced or altered ventilation resulting in potential energy savings
- Increased proportion of nitrogen in the manure, creating a more valuable macronutrient ratio
- Reduced runoff of soluble phosphorus from land applied litter because of phosphorus sorption by alum.

Description:	Litter amendments like alum suppress the formation of ammonia from ammonium in litter. Biofilters attached to animal enclosure ventilation systems detoxify ammonia. Geotextile manure covers reduce surface area and temperature of manure, therefore preventing ammonia volatilization.
Land use/Animal Type:	*Animal feeding operations (afo)* of beef heifers, dairy heifers, other cattle, hogs and pigs for breeding, hogs for slaughter, horses, broilers, layers, pullets, turkeys, sheep and lambs, milk goats, and angora goats.
Efficiency credited:	Application reduction
Effectiveness estimate:	Alum TN 50%; Biofilters TN 60%; Geotextile covers TN 15%
Reference:	UMD/MAWP

6.5.20 Alternative Watering Facilities

This BMP requires the use of alternative drinking water sources away from streams to reduce the time livestock spend near and in streams and streambanks reducing direct manure deposition to streambeds and banks and reducing riparian area erosion.

Off-Stream Watering without Fencing (remote livestock watering system alone) is a standalone BMP and is not applied to the same acre as upland prescribed grazing or upland precision intensive rotational grazing, nor can it be applied in conjunction with Off-Stream Watering with Fencing as it is assumed to be a benefit to the livestock stream access corridor when exclusion occurs. This BMP is applied against the pasture land use loadings as this is how this BMP has been tracked and reported.

Applicable NCRS Codes:

Practice components meet criteria standards under the USDA-NRCS 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 included in the Off-stream Watering with Fencing Practices include the following USDA-NRCS conservation practices:

- Heavy Use Area Protection (561)
- Pipeline (516)
- Pond (378)
- Pumping Plant (533)
- Spring Development (574)
- Streambank and Shoreline Protection (580)
- Stream Crossing (578)
- Use Exclusion (472)
- Water Harvesting Catchment (636)
- Water Well (642)
- Watering Facility (614)

Note that credit cannot be taken for each practice; one or a suite of practices might be required to meet the definition of Off-stream Watering without Fencing Practices for the credited land acreage.

Definition:	Alternative watering facilities typically involves the use of permanent or portable livestock water troughs placed away from the stream corridor. The source of water supplied to the facilities can be from any source including pipelines, spring developments, water wells, and ponds. In-stream watering facilities such as stream crossings or access points are not considered in this definition. The modeled benefits of alternative watering facilities can be applied to pasture acres in association with or without improved pasture management systems such as prescribed grazing or PIRG. They can also be applied in conjunction with or without stream access control.
Land use:	*nutrient management pasture (npa)* and *pasture (pas)*
Efficiency credited:	Efficiency
Effectiveness estimate	TN: 5%, TP: 8%, TSS: 10%
Reference:	UMD/MAWP; Pasture science panel Reccs 3/18/10, BMP Basics

6.5.21 Stream Access Control with Fencing

Off-Stream Watering with Fencing consists of stream exclusion with remote livestock watering system or protected stream access, and it is applied to the degraded stream corridor land use.

- If the stream corridor excluded is less than 35 feet wide from top-of-bank to fence line, a land use change converts acres of degraded stream corridor land use to grass without nutrients if grass; or forest if trees are planted and tracked and reported as such.
- If the stream corridor excluded is 35 feet or wider from top-of-bank to fence line, the land use change converts acres as noted above, plus includes a grass or forested riparian buffer BMP if tracked and reported separately. This BMP includes a ratio of upslope treatment area that is additive to any other pasture management efficiencies within that treatment area.
- The default values for converted degraded stream corridors that do not have documented land use or width considerations will use the most conservative values; i.e. acreage conversion to grass without nutrients land use based on a 15-foot exclusion width. This would produce a land use change BMP converting the degraded stream corridor to grass without nutrients.

Definition:	Stream access control with fencing involves excluding a strip of land with fencing along the stream corridor to provide protection from livestock. The fenced areas may be planted with trees or grass, or left to natural plant succession, and can be of various widths. To provide the modeled benefits of a functional riparian buffer, the width must be a minimum of 35 feet from top-of-bank to fence line. If an entity is installing a riparian buffer practice in conjunction with stream protection fencing, and can track and report these installations, additional upland benefits of those riparian buffers can be applied in the model. The implementation of stream fencing provides stream access control for livestock but does not necessarily exclude animals from entering the stream by incorporating limited and stabilized in-stream crossing or watering facilities. The modeled benefits of stream access control can be applied to degraded stream corridors in association with or without alternative watering facilities. They can also be applied in conjunction with or without pasture management systems such as prescribed grazing or PIRG.
Land use:	*degraded riparian pasture (trp)*
Efficiency credited:	Landuse change to *hay without nutrients* and efficiency applied to upland areas.
Effectiveness estimate:	Varies geographically TN: 13-46%(4x acres); TP: 30-45%(2x acres); TSS: 40-60%(2x acres)
Reference:	UMD/MAWP; Pasture science panel Reccs 3/18/10

6.5.22 Decision Agriculture

In practice, decision agriculture includes a broad suite of BMPs, and many are tracked and reported separately for the CBP and are credited there. Those BMPs reduce nitrogen loss, but are not credited under NUE, and include conservation tillage, crop rotation, cover crops, conservation plans, and nutrient management with incorporation or injection (NRCS 2007). This report concentrates on improved nutrient use efficiency and captures only the elements that relate to it. Examples of decision agriculture components include the following (Fixen 2005a, 2005b):

Crop Testing: detect nitrogen excess through use of a leaf color chart, corn stalk nitrate test or real time chlorophyll measurement for variable rate application. The test provides a report card on that season's NUE, taken in the fall, and provides very helpful feedback for determining rates, timing, and form for the next year.

Crop Nutrient Removal: Evaluate the gap between application and removal to maintain existing soil fertility levels through the use of charts to software.

Soil Testing: Measure soil nutrient supplying capacity to understand within field variability in soil test levels and select appropriate nutrient rate. Those results should be turned into fertilizer rate maps.

Plant and Grain Analysis: Real-time sensing of plant and grain characteristics to evaluate past nutrient management practices and produce protein maps to manage fertilizer application on a site-specific basis

Nutrient Response Measurement: Measure response to each nutrient in question with controlled experiments to refine nutrient management decisions

Economic Analysis: Analyze relationship between nutrient use decisions, yield potential, and production costs

Nutrient Source Integration: Assists in developing manure management plans to reduce the probability of water quality impairments, automates manure application records, and estimates supplemental fertilizer needs.

Environmental Risk Assessment: Environmental risk assessment reviews a specific site for its potential to impair water quality on the basis of location and transport factors

Aerial Imagery and Strip Trials (On-Farm Network 2008): When taken near the end of the growing season, aerial photos highlight the spatial variability across the field so farmers can avoid sampling in areas where planter or applicator skips, diseased or pest damaged areas, weedy patches and other non-uniform areas are responsible for spatial variability. Replicated nitrogen fertilizer strip trials are several side-by-side strips the length of a field, where farmers estimate yield differences between treatments and confirm whether the variability observed in the imagery can be attributed to nitrogen by coupling yield monitors with GPS. To provide value, strip trials need to be replicated with at least three repetitions per trial. If replicated strip trials are not feasible or growers do not have yield monitors with GPS results of stalk nitrate testing can help interpret and independently verify yield responses observed from aerial imagery or according to observed areas that appear to be under stress.

Stalk nitrate tests (On-Farm Network 2008): Stalk nitrate tests, by testing previous management activities and intensities, are the best way to guess optimal nitrogen rate. End-of-the-season stalk nitrate test shows if too low or deficient, marginal, optimal, or excess nitrogen was available to produce optimal grain yields. Use test results to improve NUE by sharing results with other local farmers with stalk results to compare their individual results to those of the group and work with specialists (extension, NRCS, consultants, researchers) familiar with the test.

Definition:	A management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield for optimum profitability, sustainability, and protection of the environment.
Land use:	*conventional tillage with manure (hwm), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw),* and *alfalfa (alf)*
Efficiency credited:	Efficiency and landuse change to nutrient management equivalent
Effectiveness estimate:	TN: 4% is applied after landuse change
Reference:	NRCS practice Precision Ag

6.5.23 Enhanced Nutrient Management

Enhanced nutrient management matches nutrient availability (from all sources) to crop need according to the long-term average yield. The objective is to balance crop uptake with nutrient availability, resulting in zero residual nutrients. Because weather is highly variable, there could be a slight decrease in yield in any one year.

The nitrogen and phosphorus recommendations used in conventional nutrient management planning are approximately 30 percent higher than what is needed to meet crop need. That is done to ensure nutrient availability as the plant grows. Under average growing conditions and average yield, approximately 30 percent of the applied nutrients will not be used by the crop. In exceptional years, yields will increase until available nutrients are depleted. In drought years, residual nutrients will be greater than the expected 30 percent. Residual nutrients will likely leave the field before the next growing season either through leaching or surface runoff, assuming no use of cover crops. That condition adversely affects off-site water quality and nutrient costs the following year.

Matching crop uptake with available nutrients (from all sources) on the basis of the long-term average yield, assumes an accurate estimation of residual (in soil) nutrients and crop uptake rate (yield). Under-estimating either condition will result in a yield loss for that year.

For that reason, some type of incentive or crop (yield) insurance is likely necessary to offset the risk of yield loss.

