Relative Agricultural Land Use Loading Ratios for Calibration of the Phase 6 Chesapeake Bay Watershed Model

A report of the:

Ag Loading Rate Review Steering Committee

Agricultural Modeling Subcommittee (AMS)

Water Quality GIT

Chesapeake Bay Program

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(The Steering Committee is also alternatively referred to as the "Sub-group" in this report)

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Table of Contents

Final Agricultural Loading Ratio Recommendations and Justifications

Charge to the Subgroup

This ad hoc subgroup of the Agricultural Modeling Subcommittee (AMS) was formed by Mark Dubin, Agricultural Technical Coordinator, with the University of Maryland Extension and the USEPA Chesapeake Bay Program Office, to serve as a science review panel to look over the references which have been collected by Tetra Tech (published literature), and Water Stewardship, Inc. (primarily grey literature). The ad hoc "panel" was requested to develop relative land use loading ratios for each of the new Phase 6.0 agricultural land uses, based on the most appropriate literature sources. The ratios were to be developed separately for nitrogen, phosphorus, and sediment.

Major Findings

Nitrogen General Approach

Agricultural N losses to the Chesapeake Bay are dominated by NO3-N leaching, with only secondary losses from runoff because nitrate, being an anion, is not retained by the soil cation exchange capacity and because nitrate is completely water soluble. The subcommittee therefore focused on literature that documented NO3-N leaching losses. However, the subcommittee also found that ranking the Phase 6.0 land uses by N leaching losses showed that land uses with high N-inputs also had high N leaching losses. Thus, land uses with large N inputs will be expected to have larger leaching and larger surface runoff losses than land uses with smaller N inputs, and if relative surface-runoff losses are desired, the NO3-N leaching loss ratios would be a practical first approximation.

The subcommittee summarized the literature data using a ratio approach; specifically, the NO3-N leaching from a given land use compared to the NO3-N leaching from fertilized corn grown for grain (i.e. the land use "corn or sorghum, grain – no manure" or simply "corn, grain – no manure" since no sorghum data were found). The ratio parameter converts the measured mass of NO3-N leached for a given land use, into a relative to "corn, grain - no manure" basis, which in effect uses fertilized corn for grain as a local standard of comparison, i.e. a local control. The subcommittee considers the ratio approach to be superior to N-loss estimates using the mass of N per unit area (i.e. kg NO3-N ha-1) because the ratio approach adjusts for local effects such as weather, soil type, tillage practices, etc., that add variability to N-loss estimates based on kg NO3-N ha-1, especially when leaching losses are being averaged over large areas. However, the improved sensitivity of the ratio approach is achieved at the expense of having fewer studies available that directly compare a given land use to "corn, grain - no manure". Never-the-less, an adequate number of studies were available that provided initial estimates of the "relative to fertilized corn" ratios in the same year and same location. In addition, because N losses are significantly affected by the N application rate, the N-leaching losses were interpolated to the losses at the economic optimum N rate or to the Land Grant University recommended N rate for each land use. The N application rate correction means that the N leaching ratios should be consistent with the common N rates used by producers in the Bay watershed.

The criteria for selecting a study to estimate a relative to "corn, grain - no manure" ratio were as follows:

1. The study was conducted in the Chesapeake Bay watershed or in nearby states with soils and climate similar to those within the Bay watershed;
2. Nitrate-N leaching was estimated by lysimetry or by fall residual NO3-N to a depth ≥ 90 cm;
3. Both the land use under consideration and corn-grain-without-manure land use were present in the same study and the same year, or were present within a few years of each other (to allow rotation studies to be considered and some large monolith lysimeter data);
4. The study included a N-response curve to estimate the economic optimum N rate or included the N rate recommended by the state Land Grant Univ. for that particular crop and land use;
5. The study did not use other N conservation practices, such as cover crops, the pre-sidedress nitrate test, nitrification inhibitors or urease inhibitors, etc. (to have data consistent to a base-line condition without N best management practices); and
6. Each year in a multi-year study, or each location in a multi-location study (i.e., each site-year) was considered to provide an independent estimate of the "relative to corn grain" ratio.

Nitrogen Loading Ratios

The final version of nitrogen loading ratios was recommended by the Ag Loading Rate Review Steering Committee to the Agriculture Working Group in their meeting on September 17, 2015.

The nitrogen loading ratios, relative to "corn, grain - no manure", for each Phase 6.0 land use are listed in Table 1. The interpretation of the ratio data for the first land use of "corn grain with manure" is that corn grain receiving manure will, on average, lose 1.4 times more NO3-N to leaching than fertilized corn for grain without manure. However, the standard error of the 1.4 average ratio is 0.2 (last column in Table 1), which indicates a significant amount of variability among the 12 data points in this land use. Since the "corn grain - with manure" land use has the most data points, and because it is a land use often identified for N management, a histogram of these 12 data points is also provided (Figure 1). This histogram illustrates several points: the variability of the ratios that range from 0.7 to 3.0, and the data's non-symmetric pattern that is influenced by several large values. This asymmetry is common for non-normally distributed data, but there are not enough data points available to identify the underlying statistical distribution. Clearly, this histogram illustrates the need for using great caution when applying the average value to individual cases. It is also noteworthy that the lower group of points in Figure 1, below the mean of 1.4, were generally points that received manure rates consistent with manure best management practices (e.g., manure analysis, manure history, spreader calibration, and matching manure rate to corn N needs). The points above 1.4 in Figure 1 were sites with a history of manure applications or with heavy manure rates. In fact, two of the sites above 1.4 did not respond to additional N fertilizer at all, meaning that the manured soil could supply all the corn N needs. Yet despite the fact that no fertilizer N was applied, the fall residual NO3-N was substantially above that of the fertilizer only residual NO3-N at the fertilizer-N economic optimum.

Table 1 also contains an unexpected result, which is the relative to "corn, grain - no manure" ratio for full-season soybeans of 0.71. This value results from the N added by full-season soybean N2 fixation. The total aboveground N content of a good soybean crop can vary between 225 and 300 kg N ha-1, with the majority of this N derived from N2 fixation. About half of this total aboveground N is removed in the soybean harvest, but the other half remains in the high-N content crop residues that readily decompose producing NO3-N that is vulnerable to leaching during the following fall-winter-spring fallow season. The relative to “corn, grain - no manure” ratios in Table 1 also capture an important generalization: that perennial crops like hay and agriculture open space land uses are quite efficient at conserving N compared to corn. This is because perennials have an actively growing crop continuously taking up N throughout the whole seven to nine month of the growing season, while annual crops have a limited growing season of about three to five months which leaves the remaining months fallow and subject to nitrate leaching. A final note is to point out that many land uses have only one or two references, and that the land uses without any references were estimated by best professional judgment calculations of the subcommittee (see Table 1 footnotes for the calculations). This current scarcity of data calls for further future evaluations of the published and unpublished literature in order to provide improved estimates of the relative to “corn, grain - no manure” ratios for all Phase 6.0 land uses.

Table 1. Phase 6.0 land uses and their corresponding relative to "corn, grain - no manure" ratios derived from published and unpublished literature (identified by italicized numbers) and from best professional judgment calculations (identified by italicized letters).

Data summary of Relative NO3-N Loading Estimates for Phase 6.0 Land Uses J.J. Meisinger			
	Phase 6.0 Land Uses (italicized numbers are citations, italicized letters are footnotes)	**Avg. ratio (# obs) to Corn, grain - no manure**	**Std. Error Mean**
1	Corn or sorghum, grain - eligible for manure *(1,2,3,10,11)*	1.40 (12)	0.20
2	Corn or sorghum, silage - eligible for manure *(10)*	1.62 (1)	NA
3	Corn or sorghum, grain - no manure *(standard of reference)*	1.00 (NA)	NA
4	Corn or sorghum, silage - no manure [*A*]	1.16 (NA)	NA
5	Small-grain w/ soybean double-crop - no manure *(9)*	0.79 (2)	0.09
6	Soybean, full-season - no manure *(3,4,5,10)*	0.71 (6)	0.11
7	Small-grain w/ forage establishment - eligible for manure [*B*]	0.84 (NA)	NA
8	Other agronomic crops (e.g., cotton, tobacco, peanuts) *(15)*	0.45 (1)	NA
9	Pasture, direct deposition - eligible for manure *(12,13,14)*	0.23 (10)	0.05
10	Hay, legume or legume-grass mix *(6,7)*	0.17 (4)	0.02
11	Other hay, (e.g., peren. grass, orch. grass, tall fescue) *(12,13)*	0.24 (4)	0.06
12	Agr. open space (e.g., peren. grass, tall fescue) *(8)*	0.10 (2)	0.01
13	Specialty crops - high input (e.g., potatoes, sweet corn) *(10)*	1.34 (1)	NA
14	Specialty crops - low input (e.g., orchards, beans, peas) [*C*]	0.31 (NA)	NA

[A] Estimated from ratio of (Corn or sorghum, silage w/ manure) / (Corn or sorghum, grain w/ manure), calculation = 1.62 / 1.40 = 1.16.

[B] Estimated from Small-grain w/ soybean double-crop w/o manure, which is adjusted to small-grain only, followed by adding in a manure factor. For example: first estimate soybean double-crop factor, assuming double-crop soybean = 50% of full-season soybean, so small-grain w/o soybean = 0.79 - (0.71 / 2) = 0.44. Then, add small-grain w/ manure factor = 0.44 + (corn, grain w/ manure - corn, grain w/o manure) = 0.44 + (1.40 -1.00) = 0.84.

[C] Estimated from Other Hay value by adding 0.07 (due to greater loading w/ annuals) = 0.24 + 0.07 = 0.31.

<u>Citation #</u> <u>Citation Brief Description</u>

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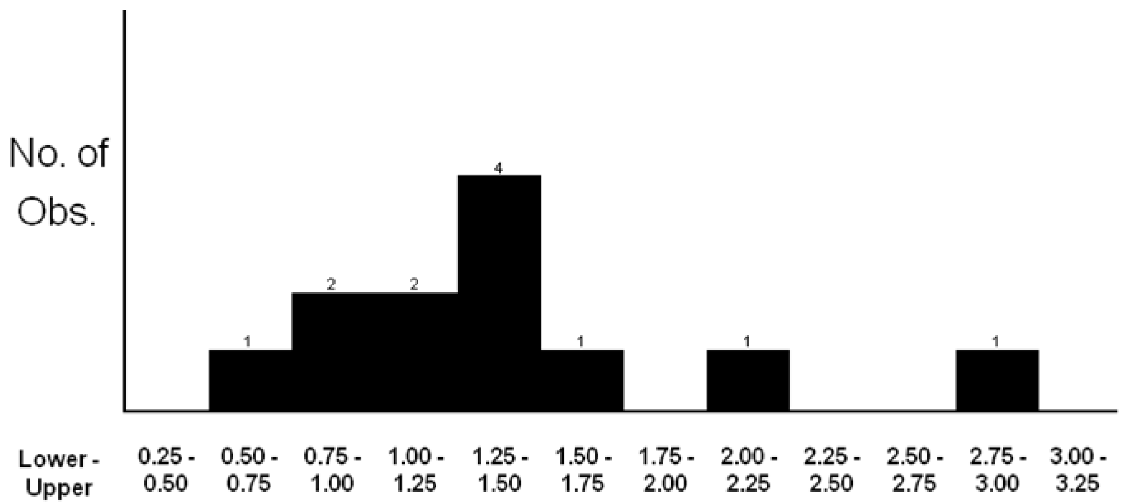


Figure 1. Frequency distribution of the "relative to corn grain with manure" to "corn grain without manure" ratio. Values on top of bars are the number of observations in each interval.

Additional relevant discussion and analysis excerpted from email exchanges and conference call discussions is provided in Appendix B.

Recommendation: Use the land use-based relative NO3-N leaching loading rates derived from a combination of literature and comparative land uses and conditions to represent total N relative loading rates, given that surface runoff N loads represent a relatively smaller 10% of total N loads and would not appreciably change the relative loading ratios.

For future review: While our Sub-group feels that these are currently the best available estimates of relative N loading rates, we also note that confidence in these estimates could be increased with additional studies for the land uses with ratios based on only 1 or 2 studies. In addition, more accurate ratios could be estimated with distributed information on local manure N application rates and crop N demand.

Sediment Loading Ratios

Upon review of the Tetra Tech and WSI literature review databases and the additional analysis provided by Yagow, the Sub-group found the literature sediment loading rates highly variable and incomplete for assessing variability among agricultural land uses, as well as among geographical provinces. Since traditional agricultural models to predict EOF erosion rates for farm conservation planning (USLE, Wischmeier and Smith, 1978; RUSLE, Renard et al., 1997; RUSLE2, USDA-ARS, 2013) have been well vetted and are based on many years of field research, the Sub-group decided to explore using output from one such model as the basis for relative loading rates for sediment.

RUSLE2 is the most current USDA-ARS model used to predict EOF erosion rates and is already in use by the Chesapeake Bay Program to generate relative sediment loading rates for Scenario Builder. RUSLE2 modeling for the Bay Program was contracted through Tetra Tech and became available to our Sub-group at the end of August 2015. Tetra Tech received information from NRCS in each state to determine appropriate length, slope, tillage instruments and dates, plant/harvest dates, representative R factor by county, and either a soil series or texture for the K factor. They performed several model simulations for conventional tillage practices and approximately 10 different crops or crop rotations for each crop management zone (CMZ) in the Chesapeake Bay Watershed. A review by members of our Sub-group verified the differential assessment of sub-factor values by state and crop management zone combinations for a range of land uses that could be associated with the desired P6 agricultural land uses. Preliminary results also addressed our Sub-group's reservations about RUSLE2's ability to represent pasture erosion rates relative to cropland more appropriately than in the original version of RUSLE. Results from this modeling will provide differential erosion rates by land use across a range of geographic regions and were deemed by our Sub-group to be most appropriate for calculation of sediment loading rates, and subsequent loading ratios, by P6 land use.

Recommendation: Since land use and geographical variability is already incorporated into the sub-factors of the erosion calculation, the Sub-group recommends that no additional adjustment for land use be made to the RUSLE2 predictions of EOF erosion. Any fractional adjustment to these loads during calibration should be applied equally to all land uses.

For future review: Although our Sub-group endorsed the use of RUSLE2 for generating sediment loads and relative loading ratios, our review revealed inconsistencies in the range of sub-factor values evaluated between states and crop management zones (CMZs). Although the overall erosion rates and relative loading ratios produced by RUSLE2 were deemed reasonable, our Sub-group strongly felt that these inconsistencies must be addressed before the relative loading rates as used by Scenario Builder will be a valid representation of erosion rates among states and CMZs.

Phosphorus Loading Ratios

Our Sub-group felt strongly that the majority of dissolved phosphorus loading was influenced by soil saturation excess, while particulate P was strongly associated with movement of sediment. These processes are simulated by the APLE model, which is being used by the Chesapeake Bay Program for generating phosphorus loads for use with Scenario Builder and for sensitivity analysis. The most recent version (APLE2.4, Vadas et al., 2014), possesses separate components for representing particulate and sediment-attached phosphorus components. The sediment-attached phosphorus in APLE2.4 is simulated as a function of RUSLE2 erosion rates, the dissolved P from soil is simulated as a function of county Mehlich-3 soil test averages and soil properties, and the dissolved components from applied chemical fertilizer and manure are based on county-distributed inputs of fertilizer sales, livestock numbers, and incorporation characteristics.

