Department Circular DEQ 9

Montana Technical Standards
for
Concentrated Animal Feeding Operations

February 2006
Montana Department of Environmental Quality

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Foreword

The Board of Environmental Review of the State of Montana, as authorized by 75-5-401(1)(a), Montana Code Annotated (MCA), has adopted the following standards for concentrated animal feeding operations. The terms “shall,” “must,” “may not”, and “required” are used to indicate enforceable provisions of these standards. Further, these terms have been bolded in order to provide clarity to the regulated community. Other terms, such as “should,” “may,” and “recommended,” indicate desirable procedures or methods.

This circular is divided into seven sections: Section 1 outlines the design criteria for animal waste management systems; Section 2 describes a method for calculating waste production; Section 3 describes the requirements for a Nutrient Management Plan; Section 4 describes the Best Management Practices applicable to production and land application areas; Section 5 describes some appropriate methods to sample waste and calibrate application equipment; Section 6 outlines the state’s technical standards for nutrient management; and Section 7 outlines the minimum recordkeeping requirements for Concentrated Animal Feeding Operations.

The design criteria specified in Section 1 are intended to define limiting values for items upon which the Department will make an evaluation of plans and specifications; and to establish, as far as practicable, uniformity of practice. Deviations from the criteria are allowed on a case-by-case basis. The individual designing the waste management system must submit a request, with appropriate technical justification, for a deviation from a specific section of the standards indicating how the criteria will be changed. Any deviation from the listed design criteria must be approved by the Department and is subject to the public notice procedures of the Montana Pollutant Discharge Elimination System permit.

Additionally, the design criteria are intended for the more conventional waste control facilities. Innovative approaches to waste containment and/or treatment are not included. The DEQ should be contacted for design guidance and criteria where such systems are being considered. Lack of description or criteria does not suggest it should not be used, but only that consideration by the DEQ will be on the basis of information submitted with the design.

The calculations included in Section 2 are provided for informational purposes only; other methods to calculate waste production may be acceptable. The state’s technical standards for nutrient management listed in Section 6 are applicable only to Large Dairy, Cattle, Swine, Poultry, and Veal Calf Concentrated Animal Feeding Operations (CAFOs) as established in Title 40 of the Code of Federal Regulations Part 412.4.

Section 1: Animal Waste Management System Design

The Administrative Rules of Montana (ARM) Section 17.30.1303 adopts by reference the federal effluent limitations for concentrated animal feeding operations as they have been codified in the July 1, 2003 edition of Title 40, Part 412, of the Code of Federal Regulations (CFR). 40 CFR Part 412 specifies the effluent limitations applicable to Large Horse, Sheep, Dairy Cow, Cattle, Veal Calf, Swine, and Poultry CAFOs. These effluent limitations specify that the production area **must** be designed, constructed, operated, and maintained to handle all the manure, litter, and process wastewater, including the runoff and direct precipitation from normal rainfall events up to a *25-year, 24-hour* rainfall event. Large swine, poultry, or veal calf CAFOs designed and built after April 14, 2003, **must** be properly designed, constructed, operated, and maintained to handle all the manure, litter, and process wastewater, including the runoff and direct precipitation from normal rainfall events up to a *100-year, 24-hour* rainfall event.

To meet this effluent limitation, the design volume of the waste control structure(s) **must** reflect the following:

- Storage period;
- Accumulated waste during storage period;
- Normal precipitation and evaporation during the storage period;
- Normal runoff during the storage period;
- Direct precipitation from a *25-year, 24-hour* (or *100-year, 24-hour*) rainfall event;
- Residual solids after liquid has been removed;
- Necessary freeboard to maintain storage integrity; and
- Minimum treatment loading, if applicable.

In order to demonstrate compliance with this effluent limitation, CAFOs **must** submit Plans and Specifications (P&S) prepared by an individual qualified to design animal waste management systems. These P&S **must** be developed in accordance with the design criteria listed in this circular. The Department will review these P&S for conformance with the listed design criteria. The Department may approve deviations from the design criteria on a case-by-case basis.

Design Criteria

A. Collection

Ditches, dikes, berms, terraces, or other such structures **must** be used to divert peak flows to the waste control structure, if necessary. The structures **must** be designed to carry the peak flow expected during the *25-year, 24-hour* rainfall event. For large swine, poultry, or veal calf CAFOs designed and built after April 14, 2003, the structures **must** be designed to carry the peak flow expected during the *100-year, 24-hour* rainfall event.

B. Waste Storage Structure

Location

Waste containment structures or the manure and wastewater disposal sites **may not** be located within state waters.

A minimum separation of 4 feet between the bottom of the pond and the maximum groundwater elevation **must** be maintained.

A minimum separation of 10 feet between the pond bottom and any bedrock formation **must** be maintained.

Wastewater containment structures or the manure and wastewater disposal sites constructed after October 1, 1993, **may not** be located within 500 feet of existing water wells.

Any waste control structures located within the 100-year floodplain **shall** be flood proofed. The top of the basin embankment **shall** be constructed at least one foot above the elevation of the 100-year flood.

Ground Water Protection

Waste containment structures **must** be sealed so that seepage loss through the seal is as low as practicably possible. Seals consisting of solids, bentonite, or synthetic liners may be considered provided the permeability, durability, and integrity of the proposed material can be satisfactorily demonstrated for anticipated conditions. Results of a testing program that substantiate the adequacy of the proposed seal **must** be incorporated into and/or accompany the design report. Testing **must** take place at the maximum operation depth. Standard ASTM procedures or acceptable similar methods **must** be used for all tests. To achieve an adequate seal in systems using soil, bentonite, or other seal materials, the coefficient of permeability (k) in centimeters per second specified for the seal **may not** exceed the value derived from the following expression: $k=3.0 \times 10^{-9}L$, where L equals the thickness of the seal in centimeters.

Finished elevations for soil and bentonite liners **may not** vary more than 3 inches from the average elevation of the bottom and should be as level as possible. Sloped pond bottoms are allowed for synthetic liners, however they **must** be uniformly sloped.

Volume Capacity

Waste containment structures **must** provide a minimum design capacity of 180 days. The design volume **must** include the following:

1. Liquid and solid manure and process-generated wastewater;
2. Process wastewater to include the normal runoff during the storage period if the structure receives runoff from the lots or pens;
3. Normal precipitation less evaporation on the pond surface. The amount of evaporation used in this calculation **may not** be more than the amount shown on the Mean Annual Shallow Lakes and Reservoirs Evaporation map provided in Attachment 1 (or other equivalent reference as approved by the Department);

4. *25-year, 24-hour* precipitation on pond surface and runoff (if structure receives runoff from an open lot). Large swine, poultry, and veal calf operations designed and built after April 14, 2003, **shall** use the *100-year, 24-hour* precipitation on the pond surface and runoff. The amount of precipitation used in this calculation **may not** be less than the amount shown on the Rainfall Frequency Atlas of the United States, National Weather Service Technical Paper Number 40, as provided in Attachment 1 (or other equivalent regional or state rainfall probability information developed from this source);
5. Additional water necessary to meet volatile solids loading or other loading rates if the structure is an anaerobic, naturally aerobic or mechanically aerated lagoon; and
6. Residual volume. An allowance of at least six inches **must** be provided in the bottom of the containment structure to accommodate materials that are not removed during emptying.

Design Characteristics

Inner and outer dike slopes **may not** be steeper than 1 vertical to 3 horizontal (1:3). Inner slopes should not be flatter than 1 vertical to 4 horizontal (1:4).

Dikes **must** be constructed of relatively impervious soil and compacted to at least 90 percent Standard Proctor Density, or as recommend by a geotechnical engineer, to form a stable structure. Vegetation and other unsuitable materials **must** be removed from the area where the embankment is to be placed.

The freeboard **may not** be less than one foot for any containment structure. Freeboard is measured from the high water mark to the bottom elevation of the emergency spillway, or lowest part of the dike or containment structure. The high water mark is the elevation in the containment structure necessary to contain the designed storage of accumulated manure and process generated wastewaters, and the *25-year, 24-hour* rainfall event or *100-year, 24-hour* rainfall event for large swine, poultry, and veal calf operations designed and built after April 14, 2003.

A containment structure or lagoon for an open lot may be constructed with an emergency spillway or overflow channel to remove water in a controlled manner when the capacity of the containment facility is exceeded. If present, the emergency spillway **must** be designed to safely pass the flow expected from at least the *25-year, 24-hour* rainfall event.

Earthen embankments of any containment structure **must** have a top width of at least 8 feet.

Adequate provision **must** be made to divert stormwater runoff around the ponds and protect pond embankments from erosion.

For large dairy, cattle, swine, poultry, and veal calf CAFOs, permanent depth markers (measuring devices) **must** be maintained in any open, liquid containment structure to show the volume required to contain a *25-year, 24-hour* rainfall event (or *100-year, 24-hour* rainfall event for large swine, poultry, and veal calf operations designed and built after April 14, 2003). A

minimum of one marker is **required** at the maximum operation level of each containment structure.

C. Waste Treatment Lagoon

The design criteria listed in Section B. "Waste Storage Structure" **must** be followed. In addition, the following criteria apply:

Anaerobic Lagoons
The design **must** be based on volatile solids loading. The loading rate for an anaerobic lagoon **may not** exceed 3.0 pounds of volatile solids per 1,000 cubic feet of pond volume. The minimum depth of liquid **shall** be 6 feet.

Naturally aerobic lagoons
The design **shall** be based on daily biochemical oxygen demand (BOD_5) loading per acre of lagoon. The loading rate for an aerobic lagoon **may not** exceed 20 pounds of BOD_5 per acre of lagoon per day. The maximum depth of liquid **shall** be 5 feet. The minimum depth at maximum drawdown **shall** be 2 feet.

Mechanically aerated lagoons
The aeration equipment **must** provide a minimum of 2.5 pounds of oxygen for each pound of BOD_5 per day. The minimum depth of liquid **shall** be 6 feet.

D. Wastewater Treatment Strip

Discharge to and through treatment strips **must** be as sheet flow. Some means, such as a ditch, curb, level spreader, or gated pipe, **must** be provided to disperse concentrated flow and ensure sheet flow across the ditch of the treatment strip.

Land grading and structural components necessary to maintain sheet flow throughout the length of the treatment strip **must** be provided as necessary.

Permanent herbaceous vegetation consisting of a single species or a mixture of grasses, legumes, and/or other forbs adapted to the soil and climate **must** be established in the treatment strip. Vegetation **must** be able to withstand anticipated wetting and/or submerged conditions.

Rapid Infiltration Treatment

Contaminated runoff **must** be pretreated by solid/liquid separation utilizing a facility such as a settling basin prior to discharge of liquid to the treatment strip.

The treatment strip **must** be uniformly graded strip or wide bottomed trapezoidal channel.

The treatment strip design **must** be based on the runoff volume from the *25-year, 24-hour* rainfall event (or *100-year, 24-hour* rainfall event for large swine, poultry, or veal calf operations designed and built after April 14, 2003).

The treatment strip's area requirements **must** be based on the soil's capacity to infiltrate and retain runoff within the root zone and the vegetation's capability to utilize the nutrient loading. The soil's ability to infiltrate and retain runoff **must** be based on its water holding capacity in the root zone, infiltration rate, permeability, and hydraulic conductivity. The determination **must** be based on the most restrictive soil layer within the root zone regardless of its thickness.

The anticipated nutrient loading **may not** exceed agronomic rates as determined by the state's technical standards listed in Section 6 of this circular.

The infiltration strip design **must** be such that the upper soil profile remains unsaturated except during storm events and returns to an unsaturated condition within two days following storm events.

Overland Flow Treatment

The design hydraulic loading rate and application rate **must** be selected based on consideration of the anticipated levels of pretreatment, quality of effluent, temperature, and other climatic conditions. A maximum hydraulic loading rate of 2.0 inches per day and an application rate of eight gallons per hour per foot of slope width **must** be used.

The application period **may not** exceed 12 hours per day and the application frequency **may not** exceed 5 days per week unless longer application periods and frequencies can be justified based on local conditions.

