The New York Phosphorus Runoff Index

User's Manual and Documentation

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Prepared for

New York State Department of Environmental Conservation
New York State Department of Agriculture and Markets

Cornell University, Ithaca, NY 14853, July 2003

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Executive Summary

- The NY Phosphorus Index (NY P Index) is a water quality tool designed to estimate the relative risk of generating phosphorus runoff from agricultural fields.

- The NY P Index replaces earlier runoff estimation tools, including Runoff Risk Levels 1-4 previously used in many Comprehensive Nutrient Management Plans (CNMP).

- The NY P Index will be implemented over the next few years on all fields in operations developing a CNMP to satisfy a Concentrated Animal Feeding Operation (CAFO) permit, Agricultural Environmental Management (AEM) requirements, or requirements by State and Federal cost share programs.

- The NY P Index does not estimate actual P loss, but rates sites for loss potential and triggers managerial changes designed to reduce both the particulate and dissolved P runoff load.

- The NY P Index score calculation is based upon information garnered from farm records, soil erosion control plans, manure and fertilization plans, and field visits.

- The NY P Index assesses current and past management practices by including soil test P and expected manure and fertilizer rate, time of year applied, and method of application (P "sources").

- The NY P Index assesses fields for the likelihood of contributing runoff to streams and waterbodies by including soil drainage class, erosion estimate, flooding frequency, presence of significant concentrated flow areas, and the distance from the edge of the field that runoff has to flow to reach a stream or ditch (P "transport").

- The NY P Index will be used to evaluate fields on a yearly basis to take into account crop rotation.

- The NY P Index score can be reduced by altering management practices: Producers and planners are encouraged to do so-many dairy and livestock farms will have some fields that require changes in management.

- Some fields will score very high on the NY P Index even with management changes; for those fields phosphorus cannot be applied.

- The NY P Index will continue to undergo changes as scientific advances are made.

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1. Introduction

Phosphorus (P) enrichment is 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 clarity. The concern over nutrient enrichment from agricultural operations led to the development of the 1999 USDA/EPA Unified National Strategy for Animal Feeding Operations (http:// www.epa.gov/npdes/pubs/finafost.pdf). Within this National Strategy all animal feeding operations (AFOs) are expected to develop and implement technically sound, economically feasible, and site-specific Comprehensive Nutrient Management Plans (CNMPs). The implementation of CNMPs should facilitate the protection of clean waterbodies, and further reduce nutrient loading to impaired waterbodies (USDA-EPA, 1998).

Since surface water is the primary source of drinking water for many public water supply systems in New York (e.g., New York City, Syracuse, etc.), P enrichment is also a major statewide environmental concern. Consequently, the New York State Department of Environmental Conservation (NYS DEC), in conjunction with the New York State Department of Agriculture and Markets (NYS DAM), is implementing the National Strategy as part of a broad environmental initiative known as the Agricultural Environmental Management (AEM) program. Livestock operations subject to meeting US-EPA Clean Water Act requirements for developing and implementing CNMPs will be required to base their nutrient management and manure application strategies on approved methodologies.

The New York Phosphorus Runoff Index has been developed to meet the NRCS NY590 nutrient management standard and to refine nutrient management planning efforts. This assessment tool results in a site vulnerability (risk) score for each field based upon site characteristics and the producer's intended crop rotation, inorganic fertilizer use and manure application practices. Although most of these factors are weighted subjectively, the NY P Index was developed so fields receiving a higher score are likely to present a higher probability of P loss through runoff. The final score ranks a field into one of four relative risk categories (low, medium, high and very high). Fields with a high or very high P Index score should be evaluated for opportunities to reduce this risk. Changes in nutrient management practices will often be sufficient to reduce risk. In other cases, sites with high scores may have to be managed to minimize P losses and further application of P nutrients may be restricted or eliminated.

It should be noted that a low or medium score does not imply that P loss does not occur. The poor timing of manure or fertilizer application relative to a rainfall or runoff event may result in substantial P losses. Nevertheless, low and medium risk rankings will allow a producer to manage livestock manure nutrient applications to the field on the basis of nitrogen (N) recommendations while more precise solutions are sought.

The NY P Index risk assessment tool does not 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 dependent on soil chemical, physical and microbial characteristics, timing of nutrient applications, landscape position, and hydrological events. A more complex and spatially based model is necessary to accurately estimate P loss from a field and the loading of P to surface waters. A spatial-based tool would further improve the identification of critical P loss sites. However, such a tool is still in the developmental stages and may be cumbersome to use even with a high-speed computer. With minimal data inputs, the NY P Index, although incapable of predicting actual P loss, can assist producers and planners in quickly identifying fields or portions of fields that present the highest risk for contributing P to receiving lakes and streams.

This manual describes the various factors important to P fate and transport, provides some documentation as to the selection and weighting of the different source and transport factors, and aids the user in calculating the NY P Index for farm fields through the use of either the NY P Index spreadsheet or Cornell Cropware. The methodology for arriving at a qualitative risk-level score is presented in detail along with some case scenarios, discussion, and interpretations of how the NY P Index can be used to identify and reduce P losses to the environment. Adjustments to the NY P Index will be made as field experience and research dictates.

2. Background

Most NRCS standards are developed at the federal level and states are expected to make local adjustments using the federal standard as a baseline. In 1999, the agency developed a policy introducing the P Index as a potential site vulnerability assessment technique when developing CNMPs. The Federal template for the NRCS Nutrient Management Standard (590) provided for three ways to allocate phosphorus when manure is land applied. The three methods were to base P applications in any combination of fertilizer and manure on: (1) agronomic soil test recommendations, (2) some pre-determined environmental soil-test threshold, or (3) a site-specific risk assessment such as a P Index. The P Index offers the greatest flexibility to producers while taking into account important field-specific differences such as soil test P level, the influences of different soil type, topography, erosion, hydrology, and other water transport properties.

The P Index concept does not consider all fields with a similar soil test P 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 the stream, even if the two fields have similar soil types, P soil test levels, and intended fertilizer and manure use. The P Index is the most flexible method offered, and thus will likely be more acceptable to producers and planners, while at the same time providing a reasonable, scientific approach to the risk for P nutrient losses.

The concept of a P Index was first proposed at the national level by Lemunyon and Gilbert in 1993 and NRCS in 1994. These proposals included factors such as soil test P, fertilizer P application rate and method, organic P application rate and method, soil erosion, irrigation erosion, and soil runoff. However, as the index concept evolved, other factors were proposed for inclusion. Those factors included hydrological sensitivity (such as saturated areas and flooding frequency), distance to waterbody, vegetation grazing management, degree of soil P saturation, soil reactive aluminum, buffer width, leaching potential, and drainage class (see Box 1). In 1998, Box 1: Factor proposed for inclusion in the P runoff index:

- Saturated areas and flooding frequency (Walter and coworkers, 1995).
- Distance to waterbody and vegetation grazing management (McFarland and coworkers, 1998).
- Degree of soil P saturation (Bolinder and coworkers, 1998).
- Soil reactive aluminum (Jokela, 2000).

Gburek and coworkers proposed using a contributing distance or return period and dividing the factors in the index into two groups: (1) P-source (soil test P, fertilizer rate and application method, and organic P rate and application method), and (2) P-transport (soil erosion, runoff class, and contributing distance). Gburek 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 the transport factors is scaled between 0.1 and 1.0.

3. General Overview of NY P Index and Ranking Site Vulnerability

The NY P Index is separated into two main components: potential sources of P ("source factors") and the potential movement of P ("transport factors"). The P source factor is determined based on soil P test values and an array of nutrient application and management factors. The value of the P source factor can be any positive number and typically reflects the pounds P/acre in the agronomic soil test plus the P_2O_5 equivalent of any nutrients applied. The range in the P source factor value will generally be from 0 to 150, although higher values are encountered.

The P transport factor is divided into separate components to arrive at a dissolved P (DP) transport factor and a particulate P (PP) transport factor. Both the dissolved P and the particulate P transport factors are scaled in the NY P Index so that the values range from 0.1 to 1.0 (a low transport capacity to a maximum transport potential). Thus, two different risk scores need to be determined for the site being evaluated.

The dissolved P Index score is calculated with Equation [1] and is primarily used to address the risk of water-soluble P loss from a field that occurs as a result of the runoff associated with saturated soil conditions ("saturation-excess"):

Dissolved P Index = P Source Factor **x** Dissolved P Transport Factor [1]

The particulate P Index score is determined with Equation [2] and reflects the risk of P loss that occurs when rainfall intensity exceeds a soils infiltration capacity causing the erosion of soil and/or manure particles ("infiltration excess"):

Particulate P Index = P Source Factor **x** Particulate P Transport Factor [2]

Table 1 shows the site vulnerability risk category associated with the score and the general nutrient management expectations for that risk category. Although both the dissolved P and the particulate P Index scores need to be assessed and reported in CNMPs, management recommendations using Table 1 are based on the higher of the two scores. When the higher score exceeds 74, further applications of P begin to be restricted (see Appendix A for a list of crop P concentrations for calculations of P removal). Note in Table 1 that when scores exceed 100, no additional P nutrient applications are allowed. If risk scores exceed 74, one should review the variables in the P Index calculation to determine which variables are adding significantly to the score. Making minor management changes, implementing appropriate conservation practices, or altering field boundaries will often result in a lower risk score and additional flexibility in nutrient applications. Of course, particular knowledge about a field and experience with farming the field may indicate a need to treat a field more strictly than the NY P Index requires. It is possible in some situations that the NY P Index may underestimate runoff risk. If common sense dictates, planners should implement more conservative practices.

Table 1: NY-PI scores, site vulnerability category, and nutrient management implications.

Ranking Value	Site Vulnerability	Management
50	Low	N based management
50 – 74	Medium	N based management with BMPs
75 – 99	High	P applications limited to crop removal*
= 100	Very High	No P_2O_5 fertilizer or manure application

* See Appendix A for crop P concentrations for P removal calculations.

4. Structure of the P Source Factor

The P source factor value that is used for the calculations in Equations [1] and [2] must first be determined with Equation [3]:

$$\text{P Source Factor} = \text{Soil Test P} + \text{Fertilizer P} + \text{Organic P} \quad [3]$$

Equation [3] illustrates that the major components of the P source consist of a combination of the soil test P level and the planned additions of inorganic and organic sources of P nutrients. Table 2 outlines how each variable in Equation [3] is determined. One can work directly through this table to determine the P Source Factor. A detailed discussion of the variables in Table 2 follows, providing additional background, justification, and demonstrating the process with mathematical formulas. These formulas are used in the NY P Index spreadsheet calculator, in the web-based NY P Index, and in Cornell Cropware, which will be discussed in subsequent sections.

Table 2: Calculation of the P Source Factor.

Step 1: Calculate the soil test contribution:

Soil Test P Contribution: Soil Test P = 1.25 **x** Morgan P (lbs/acre)*

* see section 4.1 for Mehlich-III soil test data discussion.

Step 2: Calculate the fertilizer P contribution:

Fertilizer P Contribution: Fertilizer P = (P_{fa}) **x** (P_{ft}) **x** (P_{fm})

Fertilizer P application rate (P_{fa})	Lbs P_2O_5 / acre			
Fertilizer P timing (P_{ft})	May – August 0.4	September – October 0.7	November – January 0.9	February – April 1.0
Fertilizer P method (P_{fm})	Inject or subsurface band 0.2	Broadcast and incorporate within 1-2 days 0.4; 3-5 days 0.6	Surface apply or broadcast and incorporate >5 days after application 0.8	Surface apply on frozen, snow covered or saturated ground 1.0

Step 3: Calculate the organic (manure) P contribution:

Organic P Contribution: Organic P = (P_{oa}) **x** (P_{ot}) **x** (P_{om})

Organic P application rate (P_{oa})	0.75 **x** lbs P_2O_5 (in the organic source) applied / acre			
Organic P timing (P_{ot})	May – August 0.4	September – October 0.7	November – January 0.9	February – April 1.0
Organic P method (P_{om})	Inject or subsurface band 0.2	Broadcast and incorporate within 1-2 days 0.4; 3-5 days 0.6	Surface apply or broadcast and incorporate >5 days after application 0.8	Surface apply on frozen, snow covered or saturated ground 1.0

Step 4: Calculate the total P source factor.

P Source Factor: Soil Test P + Fertilizer P + Organic P

4.1 Soil Test P

The soil test P level is an important indicator of the availability of P for crop uptake as well as the potential transport of P through runoff or leaching. Soil test P is an indicator of the net accumulation of P based on previous additions of manure and fertilizer, minus crop removal and other losses over time. High soil test P levels may occur on livestock farms as a result of the disproportionate amounts of nitrogen, phosphorus and potassium in manure relative to plant requirements and the increase in costs associated with land application as one spreads further away from the manure source.

Although different soil and land management practices influence the exact relationship, several studies have shown a strong positive correlation between soil test P levels and the dissolved P and particulate P concentrations in both surface and subsurface runoff[1]. These research results imply that a high soil test P level also means a high risk for P loss when transport occurs.

As shown in Table 2, the soil test P variable of the P source factor score is obtained with the following equation:

Soil test P = 1.25 **x** Cornell Morgan Soil Test P (lbs P/acre) [4]

The Morgan soil test utilizes a sodium acetate solution buffered at pH 4.8 and is extensively calibrated to New York's wide ranging soil chemical characteristics. Good correlations of Cornell Morgan extractable P to water extractable P were shown for some strongly acid till soils in the Catskills region by Murray (2001). Kleinman (2000) reported good correlation between Cornell Morgan soil test P and the soil P saturation level. Soil P saturation is the level at which soils are unable to be a net "consumer" of P.

Soil test P results based on Mehlich-III and modified Morgan extraction methods from other laboratories must be converted to a Cornell Nutrient Analysis Laboratory Morgan P equivalent prior to use in Equation [4]. A number of calibration equations have been developed for this purpose and it is highly advisable to consult articles on this conversion process before sending soil samples for analysis (see Ketterings and coworkers, 2001). Conversion tools developed for New York agricultural soils can be found at http://nmsp.css.cornell.edu/. For New York's CNMP permit process, only those laboratories for which conversion equations were developed and uncertainty in the interpretation of the results is known, are acceptable.

The purpose of the multiplier coefficient (1.25) in Equation [4] is to arrive at a soil test P value that is considered to be representative of an environmental threshold level. The NY P Index may begin to restrict P additions when the Morgan soil test exceeds 80 lbs P/acre. This threshold value is based upon field research conducted on acid till soils in southeastern New York within the Catskills Region of the Upper Delaware River Watershed. Soil P saturation levels were found to occur at a Morgan's soil test level ranging between 60 to 80 lbs P/acre (Kleinman et al, 1999). Although P saturation levels will likely differ depending on the soil mineralogy and soil amendments that are added over time, research findings indicate that the concentration of P in

[1] See McDowell and Sharpley (2001), Smith and coworkers (1998), Pote and coworkers (1996), and Sharpley and coworkers (1977).

runoff increases as soil test P increases. Recently, Ketterings and coworkers have initiated research in New York to determine soil P saturation for important agricultural soil groups.

4.2 Fertilizer P

Current or planned addition of fertilizer P is an important source component because fertilizer P addition may alter the soil test P level over time and it is immediately available for loss following application. The fertilizer P (FP) variable in Equation [3] is determined by:

$$FP = FP_{amount} \textbf{ x } FP_{application\ timing} \textbf{ x } FP_{application\ method} \quad [5]$$

The FP_{amount} is the amount of fertilizer expected to be applied in pounds P_2O_5/acre. Table 2 (at the beginning of section 4) shows the $FP_{application\ timing}$ and $FP_{application\ method}$ weighting coefficients used in Equation [5] to adjust the fertilizer P score.

Additions of phosphorus fertilizer increase P concentrations in runoff depending on amount applied, timing of application, and the method of application. It has been known for a long time that high rates of fertilizer P application can lead to accumulations of soil P and/or rapid losses during transport events (Neller, 1946; Romkens and Nelson, 1974; Cogger and Duxbury, 1984). P concentration in runoff can increase by as much as 300-fold above baseline values right after fertilizer application. While highly soluble fertilizers result in higher losses of dissolved P, even less soluble fertilizers such as dicalcium phosphate can increase total P losses (Sharpley and coworkers, 1978). Timing of fertilizer application relative to soil moisture and probability of runoff affect P loss (Burwell and coworkers, 1975; Haygarth and Jarvis, 1997). Phosphorus concentrations in runoff are highest in the first runoff event following an application and decrease rapidly with time. Actual runoff P concentrations vary with type and amount of fertilizer and the timing of runoff producing events after application, but the effect or opportunity for P loss generally lasts for 50 to 100 days following an application. Surface broadcast applications of fertilizer typically result in greater losses than when the fertilizer is incorporated in some manner (Kimmell and coworkers, 2001). Baker and Laflen (1982) found that the dissolved P concentration in runoff from surface broadcast applications was on average 100 times greater than in runoff where the same rate of fertilizer was incorporated to 2 inches below the soil surface.

The multipliers for the timing of application (Table 2) reflect typical soil moisture conditions and the potential risk for runoff and leaching based on the long term average seasonal water balance between precipitation and evapotranspiration. The loss of soil water to evapotranspiration during May-August dries the soil; as a result, fertilizer P applied at this time is least prone to loss from runoff and leaching events. This is also the time of year when there is active plant growth and uptake of P, so the availability for loss diminishes more quickly. The highest seasonal risk for runoff and leaching normally occurs during the period from February to April because of the accumulated soil moisture recharge and snowfall over the winter. Snowmelt and soil thawing occurs sometime during this period, resulting in high, and often saturated, soil moisture content.

The multipliers for the method of application (Table 2) indicate that the highest risk of loss occurs when fertilizer P is surface applied and not incorporated, especially at times or to soil areas highly conducive or susceptible to runoff. However, even during drier soil conditions, Van Es and coworkers (1991) found that surface applied chemicals (both sorbing and non-sorbing) are more vulnerable to transport loss when not incorporated. The P fertilizer timing and method coefficients are reduced gradually, based on length of time between surface application and incorporation (if any). Since the average time between precipitation events is about five days, Table 2 reflects a break in the multiplier when incorporation occurs before or after this amount of elapsed time. Fertilizer P that is injected and immediately mixed with the soil is assigned the lowest multiplier, along with subsurface band applications.

4.3 Organic P

As with fertilizer P, current or planned additions of organic P are also important source components. Organic P applications can quickly influence P concentrations in runoff depending on the amount applied, the timing of the application, and the method by which it is applied. The organic P (OP) variable in Equation [5] is determined by:

$$OP = 0.75 \textbf{ x } OP_{amount} \textbf{ x } OP_{application\ timing} \textbf{ x } OP_{application\ method} \qquad [6]$$

The OP_{amount} is the amount of P_2O_5 equivalent expected to be applied from manure. Where manure is applied twice on a field within a single planning year (e.g., fall and spring application), the organic P scores of both applications are calculated separately and added to obtain the final organic P score for the field.

Several studies have shown that the rate of organic P application from livestock manure is positively correlated to the P concentration in runoff and leachate (Hergert and coworkers, 1981; Mueller and coworkers, 1984; Edwards and Daniel, 1994). Some research has demonstrated that manure P transport into the soil may be greater than fertilizer P transport and this may affect runoff and leaching concentrations (Chardon and coworkers, 1997; Eghball and coworkers, 1996; Frossard and coworkers, 1989). McDowell and Sharpley (2002) reported that manure applications not only increased total P concentrations in runoff when compared with bare soil, but also increased the proportion of total P that was in the dissolved form. Their study showed total P concentration in the runoff from a bare Berks channery silt loam soil having a high soil P test level peaked at 6 ppm, 10% of which was in the dissolved P form. After manure was applied, total P concentration in the runoff peaked at 45 ppm and about half was dissolved P. Sharpley and Moyer (2000) found that 63, 84, and 91% of the total P contained in dairy, poultry, and swine slurry manures, respectively, was in the inorganic P form, which is more likely to become part of the dissolved P in runoff. In composted forms of dairy and poultry manure, 92 and 87%, respectively, of total P was in the inorganic form. Research has also shown that manure P is about 80% as effective as fertilizer P in raising soil test P levels. This is why a factor of 0.75 is applied to the organic P calculation.

Currently, the NY P Index does not distinguish among organic sources. Several studies indicate that the P in livestock manures can vary considerably in both the amount available and solubility (Box 2). Thus, additional research is needed to better evaluate and quantify P loss risks for different organic P sources. The current multiplier of 0.75 for all organic P sources may be refined in the future.

Box 2: The type and amount of P fed in the diet to dairy cows is another factor that apparently affects the amount and form of P in runoff. Dairy cows fed a high P diet (0.49%) compared to those fed a low P diet (0.31%) not only excreted more P in the manure, but the P was also more soluble. Powell and coworkers (2001) and Ebeling and coworkers (2002) land applied equal weights of manure from cows fed on either diet and measured 8-10 times more P in the runoff from the high P diet cow manure. When the manure application was adjusted so equivalent amounts of actual P were applied, the researchers still found 4-5 times more P in the runoff from the high P diet cow manure.

For simplicity, the same weighting coefficients given in Table 2, Step 2 for Fertilizer P are also applied to $OP_{\text{application timing}}$ and $OP_{\text{application method}}$ to adjust the organic P score. Geohring and coworkers (2001) found that soil wetness, timing of runoff producing events, and application method could significantly affect the loss of P from liquid dairy manure applications. In this study, more P loss occurred when manure was applied under wet soil conditions and then followed by a precipitation event. High total P concentrations ranging from 5 to 25 ppm were observed in the tile discharge during the first rain event directly after application. Concentrations were much less (about one third) when rain occurred 6 days later. Incorporation of the manure reduced the P concentrations compared to surface broadcast application and subsequently resulted in less total P loss. These results are similar to those reported in other studies (Mueller and coworkers, 1984; Harris and coworkers, 1995). As a result, the weighting coefficients for organic P are considered to follow similar general trends as those for fertilizer P in projecting the risk of P loss, but the multipliers used in the NY P Index may also need to be adjusted in the future when more research findings become available.

5. Structure of the P Transport Factor

Both dissolved and particulate P forms are a concern for water quality. To better assess and manage the potential loss of each P form, a dual transport factor calculation was developed in the NY P Index. With this methodology, it is easier to identify and evaluate what management changes are deemed necessary. For example, if the particulate P score is higher than the dissolved P score, it suggests that the P loss risk for the field is more closely associated with erosion or particulate P loss, and the nutrient loss occurs primarily through surface runoff.

