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Agricultural phosphorus management using the Oregon/Washington Phosphorus Indexes

Introduction

Phosphorus is an essential element for growth and reproduction of plants and animals. Agricultural enterprises often provide supplemental P to enhance plant and animal performance. Supplemental P inputs are provided in the form of fertilizer or manure for crops, and in the form of feed additives for animals.

Phosphorus can also pollute surface waters. Adding P to some lakes or slow-moving streams can lead to increased algae growth. When algae die and decompose in the water, oxygen is consumed. A deficit of dissolved oxygen in water can injure or kill fish and other aquatic organisms. P-induced algae blooms occasionally produce substances toxic to humans and livestock. Algae blooms triggered by P inputs also reduce the drinking water quality and recreational value of water bodies. Reduced water clarity, unpleasant swimming conditions, objectionable odors, and interference with boating and fishing can all be consequences of excess P additions to water bodies.

From a water quality protection standpoint, it is critical to prevent P from reaching surface waters. Runoff water or soil erosion from fertile landscapes moves P to lakes and streams. The science of estimating P loss to water for a particular field is qualitative. It is possible to differentiate fields into high and low site vulnerability categories based on site characteristics and site management. It is not possible to accurately predict the quantity of P loss from individual fields.

Phosphorus Indexes are field-scale qualitative assessment tools that are used by the Natural Resources Conservation Service (NRCS) and other planners to estimate the relative potential for P loss from fields into surface waters. Separate P Indexes were created for east and west of the Cascade Mountains to reflect major differences in climate and cropping systems. The Oregon and Washington P Indexes follow a format originally suggested for use by the NRCS in 1993.

This publication provides research-based information to assist agricultural professionals and their clients in identifying conservation practices that may reduce P loss from a field. This publication also provides general information about the P Index that may be useful for policy makers and others who have an interest in nutrient management in agriculture. This publication does not include all of the information needed to compute a P Index worksheet. Detailed guidance on completing and interpreting P Index worksheets is available from state or local NRCS offices, or at state NRCS Web sites (see “State P Index worksheets” in the “For more information” section of this publication).

Contents

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This publication:

- Describes P Index components (source and transport factors)
- Describes site management alternatives that reduce the likelihood of P loss from a field
- Provides references for more information on suggested management options

See references listed in "For more information—Phosphorus Indexes and water quality" at the end of this publication for additional background information on potential phosphorus impacts on water quality and the use of P Indexes in conservation planning.

Understanding the P Index concept

What is a P Index and how is it used?

Phosphorus Indexes are field-scale qualitative assessment tools that are used to estimate the relative potential for P loss from a field to surface waters. The P Index is a tool used by conservation planners to identify fields most vulnerable to off-site movement of P, and to identify strategies that reduce P loss from a field. The movement of phosphorus to surface waters may occur with eroding soil, with surface runoff or flooding (transported in soluble form), or with subsurface drainage (transported in tile lines to surface water). The P Index uses source factors (quantity of P present) and transport factors (potential for P loss to surface water) to assess site vulnerability to P loss.

The P Index is not a stand-alone tool. It is used in conjunction with other NRCS conservation practice standards (e.g., Nutrient Management Practice Standard 590) to design a conservation plan that meets the needs of the producer and protects the environment.

What factors are evaluated by the Oregon/Washington P Indexes?

Factors evaluated by the Oregon/Washington P Indexes are grouped into source and transport factors. Source factors evaluate the quantity of P present at a site. Transport factors evaluate the pathways available for P transport from the field to surface water.

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

Transport factors:

- Soil erosion (sheet and rill, wind)
- Soil erosion from sprinkler irrigation
- Soil erosion from surface irrigation (east of Cascades only)
- Runoff class
- Flooding frequency (west of Cascades only)
- Distance to surface waters/buffer width
- Subsurface drainage

What does a P Index score mean?

A numerical score for each source and transport factor is used to compute an overall P Index score for a field. This overall score is used to assign a "site vulnerability class." Site vulnerability classes for P loss are described in qualitative terms: Low, Medium, High, and Very High. Vulnerability class is a prioritization or screening tool. Significant reductions in P loss to water are most likely when improved management practices are applied to sites with the greatest vulnerability to P loss.

Are all P source and transport factors of equal importance?

Not all source and transport factors are given equal weight in calculating an overall P Index score to estimate site vulnerability to P loss. Each P Index factor was assigned a "weight," or relative importance, during the P Index development process. Relative factor weights were based on best professional judgment and research findings.

Selecting management practices to decrease P Index values

This section is designed to assist land managers who are making management decisions to reduce P loss. Each section below focuses on a P source or transport factor (line in a P Index worksheet) in the P Indexes for Oregon/Washington. If you have already completed a P Index worksheet, we suggest that you focus on P source or P transport factors that have high or very high site vulnerability scores. For each factor in the P Index, we provide:

- ➤ Description of the P Index factor
- ➤ Matrix table showing how the Indexes evaluate site characteristics or management practices for each factor (none, low, medium, high, or very high)
- ➤ Management goal
- ➤ Management options to reduce potential for P loss
- ➤ Sources of additional information

Source factor: Soil test P

Description

Agronomic soil test values are an index of plant-available P. A high soil test P level indicates a low probability of crop response to P application. The Bray P1 soil test (dilute acid-fluoride extraction) is used for western Oregon/Washington. The Olsen soil test (bicarbonate extraction) is used for eastern Oregon/Washington. Use the test specified for your region. Other soil test P analysis procedures are available from soil testing laboratories, but the P Index can be used only with the specified soil test procedures.