The anticipated nutrient loading **may not** exceed agronomic rates as determined by the state's technical standards listed in Section 6 of this circular.

Overland flow treatment **must** be constructed on soils with low permeability. The design **must** be based on the most restrictive soil layer within the root zone. The maximum allowable permeability **shall** be 0.2 inches per hour unless a natural or constructed barrier within the soil profile mitigates the potential of ground water contamination.

The minimum slope length for the applied wastewater **shall** be 40 feet.

The sloped areas to receive wastewater **must** be uniformly graded to eliminate wastewater ponding and short-circuiting for the length of the flow. Slopes **must** be equal to or greater than 2.0%, but **may not** exceed 8.0%.

Wastewater discharged from the treatment strip **must** be transferred to a waste storage facility, a waste treatment lagoon, or other facility for further treatment and/or utilization.

Other Applicable Regulations

Approval of the animal waste management system by the Department does not release the producer from complying with other applicable environmental regulations. The producer is responsible for obtaining all applicable permits and/or permissions prior to constructing the animal waste management system. Some of the applicable regulations may include, but are not limited to:

1. *ARM 36.15.101-36.15.903.* If construction is planned within a designated l00-year floodplain, permission **must** first be granted by the local planning officials or the Floodplain Management Section of the Department of Natural Resources and Conservation.
2. *ARM 36.14.101-36.14.803.* If applicable, Montana Dam Safety requirement **must** be followed. Montana Dam Safety requirements typically apply to dams having a reservoir capacity of 50 acre-feet or more.
3. *ARM 17.30.1105.* For any construction activities that disturb one or more acres of land, appropriate storm water discharge permits **must** be obtained prior to construction.
4. *Section 75-5-318, MCA.* If construction activity will cause short-term or temporary violations of state surface water quality standards for turbidity, a 318 Authorization **must** be obtained prior to initiating the project.
5. *Section 404 Federal Clean Water Act.* If construction activity will cause the placement of fill material in a wetland or a drainage with a defined "bed and bank" (erosive evidence of water flow), the U.S. Army Corps of Engineers should be contacted to determine if a 404 permit is needed.

Information to be Submitted

Plans and Specifications prepared by an individual qualified to design animal waste management systems **must** be submitted to the Department. The Department will review these P&S for conformance with the listed design criteria. As-built P&S are **required** for existing animal waste management systems. The following information **must** be included in this submittal, as applicable:

- Dimensions of outside lots or barns for livestock. For outdoor lots, specify percentage slope of lots, total drainage area of the production area and any contributing drainage area that enters the production area;
- Volume of manure and process-generated wastewater. For outdoor lots, indicate the runoff from a *25-year, 24-hour (*or *100-year, 24-hour)* rainfall event, including runoff for the period of storage;
- Overview of facility operation that relates to manure handling, including the collection, transfer, and storage of manure, the type of livestock and the number of days per year livestock are confined;
- Location and size of feed storage areas at the production area, and whether it is enclosed storage or stored outside;
- Dimensions of the waste containment structure(s) including top and bottom dimensions, relative elevation, side slopes, depth, typical cross section, volume, dimensions of embankments, etc;
- Type of liner, construction specifications and testing used to ensure integrity. Include any additional precautions and/or maintenance procedures used to ensure liner integrity;
- Designs for any inlet structures, including splash pads and an emergency spillway. Include provisions to pump or lower the liquid level of the pond and, if applicable, designs for a marker to indicate the level at which the pond should be pumped;
- For non-earthen storage facilities, include all dimensions and any other pertinent design information including, but not limited to, relative elevation of top and bottom; design of wall, floor and top;

- Dimensions of the diversions and embankments, including top and bottom width, side slopes, depth, typical major cross sections, slope, channel profile elevation compared to ground level, and flow velocity;
- Calculations used to estimate the peak flow in diversion channels;
- An operation and maintenance plan for the waste control facility detailing proper operation and maintenance including specific items that need to be inspected and the frequency of the inspections;

After construction is completed, the system designer **shall** submit a certification of completion to the Department. This certification **must** state that all construction was done in accordance with the design plans submitted to the Department.

Section 2: Calculating Waste Production

Although other approaches to calculating waste production are acceptable, this method is provided in order to assist producers in determining a rough estimate of the amount of waste produced on-site.

Manure Production

To calculate annual manure production (as-excreted), the following information is needed:

1. Number of livestock in each category (See Daily Manure Production table);
2. Average length of time on site for each category (if the number of animals in each category does not fluctuate much within a year, use the average number of head present year round);
3. Incoming and outgoing weight of livestock in each category.

The following three-step process may be used to calculate manure production:

Step 1: Calculate average animal weight

Average weight = (Incoming weight + outgoing weight) / 2

Step 2: Get manure production value for appropriate livestock category

The Daily Manure Production table contains average manure production values, as excreted, in pounds of manure per day per head:

Table 1: Daily Manure Production, as-excreted (per head per day)

Animal	Size	Total manure			Water	Density
	(lbs)	(lbs)	(cu ft)	(gal)	(%)	(lb/ft^3)
Dairy						
Calf	150	12	0.18	1.38	88	65
	250	20	0.31	2.30	88	65
Heifer	750	45	1.70	5.21	88	65
	1,000	60	0.93	6.95	88	65
Lactating Cow	1,000	111	1.79	13.36	88	62
	1,400	155	2.50	18.70	88	62
Dry Cow	1,000	51	0.82	6.14	88	62
	1,400	71	1.15	8.60	88	62
	1,700	87	1.40	10.45	88	62
Veal	250	6.6	0.11	0.79	96	62

Animal	Size	Total manure			Water	Density
	(lbs)	(lbs)	(cu ft)	(gal)	(%)	(lb/ft^3)
Beef						
Calf (confinement)	450	48	0.76	5.66	92	63
	650	69	1.09	8.18	92	63
Finishing	750	37	0.59	4.40	92	63
	1,100	54	0.86	6.46	92	63
Cow (confinement)	1,000	92	1.46	10.91	88	63
Swine						
Nursery	25	1.9	0.03	0.23	89	62
	40	3.0	0.05	0.37	89	62
Finishing	150	7.4	0.12	0.89	89	62
	180	8.9	0.14	1.07	89	62
	220	10.9	0.18	1.31	89	62
	260	12.8	0.21	1.55	89	62
	300	14.8	0.24	1.79	89	62
Gestating	300	6.8	0.11	0.82	91	62
	400	9.1	0.15	1.10	91	62
	500	11.4	0.18	1.37	91	62
Lactating	375	17.5	0.28	2.08	90	63
	500	23.4	0.37	2.78	90	63
	600	28.1	0.45	3.33	90	63
Boar	300	6.2	0.10	0.74	91	62
	400	8.2	0.13	0.99	91	62
	500	10.3	0.17	1.24	91	62
Poultry						
Broiler	2	0.19	0.003	0.023	74	63
Layer	3	0.15	0.002	0.017	75	65
Turkey (female)	10	0.47	0.007	0.056	75	63
Turkey (male)	20	0.74	0.012	0.088	75	63
Duck	4	0.44	0.007	0.053	73	62
Sheep						
Feeder lamb	100	4.1	0.06	0.5	75	63
Horse						
Sedentary	1,000	54.4	0.88	6.56	86	62
	1,000	55.5	0.90	6.70	86	62

Source: Midwest Plan Service, "Manure Characteristics", MWPS-18, Section 1, 2nd Edition

Step 3: Calculate manure production

A. Find total pounds of manure produced per head per day based on the average animal weight. If the weight is not listed in the table, linear interpolation can be used to estimate the total manure produced.
B. Multiply by the number of days confined per year.
C. Multiply by the number of head present per year.
D. Covert pounds to tons by dividing by 2,000.

Example: A feedlot has 2,500 head of cattle on average year-round. The cattle come in weighing 500 lbs. each and leave weighing 1,000 lbs. each.

Step 1:

Average weight = (500+1,000)/2 = 750 lbs/head

Steps 2 and 3:

A. Average weight = 750 lbs/head (calculated in Step 1); Pounds of manure produced per head per day = 37 pounds (From Daily Manure Production Table)
B. 37 pounds of manure per head per day x 365 days = 13,505 pounds of manure per head per year.
C. 13,505 pound of manure per head per year x 2,500 head = 33,762,500 pounds of manure per year.
D. 33,762,500 pounds of manure per year / 2,000 lbs/ton = 16,881.25 tons of manure per year produced.

Open Feedlots

Manure from open feedlots can vary widely due to climate, diet, animal density, feedlot surface, and cleaning frequency. The following Table 2 lists estimated beef feedlot manure characteristics:

Table 2: Estimated beef feedlot manure characteristics

Component	Units	Unsurfaced lot[a]	Surfaced lot[b]	
			High forage diet	High energy diet
Manure Weight	lbs / day / 1,000-lb animal	17.50	11.70	5.30
Moisture	%	45.00	53.30	52.10
Total Solids	% wet basis	55.00	46.70	47.90
	lbs / day / 1,000-lb animal	9.60	5.50	2.50
Volatile Solids	lbs / day / 1,000-lb animal	4.80	3.85	1.75
Fixed Solids	lbs / day / 1,000-lb animal	4.80	1.65	0.75
Nitrogen	lbs / day / 1,000-lb animal	0.21	--	--
Phosphorus	lbs / day / 1,000-lb animal	0.14	--	--
Potassium	lbs / day / 1,000-lb animal	0.03	--	--
Carbon: Nitrogen (C:N)	ratio	13:1	--	--

[a] Dry climate (annual rainfall less than 15 inches); annual manure removal.
[b] Dry climate; semiannual manure removal.

Source: Midwest Plan Service, "Manure Characteristics", MWPS-18, Section 1, 2nd Edition

Other Wastes to Consider

Other wastes, including bedding, waste feed, and process-generated wastewater from sources such as the milking parlor, milkhouse, silage pit seepage, flush tanks, gutters, leaking watering facilities, etc. should also be included in the total waste production calculation.

Section 3: Nutrient Management Plan

All CAFOs **shall** develop and implement a site-specific Nutrient Management Plan (NMP). The minimum elements that **must** be addressed in this NMP are as follows:

1. The type of livestock, number of days per year they are on site, and an estimate of the volume of manure generated and how the estimate was based;
2. A description of the manure handling at the facility, including how often manure is cleaned from the livestock areas and how and where manure may be temporarily stored;
3. A description of the size and volume capacity of all facilities and structures used for the collection, transport, and storage of liquid and solid manure and other wastes;
4. A description of the method in which dead animals are disposed of;
5. A description of the practices that divert clean water from contact with stored manure, confinement lots, holding pens, and stored feed materials having a waste-contributing potential;
6. A description of how animals and manure in the production area are prohibited from direct contact with state waters;
7. A description of the disposal methods for any chemicals and other contaminants handled on-site;
8. A description of the Best Management Practices (BMPs) implemented to control the runoff of pollutants from the production area and land application areas to state waters;
9. Guidance for implementation, operation, maintenance, and record keeping;
10. If manure is land applied:
    a. An aerial photograph or map and a soil map of the site where manure is to be applied;
    b. Location of any down-gradient surface waters, open tile line intake structures, sinkholes, agricultural well heads, or other conduits to surface waters and the associated manure handling or nutrient management restriction;
    c. Current and/or planned plant production sequence or crop rotation, irrigated or dryland crop;
    d. Realistic yield goals for the crops in the rotation;
    e. The specific methods of sample collection, frequency, analysis, and results used to test the nutrient content of soil, manure, litter, or process wastewater.
    f. A field-specific assessment of the potential for nitrogen and phosphorus transport from the field to surface waters as described in the state's technical standards, if applicable.
    g. Quantification of all nitrogen and phosphorus sources;
    h. Complete nutrient budget for nitrogen and phosphorus for the rotation or crop sequence;
    i. Recommended and actual nitrogen and phosphorus application rates, timing, and method of application;
    j. The form of manure (liquid or solid) and the expected frequency of land application;

k. Description of equipment used for land application, calibration procedures and records.

