<u>Addition of New Cover Crop Species with Nitrogen Reduction Efficiencies</u>

New Cover Crop Species Proposed:

- **Annual Ryegrass**
- **Annual Legumes**
- **Annual Legume plus Grass Mixtures**
- **Brassica (winter hardy)**
- **Forage Radish**
- **Forage Radish plus Grass Mixtures**
- **Triticale**
- **Oats (winter hardy)**
- **Oats (winter killed)**

Recommendations for Approval by the Water Quality Goal Implementation Team's Watershed Technical and Agricultural Workgroups

Introduction

Cover crops are one of the most valuable management practices available for protecting water quality, especially groundwater quality, which is a difficult resource to protect from non-point sources of soluble nutrients like nitrate nitrogen. Cover crops entered the Bay Model in 1997 and have been strongly endorsed by NRCS, State Environmental and Agricultural Agencies, and farm-producer advocacy groups like the Farm Bureau and The American Farmland Trust. More importantly, they have been widely adapted by producers across the Bay Watershed because in addition to conserving expensive nitrogen (N), they provide other benefits such as adding soil organic matter, improving soil structure, and improving soil health. There are also some habitat benefits provided by an actively growing off-season crop compared to the traditional fallow-weed cover, as well as some social benefits derived from seeing landscapes remaining "green" during the fall-spring seasons. However, the water quality benefits for N were the singular point of emphasis being considered by the panel for the new species.

This document summarizes the recommendations of the 2012 Cover Crop Expert Panel for New Species with accompanying Nitrogen Reduction Efficiencies. The Panel's membership was:

Panelist	Affiliation
Andy Clark	Univ. of Maryland, Sustainable Agriculture Research & Education
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Charlie White	Penn State University

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Wade Thomason	Virginia Tech
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Technical support by Steve Dressing, Don Meals, Jennifer Ferrando (TetraTech), Jeff Sweeney (EPA CBPO), Matt Johnston (UMD CBPO) and Emma Giese (CRC).	

Practice Definition

The new cover crop species will be added within the existing Traditional Cover Crop definition, no modifications of the existing definition are being recommended at this time.

This practice is recommended for revision because the existing species of rye, wheat, and barley do not adequately capture the diversity and extent of current cover crop practices being deployed in the Watershed.

The purpose of this revision is to allow the Bay Model to better represent current cover crop cultural practices and acreages, which have significantly expanded since 2007 when the Cover Crop BMP was last revised.

The purpose of the cover crop practice is to reduce nutrient losses to ground and surface water by sequestering them in a short-term crop grown after the main cropping season. The sub-categories are the cover crop species, the planting time, and the seeding method.

This practice meets the criteria standards under the USDA-NRCS National Handbook of Conservation Practices (NHCP) (http://directives.sc.egov.usda.gov/viewerFS.aspx?hid=22299) and the Field Office Technical Guides (http://www.nrcs.usda.gov/technical/efotg/) for each state.

Effectiveness Estimates with Brief Justification

The N Effectiveness Estimates are the only water quality parameter included for the new species because: 1) cover crops primarily function to trap or sequester N, with only minor reductions for phosphorus (P) and sediment (S); and 2) there are very few conservation-tillage era studies on surface runoff losses of P or S reductions for cover crops. Hence, a place holder, or interim, value of “0” will be used for the P and S effectiveness estimates for all new species, which will be replaced later with the Panel’s recommended values derived from best available data or from estimates provided from an independent agricultural model such as APEX.

Relative N Reduction Efficiency Estimates

The relative N reduction estimates for the new species were all derived from replicated field studies using peer reviewed papers, current Land Grant Univ. cover crop or forage species trials, graduate student theses, or outside grant research projects at Land Grant Universities. Each of these trials was required to have a rye treatment with either total N or ^{15}N uptake, or dry matter, measured in the spring at a time when a traditional cover crop would be terminated, or in the fall if the cover crop was not winter hardy. The presence of the rye N uptake or dry matter data provided a watershed wide “internal standard” that allowed *a direct comparison of each new species with rye, within each study*. This comparison involved simply calculating the ratio of the quantity of total N or ^{15}N uptake, or dry matter, in the new species to the corresponding measurement in rye, this ratio (e.g. = $(\text{total N uptake})_{\text{species 'A'}}$ / $(\text{total N uptake})_{\text{rye}}$) defines the term “Relative N Reduction Efficiency” used throughout this report, with the word “relative” in this context meaning “relative to rye”. The Panel calculated the final Relative N Reduction Efficiency for each new species from the average of applicable individual studies. Further details and examples of calculating the Relative N Reduction Efficiencies are in Appendix A.

