The New York Phosphorus Runoff Index: Version 2.0

User's Manual and Documentation

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Executive Summary

- The original New York Phosphorus Runoff Index (NY-PI) User's Manual was published in 2003. Version 2.0 of the NY-PI, released in 2019, reflects subsequent gains in knowledge and addresses challenges that were identified since publishing the first NY-PI.
- The NY-PI 2.0 is a field management tool designed to estimate the relative risk of phosphorus (P) runoff from agricultural fields. The original NY-PI used a source × transport approach. The NY-PI 2.0 uses a more intuitive transport × best/beneficial management practice (BMP) approach, where fields are scored based on factors that drive transport of manure and fertilizer P from agricultural fields, and scores can be lowered by implementation of BMPs that reduce the risk of P transport.
- The NY-PI 2.0 does not estimate actual P loss, reflecting challenges with accurately predicting loss of P from individual fields. It rates fields for relative risk of particulate and dissolved P runoff and triggers management changes designed to reduce P runoff risk. This approach has been shown to drive management decisions toward practices that reduce relative P losses.
- The NY-PI 2.0 is used to derive a relative risk score for each nutrient management planning cycle based on information garnered from farm records, soil erosion control plans, manure and fertilization plans, and field visits.
- The first step in development of the NY-PI 2.0 score for a field is evaluation of soil test P (STP). Fields with a Cornell Morgan STP exceeding 160 lbs/acre are generally restricted from P application because they are well above the crop response range. Fields with a STP of 100 lbs/acre or lower may receive P at rates either limited by crop nitrogen (N) needs or by annual P-crop removal rates, as long as the NY-PI 2.0 score is less than 100. Fields with a STP from 101 to 160 lbs/acre can receive P up to annual P-crop removal if the NY-PI 2.0 score is < 50.
- For fields with a Cornell Morgan STP up to 160 lbs/acre, the NY-PI 2.0 first assesses risk of runoff (potential for P transport from the field) based on field attributes. The result of the assessment is a "raw score" (prior to BMP selection).
- Farmers and planners can reduce the raw NY-PI 2.0 score with implementation of BMPs by selecting from options related to: (1) P application method; and (2) ground cover/timing.
- Farms with a whole-farm P balance (3-yr running average) at or below 12 lbs P/acre meet the feasible P balance for dairy farms in New York. These farms can apply manure at N-based rates on fields with a Cornell Morgan STP up to 100 lbs/acre, even if the NY-PI 2.0 assessment for these fields limits rates to P-based, as long as the selected BMPs to get to a P-based score are implemented.
- The NY-PI 2.0 reflects farmer and planner feedback on the original NY-PI and earlier versions of NY-PI 2.0. The new PI was tested and further improved with two datasets consisting of: (1) more than 33,000 agricultural fields in New York; and (2) two years of NY-PI and whole-farm P balance information from 27 New York dairy farms.
- Comparing NY-PI 1.0 and 2.0, the new PI has an increased capacity to provide additional water quality benefits by, among others, encouraging more ground cover or surface residue on fields, increasing acres where a manure application is placed below the soil surface and/or better timed with crop nutrient uptake, and incentivizing improved whole-farm P balances.
- The NY-PI 2.0 replaces any earlier P runoff estimation tool referenced by the NRCS 590 Nutrient Management Standard and used in Comprehensive Nutrient Management Plans (CNMP) and other conservation planning.

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1. Introduction

Phosphorus (P) enrichment continues to be a leading source of water quality impairment of the nation's lakes, streams, and rivers. The loss of P to surface waters accelerates freshwater eutrophication, resulting in algal blooms, low seasonal oxygen status, and reduced water quality and clarity. Phosphorus enrichment of lakes is an important statewide environmental concern, especially because surface water is the primary source of drinking water for many residents of New York. Phosphorus is contributed to surface waters from many sources throughout New York's watersheds and management to improve P use in each sector is critical to water quality. The concern over nutrient enrichment from agricultural operations led to the development of the 1999 USDA/EPA Unified National Strategy for Animal Feeding Operations (www.epa.gov/npdes/pubs/finafost.pdf). Since this release, many states have implemented mandatory nutrient management planning for concentrated animal feeding operations (CAFO), New York included (Czymmek et al., 2003). As a major land use in many watersheds in New York, agriculture also plays a key role in both long-standing and emerging watershed plans/initiatives to sustain and/or improve water quality in a changing climate (e.g., Nine-Element Watershed plans, Total Maximum Daily Load plans, and Harmful Algal Bloom plans). Many of the watershed plans reference additional agricultural best/beneficial management practices (BMPs) and the Agricultural Environmental Management Program (AEM) as continued priorities for improving water quality. The updated New York Phosphorus Index (NY-PI 2.0) was developed in support of the goals in these watersheds and others across New York where farming occurs.