Nutrient Management Plans **must** be developed and implemented by the deadline specified in the table below:

Table 3: Nutrient Management Plan Implementation

If you apply for a MPDES permit before December 31, 2006:	
If your CAFO is not a new source and your MPDES permit is issued before December 31, 2006	Your deadline will be set by the MT DEQ. The deadline will be no later than December 31, 2006.
If your CAFO is not a new source and your MPDES permit is issued after December 31, 2006	Your deadline is the date that you obtain coverage under an MPDES permit.
If your CAFO is a new source	Your deadline is the date that you obtain coverage under an MPDES permit.
If you apply for a MPDES permit after December 31, 2006:	
All CAFOs	Your deadline is the date that you obtain coverage under an MPDES permit. You **must** certify in your permit application that you already have a NMP and will implement the plan when your facility begins to operate.

Source: Environmental Protection Agency, Producers' Compliance Guide for CAFOs, November 2003

Nutrient Management Plans **must** be updated a minimum of once every five years; however, more frequent updates are recommended and may be required in the facility's permit. Additionally, the NMP should always reflect the current operation of the CAFO; changes to the NMP may be required if changes at the operation have occurred. Although producers are not required to use a certified planner when developing NMPs, this practice is strongly recommended. A list of certified comprehensive nutrient management planners in the state of Montana is available through the Natural Resource Conservation Service at the following website: http://techreg.usda.gov/CustLocateTSP.aspx. The use of certified crop advisors (CCA) is also encouraged. A list of CCAs is available at the following web address: http://www.agronomy.org/cca/search_cca.html.

Section 4: Best Management Practices

All CAFOs **shall** implement the Best Management Practices described below in tables 4 and 5, as appropriate:

Table 4: Production Area Best Management Practice Requirements

Production Area Requirements	Uncontaminated storm water runoff **must** be diverted away from the waste containment structure whenever possible. Some examples include: o Constructing ditches, terraces, and waterways above an open lot to divert clean water runon; o Installing gutters, downspouts, and buried conduits to divert roof drainage; o Providing more roofed area; o Decreasing open lot surface area; o Repairing or adjusting water systems to minimize water wastage; o Using practical amounts of water for cooling purposes; o Recycling water if practical and applicable.
	Confined animals **must** be prevented from contacting state waters. Animals in the production area **may not** be allowed to stand in state waters.
	Animals **must** be prohibited from entering into waste containment structures or their dikes, unless expressly stated in a facility's Operation and Maintenance plan and approved by the Department.
	Animal mortalities **must** be handled to prevent the discharge of pollutants to state waters.
	Dead animals **must not** be placed in any liquid manure, storm water, or process wastewater storage or treatment system unless the system is designed to handle dead animals.
	In accordance with Solid Waste Regulations, dead animals may be disposed of on-site, provided the animals are buried at least 2 feet underground and the following locational restrictions are maintained: o Disposal **may not** be done in a city lot or a cultivated field. o Any surface disposal **must** be done at least 200 yards away from highways, roads, or public property.
	All wastes from dipping vats, pest and parasite control units, and other facilities utilized for the application of hazardous or toxic chemicals **must** be handled and disposed of in a manner that prevents any pollutant from such materials from entering state waters.

	All facilities utilized by and operated under the authority of the permittee for the collection, transport, storage, and treatment of manure, bedding materials, silage, feeds, feed concentrates, and other substances having a waste-contributing potential **must** be managed to prevent any pollutant from such materials from entering state waters.
	For large dairy, cattle, swine, poultry, and veal calf CAFOs, a permanent depth marker which clearly indicates the minimum capacity necessary to contain the runoff and direct precipitation of the *25-year, 24-hour* rainfall event (or *100-year, 24-hour* rainfall event for large swine, poultry, and veal calf operations designed and built after April 14, 2003) **must** be installed in any open surface liquid impoundment.
	If applicable, the producer **shall** take precautions while agitating the pond to ensure that the liner is not damaged.

Table 5: Land Application Area Best Management Practice Requirements

Land Application Area Requirements	The producer **shall** develop, maintain, and implement a Nutrient Management Plan to ensure safe disposal of manure and process wastewater.
	For large dairy, cattle, swine, poultry, and veal calf CAFOs, the producer **shall** maintain at least a 100-foot setback or 35-foot vegetated buffer between any down-gradient surface waters, open tile line intake structures, sinkholes, agricultural well heads, or other conduits to surface waters.
	All permanent manure stockpiles should be removed and land applied as soon as practicable.
	Wastes **must** be applied so as to prevent any pollutant from such materials from entering state waters.
	Any permanent or temporary piping used to transfer manure to the irrigation system **must** be designed, constructed, and operated so that liquid manure is not discharged to state waters at any time during start-up, operation, and shut down.
	Irrigation practices should be managed to prevent ponding of wastewater on the land application site.
	Process wastewater or manure **may not** be spray irrigated on frozen ground.
	Surface broadcast, injection, or incorporation of liquid manure or process wastewater should not be applied on frozen or snow-covered ground. If application to frozen or snow-covered ground is absolutely necessary, the producer **shall** notify the Department prior to application so that the Department may review buffer zone requirements with the producer and respond to inquires from the public.
	Application of dry or solid manure on frozen or snow-covered ground should be avoided.

	All land areas utilized by and operated under the authority of the permittee for the application of manure, other solid waste, and liquid wastes **must** provide waste treatment through plant nutrient uptake during the growing season following application. The land application rates of solid manure, liquid manure, or other solid or liquid wastes **must** not exceed agronomic rates for nutrients, except as allowed in multi-year phosphorus applications.

Section 5: Sample Collection and Calibration Procedures

Sampling Manure

A representative manure sample **must** be analyzed a minimum of once annually for Total Kjeldahl Nitrogen, Nitrate-nitrogen, and Total Phosphorus. The results of these analyses **must** be used in determining application rates for manure, litter, and process wastewater.

The accuracy of a laboratory analysis depends on the quality of the manure sample. Manure should be sampled and analyzed before it is land applied. The sample should be collected as close to the time of land application as possible in order to provide the best information about its fertilizer value. However, it is important to allow the laboratory at least three weeks to complete the analysis and return the results. Liquid manure should always be agitated before sampling in order to obtain a representative sample.

Table 6: Sampling Manure

Sampling Solid Manure	1. Manure should be collected from at least 10 different locations that are similar in moisture, feed, hay, and bedding content. Areas near waterers, drains, and feedbunks should be avoided. If sampling stockpiled manure, manure should be collected from several depths, with the exposed outer layer of the pile-avoided. 2. The collected manure should be placed on a hard, flat surface so that a shovel or pitchfork can be used to mix the manure until uniform. 3. Several small samples should be taken from the mixture until about a gallon has been collected. 4. The mixture should be placed in a heavy weight plastic freezer bag identified with name and field. The bag should be squeezed to remove the air and then placed in a second freezer bag to prevent leakage. 5. The sample should be frozen or stored in a cool place until ready to ship.
Sampling Liquid Manure	1. The manure in the storage facility should be agitated thoroughly so that an accurate sample can be obtained. One-quart samples should be collected from at least five different tank spreader loads or locations in the manure storage facility using a clean plastic container. 2. The samples should be poured into a clean, large plastic pail. 3. The contents of the pail should be stirred thoroughly. Several cups of the swirling mixture should be transferred, using a long handled dipper, to a clean, one-quart plastic bottle until the liquid is about two inches from the top of the bottle. 4. The bottle should be placed in a heavy weight re-sealable plastic freezer bag to prevent leakage. 5. The sample should be frozen or stored in a cool place until ready to ship.

Sampling Soil

A representative 0-6-inch soil sample **must** be analyzed a minimum of once every five years for phosphorus content. The result of this analysis **must** be used in determining application rates for manure, litter, and process wastewater.

Soil sampling should be done to allow adequate leadtime for sample analysis, data interpretation, fertilizer recommendation, and application, though should be performed as close to seeding as practical.

Table 7: Sampling Soil

Sampling Soil	The goal is to collect a small sample that is homogenous and characteristic of the entire field. To minimize laboratory costs, soil samples are generally collected from several locations within a field and mixed in a clean bucket prior to submitting to an analytical laboratory. 1. Samples should be collected and divided into depth increments such as 0-6, 6-12, and 12-24 inches, as necessary. Soil samples analyzed for nitrogen require a 24" sample, whereas soil samples analyzed for phosphorus require a 6" sample. 2. Individual soil cores from a minimum of 20 locations should be collected. Uniform fields may be sampled in a simple random, stratified random, or systematic pattern such as an "X", "W", or "M". 3. Each depth increment should be mixed thoroughly in a large plastic container, sub-sampled, and placed into a plastic-lined soil sampling bag or glass jar. Laboratories will usually supply sampling bags. 4. A small volume of material should be collected from the plastic container, sealed, and sent to the laboratory for analysis.

Calibrating Spreaders

Two approaches for calibrating a manure spreader include the Load-Area and the Weight-Area methods. Although the load-area method can be used for both liquid and solid manure, the weight-area method works only with solid or semi-solid manure.

Load Area Method

The load area method is a three-step process. In order to correctly calculate the application rate, the entire capacity of the spreader should be applied.

1. Determine the amount of manure in the spreader. The most accurate way to determine the amount of manure in a spreader is weighing the spreader when it is empty and again when it is full. For a reliable estimate of spreader capacity, weigh several representative spreader loads (recommended five) to determine the average gross weight. Subtract the

empty spreader weight to calculate the average net loaded weight. If a scale is not available, volume and density estimates can be used to determine the approximate weight. For liquid manure spreaders, the volume capacity in gallons should be used.

2. Determine the distance between travel lanes and the total distance traveled.
3. Calculate the application rate. The following formulas for liquid or solid manure should be used to calculate the application rate:

Formula for Solid Manure:

$$\text{Tons per acre} = \frac{\text{Average Net Loaded Weight (lbs.)} \times 21.8}{\text{Distance Traveled (ft.)} \times \text{Distance between Travel (ft.)}}$$

Formula for Liquid Manure:

$$\text{Gallons per acre} = \frac{\text{Tank Volume (gal.)} \times 43{,}560\ \text{ft}^2/\text{acre}}{\text{Distance Traveled (ft.)} \times \text{Distance between Travel (ft.)}}$$

Weight Area Method

When a scale is not available, the application rate may be estimated by collecting manure on a tarp or sheet of plastic. This method consists of eight steps:

1. Prepare/cut three 56” x 56” tarps or sheets of plastic. The pounds of manure collected on a 56” square equals the tons of manure applied per acre.
2. Place one of the clean tarps in a large bucket and weigh both on a platform scale. Record the weight.
3. Lay the three tarps in the field near the beginning, middle, and end of the area that will be spread with one load.
4. Drive the spreader over the three tarps at a normal operating speed.
5. Fold and place the first tarp in the empty bucket without spilling the manure.
6. Weight the bucket, tarp, and manure. Subtract the weight of the clean tarp and bucket recorded in Step 2.
7. Repeat the process for each of the two remaining tarps.
8. Average the weight (pounds) of the manure collected on all three tarps. This value equals the tons of manure applied per acre.

Section 6: Technical Standards for Nutrient Management

The following technical standards for nutrient management are applicable to land application sites of Large Dairy Cow, Cattle, Swine, Poultry, and Veal Calf CAFOs. Application rates for manure, litter, and other process wastewater applied to land under the ownership and operational control of the CAFO **must** be determined according to the following procedure:

1. A field-specific assessment, as specified below, **must** be conducted to determine the appropriate basis for application rates (nitrogen or phosphorus based applications);
2. The expected crop type and yield for each field **must** be estimated, as specified below;
3. The appropriate nutrient needs for the crop **must** be determined, as specified below;
4. A nutrient budget **must** be conducted, as specified below, in order to determine the manure application rate. Representative manure and soil tests **must** be used in calculating the application rate.

Field-Specific Assessment

To determine the appropriate basis for application rates, the producer **shall** first conduct a field-specific assessment to determine the potential for phosphorus and nitrogen transport from the field to state waters. The results of this field-specific risk assessment **shall** be used to determine if manure, litter, and/or process wastewater should be land applied based on the nitrogen or phosphorus needs of the crop, or whether land application to the field(s) should be avoided.