A second major advantage of comparing all the new species to rye, is that the Bay Model calibration already includes rye as a cover crop. Thus, the final N Effectiveness Estimate for each new species can be made by simply multiplying the Relative N Reduction Efficiency (defined above) by the existing rye N Effectiveness (which is already in the Model with adjustments for spatial scale-up from plot to field, and for the hydrologic partitioning of N losses to ground water vs. surface runoff). Using the Relative N Reduction Efficiencies with the current rye N Effectiveness values thus eliminates the need to recalibrate the model for the new species (Pers. Comm. Jeff Sweeney, 4-24-2013). Further details and examples of calculating the final N Effectiveness values for the new species are given in Appendix A.

A summary of the Relative N Reduction Efficiencies for each new species and relevant specie mixtures are listed in Table 1. An example interpretation of the Relative N Reduction Efficiency values is that, on average, the total N uptake of Annual Ryegrass was 66% of the corresponding rye N uptake.

Table 1. Average relative N reduction efficiency, number of individual studies contributing to the average, and recommended planting times for the new cover crop species and species mixtures. Seeding methods are not listed because every new species will utilize seeding methods of high soil-contact/drilled, aerial/soybean, and aerial/corn according to the existing relative relations between these seeding methods in the current model.

Proposed New Species or Species Mixtures	Relative Nitrogen Reduction Efficiency (relative to Rye)	Number of Individual Studies	Recommended Planting Time [1]
Annual Ryegrass	0.66	5	Early and Normal
Annual Legume	0.16	4	Early and Normal
Annual Legume + Grass	Avg. (0.16 + Grass)	NA	Early and Normal
Brassica (winter hardy)	0.70	13	Early only
Forage Radish	0.58	12	Early only
Forage Radish + Grass	0.90	24	Early and Normal
Triticale	0.86	10	Early, Normal, & Late
Oats (winter hardy)	0.55	11	Early and Normal
Oats (winter killed)	0.40	4	Early only

[1] Early is more than two weeks before the average frost date, Normal is between the average frost date and two weeks before that date, Late is within three weeks after the average frost date.

Some noteworthy observations from Table 1 are that annual legumes are the poorest at recovering N compared to rye, but if they are grown in a grass mixture the recovery improves to an estimated average of the Relative N Reduction Efficiencies of the legume and the corresponding grass (see example calculation in Table 2). Over the course of the entire fall-spring cover crop season, a pure stand of forage radish is credited with recovering about 58% as much N as pure rye, which results from likely loss of N after the forage radish is killed by frost (commonly in mid-late Dec.) followed by decomposition of the radish residues with no growing plants present. However, a cover crop made up of a forage radish plus grass provides a continuous growing cover crop that can trap N released by radish decomposition, and results in the highest Relative N Reduction Efficiency of 90%. The grouped winter-hardy Brassica species have a somewhat higher Relative N Reduction Efficiency of 0.70 compared to forage radish because they are not killed by frost and maintain an actively growing crop throughout the winter. The total N uptake of Triticale (a cross between wheat and rye) was about 85% of the corresponding rye N uptake, while the N credit of winter-hardy Oats was 55% of rye and the N credit for the winter-killed oats was 40% to account for likely loss of some N during decomposition of oat residues in the spring.

The recommended planting windows for each of the new species are also listed in Table 1. The Panel recommended these dates based on the agronomic optimums for establishing each species, with particular attention given to the last planting dates that would likely produce acceptable growth and avoid seeding failure.

Recommended N Effectiveness Estimates

The Relative N Reduction Efficiencies from Table 1 form the basis for estimating the final N Effectiveness estimates for the Phase 5.3.2 update of the Model. Table 2 illustrates this calculation process for each new species or mixture using two planting-date windows (early and normal), and two establishment methods (drill seeded and aerial seeding into soybeans).

Table 2. Examples of new cover crop species, and cover crop mixtures, Relative N Reduction Efficiencies and final N Effectiveness values for selected planting and seeding methods in the Coastal Plain, Piedmont, or Karst physiographic regions of the Bay Model. A complete listing of the final N Effectiveness values for all categories is given in Appendix B.

