Minnesota Phosphorus Site Risk Index

Worksheet User's Guide

Department of Soil, Water, and Climate

University of Minnesota

1991 Upper Buford Cr.

St. Paul, MN 55108

Phone:
612 625-1244

Revised November 2006

The Minnesota Phosphorus Index

This document is the User's Guide for calculating risk of phosphorus (P) movement from land to water using the Minnesota P Site Risk Index. The calculation is completed by following instructions in the *Calculation Worksheet* (page 5) and using the series of support tables and figures (pages 6 to 16). Details about the development process and justification for each element in the Index are available in a companion document, "*The Minnesota Phosphorus Site Risk Index Technical Guide.*"

The Minnesota P Site Risk Index is based on the concept of independent pathways of P delivery from a field to water. The Index computes a risk score by combining input factors related to P transport and P sources within each pathway. The three pathways considered are 1) sediment-bound P from rainfall runoff, 2) soluble P from rainfall runoff, and 3) soluble and particulate P from snowmelt runoff. Wind and gully erosion are not accounted for.

I. Sediment-Bound P, Rainfall

Calculations in this pathway estimate the risk of P losses from a field to water by erosion transport processes. This pathway accounts for the following four components.

Sediment Delivery Rate. The long-term average annual sediment delivery is estimated using the Revised Universal Soil Loss Equation 2 (RUSLE2, USDA-NRCS, 2003). RUSLE2 calculations should be based on the "most limiting area of significant extent," i.e., that critical part of the field most subject to soil loss (Minnesota Natural Resources Conservation Service, 2004). Assistance in obtaining a sediment delivery estimate can be obtained from the local office of the USDA-NRCS. Estimating sediment delivery for the P Index is slightly different than estimating soil loss for conservation planning. Specifically, a complex slope (multiple segments with different gradients) should be used rather than a simple slope. This allows RUSLE2 to estimate the deposition that occurs on the toeslope. Also, annual sediment delivery figures should be used instead of rotation averages. Using a complex slope and annual results both require the use of the "science" template in RUSLE2.

Manure Factor. The manure factor is used to reduce the soil erosion estimate if manure was injected or incorporated within the last three years. Use a manure factor of one if manure is surface applied and not incorporated.

Weighted Sediment Delivery Factor. In this step, the soil erosion estimate is reduced to account for three types of sediment deposition that are not accounted for in RUSLE2: 1) deposition from runoff as it flows from the field to the nearest surface water body; 2) in-field and field edge sediment traps, including buffers, filter strips, and terraces; and 3) deposition associated with standing water, including sediment control basins, other impoundments, and natural landscape depressions (with or without surface tile inlets).

Use Table 2 to enter information about all these types of sediment deposition and to determine the weighted Sediment Delivery Factor.

At this time, buffers and filter strips should not be included in RUSLE2. RUSLE2 generally credits vegetated strips with greater reductions in sediment delivery than is measured in real fields, leading to a distorted view of how effectively vegetated strips reduce P loss risk.

To determine the **distance to surface water**, the user must decide which surface waters are of interest. Generally, a permanent stream, lake, or wetland is the primary water quality concern, but any water course that is wet most of the year (e.g., drainage ditches or intermittent streams) should be considered surface water for purposes of the P Index, because they eventually lead to streams and lakes. Sinkholes may also be considered surface water.

Sediment Total P Concentration. The concentration of total P associated with delivered sediment is estimated based on percent soil organic matter and the results of an Olsen, Bray, or Mehlich P soil test determined within the past 3 years. Table 3 is provided to make this calculation. For high P soils (>100 ppm Bray, >100 ppm Mehlich, or >50 ppm Olsen) a "Nutrient Management Phosphorus Test" is recommended.

An optional calculation is provided in Table 3 to estimate changes in soil P concentration based on crop removal or P additions since the last soil test. This optional calculation is only needed for very high P application rates or when the P Index is used for long range planning (> 5 yrs).

II. Soluble P, Rainfall

This pathway estimates the risks of soluble P losses in rainfall runoff. The risk is a function of the estimated runoff volume and the concentration of soluble P in rainfall runoff. The concentration of soluble P in rainfall runoff is the combination of soluble P originating from the soil (including injected or incorporated P fertilizer and manure applied since the last soil test) and P losses from unincorporated manure or surface fertilizer P applied during the current crop year. (Crop years are defined as the period between harvest of one crop and harvest of the succeeding crop).

Runoff Volume. A base runoff volume map is provided (Figure 2) that reflects differences in runoff due to geographic differences in historical rainfall patterns. The base runoff is then modified for site specific conditions using the **Runoff Adjustment Factor** (Table 4).

Soluble P from Soil. The concentration of soluble P in runoff is calculated from the soil test P using Table 3. As in the previous steps, the soil test should be taken within the last three years. If the optional adjustment in soil test was calculated in the Sediment-Bound P section, then the adjusted value should also be used here. Similarly, the Nutrient Management Phosphorus Test is recommended for high P soils (>100 ppm Bray, >100 ppm Mehlich, or >50 ppm Olsen).