As soil test values increase, the potential for P loss from the field using surface and subsurface transport increases (Table 1). Low site vulnerability corresponds to soil test values that are equal to, or slightly above, recommended test values in university fertilizer guides.

Management goal

Maintain soil test P at levels supported by agronomic recommendations.

Table 1. Soil test values in the OR/WA P Indexes.

	Soil test P*	
P Index rating (score)*	**West of Cascades Bray P1 extraction (ppm or mg/kg)**	**East of Cascades Olsen (bicarbonate) extraction (ppm or mg/kg)**
None (0)	< 40	< 20
Low (1)	50	30
Medium (2)	60	40
High (4)	80	60
Very High (8)	120	100

*Soil test P Index rating score calculated as: (Bray soil test P value – 40) x 0.10, or (Olsen soil test P value – 20) x 0.10.

Management options to reduce potential for P loss

- ➤ Decrease P application to levels supported by agronomic recommendations. Soil test P levels are slow to change, because of soil buffering capacity for P. Many years of reduced P inputs are usually required to significantly reduce soil test P levels.
- ➤ Increase the amount of crop biomass removed from the field. To increase P removal, consider winter cover crops, relay crops, or double-cropping. Removal of crop biomass via harvesting (hay, silage) is more effective than livestock grazing for reducing soil test P.
- ➤ If soil test values remain high, increase the level of management intensity to reduce P transport factors (see "Transport factors").

For more information

Monitoring soil nutrients using a management unit approach. PNW Extension publication 570-E. Oregon State University Extension Service. http://eesc.oregonstate.edu/agcomwebfile/edmat/pnw570-E.pdf

Management options for farms with high soil test P levels. University of Wisconsin Nutrient and Pest Management Program. http://ipcm.wisc.edu

Soil and nutrient management publications. Oregon State University Extension Service. http://eesc.oregonstate.edu/soil/

Soil sampling. University of Idaho Cooperative Extension bulletin 704. http://info.ag.uidaho.edu/resources/PDFs/EXT0704.pdf

Soil test interpretation guide. Oregon State University Extension Service publication EC 1478. http://eesc.oregonstate.edu/agcomwebfile/edmat/EC1478.pdf

Source factor: Commercial P application rate

Description

Commercial P is supplied via fertilizers. Most common inorganic P fertilizers are calcium phosphates and ammonium phosphates. Phosphates in commercial fertilizers have high water solubility. Commercial fertilizers are marketed based on P_2O_5 content. The P Index uses units of lb P_2O_5 applied per acre (Table 2).

Table 2. Phosphorus application rate in the OR/WA P Indexes (east or west of the Cascades).

P Index rating (score)*	P application rate (lb P_2O_5 per acre)
None (0)	0
Low (1)	50
Medium (2)	100
High (4)	200
Very High (8)	400

*Phosphorus application rate score calculated as: lb P_2O_5 applied x 0.02.

Management goal

Apply P at rates supported by agronomic recommendations.

Management options to reduce potential for P loss

- Apply fertilizer P only when: (1) soil tests indicate a probable yield response to additional P, and (2) P is not supplied by manure or another organic source.
- Evaluate the need for starter P at seeding for fields that have high soil test P.
- Credit manure applications as a source of plant-available P.
- Inject or band fertilizer P below the soil surface to increase P utilization efficiency and reduce potential for P loss.
- See "Whole-farm nutrient management" references in next section ("Organic P application rate") for specific ideas on how to improve whole-farm nutrient balance.

For more information

Fertilizer guides. University of Idaho Cooperative Extension. http://www.uidaho.edu/wq/wqfert/wqfertls.html

Fertilizer guides. Washington State University Extension. http://pubs.wsu.edu/cgi-bin/pubs/index.html

Soil and nutrient management publications. Oregon State University Extension Service. http://eesc.oregonstate.edu/soil/

Soil sampling. University of Idaho Cooperative Extension bulletin 704. http://info.ag.uidaho.edu/resources/PDFs/EXT0704.pdf

Soil test interpretation guide. Oregon State University Extension Service publication EC 1478. http://eesc.oregonstate.edu/agcomwebfile/edmat/EC1478.pdf

Source factor: Organic P application rate

Description

Organic P sources include livestock manures, biosolids, composts, etc. Organic P application rate is the annual quantity of P applied per acre per year. Rough estimates are used for organic P rates. Phosphorus concentrations in manure and other organic materials vary depending on moisture content, storage duration and storage method, and other factors. Also, manures are difficult to spread evenly. To estimate organic P application rate, one needs measurements of the weight of manure applied, its moisture content, and its total P concentration. Total P in manure is considered equivalent to fertilizer P in calculating a P Index score. Phosphorus application amounts in the P Index are in units of P_2O_5, while P in manure analyses is reported in units of P or P_2O_5. If manure analyses are reported as P, multiply by 2.29 to convert P to P_2O_5 ($P \times 2.29 = P_2O_5$). Organic P application rate is evaluated using the same table used for commercial P application rate (Table 2).

