Phosphorus Management within Multi-State Watersheds

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Purpose of this publication

Management of phosphorus (P) on agricultural fields must be based on nutrient management planning, which requires soil testing for commercial fertilizer or P-Indices for animal waste recommendations. Generally, soil testing and P-Indices produce state-specific recommendations. For farmers working across state boundaries, differences in soil test interpretations and resulting recommendations for commercial P fertilizer or animal waste application rates can be confusing. It is the intent of this paper to explore the basis behind some of the recommendation and policy differences that arise across state boundaries in making P management recommendations.

Introduction

Most agricultural management recommendations have been developed at the state level. Even federal agricultural programs that set a national standard may be modified by each state. For example, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has established national standards for many agricultural best management practices, including nutrient management. Yet the standards can be, and most often are, modified to match state conditions and requirements as long as the state standards are more restrictive than the national standards. A new program - The Conservation Security Program (CSP) – is, however, managed on a watershed rather than a state basis. Under CSP, farmers are rewarded for good conservation practices, including nutrient management (USDA-NRCS, 2006). Over 20 CSP watersheds cross state boundaries, including some that straddle three states (e.g. Upper Beaver-OK/TX/NM and St. Joseph-MI/IN/OH). As federal programs become more watershed-based and cross state boundaries, or as farmers expand across state lines, large divergences in nutrient recommendations, standards such as USDA-NRCS Code 590, and P-Indices will be difficult for producers to understand and will undermine the veracity of information they receive from land grant universities and federal agencies. Thus, it is important to ensure some uniformity in recommendations and standards governing P management.

Soil Testing and P Recommendations

Soil testing and the associated plant nutrient recommendations developed from an increased understanding of the soils' capacity to provide nutrients to crops (Kitchen, 1948). The use of soil extracts to determine plant nutrient needs originated in the late 1920s and early 1930s when many of the popular soil tests extracts (Troug, Bray, and Morgan) were devised (Peck and Soltanpour, 1990). These, and other varied extracts, were developed due to differences in soils and mineralogy. Local crop field trials allowed the soil tests to be calibrated to develop fertilizer recommendations.

By the late 1940s, soil testing was conducted in state-run laboratories and the results were being accepted by producers. As early as 1947, a national soil and fertilizer research committee was organized “to consider the national aspects of soils research, and to advise the Land-Grant College Association and the USDA on soil, fertilizer, and irrigation research problems” (Nelson et al., 1951). This group was composed of four regional divisions (Southern, North Eastern, North Central, and Western) and continues today with a few additional regional workgroups, but with a similar charge: exchange soil testing information and minimize differences in soil testing methodologies, results and recommendations within a region. Much of the focus of these groups has centered on soil testing for P and potassium (K), as nitrogen (N) fertilizer recommendations from soil test results in humid areas have been more difficult to determine. However, limited funding support for these groups and regional efforts has moderated their activity and progress.

Historically, most producers have worked within state boundaries, so P nutrient recommendation differences between states were generally not an issue. However, USDA-NRCS recently was challenged to explain differences in nutrient recommendations where efforts to implement federal programs within a watershed crossed state boundaries. A workgroup was tasked to compare soil test recommendations for P, K, and N across state boundaries. Comparisons were made between selected states representing the three NRCS regions West: Oregon, Idaho and Washington; Central: Kansas, Nebraska, Oklahoma; and East: Virginia, North Carolina and Tennessee (McFarland et al., 2006). Results showed that while differences in soil test methods and philosophies do exist among states within a region, recommendations generally were not substantively different where sufficient field calibration had been possible (Table 1). Recommendations for fertilizer P were remarkably consistent among states within a region for the major crops evaluated; variations generally were less than 10%. There were some exceptions: corn; the “Very High” soil test category for potatoes and the “Very Low” category for wheat in the Western region; soybean in the Eastern region. Some of these differences could be explained by the soil test values different states used to establish discrete categories of “Very Low”, “Low”, etc.; others could be explained due to the fact that supporting data were limited or very dated. It was also found that management practices, such as method of application (band vs. broadcast) significantly affected recommendations and apparent consistency. For example, the Washington recommendation for wheat is based on subsurface band placement and is doubled if fertilizer is applied broadcast, while Idaho makes no distinction based on method of application. Other differences were based on soil testing philosophy; North Carolina uses a soil test sufficiency approach whereas Tennessee includes yield goal as part of their recommendation for corn.

