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Arkansas Phosphorus Index

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Introduction

The Arkansas Phosphorus Index (API) is used to assess the risk of phosphorus (P) runoff from pastures and hayland as part of farm nutrient management plan (NMP) development. Nutrient management plans are required by farmers in nutrient surplus areas of Arkansas (see Fact Sheet FSA9529) who apply P with manure or biosolids. As such, it is basically used to determine maximum application rates of P on pastures, as a function of source potential (i.e., soil and manure management), transport potential (i.e., risk of runoff and erosion, field slope and proximity to streams), presence of best management practices (BMPs) and an acceptable level of risk. This publication details the structure, use and interpretation of the recently revised API, which from January 2010 is used in preparing nutrient management plans in Arkansas. Development of the API was a collaborative group effort involving many stakeholders within Arkansas who are listed at the end of this publication.

Structure of the Phosphorus Index

The API is multiplicative in nature and assigns a risk value for P loss in runoff as follows:

P Index = P Source Potential * P Transport Potential * BMPs Multiplier

Seven site characteristics are included in the API which are grouped into either P Source or P Transport Potential categories. Phosphorus Source Potential characteristics are (1) soil test P and (2) soluble P application rate, while the P Transport Potential characteristics are (3) soil erosion, (4) soil runoff class, (5) flooding frequency, (6) application method and (7) timing of P application.

In addition to management practices that influence site characteristics, there are nine BMPs that can be considered to reduce P runoff risk. The landowner has the option to implement one or a combination of diversions, terraces, ponds, filter strips, grassed waterways, paddock fencing, riparian forest buffers, riparian herbaceous buffers and field borders to meet his or her conditions and preferences.

The P Source Potential, P Transport Potential and BMP Multiplier are determined independently, as described below, before determining the overall API.

P Source Potential

The estimated P Source Potential is calculated as follows:

$$\text{P Source Potential} = WEP_{coef} * (WEP_{applied} + MNRL_{coef} * (TP_{applied} - WEP_{applied})) + STP_{coef} * STP$$

STP: Soil test P (lbs/acre) is determined by the standard Mehlich-3 extraction method for a 0-4 inch soil sample (see Fact Sheet FSA1035 for proper soil sampling procedures). This is the method used by the University of Arkansas Soil Laboratory. To obtain STP input value in lbs P/acre, the laboratory results in parts per million (ppm) should be multiplied by 1.33.

$WEP_{applied}$: Water extractable P (lbs WEP/acre) is the amount of water soluble P applied with manure or biosolids. The University of Arkansas Diagnostics Laboratory follows national standard procedures to estimate WEP. It is determined by multiplying $WEP_{applied}$ (lbs/ton of manure) by the manure application rate (tons/acre).

$TP_{applied}$: Total amount of P applied (lbs P/acre) with manure or biosolids. The University of Arkansas Diagnostics Laboratory follows national standard procedures to estimate total P. It is determined by multiplying $TP_{applied}$ (lbs/ton of manure) by the manure application rate (tons/acre).

MNRL: There is a continued but slow release of P from manure or biosolid after land application which can contribute additional P in runoff. To account for this, a mineralization factor (MNRL) of 0.05 (5% of non-WEP total P) for untreated material and 0.005 (0.5% of non-WEP total P) for alum-treated materials is included in the P Source Potential calculation.

The lower mineralization factor for alum-treated material reflects the fact that aluminum (Al) from added alum binds with P in a mineral rather than organic form. Thus, there is a lower potential for organic P mineralization in alum-treated material. Liquid manures treated with aluminum chloride to reduce WEP would also use the 0.005 mineralization factor. In order for biosolids to be considered "alum-treated," they must have an Al:P mole ratio of 0.1 or greater (i.e., at least one molecule of Al to every molecule of P).

WEP_{coef} and STP_{coef}: These P source coefficients were determined from runoff P load data collected during rainfall simulation studies using various poultry litters, swine slurries and biosolids (Table 1). WEP_{coef} varies for the different source materials to be land applied, while STP_{coef} is always 0.0018.

Management history of the manure determines whether a liquid or dry manure WEP_{coef} should be used. If water has been used in the handling and treatment process, such as for swine manure that has been flushed from the house into a holding pond, the liquid manure WEP_{coef} should be used. If water has not been used, such as for poultry housed on bedding, the dry manure WEP_{coef} should be used.

Table 1. P source coefficients

P Source Potential	$WEP_{coef}*(WEP_{applied} + MNRL_{coef}*(TP_{applied} - WEP_{applied})) + STP_{coef}*STP$		
API variable†	WEP_{coef}	$MNRL_{coef}$	STP_{coef}
Dry litter, not treated	0.095	0.05	0.0018
Dry litter, treated¶	0.095	0.005	0.0018
Liquid manure, not treated	0.031	0.05	0.0018
Liquid manure, treated	0.031	0.005	0.0018
Biosolid cake	0.058	0.05	0.0018
Biosolid cake, treated§	0.058	0.005	0.0018
Liquid biosolid	0.029	0.05	0.0018
Liquid biosolid, treated	0.029	0.005	0.0018

† Units for both $WEP_{applied}$ and STP are lbs P/acre.