In order to provide flexibility, the Department has established two different methods for conducting this field-specific assessment. The producer has the option of conducting the Phosphorus Index, as detailed in Attachment 2, or taking a representative soil sample and having it analyzed for phosphorus (Olsen P test).

If the Phosphorus Index (PI) is used to conduct a field-specific assessment, the calculated PI rating **must** be used to determine the appropriate application basis, as follows:

Table 8: Phosphorus Application based on PI

Phosphorus Index Risk Rating	Application Basis
Low	Nitrogen need
Medium	Nitrogen need
High	Phosphorus need up to crop removal
Very High	Phosphorus crop removal or no application

Source: NRCS Specification MT590, July 2002

If a representative soil sample is used to conduct a field-specific assessment, the Olsen P test results, in ppm, **must** be used to determine the appropriate application basis, as follows:

Table 9: Phosphorus Application from Soil Test Results

Olsen P Soil Test (ppm)	Application Basis
≤ 8.0	Nitrogen need
8.1-25.0	Nitrogen need
25.1-100.0	Phosphorus need
100.1-150.0	Phosphorus need up to crop removal
>150.0	No application

Source: NRCS Specification MT590, July 2002

Expected Crop Yield

Actual yield records from previous years **shall** be used to estimate the crop yields for the upcoming season, using the following equation:

Estimated Yield, bu/acre or t/a = 1.05 x Average Yield in bu/acre or t/a (based on past records)

Yield goals for cereals and safflower can be estimated using an alternative method as described in NRCS Code 590 (included in Attachment 4 of this circular).

Nutrient Needs of Crop

The Fertilizer Guidelines for Montana Crops published by Montana State University Extension Service Educational Bulletin 161 in January 2003 (included in Attachment 3 of this circular) **must** be used to determine crop nutrient needs based on the appropriate basis for application rates (nitrogen or phosphorus based applications), crop type, and estimated yield. For crops not listed in this bulletin, the Department may approve the use of site-specific information to determine fertilizer rates.

Nutrient Budget

Once the estimated nutrient needs of the crop, in lbs/acre, have been determined the producer **shall** conduct a nutrient budget. This nutrient budget accounts for all sources of nutrients available to the crop. These other sources include:

- Credits from previous legume crops. Legume plants fix atmospheric nitrogen and bring it into the soil. The amount of nitrogen added by legume production varies according to plant species and growing conditions. The following table 10 **must** be used to determine the appropriate legume crop credits for Montana:

Table 10. Legume Crop Credits

Legume	Nitrogen Fixation (lbs/acre)*
Alfalfa (after harvest)	40-80
Alfalfa (green manure)	80-90
Spring Pea	40-90
Winter Pea	70-100
Lentil	30-100
Chickpea	30-90
Fababean	50-125
Lupin	50-55
Hairy Vetch	90-100
Sweetclover (annual)	15-20
Sweetclover (biennial)	80-150
Red Clover	50-125
Black Medic	15-25
*The maximum N fixation in lbs/acre **must** be used unless appropriate justification is given showing lower N fixation is appropriate. In all cases, the N fixation used **must** be within the ranges specified above.	

Source: NRCS Specification MT590, July 2002

- Residuals from past manure applications. Nitrogen is a mobile nutrient that occurs in many forms. Not all nitrogen in land-applied manure is available to the crop during the year of application. Organic material decomposition is required before it is made available for plants. A percentage of last year's nitrogen and an even smaller percentage of the previous year's nitrogen will become plant-available during the current crop season. Therefore, mineralization rates as specified in Table 11 **must** be used to determine the amount of nitrogen available from previous manure application(s). Typically, organic phosphorus is considered 100% plant-available the year of application. Therefore, no residual amounts of phosphorus need to be calculated.

Table 11. Mineralization Rates

Type of Waste	1st Year after Application Fraction Available*	2nd Year After Application Fraction Available
Fresh poultry manure	0.90	0.02
Fresh swine manure	0.75	0.04
Fresh Cattle manure	0.70	0.04
Fresh sheep and horse manure	0.60	0.06
Liquid manure, covered tank	0.65	0.05
Liquid manure, storage pond	0.65	0.05
Solid manure, stack	0.60	0.06
Solid manure, open pit	0.55	0.05
Manure pack, roofed	0.50	0.05
Manure pack, open feedlot	0.45	0.05
Storage pond effluent	0.40	0.06
Oxidation ditch effluent	0.40	0.06
Aerobic lagoon effluent	0.40	0.06
Anaerobic lagoon effluent	0.30	0.06
* If irrigated, reduce 1st year mineralization by 0.05		

Source: NRCS Specification MT633, August 2001

- Nutrients supplied by commercial fertilizer. Animal manure does not have the same nutrient value as commercial fertilizer. Because animal manure contains relatively high concentrations of phosphorus, crops are not always supplied with enough nitrogen when manure is applied on a phosphorus basis. For that reason, farmers often supplement animal manure applications with commercial fertilizer to meet the crop's total nitrogen requirements. CAFOs **shall** include nutrient contribution from this other source in manure application rate calculations.

- Irrigation water. Irrigation water often contains some nitrogen in the form of nitrate nitrogen. Also, contaminated storm water runoff contains nutrients. CAFOs **shall** include nutrient contributions from this source in manure application rate calculations. A nutrient analysis of the irrigation water **must** be conducted to calculate the amount of nitrate nitrogen applied with irrigation water (ppm, mg/L).

In addition, because nitrogen losses occur through volatilization, the availability of nitrogen to crops is affected by the application method used (ie. broadcast, incorporated, etc.). Nitrogen availability **must** be adjusted to reflect the method of application as specified in Table 12.

TABLE 12. NITROGEN AVAILABILITY AND LOSS AS AFFECTED BY METHOD OF APPLICATION

Application Method	Nitrogen Availability and Loss as Affected by Method of Application
Injection (sweep)	0.90
Injection (knife)	0.95
Broadcast (incorporated within 12 hours)	0.7
Broadcast (incorporated after 12 hours, but before 4 days)	0.6
Broadcast (incorporated after 4 days)	0.5
Sprinkling	0.75

Source: NRCS Specification MT633, August 2001

The following table 13 **must** be used to conduct a nutrient budget:

Table 13. Nutrient Budget Worksheet

Nutrient Budget	Nitrogen-based Application	Phosphorus-based Application
Crop Nutrient Needs, lbs/acre (from MSU EB161, January 2003)		
(-) Credits from previous legume crops, lbs/acre (from Table 10)		
(-) Residuals from past manure production, lbs/acre (lbs/acre applied in previous year(s) x fractions listed in Table 11)		
(-) Nutrients supplied by commercial fertilizer and Biosolids, lbs/acre		
(-) Nutrients supplied in irrigation water, ppm or mg/L (from nutrient analysis)		
= Additional Nutrients Needed, lbs/acre		
Total Nitrogen and Phosphorus in manure, lbs/ton or lbs/1,000 gal (from manure test)		
(x) Nutrient Availability factor (for Nitrogen based application see Table 12 above; for Phosphorus based application use 1.0)		
= Available Nutrients in Manure, lbs/ton or lbs/1,000 gal		
Additional Nutrients needed, lbs/acre (calculated above)		
(/) Available Nutrients in Manure, lbs/ton or lbs/1,000 gal (calculated above)		
= Manure Application Rate, tons/acre or 1,000 gal/acre		

Multi-Year Phosphorus Application Rate

In some situations, it may be necessary to use a multi-year phosphorus application rate. This approach consists of applying a single application of manure at a rate equal to the recommended phosphorus application rate or estimated phosphorus removal in harvested plant biomass for the crop rotation for multiple years in the crop sequence. These applications may provide the phosphorus needed for multiple years.

In this situation, CAFOs **may not** apply additional phosphorus to these fields until the amount applied in the single year had been removed through plant uptake and harvest. However, even under the multi-year application rate, CAFOs **may not** exceed the annual nitrogen recommendation of the year of application. In addition, the Phosphorus Index **must** be used to evaluate the potential for phosphorus runoff to surface waters. Fields with a Very High PI rating **may not** utilize a multi-year phosphorus application.

Other Acceptable Methods

The Natural Resources Conservation Service has developed standards for nutrient management and waste utilization. These methods, included in Attachments 4 and 5, may be used in lieu of the above-mentioned technical standards for nutrient management provided the following conditions are met:

- A field-specific assessment of the potential for nitrogen and phosphorus transport from the field to surface waters **must** be conducted;
- The form, source, amount, timing, and method of application of nutrients on each field to achieve realistic production goals, while minimizing nitrogen and phosphorus movement to surface waters **must** be addressed;
- Appropriate flexibilities for the CAFO to implement multi-year phosphorus application on fields as described above **must** be included;
- Manure **must** be sampled a minimum of once annually for nitrogen and phosphorus content;
- Soil **must** be analyzed a minimum of once every five years for phosphorus content; and,
- The results of the manure and soil sampling analyses **must** be used in determining application rates of manure, litter, and other process wastewater.

Section 7: Recordkeeping Requirements

Producers **shall** maintain all records on-site for a period of at least 5 years, or longer if required by the Department. Records **must** be made available upon request.

All CAFOs **shall**, at a minimum, maintain the following records:

- A copy of a site-specific Nutrient Management Plan;
- The results of any manure, litter, and process wastewater sampling and analysis;
- The results of any soil sampling and analysis; and
- Records that document the implementation of the Nutrient Management Plan.

Transfer of Manure, Litter, and Process wastewater

In addition to the records listed above, all Large CAFOs **shall** maintain records of the transfer of manure, litter, and process wastewater to other persons. These transfer records **must** include:

- Date of transfer;
- Recipient name and address;
- Approximate amount of manure, litter, or process wastewater transferred to other persons; and
- Verification that prior to transferring manure, litter, or process wastewater to other persons, the CAFO has provided the recipient of the manure, litter, or process wastewater with the most current nutrient analysis.

Additional Recordkeeping

In addition to the records required above, large dairy cow, cattle, veal calf, swine and poultry CAFOs **shall** keep records pertaining to the production area and land application area(s), as follows:

For production areas, there **must** be routine visual inspections. At a minimum, the following items **must** be inspected and documented:

- Records of weekly inspections of storm water diversion devices, runoff diversion structures, and devices channeling contaminated storm water to the wastewater and manure storage and containment structure;
- Records of daily inspections of water lines, including drinking water or cooling water lines;
- Weekly records of the depth marker reading for manure and process wastewater in any open liquid storage structure(s);
- Records of anything the producer did to correct problems found during inspections. If it takes longer than 30 days to correct the problem, records documenting the reasons the problem(s) could not be corrected right away **must** be kept;
- Records of mortality management and practices;
- Records of the current design of the manure and litter storage structure(s), including, but not limited to:
    - the volume of solids accumulation;
    - approximate number of days' worth of storage capacity;
    - design treatment volume; and

        - total design volume;
    - Records of overflows from the production area(s), including the date, time, and estimated volume of overflow.

For land application area(s):
- Expected crop yields;
- Date(s) manure, litter, or process wastewater is applied to each field;
- Weather conditions 24 hours before, during, and 24 hours after manure, litter, or process wastewater is land applied;
- How manure, litter, process wastewater, and soil was sampled and the test methods used to analyze the sample;
- Laboratory sample results of the manure, litter, process wastewater, and soil analyses;
- How application rates for manure, litter, and process wastewater were calculated;
- Calculations used to decide how much nitrogen and phosphorus to apply to each field;
- Calculations showing the total amount of nitrogen and phosphorus actually applied to each field;
- Explanation of how manure, litter, and/or process wastewater is land applied; and
- Dates application equipment was inspected.

