**NATURAL RESOURCES CONSERVATION SERVICE**

**CONSERVATION PRACTICE STANDARD**

# NUTRIENT MANAGEMENT

**(Ac.)**

**CODE 590**

## DEFINITION

Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments.

## PURPOSE

- To budget, supply, and conserve nutrients for plant production.
- To minimize agricultural nonpoint source pollution of surface and groundwater resources.
- To properly utilize manure and other organic by-products (including municipal and industrial biosolids) as a plant nutrient source.
- To protect air quality by reducing odors, nitrogen emissions (ammonia, oxides of nitrogen), and the formation of atmospheric particulates.
- To maintain or improve the physical, chemical, and biological condition of soil.

## CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all lands where plant nutrients and soil amendments are applied. This standard does not apply to one-time nutrient applications to establish perennial crops.

## CRITERIA - GENERAL CRITERIA APPLICABLE TO ALL PURPOSES

A nutrient budget for nitrogen, phosphorus, and potassium must be developed that considers all potential sources of these nutrients including, but not limited to, green manures, legumes, crop residues, compost, animal manure, organic by-products, biosolids, waste water, organic matter, soil biological activity, commercial fertilizer, and irrigation water.

Realistic yield goals shall be clearly documented and shall be established using the best available records and information from similar fields and management systems in the location of interest. Potential sources that may provide yield potential documentation include one of the following:

1. Yield data collected from the field for five (5) or more crop years. Ignore the highest and lowest years and calculate the mean of the remaining three. Add 10 percent to the mean yield to allow for potential to improve yield.

2. Crop yield estimates from county soil survey adjusted by soil-based crop productivity indices. Crop productivity indices can be found in “Productivity of Missouri Soils”, published by NRCS.

3. County average yield data collected by the National Agricultural Statistics Service.

4. Fully documented alternative systems to determine yield goals.

For new crops or varieties, industry yield recommendations may be used until documented yield information is available.

To avoid salt damage, the rate and placement of applied nitrogen and potassium in starter fertilizer must be consistent with University of Missouri-Columbia guidelines, or industry practice recognized by the University of Missouri-Columbia.

The Missouri Leaching Index must be completed for all sites.

The Missouri Phosphorus Index risk assessment must be completed when:

- soil loss for the soil sampling cycle exceeds the tolerable soil loss "T."
- phosphorus application rate exceeds University of Missouri-Columbia fertility rate guidelines for the planned crop(s), or
- the planned area is within a phosphorus-impaired watershed (contributes to 303d-listed water bodies).

No manure applications are permitted in areas contained within minimum application setbacks (e.g., sinkholes, wellheads, gullies, ditches, or surface inlets). See Appendix C.

Soil pH must be maintained in a range that ensures an adequate level for crop nutrient availability and utilization. Refer to University of Missouri-Columbia guidance for liming recommendations using the *Recommendations Online* tool at http://soilplantlab.missouri.edu/soil/recommendationsonline.aspx

The rate and timing of irrigation water applications must minimize the risk of nutrient loss to surface and groundwater.

Enhanced efficiency fertilizers used in Missouri must be accepted for use by the Missouri Fertilizer/Ag Lime Control Service which verifies product guarantees, ingredients, and label claims.

On organic operations, the nutrient sources and management must be consistent with the USDA's National Organic Program while not exceeding maximum allowable fertilizer rate recommendations.

**Soil, Manure, and Tissue Sampling and Laboratory Analyses (Testing)**

Nutrient planning must be based on current soil, manure, and (where used as supplemental information) tissue test results developed in accordance with University of Missouri-Columbia guidance, or industry practice, if recognized by the University of Missouri-Columbia.

Criteria for soil and tissue sample collection – Soil and tissue samples shall be collected and prepared according to University of Missouri-Columbia guidance. For specific guidance, refer to University of Missouri-Columbia Extension Guide Sheets G9131 –*Sampling Plant Tissue and Soil for Analysis*, G9217 – *Soil Sampling Hayfields and Row Crops*, and G9215 – *Soil Sampling Pastures*.

Soil tests used to develop a nutrient plan shall be less than two years old. The soil sampling schedule developed for the nutrient plan will then ensure that fields are sampled at least once every four years. More frequent sampling will be required if fertilizer recommendations use a nutrient buildup period of less than four years.

When possible, avoid soil sampling within six months following the application of a phosphorus nutrient source or an agricultural lime application.

A composite soil sample will be collected to represent approximately 20 acres or less. Composite samples shall consist of no fewer than 10 soil cores. Recommended sampling intensity is 10 to 15 soil cores on fields with little expected variability (e.g., row crop and hayfields receiving broadcast fertilizer applications) and 15 to 20 soil cores on fields expected to have significant variability (e.g., pastures and fields with a history of banded fertilizer or manure applications). Grid sampling representing 3-acre areas or less will be accepted in lieu of composite samples. Grid soil samples shall consist of approximately 10 soil cores collected within a 30-ft diameter of a central geo-referenced sampling point. Grid sampling strategies that differ significantly from this guidance should be documented as part of the nutrient management component of the conservation plan.

The soil sampling method will be modified to address special production or environmental concerns when permanent vegetative cover or long-term no-till is used in combination with surface-applied nutrients. Shallow sampling for pH and phosphorus may be warranted.

Tissue sampling and testing may be used to determine crop-specific nutrient deficiencies. Sampling methods shall be completed according to University of Missouri-Columbia recommendations. For specific guidance, refer to University of Missouri-Columbia Extension Guide Sheet IPM1016 – *Crop Nutrient Deficiencies and Toxicities*.

Criteria for soil and tissue sample analyses – Soil and tissue sample analyses shall follow

University of Missouri-Columbia guidance when available. A list of currently acceptable analysis methods can be found at http://soilplantlab.missouri.edu/soil/msta.aspx. Analyses of soil samples shall be performed by laboratories using acceptable analysis methods, and that are accepted by the Missouri Soil Testing Association (see a current listing of accredited laboratories at http://soilplantlab.missouri.edu/soil/msta.aspx).