¶ Treated dry and liquid manures refers to treatment with aluminum compounds to reduce soluble P concentrations in the litter or manure.

§ Treated biosolids have an aluminum to P (Al:P) mole ratio of 1.0 or greater.

P Transport Potential

Five factors influencing P transport are considered in estimating P Transport Potential: soil erosion, soil runoff class, flooding frequency, method of application and timing of application (Table 2). Each factor is divided into classes with each class associated with a specific loss rating value.

P Transport Potential is the sum of all the loss rating values as follows:

P Transport Potential = soil erosion + runoff class + flooding frequency + application method + application timing

Soil Erosion: Soil erosion is to be estimated by RUSLE2, a computerized method used by USDA Natural Resources Conservation Service (NRCS) to estimate soil loss in tons/ac/year in the API. Well-managed pasture systems would be expected to have negligible annual erosion; hence, this value is typically near zero.

Soil Runoff Class: Soil runoff class is determined from slope gradient and runoff curve number of a given soil (Tables 3 and 4). While slope will vary across a field, typical field slope can be roughly estimated from NRCS soil classification/survey information (available at http://soildatamart.nrcs.usda.gov and http://websoilsurvey.nrcs.usda.gov), with site visits providing the opportunity to refine the estimate. The runoff curve number is a factor of pasture management and soil hydrologic group (Table 3). This is based on runoff predicted from a 40-acre field for a one-year, 24-hour storm event (i.e., in units of cubic feet per second – cfs). The soil runoff classes are Negligible (0.2-0.4 cfs/ac/in), Very Low (0.5-0.6 cfs/ac/in), Low (0.7-0.8 cfs/ac/in), Moderate (0.9-1.0 cfs/ac/in), High (1.1-1.2 cfs/ac/in) and Very High (1.3-1.4 cfs/ac/in).

Pasture Management and Runoff Curve Numbers: In the API, pasture management is classified as continuously grazed, rotationally grazed or hayed only (Table 4). Continuously grazed pastures are also broken down between those that have greater than or less than 0.75 animal units/acre; where an animal unit is defined as 1,000 lbs of live animal weight. The effect of cattle grazing has an important bearing on site hydrology and runoff potential. A pasture under continuous grazing would be expected to have a higher risk for P runoff than a pasture with rotational grazing. This is due to compaction and additional P inputs from cattle.

The soil hydrologic group for the predominant soil for the field can be found in the NRCS soil classification/survey information (available at http://soildatamart.nrcs.usda.gov and http://websoilsurvey.nrcs.usda.gov).

Table 2. Phosphorus transport potential characteristics and calculations

Site Characteristic	Description						Loss Rating Value
Soil erosion (tons/ac/yr)	<1	1 to 2	2 to 3	3 to 5	>5		
Loss rating value	0	0.1	0.2	0. 4	1		LRV
Soil runoff class	Negligible	V. Low	Low	Moderate	High	V. High	
Loss rating value	0.1	0.15	0.2	0.5	1.0	1.5	LRV
Flooding frequency	None to very rare	Rare	Occasional	Frequent			
Loss rating value	0	0.2	0.5	2.0			LRV
Application method	Incorporated	Surface applied	Surface applied on frozen ground or snow				
Loss rating value	0.1	0.2	0.5				LRV
Application timing	July-Oct	March-June	Nov-Feb				
Loss rating value	0.1	0.25	0.6				LRV

Table 3. Runoff class based on site slope and curve number

		Runoff Curve Number†						
		<60	60-65	66-70	71-75	76-80	81-85	>85
Slope %	<1	N	N	N	N	VL	VL	VL
	1	N	N	VL	VL	VL	L	L
	2	N	VL	VL	VL	L	L	M
	3	N	VL	VL	L	L	M	M
	4	N	VL	L	L	M	M	M
	5	N	VL	L	L	M	M	H
	6	N	VL	L	M	M	H	H
	7	N	L	L	M	M	H	H
	8	N	L	L	M	M	H	VH
	9	N	L	L	M	H	H	VH
	10	N	L	M	M	H	H	VH
	11	N	L	M	M	H	H	VH
	12	N	L	M	M	H	VH	VH
	13	N	L	M	M	H	VH	VH
	14	N	L	M	H	H	VH	VH
	15	N	L	M	H	H	VH	VH
	>15	N	L	M	H	H	VH	VH

†Runoff curve numbers for pasture and its management are given in Table 4.

Table 4. Influence of grazing management on runoff curve numbers used in the API

Pasture Use	Soil Hydrologic Group			
	A	B	C	D
Continuously grazed > 0.75 An. Units/ac	68	79	86	89
Continuously grazed < 0.75 An. Units/ac	49	69	79	84
Rotational Grazing	39	61	74	80
Hayland	30	58	71	78

Flooding Frequency: Flooding frequency includes four categories: none to very rare, rare, occasional and frequent, and for any given site can be found through NRCS soil classification/survey information (available at http://soildatamart.nrcs.usda.gov and http://websoilsurvey.nrcs.usda.gov).