Proposed New Species, or Reference Species (i.e. Rye)	Relative Nitrogen Reduction Efficiency (relative to rye)	Final Nitrogen Effectiveness for Phase 5.3.2
----------- Early planting by Drill seeding (high soil contact) -----------		
Annual Ryegrass (ARG)	0.66	0.30
Annual Legume	0.16	0.07
Annual Legume + Grass	Avg. (0.16 + Grass)	0.19 (Leg.+ ARG)
Brassica (winter hardy)	0.70	0.32
Forage Radish	0.58	0.26

Forage Radish + Grass	0.90	0.40
Triticale	0.86	0.39
Oats (winter hardy)	0.55	0.25
Oats (winter killed)	0.40	0.18
Rye (Ref. Species)	1.00	0.45
------ Early planting, Aerial seeding in Soybeans (low soil contact) ------		
Annual Ryegrass (ARG)	0.66	0.20
Annual Legume	0.16	0.05
Annual Legume + Grass	Avg. (0.16 + Grass)	0.13 (Leg.+ ARG)
Brassica (winter hardy)	0.70	0.22
Forage Radish	0.58	0.18
Forage Radish + Grass	0.90	0.28
Triticale	0.86	0.27
Oats (winter hardy)	0.55	0.17
Oats (winter killed)	0.40	0.12
Rye (Ref. Value)	1.00	0.31
---------- Normal planting by Drill seeding (high soil contact) ----------		
Annual Ryegrass (ARG)	0.66	0.27
Annual Legume	0.16	0.06
Annual Legume + Grass	Avg. (0.16 + Grass)	0.17 (Leg.+ ARG)
Brassica (winter hardy)	NA[1]	NA
Forage Radish	NA	NA
Forage Radish + Grass	0.90	0.37
Triticale	0.86	0.35
Oats (winter hardy)	0.55	0.23
Oats (winter killed)	NA	NA
Rye (Ref. Value)	1.00	0.41

[1] Only recommended for early planting time, not for normal planting time.

Calculating the final N Effectiveness values for each new species or mixture simply involves multiplying the Relative N Reduction Efficiency for each new entry by the corresponding rye N Effectiveness value that is currently in the calibrated model. For example, in the Atlantic Coastal Plain, Piedmont, or Karst regions an early seeded cover crop of Annual Ryegrass using a drill (high soil contact seeding) would be assigned a final N Effectiveness value of 0.30 (= (0.66 for ARG)*(0.45 for Rye planted early by drill)). The N effectiveness for an Annual Legume plus Annual Ryegrass mixture would begin by averaging the legume and grass Relative N Reduction Efficiencies, which is 0.41(= average (0.66 for annual ryegrass and 0.16 for the legume)), and then multiplying the mixture Relative N Reduction Efficiency by the rye N Effectiveness to give a final N effectiveness of 0.19 (= 0.41*0.45 (for Rye planted early by drill, which rounds to 0.19)). Corresponding calculations are illustrated in Table 2 for the other two planting times and the two seeding methods, with each scenario using the current rye N Effectiveness value for the corresponding planting time and seeding method.

The Panel recommends that the other planting method cells in the new species Cover Crop N Effectiveness list be somewhat simplified by combining the current "Drill" and "Other" categories into a single planting method of "High soil contact". The Panel also recommends maintaining the Aerial seeding category as two separate classes, one for soybean and one for corn, to adjust for the higher stand establishments of aerially seeded covers into soybean, which is documented in the original Mid-Atlantic Water Quality Program justification (MAWQP. 2007. Reduction for Aerial Seeding. p. 110-113).

Description of New Species and Estimation of Relative N Reduction Efficiency

This section provides a short description of each new species, or mixture, and a summary of how the Relative N Reduction Efficiencies for each new entry were developed. Appendix A contains a detailed description of the specific literature sources and the calculations of the Relative N Reduction Efficiencies for each new species or mixture.

Annual Ryegrass

Annual Ryegrass, also known as Italian Ryegrass, is a cool season annual grass that does a good job of accumulating nutrients, although it does not grow as well as rye during the colder months in the Bay watershed. It has an extensive soil holding root system that establishes quickly, which is the basis for its reputation as a soil erosion fighter. It is a common component of mixtures, where it is often aerial seeded (USDA, SARE 2007).

