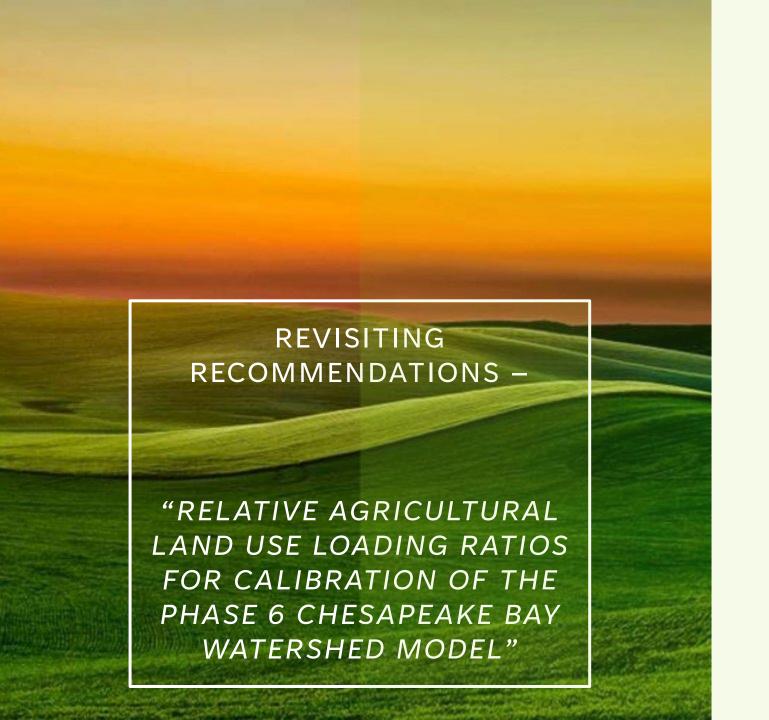# REVISITING RECOMMENDATIONS –

"RELATIVE AGRICULTURAL LAND USE LOADING RATIOS FOR CALIBRATION OF THE PHASE 6 CHESAPEAKE BAY WATERSHED MODEL"

CBP Agricultural Modeling Team Meeting
March 8, 2024

REVISITING RECOMMENDATIONS –

"RELATIVE AGRICULTURAL LAND USE LOADING RATIOS FOR CALIBRATION OF THE PHASE 6 CHESAPEAKE BAY WATERSHED MODEL"

Agenda -

Ag Loading Rate Review Steering Committee

Developing a Nitrogen-Based Approach

Nitrogen Loading Rate Ratio Recommendations

Sediment Loading Rate Recommendations

Phosphorus Loading Rate Recommendations

Recommendation Summary

Questions

AG LOADING RATE REVIEW STEERING COMMITTEE

AG LOADING RATE REVIEW STEERING COMMITTEE CHARGE

- Steering committee was established on March 25, 2015.

- An ad hoc subgroup of the Agricultural Modeling Subcommittee (AMS), the steering committee was charged to serve as a science review panel to evaluate the references which were collected by Tetra Tech (published literature), and Water Stewardship, Inc. (primarily grey literature) for Phase 6.0 model development.

- 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.

AG LOADING RATE REVIEW STEERING COMMITTEE

A diverse agricultural steering committee membership with members representing:

- USDA-ARS (2)
- land grant universities (5)
- scientific NGOs (3)
- state agricultural agencies (1)

Name	Affiliation	Email	Phone
Tom Jordan, Chair	SERC	jordanth@si.edu	(443) 482-2209
Jack Meisinger	ARS	John.Meisinger@ars.usda.gov	(301) 504-5276
Ken Staver	UMD	kstaver@umd.edu	(410) 827-8056 ext.111
Wade Thomason	VT	wthomaso@vt.edu	(540) 231-2988
Doug Beegle	PSU	dbb@psu.edu	(814) 863-1016
John Spargo	PSU	jts29@psu.edu	(814) 865-9155
Greg Albrecht	NYS-DAM	greg.albrecht@agriculture.ny.gov	(607) 330-1242
Gene Yagow	VT	eyagow@vt.edu	(540) 231-2538
Jim Cropper	NEPC	jbcropper@yahoo.com	(336) 855-7594
Curt Dell	ARS	curtis.dell@ars.usda.gov	(814) 863-0984
Don Weller	SERC	wellerd@si.edu	(443) 482-2214