Definition:	Based on research, the nutrient management rates of nitrogen application are set approximately 35% higher than what a crop needs to ensure nitrogen availability under optimal growing conditions. In a yield reserve program using enhanced nutrient management, the farmer would reduce the nitrogen application rate by 15%. An incentive or crop insurance is used to cover the risk of yield loss. This BMP effectiveness estimate is based on a reduction in nitrogen

	loss resulting from nutrient application to cropland 15% lower than the nutrient management recommendation. The effectiveness estimate is based on conservativeness and data from a program run by American Farmland Trust.
Land use:	*conventional tillage with manure (hwm), conventional tillage without manure (hom), conservation tillage with manure (lwm), hay-fertilized (hyw),* and *alfalfa (alf)*
Efficiency credited:	Efficiency and landuse change to nutrient management equivalent.
Effectiveness estimate:	TN: 7% is applied after landuse change.
Reference:	UMD/MAWP

6.5.24 Horse Pasture Management

Horse pasture management includes maintaining a 50 percent pasture cover with managed species (desirable inherent) and managing high traffic areas. High traffic area management is used to reduce the highest load contributing areas associated with pasture lands, and maintaining a 50 percent cover will improve the pasture to further reduce erosion and nutrient loss. High traffic areas are concentration areas within the pasture where the grass is sparse or nonexistent. Those often are feeding areas, such as hay deposits around fence lines. The areas are treated as sacrifice areas.

Horse pasture management does not include off-stream watering with and without fencing; instead, the stream protection BMPs are credited as separate practices. Where pastures are in contact with a stream, managing animal contact to the stream is necessary. The dominant source of nutrient and sediment loss from pasture lands is associated with animal contact with the stream. Also, overstocking causes many nutrient and sediment problems. Horse pasture management plans should include pasture management, heavy use area improvement, and management of stocking densities.

Definition:	Stabilizing overused small pasture containment areas (animal concentration area) adjacent to animal shelters or farmstead.
Land use:	*pasture (pas)* and *nutrient management pasture (npa)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: N/A TP: 20% TSS: 40%
Reference:	UMD/MAWP

6.5.25 Prescribed Grazing

Prescribed grazing, which typically includes forms of rotational grazing, limits the manure load and other impacts of livestock to pasture. Other benefits of this BMP system include improved infiltration/runoff characteristics, healthier grass stands, reduced need for fertilizers or other inputs, and reduced erosion.

This BMP uses pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes or other degraded areas of the upland pastures. This BMP is applied to upland pasture acres *not* associated with streams, or with streams with livestock exclusion fencing. Other benefits of this part of this BMP system include improved infiltration/runoff characteristics, healthier grass stands, reduced need for fertilizers or other inputs, and reduced erosion.

Definition:	This practice utilizes a range of pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas. Prescribed grazing can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank). The modeled benefits of prescribed grazing practices can be applied to pasture acres in association with or without alternative watering facilities. They can also be applied in conjunction with or without stream access control. Pastures under the proscribed grazing systems are defined as having a vegetative cover of 60% or greater.
Land use:	*pasture (pas)* and *nutrient management pasture (npa)*
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies geographically: TN: 9-11%, TP: 24%, TSS: 30%
Reference:	Pasture science panel Reccs 3/18/10

6.5.26 Precision Intensive Rotational Grazing

This BMP uses pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes or other degraded areas of the upland pastures. This BMP is applied to upland pasture acres *not* associated with streams, or with streams with livestock exclusion fencing. This BMP requires intensive management of livestock rotation similar to Managed Intensive Grazing systems (MIG) that have very short rotation schedules. Other benefits of this part of this BMP system include improved infiltration/runoff characteristics, healthier grass stands, reduced need for fertilizers or other inputs, and reduced erosion.

Definition:	This practice utilizes more intensive forms pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas of the upland pastures. Precision intensive rotational grazing (PRIG) can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank). The modeled benefits of the PIRG practice can be applied to pasture acres in association with or without alternative watering facilities. They can also be applied in conjunction with or without stream access control. This practice requires intensive management of livestock rotation, also known as Managed Intensive Grazing systems (MIG), that have very short

	rotation schedules. Pastures are defined as having a vegetative cover of 60% or greater.
Land use:	*pasture (pas)* and *nutrient management pasture (npa)*
Efficiency credited:	Efficiency
Effectiveness estimate:	Varies geographically: TN: 9-11%, TP: 24%, TSS: 30%
Reference:	Pasture science panel Reccs 3/18/10

6.6 Forestry Management Practices

6.6.1 Forest Harvesting Practices

Commercial tree harvest operations disturb ground cover, expose soil, and open the forest floor to direct sunlight and rainfall. Log landings, skid trails, and haul roads are the primary areas of disturbance. A system of integrated conservation practices will prevent off-site sediment impact, protect stream crossings, and neutralize stormwater runoff, provided they are installed in the proper location, meet design specifications, and are maintained.

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

Forest harvesting practices compose a suite of practices that reduce sediment and nutrient pollution to water bodies originating from forest harvesting activities at managed levels. Such activities include road, trail, and landing construction, use, and closure; harvesting and log removal activities; and site preparation or within-rotation treatments.

Components consisting of conservation measures included in the Forest Harvesting Practices definition include the following USDA-NRCS conservation practices:

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

(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.
Actual annual harvested (disturbed) forest acreage is unknown, so individual county percentages are provided by the Forestry workgroup.

Definition:	Forest harvesting practices are a suite of BMPs that minimize the environmental impacts of road building, log removal, site preparation, and forest management. These practices help reduce suspended sediments and associated nutrients that can result from forest operations.
Land Use:	*harvested forest(hvf)* and *forests, woodlots, and wooded (for)*
Efficiency Credited	Efficiency
Effectiveness	TN: 50%, TP: 60%, TSS: 60%

Estimate	
Reference	UMD/MAWP

6.7 Urban Practices

6.7.1 Dry Detention and Extended Detention Basins

Dry extended detention (ED) basins are depressions created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Dry ED basins are designed to dry out between storm events, in contrast with wet ponds, which contain standing water permanently. As such, they are similar in construction and function to dry detention basins, except that the duration of detention of stormwater is designed to be longer, theoretically improving treatment effectiveness. In the literature, dry ED basins are often lumped with, or considered as, dry detention basins. However, some sources clarify that dry ED basins have specific structures that act to retain stormwater for some minimum period (e.g., 24 hours) following a storm event, using a secondary low-flow orifice feature. Dry detention basins are distinguished from dry extended detention basins in that the design of the latter uses a control low flow outlet that releases water over a given period. A dry detention basin does not use a low-flow outlet directly discharging to the stream and retaining water for a shorter period than the dry extended detention basin design.

The surface of the detention basin itself often consists of planted grass or can consist of concrete or some other liner. The grassed surfaces require periodic mowing but can improve trapping of sediments compared with smooth surfaces such as concrete, and can allow infiltration of stormwater if the underlying soil is permeable. Ancillary treatment structures such as wetlands or permanent pools can also be built in series with dry ED basins, an arrangement sometimes referred to as a *treatment train.*

The water quality functions of dry extended detention ponds operate primarily by removing suspended particles via settling because of decreased water velocity. If plants such as grasses are present, they can further reduce velocity by increasing roughness of the surface. Nitrogen and phosphorus can be removed via settling of particulate forms and plant and microbial uptake. Phosphorus can also sorb to soil particles. Significant removal of nitrate is unlikely because the aerobic soil conditions are not favorable to microbial denitrification. These stormwater BMPs are designed to store surface runoff water and release it slowly to streams, attenuating flood peaks resulting from storms. That hydrologic function of detention basins is often considered a water quality function that helps to reduce stream channel incision, bank erosion, and loss of in-stream habitat structures that is typical of streams in urban areas with extensive watershed areas covered by impervious surfaces such as building, roads, and parking lots (Schueler 1994).

Definition:	Dry extended detention (ED) basins are depressions created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Dry ED basins are designed to dry out between storm events, in

	contrast with wet ponds, which contain standing water permanently. As such, they are similar in construction and function to dry detention basins, except that the duration of detention of stormwater is designed to be longer, theoretically improving treatment effectiveness.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul), low-intensity developed impervious (iml),* and *combined sewer system (css)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 20%, TP: 20%, TSS: 60%
Reference:	UMD/MAWP

6.7.2 Dry Detention Basins and Hydrodynamic Structures

Dry detention basins are depressions or basins created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Dry detention ponds are designed to dry out between storm events, in contrast with wet ponds, which contain standing water permanently. The surface of the detention basin itself often consists of planted grass or can consist of concrete or some other liner. The grassed surfaces require periodic mowing but can improve trapping of sediments compared with smooth surfaces such as concrete and can also allow infiltration of stormwater if the underlying soil is permeable. Structures to reduce flow velocity such as rock berms can also be included, for example as seen in the second photograph above. Dry detention basins can also consist of belowground tanks or vaults that temporarily store stormwater.

Hydrodynamic structures are devices designed to improve quality of stormwater using features such as swirl concentrators, grit chambers, oil barriers, baffles, micropools, and absorbent pads that are designed to remove sediments, nutrients, metals, organic chemicals, or oil and grease from urban runoff. These are generally proprietary devices such as Stormceptor®, StormVault®, and Vortechs® that are installed belowground, thereby allowing use of aboveground space for parking or other uses. They also can be effective in removing contaminants that are not removed by less highly-engineered systems. However, they can also require greater maintenance than other BMPs and might not be economical for large runoff volumes.