The Mid-Atlantic Soil Testing and Plant Analysis Workgroup (MASTPAWG) did a comparison of soil test interpretations and recommendations across 11 soil test labs from South Carolina to Pennsylvania (Donohue et. al., 2005). This group and their evaluation are unique in that it includes both public and private labs. This study also found reasonable agreement in soil test P interpretations and recommendations with a few exceptions. One of the main sources of differences was the different approach used by the labs to develop interpretations and recommendations. In an effort to reduce inconsistencies, this group proposed a set of standard, well defined strategic soil test parameters that are usually readily accessible from existing soil test calibration data. The parameters are: maximum P recommended at 0 soil test level, critical level of no response to added P, P recommendation at the critical level, and the soil test level where the P recommendation is 0. This is another example of regional work groups working across state lines to improve soil testing.

Differences in P recommendations between states may be a result of soil test philosophy. Some states use sufficiency for P recommendations, where others may use yield. State-to-state variation in fertilizer recommendations may occur due to lack of sufficient yield-based sensitivity in recommendations. In some cases, insufficient field validation data may be present to support more prescriptive rate recommendations. It appears, however, that soil test recommendations with regard to P are reasonably similar across state boundaries and should generally not result in divergent recommendations. In part, this is probably due to the continuous dialogue of the regional soil testing work groups.

CSP Enhancements and Code 590 Standards

Consistency among land grant university fertilizer recommendations across state boundaries for similar environments and cropping systems is one aspect of a unified approach to resource management. Consistency in the CSP and Code 590 standard also is necessary to successfully implement conservation programs in watersheds that cross state boundaries, and particularly for growers owning land within such a watershed.

In 2005, three cross-boundary watersheds were selected for the CSP program in the Pacific Northwest. Washington shares two of these watersheds with Oregon (Lower Grande Ronde and Middle Columbia-Hood) and one with Idaho (Rock). A comparison of 2005 CSP enhancements and payments for nutrient related practices among these three states revealed key differences (Table 2). States elected to adopt different enhancements (example: use of nitrification inhibitors, subsurface placement of fertilizers, etc.), defined similar enhancements differently (example: tissue testing, use of non-synthetic fertilizers), and paid different rates than neighboring states for the same enhancements (example: split N applications, precision agriculture). Similar discrepancies exist in enhancements adopted for 2006 CSP watersheds, though none of the selected watersheds cross state boundaries in Washington, Oregon and Idaho.

Differences in the Code 590 standard between Oregon, Washington, and Idaho also are apparent. Requirements such as soil testing frequency, P threshold values for waste applications, and the basis for nutrient application rates (N vs. P) are different, particularly between Washington/Oregon and Idaho. A similar comparison of state Code 590 standard in the southern states revealed similar discrepancies in P management.

Differences in CSP enhancements and the Code 590 standard not based on resource concerns within a watershed contribute to a sense of randomness and inequity when crossing state boundaries. These differences also make the program difficult to implement in watersheds that cross state lines. USDA-NRCS Code 590 standards and CSP requirements should, like state P fertilizer recommendations, be similar for common environments and production systems, particularly in watersheds that cross state boundaries.

P-Indices

Many fields to which animal waste has been applied contain sufficient, if not excessive, levels of nutrients – particularly P. In an attempt to reduce P loss from agricultural fields, the USDA–NRCS Code 590 standard is used when animal waste is applied (USDA/NRCS, 1999). The standard requires all states to adopt one of three approaches to controlling non-point source P losses from fields receiving manure: 1) establish a soil test P (STP) threshold based upon crop requirements and above which P applications are restricted; 2) establish an alternative STP threshold using water quality (rather than agronomic) criteria; 3) develop a P-Index to target remedial measures at fields of greatest risk for P loss. The P-Index option was developed by NRCS (Lemunyon and Gilbert, 1993) because the use of STP thresholds (options 1 and 2) was widely viewed as unduly restrictive and potentially ineffective at curtailing non-point source P losses. To-date, twenty-three states have adopted the P-Index, either directly or with modifications from the original concept, 25 states use a combination of the P-Index and/or environmental P threshold, and two states (California and Connecticut) use STP crop response (Sharpley et al., 2003). Since the majority of states use a P-Index, if animal waste is applied across state boundaries most nutrient management plans will include P-Indices.