Soluble P from Applied Fertilizer or Manure. This step accounts for direct losses of soluble P associated with fertilizer and manure applied during the spring, summer, or fall (April 1 through November 15). The highest risk of a direct loss of applied P occurs when P is surface applied without incorporation. The risk decreases as a function of the incorporation efficiency of the tillage tool used. The calculation gives a zero risk of direct P loss for injected P applications, on the assumption that no manure is left at the surface. A worksheet (Table 5) is provided to determine rate of P applied with manure based on the manure application rate and the concentration of P in manure. It is recommended that a manure analysis be performed for each application period, but if a manure analysis is not available, the P content can be estimated from Table 8.

III. Soluble P, Snowmelt

This pathway assesses the risk of P loss in snowmelt runoff. An estimate of the volume of runoff is made based on historical snow records and soil roughness. The mass of P loss is estimated as a percentage of P on the soil surface in crop residue or P applied during winter as manure or fertilizer.

Snowmelt Runoff Factor. A map is provided (Figure 3) that shows the potential snowmelt runoff for different areas of the state. The base snowmelt runoff volume represents the potential maximum runoff for a geographic area. The **Fall Soil Condition** factor (Table 6) uses site-specific conditions to modify the actual snowmelt runoff volume.

P Sources for Snowmelt. Phosphorus lost in snowmelt runoff can originate from crop residue or from winter applied fertilizer or manure. The amount of P in **crop residue** is based on crop, crop yield, and tillage practice (Table 7). **Winter applied P** is defined as any application occurring after November 15 and before April 1. A worksheet is provided to calculate the quantity of P applied as fertilizer or manure during this time period (Table 5). To determine rate of P applied with manure, both the manure application rate and the concentration of P in manure are required. It is recommended that a manure analysis be performed for each application period. If a manure analysis is not available, the P content can be estimated from Table 8.

Overall Risk

The overall P site risk score is the sum of the risk values for each of the three pathways. The calculated risk is classified as very low, low, medium, high, or very high (Table 9). When risk is in the very low or low categories, no changes or minor changes in management are recommended. In the medium risk category, small improvements in management may be necessary to lower the risk of P losses, and the producer should avoid management practices that increase the risk of P losses. In the high risk category, moderate improvements in management are recommended to reduce the P Index. In the very high risk category, multiple and possibly large improvements in management practices are recommended.

By noting which pathway accounts for most of the P loss risk, users can identify the causes of high risk and can suggest management practices that will be most effective for reducing risk. Recommended practices are listed in Table 9.

Minnesota Phosphorus Site Risk Index

Calculation Worksheet

Use this worksheet and the accompanying tables and figures to calculate the Minnesota Phosphorus Site Risk Index Score. For each pathway, the first row of cells names the factor, the second row explains where to obtain the value, and the third row provides space to enter the value and perform the calculations. Multiply all four factors of each pathway, and then add the results from the three pathways to get a total risk. Table 9 provides management recommendations based on the results.

Pathway I. Sediment Bound P, Rainfall

Sediment Delivery Rate		Manure Factor		Weighted Sediment Delivery Factor		Soil Total P Concentration		SEDIMENT-BOUND P LOSS RISK
RUSLE2		Table 1		Table 2		Table 3, line 10		Multiply all factors and enter value here
	x		**x**		**x**		=	

+

Pathway II. Soluble P, Rainfall

Base Runoff Volume		Runoff Adjustment Factor		Soluble Soil P + Applied P		Coefficient		RAINFALL RUNOFF P LOSS RISK
Figure 2		Table 4		Table 3 line 11 + Table 5A line 8 Add the 2 values		Constant		Multiply all factors and enter value here
	x		**x**		**x**	**0.22**	=	

+

Pathway III. Soluble P, Snowmelt

Snowmelt Runoff Factor		Fall Soil Condition Factor		Residue P + Surface Applied P		Coefficient		SNOWMELT RUNOFF P LOSS RISK
Figure 3		Table 6		Table 7 + Table 5B Line 14 Add the 2 values		Constant		Multiply all factors and enter value here
	x		**x**		**x**	**0.18**	=	

↓

Total P Loss Risk

Relative risk rating and management recommendations from Table 9:

TOTAL P LOSS RISK
Sum risks from all pathways

Table 1. Manure Factor[a, b]

Manure Application Method	Manure Factor c
Broadcast and incorporated or injected	0.75
No manure applied or unincorporated manure	1.0

[a]For manure applied within the last 3 years.
[b]Manure application is not permitted within 25 ft. of surface water (perennial and intermittent streams, lakes and protected wetlands, and drainage ditches without berms). Manure applied within 300 ft. of surface water or a surface tile inlet must be injected or incorporated within 24 hr. and before rainfall (see Applying Manure in Sensitive Areas, MPCA and NRCS).
[c]Gilley and Risse, 2000.

Figure 1. SDR vs. Flow Distance from Edge of Field to Nearest Surface Water.