Annual Reporting Requirements

All CAFOs **shall** submit an annual report to the Department by no later than January 28th of each year. The annual report **must** include:
- The number and type of animals, whether in open confinement or housed under roof;
- Estimated amount of total manure, litter, and process wastewater generated by the CAFO in the previous 12 months (tons/gallons);
- Estimated amount of total manure, litter, and process wastewater transferred to other persons by the CAFO in the previous 12 months (tons/gallons);
- Total number of acres for land application covered by the Nutrient Management Plan developed in accordance with the elements specified in this circular;
- Total number of acres under control of the CAFO that were used for land application of manure, litter, and process wastewater in the previous 12 months;
- Summary of all manure, litter, and process wastewater discharges from the production area that have occurred in the previous 12 months, including date, time, and approximate volume; and
- A statement indicating whether the current version of the CAFO's Nutrient Management Plan was developed or approved by a certified nutrient management planner. (Note: Nutrient Management Plans are not required to be developed or approved by a certified nutrient management planner.)

Definitions

'25-year, 24-hour rainfall event' and *'100-year, 24-hour rainfall event'* mean precipitation events with a probability recurrence interval of once in twenty five years, or one hundred years, respectively, as defined by the National Weather Service in Technical Paper No. 40, "Rainfall Frequency Atlas of the United States," May, 1961, or equivalent regional or State rainfall probably information developed from this source.

'Agronomic rates' means the recommended number of pounds of nutrient elements per acre required to achieve realistic crop yields as given in Montana State University Extension Bulletin 161, January 2003, for the growing season following application.

'Land application area' means land under the control of an animal feeding operation owner or operator, whether it is owned, rented, or leased, to which manure, litter, or process wastewater from the production area is or may be applied.

'Multi-year phosphorus application' means phosphorus applied to a field in excess of the crop needs for that year. In multi-year phosphorus applications, no additional manure, litter, or process wastewater is applied to the same land in subsequent years until the applied phosphorus has been removed from the field via harvest and crop removal.

'Owner/Operator' means any person who owns, leases, operates, controls, or supervises a Concentrated Animal Feeding Operation.

'Overflow' means the discharge of manure or process wastewater resulting from the filling of wastewater or manure storage structures beyond the point at which no more manure, process wastewater, or storm water can be contained by the structure.

'Process wastewater' means water directly or indirectly used in the operation of the CAFO for any or all of the following: spillage or overflow from animal or poultry watering systems; washing, cleaning, or flushing pens, barns, manure pits, or other CAFO facilities, direct contact swimming, washing, or spray cooling of animals, or dust control. Process wastewater also includes any water which comes into contact with any raw materials, products, or byproducts including manure, litter, feed, milk, eggs, or bedding.

'Production area' means that part of an animal feeding operation that includes the animal confinement area, the manure storage area, the raw materials storage area, and the waste containment areas. The animal confinement area includes but is not limited to open lots, housed lots, feedlots, confinement houses, stall barns, free stall barns, milkrooms, milking centers, cowyards, barnyards, medication pens, walkers, animal walkways, and stables. The manure storage area includes but is not limited to lagoons, runoff ponds, storage sheds, stockpiles, under house or pit storages, liquid impoundments, static piles, and composting piles. The raw material storage area includes but is not limited to feed silos, silage bunkers, and bedding materials. The waste containment area includes but is not limited to settling basins, and areas within berms and diversions which separate uncontaminated storm water. Also included in the definition of production area is any egg washing or egg processing facility, and any area used in the storage, handling, treatment, or disposal of mortalities.

'Setback' means a specified distance from surface waters or potential conduits to surface waters where manure, litter, and process wastewater may not be land applied. Examples of conduits to surface waters include, but are not limited to: open tile line intake structures, sinkholes, and agricultural well heads.

'State Waters' means a body of water, irrigation system, or drainage system, either surface or underground, except irrigation waters where the waters are used up within the irrigation system and the waters are not returned to any other state waters.

'Vegetated Buffer' means a narrow, permanent strip of dense perennial vegetation established parallel to the contours of and perpendicular to the dominant slope of the field for the purpose of slowing water runoff, enhancing water infiltration, and minimizing the risk of any potential nutrients or pollutants from leaving the field and reaching surface waters.

