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The Nebraska Phosphorus Index (2005): Background and Users Guide

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This publication provides the basis and procedure for use of a phosphorus (P) index to assess risk of P delivery from agricultural land to surface waters. The P Index is intended for planning as well as regulatory and educational purposes.

Phosphorus (P) is an essential nutrient for the growth of both crops and aquatic vegetation. Phosphorus, either in inorganic form such as with fertilizer or in organic form as with animal manures, often needs to be applied to the land for optimal crop growth. An important byproduct of animal feeding is manure that contains P. Land application of manure can be beneficial to crop production, but also can result in increased risk of P loss to surface waters. Phosphorus indexes are tools for the assessment of the potential for P delivery from agricultural lands to surface waters. Effective Jan. 1, 2007, operators of large concentrated animal feeding operations (CAFOs) in Nebraska need to assess the risk of P delivery to surface waters from each field before manure can be applied by using a P index. This assessment needs to be done once every five years.

The Nebraska P Index (2005) is a tool for risk assessment, land management planning, education of factors contributing to P loss, and regulation of P application to agricultural land. The Nebraska P Index (2005) was developed through the integration of concepts from an earlier Nebraska P index (Kucera, 2000; revised in 2004); an index developed for Iowa (Iowa NRCS, 2004; *http://www.ia.nrcs.usda.gov/technical/Phosphorus/phosphorusstandard.html*); and recent research findings.

The P index considers source and transport factors to estimate P loss to surface waters. The source factors allow assessment of the quantity and forms of P present at the site *(Table 1)*. The transport factors allow assessment of the potential for transport of P from the site to a water body.

Table 1. Source and transport factors that contribute to the potential for P loss from agricultural lands to surface waters.

Site and management factors	*Transport factors*[1]
Soil P level	Runoff volume
P application practices including time, rate and method of application	Erosion from rainfall and snowmelt events and from irrigation events
Field management practices such as tillage practices and use of cover crops	Distance from P source to concentrated water flow or a water body

[1]Other possible transport factors that are not considered in the Nebraska P index include: surface and sub-surface drainage; percolation and underground movement of phosphorus to seepage areas; and atmospheric deposition that may be associated with wind erosion. These are relatively minor transport factors, as compared to runoff volume and erosion, for phosphorus delivery from fields to surface waters in Nebraska.

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The P index was designed to be used on the basis of a whole field or management units within a field. In many fields, risk of P loss is often considerably greater for part of a field than for the whole field and it may be economically and environmentally advantageous to do the P loss risk assessment by zones within fields.

The Structure of the Nebraska P Index (2005)

The Worksheets

The P index (*http://cnmp.unl.edu/cnmpsoftware2.html*) is developed as a spreadsheet to ease calculations. Tabs to worksheets are found at the bottom of the screen.

1. **Nebraska P-Index** is the worksheet of greatest concern to the user. All data is entered here and the results are presented.
2. **Summary** contains the summarized record of P index evaluations for up to six fields. The records are numbered one to six and coincide with the run number at the top of the **Nebraska P-Index** worksheet.
3. **Ephemeral** is a worksheet that contains two tools for estimating sediment loss due to ephemeral gully (3- to 18-inch depth) erosion. The first tool calculates an estimate of ephemeral gully erosion after entering values for total length of all ephemeral gullies in the field and their average width and depth. The second tool automatically estimates ephemeral erosion, considering the rate of sheet and rill erosion, location in the state and conservation practices.
4. **Landform Regions** contains a list and map of Nebraska showing the regions. The user can access this from the **Nebraska P-Index** worksheet.
5. **Code 393** is the Natural Resource Conservation Service (NRCS) standard for filter strips. The user can access this from the **Nebraska P-Index** worksheet.

The Components

The P index has erosion and runoff components which integrate source and transport factors to give component risk values. The irrigation and manure components modify the risk values for the erosion and runoff components. An estimate of sheet and rill erosion is calculated once data entry for a field is competed. The sum of the risk value of both the erosion and runoff components is the P index score. It is shown in the lower right part of the **Nebraska P Index** worksheet.