Management goal

Apply P at rates supported by agronomic recommendations.

Management options to reduce potential for P loss

- ➤ Collect and analyze manure to determine its total P concentration.
- ➤ Calibrate manure application equipment and keep records of date, rate, and field where manure was applied. Periodically, evaluate planned vs. actual manure application rates and make adjustments for the next application.
- ➤ Consider improvements in whole-farm nutrient management to reduce the quantity of manure P and fertilizer P. Whole-farm management improves the balance of nutrient imports and nutrient exports on a farm. Whole-farm nutrient management may focus on:
  1. Reducing the amount of P brought to the farm in fertilizers or feeds
  2. Increasing the utilization and removal of P by harvested crops
  3. Increasing the amount of P leaving the farm via off-farm manure marketing or distribution
- ➤ See "Whole-farm nutrient management" references below for specific ideas on how to improve whole-farm nutrient balance.
- ➤ Use soil tests and/or plant tissue analyses to adjust application rates on a field-by-field basis.
- ➤ Practices that reduce ammonia-N loss from manure in storage or at application will increase the N:P ratio in manure, allowing reduced manure application rates to meet crop N needs.
- ➤ Alum or other additives can reduce the solubility of P in manure and the potential for loss to water. In the future, the P Index may be adjusted to assign a lower P loss potential to manures or biosolids treated with alum or other additives that reduce P solubility.

For more information

Manure application

Date, rate, and place: The field book for dairy manure applicators. PNW Extension publication 506. Oregon State University Extension Service. http://eesc.oregonstate.edu/agcomwebfile/edmat/PNW506.pdf

Fertilizing with manure. PNW Extension publication 533. Washington State University Extension. http://cru84.cahe.wsu.edu/cgi-bin/pubs/PNW0533.html

Which test is best? Customizing dairy manure nutrient testing. PNW Extension publication 505. Oregon State University Extension Service. http://eesc.oregonstate.edu/agcomwebfile/edmat/PNW505.pdf

Manure management planner software. Purdue University. http://www.agry.purdue.edu/mmp/

Whole-farm nutrient management

Animal diet modification to decrease the potential for nitrogen and phosphorus pollution. Council for Agricultural Science and Technology (CAST). http://www.cast-science.org/cast- science.lh/pubs/animaldietmodif_tf.htm

Dietary phosphorus considerations in dairy management. University of Wisconsin Nutrient and Pest Management Program. http://ipcm.wisc.edu

Livestock and Poultry Environmental Stewardship (LPES) curriculum. Midwest Plan Service. http://www.lpes.org/

Management options for farms with high soil test P levels. University of Wisconsin Nutrient and Pest Management Program. http://ipcm.wisc.edu

Source factor: Commercial P application method

Description

Management practices that leave fertilizer P on the soil surface increase the potential for P loss (Table 3, page 6). Potential P loss from surface application is greatest when P is applied during high rainfall months, or when P can be transported off-site with irrigation water runoff. Potential P loss is reduced by injecting P below the soil surface or incorporating P into soil with tillage.

Management goal

Reduce the potential for P loss via surface runoff.

Management options to reduce potential for P loss

- ➤ Apply fertilizer P at planting. This practice provides maximum P availability for the crop and reduces the potential for P loss prior to planting.
- ➤ Place fertilizer in a band below the soil surface. Banded subsurface P applications reduce the potential for P loss via surface runoff. Smaller amounts of banded or knifed P are often as effective as larger amounts of broadcast P.

Table 3. Phosphorus application method in the OR/WA P Indexes.

P Index rating	P application method and/or timing*	
	West of Cascades	**East of Cascades**
None	No application	No application
Low	Injected or placed below the soil surface (banded) deeper than 2 inches, *or* incorporated within 5 days of application from March through September	Injected or placed below the soil surface (banded) deeper than 2 inches, *or* incorporated immediately by plowing
Medium	Incorporated within 5 days of application from October through February,** *or* surface-applied without incorporation March through August	Incorporated deeper than 3 inches by disking, chiseling, etc.
High	Incorporated more than 5 days after application, *or* surface-applied without incorporation September through October**	Incorporated less than 3 inches deep by harrowing, etc.
Very High	Surface-applied November through February**	Surface-applied—not incorporated prior to irrigation or winter precipitation

*Use this table for commercial (P fertilizer) or organic P source (manure, biosolids, compost, etc.).
**Manure or fertilizer application is restricted during winter months in some counties. Check with the local soil and water conservation district or NRCS Service Center to determine applicable restrictions on winter P applications.

➤ Incorporate broadcast P fertilizer with tillage. Broadcast P is most effective when it can be incorporated into the root zone with tillage.

➤ For perennial crops, apply P as a single, high-rate broadcast P application tilled into the soil prior to planting. Annual broadcast P applications to perennial crops are less effective in supplying P to the crop. After the establishment year, incorporation of P into soil using tillage is not feasible for many perennial crops.