Only a few papers have explored P-Index comparisons. Benning and Wortmann (2005) compared components of four Midwestern P-Indices (Iowa, Kansas, Missouri, and Nebraska) by varying specific field components: soil test P level, distance to surface water, P application rates and timing, and erosion rates. The authors found that the relative effect of these components on P-Index risk scores varied dramatically from state to state. Some P-Indices did not account for timing of applied P, whereas others were highly sensitive to applied P rate, but not erosion. For instance, when Mehlich 3 soil test P increased from 30 to 200 mg kg^{-1}, the corresponding dissolved P in runoff varied by 128 to 775%, depending on the P-Index used. The comparison by Benning and Wortmann suggests that if these indices were used within their states as part of a nutrient management plan, contiguous fields with similar current management that cross state boundaries may have very different P-Index ratings associated with them. Since P-Index ratings determine animal waste application rates, these different ratings may impose extremely different nutrient management strategies for contiguous fields.

Harmel et al. (2005) compared ratings from the Texas, Iowa, and Arkansas P-Indices to measured P loads from pasture and croplands located in the Texas Blackland Prairie. Results demonstrated reasonable relative loss estimates of P using the P-Indices for Texas and Iowa, even though the two P-Indices are very different. The Arkansas P-Index did a poorer job of predicting P loads for Texas Blackland soils, but as noted, was not developed for Texas conditions.

States in the Chesapeake Bay Watershed have worked together extensively as they developed their individual state P-Indices. The Chesapeake Bay watershed is very diverse ranging from the Eastern Shore Coastal Plain to the Appalachian Mountains. Consequently, this has resulted in necessary differences in the P-Indices in the Chesapeake Bay states. However, a concerted effort was made in the waterhshed to minimize differences as much as possible in similar physiographic areas across state lines. In 2003, a field evaluation of the Delaware, Maryland, and Virginia P-Indices was conducted in three Eastern Shore counties in Delaware, Maryland, and Virginia and those indices along with the Pennsylvania P-Index were compared in fields in an upland county in western Maryland.

Each state P-Index was run on the 10 fields and the final P-Index categories were compared (Figure 1). While there were some numerical differences in the P-Index values, the rankings were remarkably consistent. In addition to collaborating on the fundamental structure and parameters in the P-Indices, the states in the Chesapeake Bay watershed have agreed on a consistent scale for the P-Index by establishing a P-Index value of 100 for the very high category in all states in the region.

In a soon-to-be published article, Osmond et al. (2006) compared 12 southern P-Indices. Scenarios were developed for three agricultural systems: pasture, upland cropped soils and drained cropped soils. When state P-Indices were compared within an agricultural system and for the same set of conditions, P-Index ratings for the 12 states ranged from Low to Very High; the pasture agricultural system is provided as an example (Table 3). In addition to the ratings varying across states, the management implications of the same rating were not necessarily identical. For instance, a Very High Alabama P-Index rating allows producers to apply animal waste at a rate of crop removal P, whereas a Very High Georgia P-Index rating requires the discontinuation of P application.

The P-Index comparison results demonstrate that adjacent states with cross-boundary nutrient management programs may have diverse nutrient management requirements. For example, Tennessee and Kentucky share a CSP watershed, the Barren watershed. For four of the scenarios developed for pasture conditions, the P-Index ratings would be the same for fields in the Barren watershed (Table 3). The P-Index ratings in six of the pasture scenarios, however, would be different depending on which states' index is utilized.

Summary and Conclusions

Phosphorus management across state boundaries presents some important challenges. Phosphorus recommendations from state soil testing labs appear to be in general alignment and, thus, should usually produce similar results and recommendations between states with similar soils, climate and cropping systems. If, however, nutrient management plans require a P-Index, large differences in animal waste and/or inorganic fertilizer recommendations across state boundaries may occur due to rating differences. This is because each state was allowed and encouraged to develop its own P-Index. As a result, not only are there substantive differences in P-Index ratings among states, but even more important and problematic are state-to-state variations in the interpretation of the same P-Index rating. In some regions, such as Delaware, Maryland, New York and Pennsylvania, informal working groups arose during the development of state P-Indices. This led to more uniform cross-boundary P indices but was more the exception than the rule.