The **erosion component** (potential delivery of sediment P to surface water) gives an approximate estimate of the P delivered in sediment (lb P/ac/yr) which will eventually be available for use by aquatic vegetation (Mallarino et al., 2002). It assumes that 70 percent of sediment P will become bio-available to aquatic vegetation over time. The erosion component is a function of six factors.

1. Rate of sheet and rill erosion is estimated in tons per acre per year. This erosion rate may be best estimated with RUSLE2, but other means of estimating erosion, such as the Universal Soil Loss Equation or RUSLE1, may be acceptable. The Nebraska P Index (2005) does, however, calculate an estimate of sheet and rill erosion as a function of county precipitation, soil erosivity, slope length and gradient, cropping system, tillage practices, conservation practices and irrigation; this estimate is accurate enough for most fields.
2. Ephemeral gully and classical gully erosion (t/ac/yr) are estimated and prorated over the whole field or management unit. The P index provides two tools for estimating ephemeral gully erosion; see the section on the **Ephemeral** worksheet.
3. The sediment delivery ratio is estimated in consideration of land form and mean distance from the center of the slopes feeding runoff water to a water body or perennial or intermittent stream lying adjacent to or in the field, or to the nearest road ditch or other man-made conveyance lying outside the field that directs runoff water into intermittent or perennial streams, lakes or other water bodies.
4. Use of conservation practices is indicated by selection from a drop-down list and credit is given to their sediment trap efficiency.
5. Phosphorus enrichment of runoff is estimated considering tillage, surface cover and vegetative buffer or filter strip width.
6. Soil test P (STP; Bray-P1, Mehlich 3, or Olsen) is used to estimate total soil P (TP). The equations for medium and fine textured soils are TP = 400 + (2.5 x STP) when using the Bray-P1 or Mehlich-3 soil test and TP = 400 + (3.6 x STP) when using the Olsen test. For sandy soils, TP = 250 + (2 x STP) with the Bray-P1 or Mehlich-3 test and TP = 250 + (3 x STP) with the Olsen P test.

The **runoff (water loss) component** estimates the amount of dissolved P (orthophosphate P and other dissolved P) delivered with runoff water (Mallarino et al., 2002). It is a function of:

1. Mean county precipitation and percent of rainfall events that are greater than 0.75 inch;
2. Runoff curve numbers which are calculated from soil property information, land use and management practices;

Table 2. Factor values for erosion risk with furrow irrigation.

Furrow flow rate / *Furrow slope*	*Soil Erodibility*											
	Very erodible soil[1]				*Erodible soil*[2]				*Erosion resistant soil*[3]			
	<0.5%	*0.5-1.0%*	*1.0-1.5%*	*>1.5%*	*<0.5%*	*0.5-1.0%*	*1.0-1.5%*	*>1.5%*	*<0.5%*	*0.5-1.0%*	*1.0-1.5%*	*>1.5%*
Gallons/min/furrow	rating											
<5	1.5	1.5	12	12	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
10	1.5	12	12	12	1.5	1.5	6	6	1.5	1.5	3	3
15	12	12	12	12	1.5	6	6	6	1.5	3	3	3
>20	12	12	12	12	6	6	6	6	1.5	3	3	3
If an irrigated field includes tail water pit with total recapture, use a rating of 0. If polyacrylamide (PAM) is used, use a rating of 1.5.												

[1]Very erodible soils (silt, fine and very fine sandy loam, loamy fine sand, loam, and very fine sand soils)
[2]Erodible soils (silt loam soils)
[3]Erosion resistant soils (silty clay, clay, and clay loam soils)

3. An estimate of dissolved soil P (DP) estimated from soil test P where DP = 0.05 + (STP x 0.005); and
4. P application rate, time and method.

The **irrigation component** considers sprinkler and furrow irrigation. The runoff P risk factor is increased by 10 percent with sprinkler irrigation due to increased runoff potential should a heavy rainfall event occur when the soil is wet following irrigation. Risk with furrow irrigation is primarily due to increased erosion potential and the irrigation erosion factor is determined considering soil erodibility, rate of water flow (gal/min/furrow), furrow slope, use of polyacrylamide (PAM) and the presence of a re-use pit for recycling irrigation water *(Table 2)*.

