NATURAL RESOURCES CONSERVATION SERVICE
MONTANA CONSERVATION PRACTICE SPECIFICATION

NUTRIENT MANAGEMENT (ACRE)

PRECISION AGRICULTURE

CODE 590

PRODUCER	**TRACT. / FIELD NO. / CTU**

DEFINITION: Nutrient management is managing the source, rate, form, timing, and placement of nutrients.

PURPOSE: Nutrient management effectively and efficiently uses scarce nutrient resources to adequately supply appropriate soil and plant nutrients to produce food, forage, fiber, and cover while minimizing environmental degradation. Precision nutrient management is applicable to all lands where plant nutrients and soil amendments are applied at variable rates.

Precision agriculture uses the best available technologies to tailor soil and crop nutrient management to fit the variation in site-specific conditions found in smaller areas of larger management units. Precision agricultural methods are used to collect the information that is needed to more precisely evaluate input production factors, more accurately predict crop yields, and more precisely apply variable rates of nutrients.

CONSERVATION MANAGEMENT SYSTEMS

Nutrient management is a component of a conservation management system. It is used in conjunction with crop rotation, residue management, pest management, conservation buffer practices, waste utilizations, and/or other practices needed on a site-specific basis to address natural resource concerns and producer objectives. The major role of precision nutrient management is to use accurate information about within field variability to minimize nutrient losses and optimize inputs thus helping protect surface and ground water supplies while maximizing net production and profits.

PRECISION NUTRIENT MANAGEMENT PLANNING

A precision nutrient management plan is a dynamic tool, and once developed must be monitored and adjusted on an annual basis. As a minimum, a nutrient budget for nitrogen, phosphorus, and potassium will be designed that considers all sources of nutrients including animal manures, organic by-products, waste water, irrigation water, commercial fertilizer, crop residues, legumes, atmospheric deposition, and mineralization.

Precision nutrient management must strive to:

- Identify within field variability and delineate corresponding management zones
- Obtain realistic yield goals for each management unit and zone
- Compare performance of nutrient rate, timing, placement, and other alternatives
- Determine causes of yield losses due to natural, equipment and human induced factors
- Conduct cost and return assessment of variable and fixed costs of production for management zones
- Identify nutrient sufficiency, deficiency, and toxicity zones
- Detect other productivity problems and soil amendment options.

Specification MT590A-2

BASIC COMPONENTS OF PRECISION NUTRIENT MANAGEMENT

Field Visit – No matter how detailed the imagery, a field visit and producer involvement is invaluable. Imagery does not always show within field variations that are induced by management decisions, climatic conditions, geologic characteristics, or and other sources of variation. Whereas, producer input may explain such variations.

Field Boundaries – Although not considered in most cases, it is important to digitize field boundaries on site. On-site delineation of boundaries will greatly assist the accuracy of where other digitized data aligns. Digitizing field boundaries on imagery is often times not accurate enough and may affect location accuracy of other digitized data layers.

Equipment – Yield monitoring systems are an integral part of precision agriculture. A yield monitoring system must include:

- GPS and differential correction for position information during harvest
- Grain flow sensor to ensure grain flow rate at harvest
- Moisture sensor to measure grain or other product moisture
- Speed sensor (speedometer) to determine the speed at which the combine is operating
- Header position switch to control yield monitor data logging
- Memory card with data output card.

Yield Data – Yield data is one of the most important data elements that can be utilized to design a nutrient management plan. Digitized yield monitoring is critical in effectively designing precision agriculture nutrient management prescriptions, and should be collected annually and incorporated as a data layer for following year prescriptions.

Yield Monitor Calibration – All yield monitors must be calibrated according to the manufacturer's specification.

Soil Survey – Digitized soil survey mapping and associated data is an essential layer that should *always* be utilized with precision agriculture nutrient management design. Soil survey information provides valuable information including such characteristics as soil texture, horizon depth, hydraulic conductivity, physical and chemical properties, erosivity, and numerous other factors that might affect site potential. SSURGO (Soil Survey Geographic database) is digitized soil mapping that is available for most counties in Montana at http://soildatamart.nrcs.usda.gov/.

Soil Sampling – The process of soil sampling is extrememly important for making accurate prescriptions. Depending on the precision technology utilized, soil sampling is completed first, digitizing each sample location. The analysis of these samples can then be used as another layer along with imagery and SSURGO, and other layers, to determine management zones. In general, numerous sub-samples must be collected to provide the most accurate nutrient concentration depiction.

Other methods of precision nutrient management will require the identification of zones first, then subsequent zone soil sampling. This process may require adjustment of zone boundaries after analysis results are considered.