Criteria for manure testing and analysis-
Manure testing analyses must be performed by laboratories successfully meeting the requirements and performance standards of the Manure Testing Laboratory Certification program (MTLCP) under the auspices of the Minnesota Department of Agriculture, or other NRCS-approved program that considers laboratory performance and proficiency to assure accurate manure test results. A listing of laboratories meeting these proficiency criteria can be found at: http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp**.**

Guidance pertaining to the actual manure and other organic by-product sampling, handling, and analysis is contained in the section titled *Additional Criteria Applicable to Properly Utilize Manure or Organic By-Products as a Plant Nutrient Source.*

**Nutrient Application Rates.**

Recommended nutrient application rates shall be based on University of Missouri-Columbia recommendations that consider current soil test results, plant tissue tests where relevant, realistic yield goals, and management capabilities. Planned nutrient application rates for nitrogen, phosphorus, and potassium must not exceed University of Missouri-Columbia guidelines. Current recommendation guidance is provided by the *Recommendations Online* tool located at http://soilplantlab.missouri.edu/soil/recommendationsonline.aspx. Fertilizer recommendations shall be based on nutrient sufficiency categories supplied by the University of Missouri-Columbia. When the University of Missouri-Columbia does not provide specific guidance for a nutrient and (or) crop, guidance from another land-grant university may be followed if the University of Missouri-Columbia accepts these recommendations. Application rates less than recommended rates are allowable when the producer's objectives are met.

The planned rates of nutrient application, as documented in the nutrient budget, shall be determined based on the following guidance:

- Nitrogen Application – Planned nitrogen application rates shall match the recommended rates as closely as possible. Applied nitrogen shall not exceed the recommended amounts in the nutrient management portion of the conservation plan by the greater of 10 percent or 10 pounds per acre.
- If, after following well-planned nitrogen management, a nitrogen deficiency can be documented, supplemental nitrogen fertilizer is allowed. Documenting nitrogen deficiency requires comparison of a nitrogen-sufficient part of the field with the deficient area using tissue-nitrogen testing through either chlorophyll meter or crop canopy color sensing. If tissue-nitrogen sensed using chlorophyll meter or crop canopy color on the deficient areas are less than 95% of the sufficient area, supplemental nitrogen may be applied. Guidance for implementing supplemental nitrogen applications can be found in NRCS Agronomy Technical Guide No. 35.
- Phosphorus Application – Planned phosphorus application rates for the soil test cycle shall match the recommended rates as closely as possible.
- Applications of phosphorus may be made for soil buildup (the buildup period shall not exceed 12 years) and maintenance needs as annual or multi-year treatments. A single application to meet the recommended phosphorus for multiple years in a cropping sequence may supply the calculated phosphorus need for the soil test cycle, not to exceed four years. Phosphorus applications shall not exceed the target application rate by the greater of 10 percent or 10 pounds per acre for the soil test cycle.
- Missouri Phosphorus Loss Assessment Tools – The risk of phosphorus loss from a

- site and guidance for applications of phosphorus nutrients may be determined by one of the following methods (see criteria in Appendix D):
    - Missouri Soil Test Phosphorus Method – Soil loss must be less than "T." When the Missouri soil test phosphorus rating is "Very Low", "Low", or "Medium" phosphorus may be applied to meet fertilizer phosphorus recommendations for the soil test cycle. When the soil test phosphorus level is "High" phosphorus may be applied not to exceed crop removal for the soil test cycle. When the soil test phosphorus level is "Very High" phosphorus should not be applied.
    - Missouri Phosphorus Index Method -- When the Missouri Phosphorus Index rating is "Low" or "Medium" phosphorus may be applied in excess of phosphorus removal rates not to exceed the allowable annual nitrogen recommendation and the phosphorus recommendation for the soil test cycle. When the Missouri Phosphorus Index rating is "High" phosphorus may be applied to meet crop removal for the soil test cycle. When the Phosphorus Index rating is "Very High" phosphorus should not be applied. When the Phosphorus Index rating is "High" or "Very High", information shall be included in the conservation plan concerning conservation practices and management activities that can reduce the potential for phosphorus movement from the application site.
- Potassium Application – Potassium shall not be applied in situations where excess (greater than soil test potassium recommendation) causes unacceptable nutrient imbalances in crops or forages. When forage quality is an issue associated with excess potassium application, University of Missouri-Columbia guidelines shall be used to set forage quality criteria.
- Crop nutrient removal (nutrients removed in harvested plant materials) is an important component of the maintenance portion of the fertilizer recommendation. Acceptable crop removal rates can be found in Appendix B.
- Other Plant Nutrients – Other plant nutrients shall not be applied in situations where amounts greater than soil test recommendation cause unacceptable environmental impact.
- Starter Fertilizers – When starter fertilizers or pop-up fertilizers are used, they shall be included in the overall nutrient budget and applied in accordance with University of Missouri-Columbia recommendations.
- Field-Level Fertilizer Applications – Fertilizer recommendations used to develop nutrient budgets shall be based on 20-acre field areas. Adjoining 20-acre field areas may be combined if the fertilizer rate does not exceed the lowest recommended rate of each individual nutrient.
- Incidental Nutrient Applications – Commercially available fertilizer formulations sometimes contain secondary amounts of nutrients in addition to a primary nutrient. Examples include the common phosphorus fertilizers MAP (mono-ammonium phosphate [$NH_4H_2PO_4$]) and DAP (diammonium phosphate [$(NH_4)_2HPO_4$]). All nitrogen, phosphorus, and potassium applied in a fertilizer formulation must be included in the nutrient budget and the application from all sources shall not exceed the annual utilization of nitrogen.
- Agricultural Lime – Soil amendments shall be applied based on soil test results to adjust soil pH to an adequate level for crop nutrient availability and utilization.
    - Application of the recommended amount of liming material shall be planned and made during the current soil testing cycle. Refer to University of Missouri Extension Guide Sheet G9102 – *Liming Missouri Soils* for the desired soil $pH_{(salt)}$ ranges for Missouri crops.
    - If soil test results recommend less than 600 lbs ENM of liming material, application may be deferred until the next soil testing cycle. Acceptable liming materials are those approved by the Missouri AgLime Control Service (see http://aes.missouri.edu/pfcs/).