Use the 5000 ft. value (SDR = 0.17) for flow distances greater than 5000 ft.

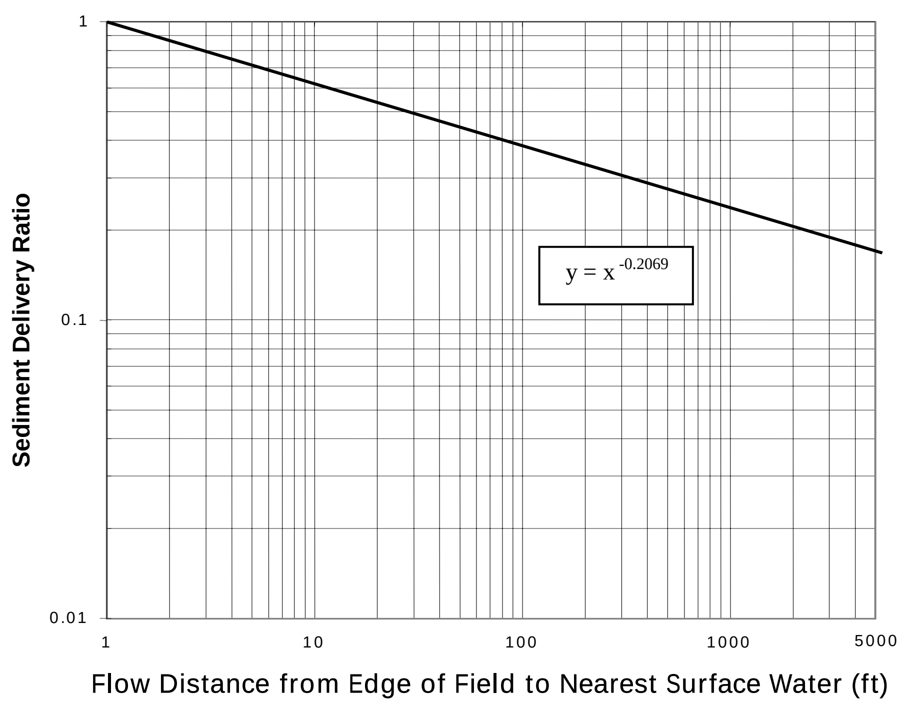

Table 2. Weighted Sediment Delivery Factor[a]

Natural Depressions (Prairie Potholes) **1. Contributing area.** Enter the proportion of the field that drains to natural depressions, as a decimal. (E.g., if ¾ of the field drains to depressions, enter 0.75. If there are no depressions, enter 0.)	1.	
2. Inlets and depressions. Enter the factor that represents most of the depressions: *Depressions without inlets* *0.05* *Depressions with rock/gravel inlets* *0.15* *Depressions with open surface tile inlets* *0.2* *No depressions* *1*	2.	
3. Sediment delivery factor for depressions Multiply line 1 by line 2.	3.	
Distance to Water **4. Sediment delivery ratio based on distance.** Enter the sediment delivery ratio from Figure 1 (previous page).	4.	
Sediment Traps **5. Sediment traps.** If the field has any of the following sediment traps that meet NRCS Practice Standard Guidelines, enter the appropriate factor. If you have more than one, choose the smallest factor. If you included any of these in your RUSLE2 calculation, do not include them here. *Impoundment with runoff storage* *0.05* *Water and sediment control basin* *0.2* *Terraces* *0.4* *Buffer or filter strip* *0.5* *None* *1*	5.	
6. Enter the smaller of line 4 or line 5**.**	6.	
7. Proportion of runoff not draining to depressions (as a decimal) Enter 1 minus the value entered in line 1. If no natural depressions, enter 1.	7.	
8. Multiply line 6 by line 7.	8.	
Weighted Sediment Delivery Factor **9.** Add line 8 plus line 3.	9.	

[a] Trapping factors for standard surface tile inlets and gravel inlet structures based on Minnesota research data (Ranaivoson, 2004; Ginting et al., 2000; Gieseke, 2000). Factors for impoundments and water & sediment control basins from the Iowa P Index (Iowa NRCS, 2001, Table 1).

Table 3. Soil Phosphorus Worksheet

Soil test phosphorus values are an important input for the P Index calculation. You are encouraged to use a soil analysis within the past 3 years. This worksheet converts your soil test results to the format required in the P Index calculations. Read your soil test report carefully as you do each of the following steps. Be equally as careful when entering applied P values.