➤ Choose tillage methods that minimize soil erosion. Maintain crop residues or vegetative cover on the soil surface, and consider edge-of-field measures (see page 11) to reduce P loss to water bodies.

➤ Avoid application to frozen, snow-covered, or saturated soil.

➤ Maintain soil tilth to promote infiltration of water into soil.

For more information

Best management practices for phosphorus management to protect surface water. University of Idaho Cooperative Extension publication CIS 963. http://www.uidaho.edu/wq/wqpubs/cis963.html

Fertilizer guides. University of Idaho. http://www.uidaho.edu/wq/wqfert/wqfertls.html

Fertilizer guides. Washington State University Extension. http://pubs.wsu.edu/cgi-bin/pubs/index.html

Phosphorus fertilization: Broadcast, banding and starter. Washington State University Extension publication EB1637. http://cru.cahe.wsu.edu/CEPublications/eb1637/eb1637.html

Soil and nutrient management publications. Oregon State University Extension Service. http://eesc.oregonstate.edu/soil/

Source factor: Organic P application method

Description

Application practices that leave manure on the soil surface increase site vulnerability to P loss. Site vulnerability to P loss is greatest when manure applications are made at times and locations where surface runoff or erosion are likely. In the Oregon/Washington P Indexes, organic P application method is evaluated using the same table used for commercial P application method (Table 3).

Management goal

Reduce potential for P loss via surface runoff.

Management options to reduce potential for P loss

➤ Apply manure during late spring or summer, when runoff is unlikely. Use appropriate summer manure application rates to avoid excess nitrate-N accumulation in soil at the end of the growing season.

- ➤ Incorporate P with tillage into the soil.
- ➤ Choose tillage methods that minimize soil erosion. Where tillage is not feasible, maintain crop residues or vegetative cover on the soil surface, and consider edge-of-field measures to reduce P loss to water bodies.
- ➤ Avoid application to frozen, snow-covered, or saturated soil.
- ➤ Injection or knifing of manure may offer opportunities in some cropping systems to conserve N and reduce P loss.
- ➤ Apply dilute liquid manures (e.g., lagoon water) to pastures or perennial grasses where tillage is not feasible; target solid manure application to row-crop fields with tillage.
- ➤ Maintain soil tilth to promote infiltration of water into soil.

For more information

See "Whole-farm nutrient management" in the "Organic P application rate" section of this publication.

Transport factor: Soil erosion

Description

Soil erosion occurs when soil particles are detached and moved within a field. Erosion within a field does not necessarily mean that soil particles are lost from the field. Soil erosion includes sheet, rill, and wind erosion. Water erosion occurs via detachment of soil particles by raindrop impact and via surface flow on saturated or frozen soil. Sheet and rill erosion are estimated with the NRCS Revised Universal Soil Loss Equation (RUSLE). Soil detachment and movement by wind are estimated using the NRCS Wind Erosion Equation (WEQ). Both soil loss models, available from NRCS field offices, predict long-term average erosion rates, over the entire crop rotation, in tons of soil loss per acre per year. They do not predict soil transport and delivery to a water body for a storm event.

Keep in mind that management practices that reduce soil erosion (movement of particulate bound P) play a dominant role in reducing total P loss from the field (Table 4). Soluble P is usually a small fraction of total P loss in tilled systems, but it becomes a larger proportion of total P loss at sites with perennial vegetative cover. Erosion control practices usually reduce the volume of surface runoff and the sediment concentration in the runoff (turbidity). Erosion control practices may not always reduce soluble P concentrations in runoff. Sometimes soluble P in runoff increases with a perennial vegetative cover because P is lost from crop residues present on the soil surface.

Table 4. Soil erosion in the OR/WA P Indexes.

P Index rating	Soil erosion rate (ton/acre/year)
None	< 1
Low	1–3
Medium	4–6
High	7–15
Very High	> 15

Management goal

Reduce soil erosion potential.

Management options to reduce potential for P loss

Any practice that improves surface soil tilth and increases water infiltration rates into the soil will help to reduce erosion. Suggested practices include:

- ➤ Keep crop residues on the soil surface.
- ➤ Minimize duration of bare soil exposure.
- ➤ Use conservation tillage practices that reduce soil disturbance and retain crop residue on the soil surface.
- ➤ Reduce or minimize soil compaction.

Other practices to reduce erosion include:

- ➤ Reduce slope length via construction of terraces, diversions, or other conservation practices.
- ➤ Establish buffer strips and/or grassed waterways to trap sediment and reduce erosion in areas of the field where surface water collects.

Erosion control practices may be eligible for cost-share funding when implemented according to NRCS specifications. Contact your local NRCS Service Center or conservation district office for more information.

For more information

Soil management for small farms. Washington State University Extension publication EB1895. http://cru84.cahe.wsu.edu/cgi-bin/pubs/index.html

Using cover crops in Oregon. Oregon State University Extension Service publication EM 8704. http://eesc.oregonstate.edu/agcomwebfile/edmat/EM8704.pdf

Pacific Northwest conservation tillage handbook. Washington State University Extension. http://pnwsteep.wsu.edu/tillagehandbook/index.htm

Transport factor: Soil erosion from sprinkler irrigation

Description

Sprinkler irrigation has a limited potential for P movement from a field when water application rate and soil infiltration rate are closely matched. It is more efficient than flood or furrow irrigation. Little or no runoff is present with good management. Potential runoff via sprinkler irrigation is estimated by comparing the application rate (inches of water per hour) with the infiltration rate of the soil (Table 5). You also may evaluate runoff and soil erosion in the field. Look for visible runoff at field borders.