  - Liming materials will be applied and incorporated prior to planting when inversion tillage is used to prepare a seedbed. Deep incorporation of agricultural lime will improve crop rooting depths, increase available nutrients, and improve crop yields.
  - To establish a legume crop, lime should be applied at least three months prior to planting. Liming materials will be applied to established forages or no-till crop rotations as a surface application without incorporation.
- The nutrient management component of the conservation plan may be modified to correct any nutrient deficiencies identified by tissue testing. For example, tests such as crop canopy color sensing for nitrogen status may be used to evaluate and adjust nitrogen application rates.

**Nutrient Sources**

Nutrient sources utilized must be compatible with the application timing, tillage and planting system, soil properties, crop, crop rotation, soil organic content, and local climate to minimize risk to the environment.

Manure is an important and valuable source of nutrients for crop production. For guidance on its use as a plant nutrient source refer to the section titled *Additional Criteria Applicable to Properly Utilize Manure or Other Organic By-Products as a Plant Nutrient Source* later in this document.

**Nutrient Application Timing and Placement**

Nutrient application timing -- Timing of nitrogen application shall correspond as closely as possible with plant nutrient uptake characteristics, while considering cropping system limitations, weather and climatic conditions, risk assessment tools (i.e., Leaching Index), and field accessibility. Options for timing of nitrogen application may be expanded if steps are taken to adequately minimize leaching of nitrate. Fall applications of nitrogen for spring-seeded crops are not recommended. However, if fall nitrogen applications are made, follow guidance given in Appendix E.

Assessment tools that evaluate the potential for nitrogen and phosphorus transport from the field include the Missouri Leaching Index (eFOTG Section II B-3) and the Missouri Phosphorus Loss Assessment Tools (Appendix D).

The results of assessments from these tools shall be discussed with the landowner and decisions regarding actions to mitigate nitrogen and phosphorus losses will be included in the conservation system and nutrient management planning. Possible actions to mitigate nutrient losses include:

- Apply only the nitrogen needed to meet the planned realistic yield goal and as close to the time of plant utilization as possible.
  - Do not apply nitrogen before February 1 south of I-70 and March 1 north of I-70 for spring-seeded row crops.
  - Fall nitrogen applications on fall-seeded grain crops shall not exceed 50 lbs N/acre.
  - Fall nitrogen applications on forage crops shall not exceed 60% of annual need.
- Use split applications, slow-release fertilizers, and/or nitrification inhibitors where runoff or leaching is a concern.
- Injection of nutrients on the contour can reduce soluble nutrient losses in runoff. Consider incorporating nutrients if the impact on soil loss is compatible with soil conservation goals.
- Use the stalk nitrate tissue test to adjust nitrogen fertilizer applications if the University of Missouri-Columbia provides guidance for these adjustments.
- Use local water budgets as a guide to determine when the greatest likelihood for runoff or deep percolation will occur.

Nutrients must not be surface-applied if offsite nutrient losses are likely. This precludes spreading on:

- frozen and/or snow-covered soils, or
- when the top 2 inches of soil are saturated from rainfall or snow melt.

Exceptions for these surface-application criteria can be made when conservation practices and management techniques are followed that prevent the offsite delivery of nutrients. Slopes cannot exceed 10% and application setback distances for manure applications must be followed. In addition, one

or more of the following conditions must be met:

- Soil loss is less than the tolerable soil loss ("T").
- A continuous field border greater than 30 feet wide must protect all areas where surface water can exit.
- Organic residue and (or) living covers (e.g., cover crop, permanent pasture) protect greater than 80% of soil surface.
- Farms that produce and store significant quantities of manure are subject to greater scrutiny for the handling and land application of the manure they produce. For procedures applicable to animal operations during extreme weather events such as chronic or catastrophic rainfall, consider guidance provided by the Missouri Department of Natural Resources at: http://www.dnr.mo.gov/pubs/pub2422.pdf.

Application placement methods that reduce the risk of nutrient transport to surface and ground water, or into the atmosphere shall be employed.

To minimize nutrient losses:

- Apply nutrient materials uniformly to application area(s), except when variable-rate application is employed using site-specific management.
- On irrigated farms, incorporate water management to conform to the IRRIGATION WATER MANAGEMENT (449) conservation practice standard. The nutrient content of the irrigation water shall be determined by periodic water analysis and considered when balancing nutrient needs. An annual water analysis will be required when the water supply contributes 10 percent or more of the crop or forage need of at least one primary nutrient (nitrogen, phosphorus, or potassium).
- Calibrate equipment to apply fertilizer products uniformly and at acceptable rates. Design a system to apply fertilizer blends at rates that are efficient for the application equipment and require minimal changes or adjustments between fields.
- Avoid application of anhydrous ammonia on wet soils or other situations where application slots will not seal adequately.
- Avoid surface application of urea-based fertilizers in no-till unless steps are taken to minimize loss as ammonia.

**Additional Criteria to Minimize Agricultural Nonpoint Source Pollution of Surface and Groundwater**

Planners must use the current Missouri NRCS-risk of nutrient and soil loss. These tools include RUSLE2 to estimate soil loss, the Missouri Leaching Index, and the Missouri Phosphorus Loss Assessment Tools. Identified resource concerns must be addressed to meet current planning criteria (quality criteria).

