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Phosphorus Management Strategies for Delaware's Agricultural Soils: The Phosphorus Site Index

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Introduction and Purpose

Long-term use of fertilizer and manure nutrients on the Delmarva Peninsula has led to an enrichment of agricultural soils with phosphorus (P). Consequently, many soils in Delaware are now considered "excessive" in soil test P (Figure 1). In some situations, soils with "excessive" soil test P contribute to eutrophication of surface waters; therefore, P management strategies that maintain both agricultural profitability and environmental quality are necessary. One such P management tool is the P Site Index, defined as "…a tool designed to assess the relative risk of P loss from agricultural fields based on site characteristics that affect the transport of P and P source and management factors". The P Site Index is most useful for fields that receive manure or other organic P sources, as inorganic P sources can be more easily balanced to meet crop needs.

This document provides an overview of the Delaware P Site Index (also referred to as the P Index). Practitioners of the P Site Index are strongly recommended to review the ***Technical Guidance Manual for the P Site Index*** (available at http://www.udel.edu/00151) for detailed instructions on how to conduct field assessments using the Delaware P Site Index.

Origins of the Phosphorus Site Index

In 1990, the USDA Soil Conservation Service (now the USDA Natural Resources Conservation Service or USDA-NRCS) formed a national work group of scientists from Universities, Cooperative Extension, and the USDA Agricultural Research Service to develop a P-indexing procedure that could identify soils, landforms, and management practices with the potential for unfavorable impacts on water bodies because of P losses from agricultural soils. The long-term goals of this national work group were to:

- Develop an easily used, site-specific, field rating system (referred to as the P Site Index) for USDA-NRCS technical specialists, Cooperative Extension, crop consultants, farmers and others that rates soils according to their relative potential for P loss to surface waters.
- Relate the P Site Index to the sensitivity of receiving waters to eutrophication.
- Develop agricultural management practices that minimize the buildup of soil P to excessive levels and the transport of P from soils to sensitive water bodies.

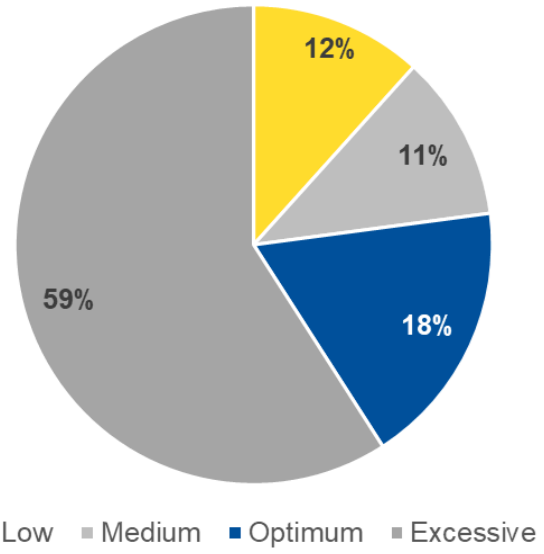

Figure 1. Percentages of agricultural soil samples in each soil test category in Delaware based on soil samples submitted to the University of Delaware Soil Testing Laboratory from 2020 – 2025.

The P Site Index was designed to assess the relative risks of P loss from differing fields, not to estimate the actual quantity of P lost in runoff. The P Site

Index risk assessment allows us to identify critical source areas (areas with an increased risk of P loss due to the site hydrology and presence of a P source) and target the use of best management practices (BMPs) in priority locations within a watershed to achieve the greatest water quality benefits.

The P Site Index accounts for site-specific source and transport factors that may influence the potential for P loss from a particular site. Agronomic or environmental soil test P thresholds were also suggested as an alternative way to limit P applications for soils. However, unlike the P Site Index, use of soil test thresholds to limit P applications represents a one-size fits all approach to P management, which does not account for variations in soil types, hydrologic connectivity between cropland and surface waters, and nutrient management practices (e.g., source, rate, method, and timing of P applications). As a result, the P Site Index approach was adopted as standard practice for nutrient management throughout the US, particularly as a component of the USDA-NRCS Nutrient Management Conservation Practice Standard (Code 590) and the US Environmental Protection Agency's Concentrated Animal Feeding Operation (CAFO) rule.

The Delaware Phosphorus Site Index

The Delaware P Site Index evaluates 12 characteristics, which are separated into two groups: site factors affecting P transport (Part A; Table 1) and P source and management factors (Part B; Table 2) to obtain an overall rating of the potential for P loss at a site. Grouping these factors makes it possible to obtain separate risk assessments for P transport from a site (based on factors such as topography, hydrology, and proximity to surface waters; Part A), and for P source and management practices (based on factors such as soil test P, fertilizer/manure P management; Part B).