	1. Enter the **soil test phosphorus** concentration from the test report.	1.	
	2. Convert to ppm. If the units are lbs P_2O_5/ac, then divide box 1 by 4.5 and enter in box 2. If the soil test report gives phosphorus in parts per million (ppm), then copy the value from box 1 to box 2. .	2.	
	3. Convert to Olsen Test P. Bray P-1 x 0.71 = Olsen P Mehlich P x 0.65 = Olsen P Use the above equations to convert Bray or Mehlich P test results to an Olsen equivalent. If the value was already an Olsen test, then re-enter the value from line 2.	3.	
Optional Adjusted Soil Test	*Lines 4-8 are optional calculations that will estimate the change in soil test P since last soil test to the present or a future time due to incorporation or injection of P. Use this option for long range planning when manure application rates are high.* **4**. Enter the number of **years since the last soil test** to the end of the projection.	4.	
	5. P removed: For harvested crops, multiply line 4 by 30 and enter the value. For non-harvested crops, enter 0.	5.	
	6. P added: Enter the total lbs P_2O_5 added as fertilizer and manure since the last soil test to the end of the projection.	6.	
	7. Subtract line 5 from line 6. Values may be positive or negative.	7.	
	8. Soil buffering factor. For sandy loam or coarser textured soils, multiply line 7 by 0.05, for loam or finer texture soil, multiply line 7 by 0.03, for calcareous soils (pH> 7.4), multiply line 7 by 0.02.	8.	
	9. Adjusted Olsen soil test P = line 3 + line 8 If you did not do optional calculation, then enter the value from line 3.	9.	
	10. Calculate soil Total P concentration: Total P (lb P/ton) = (0.00497 x line 9) + (0.0725 x %OM) + 0.6322	10.	
	11. Calculate Soluble Soil P concentration: Soluble Soil P Concentration (ppm) = 0.0106 x line 9	11.	

Figure 2 -- Estimated Base Rainfall Runoff
From Minnesota NRCS, unpublished. Assumes Runoff Curve Number (RCN) of 78 and average hydrologic condition (infiltration capacity).

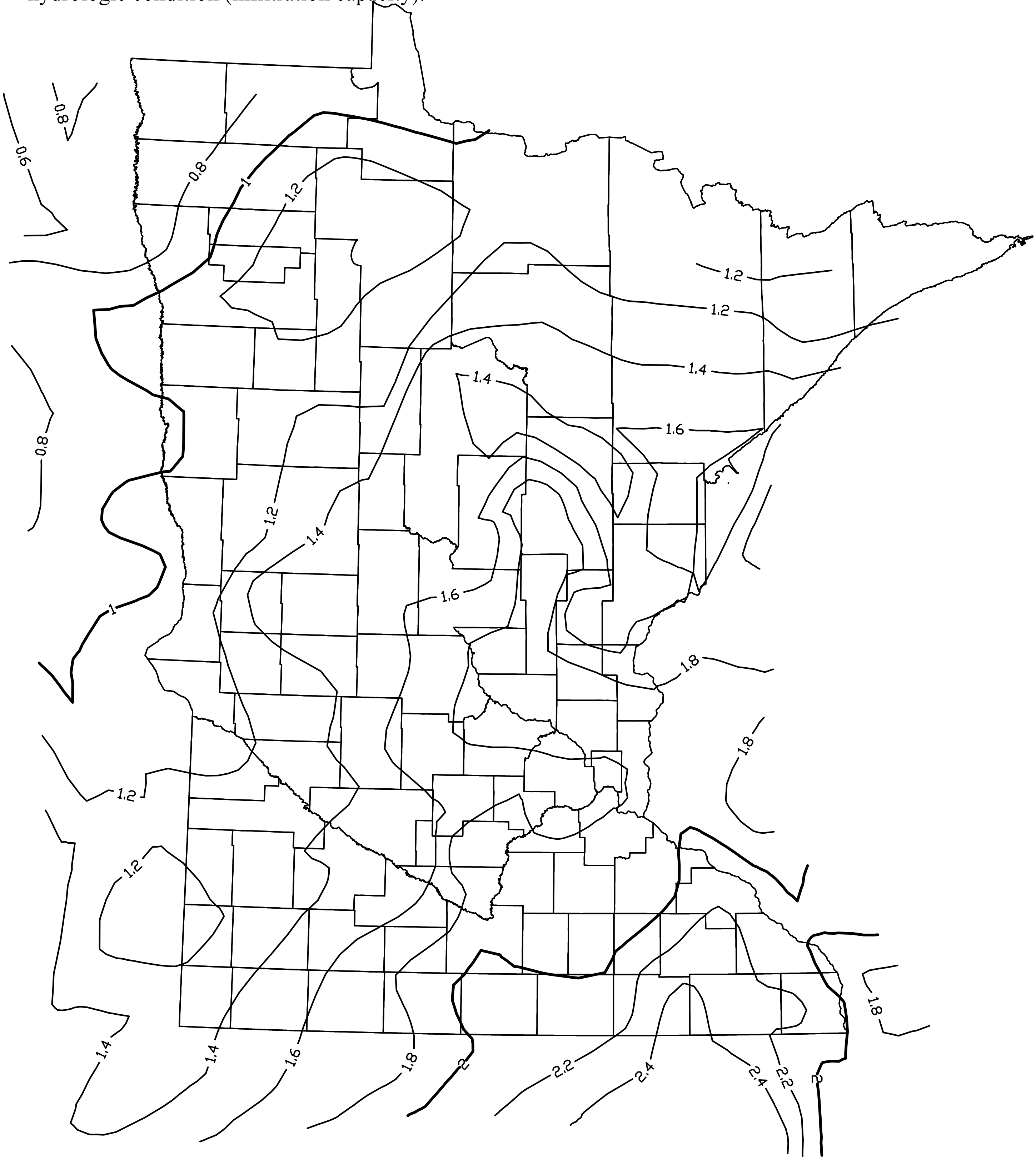

Table 4. Rainfall Runoff Adjustment Factors for Different Soil Drainage Classes and Amount and Types of Vegetative Cover[a]