When there is a high risk of transport of nutrients, conservation practices must be coordinated to avoid, control, or trap manure and nutrients before they can leave the field by surface or subsurface drainage (e.g., tile). The number of applications and the application rates must also be considered to limit the transport of nutrients to tile. Consider:

- slow- and controlled-release fertilizers
- nitrification and urease inhibitors
- incorporation or injection
- timing and number of applications
- soil nitrate and organic N testing
- coordinate nutrient applications with optimum crop nutrient uptake
- cornstalk nitrate test, pre-sidedress nitrate test, and pre-plant nitrate test
- tissue testing, chlorophyll meters, and spectral analysis technologies

**Additional Criteria Applicable to Properly Utilize Manure or Organic By-Products as a Plant Nutrient Source**

General Applicability:

When manures are applied and soil salinity is a concern, salt concentrations must be monitored to prevent potential crop damage and/or reduced soil quality.

The total single application of liquid manure:

- must not exceed the soil's infiltration or water holding capacity based on crop rooting depth, and

- must be adjusted to avoid runoff or loss to subsurface tile drains.

Crop production activities and nutrient use efficiency technologies must be coordinated to take advantage of mineralized plant-available nitrogen to minimize the potential for nitrogen losses due to denitrification or ammonia volatilization. To determine the plant-available nitrogen added in manure and organic by-products, use the PAN calculator located at: http://www.nmplanner.missouri.edu/tools/pan_calculator.asp.

When animal manures or other organic by-products are applied, nitrogen and phosphorus application rates, timing, and placement must be planned based on risk assessment results as determined by the Missouri Leaching Index and the Missouri Phosphorus Loss Assessment.

Missouri Phosphorus Loss Assessment tools generate a rating that shall be interpreted using guidance in Appendix D. Include:

- a record of the assessment method selected and the assessment rating for each field or subfield,
- an *application priority list* of available fields that considers current and projected nitrogen and (or) phosphorus status, manure storage status, and field application logistics,
- information concerning conservation practices and management activities that can reduce the potential for phosphorus movement from the application site.

The results of the risk assessments and any specific recommendations *shall be discussed with the producer* during the development of the nutrient management portion of the conservation plan.

Areas contained within established minimum application setbacks shall not receive direct application of manure nutrients. Minimum setback distances are provided in Appendix Table C. City or county regulations may extend state-specified minimum setback distances.

Manure and organic by-products shall not be applied on land having a slope greater than 20 percent.

Criteria for Nutrient Application Rates for Applications of Manure and Organic By-Products:

All unique sources of land-applied manure must be sampled at least once per year and tested for the following elements: total nitrogen, ammonium-nitrogen, total phosphorus, total potassium, and percent moisture or dry matter. If excessive salt concentrations are a concern, analyze the manure sample's electrical conductivity. In some cases substantial annual variation in nutrient concentrations may require sampling a manure source more than once per year. For example, unagitated lagoons can have significantly higher total nitrogen concentrations in spring compared to fall.

When possible, sample and analyze manure just prior to the primary time for land application of manure so the results are available for calculating manure application rates. In some cases it is only possible to get a representative sample during land application (for example, agitated manure pits). In these cases, historic values should be used to calculate application rates and the manure sampled during application should be used to contribute to the historic record of sample results.

Samples shall be collected and prepared according to University of Missouri-Columbia recommendations (see University of Missouri Extension Guide Sheets EQ215 -- *Laboratory Analysis of Manure* and G9340 -- *Sampling Poultry Litter for Manure Testing*) and according to state and local regulations.

When writing a nutrient management plan use professional judgment to determine if the most recent manure test or some summary of past tests best estimates the nutrient concentration in the manure storage and *document this decision in the nutrient management plan*. When planning for new operations use professional judgment to determine if "book values", feed-based, or manure test results from similar storage facilities provides the best estimate of manure nutrient concentration. For book values refer to the *NRCS Agricultural Waste Management Field Handbook* and Midwest Plan Service No. 18, Section 1 (2nd Edition), *Manure Characteristics*. For book values and feed-based estimates of nutrient generation refer to ASAE D384, *Manure Production and Characteristics*.

The planned rates of nitrogen and phosphorus applied recorded in the plan shall be determined based on the following guidance:

Nitrogen Application Rates

When animal manures or organic by-products are applied, the planned rates of nitrogen application shall consider:

- Plant-available nitrogen (PAN). For most sources of manure not all the nitrogen is available to the plant in the year of application. PAN in the manure must be determined according to the methods approved by the Missouri Department of Natural Resources for all manure applications. Manure application rate should be based on the PAN in the manure and should not exceed the annual nitrogen need of the crop adjusted for other sources of nitrogen applied to the crop. Nitrogen rates in the years following manure application must be adjusted for residual nitrogen available from manure.
- Plant uptake characteristics. When animal manures or organic by-products are used, the nitrogen availability of the planned application rates shall match plant uptake characteristics as closely as possible, taking into consideration the timing of nutrient application(s) in order to minimize leaching and atmospheric losses.
- Management activities and technologies that effectively utilize mineralized nitrogen and that minimize nitrogen losses through denitrification and ammonia volatilization.
- Application on legumes. Manure or organic by-products may be applied on legumes at rates not to exceed the estimated removal of nitrogen in harvested plant biomass. When manure or organic by-products are applied to legumes, the Leaching Index shall be used as a risk assessment for nitrate leaching. Manure or organic by-products may be applied on legumes at rates equal to the estimated removal of nitrogen in harvested plant biomass, not to exceed University of Missouri-Columbia recommendations.
- Supplemental inorganic nitrogen fertilizer. In some situations manure nitrogen is not applied at rates high enough to meet plant need. When required, an additional nitrogen application from non-organic sources may supplement manure plant-available nitrogen to produce the recommended total amount of nitrogen. Planned total nitrogen (plant-available organic plus inorganic fertilizer nitrogen) application rates shall not exceed annual crop nitrogen need by the greater of 10 percent or 10 pounds per acre in any given year.