The water quality functions of dry detention ponds operate primarily by removing suspended particles via settling because of decreased water velocity. If plants such as grasses are present, they can further reduce velocity by increasing roughness of the surface. Nitrogen and phosphorus can be removed via settling of particulate forms and plant and microbial uptake. Phosphorus can also sorb to soil particles. Significant removal of nitrate is unlikely because the aerobic soil conditions are not favorable to microbial denitrification. These stormwater BMPs are designed to store surface runoff water and release it slowly to streams, attenuating flood peaks resulting from storms. This hydrologic function of detention basins is often considered a water quality function that helps to reduce stream channel incision, bank erosion, and loss of instream habitat structures that is typical of streams in urban areas with extensive watershed areas covered by impervious surfaces such as building, roads, and parking lots (Schueler 1994).

Detention basins provide little habitat value for organisms other than soil invertebrates, and if they are constructed from cement, even that function is negligible. Hydrodynamic structures provide essentially zero habitat other than for microbial communities.

A number of definitions of various configurations of urban dry detention basin and hydrodynamic structure BMPs have been developed. Those include

- Dry detention ponds and hydrodynamic structure practices are used to moderate flows and remain dry between storm events. These are storm water design features that provide a gradual release of water to increase the settling of pollutants and protect downstream channels from frequent storm events. A variety of products for these storm water inlets known as swirl separators, or hydrodynamic structures, are modifications of the traditional oil-grit separator and include an internal component that creates a swirling motion as storm water flows through a cylindrical chamber. These designs allow sediment to settle out as storm water moves in this swirling path. Additional compartments or chambers are sometimes present to trap oil and other floatables (CBP 2006).
- Dry Pond: Designed to moderate influence on peak flows and drains completely between storm events (Idaho Department of Environmental Quality 1998).
- Underground Dry Detention Facility: Designed to dry out between storms and provides storage below ground in tanks and vaults (Idaho Department of Environmental Quality 1998).
- Hydrodynamic structures are not considered a standalone BMP. They act similar to a dry detention pond and, therefore, are included in this group.

Definition:	<u>Dry detention basins</u> are depressions or basins created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. <u>Hydrodynamic structures</u> are devices designed to improve quality of stormwater using features such as swirl concentrators, grit chambers, oil barriers, baffles, micropools, and absorbent pads that are designed to remove sediments, nutrients, metals, organic chemicals, or oil and grease from urban runoff.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul), low-intensity developed impervious (iml)*, and *combined sewer system (css)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 5%, TP: 10%, TSS: 10%
Reference:	UMD/MAWP

6.7.3 Erosion and Sediment Control of Construction Sites

Developing land for industrial, commercial, or residential uses include activities such as clearing and grading. Removing vegetation and disturbing soil from development and construction leave soil exposed and susceptible to erosion by wind and water. Nitrogen and phosphorus can also be transported from development sites via adsorption to eroded soil particles or dissolution in runoff from exposed areas. Erosion and sediment control practices protect water resources from sediment pollution and increases in runoff associated with land development activities. By retaining soil on-site, sediment and attached nutrients are prevented from leaving disturbed areas and polluting streams.

The water quality functions of erosion and sediment control BMPs result from diversion of surface runoff treatment areas (e.g. using terracing, berms, or swales), reducing water velocity (e.g., using check dams), filtration (e.g., by silt fences), and by removing suspended particle via settling or infiltration. Grasses are often planted on exposed soils, sometimes stabilized with nets or mats, to reduce erosion, and in swales to reduce velocity by increasing roughness of the surface. Nitrogen and phosphorus can be removed via settling of particulate forms and plant and microbial uptake. Phosphorus can also sorb to soil particles. Significant removal of nitrate is unlikely because the aerobic soil conditions are not favorable to microbial denitrification (an exception would be sediment ponds with permanent standing water). The combined effect of these types of BMPs are likely to promote infiltration, reduce runoff velocity, and store surface runoff water, attenuating flood peaks resulting from storms. That hydrologic function is considered a water quality function that helps to reduce stream channel incision, bank erosion, and loss of in-stream habitat structures that is typical of streams in urban areas with extensive watershed areas covered by impervious surfaces such as building, roads, and parking lots (Schueler 1994).

Definition:	Erosion and sediment control practices protect water resources from sediment pollution and increases in runoff associated with land development activities. By retaining soil on-site, sediment and attached nutrients are prevented from leaving disturbed areas and polluting streams.
Land use:	*bare-construction (bar)* and *low-intensity developed pervious (pul)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 25%, TP: 40%, TSS: 40%
Reference:	UMD/MAWP

6.7.4 Urban Filtering Practices

Urban filtering practices capture and temporarily store runoff and pass it through a filter bed of either sand or an organic media. There are various sand filter designs, such as aboveground, belowground, and perimeter designs. An organic media filter uses another medium besides sand to enhance pollutant removal for many compounds because of the increased cation exchange capacity achieved by increasing the organic matter. The systems require yearly inspection and maintenance to receive pollutant reduction credit.

If the media are periodically removed and replaced, effectiveness is maintained, if filters are not replaced they will likely clog or leach pollutants. Organic filters are more effective at removing heavy metals but can leach nutrients if the organic matter begins to break down. Research shows sand filters have negligible retention (Strecker et al. 2004). With organic filters, sites can achieve higher retention. Therefore, no runoff reduction is associated with filters. The systems filter materials and then water is returned to the conveyance system. If runoff is first filtered and then infiltrated, the BMP becomes an infiltration BMP. Other benefits include heavy metal removal with organic media.

Maintenance: Filter performance will become zero without maintenance. They can clog within 6 months, and the pollutant removal values used here are based on at least annual inspection and maintenance to ensure proper performance. Filters require at least yearly inspection. Sediment and floatable contaminants should be removed, and periodic replacement of filter media is needed.

Definition:	Practices that capture and temporarily store runoff and pass it through a filter bed of either sand or an organic media. There are various sand filter designs, such as above ground, below ground, perimeter, etc. An organic media filter uses another medium besides sand to enhance pollutant removal for many compounds due to the increased cation exchange capacity achieved by increasing the organic matter. These systems require yearly inspection and maintenance to receive pollutant reduction credit.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul), low-intensity developed impervious (iml), combined sewer system (css),* and *extractive - active/abandoned mines (ext)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 40%, TP: 60%, TSS: 80%
Reference:	UMD/MAWP

6.7.5 Urban Infiltration Practices with Sand and/or Vegetation

This practice is characterized by a depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems provide complete infiltration. Design specifications require infiltration basins and trenches to be built in good soil; they are not constructed on poor soils, such as C and D soil types. Engineers are required to test the soil before approved to build is issued. To receive credit over the longer term, jurisdictions must conduct yearly inspections to determine if the basin or trench is still infiltrating runoff. Other benefits include heavy metal removal, runoff reduction, and groundwater recharge.

Effectiveness (applied to the runoff from acres treated):
From a removal perspective, infiltration basins and trenches function like sand filters.
It is difficult to monitor actual pollutant removal because the water is infiltrating below the surface and only a portion of it is captured. The pollutant removal for infiltration basins and trenches is equated to the sand filter value.

Some basins/trenches are lined with rocks, while some have vegetation. Systems solely lined with rocks have some TSS and TP removal. Rock-lined basins have a layer of soil; thus, TP is removed, but without vegetation, TN is not removed. The ideal basin has no surface discharge, with 100 percent infiltration. With larger events, some surface overflow or bypass occurs, and no treatment results for the overflow. What is infiltrated captures most of the TSS moving through the system, some TP removal occurs, but very little TN is removed.

Runoff reduction is estimated to be 80 percent on the basis of CWP (2008) memo. The table shows a runoff reduction range of 60–90 percent with CWP best professional judgment range of 50–90 percent. The 50 percent, however, is for sites where an underdrain must be used. The CBP assumes that basins and trenches are not constructed on sites needing to use an underdrain, given the intent of the practice. Assuming the practice is designed with adequate pretreatment and soil infiltration testing, 80 percent RR is used and is a more conservative value than the 90 percent assigned by CWP (2008).

The CWP technical memo recommends 25 percent for TP and 15 percent for TN. A 15 percent reduction in TN is used here for systems with sand or vegetation, and 0 percent TN removal for systems without sand or vegetation, to be consistent with the other infiltration and filtration BMPs in this report and to be conservative.

A PR of 95 percent for TSS is assigned on the basis of infiltration numbers from the University of New Hampshire Stormwater Center 2007 annual report.

$TR = RR + \{(100 - RR) \times PR\}$

Where:
TR – total removal
RR – runoff removal
PR – pollutant removal

Total removal:
TSS: $80 + \{(100\text{-}80) \times .95\} = 95$
TP: $80 + \{(100\text{-}80) \times .25\} = 85$
TN with sand and/or vegetation: $80 + \{(100\text{-}80) \times 15\} = 85$
TN without sand and/or vegetation: $80 + \{(100\text{-}80) \times 0\} = 80$
Values are rounded down to the nearest factor of 5

Error Bars:
Because of the lack of research on infiltration basins and trenches compared to other infiltration techniques, sand filter error bar values are used as infiltration basins and trenches function like a sand filter:
TN 10
TP 15
TSS 10 – as the TR value is 95 percent, crop the +10 to +5 so TR is not above 100 percent

Maintenance:

Because infiltration is the main mechanism that reduces runoff and pollutants, maintaining infiltration is critical. As clogging occurs, flow begins to bypass the BMP. Such systems will capture much sediment, so maintenance is key.