The NY-PI 2.0 provides an estimate of site vulnerability risk (score) for each field based upon site characteristics and the producer's management, especially relating to manure application practices. The NY-PI 2.0 was designed to rank fields by probability of P loss to surface water. The final score ranks a field into one of four relative risk categories (low, medium, high, and very high). Changes in field-based BMPs will often be sufficient to reduce the NY-PI 2.0 score below 100. In other cases, more comprehensive changes may need to be implemented to minimize potential P losses and application of P nutrients may be restricted or eliminated.

It must be noted that a low or medium score does not imply that P loss does not occur. Poor timing of manure or fertilizer application relative to a rainfall or runoff event may still result in significant P loss from the field. For guidance to answer the question "Given the current soil and ground conditions and the weather forecast, should manure be applied to all or part of this field today?", see http://nmsp.cals.cornell.edu/publications/files/WinterSpreadingGuidelines2015.pdf.

The NY-PI 2.0 is a planning tool and is not designed to estimate the actual P loss in pounds/acre per year from a site. Actual P losses are very difficult to predict and quantify, because P nutrient sources and concentrations in the soil and runoff are highly variable and dependent on soil chemical, physical and biological characteristics, timing of nutrient applications, landscape position, and rainfall and runoff events. The NY-PI 2.0 has been designed to promote practices that reduce the risk of P loss. With data inputs that are readily available, the NY-PI 2.0 allows for rapid identification of fields that present a high risk for contributing P to lakes and streams so that users can then select management practices to reduce the risk of P loss.

Throughout this document we use the phrase "best/beneficial management practices". The phrase "best management practices" is widely used and accepted across agriculture in the United States. However, practices referenced in the NY-PI 2.0 should be considered "beneficial management practices" in the sense that all of the practices listed are expected to reduce risk, but no single practice or combination of practices will necessarily work best in all situations.

This manual describes the various factors important to P transport, provides documentation as to the selection and weighting of the site and management factors, and aids the user in calculating the NY-PI 2.0 for farm fields. The methodology for arriving at a qualitative risk-level score is presented in detail along with case scenarios, discussion, and interpretations of how the NY-PI 2.0 can be used to identify and reduce P losses to the environment.

2. Background

The United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) maintains conservation practice standards that are developed at the federal level to help agricultural operations and the environment. Individual states are expected to make local adjustments using the federal standard as a baseline. In 1999, the agency developed a policy that introduced the PI as a potential site vulnerability assessment technique when developing CNMPs. The federal template for the NRCS Nutrient Management Conservation Practice Standard (CPS 590) provided three ways to allocate P when manure is land-applied, where P applications in any combination of fertilizer and manure are based on: (1) agronomic soil test P (STP) based crop nutrient recommendations, (2) environmental soil test threshold, or (3) a site-specific risk assessment such as a PI. Generally, the PI concept developed by NRCS offers flexibility to farmers while taking into account important field-specific differences such as STP level, soil type, topography, erosion, hydrology, and other water transport-related properties.

The PI concept does not consider all fields with a similar STP level to contribute equally to P losses to the environment. For example, a field that is adjacent to a stream will be evaluated differently than a field far away from a stream, even if the two fields have similar soil type, STP levels, and planned management. The PI is a flexible means to support water quality goals while also providing scientifically sound options to farmers and advisors for land management.

The concept of a PI was first proposed at the national level by Lemunyon and Gilbert in 1993 and then by NRCS in 1994. These proposals included factors such as STP, fertilizer P application rate and method, manure P application rate and method, soil erosion, irrigation erosion, and soil runoff. However, as the PI concept evolved, other factors were proposed for inclusion. Those factors included hydrological sensitivity (such as saturated areas and flooding frequency), distance to surface water, vegetation management, grazing management, degree of soil P saturation, soil reactive aluminum, buffer width, leaching potential, and drainage class (McFarland et al., 1998; Walter et al.,1995; Bolinder et al., 1998; Jokela, 2000). Gburek et al. (1998) proposed to use a contributing distance or return period and to divide the factors in the index into two groups: (1) P-source (STP, fertilizer rate and application method, and manure P rate and application method), and (2) P-transport (soil erosion, runoff class, and contributing distance). Gburek et al. (1998) suggested summing each of the source and transport factors, and then multiplying the sum of the source factors by the sum of the transport factors. The sum of the source factors could be 1 to 1000 or more, while the sum of transport factors was scaled between 0.1 and 1.0. The original NY-PI followed this format (Czymmek et al., 2013).