The specific site and transport characteristics used in Part A of the Delaware PSI include:

- Soil erosion – Estimates soil loss by sheet and rill erosion; erosion is determined using the Revised Universal Soil Loss Equation (RUSLE). All factors for the RUSLE can be obtained from a county soil survey, a few readily determined field measurements (slope, cover, etc.) and information on past field management practices (crop rotations).
- Soil surface runoff class – Estimates the likelihood for runoff based on soil permeability and slope of the predominant soil type in each field as determined from a county soil survey.
- Subsurface drainage – Estimates the potential for P transport to nearby streams and drainage ditches via subsurface flow using the depth to the seasonal high water table and the soil drainage class of the predominant soil type in each field as determined from a county soil survey.
- Leaching potential – Estimates the potential for P to leach below the root zone based on soil physical and chemical properties and the depth to the seasonal high water table.
- Distance from field to surface water – Describes the distance from the edge of the field to nearby water bodies or other permanent conduits that connect the field to surface waters (as measured in the field). Integrates the effects of vegetative buffers (type, width) present in the field.
- Priority of receiving water – Prioritizes watersheds, in terms of protection of surface waters from nonpoint source pollution by P, based on the presumption that some waters require a greater degree of protection than others.

The specific source and management characteristics used in Part B of the Delaware PSI include:

- Soil test P value – The soil test P is expressed as fertility index values (FIV), which is a unitless value that is proportional to soil test P concentration. The FIV system uses four categories (Low, Medium, Optimum and Excessive) and is based on the probability of obtaining a profitable plant response to addition of P in fertilizers or other soil amendments.
- Phosphorus fertilizer application rate – The planned amount of inorganic P in pounds P_2O_5 per acre that will be applied to the crop.
- Phosphorus fertilizer application method – Describes the planned inorganic P source application method (e.g., broadcast with incorporation, banded, etc.) and time of year the organic P source will be applied. This information is obtained from the nutrient user.

Table 1: Site factors affecting transport of phosphorus as used in Part A of the Delaware P Site Index.

Characteristics	**Phosphorus Loss Rating**					**Value**
PART A: SITE AND TRANSPORT CHARACTERISTICS						
Soil Erosion	2 × [Soil erosion value from RUSLE (tons/acre)]					
Soil Surface Runoff Class	Very Low 0	Low 2	Medium 4	High 6	Very High 8	
Subsurface Drainage	Very Low 0	Low 2	Medium 4	High 6	Very High 8	
Leaching Potential	Low 0		Medium 2	High 4		
Distance from Edge of Field to Surface Water	>100 ft 0	< 100 ft AND > 50 ft vegetated buffer OR < 100 ft AND > 25 ft vegetated buffer AND > 25 ft additional no P application zone 2	< 100 ft AND > 25 ft vegetated buffer AND < 25 ft additional no P application zone 4	< 100 ft AND < 25 ft vegetated buffer AND > 25 ft additional no P application zone 6	< 100 AND < ft vegetated buffer AND < ft additional no P application zone	
Priority of Receiving Water	Very Low 0	Low 1	Medium 2	High 3	Very High 4	
Part A Calculations	Sum of Site and Transport Characteristics					
	Scaling Factor					×0.02
	Total Site and Transport Values for Part A					

Table 2: Phosphorus source and management practices affecting the risk of phosphorus loss as used in Part B of the Delaware P Site Index.

Characteristics	Phosphorus Loss Rating					Value
PART B: PHOSPHORUS SOURCE AND MANAGEMENT PRACTICES						
Soil Test P Fertility Index Value (FIV)	0.2 × [FIV from University of Delaware Soil Test]					
P Fertilizer Application Rate	0.6 × [lbs P_2O_5 applied per acre]					
P Fertilizer Application Method and Timing	None 0	Injected or banded below surface at least 2" 15	Incorporated within 5 days of application 30	Surface applied March through November OR incorporated in >5 days after application 45	Surface applied December through February 60	
Organic P Application Rate	PSC (Table 3) × [lbs P_2O_5 applied per acre]					
Organic P Application Method and Timing	None 0	Injected or banded below surface at least 2" 15	Incorporated within 5 days of application 30	Surface applied March through November or incorporated in >5 days after application 45	Surface applied December through February 60	
Total P Source and Management Value for Part B						

- Organic P source application rate – The planned amount of P in pounds P_2O_5 per acre that will be applied to the soil when manures, biosolids, composts or other organic P sources are used. The P application rate is then multiplied by a Phosphorus Source Coefficient (PSC; Table 3) to account for differences in P solubility and plant availability between organic P sources. The default PSC is 0.6, a value that is also used for inorganic fertilizer P.
- Organic P source application method – Describes the planned organic P source application method (e.g., surface applied, incorporated, etc.) and time of year the organic P source will be applied. This information is obtained from the nutrient user.