Soil hydrologic group[b]	A			B			C			D		
Surface cover[c] (%)	**<5**	**5-20**	**>20**	**<5**	**5-20**	**>20**	**<5**	**5-20**	**>20**	**<5**	**5-20**	**>20**
Vegetation type	**-------- Adjustment Factor --------**											
Row crops	0.56	0.42	0.25	1.35	1.00	0.75	2.63	1.96	1.48	3.58	2.65	1.98
Small grains	0.27	0.22	0.15	0.84	0.67	0.55	1.82	1.48	1.23	2.63	2.17	1.82
Alfalfa and other forages	----	----	0.12	----	----	0.55	----	----	1.37	----	----	1.98
Pasture[d]	----	----	0.02	----	----	0.30	----	----	1.08	----	----	1.82
CRP and other ungrazed, permanent vegetation[e]	----	----	0.01	----	----	0.12	----	----	0.50	----	----	1.00
Woodland[f]	----	----	0.01	----	----	0.15	----	----	0.62	----	----	1.10

[a]USDA-NRCS, 1990. *Engineering Field Manual*.
[b]Use hydrologic group B for soils where subsurface drainage systems have been installed to improve naturally poor drainage conditions.
[c]For cultivated crops, percent residue cover after planting.
[d]Based on pastures in "fair" condition (50-75% ground cover and not heavily grazed).
[e]Meadows, native prairie, golf courses, and similar areas.
[f]Based on a woodland in "fair" condition (50-75% ground cover and not heavily grazed).

Table 5. Applied Phosphorus Worksheet

This worksheet is used to assess the risk of a direct loss of applied P. Winter and non-winter fertilizer or manure applications are calculated separately. For injected manure, a value of zero will be derived.

Table 5A: Non-Winter P Applications (April 1-November 14)

1. Fertilizer P: Enter the amount of surface applied fertilizer in lbs P_2O_5/ac.	1.	
2. Manure amount: Enter the amount of surface applied manure in T/ac or 1000 gal/ac.	2.	
3. Manure test: Enter the P_2O_5 content of the surface applied manure (from analysis or Table 8) in lbs P_2O_5/T or lbs P_2O_5/1000 gal.	3.	
4. Manure P: Multiply line 2 by line 3.	4.	
5. Fertilizer + manure P: Add line 1 and line 4.	5.	
6. Incorporation factor Enter the value that most closely matches the incorporation method within one week of application. *Tillage* — *P Fraction at surface* *No Incorporation* — *1.0* *Disk* *Small* — *0.5* *Large* — *0.4* *Chisel* *Sweeps* — *0.45* *Straight* — *0.35* *Twisted* — *0.25* *Disk-Chisel* — *0.15* *Moldboard plow* — *0.05* *Inject* — *0*	6.	
7. P at surface (P_2O_5/ac): Multiply line 5 by line 6	7.	
8. P available at surface (ppm P): Multiply line 7 by 0.044	8.	

Table 5B: Winter P Applications (November 15 - March 31)

9. Fertilizer P: Enter the amount of surface applied fertilizer in lbs P_2O_5/ac	9.	
10. Manure amount: Enter the amount of surface applied manure in t/ac or 1000 gal/ac.	10.	
11. Manure test: Enter the P_2O_5 content of the surface applied manure (from analysis or Table 8) - lbs P_2O_5/t or lbs P_2O_5/1000 gal	11.	
12. Manure P: Multiply line 10 by line 11	12.	
13. Fertilizer + manure P (lbs P2O5/ac): Add line 9 and line 12	13.	
14. P available at surface (lbs P/ac): Multiply line 13 by 0.44	14.	

Figure 3. Snowmelt Runoff Factors for Different Regions of Minnesota.

Large numbers (0.5, 0.8, 1.15, and 1.45) are the snowmelt runoff factors for use in the snowmelt pathway. These four snowmelt runoff regions are separated by Average Snow Water Equivalent Isolines for March 16-31. (Source: USDC – Weather Bureau Technical Paper No. 50: *Frequency of Maximum Water Equivalent of March Snow Cover in North Central United States*).