There is a strong basis for separating and identifying dissolved P loss and not just basing the NY P Index on particulate or total P. First of all, the concern regarding dissolved P loss is that it is immediately bio-available for algal growth and only a few parts per million can saturate algal growth in most surface water systems (Correll, 1998). Particulate P, or the P fixed to eroded soil minerals, must first be broken down into a dissolved P form in order to be bio-available to algae; and during this process, the eroded soil is subject to settling out of the water column. Since most P is believed to be transported via erosion, many agricultural best management practice (BMP) recommendations have focused in the past on the surface water pathways and erosion (particulate P loss) controls. Unfortunately, the anticipated reductions in particulate P or total P losses have not always resulted in improved water quality (Effler and Bader, 1998; Heathwaite and coworkers, 1996). As a result, lake and reservoir managers are becoming increasingly concerned about dissolved P concentrations.

Secondly, dissolved and particulate P are lost in varying amounts depending on the processes involved (i.e, surface residue, soil organic matter, fresh manure), and the predominant transport pathway (i.e., surface versus subsurface flow). For example, Gaynor and Bissonnette (1992) found that while conservation tillage (e.g., no-till, ridge till) effectively reduced soil erosion and particulate P loss, the transport of dissolved P and total P were greater than in the conventional tillage treatment. Although surface residues can reduce soil displacement and movement resulting in a lower particulate P loss from a field, the effect may be offset because the higher organic and moisture content in the residue promotes organic mineralization of P and the dissolution of weakly bound soil P near the surface to dissolved P. Since the amount and pathway of water lost was basically similar in this study, conservation tillage only changed the form in which P was lost. The percentages of dissolved and particulate P in surface and subsurface runoff can thus vary greatly with type of nutrient addition and land cover.

The predominant transport pathway is an important consideration when determining the form of P loss. The ratio of particulate P to the total P is generally higher in surface runoff, whereas the ratio of dissolved P to total P is generally higher in subsurface water transport. Since the percentage of dissolved P in runoff from heavily fertilized croplands typically ranges between 5 to 50 percent, particulate P is generally the predominant form of P lost from tilled croplands. On the other hand, dissolved P (30-90 percent) is generally the predominant form of P lost from forests and grasslands (Gilliam and coworkers, 1999; Heckrath and coworkers, 1995). Several studies have shown that the subsurface leaching of dissolved P can occur rapidly through shallow soils (Scott and coworkers, 1998) including lateral flows through the soil until surfacing at a seep or ditch (Wood, 1998), through subsurface drains (Geohring, 1999; Ulén and Persson, 1999; Haygarth and coworkers, 1998; Sims and coworkers, 1998), or more slowly to deeper groundwater (Spruill, 2000; Lowrance and coworkers, 1985). Since total P losses from croplands typically range from 1 to 4 lbs/acre for mineral soils and from 1 to 33 lbs/acre for organic soils (Gilliam and coworkers, 1999), the long held concept that losses of P are not significant may be true from an agronomic perspective. However, water bodies are very sensitive to the dissolved P inputs and so the contribution of dissolved P to watercourses may be environmentally significant.

Eghball and Gilley (1999) concluded that particulate P loss is better correlated to erosion or soil loss, whereas dissolved P is dependent on the amount of water lost. This leads to the third point for having both a particulate and a dissolved component in the NY P Index. The soils and hydrology in the Northeastern US are unique because of the abundance of cool, wet and/or shallow soils in a highly undulating landscape. This has an effect on how runoff is generated in the landscape and moves into waterbodies. Most hydrological models and phosphorus indices assume runoff is generated when the rainfall rate exceeds the infiltration rate of the soil, a phenomenon termed *infiltration-excess overland flow*. However, Steenhuis and Muck (1988) found that soils of the Northeast, especially the shallow hillside soils maintained in grass and pasture, have infiltration rates that are rarely exceeded by the rainfall rate. Similar conclusions were drawn by Merwin and coworkers (1994) and Dunne and Black (1970). Runoff from these soils occurs because the soil becomes saturated quickly during a storm, termed *saturation-excess overland flow*. Areas prone to saturation either have a high ground water table or an impermeable layer (fragipan) or bedrock at shallow depth.

The runoff mechanism is important because it determines the relative proportions of particulate and dissolved P that are lost in the total annual runoff. Where *infiltration-excess* runoff occurs, a large amount of particulate P can be lost during a single intense storm event even though the runoff volume is a small amount of the total annual runoff. In areas prone to *saturation-excess*, both particulate and dissolved P losses are usually small during a single intense storm event because of the minimal amount of surface runoff and inter-flow produced. However, over the course of the year and especially when precipitation amounts begin to exceed evapotranspiration, the runoff and inter-flow is important and results in the formation of saturated areas at the bottom of slopes, usually in concave areas, or quickly resurfaces in seeps and ditches. It is important to note that the runoff mechanism may not always be the same because a shallow hillside soil maintained in pasture for a long time, and exhibiting *saturation-excess overland flow*, can rapidly be changed to one that exhibits *infiltration-excess overland flow* when the soil is tilled. Another reason the runoff mechanism is so important to evaluating the risk of P loss is that it governs the runoff location. The location of *infiltration-excess runoff* generation depends on soil type (i.e., infiltration rate, soil erodibility) but is independent of position in the landscape. Conversely, the position in the landscape and the soil depth (i.e., available water storage capacity) are the important parameters determining the runoff location for *saturation-excess overland flow*. As a result, each runoff mechanism generates runoff at different locations in the landscape and when P is applied in a vulnerable location, it is more readily lost. The *infiltration-excess runoff* interacts with the soil surface and results in erosion and proportionately greater losses of particulate P during usually brief, intense, hit or miss events. On the other hand, *saturation-excess overland flow* engages a greater depth of the soil profile, produces proportionately more dissolved P, and may continue to produce flow for long durations as long as precipitation exceeds evaporation. Consequently, the NY P Index utilizes both a dissolved and a particulate P Index to better identify which process is likely to produce a greater risk for P loss.

5.1 Dissolved P Transport

The dissolved P Index and dissolved P (DP) transport factor to be determined using Equation [7] require input variables that reflect the *saturation-excess overland flow* runoff and leaching concept. The value of the dissolved P transport factor for use in Equation [7] is determined by:

$$\text{DP Transport Factor} = \text{Soil drainage} + \text{Flooding frequency} + \text{Flow distance to stream} \quad [7]$$

Table 3 outlines the variables used to determine the dissolved P transport factor. It should be noted that if the sum of the soil drainage, flooding frequency, and flow distance to stream variables in Equation [7] exceed 1.0, the value of the dissolved P transport factor is set to a maximum of 1.0.

The soil drainage classification is readily determined from the soil survey and is not modified if drainage practices have been installed. The value of the soil drainage contribution to use in Equation [7] for different soil drainage classifications is given in Table 3. Although various forms of mineral bound P in the soil are more soluble under oxygen-limited conditions and plant uptake of P is also generally limited, the important implication of the drainage classification for the NY P Index is that on average, less well drained soils have higher moisture content for a longer period of time than better drained soils. This increases the risk for P transport.

Table 3: Calculation of the Dissolved P Transport Factor.

Step 1: Determine the soil drainage contribution.

Soil Drainage	Well to excessively well drained 0.1	Moderately well drained 0.3	Somewhat poorly drained 0.7	Poorly or very poorly drained 1.0

Step 2: Determine the flooding frequency contribution.

Flooding Frequency	Rare / Never > 100 years 0	Occasional 10 – 100 years 0.2	Frequent < 10 years 1.0

Step 3: Determine the flow distance contribution.

Flow Distance in feet to blue line stream (or equivalent) as depicted on a topographic map and confirmed based on field evaluation	Intermittent Stream >200 feet Perennial Stream >300 feet	Intermittent Stream 25 to 200 feet Perennial Stream 50 to 300 feet	Intermittent Stream <25 feet Perennial Stream < 50 feet
	0	Intermittent Stream 1 – (Distance–25)/175 Perennial Stream 1 – (Distance–50)/250	1.0

* Intermittent streams are generally depicted with a dashed blue line on topographic maps and perennial streams are shown with a solid blue line.

Step 4: Determine the dissolved P transport factor.

Dissolved P Transport Factor = Drainage + Flooding Frequency + Flow Distance*

* if the Dissolved P Transport Factor exceeds 1, the value is set to 1.

In general, the soil drainage classification describes the ease with which a soil drains off excess water by percolation or, essentially, the length of time a soil will remain in a wet and saturated condition. There are several different reasons why water does not percolate vertically or laterally in a soil classified as poorly drained. One reason may be the inherent nature of the soil void space, for example, the very small diameter pores in a clay soil which do not conduct water readily under saturated conditions and which have a high potential to retain water in unsaturated conditions. In certain conditions, some coarse gravelly or sandy soils are also classified as poorly drained. High precipitation to evaporation ratios, soil layers restricting downward water movement, and accumulation of water in low areas of the landscape are all interrelated factors contributing to poorly drained soils. Soils at the bottom of a slope and adjacent to water courses are often classified as poorly drained because shallow groundwater frequently moves toward streams rather than straight down into deeper layers of the earth's crust.

Precipitation falling on poorly drained soils produces more runoff than when falling on better drained soils because the poorly drained soil has limited water storage capacity. Frankenberger (1996) found that runoff correlated strongly with soil drainage class and depth to water table. On the other hand, runoff production was not well correlated with hydrologic soil group, runoff curve number, or soil slope. As a result, soil drainage class was selected as an important transport indicator in the NY P Index, and one that would most likely serve as an indicator for dissolved P transport.

Each soil type is assigned a flooding frequency classification (see Appendix B). Sometimes this information may be available on flood hazard boundary maps as well. Occasionally, the construction of dams will alter the flooding frequency: areas below the dams may flood less often and areas immediately upstream may flood more often. Planners need to be aware of these situations and, with documented reasoning, adjust the flooding frequency accordingly. The weighting coefficients to be used in Equation [7] for different flooding frequencies are given in Table 3. Since the temporal duration of a flooding event is not considered to be very important to the overall transport of dissolved P, there is no further 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. Consequently, the weighting coefficients given in Table 3 are primarily used to rapidly raise the transport score in order to flag those areas subjected to flooding conditions. For most circumstances in NY, frequent flooding will occur in conjunction with poorly drained soils or in close proximity to streams.

Before discussing flow path and distance, there are a few definitions that need to be set out. Firstly: perennial streams, intermittent streams and concentrated flows. Perennial streams (or other perennial waterbodies) 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 present only during those parts of the year when the water table is relatively high. Most concentrated flows are not specifically depicted on topographic maps (though they may show up through contour lines) but are often marked on soil conservation plan maps. These are areas where water sometimes flows for a short time after a significant rainfall. Concentrated flows that are extensive enough to require treatment from an erosion control standpoint are to be considered in the P Index. The P Index relies on topographic maps to help planners to identify streams. 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 State depict all streams with a solid blue line. Also, since some topographic surveys were completed 20-30 or more years ago, the maps do not reflect more recent drainage work. This all adds up to the need for a field inspection to confirm topographic information. Planners should not ignore a stream just because it is not depicted on the topographic map, nor is a planner bound to labeling all streams perennial in a county where the topographic maps do not differentiate between perennial and intermittent streams. Planners should document any decisions that deviate from topographic designations. Complete topographic maps for the state 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 http://www.nysgis.state.ny.us/).

The flow distance or distance to a watercourse (blue line stream or equivalent) is the drainage path that excess runoff water takes as it leaves the edge of a field and finds it way down slope to a stream. 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 and identify the general direction and distance of flow for the majority of the runoff that leaves the field or management unit being evaluated. For example, road ditches frequently receive some surface runoff from fields, but it is often only 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. Road ditches are also often challenging to label perennial, intermittent or concentrated flow. 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, 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 will classify as an intermittent stream.

Since the NY P Index separates the determination of flow distance into a distance to either perennial or intermittent type watercourses, it utilizes different distance (or setback) criteria for each in determining the transport weighting coefficient for Equation [7] (see Table 3). This separation acknowledges the different spatial position of a watercourse in the landscape whereby an intermittent stream is likely to have a smaller contributing area and the groundwater table is not always intersecting the streambed. As a result, the transport or risk of P loss via an intermittent watercourse is attenuated at times compared to the perennial counterpart.

The objective for the flow distance is to be a representative distance over which runoff or leaching water has an opportunity to interact with vegetation and/or soil. The concept of flow distance in reducing the nutrient load of water has been around for a long time, particularly with regards to the removal of sediments. Stevens (1936) observed that sediment delivery to a lake was reduced by vegetative growth above it, and Brown (1943) coined the term "vegetative screen" to describe a growth of dense vegetation through which sediment-laden water must flow prior to entering a reservoir. In attempts to quantify the effects of flow distance, Wilson (1967) determined that Bermuda grass strips of 10, 50, and 400 feet in width were necessary to maximize the removal of sand, silt, and clay particles from runoff waters, respectively. Several other studies have been done to quantify and establish relationships between flow distance and the effectiveness of P removal from both non-point and more concentrated sources (Box 3).

> Box 3: The scientific literature contains numerous studies that indicate that flow distances or buffer widths ranging anywhere from 10 to 650 feet are effective in reducing total P by 30 to 95%, depending on site-specific conditions (Bingham and coworkers, 1980; Peterjohn and Correl, 1984; Lowrance and coworkers, 1985; Cooper and Gilliam, 1986; Cooke, 1988; Dillaha and coworkers 1988 and 1989; Magette and coworkers, 1989; Parsons and coworkers, 1994; Castelle and coworkers, 1994; Daniels and Gilliam, 1996; and Uusi-Kämppä and coworkers, 2000). McDowell and Sharpley (2002) found that the concentrations of all P fractions decreased with increasing flow path length, but attributed the reduction in dissolved P to dilution rather than P sorption. They also suggested that the minimum distance between manure application sites and the stream should be at least 80 and 570 feet for low and high soil test P soils, respectively, in order to reduce P concentrations at the stream to 0.1 ppm. The primary benefit of the flow distance separation appears to be in removing particulate P. Several of the studies cited above did not report a significant reduction in the dissolved P concentration.

Although the flow distance and the weighting coefficients used in Table 3 are necessarily simplified and may not be indicative for dissolved P, these weighting coefficients generally reflect the range of buffer distance effectiveness reported in the literature. Thus, a properly determined flow distance should also reflect the general risk of total P loss. The site-specific conditions having the greatest effect on removing P in the flow path appear to be the hydrology and the soils. Studies by Heatwole and Shanholtz (1991) and Chaubey and coworkers (2000) suggest that the flow path distance is of greater importance than the land slope in the delivery of nutrients to the watercourse so, outside of the RUSLE input, slope has not been separately included in the NY P Index. The research to date also does not provide any definitive answers as to whether grass or tree vegetation in the flow path makes any difference in the amount of P removed so no further delineation of buffer type, quality, or flow distance characterization is included at this time.

5.2 Particulate P Transport

Particulate P is the phosphorus that is bound or fixed in eroding soil or manure particles. Dissolved P is also lost simultaneously in the erosion process, but dissolved P generally constitutes a lesser amount of the total P loss during erosion events. The particulate P Index and particulate P transport factor to be determined for Equation [2] require input variables that reflect the *infiltration-excess overland flow* runoff and erosion producing mechanism. The value of the particulate P transport factor for use in Equation [2] is determined by:

$$\text{PP Transport Factor} = (0.1 \times \text{Soil erosion}) + \text{Flooding frequency} + \text{Flow distance} + \text{Concentrated flow} \qquad [8]$$

Table 4: Calculating of the particulate P transport factor.

Step 1: Determine the flooding frequency contribution.

Flooding Frequency	Rare / Never > 100 years 0	Occasional 10 – 100 years 0.2	Frequent < 10 years 1.0

Step 2: Determine the flow distance contribution.

Flow Distance in feet to blue line stream (or equivalent) as depicted on a topographic map and confirmed based on field evaluation	Intermittent Stream >200 feet Perennial Stream >300 feet -------------------- 0	Intermittent Stream 25 to 200 feet Perennial Stream 50 to 300 feet ------------------------ Intermittent Stream 1 – (Distance–25)/175 Perennial Stream 1 – (Distance–50)/250	Intermittent Stream <25 feet Perennial Stream < 50 feet ------------------- 1.0

* Intermittent streams are generally depicted with a dashed blue line on topographic maps and perennial streams are shown with a solid blue line.

Step 3: Determine the soil erosion contribution.

Soil erosion (value from RUSLE model)	0.1 x RUSLE Erosion rate (tons/acre)

Step 4: Determine the concentrated flow contribution.

Is a concentrated flow present in the field?	No 0	Yes 0.2

Step 5: Determine the particulate P transport factor.

Particulate P Transport Factor = Flooding Frequency + Flow Distance + Soil Erosion + Concentrated Flow*

* if the Particulate P Transport Factor exceeds 1, the value is set to 1.

Table 4 outlines the variables used to determine the particulate P transport factor. Similar to the dissolved P transport factor calculation, if the sum of the soil erosion, flooding frequency, flow distance to stream, and concentrated flow variables in Equation [8] exceed 1, the value of the particulate P transport factor is set to 1. Thus, the dissolved and particulate P transport factors represent a percentage that cannot exceed 100% of the P source factor when calculating the final dissolved P Index and particulate P Index risk scores.

The particulate P transport factor (Equation [8]) is similar to the dissolved P transport factor (Equation [7]) in that both include the same flooding frequency and flow distance to stream factors with the same weighting coefficients (note Tables 3 and 4). Thus, the same values determined for flooding frequency and flow distance in Table 3 are also used in Table 4 to determine the particulate P transport factor.

5.3 RUSLE

Soil erosion is given consideration as a particulate P transport factor because it is the predominate mode for particulate P loss. The soil erosion rate for a field site must first be estimated with the Revised Universal Soil Loss Equation (RUSLE). RUSLE was developed to evaluate sheet and rill erosion for different types of agricultural cropping systems. RUSLE is an improved version of what was previously termed the Universal Soil Loss Equation (USLE) that was developed from field plot studies by Wischmeier and Smith (1978). Because of the complex interacting processes and data requirements of the USLE equation, Renard et al (1991), with input from many USDA-ARS and university scientists, developed RUSLE for computer applications. RUSLE is used to guide conservation planning, to inventory erosion rates over large areas, and to estimate sediment production on upland areas that might become sediment yield in watersheds. It can be used on cropland, pastureland, rangeland, disturbed forestland, construction sites, mined land, reclaimed land, landfills, military lands, and other areas where mineral soil is exposed to raindrop impact and surface overland flow produced by rainfall intensities that exceed infiltration rate. Version 2 of RUSLE estimates soil loss, sediment yield, and sediment characteristics from rill and interrill (sheet and rill) erosion caused by rainfall and its associated overland flow. RUSLE2 uses factors that represent the effects of climatic erosivity, soil erodibility, topography, cover-management, and support practices to compute erosion. The RUSLE2 database and its rules and procedures are used to describe a site-specific condition; once given a description, RUSLE2 estimates erosion. The software is available from http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. For updates on RUSLE2 issues in New York State, be sure to visit the NRCS-NY electronic Field Office Technical Guide (eFOTG) at http://www.nrcs.usda.gov/technical/efotg/ and click on the map of NY State.

In the RUSLE2 worksheet, the user enters the location, soil type, slope topography, and field management (crop rotation and tillage system). The program predicts soil loss and reports it on the screen as "Soil loss for conservation plan in ton/acre per year". To calculate the P transport factor in the NY P Index, this predicted soil loss is multiplied by 0.1 as shown in Table 4 or Equation [8]. This adjustment is included in the NY P Index to take into account that a small amount of natural soil erosion is generally unavoidable. A 0.1 multiplier of 10 tons/acre soil loss will result in a maximum value of 1. It should be noted that RUSLE2 calculates annual average soil loss in tons per acre *over a rotation*. Within a rotation, the erosion rate in any given year can be substantially higher, for example, the third year of corn in 3-year corn / 4-year hay rotation can be as large as 10 or 20 tons per acre. At the present time, it is difficult to obtain year by year erosion rates from the RUSLE2 software. Expect future versions of the P Index to consider year by year erosion rates when the estimates are readily available.

5.4 Concentrated Flow

The determination of whether or not a concentrated flow path is present in the field should be made from field inspection. The current resolution of contour lines on topographic maps may not be sufficient to determine whether a concentrated flow path is present. Concentrated flow is somewhat loosely defined, but generally refers to situations where enough runoff water has come together within the field such that it flows as a small stream during rainfall events. This concentrated flow is thus sufficient to begin forming rill and gully types of erosion. A rill or gully which cannot be removed (i.e., smoothed out) during normal tillage operations is considered a concentrated flow for P Index purposes. Table 4 shows the weighting coefficient to add into Equation [8] when concentrated flow is present.

6. Using the Excel Spreadsheet Calculator

In addition to being an integral component of Cornell Cropware (see section 8), the NY P Index exists on its own as an MS Excel® spreadsheet (Figure 1). The spreadsheet can be downloaded at: http://nmsp.css.cornell.edu/publications/pindex.asp. This spreadsheet was developed to help gain experience with the P Index on a field by field basis, independent of other factors used in developing a full nutrient management plan with Cornell Cropware. The following steps provide a guide to using the calculator. Once finished, you will have entered the data for Example 1 in Section 8.

6.1 Spreadsheet overview

The spreadsheet shown in Figure 1 consists of six columns: the left-most column for outlining the necessary inputs and the resulting outputs and the remaining five columns for entering data from individual fields. Moving from top to bottom, the spreadsheet offers the input categories used to characterize the "Source Factor", the "Dissolved P Transport Factor", and the "Particulate P Transport Factor", as explained in Sections 4 and 5. Below the inputs, the scores for the "Dissolved P Index" and the "Particulate P Index" are displayed, followed by the resulting "Management Recommendation", as outlined in Table 1 of Section 3. The "Management Recommendation" is based on the higher of the two scores (dissolved and particulate P Index scores). The remaining rows show the extent to which various management decisions and field characteristics influence the P Index score. This is useful when considering where management could be changed to reduce the final P Index score.