Table 5. Soil erosion from sprinkler irrigation in the OR/WA P Indexes.

	Soil erosion from sprinkler irrigation	
P Index rating	**Evaluated without a site visit**	**Evaluated by site visit**
None	No sprinkler irrigation	
Low	Irrigation water application rate < soil infiltration rate	No visible runoff at field borders
Medium	Application rate = infiltration rate	Little to no runoff at field borders
High	Application rate > infiltration rate	Visible runoff at field borders
Very High	Application rate > infiltration rate	Excessive runoff visible at field borders. Rills and gullies present

Management goal

Reduce or eliminate runoff from sprinkler irrigation.

Management options to reduce potential for P loss

- ➤ Reduce water application rate to match soil infiltration rate:
  1. Review system design and soil infiltration rates to ensure optimum design.
  2. Use irrigation management to best meet crop water requirements.
  3. Maintain and calibrate irrigation equipment to maximize application uniformity.
- ➤ Maintain optimum soil infiltration rate:
  1. Maintain crop residue on the soil surface.
  2. Minimize compaction.
  3. Perform tillage with dammer-diker.
  4. Add polyacrylamide (PAM) to irrigation water.

Soil conservation practices (modifications to irrigation system or other erosion control practices) may be eligible for cost-share funding when implemented according to NRCS specifications. Contact your local NRCS Service Center or conservation district office for more information.

For more information

A ready reference for irrigation manual of practice. Washington State University Extension publication EB1810. http://cru.cahe.wsu.edu/CEPublications/eb1810/eb1810.html

Irrigation management practices checklist for Oregon. Oregon State University Extension Service publication EM 8644. http://biosys.bre.orst.edu/bre/docs/irrigation.htm

Irrigation management practices to protect ground water and surface water quality. Washington State University Extension publication EM4885. http://cru.cahe.wsu.edu/CEPublications/em4885/em4885.pdf

Irrigation runoff control strategies. PNW Extension publication 287. Oregon State University Extension Service. http://eesc.oregonstate.edu/agcomwebfile/edmat/html/pnw/pnw287/pnw287.html

Western Oregon irrigation guides. Oregon State University Extension Service publication EM 8713. http://eesc.oregonstate.edu/agcomwebfile/edmat/EM8713.pdf

Western Oregon irrigation guides. Background and references. Oregon State University. http://biosys.bre.orst.edu/bre/Docs/backgrou.pdf

Transport factor: Soil erosion from surface irrigation

Description

Surface irrigation water is applied to the field through furrows, basins, or flooding. Some excess water must reach the end of the field in all surface irrigation systems. Phosphorus can be lost from the field as soluble P in runoff and particulate P on eroded soil particles (Table 6). In Oregon, erosion rates are estimated using the Surface Irrigation Soil Loss model (SISL; Idaho NRCS Agronomy Tech Note 32; June 2000). In Washington, erosion is estimated using the Furrow Sediment and Erosion (FUSED) model. Both models predict average sediment delivery to the bottom of irrigated fields in tons per acre per year. These models do not predict sediment transport and delivery to a water body.

Table 6. Soil erosion from surface irrigation in the OR/WA P Indexes.

P Index rating	Soil erosion from surface irrigation (ton/acre/year)
None	< 1
Low	1–3 or tailwater return flow in place
Medium	4–6
High	7–15
Very High	> 15

Management goal

Reduce or eliminate tailwater and sediment loss from the field.

Management options to reduce potential for P loss

- Convert to more efficient irrigation system such as sprinkler or drip.
- Improve efficiency of surface irrigation using methods such as surge flow or land-leveling.
- Maintain or improve soil infiltration rates:
  1. Maintain surface crop residue.
  2. Prevent and/or reduce soil compaction.
  3. Add polyacrylamide (PAM) to irrigation water.
- Reduce the number or duration of irrigations via improved irrigation scheduling.
- Install structures to reduce tailwater and sediment loss from the field:
  1. Settling basins to remove sediment from runoff
  2. Return-flow irrigation to minimize tailwater losses from field
  3. Field perimeter berm to prevent surface tailwater from leaving field
  4. Practices or structures to protect against erosion in tailwater collection ditches
  5. Filter strips, vegetative barriers, and other conservation buffers to entrap sediment at the field edge

Soil conservation practices (e.g., modifications to irrigation system or other erosion control practices) may be eligible for cost-share funding when implemented according to NRCS specifications. Contact your local NRCS Service Center or conservation district office for more information.

