TECHNICAL NOTES

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THE PHOSPHORUS INDEX

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The Phosphorus Index for Oregon was developed by a nutrient management advisory group comprised of members from the Natural Resources Conservation Service in Oregon and Washington, Oregon State University, Washington State University, and the agricultural industry.

The Phosphorus Index is a field-level assessment tool designed to evaluate the relative potential for off-site movement of phosphorus from the landscape. The purpose of the Phosphorus Index is to provide field personnel, watershed planners, and land managers with a tool to assess various soils, landforms, and management practices for potential risk of phosphorus movement into surface waters. Conservation planners can use the Phosphorus Index to develop alternatives that include management and conservation practices that will reduce the potential for phosphorus transport to surface waters.

Phosphorus Concerns in the Environment

Eutrophication is the process of enrichment of water with nutrients, mainly phosphorus and nitrogen, which results in excessive growth of algae and nuisance aquatic plants. The movement of phosphorus in runoff and eroded sediment from agricultural land to surface water can accelerate eutrophication. Phosphorus is the limiting nutrient in most fresh water systems. The eutrophic condition and excessive aquatic plant growth cause depletion of oxygen in water due to heavy oxygen demand by microorganisms as they decompose organic material. The pH of water also increases as algae and other aquatic plants consume carbon dioxide.

Eutrophication impairs water use for fisheries, wildlife, recreation, agriculture, industry, and drinking due to excessive growth of algae and other aquatic plants. Some blue-green algae can form compounds that are toxic to livestock, humans, and other animals. Accelerated eutrophication is often associated with increases in water pH, causing an increase in ammonia concentrations, which can be harmful to fish and other aquatic animals.

Phosphorus Movement in the Landscape

Phosphorus movement in runoff occurs in sediment-bound and dissolved forms. Sediment P is attached to mineral and organic particles and is transported during erosion events. In general, sediment P contributes about 60 to 90 percent of the P transported in runoff from most cultivated land. Dissolved P makes up the largest portion of the total P in runoff from non-cultivated lands such as pastures, hayland, forests, and cropland using no-till practices. Most sediment P is not readily available for algae and plant uptake because it is chemically bound with mineral (particularly iron, aluminum, and calcium) and organic compounds. Sediment P can however represent a long-term source of P for algae and aquatic plant uptake from the water body. Most dissolved P is immediately available for aquatic plant uptake.

Phosphorus Movement Factors

The main factors influencing P movement can be separated into two main categories: **transport and source factors.** The following factors are considered in the Phosphorus Index for Oregon.

Transport factors:
- Yearly erosion rate by crop(sheet and rill, wind)
- Irrigation-induced erosion
- Runoff class
- Flooding frequency
- Distance to surface waters / buffer width
- Subsurface drainage

Source Factors:
- Soil test P concentration
- Commercial P fertilizer application rate
- Commercial P fertilizer application method
- Organic P source application rate
- Organic P source application method

Each factor is assigned a ***Phosphorus Loss Rating*** of ***None, Low, Medium, High, or Very High*** based on the relative risk of phosphorus transport to surface waters. In addition, each factor is assigned a ***Factor Weight*** ranging from 0.25 to 1.50, based on the relative contribution of that factor to P transport.

Separate Phosphorus Indices were developed for Western and Eastern Oregon. Differences in cropping systems, tillage practices, irrigation systems, climatic factors, and soil phosphorus testing methods across the state made it necessary to have separate indices.

Descriptions of Phosphorus Index Factors

Yearly Soil Erosion

This factor includes both sheet and rill and wind erosion. Irrigation-induced erosion is addressed in other factors. Sheet and rill erosion is the detachment of soil particles by raindrop impact, surface runoff from rainfall, and snowmelt runoff on frozen or thawing soil. Wind erosion is the detachment and transport of soil particles by wind forces. Sheet and rill erosion rates are estimated with the Revised Universal Soil Loss Equation (RUSLE2). Wind erosion rates are estimated using the Wind Erosion Equation (WEQ). These soil loss models predict long-term average erosion rates, over the entire crop rotation, in tons of soil loss per acre per year.