Phosphorus Application Rates

When manure or organic by-products are used, the planned rates of phosphorus application shall be consistent with the Missouri Phosphorus Loss Assessment. Choose either strategy described below as appropriate:

- Soil Test. Apply manure at nitrogen-based rates when additional phosphorus is needed and likely will increase crop yield. A soil test phosphorus rating of “Very Low”, “Low”, or “Medium” will allow organic nutrients to be applied on a nitrogen basis, i.e., manure phosphorus may be applied to meet fertilizer phosphorus recommendations for the soil test cycle. When the soil test phosphorus level is “High” manure phosphorus may be applied not to exceed crop removal for the soil test cycle. When the soil test phosphorus level is “Very High” manure phosphorus should not be applied (See Appendix D, Table 1).

- Missouri Phosphorus Index. When the Missouri Phosphorus Index rating is “Low” or “Medium” manure phosphorus may be applied in excess of phosphorus removal rates not to exceed the allowable annual nitrogen recommendation and the phosphorus recommendation for the soil test cycle. When the Missouri Phosphorus Index rating is “High” manure phosphorus may be applied to meet crop removal for the soil test cycle. When the Phosphorus Index rating is “Very High” manure phosphorus should not be applied. When the Phosphorus Index rating is “High” or “Very High”, information shall be included in the conservation plan concerning conservation practices and management activities that can reduce the potential for manure phosphorus movement from the application site (See Appendix D, Table 2).

Phosphorus-based manure applications may be made at a rate equal to the recommended phosphorus application or estimated phosphorus removal in harvested plant biomass for the crop rotation or multiple years in the crop sequence. When such applications are made, the application rate shall:

- not exceed the recommended nitrogen application rate during the year of application, or
- not exceed the estimated nitrogen removal in harvested plant biomass during the year of application when there is no recommended nitrogen application, and
- ensure that the amount of phosphorus banked in the soil in excess of annual crop removal will not exceed four years of crop removal, or fertilizer recommendation, whichever is greater.

**Additional Requirements**

- Biosolids (sewage sludge) shall be applied in accordance with USEPA regulations [40 CFR Parts 403 (Pretreatment) and 503 (Biosolids)] and other state and/or local regulations regarding the use of biosolids as a nutrient source.

- When sewage sludge (biosolids) is applied, the accumulation of potential pollutants (including arsenic, cadmium, copper, lead, mercury, selenium, and zinc) in the soil shall be monitored in accordance with the US Code, Reference 40 CFR, Parts 403 and 503, and/or any applicable state and local laws or regulations.

- The application rate (in/hr) of liquid materials applied shall not exceed the soil in-take/infiltration rate and shall be adjusted to minimize ponding and to avoid runoff. The total application shall not exceed the field capacity of the soil and shall be adjusted, as needed, to minimize loss to sub-surface tile drains.

**Additional Criteria to Protect Air Quality by Reducing Odors, Nitrogen Emissions and the Formation of Atmospheric Particulates**

To address air quality concerns caused by odor, nitrogen, sulfur, and/or particulate emissions; the source, timing, amount, and placement of nutrients must be adjusted to minimize the negative impact of these emissions on the environment and human health. One or more of the following may be used:

- slow or controlled release fertilizers
- nitrification inhibitors
- urease inhibitors
- nutrient enhancement technologies
- incorporation
- injection
- stabilized nitrogen fertilizers
- residue and tillage management
- no-till or strip-till
- other technologies that minimize the impact of these emissions

Do not apply poultry litter, manure, or organic by-products of similar dryness/density when there is a high probability that wind will blow the material offsite.

**Additional Criteria to Improve or Maintain the Physical, Chemical, and Biological Condition of the Soil**

Time the application of nutrients to avoid periods when field activities will result in soil compaction.

In areas where salinity is a concern, select nutrient sources that minimize the buildup of soil salts.

**CONSIDERATIONS**

Use no-till/strip-till in combination with cover crops to sequester nutrients, increase soil organic matter, increase aggregate stability, reduce compaction, improve infiltration, and enhance soil biological activity to improve nutrient use efficiency.

Use cropping management strategies such as cover crops, crop rotations, and crop rotations with perennials to improve nutrient cycling and reduce energy inputs.

Use variable-rate nitrogen application based on chlorophyll concentration of the growing crop.

Variable-rate application of phosphorus, potassium, and lime based on site-specific variability in soil test values can improve productivity in certain circumstances.

Develop site-specific yield maps using a yield monitoring system. Use the data to further diagnose low- and high- yield areas, or zones, and make the necessary management changes. See Title 190, Agronomy Technical Note 190.AGR.3, *Precision Nutrient Management Planning*.

Use manure management conservation practices to manage manure nutrients to limit losses prior to nutrient utilization.

Apply manure at a rate that will result in an "improving" Soil Conditioning Index (SCI) without exceeding acceptable risk of nitrogen or phosphorus loss.

Use legume crops and cover crops to provide nitrogen through biological fixation and nutrient recycling.

Modify animal feed diets to reduce the nutrient content of manure following guidance contained in Conservation Practice Standard Code 592, Feed Management.

Soil test information should be no older than 1 year when developing new plans.

Excessive levels of some nutrients can cause induced deficiencies of other nutrients, e.g., high soil test phosphorus levels can result in zinc deficiency in corn.

Use soil tests, plant tissue analyses, and field observations to check for secondary plant nutrient deficiencies or toxicity that may impact plant growth or availability of the primary nutrients.