An analysis and review of select studies were made by members of our Sub-group to define expected ranges of phosphorus loads, especially for pasture, whose loading rates from the Phase 5.3.2 model were deemed excessively high (See Appendix B for extended discussion of this analysis). Then, based on example APLE simulated loads for select land use types, our sub-group endorsed using APLE as the basis for phosphorus loads by P6 land use, in lieu of assigning P loads by land use literature values alone.

Recommendation: Since the APLE2.4 simulated phosphorus loads also encompass sub-factors that incorporate land use and geographically-distributed characteristics, our Sub-group also endorsed using

APLE 2.4 as a reasonable basis for P6 land use derived phosphorus loads. Since land use and geographical variability is already incorporated into the phosphorus calculation, the Sub-group recommends no additional adjustment for land use be made to the APLE2.4 predictions of EOF phosphorus loads. Any fractional adjustment to these loads during calibration should also be applied equally to all land uses.

For future review: Although our Sub-group endorsed the use of APLE2.4 for generating phosphorus loads and relative loading ratios, current results from APLE2.4 simulated phosphorus loads are based on RUSLE and soil P concentrations from Phase 5.3.2, and simulated results using the RUSLE2 erosion loads and the updated soil P test results should be reviewed for consistency, and also to ensure that the ability of the APLE2.4 model to differentiate between manure from grazing animals and spread manure is being utilized.

Additional Discussions of Importance

Literature compilations by Tetra Tech and Watershed Stewardship, Inc. were provided to our Sub-Committee to assist in answering the charges put before our group related to loading rates and relative ratios for the new set of Phase 6 land uses, without the benefit of water quality management practices. After review by our Sub-committee and additional analysis by Gene Yagow, Virginia Tech, who was contracted by our Sub-Committee, we found that, although the literature compilations provided a great deal of information about land use loading rates in general, they did not provide the information that was specifically needed to address the charge given to our Sub-group. If another literature review is contracted, the review should be carried out with oversight of a group such as our Sub-group, which would provide guidance in the search and selection of relevant literature or unpublished information.

Preliminary Ratios provided to the Ag Working Group

The preliminary relative loading ratios provided to the AMS in April in the “Relative NO3-N Estimates 04-16-15 5PM version.xlsx” spreadsheet, and further refined on April 18, 2015, are shown in Table 2.

Table 2. Preliminary Relative Loading Ratios for P6 Agricultural Land uses provided to CBP Modelers (04-18-15)

Land Use	Manure	Rel. N Loading (leach. + runoff)	Rel. P Loading (runoff)	Literature of Source of Data
Corn grain	**No**	**1.00**	**1.00**	By definition, each study had a corn grain reference point
Corn silage	**No**	**1.09**	**1.00**	
Corn grain	**Yes**	**1.27**	**1.50**	Fox et al.; 3 yrs; SE mean = 0.18; pan lysim., ,man. w/ BMP in effect Staver et al.; best prof. judge. of deep cores
Corn silage	**Yes**	**1.59**	**1.80**	Staver et al.; best prof. judge. of deep cores
Soybean, full season	**No**	**0.88**	**0.70**	Fox et al.; 2 obs. (yrs), SE mean = 0.31; pan & wick lysimeters Owens et al.; with rye cover crop, Sb leaching is underestimated Meisinger et al., 10 ft.deep (~3 growing seasons) soil cores Staver et al., best prof judgement of deep cores
Small grain & Soybean	**No**	**0.82**	**0.60**	Spargo et al., wick lysimeters, 2 rotation cycles, 2 soils
Small grain & Forage	**Yes**	**0.95**	**0.80**	
Other Agronomic	**Yes**	**0.55**	**0.50**	
Legume or mixed Hay	**Yes**	**0.16**	**0.40**	Fox et al.; Alfalfa, only 1 obs. Owens et al., Alf. & Orch. Gr. Hay 2 yrs after 3 yrs of corn
Grass or other Hay	**Yes**	**0.14**	**0.40**	
Pasture	**Yes**	**0.11**	**0.50**	
Ag Open Space	**No**	**0.04**	**0.20**	Fox et al.; v. low N input, ck plots, 5 obs. (yrs), SE mean = 0.02; lower if perennial
Special Crops, high	**Yes**	**1.41**	**1.80**	Staver et al.; best prof. judge. of deep cores
Special Crops, low	**Yes**	**0.32**	**0.30**	

Further Discussions on Setting Relative Nitrogen Ratios

The value of total N losses for full-season soybeans at 0.9 of corn is a bit high. Surface runoff N losses were found to be about 30% less from soybeans than corn, and spring leaching potential was reduced due to later tillage and spring burndown. It is tricky in corn-soybean rotation data to sort out precisely what fraction of subsurface losses is from which crop, especially in a calendar year. However, the general literature values and best professional judgment view is that N losses from soybeans are only somewhat lower than corn, because N fixation inputs (which are poorly characterized) are apparently substituting for fertilizer inputs. In addition, it's likely that the controlled studies tended to use lower N rates for corn than what are used in the real world, especially during the 1985 era.

The Agricultural Loading Rate Review Subgroup was asked to provide these general summaries in terms of a "relative to corn" basis on a very short time-frame. The subgroup responded accordingly with our best professional judgment estimates, but it was our view that these were short-term temporary estimates to allow beta-version development and testing of the phase-6 model with more deliberate and research estimates provided at a later time.

Scoping out an Approach for Relative Phosphorus and Sediment Ratios

Our group was concerned about the lack of published data relevant to setting the phosphorus and sediment relative ratios and considered taking a modeling approach for setting relative loads. Our Sub-group focused on the RUSLE2 model for sediment and the APLE model for phosphorus. Regarding our group's interest in RUSLE2, it was noted that the CBP was working to contract that work with Tetra Tech.

Jeremy Hanson noted that, at that time, the contracting and task details were still being worked out by CBPO staff, but since the modeling team will have the results from those RUSLE2 runs, this group should not duplicate the effort for doing RUSLE2 runs to derive estimated relative sediment rates. He stated that the group shouldn't feel obligated to suggest a different number for every individual land use; if there are similarities between the land use types they can have similar or the same relative loading rates. He suggested that the group continue to move forward and provide its recommendations under its current schedule, and perhaps the whole group or a portion of the group circle back to review the results of the new RUSLE2 runs when they are completed.

Ken Staver commented that distinguishing between crop types for phosphorus may not account for more important factors such as soil-P. Mark Dubin explained that the Watershed Model will be incorporating aspects like soil-P using APLE. Perhaps we could suggest a different filter than crop type for P loading rates. Jack Meisinger was agreeable to Ken's idea, i.e. think of soil-test-P and erosion as a primary level, and crop type as a secondary level. He suggested that we set soil-test P aside for now since that data will not be readily available for ~10 years, but the erosion data would be available now. Gene Yagow also agreed with Ken's suggestion that P could essentially be a function of RUSLE2 and sediment.

<u>September 2, 2015 Conference Call</u>

Gene Yagow provided a review of the initial RUSLE2 input/output data provided by Tetra Tech. His and other comments were submitted to the contractor through Mark Dubin regarding c-factor values that looked either very low or very high relative to the values for a given crop type across all state/cmz combinations. Although the values were initially identified from a visual inspection, most proved in a later analysis to be greater or less than 2 standard deviations from the median across all state/cmz combinations. These outlier c-factor values appear to be related to outlying values from the residue cover% and/or canopy cover% sub-factors that have been evaluated for each state/CMZ combination.

Although our Sub-group endorsed the use of RUSLE2 for generating sediment loads and relative loading ratios, our review revealed inconsistencies in the evaluation of sub-factor values between states and crop management zones (CMZs). These inconsistencies are illustrated below in Tables 3 and 4. Table 3 provides an example whereby calculated c-factor values for some state/CMZ combinations were either very high or very low, relative to the median value for all combinations. Since the RUSLE2 c-factor is calculated from a number of sub-factors, our review of these also revealed apparent inconsistencies in evaluation across state/CMZ combinations as illustrated in Table 4 for the monthly "crop residue %" for the pasture/range land use. Although the overall erosion rates and relative loading ratios produced by RUSLE2 were deemed reasonable, our Sub-group strongly felt that these inconsistencies must be addressed before the relative loading rates as used by Scenario Builder will be a valid representation of erosion rates among states and CMZs.

Table 3. RUSLE2 "c-factor" variability among state/CMZ combinations

RUSLE2 Crop Type	DE	MD				NY	PA		VA			WV	c-factors by crop	
	59	4.1	59	65	66	4.1	4.1	65	64	66	67	62	average	median
Alfalfa Hay Harvested Area	0.09	0.05	0.17	0.12	0.01	0.04	0.04	0.10	0.01	0.01	0.01	0.08	0.06	0.05
Broccoli, spring												0.34	0.34	
Cabbage						0.40							0.40	
Corn & Wheat			0.06	0.21	0.06		0.07	0.07	0.27	0.06	0.07		0.11	0.07
Corn for Grain	0.21	0.15	0.21	0.17	0.19	0.14	0.15	0.15	0.19	0.20	0.21	0.16	0.18	0.18
Corn for Silage	0.43	0.32	0.40	0.35	0.37	0.33	0.34	0.34	0.41	0.43	0.46	0.38	0.38	0.37
Cucumber	0.53	0.34	0.53	0.66	0.21		0.13	0.35					0.39	0.35
Other managed hay Harvested Area	0.06	0.01	0.15	0.01	0.15	0.10	0.01	0.01	0.00	0.00	0.00	0.08	0.05	0.01
Pasture / Range	0.15	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.03	0.02	0.01
Potato	0.63	0.64	0.63	0.82	0.83	0.63			0.55	0.59	0.61	0.68	0.66	0.63
Snap Beans	0.58												0.58	
Soybean	0.30		0.30	0.21	0.24	0.17	0.19	0.19	0.21	0.22	0.24	0.23	0.23	0.22
Soybean & Wheat	0.03		0.15	0.13	0.15			0.12	0.18	0.20	0.20	0.13	0.14	0.15
Soybean Wheat - Relay							0.07						0.07	
Tomato									0.35	0.37	0.40		0.37	
Watermelon		0.18	0.24	0.23	0.24		0.22	0.22					0.22	0.23
Wheat for Grain	0.08		0.25	0.22	0.24	0.28	0.29	0.21	0.17	0.19	0.20	0.20	0.21	0.21
Average C-factors by state/CMZ	**0.28**	**0.21**	**0.26**	**0.26**	**0.22**	**0.22**	**0.14**	**0.16**	**0.21**	**0.21**	**0.22**	**0.23**	**0.22**	
Specialty - low and high inputs	0.58	0.39	0.46	0.57	0.43	0.51	0.18	0.29	0.45	0.48	0.50	0.51	0.45	0.47

(average of: broccoli, cabbage, cucumber, potato, snap beans, tomato, watermelon)

- low C-factor value relative to other state/CMZ average values for the same crop

- high C-factor value relative to other state/CMZ average values for the same crop

cmz = Crop Management Zones

Table 4. RUSLE2 "crop residue %" variability for Pasture/Range among state/CMZ combinations

State:	DE	MD				NY	PA		VA			WV
CMZ:	59	4.1	59	65	66	4.1	4.1	65	64	66	67	62
Month	**crop residue %**											
Jan	31	55	20	43	44	56	7	27	32	30	29	73
Feb	30	54	19	44	44	57	7	27	39	37	36	72
Mar	24	53	33	41	41	56	6	32	36	33	33	70
Apr	18	46	47	42	40	18	5	36	34	31	31	58
May	16	39	36	32	30	1	4	29	33	30	29	40
Jun	21	32	38	34	33	1	3	27	32	28	28	42
Jul	27	30	50	49	48	1	6	32	30	27	26	52
Aug	22	29	47	48	47	0	9	29	27	25	24	63
Sep	16	28	38	40	38	0	9	24	26	24	23	72
Oct	25	40	26	37	36	11	6	22	24	22	21	76
Nov	29	50	22	40	40	25	6	25	24	22	21	75
Dec	33	55	21	42	43	47	7	26	24	22	22	74
Average	**24**	**43**	**33**	**41**	**40**	**23**	**6**	**28**	**30**	**27**	**27**	**64**

For our purposes, the RUSLE2 crop types needed to be mapped to the list of P6 agricultural land uses. Table 5 provides an initial scheme to make these assignments. The only P6 land use without an obvious corresponding crop type is "Ag open space". Jim suggested using "Other Hay" to map to "Open Space", and others concurred.

Table 5. RUSLE2 Crop Types Mapped to P6 Agricultural Landuses

LU Code	P 6 Agricultural Land Uses	RUSLE2 Crop Types
1	Corn or sorghum grain - elig. for manure	Corn for Grain
2	Corn or sorghum silage - elig. for manure	Corn for Silage
3	Corn or sorghum grain - no manure	Corn for Grain
4	Corn or sorghum silage - no manure	Corn for Silage
5	Sm gr & soybean - no manure	Soybean & Wheat
6	Full season soybean - no manure	Soybean
7	Sm gr & gr - elig. for manure	Soybean & Wheat
8	Other Agronomic Crops	Corn & Wheat
9	Pasture - direct dep; elig. for manure	Pasture / Range
10	Legume (or legume-grass mix) Hay	Alfalfa Hay Harvested Area
11	Other Hay	Other managed hay Harvested Area
12	Ag open space	
13	Specialty- high input	Average of all specialty crops
14	Specialty - Low input	Average of all specialty crops

Finally, our Sub-Group wanted to review the pasture erosion rates, relative to Corn for Grain, in order to feel confident that they were properly represented, and that the concerns with elevated pasture rates from the previous RUSLE version used in the P5 version of the Bay model had been addressed. Table 6 contains the median values of the c-factor and erosion rates for the RUSLE2 Pasture / Range and Corn for Grain land uses from the previous tables. The median values were used for this comparison, in order to avoid bias from the extreme values noted earlier.

Table 6. Comparison of Pasture/Range and Corn for Grain RUSLE2 Median Values

RUSLE2 Crop Type	c-factor	Erosion rate (lbs/ac/yr)
Pasture / Range	0.006	256
Corn for Grain	0.179	8,923

Jack presented an update on the N data analysis. He’s looking for studies where only 1 observation is available. Pasture studies don’t often have parallel corn studies for relative ratio calculation. Wade Thomason provided some additional lysimeter plot data for corn and pasture. Mention was also made of the Coshocton data. The pasture data in the Kilmer study had no companion corn data and was not used. Jack, Wade, and Jim then worked on finishing up revising the relative N loading ratios.

Additionally, Jack requested relative amounts of the P6 land uses to help us understand the relative importance of the various land use ratios. Gary said he could provide that. Mark was also asked for clarification in the P6 land uses, especially “Other agronomic crops”, Specialty-High input” and “Specialty – Low input”.

A post-meeting summary of the data provided by Gary for 1997 is shown in Table 7.