The Phosphorus Index requires an entry of the annual erosion rate by crop for the year(s) of the manure application. This provides a more accurate way to assess the risk of manure and nutrient runoff. Instructions for pulling annual soil loss values from RUSLE2 and WEQ are outlined in "**Procedures for Making a Phosphorus Index Assessment"** beginning on Page 6.

RUSLE2 and WEQ do not predict sediment transport and delivery to a water body. The prediction models are used here in the Phosphorus Index to quantify the movement of soil, thus potential for sediment and attached phosphorus transport on a slope or unsheltered distance toward a water body.

Soil Erosion from Sprinkler Irrigation

This factor is evaluated by comparing the application rate of the sprinkler irrigation system (inches of water per hour) with the infiltration rate of the soil. A visual assessment of runoff and soil erosion caused by irrigation water is also conducted to assign a *Phosphorus Loss Rating* to this factor.

Soil Erosion from Surface Irrigation

This factor is used on fields that are surface irrigated through furrows or corrugations with devices such as siphon tubes or gated pipe. Erosion rates are evaluated using the Surface Irrigation Soil Loss (SISL) model described in Agronomy Technical Note 35. SISL predicts average sediment delivery to the bottom of irrigated fields, in tons per acre per year. SISL does not predict sediment transport and delivery to a water body. Erosion prediction models are used in the Phosphorus Index to quantify the movement of soil, thus potential for sediment and attached phosphorus transport toward a water body. This factor is used only in the Eastern Oregon Phosphorus Index.

Runoff Class

The *runoff class* is determined from the *hydrologic group* assigned to the soil map units in a field, and the average slope gradient. *Hydrologic groups* are groups of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonally high water table, intake rate and permeability after prolonged wetting, and depth to a very slowly permeable layer. (National Soil Survey Handbook, Part 618.35). Criteria for runoff classes are given under ***Procedures for Making a Phosphorus Index Assessment*** in this document.

Flooding Frequency Class

Flooding is the temporary covering of the soil surface by flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, inflow from high tides, or any combination of sources. Floodwaters can carry both sediment-bound and dissolved P into surface waters. Estimates of flooding frequency are based on the interpretation of soil properties and other evidence gathered during soil survey fieldwork. Flooding frequency is defined as the number of times flooding occurs over a period of time and is expressed as a class. Definitions of flooding frequency classes are given under ***Procedures for Making a Phosphorus Index Assessment*** in this document.

Distance to Perennial Surface waters / Buffer Widths

This factor considers the flow distance from the edge of the field to the closest perennial surface water, which may include streams, lakes, and those irrigation and drainage ditches that contain water year around. It also considers the presence and width of a vegetated buffer adjacent to that surface water. The closer the edge of the field is to surface water, the higher the potential risk of P transport to that water.

Vegetated buffers are effective in trapping sediment-bound P in runoff water. They are less effective in reducing dissolved P transport. Dissolved P can flow through a buffer and enter surface water. The wider the vegetated buffer, the more effective it will be in reducing total P transport to surface water. Vegetated buffers that are commonly used adjacent to perennial water include filter strips (NRCS Standard 393) and riparian forest buffers (NRCS Standard 391).

Subsurface Drainage

Recent research has shown that P can leach through the soil profile, and the risk of leaching is directly related to the soil test P concentration in the soil. The higher the P concentration, the greater the potential for leaching. When subsurface drainage is present, such as perforated pipe tile drains, dissolved and sediment-bound P can enter the drains and be directly transported to surface water at the drain outlet. This factor therefore considers whether tile drains are present in the field, and the soil test P concentration.

Soil Test P

A soil sample from the site is necessary to assess the level of "available P" in the surface layer of the soil. Available P is the level customarily reported in a soil test analysis by commercial soil test laboratories. The soil test level for "available P" does not ascertain the total P in the soil. It does however, give an indication of the amount of total P that may be present because of the general relationship between the forms of P (organic, adsorbed, and labile) and the dissolved P available for crop uptake. The higher the soil test P level, the greater the risk of P transport to surface waters.

The depth at which soil samples are collected for available P analysis should be determined from the fertilizer or nutrient management guides for the crops being grown on the site. These guides are available from Oregon State University or Washington State University Cooperative Extension Services. Sampling depth is normally 0 to 6 inches or 0 to 12 inches for cultivated crops, and generally corresponds to typical depth of primary tillage. For established pastures that have not been cultivated for many years, a sample depth of 0 to 3 inches may be appropriate because P tends to be concentrated near the surface when the soil is not cultivated.