Attachment 1: Design Maps

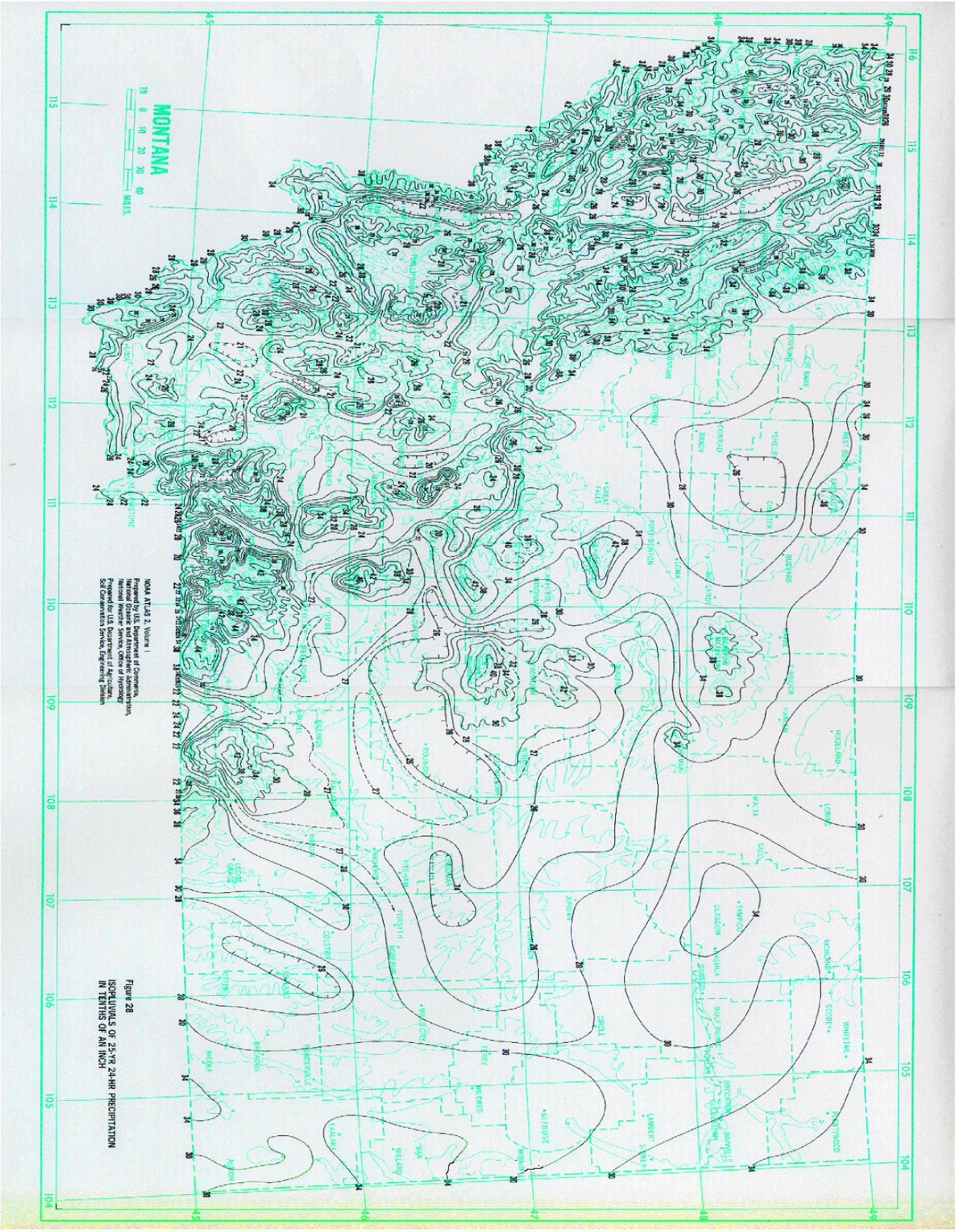

Figure 28
ISOPLUVIALS OF 25-YR 24-HR PRECIPITATION
IN TENTHS OF AN INCH

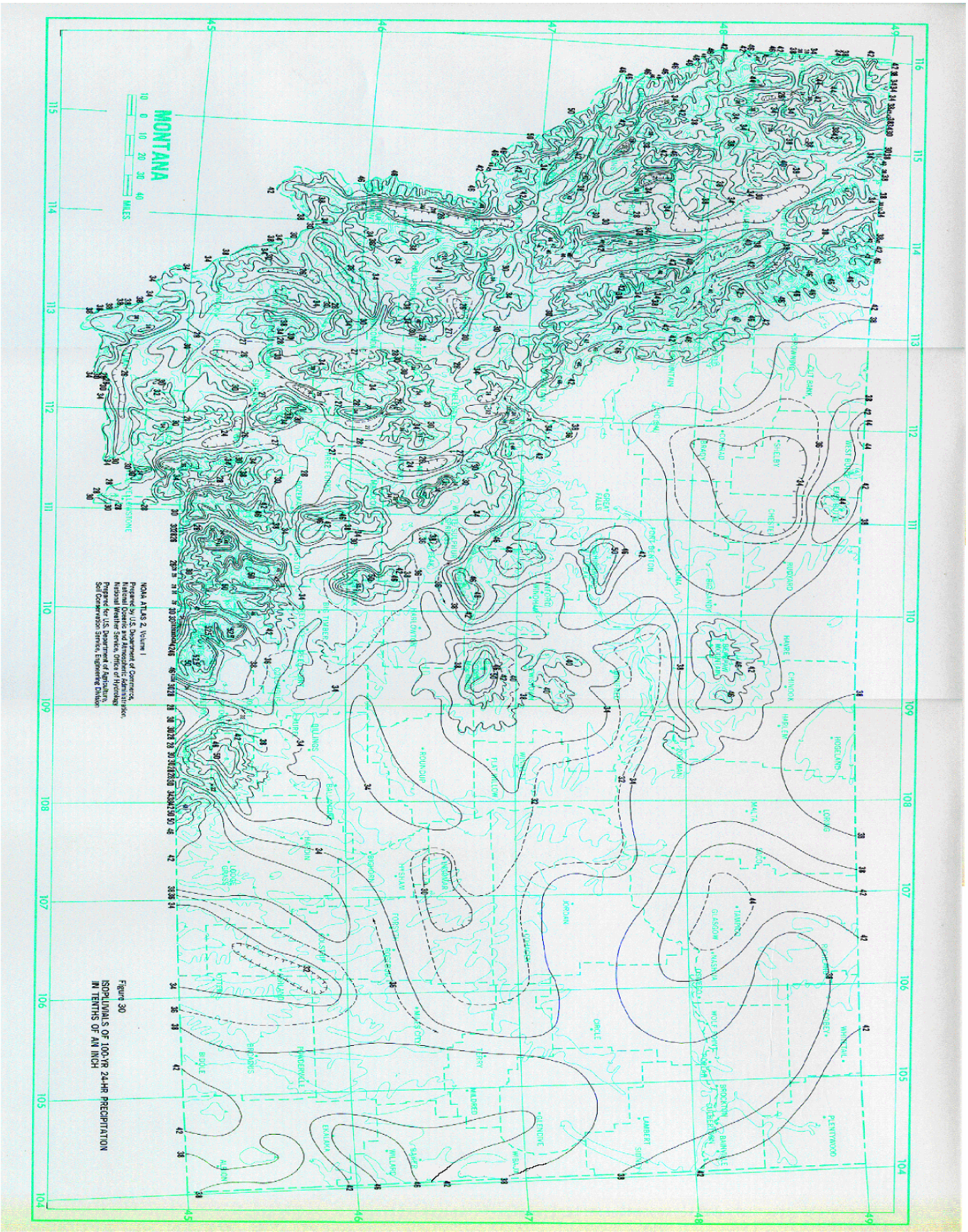

Figure 30
ISOPLUVIALS OF 100-YR 24-HR PRECIPITATION
IN TENTHS OF AN INCH

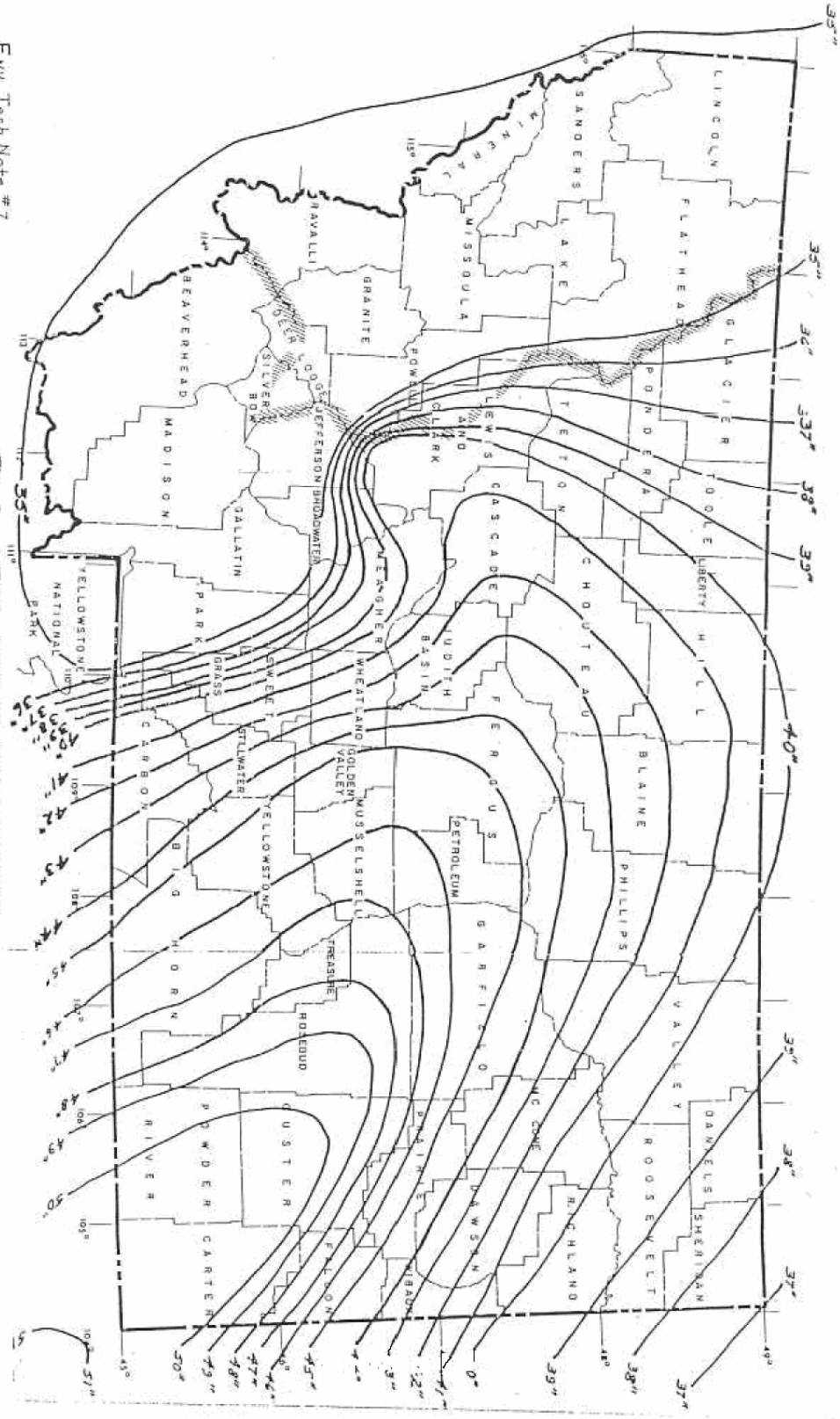

Fig. 2 MEAN ANNUAL EVAPORATION
SHALLOW LAKES AND RESERVOIRS

ENV. Tech Note #7
Feb. 1974

Attachment 2: Phosphorus Index Assessment for Montana

Natural Resources Conservation Service Agronomy Technical Note No. 80.1
February 2001

United States Department of Agriculture
NATURAL RESOURCES CONSERVATION SERVICE
Nutrient Management
Agronomy Technical Note No. 80.1
February 2001

ECOLOGICAL SCIENCES—AGRONOMY TECHNICAL NOTE

PHOSPHORUS INDEX ASSESSMENT FOR MONTANA

Richard A. Fasching, State Agronomist

Phosphorus Concerns in the Environment

Phosphorus (P) is an essential nutrient for plant and animal growth and its use has been long recognized as necessary to maintain profitable crop and animal production. However, phosphorus can also increase the biological productivity of surface waters by accelerating eutrophication, the natural aging process of lakes and streams brought on by nutrient enrichment. Human activity can greatly accelerate the eutrophication process through activities that increase nutrient loading to water.

The U.S. Environmental Protection Agency (1996) identified eutrophication as the main cause of impaired surface water quality in the United States. Eutrophication restricts water use for fisheries, recreation, industry, and drinking due to the increased growth of undesirable algae and aquatic weeds and to oxygen shortages caused by their death and decomposition. Associated periodic surface blooms of blue-green algae can occur in drinking water supplies and may pose a serious health hazard to animals and humans.

Eutrophication of most fresh water is accelerated by P inputs. Although exchangeable atmosphere and water sources of nitrogen and carbon are also essential to the growth of aquatic biota they are difficult to control. Thus, P is considered the most limiting element, and its control is of prime importance in protecting and improving Montana surface waters.

Surface water concentrations of P above 0.02 ppm generally accelerate eutrophication. These values are an order of magnitude lower than P concentrations in soil solution critical for plant growth (0.2 to 0.3 ppm), emphasizing the disparity between critical lake and soil P concentrations and the importance of controlling P losses to limit eutrophication.

P Index Concept

Nonpoint source P pollution of surface waters is a complex set of processes that involves P application, build up in soils, and transport to surface waters. High P application in the form of P fertilizer or manure can increase the risk of P transport to surface waters. However, unless there is loss in runoff (solution or adsorbtion), risk in minimal. Extremely high soil test P also increases the risk of P enrichment, but there must be dissolution and transport of P before there is an environmental concern.

The P Index is a field-level assessment tool that ranks the relative potential for off-site movement of phosphorus from the landscape. The purpose of the phosphorus index is to provide field staffs, watershed planners, and land users with a tool to assess the various land forms and management practices for potential risk of phosphorus movement toward water bodies. The ranking of the Phosphorus Index identifies sites where the risk of phosphorus movement may be relatively higher than from other sites. The P Index can also be used to develop planning considerations that can be provided to the land user. From these planning considerations alternatives are provided to the producer to minimize the potential phosphorus movement from the landscape.

Factors Affecting P Loss

Phosphorus is transported from manure application sites by runoff water. Phosphorus in runoff is made up of adsorbed P (P attached to soil particles), water soluble P and organic P (found in manure/residue/organic matter). Adsorbed P transported by water erosion normally accounts for a large portion of P lost from a site. However, when P soil test levels increase, the amount of water-soluble P in runoff increases.

Reducing rates of manure or fertilizer P decreases the risk of P loss. Applying fertilizer P and manure closer to crop uptake, and injecting or incorporating manure reduces the risk of P loss. Concentrated surface water runoff is largely responsible for transporting most P lost from the manure application site and can enter directly into streams and lakes. When manure is applied farther away from areas where surface water runoff concentrates, the potential for P loss decreases. Additionally, when buffers are used to protect down slope areas the potential for P loss to surface water is reduced. Irrigation induced erosion also substantially increases the potential for P loss.

The P Index uses ten specific field characteristics and management practices to obtain a rating for each field. Not all field features and management practices have the same influence on potential P loss. Research has shown that relative differences exist in the importance of each field feature to P loss. Thus, site characteristics have been placed in categories and assigned a weight factor based on relative impact on P movement from the site. Instructions and definitions are provided for each factor. Each category's weight factor is multiplied by its risk value to get a weighted risk factor for each specific category. All categories are rated and the overall risk rating for the site is the sum of all values (refer to TABLE 3). TABLE 3 is available as a .pdf worksheet on the Montana NRCS home page address: *http/www.mt.nrcs.usda.gov/*

TABLE 1. PHOSPHORUS LOSS CATEGORIES AND WEIGHT FACTORS

FIELD FEATURE/MANAGEMENT PRACTICE	WEIGHTED FACTOR
Soil Erosion	1.5
Furrow Irrigation Erosion	1.5
Sprinkler Irr. Erosion/runoff	0.5
Runoff class	0.5
Soil test P (Bray P1 or Olson)	1.0
Commercial P fertilizer application rate	1.0
Commercial P fertilizer application method	1.0
Manure/organic P application rate	1.0
Manure/organic P application method	1.0
Distance to concentrated surface water flow	1.0

The risk rating for each category is as follows:

- None = 0 (not applicable N/A)
- Low = 1
- Medium = 2
- High = 4
- Very High = 8

Category Descriptions and Instructions

Individual sections from TABLE 3 are provided here to assist in determining the weighted risk factor for each category. After reviewing the descriptions and instructions for each category, assign a risk value and calculate the weighted risk factor using the Phosphorus Index Rating worksheet.

1. Soil Erosion

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Soil Erosion	**N/A**	**<5 ton/ac/yr**	**5-10 tons/ac/yr**	**10-15 tons/ac/yr**	**>15 tons/ac/yr**		**X 1.5**	

Soil erosion is the movement of soil from the site due to runoff. This category is quantified in tons/acre/year. Water erosion can be predicted using the Revised Universal Soil Loss Equation (RUSLE) found in the Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG). Erosion predictions are calculated based on precipitation, rainfall intensity, soil characteristics, slope gradient and slope length, cropping system, and supporting practices including terraces, contour farming, etc.

2. Furrow Irrigation Erosion

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Furrow Irrigation Erosion	**N/A**	**Tailwater recovery, QS >6 very erodible soils, or QS >10 other soils**	**QS >10 for erosion resistant soils**	**QS >10 for erodible soils**	**QA >6 for very erodible soils**		**X 1.5**	

Adsorbed P and other nutrients can be lost due to erosive flows within the furrow. QS value is determined by furrow flow rate (gallons per minute - gpm), soil texture, and furrow slope. Tailwater recovery means that a system is in place that captures irrigation runoff (e.g. pit) and is re-used again for irrigation after sediment has settled out. Furrow flow rate and slope are accounted for as follows:

QS value = Furrow Flow Rate (gpm) X Furrow Slope (%)

Example: QS = _____ 20 gpm __ X ____0.5% = 10 .

Soils are broken down into three surface texture categories based on susceptibility to furrow irrigation induced erosion. Refer to published soil survey data for soil texture classifications.

- Very erodible Soils - soils with silt, fine and very fine sandy loam, loamy fine sand, and loamy very fine sand textures.
- Erodible soils - silt loam and loam soils.
- Erosion-resistant soils - soils with silty clay, clay, and clay loam textures.

3. Sprinkler Irrigation Erosion

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Sprinkler Irrigation Erosion	All sites 0-3% slope, all sandy sites, or site evaluation indicates little or no runoff, large spray on silts 3-8%	Medium spray on silty soils 3-15% slopes, large spray on silty soils 8-15% slope low spray on silt soils 3-8%,large spray on clay soil 3-15% slope	Medium spray on clay soils 3-8% slopes, large spray on clay , soils >15% slope, medium spray on silt soil >15% slope	Medium spray on clay soils >8% slope, low spray on clay soil 3-8% slope, low spray on silty soils >15% slopes	Low spray on clay soils >8% slopes.		X 0.5	

This category rates the potential for sprinkler irrigation induced erosion. Spray type, soil texture and soil gradient impact sprinkler irrigation induced erosion. When a comprehensive evaluation of irrigation induced runoff indicates little or no runoff will occur, this category is not applicable (N/A) and is given a rating of (0).

Spray type

- Large spray = nozzle wetted diameter is > 50 feet.
- Medium spray = nozzle wetted diameter is 20-50 feet.
- Low spray = nozzle wetted diameter is < 20 feet.

Slope

- Percent of slope on the application site being evaluated.

Texture

- Sandy textured (fine and very fine sandy loam, loamy fine sand, and loamy very fine sand).
- Silt (silt, silt loam, loam).
- Clay (silty clay, silty clay loam, clay and clay loam).