For more information

Polyacrylamide (PAM) research page. USDA-ARS. Kimberly, ID. http://kimberly.ars.usda.gov/pampage.shtml

Strategies for reducing irrigation water use. Oregon State University Extension Service publication EM 8783. http://eesc.oregonstate.edu/agcomwebfile/edmat/html/em/em8783/em8783.html

Irrigation systems for Idaho agriculture. University of Idaho Cooperative Extension publication CIS 1055. http://info.ag.uidaho.edu/resources/PDFs/CIS1055.pdf

Tailwater recovery for surface irrigation. Colorado State University Extension publication 4.709. http://www.ext.colostate.edu/pubs/crops/04709.html

Malheur County best management practices. Malheur Experiment Station, Oregon State University. http://www.cropinfo.net/bestpractices/Malcountybmp.html

Transport factor: Runoff class

Description

The runoff class is determined by inherent soil and site factors. Soil/site characteristics that are factored into runoff class include soil depth, slope, soil permeability, and the depth to a seasonally high water table. Runoff class ratings for Oregon soils are available from a database maintained by the state NRCS office. Runoff class cannot be modified by management. Management practices that can reduce the potential for runoff and erosion from a site are addressed in the Oregon/Washington P Index under "Soil erosion."

Table 7. Runoff classes in the OR/WA P Indexes.

P Index rating	Runoff class
None	Negligible
Low	Very low or low
Medium	Medium
High	High
Very High	Very high

Transport factor: Flooding frequency class (western Oregon and Washington only)

Description

Winter floods can move P from a field into surface water bodies. This situation is more widespread and frequent west of the Cascades. Flooding is included as a transport factor in the west of Cascades P Index, but not in the east of Cascades P Index. Flooding moves organic P left on the surface from manure applications, grazing animals, or crop residues. Flooding also moves P via soil erosion and bank cutting. Flooding Frequency classes are defined in the National Soil Survey Handbook, Part 618.26 (NRCS). The physical layout of the farm as well as management practices should be designed to minimize off-site P movement when flooding occurs.

Table 8. Flooding frequency class in the OR/WA P Indexes.

P Index rating	Flooding frequency class
None	None or very rare
Low	Rare
Medium	Occasional
High	Frequent
Very High	Very frequent

Management goal

Minimize P loss to water via floodwaters.

Management options to reduce potential for P loss

- ➤ Stockpile manure, silage, and other organic sources outside of floodplain.
- ➤ Apply manure only during summer months to fields in "frequent" or "very frequent" flooding frequency classes.
- ➤ Maintain permanent vegetative cover (e.g., perennial grass), or plant a cover crop in early fall.
- ➤ Apply dilute liquid manure that will infiltrate the soil and not remain on the soil surface.

Transport factor: Distance to perennial surface waters/buffer width

Description

Fields that are adjacent to perennial surface water, or fields having a short flow path to nearby water bodies, have the highest vulnerability to P loss (Table 9, page 11). Modifications to the physical condition of the edge of the field can reduce delivery of P to a water body.

Table 9. Distance to perennial surface waters/buffer widths in the OR/WA P Indexes.

	Distance to perennial waters/buffer widths	
P Index rating	Distance to perennial surface water (ft)	Buffer width next to surface water as determined by site visit (ft)
None	> 500	> 30 ft or meets NRCS standard
Low	300–500	20–30
Medium	200–299	10–19
High	100–199	< 10
Very High	< 100	no buffer, *or* return flow from surface irrigation occurs with no buffer

Management goal

Minimize the potential for runoff water and sediment to leave the field.

Management options to reduce potential for P loss

Movement of soluble P and particulate P can be reduced by modification of the edge-of-field features:

- Eliminate or reduce P application in areas adjacent to surface water.
- Maintain vegetative buffers to trap particulate P in runoff and potentially reduce soluble P in runoff. Effective vegetative buffers can be designed to meet the needs of the landowner and to meet NRCS conservation practice standards (NRCS Conservation Practice Standards 393, 391, and 601). The minimum width needed for an effective buffer depends on vegetation, width, and slope.
- Soil berms at the field edge can sometimes be used to prevent runoff from the field in low precipitation areas east of the Cascades. This practice should include provision for controlled overflow or removal of water following intense storm events or an irrigation system malfunction.
- For surface-irrigated sites, install sediment basins, conservation buffers, and/or irrigation return flow systems.

Soil conservation practices (e.g., vegetative buffers or erosion control practices) may be eligible for cost-share funding when implemented according to NRCS specifications. Contact your local NRCS Service Center or conservation district office for more information.

For more information

Vegetative filter strips for agriculture. Nebraska Cooperative Extension publication NF 97-352. http://www.ianr.unl.edu/pubs/water/nf352.htm

Vegetative filter strips for improved water quality. Iowa State University Extension publication PM1507. http://www.extension.iastate.edu/Publications/PM1507.pdf

Conservation buffers. Core 4 conservation practices. Conservation Technology Information Center. Purdue University. http://www.ctic.purdue.edu/Core4/buffer/Buffers.html

Why are different P Indexes used east and west of the Cascades?

The Natural Resources Conservation Service (NRCS), in consultation with university and private agronomists, developed separate P Indexes for east and west of the Cascades in 2000–2001. Both Indexes evaluate similar P source and P transport factors, but they reflect important differences in soil characteristics and climate. Differences between the east of Cascades and west of Cascades P Index for Oregon and Washington include the following.