The erosion and runoff components are adjusted by the **manure component** which accounts for beneficial effects on soil properties due to previous applications of manure. The values for the erosion and runoff components are reduced by two percent per ton of the mean annual rate of manure application on a dry weight basis.

Interpretation of the P Loss Ratings

The P index risk value is the sum of the erosion and runoff components. The risk scores fall into four risk levels.

- **Low (0-2).** Current practices keep water quality impairment due to agricultural P pollution low. Manure can be applied at rates sufficient to meet crop N needs.
- **Medium (2-5).** Delivery of agricultural P may cause some water quality impairment and consideration should be given to alternative conservation and P management practices. Manure can be applied at rates sufficient to meet crop N needs.
- **High (5-15).** Phosphorus loss from the field causes much water quality impairment. Remedial action, such as alternative conservation measures or P management practices, is recommended. Manure can be applied, but the amount of P applied should not exceed the amount of crop P removed. Manure can be applied to meet a crop's N need in one or more applications during a five-year period, but P applied should not exceed crop removal during that five-year period.
- **Very high (>15).** Impairment of water quality is extreme and remedial action is urgently recommended. Phosphorus application should be discontinued. Improved conservation measures should be implemented.

Using the Nebraska P Index (2005)

Information is needed for each field or management unit within a field in order to calculate a P index value *(Table 3)*. The information may be obtained from the farm operator, records and reports, and observation. The information is entered into the white cells of the **Nebraska P index** and **Ephemeral** worksheets. Values in yellow boxes are calculated based on information entered in the white boxes or selected from drop-down lists. Phosphorus index values appear in the red boxes. Throughout the **Nebraska P-Index** worksheet are **Notes** which give further explanation; move the cursor over the red arrow to the upper right of the **Note** and the message will open.

1. At the top of **Nebraska P-Index** worksheet, enter appropriate information, including field name; option if one or more assessments is done for a field such as to evaluate alternative management practices; person using the P index; and the client. The run number (1-6) is normally assigned automatically. It can be specified, for example, to revise the record of a previous assessed field.
2. Select the **County** in which the field is located from a dropdown list. The P index then accesses relevant rainfall and soils information.
3. From the **Soil Type** dropdown list, select the predominant soil unit, including the correct slope class, for the field
4. Gross erosion is determined next.
    a. Give an estimate of mean annual loss of soil to **Sheet and Rill** erosion for this field/ management unit. The estimate might be determined using RUSLE 2 (*http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm*) or by other means, or obtained from the local NRCS office. The P Index has an erosion calculator which produces an estimate once all other information for the field has been entered. To use this option, leave the sheet and rill estimate blank until other data has been entered, and then click on "Use estimate" next to the erosion estimate found on the right side of the **Nebraska P-Index** worksheet.
    b. Give estimates for **Ephemeral** and **Gully** erosion for the full management unit and the number of acres in the management unit. Clicking on **Estimate** next to **Ephemeral** provides guidance and two options for estimating ephemeral erosion.
    c. An estimate for classical or perennial **Gully** erosion can be given. If such a gully exists in the field and has not been well stabilized, e.g. with perennial vegetation, seek assistance to estimate the mean annual rate of erosion due to cutting the gully wider, deeper and/or longer.
5. Select a relevant **Conservation Practice** such as terraces from the dropdown list.
6. For **Landform Region**, select the correct part of Nebraska by clicking **View Map and Choose**. Click on a digit of the white number on the map for the correct landform region, and you will be returned to the main worksheet.
7. Enter average distance in feet for the drainage basin lying in a management unit to the nearest intermittent or perennial stream, canal or road ditch, or to another surface water body nearer than the channalized flow. More details are provided in the associated **Note**.
8. Select the **Grassed Filter Strip Width** from the dropdown list. A **Note** as well as a **Hot link** to the NRCS 393 Standard provides information on filter strips.
9. Move to the top of the central part of the **Nebraska P-Index** worksheet.
10. There are three dropdown lists for **Tillage and Cropping System.** In the **Tillage 1** dropdown list, select to indicate if the field is tilled, no-till, or in perennial vegetation. This choice affects the options offered in the **Tillage 2** and **Cropping System** dropdown lists. The **Notes** further define tillage and cropping system choices.
11. For soil test P, select **Phosphorus Test** method (Bray-P1, Mehlich 3 or Olsen) from the dropdown list and enter the P test result for the 0-8 inch depth.
12. Enter the mean annual **Application Rate** for phosphate in fertilizer and organic materials, e.g. manure, compost, and bio-solids. Select the application time and method from the dropdown list.
13. Select **Type of Irrigation** from the dropdown list. If furrow is selected, enter **flow rate** in gallons per minute per furrow and **furrow slope**.
14. Enter a value for **Manure Component**. It is explained in the associated **Note** that this is the mean annual rate of application on a dry weight basis (tons per acre per year, dry weight) and an example calculation is given.
15. The calculated partial P index values are given in yellow boxes for the **Erosion Component** and **Runoff Component.**
16. Upon filling in the white boxes on the P index spreadsheet, view the **Erosion Estimator value**. If you wish to use this as your sheet and rill erosion value, click on the "Use estimate" gray box. If using the Option #2 for the Ephemeral Estimate, go to Option #2 in the **Ephemeral** worksheet and click the "Transfer" button to receive the value in the **Nebraska P Index** worksheet.
17. The overall **P Index Value** is given in the red box on the right side of the worksheet. If you have used the Erosion Estimator for Sheet and Rill Erosion and the P Index Value borders on a risk class, e.g. between 14 to 16, you will receive a message indicating that actual RUSLE2 values should be used for a more accurate erosion estimate.