Each of the 12 characteristics in the P Site Index is assigned a numerical value from an interpretive rating scale (i.e., low, medium, high, or very high) or from

Table 3: Standard phosphorus source coefficients (PSCs), which are used in the phosphorus site index to account for difference in the solubility of phosphorus in different organic amendments.

Organic P Source	Phosphorus Source Coefficient (PSC)
Default	0.6
Swine manure	0.6
Other manures (beef, dairy, poultry, horse, etc.)	0.5
Biological phosphorus removal (BPR) biosolids	0.5
Biological nutrient removal (BNR) biosolids	0.5
Biosolids from wastewater treatment (all except BPR and BNR)	0.2

calculations using a weighting factor based on the relationship between the characteristic and the potential for P loss from the site.

At present, the interpretive ratings and weighting factors for each of the characteristics are based on the best professional judgment of the scientists who developed the P Site Index. Research continues to determine the need for adjustments in the interpretive ratings or weighting factors.

Phosphorus Site Index Ratings and Generalized Interpretation

Once the risk assessments for P transport from a site (Part A) and for P source and management practices (Part B) are calculated, the final P Site Index Rating is determined by the following equation:

PSI Rating = [Part A Total] × [Part B Total]

Based on the final P Site Index rating, sites are assigned to one of four categories. Each category includes a generalized interpretation of the P loss potential and appropriate P management actions. The P Site Index categories and generalized interpretations are:

Phosphorus Site Index Rating < 50. **LOW** potential for P movement from the site given current management practices and site characteristics. There is a low probability of an adverse impact to surface waters from P losses from the site. Nitrogen-based nutrient management planning is satisfactory for the site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management.

Phosphorus Site Index Rating = 50 – 75. **MEDIUM** potential for P movement from the site given current management practices and site characteristics. Practices should be implemented to reduce P losses by surface runoff, subsurface flow, and erosion. Nitrogen-based nutrient management should be implemented no more than one year of a crop rotation. Phosphorus-based nutrient management should be implemented in other years of the crop rotation, during which time P applications should be limited to the amount expected to be removed from the field by crop harvest or soil test based P application recommendations, whichever is greater.

Phosphorus Site Index Rating = 76 – 100. **HIGH** potential for P movement from the site given current management practices and site characteristics. Phosphorus-based nutrient management should be used for the site. Phosphorus applications should be limited to the amount expected to be removed from the field by crop harvest or soil test based P application recommendations. All practical management practices for reducing P losses by surface runoff, subsurface flow, or erosion should be implemented.

Phosphorus Site Index Rating > 100. **VERY HIGH** potential for P movement from the site given current management practices and site characteristics. No P should be applied to the site. Active remediation techniques should be implemented in an effort to reduce the P loss potential from the site.

It is important to note that a risk rating of LOW or MEDIUM does not permit the application of inorganic P or organic P sources at rates exceeding the proposed rates of P that were used as inputs in Part B of the P Site Index. If you would like to apply

at higher rates, you must rerun the P Site Index and input the higher rates inorganic P rates in Part B and follow the new interpretation. The same applies to application method and timing.

Using the Delaware Phosphorus Site Index

The Delaware Nutrient Management Act (3 Del. C. § 2202) defines a "high P soil" as any soil with a Mehlich-3 soil test value greater than 150 FIV (equivalent to 150 ppm or 300 lb/acre). This legal definition of "high P soils" is different from the agronomic interpretation of high or excessive soil test P (>100 FIV). Detailed information about "high P soils" is available in *Defining High P Soils in Delaware* (available at http://www.udel.edu/0013366).

In brief, Delaware law (3 Del. C. § 2247) limits applications of P to "high P soils" to total P removal in a planned crop rotation unless a different management practice is permitted after conducting the Delaware P Site Index. The Delaware P Site Index is **recommended** to guide P management for fields with Mehlich 3 soil test concentrations between 150 and 499 FIV and is **required** for all fields with Mehlich 3 soil test P concentrations >499 FIV.

Detailed information about how to conduct field assessments using the P Site Index is available in the *Technical Guidance Manual for the Phosphorus Site Index* at (available at http://www.udel.edu/00151). If additional guidance is needed, P Site Index practitioners should contact University of Delaware Cooperative Extension, the USDA-NRCS, or the local conservation district.

Summary

The Delaware P Site Index is a management tool that was designed to assess the relative risk of P loss from agricultural fields. The P Site Index evaluates 12 characteristics, which are separated into two groups: site factors affecting P transport (Part A) and P source and management factors (Part B) to obtain an overall rating of the potential for P loss at a site. The P Site Index is most useful for fields that receive manure or other organic P sources, as inorganic P sources can be more easily balanced to meet crop needs.

Based on the final P Site Index rating, sites are assigned to one of four risk categories. Each category includes a generalized interpretation of the P loss potential and appropriate P management actions.

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