4. Runoff Class

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Runoff Class	Negligible	Very Low or low	Medium	High	Very High		X 0.5	

The runoff class of a site is based on the least permeable soil layer in the top three feet. Permeability classes for specific soils can be found in the soil series description in the published soil survey manual or in NASIS. Slope and soil permeability class must be determined, then runoff class can be determined (refer to TABLE 2).

TABLE 2. RUNOFF CLASS

SLOPE %	Soil Permeability Class				
	VERY RAPID (>20.0 in/hr)	**MODERATELY RAPID** (2.06.0 in/hr and **RAPID** (6.020.0 in/hr)	**MODERATE** (0.602.0 in/hr) **AND MODERATELY SLOW** (0.200.60 in/hr)	**SLOW** (0.060.20 in/hr)	**VERY SLOW** (<0.06 in/hr)
Depressions	Negligible	Negligible	Negligible	Negligible	Negligible
0-1%	Negligible	Negligible	Negligible	Low	Low
1-5%	Negligible	Very Low	Low	Medium	High
5-10%	Very Low	Low	Medium	High	Very High
10-20%	Very Low	Low	Medium	High	Very High
>20%	Low	Medium	High	Very High	Very High

5. **Soil Test Phosphorus** (use only one soil test category)

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Bray P1 Soil Test P	---	<30 ppm	30-60 ppm	60-120 ppm	>120 ppm		X 1.0	
Olson Soil Test P	---	<20 ppm	20-40 ppm	40-80 ppm	>80 ppm		X 1.0	

Bray P1 soil tests are typically used on soils with a pH of 7.0 or less, while Olson (sodium bicarbonate) soil tests are utilized on soils with a pH greater than 7.0 and contain calcium carbonate. Phosphorus soil tests should be taken from the top 6" of the soil.

6. Commercial P Fertilizer Application Method

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR

Commercial P Fertilizer Application Method	None Applied	Placed with planter or injected deeper than 2 inches.	Incorporated <3 months prior to planting or surface applied during the growing season.	Incorporated >3 months before crop or surface applied <3 months before crop emerges.	Surface applied >3 months before crop emerges.		X 1.0	

The manner in which P fertilizer is applied to the soil and the time that fertilizer is exposed on the soil surface impacts potential P loss. Incorporation implies that fertilizer P is incorporated into the soil a minimum of two inches. The categories of increasing severity, LOW to VERY HIGH, depict the longer surface exposure time between fertilizer application and crop utilization.

7. Commercial P Fertilizer Application Rate

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Commercial P Fertilizer Application Rate	None Applied	<30 lbs/ac P_2O_5	3190 lbs/ac P_2O_5	91150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	

Commercial P fertilizer application rate is the amount, in pounds per acre (lbs/ac), of phosphate fertilizer (P_2O_5) that is applied. This does not include phosphorus from organic sources (manure).

8. Manure/Organic P Source Application Method

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Organic P Source Application Method	None Applied	Injected deeper than 2 inches	Incorporated <3 months prior to planting or surface applied during growing season.	Incorporated >3 months before crop or surface applied < 3 months before crop emerges.	Surface applied to pasture or applied >3 months before crop emerges.		X 1.0	

The manner in which manure is applied to the soil and the time it is exposed on the soil surface impacts potential P loss. Incorporation implies that manure is incorporated into the soil a minimum of two inches. The categories of increasing severity, LOW to VERY HIGH, depict the longer surface exposure time between manure application, incorporation, and crop utilization

9. Manure/Organic P Source Application Rate

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Organic P Application Rate	None Applied	<30 lbs/ac P_2O_5	3190 lbs/ac P_2O_5	91150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	

10. Distance to Concentrated Surface Water Flow

SITE CATEGORY	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Distance to Concentrated Surface Water Flow	>1,000 feet	2001000 feet, or functioning grasses waterways in concentrated surface water	100200 feet	<100 feet	0 feet or applications are directly into concentrated surface water flow areas.		X 1.0	

This category is an estimate of distance between the application site, and the point where runoff water concentrates. Use zero for distance if manure or fertilizer P is applied directly in concentrated flow areas (eg. drainage course, ditch) that delivers runoff water into intermittent or perennial streams, lakes or water bodies. If concentrated flow areas do not deliver runoff directly into a stream or other water body (concentrated flow spreads prior to entering the stream or other water body), use the distance from where runoff exits the application site to the point where it enters a stream or other water body. Installation of grassed waterways in concentrated flow areas will reduce the risk of sediment-P loss due to concentrated water flow.

Completing Risk Ratings

Each site category's weighting factor in TABLE 3 is multiplied by the site risk rating (value) to get a weighted risk value. All categories are rated (according to individual category instructions), and the overall rating is the sum of all values. After individual sites/fields are rated, refer to the appropriate vulnerability rating in Table 4.

TABLE 3. PHOSPHORUS INDEX ASSESSMENT

SITE CATEGORY FACTOR	NONE (0)	LOW (1)	MEDIUM (2)	HIGH (4)	VERY HIGH (8)	RISK VALUE (0,1,2,4,8)	WEIGHT FACTOR	WEIGHTED RISK FACTOR
Soil Erosion	**N/A**	**<5 ton/ac/yr**	**5-10 tons/ac/yr**	**10-15 tons/ac/yr**	**>15 tons/ac/yr**		**X 1.5**	
Furrow Irrigation Erosion	**N/A**	**Tailwater recovery, QS >6 very erodible soils, or QS >10 other soils**	**QS >10 for erosdion resistant soils**	**QS >10 for erodible soils**	**QA >6 for very erodible soils**		**X 1.5**	
Sprinkler Irrigation Erosion	All sites 0-3% slope, all sandy sites, or site evaluation indicates little or no runoff, large spray on silts 3-8%	Medium spray on silty soils 3-15% slopes, large spray on silty soils 8-15% slope, low spray on silt soils 3-8%,large spray on clay soil 3-15% slope	Medium spray on clay soils 3-8% slopes, large spray on clay soils >15% slope, medium spray on silt soil >15% slope	Medium spray on clay soils >8% slope, low spray on clay soil 3-8% slope, low spray on silty soils >15% slopes	Low spray on clay soils >8% slopes.		X 0.5	
Runoff Class	Negligible	Very Low or low	Medium	High	Very High		X 0.5	
Bray P1 Soil Test P	---	<30 ppm	30-60 ppm	60-120 ppm	>120 ppm		X 1.0	
Olson Soil Test P	---	<20 ppm	20-40 ppm	40-80 ppm	>80 ppm		X 1.0	
Commercial P Fertilizer Application Method	None Applied	Placed with planter or injected deeper than 2 inches.	Incorporated <3 months prior to planting or surface applied during the growing season.	Incorporated >3 months before crop or surface applied <3 months before crop emerges.	Surface applied >3 months before crop emerges.		X 1.0	
Commercial P Fertilizer Application Method	None Applied	Placed with planter or injected deeper than 2 inches.	Incorporated <3 months prior to planting or surface applied <3 months before crop.	Incorporated >3 months before crop or surface applied <3 months before crop.	Surface applied >3 months before crop emerges.		X 1.0	
Commercial P Fertilizer Application Rate	None Applied	<30 lbs/ac P_2O_5	31–90 lbs/ac P_2O_5	91–150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	
Organic P Source Application Method	None Applied	Injected deeper than 2 inches	Incorporated <3 months prior to planting or surface applied during growing season.	Incorporated >3 months before crop or surface applied < 3 months before crop emerges.	Surface applied to pasture or >3 months before crop emerges.		X 1.0	
Organic P Application Rate	None Applied	<30 lbs/ac P_2O_5	31–90 lbs/ac P_2O_5	91–150 lbs/ac P_2O_5	>150 lbs/ac P_2O_5		X 1.0	
Distance to Concentrated Surface Water Flow	>1,000 feet	200–1000 feet, or functioning grasses waterways in concentrated surface water	100–200 feet	<100 feet	0 feet or applications are directly into concentrated surface water flow areas.		X 1.0	
Site/Field Total Phosphorus Index Value								

Interpreting Results of Site Vulnerability Ratings

After multiplying the weighting factor by the risk value for each category and totaling all values in TABLE 3, assign the overall site/field vulnerability to phosphorus loss from TABLE 4.

TABLE 4. SITE/FIELD VULNERABILITY TO PHOSPHORUS LOSS

Total of Weighted Risk Values	Site Vulnerability	Site/Field Number(s)
<11	LOW	
11-21	MEDIUM	
22-43	HIGH	
> 43	VERY HIGH	

Vulnerability Definitions

LOW - This site has a low potential for P movement from the site. If farming practices are maintained at the current level there should be a low probability of an adverse impact to surface resources.

MEDIUM - This site has a medium potential for P movement from the site. There is a greater probability of an adverse impact to surface water resources than from a low rated site. Some remedial action such as using P management measures (i.e. filter strips, grassed waterways, application setbacks, manure injection or incorporation) should be taken to lessen the probability of P movement.

HIGH - This site has a high potential for P movement from the site. There is a higher probability of an adverse impact to surface water than medium sites unless remedial action is taken. Soil and water conservation (refer to soil erosion category for conservation options) as well as P management measures (i.e. P based manure application rates) should be taken to reduce the risk of P movement and probable water quality degradation

VERY HIGH - This site has a very high potential for P movement from the site. There is a very high probability for an adverse impact to surface water. Remedial action should be taken to reduce the risk of P movement. Soil and water conservation practices and a phosphorus management plan are needed to reduce the potential of water quality degradation.

Practices utilized to reduce P loss can vary from one site to the next. Site categories that have the highest weighted risk value are the most critical factors impacting P loss. Practices that reduce the risk value of these categories are the most effective.

Effective practices can include: P management measures such as planting high P-use crops, rotating manure application sites, reduced manure application rates, manure application set-backs from areas where runoff concentrates, application method (injection or incorporation versus broadcast), timing (growing season, spring and split applications versus fall or applications to frozen/snow covered ground), and soil and water conservation practices such as residue management, terraces, contouring, grassed waterways, filter strips, etc.

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Attachment 3: Fertilizer Guidelines for Montana Crops