Table 7. 1997 Land Use Distribution by Land Use

LoadSource	Cropland Area	
	Acres	% of Total
Pasture	3,595,223	28.9%
Other Hay	1,947,683	15.6%
Grain without Manure	1,253,584	10.1%
Full Season Soybeans	1,237,398	9.9%
Legume Hay	921,761	7.4%
Small Grains and Soybea	843,008	6.8%
Small Grains and Grains	631,886	5.1%
Silage without Manure	588,338	4.7%
Grain with Manure	466,948	3.7%
Silage with Manure	250,184	2.0%
Ag Open Space	234,842	1.9%
Specialty Crop Low	195,141	1.6%
Other Agronomic Crops	195,099	1.6%
Specialty Crop High	96,808	0.8%
Grand Total	**12,457,904**	

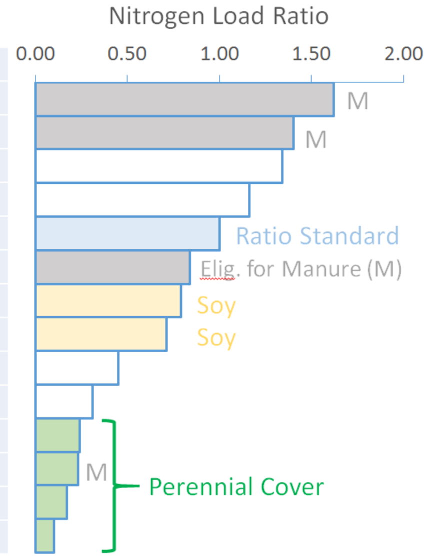
Summary of the September 28, 2015 Presentation to WQGIT

Tom Jordan and Gene Yagow presented an overview of the work of our Ag Land Use Loading Ratio Subgroup (an Ad hoc subgroup of the Ag Modeling Subcommittee) via conference call.

- Our task was to estimate relative edge-of-field loading ratios of N, P, and sediment for 14 Ag land uses for the phase 6 Watershed Model. Edge of field is defined by the ground surface boundary and by the depth limit of the rooting zone. Loading ratios are relative to corn or sorghum grain without manure because this crop type is widespread and may supply much of the edge of field loads in the Chesapeake Watershed. Loading ratios are for ag land uses without BMPs.
- Loading ratios were used as opposed to loading rates because ratios are probably less variable than loading rates, and loading rates vary with local soil and hydro-geological conditions as well as with crop type. Therefore, loading ratios of crop types vary less across regions than do loading rates, and fewer literature values are needed to establish ratios but must compare loads within similar conditions.
- Nitrogen
    - N loads are mainly from leaching of nitrate below rooting zone. Surface runoff of N probably has a negligible effect on total N load ratios, and crops with perennial cover have relatively low loads.
    - The effects of manure applications are dependent on application rate and crop N demand, and that more accurate load ratios could be estimated with information on local manure N application rates and crop N demand.

- We estimated average N load ratio for crops receiving average manure applications (assuming that all manure-eligible lands get manure), as illustrated in Figure 2.

	Load Ratio	Std Err
Corn Silage Manure	1.62	
Corn Grain Manure	1.40	0.20
Specialty High	1.34	
Corn Silage *	1.16	
Corn Grain	1.00	
Sm Grain & Forage M.*	0.84	
Sm Grain & Soy	0.79	0.09
Full Season Soy	0.71	0.11
Other Ag Crops	0.45	
Specialty Low *	0.31	
Other Hay	0.24	0.06
Pasture Manure	0.23	0.06
Legume or Mix	0.17	0.02
Ag Open	0.10	0.01



* BPJ estimate by analogies to other crops

Figure 2. Nitrogen Load Ratio Relative to Corn (or Sorghum) Grain Without Manure

- In order to assess the relative impact of these relative ratios, we area-weighted the relative ratios by area of each land use throughout the Chesapeake Bay (1997 land use, Gary Shenk, personal communication), as shown in Figure 3. This figure shows that, in addition to the land use of our relative standard (Corn Grain without manure), the ratios that are deemed to be most critical will be for full season soybeans and pasture, because of their large land areas.

Abbrev Land Use	Load Ratio	Std Err	Acres	Area Wted Ratio
Corn Grain	1.00		1,253,584	1.00
Full Season Soy	0.71	0.11	1,237,398	0.70
Pasture M	0.23	0.06	3,595,223	0.66
Corn Silage	1.16		588,338	0.54
Corn Grain M	1.40	0.20	466,948	0.52
Sm Gr Forage M	0.84		631,886	0.42
Other Hay	0.24	0.06	1,947,683	0.37
Corn Silage M	1.62		250,184	0.32
Sm Gr Soy M	0.79	0.09	421,504	0.27
Legume or Mix	0.17	0.02	921,761	0.13
Specialty High	1.34		96,808	0.10
Other Ag Crops	0.45		195,099	0.07
Specialty Low	0.31		195,141	0.05
Ag Open	0.10	0.01	234,842	0.02

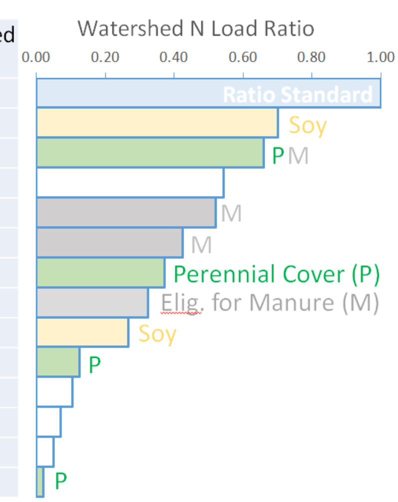


Figure 3. Area Weighted N Load Ratio Relative to Corn (or Sorghum) Grain Without Manure (Areas are coverage throughout the C. Bay watershed)

- Sediment
    - Crop type alone does not determine sediment load. Sediment loads are also affected by rainfall-runoff, soil erodibility, slope, etc. Since these factors are incorporated into the Revised Universal Soil Loss Equation (RUSLE), a field research-based model of sediment load, and since RUSLE2 is being used for creating inputs for the Chesapeake Bay Watershed Model via Scenario Builder, we believe that RUSLE2 is the best option for assessing relative sediment loading rates.
- Phosphorus
    - P loads are already being estimated by CBP using the Annual Phosphorus Loss Estimator (APLE) model.
    - Sediment-attached P load is a function of RUSLE2 erosion rates and soil P content.
    - Dissolved P load is estimated by APLE from information on manure and fertilizer application rates and soil P content.
- Caveats on the use of RUSLE2 and APLE simulation results
    - RUSLE2: The relative evaluated RUSLE2 sub-factor values among states should be re-assessed for consistency. An initial review indicated inconsistencies in the crop canopy and crop residue sub-factors for pasture and hay.
    - APLE: Initial estimated pasture P loads were high compared to literature values, possibly due to inability to distinguish effects of spread manure vs. manure deposited by grazing animals. The use of state/crop soil test results should improve the range and relative values of soil P. Explicit incorporation of data to represent grazing animals should improve manure inputs.
- The Final Recommended P6 Land Use Relative Loading Ratios were shown previously in Table 1 on page 7.

Summary of Items for Possible Future Consideration

- The addition of non-manured pasture land use separate from manured pasture land use
- Review of RUSLE2 relative crop cover and canopy cover sub-factor values
- Review of nursery loading rates
- Review APLE incorporation of dung deposition in pastures
- Review of baseline corn loading rate
- Review of N load ratios for land uses with small numbers of relevant studies
- Consideration of manure application to Full-Season Soybeans
- Review derivation of "time spent in pastures" and animal numbers derived from Ag Census
- Review state soil test P values as incorporated into APLE simulations
- Review turf grass acreage relative to agricultural land
- The P5.3.2 model needs edge-of-stream loading rate estimates (so riparian zones and wetlands need to be considered somewhere). Clarify whether the P6 model uses an edge-of-field or bottom-of-root-zone boundary, or the old edge-of-stream boundary.

Reference List of Most Appropriate and Relevant Studies influencing the Final Recommendations

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Appendix A: Review and Analysis of Tetra Tech and Water Stewardship Literature Compilations

Final Report on Work Performed for the Agricultural Land Use Loading Rate Steering Committee

Gene Yagow **October 22, 2015**

This is the final report of work sub-contracted to me in May 2015 to assist with additional data analysis of the Tetra Tech and WSI literature review databases for the ad-hoc Agricultural Land Use Loading Rates Steering Committee. The major task of the Steering Committee was to develop relative loading ratios for nitrogen, phosphorus, and sediment between the new set of P6 agricultural land use categories.

Gene Yagow, Sr. Research Scientist at the Virginia Tech Biological Systems Engineering Department was contracted to assist the Steering Committee with this task. Data from the following sources were reviewed: the Tetra Tech loads spreadsheet, the WSI loads spreadsheet, "control" treatment data for individual land uses identified in the 2000 BMP Effectiveness Database (Yagow et al., 2000), and additional papers suggested by members of the Steering Committee. Data from these sources were than filtered with the following revised set of criteria, as discussed with and determined by the subgroup:

- Studies from states within or neighboring the Chesapeake Bay
- Data records that relate to an individual P6 land use
- Data that correspond with a pre-BMP or control condition
- Multiple-year studies, preferably with natural rainfall

The goal was to assemble and analyze a refined database of average annual loads. This will serve as a starting point for the subgroup to use in developing relative ag loading ratios. Where loads were not quantified, as in concentration data from tiles and wells, or where studies provided relative loads or concentrations between interpreted P6 land uses, a separate analysis was conducted to the extent possible. Selection of filtered data that met the above criteria and analyses of average annual loads and relative load or concentration ratios, together with prior subgroup analyses and other selected studies, were then provided to the Steering Committee to assist them in refining their first-cut relative loading ratios, which were presented to the Agricultural Modeling Subcommittee in late April.

This report is supplemented by data in the "AgLoadingRatios_061615.xlsx" Excel spreadsheet. The names of the worksheets containing data related to each of the following sections are referenced in the text and included in square brackets.

Average Annual Load Data Selection

The final Tetra Tech spreadsheet named "Master File 12-10-2014 CLEAN final.xlsx" included information from 75 pollutant load studies that included 2,898 data records [Original Master]. The land uses in each data record were cross-walked with P6 land uses, where possible, similar to the procedure used by WSI in their 3-30-2015 spreadsheet. This list was then filtered by Bay states plus Ohio (OH) and North Carolina (NC), producing a reduced set of 25 load studies and 422 data records. Two columns were added – "Corresponding CBP Phase 6.0 WSM Landuse" and "Common_Param". These were used to map common P6 land use categories and common N, P, and Sediment parameters to those used in each study.

Selected data record were further reviewed and records removed that did not primarily reflect a P6 land use, did not have a solid basis for computing annual averages (studies based on a handful of storms or simulated rainfall events), or appeared to incorporate a BMP. Additionally, several studies (JF011, JF056, DM099) were reported with separate data records for surface and shallow water loads, which were combined into single entries to prevent them from being averaged instead of summed in subsequent analyses. This resulted in a final selection of 11 studies and 136 data records from the Tetra Tech study.

A similar procedure was applied to the WSI data contained in the "WSI Lit Rev Results, 3-30-2015.xlsx" spreadsheet. This spreadsheet contains data from 30 studies and 474 data records. Filtering the data by Bay states plus Delaware (DE) resulted in 21 studies and 309 data records. Additional data records were removed where they did not primarily reflect a P6 land use (including 144 records classified as Mixed Landuse), were based on a handful of storms or simulated events, or appeared to incorporate a BMP. This resulted in a selection of 5 studies and 64 data records from the WSI study.

The BMP Effectiveness Database developed for the Chesapeake Bay Nutrient Sub-committee in 2000 contains 4,921 data records for a variety of BMPs with each BMP containing data for a "control" against which each BMP was measured. This database was then explored for data from single land use watersheds that were listed as either "pre-BMP" or "control" treatments within the Bay states or neighboring states (DE, OH, NC). Data records filtered by states resulted in 2,354 data records, with subsequent filtering by "control" treatments resulting in 1,001 data records. Removing simulated rainfall and short-term studies reduced this set to 45 studies and 606 data records. Since this database contains a range of other parameters besides N, P, and sediment-related parameters, those data records were also filtered out (80 data records). Studies that duplicated Tetra Tech or WSI studies were also removed. Explicit land uses were then identified from these studies and assigned a P6 land use. This sub-set of data records were then evaluated individually to filter for matches with individual P6 land uses and otherwise comparability with the Tetra Tech and WSI annual load data. Data were extracted for matching with a reduced set of common column headings for merging with the Tetra Tech and WSI sub-sets, resulting in the addition of 5 studies and 44 data records. Overall, the Annual Loads analysis was based on 21 studies and 244 data records, as included in [Data_for_InLoads]. A list of the included studies begins on line 253, and a list of unique studies, sites, and treatments within the Chesapeake Bay and neighboring states begins on line 278. These studies are summarized in Table A.1.

Table A.1. List of Unique Loads Studies, Sites, and Treatments within the Chesapeake Bay and Neighboring States