Technical Support Staff

Name	Affiliation	Email	Phone
Gary Shenk	CBPO	gshenk@chesapeakebay.net	(410) 267-5745
Matt Johnston	UMD	mjohnston@chesapeakebay.net	(410) 267-5707
Mark Dubin	UMD	mdubin@chesapeakebay.net	(410) 267-9833
Emma Giese	CRC	egiese@chesapeakebay.net	(410) 295-1380
Sally Szydiowski	WS	sallyb@waterstewardshipinc.org	(443) 699-5173
Olivia Devereux	Tt	olivia@devereuxconsulting.com	(301) 325-7449

Acknowledgement of Additional Contributions to this Review

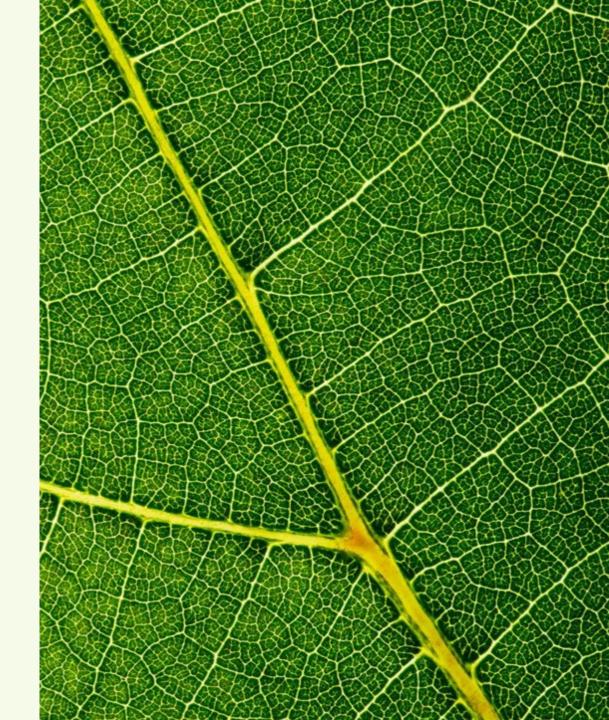| Name	Affiliation	Contribution	
Peter Cada	Tt	For providing preliminary RUSLE2 data	
Peter Claggett	CBPO	For information regarding GIS processing of select RUSLE inputs	
Guido Yactayo	CBPO	For providing preliminary APLE data and explanation	
Alisha Mulkey	CBPO	For providing additional insights on APLE simulations	
Bill Angstadt	AgWG	For suggestions of additional studies to consider	
Alison Eagle	Duke Univ.	For presenting information on her nitrogen loss meta-analysis research	
Joel Blomquist	USGS	For providing information regarding nursery loadings	

LITERATURE COMPILATIONS

- The steering committee was provided literature compilations previously developed by Tetra Tech (Tt) (EPA contract) on published literature for agricultural and forest land uses, and by Water Stewardship, Inc. (WSI) (Virginia Tech contract) on non-published agricultural literature, for developing Phase 6 model recommendations for pre-BMP land use loading rates.

- The CBP AgWG did not approve of the CBP Phase 6 model recommendation report for pre-BMP agricultural land use loading rates, and instead requested a review by the AMS.

- The literature compilations from Tt and WSI assisted the steering committee in addressing it's charge to recommend loading rates and relative ratios for the new set of Phase 6 land uses, without the benefit of water quality management practices (pre-BMP condition).

LITERATURE COMPILATIONS

- After a review of the Tt and WSI literature compilations by the steering committee, an additional literature review and data analysis was by provided by Gene Yagow, Virginia Tech, who was contracted by the steering committee.

- The analysis findings were that, although the Tt and WSI 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 the steering committee.

DEVELOPING A NITROGEN-BASED APPROACH

DEVELOPING A NITROGEN-BASED APPROACH

- Agricultural N losses to the Chesapeake Bay are dominated by Nitrate (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 steering committee therefore focused on literature that documented NO3-N leaching losses.

- However, the steering committee also found that ranking the Phase 6.0 land uses by Nitrogen (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.