Soil Tests – Where methodologies use soil tests to determine nutrient management zones, current soil tests must be used to effectively plan for nutrient application. Current soil tests are those that are no more than three years old. Due to potential annual variability, nitrogen must be tested each year a crop is grown. Phosphorus and potassium may be completed once every three years until a baseline, or consistent database, is established. GPS (Geographic Positioning System) locations should be collected at the points where soil tests are conducted. An electronic file of the GPS point data with nutrient

attributes should be included with the nutrient management plan. Regular testing of soil nutrient availability is essential for precision nutrient management decision-making. Soil tests should be completed as close as possible to the time of seeding for the most accurate results.

Nutrient Budget – Precision agriculture nutrient management techniques identify and address with-in field variation. A nutrient budget for each nutrient that will be variably applied is required in the design of the nutrient management plan and must considers all sources of nutrients including animal manures, organic by-products, waste water, irrigation water, commercial fertilizer, crop residues, legumes, atmospheric deposition, and mineralization. NRCS form MT-ECS-590B Nutrient Budget, available electronically at http://efotg.nrcs.usda.gov/references/public/MT/590_jobsheet_2006.pdf or similar form that addresses all of the above considerations, must be used in the nutrient management design prescription to meet producer objectives. When real time variable nutrient application is practiced, pre-application map, target rate, and as-applied rate maps are required to document budget process (the NRCS budget form is not required).

Nutrient Application Data – Nutrients must be applied using equipment that has GPS and variable rate capability. The nutrient application prescription is provided to the producer and the nutrient applicator who then applies nutrients according to the prescription. A digitized application record must be recorded by the applicator as nutrients are applied. This digitized data layer is required to document nutrient application and can also be used to analyze potential variation for following year prescriptions.

Nutrient Management Zones – A zone is "site potential". Each established management zone will have one application rate prescription. Because precision agriculture technology is rapidly changing, however, variable rate equipment technology can effectively apply numerous (i.e., up to 250 or more) rates of nutrients based on vegetative index variation. Where this type of equipment is used, a "range of rates" may be designed across a particular zone (rather than only one specific rate per zone). The number of zones is dependent on variables within the field and should be designed in accordance with the capabilities of the application equipment and the needs of the producer. Initial delineations of nutrient management zones can be determined using any one, or a combination of the following methods:

1. Multi-spectral **satellite imagery or aerial ortho-photography** can be used. Multi-spectral remote sensing should accurately portray field conditions for the yield goal defined. It should be noted that there are significant differences in data quality of imagery from year-to-year. Multi-spectral satellite imagery should have a spatial resolution no greater than 30 meters, and at a minimum, must have spectral data from the red and near-infrared bands. Aerial ortho-photography should have a spatial resolution no greater than five meters and must be displayed as natural color or color infrared. Imagery with dates corresponding to seasons of drought or extreme moisture should be avoided as it is difficult to correlate with actual within-field variability due to nutrient status. Using image analysis software or photo interpretation, evaluate imagery for information representing variations in soil color, soil moisture, crop vigor, crop production (example: vegetative indexing), pest infestations, nutrient deficiency or sufficiency, toxicity, etc. Manually or electronically delineate initial management zones for variable rate nutrient applications and transfer the delineations to the nutrient application software. In all cases, the vintage (date) and source of the photography utilized must be provided.

   This process requires digital soil survey data as a layer, and if possible, digital yield data from previous years. Soil sampling may be completed prior to establishment of the zones or after zone establishment to develop nutrient budgets. Note that if sampling is completed post zone establishment, it may be necessary to adjust zones dependant on sample analysis.

2. **Grid soil sampling** involves dividing a field into equal square or rectangular sections (grids) of several acres in size. Collect one soil test (one from 0-6" and one from 6-24") per four acres on fields of less than 50 acres in size or one soil test per five acres in size on fields greater than 50 acres. As a minimum, sample analysis must include NO_3 (Nitrate), Phosphorus, Potassium, Organic Matter (OM), pH, and Electro-Conductivity (EC). Management zones should then be determined based on

an interpretation of measurable differences in nutrient status within the management unit in addition to other layers utilized, i.e., previous years yield data, digitized scouting reports, soil survey layers, etc.

Additional soil testing is not required after zones are established.

3. Use **electro-conductivity (EC) monitoring** to express measurable differences in soil texture, structure, organic matter, drainage, topsoil depth, soil water contents, and other soil characteristics. Management zones should then be determined based on an interpretation of measurable differences in soil properties within the management unit along with layers of other applicable digital data, i.e., digitized yield data, scouting reports, soil survey layers, etc.

   Soil sampling is required to correlate EC readings prior to setting the zones and application rates.

4. **Land-based optical sensing** is a form of utilizing vegetative indices to optically scan the growing crop in real time and respond to variability. Where this type of precision ag. is practiced, soil sampling may not be necessary to establish zones, however, it is still recommended that at least a bulk sample be analyzed. Where required, establish calibration according to manufacturer's recommendations. Soil sampling within the three primary management zones should be completed after harvest to validate nutrient applications and prepare for the following year's crop(s).