Report_ID	SiteID	TreatmentID	Orig_LU	Corresponding CBP Phase 6.0 WSM Landuse
7	21	Conventional Tillage	conventional till corn	Corn or sorghum grain - elig. for manure
318	66	SG-pre	Summer grazing pastures, pre-BMP period	Pasture - direct dep; elig. for manure
318	66	WGF-pre	winter grazing and feeding, pre-BMP	Pasture - direct dep; elig. for manure
333	88	AboveBuffer	Data from agricultural runoff and subsurface flow	Corn or sorghum grain - elig. for manure
491	199	pre-BMP	The pre-BMP period consisted of 8 months of data between 08	Non-permitted feeding operation space
506	208	QODpre	Livestock intensive sub-watershed	Non-permitted feeding operation space
DM058	WS129		Pasture	Pasture - direct dep; elig. for manure
DM070		L	Coastal bermudagrass	Other Hay
DM070		M	Coastal bermudagrass	Other Hay
DM070		H	Coastal bermudagrass	Other Hay
DM071		F - fertilizer	tall fescue forage	Other Hay
DM071		M - swine manure slurry	tall fescue forage	Other Hay
DM099	102	Medium fertility	beef pasture	Pasture - direct dep; elig. for manure
DM099	103	High fertility	beef pasture	Pasture - direct dep; elig. for manure
DM099	104	Medium fertility	beef pasture	Pasture - direct dep; elig. for manure
DM099	106	High fertility	beef pasture	Pasture - direct dep; elig. for manure
DM099	110	High fertility	beef pasture	Pasture - direct dep; elig. for manure
DM099	121	High fertility	beef pasture	Pasture - direct dep; elig. for manure
DM099	129	Medium fertility	beef pasture	Pasture - direct dep; elig. for manure
DM099	135	Medium fertility	beef pasture	Pasture - direct dep; elig. for manure
DM112	Pasture	Cont-PRE	Pasture	Pasture - direct dep; elig. for manure
DM112	Pasture	Treat-PRE	Pasture	Pasture - direct dep; elig. for manure
DM112	Pasture	Cont-POST	Pasture	Pasture - direct dep; elig. for manure
JF011	SG (summer grazed pastures)	first 5 years (lower fert N rate)	Grazing	Pasture - direct dep; elig. for manure
JF011	WF/SG (summer grazed winter fed pa	first 5 years (lower fert N rate)	Grazing, winter feeding	Pasture - direct dep; elig. for manure
JF053		Dairy Manure, Broadcast	Continuous corn (silage)	Corn or sorghum silage - elig. for manure
JF053		Swine Manure, Broadcast	Continuous corn (silage)	Corn or sorghum silage - elig. for manure
JF053		Dairy Manure, Control (No Manure)	Continuous corn (silage)	Corn or sorghum silage - no manure
JF053		Swine Manure, Control (No Manure)	Continuous corn (silage)	Corn or sorghum silage - no manure
JF056	SG (summer grazed pastures)	First 5 years (commercial N applied)	Grazing	Pasture - direct dep; elig. for manure
JF056	SG (summer grazed pastures)	Second 8 years (N supplied by interseeded le	Grazing	Pasture - direct dep; elig. for manure
JF056	WGFA (Winter grazed feeding area)	First 5 years (commercial N applied)	Grazing	Pasture - direct dep; elig. for manure
JF056	WGFA (Winter grazed feeding area)	Second 8 years (N supplied by interseeded le	Grazing	Pasture - direct dep; elig. for manure
SD023	WS1	Lightly fertilized	pasture, primarily bluegrass (Poa pratensis L.)	Pasture - direct dep; elig. for manure
SD023	WS2	Highly fertilized	pasture, primarily bluegrass (Poa pratensis L.)	Pasture - direct dep; elig. for manure
SD074	Beans-Wheat	High Fert-Poor Manage	Beans (Phaseolus vulagaris L.) -Wheat (Triticum aestivum L.)	Sm gr & soybean - no manure
SD074	Beans-Wheat	Moderate Fert-Poor Manage	Beans (Phaseolus vulagaris L.) -Wheat (Triticum aestivum L.)	Sm gr & soybean - no manure
SD074	Corn	High Fert-Poor Manage	Corn (Zea mays L.)	Corn or sorghum grain - elig. for manure
SD074	Corn	Moderate Fert-Poor Manage	Corn (Zea mays L.)	Corn or sorghum grain - elig. for manure
SD074	Wheat	High Fert-Poor Manage	Wheat (Triticum aestivum L.)	Sm gr & gr - elig. for manure
SD074	Wheat	Moderate Fert-Poor Manage	Wheat (Triticum aestivum L.)	Sm gr & gr - elig. for manure
SD080		CT	Continuous corn for grain-fall fallow 1985-1987; corn for grain-	Corn or sorghum grain - elig. for manure
SD080		NT	Continuous corn for grain-fall fallow 1985-1987; corn for grain-	Corn or sorghum grain - elig. for manure
WSI001	Plot 1	silage corn	silage corn	Corn or sorghum silage - no manure
WSI001	Plot 2	silage corn	silage corn	Corn or sorghum silage - elig. for manure
WSI001	Plot 3	silage corn	silage corn	Corn or sorghum silage - elig. for manure
WSI005	Piedmont Poultry	No nutrient mangeament plan	pasture	Pasture - direct dep; elig. for manure
WSI005	Southwest Dairy	No nutrient mangeament plan	row crop (2 yr rotation of corn and rye cover followed by a sma	Corn or sorghum silage - elig. for manure
WSI012		Corn grain-corn grain	Corn grain-corn grain	Corn or sorghum grain - no manure
WSI012		Soybeans-soybeans	Soybeans-soybeans	Full season soybean - no manure
WSI012		Soybeans + wheat cover	Soybeans + wheat cover	Sm gr & soybean - no manure
WSI018	Site 1- Field B2	control area, no BMPs, conventional tillage	Corn	Corn or sorghum grain - no manure
WSI018	Site 1- Field B2	control area, no BMPs, conventional tillage	Soybeans	Full season soybean - no manure
WSI018	Site 1- Field B2	control area, no BMPs, conventional tillage	Soybeans	Full season soybean - no manure
WSI018	Site 1- Field B2	control area, no BMPs, conventional tillage	Soybeans/wheat	Sm gr & soybean - no manure
WSI018	Site 2- Field H1	no-till production in former pastureland	Corn	Corn or sorghum grain - no manure
WSI018	Site 2- Field H1	no-till production in former pastureland	Soybeans	Full season soybean - no manure
WSI018	Site 3- Field F	grassed waterway on somewhat poorly drain	Corn	Corn or sorghum grain - no manure
WSI018	Site 4- Field B3	outlet of field diversion	Set aside	Ag open space
WSI018	Site 4- Field B3	outlet of field diversion	Soybeans	Full season soybean - no manure
WSI018	Site 5- Field B3	inlet of grassed waterway serving as outlet fo	Set aside	Ag open space
WSI018	Site 5- Field B3	inlet of grassed waterway serving as outlet fo	Soybeans	Full season soybean - no manure
WSI018	Site 6- Field D	combination of grassed waterway and critical	Soybeans	Full season soybean - no manure
WSI018	Site 6- Field D	combination of grassed waterway and critical	Soybeans/wheat	Sm gr & soybean - no manure
WSI023	Control Basin	no fencing	Pasture (loads may be influenced by runoff from other landuses as well- approximately 70% of land adjacent to streambanks in the study area is pasture)	Pasture - direct dep; elig. for manure

Although originally envisioned as a once-through filtering of the source data, in reality it was an iterative process as nuances in each data record were explored or, in some cases, the original studies reviewed to clarify the land use, presence or absence of manure, applicable monitoring period for a control or pre-BMP condition, flow regime, and/or load or concentration values and units.

A cross-walk of various N, P, and sediment-related parameters was used to consolidate loading values into the 3 primary loads of interest – N, P, and sediment – and is shown in Table A.2. A summary of the Tetra Tech, WSI and selected 2000 BMP Effectiveness Database studies, which analysis they were used in, if any, and a thumbnail rationale for their use or exclusion is included in [Original Master] beginning at line 2904.

Table A.2: Parameter Cross-walk

OrigParm	Common_Param
Dissolved NH3-N	N, dissolved inorganic
Dissolved NO3-N	N, dissolved inorganic
Nitrate (NO3)	N, dissolved inorganic
ammonium (NH4)	N, dissolved inorganic
Dissolved Inorganic N	N, dissolved inorganic
Nitrite (NO2)	N, dissolved inorganic
Nitrite+Nitrate (NO2+ NO3)	N, dissolved inorganic
Dissolved Total N	N, dissolved inorganic
Total Ammoniacal N (NO3 + NH4)	N, dissolved inorganic
NO3-N	N, dissolved inorganic
NO3-N	N, dissolved inorganic
Total NO3	N, dissolved inorganic
NH4-N	N, dissolved inorganic
N, ammonium	N, dissolved inorganic
N, nitrate	N, dissolved inorganic
nitrogen, nitrate	N, dissolved inorganic
nitrogen, ammonium	N, dissolved inorganic
N, soluble	N, dissolved inorganic
Dissolved Organic N	N, dissolved organic
Total Organic N	N, TKN
TKN (total Kjeldahl N)	N, TKN
Particulate N	N, TKN
Total Ammonia + Organic N	N, TKN
TKN	N, TKN
Organic N	N, TKN
N, TKN	N, TKN
N, soluble organic	N, TKN
N, particulate	N, TKN
TN	N, Total
Total N	N, Total
N	N, total
N, total	N, total
N, total	N, total
nitrogen, total	N, total
Dissolved P	P, dissolved inorganic
Total Orthophosphate or Inorganic Phosphate	P, dissolved inorganic
Dissolved Total P	P, dissolved inorganic
DRP (dissolved reactive P)	P, dissolved inorganic
Dissolved Orthophosphate or Inorganic Phosphate	P, dissolved inorganic
SRP (Soluble Reactive P)	P, dissolved inorganic
BPP (biologically available particulate P)	P, dissolved inorganic
DMRP (dissolved molybdate reactive P)	P, dissolved inorganic
Soluble Inorganic P	P, dissolved inorganic
DMRP	P, dissolved inorganic
PO4-P	P, dissolved inorganic
Soluble P	P, dissolved inorganic
PO4-P	P, dissolved inorganic
P, soluble	P, dissolved inorganic
phosphorus, ortho	P, dissolved inorganic
P, total filtered	P, dissolved inorganic
TKP (total Kjeldahl P)	P, dissolved organic
Dissolved Organic P	P, dissolved organic
Particulate P	P, suspended
Sediment Total P	P, suspended
TP	P, total
Total P	P, total
AAP (algal-available P)	P, total
TP	P, total
P	P, total
P, total	P, total
phosphorus, total	P, total
Total Suspended Solids (TSS)	Sediment
TSS	Sediment
Total Solids	Sediment
Suspended Sediment (SSC)	Sediment
Total Sediment	Sediment
Suspended sediment	Sediment
soil loss	Sediment
total suspended solids	Sediment
soluble solids	Sediment
Total solids	Sediment

Analysis of Average Annual Load Data

Based on the selected annual load data in [Data_for_InLoads], a series of pivot tables and supplementary calculations were used to summarize average annual loads for all of the included P6 land use categories, and then use them to calculate relative ratios to the “Corn or sorghum grain – no manure” P6 land use category in [Pivot_InLoads].

Pivot table L1 was created to summarize average annual loads by study, site, pathway, and treatment. This essentially is the finest detail that averages data from multiple years (where individual years were recorded as individual records) and aggregates average annual loads into common N, P, and sediment parameters. This table can be used to identify individual study/site/treatment combinations that may be biasing average annual loads and, therefore, ratios for individual P6 land use categories.

Pivot table L2 summarizes the same data, but averages multiple treatments that represent the same P6 land use category, such as multiple fertilization levels or variations in tillage methods. Since not all studies reported total nitrogen (TN) or total phosphorus (TP), in their absence, the sum of reported dissolved and particulate fractions were used to calculate TN and/or TP.

Table L3 was manually created to calculate ratios to “Corn and sorghum grain – no manure”. Average TN, TP, and Sediment loads were first calculated for all studies with this land use and then ratios of each P6 land use category by study and pathway were calculated by dividing their respective loads by those for “Corn or sorghum grain – no manure”. Extremely high values were flagged with a yellow background and extremely low values with blue. Pivot table L4 summarizes the ratios and averages them by P6 land use category, the desired endpoint for the analysis of this annual load data.

Relative Load and Concentration Ratios Data Selection

Data records from those studies that were within the Chesapeake Bay watershed or neighboring states but not deemed appropriate for the annual loads analysis were further examined to see if they contained data from multiple identifiable P6 land uses that could be used to calculate relative ratios between those land uses. These data consisted of studies that reported concentration data, not captured by the annual loads data, and short-term studies, such as from rainfall simulation studies. A total of 6 studies with 57 data records fell into this category in [Data_for_InRatios]. A list of the included studies begins on line 65, and a list of unique studies, sites, and treatments within the Chesapeake Bay and neighboring states begins on line 76.

Analysis of Relative Load and Concentration Ratios Data

Similar to the analysis of Average Annual Load data, a series of pivot tables and supplementary calculations were used to calculate relative ratios to the “Corn or sorghum grain – no manure” P6 land use category in [Pivot_InRatios]. However, rather than annual loads, ratios were developed between the identifiable P6 land use categories based on parameter values with comparable units other than lbs/ac/yr, such as lbs/ac or mg/L. These studies are summarized in Table A.3.

Table A.3: List of Unique Relative Ratio Studies, Sites, and Treatments within the Chesapeake Bay and Neighboring States

Report_ID	SiteID	TreatmentID	Orig_LU	Corresponding CBP Phase 6.0 WSM Landuse
369	187	CTc-c	conventional tilled continuous corn	Corn or sorghum grain - no manure
369	187	CTs-s	conventional tilled continuous soybeans	Full season soybean - no manure
369	187	CTs+wc	conventional tilled soybeans + wheat cover	Sm gr & soybean - no manure
DM038	113	Improved practice	corn	Corn or sorghum grain - elig. for manure
DM038	118	Prevailing practice	corn	Corn or sorghum grain - elig. for manure
DM038	113	Improved practice	wheat	Sm gr & gr - elig. for manure
DM038	118	Prevailing practice no manure	wheat	Sm gr & gr - elig. for manure
DM038	Apple orchard		apple orchard	Specialty - Low input
WSI001	Plot 2		silage corn	Corn or sorghum silage - elig. for manure
WSI001	Plot 3		silage corn	Corn or sorghum silage - elig. for manure
WSI001	Plot 1		silage corn	Corn or sorghum silage - no manure
WSI006	Fields F and T	manured fields	corn	Corn or sorghum grain - elig. for manure
WSI006	Fields S and D	un-manured fields	corn	Corn or sorghum grain -no manure
WSI016			corn	Corn or sorghum grain - elig. for manure
WSI016			full-season soybeans	Full season soybean - no manure
WSI016			hay	Other Hay
WSI016			pasture	Pasture - direct dep; elig. for manure
WSI016			vegetables	Specialty- high input
WSI020		Practices in place in 2011	Hayland not in rotation with crops	Other Hay
WSI020		Practices in place in 2011	Pasture and grazing land not in rotation with crops	Pasture - direct dep; elig. for manure

Pivot table R1 summarizes average nitrogen, phosphorus and sediment component values by normalized unit based on the data in [Data_for_InRatios].

Pivot table R2 summarizes the same data, but averages multiple sites or treatments that represent the same P6 land use category, such as multiple plots. Since not all studies reported total nitrogen (TN) or total phosphorus (TP), in their absence, the sum of reported dissolved and particulate fractions were used to calculate TN and/or TP.

Table L3 was manually created to calculate ratios between 2 or more P6 land use categories within each study. Within each study, one P6 land use category was selected as the reference, and where that land use category was not “Corn or sorghum grain – no manure”, a procedure was needed to adjust all ratios relative to “Corn or sorghum grain – no manure” as with the Loads data ratios. In order to do this, the selected reference P6 land use in each study was assigned the 04-17-15 preliminary ratio of TN or TP assigned by the sub-committee for that land use category. For example, if “Corn or sorghum grain – elig. for manure” was the reference land use, values of 1.27 and 1.50 would be used for TN and TP, respectively. The ratio for Sediment was assumed equal to that of TP. The ratio between land uses within each study with comparable units was then calculated as the average value of the comparable land use with that of the reference and multiplied by the TN, TP, or Sediment ratio of the reference land use for that study. In that way, the calculated ratios were normalized by the previously assessed ratios and became comparable between studies and with the Loads ratios. In one study, where surface and subsurface loads were reported separately, they were combined for this analysis. Pivot table L4 then summarizes the ratios and averages them by P6 land use category, the desired endpoint for the analysis of this relative ratio data.

Preliminary Sub-Committee Ratios

During the April 17, 2015 conference call of the Ag Land Use Loading Rates Review Steering Committee, a preliminary set of relative nitrogen and phosphorus ratios were decided upon by consensus of the members, with all ratios relative to the "Corn and sorghum grain – no manure" P6 land use category. The source data considered for these decisions are included in the "Relative NO3-N Estimates 04-17-15 5pm version2.xlsx" spreadsheet, with ratios included in [Committee_Ratios].

Additional Studies Reviewed

Several additional studies, suggested by Steering Committee members, were also reviewed, appropriate data extracted and relative ratios calculated. These included a study by Hively et al. (2005) and unpublished data from the Mahantango Creek watershed rainfall simulator studies provided by J. Cropper. These data and associated analyses are included in [Additional Studies]. Data were also extracted from another study by Harmel et al. (2006). Although data from this study were not used explicitly, relative ratios were developed from summarized load data from about 40 other outside the watershed studies for a range of land uses.

Although not primary data, sub-sets of the Tetra Tech and WSI data from outside of the Chesapeake Bay and neighboring states were assembled in [Data_for_OutLoads] and [Data_for_OutRatios] using similar filtering procedures as for the data from within the Chesapeake Bay watershed and neighboring states, as described previously. A list of the included studies in [Data_for_OutLoads] begins on line 1673, and a list of unique studies, sites, and treatments within the Chesapeake Bay and neighboring states begins on line 1722; a list of the included studies in [Data_for_OutRatios] begins on line 111, and a list of unique studies, sites, and treatments within the Chesapeake Bay and neighboring states begins on line 122. Analysis procedures used to analyze the out of watershed data in [Pivot_OutLoads] and [Pivot_OutRatios] were identical to those used with the InLoads and InRatios data, respectively.