NYS P INDEX CALCULATOR Version 2 (May 1, 2003) The NY P Index was developed by the NY P Index Working Group. This Excel spreadsheet was developed by Q.M. Ketterings, G. Albrecht, K. Ganoe and K. Czymmek.		
SOURCE FACTOR	**Field 1**	**Field 2**
Soil test P (Morgan P in lbs P/acre)	50	50
Fertilizer P application rate (lbs P_2O_5/acre)	10	20
Fertilizer P application timing	May-August	May-August
Fertilizer P application method	Injected or subsurface banded	Injected or subsurface banded
Organic P application #1 rate (lbs P_2O_5/acre)	100	40
Organic P application #1 timing	May-August	September-October
Organic P application #1 method	Surface applied or broadcast/incorporated after 5 days	Surface applied on frozen, snow covered or saturated ground
Organic P application #2 rate (lbs P_2O_5/acre)	0	50
Organic P application #2 timing	None applied	February-April
Organic P application #2 method	None applied	Surface applied or broadcast/incorporated after 5 days
DISSOLVED P TRANSPORT FACTOR		
Soil drainage class	Moderately well drained	Moderately well drained
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	150	150
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line
PARTICULATE P TRANSPORT FACTOR		
Erosion (RUSLE in tons/acre)	2	2
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	150	150
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line
Concentrated flow?	No (not present)	Yes (present)
DISSOLVED P INDEX	51	67
	Medium	Medium
PARTICULATE P INDEX	42	79
	Low	High
Management Recommendation	**N based management with BMPs**	**P application not to exceed crop removal**
TOTAL SOURCE SCORE	87	115
Soil test P contribution	63	63
Fertilizer P contribution	1	2
Organic P contribution	24	51
TOTAL DISSOLVED TRANSPORT SCORE	0.6	0.6
Flow distance contribution	0.3	0.3
TOTAL PARTICULATE TRANSPORT SCORE	0.5	0.7
Erosion contribution	0.2	0.2
Flow distance contribution	0.3	0.3
Concentrated flow contribution	0.0	0.2

Figure 1: P Index calculator (http://nmsp.css.cornell.edu/publications/pindex.asp).

6.2 Entering data

The data entry cells are shaded orange, indicating that all other cells are populated with calculated values. With the spreadsheet open, try entering the following data for *Example 1* in Section 7.

Source Factor

Soil test P (Morgan P in lbs P/acre)	10
Fertilizer P application rate (lbs P_2O_5/acre)	20
Fertilizer P application timing	May-August
Fertilizer P application method	Injected or subsurface banded

The soil test P data must be from the Cornell Nutrient Analysis Laboratory (CNAL). If you have soil test results from Brookside Laboratories Inc., Spectrum Analytic Inc., A&L Eastern Laboratories Inc., A&L Canada Laboratories Inc. or the laboratory of the University of Vermont, you must first convert these into a Cornell Morgan P equivalent using the soil test conversion equations found on the Nutrient Management Spear Program website (http://nmsp.css.cornell.edu). The Mehlich-III soil test extracts significantly more P than the Morgan soil test. Because of this, failure to convert Mehlich-III data to a Cornell Morgan equivalent will result in a much higher P Index score.

The fertilizer P application rate can be calculated by multiplying the % P_2O_5 of the fertilizer (i.e., use the middle number of the N-$\underline{P_2O_5}$-K_2O fertilizer composition) with the pounds of fertilizer material applied per acre. For instance, applying 200 lbs/acre of 20-<u>10</u>-10 fertilizer would apply 20 lbs P_2O_5/acre (200 lbs fertilizer applied/acre x 0.10).

Continuing with the organic P applications, you will notice that the P Index allows you to characterize two applications of organic P (e.g., P in manure) per year. This allows you to more accurately describe management within the P Index. For instance, if a farm topdresses manure in the fall and then layers a second application in the spring with incorporation in 1-2 days, each application should be characterized according to its actual rate, timing, and method. In *Example 1*, a single application is characterized, so the second organic P application entries will remain empty (see *Example 4* in Section 7 for a field receiving two manure applications per year). The organic P inputs for *Example 1* begin with the organic P application rate in lbs P_2O_5/acre. To calculate this value, one must multiply the manure application rate (i.e., tons/acre or gallons/acre) with the manure analysis (i.e., lbs P_2O_5/ton or lbs P_2O_5/1000 gallons, respectively[2]). In the first scenario, the application rate is calculated as follows:

(25 tons manure applied/acre) **x** (5 lbs P_2O_5/ton) = 125 lbs P_2O_5/acre

[2] Some manure testing laboratories provide P and P_2O_5 values. Be sure to use P_2O_5 and not P if the laboratory supplies both numbers. If the testing lab supplies P only, multiply by 2.3 to convert to P_2O_5. For example: if the manure test is 1 lbs P per 1,000 gallons, this equals 1*2.3=2.3 lbs of P_2O_5 per 1,000 gallons.

NYS P INDEX CALCULATOR Version 2 (May 1, 2003) The NY P Index was developed by the NY P Index Working Group.	
Table 1: Fertilizer/Organic P application timing.	
February-April	1.0
May-August	0.4
None applied	0.0
November-January	0.9
September-October	0.7
Table 2: Fertilizer and Organic P application method.	
Broadcast + incorporated in 1-2 days	0.4
Broadcast + incorporated in 3-5 days	0.6
Injected or subsurface banded	0.2
None applied	0
Surface applied on frozen or snow covered or saturated ground	1
Surface applied or broadcast/incorporated after 5 days	0.8
Table 3: Soil Drainage Class.	
Moderately well drained	0.3
Poorly or very poorly drained	1
Somewhat poorly drained	0.7
Well/excessively well drained	0.1
Table 4: Flooding Frequency.	
Frequent (<10 years frequency)	1
Occasional (once in 10-100 years)	0.2
Rare (>100 years) or never	0
Table 5: Topomap Blue Line Stream Type.	
Intermittent - Dashed Blue Line	1
Perennial - Solid Blue Line	2
Table 6: Concentrated Flow?	
No	0
Yes	0.2

Figure 2: NY P Index Lookup Table.

Using the spreadsheet calculator, enter the following inputs for organic P application:

Source Factor (Continued)

Organic P application #1 rate (lbs P_2O_5/acre)	125
Organic P application #1 timing	February-April
Organic P application #1 method	Surface applied on frozen, snow covered or saturated ground
Organic P application #2 rate (lbs P_2O_5/acre)	0
Organic P application #2 timing	None applied
Organic P application #2 method	None applied

Continue by entering the inputs for the transport factors. You will notice that the flooding frequency, flow distance, and stream type for the particulate P transport factor are carried over from the inputs for the dissolved P transport factors to reduce data entry effort.

Dissolved P Transport Factor

Soil drainage class	Somewhat poorly drained
Flooding frequency	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	0
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line

Particulate P Transport Factor

Erosion (RUSLE in tons/acre)	2
Flooding frequency	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	0
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line
Concentrated flow?	No (not present)

Now that you have a feel for entering data and maneuvering around the spreadsheet, continue to Section 7 to gain experience with the impact that management changes can have on P Index scores across a number of scenarios relevant to New York State.

7. Examples and Management Alternatives

Many of the inputs needed to derive the NY P Index for a field can be obtained in the office either from published documents such as soil surveys and topographic maps or from farm records and plans (see Box 6). Runoff flow direction can be estimated in the office using topographic maps and confirmed in the field. Topographic maps portray intermittent and perennial "blue line" streams, again requiring field confirmation. Soil conservation plans show planned or existing water management structures that may be more or less obvious in the field depending on the time of year visited. Each of these resources can provide important clues as to what can be expected in the field.

Although reviewing soil maps, topographic maps, and soil conservation plans can provide an initial assessment of the inputs needed, an accurate estimate of the NY P Index cannot be obtained from the office only. Field verification of map-derived inputs is needed. Such verification can be done when visiting fields to collect soil samples or RUSLE data.

The most challenging aspect of the NY P Index relates to the estimation of flow path and distance. Flow path is the direction that surface runoff water takes upon exiting the downslope area(s) of the field. Since water may flow out of a field in 2 or 3 distinctly different directions, planners must identify the general area where the largest portion of the surface runoff water leaves the field. Once the predominant flow direction is identified, the evaluation is completed by measuring the length of the path the water must travel to reach the first intermittent or perennial waterbody it comes to; this is called the flow distance. The flow distance may be estimated by pacing, using a viewfinder, or other reasonably accurate methods. Scaling from the office needs to be confirmed by a field measurement. If runoff is discharged from two areas of similar size, the area more sensitive from a water quality standpoint should be evaluated. Because the flow path, concentrated flow, and intermittent stream concepts are difficult to assess in practice, serious P Index users are strongly encouraged to attend a P Index field walk session. A session can be arranged by contacting Karl Czymmek, senior extension associate with ProDairy, at kjc12@cornell.edu.

Box 6: NY P Index Checklist:

Office related:

- Soil test for each field or management unit (less than 3 years old).
- Expected fertilizer P_2O_5 rate, timing of application and method of application.
- Expected manure P_2O_5 rate, timing of application and method of application.
- RUSLE "A" factor (actual erosion estimate).
- Drainage class and flooding frequency for the predominant soil type from the Soil Survey.
- Topographic maps for stream evaluation and general flow path / direction.

Field related:

- Collect soil tests and/or RUSLE data if not available
- Identify presence or absence of concentrated flows within the field
- Identify flow path and distance from edge of field to first intermittent or perennial stream
- This field visit can also be used to identify hydrologically sensitive areas, proximate well locations and any manure spreading setback requirements necessary to meet the basic elements of the NRCS nutrient management standard

The examples in this section look at fields in various *representative* landscapes around New York State. *Unusual* situations will be encountered from time to time. For example, some fields will have a soil test P level so high that no changes in management will reduce the score enough to accommodate additional manure spreading. In those situations, a crop response to addition of P is highly unlikely and additional manure and/or fertilizer P applications are very difficult to justify. In other situations, contour or other ditches may discharge into woodland and the water disperses without an obvious connection with a natural stream. In those situations, because of the dispersion, a maximum flow distance (>300 feet) can be recorded for the field being evaluated.

Planners must keep in mind that changes made to practices applied to individual fields may have significant additive impact across the farm. For example, if a farm has limited resources available for storing and incorporating manure, the planner cannot reasonably expect that substantial quantities of spring applied manure on corn ground will be incorporated.

Example 1:

Scenario 1 (Photo 1) represents relatively flat, generally less well drained landscapes that were formed beneath shallow lakes and largely consist of relatively fine sediments with silty clay loam or clay loam textures. Natural streams and numerous man-made ditches bisect the landscape and many agricultural fields are intensively tile drained to achieve optimum crop production. Erosion is generally low but there can be considerable runoff during peak periods, especially early in the spring following snow melt. This type of landscape can be found in the St Lawrence, Champlain, Hudson, Erie and Ontario Basins.

This example consists of a somewhat poorly drained Rhinebeck soil that is in a corn silage/intensive grass rotation. While there is often some ponded water in spring, the field rarely floods and erosion is estimated at 2 tons per acre average across the rotation. The down-slope edge of the field is bordered by a drainage ditch that runs several months during the year and most runoff water from the field drains toward this ditch. The soil is classified as high in phosphorus with a Cornell soil test of 10 lbs Morgan extractable P/acre. The producer intends to apply 20 lbs P_2O_5 as banded starter fertilizer in May in addition to a surface application of 125 lbs of P_2O_5 from manure on frozen soil during February.


Photo 1: St Lawrence River Valley landscape.

The NY P Index spreadsheet calculates both the dissolved and particulate P Index scores as 108 (Figure 3). This classifies the field as "Very High" for its risk of P runoff. Since both scores must be below 100 in order for the field to receive manure, some changes in intended practices must be made.

The quickest way to identify what factors are the greatest contributors to P runoff risk is to look at the contributions of the source and the transport functions listed underneath the P Index scores and management recommendation in the spreadsheet. For this particular example, we calculated a total source score of 108. The soil test P contribution was 13, the fertilizer P contribution was 2 and the organic P contribution was 94. It is obvious from these scores that the greatest reductions in P Index score are expected with changes in manure management. What are the options?

The initial scenario was to apply 125 lbs P_2O_5 from manure during February on, in all likelihood, frozen soil. From a runoff standpoint, February through April is considered the most risky time of the year for manure application, so one option is to change the time of application. By shifting the time of spreading to November, the scores for both dissolved and particulate P drop from 108 (very high) to 82 (high). The score is reduced for two reasons: (1) November *timing* of manure application poses a somewhat lower risk; and (2) the soil is less likely to be frozen, so the broadcast *method* also poses a somewhat lower runoff risk. However, a score of 82 still means that P applications are limited to P crop removal (Figure 3). The corn silage yield potential of a tile drained Rhinebeck soil is around 20 tons/acre (35% dry matter) and this crop is expected to remove about 86 lbs of P_2O_5 (see appendix A for crop removal estimates). Thus, with a score of 82, the manure application needs to be reduced to no more than 86 lbs of P_2O_5. However, more can be done to reduce the P Index of this site without having to reduce the manure application.

NYS P INDEX CALCULATOR Version 2 (May 1, 2003) The NY P Index was developed by the NY P Index Working Group.			
SOURCE FACTOR	Example 1	Alternative 1a	Alternative 1b
Soil test P (Morgan P in lbs P/acre)	10	10	10
Fertilizer P application rate (lbs P_2O_5/acre)	20	20	20
Fertilizer P application timing	May-August	May-August	May-August
Fertilizer P application method	Injected or subsurface banded	Injected or subsurface banded	Injected or subsurface banded
Organic P application #1 rate (lbs P_2O_5/acre)	125	125	125
Organic P application #1 timing	February-April	November-January	November-January
Organic P application #1 method	Surface applied on frozen, snow covered or saturated ground	Surface applied or broadcast/incorporated after 5 days	Surface applied or broadcast/incorporated after 5 days
Organic P application #2 rate (lbs P_2O_5/acre)	0	0	0
Organic P application #2 timing	None applied	None applied	None applied
Organic P application #2 method	None applied	None applied	None applied
DISSOLVED P TRANSPORT FACTOR			
Soil drainage class	Somewhat poorly drained	Somewhat poorly drained	Somewhat poorly drained
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	0	0	175
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line
PARTICULATE P TRANSPORT FACTOR			
Erosion (RUSLE in tons/acre)	2	2	2
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	0	0	175
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line
Concentrated flow?	No (not present)	No (not present)	No (not present)
DISSOLVED P INDEX	108	82	69
	Very High	High	Medium
PARTICULATE P INDEX	108	82	28
	Very High	High	Low
Management Recommendation	No fertilizer P_2O_5 or manure applications	P application not to exceed crop removal	N based management with BMPs
TOTAL SOURCE SCORE	108	82	82
Soil test P contribution	13	13	13
Fertilizer P contribution	2	2	2
Organic P contribution	94	68	68
TOTAL DISSOLVED TRANSPORT SCORE	1.0	1.0	0.8
Flow distance contribution	1.0	1.0	0.1
TOTAL PARTICULATE TRANSPORT SCORE	1.0	1.0	0.3
Erosion contribution	0.2	0.2	0.2
Flow distance contribution	1.0	1.0	0.1
Concentrated flow contribution	0.0	0.0	0.0

Figure 3: Original scenario for a somewhat poorly drained field in Northern NY and acceptable alternatives including a change in time of application of manure from February-April to November (Alternative 1a) and establishing a spreading setback of 175 feet (Alternative 1b).

Figure 3 shows that the dissolved and the particulate transport factors are both 1.0. Looking at the flow distance contribution, it becomes obvious that under the proposed scenarios flow distance alone causes maximum transport risk. Although reducing erosion and eliminating concentrated flows in the field are always good practices, those practices will not reduce the risk for P loss from this field nearly as much as increasing the flow distance by implementing a manure spreading setback. If a manure spreading setback of 175 feet from the edge of the ditch is established, the scores for this field drop from 82 to 69 (Medium) for the dissolved P Index and to 28 (Low) for the particulate P Index (Figure 3). Thus, a 175 foot setback would allow for a manure application rate of 125 lbs/acre P_2O_5 in November if the soil is not expected to be frozen. Of course, reducing the manure rate to no more than crop removal is always recommended for fields that are classified as high or very high in soil test P.

Example 2:

Our second example represents the rolling to hilly, generally well-drained terrain of Central New York State found in the Finger Lakes Region (Photo 2), along the NYS Thruway and through the Mohawk River Valley. The loam and silt loam soils are derived from glacial till and are medium to high in lime content. Fast-moving streams have formed deep cuts in some parts of the landscape. Ditches remove excess water mainly in spring and fall and are found in the low areas for the purpose of draining small pockets of less well-drained soil; tile patterns are usually random. Concentrated flows are evident, especially in steeper parts of the landscape.

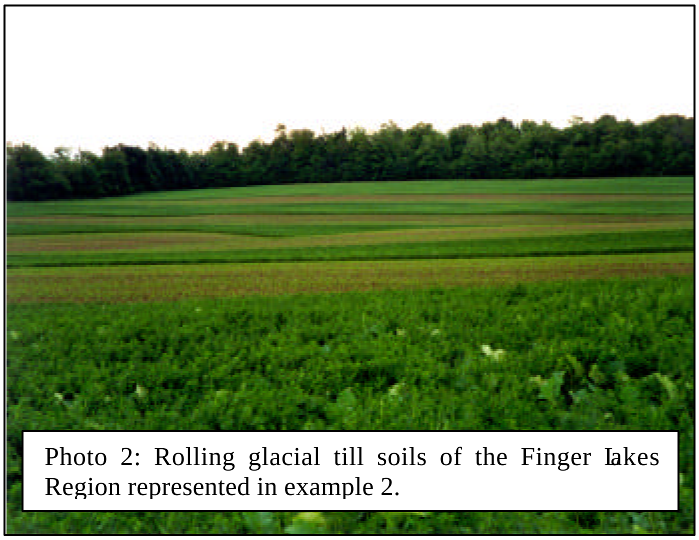


Photo 2: Rolling glacial till soils of the Finger Lakes Region represented in example 2.

For this example consider a well-drained Honeoye soil in a corn silage/alfalfa grass hay rotation. The Cornell Morgan soil test of 43 lbs P/acre rates as Very High based upon Cornell Guidelines. The producer plans to apply 10 lbs P_2O_5/acre in the banded starter fertilizer blend in May. He expects to surface apply 150 lbs P_2O_5/acre as manure in late winter, a rate designed to meet the N requirements of the subsequent corn crop. The silage yield potential of a Honeoye soil is estimated at 23 tons/acre (35% dry matter) which corresponds with a removal rate of approximately 100 lbs of P_2O_5. The majority of runoff flows toward a shallow, vegetated road ditch that runs 75 feet before reaching an intermittent stream. The field does not flood, there are no concentrated flow areas that require treatment and RUSLE is estimated at 3 tons per acre. Under these conditions, the field scores 136 for the dissolved P Index and 167 for the particulate P Index. Both indices are very high, indicating that management changes are required if manure is to be applied.

One possibility is to implement a manure spreading setback of 100 feet along the road ditch, which receives most of the runoff. This reduces the dissolved P score to 41 (Low) and the particulate P score to 74 (Medium), allowing for winter spreading at the intended rate of 150 lbs P_2O_5/acre.

NYS P INDEX CALCULATOR Version 2 (May 1, 2003) The NY P Index was developed by the NY P Index Working Group.			
SOURCE FACTOR	Example 2	Alternative 2a	Alternative 2b
Soil test P (Morgan P in lbs P/acre)	43	43	43
Fertilizer P application rate (lbs P_2O_5/acre)	10	10	10
Fertilizer P application timing	May-August	May-August	May-August
Fertilizer P application method	Injected or subsurface banded	Injected or subsurface banded	Injected or subsurface banded
Organic P application #1 rate (lbs P_2O_5/acre)	150	150	150
Organic P application #1 timing	February-April	February-April	May-August
Organic P application #1 method	Surface applied on frozen, snow covered or saturated ground	Surface applied on frozen, snow covered or saturated ground	Injected or subsurface banded
Organic P application #2 rate (lbs P_2O_5/acre)	0	0	0
Organic P application #2 timing	None applied	None applied	None applied
Organic P application #2 method	None applied	None applied	None applied
DISSOLVED P TRANSPORT FACTOR			
Soil drainage class	Well/excessively well drained	Well/excessively well drained	Well/excessively well drained
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	75	175	75
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line
PARTICULATE P TRANSPORT FACTOR			
Erosion (RUSLE in tons/acre)	3	3	3
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	75	175	75
Stream type (blue line on topomap or equivalent)	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line	Intermittent - Dashed Blue Line
Concentrated flow?	No (not present)	No (not present)	No (not present)
DISSOLVED P INDEX	136	41	52
	Very High	Low	Medium
PARTICULATE P INDEX	167	74	64
	Very High	Medium	Medium
Management Recommendation	No fertilizer P_2O_5 or manure applications	N based management with BMPs	N based management with BMPs
TOTAL SOURCE SCORE	167	167	64
Soil test P contribution	54	54	54
Fertilizer P contribution	1	1	1
Organic P contribution	113	113	9
TOTAL DISSOLVED TRANSPORT SCORE	0.8	0.2	0.8
Flow distance contribution	0.7	0.1	0.7
TOTAL PARTICULATE TRANSPORT SCORE	1.0	0.4	1.0
Erosion contribution	0.3	0.3	0.3
Flow distance contribution	0.7	0.1	0.7
Concentrated flow contribution	0.0	0.0	0.0

Figure 4: P Index scores for *Example 2*, a rolling to hilly, well-drained terrain of Central New York. A drastic reduction in P Index is obtained by implementing a spreading setback of 100 feet from the edge of the field (Alternative 2a). A similar reduction can be obtained by injecting manure in May instead of a surface application in March (Alternative 2b).

A similar result can be achieved (without a manure spreading setback) by changing the time of application to spring (May) and injecting the manure. In this case the scores become 52 and 64 (both Medium) for the dissolved and the particulate P Index, respectively, which again allows for management according to nitrogen needs of the crop. However, since approximately 65% of the inorganic (NH_4-N) is now expected to be available to the corn crop due to incorporation in the spring, the total application rate of manure will need to be reduced to avoid over-application (and hence potential leaching) of nitrogen.

Another option for reducing the P Index scores is to frost-till in late winter or early spring, if conditions are appropriate. If manure is applied at the rate of 100 lbs P_2O_5/acre by frost injection between early February and the end of April, no setback is necessary as the P Index scores become 57 and 70 for the dissolved and the particulate P Index, respectively.

Field strips, an additional option, present a simple mechanism for instituting manure spreading setbacks. As the strips proceed up the hill, the width of each strip typically increases the flow distance, reducing the P Index score correspondingly. Planners may elect to change manure timing and method of application on one or two strips with the shortest flow distance to water while being less restrictive with the upper strips.

Example 3:

The third scenario represents the acidic, upland glacial till soils found in much of the Southern Tier and portions of Eastern New York (Photo 3). The upland areas in this landscape are typically bisected by fast flowing streams that have formed gullies. Soils can be well or moderately well drained silt loam textures, but considerable portions of the landscape consist of somewhat poorly drained silt loam soils with fragipans. Contour diversion ditches are often necessary to manage water as well as soil erosion, and tile drainage is usually randomly patterned. Concentrated flow areas exist throughout the landscape and many have been treated with grass waterways.