Factors that Create Variability in Performance

Shut off event for all infiltration and filtration practices:

Most BMPs are designed for a 1-inch storm event to capture the water quality volume. With a 1.5-inch to 2-inch rain event, all practices begin to show bypass flow or overflow. Some sites can handle more runoff but after 1 inch, most sites become inundated. To determine the sizing criteria and water quality rainfall depth, engineers work backward starting with the total impervious area. The CBP Watershed Model shuts down treatment for all flow beyond 1 inch.

Effectiveness Estimate—Range of values

Equation Used to Determine Effectiveness Estimates:

TR = RR + {100 – RR) × PR}

TR – total removal

RR – runoff removal

PR – pollutant removal

Tiered approach to range:

Starting with year 2 and continuing on, use a random sampling of the range as done for the range of performance values for nutrients.

For TSS pollutant removal, initial (first year) instillations will be at the low end of range and up (bottom of error bar) to the median. For nutrient removal, use random sampling of the range because scientists do not have an understanding of vegetative management and its effect on nutrient removal and cycles. While some locations cut vegetation back, some let it grow wild. By using random sampling within the range, that accounts for time needed to establish vegetation and the variability in managing vegetation once it becomes established.

How It Is Modeled

When a jurisdiction cannot report which soil type or if an underdrain is present, the value with the lowest mass removal is used (per WTWG policy). For example, when soil type and the presence of underdrains cannot be determined for bioretention the C and D soil types with underdrain estimates (TP = 45 percent, TN 25 = percent, and TSS = 55 percent) are assigned as these are the lowest effectiveness estimates. For vegetated open channels the C and D soil types soils without an underdrain (TP = 10 percent, TN = 10 percent, and TSS = 50 percent) is assigned. The values for C and D soils with an underdrain and no sand or vegetation are assigned (TP = 20 percent, TN = 10 percent and TSS = 55 percent) to permeable pavement and pavers. The infiltration trenches and basins default values are for A and B soils with no underdrain and no sand or vegetation (TP = 85 percent, TN = 80 percent, and TSS = 95 percent).

Definition:	A depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems

	provide complete infiltration. Design specifications require infiltration basins and trenches to be build in good soil, they are not constructed on poor soils, such as C and D soil types. Engineers are required to test the soil before approved to build is issued. To receive credit over the longer term, jurisdictions must conduct yearly inspections to determine if the basin or trench is still infiltrating runoff.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul), low-intensity developed impervious (iml), combined sewer system (css)*, and *extractive - active/abandoned mines (ext)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 85%, TP: 85%, TSS: 90%
Reference:	UMD/MAWP

6.7.6 Wetlands and Wet Ponds

A water impoundment structure that intercepts stormwater runoff then releases it to an open water system at a specified flow rate. These structures retain a permanent pool and usually have retention times sufficient to allow settlement of some portion of the intercepted sediments and attached nutrients/toxics. Until recently, the practices were designed specifically to meet water quantity, not water quality objectives. There is little or no vegetation living in the pooled area, nor are outfalls directed through vegetated areas before open water release. Nitrogen reduction is minimal.

Wet ponds and wetlands used as a BMP for managing urban stormwater runoff are man-made landscape features that have characteristics and functions similar to their natural counterparts. Wet ponds are depressions or basins created by excavation or berm construction that receive sufficient water via runoff, precipitation, and groundwater to contain standing water year-round at depths too deep to support rooted emergent or floating-leaved vegetation (in contrast with dry ponds, which dry out between precipitation events). Wetlands, on the other hand, have soils that are saturated with water or flooded with shallow water that support rooted floating or emergent aquatic vegetation (e.g. cattails). Some systems can contain submergent vegetation, or emergent vegetation along the shorelines, blurring the distinction between the two.

While there are similarities between natural and stormwater wetlands or wet ponds, there are also differences. In general, stormwater systems have a water balance dominated by surface runoff (rather than groundwater), *flashy* hydroperiods, well-defined boundaries, low species diversity and habitat value, and elevated contaminant and sediment concentrations compared with their natural counterparts (Schueler 1992).

Historically, stormwater management has concentrated on water quantity i.e., peak flow management, not water quality. In general, stormwater wet pond designs did not offer mechanisms (retention times, shallow water depths) for significant water quality reduction. In many cases the systems, because of design features (expansion limitations, steep interior side slopes), are not easy candidates for retrofits.

The water quality functions of urban wet ponds and wetland BMPs operate via similar mechanisms to those occurring in natural systems. Suspended particles are removed via settling resulting from low water velocities in the systems and physical filtration by plants if present (Schueler 1992; Brix 1993). Nitrogen is removed primarily via plant and microbial uptake, nitrification-denitrification reactions, and particulate settling, while phosphorus is removed primarily via soil sorption and settling of phosphorus sorbed to particulate matter. Wetlands and wet ponds can also remove, transform, or retain metals, pesticides, pathogens, oils, and other organic and inorganic constituents of surface runoff (Kadlec and Knight 1996; Mitsch and Gosselink 2000; BMP Database 2007). Furthermore, many stormwater BMPs are designed to store surface runoff water, releasing it slowly to streams with the goal of attenuating flood peaks resulting from storms. This hydrologic function of wet ponds and wetlands is often considered a water quality function that helps to reduce stream channel incision, bank erosion, and loss of in-stream habitat structures that is typical of streams in urban areas with extensive watershed areas covered by impervious surfaces such as building, roads, and parking lots (Schueler 1994).

In addition to water quality functions, wetland BMPs, and to a lesser extent wet pond BMPs provide habitat for fish, aquatic invertebrates, birds, mammals, reptiles, and amphibians (Schueler 1992). However, if not designed properly, the structures can also provide habitat for disease vectors such as mosquitoes (NC State 2005). Wet ponds and wetland BMPs can also be important for human quality of life, providing aesthetic or recreational value. Because they are often small and isolated from other habitats such as forests and streams, plant and wildlife species diversity might be low. Nonetheless, their presence in otherwise highly developed landscapes can increase their value as habitat for wildlife as well as use by humans (Mitsch and Gosselink 2000).

Definition:	A water impoundment structure that intercepts stormwater runoff then releases it to an open water system at a specified flow rate. These structures retain a permanent pool and usually have retention times sufficient to allow settlement of some portion of the intercepted sediments and attached nutrients/toxics. Until recently, these practices were designed specifically to meet water quantity, not water quality objectives. There is little or no vegetation living within the pooled area nor are outfalls directed through vegetated areas prior to open water release. Nitrogen reduction is minimal.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul), low-intensity developed impervious (iml), combined sewer system (css),* and *extractive - active/abandoned mines (ext)*
Efficiency credited:	Effectiveness
Effectiveness estimate:	TN: 20%, TP: 45%, TSS: 60%
Reference:	UMD/MAWP

6.7.7 Urban Infiltration Practices without Sand or Vegetation

This is an urban infiltration practice that uses a depression to form an infiltration basin where sediment is trapped and water infiltrates the soil, but no underdrains are associated with infiltration basins and trenches because by definition the systems provide complete infiltration. Design specifications require infiltration basins and trenches to be built in good soil; they are not constructed on poor soils, such as C and D soil types. Engineers are required to test the soil before approved to build is issued. To receive credit over the longer term, jurisdictions must conduct yearly inspections to determine if the basin or trench is still infiltrating runoff. Other benefits include heavy metal removal, runoff reduction, and groundwater recharge.

<u>Effectiveness (applied to the runoff from acres treated):</u>
From a removal perspective, infiltration basins and trenches function like sand filters. It is difficult to monitor actual pollutant removal because the water is infiltrating below the surface and only a portion of it is captured. The pollutant removal for infiltration basins and trenches is equated to the sand filter value.

Some basins/trenches are lined with rocks, while some have vegetation. Systems solely lined with rocks have some TSS and TP removal. Rock lined basins have a layer of soil thus TP is removed, but without vegetation TN is not removed. The ideal basin has no surface discharge, with 100 percent infiltration. With larger events, some surface overflow or bypass occurs and no treatment results for the overflow. What is infiltrated captures most of the TSS moving through the system, some TP removal occurs, but very little TN is removed.

Runoff reduction is estimated to be 80 percent, on the basis of CWP (2008) memo. The table shows a runoff reduction range of 60–90 percent with CWP best professional judgment range of 50–90 percent. The 50 percent, however, is for sites where an underdrain must be used. The CBP assumes that basins and trenches are not constructed on sites needing to use an underdrain, given the intent of the practice. Assuming the practice is designed with adequate pretreatment and soil infiltration testing, 80 percent RR is used and is a more conservative value than the 90 percent assigned by CWP (2008).

The CWP technical memo recommends 25 percent for TP and 15 percent for TN. A 15 percent reduction in TN is used here for systems with sand or vegetation, and 0 percent TN removal for systems without sand or vegetation, to be consistent with the other infiltration and filtration BMPs in this report and to be conservative.

A PR of 95 percent for TSS is assigned on the basis of infiltration numbers from the University of New Hampshire Stormwater Center 2007 annual report.

$$TR = RR + \{(100 - RR) \times PR\}$$

Where:
TR – total removal
RR – runoff removal
PR – pollutant removal

Total removal:
TSS: 80 + {(100-80) × .95} = 95
TP: 80 + {(100-80) × .25} = 85
TN with sand and/or vegetation: 80 + {(100-80) × 15} = 85
TN without sand and/or vegetation: 80 + {(100-80) × 0} = 80
Values are rounded down to the nearest factor of 5

Error Bars:
Because of the lack of research on infiltration basins and trenches compared to other infiltration techniques, sand filter error bar values are used as infiltration basins and trenches function like a sand filter:
TN 10
TP 15
TSS 10 – as the TR value is 95 percent, crop the +10 to +5 so TR is not above 100 percent

Maintenance:
As infiltration is the main mechanism that reduces runoff and pollutants, maintaining infiltration is critical. As clogging occurs flow begins to bypass the BMP. The systems will capture a lot of sediment, so maintenance is key.