The Panel utilized five individual studies from within the Bay watershed to estimate the Relative N Reduction Efficiency, two from PA, two from MD, and one from NY. All studies were planted in the early- or normal-planting period and all harvests were in mid-April to early-May (MD and PA), or in mid-May (NY), which is consistent with spring crop development.

The five site-years of data were summarized by calculating a simple weighted average (each mean was weighted by the number of site-years it contained), which produced a final weighted average Relative N Reduction Efficiency of 0.66 that is listed in Tables 1 and 2.

A summary of the studies and methods to estimate the Annual Ryegrass Relative N Reduction Efficiencies follows:

a) The PA data (Houser et al.,2012 & 2013) were from the “Short-lived cool-season forage trial” planted in 2011 and 2012 that received 30 lbs starter-N/ac in the fall and 100 lbs N/ac in the spring for all entries, including the rye reference entry. The PA data consisted of the yearly average total N uptake across five annual ryegrass varieties that were all present in 2011 and 2012, which contributed two individual site-years of data having an average Relative N Reduction Efficiency of 0.77.

b) The MD data were from the peer-reviewed publication of Shipley et al, (1992) that added a luxury amount of ^{15}N labeled fertilizer to corn and measured the fall residual soil ^{15}N, followed by establishment of fall cover crops of annual ryegrass and rye, and measurement of the ^{15}N in these covers the following spring. This study was conducted in the 1986-87 and 1987-88 cover crop seasons on the Eastern Shore of MD. The average Relative N Reduction from these two site-years was 0.68.

c) The NY data are from an unpublished NRCS study in 2010 that evaluated cover crop planting dates (three Sept planting dates) that compared spring dry matter (DM) production from annual ryegrass to that of rye. The Panel chose to accept DM data as a surrogate for total N uptake since annual ryegrass and rye are both cool-season grasses, and because the NY data added information capturing the large north-south range of growing conditions within the Bay watershed. The NY data were averaged across the three planting dates which produced a Relative DM Production Efficiency of 0.40 for annual ryegrass.

Annual Legumes and Grass Legume Mixtures

Annual legume cover crops are winter annuals that are primarily used to supply N to the next crop due to their ability to fix significant quantities of atmospheric N. But they also provide a living crop that can scavenge small amounts of residual nutrients as well as provide some erosion protection during the spring runoff season (USDA, SARE, 2007).

In the Bay watershed, the most common annual legumes are Hairy Vetch and Crimson Clover. The Panel recommends combining these two legume species, and other winter annual legumes, into one category because all the existing data on legume recovery of residual N studied either hairy vetch and/or crimson clover. Another reason to include pure legume stands is the rapidly growing popularity of grass-legume mixtures, which can absorb significant quantities of fall nutrients by the grass species in the mixture. Thus, the Panel recommends adding both the Annual Legume and Annual Legume plus Grass categories to the Phase 5.3.2 update.

There were only two peer-reviewed studies, each with two site-years of data, available for estimating the Relative N Reduction Efficiency for annual legumes in the Bay watershed. This is because ^{15}N is needed to directly estimate the recovery of fall N in a legume, which also contains N derived from decomposition of soil organic matter plus large quantities of N derived from atmospheric fixation. Both of these studies used early- and normal-planting dates along with a mid-April harvest.

The four site-years of ^{15}N data produced a final weighted average estimate of the Annual Legume Relative N Reduction Efficiency of 0.16, with the Panel recommending that the estimate for an Annual Legume plus Grass mixture should be the average of the Annual Legume and the Grass component.

A summary of these two Bay area Annual Legume studies is given below, along with a summary of two other studies that provide corroborating data for the results from the Bay area research:

a) The peer-reviewed ^{15}N publication of Shipley et al, (1992), described above in the Annual Ryegrass section, also documented the recovery of fall ^{15}N labeled fertilizer by hairy vetch, crimson clover, and rye in a silt loam soil on Maryland's Eastern Shore. The average Relative N Reduction Efficiency from the 1986-87 and 1987-88 cover crop seasons was 0.22 for hairy vetch and 0.17 for crimson clover, which gives a combined average Relative N Reduction Efficiency for Annual Legumes of 0.19.