In this example, the field is predominantly moderately well-drained Mardin soil in a corn silage/alfalfa grass rotation. The soil test is 20 lbs P/acre (Cornell Morgan extraction) and the producer plans to band 20 lbs P_2O_5/acre with starter fertilizer and to surface apply 100 lbs P_2O_5/acre as manure during the February-April period. The field is not prone to flooding and the soil erosion rate is estimated at 3 tons/acre. Concentrated flows are present and runoff predominantly flows to a shallow diversion ditch that travels 25 feet from the edge of the field to a seasonal stream. Under this set of conditions, the field scores 102 (very high) on both the dissolved and particulate P indices (Figure 5).

Photo 3: Upland areas of the Southern Tier and Eastern New York represented in *Example 3*.

NYS P INDEX CALCULATOR Version 2 (May 1, 2003) The NY P Index was developed by the NY P Index Working Group.			
SOURCE FACTOR	**Example 3**	**Alternative 3a**	**Alternative 3b**
Soil test P (Morgan P in lbs P/acre)	20	20	20
Fertilizer P application rate (lbs P_2O_5/acre)	20	20	20
Fertilizer P application timing	May-August	May-August	May-August
Fertilizer P application method	Injected or subsurface banded	Injected or subsurface banded	Injected or subsurface banded
Organic P application #1 rate (lbs P_2O_5/acre)	100	40	40
Organic P application #1 timing	February-April	February-April	February-April
Organic P application #1 method	Surface applied on frozen, snow covered or saturated ground	Surface applied on frozen, snow covered or saturated ground	Surface applied on frozen, snow covered or saturated ground
Organic P application #2 rate (lbs P_2O_5/acre)	0	60	60
Organic P application #2 timing	None applied	September-October	September-October
Organic P application #2 method	None applied	Surface applied or broadcast/incorporated after 5 days	Surface applied or broadcast/incorporated after 5 days
DISSOLVED P TRANSPORT FACTOR			
Soil drainage class	Moderately well drained	Moderately well drained	Moderately well drained
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	25	25	200
Stream type (blue line on topomap or equivalent)	Perennial - Solid Blue Line	Perennial - Solid Blue Line	Perennial - Solid Blue Line
PARTICULATE P TRANSPORT FACTOR			
Erosion (RUSLE in tons/acre)	3	3	3
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	25	25	200
Stream type (blue line on topomap or equivalent)	Perennial - Solid Blue Line	Perennial - Solid Blue Line	Perennial - Solid Blue Line
Concentrated flow?	Yes (present)	Yes (present)	Yes (present)
DISSOLVED P INDEX	102	82	57
	Very High	High	Medium
PARTICULATE P INDEX	102	82	74
	Very High	High	Medium
Management Recommendation	**No fertilizer P_2O_5 or manure applications**	**P application not to exceed crop removal**	**N based management with BMPs**
TOTAL SOURCE SCORE	102	82	82
Soil test P contribution	25	25	25
Fertilizer P contribution	2	2	2
Organic P contribution	75	55	55
TOTAL DISSOLVED TRANSPORT SCORE	1.0	1.0	0.7
Flow distance contribution	1.0	1.0	0.4
TOTAL PARTICULATE TRANSPORT SCORE	1.0	1.0	0.9
Erosion contribution	0.3	0.3	0.3
Flow distance contribution	1.0	1.0	0.4
Concentrated flow contribution	0.2	0.2	0.2

Figure 5: P indices for *Example 3*. A drastic reduction in P Index is obtained with a shift in timing of application from spreading on frozen soil in February-April to surface application in September-October (Alternative 3a). A similar reduction can be obtained with a total manure P reduction to 85 lbs P_2O_5/acre and a setback of 175 feet (Alternative 3b).

Assuming this operation has other fields that can receive winter-spread manure, shifting 60% of the planned application to an early fall period (September/October) is enough to reduce both P Index scores to 82 (High). Scores of 57 and 74 (Medium) for the dissolved and particulate P indices, respectively, can be achieved by also implementing a spreading setback from the edge of the field of 175 feet (making the total flow distance 200 feet).

Example 4:

This example represents the glacial outwash and alluvial soils characteristic of Southern Tier valleys, the Cortland Valley being a prime example (Photo 4). These soils formed from coarse sediments, gravel and often cobblestone as glacial melt-water dispersed, or from somewhat less coarse deposits of river-carried sediment. Either way, this landscape tends to be well- to excessively well-drained. Some of the alluvial soils continue to be prone to flooding. Tile drainage is rarely needed and in many cases road ditches are shallow or non-existent because the soil is so well drained.

The field in this example is bordered by a perennial stream. It is somewhat undulating and consists of the well-drained Palmyra soil. As is often the case in this landscape, the undulations generally run parallel to the stream rather than directly to it. The Cornell Morgan soil test is 64 lbs P/acre and the producer plans to use a starter fertilizer consisting of nitrogen only. Manure will be spread daily throughout the winter, approximately 60 lbs of P_2O_5 equivalent from December through January, and an additional 80 lbs P_2O_5 equivalent from February through April. This field does not flood, does not have concentrated flows significant enough to treat, and RUSLE erosion is 3 tons/acre. Because the undulations mainly flow to the next field down slope before reaching the perennial stream, the flow distance is 225 feet. Under these conditions, the New York P Index scores are 69 (Medium) for the dissolved P Index and 103 (Very High) for the particulate P Index. Once again, the particulate P Index must be reduced if the field is to receive manure.

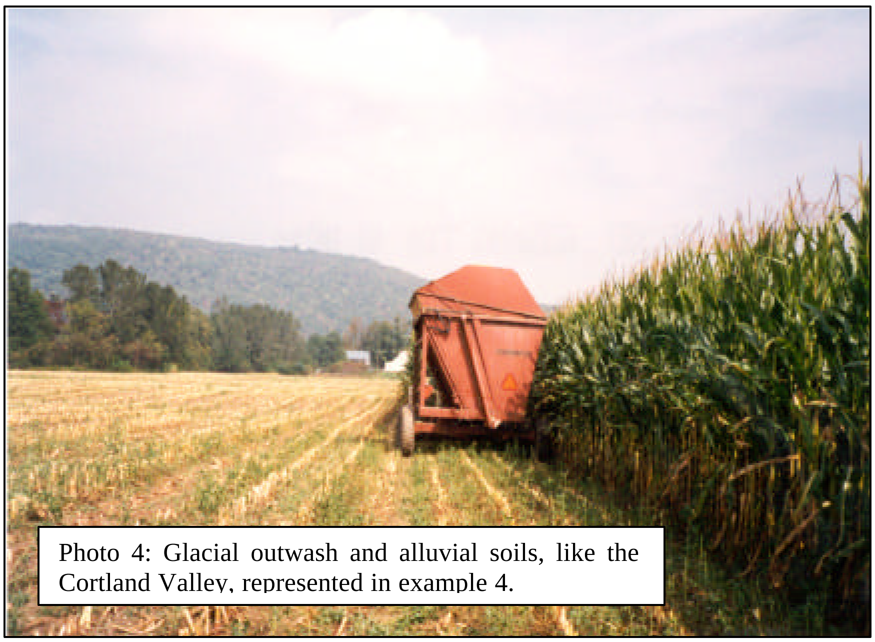


Photo 4: Glacial outwash and alluvial soils, like the Cortland Valley, represented in example 4.

One way to do this is to shift manure intended for February-April into early May and incorporate within 1-2 days. This reduces the dissolved P Index to 49 (Low) and the particulate P Index to 73 (Medium). Many farms have short-term storage and can save up enough manure to cover a field or two during the spring planting season.

NYS P INDEX CALCULATOR Version 2 (May 1, 2003) The NY P Index was developed by the NY P Index Working Group.		
SOURCE FACTOR	Example 4	Alternative 4a
Soil test P (Morgan P in lbs P/acre)	64	64
Fertilizer P application rate (lbs P_2O_5/acre)	0	0
Fertilizer P application timing	None applied	None applied
Fertilizer P application method	None applied	None applied
Organic P application #1 rate (lbs P_2O_5/acre)	60	60
Organic P application #1 timing	November-January	November-January
Organic P application #1 method	Surface applied or broadcast/incorporated after 5 days	Surface applied or broadcast/incorporated after 5 days
Organic P application #2 rate (lbs P_2O_5/acre)	80	80
Organic P application #2 timing	February-April	May-August
Organic P application #2 method	Surface applied on frozen or snow covered or saturated ground	Broadcast + incorporated in 1-2 days
DISSOLVED P TRANSPORT FACTOR		
Soil drainage class	Well/excessively well drained	Well/excessively well drained
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	225	225
Stream type (blue line on topomap or equivalent)	Perennial - Solid Blue Line	Perennial - Solid Blue Line
PARTICULATE P TRANSPORT FACTOR		
Erosion (RUSLE in tons/acre)	3	3
Flooding frequency	Rare (>100 years) or never	Rare (>100 years) or never
Flow distance to blue line or equivalent (feet)	225	225
Stream type (blue line on topomap or equivalent)	Perennial - Solid Blue Line	Perennial - Solid Blue Line
Concentrated flow?	No (not present)	No (not present)
DISSOLVED P INDEX	69	49
	Medium	Low
PARTICULATE P INDEX	103	73
	Very High	Medium
Management Recommendation	No fertilizer P_2O_5 or manure applications	N based management with BMPs
TOTAL SOURCE SCORE	172	122
Soil test P contribution	80	80
Fertilizer P contribution	0	0
Organic P contribution	92	42
TOTAL DISSOLVED TRANSPORT SCORE	0.4	0.4
Flow distance contribution	0.3	0.3
TOTAL PARTICULATE TRANSPORT SCORE	0.6	0.6
Erosion contribution	0.3	0.3
Flow distance contribution	0.3	0.3
Concentrated flow contribution	0.0	0.0

Figure 6: New York P Index for *Example 4*, glacial outwash and alluvial soils and landscapes characteristic of Southern Tier valleys. One way to reduce the P Index scores is to shift manure intended for February-April into early May and incorporate within 1-2 days (Alternative 4a).

8. Using Cornell Cropware to Calculate the NY P Index

Cornell Cropware[3] is a software tool for developing nutrient management plans consistent with the Natural Resources Conservation Service Nutrient Management Standard (NRCS-NY 590). In doing so, it integrates the NY P Index with the Nitrate Leaching Index, soil test conversion equations, Cornell crop nutrient guidelines, and on-farm logistics of manure, fertilizer, and crop management. This integration of tools in Cropware, allows users to consider all of a farm's fields and all of its manure sources when deciding which fields are best suited to receive manure and/or fertilizer for healthy crops and a clean environment. The steps for developing a nutrient management plan with Cropware are outlined in Figure 7, below.

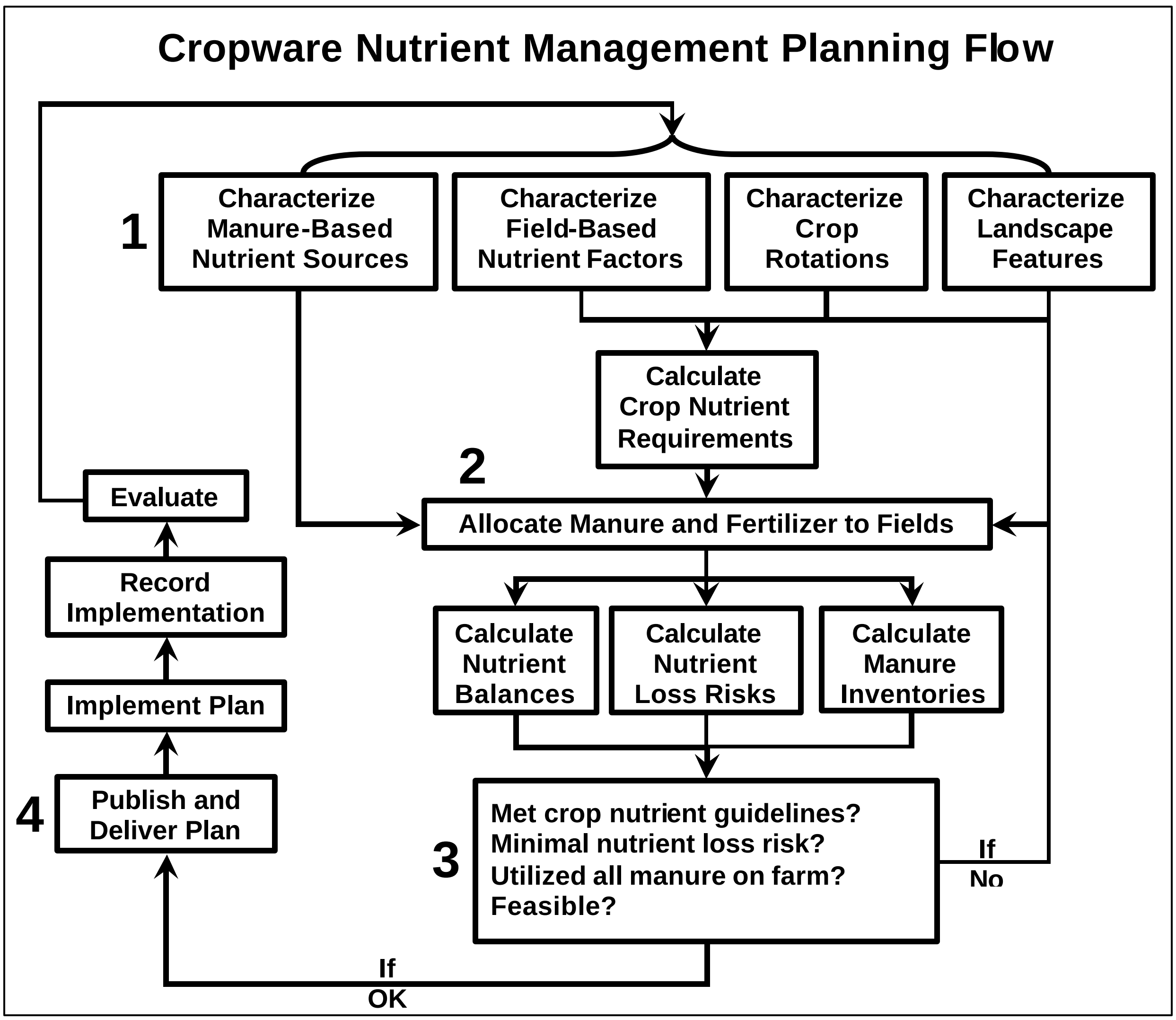


Figure 7: Diagram of the basic process of nutrient management planning with Cropware.

[3] Cornell Cropware can be downloaded from the Nutrient Management Spear Program website (http://nmsp.css.cornell.edu/)

Considering the flow from the top, the planner must first characterize the manure sources and fields (Step 1). Based on this information, Cropware will calculate crop nutrient requirements for the plan year. Next, the planner will consider the crop nutrient requirements, NY P Index, N Leaching Index, manure inventories, and other on-farm logistics to initially allocate manure and fertilizer across the fields (Step 2). Cropware will calculate nutrient balances and P Index scores per field, as well as manure inventories for all sources. Based on such calculations, the planner may need to re-allocate manure and/or fertilizer to fields to better satisfy the questions posed in Step 3. Specific to the P Index, this step can be used to reduce the P Index scores by changing management relative to the first run-through as discussed in section 7. Such management changes could include:

- Modifications in the timing, rate, and/or method of manure and fertilizer applications.
- Increases in flow distance through the use of no spreading buffers.
- Reductions in the RUSLE predicted soil loss through changes in crop rotation management.
- Adoption of best management practices to address concentrated flows.

Once satisfied with the revisions, the planner is set to create reports and deliver the plan to their client for review and implementation (Step 4).

Let's step through this process in Cropware, focusing on the P Index. To gain a better understanding of the full, comprehensive use of Cropware, consult the Help section of Cropware.

8.1 Characterizing the farm

Before planning manure and fertilizer applications according to the NY P Index, N Leaching Index, crop nutrient guidelines, and so on, the planner must characterize the manure sources and the fields (Step 1).

Manure:

Within Cropware, the Manure screen (Figure 8) is used to define the quantity of manure available for application, the nutrient analyses of the manures, and the storage capacity for each manure source. Such information is used in determining the organic P contribution to the P Index.

Manure quantities can be entered within the "Manure Source Data" tab, directly from records, using the "Estimate Using Farm Records" option; from a description of the herd, using the "Estimate Using Animal Parameters" option; or by entering the number of spreader loads, using the "Estimate Using Number and Average Weight of Manure Applications" option.

Manure analyses for each manure source can be entered on the "Manure Analysis" tab, shown in Figure 9, and finally, the manure storage capacity can be calculated using the "Manure Storage" tab, shown in Figure 10. A farm's manure storage capacity can influence the timing of manure applications, thereby making it an important practical consideration in planning with the P Index.

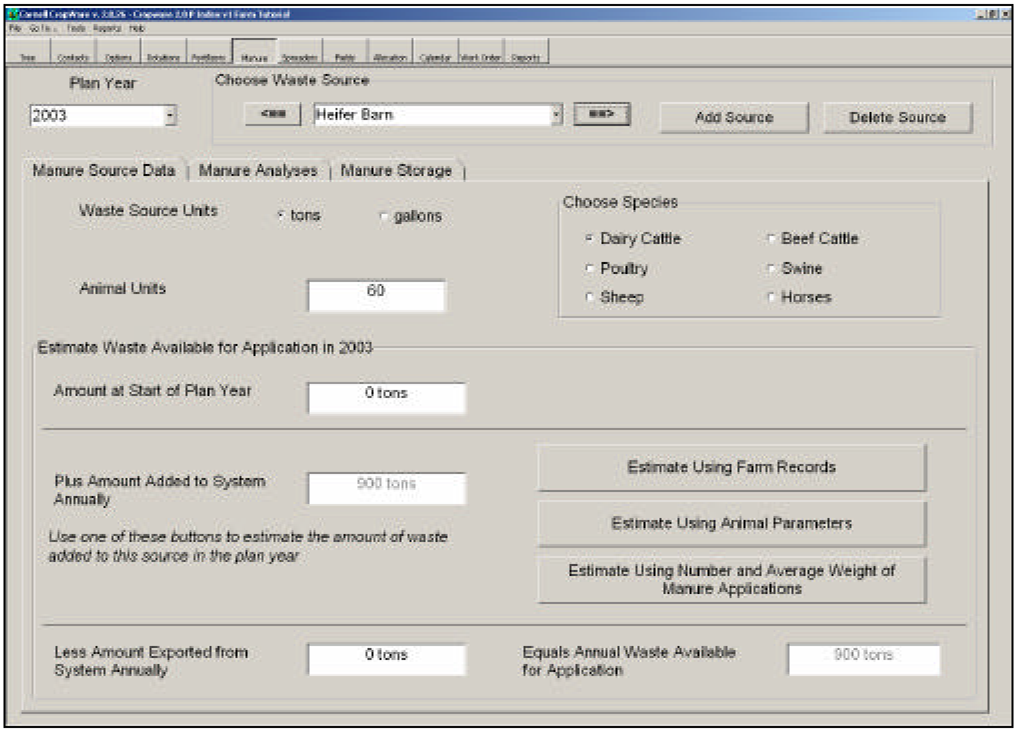


Figure 8: The Manure Source Data tab within the Manure screen in Cropware helps the user determine the amount of manure available for application.

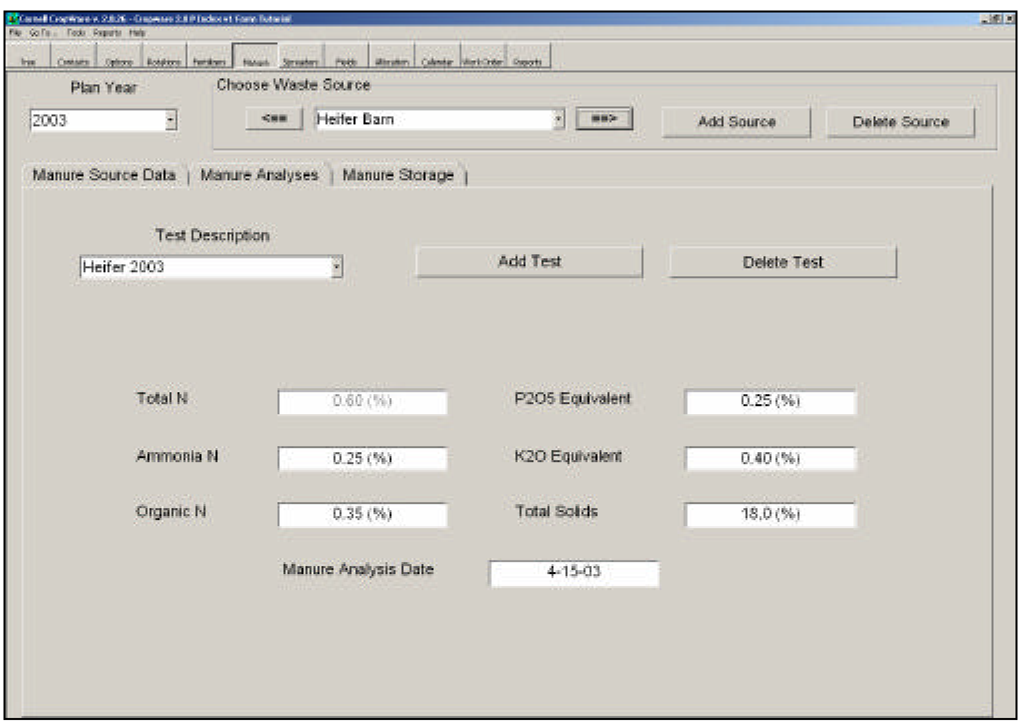


Figure 9: The Manure Analysis tab enables the user to input manure analysis results.