Application Method: Application methods are grouped into three areas: incorporated, surface applied or surface applied on frozen or snow-covered ground. The associated loss rating values of 0.1, 0.2 and 0.5 reflect the estimated risk of P transport during seasonal rainfall events.

Application Timing: The effect of application timing on P runoff potential is categorized into three periods of equal length (July-Oct, March-June and Nov-Feb), which are associated with loss rating factors 0.1, 0.25 and 0.60, respectively. These times were chosen after evaluating historical rainfall and stream flow data.

Best Management Practices (BMPs) Multiplier

In addition to the management practices considered in the Source and Transport Potential factors, there are nine BMPs that can be considered for implementation to decrease the risk of P runoff. The credited effectiveness in decreasing P runoff and associated Conservation Practice Standards for these BMPs are shown in Table 5. The method to estimate the effectiveness of the implemented BMPs in reducing P transport in runoff is:

$$\text{BMPs Multiplier} = (1-\text{Effectiveness}_1) * (1-\text{Effectiveness}_2) * \cdots * (1-\text{Effectiveness}_9)$$

The effectiveness values are the BMP credits given in Table 5 expressed in a fractional format. That is, 20% would be expressed as 0.20. If a BMP is not implemented, it is assigned an effectiveness of 0. As a consequence, if no BMPs are implemented, the BMP multiplier will be equal to 1.0. If BMPs are used, then the BMP multiplier will have a value of less than 1.

Table 5. Credit given in the revised API for various BMPs whose implementation meet NRCS Conservation Practice Standards
(see http://www.nrcs.usda.gov/technical/Standards/nhcp.html)

Best Management Practice	CPS#	Credit
Diversion	362	5%
Terrace	600	10%
Pond	378	20%
Fenced pond		30%
Filter strip	393	20%
Fenced filter strip		30%
Grassed waterway	412	10%
Fencing	382	30%
Riparian forest buffer	391	20%
Fenced riparian forest buffer		35%
Riparian herbaceous cover	390	20%
Fenced riparian herbaceous cover		30%
Field borders	386	10%

The effectiveness rating given for a pond will depend on how much of the field drains into the pond. Nutrient management plan writers must make a professional judgment on percentage of field that drains into pond and the assigned effectiveness adjusted by that percentage. Determination of the percentage of the field draining to the pond should be based on topographic maps and site visits.

There are three additional potential adjustments regarding BMPs. If a pond is fenced, then the assigned effectiveness is increased from 20% to 30%. If a riparian forest buffer is fenced, then an effectiveness of 35% should be assigned for the combination. If fencing is used in conjunction with filter strips or riparian herbaceous buffers, an effectiveness of 30% should be assigned for the combination.

Risk Interpretation

Based on the API site rating, fields are assigned a P Index risk class of low, medium, high or very high based on the resulting numeric value. Each class is associated with interpretations and recommendations as shown in Table 6. Recommendations range from cautions regarding buildup of soil P levels for the low risk class, to no additional P applications until soil P levels and P Index values are reduced for the very high class.

It should be noted that the recommendations are not expressed in nitrogen (N) or P-based application rates, as P application rates are inputs for the calculation of P Index values. While the API does not address environmental concerns associated with N applications, application rates should never exceed the crops' N requirement. In practice, the P Index value specified in the plan determines the maximum P application for the life of the plan. Application rates below those used to estimate the P runoff risk will result in a lower risk, assuming all other factors remain the same.

Background Information and Reading

Arkansas Natural Resources Commission Title 20. 2010. *Rules governing the Arkansas Nutrient Management Planner certification program.* The Revised Arkansas Phosphorus Index by Moore, P.A., Jr., A. Sharpley, W. Delp, B. Haggard, T. Daniel, K. VanDevender, A. Baber and M. Daniel. http://www.anrc.arkansas.gov/Title%2020%2012-10-09.pdf.

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Table 6. Interpretation and recommendations for the revised Arkansas Phosphorus Index

P Index Value	Site Interpretations and Recommendations
LOW	Caution against long-term buildup of P in the soil.
MEDIUM	Evaluate the Index and determine any field areas that could cause long-term concerns. Consider adding BMPs.
HIGH	Evaluate the Index and determine elevation cause. Add appropriate BMPs and/or reduce P application. The immediate planning target is an API value in the Medium class or lower. If this cannot be achieved with realistic BMPs and/or reduced P rates in the short-term, then a conservation plan needs to be developed with a long-term goal of an API value in the Medium class or lower.
VERY HIGH	No P application. Add BMPs to decrease this value below the Very High class in the short-term and develop a conservation plan that would reduce the API value to a lower risk category, with a long-term goal of an API in the Medium class or lower.

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