Potassium should not be applied in situations where an excess (greater than soil test potassium recommendation) causes nutrient imbalances in crops or forages.

Workers should be protected from and avoid unnecessary contact with plant nutrient sources. Extra caution must be taken when handling anhydrous ammonia or when dealing with organic wastes stored in unventilated enclosures.

Material generated from cleaning nutrient application equipment should be utilized in an environmentally safe manner. Excess material should be collected and stored or field applied in an appropriate manner.

Nutrient containers should be recycled in compliance with State and local guidelines or regulations.

**Considerations to Minimize Agricultural Nonpoint Source Pollution of Surface and Groundwater**

Use conservation practices that slow runoff, reduce erosion, and increase infiltration, e.g., filter strip, contour farming, or contour buffer strips. These practices can also reduce the loss of nitrates or soluble phosphorus.

Use application methods and timing strategies that reduce the risk of nutrient transport by ground and surface waters, such as:

- split applications of nitrogen to deliver nutrients during periods of maximum crop utilization,
- banded applications of nitrogen and/or phosphorus to improve nutrient availability,
- drainage water management to reduce nutrient discharge through drainage systems, and
- incorporation of surface-applied manures or organic by-products if precipitation capable of producing runoff or erosion is forecast within the time of planned application.

Use the agricultural chemical storage facility conservation practice to protect air, soil, and water quality.

**Considerations to Protect Air Quality by Reducing Nitrogen and/or Particulate Emissions to the Atmosphere**

Avoid applying manure and other by-products upwind of inhabited areas.

Use high-efficiency irrigation technologies (e.g., reduced-pressure drop nozzles for center pivots) to reduce the potential for nutrient losses.

**PLANS AND SPECIFICATIONS**

The following components must be included in the nutrient management plan:

- aerial site photograph(s)/imagery or site map(s), and a soil survey map of the site,
- soil information including: soil type surface texture, pH, drainage class, permeability, available water capacity, depth to water table, restrictive features, and flooding and/or ponding frequency,
- location of designated sensitive areas and the associated nutrient application restrictions and setbacks,
- for manure applications, location of nearby residences, or other locations where humans may be present on a regular basis, and any identified meteorological (e.g., prevailing winds at different times of the year), or topographical influences that may affect the transport of odors to those locations,
- results of approved risk assessment tools for nitrogen, phosphorus, and erosion losses,
- documentation establishing that the application site presents low risk for phosphorus transport to local water when phosphorus is applied in excess of crop removal.
- current and/or planned plant production sequence or crop rotation,
- soil, water, compost, manure, organic by-product, and plant tissue sample analyses applicable to the plan,
- soil test phosphorus and/or risk assessment levels at which the plan would require that no phosphorus in any form be applied,
- when soil phosphorus levels are increasing, include a discussion of the risk associated with phosphorus accumulation and a proposed phosphorus draw-down strategy as well as a priority listing of fields for application,
- realistic yield goals for the crops,
- complete nutrient budget for nitrogen, phosphorus, and potassium for the plant production sequence or crop rotation,
- listing and quantification of all nutrient sources and form,
- all enhanced efficiency fertilizer products that are planned for use,
- in accordance with the nitrogen and phosphorus risk assessment tool(s), specify the recommended nutrient application source, timing, amount (except for precision/variable rate applications specify method used to determine rate), and placement of plant nutrients for each field or management unit, and
- guidance for implementation, operation and maintenance, and recordkeeping.

In addition, the following components must be included in a precision/variable rate nutrient management plan:

- Document the geo-referenced field boundary and data collected that were processed and analyzed as a GIS layer or layers to generate nutrient or soil amendment recommendations.
- Document the nutrient recommendation guidance and recommendation equations used to convert the GIS base data layer or layers to a nutrient source material recommendation GIS layer or layers.
- Document if a variable-rate nutrient or soil amendment application was made.
- Provide application records per management zone or as applied map within individual field boundaries (or electronic records) documenting source, timing, method, and rate of all applications that resulted from use of the precision agriculture process for nutrient or soil amendment applications.
- Maintain the electronic records of the GIS data layers and nutrient applications for at least 5 years.

If increases in soil phosphorus levels are expected (i.e., when N-based rates are used), the nutrient management plan must document:

- the soil phosphorus levels at which it is desirable to convert to phosphorus based planning and/or no further phosphorus application,
- the potential plan for soil test phosphorus drawdown from the production and harvesting of crops, and

management activities or techniques used to reduce the potential for phosphorus transport and loss,

- for AFOs, a quantification of manure produced in excess of crop nutrient requirements, and
- a long-term strategy and proposed implementation timeline for reducing soil P to levels that protect water quality and allow for application of P at crop-removal rates,
- a rationale for P applications in excess of crop removal when the phosphorus risk assessment equates to a low risk for P transport to surface or groundwater.

**OPERATION AND MAINTENANCE**

Conduct periodic plan reviews to determine if adjustments or modifications to the plan are needed. At a minimum, plans must be reviewed and revised, as needed with each soil test cycle, changes in manure volume or analysis, crops, or crop management.

Fields receiving animal manures and/or biosolids must be monitored for the accumulation of heavy metals and phosphorus in accordance with land- grant university guidance and State law.

Significant changes in animal numbers, management, and feed management will necessitate additional manure analyses to establish a revised average nutrient content.

Calibrate application equipment to ensure accurate distribution of material at planned rates.

Document the nutrient application rate. When the applied rate differs from the planned rate, provide appropriate documentation for the change.

Records must be maintained for at least 5 years to document plan implementation and maintenance. As applicable, records include:

- soil, plant tissue, water, manure, and organic by-product analyses resulting in recommendations for nutrient application,
- quantities, analyses and sources of nutrients applied,
- dates, and method(s) of nutrient applications, source of nutrients, and rates of application,
- weather conditions and soil moisture at the time of application; lapsed time to manure incorporation; rainfall or irrigation event,
- crops planted, planting and harvest dates, yields, nutrient analyses of harvested biomass, and crop residues removed,
- dates of plan review, name of reviewer, and recommended changes resulting from the review, and
- all enhanced efficiency fertilizer products used.