b) The second peer-reviewed ^{15}N publication was by Ranells & Wagger (1997) who added ^{15}N labeled nitrate to fall seeded crimson clover, rye, and a crimson clover plus rye mixture in a loamy sand soil on North Carolina's Eastern Shore. The average Relative N Recovery Efficiency for crimson clover over the 1993-1994 and 1994-1995 cover crop seasons was 0.09. The lower ^{15}N recovery by crimson clover in the NC study is likely due to greater ^{15}N leaching in the coarse-textured loamy sand soil, compared to the finer-textured silt loam in MD. The average Relative N Reduction Efficiency of the crimson clover plus rye mixture was 0.47, which is satisfactory support for using this study's average Relative N Reduction Efficiency of rye (i.e., 1.00) and crimson clover (i.e., 0.09) to estimate the Relative N Reduction Efficiency of the mixture. No other studies could be found in the literature that would provide other estimates of the Relative N Reduction Efficiency of a legume plus grass mixture.

c) Two other studies were also identified that provided corroborative data on N recoveries by legumes vs. grasses, and on the value of legume-grass mixtures. These studies could not be used to estimate a Relative N Reduction Efficiency because they did not have a direct comparison data with rye. Gabreil and Quemada (2011) conducted a ^{15}N recovery study with barley and hairy vetch in Spain and reported that barley recovered 10% of the residual ^{15}N, while vetch recovered only 1%. In Oregon, Feaga et al. (2010) used multi-year field lysimeter data to document that the average nitrate concentration in drainage below grass covers was 34% less than without a cover; while a vetch-triticale mixture averaged 19% less than without a cover. These two studies support the view that grasses are much better than legumes at recovering residual N, and that a legume-grass cover is about half as effective as a pure grass cover at reducing the nitrate concentration in soil drainage water.

Brassicas (winter-hardy)

Two species of winter-hardy *Brassicas* are proposed for inclusion in the model: Canola and Rape. Both are technically rapeseed, and both can take up significant amounts of N, often comparable to rye, but only if planted early. The winter-hardy Brassicas provide full fall-winter-spring crop growth and residue cover that avoids possible residue decomposition losses while providing soil cover to manage erosion.

The Panel reviewed 13 site-years of data. Studies from within the Bay watershed include three site-years from a peer-reviewed MD study, six site-years from an unpublished VA study, and one site-year from an extension publication and PA. Other studies that the Panel considered valid and which had a direct comparison to rye, were from peer-reviewed research done in Oregon (two site-years) and France (one site-year).

Rape and Canola are grouped together because they have similar fall and spring growth in the Bay watershed. Both should be planted early; they survive the winter and continue to accumulate biomass and N in the spring, as well as provide soil cover for erosion control.

The 13 site-years of data were initially summarized by calculating a simple weighted average as above, which produced a final weighted average Relative N Reduction Efficiency of 0.80. However, due to high pre-planting available N and very early planting in some site-years, and because of the wide range of N uptakes for rape; the Panel unanimously voted to recommend a more conservative Relative N Reduction Efficiency of 0.70.

The data summary for rape and canola listed in Tables 1 and 2 are summarized below:

a) The largest data set is from the Eastern and Western VA studies (Pers. Comm. Wade Thomason) in 2010-2012 (3 site-years each). The studies include rye, pure oats and an oat plus canola mixture. Cover crops were planted in the early-planting period for each location and followed cash grain-crops. The average canola N uptake value (57 lbs N/ac) was estimated by subtracting the pure oat uptake (17 lbs N/ac) from the oat/canola mixture uptake (74 lbs N/ac), while the rye N uptake was 98 lbs N/ac. Thus, the average Relative N Reduction for canola from these six site-years was 0.62.

b) The MD data (Dean and Weil, 2009) is based on one site-year (2004) from the Piedmont and two site-years (2003) from the Coastal Plain. In two of these studies, rape and rye were planted following mowing of a soybean crop that added an estimated 208 and 205 lbs of available N/ac to the soil. The average N uptake for the rye from these three site-years was 81 lbs N/ac and the Relative N Reduction Efficiency was 1.2. However, due to the high N environment in these studies, the Panel voted unanimously to adjust the final efficiency for rape as described above.

c) The PA data (Finney and Kaye, 2013) came from 1 site-year of data (2011). The Hagerstown soil was conventionally tilled following an oat crop; rye and rape were planted in late August and harvested in mid-May, 2012. Rape N uptake was 108 lbs N/ac compared to 67 lbs N/ac for rye, giving a Relative N Reduction of 1.6.