As cross-boundary watersheds are selected for inclusion in federal programs, it will be important for state and federal agencies to work together to ensure a modicum of uniformity in approach: soil testing, P-Index, and USDA-NRCS 590 standard. Ideally, P-Indices should be developed for physiographic regions rather than political regions. Even within states, conditions vary so much that questions have been raised about the adequacy of a single P Index for most states. For example, many of the Mid-Atlantic States go from coastal plain to the Appalachian Mountains. Most P-Indices are biased toward the most common or average agricultural conditions or toward the areas with the greatest potential P problems in that state, although one state, North Carolina developed a P-Index to account for the existent physiographic variability. This can result in inconsistencies both within the state and especially from state to state where the most common conditions are different, but significant areas with similar conditions also exist. Thus, in the Mid-Atlantic region it probably would be better to have a coastal plain P Index and a Piedmont/Mountain P Index rather than separate DE, MD, PA, and VA P Indices. Unfortunately, some of these processes are driven by policy and politics rather than just science, as underscored by the legal dispute between Oklahoma and Arkansas where a federal judge has imposed the P-Index that will be used in the contested cross-boundary watershed. Efforts to encourage greater coordination among states during the development and implementation of new programs may be the best approach for achieving consistency in the pursuit of resource management and environmental goals.

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Table 1. Soil Test P Recommendation Differences for major crops in Western and Eastern regions of the U.S.

Western Comparison

Phosphorus (lbs P2O5/acre)

Crop	Yield Goal (if applicable)	Very Low			Low			Medium			High			Very High		
		0 ppm	0-5 ppm	2 ppm	5 ppm		4 ppm	10 ppm	5-12 ppm	6-8 ppm	15 ppm	>12 ppm	10 ppm	20 ppm		>10 ppm
Corn	(bu/acre)	ID	OR	WA	ID	OR	WA	ID	OR	WA	ID	OR	WA	ID	OR	WA
(irrigated)	100	180	100-150	295	100		204	20	0-100	115-160	0	20-30	68	0		0
	150	180	100-150	295	100		204	20	0-100	115-160	0	20-30	68	0		0
	200	180	100-150	295	100		204	20	0-100	115-160	0	20-30	68	0		0

		Very Low			Low			Medium			High			Very High		
		0 ppm	3 ppm	3 ppm	5 ppm	6 ppm	6 ppm	10 ppm	9 ppm	9 ppm	15 ppm	12 ppm	12 ppm	20 ppm	12-20 ppm	12-20 ppm
Potatoes	(cwt/acre)	ID	OR	WA	ID	OR	WA	ID	OR	WA	ID	OR	WA	ID	OR	WA
	300	320	295	295	240	204	204	160	159	159	80	114	114	0	68	68
	400	320	295	295	240	204	204	160	159	159	80	114	114	0	68	68
	500	320	295	295	240	204	204	160	159	159	80	114	114	0	68	68
	600	320	295	295	240	204	204	160	159	159	80	114	114	0	68	68

		Very Low			Low			Medium			High			Very High		
		0-8 ppm	0-5 ppm	0-4 ppm	8-10 ppm	6-10 ppm	4-8 ppm	10-12 ppm	11-15 ppm	8-12 ppm	>12 ppm	>15 ppm	12-16 ppm			>16 ppm
Wheat	(bu/acre)	ID	OR	WA	ID	OR	WA	ID	OR	WA	ID	OR	WA	ID	OR	WA
(dryland)	50	60	30-35	40	40	20-30	30	20	10-20	20	0	0	10			starter
	75	60	30-35	40	40	20-30	30	20	10-20	20	0	0	10			starter
	100	60	30-35	40	40	20-30	30	20	10-20	20	0	0	10			starter

Additional Explanation

Idaho P recommendations increase with soil free lime content. Lime contents of 0 and 5% assumed for examples with potatoes and corn, respectively.
Oregon guide for corn recommends P be applied in a 2 by 2 band in cool soil even when soil test levels exceeds 12 ppm.
None of the guides vary P recommendation with yield.
Washington guide includes provisions for starter applications of P for wheat even when soil test levels exceed 16 ppm. This has been supported by current research.
Washington guide for wheat is based on subsurface-banding of P; guide recommends 2x rate if fertilizer is broadcast.
Oregon and Washington use the same fertilizer guide for potatoes (see bibliography for citation).