In eastern Oregon, soil test P levels should be determined using the Olsen (sodium bicarbonate) extraction method. In western Oregon, the Bray P1 extraction method should be used.

P Fertilizer Application Rate

The P fertilizer application rate is the amount of commercial phosphate fertilizer (P_20_5), in pounds per acre per year, which is applied to the soil. This factor does not include phosphorus from organic sources. The higher the application rate, the greater the risk of P transport to surface waters.

Commercial P Fertilizer Application Method

The manner in which P fertilizer is applied to the soil and the length of time that fertilizer remains on the soil surface will affect potential P movement. Banding or incorporating P fertilizer into the soil reduces the risk of P transport. P fertilizer that is surface applied, and not incorporated into the soil, has a higher risk of transport to surface water.

The time of year that P fertilizer is applied also affects the risk of P movement. P fertilizer that is applied during the winter and early spring in Western Oregon, when heavy or prolonged precipitation events are likely to occur, creates a higher risk of P transport than applications made from mid-spring to early fall. In Eastern Oregon, there is a greater risk of P transport when fertilizer is surface applied and not incorporated prior to irrigation or winter precipitation.

Organic P Source Application Rate

The organic P source application rate is the amount of phosphate (P_2O_5) contained in organic material that is applied to the soil, in pounds per acre per year. An analysis of the organic material is desirable to determine the phosphorus content. When an analysis of the organic material is not available, values from the Animal Waste Management Field Handbook can be used. The higher the application rate, the greater the risk of P transport to surface waters.

Organic P Source Application Method

The manner in which organic P material is applied to the soil, and the length of time it remains on the soil surface will affect potential P movement. Injecting or incorporating organic P sources into the soil reduces the risk of P transport. Organic P material that is surface applied, and not incorporated into the soil, has a higher risk of transport to surface water.

The time of year that organic P is applied also affects the risk of P movement. Organic P that is applied during the winter and early spring in western Oregon, when heavy or prolonged precipitation events are likely to occur, creates a higher risk of P transport than applications made from mid-spring to early fall. In Eastern Oregon, there is a greater risk of P transport when organic material is surface applied and not incorporated prior to irrigation or winter precipitation.

Procedures for Making a Phosphorus Index Assessment

Use the Phosphorus Index Worksheets in Appendix 1 for Western Oregon, Appendix 2 for Eastern Oregon, to make a field assessment of P transport potential. The worksheets are designed to be used on individual fields. Normally a worksheet is completed for each field. A single assessment can be made for a group of fields if the user is certain that all the source and transport factors are the same for each field.

For each transport and source factor, except those determined by formulas, the *Weighted Rating Value* has been calculated on the worksheets by multiplying the *Factor Weight* by the *Phosphorus Loss Rating*. For example, a site with a Soil Erosion rate (RUSLE) of 5 tons per acre per year receives a *Phosphorus Loss Rating* of *Medium* or 2 points. The *Factor Weight* of 1.5 multiplied by 2 points results in 3 points for the *Weighted Rating Value*. This value is given in parentheses at the bottom of the cell that contain the 4-6 tons per acre per year soil erosion rate.

The worksheets are designed so that an assessment can be made for both the *current* and *planned* conditions. For example, during the planning process a producer may select a conservation system alternative that would reduce soil erosion rates, and also install a vegetated buffer next to a perennial stream. This system would reduce the risk of P transport and would result in a lower *Phosphorus Index Total Rating Value*. See Appendix 3 for an example of a completed Phosphorus Index Worksheet. Electronic copies of the Phosphorus Index worksheets are available on the NRCS Oregon home page under Technology/Oregon Ecological Sciences/Agronomy/Oregon Agronomy Technical Notes/The Phosphorus Index, Agronomy Technical Note #26.