A list of references for the Chesapeake Bay area was received from Alison Eagle that she used as part of her study. Upon review of the list, it was discovered that four of the five references had already been identified as additional studies by members of the Steering Committee as part of the discussions for determination of the preliminary ratios in April. The fifth reference was from the Vermont area, which committee members thought was not applicable for our analysis.

Subsequent to recommendations from a Steering Committee member, a paper by Vadas et al., 2014 was added to the analysis. Since the study occurred in Wisconsin, the data from the study were added to the [OutLoads] database.

Preliminary Worksheet for the Second Assessment

All of the ratios between P6 land use categories developed from the Annual Loads, Relative Ratios, Sub-committee ruminations, and additional studies are combined in [CombinedRatios]. Separate tables for Total Nitrogen, Total Phosphorus, and Sediment were created for displaying ratios resulting from the previous analyses in a format intended to assist the Steering Committee members in their determination of ratios during the next round of deliberations.

Refinements were made to the compilation worksheet based on discussions during the June 22, 2015 Steering Committee conference call. The revised spreadsheet named "AgLoadingRatios_062215b.xlsx" included the following changes from the previous version:

- Several edits were made to mis-interpreted units
- One modeling study with the high N reference value was removed
- Where data were available, Dissolved P:Total P ratios were calculated and summarized by P6 land use category. These ratios were calculated in the individual Pivot worksheets and then summarized in the CombinedRatios worksheet and in Table A.4.
- In a similar fashion, where data were available, Surface N:Combined N and Surface P:Combined P ratios were calculated in the Pivot worksheets and summarized in the CombinedRatios worksheet and in Table A.4.

Table A.4. Nitrogen and Phosphorus Component Ratios

		Surface N:Combined N Ratio					Surface P:Combined P Ratio					Dissolved P:Total P Ratio					
		InLoads	InRatios	Addt'l.	OutLoads	OutRatios	InLoads	InRatios	Addt'l.	OutLoads	OutRatios	InLoads	InRatios	Hively	Mahantango	OutLoads	OutRatios
	Corresponding CBP Phase 6.0 WSM Landuse																
1	Corn or sorghum grain - elig. for manure	#N/A	0.000	--	0.000	--	0.118	0.000	--	0.845	--	0.180	--	#N/A	#N/A	0.612	#N/A
2	Corn or sorghum silage - elig. for manure	#N/A	#N/A	--	0.000	--	0.000	#N/A	--	0.723	--	0.318	--	0.136	#N/A	0.280	#DIV/0!
3	Corn or sorghum grain - no manure	#N/A	0.000	--	0.000	--	0.000	0.000	--	0.000	--	#DIV/0!	--	#N/A	#N/A	0.200	#DIV/0!
4	Corn or sorghum silage - no manure	#N/A	0.000	--	0.000	--	0.000	0.705	--	0.876	--	0.192	--	#N/A	#N/A	0.372	#N/A
5	Sm gr & soybean - no manure	#N/A	0.000	--	#N/A	--	0.000	0.000	--	#N/A	--	#DIV/0!	--	#N/A	#N/A	#N/A	0.529
6	Full season soybean - no manure	#N/A	0.000	--	#N/A	--	0.000	0.000	--	#N/A	--	#DIV/0!	--	#N/A	#N/A	#N/A	0.081
7	Sm gr & gr - elig. for manure	#N/A	0.000	--	0.000	--	#N/A	0.000	--	0.000	--	#N/A	--	#N/A	#N/A	0.231	0.174
8	Other Agronomic Crops	#N/A	#N/A	--	0.000	--	#N/A	#N/A	--	0.000	--	#N/A	--	#N/A	#N/A	0.508	#N/A
9	Pasture - direct dep; elig. for manure	0.159	0.000	--	0.000	--	1.023	0.000	--	0.633	--	0.407	--	0.496	0.604	0.545	0.486
10	Legume (or legume-grass mix) Hay	#N/A	#N/A	--	0.385	--	#N/A	#N/A	--	0.881	--	#N/A	--	#N/A	#N/A	0.707	#N/A
11	Other Hay	0.000	0.020	--	0.000	--	0.000	0.137	--	0.000	--	#DIV/0!	--	0.716	0.152	0.772	#N/A
12	Ag open space	0.000	#N/A	--	0.860	--	0.000	#N/A	--	0.910	--	#DIV/0!	--	#N/A	#N/A	0.748	0.700
13	Specialty- high input	#N/A	0.000	--	#N/A	--	#N/A	0.000	--	#N/A	--	#N/A	--	#N/A	#N/A	#N/A	#N/A
14	Specialty - Low input	#N/A	0.000	--	#N/A	--	#N/A	0.000	--	#N/A	--	#N/A	--	#N/A	#N/A	#N/A	#N/A
15	Impervious farmstead	#N/A	#N/A	--	#N/A	--	#N/A	#N/A	--	#N/A	--	#N/A	--	#N/A	#N/A	#N/A	#N/A
16	Pervious farmstead	#N/A	#N/A	--	#N/A	--	#N/A	#N/A	--	#N/A	--	#N/A	--	#N/A	#N/A	#N/A	#N/A
17	Non-permitted feeding operation space	0.000	#N/A	--	#N/A	--	0.000	#N/A	--	#N/A	--	0.275	--	0.542	#N/A	#N/A	#N/A
18	Permitted feeding operation space	#N/A	#N/A	--	#N/A	--	#N/A	#N/A	--	#N/A	--	#N/A	--	#N/A	#N/A	#N/A	#N/A

Deliberations by the Sub-group, subsequent to presentation of the results of my analysis, determined that even the screened data from my analysis provided wide ranges for some land uses and loading rates inconsistent with best professional judgement of members of the group. Discussions at the July 6, 2015 conference call eventually led the Sub-group to abandon reliance on these literature databases, and instead to work from individual studies identified by Sub-group members for the nitrogen loading ratios.

Presentations of the Sub-group's progress and preliminary recommendations were given to the Modeling Work Group (MWG) on July 21, 2015 and to the Water Quality Goal Implementation Team (WQGIT) on August 24, 2015. Additional work to derive the Sub-group's final relative loading ratio recommendations was performed as a regular member of the Sub-group. Presentations of the Sub-group's final recommendations were presented as a team effort in conjunction with Tom Jordan and Jack Meisinger to the Agriculture Working Group (AgWG) on September 17, 2015 (with final approval received on September 22, 2015) and to the WQGIT on September 28, 2015, where our recommendations received their final approval.

Database and Initial Sub-Group References

Full citations for all studies included in the various analyses are listed by the type of analysis, with the exception of the OutData studies, whose full list is in the original Tetra Tech spreadsheet ("Master File 12-10-2014 CLEAN final.xlsx"). The study citations are also included in the [Reference] worksheet. Studies are listed in alphabetical order within each section, and are prefaced with their Study ID designation from the respective Tetra Tech and WSI reports, and the 2000 BMP Effectiveness Database. WSI study IDs are prefaced with "WSI", 2000 BMP Effectiveness studies with plain numbers, and the Tetra Tech studies with a 2-letter preface.

A. Within the Chesapeake Loads Studies

7: Angle, J.S., G. McClung, M.S. McIntosh, P.M. Thomas, and D.C. Wolf. 1984. Nutrient Losses in Runoff from Conventional and No Till Corn Watersheds. J. Environ. Qual. 13(3):431-435.

506: Brannan, K. M., S. Mostaghimi, P. W. McClellan, and S. Inamdar. 1999. Animal waste BMP impacts on sediment and nutrient losses in runoff from the Owl Run watershed. Paper No. 99-2193. 2000 ASAE International Meeting. American Society of Agricultural Engineers: St. Joseph, Michigan.

WSI001: Galeone, D. G. (1996). Factors Affecting Phosphorus Transport at a Conventionally-Farmed Site in Lancaster County, Pennsylvania, 1992-95. US Department of the Interior, US Geological Survey Water-Resources Investigations Report 96-4168.

WSI023: Galeone, D. G. (1999). Calibration of Paired Basins Prior to Streambank Fencing of Pasture Land. Journal of Environmental Quality, 28(6), 1853-1863.

SD023: Kilmer, V. J., Gilliam, J. W., Lutz, J. F., Joyce, R. T., & Eklund, C. D. (1974). Nutrient Losses from Fertilized Grassed Watersheds in Western North Carolina. Journal of Environmental Quality, 3(3), 214-219.

SD074: Klausner, S. D., Zwerman, P. J., & Ellis, D. F. (1974). Surface Runoff Losses of Soluble Nitrogen and Phosphorus under Two Systems of Soil Management. Journal of environmental quality, 3(1), 42-46.

DM112: Line, D.E. and D.L Osmond. 2014 Final Report: Lake Jordan Paired Watershed Study; Part II. NC DENR Contract Number EW 3639. NC State Univ., Raleigh.

WSI018: Magette, W. L., Weismiller, R. A., Lessley, B. V., Wood, J. D., & Miller, C. F. (1990). Demonstrating Agricultural Best Management Practice Implementation and Impacts on a Commercial Farm. ASAE-Applied Engineering in Agriculture, 6, 45-52.

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JF056: Owens, L. B., Van Keuren, R. W., & Edwards, W. M. (1998). Budgets of Non-nitrogen Nutrients in a High Fertility Pasture System. Agriculture, Ecosystems & Environment, 70(1), 7-18.

JF011: Owens, L. B., Van Keuren, R. W., & Edwards, W. M. (2003). Non-Nitrogen Nutrient Inputs and Outputs for Fertilized Pastures in Silt Loam Soils in Four Small Ohio Watersheds. Agriculture, Ecosystems & Environment, 97(1), 117-130.

318: Owens, L.B., W.M. Edwards, and R.W. Van Keuren. 1994. Groundwater nitrate levels under fertilized grass and grass-legume pastures. J. Environ. Qual. 23:752-758.

333: Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. Ecology 65(5):1466-1475.

WSI012: Roka, F.M., Levins, R.A., Lessley, B.V., & Magette, W.L. (1990). Reducing Field Losses of Nitrogen: Is Erosion Control Enough? Journal of Soil and water Conservation. 45(1), 144-147.

JF053: Rotz, C. A., Kleinman, P. J. A., Dell, C. J., Veith, T. L., & Beegle, D. B. (2011). Environmental and Economic Comparisons of Manure Application Methods in Farming Systems. Journal of Environmental Quality, 40(2), 438-448.

SD080: Staver, K. W., & Brinsfield, R. B. (1995). The Effect of Erosion Control Practices on Phosphorus Transport from Coastal Plain Agricultural Watersheds. In Proceedings 1994 Chesapeake Bay Research Conference Chesapeake Bay Research Consortium Publication (No. 149, pp. 215-222).

WSI005: VanDyke, L.S., Pease, J.W., Bosch, D.J., & Baker, J.C. (1999). Nutrient Management Planning on Four Virginia Livestock Farms: Impacts on Net Income and Nutrient Losses. Journal of Soil and Water Conservation. 54(2), 499-505.

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B. *Within the Chesapeake Relative Ratios Studies*

WSI001: Galeone, D. G. (1996). Factors Affecting Phosphorus Transport at a Conventionally-Farmed Site in Lancaster County, Pennsylvania, 1992-95. US Department of the Interior, US Geological Survey Water-Resources Investigations Report 96-4168.

WSI016: Gutiérrez-Magness, A. L., & Raffensperger, J. P. (2003). Development, Calibration, and Analysis of a Hydrologic and Water-Quality Model of the Delaware Inland Bays Watershed. US Department of the Interior, US Geological Survey. USGS Water-Resources Investigations Report 03-4124.

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WSI006: Weil, R. R., Weismiller, R. A., & Turner, R. S. (1990). Nitrate Contamination of Groundwater under irrigated coastal plain soils. Journal of Environmental Quality, 19(3), 441-448.

C. Sub-committee Initial Assessment Studies and Sources

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Appendix B: Summary of the Ag Loading Rate Review Subgroup Charge and Discussions

This ad hoc subgroup of the Agricultural Modeling Subcommittee (AMS) was formed by Mark Dubin, Agricultural Technical Coordinator, with the University of Maryland Extension and the USEPA Chesapeake Bay Program Office, to serve as a science review panel to look over the references which have been collected by Tetra Tech (published literature), and Water Stewardship, Inc. (primarily grey literature). The ad hoc "panel" was requested to develop relative land use loading ratios for each of the new Phase 6.0 agricultural land uses, based on the most appropriate literature sources. The ratios were to be developed separately for nitrogen, phosphorus, and sediment.

The inaugural meeting of the subgroup was held on March 25, 2015 at the Smithsonian Environmental Research Center (SERC) in Edgewater, Maryland, with a conference line for those members who could not attend in person. The Subgroup membership is listed below:

Literature Review Process Proposal

The subgroup was provided published and grey agricultural literature sources and research data identified by Tetra Tech and Water Stewardship to initiate the literature review process during the March 25th meeting. The following review process is proposed for use by the subgroup to develop recommendations for review by the Agricultural Modeling Subcommittee on April 3, 2015.

1. An overview and discussion of provided literature sources, and group consensus on general recommendations will be held during the early afternoon of March 25th. The subgroup's review process and recommendation components will be finalized.
2. Proposed to identify small focused review groups within the membership of the subgroup based on field of expertise.
3. Proposed to assign literature reviews to groups based on Phase 6.0 general land use groupings; see Strawman example.
4. Proposed that review groups will focus on Tetra Tech and Water Stewardship citations and data identified to their assigned land use grouping.
5. Proposed that review group recommendations will assign each citation or research data set a pass/fail/maybe designation Designations would be based on:
    - a.) relevance to land management activities, soils, and environmental conditions in the Chesapeake Bay watershed
    - b.) research limitations or process concerns with the research paper or project
6. Proposed that the review groups will consider if feasible, providing a range of relative loading values for assigned Phase 6.0 land uses based on recommended standard "pass" citations or research data. Phase 5.3.2 relative loading values could serve as a reference starting point.
7. Recommendations from the review groups will be provided by Wednesday, April 1st for collation of the material into one document for subgroup review for fatal flaws.

8. The collated recommendations will be presented to the Agricultural Modeling Subcommittee (AMS) on Friday, April 3rd for approval. Tom Jordan will present the recommendations as chair of the review subgroup. Curt Dell serves as the Chair of the AMS and several members of the subgroup are also members of the AMS.
9. The AMS approved recommendations will be provided to the Agriculture Workgroup (AgWG) for review and approval in early April.
10. The CBPO modeling team will utilize the recommendations for developing Phase 6.0 beta version relative loading rates for agricultural land uses.
11. The CBPO will provide the relative loading rates for Phase 6.0 beta version agricultural land uses to the Modeling Workgroup for approval on April 22-24, 2015

The subgroup recommendations are proposed to be utilized in the development of relative loading rates for the Phase 6.0 beta version agricultural land uses. A second meeting of the subgroup is being proposed in late 2015 /early 2016 to review the Phase 6.0 beta version agricultural loading values and provide a recommendation on potential modifications to how the citations and research data are utilized to develop the relative loading values, as well as the actual beta version loading values themselves. The recommendations are to be used to modify the beta version for development of the final Phase 6.0 version in late 2016.