The NY-PI 2.0 relies on many of the same input factors that planners have been collecting in the original NY-PI, consistent with planner feedback (Cela et al., 2016), but the format is altered. Like the original, the NY-PI 2.0 score is field specific but has a transport × BMP approach (Ketterings et al., 2017; Ros et al., 2019; 2020). This means that the relative risk of P transport is determined first based on field P transport risk indicators, and then scores can be mitigated with implementation of BMPs that reduce P transport risk.

3. General Structure and Ranking Site Vulnerability

Consistent with the original NY-PI and NRCS guidance, the NY-PI 2.0 identifies four P-loss interpretation categories: (1) low; (2) medium; (3) high; or (4) very high. Depending on the STP level of the field, these four P loss interpretation categories translate into one of three management implications for a field:

- “N-based” (manure and fertilizer application not to exceed annual nitrogen (N) needs for the crop grown based on the Cornell Nutrient Guidelines);
- “P-based” (manure and fertilizer P application not to exceed annual P removal with harvest of that crop);
- “Zero P” (no manure or fertilizer P).

Annual crop removal of P can be determined by multiplying yield potential for the predominant soil type in the field or measured yield (3-year running average) and P content. Book values for P content of field crops can be obtained from the NRCS Crop Nutrient Database (https://plants.sc.egov.usda.gov/npk/main).

If the STP of a field is less than 40 lbs/acre Cornell Morgan P (Morgan, 1941) or equivalent, the NY-PI 2.0 score must be reduced below 100 if manure is to be applied, and below 75 if rates are to be N-based (see Table 1). From 40-100 lbs/acre STP, the NY-PI 2.0 score must be below 100 if manure is to be applied, application must be P-based or lower if the score is from 50-99 and can be N-based if the score is < 50. From 101-160 lbs/acre STP, P-based management is allowed only if a field has a NY-PI 2.0 score < 50. Fields with STP levels greater than 160 lbs/acre cannot receive additional P (see section 7 for an exception for “Incidental P Application”).

Table 1: Overall interpretation and management implication of the NY-PI 2.0.

Overall interpretation (transport factor score × BMP score × 10)					
		Management implication			
P-loss risk	PI score	Soil test P (Cornell Morgan extraction in lbs/acre)[1]			
		< 40	40-100	101-160	> 160
Low	< 50	N-based	N-based	P-based	Zero P
Medium	50-74	N-based	P-based	Zero P	Zero P
High	75-99	P-based	P-based	Zero P	Zero P
Very high	≥ 100	Zero P	Zero P	Zero P	Zero P

[1]When Cornell crop guidelines call for P above the STP or rate limits in this table, P can be added to not exceed land grant guidelines as long as the NY-PI 2.0 score is 100 or lower.

The NY-PI 2.0, like the previous version, uses the Cornell Morgan soil test for STP input. While Cornell Morgan is the preferred test to develop agronomic guidelines for crop management and in the NY-PI 2.0, its use is not mandatory; STP results based on Mehlich-3 and Modified Morgan extraction methods can be used but must be converted to a Cornell Morgan P equivalent prior to use in the NY-PI 2.0. Conversion tools developed for New York agricultural soils can be found at: http://nmsp.cals.cornell.edu/. Use of a conversion step adds uncertainty to the STP value.

The NY-PI 2.0 score of a field is obtained by multiplying the sum of transport factor coefficients by the BMP coefficients of selected practices planned for the field. In many cases, if a management implication is deemed undesirable, the planner can select a different combination of BMPs to reduce risk and achieve the desired management implication.

4. Phosphorus Transport Factors

4.1 General Structure

Two types of P loss were recognized in the original NY-PI: dissolved P (DP) and particulate P (PP). Dissolved P is P in solution (i.e., in runoff or drainage water) and mostly immediately bio-available for algal growth. Particulate P is organic P or inorganic P sorbed to or incorporated in soil minerals, which must first be broken down into a dissolved P form to be bio-available to algae. Loss of DP and PP are both a concern for water quality. To better assess and manage the potential loss of each P form, elements of the DP and PP transport factors from the original NY-PI were retained in the NY-PI 2.0. Coefficients differ for these P forms in the Hydrologic Soil Group (HSG) and Vegetated Flow Distance (VFD) categories, while erosion is only a factor in the PP score (see Table 2). The sum of the transport factor coefficients multiplied by 10 determines a field's transport score. This score is determined for both DP and PP. The management implication is determined by the greater of the two scores. Both scores must be below 100 for manure or fertilizer P to be applied.

Table 2: Transport factors and coefficients included in the NY-PI 2.0. Coefficients are added and both the DP and PP sums are multiplied by 10 to obtain a field's raw PI score (without BMP reduction). The management implication is determined by the greater of the two scores and both scores must be below 100 for manure or fertilizer P to be applied.