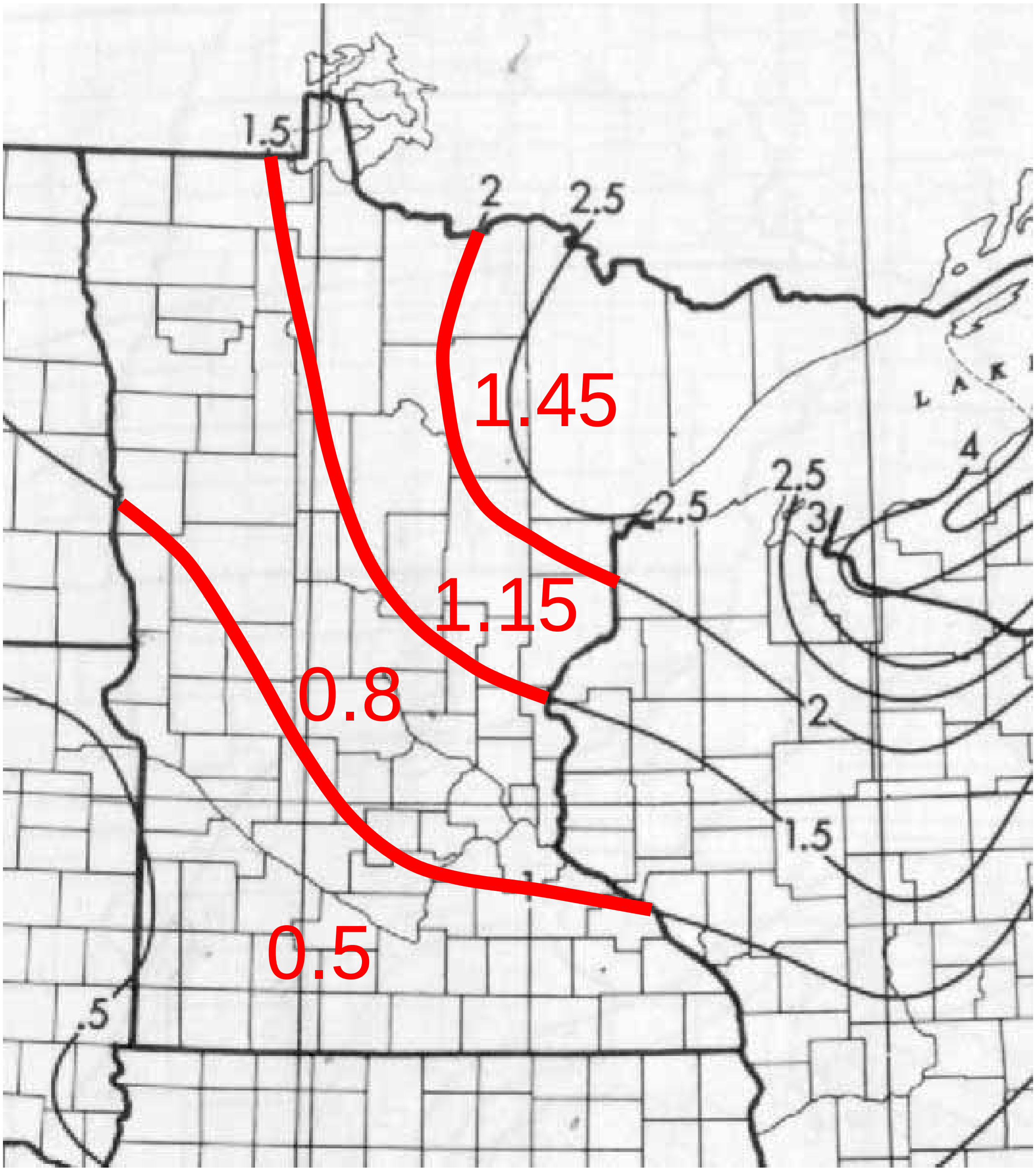

Table 6. Fall Soil Condition Factors for Snowmelt Runoff Transport[a]

For fall manure injections with no other fall tillage, choose "Anhydrous Ammonia" for low disturbance injections or "Fall Disk" for high disturbance injections.

	Tillage and Planting Orientation[b, c]	
Type of Fall Tillage	Up and Down Slope	Cross Slope/Contour
No Fall Tillage	1.00	0.75
Anhydrous Ammonia (with no other fall tillage)	0.85	0.70
Ridge Till	0.75	0.40
Fall Disk	0.75	0.60
Chisel Plow, Strip Till	0.60	0.40
Moldboard Plow	0.30	0.20

[a]Based on data from Ginting et al., 1998; Hansen et al., 2000; Hansen et al., 2001; Munyankusi, 1999.
[b]Use No Fall Tillage values for pasture, CRP, and similar conditions.
[c]For relatively flat fields, use the Cross Slope/Contour column.

Table 7. Estimated P Content of Surface Crop Residue Following Different Crops, Yields, and Fall Tillage Operations.

If your crop is not listed, choose one that leaves a similar amount and type of cover in the fall.