DEVELOPING NITROGEN LOADING RATE RATIOS

- The steering committee summarized the literature data using a ratio approach; specifically, the NO_3-N leaching from a given land use compared to the NO_3-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 NO_3-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.

DEVELOPING NITROGEN LOADING RATE RATIOS

- The steering committee considered 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.

DEVELOPING NITROGEN LOADING RATE RATIOS

- 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.

CRITERIA FOR SELECTING STUDIES TO ESTIMATE A RELATIVE TO "CORN, GRAIN – NO MANURE" RATIO

Reference Selection Criteria:

- The study was conducted in the Chesapeake Bay watershed or in nearby states with soils and climate similar to those within the Bay watershed;

- Nitrate-N leaching was estimated by lysimetry or by fall residual NO3-N to a depth $\geq$ 90 cm;

- 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);

CRITERIA FOR SELECTING STUDIES TO ESTIMATE A RELATIVE TO "CORN, GRAIN – NO MANURE" RATIO

Reference Selection Criteria continued:

- 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;

- 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 baseline condition without N best management practices); and

CRITERIA FOR SELECTING STUDIES TO ESTIMATE A RELATIVE TO "CORN, GRAIN – NO MANURE" RATIO

Reference Selection Criteria continued:

- 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 RATE RATIO RECOMMENDATIONS

TABLE 1
NITROGEN LOADING RATIOS

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.

TABLE 1
NITROGEN LOADING RATIOS

Citations for 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).

Citation #	Citation Brief Description
1.	Jemison and Fox, 1994, J. Environ. Qual. 23:337-343.
2.	Roth and Fox, 1990, J. Environ. Qual. 19:243-248.
3.	Ritter et al., 1990, J Irrigation and Drainage Eng. 116:738-351.
4.	Zhu and Fox, 2003, Agron. J. 95:1028-1033.
5.	Parkin and Meisinger, 1989, J. Environ. Qual. 18:12-16 ; Meisinger Pers. Comm., from deep soil cores of same study.
6.	Toth and Fox, 1998, J. Environ. Qual. 27:1027-1033.
7.	Owens, 1987, J. Environ. Qual. 34:34-38; Chichester, 1977, J. Environ. Qual. 6:211-217.
8.	Angle, et al., 1989, Agr. Ecosystems and Environ. 25:279-286.
9.	Spargo et al., 2009, Agronomy Abstract Poster 53228 and 2015 Personal Communication.
10.	Staver, 2015, Personal Communication.
11.	Angle, et al., 1993, J. Environ. Qual. 22:141-147.
12.	Stout et al., 2000, Agr. Ecosystems & Environ. 77:203-210.
13.	Jabro et al., 1997, J. Environ. Qual. 26:89-94.
14.	Owens et al., 2012, J. Environ. Qual. 41:106-113.
15.	Wilson et al., 1995, Am. Soc. Agric. Eng. Spec. Pub. Clean Water, Clean Environ. - 21st Cent. Vol. II

INTERPRETATION OF 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.
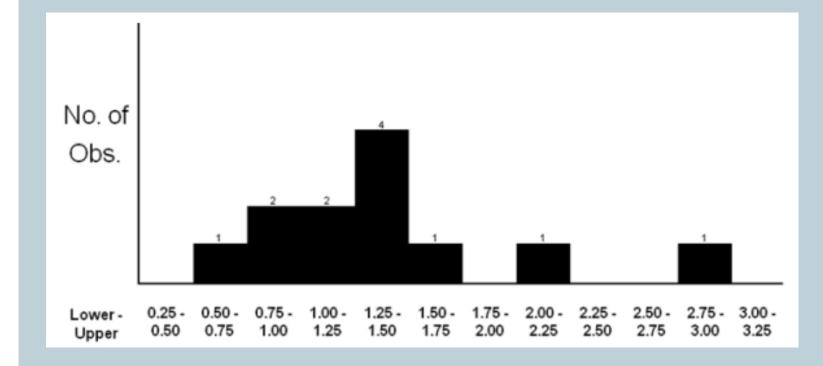
INTERPRETATION OF TABLE 1