Raw Score = Transport Factor Score × 10 (DP score = FD+ VFD_{DP}+FF+ HSG_{DP} + CF; PP score = FD+ VFD_{PP} +FF+ HSG_{PP}+E+ CF)					
Factor	Option	Coefficient	Factor	Option	Coefficient
Flow distance (FD) to stream in ft	> 500	0	Hydrologic soil group (HSG)	A	DP: 0 PP: 0
	301-500	4		B	DP: 4 PP: 1
	101-300	6		C	DP: 6 PP: 3
	≤ 100	8		D	DP: 8 PP: 5
Vegetated flow distance (VFD)[1]	<35 ft	0	Erosion (E)[2] in ton/acre	≤ 1.0	0
	≥35 ft	DP: -2 PP: -4		1.1-3.0	1
Flooding frequency (FF)	Never	0		3.1-5.0	3
	Occasionally	2		> 5	5
	Frequent	5	Concentrated flow (CF)	None/treated	0
				Untreated	4

[1] Only for fields with FD ≤500 ft. [2] Determined by the RUSLE2 A-value (yearly).

4.2 Flow Distance from Edge of Field to Stream

At the heart of the flow distance factor lies the following question: when water leaves a field, how far must it flow overland before first reaching an intermittent or perennial stream? Once water is in a conveyance that is large enough to flow for several months per year (intermittent), the opportunity for removal of sediment or nutrients is low. Therefore, the flow distance starts at the edge of the field where the majority of runoff is deemed to leave and follows the path of flow until the first contact with either an intermittent or perennial stream. Wetlands are defined as waters of the state and flow distance ends at the wetland boundary as if it were an intermittent or perennial stream. Though the NY-PI 2.0 no longer requires distinction between intermittent or perennial streams, awareness of attributes of each may help to best determine where the flow distance ends when evaluating fields:

- Perennial streams (or other perennial waterbodies) generally contain water 365 days per year, though in some dry periods smaller perennial streams may dry up for a short time.
- Intermittent streams or waterbodies contain water on a seasonal basis only during most years. Another way to consider intermittent streams is that in most years water is flowing during those parts of the year when the water table is relatively high.

Be careful when relying on topographic maps for stream determinations. Most topographic maps depict perennial streams with a solid blue line (hence the phrase "blue line" stream) and intermittent streams with a dashed blue line, although some topographic maps for NY depict all streams with a solid blue line. Also, because data for many topographic maps were collected decades ago, the maps do not reflect more recent drainage work. A field visit is necessary to confirm topographic information; existing streams that do not show up on a topographic map still need to be included in NY-PI 2.0 evaluation. Further, if there is supporting information that a historic stream has been moved, or the determination was incorrect, planners may enter the more realistic determination in the NY-PI 2.0 and keep documentation notes with the logic behind the decision in case questions arise during an inspection. Complete topographic maps for NY are available in both print and digital form through the New York State Office for Technology, Center for Geographic Information, 2nd Floor Kenmore Building, 74 N. Pearl St., Albany, NY 12207 (518-443-2042 or see the New York State GIS Clearinghouse web site at https://gis.ny.gov/).

The flow distance or distance to a watercourse is the drainage path that runoff water takes when overland flow occurs as it leaves the edge of a field and flows toward an intermittent or perennial stream. The objective for the flow distance is to represent a typical or average distance over which runoff has an opportunity to be filtered through interaction with vegetation and/or soil. For a first assessment, the flow path and distance can be approximated from topographic maps where the flow path runs perpendicular to the contour lines, but this needs to be confirmed by field inspection. There may be more than one flow path leaving a field. Often there are several flow paths heading in the same general direction. Other times, multiple flow paths may head in very different directions. Planners are expected to evaluate these situations using best professional judgment to estimate the general direction and distance of flow for the majority of the overland flow that leaves the field being evaluated (planners should consider documenting their rationale in field notes to address questions in case they arise later). For example, road ditches frequently receive some surface runoff from fields, but it may only be a small portion of the total runoff. A road ditch is considered part of the flow path only if it receives the majority of runoff from the field. If a road ditch does not receive the majority of runoff from the field, it is not necessary to apply a label. In well-drained locations, the road ditch may receive the majority of runoff, but runoff occurs infrequently due to the drainage. In cases like this, the road ditch is essentially functioning as a concentrated flow outside of the field, and it is counted as part of the flow distance until it discharges to an intermittent or perennial stream. In other cases, a road ditch may be serving a larger watershed and can be categorized as an intermittent or sometimes a perennial stream.

4.3 Vegetated Flow Distance (VFD)

Vegetation in a flow path from the edge of the field to a stream can play an important role in reducing P losses and, for this reason, should be encouraged in appropriate circumstances. A VFD is defined as an area of perennial vegetation that is at least 35 feet long with the ability to intercept flow, slow velocity and treat water leaving the field in a substantially diffuse flow regime. In some cases, a whole field lies in the downgradient flow of an upgradient field. In such a case, if the downgradient field is permanent sod or has a perennial hay crop in the rotation and provides at least 35 feet of flow distance, it may be considered a VFD when the sod is present.