Table 7A: Perennial Crops and Vegetation	Yield or stocking density (tons/acre or animal units/acre)	Standing vegetation in the fall (dry wt, tons/acre)	**P in surface vegetation** lb P/acre
Alfalfa and other forages[c] (2 yield levels)	4	0.5	**3**
	8	1.0	**6**
Pasture[d] (3 stocking densities)	1.5	0.25	**1**
	1	0.5	**2**
	0.75	0.75	**3**
CRP and other ungrazed permanent vegetation[e]		3.0	**12**

Table 7B: Annual Crops		**Surface Residue P** (lb P /acre)									
		Fall Tillage (No Anhydrous Ammonia)					Fall tillage and Fall Anhydrous Ammonia				
	Yield	NT	RT	CP	MP	DISK	NT	RT	CP	MP	DISK
Corn, grain[a] (bu/ac)	80	5.2	5.2	2.2	0.2	3.4	4.3	4.3	1.5	0.2	2.3
	100	7.5	7.5	3.2	0.3	4.8	6.2	6.2	2.2	0.3	3.3
	150	10.0	10.0	4.2	0.4	6.5	8.2	8.2	2.9	0.4	4.5
	180	12.5	12.5	5.3	0.5	8.1	10.3	10.3	3.6	0.4	5.6
Corn, silage[a] (t/ac)	15	0.7	0.7	0.2	0	0.4	0.6	0.6	0.2	0	0.3
	25	1.1	1.1	0.4	0	0.6	1	1	0.3	0	0.5
	35	1.5	1.5	0.5	0	0.8	1.4	1.4	0.4	0	0.7
Soybeans[a,b] (bu/ac)	30	1.9	1.9	0.3	0.1	0.6	0.5	0.5	0.1	0.0	0.2
	40	2.6	2.6	0.4	0.1	0.8	0.7	0.7	0.1	0.1	0.3
	50	2.8	2.8	0.6	0.2	1.0	0.9	0.9	0.2	0.1	0.4
	60	3.8	3.8	0.6	0.2	1.1	1.1	1.1	0.2	0.1	0.5
Wheat[a] (bu/ac)	40	3.2	3.2	1.1	0.1	1.7	2.2	2.2	0.8	0.1	1.1
	60	4.0	4.0	1.4	0.1	2.1	2.8	2.8	1.0	0.1	1.4
	80	4.3	4.3	1.8	0.1	2.7	3.5	3.5	1.3	0.1	1.8
Oats[a] (bu/ac)	80	5.6	5.6	2.6	0.2	3.7	4.8	4.8	1.7	0.2	2.6
	100	8.7	8.7	4.1	0.3	5.8	7.5	7.5	2.7	0.3	4.1
Barley[a] (bu/ac)	65	3.1	3.1	1.2	0.1	1.8	2.4	2.4	0.9	0.1	1.3
	100	5.3	5.3	2.1	0.2	3.1	4.1	4.1	1.5	0.1	2.2

NT = no fall tillage, RT = ridge till, CP = chisel plow, MP = moldboard plow

[a] Estimates of residue P calculated using data from: Halsey, 1986; Wischmeier, 1973; Hanway and Olsen, 1980.
[b] P content of surface soybean residue assumes that leaf P is leached into the soil before the soil freezes.
[c] Values estimate the amount of P in fall re-growth for alfalfa, grass, or mixed forage stands that will be over-wintered and remain in hay the following year. Assumes a P concentration in re-growth of 0.3% for both legumes and grasses. Mays et al., 1980.
[d] Assumes primarily grass with an average P concentration in ungrazed fall growth of 0.2%. Mays et al., 1980.
[e] Assumes an average P concentration of 0.2%.

Table 8. Approximate Phosphorus (P_2O_5) Content[a] of Manure from Different Types of Livestock and for Different Management Conditions.

Solid Manure	
Animal Species	**P_2O_5**
	lb/ton
Swine	8
Dairy	3
Beef	4
Poultry	46
Turkey	50
Sheep[c]	10
Horse[c]	4

Liquid Manure		
Animal Species	**Waste Handling System**	**P_2O_5**
		lb/1000 gal
Swine	Slurry[b]	35
	Anaerobic lagoon	2.2
Dairy	Slurry[b]	15
	Anaerobic lagoon	2.7
Beef	Slurry[b]	17
	Anaerobic lagoon	2.9
Poultry	Slurry[b]	43
	Anaerobic lagoon	3.6
Turkeys	Slurry[b]	39

Manure P from Grazed Livestock[d]	
Animal Species	**Annual P_2O_5 on Pasture Surface**
	lb/acre per animal unit[e]
Dairy	29.7
Beef	31.2
Sheep	30.4
Horse	16.7

[a] Values adapted from MidWest Plan Service, 2001.
[b] Underfloor pits, outdoor storage tanks or basins, and continuous pumping systems with drag-hose injection.
[c] MidWest Plan Service, 1993.
[d] Assumes an annual grazing season of May 15 to Oct. 15.
[e] One animal unit is 1,000 lb of any type of livestock.

Table 9. Interpretation of Total P Loss Risk

Total P Loss Risk	Relative Risk	Recommended Changes
0 to 1	Very Low	None
1 to 2	Low	Minor changes in management.
2 to 4	Medium	Small improvements in management may be necessary to lower the risk of P losses. The producer should avoid management practices that increase the risk of P losses.
4 to 6	High	Moderate improvements in management are recommended to reduce the risk of P losses.
>6	Very High	Multiple and possibly large improvements in management practices are recommended.