Zone Soil Sampling – Collect representative soil tests for each zone established above. If grid soil sampling was completed, this step can be skipped. Otherwise, zone soil sampling must be completed as indicated above. The number of soils samples and sub-samples required must follow Montana State University (MSU) guidelines for soil testing, but must be "representative" of the zone. For dryland cropping systems, soil samples must be collected, as a minimum, at 0-6" and 6-24" for nitrate-nitrogen and 0-6" for phosphorus, and potassium. Where deep leaching of nitrate-nitrogen is a concern, soil tests must be completed to 36". For irrigated cropping systems, soil samples must be collected, as a minimum, at 0-6" for nitrate-nitrogen, phosphorus, and potassium and 6-24" for nitrate-nitrogen. Where deep leaching of nitrate-nitrogen is a concern, soil tests must be completed to 48" for nitrate-nitrogen.

Apply Nutrients – After the zone map is developed, and soil samples are collected and soil analysis obtained, apply nutrients using variable rate application. This requires the use of GPS-guided application equipment capable of interpreting digital management zone information. A minimum of three application rates is typically implemented; high, medium, and low nutrient quantities based on realistic yield goals and cost.

Nutrient Application Timing – Apply nutrients as close to time of utilization as possible. This will ensure that potential for leaching, runoff, or volatilization will be minimized. Nitrogen application in the fall is not recommended except for fall seeded crops, with the exception of "starter fertilizer".

Field Risk Assessment – When animal manure or other organic by-products are applied, a site-specific assessment of the potential for phosphorus transport from the field must be completed using the Montana Phosphorus Index (PI). When the PI is completed, a copy of it will be attached to this specification.

When the PI assessment rating is **N/A**, **low**, or **medium**, nitrogen-based phosphorus application plans will be developed such that manure application rates of nitrogen do not exceed crop and soil needs based on the nutrient budget, see Field Office Technical Guide (FOTG), Section IV, Specification, Nutrient Management (Code 590), Table 8.

When the PI assessment rating is **high**, phosphorus-based plans will be developed such that manure application rates of phosphorus do not exceed crop removal rates, see Field Office Technical Guide (FOTG), Section IV, Specification, Nutrient Management (Code 590), Table 9.

When the PI assessment rating is **very high**, phosphorus-based plans will be developed such that manure application rates of phosphorus do not exceed crop removal rates or no application of manure will be recommended, see Field Office Technical Guide (FOTG), Section IV, Specification, Nutrient Management (Code 590), Table 9.

NUTRIENT MANAGEMENT ASSESSMENT

Make a site-specific environmental assessment of the potential risk of nutrient management. The boundary of the nutrient management assessment is the Agricultural Management Zone (AMZ), which is defined as the edge of field, bottom of the root zone, and top of crop canopy.

Within an area designated as having impaired or protected natural resources (soil, water, air, plants, and animals), the nutrient management plan should include an assessment of the potential risk for nitrogen and phosphorus to contribute to water quality impairment.

YIELD MONITORING

Yield Map Development – Use a GPS-guided yield monitor to track field variations and make future adjustments of nutrient application. The data collected from the yield monitor is downloaded and imported into an appropriate software package. Post processing of the yield data must be completed by range, equal count, or customized yield ranges. The counts or ranges of yield data are then used to develop yield maps with color-coded displays of the classes, ranges or counts of yield values within the fields. The development of accurate yield maps from the yield data requires an appropriate data interpolation method to be used. Different methods of data interpolation such as Kriging or nearest
neighbor are incorporated into different manufacturer's software. It is important to make comparisons between yield maps produced by different data interpolation methods to determine the most accurate representation of the within and between field yield variations. A digital copy of yield data files and maps with summarized yield data should be included with the conservation plan. Where yield data is required, interpolation and correlation to the developed zone map must be provided to field offices for documentation purposes.

Yield Map Interpretation – Identify yield variability due to topographic features, natural fertility, equipment-induced, management-induced, pest-induced, and/or other factors. The nutrient levels corresponding with GPS points from the soil tests should be displayed on yield maps to aid with interpretation. If available, additional GPS point data for other factors can also be used to aid in the interpretation of yield maps. Other field variation characteristics can be collected, digitized, and interpreted in the refined development of management zones. Characteristics such as insect, disease, or weed infestations can be used as additional layers when assessing precision nutrient application rates. Annual yield variation can be used as additional layers when developing and modifying management zones.

MAPS

All methods of precision nutrient management require documentation of management zone establishment, nutrient budget and associated components, and nutrient application. Typically documentation includes (depending on the method used) digital soil survey imagery, aerial imagery, aerial imagery dates and source, soil sample locations, soil sample analysis, nutrient budget for each zone, zone map (target rate), yield projections, previous year's yield data, pre-application sensed data (vegetative indexes or grid sampling maps), and as-applied maps.