The Agricultural Loading Rate Review subgroup was formed to help provide estimates of relative loading ratios from various agricultural land types for use in Phase 6.0 of the Chesapeake Bay Watershed model.

Inaugural Subgroup Meeting on March 25, 2015

We first met on March 25, 2015, to examine information on loading rates in published studies reviewed by Tetra Tech (TT) and in unpublished studies compiled by Sally Szydlowski of Water Stewardship. The TT review includes a summary document reporting mean loading rates gleaned from the published studies, but before accepting these rates, we examined the database on the studies that TT assembled in a spreadsheet.

We were concerned by some aspects of the TT review. TT noted that loading rates seemed to rise sharply (more than double, p. 31-33 of Tt report) in reports published after 1995 and therefore chose to ignore reports from before 1995. This concerned us because we could not understand why the rates would rise suddenly in 1995. TT also attempted to adjust loading rates if BMPs were present to estimate the loading without BMPs. We wanted to understand how this was done. In addition, some of the studies were from regions distant and different from the Chesapeake watershed. We felt that such studies should probably be excluded when estimating loading rates for the Chesapeake watershed. Some of the loading rates in the TT review were also from models and some were based on measurements. We wanted to examine those based on measurements first.

After our initial meeting, Gary Shenk examined the TT review and noted that only 4 of the 76 studies cited were within the Bay watershed, used measurements rather than modeling, and did not attempt to adjust for BMP effects. Those 4 studies were for corn and corn rotations. Only 12 of the 76 studies were in the Bay watershed but there may be applicable information in studies outside of the Bay watershed but in comparable regions.

March 31, 2015 Conference Call

In a subsequent phone conference March 31, 2015, the work group discussed short-term and long-term approaches to obtaining the best estimates of agricultural nutrient loading.

The short-term plan would address the immediate need of the modelers to have estimates of relative loading ratios for various agricultural land types by April 20th. This would rely on best professional judgment from experts within the work group who would rely on their own knowledge, in addition to information assembled by TT and Water Stewardship. Phase 5.0 loadings may in some cases be a useful starting reference point. Different members of the work group will focus on different crop types and on surface runoff loads or subsurface leaching loads (primarily nitrate leaching) according to expertise. We will probably set loading ratios relative to corn crops because there is likely more information on loadings for corn crops than for others. Also, corn crops are likely to be major sources of agricultural nutrients released from the Bay watershed. We recognize that loadings of some agricultural land types such as pasture may be highly variable, poorly understood, and therefore quite difficult to estimate. Also, an understanding of nutrient sinks in riparian zones and wetlands will be crucial to understanding delivery of agricultural nutrient loads.

The long-term plan would replace the short-term estimates with better supported estimates within one year, which would still allow incorporation into the Phase 6.0 beta model.

Request for Assistance

The subgroup decided that additional analysis of the data provided by Tetra Tech and WSI was necessary in order to provide improved estimates of relative loading rates, and requested assistance from Mark Dubin and the Agricultural Modeling Sub-committee. In response to the subgroup's request for an additional effort to develop improved Phase 6 agricultural land use loading estimates, the Bay Program office agreed to provide resources for this effort through Virginia Tech's Cooperative Agreement with the Chesapeake Bay Program. A Scope of Work (SOW) was developed by Jeremy Hanson and Brian Benham, and reviewed by Mark Dubin and Tom Jordan. Gene Yagow (a member of the subgroup) was approached about taking on this project and consented to perform the assigned tasks with a very short timeline (most of the work was expected to be completed by early July) in order to assist the subgroup in accomplishing its main task. The SOW lays out the complete timeline needed to conform to the schedule for the Phase 6 Watershed Model. Specifically, this will require review and approval from the Ag Modeling Subcommittee, Modeling Workgroup and Ag Workgroup by the end of September. The subgroup has been redefined as the "Steering Committee" in the SOW. Following are the tasks as laid out in the SOW.

Task #1 – Evaluate citations/resources compiled through CBP literature reviews

The individual will consider citations/resources from two recent data assimilation projects funded by the CBP and conducted by Tetra Tech and Water Stewardship, Inc. Based on criteria provided by the Agricultural Land Use

Loading Rate Steering Committee (Steering Committee) in an initial conference call to be scheduled as soon as possible by the Steering Committee, the individual will evaluate the applicability and quality of the citations/resources assembled by the previous projects, and determine whether to include them in his/her analysis (Task #2). The majority of citations/resources vetted under this task will be peer-reviewed literature, but data from gray literature or unpublished sources may also be considered as appropriate. Working together, the Steering Committee and/or individual engaged in this project may add additional relevant data sources not identified through the two previous literature synthesis projects, but a new literature search does not need to be conducted.

Task #2 – Analysis of relevant data to develop loading estimates

The individual engaged in this project will compile and analyze data from the applicable sources identified under Task #1. With the Steering Committee's guidance, the analysis will generate relative annual pre-BMP loading estimates for TN, TP and sediment across the 16 proposed Phase 6 agricultural land uses.

Task #3 – Develop report

The individual engaged in this project will write a report to document the methods, conclusions (including loading rates), references and other relevant information as requested by the Steering Committee and CBP staff.

Task #4 – Present report to appropriate CBP Partnership workgroups for their review and consideration and finalize report

Following a review of the draft report by the Steering Committee and CBP Staff, the report will be presented to relevant CBP workgroups, including the Agriculture Workgroup (AgWG), Agriculture Modeling Subcommittee (AMS), and Modeling Workgroup (MWG), for their review and approval. Comments and questions raised because of these presentations may require clarifying edits or other adjustments to the report before it becomes final.

After Gene's acceptance in mid-May, a conference call was arranged and set for May 26, 2015 to get all Steering Committee members on the same page about the project and objectives, and for the Steering Committee to give Gene the guidance and input needed to get started and carry out his tasks.

<u>May 26, 2015 Conference Call</u>

During the May 26th conference call, Jeff Sweeney reiterated that CBP modelers were interested in relative loading rates, so that although we might start with absolute loading rates from the literature, ultimately relative ratios were most important. Gene Yagow then opened his invitation for guidance from the group by summarizing his interpretation of the subgroup's screening criteria that he was being asked to apply to the Tetra Tech and WSI studies and/or data records, including:

- Using data from neighboring states in addition to those within the Chesapeake Bay.
- Using data for control or pre-implementation scenarios in BMP studies.
- Using studies with sufficient data to generate average annual loads.

Additional suggestions from the Steering Committee included:

- Jim Cropper's recommendation to eliminate studies that did not represent true field conditions, such as those that used artificial or reconstituted dung patties.
- Provide separate treatment for leaching studies from surface runoff studies.
- Use only data records that align with specific P6 landuses.

- Jeff Sweeney's recommendation against using SPARROW estimates to try and distinguish between landuse loadings, although he did feel in general that some modeling studies could be used as backup justification for published research.
- Jack Meisinger's recommendation not to eliminate studies just because they only reported on concentrations rather than mass. They could still be useful for calculating relative ratios between landuses, if water recharge rates are similar to corn or another reference crop.

Two meta-analysis presentations were provided by Bill Angstadt for consideration by the Steering Committee. After review, the Kansas State study was found to focus on the influence of fertilizer management on crop response yield, and did not provide pollutant loading rates from different ag landuses as needed for our analysis. The Duke University study showed promise, although it was primarily a Mid-West study that focused on only corn receiving fertilizer N. The author of the study was invited to the next Steering Committee conference call.

June 22, 2015 Conference Call

The next Steering Committee conference call was held on June 22, 2015. Gene Yagow presented an update on the work that he had done to date in reviewing and analyzing the literature (the final report is Appendix A). He emphasized that the ratios he was able to tease from the literature did not cover all land; and even where data were available, some ratios will need more interpretation and refinement, and will need to be supplemented by the expertise and best professional judgment of Steering Committee members (similar to what was done in producing the preliminary ratios). In addition, he will need assistance in providing justification for the final estimates, especially where database-based ratios are not used.

Alison Eagle was in attendance and briefly discussed the nature and extent of her research, especially as it may apply to the Chesapeake Bay. She graciously agreed to send a list of references from her study that were relevant to our area.

To further refine our relative ratios, Jack Meisinger suggested forming separate N, P, and sediment workgroups, although some people like Jim Cropper preferred to work across a land use, e.g. pasture. Gene mentioned that breaking up tasks by study would avoid everybody having to go through each reference for separate pollutants. Gene agreed to post all of the references in pdf-format to an ftp site for access by all committee members.

Because of the lack of good studies with sediment data, there was discussion about using RUSLE2 to guide setting relative sediment ratios. Jim Cropper and Jack Meisinger suggested various possible contacts, including someone in Virginia NRCS that might be able to assist in running RUSLE2 scenarios for each of the P6 land uses. A suggestion was made that possibly the sediment ratios were consistent with particulate P, and that ratios between dissolved P and total P could be added to reflect contributions due to P saturation.

July 6, 2015 Conference Call

Gene reviewed the latest version of his draft report and how he framed it from the group's perspective. Tom noted that some of the figures seemed much different from the initial numbers this group recommended a few months ago. Gene noted that the available studies are not all directly comparable so the resulting numbers can be a mixed bag. Trying to back out what portion of the combined loads were surface loads. Jack noted the initial ratios were the group's best interpretation of what was going on, so the analysis would help expand on the previous numbers. Mark asked about the lack of numbers in the nitrogen columns for the corn land uses in Table 5. Gene noted the table was derived from the TT and WSI sources, and additional studies from the group did not provide comparable data that could be added to the table. Tom directed participants' attention to Table 2. He pointed out the differences between the initial assessment and the loads database summary. Ken felt the differences may be a result of apples-oranges data.

The group discussed that it may help to take a closer look at the combined database spreadsheet and pick out certain studies that may be outliers or not representative. Gene pointed out that the high pasture numbers were mainly a result of two studies, 1999 in PA/VA and 1994 in Ohio. Tom suggested we could perhaps plot the data to see where it clumps or when it is an order of magnitude higher. Gene noted there it would take a large number of such plots to cover the various data types, and may only have a couple points in a given plot. Jack suggested that we could, perhaps, include some statistics (e.g., standard deviation, number of studies) that could give a better sense of how solid or reliable the numbers may be. Gene mentioned that some studies provide an average number for a multiple-year period. Some studies provide multiple data points while others provide only a few or just one. It gets complicated when digging into the data and methods behind each data point. Gene will attempt to associate the data points with the number of years behind it. Tom suggested that the group give some kind of estimate or idea of which numbers or data points the group has the most confidence in, or which are the strongest/weakest. We don't want to pretend that uncertainties aren't there; want to acknowledge the uncertainties for future reference by the partnership.

July 13, 2015 Conference Call

Review of current status:

- Sediment: The group was comfortable using RUSLE2 to set relative loading estimates. There was general agreement that it's the best option available, though there could still be room for improvement. The group still needs to see the RUSLE2 results and data, but based on current understanding and discussions, it seems like a reasonable approach.
- For phosphorus, there was general agreement that a RUSLE2 and APLE could be used in combination to develop land use loading relationships for phosphorus.
- For nitrogen: Jack noted he was working with John to go a little more in-depth in some of the studies for N. Jack and Jim (for pasture) agreed to send Gene updates on their work by COB Wednesday.

August 26, 2015 Conference Call

The CBP Modeling Team confirmed the details of their RUSLE2 modeling, including that they were using RUSLE2 version 2.5.2.13 (Sep 3 2014), that annual NASS cropland data was used as the source of land use, aggregated to 2 crop types, and that it produced comparable EOF erosion rates. The simulations were over 6 years and noted the number of times any given cell was classified as either crop or pasture. They also confirmed the availability of land use characteristics and RUSLE2 sub-factor values distributed by state and crop management zones (CMZs).

August 27, 2015 Conference Call

The discussion on this call centered primarily around nitrogen. Findings reported:

- Shenandoah Valley PSNT samples: 28% > 30 ppm
- SE PA, Beegle data, many stalk NO3-N >> optimum
- Open space loading rates of 5 lbs N/ac-yr comparable to atmospheric N deposition inputs
- Jack's data, primarily lysimeter and soil cores: surface runoff ≈5%, less than originally estimated 10%
- Methodology reported in the literature does not always match the title or presumed prior land use
- Jim Cropper repeated concerns about high pasture loads, since slope lengths are very short with debris dams every few feet in normal pastures

Appendix C: Relevant Extended Excerpts from Discussion and Review Comments

P vs. N loads from various crops and a comment on estimated N loads from soybeans, Ken Staver (April 20, 2015): The estimates of relative P losses from different crop specific land uses in this spreadsheet are based primarily on annual P inputs, which co-vary with annual N inputs where manure is applied. However, unlike short-term N losses, which are highly influenced by N surpluses relative to crop uptake, P losses also can be highly influenced by soil erosion which is affected by site characteristics and tillage, how P containing materials are applied, and the soil P content as a result of historical P application rates. These are factors not related to a particular crop type, except in the case of perennial crops that are not tilled. The estimates for relative P loss in this table generally are for the case of all other factors being the same, and none being too extreme. Any effort to accurately model P losses from cropland in the Chesapeake Bay watershed will need to account for the wide range in potential for surface runoff generation and erosion, and soil P concentration that exist across the Bay watershed and have not to date been well characterized.

Just one other comment on N, I think having total N losses for full-season soybeans at 0.9 of corn is a bit high. We have found surface runoff N losses to be about 30% less from soybeans than corn, and spring leaching potential is reduced due to later tillage and spring burndown. It is tricky in corn soybean rotations to sort out precisely what fraction of subsurface losses comes from which crop, especially in a calendar year. Plus, I think controlled studies tend to use lower N rates for corn than what are used in the real world, especially if we are talking about 1985.

This group was asked to provide these general numbers on a very short time frame and it was not our idea that this was the best way to go.

Pasture P loads, Alisha Mulkey (June 12, 2015): I looked more closely at the pasture (PAS) slides from yesterday and while I am confident that Guido is using APLE correctly, I am leery of the PAS results and drawing too many conclusions on the sensitivity analysis. I have included some comments on the presentation.

Primarily, the average manure application being assumed to an acre of PAS is 4.5x an acre of cropland! This is unrealistic and appears to be biasing the output. The results are compounded by

1) I assumed the initial Mehlich-3P ppm for each county was the same in year 1 on PAS and cropland. This may also be unrealistic but another early soils data set was not available. We need to continue to discuss as a group what the best soils data should be to initialize APLE sensitivity because it is a critical sensitivity factor.

2) I assumed a PAS setting had a low degree of mixing (i.e. no tillage) and a shallow first soil layer as a result. Without a greater and deeper degree of mixing, the soil P will accumulate quickly in the shallow layer creating quick changes in the Mehlich-3P and increased dissolved P runoff. While this is supported in the literature for acreage under continuous no-till, I don't know that it is supported for PAS acreages?? I would ask Ken or others their opinion on this.

While we won't have new PAS inputs from Scenario Builder, I wonder if we used a proxy data set with manure inputs more comparable to cropland how that would change the sensitivity results?