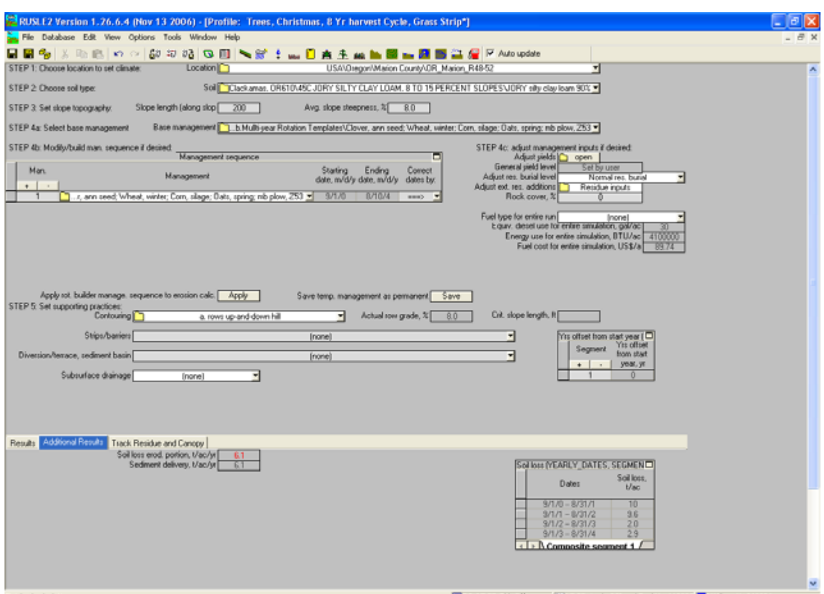
Instructions for the Phosphorus Index Worksheets

1. **Site information –** Enter information about the fields included in the assessment. Include information on soil map units, soil test P level and lab method, soil sample depth, crop rotation, and the person(s) making the assessment

2. **Yearly Soil Erosion –** Use the Revised Universal Soil Loss Equation (RUSLE2) and/or Wind Erosion Equation (WEQ) to determine average annual erosion rates over the crop rotation. See Section 1 of the Field Office Technical Guide for RUSLE and WEQ instructions.

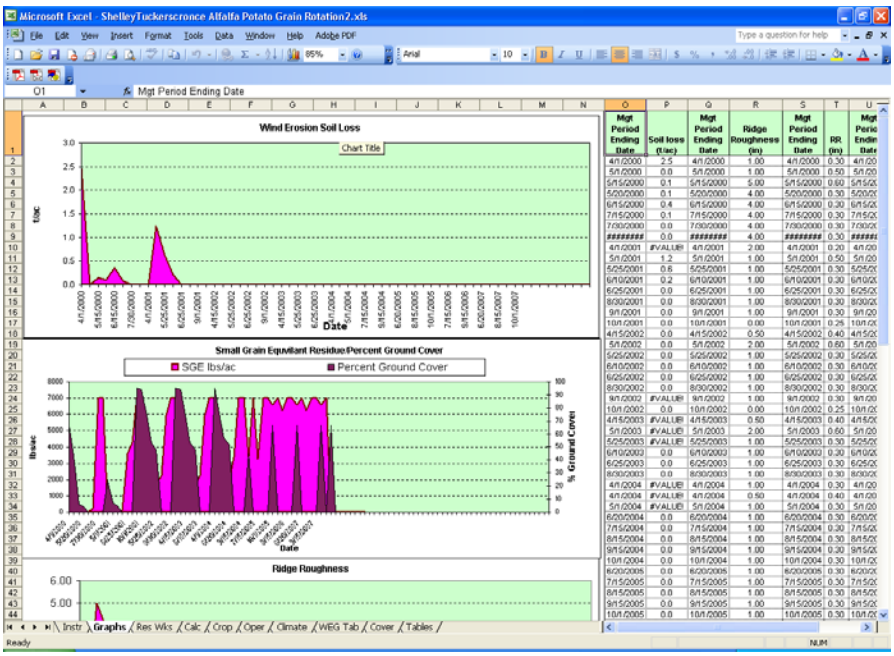
   As described previously, the Phosphorus Index requires an entry of the <u>yearly</u> erosion rate by crop for the year(s) of the manure application.

   To find this yearly value in RUSLE2, run a Profile to determine average annual erosion over the rotation as usual. Then, view yearly erosion rates by navigating to the bottom of the Profile screen and selecting the "Additional Results" tab. On the right hand side of the screen is a table titled "Soil Loss, YEARLY DATES, SEGMENT." To determine the yearly erosion rate by crop for the crop year(s) of the manure application, pull the soil loss values from the appropriate period(s), and add together if needed.