Factors that Create Variability in Performance
Shut-off event for all infiltration and filtration practices:
Most BMPs are designed for a 1-inch storm event to capture the water quality volume. With a 1.5-inch to 2-inch rain event, all practices begin to show bypass flow or overflow. Some sites can handle more runoff but after 1 inch most sites become inundated. To determine the sizing criteria and water quality rainfall depth, engineers work backwards starting with the total impervious area. The CBP Watershed Model shuts down treatment for all flow beyond 1 inch.

Effectiveness Estimate—Range of values
Equation Used to Determine Effectiveness Estimates:
TR = RR + {100 – RR) × PR}
TR – total removal
RR – runoff removal
PR – pollutant removal

Tiered approach to range:

Starting with year 2 and continuing on, use a random sampling of the range as done for the range of performance values for nutrients.

For TSS pollutant removal, initial (first year) instillations will be at the low end of range and up (bottom of error bar) to the median. For nutrient removal, use random sampling of the range because scientists do not have an understand of vegetative management and its effect on nutrient removal and cycles. While some locations cut vegetation back, some let it grow wild. By using random sampling within the range this accounts for time needed to establish vegetation and the variability in managing vegetation once it becomes established.

How It Is Modeled

When a jurisdiction cannot report which soil type or if an underdrain is present the value with the lowest mass removal is used (per WTWG policy). For example, when soil type and the presence of underdrains cannot be determined for bioretention the C and D soil types with underdrain estimates (TP = 45 percent, TN = 25 percent, and TSS = 55 percent) are assigned as these are the lowest effectiveness estimates. For vegetated open channels the C/D soils without an underdrain (TP = 10 percent, TN = 10 percent, and TSS = 50 percent) is assigned. The values for C/D soil with an underdrain and no sand or vegetation are assigned (TP = 20 percent, TN = 10 percent and TSS = 55 percent) to permeable pavement and pavers. The infiltration trenches and basins default values are for A and B soils with no underdrain and no sand or vegetation (TP = 85 percent, TN = 80 percent, and TSS = 95 percent).

Definition:	A depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems provide complete infiltration.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul), low-intensity developed impervious (iml), combined sewer system (css),* and *extractive - active/abandoned mines (ext)*
Efficiency credited:	Effectiveness
Effectiveness estimate:	TN: 80%, TP: 85%, TSS: 90%
Reference:	UMD/MAWP

6.7.8 Dirt and Gravel Road Stormwater Management Control

In many rural areas of the Ridge and Valley, Piedmont, and Allegheny Plateau, local (county) roads are unpaved. Often, the roads were initially constructed as part of a logging operation and over time were integrated into the local community transportation system.

In most cases, the roads are gravel or packed soil surfaces. They do not have stormwater management controls, nor were they built to minimize erosion effects on local streams during severe rainfall events. The road edge often becomes the collection point for concentrated stormwater flows resulting in gully erosion and high sediment loads to streams.

Although the stormwater practices used to address this problem are site specific, the overall objective is to minimize stormwater runoff concentration and velocity, protect areas of concentrated flow from erosion, and prevent degradation of water quality or habit in local streams.

Definition:	Minimize stormwater runoff concentration and velocity, protect areas of concentrated flow from erosion, and prevent degradation of water quality or habit in local streams. There are three types with varying reductions: driving surface aggregate (DSA), no DSA, and DSA with outlets
Land use:	*forests, woodlots and wooded (for), high-intensity developed pervious (puh),* and *low-intensity developed pervious (pul)*
Efficiency credited:	Load reduction

Effectiveness estimate:	The mass of sediment reduced per linear foot of treated dirt or gravel road depends on the presence or absence of DSA. The greatest reductions for this management practice are for DSA combined with outlets = 3.6 lbs sediment/ft; followed by DSA alone = 2.96 lbs sediment/ft; and no DSA = 1.76 lbs sediment/ft.
Reference:	UMD/MAWP, Erosion and Sediment Control CBC Final Report

6.7.9 Septic Connections

Definition:	This is when septic systems get converted to public sewer. This reduces the number of systems because the waste is sent into the sewer and treated at a wastewater treatment plant.
Land use:	*onsite wastewater management systems (sep)*
Efficiency credited:	Systems change
Effectiveness estimate:	N/A
Reference:	Appendix H

6.7.10 Urban Nutrient Management

Urban areas are divided into pervious and impervious urban areas in the Chesapeake Bay Watershed Model. Pervious urban areas account for suburban areas, parks, lawns, and areas in which water is able to percolate through the soil. Alternatively, impervious urban land are areas such as roads, paved lots, and rooftops where water is unable to percolate through the soil profile. These lands use groups are derived from CBP Land Use (CBPLU) categories and are described in Watershed Model Appendix E: Watershed Land Uses and Model Linkages to the Airshed and Estuarine Models. The following equations use CBP Land Use estimates to calculate the two categories of urban areas:

(2) Pervious Urban = (CBPLU High Intensity Urban × 0.15) + (CBPLU Low Intensity Urban × 0.6) + (CBPLU Herbaceous Urban × 0.9) + (CBPLU Urban × 0.9) + (CBPLU Exposed × 0.6)

(3) Impervious Urban = (CBPLU High Intensity Urban × 0.85)+(CBPLU Low Intensity Urban× 0.4) + (CBPLU Herbaceous Urban × 0.1) + (CBPLU Urban × 0.1) + (CBPLU Exposed × 0.4)

Generally, on a portion of pervious urban acres including some lawns, golf courses, and portions of park land, intensive turf management practices are applied. For those areas, an estimated recommended fertilizer application is 130 pounds of nitrogen/acre. A portion of the pervious urban areas has little or no turf maintenance and has fertilizer applied only once every 3 years, if at all. Such areas can include lawns, medians of highways, roadside rights of way, and portions of parks. Considering the differences in the amount of fertilizer applied to various types of pervious land and the limitation of the use of the various types of urban land use averaged to represent a single urban land use, an average fertilizer application of 50 pounds of nitrogen/acre/year is applied to all pervious land in the Phase 5.3 Watershed Model. Fertilizer is usually applied during the spring and early fall. For that reason, the timing of fertilizer applications are split into eight periods each with a distribution of 10 days. The applications begin on the following days and last for 10 days; March 9, April 9, May 9, June 9, July 9, August 9, September 9, and October 9. With the implementation of the urban nutrient management practice, a reduction of urban fertilizer is applied. Urban nutrient management involves public education (targeting urban/suburban residents and businesses) to encourage reduction of excessive fertilizer use. The CBP Nutrient Subcommittee's Tributary Strategy Workgroup has estimated that urban nutrient management reduces nitrogen loads by 17 percent and phosphorus loads by 22 percent.

Definition:	Urban nutrient management involves the reduction of fertilizer to grass lawns and other urban areas. The implementation of urban nutrient management is based on public education and awareness, targeting suburban residences and businesses, with emphasis on reducing excessive fertilizer use
Land use:	*high-intensity developed pervious (puh)* and *low-intensity developed pervious (pul)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 17%, TP: 22%, TSS: N/A
Reference:	Appendix H

6.7.11 Septic Pumping

For onsite wastewater management systems (OSWMS), commonly called septic systems, nutrient reductions are achieved through three types of management practices. Those practices are frequent maintenance and pumping, connection of OSWMS to sewage treatment systems, and OSWMS denitrification. For all the septic system BMPs, the nutrient reduction efficiency is applied only to nitrogen as it is assumed that phosphorus is entirely treated by OSWMS.

Whenever septic tanks are pumped and septage removed, the OSWMS has an increased capacity to remove settable and floatable solids from the wastewater (Robillard and Martin 1990a). Septic tank pumping promotes biological digestion of a portion of the solids and allows for storage space for the remaining undigested solid portion of the wastewater. OSWMS effluent flows out of septic tanks and into an underground soil adsorption system (field). The pumping of septic tanks is one of several measures that can be implemented to protect soil adsorption systems from clogging and failure (Robillard and Martin 1990b). This measure reduces the nitrogen loads by an estimated 5 percent. The level of BMP implementation is reported by signatory states as the number of systems implemented. A ratio is formed of the number of pumpouts reported and the total number of septic systems. If a system fails, soil adsorption fields are often unable to adequately filter and treat wastewater; consequently non-treated septic system effluent can drain directly into ground and surface water sources.

Definition:	Septic systems achieve nutrient reductions through several types of management practices, including frequent maintenance and pumping. On average, septic tanks need to be pumped once every three to five years to maintain effectiveness. The pumping of septic tanks is one of several measures that can be implemented to protect soil absorption systems from failure. When septic tanks are pumped and sewage removed, the septic system's capacity to remove settable and floatable solids from wastewater is increased.

Land use:	*onsite wastewater management systems (sep)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 55%
Reference:	Appendix H, BMP Basics

6.7.12 Septic Denitrification

Denitrification in OSWMSs is accomplished through a sand mound system with effluent recirculation. The nitrogen load is reduced by 50 percent when denitrification is incorporated in septic systems.