The planner needs to carefully evaluate the potential effectiveness of the vegetation. To intercept, slow, and treat flows, VFDs should be sufficiently vegetated (consider 80% or more vegetated ground cover as a guide). In some cases, most of the water may be leaving through a concentrated flow channel where water is cutting or rapidly moving through the vegetation, thus avoiding any substantial vegetative treatment. In such cases, the vegetation may be ineffective and should not be given credit. Thus, if an upgradient field's flow distance is through a treated concentrated flow in the field, below, the treated concentrated flow would not be considered a VFD for the upgradient field.

While the absence of a VFD is not penalized, the presence of one results in an important transport score reduction for both DP (-2) and PP (-4), reflecting the greater efficiency in reducing PP loss than DP loss. This is only applied for fields with a flow distance ≤500 ft.

4.4 Flooding Frequency (FF)

Each soil type is assigned a flooding frequency classification. The flooding frequency data for New York soil types can be obtained on the eFOTG website of NRCS (https://efotg.sc.egov.usda.gov/#/). Choose New York and click "submit". Click Section II. Click Soil Information. Click on: Flooding Frequency and Ponding Frequency Soil Data for New York. The file is a downloadable excel file. Sometimes this information may be available on flood hazard boundary maps as well. Frequent flooding implies flooding at least once in less than 10 years. Occasional flooding is defined as once every 10 to 100 years. If a field floods once in more than 100 years, it is classified as rare/never.

Dam construction or other factors can alter the flooding frequency upstream and downstream. For example, areas below a dam may flood less often and areas immediately upstream may flood more often. Planners need to be aware of these situations and, with historical information and documented reasoning, adjust the flooding frequency accordingly. The duration of a flooding period is not considered to be very important to the overall transport of dissolved P, so there is no further adjustment or correction for the flooding duration. Although it is apparent that flooding may be an important transport phenomenon, the significance to P loss will depend greatly on the connectivity to water courses and the flow velocities that develop. Flooding may also result in nutrient entrapment and deposition under some circumstances. The risk of actual P loss with flooding frequency is difficult to quantify without a great deal more information.

4.5 Hydrologic Soil Group (HSG)

The natural soil drainage classification that was used in the original NY-PI is replaced in the NY-PI 2.0 by hydrologic soil group (HSG), assigned by county for specific soil types (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Using the HSG of the predominant soil type in a field allows the NY-PI 2.0 to address natural (surface) runoff potential of a soil, as well as a reduction in runoff potential of certain soils when adequate subsurface drainage is installed. Some soils with high permeability are assigned to HSG "D" due to a high natural water table. When adequately drained, the runoff potential of these soils is reduced, less surface runoff is expected, and they are assigned a dual HSG such as A/D, B/D or C/D, with the first letter representing the adequately drained condition. Adequate drainage is generally defined as seasonal high water-table at least 24 inches below the soil surface. When the planner determines that adequate drainage is installed in a field, the first HSG letter in the pairing can be used in the NY-PI 2.0. The HSG data for New York are updated by NRCS staff on July 1st each year. The most updated data file can be obtained from the electronic Field Office Technical Guide (eFOTG of NRCS: https://efotg.sc.egov.usda.gov/#/). Choose New York, submit. Click Section II. Click Soil Information. Click on: Hydrologic Soil Group Data for New York. The file is an excel file that is downloadable.

Some bedrock-controlled soils may have an HSG rating of D as bedrock is generally considered a limiting feature to the downward movement of water and thus these soils are considered more prone to runoff. However, the site-specific nature of the underlying bedrock may allow more water infiltration (thus less runoff potential) than what a D HSG rating indicates. Planners can input an HSG of C or B into the NY-PI 2.0 for these D soils when all the following conditions from the Web Soil Survey map unit descriptions apply:

- Soils are less than 40 inches to bedrock;
- Natural drainage is well drained or better;
- There is a soil rating of no ponding or flooding; and
- Seasonal high-water table remains below 23 inches.

In addition to documentation of the above soil properties, planners need to justify the input switch in the CNMP and confirm that normal agronomic crop management is not affected by seasonal wetness (i.e. normal planting times, average or above yields, soil is conducive to intensive crops management of crops such as corn, alfalfa, or other crops that are not impacted by wetness).