RUSLE2 Profile Screen: Note Additional Results tab highlighted in blue at the bottom.

To determine the yearly erosion rate by crop for the year of the manure application in WEQ, follow established instructions to complete the WEQ run for the rotation. Crop year erosion rates by period can be viewed by selecting the "Graphs" tab at the bottom of the screen, and pulling the soil loss values from the appropriate period(s), and adding together, if needed.



WEQ Spreadsheet at the "Graphs" tab.

For fields where both sheet and rill and wind erosion occur, the yearly erosion rates should be combined.

3. **Soil Erosion from Sprinkler Irrigation** – Evaluate the application rate of the existing and/or planned irrigation system. Compare the application rate to the infiltration rate of the soil map units. Oregon Engineering Handbook Irrigation Guide, Part OR681, and Irrigation Water Management (Version 2.0) software have information on sprinkler infiltration rates for most irrigated soils. Make a field visit to visually assess the erosion and runoff that occurs as a result of irrigation water applications.

4. **Soil Erosion from Surface Irrigation** (Eastern Oregon only) – Use the Surface Irrigation Soil Loss (SISL) average erosion rate estimate for the entire crop rotation. See Agronomy Technical Note 35 for SISL instructions. Assign a *Low* Phosphorus Loss Rating for this factor if a well functioning tail water return flow/reuse (pump back) system is in place.

5. **Runoff Class –** Use the following table to select the *Runoff Class* when field slope measurements are available. The Phosphorus Index Soils Data in Appendix 4 contain the *Hydrologic Groups* and *Runoff Classes* based on the average slope of soil map units. Field slope measurements are preferable for determining the *Runoff Class*, especially for soil map units with broad slope classes. Hydrologic groups assigned to soil map units can also be found in the FOCS soil database *Water Features* table. There are separate Factor Weights for nonirrigated and irrigated conditions in the Eastern Oregon worksheet.

Slope (%)	Hydrologic Group			
	A	B	C	D
	Runoff Classes			
< 1	Negligible	Negligible	Low	Low
1 – 5	Negligible	Low	Medium	Medium
6 – 10	Very Low	Medium	High	High
11 – 20	Low	Medium	High	Very High
> 20	Medium	High	Very High	Very High

6. **Flooding Frequency Class** (Western Oregon only) – Use the class assigned in Appendix 4 – Soils Data for the Phosphorus Index unless more accurate local information on flooding frequency is available. *Flooding Frequency Classes* are defined as follows (National Soil Survey Handbook, Part 618.26):

   None – No reasonable possibility of flooding; near zero percent chance of flooding in any year or less than 1 time in 500 years.

   Very Rare – Flooding is very unlikely but possible under extremely unusual weather conditions; less than 1 percent chance of flooding in any year or less than 1 time in 100 years but at least 1 time in 500 years.

   Rare – Flooding unlikely but possible under unusual weather conditions; 1 to 5 percent chance of flooding in any year or 1 to 5 times in 100 years.

   Occasional – Flooding is expected infrequently under usual weather conditions; 5 to 50 percent chance of flooding in any year or 5 to 50 times in 100 years.

   Frequent – Flooding is likely to occur often under usual weather conditions; more than a 50 percent chance of flooding in any year or more than 50 times in 100 years, but less than a 50 percent chance of flooding in all months in any year.

   Very Frequent – Flooding is likely to occur very often under usual weather conditions; more than a 50 percent chance of flooding in all months of any year.

   Flooding frequency classes assigned to soil map units can also be found in the FOCS soil database *Water Features* table.

7. **Distance to Perennial Surface Waters / Buffer Widths** – Determine the shortest distance from the edge of the field **down slope** to a perennial surface water body, which may include streams, lakes, and those irrigation and drainage ditches that contain water year around. Topographic maps, soil survey maps, local information, and field observations can be used to identify perennial surface waters. Determine the average width of existing and planned vegetated buffers adjacent to the perennial surface water. The buffer should meet NRCS technical standards in order to be considered in the rating.

8. **Subsurface Drainage –** Determine whether subsurface drainage, such as perforated tile drains, are present in the field. If drains are present, use the soil test P level to determine the *Phosphorus Loss Rating*.