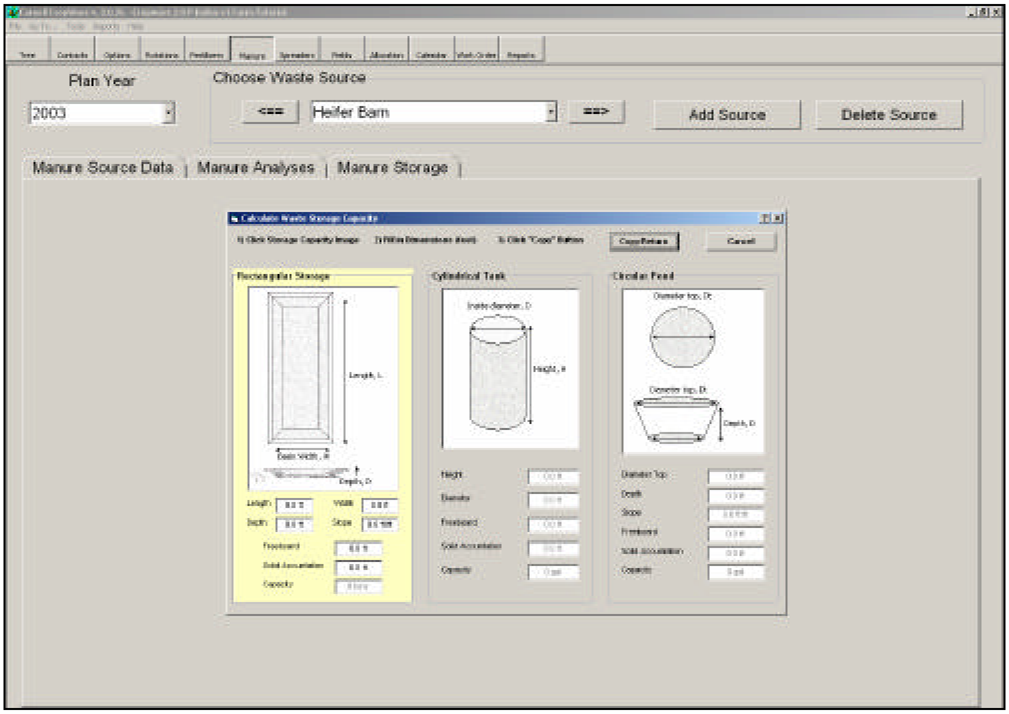


Figure 10: The Manure Storage tab assists the user in estimating manure storage capacities.

Fields:

The Fields screen in Cropware (Figure 11) organizes the basic inputs used to characterize a farm's fields.

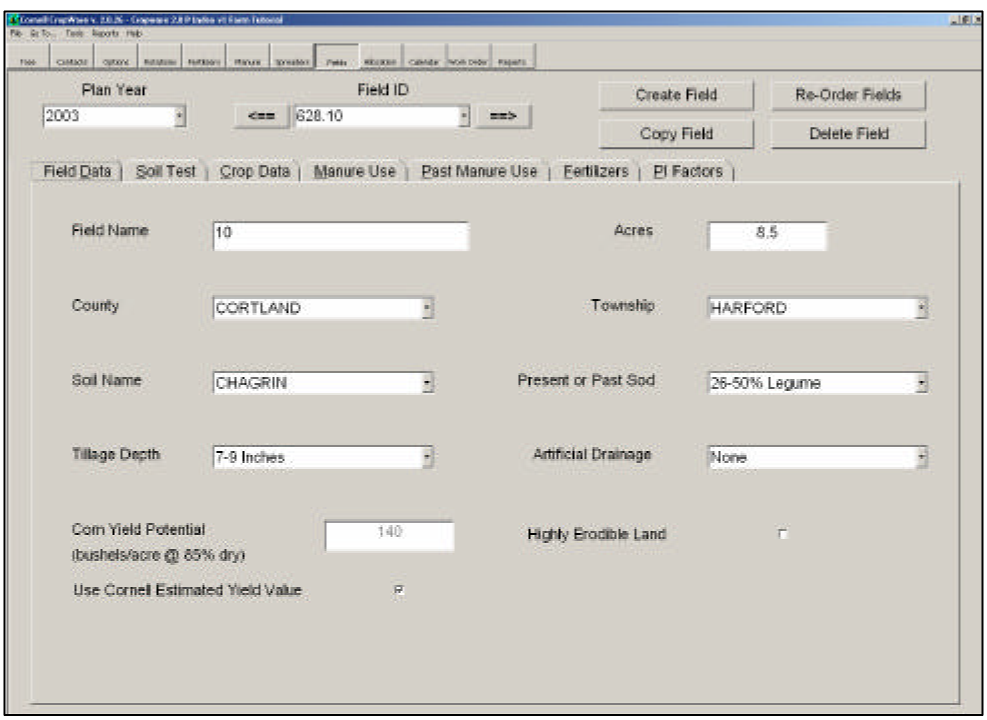


Figure 11: The Fields screen in Cornell Cropware enables the user to characterize each field. The "Field Data" tab captures basic background information about a field.

Seven tabs are used to characterize each field. On the "Field Data" tab shown above (Figure 11), the "Soil Name" is used to set default "Soil Drainage" and "Flooding Frequency" inputs for the Transport factors. The resulting default "Soil Drainage" and "Flooding Frequency" inputs can be changed, if necessary, on the "PI Factors" tab.

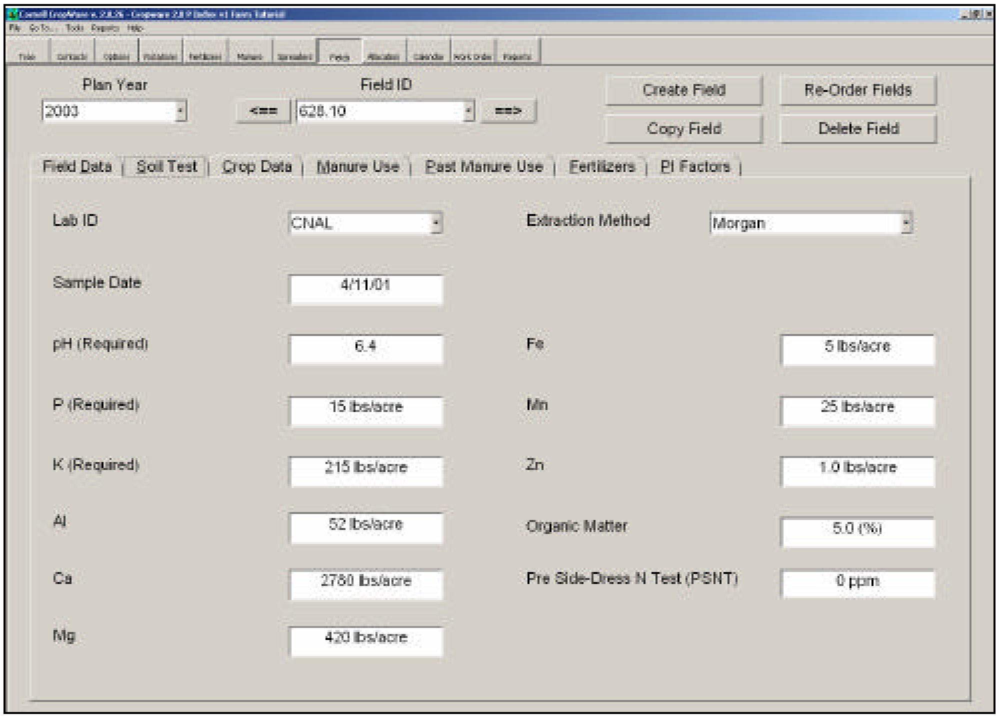


Figure 12: The Soil Test tab captures soil analysis results.

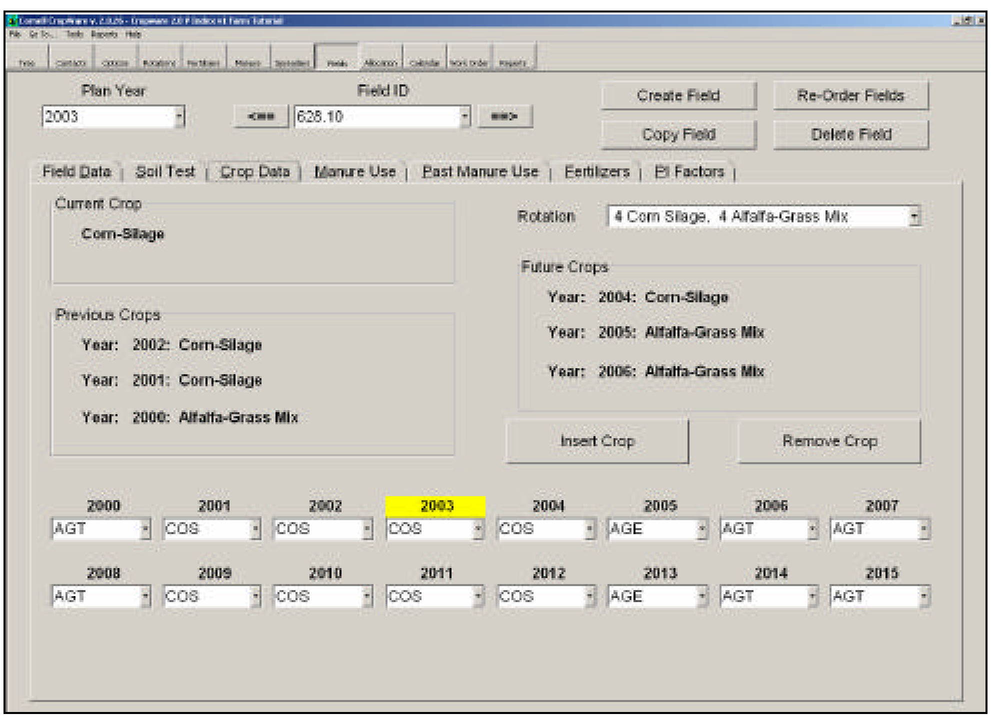


Figure 13: The Crop Data tab allows the user to characterize the crop rotation.

Soil Test information is entered on the "Soil Test" tab (Figure 12). If the soil analysis was performed by the Cornell Nutrient Analysis Lab (CNAL), then the soil test phosphorus value (lbs P/acre) can be directly entered into the "P (Required)" cell. If another soil test laboratory is used, then other inputs, specifically Al, Ca and pH, are required in order to convert the analyses into CNAL Morgan extraction equivalents (See section 4.1).

The "Crop Data" tab (Figure 13) is used to define the crop rotation. This information is critical to the planner, because it aids in defining the crop nutrient guidelines and thereby influences the application of manure and fertilizer nutrients.

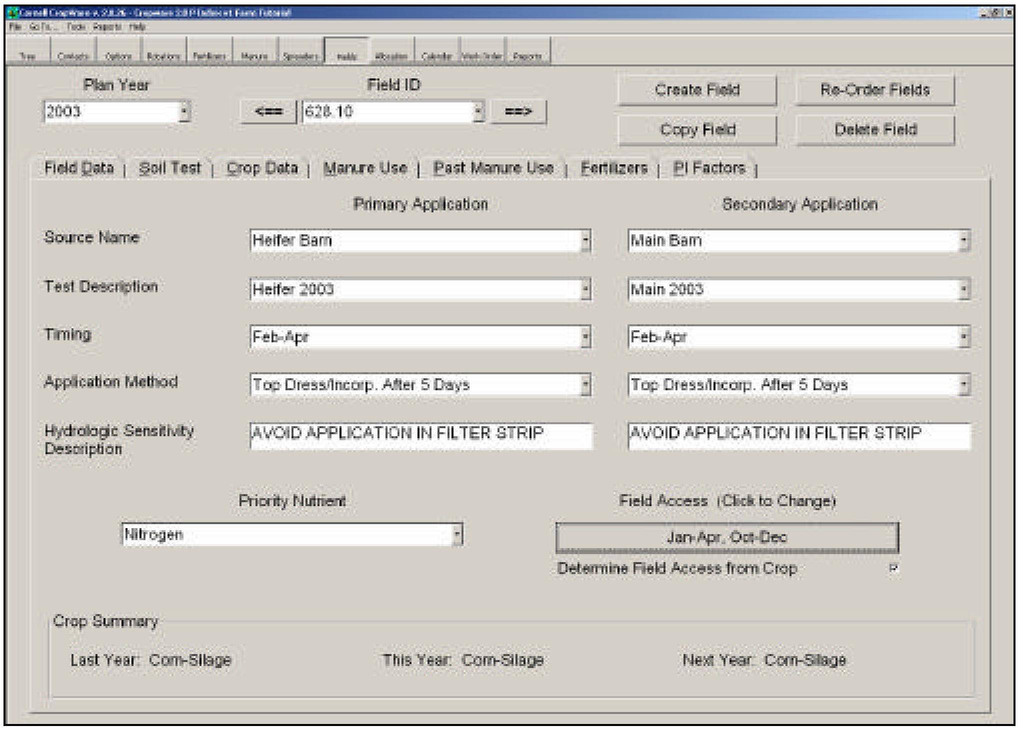


Figure 14: The Manure Use tab enables the user to characterize up to two separate manure application events per field.

The "Manure Use" tab (Figure 14) is used to characterize the manure applications for the upcoming plan year in terms of source, timing, and method of application. The manure source, test and rate may also be selected on the Allocation screen (Figure 18), where the user has more information about other fields and manure sources in view. Regarding manure application timing and method, the default settings are "Feb-Apr" and "Top Dress/Incorp. After 5 Days". If you have information that is contrary to the default settings at this step in the planning process, then change the default settings. Otherwise, maintain the default settings for timing and method, because they represent a higher risk management and thereby establish a conservative base from which to plan. For example, if after planning initial manure and fertilizer applications on the Allocation screen, one finds that a field's P Index score is High or Very High, then a potentially simple, risk reducing management change could be to switch the timing and/or method to a setting less prone to P loss. This will be discussed in greater detail in Section 8.3.

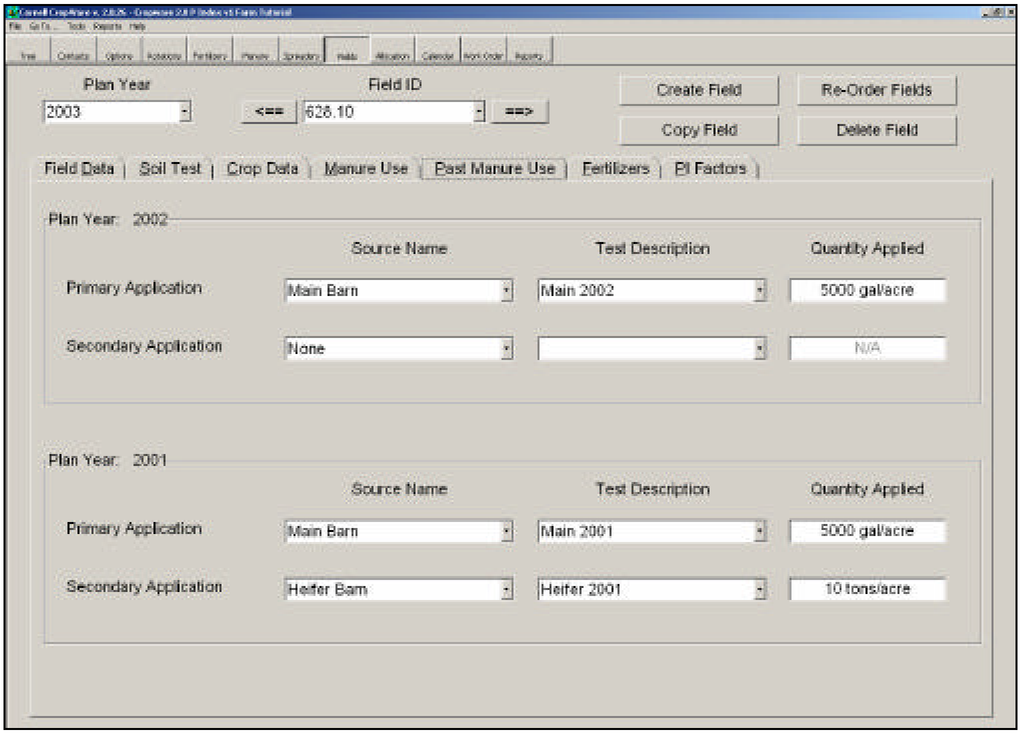


Figure 15: The Past Manure Use tab helps the user enter information about manure applications from the past two years.

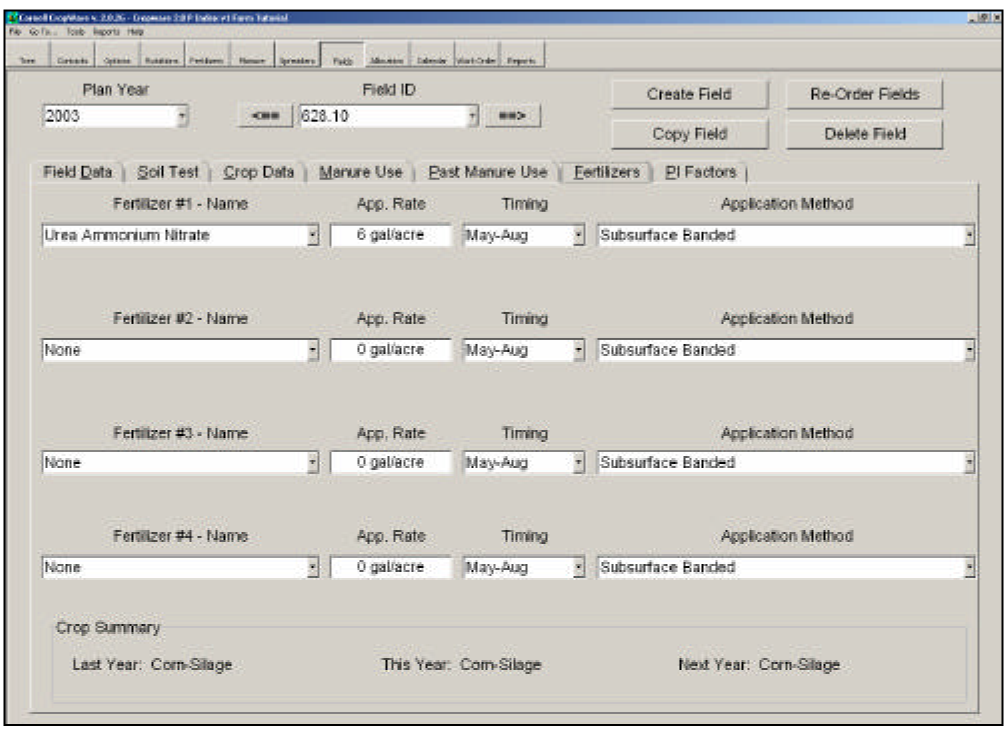


Figure 16: The Fertilizers tab captures information about up to four fertilizer applications per field.

The "Past Manure Use" tab (Figure 15) documents manure applications from the last two years in order to calculate nitrogen credits from those applications. This is relevant to the P Index in that it impacts crop nitrogen guidelines and, therefore, planned manure applications on the Allocation screen.

The "Fertilizers" tab (Figure 16) is used to select up to four different fertilizers or fertilizer application events, including rate, timing, and method. As noted earlier, the fertilizer material and rate may be selected on the Allocation screen (Figure 18), where the user has more information about other fields in view.

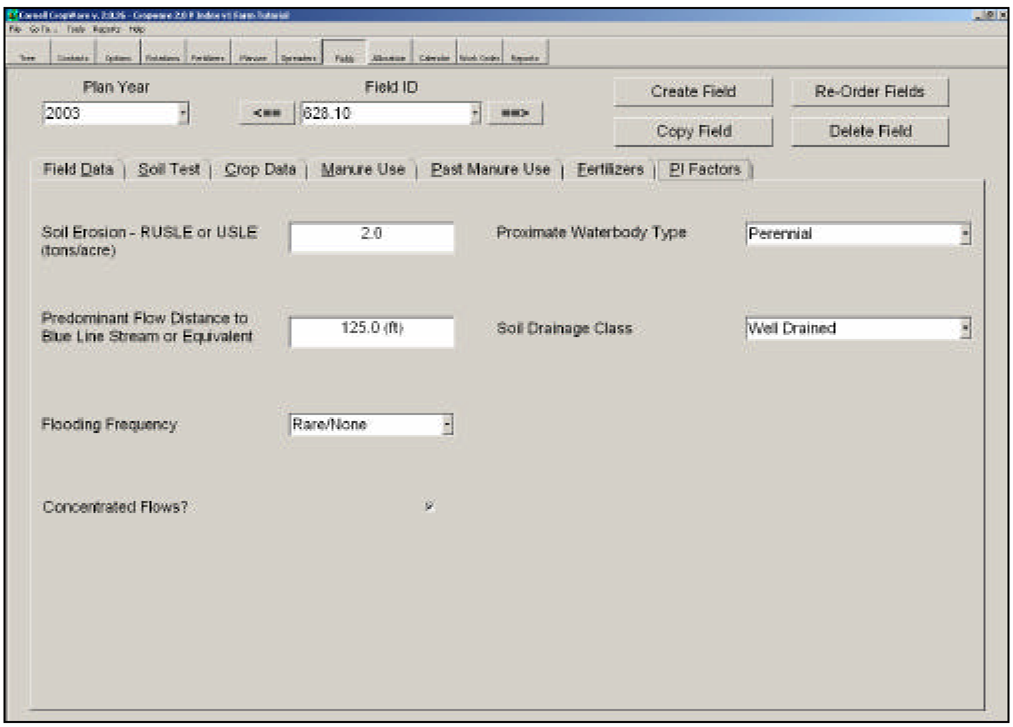


Figure 17: The PI Factors tab captures the remaining information required for the P Index.

The "PI Factors" tab (Figure 17) captures the remaining inputs necessary for the P Index. The RUSLE "A" value should be entered into the "Soil Erosion" cell. The "Proximate Waterbody Type" allows for the selection of "None", "Intermittent", or "Perennial" and is used in combination with the "Predominant Flow Distance to Blue Line Stream or Equivalent" in calculation of the Transport factor. "Soil Drainage Class" and "Flooding Frequency" values are based on the "Soil Name" selection on the "Field Data" tab (Figure 11). The "Concentrated Flow" box is used to indicate whether a field has a concentrated flow (a checked box signals "Yes" and an unchecked box means "No").

8.2 Allocating manure and fertilizer

Now that the manure sources and fields have been characterized, Cropware will compute crop nutrient guidelines and manure inventories. The planner must consider the crop nutrient guidelines, P Index, N Leaching Index, manure inventories, and other on-farm logistics to initially allocate manure and fertilizer across the fields (Step 2). Cropware will then calculate nutrient balances and P Index scores per field, as well as manure inventories for all sources. This is accomplished on the Allocation screen, shown in Figure 18.