Additional records for precision/variable rate sites must include:

- maps identifying the variable application source, timing, amount, and placement of all plant nutrients applied, and
- GPS-based yield maps for crops where yields can be digitally collected.

**REFERENCES**

Association of American Plant Food Control Officials (AAPFCO). 2011. AAPFCO Official Publication no. 64. AAPFCO Inc., Little Rock, AR.

Follett, R.F. 2001. Nitrogen transformation and transport processes. *In* Nitrogen in the environment; sources, problems, and solutions, (eds.) R.F. Follett and J. Hatfield, pp. 17-44. Elsevier Science Publishers. The Netherlands. 520 pp.

Schepers, J.S., and W.R. Ruan, (eds.) 2008. Nitrogen in agricultural systems. Agron. Monogr. no. 49, American Society of Agronomy (ASA), Crop Science Society of America (CSSA), Soil Science Society of America (SSSA). Madison, WI.

Sims, J.T. (ed.) 2005. Phosphorus: Agriculture and the environment. Agron. Monogr. no. 46. ASA, CSSA, and SSSA, Madison, WI.

Stevenson, F.J. (ed.) 1982. Nitrogen in agricultural soils. Agron. Series 22. ASA, CSSA, and SSSA, Madison, WI.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2010.

Agronomy Technical Note, (TN) 190-AGR-3, Precision Nutrient Management Planning. Washington, DC.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2011. Title 190, General Manual, (GM), Part 402, Nutrient Management. Washington, DC.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2011, Title 190, National Instruction (NI), Part 302, Nutrient Management Policy Implementation. Washington, DC.

# APPENDIX A

## MISSOURI RESOURCES AND LINKS

### QUICK REFERENCE--INTERNET LINKS

Missouri Fertilizer Recommendation Tool

http://soilplantlab.missouri.edu/soil/recommendationsonline.aspx

Approved Soil Testing Laboratories for Missouri

http://soilplantlab.missouri.edu/soil/msta.aspx

Approved Manure Testing Laboratories for Missouri

http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp

Missouri Phosphorus Index

http://www.mo.nrcs.usda.gov/technical/nut_mgmt_index.html

Missouri Plant-Available Nitrogen Calculator

http://www.nmplanner.missouri.edu/tools/pan_calculator.asp

Resources for Nutrient Management Planners

http://www.nmplanner.missouri.edu/

Technical References for NRCS Nutrient Management Planners

http://www.mo.nrcs.usda.gov/technical/technotes_index.html

## APPENDIX B

## AGRONOMIC CROP NUTRIENT REMOVAL ESTIMATES

| Crop code[1] | Crop | Source | Yield unit | Yield wt. | Moisture content | Nitrogen removal | $P_2O_5$ removal | $K_2O_5$ removal |
|---|---|---|---|---|---|---|---|---|
| | | | | | % | *Pounds per yield unit* | | |
| **100** | Barley | Beef NRC, 2000[2] | bushel | 48 | 14.5 | 0.87 | 0.33 | 0.29 |
| **101** | Buckwheat | Other[4] | pound | 1 | | 0.05 | 0.007 | 0.003 |
| **102** | Cotton | Other[4] | pound | 1 | | - | 0.038 | 0.035 |
| **103** | Corn Grain | Beef NRC, 2000[2] | bushel | 56 | 15.5 | 0.74 | 0.32 | 0.25 |
| **104** | Corn Silage | Dairy NRC, 2001[3] | ton | 2000 | 65 | 10 | 4.1 | 10 |
| **109** | Oats | Beef NRC, 2000[2] | bushel | 32 | 14 | 0.60 | 0.26 | 0.17 |
| **110** | Popcorn | Other[4] | pound | 1 | | 0.016 | 0.008 | 0.005 |
| **111** | Rice | Other[4] | pound | 1 | | 0.013 | 0.0065 | 0.004 |
| **112** | Rye | Other[4] | bushel | 56 | 14 | 1.2 | 0.34 | 0.34 |
| **113** | Sorghum grain | Beef NRC, 2000[2] | pound | 56 | 13 | 0.98 | 0.38 | 0.26 |
| **114** | Sorghum silage | Dairy NRC, 2001[3] | ton | 2000 | 65 | 10 | 3.3 | 15 |
| **115** | Soybean | Beef NRC, 2000[2] | bushel | 60 | 13 | 3.4 | 0.80 | 1.30 |
| **116** | Sugar beets | Other[4] | ton | 2000 | | 4 | 1.33 | 3.33 |
| **117** | Sunflowers | Dairy NRC, 2001[3] | pound | 1 | 10 | 0.028 | 0.010 | 0.012 |
| **118** | Tobacco | Other[4] | bushel | | | 0.036 | 0.004 | 0.007 |
| **119** | Wheat | Dairy NRC, 2001[3] | bushel | 60 | 13.5 | 1.18 | 0.50 | 0.30 |
| **10** | Alfalfa-grass hay | Beef NRC, 2000[2] | ton | 2000 | 10 | 54 | 11 | 53 |
| **14** | Bermudagrass hay | Dairy NRC, 2001[3] | ton | 2000 | 10 | 30 | 11 | 40 |
| **16** | Clover-grass hay | Dairy NRC, 2001[3] | ton | 2000 | 10 | 55 | 13 | 57 |
| **18** | Cool season grass hay | Dairy NRC, 2001[3] | ton | 2000 | 10 | 38 | 12 | 47 |
| **22** | Lespedeza-grass hay | Other[4] | ton | 2000 | 10 | - | 8.8 | 20 |
| **24** | Sudangrass hay | Dairy NRC, 2001[3] | ton | 2000 | 10 | 27 | 8 | 52 |
| **26** | Warm season grass hay | Other[4] | ton | 2000 | 10 | - | - | - |

[1]Crop codes are used by the University of Missouri Recommendations Online Tool (http://soilplantlab.missouri.edu/soil/scripts/manualentry.aspx).