d) Data from France (Muller, Denys, Borlet and Mariotti, 1989) was included because it included a rye cover crop whose values were similar to data from the Bay watershed. These data (one site-year) followed wheat and also demonstrate the effect of slightly later planting (but still in the early-planting period) on rape N uptake, which was harvested in early March. Rye N uptake was 120 lbs N/ac and rape uptake was 23 lbs N/ac, resulting in a Relative N Reduction for rape of 0.19.

e) Data from Oregon (Fernando et al., 1996) was included because the Adkins fine sandy loam and rainfall pattern is similar to the Bay watershed. The other cover crops in this study (rye, wheat and triticale) also had N uptakes that corresponded well with data from the Bay watershed. Two site-years of data were reported (1992-1993) and 1993-1994) as part of this Ph.D thesis. Cover crops were planted in mid-September and harvested in mid March or early April. The average rye N uptake was 102 lbs N/ac while rape was 68 lbs N/ac, giving a Relative N Reduction was 0.62.

Forage Radish

The Forage Radish, also known as tillage radish, is a popular deep-rooted cover crop that grows fast with warm weather and an ample supply of N. It can recover substantial quantities of residual N, and often accumulates as much, or more, N in the fall than rye. However, it is subject to winter killing following a few days below 25 F. After winter-kill the radish residues decompose rapidly, leaving the soil bare and producing some nitrate-N during the remaining winter and early-spring season.

Twelve site-years of Forage Radish N uptake data, with corresponding rye data, were available from MD, PA, and VA with all planting done during the early-planting period. All harvests were in mid-April to early-May, which is consistent with crop development in the spring.

The 12 site-years of data were initially summarized by calculating a simple weighted average as above, which produced a final weighted average Relative N Reduction Efficiency for forage radish of 1.00. However, due to high pre-plant available N and very early planting in some site-years, and because of the wide range of N uptakes for forage radish compared to rye; the Panel chose to conduct an anonymous poll to allow each member to submit their estimate of the radish Relative N Reduction Efficiency. The Panel then pursued detailed discussions about various interpretations of the data. The Panel concluded by voting unanimously to recommend acceptance of the average Relative N Reduction Efficiency from the anonymous poll, which is 0.58.

The summary for the forage radish data are given below:

a) The largest data set is from the Eastern and Western VA studies (pers. comm. Wade Thomason) in 2010-2012, with each area contributing 3 site-years of data. These studies included fall N uptakes for rye and pure radish, with the details of this study given in the Brassica (winter-hardy) section above. The average N uptakes, in lbs N/ac, in Eastern VA were 62 and 53, for rye and radish, respectively. The corresponding N uptakes (lbs N/ac) for the Western VA were 134 and 96, for rye and radish, respectively. These six site-years of data produced an average Relative N Reduction for forage radish of 0.79.

b) The MD data is from is based on two site-years from the Piedmont and three site-years from the Coastal Plain. In three of these studies, the radish and rye were planted following mowing of a soybean crop that added an estimated several hundred of N/ac to the soil. The average fall N uptake for the rye from these five site-years was 106 lbs N/ac, while corresponding value for forage radish was 130 lb N/ac. These data provide a Relative N Reduction Efficiency of 1.23.

c) The PA data was from an Extension demonstration study from one site-year of data (2011), which is described above in the Brassica section. The forage radish N uptake was 27 lbs N/ac compared to 67 lbs N/ac for rye, giving a Relative N Reduction of 0.40.

Forage Radish and Grass

The general biological characteristics and uses of Forage Radish and Grass cover crops can be gleaned from their accompanying descriptions in the Forage Radish and Triticale species sections. The Forage Radish plus Grass category is listed as a separate group because: i) it combines two distinctly different species, each contributing their own advantages to the resulting mixture, and ii) there is a strong data base available for estimating the Relative N Reduction Efficiency for this mixture.

The Panel utilized individual studies from PA and VA that provided 24 site-years of data for estimating the Relative N Reduction Efficiency for a Forage Radish plus Grass mixture. All studies were planted in the early- or normal-planting period and all harvests were in mid-April to early-May, which is consistent with crop development in the spring.

The 24 site-years of Forage Radish plus Grass data were summarized using a weighted average based on the number of site-years in each mean, which produced a final Relative N Reduction Efficiency of 0.90 for Forage Radish plus Grass.