Definition:	Septic denitrification represents the replacement of traditional septic systems with more advanced systems that have additional nitrogen removal capabilities. Traditional septic systems usually consist of a large tank designed to hold the wastewater allowing grits and solids time for settling and decomposition. Wastewater then flows to the second component, the drainfield. An enhanced septic system like that shown can provide further treatment of nitrogen through processes that encourage denitrification of the wastewater.
Land use:	*onsite wastewater management systems (sep)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 50%
Reference:	Appendix H, BMP Basics

6.7.13 Urban Tree Planting

The tree planting BMP includes any tree plantings on any site except those along rivers and streams. Plantings along rivers and streams are considered riparian buffers and are treated differently. The definition of tree planting does not include reforestation. Reforestation replaces trees removed during timber harvest and does not result in an additional nutrient reduction or an increase in the forest acreage.

Definition:	Urban tree planting is planting trees on urban pervious areas at a rate that would produce a forest-like condition over time. The intent of the planting is to eventually convert the urban area to forest. If the trees are planted as part of the urban landscape, with no intention to covert the area to forest, then this would not count as urban tree planting
Land use:	*high-intensity developed pervious (puh)* and *low-intensity developed pervious (pul)*
Efficiency credited:	Land use change to *forest and woodlot*
Effectiveness estimate:	N/A
Reference:	Appendix H, BMP Basics

6.7.14 Urban Forest Conservation

Forest conservation land use conversion is based on estimates in the amount of forest land saved between 1993 and 2000 as a result of Maryland's Forest Conservation Act. Incorporating forest conservation practices consist of a land use conversion from developed land (pervious urban) to forest. Maryland's Forest Conservation Act helps to maintain and enhance forest cover by requiring the identification of priority areas for forest retention, setting guidelines for development that require the retention of 15–50 percent of the forested area, and replanting of cleared areas. Priority areas are designated as 100-year flood plains, intermittent and perennial streams and their buffers, steep slopes, and critical habitats. This BMP reduces deforestation created by urban development by requiring that a certain percentage of developed land remain as forested land. Substituting forest land for what would otherwise be urban land is best understood in the context of how the Phase 4 Watershed Model projects land use. For any year other than 1990, the year of the CBP land use database, land use is projected forward or backward according to population. As population increases in a model segment, urban land use area increases proportional to the 1990 urban land use and population, and the land uses of forest and agriculture, proportionally decrease. Forest Conservation Act BMPs reduce the constant rate of urbanization as projected through population growth.

Definition:	Urban forest conservation applies only to Maryland at this time. This BMP in Maryland is the implementation of the Maryland Forest Conservation Act that requires developers to maintain at least 20% of a development site in trees (forest condition). This is actually a preventative type of BMP which alters the rate of urban conversion. The acreage is calculated from the annual urban increase (population based). The 20% is specific to the Maryland Act and could be different for each jurisdiction or various locations within a jurisdiction.
Land use:	*high-intensity developed pervious (puh)* and *low-intensity developed pervious (pul)*
Efficiency credited:	Land use change to *forest and woodlot*
Effectiveness estimate:	N/A
Reference:	Appendix H

6.7.15 Urban Growth Reduction

Definition:	Change from urban to non-urban landuse in forecasted conditions.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul),* and *low-intensity developed impervious (iml)*
Efficiency credited:	Landuse change to non-urban landuses
Effectiveness estimate:	N/A
Reference:	Old NPS table

6.7.16 Stream Restoration in Urban Areas

Stream restoration in urban areas is used to restore the urban stream ecosystem by restoring the natural hydrology and landscape of a stream. Stream restoration in urban areas is used to help improve habitat and water quality conditions in degraded streams. Typically, streams in need of restoring have watershed conditions that have destabilized the stream channel and eroded streambanks. The objectives for stream restoration in urban areas include reducing stream channel erosion, promoting physical channel stability, reducing the transport of pollutants downstream, and working toward a stable habitat with a self-sustaining, diverse aquatic community. Stream restoration activities in urban areas should result in a stable stream channel that experiences no net aggradation or degradation over time.

As a result, relatively minor storm events can produce surface water quantities that overwhelm established stream channels. This results in streambank erosion and channel cutting that will continue unless peak flows are reduced or streambanks/channels are protected.

Definition:	Stream restoration in urban areas is used to restore the urban stream ecosystem by restoring the natural hydrology and landscape of a stream, to improve habitat and water quality conditions..
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul),* and *low-intensity developed impervious (iml)*
Efficiency credited:	Load reduction
Effectiveness estimate:	N/A
Reference:	WCS Reccs

6.7.17 Urban Forest Buffers

Definition:	An area of trees at least 35 feet wide on one side of a stream, usually accompanied by trees, shrubs and other vegetation, that is adjacent to a body of water. The riparian area is managed to maintain the integrity of stream channels and shorelines, to reduce the impacts of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals.
Land use:	*high-intensity developed pervious (puh)* and *low-intensity developed pervious (pul)*
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 25%, TP: 50%. TSS: 50%
Reference:	UMD/MAWP, Forest Buffer White Paper

6.7.18 Street Sweeping

Definition:	Street sweeping and storm drain cleanout practices rank among the oldest practices used by communities for a variety of purposes to provide a clean and healthy environment, and more recently to comply

	with their National Pollutant Discharge Elimination System stormwater permits. The ability for these practices to achieve pollutant reductions is uncertain given current research findings. Only a few street sweeping studies provide sufficient data to statistically determine the impact of street sweeping and storm drain cleanouts on water quality and to quantify their improvements. The ability to quantify pollutant loading reductions from street sweeping is challenging given the range and variability of factors that impact its performance, such as the street sweeping technology, frequency and conditions of operation in addition to catchment characteristics. Fewer studies are available to evaluate the pollutant reduction capabilities due to storm drain inlet or catch basin cleanouts.
Land use:	Imh, iml
Efficiency credited:	Efficiency
Effectiveness estimate:	TN: 3%, TP: 3%, TSS: 9%
Reference:	Street sweeping

6.8 Restoration, Shoreline Protection, and Other Management Practices

6.8.1 Tree Planting

Tree planting includes any tree planting, except those used to establish riparian forest buffers, targeting lands that are highly erodible or identified as critical resource areas. Tree planting is also called afforestation. This BMP results in a land use conversion from row crop to forest. It is assumed that the density of the plantings is sufficient to produce a forest-like condition over time

Definition:	Urban tree planting is planting trees on urban pervious areas at a rate that would produce a forest-like condition over time. The intent of the planting is to eventually convert the urban area to forest. If the trees are planted as part of the urban landscape, with no intention to covert the area to forest, then this would not count as urban tree planting
Land use:	*high-intensity developed pervious (puh)* and *low-intensity developed pervious (pul)*
Efficiency credited:	Landuse change to *forest and woodlots*
Effectiveness estimate:	N/A
Reference:	Appendix H

6.8.2 Stream Restoration

Stream restoration is a collection of site-specific engineering techniques used to stabilize an eroding streambank and channel. The objective is to prevent further streambank damage and cropland loss by correcting unstable eroding streambanks using a variety of techniques to improve water quality by reducing nutrients and sediment entering the stream. These are riparian areas not associated with animal entry. This BMP is treated as a load reduction in the model, so nutrient and sediment contribution from the adjacent land is less than land adjacent to other streams.

Definition:	A collection of site-specific engineering techniques used to stabilize an eroding streambank and channel. These are areas not associated with animal entry.
Land use:	*conventional tillage with manure (hwm), nutrient management conventional tillage with manure(nhi), conventional tillage without manure (hom), nutrient management conventional tillage without manure (nho), conservation tillage with manure (lwm), nutrient management conservation tillage with manure (nlo), hay-fertilized (hyw), nutrient management hay (nhy), alfalfa (alf), nutrient management alfalfa (nal), hay without nutrients (hyo), pasture (pas),* and *nutrient management pasture (npa)*
Efficiency credited:	Load reduction
Effectiveness estimate:	0.02 lbs N/ ft; 0.003 lbs P/ft; 2 lbs Sed/ft
Reference:	UMD/MAWP

6.8.3 Wetland Restoration

Wetland Restoration and Creation:

Wetland Restoration: Returning natural/historic functions to a *former* wetland. Results in a gain in wetland acres. Nutrients and suspended particles are removed via settling. Nitrogen is further removed primarily via plant and microbial uptake and nitrification-denitrification reactions, while phosphorus is further removed by soil sorption.

Wetland Creation: Developing a wetland that did not previously exists on an upland or deepwater site. Results in a gain in wetland acres. Nutrients and suspended particles are removed via settling. Nitrogen is further removed primarily via plant and microbial uptake and nitrification-denitrification reactions, while phosphorus is further removed by soil sorption.

The CBP will use the following definitions to classify wetland restoration on agricultural land and wetland creation:

Reestablishment (restore)—Manipulating the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a *former* wetland. Results in a gain in wetland acres.

Establishment (create)—Manipulating the physical, chemical, or biological characteristics present to develop a wetland that did not previously exists on an upland or deepwater site. Results in a gain in wetland acres.

This BMP report discusses the water quality benefits of wetland restoration and wetland creation. The literature search for this report captures the water quality benefits that wetlands provide and literature on the wildlife, mitigation wetlands, and natural wetlands is not discussed. In addition these systems are not designed to treat wastewater, because they are not designed like a stormwater facility nor intended to have the same maintenance as a stormwater facility.