Recommended management practices

To reduce losses of sediment-bound P in rainfall runoff (Pathway 1):

- ✓ Reduce erosion by
  - reducing tillage,
  - increasing residue cover left after planting,
  - converting to permanent vegetation,
  - adding forages, cover crops, or small grains to the crop rotation,
  - planting on the contour.
- ✓ Add sediment traps such as buffer strips.
- ✓ Prevent or reduce high soil test P levels.

To reduce losses of soluble P in rainfall runoff (Pathway 2):

- ✓ Reduce runoff by
  - increasing residue cover after planting,
  - growing forages, small grains, or permanent vegetation.
- ✓ Incorporate or inject all manure and fertilizer.
- ✓ Minimize over-application of manure.
- ✓ Prevent or reduce soil test P levels.

To reduce losses of soluble P in snowmelt runoff (Pathway 3):

- ✓ Eliminate application of manure on frozen ground.
- ✓ Leave soil surface rough in the fall.
- ✓ Till across the slope.

References

Gieseke, T.M. 2000. A comparison of sediment and phosphorus losses from rock inlets and open tile inlets in the lower Minnesota river basin. M.S. Thesis. Minnesota State University, Mankato, MN.

Gilley, J.E. and L.M. Risse. 2000. Runoff and soil loss as affected by the application of manure. Trans. ASAE. 43:1583-1588.

Ginting, D., J.F. Moncrief, and S.C. Gupta. 2000. Runoff and contaminant losses into surface tile inlets draining lacustrine positions. J. Environ. Qual. 29:551-560.

Ginting, D., J.F. Moncrief, S.C. Gupta, S.D. Evans. 1998. Interaction between manure and tillage system on phosphorus uptake and runoff losses. J. Environ. Qual. 27:1403-1410.

Halsey, C. 1986. Managing surface residue for erosion control (ch.1, Fig. 2 and Tables 1 and 3). In: Conservation Tillage for Minnesota, AG-BU-2402. Minnesota Extension Service.

Hansen, N.C., A.Z.H. Ranaivoson, J.F. Moncrief., J.J. Xia, E. Dorsey, and S.C. Gupta 2001. Acceleration of adoption of best management practices for reducing agricultural nonpoint source pollution using a paired watershed technique to support an educational effort. Twin Cities Water Quality Initiative Project. Interim report submitted to the Metropolitan Council, Natural Resources Division.

Hansen, N.C., S.C. Gupta, and J.F. Moncrief. 2000. Snowmelt runoff, sediment, and phosphorus losses under three different tillage systems. Soil Till. Res. 57: 93-100.

Hanway, J.J. and R.A. Olsen. 1980. Phosphate nutrition of corn, sorghum, soybeans, and small grains (ch. 24, Table 3). In: The Role of Phosphorus in Agriculture. ASA-CSSA-SSSA.

Iowa Natural Resources Conservation Service (NRCS). 2001. Iowa Technical Note No. 25, Iowa Phosphorus Index.

Mays, D.A., S.R. Wilkinson, and C.V. Cole. 1980. Phosphorus nutrition of forages (ch. 28, Tables 6 and 8). In: The Role of Phosphorus in Agriculture. ASA-CSSA-SSSA.

MidWest Plan Service. 2001. Manure Characteristics (Tables 6, 8, and 11) and Manure Storages (Tables 5-3, 5-4, and 5-5). MWPS-18, Sections 1 and 2. Iowa State University.

MidWest Plan Service. 1993. Livestock Waste Facilities Handbook (Table 10-6). MWPS-18, 3rd ed. Iowa State University.

Minnesota Natural Resources Conservation Service. 2004. Most limiting area of significant extent. Agronomy Tech Note #MN-14. Available online at http://www.mn.nrcs.usda.gov/technical/ecs/TechNotes/AgronTechNote14.pdf (Verified 18May05.)

Minnesota Pollution Control Agency (MPCA) and Natural Resources Conservation Service (NRCS). Applying manure in sensitive areas.

Munyankusi, E. 1999. Tillage and timing of manure application impacts on water quality in karst terrains. Ph.D Thesis. University of Minnesota. St. Paul, MN.

Ranaivoson, A.Z.H. 2004. Effect of fall tillage following soybeans and the presence of rock filters on runoff, losses of solids, organic matter, and phosphorus on a field scale. Ph.D. Thesis, University of Minnesota. St. Paul, MN.

USDA - Natural Resources Conservation Service. 2003. User's Guide, Revised Universal Soil Loss Equation Version 2 (RUSLE2).

USDA - Natural Resources Conservation Service. 1990. Engineering Field Manual. Chapter 2, Estimating runoff and peak discharges.

USDC. Frequency of maximum water equivalent of March snow cover in north central United States. Weather Bureau Technical Paper No. 50.

Wischmeier, W.H. 1973. Conservation tillage to control water erosion (Fig. 2). In: Conservation Tillage Proceedings. Soil Conservation Society.