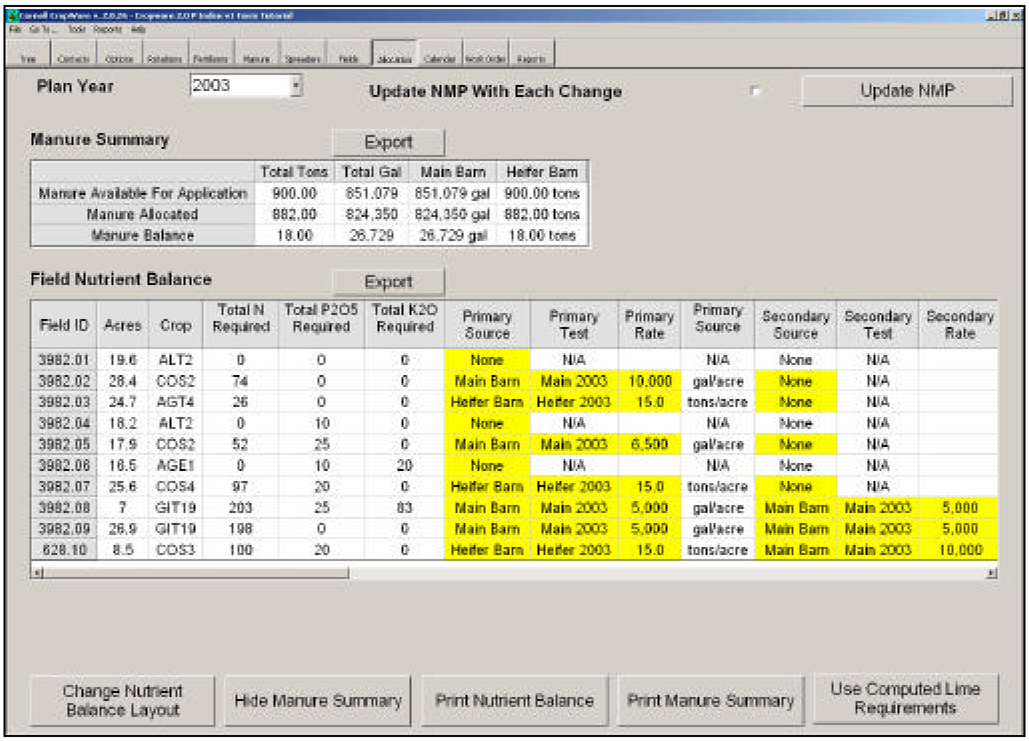
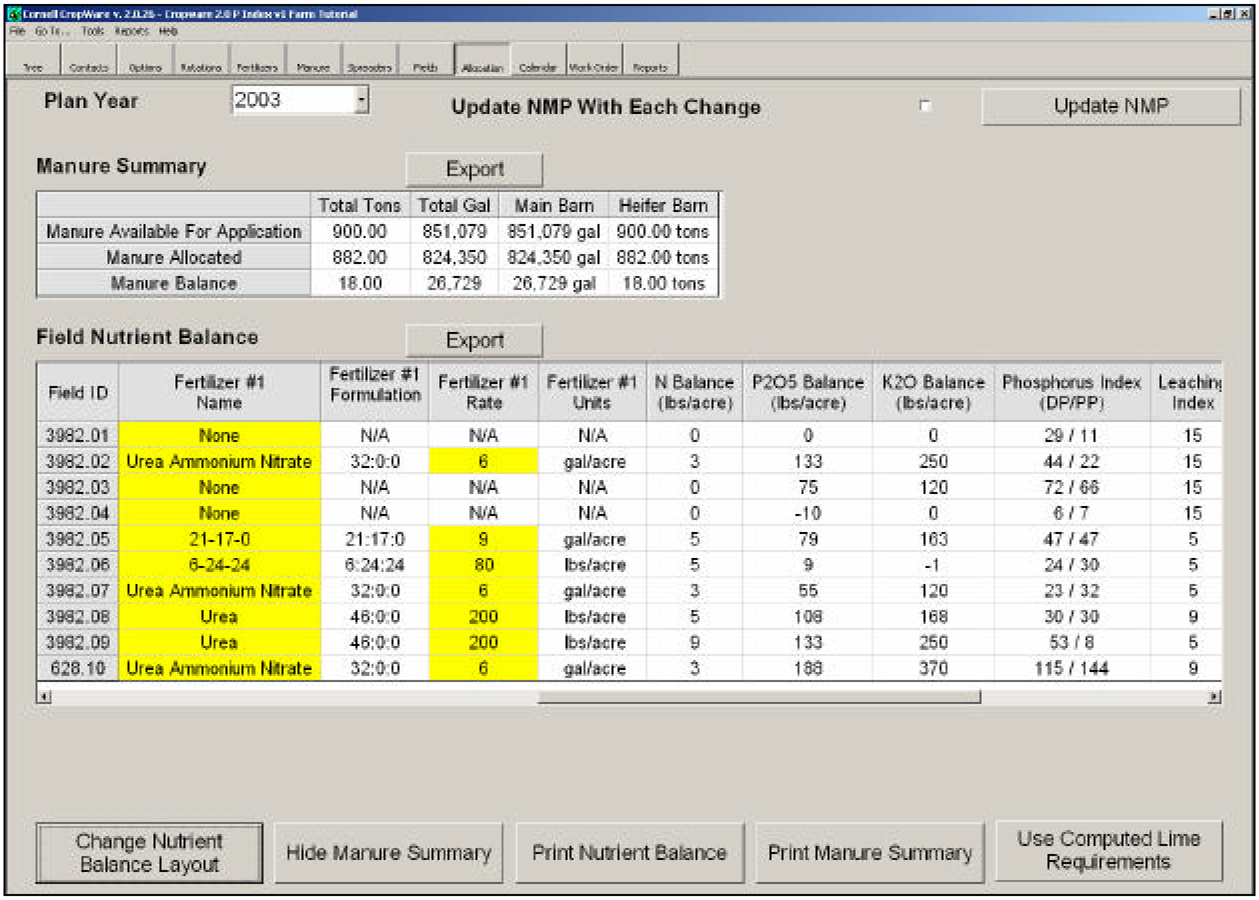


Figure 18: The Allocation screen integrates manure inventories, crop nutrient guidelines, and environmental risk indices on a single screen to facilitate planning.

The Allocation screen allows the user to consider running totals of manure inventories in the "Manure Summary" grid as well as nutrient guidelines, nutrient balances, and environmental risk indices in the "Field Nutrient Balance" grid. To further explain the Allocation screen, consider field 628.10 (Figure 18). This third year corn field has total N, P_2O_5, and K_2O requirements of 100, 20, and 0 lbs/acre, respectively. By clicking on the Primary Source cell for field 628.10, the planner chose the Heifer Barn manure source. Similarly, the planner also selected the Heifer 2003 manure test and a rate of 15 tons/acre. For a second coat of manure, the planner chose the Main Barn source with a rate of 10,000 gallons/acre.

By scrolling to the right on the Allocation screen, we see that the planner supplemented the manure applications with a starter fertilizer application of 6 gallons/acre of urea ammonium nitrate liquid fertilizer (Figure 19).



	Total Tons	Total Gal	Main Barn	Heifer Barn
Manure Available For Application	900.00	851,079	851,079 gal	900.00 tons
Manure Allocated	882.00	824,350	824,350 gal	882.00 tons
Manure Balance	18.00	26,729	26,729 gal	18.00 tons

Field ID	Fertilizer #1 Name	Fertilizer #1 Formulation	Fertilizer #1 Rate	Fertilizer #1 Units	N Balance (lbs/acre)	P2O5 Balance (lbs/acre)	K2O Balance (lbs/acre)	Phosphorus Index (DP/PP)	Leaching Index
3982.01	None	N/A	N/A	N/A	0	0	0	29 / 11	15
3982.02	Urea Ammonium Nitrate	32:0:0	6	gal/acre	3	133	250	44 / 22	15
3982.03	None	N/A	N/A	N/A	0	75	120	72 / 66	15
3982.04	None	N/A	N/A	N/A	0	-10	0	6 / 7	15
3982.05	21-17-0	21:17:0	9	gal/acre	5	79	163	47 / 47	5
3982.06	6-24-24	6:24:24	80	lbs/acre	5	9	-1	24 / 30	5
3982.07	Urea Ammonium Nitrate	32:0:0	6	gal/acre	3	55	120	23 / 32	5
3982.08	Urea	46:0:0	200	lbs/acre	5	108	168	30 / 30	9
3982.09	Urea	46:0:0	200	lbs/acre	9	133	250	53 / 8	5
628.10	Urea Ammonium Nitrate	32:0:0	6	gal/acre	3	188	370	115 / 144	9

Figure 19: The Allocation screen; notice the Very High P Index scores.

Continuing to the right, you will see that the N balance is 3 lbs/acre and the Phosphorus Index is 115 for the dissolved P Index (DP) and 144 for the particulate P Index (PP). Finally, as a result of the planned applications, the "Manure Balance" in the "Manure Summary" grid indicates that most of the manure available has been allocated (an important consideration, especially for farms without manure storage).

8.3 Revising the initial plan

At this point the planner must take stock of how well the major objectives of Step 3 of the planning process have been satisfied (Figure 7):

- Have crop nutrient guidelines been satisfied?
- Is management appropriate for the P Index and N Leaching Index?
- Has all of the available manure been planned for application?
- Can the plan be implemented on the farm?

By focusing on field 628.10 again, we see that the N balance is satisfactory, the N Leaching Index is moderate, and the bulk of the manure from the Main Barn and Heifer Barn has been planned for application. The P Index, though, is Very High for both the dissolved P and particulate P Indices. This means that no additional phosphorus is to be applied to the field (Table 1). As a result, the planner must revise the plan to lower the P Index scores. As stated earlier in this section, such management changes could include:

- Modifications in the timing, rate, and/or method of manure and/or fertilizer applications.
- Increases in flow distance through the use of no spreading buffers.
- Reductions in the RUSLE predicted soil loss through changes in crop rotation management.
- Adoption of best management practices to address concentrated flows.

A number of management changes and/or combinations of management changes could be used to satisfy the objectives outlined in Step 3. The following scenarios represent a sampling of management changes aimed at reducing the risk of phosphorus loss.

__Management Change Scenario 1:__

Scenario 1 involves changes in the Transport factor of the P Index. By navigating back to the "PI Factors" tab within the Fields screen for field 628.10 (Figure 17), notice that the "Predominant Flow Distance" is 125 feet and that untreated "Concentrated Flows" exist in the field. By creating a spreading setback of 125 feet within the field, the "Predominant Flow Distance" could be increased to 250 feet and the concentrated flow could be eliminated by installing a grass waterway (Figure 20).

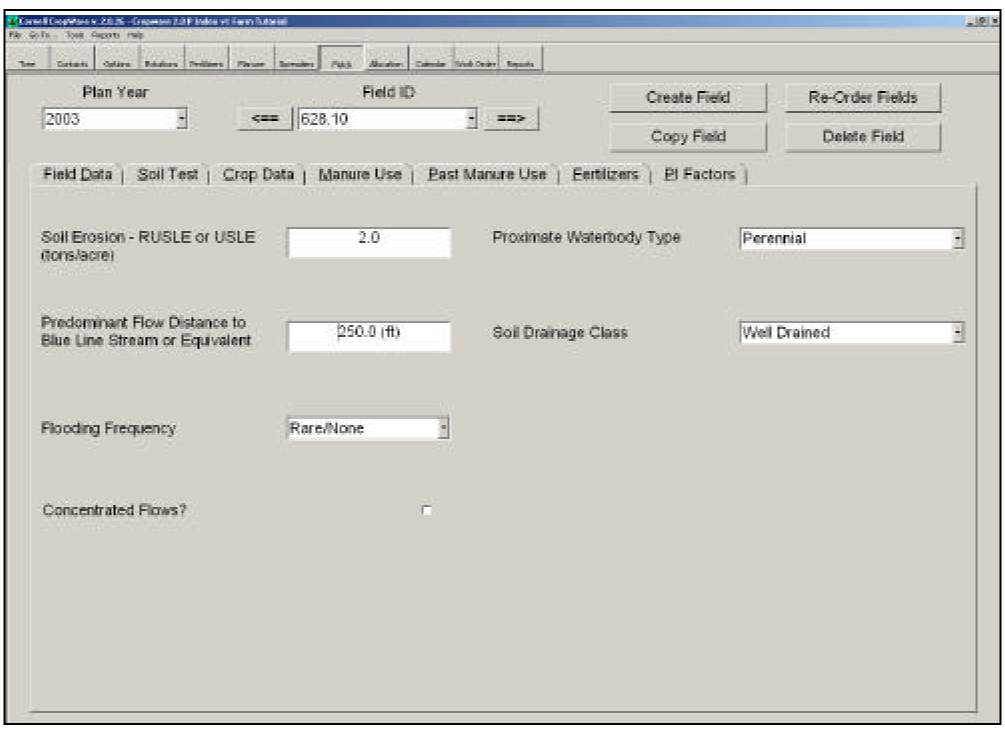
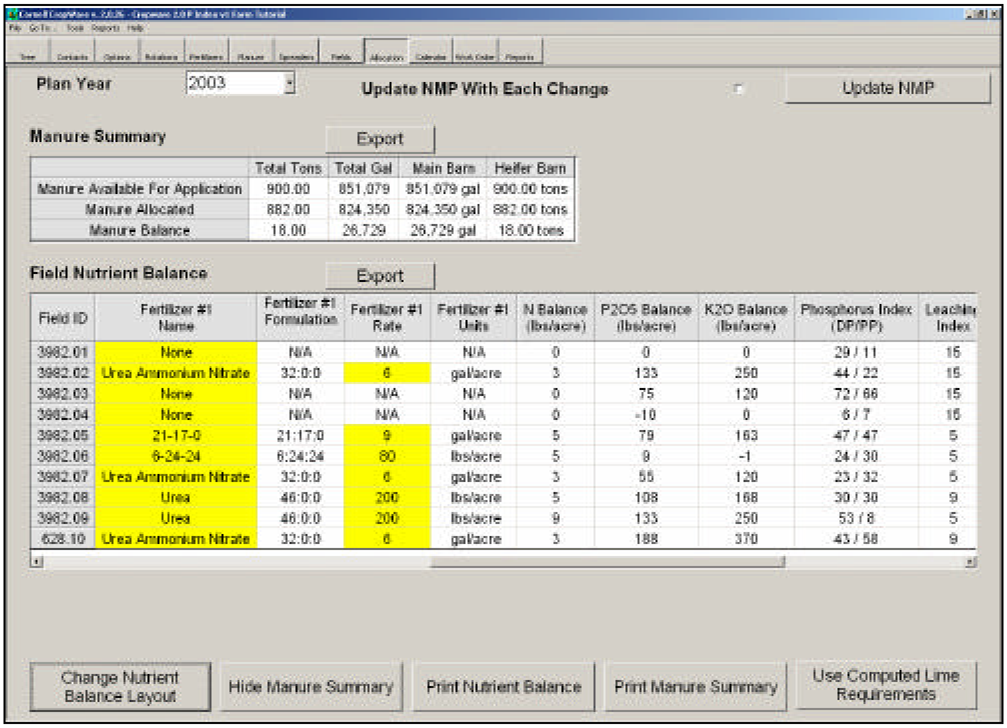


Figure 20: Returning to the PI Factors tab of the Fields screen, the planner revised the plan by increasing the flow distance and eliminating the concentrated flow.

The producer viewed both changes as feasible and the resulting P Index scores were reduced to 43/58 (Figure 21). Considering the higher of the two P Index scores, this field is classified as Medium risk, allowing N based management with best management practices to curb nutrient loss (Table 1).



	Total Tons	Total Gal	Main Barn	Heifer Barn
Manure Available For Application	900.00	851,079	851,079 gal	900.00 tons
Manure Allocated	882.00	824,350	824,350 gal	882.00 tons
Manure Balance	18.00	26,729	26,729 gal	18.00 tons

Field ID	Fertilizer #1 Name	Fertilizer #1 Formulation	Fertilizer #1 Rate	Fertilizer #1 Units	N Balance (lbs/acre)	P2O5 Balance (lbs/acre)	K2O Balance (lbs/acre)	Phosphorus Index (DP/PP)	Leaching Index
3982.01	None	N/A	N/A	N/A	0	0	0	29 / 11	15
3982.02	Urea Ammonium Nitrate	32:0:0	6	gal/acre	3	133	250	44 / 22	15
3982.03	None	N/A	N/A	N/A	0	75	120	72 / 66	15
3982.04	None	N/A	N/A	N/A	0	-10	0	6 / 7	15
3982.05	21-17-0	21:17:0	9	gal/acre	5	79	163	47 / 47	5
3982.06	6-24-24	6:24:24	80	lbs/acre	5	9	-1	24 / 30	5
3982.07	Urea Ammonium Nitrate	32:0:0	6	gal/acre	3	55	120	23 / 32	5
3982.08	Urea	46:0:0	200	lbs/acre	5	108	168	30 / 30	9
3982.09	Urea	46:0:0	200	lbs/acre	9	133	250	53 / 8	5
628.10	Urea Ammonium Nitrate	32:0:0	6	gal/acre	3	188	370	43 / 58	9

Figure 21: The changes in Transport factors resulted in reduced P Index scores, as shown on the Allocation screen.

The creation of a spreading setback of 125 feet within field 628.10 results in a new management unit separate from field 628.10. To reflect this change, a new field should be created to represent the no-spreading buffer area, originally within field 628.10. This can be performed in the Fields screen. The "Copy Field" function should be used to copy the original field 628.10 once with the "Field ID", 628.10A, and a second time with the "Field ID", 628.10B.

The correct acreage can be assigned to each new field, for example 7.5 acres and 1.0 acres for fields 628.10A and 628.10B, respectively. Finally, the "Delete Field" function is used to delete the original field 628.10. If needed, the "Re-Order Fields" button can be used to re-arrange the list of fields.

Returning to the Allocation screen, you will see that both 628.10A and 628.10B exist as independent fields (Figure 22). It is now possible to develop a simple nutrient management plan for the spreading setback area (i.e., 628.10B), to ensure productive and environmentally sound crop production in this newly created management unit.

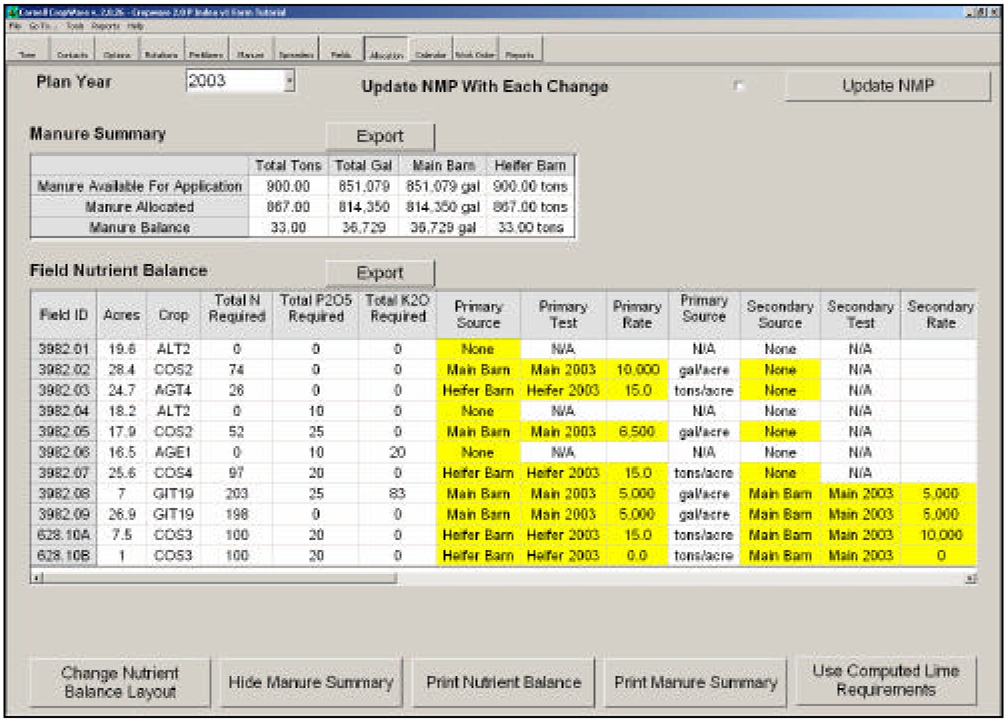


Figure 22: The updated field distinctions now appear on the Allocation screen.

Management Change Scenario 2:

Considering Scenario 1 with field 628.10, if the spreading setback was the only feasible change for the field, the resulting P Index scores would be 43/86. Considering the higher of the two P Index scores, this field is classified as High risk, limiting applications of manure and fertilizer to the P_2O_5 removal of the crop (Table 1). In order to determine the rate of manure necessary to meet P_2O_5 crop removal, consider the following steps:

1. Estimate the dry matter (DM) yield of the crop (e.g., 20 tons/acre corn silage (COS) on a Chagrin soil with 35% DM = 7 tons DM yield/acre).
2. Determine the P_2O_5 content of the DM from Appendix A (e.g., 0.62% P_2O_5 for COS).
3. Calculate the lbs of P_2O_5 removal per acre (e.g., 7 tons DM/acre x 2000 lbs/ton x 0.0062 = 87 lbs P_2O_5 removal/acre).
4. Go to the Allocation screen in Cropware:
    a. Remove any manure allocated to the field.
    b. Consider the "P_2O_5 Balance" column, add the P_2O_5 removal rate calculated above to the balance and record the result on the side (e.g., -20 + 87 = 67 lbs P_2O_5/acre).
    c. Allocate manure until the "P_2O_5 Balance" value equals the calculated result from step 4b, above.
    d. Such an allocation may reduce the P Index score to well below the High category, as in this example with field 628.10. If deemed the best use of manure for crop production and water quality, additional manure could be allocated to this field with the stipulation that the P Index scores remain in the Medium category.