4.6 Erosion (E)

Soil erosion is given consideration as a P transport factor because it is the predominant mode of particulate P loss. The soil erosion rate for a field site must first be estimated using the Revised Universal Soil Loss Equation Version 2 (RUSLE2). RUSLE2 was developed to evaluate sheet and rill erosion for different types of agricultural cropping systems, mineral soils exposed to raindrop impact and field locations where overland flow is produced by rainfall intensities exceeding infiltration capacity. RUSLE2 is used to inventory existing erosion rates of a defined planning unit or field, guide conservation planning for alternatives to keep soil erosion within acceptable rates on the planning unit, and to estimate if sediment loss from erosion is likely to reach downslope lands, nearby streams, and/or waterbodies. RUSLE2 estimates soil loss, sediment yield, and sediment characteristics from rill and inter-rill (sheet and rill) erosion caused by rainfall and associated overland flow on a field-determined critical dominant hillslope profile within a defined field boundary. RUSLE2 uses factors that represent the effects of climatic erosivity, soil erodibility, topography, cover-management, and soil conservation practices to compute erosion. The user enters the location, soil type, slope topography, and field management (crop rotation, tillage system, etc.). The RUSLE2 program predicts and reports yearly soil loss in tons/acre. The predicted soil loss for the crop year being planned (RUSLE2 A factor) is used to select the erosion coefficient for the transport factor score in the NY-PI 2.0. The RUSLE2 software is available from http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. For updates on RUSLE2 issues in New York, visit eFOTG at https://efotg.sc.egov.usda.gov/#/, select New York from the drop-down menu, select Section I, Erosion Prediction, Water Erosion, and then RUSLE2.

4.7 Concentrated Flow (CF) Within a Field

Concentrated flows are areas where water flows over the surface for a short time after a significant rainfall event and flow is sufficient to initiate ephemeral gully or gully erosion. These areas of visually observable channelized erosion tend to recur after tillage operations and tend to deepen and widen over time within the same areas of the field. Untreated concentrated flows often leave the field and eventually connect to intermittent or perennial streams beyond the field boundary. Untreated, these areas can transition to classic gullies that cannot be farmed and take on an intermittent stream characteristic within the former field boundary. Concentrated flow areas of this magnitude within field boundaries need to be treated with a BMP(s) under the NRCS 590 Nutrient Management Standard. Common treatment options may include grassed waterways, water and sediment control basins, diversions, other structural soil conservation practices, and/or cultural practices to address the erosion. Until such areas within fields are adequately treated, they are considered an "untreated concentrated flow". If a concentrated flow is present in a field under evaluation, the transport factor coefficient in the NY-PI 2.0 for the field is "4" while if the concentrated flow is treated, the coefficient is "0" (Table 2). Some fields may have concentrated flows that end within a field or that are stable (i.e. no observable ephemeral gully or gully erosion occurring due to soil, topography, surface cover, or hydrology). In these situations, the field can receive a score of "0" for concentrated flow for NY-PI 2.0 assessment. Most concentrated flows are not specifically depicted on topographic maps (though they may show up through contour lines), but they may be marked on soil conservation plan maps. As water flow patterns, rainfall, and field features continue to change, planners and farmers need to remain vigilant for newly developing concentrated flows in fields. It is a good practice to evaluate fields for concentrated flows each time soil samples are collected.

5. Best/Beneficial Management Practice Factors

The term "Best/Beneficial management practices", as used in this manual (and perhaps more accurately referred to as "beneficial management practices"), are practices considered likely to contribute to reductions in P loss. Practices selected can vary significantly depending on many factors, including crop rotation, farm resources and goals, and are often implemented in various combinations where some individual and combinations of practices have greater potential effects than others. The NY-PI 2.0 employs two groups of practices (select one from each category) that interact to reduce the raw NY-PI score: method of P application and ground cover/timing. This is shown in Table 3.

There are five practices listed in the method section and six practices in the ground cover/timing section. A practice such as surface application of manure (method of application score of 1.0) on bare ground more than 2 weeks before spring planting (ground cover and timing score of 1.0) does not reduce the PI score for a field because this combination of method of application and timing related to ground coverage and crop growth is considered most risky in terms of P loss potential. All other options serve to reduce the overall P loss risk (and thus the PI score). For example, surface spread manure with a 100-ft setback (method of application score of 0.8) on a winter hardy cover crop (ground cover and timing score of 0.8), will reduce the raw NY-PI 2.0 score to 64% of the original score (0.8 × 0.8 = 0.64). Additional practices can be added in future years as knowledge about effectiveness of BMPs grows over time.

Table 3: Best/beneficial management practices (BMPs) of the NY-PI 2.0. Select one from each category (method and ground cover/timing) to determine the final PI score after BMPs.