These wetland treatment system designs have an even flow distribution and adequate retention time. The temporal variability of water flow through wetlands also results in variability of water detention times, which in turn affects the removal efficiencies. The longer water is detained in a wetland, the more material can be removed from the water within the wetland. As flow variability increases, the effective water detention time decreases and therefore the removal efficiency decreases (Jordan et al. 2003). It is intuitively clear that a wetland with steady water flow is likely to have higher removal rate than a wetland with the same amount of annual flow concentrated during a few days of high flow. Understanding such temporal flow conditions is necessary to provide estimated effectiveness.

Practice components meet criteria standards under the USDA-NRCS 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 included in the Wetland Restoration Practices on Agricultural Land, and Wetland Creation, include the following USDA-NRCS conservation practices:

- Constructed Wetland (656)
- Wetland Creation (658)
- Wetland Restoration (657)

Restored versus created wetlands

It is important to distinguish wetland restoration from wetland creation. Agricultural wetland restoration activities reestablish the natural hydraulic condition in a field that existed before the installation of subsurface or surface drainage. In contrast, *wetland creation* establishes a wetland in a place where none previously existed. Created wetlands can use artificial or highly engineered hydrology. Often created wetlands have regulated water inputs, with water being pumped or fed in at steady controlled rates. In contrast, restored wetlands generally have natural or unregulated water inputs, with water entering through surface or subsurface flows at variable uncontrolled rates.

Definition:	Reestablishment (restore)—Manipulating the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a *former* wetland. Results in a gain in wetland acres. Establishment (create)—Manipulating the physical, chemical, or biological characteristics present to develop a wetland that did not previously exist on an upland or deepwater site. Results in a gain in wetland acres.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul),* and *low-intensity developed impervious (iml)*

Efficiency credited:	Efficiency
Effectiveness estimate:	Varies TN: 7-25%, TP: 12-50%, TSS: 4-15%
Reference:	UMD/MAWP

6.8.4 Abandoned Mine Reclamation

Definition:	Abandoned mine reclamation stabilizes the soil on lands mined for coal or affected by mining, such as wastebanks, coal processing, or other coal mining processes.
Land use:	Acreage identified as abandoned mine reclamation is taken proportionally out of pervious and impervious urban and added to hay without nutrients.
Efficiency credited:	Land use change - acreage identified as abandoned mine reclamation is taken proportionally out of pervious and impervious urban and added to hay without nutrients.
Effectiveness estimate:	N/A
Reference:	BMP Basics

6.8.5 Nonstructural Shoreline Control

Shoreline management BMPs are outside the domain of the Phase 5.3 Model but are used to modify the Phase 5.3 nutrient and sediment outputs when the Phase 5.3 Model is used to load other models such as the Water Quality and Sediment Transport Model of the Chesapeake Bay (Cerco et al. 2010).

Tidal structural and nonstructural erosion control measures stabilize the eroding shoreline. Structural shore erosion controls include stone revetments and breakwaters and nonstructural erosion control practices focus on the use of native vegetation to stabilize shorelines. Where wave energy is too high for the nonstructural approach, structural methods are employed.

Structural shoreline erosion controls are designed to protect eroding shorelines by armoring the shoreline to dissipate incoming wave energy while protecting unconsolidated bank sediments. Shoreline hardening, offshore breakwaters, headland controls, and breakwater systems are applicable in areas of higher erosion rates or where wave energy is too great for vegetative alternatives.

Nutrient Reduction Efficiency

The nutrient reduction efficiency of structural shoreline erosion controls is related to the sediment control efficiency, as the sediments controlled by the BMP have associated nutrients.

Definition:	Nonstructural tidal shoreline erosion control projects are bioengineering techniques that create vegetated wetlands for protection of the shoreline. The controls are designed to protect eroding shorelines by creating vegetated wetlands, which dissipate incoming wave energy

	while protecting unconsolidated bank sediments. A transition zone is created between the erodible uplands and open water. These wetlands help prevent nutrient-laden sediments from entering the waters.
Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul),* and *low-intensity developed impervious (iml)*
Efficiency credited:	Load reduction
Effectiveness estimate:	N/A Possible values: TN: 75%, TP: 75%, TSS: 75%
Reference:	Appendix H, BMP Basics

6.8.6 Structural Shoreline Control

Shoreline hardening projects are rigid, barrier-type structures that include riprap, revetments, bulkheads, groins, and seawalls to prevent or reduce shoreline erosion particularly from wave action, but also from currents, tides runoff and other erosive flows.

Depending on the design, structural shoreline erosion controls can help shorelines withstand wave impact, trap sand, and, in general effectively prevent fastland erosion at the site of protection. However, structural shoreline erosion controls can prevent the shoreline’s natural response of beaches and tidal wetlands to fastland erosion which is a migration inland. Hardened shorelines can limit the shoreline’s ability to migrate while effectively starving adjacent beaches and wetlands of necessary sediment inputs. Furthermore, hard shoreline protection structures can increase bottom scour and erosion in the nearshore zone in front of the structures because they tend to reflect the oncoming wave energy (U.S. Army Corps of Engineers 2002). They also can decrease the diversity and quality of habitats on both sides of the structure and impede those natural processes that are necessary and beneficial for healthy aquatic ecosystems. The cost of structural shoreline erosion controls limits their implementation. Private landowners control approximately 85 percent of Chesapeake shoreline (Claggett 2005), and bear the majority of the financial burden for erosion controls.

If bank stability was the only consideration in the BMP efficiency, a value of 90–100 percent for sediment could be assigned to shoreline hardening. If bank stability, beach scour and adjacent and down-drift impacts are considered in the efficiency, the BMP efficiency would need to be downgraded to about 50 to 75 percent. However documentation on adjacent and down-drift impacts of properly designed and constructed measures is sparse. When reporting sediment and nutrient savings for implemented shoreline erosion control measures for Virginia tributary strategy reports, an efficiency of 75 percent was used.

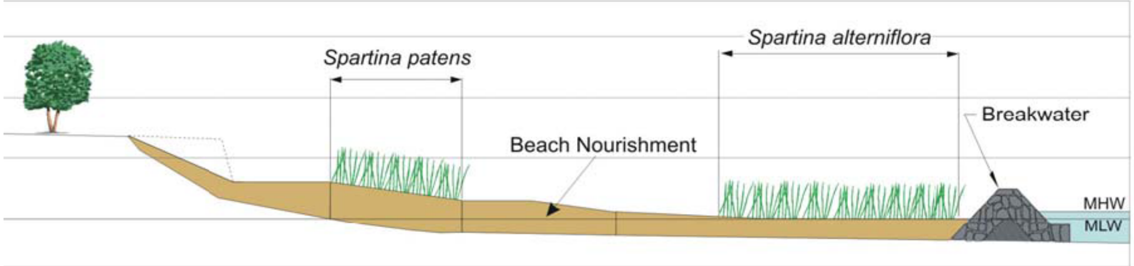
Definition:	Structural tidal shoreline erosion control is designed to protect eroding shorelines by armoring the shoreline to dissipate incoming wave energy while protecting unconsolidated bank sediments. These practices are applicable in areas of higher erosion rates or where wave energy is too strong for vegetation alternatives. These projects are rigid, barrier-type structures that result in a *hardening* of the shoreline to protect against the action of waves, currents, tides, wind driven water, runoff storms, or groundwater seepage that erodes shorelines.

Land use:	*high-intensity developed impervious (imh), high-intensity developed pervious (puh), low-intensity developed pervious (pul),* and *low-intensity developed impervious (iml)*
Efficiency credited:	Load reduction
Effectiveness estimate:	N/A Possible values: TN: 75%, TP: 75%, TSS: 75%
Reference:	Appendix H, BMP Basics

6.8.7 Offshore Breakwater

An offshore breakwater is a structure positioned a short distance from the shore to deflect the force of incoming waves to protect the shoreline from erosive wave energy.

Breakwater systems are also known as living shorelines. Breakwater systems are typically a combination of structures, practices, and vegetative measures, including beach nourishment, wetlands, and dune plantings that are positioned along a shore to deflect and dissipate the force of waves to protect the shoreline. The CBP recommends living shorelines for areas with erosion of 2 feet per year or less (Sediment Workgroup—Chesapeake Bay Program 2005).



Source: Hardaway and Byrne 1999

Figure 6-2. Typical cross-section of a breakwater system.

The efficiency of a breakwater is site specific. Breakwaters installed along a shoreline protect a portion of the shore from erosion, while the unprotected segments can continue to erode. The eroded material is deposited behind the breakwater and builds a protective beach. Over time, this erosion–deposition cycle continues until the area reaches a state of equilibrium. Once equilibrium is achieved, the erosion–deposition cycle is balanced, and the entire project area is protected. Therefore, the efficiency over time varies. In addition, the project can have adjacent and downdrift effects. Therefore, the efficiency varies, but an overall estimated 40 percent sediment reduction for offshore breakwaters is applied. The implementation of a breakwater system is effective in protecting the shoreline from erosion and minimizes adjacent and downdrift effects. Using beach nourishment in conjunction with wetlands and dune plantings eliminates the erosion/deposition cycle associated with the use of breakwaters alone. Therefore, the efficiency is 90 to 100 percent for beach nourishment in conjunction with wetlands and dune plantings. When reporting sediment and nutrient savings for implemented shoreline erosion control measures for tributary strategy reporting, an efficiency of 75 percent was used in Virginia's tributary strategies.

6.8.8 Headland Control

A headland control is a structure that creates or protects an erosion resistant point or points of land, allowing adjacent embayments to achieve a stable configuration.