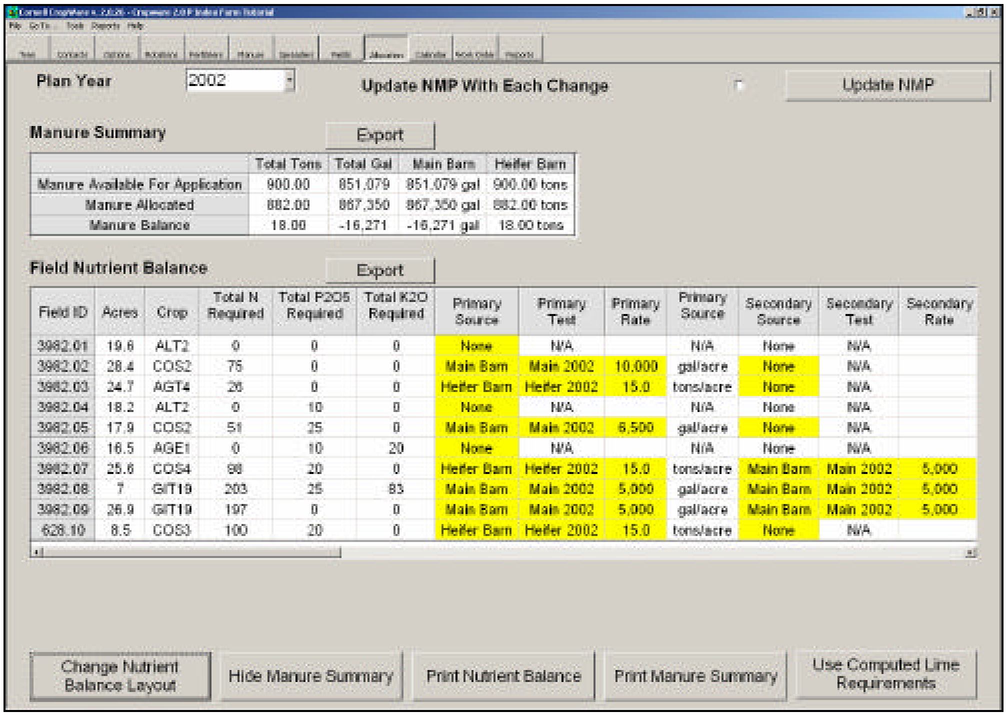


Figure 23: The shift in manure from field 628.10 to field 3982.07 and the updated manure inventories are shown on the Allocation screen.

Management Change Scenario 3:

An alternative to changing Transport factors could be to modify management considered in the Source factor calculations. The planner first shifted the timing of both manure applications from "Feb-Apr" to "Sept-Oct" on the Fields—Manure Use screen. In this case, the change resulted in a slight, but inadequate reduction in the DP/PP scores, to 85/106. Incorporation of manure was not an option on this farm, because of the lack of manure storage, so the planner considered reducing the amount of manure applied to field 628.10. The planner removed the second application (10,000 gallons/acre from the Main Barn) from field 628.10, but upon checking the manure inventories, realized that 85,000 additional gallons of manure were now unplanned. By applying 5,000 gallons/acre of Main Barn manure as a second application to field 3982.07 (another field with a significant nutrient requirement), the manure inventory constraint was satisfied (Figure 23). But what about the nutrient balances and P Index scores for both fields?

The nitrogen balance was restored by adjusting the amount of recommended sidedress nitrogen fertilizer in the Fertilizer #2 category for both fields (Figure 24); notice the 7 gallons/acre and 15 gallons/acre of urea ammonium nitrate for fields 3982.07 and 628.10, respectively. Through changes in management, the P Index Source factor was reduced. The P Index scores are now in the medium range for both field 3982.07 (35/48) and field 628.10 (47/59), necessitating N based management with best management practices (Table 1).

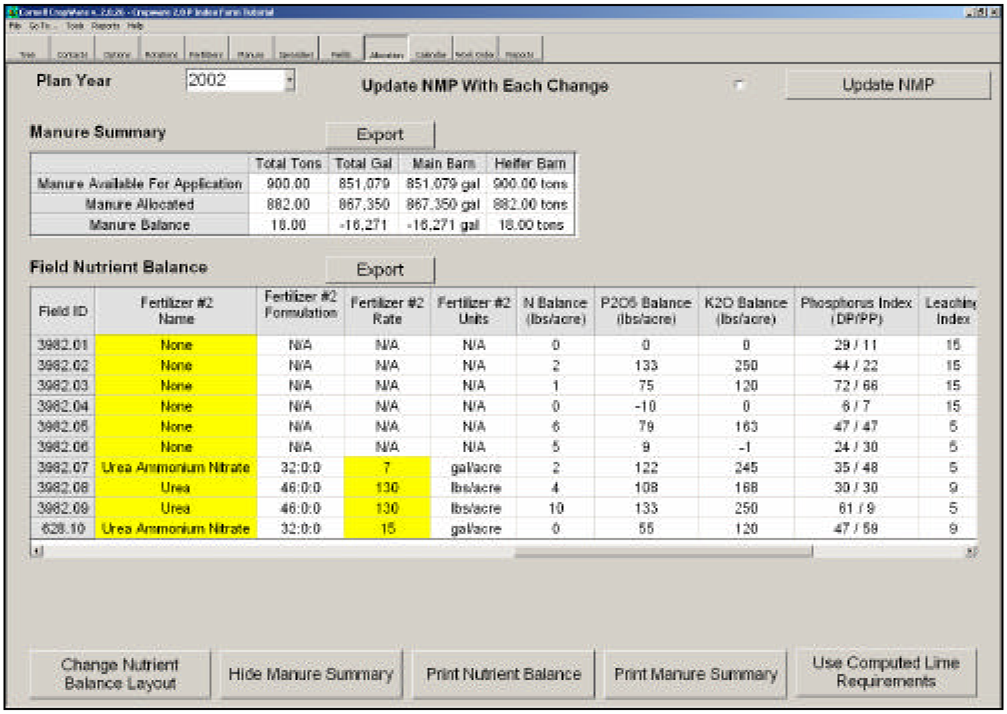


Figure 24: The impact on the P Index scores is shown on the Allocation screen.

A planner may check the feasibility of the plan by using the Calendar screen to determine whether or not the plan is possible when field access and manure supply are considered (Figure 25). The Calendar screen is comprised of a grid for planning manure applications for each month of the plan year. The "Planned Quantity" of manure is the total recommended amount of manure per field calculated from the planner's work on the Allocation screen. The shaded months represent those months when spreading is difficult, due to constraints with field accessibility, labor and equipment availability, etc. The bottom grid tracks manure inventories on a monthly basis as allocations are made on the upper grid. When considering both grids, the planner aims to completely allocate all of the manure as planned on the Allocation screen (i.e., the Quantity Difference column values are approximately zero) while not applying more manure than is available in a given month or, conversely, not allowing manure to accumulate beyond the capacity of storage structures. If this is not possible, then manure plans on the Allocation screen will require modification.

Once the more tactical, temporal allocation plan is completed, the planner can click the "Update PI" button to set the manure Timings for the P Index according to the inputs on the Calendar screen. By navigating back to the "Manure Use" tab within the Fields screen, the planner will see that the manure application timings have been updated to correspond with the Calendar screen.

As a final thought for this section, it is often helpful to begin a nutrient management plan by characterizing the current level of manure and fertilizer management on the farm. Allocating nutrients with consideration for the crop nutrient guidelines, the NY P Index, the N leaching Index, and on-farm logistics will likely highlight areas for improvement. Regardless of the approach toward improvement, a nutrient management plan will likely require some revisions through Cropware as well as consultations with the client before becoming feasible, environmentally sound, and ready for implementation.

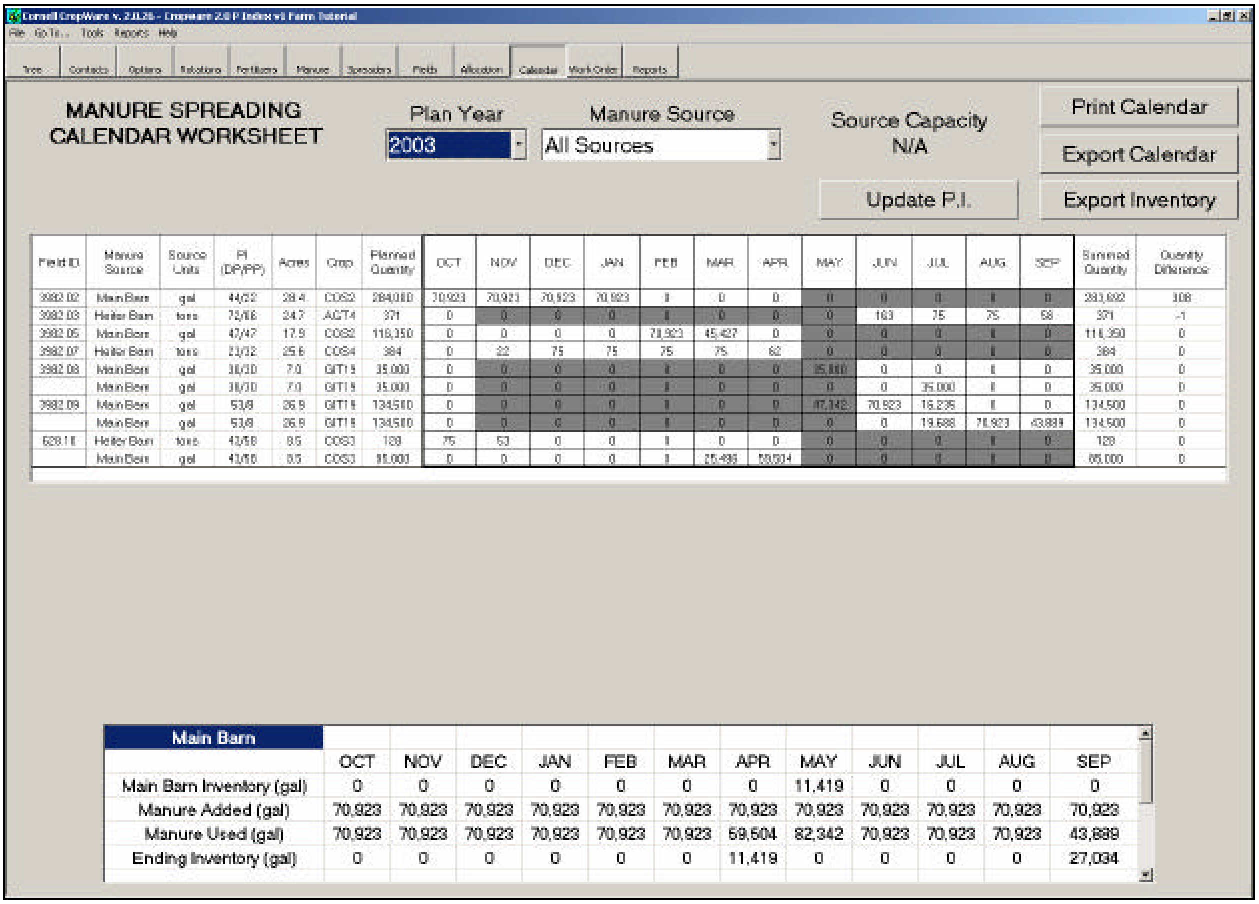


Figure 25: The Calendar screen enables the user to determine the feasibility of the plan developed on the Allocation screen.

8.4 Publish and deliver the plan

Once revisions have been made, Cropware offers many options for reporting the plan for review or implementation by the client (Figure 26). Of the pre-defined reports available in the Reports screen of Cropware, the "Nutrient Management Plan" report provides the user with a balance sheet of nutrient requirements and sources as well as the P Index scores all on a per field basis. The "Fertilizer and Manure Management" report provides a recipe for implementation, including the basic recommendations for manure, fertilizer, and lime applications. The "Field Details Report" offers a detailed, per field summary of the inputs and guidelines for implementation. Finally, the Custom Report tool allows planners to build their own reports to satisfy their particular nutrient management planning needs.

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Nutrient Management Plan

Field ID	Field Name	Acres	2003 Crop	Residual Sod N	Gross N Req.	Residual Manure N	Total Nutrients Required (lb/a)			Nutrients From Applied Manure (lb/a)			Nutrients From Fertilizer (lb/a)			Nutrient Balance (lb/a)			PI (DP/PP)	LI
							N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O		
3982.01	1	19.6	ALT2	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	29 / 11	15
3982.02	2	28.4	COS2	36	85	11	74	0	0	55	133	250	21	0	0	3	133	250	44 / 22	15
3982.03	3	24.7	AGT4	0	40	14	26	0	0	26	75	120	0	0	0	0	75	120	72 / 66	15
3982.04	4	18.2	ALT2	0	0	21	0	10	0	0	0	0	0	0	0	0	-10	0	6 / 7	15
3982.05	5	17.9	COS2	24	78	26	52	25	0	36	87	163	21	17	0	5	79	163	47 / 47	5
3982.06	6	16.5	AGE1	0	0	20	0	10	20	0	0	0	5	19	19	5	9	-1	24 / 30	5
3982.07	7	25.6	COS4	0	109	12	97	20	0	26	75	120	74	0	0	3	55	120	23 / 32	5
3982.08	8	7.0	GIT19	0	225	22	203	25	83	55	133	250	152	0	0	5	108	168	30 / 30	9
3982.09	9	26.9	GIT19	0	225	27	198	0	0	55	133	250	152	0	0	9	133	250	53 / 8	5
628.10	10	8.5	COS3	13	117	17	100	20	0	32	88	145	21	0	0	-47	68	145	22 / 43	9

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Fertilizer and Manure Management Report

Field ID	Field Name	Crop	Acres	Manure Application	Manure App. Timing	Fertilizer Application (Qty/Acre)				Lime Req. (tons 100% ENV Lime/acre)	Latest Soil Sample	Comments
						#1	#2	#3	#4			
3982.01	1	ALT2	19.6							0.0	4/11/01	
3982.02	2	COS2	28.4	Main Barn: 10,000 gal/acre	Nov-Jan	6 gal Urea Ammonium Nitrate				0.0	4/11/01	
3982.03	3	AGT4	24.7	Heifer Barn: 15 tons/acre	Sep-Oct					1.0	3/30/00	
3982.04	4	ALT2	18.2							0.0	4/11/01	
3982.05	5	COS2	17.9	Main Barn: 6,500 gal/acre	Feb-Apr	9 gal 21-17-0				0.0	4/11/01	
3982.06	6	AGE1	16.5			80 lbs 6-24-24				0.0	4/11/01	
3982.07	7	COS4	25.6	Heifer Barn: 15 tons/acre	Feb-Apr	6 gal Urea Ammonium Nitrate	15 gal Urea Ammonium Nitrate			0.0	4/11/01	
3982.08	8	GIT19	7.0	Main Barn: 5,000 gal/acre Main Barn: 5,000 gal/acre	Main Barn: May-Aug Main Barn: May-Aug	200 lbs Urea	130 lbs Urea			2.0	11/1/99	
3982.09	9	GIT19	26.9	Main Barn: 5,000 gal/acre Main Barn: 5,000 gal/acre	Main Barn: May-Aug Main Barn: Sep-Oct	200 lbs Urea	130 lbs Urea			0.0	11/30/99	
628.10	10	COS3	8.5	Heifer Barn: 15 tons/acre Main Barn: 1,000 gal/acre	Heifer Barn: Feb-Apr Main Barn: Feb-Apr	6 gal Urea Ammonium Nitrate	0 gal Urea Ammonium Nitrate			1.0	4/11/01	

Cornell CropWare was used in this evaluation. No guarantee/warranty of results is made or implied.

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Field Detail Report - 628.10 (10), 8.5 acres

Crop Rotation

Plan Year	2000	2001	2002	2003	2004	2005
Crop/Standing Year	AGT4	COS1	COS2	COS3	COS4	AGE1

Soil

Soil Name: CHAGRIN Artificial Drainage: None Soil Group: 3
Tillage Depth: 7-9 Inches Percent Sod: 26-50% Legume

Risk Factor

Highly Erodible: False Hydrologic Sensitivity: AVOID APPLICATION IN FILTER STRIP & AVOID APPLICATION IN FILTER ST
Hydrologic Group: B

	Value	V. Low	Low	Medium	High	V. High
PI-DP	21.5					
PI-PP	43.1					
LI	9.0					

Soil Test Results (Lab: CNAL - Extraction Method: Morgan - Sample Date: 4/11/01)

	Value	V. Low	Low	Medium	High	V. High
pH	6.4					
Phosphorus (lbs/Acre)	15.0					
Potassium (lbs/acre)	215.0					
Magnesium (lbs/Acre)	420.0					
Calcium (lbs/acre)	2780.0					
Ex. Acidity (ME/100g)	14.0					

Nutrient and Lime Requirements For 2003 Plan Year

Lime: 1.0 (tons 100% ENV Lime/acre) Phosphate: 20 (lbs P2O5/acre)
Nitrogen: 100 (lbs N/acre) Potash: 0 (lbs K2O/acre)

Nutrient Management Plan (2003)

Manure Application	Test	Rate	Application Method	Timing
Heifer Barn	Heifer 2003	15.0 tons/acre	Top Dress/Incorp. After 5 Days	Feb-Apr
Main Barn	Main 2003	1,000 gal/acre	Top Dress/Incorp. After 5 Days	Feb-Apr

Fertilizer Name	Rate
Urea Ammonium Nitrate	6 gal/Acre
Urea Ammonium Nitrate	0 gal/Acre

Cornell CropWare was used in this evaluation. No guarantee/warranty of results is made or implied.

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Custom Report

ID	Acres	Current Crop	PI-DP	PI-PP	Manure #1 Source	Manure #1 Applied/acre	Manure #1 Units
3982.01	19.6	ALT	29	11	None	N/A	N/A
3982.02	28.4	COS	44	22	Main Barn	10,000	gal
3982.03	24.7	AGT	72	66	Heifer Barn	15.00	tons
3982.04	18.2	ALT	6	7	None	N/A	N/A
3982.05	17.9	COS	47	47	Main Barn	6,500	gal
3982.06	16.5	AGE	24	30	None	N/A	N/A
3982.07	25.6	COS	23	32	Heifer Barn	15.00	tons
3982.08	7.0	GIT	30	30	Main Barn	5,000	gal
3982.09	26.9	GIT	53	8	Main Barn	5,000	gal
628.10	8.5	COS	22	43	Heifer Barn	15.00	tons

Figure 26: Examples of Cropware reports: Nutrient Management Plan (top), Fertilizer and Manure Management Report (middle left), Field Details Report (middle right), and the Custom Report (bottom).

Summary

The Phosphorus Index for New York State (NY P Index) 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 further *reduce* phosphorus nutrient loading to impaired surface waterbodies. The NY P Index is not a quantitative tool. In other words, it will not address the *actual* nutrient retention or losses from agricultural operations in the context of Total Maximum Daily Loads (TMDLs), but, rather, is a step toward eventual quantification of P losses from fields. However, the purpose of the P Index is to rank agricultural field vulnerability to phosphorus loss so fields posing a high risk to surface water quality impairment can be identified. The fields identified as high risk can then quickly be targeted for more careful evaluation. Producers are encouraged to make management changes or implement site-specific management improvements to reduce the risk of nutrient losses from high risk areas.

The NY P Index risk assessment tool is designed to address losses of both particulate and dissolved phosphorus. Since dissolved phosphorus can be transported in both surface and shallow subsurface water flows, different assessment factors are used to acknowledge these differences. The objective of this approach is to better assess losses of dissolved phosphorus, which are rapidly available to algae and other aquatic plant life. The NY P Index tool combines various *sources* of phosphorus with different water *transport* mechanisms to arrive at a risk level score. Risk levels are divided into four categories whereby the highest risk level implies that no more additional phosphorus should be applied to the area. Depending on the weighting of individual factors that make up the source and transport scores, management changes or site improvements may or may not sufficiently alter the risk score. Nevertheless, this approach in the P Index allows for considerable flexibility in nutrient management within certain upper limits of nutrient loss risk.

The NY P Index is designed to be a flexible yet scientifically reasonable approach to assisting agricultural producers and planners in identifying field areas that present the highest risk of contributing phosphorus to lakes and streams. It should be a more viable and acceptable approach to nutrient management because it combines factors of sources of phosphorus that may reside (i.e., soil phosphorus) or be placed at risk in the path of water transport. Nutrient loading outside of critical management areas would still be considered acceptable. The NY P Index should serve as a rapid assessment and educational tool until more viable or quantitative-based tools are available.

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Appendix

Appendix A: Phosphorus Concentrations of Field Crops and Vegetables.

To obtain P_2O_5 removal rates, multiply yield in lbs/acre with dry matter content in % and P_2O_5 concentration in % and divide the final answer by 10,000. For example, estimated P_2O_5 removal by a 20 tons/acre corn silage crop at 35% dry matter amounts to 20*2000*35*0.62/10,000 = 87 lbs P_2O_5. This equals 4.3 lbs P_2O_5 per ton of silage (35% dry matter). All data on vegetable crops and the data on field crops marked with an asterisk (*) were obtained from the NRCS Plant Database (http://npk.nrcs.usda.gov). All other field crop data were obtained from DairyOne, Inc.

Appendix A: P concentrations for crop removal of field and vegetable crops.

Field Crops		%P	$\%P_2O_5$	Vegetable Crops*		%P	$\%P_2O_5$
		% of dry matter				% of dry matter	
ALT	Alfalfa	0.33	0.76	ASP	Asparagus	0.71	1.62
AGE/ AGT	Alfalfa-grass mix	0.23	0.53	BDR	Beans – Dry	0.53	1.22
ABE/ ABT	Alfalfa-trefoil-grass	0.23	0.53	BET	Beets	0.34	0.79
BTE/ BTT	Birdsfoot trefoil	0.23	0.53	BNL	Beans – Lima	0.45	1.03
BGE/ BGT	Birdsfoot trefoil-grass	0.23	0.53	BNS	Beans – Snap	0.50	1.14
BCE/ BCT	Birdsfoot trefoil-clover	0.23	0.53	BRP	Broccoli – Transplanted	0.75	1.73
BSE/ BST	Birdsfoot trefoil-seed	0.23	0.53	BRS	Broccoli – Seeded	0.75	1.73
CLE/ CLT	Clover	0.34	0.78	BUS	Brussels Sprouts	0.51	1.17
CGE/ CGT	Clover-grass	0.24	0.55	CAR	Carrots	0.33	0.75
CSE/ CST	Clover-seed production	0.34	0.78	CBP	Cabbage – Transplanted	0.36	0.82
CVE/ CVT	Crownvetch	0.34	0.78	CBS	Cabbage – Seeded	0.36	0.82

Appendix A (continued).

Field Crops		%P	$\%P_2O_5$	Vegetable Crops*		%P	$\%P_2O_5$
		% of dry matter				% of dry matter	
GRE/ GRT	Grasses	0.28	0.64	CEL	Celery	0.67	1.52
GIE/ GIT	Grass-intensive management	0.34	0.78	CFP	Cauliflower – Transplanted	0.66	1.52
PIE/ PIT	Pasture-grazing rotational	0.34	0.78	CFS	Cauliflower – Seeded	0.66	1.52
PGE/ PGT	Pasture with Improved grass	0.34	0.78	CKP	Cucumber – Transplanted	0.53	1.20
PLE/ PLT	Pasture with legumes	0.24	0.55	CKS	Cucumber – Seeded	0.53	1.20
PNT	Pasture with native grasses	0.34	0.78	EGG	Eggplant	0.31	0.72
WPE/ WPT	Waterways, pond dikes	0.15	0.34	END	Endive	0.45	1.03
BSP	Barley-spring	0.29	0.66	LET	Lettuce	0.60	1.37
BSS	Barley-spring with legume	0.29	0.66	MML	Muskmelon	0.22	0.50
BWI	Barley-winter	0.29	0.66	ONP	Onion – Transplanted	0.30	0.69
BWS	Barley-winter with legume	0.29	0.66	ONS	Onion – Seeded	0.30	0.69
BUK*	Buckwheat	0.36	0.82	PEA	Peas	0.49	1.13
COG	Corn-grain	0.31	0.71	PEP	Peppers	0.34	0.77
COS	Corn-silage	0.27	0.62	POT	Potato	0.24	0.55
MIL*	Millet	0.34	0.78	PSN	Parsnips	0.36	0.83
OAT*	Oats	0.31	0.71	PUM	Pumpkins	0.39	0.90

Appendix A (continued).