Eastern Comparison

Crop	Yield Goal	Very Low			Low			Medium			High			Very High		
	(if applicable)	quantity and unit of measure			quantity and unit of measure			quantity and unit of measure			quantity and unit of measure			quantity and unit of measure		
Corn	(bu/acre)	NC	VA	TN	NC	VA	TN	NC	VA	TN	NC	VA	TN	NC	VA	TN
Mineral -4*	100-125	120-150	120	100	80-120	80-100	100	30-80	40-80	50	0-20	20-40	25	0	0	0
Organic-5*	125-150	110-150		120	50-100		120	0-50		60	0		30	0		0
	150-175			140			140			70			35			0
	175-200			160			160			80			40			0
	200-225			180			180			90			45			0

		Very Low			Low			Medium			High			Very High		
		quantity and unit of measure			quantity and unit of measure			quantity and unit of measure			quantity and unit of measure			quantity and unit of measure		
Soybean	(bale/acre)	NC	VA	TN	NC	VA	TN	NC	VA	TN	NC	VA	TN	NC	VA	TN
Mineral -4*		120-150	120	40	80-120	80-100	40	30-80	40-80	20	0-20	20-40	0	0	0	0
Organic-5*		110-150			50-100			0-50			0			0		

		Very Low			Low			Medium			High			Very High		
		quantity and unit of measure			quantity and unit of measure			quantity and unit of measure			quantity and unit of measure			quantity and unit of measure		
Wheat	(bu/acre)	NC	VA	TN	NC	VA	TN	NC	VA	TN	NC	VA	TN	NC	VA	TN
Mineral -4*		120-150	120	80	80-120	80-100	80	30-80	40-80	40	0-20	20-40	0	0	0	0
Organic-5*		110-150			50-100			0-50			0			0		

Additional Explanation

1) No Very Low soil test class in TN. Note: Soil extract is Mehlich 1; not Mehlich 3 as used in NC. Soil test recommendations can be found at http://bioengr.ag.utk.edu/SoilTestLab/pubList.asp
Mineral - 4*:NC does not use yield goal for P recommendations. The values range based on index readings and are a function of soil class, and these values are for mineral soils based on humic acid determination.
For more information please see http://www.agr.state.nc.us/agronomi/obook.htm
Organic - 5*:NC does not use yield goal for P recommendations. The values range based on index readings and are a function of soil class, and these values are for organic soils based on humic acid determination.
For more information please see http://www.agr.state.nc.us/agronomi/obook.htm
Virginia: Except for the Very High category, we use "-" and "+" categories. For example, L-, L & L+, with recommendations of 120, 100 and 80 lbs/acre, respectively for corn. VA Tech Soil Testing Laboratory uses the Mehlich 1 extract.

Table 2. Comparison of CSP enhancements relating to nutrient management adopted in Idaho, Oregon and Washington for 2005 watersheds. Information adapted from enhancement lists posted on USDA-NRCS web sites in the respective states.

Enhancement	**Idaho**		**Oregon**		**Washington**	
	Adopted	Payment	Adopted	Payment	Adopted	Payment
Manage feeds to reduce P excretion by livestock	√	$750/yr				
Manage nutrient utilization by double cropping	√	$12/ac/yr				
Manage animal wastes by incorporating within 1 day	√	$2.50/ac/yr				
Manage nutrient timing and application….tissue testing	√	$14/ac/yr			√	$14/ac/yr
Utilize soil/manure/plant tissue testing results			√	$1/ac/yr		
Deep soil test for nitrogen			√	$.25/ac/yr		
Apply annual results of complete soil tests					√	$3/ac/yr
Use nitrification inhibitors or slow release N fertilizer	√	$6/ac/yr			√	$6/ac/yr
Optimize nutrient utilization…split N application	√	$6/ac/yr	√	$3/ac/yr	√	$14/ac/yr
Manage nutrients through precision agriculture	√	$3.50/ac/yr	√	$10/ac/yr	√	$4/ac/yr
Manage yield variability through yield monitoring					√	$2/ac/yr
Riparian buffers 2x standard practices width	√	$100/ac/yr			√	$100/ac/yr
Manage nutrients using LGU recommendations	√	$12/ac/yr				
Inject/side dress/band fertilizer			√	$2/ac/yr		
Use non-synthetic fertilizers			√	$6/ac/yr		
Manage inputs to meet organic certification					√	$10/ac/yr
Manage soil pH utilizing soil test recommendations					√	$3/ac/yr
Manage cover crops to utilize nutrients/reduce erosion					√	$10/ac/yr
Manage soil quality by applying compost					√	$5/ac/yr