Headland controls allow for long stretches of shoreline to be protected with a minimum of structures. As with breakwaters, selected points are protected, and the land between the points is allowed to erode. Ideally, over time, equilibrium is reached, and a stable embayment is created. Therefore, the efficiency of the headland control practice varies as time progresses with the formation of the stable embayment. When equilibrium is reached, the efficiency is 90 to 100 percent. For modeling purposes, the recommendation is to use an efficiency of 50 percent for the life of the measure.

6.9 Land Use Changes Due to BMP Implementation

The base scenario-year land uses are modified according to the information on BMP implementation supplied by individual state agencies. Nutrient or sediment load reductions resulting from land use changes because of BMPs implementation are simulated in the Watershed Model, such as the case when higher-yielding land uses such as *conventional tillage with manure* are converted to the ones exporting lower levels of pollutants such as *conservation tillage with manure*.

Calculating the changes in land uses is carried out in a sequence, following the methodologies described above and with the noted limitations. In all cases, proportional allocations of the high-yielding land use to other land use categories are determined after land use acreage are already adjusted for previously applied/listed BMPs.

- Conservation Tillage—Conservation tillage data from Maryland DNR by land-segment is used as the acreage of low-till for Maryland. Conservation tillage acreage in all other Bay watershed jurisdictions is determined through the process described above. For historic- and current-year model scenarios, if the claimed low-till acreage exceeds 75 percent of the total tilled land of the base scenario in a county-segment, only 75 percent of tilled land is allowed in conservation-tillage—a constraint established by the CBP Tributary Strategy Workgroup to reflect the inability to apply conservation tillage to all crops.

- Forested Buffers—Forest buffer acreage by land-segment is taken proportionally out of conventional tillage, conservation tillage, and hay and added to forest. Proportions of conventional tillage, conservation tillage, and hay are determined after land use acreage is adjusted for conservation tillage.

- Wetland restoration—Wetland restoration area by county-segment is taken proportionally out of conventional tillage, conservation tillage, and hay and is converted to forest in model simulation. Proportions of conventional tillage, conservation tillage, and hay are determined after land use acreage is adjusted for previously applied BMPs.

- Retirement of Erodible Land/CRP—CRP acres are taken proportionally out of conventional tillage, conservation tillage, and hay and added to mixed open by land-segment The sum of CRP land retirement, forest buffers, and wetland restoration acres cannot exceed 25 percent of the total cropland by land-segment. If this criterion is violated, CRP acreage is calculated as 25 percent of the total cropland acres minus forest buffer and wetland restoration acres, before proportional reductions in cropland and hay are determined.

- Grass Buffers—Grass buffer acreage by county-segment is taken proportionally out of conventional tillage and conservation tillage and added to hay without nutrients.
- Forest Conservation—Forest conservation acres are taken from pervious urban and added to forest by county-segment. If forest conservation acreage exceeds pervious urban, the excess is taken from hay without nutrients.
- Tree Planting (Agriculture)—Tree planting acres on agricultural land are taken proportionally out of conventional tillage, conservation tillage, and pasture, and added to forest by land-segment.
- Tree Planting (Mixed Open)—Tree planting acres in urban developed areas are taken from that category and added to forest by land-segment.
- Abandoned Mine Reclamation—Acreage identified as abandoned mine reclamation is taken proportionally out of pervious and impervious urban and added to hay without nutrients.

6.10 BMP Annual Time Series

The structure of the Phase 5.3 Model allows annual changes in land use and in BMPs as explained in more detail in Section 12. The complete time series of information on BMPs as applied in the Phase 5.3 land-segments from 1985 to 2005 are at the Chesapeake Community Modeling Program's (CCMP) Phase 5.3 data library on the Web at http://ches.communitymodeling.org/models/CBPhase5/datalibrary.php.

Table 6-4 summarizes the Phase 5.3 Model BMPs and their efficiencies.

Table 6-4. Nonpoint source best management practices and efficiencies currently used in Scenario Builder. Values in parentheses are in process of receiving of final approval.

Agriculture BMPs	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Nutrient Management	Landuse Change	N/A	N/A	N/A
Forest Buffers (varies by region; see Appendix 2)	Efficiency, Landuse Change	19-65%	30-45%	40-60%
Wetland Restoration (varies by region; see Appendix 2)	Efficiency	7-25%	12-50%	4-15%
Land Retirement	Landuse Change	N//A	N/A	N/A
Grass Buffers (varies by region; see Appendix 2)	Efficiency, Landuse Change	13-46%	30-45%	40-60%
Non-Urban Stream Restoration	Mass reduction/length	0.02 lb/ft	0.003 lb/ft	2 lb/ft
Tree Planting	Landuse Change	N/A	N/A	N/A
Carbon Sequestration/Alternative Crops	Landuse Change	N/A	N/A	N/A
Conservation Tillage	Landuse Change	N/A	N/A	N/A
Continuous No-Till (varies by region; see	Efficiency	(10-15%)	(20-40%)	(70%)

Appendix 2)					
Enhanced Nutrient Management		Efficiency	(7%)	(N/A)	(N/A)
Decision Agriculture		Efficiency	(4%)	(N/A)	(N/A)
Conservation Plans	High-till	Efficiency	8%	15%	25%
	Low-till	Efficiency	3%	5%	8%
	All hay	Efficiency	3%	5%	8%
	Pasture	Efficiency	5%	10%	14%
Cover Crops (see Appendix 1)		Efficiency	Varies	Varies	Varies
Commodity Cover Crops (see Appendix 2)		Efficiency	Varies	Varies	Varies
Stream Access Control with Fencing		Landuse Change	N/A	N/A	N/A
Alternative Watering Facility		Efficiency	5%	8%	10%
Prescribed Grazing/PIRG		Efficiency	9%	24%	30%
Horse Pasture Management		Efficiency	N/A	20%	40%
Animal Waste Management Livestock		Efficiency	75%	75%	N/A
Animal Waste Management Poultry		Efficiency	75%	75%	N/A
Barnyard Runoff Control		Efficiency	20%	20%	40%
Loafing Lot Management		Efficiency	20%	20%	40%
Mortality Composters		Efficiency	40%	10%	N/A
Water Control Structures		Efficiency	33%	N/A	N/A
Poultry Phytase		Application Reduction	N/A	N/A	N/A
Swine Phytase		Application Reduction	N/A	N/A	N/A
Dairy Precision Feeding and Forage Management		Application Reduction	N/A	N/A	N/A
Poultry Litter Transport		Application Reduction	N/A	N/A	N/A
Ammonia Emissions Reduction (interim)		Application Reduction	15-60%	N/A	N/A
Poultry Litter Injection (interim)		Efficiency	25%	0%	0%
Liquid Manure Injection (interim)		Efficiency	25%	0%	0%
Phosphorus Sorbing Materials in Ditches (interim)		Efficiency	40%	0%	0%
Resource BMPs		***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Forest Harvesting Practices		Efficiency	50%	60%	60%
Dirt & Gravel Road Erosion & Sediment Control – Driving Surface Aggregate + Raising the Roadbed		Mass reduction/length	0	0	2.96 lb/ft
Dirt & Gravel Road Erosion & Sediment Control – with outlets		Mass reduction/length	0	0	3.6 lb/ft
Dirt & Gravel Road Erosion & Sediment Control – outlets only		Mass reduction/length	0	0	1.76 lb/ft
Urban BMPs		***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Forest Conservation		Landuse Change	N/A	N/A	N/A
Urban Growth Reduction		Landuse Change	N/A	N/A	N/A
Impervious Urban Surface Reduction		Landuse Change	N/A	N/A	N/A

Forest Buffers		Efficiency, Landuse Change	25%	50%	50%
Tree Planting		Landuse Change	N/A	N/A	N/A
Abandoned Mine Reclamation		Landuse Change	N/A	N/A	N/A
Wet Ponds and Wetlands		Efficiency	20%	45%	60%
Dry Detention Ponds and Hydrodynamic Structures		Efficiency	5%	10%	10%
Dry Extended Detention Ponds		Efficiency	20%	20%	60%
Infiltration Practices w/o Sand, Veg.		Efficiency	80%	85%	95%
Infiltration Practices w/ Sand, Veg.		Efficiency	85%	85%	95%
Filtering Practices		Efficiency	40%	60%	80%
Erosion and Sediment Control		Efficiency	25%	40%	40%
Nutrient Management		Efficiency	17%	22%	N/A
Street Sweeping		Efficiency	3%	3%	9%
Urban Stream Restoration		Load reduction/length	0.02 lb/ft	0.003 lb/ft	2 lb/ft
Septic Connections		Systems Change	N/A	N/A	N/A
Septic Denitrification		Efficiency	50%	N/A	N/A
Septic Pumping		Efficiency	5%	N/A	N/A
Bioretention	C/D soils, underdrain	Efficiency	25%	45%	55%
	A/B soils, underdrain	Efficiency	70%	75%	80%
	A/B soils, no underdrain	Efficiency	80%	85%	90%
Vegetated Open Channels	C/D soils, no underdrain	Efficiency	10%	10%	50%
	A/B soils, no underdrain	Efficiency	45%	45%	70%
Bioswale		Efficiency	70%	75%	80%
Permeable Pavement w/o Sand, Veg.	C/D soils, underdrain	Efficiency	10%	20%	55%
	A/B soils, underdrain	Efficiency	45%	50%	70%
	A/B soils, no underdrain	Efficiency	75%	80%	85%
Permeable Pavement w/ Sand, Veg.	C/D soils, underdrain	Efficiency	20%	20%	55%
	A/B soils, underdrain	Efficiency	50%	50%	70%
	A/B soils, no underdrain	Efficiency	80%	80%	85%

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