Best/beneficial management practices (BMP score = method × ground cover and timing score)	
Method of applications	**Coefficient**
Surface spread without setback	1.0
Surface spread with ≥100-ft setback from the field boundary (start of the predominant flow path)[1]	0.8
Surface spread with ≥35-ft managed vegetated (sod/harvested) setback from the field boundary (start of the predominant flow path)[1]	0.7
Incorporation within 24 hours with ≥15-ft setback from down-gradient surface waters	0.7
Injection with ≥15-ft setback from down-gradient surface waters	0.5
Ground cover/timing	
Bare ground and more than 2 weeks before planting	1.0
Bare ground and within 2 weeks of planting (in spring)	0.8
Winter-hardy cover crop (fall/winter)	0.8
Whole-plant crop residue (~80% or more ground cover, e.g. corn grain)	0.7
Sod after last cutting (fall/winter)	0.6
Growing sod or row crop/planting green	0.5

[1] Only for fields with FD ≤ 500 ft. Setbacks are within field boundaries.

5.1 Method of Application

Method of application refers to the way that manure or fertilizer P is applied to fields, and includes four BMPs:

- *Setback from the field boundary (start of the predominant flow path):* The manure spreading setback creates an area within a field boundary that does not get manure, implemented along the down-gradient edge of the field. When the setback is 100 feet or more, credit may be taken in the Best/Beneficial Management Practices section of the NY-PI 2.0. This option is not available when a field has more than 500 ft of flow distance from the field edge to down-gradient surface water.
- *Vegetated setback from the field boundary (start of the predominant flow path):* This is a vegetated strip of perennial grass within the field boundary, implemented along the down-gradient edge of the field, that does not receive manure but gets harvested at least once annually. When the vegetated strip is 35 feet or more, credit may be taken in the Best/Beneficial Management Practices section of the NY-PI 2.0. This option is not available when a field has more than 500 ft of flow distance from the field edge to down-gradient surface water.
- *Incorporation:* The use of an aeration tool or other tillage implement to mix manure and

soil to improve interface between soil and manure.
- *Injection:* Direct sub-surface placement of manure into the soil leaving little or no manure on the soil surface.

Recent research on long-term no-till plots indicates that shallow disk injection of manure substantially reduced dissolved P loss and did not increase soil erosion when compared to surface application of manure on neighboring plots (Miller et al., 2019). Given the losses shown in the Miller study, no preference will be given to no-till when manure is surface applied. Producers are encouraged to find injection options, such as shallow disk injection, that can meet no-till objectives or USDA program requirements if necessary.

5.2 Ground Cover and Timing

Ground cover and timing relates to field surface residue coverage and timing relative to crop growth. Risk of loss of P is reduced when fields have ground coverage and manure is applied close to crop uptake of nutrients. Additional definitions include:

- *Winter-hardy cover crop:*
  Cereal rye, triticale, wheat, or other cereal crop that is likely to overwinter in most circumstances and have adequate biomass to reduce runoff. While oats may overwinter on some fields in some years, they are too cold-sensitive to meet this requirement.
- *Planting green:*
  The practice of planting into a living crop that is terminated around the time of planting.

6. Adaptive Management Option

Farms with a whole-farm P mass balance (3-yr running average) at or below 12 lbs P/acre meet the feasible balances for dairy farms in New York (Cela et al., 2014; 2017; Soberon et al., 2015). These farms are permitted to apply manure at N-based rates on fields with STP < 100 lbs/acre, even if the initial NY-PI 2.0 assessments for these fields limits rates to P-based, as long as the selected BMPs to get to the P-based score are implemented. This changes the interpretation table from what is shown in Table 1 to Table 4 (changes are noted in shaded, italicized text).

Table 4: Overall interpretation and management implication of the NY-PI 2.0 for farms with a 3-year running average whole farm P balance below 12 lbs P/acre.

Overall interpretation (transport factor score × BMP score × 10)					
Management implication					
P-loss risk	PI score	Soil test P (Cornell Morgan extraction in lbs/acre) [1]			
		< 40	40-100	101-160	> 160
Low	< 50	N-based	N-based	P-based	Zero P
Medium	50-74	N-based	*N-based*	Zero P	Zero P
High	75-99	*N-based*	*N-based*	Zero P	Zero P
Very high	≥ 100	Zero P	Zero P	Zero P	Zero P

[1]When Cornell crop guidelines call for P above the STP or rate limits in this table, P can be added to not exceed land grant guidelines as long as the NY-PI 2.0 score is 100 or lower.

The adaptive management option is designed to help improve whole-farm P management on a medium- to long-term time scale by rewarding good P management that occurs across all farm operations, including precision feeding (Soberon et al., 2013). For more information on whole-farm nutrient mass balance assessments and to access data input sheets and NMB software, see: http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/MassBalances.html.