18. Click the **Summary** button to create a summary report. Click the Summary worksheet tab to go to this worksheet in order to view, save and print one or more summaries.

Repeated scenarios can be run for a field, changing management practices to assess the effectiveness of various management practices and combinations of practices. Each scenario is given a name and the data from the previous scenario can be carried forward so that only the variable or variables that are changed for the new scenario need to be entered. Detailed outputs for these scenarios are tabulated in a worksheet that can be saved and printed for further study.

Using the P Index to Compare Management Scenarios: an Example

Consider the information presented in *Table 3* for a hypothetical field to create a base scenario. For the information given, the P index score is 5.36 with a risk rating of *High*. Let's consider the effects of several alternatives on the base scenario. After each change, return to the base scenario before making another change.

1. If manure application continues and Bray P is increased to 160 ppm, the P index score is 5 with a risk rating of *High*.
2. If the land is protected with tile inlet terraces, the P index score is 0.88 with a risk rating of *Low*.
3. If 25-foot buffer strips are established between this field and concentrated water flow or the surface water body, the P index score is 4.62 with a risk rating of *Medium*.
4. If the manure is incorporated within 24 hours of application and assuming no increase in erosion, the P index score is 5.34 with a risk rating of *High*.
5. If distance from the middle of the sub-field to concentrated water flow is reduced from 600 to 150 feet, the P index score is 7.41 with a risk rating of *High*.

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Table 3. Form for collection of data required to run the P Index. Assessment may be on a whole field basis or on management zones within fields.

Field name	*County*	*Field area (acres)*	*Conservation practice*	*Ephemeral gullies (gullies 3-18" deep)*			*Distance (ft) field center to nearest water, stream or road ditch*	*Filter strip width*	*Land use/ cropping system*
				Total length	*Mean depth*	*Mean width*			
West 1/4	***Colfax***	***40***	***none***	***1200 ft***	***0.5 ft***	***1 ft***	***600 ft***	***7 ft***	***Row crops, tillage***

Field No.	*Soil type and slope*	*Soil P*		*Fertilizer + manure P_2O_5 application*		*Sprinkler irrigation*	*Furrow irrigation*				*Mean manure application tons/yr, d.wt.*
		Test	*ppm*	*Lbs/ac/yr*	*Method*		*Rate gpm*	*Furrow slope*	*PAM*	*Reuse pit*	
1	***Nora 6-11 %***	***Bray***	***95***	***100***	***Surf app***	***No***	***No***	***No***	***No***	***No***	***10***