Sediment and P loads from pasture and hayland, Jim Cropper (July 7, 2015): Hayland and pasture are low contributors of both P and sediment. RUSLE2 was being improved for pastureland when I retired from NRCS. I have not seen sediment loss values from RUSLE2 to evaluate whether or not they are realistic based on observed values from either rainfall simulation runs or gauging station data from small catchments. I suspect that they may still be higher than they should be. Most of RUSLE was calibrated on cropland that is for the most part tilled in one fashion or another even so-called no-till, since the seed slot itself is tilled with a coulter of one design or another. Pastureland that is a permanent landuse and not one in rotation with row crops is on consolidated soil with very good soil structure, a very different soil medium much more resistant to sheet and rill erosion that generally has ground cover approaching 100% except at some heavy use areas near gates, cow paths, around hay or feed bunks and water troughs, and sometimes under shade. Most pastures also have some degree of soil compaction in the upper 2 inches of the soil making them even more resistant to sheet and rill erosion unless severely overgrazed so that ground cover is sparse, 50 percent or less. Soil loss from pastures with >75% ground cover is usually less than 200 pounds per acre per year. This may be less than RUSLE2 is able to predict. Hayland erosion rates from RUSLE2 may also be higher than can be realistically expected. It is very critical what users are using for ground cover and canopy cover at all times in their crop files for hayland - grass or alfalfa, tall forage plants versus mowed off forage plants, and wintertime ground cover. If those ground cover estimates are erroneously low, erosion rates may be rather high. Soil tilth under alfalfa is quite good after the seeding year and improves with stand longevity for the first 3 years.

I have lobbied for some time that pasture needs to be broken into two land uses, manured and unmanured. However, I will concede that it is a stopgap, coarse measure for use by a computer model that I consider to be too broad-brush to begin with. The amount of pastureland that actually receives confinement waste in the Bay Watershed has never been established and perhaps would not catch every situation anyway. Former cropland near a dairy barn converted to dairy pasture is usually extremely high in soil test P (STP) and that would not be captured by manured pastureland acreage unless currently manured (I would hope not as it will drive STP up even higher). … With the Peter Vadas paper that was published last November, I am willing to accept APLE as a good tool to predict P runoff from pastures. ... Although STP is often a fairly good predictor of P loss on pastures, it takes a much higher STP on pastures than those on cropland to generate the same P loss in runoff. Values of STP that I considered were quite high in the Mahantango rainfall simulator plots on pasture still yielded very small losses of P and these were from plots that were 10-foot wide by 35-foot long downslope, not the small rainfall simulators typically used on cropfields and pastures in other studies. … The Vadas paper took some recent small catchment observations (edge of field values in my estimation) and combined that with work from 19 published studies that included work by L. B. Owens at Coshocton, OH. You will note on the plots on page 129 that of those 19 studies there were some outliers (4) while the rest were clustered at the lower left hand corner of both graphs, total P and dissolved P. The rainfall simulator study done on pastureland in the Mahantango Watershed in south central PA yielded very comparable values to that found on the UW-Platteville pastures so it too would fit down at the lower left hand corner of both graphs in the Vadas paper as well. … APLE was modified by Vadas to account for differences in cow pies versus spread manure. It is critical that this be done if APLE is to be used elsewhere to predict P losses from pasture.

Soil loss from pasture and hayland, Jim Cropper (July 17, 2015): The loading rate values from the 1987 NRI were calculated using the Universal Soil Loss Equation (USLE) which yielded very high erosion rates for pasture and hayland. USLE tended to produce overestimates of soil loss for all land uses since it was calibrated with soil erosion plots under tillage operations and plant population numbers that are no longer used on much of the cropland today. Chisel plow versus moldboard plowing versus mulch tillage to no-till methods. Corn populations went from 12,000 or less to over 30,000 plants per acre. Farmers went to narrower rows on most commodity row crops so crop canopy closure is much more complete and accomplished earlier in the growing season. Pasture and hayland erosion rates were not verified by many plot trials if any. A lot of what came out of the publication about USLE was that it was done mostly with statistics and expert opinion. With no real numbers or very few to work with, conservatism reigned so they erred to the high side. The other problem on pastures is that any observations that were made were made on pastures were from unimproved ones with forage species that were unimproved culturally or an artifact of the 1930's Dust Bowl with grass species no longer present in today's pastures, much different from the ones in existence today. Therefore, the 1.5 tons per acre and the 1.6 tons per acre soil loss on hayland and pasture are much higher than they should be.

Looking at the County values, that were calculated using the Revised Universal Soil Loss Equation (RUSLE), it would appear to depend on who calculated the values more than the physical attributes present in a County. Many of the values that are less than a 0.3 ton per acre are probably close to reality, although 600 pounds per acre is still quite high but possible on heavily grazed pastures on slopes of 20 percent or more. Others that are over a ton per acre or worse indicate to me improper use of RUSLE. In one County, the pasture erosion rate is 4 times higher than the conventionally tilled cropland. Yet, the hayland value seems reasonable. If this data was to be used, some judgment would have to be made to throw out aberrant values such as that one for pasture, or go back and make sure the entry was lifted from the original report correctly. Even if the pasture was on much steeper slopes than the cropland, it is not likely that it would have an erosion rate 4 times higher than tilled soil on a more moderate slope. These county values have many different people doing the RUSLE calculations. It can be difficult to get consistency and accuracy with that many people using RUSLE. Skill levels can be quite different especially with a new technique that is much more time-consuming than USLE was. It also depends on how rigorously the field data was collected.

I worked on RUSLE from the time I got to the Northeast National Technical Center of USDA-NRCS until I left to go to the Grazing Lands Technology Institute while stationed at University Park, PA. I developed the original crops files for pasture and hayland for RUSLE 1 using all available research on root mass and cover characteristics of forage plants. Once I got to Greensboro before retiring from NRCS, I was only peripherally involved with RUSLE 2 development. I evaluated a new module in it that was set up to evaluate pastures more thoroughly. I gave them some advice on how to get it to model pasture more realistically as it pertains to ground cover under various grazing management methods. I do not know how that module turned out. I suspect it does a much better job since it was capable of modeling different grazing methods.

N loss from pasture and hayland, Jim Cropper (August 28, 2015): Since we lacked some values for nitrogen and nitrate nitrogen values for pasture and other hayland, I went back to the review paper I did back in July and added some more information to it concerning nitrogen. … However, for Jack's table, I used the McMullen et al. (2012) paper that looks at lysimeter leachate over an 8-year period. They indicate that not much nitrate nitrogen makes it through the soil profile in a tall fescue hay stand. They call it a pasture, but it was treated as hayland over the 8-year period. The title should have indicated it was a former pasture that had received poultry litter for some time. Interestingly enough broiler litter rates had no effect on nitrate nitrogen leaching concentrations.

The Kilmer (1974) paper looked at nitrogen losses from two pastured watersheds. This experiment captures both runoff and ground water so it is an approximate total N loss from the two watersheds. They do admit that they may not be capturing all groundwater at the flume, but it was sunk into bedrock. They feel there is a good chance that rock fractures may be diverting some groundwater away from the flumes. The two watersheds are dissimilar in their previous and current management. WS 2 received more nitrogen fertilizer than WS 1. WS 2 was also cropland prior to being seeded to bluegrass to create a pasture.

The Vadas (2014) paper has some nitrogen runoff loading rates information even though it was concentrating on P loading rates.

I have also attached the gray literature that came from the ARS Mahantango Watershed that I summarized from an original spreadsheet prepared by Andrew Sharpley (Cropper and Sharpley, 2015). It has some limited nitrate nitrogen and total nitrogen data in it.

N loss from pasture, Jim Cropper (September 1, 2015): Bill Stout was a good friend of mine. He passed away shortly after that research paper was published (Stout et al., 2000). His data is an outlier. As I recall the study he did used soil columns that were surrounded by steel casing driven into a silt loam soil with a collection plate underneath the soil column. Although this is in the landscape, almost invariably no matter how careful the casings are driven into the ground, there is preferential flow path between the steel casing and the soil column that develops either immediately or shortly thereafter especially in small diameter soil cores of 3 feet or less. You basically set up a large macropore around the entire soil core. Another thing (most important) about this experiment is that it focused on the effect of a urine spot had on nitrogen leaching underneath it, not over an entire pasture. Since urine spots make up a small percentage of a pasture's area in any given year, this nitrogen leaching rate is the most possible, not an average rate of N leaching over the entire pasture.

The rate of application of N at a urine spot from a dairy cow can approach 1000 pounds per acre far above the agronomic rate that would ordinarily be applied to a pasture. The given rate often cited in 200 pounds of N per acre and even this has been found to be way too much especially if applied all at once. Fifty pounds per acre in early spring has been found to be effective, mostly because soil N is not being released for plant uptake until the soil temperature starts to rebound from its winter lows. Once soil N does become available, additional N that ends up being applied to recent urine spots from a broadcast application is a total waste of N fertilizer. Rotationally grazed pastures tend over time to have much more uniformly distributed urine spots and there is much less need for any additional N to be applied, perhaps 50 pounds per year would be enough if there is no legume component in the pasture sward. Continuously grazed pastures tend to have concentrated spots where urine and dung are deposited much more frequently than elsewhere in the pasture where the animals simply graze grass or walk through it on their way to somewhere else. More of the dung and urine is deposited in shady areas, at water troughs, hay bunks, and at gate openings (for dairy cow pastures) where they congregate just before milking time at least in the late afternoon or evening.

I suspect the McMullen and Brye paper might actually be the best available for Other Hayland. Although they call it a pasture, it was a former pasture that was treated as a hay stand during the 8 years of the study. No grazing occurred at all during the 8 years of the study at the lysimeter site.

N loss from pasture, Jim Cropper (September 2, 2015): I kept thinking there had to be something more definitive from Coshocton for beef pastures and I found a research paper done in 2012, "Inputs and Losses by Surface Runoff and Subsurface Leaching for Pastures Managed by Continuous or Rotational Stocking" by L. B. Owens, D. J. Barker, S. C. Loerch, M. J. Shipitalo, J. V. Bonta, and R. M. Sulc in J. Environmental Quality 41:106–113 (2012). Although the use of different types of commercial N fertilizer tended to confound things a bit, I believe it gets us to something reasonable. They were more judicious in fertilizing with total N of just 100 pounds per acre. The dairy pasture studies done at Penn State with ARS were heavy with the N. I am not sure that most farmers would put that much fertilizer down on a pasture especially a MIG pasture which is already well fertilized with what the cow leaves behind since they usually are being fed a partial TMR after milking and before the return back to the pasture unless they are an organic herd that is trying to avoid feeding any high priced organic grain. Even with this Coshocton study, 100 pounds per acre is high for beef pastures. Until recently with the drought in the Southwest decimating beef herds so that the price of beef skyrocketed, there was little incentive to use N fertilizer on beef cow-calf pastures when it was hard to get a break-even price on the calves sold after weaning.

Although they say in the Owens paper (Owens et al., 2012) that subsurface loss of nitrate was not affected by grazing method, it would appear that if there had been less variability in the observed results that frequent rotational and weekly rotational were lowest in loss of nitrate when the N fertilizer source was something other than ammonium nitrate. Continuous grazing was only studied on two watersheds in the last-5 year study, but was higher in nitrate lost to subsurface flow than frequent rotational grazing on the other two watersheds. The first 5-year study all 4 watersheds were grazed on a weekly rotational study. However, 2 watersheds were fertilized with ammonium nitrate for 4 years while the other two were fertilized with ammonium sulfate for 3 years until 2004 then switched to ammonium nitrate. First year, 2000, no fertilizer was spread. Eventually they went to using urea on all 4 watersheds in the second study starting in 2007. Annual Nitrate runoff values ranged from 0.1 kg/ha to 0.5 kg/ha. Total N runoff values ranged from 0.3 kg/ha to 3.1 kg/ha.

Nitrate subsurface loss values ranged from 11.3 kg/ha to 22.7 kg/ha (very wet 5-year period & ammonium nitrate fertilizer). More subsurface loss of nitrate during dormant period was similar to Chesapeake Bay Watershed soil water balance. Precipitation exceeds soil storage during dormant season when ET is lowest.

N loss from pasture, Jack Meisinger (September 2, 2015): The Pasture LU is still a work in progress, with the McMullen paper being a paper still under consideration; it could have useful data, but the AR pasture system and soils don't transfer well to the Bay Watershed (opinions that Wade Thomason and I both hold) and I'm not sure there is a companion corn study with N leaching available for making the Relative to Corn calculation. Bottom line: both the McMullen and Vadas studies are works in progress, or under consideration.

Approach to estimating relative N loads, Jack Meisinger (September 3, 2015): My rational for selecting the data focused on choosing the most relevant and trustworthy data for our Relative to Corn ratios.

I only used the 1991-92 paper of Toth and Fox because the lysimeter pits flooded for several weeks during the large spring thaw season in 1993 and 1994 (see p.1029 paragraph beginning "Following the melting …..") which means these years have missing values for drainage and nitrate conc. for a very important part of the year – therefore, I did not use the 1992-93 or the 1993-94 data, which left only the 1991-92 data for use. I realize the 1992-93 and 1993-94 data appear to be "reasonable", but they don't change the actual relative to corn ratio much, and allowing them "in" would leave the sub-committee open to significant criticism (my opinion) if/when the report is reviewed or challenged.

I reviewed the Bergstrom paper, but I consider it to be out of the domain of the Bay Watershed. However, it could easily be listed as a supplementary study in the final sub-committee report that provides general support for the Other Hay category, even though the Bergstrom data were not directly used to estimate the Other Hay category. We did this for several "out of the Watershed domain" papers in the Cover Crop Panel and it was well received.

Approach to estimating N loads, Tom Jordan (September 4, 2015): I am wondering whether snap beans, dry edible beans, and peanuts would be analogous to soybeans as annual legume crops. Maybe the orchards and nursery crops would be more like hay, because the cover is mostly continuous. Harvest of the nursery crop would be a discontinuity of cover but the roots are removed too. I am not sure how to classify tobacco and cotton because they are low input but discontinuous cover. Some of these analogies are mixed across the land use types.

It is hard to pick a number for N load from these crops or land use types. However, I don't think our choice would make a big difference in the watershed model. The areas are relatively small and the N loads are likely to be low. Maybe we could give the modelers a range of plausible ratio values, e.g. 0.1-0.5. The modelers could then test the sensitivity of the model to the ratio being at one extreme or the other. What do you think?

I was surprised by the magnitude of the turf grass area. Is this all non-agronomic, such as lawns and golf courses? This does not seem possible. To my eye, maps and aerial photos of the Chesapeake watershed show much more agricultural land than lawns.

Relative importance of N loads from different land use types, Tom Jordan (September 8, 2015): I multiplied the N load ratio (from Jack's latest estimate) times the acres (1997 land use areas, Gary Shenk personal communication) to get an estimate of the relative importance of the ag land use as an N source for the whole Chesapeake watershed.

The most important crop is our standard corn without manure (sorghum is a minor part of that category too). After corn without manure, the most important N sources are full season soybean and pasture. Of those top three sources, pasture probably has the highest level of uncertainty due to the variability of management and settings of pastures. Maybe in the future (beyond our deadline), the pasture category should be subdivided according to factors that might influence N loads.

In general, I think the variability of manure applications may be one of the biggest sources of uncertainty in the nutrient loads for crops eligible for manure. This could be an important source of uncertainty for the Chesapeake watershed in general.

Two of the crops where BPJ was needed seem to have trivial importance for N load (other ag crops and specialty low input). Another BPJ crop, corn or sorghum silage with no manure, has a high level of importance, but I think our rationale for the load ratio is fairly sound. The final BPJ crop (small grain with forage) has a moderate level of importance, so this one might warrant more attention in the future (beyond the deadline we are facing).