7. Incidental P Application

Incidental P applications with treated effluent (P_2O_5 equivalent is less than 1 pound per thousand gallons) or a very dilute source (full collection of high flow bunk runoff) may occur to fields with STP > 160 lbs/acre with crops that are harvested given the following conditions:

- The NY-PI 2.0 score for the field is 100 or lower.
- A P drawdown plan is put in place by the farm management and AEM certified planner. This plan includes annual soil testing to show that P levels are decreasing over time.
- Applications are limited to the lesser of 20 lbs P_2O_5/acre or 25% of crop removal.
- Applied material must have attributes that provide other benefits to crop yield and therefore increase P removal, such as supplying irrigation water and/or nitrogen.
- Dairy farms should track whole-farm nutrient mass balance to ensure that P is being managed optimally across the farm (at or below 12 lbs P/acre).

Summary

The New York P Runoff Index 2.0 is a qualitative risk-based assessment tool designed to enhance nutrient management planning for agricultural operations. The goal of implementing the P Index is to *protect* clean surface waterbodies and to *reduce* P loss to impaired surface waterbodies. The NY-PI 2.0 does not quantify P loss. For this reason, it will not address the *actual* nutrient retention or losses from agricultural operations in the context of a Total Maximum Daily Load (TMDL). The purpose of NY-PI 2.0 is to assess vulnerability of agricultural fields to P loss and incentivize adoption of beneficial practices to reduce the risk of P loss from each location.

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Appendix: New York Phosphorus Runoff Index 2.0

The NY-PI 2.0 uses a transport × best/beneficial management practice (BMP) approach. A field transport score for dissolved P (DP) and particulate P (PP) is calculated based on transport factors and reduced by applying BMPs. The adjusted score and soil test P (STP) result in a management implication (the greater of the DP and PP scores; both scores must be ≤100 for P to be applied).

Overall interpretation (transport factor score × BMP score × 10)					
		Management implication[1]			
P-loss risk	PI score	Soil test P (Cornell Morgan extraction in lbs/acre)			
		< 40	40-100	101-160	> 160
Low	< 50	N-based	N-based	P-based	Zero P
Medium	50-74	N-based	P-based	Zero P	Zero P
High	75-99	P-based	P-based	Zero P	Zero P
Very high	≥ 100	Zero P	Zero P	Zero P	Zero P

Transport Score (Sum of Transport Factor Scores × 10) (DP score = FD+ VFD_{DP}+FF+ HSG_{DP} + CF; PP score = FD+ VFD_{PP} +FF+ HSG_{PP}+E+ CF)							
Factor	Option	Coefficient		Factor	Option	Coefficient	
Flow distance (FD) to stream in ft	> 500	0		Hydrologic soil group (HSG)	A	DP: 0	PP: 0
	301-500	4			B	DP: 4	PP: 1
	101-300	6			C	DP: 6	PP: 3
	≤ 100	8			D	DP: 8	PP: 5
Vegetated flow distance (VFD)[2]	<35 ft	0		Erosion (E)[3] in ton/acre	≤ 1.0	0	
	≥35 ft	DP: -2	PP: -4		1.1-3.0	1	
Flooding frequency (FF)	Never	0			3.1-5.0	3	
	Occasionally	2			> 5.0	5	
	Frequent	5		Concentrated flow (CF)	None/treated	0	
					Present	4	

Best/beneficial management practices (BMP score = method × ground cover and timing score)	
Method of applications	Coefficient
Surface spread without setback	1.0
Surface spread with ≥100-ft setback from the field boundary (start of the predominant flow path)[2]	0.8
Surface spread with ≥35-ft managed vegetated (sod/harvested) setback from the field boundary (start of the predominant flow path)[2]	0.7
Incorporation within 24 hours with ≥15-ft setback from down-gradient surface waters	0.7
Injection with ≥15-ft setback from down-gradient surface waters	0.5
Ground cover and timing	
Bare ground and more than 2 weeks before planting	1.0
Bare ground and within 2 weeks of planting (in spring)	0.8
Winter-hardy cover crop (fall/winter)	0.8
Whole-plant crop residue (~80% or more ground cover, e.g. corn grain)	0.7
Sod after last cutting (fall/winter)	0.6
Growing sod or row crop/planting green	0.5

[1] Implications: 'N-based' can receive manure based on the crop's N needs; 'P-based' restricts manure applications to annual crop P removal equivalence; 'Zero P' means no P from any source. When Cornell crop guidelines call for P above the STP or rate limits in this table, P can be added to not exceed land grant guidelines as long as the NY-PI 2.0 score is 100 or lower. Farms with a whole-farm P mass balance (3-yr running average) at or below 12 lbs P/acre can apply manure at N based rates on fields with STP ≤ 100 lbs/acre, even if the initial NY-PI 2.0 score limits rates to P-based, as long as the selected BMPs to get to a P-based score are implemented. [2]Only for fields with FD ≤ 500 ft. Setbacks are within field boundaries. [3]Determined by the RUSLE2 A-value (yearly).