P transport

West of the Cascades, runoff from rainfall is likely from most sites. East of the Cascades, annual precipitation typically is lower, and many sites lack a significant potential for P transport to water bodies. The east and west of Cascades P Indexes address this difference in potential for P transport as follows.

The east of the Cascades Oregon/Washington P Index estimates that sites without a significant transport mechanism (runoff, erosion, subsurface drainage) will have a low potential for P loss, regardless of the quantity of source P present at the site. The east of the Cascades P Index calculates an overall P Index score (site vulnerability class) by *multiplying* the site P source score by the site P transport score.

The west of Cascades P Index considers P source to have equal importance at all sites, because the potential for catastrophic transport of P (runoff, erosion, subsurface drainage) exists at virtually all sites during winter months. The west of the Cascades P Index calculates an overall P Index score (site vulnerability class) by *adding* the site P source score to the site P transport score.

Flooding frequency

Winter floods can move P from the land surface into surface water bodies. Flooding is a common transport pathway west of the Cascades and a rare transport pathway east of the Cascades. Flooding is included as a transport factor in the west of the Cascades P Index, but not in the east of the Cascades P Index.

Soil test method

The P Indexes use the prevailing agronomic soil test for each region. West of the Cascades, the Bray P1 test is used as the basis for fertilizer recommendations in university fertilizer guides. East of the Cascades, the Olsen (bicarbonate) soil test method is used to support P fertilizer recommendations.

The Morgan soil P test, used by some laboratories to support agronomic P recommendations, is *not* suitable for use with the Oregon and Washington P Indexes.

Erosion from surface irrigation

The east of the Cascades P Index addresses erosion from surface (e.g., furrow) irrigation. West of the Cascades, surface irrigation systems are rare, so this factor is not included in the P Index.

Transport factor: subsurface drainage

Description

Phosphorus can leach through the soil profile, but the potential for P leaching loss is small for most soils and cropping systems. The amount of P leached depends on soil test P levels, the physical condition of the soil, and the amount of water moving through the soil profile. The presence of subsurface drains increases the potential for transport of leached P to water bodies (Table 10). The highest potential for subsurface transport from the field is associated with soil physical conditions that provide direct pathways from the soil surface to the subsurface drain, and subsequently to surface waters. Subsurface drains sometimes contribute to reductions in P loss by reducing surface runoff and soil erosion from saturated soil.

Management goal

Reduce P transport to surface water via leaching to groundwater, perched water tables, or subsurface drains.

Management options to reduce potential for P loss

- Maintain soil test P levels at levels supported by agronomic recommendations.
- Manage irrigation water to avoid subsurface transport during summer months.
- Maintain subsurface drainage systems to prevent direct movement of sediment, manure, and P fertilizers into the drainage system.
- Tillage and reseeding of perennial forages may be used to reduce movement of water and P through the soil in large, structured pores such as vole, worm, and root channels.

Appropriate conservation practices may be eligible for cost-share funding when implemented according to NRCS specifications. Contact your local NRCS Service Center or conservation district office for more information.

For more information

See “Source factor: Soil test P” in this publication.

Phosphorus transport into subsurface drains by macropores after manure applications: Implications for best manure management practices. Cornell University. http://www.bee.cornell.edu/research/SoilandWater/HTML/~transport.htm#_1_11

Table 10. Subsurface drainage in the OR/WA P Indexes.

	West of Cascades		East of Cascades	
P Index rating	**Subsurface drains present?**	**Bray soil test P (ppm)**	**Subsurface drains present?**	**Olsen soil test P (ppm)**
None	No		No	
Low	Yes	< 60	Yes	< 40
Medium	Yes	61–140	Yes	40–120
High	Yes	141–190	Yes	121–170
Very High	Yes	> 190	Yes	> 170

Questions and answers

Why were P Indexes created for Oregon and Washington?

Prior to 1999, nutrient management plans focused primarily on nitrogen management. The NRCS national specification for nutrient management was revised in 1999 to include phosphorus management. State NRCS offices were given 2 years to develop criteria for P-based nutrient management.

Does Idaho have a P Index?

The Idaho P Index is not currently being used as a stand-alone conservation tool. The Idaho P Index is integrated into a software tool, the OnePlan Nutrient Management Planner (NMP), which was developed for the purpose of generating nutrient management plans and recommendations for best management practices. Factors considered in the Idaho P Index are: soil test P, P application rate, P application method, runoff class/runoff index, runoff conservation practices, soil erosion/irrigation erosion, and distance to nearest receiving water body.

See "For more information" at the end of this publication for links to Idaho OnePlan and conservation practice standards for Idaho.

What is the history of the P Index?

In the early 1990s, a national team of agricultural professionals and scientists developed the concept of a P Index to address concerns about the effects of P on water quality. The initial P Index was published in a peer-reviewed journal in 1993. The P Index was a new approach that incorporated a large body of research findings into a practical format for use by conservation planners. Additional research over the past 10 years has demonstrated that the P Index is a valuable tool. At the state level, NRCS has worked together with public and private agronomists, soil scientists, agricultural engineers, and other interested parties to adapt the P Index concept to local conditions. Adaptations of the P Index are now used by NRCS as a part of the conservation planning process across the U.S.

Was Pacific Northwest research data used in developing the P Indexes for Oregon and Washington?