9. **Soil Test P –** Enter the soil test P level (ppm) for the field into the formula to calculate the *Phosphorus Loss Rating*. The Olsen (sodium bicarbonate) extraction method should be used in Eastern Oregon. The Bray P1 method should be used in Western Oregon.

10. **Commercial P Fertilizer Application Rate –** Enter the phosphate (P_2O_5) fertilizer application rate for the field into the formula to calculate the *Phosphorus Loss Rating*. Average annual application rates over the entire crop rotation should be used for this factor. Elemental P can be converted to P_2O_5 according to the following formula: $P \times 2.29 = P_2O_5$

11. **Commercial P Fertilizer Application Method –** Select the predominant method used to apply commercial P fertilizer and the timing of applications

12. **Organic P Source Application Rate –** Enter the organic source P_2O_5 application rate for the field into the formula to calculate the Phosphorus Loss Rating. Average annual application rates over the entire crop rotation should be used for this factor. Elemental P can be converted to P_2O_5 according to the following formula: $P \times 2.29 = P_2O_5$

13. **Organic P Source Application Method –** Determine the predominant method used to apply organic sources of P and the timing of applications.

14. Sum the Transport and Source Factor *Weighted Rating Values* and use the formulas on the worksheets to determine the *Total Rating Value* and *Site Vulnerability Class*.

Interpretations of the Phosphorus Index Site Vulnerability Class

LOW – The site has a LOW potential for P movement from the site. If farming practices are maintained at current levels, the probability of an adverse impact to surface water resources from P losses from this site are low.

MEDIUM **–** The site has a MEDIUM potential for P movement from the site. The probability for an adverse impact to surface water resources is greater than that from a LOW vulnerability rated site. Some remedial action should be taken to lessen the probability of P movement.

HIGH **–** The site has a HIGH potential for P movement from the site. There is a high probability for an adverse impact to surface water resources unless remedial action is taken. Soil and water conservation as well as phosphorus management practices are necessary to reduce the risk of P movement and probable water quality degradation.

VERY HIGH **–** The site has a VERY HIGH potential for P movement from the site. The probability for an adverse impact to surface water resources is very high. Remedial action is required to reduce the risk of P movement. All necessary soil and water conservation practices plus a phosphorus management plan must be put in place to reduce the potential of water quality degradation.

Precautions in the Use of the Phosphorus Index

The Phosphorus Index is an assessment tool to be used by planners and land managers to assess the risk of phosphorus transport toward a water body. It also can be used to identify the critical factors of soil, topography, and management that most influence the movement. Using these factors, the index can help in the selection of management alternatives that would significantly address the potential impact to surface water quality and reduce the risk. The index is intended to be part of the planning process that takes place between the land manager and resource planner.

The Phosphorus Index is not designed to be used to determine whether land managers are in compliance with water quality regulations or standards that have been established by local, state, or federal agencies. Any attempt to use this index for regulatory purposes would be beyond the intent of the assessment tool and the concept and philosophy of the group that developed it.

Links to Examples, Forms, and Soils Databases:

Eastern Oregon Example:
ftp://ftp-fc.sc.egov.usda.gov/OR/Technical_Notes/Agronomy/Agronomy26_PIndex_EasternOR_Example.pdf

Western Oregon Example:
ftp://ftp-fc.sc.egov.usda.gov/OR/Technical_Notes/Agronomy/Agronomy26_PIndex_WesternOR_Example.pdf

Eastern Oregon Form:
ftp://ftp-fc.sc.egov.usda.gov/OR/Technical_Notes/Agronomy/Agronomy26_PIndex_Worksheet_EasternOR.pdf

Western Oregon Form:
ftp://ftp-fc.sc.egov.usda.gov/OR/Technical_Notes/Agronomy/Agronomy26_PIndex_Worksheet_Western_OR.pdf

Eastern Oregon Soils Database:
ftp://ftp-fc.sc.egov.usda.gov/OR/Technical_Notes/Agronomy/Agronomy26_Pindex_Eastside_Soils.xls

Western Oregon Soils Database:
ftp://ftp-fc.sc.egov.usda.gov/OR/Technical_Notes/Agronomy/Agronomy26_Pindex_Westside_Soils.xls