- 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 nonnormally distributed data, but there are not enough data points available to identify the underlying statistical distribution.
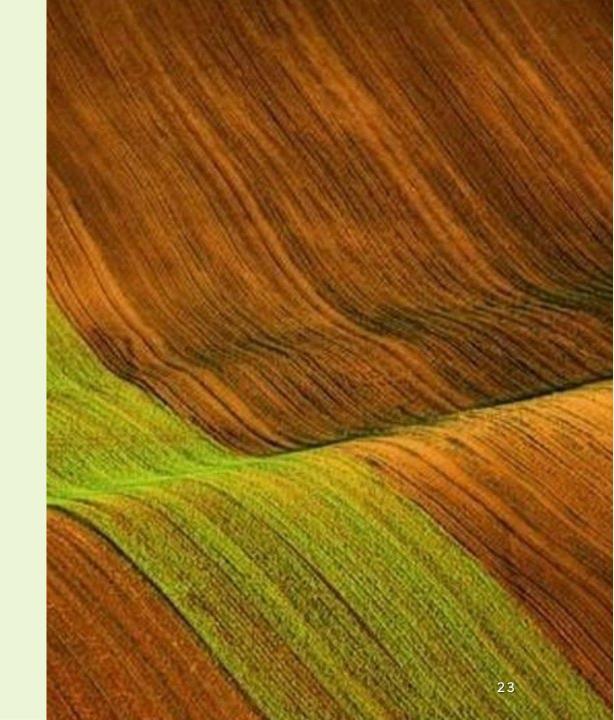
TABLE 1
NITROGEN LOADING RATIOS

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.

NITROGEN LOADING RATE RECOMMENDATION

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.

SEDIMENT LOADING RATE RECOMMENDATIONS

DEVELOPING SEDIMENT LOADING RATE RATIOS

- Upon review of the Tetra Tech and WSI literature review databases and the additional analysis provided by Gene Yagow (VT), the steering committee 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 steering committee decided to explore using output from one such model as the basis for relative loading rates for sediment.

DEVELOPING SEDIMENT LOADING RATE RATIOS

- 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 the Steering committee in 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 9 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.

DEVELOPING SEDIMENT LOADING RATE RATIOS

- A review by members of the Steering committee 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 the Steering committee'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 the steering committee to be most appropriate for calculation of sediment loading rates, and subsequent loading ratios, by P6 land use.

SEDIMENT LOADING RATE RECOMMENDATION

Recommendation: Since land use and geographical variability is already incorporated into the subfactors of the erosion calculation, the steering committee 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.

PHOSPHORUS LOADING RATE RECOMMENDATIONS

DEVELOPING PHOSPHORUS LOADING RATE RATIOS

- The steering committee 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 (APLE 2.4, Vadas et al., 2014), possesses separate components for representing particulate and sediment-attached phosphorus components.

DEVELOPING PHOSPHORUS LOADING RATE RATIOS

- The sediment-attached phosphorus in APLE 2.4 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.

DEVELOPING PHOSPHORUS LOADING RATE RATIOS

- An analysis and review of select studies were made by members of the steering committee 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, the steering committee 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.

PHOSPHORUS LOADING RATE RECOMMENDATION

Recommendation: Since the APLE 2.4 simulated phosphorus loads also encompass sub-factors that incorporate land use and geographically-distributed characteristics, the steering committee 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 steering committee recommends no additional adjustment for land use be made to the APLE 2.4 predictions of EOF phosphorus loads. Any fractional adjustment to these loads during calibration should also be applied equally to all land uses.

RECOMMENDATION SUMMARY

RECOMMENDATION SUMMARY

P6 Ag Loading Rate Review –

- CBP AgWG Recommended and Approved
- Diverse Agricultural Science-based Steering Committee
- Multi-sourced Literature Compilation (Published/Gray)
- Extensive Documented Panel Recommendation Report

- Steering committee's recommendation report published December 17, 2015.
- N Ratio Recommendations –
  - N03-N Loss Ratios Focused using Corn Grain w/o Manure as Control Land Use
- Sediment Recommendations -
  - RUSLE2 Based Calculations by Geographic Land Use
- Phosphorus Recommendations -
  - APL 2.4 Based Calculations by Geographic Land Use

THANK YOU

Mark Dubin

CBPO Senior Agricultural Advisor

University of Maryland Extension

mdubin06@umd.edu

mdubin@chesapeakebay.net

www.chesapeakebay.net