A summary of the data and the methods to estimate the Forage Radish and Grass Relative N Reduction Efficiencies follows:

a) The Pennsylvania Cover Crop after Corn Silage Trial was the main source of data. This is an unpublished (still in progress) data set from Dr. Sjoerd Duiker containing two years of data from 10 (2011-12) or 9 (2012-13) different on-farm field locations across PA. Each location followed silage corn and contained a direct comparison of the total N uptake of rye vs. a forage radish plus rye mixture. The average Relative N Reduction Efficiency from these 19 site-years of data was 0.93.

b) The other PA data came from the "Short-lived cool-season forage trial" of Houser et al. (2011 and 2012) that is described in the Annual Ryegrass section. In this trial rye was compared to a mixture Forage Radish plus Annual Ryegrass, which produced a Relative N Reduction Efficiency of 0.76.

c) The VA data is from the Radish and Mixed Species trial that is summarized in the Brassica section and contains three years of western VA data comparing rye with a mixture of forage radish plus rye plus annual ryegrass (a three species mixture containing two grasses). The resulting Relative N Reduction Efficiency is 0.79.

Oats (winter-hardy) and Oats (winter-killed)

Oats is a cool season annual cereal having varieties that are winter hardy in some areas of the Bay watershed, and some varieties that are winter killed. Oats are primarily used as a short-term N scavenger with secondary benefits of reducing soil erosion. In circumstances where herbicides are not used a winter-killed oat variety is often preferred to other winter-hardy cereal covers.

Virginia provided the most complete data base for winter-hardy oats, which was 11 years of data (Smith et al., 2009) comparing total N uptake from a single winter-hardy variety with corresponding data from rye. The Panel recommended that the planting periods for winter-hardy oats be early and normal, while the planting period for winter-killed oats should be early. The winter-hardy oat data also provided the base line for estimating the winter-killed Estimated N Reduction Efficiency, which is described in more detail below. The final Relative N Reduction Efficiency of winter-hardy oats is 0.55, and for winter-killed oats is 0.40.

A summary of the data and the methods to estimate the oat Relative N Reduction Efficiencies follows:

a) The source of data for winter-hardy oats was the Virginia small grain forage variety testing report: long-term summary (1994-2004) reported by Smith et al. (2009). This study received 25-30 lbs starter-N/ac in the fall and 60 lbs N/ac in the spring for all entries, including the rye reference entry. The VA study documented the average total N uptake for a single winter-hardy oat variety and a single rye variety that were both present in 11years of the long-term study, thus providing 11site-years of data having an average Relative N Reduction Efficiency of 0.55.

b) The winter-killed oat Relative N Reduction Efficiency was estimated from the above winter-hardy oat data base that was adjusted for estimates of over-winter N loss. One approach was based on the assumption that all the fall nitrate-N content of oats (data provided by pers. comm. with Ms. Natalie Lounsbury, Univ. MD) was lost, which amounted to an 18% loss of the oat total N. The second approach was based on the loss of total N in the oat residues during the over-winter period from another unpublished (pers. comm. Dr. Wade Thomason) three-year VA trial studying Radish and Mixed Species Cover Crops, which amounted to a 36% loss in oat total N. These two loss estimates were averaged together and related to the rye N uptake, which resulted in a Relative N Reduction Efficiency for winter-killed oat of 0.40.

Triticale

Triticale is a cool season annual cereal that is a cross between wheat and rye, giving it characteristics from each parent. It serves the dual purpose roles of being a N scavenger and an erosion fighter. It grows almost as well as rye in cold months, but is easier to manage in the spring because it is less subject to the rapid spring growth, that can difficult to manage with rye.

The Panel utilized individual studies from MD, NY, PA, and VA that provided ten site-years of data for estimating the Relative N Reduction Efficiency for triticale. All studies were planted in the early- or normal-planting period and all harvests were in mid-April to early-May or in mid-May (NY), which is consistent with crop development in the spring. These studies did not include a late planting, but in the Panel's professional judgment it recommends including a late-planted category, this is the same procedure used by the last 2007 Cover Crop Panel for the late-planting category of rye and wheat (MAWQP, Cover Crop Report, 2007).

The ten site-years of triticale and rye data were summarized using a weighted average based on the number of site-years in each mean as before, which produced a final Relative N Reduction Efficiency of 0.86 for triticale that is listed in Tables 1 and 2.