When the Indexes for Oregon and Washington were created in 2000–2001, limited data for Pacific Northwest conditions existed to validate many of the source and transport factors present in the Oregon/Washington P Indexes. Research findings from other regions and best professional judgment of Pacific Northwest scientists were used in developing the source and transport factors used in the Oregon/Washington Indexes. Further research to validate and enhance the Indexes is encouraged. The Indexes will be adjusted periodically based on emerging research findings.

What are the limitations of the P Index approach?

P Indexes assess P loss potential for a field over an entire crop rotation. Thus, P Indexes have a limited ability to assess changes in site characteristics and management practices that occur across time and space within the rotation. Limitations of the P Index approach include the following.

1. The P Index for a field is computed for average conditions expected to be present during a crop rotation. Within a rotation, potential for P loss may vary considerably. For example, potential P loss is greater for a fall-seeded pasture than it is for an established pasture.
2. Fields behave differently, subject to the combination of soil, source, and transport characteristics present. Fields with the same P Index rating (low, medium, high, or very high vulnerability to P loss) may contribute different amounts of off-site P under specific environmental conditions (e.g., flooding).
3. The P Index does not describe all factors influencing P loss. Some practices suggested here to reduce site vulnerability to P loss (e.g., reducing or minimizing soil compaction) will not result in a lower P Index score.
4. If the P Index is not integrated into the nutrient management and conservation planning process, the P Index will simply provide a potential risk rating for the field and will not lead to improved management practices.

What other considerations should be made in selecting management practices to reduce P loss?

The impact of any management practice designed to reduce P loss should be considered in the context of overall conservation goals for the field and the farm. For example, a compromise must be made between tillage to incorporate P (reducing P source) and soil erosion resulting from tillage (increasing P transport). The P Index assesses field-scale P management, but implementation of improved field-scale management practices is not always the most effective way to reduce P loss from a field. Some fields contain critical source areas for P loss such as springs, floodplains, or other areas of concentrated overland flow. Critical source areas are best observed by visiting the field when runoff occurs. When critical source areas exist within a field, they may need to be managed separately from the rest of the field. Implementing a conservation practice within these critical areas of a field may reduce P loss more than other conservation practices applied across the entire field.

Can the P Index be used to assess regulatory compliance?

Phosphorus Indexes cannot 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. The P Index does not predict the quantity of P lost from a field or the concentration of P in runoff water. The Index was created only for use in a conservation planning process that takes place between a land manager and a resource planner.

For more information

Phosphorus Indexes and water quality

Agricultural phosphorus and eutrophication. Agricultural Research Service (USDA-ARS). http://www.ars.usda.gov/is/np/indexpubs.html

Lemunyon, J.L. and R.G. Gilbert. 1993. The concept and need for a phosphorus assessment tool. *Journal of Production Agriculture* 6: 483–486.

Sharpley, A.N., J.L. Weld, D.B. Beegle, P.J.A. Kleinmann, W.J. Gburek, P.A. Moore, and G. Mullins. 2003. Development of phosphorus indices for nutrient management planning strategies in the United States. *Journal of Soil and Water Conservation* 58 (3): 138–151.

Understanding soil phosphorus: An overview of phosphorus, water quality, and agricultural management practices. University of Wisconsin Nutrient and Pest Management Program publication A3771. http://ipcm.wisc.edu

A procedure to estimate the response of aquatic systems to changes in phosphorus and nitrogen inputs. USDA-NRCS. National Water and Climate Center. http://www.soil.ncsu.edu/sera17/publications/AquaticSensitivity/aqusens.pdf

Natural Resources Conservation Service publications

State P Index worksheets

Idaho NRCS Phosphorus Index. Idaho P Index is not a separate tool. It is integrated into Idaho OnePlan. http://www.oneplan.org/

Oregon NRCS Phosphorus Index files. At: Oregon State University Western Integrated Nutrient Management Project Web site: http://cropandsoil.oregonstate.edu/nm/P_Index.htm

or Oregon NRCS file transfer protocol (ftp) site: ftp://ftp.or.nrcs.usda.gov/pub/agronomy/Phosphorus_Index/

Washington NRCS Phosphorus Index files. http://efotg.nrcs.usda.gov/references/public/WA/NRCS-WA_WQ_TN2_Phosphorus_Index.pdf

Technical specifications for conservation practices

Agricultural waste management field handbook. National engineering handbook (NEH). Part 651. http://www.ftw.nrcs.usda.gov/awmfh.html

National NRCS technical guide (electronic), or eFOTG. http://www.nrcs.usda.gov/technical/efotg/

Idaho Field Office technical guide (electronic), or FOTGe. Section IV. Idaho conservation practices. Access from National NRCS technical Web site: http://www.nrcs.usda.gov/technical/efotg/

Oregon Field Office technical guide (electronic), or FOTGe. Section IV, 2. Conservation practice specifications and job sheets. Access from National NRCS technical Web site: http://www.nrcs.usda.gov/technical/efotg/

Washington Field Office technical guide (electronic), or FOTGe. Section IV. 2. Washington NRCS index of conservation practices. Access from National NRCS technical Web site: http://www.nrcs.usda.gov/technical/efotg/

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