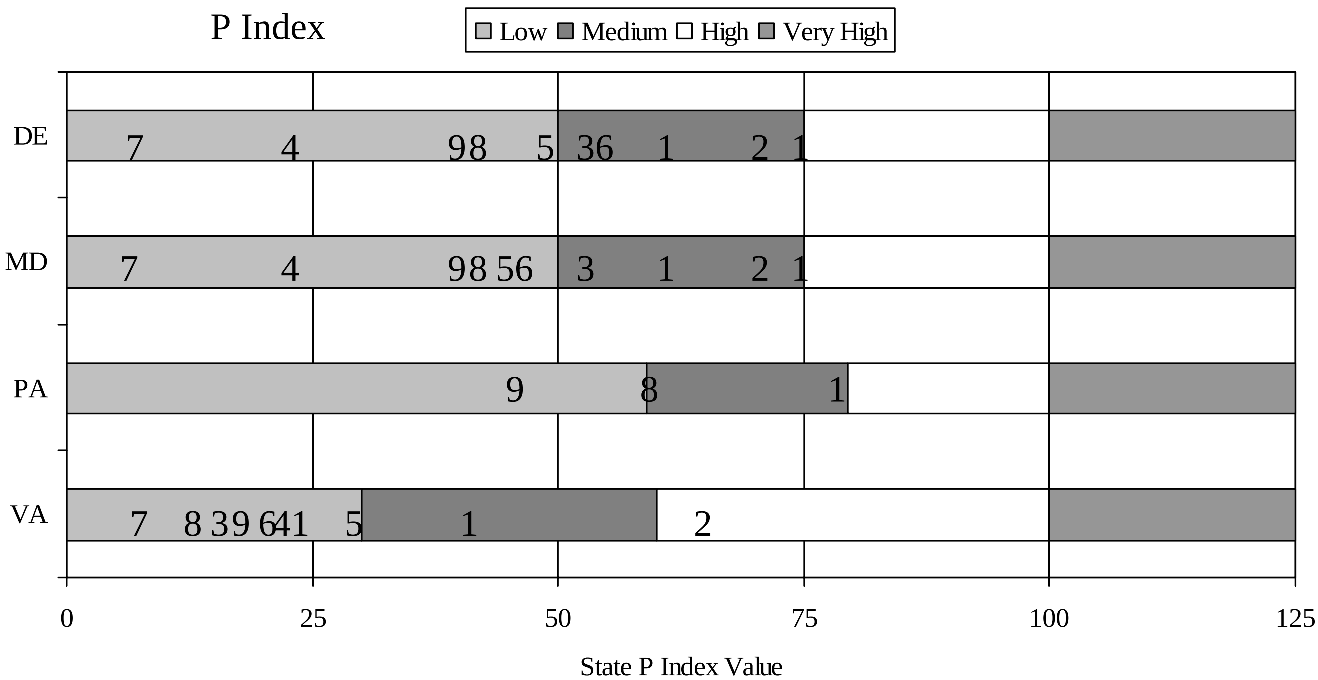

Figure 1. Comparison of P Index values and categories using the DE, MD, PA, and VA P-Indices on10 fields in 4 states in the Chesapeake Bay Watershed. Numbers in the chart refer to the site number evaluated. (Coale, unpublished)

Table 3. Southern state P-Indices ratings for different scenario conditions in pastures.

Pasture Scenario Comparisons			**P-Index Rating**			
STP Mehlich 3 (mg kg^{-1})	**Broiler Litter (Mg ha^{-1}/ton ac^{-1})**	**Buffer**	**Low**	**Medium**	**High**	**V. High**
75	4.5/2.0	No	AL, FL, GA, LA, MS, NC, SC	AR	KY, TN, TX	OK
75	9.0/4.0	No	GA, LA, MS, NC	AL, FL, SC	AR, KY, TN, TX	OK
75	13.5/6.0	No	GA, MS, NC	FL	KY, LA, SC, TX	AL, AR, OK, TN
75	13.5/6.0	Yes	GA, LA, MS, NC	FL, SC	AL, AR, KY, OK, TN, TX	
75	17.9/8.0	No	GA, MS, NC		FL, KY, LA, SC, TX	AL, AR, OK, TN
75	17.9/8.0	Yes	GA, LA, MS, NC	FL, SC	AL, AR, KY, OK, TN, TX	
150	13.5/6.0	No	MS, NC	GA	FL, KY, LA, SC, TX	AL, AR, OK, TN
150	13.5/6.0	Yes	GA, LA, MS, NC	FL, SC	KY, OK, TX	AL, AR, TN
150	17.9/8.0	No	MS, NC	GA	FL, KY, SC, TX	AL, AR, LA, OK, TN
150	17.9/8.0	Yes	GA, MS, NC	LA	FL, KY, OK, SC, TX	AL, AR, TN