Summaries of the triticale data are:

a) The MD cover crop studies with triticale were the peer-reviewed paper of Coale et al. (2001) and unpublished 2004 data from Dr. Ken Staver. Each study contributed one site-year with the Staver study reporting a Relative N Reduction Efficiency of 0.84 and the Coale et al. reporting 1.15, which indicates that triticale took up about 15% more N than rye – a fact that should be occasionally expected since rye was one of the parents of triticale.

b) The NY data are from the same unpublished 2010 NRCS cover crop planting date study that is described in the Annual Ryegrass section. The NY data were averaged across the three planting dates which produced a Relative DM Production Efficiency of 0.64 for triticale.

c) The PA data from the "Short-lived cool-season forage trial" planted in 2012 (Houser et al., 2012 & 2013) are the basis for the Estimated N Reduction Efficiency. A summarized description of this study is given in the Annual Ryegrass section. The triticale total N uptake contributed a single site-year of data having an average Relative N Reduction Efficiency of 0.70.

d) The largest triticale data set came from the Virginia small grain forage variety testing report: long-term summary (1994-2004) reported by Smith et al. (2009). The VA study received 25-30 lbs starter-N/ac in the fall and 60 lbs N/ac in the spring for all entries, including the rye reference entry. The VA data consisted of the average total N uptake for a single triticale variety and a single rye variety that were both present in 6 years of the long-term study, thus providing six site-years of data having an average Relative N Reduction Efficiency of 0.88.

Technical Requirements for Entering the Cover Crops BMPs into Scenario Builder and the Watershed Model

Background: In June, 2013 the Water Quality Goal Implementation Team (WQGIT) agreed that each BMP expert panel would work with CBPO staff and the Watershed Technical Workgroup (WTWG) to develop a technical appendix for each expert report. The purpose of the technical appendix is to describe how the expert panel's recommendations will be integrated into the modeling tools including NEIEN, Scenario Builder and the Watershed Model.

Q1: What are the efficiency reductions a jurisdiction can claim for implementing and reporting the new cover crop species?
A1: The table below shows the reduction efficiencies for nitrogen for each of the new cover crop species (INSERT REFERENCE). INSERT TABLE OF REDUCTION EFFICIENCIES AND SPECIES

Q2: Why is there no credit given for phosphorus or sediment for the new cover crops species?
A2: As of publication of this document, the panel is recommending that consideration of phosphorus and sediment reductions for the new species will take place at a later time, due to the lack of data on the effect of cover crops on phosphorus and sediment losses. The panel's final Phase 5.3.2 report will therefore address nitrogen, and will consider phosphorus and sediment reductions for all species at a later time, most likely when the expanded modeling expertise with the NRCS APEX model is available.

Q3: How is the reduction actually calculated in Scenario Builder and the Watershed Model?

A3: The total load reduction is determined by the Watershed Model as the product of the efficiency reduction listed in Table 1, the acres of agricultural land within the model segment with cover crops reported, and the total nitrogen load simulated for the model segment for those agricultural acres.

Q4: Did the panel alter the way existing cover crop species receive credit?
A4: No. The expert panel recommended that the current cover crop species be simulated in the same way they have historically been simulated using the Phase 5.3.2 Watershed Model (INSERT REFERENCE).

Q5: What does a jurisdiction need to report in order to receive credit for cover crop species?
A5: Jurisdictions should report the following information:

- Cover Crop Type: Species of cover crop
- Planting Method: Aerial, Drilled, Other
- Planting Time Period: Early, Standard, Late
- Crop preceding Cover Crop: Corn, Soybean
- Acres: Number of acres with reported species within geographic reporting unit
- Location: Approved NEIEN geographies: County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4), State (CBWS Only)
- Date of Implementation: Year cover crop was planted

Q6: Can a jurisdiction still receive credit if it cannot report the planting method, planting time, or preceding crop?
A6: Yes. Jurisdictions should always report the most specific information available to them for each cover crop acre. However, if information is not reported, Scenario Builder will credit the jurisdiction with the closest available cover crop type, planting method and planting time period. For example, if a jurisdiction can define cover crop type and planting method, but cannot define planting time period, then Scenario Builder will assume the planting time period was late. In this way, jurisdictions will need to specify more information in order to take advantage of the higher efficiencies related to earlier planting time periods or more effective planting methods.