Field Crops		%P	$\%P_2O_5$	Vegetable Crops*		%P	$\%P_2O_5$
		% of dry matter				% of dry matter	
OAS	Oats-seeded with legume	0.30	0.69	RAD	Radishes	0.44	1.01
RYC	Rye-cover crop	0.36	0.82	RHU	Rhubarb	0.23	0.54
RYS	Rye-seed production	0.36	0.82	RUT	Rutabagas	0.41	0.94
SOG	Sorghum-grain	0.22	0.50	SPF	Spinach – Fall	0.54	1.24
SOF	Sorghum-forage	0.22	0.50	SPS	Spinach – Spring	0.54	1.24
SSH	Sorghum-sudangrass hybrid	0.50	1.15	SQS	Squash – Summer	0.49	1.12
SUD	Sudangrass	0.50	1.15	SQW	Squash – Winter	0.27	0.62
SOY	Soybeans	0.65	1.49	SWC	Sweetcorn	0.38	0.88
SUN	Sunflower	1.02	2.34	TOM	Tomato	0.47	1.08
TRP	Triticale/peas	0.30	0.69	TUR	Turnips	0.37	0.86
WHT	Wheat	0.29	0.66	WAT	Watermelon	0.11	0.26

Downloadable from: http://nmsp.css.cornell.edu/. Last updated: May 19, 2003.

Appendix B: Flooding Frequency and Drainage Class of New York Soils

Drainage Class: V = very poorly drained; P = poorly drained; S = somewhat poorly drained; M = moderately well drained; W = well drained; E = excessively well drained.

Soil Series	Drainage Class	Flooding Frequency
Acton	M	Rare/none
Adams	W	Rare/none
Adirondack	W	Rare/none
Adjidaumo	P	Frequent
Adrian	V	Rare/none
Agawam	W	Rare/none
Albia	S	Rare/none
Albrights	M	Rare/none
Alden	V	Rare/none
Allagash	W	Rare/none
Allard	W	Rare/none
Allendale	P	Rare/none
Allis	P	Rare/none
Alluvial land	S	Rare/none
Almond	S	Rare/none
Alps	M	Rare/none
Altmar	M	Rare/none
Alton	W	Rare/none
Amboy	W	Rare/none
Amenia	M	Rare/none
Angola	S	Rare/none
Appleton	S	Rare/none
Arkport	W	Rare/none
Armagh	P	Rare/none
Arnot	W	Rare/none
Ashville	V	Rare/none
Atherton	P	Rare/none
Atkins	V	Frequent
Atsion	P	Rare/none
Au gres	S	Rare/none
Aurelie	P	Rare/none
Aurora	M	Rare/none
Barbour	W	Occasional
Barcelona	S	Rare/none
Barre	P	Rare/none
Bash	S	Frequent

Soil Series	Drainage Class	Flooding Frequency
Basher	M	Occasional
Bath	W	Rare/none
Becket	W	Rare/none
Becraft	M	Rare/none
Belgrade	M	Rare/none
Benson	E	Rare/none
Berkshire	W	Rare/none
Bernardston	W	Rare/none
Berrien	M	Rare/none
Berryland	V	Frequent
Beseman	V	Rare/none
Bice	W	Rare/none
Biddeford	V	Rare/none
Birdsall	V	Rare/none
Blasdell	W	Rare/none
Bombay	M	Rare/none
Bonaparte	E	Rare/none
Bono	V	Rare/none
Boots	V	Rare/none
Borosaprists	V	Rare/none
Boynton	P	Rare/none
Braceville	M	Rare/none
Brayton	S	Rare/none
Bridgehampton	W	Rare/none
Bridport	S	Rare/none
Briggs	W	Rare/none
Brinkerton	P	Rare/none
Broadalbin	M	Rare/none
Brockport	S	Rare/none
Brookfield	W	Rare/none
Buckland	W	Rare/none
Bucksport	V	Rare/none
Budd	W	Rare/none
Burdett	S	Rare/none
Burnham	P	Rare/none
Busti	S	Rare/none

Appendix B (continued).

Soil Series	Drainage Class	Flooding Frequency
Buxton	M	Rare/none
Cambria	P	Rare/none
Cambridge	M	Rare/none
Camillus	W	Rare/none
Camroden	S	Rare/none
Canaan	E	Rare/none
Canaan-rock outcrop	E	Rare/none
Canadice	P	Rare/none
Canandaigua	P	Rare/none
Canaseraga	M	Rare/none
Canastota	M	Rare/none
Caneadea	S	Rare/none
Canfield	M	Rare/none
Canton	W	Rare/none
Carbondale	V	Rare/none
Carlisle	V	Rare/none
Carrollton	W	Rare/none
Carver	E	Rare/none
Carver-plymouth	E	Rare/none
Castile	W	Rare/none
Cathro	V	Rare/none
Cathro-greenwood	V	Rare/none
Cattaraugus	W	Rare/none
Cavode	S	Rare/none
Cayuga	W	Rare/none
Cazenovia	M	Rare/none
Ceresco	M	Rare/none
Chadakoin	W	Rare/none
Chagrin	W	Occasional
Champlain	E	Rare/none
Charles	P	Frequent
Charlton	W	Rare/none
Chatfield (e)	E	Rare/none
Chatfield (we)	W	Rare/none
Chaumont	S	Rare/none
Chautauqua	M	Rare/none
Cheektowaga	P	Rare/none
Chenango	W	Rare/none
Cheshire	W	Rare/none

Soil Series	Drainage Class	Flooding Frequency
Chippeny	V	Rare/none
Chippewa	P	Rare/none
Churchville	S	Rare/none
Cicero	S	Rare/none
Clarkson	M	Rare/none
Claverack	M	Rare/none
Clymer	W	Rare/none
Cohoctah	P	Frequent
Collamer	M	Rare/none
Colonie	W	Rare/none
Colosse	E	Rare/none
Colrain	W	Rare/none
Colton	E	Rare/none
Colwood	P	Rare/none
Conesus	M	Rare/none
Conotton	W	Rare/none
Constable	W	Rare/none
Cook	V	Rare/none
Copake	W	Rare/none
Cornish	S	Occasional
Cosad	S	Rare/none
Cossayuna	W	Rare/none
Covert	M	Rare/none
Coveytown	S	Rare/none
Covington	P	Rare/none
Crary	M	Rare/none
Croghan	M	Rare/none
Culvers	M	Rare/none
Dalbo	M	Rare/none
Dalton	S	Rare/none
Danley	M	Rare/none
Dannemora	P	Rare/none
Darien	S	Rare/none
Dawson	V	Rare/none
Deerfield	M	Rare/none
Deford	P	Rare/none
Dekalb	W	Rare/none
Depeyster	M	Rare/none
Deposit	M	Occasional
Derb	S	Rare/none

Appendix B (continued).

Soil Series	Drainage Class	Flooding Frequency
Dixmont	M	Rare/none
Dorval	V	Rare/none
Dover	W	Rare/none
Duane	M	Rare/none
Dunkirk	W	Rare/none
Dutchess	W	Rare/none
Duxbury	W	Rare/none
Edwards	V	Rare/none
Eel	M	Occasional
Eelweir	M	Rare/none
Elka	W	Rare/none
Ellery	P	Rare/none
Elmridge	M	Rare/none
Elmwood	M	Rare/none
Elnora	M	Rare/none
Empeyville	M	Rare/none
Enfield	W	Rare/none
Ensley	P	Rare/none
Erie	S	Rare/none
Ernest	W	Rare/none
Essex	W	Rare/none
Fahey	M	Rare/none
Farmington	W	Rare/none
Farnham	M	Rare/none
Fernlake	E	Rare/none
Flackville	M	Rare/none
Fonda	V	Rare/none
Franklinville	W	Rare/none
Fredon	S	Occasional
Freetown	V	Rare/none
Fremont	S	Rare/none
Frenchtown	P	Rare/none
Frewsburg	S	Rare/none
Fryeburg	W	Rare/none
Fulton	P	Rare/none
Gage	P	Rare/none
Galen	M	Rare/none
Galestown	E	Rare/none
Galoo	W	Rare/none
Galoo-rock outcrop	W	Rare/none

Soil Series	Drainage Class	Flooding Frequency
Galway	W	Rare/none
Genesee	W	Occasional
Georgia	M	Rare/none
Getzville	P	Rare/none
Gilpen	W	Rare/none
Gilpin	W	Rare/none
Glebe	W	Rare/none
Glebe-saddleback	W	Rare/none
Glendora	W	Rare/none
Glenfield	V	Rare/none
Gloucester	E	Rare/none
Glover	E	Rare/none
Gougeville	V	Rare/none
Granby	P	Rare/none
Grattan	E	Rare/none
Greene	S	Rare/none
Greenwood	V	Rare/none
Grenville	W	Rare/none
Gretor	S	Rare/none
Groton	M	Rare/none
Groveton	W	Rare/none
Guff	P	Rare/none
Guffin	P	Rare/none
Gulf	P	Rare/none
Hadley	W	Rare/none
Haights	W	Rare/none
Haights-gulf	P	Rare/none
Hailesboro	S	Rare/none
Halcott	W	Rare/none
Halsey	V	Rare/none
Hamlin	W	Occasional
Hamplain	W	Rare/none
Hannawa	P	Rare/none
Hartland	W	Rare/none
Haven	W	Rare/none
Hawksnest	W	Rare/none
Hempstead	W	Rare/none
Henrietta	V	Rare/none
Herkimer	M	Rare/none
Hermon	W	Rare/none

Appendix B (continued).

Soil Series	Drainage Class	Flooding Frequency
Hero	M	Rare/none
Heuvelton	M	Rare/none
Hilton	M	Rare/none
Hinckley	E	Rare/none
Hinesburg	W	Rare/none
Hogansburg	M	Rare/none
Hogback	M	Rare/none
Hogback-ricker	M	Rare/none
Holderton	S	Occasional
Hollis	S	Rare/none
Holly	P	Frequent
Holyoke	W	Rare/none
Holyoke-rock outcrop	W	Rare/none
Homer	S	Rare/none
Honeoye	W	Rare/none
Hoosic	W	Rare/none
Hornell	S	Rare/none
Hornellsville	S	Rare/none
Houghtonville	W	Rare/none
Houghtonville-rawson	W	Rare/none
Houseville	S	Rare/none
Howard	W	Rare/none
Hudson	M	Rare/none
Hulberton	S	Rare/none
Ilion	P	Rare/none
Insula	W	Rare/none
Ipswich	V	Frequent
Ira	M	Rare/none
Ischua	M	Rare/none
Ivory	S	Rare/none
Jebavy	P	Rare/none
Joliet	P	Frequent
Junius	P	Rare/none
Kalurah	M	Rare/none
Kanona	S	Rare/none
Kars	W	Rare/none
Kearsarge	E	Rare/none
Kendaia	S	Rare/none

Soil Series	Drainage Class	Flooding Frequency
Kibbie	S	Rare/none
Kingsbury	S	Rare/none
Kinzua	W	Rare/none
Knickerbocker	E	Rare/none
Lackawanna	W	Rare/none
Lagross	W	Rare/none
Lagross-haights	W	Rare/none
Lairdsville	M	Rare/none
Lakemont	P	Rare/none
Lakewood	E	Rare/none
Lamson	P	Rare/none
Lanesboro	W	Rare/none
Langford	W	Rare/none
Lansing	W	Rare/none
Leck kill	W	Rare/none
Leicester	P	Rare/none
Leon	P	Rare/none
Lewbath	W	Rare/none
Lewbeach	W	Rare/none
Leyden	M	Rare/none
Lima	M	Rare/none
Limerick	P	Frequent
Linden	W	Rare/none
Linlithgo	S	Occasional
Livingston	V	Rare/none
Lobdell	M	Occasional
Lockport	S	Rare/none
Lorain	P	Rare/none
Lordstown	W	Rare/none
Lovewell	M	Occasional
Lowville	W	Rare/none
Loxley	V	Rare/none
Lucas	M	Rare/none
Ludlow	M	Rare/none
Lupton	V	Rare/none
Lyman	E	Rare/none
Lyman-becket-berkshire	E	Rare/none
Lyme	P	Rare/none
Lyons	P	Rare/none

Appendix B (continued).

Soil Series	Drainage Class	Flooding Frequency
Machias	M	Rare/none
Macomber	W	Rare/none
Macomber-taconic	W	Rare/none
Madalin	P	Rare/none
Madawaska	M	Rare/none
Madrid	W	Rare/none
Malone	S	Rare/none
Manahawkin	V	Frequent
Mandy	W	Rare/none
Manheim	S	Rare/none
Manhoning	S	Rare/none
Manlius	W	Rare/none
Mansfield	V	Rare/none
Maplecrest	W	Rare/none
Marcy	P	Rare/none
Mardin	M	Rare/none
Marilla	M	Rare/none
Markey	V	Rare/none
Marlow	W	Rare/none
Martisco	V	Frequent
Massena	S	Rare/none
Matoon	S	Rare/none
Matunuck	V	Frequent
Medihemists	V	Rare/none
Medina	W	Rare/none
Medomak	V	Frequent
Melrose	W	Rare/none
Menlo	P	Rare/none
Mentor	W	Rare/none
Merrimac	W	Rare/none
Middlebrook	M	Rare/none
Middlebrook-mongaup	M	Rare/none
Middlebury	M	Occasional
Millis	W	Rare/none
Millsite	W	Rare/none
Mineola	M	Rare/none
Miner	P	Rare/none
Mino	S	Rare/none
Minoa	S	Rare/none

Soil Series	Drainage Class	Flooding Frequency
Mohawk	W	Rare/none
Moira	M	Rare/none
Monadnock	W	Rare/none
Monarda	S	Rare/none
Mongaup	W	Rare/none
Montauk	W	Rare/none
Mooers	M	Rare/none
Morocco	P	Rare/none
Morris	S	Rare/none
Mosherville	S	Rare/none
Muck	V	Rare/none
Muck-peat	V	Rare/none
Mundal	W	Rare/none
Mundalite	W	Rare/none
Mundalite-rawsonville	W	Rare/none
Munson	S	Rare/none
Munuscong	P	Rare/none
Muskego	V	Rare/none
Muskellunge	S	Rare/none
Napoleon	V	Rare/none
Napoli	S	Rare/none
Nassau	E	Rare/none
Naumburg	S	Rare/none
Nehasne	W	Rare/none
Nellis	W	Rare/none
Neversink	P	Rare/none
Newfane	W	Rare/none
Newstead	S	Rare/none
Newton	V	Rare/none
Niagara	S	Rare/none
Nicholville	M	Rare/none
Ninigret	M	Rare/none
Norchip	P	Rare/none
Norwell	S	Rare/none
Norwich	V	Rare/none
Nunda	M	Rare/none
Oakville	W	Rare/none
Occum	W	Occasional
Odessa	S	Rare/none

Appendix B (continued).

Soil Series	Drainage Class	Flooding Frequency
Ogdensburg	S	Rare/none
Olean	M	Rare/none
Ondawa	W	Occasional
Oneida	S	Rare/none
Onoville	M	Rare/none
Ontario	W	Rare/none
Onteora	S	Rare/none
Ontusia	S	Rare/none
Oquaga	W	Rare/none
Oramel	S	Rare/none
Organic	V	Rare/none
Orpark	S	Rare/none
Orwell	P	Rare/none
Ossipee	V	Rare/none
Otego	M	Occasional
Otisville	E	Rare/none
Ottawa	W	Rare/none
Ovid	S	Rare/none
Palatine	W	Rare/none
Palms	V	Frequent
Palmyra	W	Rare/none
Panton	P	Rare/none
Papakating	P	Frequent
Parishville	M	Rare/none
Parsippany	P	Rare/none
Patchin	P	Rare/none
Pawcatuck	V	Frequent
Pawling	M	Occasional
Paxton	W	Rare/none
Peacham	P	Rare/none
Peat	V	Rare/none
Peat-muck	V	Rare/none
Peru	M	Rare/none
Petoskey	W	Rare/none
Phelps	M	Rare/none
Philo	M	Occasional
Pillsbury	S	Rare/none
Pinckney	M	Rare/none
Pipestone	S	Rare/none
Pittsfield	W	Rare/none
Pittstown	M	Rare/none
Plainbo	E	Rare/none
Plainfield	E	Rare/none
Plessis	S	Rare/none
Plymouth	E	Rare/none
Podunk	M	Occasional
Poland	W	Rare/none
Pompton	M	Rare/none
Pootatuck	M	Occasional
Pope	W	Occasional
Potsdam	W	Rare/none
Poygan	V	Rare/none
Punsit	S	Rare/none
Pyrities	W	Rare/none
Quetico	W	Rare/none
Quetico-rock outcrop	W	Rare/none
Raquette	S	Rare/none
Rawsonville	W	Rare/none
Rawsonville-beseman	W	Rare/none
Rayne	W	Rare/none
Raynham	S	Occasional
Raypol	P	Rare/none
Red hook	S	Rare/none
Redwater	S	Frequent
Remsen	S	Rare/none
Retsof	S	Rare/none
Rexford	S	Rare/none
Rhinebeck	S	Rare/none
Ricker	E	Rare/none
Ricker-lyman	E	Rare/none
Ridgebury	P	Rare/none
Rifle	V	Rare/none
Riga	M	Rare/none
Rippowam	P	Frequent
Riverhead	W	Rare/none
Rockaway	W	Rare/none
Romulus	P	Rare/none
Ross	W	Rare/none

Appendix B (continued).

Soil Series	Drainage Class	Flooding Frequency
Roundabout	S	Rare/none
Rumney	P	Frequent
Runeberg	P	Rare/none
Ruse	P	Rare/none
Rushford	M	Rare/none
Saco	V	Frequent
Salamanca	M	Rare/none
Salmon	W	Rare/none
Saprists	V	Rare/none
Saugatuck	S	Rare/none
Scantic	P	Rare/none
Scarboro	P	Rare/none
Schoharie	M	Rare/none
Schroon	M	Rare/none
Schuyler	M	Rare/none
Scio	M	Rare/none
Scituate	M	Rare/none
Scriba	S	Rare/none
Searsport	P	Rare/none
Shaker	P	Rare/none
Shoreham	V	Rare/none
Sisk	V	Rare/none
Skerry	M	Rare/none
Sloan	V	Frequent
Sodus	W	Rare/none
Somerset	P	Rare/none
St johns	P	Rare/none
Staatsburg	W	Rare/none
Stafford	S	Rare/none
Steamburg	M	Rare/none
Stetson	W	Rare/none
Stissing	P	Rare/none
Stockbridge	W	Rare/none
Stockholm	P	Rare/none
Stowe	W	Rare/none
Sudbury	M	Rare/none
Suffield	M	Rare/none
Summerville	E	Rare/none
Sun	V	Rare/none
Sunapee	M	Rare/none

Soil Series	Drainage Class	Flooding Frequency
Suncook	E	Occasional
Suny	P	Rare/none
Surplus	V	Rare/none
Surplus-sisk	V	Rare/none
Sutton	M	Rare/none
Swanton	P	Rare/none
Swartswood	W	Rare/none
Swormville	S	Rare/none
Taconic	W	Rare/none
Taconic-macomber	W	Rare/none
Tawas	V	Rare/none
Teel	M	Frequent
Tioga	W	Occasional
Toledo	V	Rare/none
Tonawanda	S	Rare/none
Tor	S	Rare/none
Torull	S	Rare/none
Towerville	M	Rare/none
Trestle	W	Occasional
Trout river	E	Rare/none
Troy	M	Rare/none
Trumbull	P	Rare/none
Tughill	V	Rare/none
Tuller	S	Rare/none
Tunbridge	W	Rare/none
Tunbridge-adirondack	W	Rare/none
Tunkhannock	W	Rare/none
Turin	S	Rare/none
Tuscarora	M	Rare/none
Unadilla	W	Rare/none
Valois	W	Rare/none
Varick	P	Rare/none
Varysburg	W	Rare/none
Venango	S	Rare/none
Vergennes	M	Rare/none
Vly	W	Rare/none
Volusia	S	Rare/none
Waddington	W	Rare/none
Wainola	S	Rare/none

Appendix B (continued).

Soil Series	Drainage Class	Flooding Frequency
Wakeland	S	Frequent
Wakeville	S	Occasional
Wallace	E	Rare/none
Wallington	S	Rare/none
Wallkill	V	Frequent
Walpole	P	Rare/none
Walton	W	Rare/none
Wampsville	W	Rare/none
Wappinger	W	Occasional
Wareham	P	Rare/none
Warners	V	Frequent
Wassaic	M	Rare/none
Watchaug	M	Rare/none
Waumbeck	M	Rare/none
Wayland	P	Frequent
Weaver	M	Occasional
Wegatchie	P	Rare/none
Wellsboro	M	Rare/none
Wenonah	W	Occasional
Westbury	S	Rare/none
Westland	V	Rare/none
Wethersfield	W	Rare/none
Wharton	M	Rare/none
Whately	V	Rare/none
Whippany	S	Rare/none
Whitelaw	W	Rare/none
Whitman	V	Rare/none

Soil Series	Drainage Class	Flooding Frequency
Wilbraham	S	Rare/none
Willdin	M	Rare/none
Willette	V	Rare/none
Williamson	M	Rare/none
Willowemock	M	Rare/none
Wilmington	P	Rare/none
Wilpoint	M	Rare/none
Windsor	E	Rare/none
Winooski	M	Rare/none
Wolcottsburg	P	Rare/none
Wonsqueak	V	Rare/none
Woodbridge	M	Rare/none
Woodlawn	W	Rare/none
Woodstock	E	Rare/none
Woodstock-rock outcrop	E	Rare/none
Wooster	W	Rare/none
Woostern	W	Rare/none
Woostern-bath-valois	W	Rare/none
Worden	S	Rare/none
Worth	W	Rare/none
Wurtsboro	M	Rare/none
Wyalusing	P	Frequent
Yalesville	W	Rare/none
Yorkshire	M	Rare/none