[2]Beef NRC, 2000—**"Nutrient Requirements of Beef Cattle", Seventh Revised Edition, (Update),** National Research Council, National Academy Press, Washington, D.C. 2000.

[3]Dairy NRC, 2001—**"Nutrient Requirements of Dairy Cattle", Seventh Revised Edition",** National Research Council, National Academy Press, Washington, D.C. 2001.

[4]Other, currently based on the previous Soil Test Interpretations Handbook (5/2006).

## APPENDIX C

## MANURE APPLICATION SETBACK FEATURES AND DISTANCES FOR MISSOURI

For all plans following Missouri NRCS practice standard guidelines. (Must be consistent with Missouri Department of Natural Resources regulations.)

| Setback feature | Application conditions | Distance (ft) |
|---|---|---|
| **Public or private drinking water well or other wells including unplugged abandon wells** | All application methods | 300 |
| **Public or private drinking water lake or impoundment** | All application methods | 300 |
| **Public or private drinking water structure** | All application methods | 300 |
| **Classified waters of the state not used as a water supply as defined in 10 CSR 20-7.031(1)F** | Up-gradient, ≥35 permanently vegetated buffer | 35 |
| | Up-gradient, <35 permanently vegetated buffer | 100 |
| | Down-gradient | 35 |
| **Unclassified public and privately owned lakes and impoundments not used as a water supply including impoundments with no outlets and wetlands** | Up-gradient, ≥35 permanently vegetated buffer | 35 |
| | Up-gradient, <35 permanently vegetated buffer | 100 |
| | Down-gradient | 35 |
| **Unclassified perennial streams, intermittent streams, canals, and drainage ditches** | Up-gradient, ≥35 permanently vegetated buffer | 35 |
| | Up-gradient, <35 permanently vegetated buffer | 100 |
| | Down-gradient | 0 |
| **Losing stream** | All application methods | 300 |
| **Cave entrance** | All application methods | 300 |
| **Spring** | All application methods | 300 |
| **Active sinkhole** | All application methods | 300 |
| **Non-owned occupied residence** | Spray irrigation only | 150 |
| **Public use area including non-owned business** | Spray irrigation only | 150 |
| **Public road** | All application methods | 50 |
| **Property boundary** | All application methods | 50 |

# APPENDIX D

# PHOSPHORUS LOSS ASSESSMENT TOOLS AND RATINGS

**In Missouri one of two options shall be used for all phosphorus applications.**

**(1) Soil Test Phosphorus Method (soil loss <T) --**

When soil test phosphorus levels are used, phosphorus may be applied at rates consistent with Table 1.

**Table 1. Soil Test Phosphorus Values**

| Soil Test Phosphorus Rating† | Phosphorus Application | |
|---|---|---|
| **Very low** | Nitrogen-Based | Application to meet fertilizer phosphorus recommendations |
| **Low** | Nitrogen-Based | |
| **Medium** | Nitrogen-Based | |
| **High** | Application of Phosphorus Not To Exceed Crop Removal | |
| **Very High** | Phosphorus Should Not Be Recommended | |

†Use methods and interpretations accepted by the University of Missouri-Columbia

**(2) Missouri Phosphorus Index Method –**

When the Phosphorus Index method is used, phosphorus may be applied at rates consistent with Table 2. The Missouri Phosphorus Index may be obtained at http://www.mo.nrcs.usda.gov/technical/nut_mgmt_index.html.

**Table 2. Phosphorus Index Interpretations**

| Phosphorus Index Rating | For Manure and Organic By-product Applications† | For Commercial Fertilizer Applications‡ |
|---|---|---|
| **Low Risk** | Application of manure phosphorus in excess of crop removal allowed not to exceed fertilizer recommendations | Phosphorus fertilizer applications can build soil test phosphorus levels |
| **Medium Risk** | | |
| **High Risk** | Phosphorus applications shall not exceed crop removal | Phosphorus application rates shall not exceed recommendations |
| **Very High Risk** | Phosphorus Should Not Be Recommended | |

†Use for all manure and organic by-products applications
‡Use when soil loss estimate from RUSLE2 predicts soil loss in excess of the tolerable soil loss (“T”)

## APPENDIX E

## GUIDANCE FOR APPLICATION OF NITRIFICATION INHIBITORS IN MISSOURI

NOTE: This guidance is condensed from Agronomy Technical Guide No. 34 (http://www.mo.nrcs.usda.gov/technical/technotes_index.html)

Nitrification inhibitors are bactericides applied with anhydrous ammonia fertilizers to slow the conversion of ammonium to nitrate. To reduce the rate of conversion of ammonium to nitrate, it is recommended that anhydrous ammonia with nitrification inhibitor be applied only after the 6-inch soil temperature falls below 50ºF in autumn and winter.

Permissible application dates for anhydrous ammonia with nitrification inhibitor in Missouri are shown in the map below. The state has been divided into three climatic zones that estimate the date when 6-inch soil temperature will stay below 50ºF. For Zone 1, anhydrous ammonia with nitrification inhibitor can be applied any time after November 15. For Zone 2, anhydrous ammonia with nitrification inhibitor can be applied anytime after December 1. For Zone 3, anhydrous ammonia with nitrification inhibitor should be delayed until after January 1. To avoid unacceptable delays in plant availability, do not apply anhydrous ammonia with nitrification inhibitor after March 1. Anhydrous ammonia may be applied without nitrification inhibitor after March 1 for all zones.