Possible problems with APLE estimates of pasture P loads, Jim Cropper (September 11, 2015): I reviewed the APLE results quickly and I see the average is about triple of what Peter Vadas found for pasture in his paper: "Monitoring runoff from cattle-grazed pastures for a phosphorus loss quantification tool." that was in Agriculture, Ecosystems and Environment 199 (2015): 124–131. I am not sure if they are using the APLE version that Vadas modified to better calibrate APLE for pastures. Dung application versus broadcast application by manure spreaders has a significant effect on how much P is lost to runoff. Or, it could be the procedure used to arrive at estimates within the Bay that have nothing to do with the APLE application itself. I note that P values are very high in Lancaster Co and on the Eastern shore for pastures. The pastures in Lancaster County, PA tend to be small acreages relegated to stream corridors in many instances, and in all likelihood the "pastured" livestock are fed more stored forage and feed than they get from the pasture grass when they are dairy cows. On the Eastern Shore, there are very few pastures to begin with and most are also quite small. Again, this is an area dominated by cropland and very little arable land is "wasted" on pasture.

The small dataset that Economic Research Service had was inconclusive on the number of acres of pasture receiving confinement manure. It was a very small sample, 10%, of all the poultry operations in the states of Delaware, Maryland, Pennsylvania, and Virginia. The form is quite long and detailed in several aspects of farm management, so the number of people interested in spending the time to fill it out were few. Of the respondents, half of the contract growers had no cropland, but did run beef cattle.

One could assume that these contract growers had pasture. However, the questionnaire did not ask for pasture acres so only one respondent reported spreading manure on 285 acres of pasture (other crop acres category). Unless, the states have data from CNMP's that indicate what acreage the litter is spread on, pasture, corn, hay, etc., it creates a large area of uncertainty of what amount of pasture is receiving additions of confinement manure. Much of it does not in areas away from poultry operations. Dairy farms are still mostly confinement operations and even dairy farms that do pasture milk cows are loath generally to apply it to pastures at least during the growing season and probably should not under any circumstance since dairy cows are fed either a partial total mixed ration or grain and hay while on pasture. These feedstuffs help fertilize the pastures beyond what is returned from the forage grazed off and can cause over-fertilization in and of itself, hence the BMP, precision feeding. I bring this up because it seems, to get this type of P runoff from pasture, someone has to be assuming that all pasture acres within these hotspot counties are fertilized with confinement wastes or the livestock are being fed cropland raised feed on these small pastures (more likely the case). However, these small pastures seem to be skewing the average inordinately.

N leaching vs. surface runoff, Jack Meisinger (September 12, 2015): …the ratios are for total N (leaching N + surface runoff N). We decided to estimate the surface runoff losses with the same relative to corn ratios that we have for nitrate leaching, mostly because a) there is little or no data from the Bay Watershed documenting both surface runoff N losses and nitrate N leaching, and b) what literature we do have is consistent with the common-knowledge view that N runoff losses are much less than N leaching losses. So we have used the approach that the Land Use Relative to Corn ratios for N leaching are also appropriate for surface runoff losses, and we chose the value of 10% as a representative figure. For example, the Corn Grain with Manure Land use has a Relative to Corn Gr w/o Manure value of about 1.4, which is also consistent with the expected greater N losses in surface runoff. Likewise, the lower N leaching loss ratios for the forages are also consistent with the expected lower surface runoff losses from perennials. Taking this path also has the advantage that we don't have to do any manipulations/calculation adjustments to the N leaching rations to convert them to total-N loss ratios.

APLE and RUSLE 2 may overestimate P runoff from pastures, Jim Cropper (September 15, 2015): … the AVERAGE value for P runoff on pastures in the Chesapeake Bay calculated by APLE presented by Mulkey and Yactayo is higher than the range found in the Vadas et al. (2014) paper for all pastures that he used in his review of the literature. Something seems amiss. I was wondering if the APLE runs used in the Bay watershed used the modified APLE program for pastures in the Watershed. Dr. Peter Vadas modified APLE to give more realistic P runoff values since a cow pie is distributed much more infrequently than manure that is applied with a manure spreader. Many pastures, especially the steep ones, do not receive confinement manure that is spread about as a "thin" coat with lots of surface area to be leached of P when an infrequent runoff event occurs on pasture. Quote from Vadas et al. (2014) paper: "pastures typically have less nutrient inputs and soil erosion than row crops." The distortion might be caused in some instances on land called pasture that are really extensive feedlots for dairy cows that happen to have some grass survive on them. Yes, these unpaved feedlots will have elevated P runoff coming off them and at much more frequent runoff events. They would be outliers that, since they are considered pastures, skew all the pasture data to a much higher average P runoff value. Vadas et al (2014) said: "For example, of the 20 pasture runoff studies in Table 2, about 85% of the site years had less than 2.0 kg/ha of annual total P loss and less than 1.5 kg/ha of dissolved P loss." Therefore, outliers are possible for various reasons.

Looking at the data from Summary of APLE Research Findings, it appears the inflated RUSLE2 erosion rates may be part of the problem causing particulate P to be higher than that found in the research literature. Looking at the table on slide 11 of the APLE Summary Output Manure Dissolved P column, it would appear that the dissolved P value is most likely inflated as well. I wonder if the Vadas et al. modifications for determining P runoff from pastures were used. I quote from Vadas et al. (2014) paper two paragraphs:

> "The important new parts of APLE to validate for pasture P runoff were the assumptions for dung production and P content (Table 1) and Eq. (7) to reduce dung P loss in runoff according to the amount of field area covered by dung. Runoff P prediction results in Fig. 3 suggest that these two parts of the model provided reliable estimates of pasture P runoff. In fact, without the dung area reduction factor (Eq. (7)), which would ultimately treat grazing dung the same as machine-applied manure, P loss predictions were about 50% greater than measured data. This demonstrates the importance of simulating dung deposited during grazing differently from machine-applied manure.
>
> We also conducted a model sensitivity analysis to determine how much assumptions about dung and P production as well as dung cover influence model predictions compared to runoff volume, which is the model transport variable for manure P loss. To do this, we determined how much both increasing and decreasing each variable by 10% and 20% changed model predictions for manure P loss in runoff. Specific model variables changed were runoff amount, the amount of dung total P excreted by grazing cattle, the WEP (water extractable P) content of the grazing dung, the amount of area covered by the dung, and the reduction factor in Eq. (7). Sensitivity results are shown in Table 6. The model was most sensitive to changes in annual runoff, showing this transport factor significantly influences model prediction of dung P loss. The model was linearly sensitive to assumptions for dung total P excretion and the dung P loss reduction factor, so that each unit change in input had the same unit change in output. These changes were also nearly as much as changes for runoff volume, showing that the new assumptions developed in this project for dung P excretion and dung reduction factor are important model parameters. Model predictions were least sensitive to changes in dung WEP content and dung area covered, with the influence of these parameters about half of the influence of the previous parameters."

It would appear that particulate P and dissolved P runoff are being over-estimated for two reasons in the current APLE runs: Inflated sheet and rill erosion values and not applying the Vadas modifications to calculating dissolved P from pastures that only receive dung from grazing livestock. In the case of beef and small ruminant pastures, this is likely the only type of manure being received that affects the P concentrations in runoff. (On farms where poultry and beef are raised, then poultry litter is most likely being spread on the pastures along with some crop acres if they have them.) Dairy pastures are a different story since lactating dairy cows are fed other feedstuffs while they are on pasture, and in the case, of extensive feedlots, they get nearly all their feed from storage and very little from the grass growing on the lot itself. Dairy pastures make up a small portion of the total pasture in the Watershed since few animals, lactating cows in particular, are pastured. Most are confined to a free stall or other paved area, or on unpaved feedlots. Organic dairies are required to have their lactating cows on pasture during the growing season and there are a hand-full of non-organic dairy farms that pasture their cows. This might make up 10-20% of all dairies in the Watershed.

APLE6 Guido Yactayo (September 24, 2015): APLE6 (the one I wrote in fortran) needs three input files. Attached are the input files I currently use in the high till simulation. The data are from 1992 to 2005, everything else is repeated.

Precipitation, clay and organic matter are HSPF inputs. I'm using stormflow and sediment output from HSPF pltgen.

Depth and percent of incorporation are described in the APLE 2.4 documentation. Here is where we made some assumptions to differentiate high till and pasture.

SB builder provides the fertilizer inputs. Manure is based on animal numbers from the ag census and fertilizer is based on crop need and yield, also from the agcensus. Animals grazing are consider in the pasture simulation only (DIRECT_MANURE). Pasture landuse scenarios require additional input on the amount of direct excretion occurring by animals grazing and the acreage. This data also comes from SBuilder.

Currently APLE6 does not interact with p532. However I'm using p532 acres, transport factors, bmps and delivery factors to calculate delivered loads to the Bay.

Probably you already know the pasture rates are higher than hightill. I've been told SB builder team is aware and it will be addressed in the next phase. I have calculated delivered loads only to compare with other models.

APLE6 output is being used mainly to calculate model sensitivities that inform the phase 6 simulation. Furthermore these sensitivities are used to calculate Phase 6 targets. …the summary output (EOF) files I sent are actually EOS without BMPs. These are the type of files and export rates used in the sensitivity analysis.

High N inputs to some nursery crops, Joel Blomquist (September 28, 2015): While listening to the GIT presentation this afternoon, I was struck by the grouping of nursery in low-application class. My curiosity led me to a University of California pub citing astronomical rates, see below.

Current Nitrogen Use Patterns and Consequences (http://anrcatalog.ucanr.edu/pdf/8221.pdf)

Nitrogen usually is applied to ornamental crops in amounts that exceed the plants' needs. Where fertilizers are injected into the irrigation water, nitrogen fertilizer over- use can also result from application of excessive amounts of water and from over- spray that misses the plant containers or beds. Nitrogen application rates vary widely among nurseries and greenhouses, but typical annual values range from 1,000 to 7,000 lb/acre (1,100 – 7,800 kg/ha) (Cabrera et al. 1993). Nitrogen uptake by crops is also variable, but for most ornamental crops nitrogen uptake over the course of a year is between 400 and 1,000 lb/acre (450 – 1,100 kg/ha), which means the typical amount applied is more than six times more than is needed for plant growth.

N loss from nursery crops, Mark Dubin (September 28, 2015): Nursery land use acres seem to be expanding in some areas in the watershed by my observation as well. We have a new Phase 6.0 BMP panel forming which incorporates nursery runoff management based on a panel charge developed by a professional group. The charge describes several types of nursery operations with varying levels of nutrient inputs, and consequently potential nutrient losses. The general categories included greenhouse, container, and field-grown operations, in a relative descending order of nutrient inputs and environmental losses. The last category, field-grown, can operate with extremely low inputs of nutrients, especially N, depending on the crop being raised. Higher inputs of N can actually be counter-productive for the crop.

The current Phase 5.3.2 models combine all forms of nursery into one loading value, based on the highest nutrient input system (greenhouses), so this is an attempt to describe the level of variation between the systems through high and low input land uses. I expect we will have additional information coming forthwith from the new BMP panel as well.

Estimating manure N load to pastures, Jim Cropper (September 30, 2015): I for some time had concerns about how the livestock data from the 2012 Census of Agriculture was used to generate manure loading on pastures. When I saw slide 36 in the Phase 6 Scenario Builder 101 Power Point presentation presented by Curt and Matt at the last Ag Workgroup meeting and teleconference, I thought this would be good opportunity to do a version of direct deposit of N on pastures using NASS 2012 Census of Agriculture data for Washington County, MD and other pertinent references (references are listed at the end of the attached document). This way I could compare N loading rate numbers from what I got from that in the slide for a particular county. Sometimes it is easier to explain by example rather than get too deeply into the weeds of statistics.

A spreadsheet that I developed, entitled "Using NASS County Level Livestock Data - an Analysis of Washington County, MD N loading on Pastureland by Direct Deposition", that I put together over the past 4 days, outlines a procedure that I feel is absolutely necessary to get a reasonable estimate of direct deposition of N on pasture from grazing livestock. This is particularly true if some livestock types and classes will never be on pastures. Dairy cattle are mostly confined now. There are few conventional dairymen or women that stock their lactating herds on pasture except for those that are operating organic dairies. Therefore, if there is any significant dairy cow numbers in a county, a reasonable estimate must be provided for that county on how many dairy cows are actually pastured. Most dairy young stock are probably pastured, but even this may not be the case on large dairies. In large western US dairies the dairy animals are kept on concrete from birth until being hauled away to a rendering or meatpacking plant. To do this paper, I made some assumptions having worked on the family dairy farm and working with lots of dairy farmers over the years that are either in the Bay Watershed or ran similar operations in Illinois, Wisconsin, North Carolina, and New York.

The cattle table at the County level requires being broken down further to be of any use at all in predicting N loading by direct deposit. Other Cattle is a large category containing yearling heifers, calves, bulls, and steers. These are disparate classes of cattle of different weights and N excretion rates. Since milk cow and beef cow numbers are given in the cattle table, this allows us to parse out how many calves are born from each type and which ones are likely to stick around for a while and then using survival rate data, determining with a reasonable degree of precision how many survive to remain in the tally of Other Cattle. After accounting for calves, we can move on to the other classes in the Other Cattle category. I have detailed my methodology and assumptions in the attached paper. It takes into account some other seemingly unimportant information in the cattle table to help make some valid assumptions about steers, bulls, and yearling heifers. Using the dairy waste characteristics table from the NRCS Ag. Waste Mgt. Field Handbook even requires figuring out the daily average production of milk for a dairy cow to adjust their N excretion value.

The net outcome of this exercise was to find that N loading was less than half of what was shown in slide 36 from the Phase 6 Scenario Builder 101 Power Point presentation presented by Curt and Matt at the last Ag Workgroup meeting and teleconference. It is also important to include all pasture acres, slide 36 did not include woodland pastured. It is not be the best idea to pasture woodlands, especially eastern hardwoods, but it happens. It is pasture and must be included in pasture acres for the County. Most are hopefully stocked at a much lower rate than open pastures, but we do not know that for an absolute fact. Since direct deposition of dung and urine occur there, these pasture acres must be included in the mix.

I would urge that this type of methodology be adopted Bay-wide. Otherwise, N loading estimates will not be very close to reality and the same would go for P loading estimates even with APLE as the direct deposit input data would be too high to begin with. Pastures that receive only direct deposited urine and dung are nearly always N deficient unless the livestock are fed hay in the same area for several years or are fed more stored forage and concentrates while on pasture than they get from grazing the grass in pastures. The later situation is most typical of dairy cow pastures.

The other point that is important is the methodology used to determine what the rate of N should be on various land uses in the table. In the same slide 36, pasture, for instance, was given a very low N crop need value. If the acres of pasture are divided into that value, it ends up being only 15 pounds of N per acre. This is off by a factor of 10. If it is mostly a grass sward with no legume component of any importance (<5%), a productive pasture would need 150 pounds per acre to maintain the soil N balance. Anything less than that would drive soil N down over time and the pasture would become less productive. The Other Hay value is also quite low. Other Hay in particular must be fed N yearly by one means or another. All the top growth is removed as hay and no N is returned unless manure or chemical fertilizers replace the N removed in the forage. I have seen plenty of N deficient hayfields around the Nation while I was the National Forage Agronomist for NRCS.