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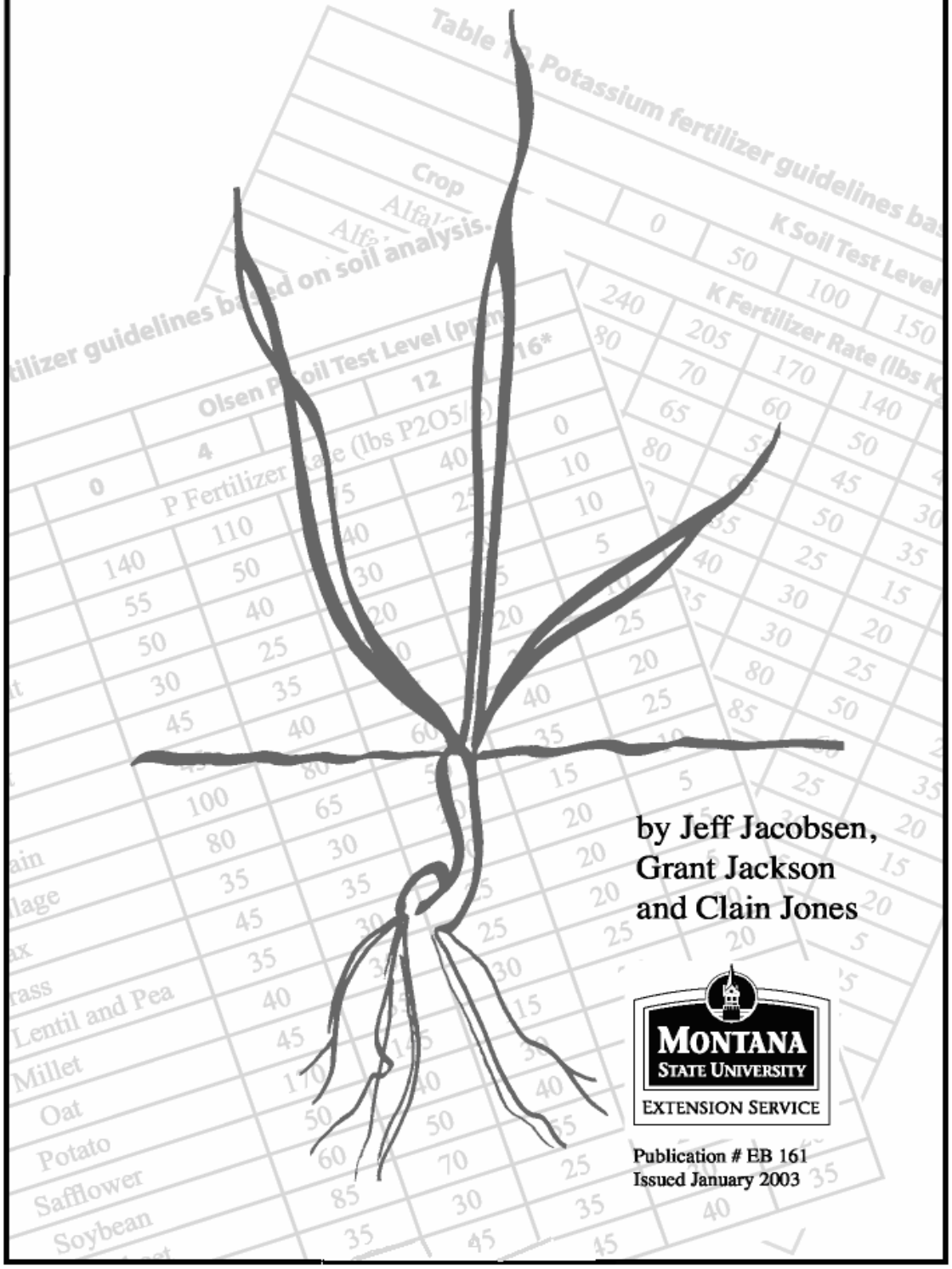
FERTILIZER GUIDELINES
for Montana Crops



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Fertilizer Guidelines for Montana Crops

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Introduction

Nitrogen (N), phosphorus (P), potassium (K) and other fertilizers can increase crop yield and quality when soil analysis indicates deficiencies, soil nutrients are unavailable, past history would predict a response, and other agronomic practices are optimum. The following soil analysis guidelines (Tables 1-17 for N, 18 for P, 19 for K, and 20 for micronutrients) are primarily based on research conducted in Montana, but where current or any data is not available, we have used a compilation of research from surrounding states and provinces to develop the tables.

These tables provide guidelines in terms of fertilizer rates for a range of yield potentials, available N and soil analysis values for P, K and micronutrients. Fertilizer guidelines assume that growth-limiting factors such as sodium and salts are not limiting growth.

Nitrogen

The soil analysis for available N is for NO_3-N to a depth of 2 feet. Deeper soil samples for N or other soil mobile nutrients (sulfur, boron and chloride) will improve the reliability of N and other mobile nutrient fertilizer guidelines. When organic matter mineralizes it has the potential to release N into the soil for potential plant uptake. The Montana N fertilizer guidelines assume an average organic matter level of 2%. This is directly incorporated into our recommendations on available N requirements. For soils that have organic matter (O.M.) levels that exceed 2%, additional N will be released to the soil through mineralization at a rate of 15-20 lbs N/a for each 1% of O.M. Therefore, N fertilizer rates can be decreased by 15-20 lbs N/a, if the soil has 3% O.M. or more. With small grain residues remaining on the soil surface and broadcast N applications, 10 lbs N/a can be added per 1000 lb residue/a, up to a total of 40 lbs N/a. Montana research indicates that additional N is not needed. Split N applications may be warranted on coarse-textured soils.

Phosphorous and Potassium

Phosphorus and K guidelines (Tables 18 and 19) are based on a sample taken from 6 inches in depth and assume band placement of fertilizer material. The P and /or K rate may need to be increased for broadcast applications particularly on low to medium testing soils or where past experience has indicated a response to applied fertilizer.

Potassium fertilizer response information is accurate approximately 30% of the time. Therefore, site- and year-specific response information is particularly important. Starter applications (10-20 lbs nutrient/a) are recommended for all crops (particularly spring crops), since the soils are typically cold and ideally wet, which limits the initial availability of residual N, P, and K.

Variability within Sites

The soil analysis values are based on soil samples that represent a field or areas within a field. Interpolation may be necessary to determine the suggested level of a specific nutrient to be applied. Special condition comments are provided to enhance nutrient management practices and, in particular, avoid problems and optimize inputs. P and K recommendations are independent of yield and are based on typical yields for Montana. Table 21 provides crop replacement/removal values for the harvested portion, if needed.

Applying Site-specific Information

When site-specific information is available or is known through actual field experiences, use it to develop unique guidelines for fertilizer applications. The research-based information presented in these tables is from multiple sites over multiple years, spanning unique environments and, ultimately, representing average response information for Montana and the Northern Great Plains. Therefore, this information will not take into account annual variability in climate prior to and during the growing season. Without question, local expertise should be used to ultimately determine fertilizer rates.

Adapting to your Conditions

The guidelines are for a single season of cropping and do not represent a build- or fertilize-the-soil philosophy. Based on economics, soil factors and level of management, a land manager may want to put more P and/or K in a field in a given year. Assuming no soil erosion occurs (for P and K losses) or leaching (for N losses), these agronomic rates will not impact water quality.

Specific differences in soil, climate, management intensity and other unique site factors should be integrated into final decisions on fertilizer rates. General crop removal rates for numerous essential elements are presented in Table 21. These are based on the dry matter unit presented, using the best available data. These should not be considered absolute, since factors such as cultivar, climate and agronomic practices can influence nutrient concentrations.

Sulfur and Micronutrients

Although sulfur (S) guidelines are not presented, deficiencies are increasingly common on Montana soils with low soil S levels, low gypsum levels, or when gypsum is present, but it is positioned in the soil profile out of the rooting zone. Compounding this diagnostic problem is the fact that the analytical procedures for S soil analysis sometimes do not accurately reflect or relate to crop response from S fertilizer applications. Canola and forages have been demonstrated to be responsive to S applications.

General micronutrient guidelines are presented based on a 6-inch sample depth. However, deficiencies are not common, so minimal research has been conducted on micronutrients in the Northern Great Plains.

Alfalfa/grass

Table 1. Alfalfa/grass N guidelines.

ALFALFA/GRASS				
Yield Potential (t/a)*	80/20	60/40	40/60	20/80
	———N fertilizer (lbs/a)———			
1	5	10	15	20
2	10	20	30	40
3	15	30	45	60
4	20	40	60	80
5	25	50	75	100
6	30	60	90	120

*Attainable yield when *all* growth factors optimized.

Special Conditions

- Inoculation with nodule forming N-fixing bacteria is advised for establishment of legumes on fields not previously cropped to legumes.
- Inoculation is essential to meet N demand from N fixation, if native inoculum is not sufficient.
- Plowed down alfalfa stubble adds some fixed N to the soil. In general, the first crop after alfalfa or sweet clover will add 35-50 lbs N/a.
- Broadcasting is the most efficient method of fertilizer application on established perennial crops. Recent data show deep band applications of P in old alfalfa stands is effective.
- Under dryland conditions and low P/K soil levels, it would be better to “build up” or increase the available level of P and/or K in the soil before planting alfalfa or other perennial hay crops.
- For established alfalfa when fertilizer is recommended, the above fertilizer is to be applied annually as long as the stand is maintained.
- For all new grass seedings, the above recommendation is for the seeding year and subsequent annual applications. For the seeding year, do not apply more than 20 lbs N/a.
- The above recommendation may be applied for cool season grasses in the late fall or early spring. For warm season grasses, apply about mid-May.
- N fertilization of grass-legume mixtures will usually increase the grass yield in relation to legumes. Legumes will be more competitive, if phosphorus (P) rates are adequate.
- Frequently, the legume percentage in the forage can be increased by applying high rates of P and little or no N fertilizer. If more than 50% of the plants are legumes, assuming good stands and available water, lack of P in soil is the major cause of poor production.

Table 2. Feed and malt barley N guidelines based on soil analysis.

BARLEY - FEED		BARLEY - MALT	
Yield Potential (bu/a) *	Available N (lbs/a) **	Yield Potential (bu/a) *	Available N (lbs/a) **
40	64	60	72
60	96	70	84
80	128	80	96
100	160	90	108
120	192	100	120
140	224	110	132
		120	144

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- Drill-row applications of N+K_2O should not exceed 30 lbs/a. When using urea as the N source, drill-row applications of N+K_2O should not exceed 15 lbs/a with a 6-7 inch row spacing. When using a wider row spacing, do not apply any urea with the seed. With newer drills and openers, the mixture of seed, fertilizer and soil is much greater, so more fertilizer can be placed in the "row" due to the dilution of potential detrimental impacts from salts and ammonia on germination and growth.
- Applying N fertilizer on well-drained sandy soils in the fall is not recommended because of possible loss by leaching.
- If protein levels of malt barley produced on your fields have been over acceptable levels, reduce the recommended rates by 20 lbs N/a.
- Fertilization with K at 20 (dryland) to 30 (irrigated) lbs K_2O/a is generally recommended for malt barley regardless of soil analysis.
- Barley grown for hay should be fertilized with the above N guidelines. If any plant stress (e.g. drought) is present, the potential hay should be checked for nitrates.

Dry Bean

Table 3. Dry Bean N guidelines based on soil analysis.

DRY BEAN	
Yield Potential (lbs/a) *	Available N (lbs/a) **
1000	50
1400	70
1800	90
2200	110
2600	130
3000	150

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- Dry edible beans are legumes which respond to N fertilizer and are very salt sensitive. If N is applied as a starter, it should not be in contact with the seed. Inoculation is essential to help meet N demand from N fixation. Some bushtype varieties will use more N for pod production compared to vine-type varieties.
- It usually takes several weeks after emergence for legumes to start producing their own N and dry beans are very ineffective in fixing N. Use of higher rates of N, however, may slow maturing and increase harvest problems. Responses to P and K are not always noticeable in the year of application. Approximately 60 percent of the P and 50 percent of the K used by edible bean plants is removed from the field when the seed is harvested.
- Dry bean can be N deficient even though they are legumes. Such deficiency can occur with cool wet growing conditions, especially in the first weeks of growth. Also, poor nodulation and/or inefficient strains of Rhizobia will fix less N than the plants require, resulting in N deficiency.
- Dry bean is sensitive to Zn and Fe deficiencies. High P can induce Zn deficiencies, even at adequate soil test levels.
- With an Fe soil test below 3.0 ppm, Fe availability is low. With an Fe soil test of 3.0-5.0 ppm, Fe availability is marginal. Direct Fe fertilization usually does not produce an economic return, and as the season warms up and the soil dries out, more Fe may become available to the crop. Incorporation of O.M. and improved drainage can help Fe availability. Also, avoid planting dry bean after sugarbeet, particularly if residual soil NO_3-N levels are high.
- Zn recommendation is based on use of inorganic product such as zinc sulfate which is broadcast and plowed down. One application should be effective for 2 to 4 years. Banding near the seed (2x2) has been found to be more effective per lb Zn than broadcast or incorporated applications.

Table 4. Buckwheat N guidelines based on soil analysis.

BUCKWHEAT	
Yield Potential (bu/a) *	**Available N (lbs/a) ****
25	55
30	66
35	77
40	88
45	99
50	110

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- $N+K_2O$ applications in contact with the seed should not exceed 10 lbs/a. N from urea, and DAP (18-46-0) should NOT be placed with the seed.

Canola/mustard/rapeseed

Table 5. Canola/mustard/rapeseed N guidelines based on soil analysis.

CANOLA/MUSTARD/RAPESEED	
Yield Potential (lbs/a) *	Available N (lbs/a) **
800	52
1200	78
1600	104
2000	130
2400	156
2800	182

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- N+K_2O applications in contact with the seed should not exceed 10 lbs/a. Nitrogen from urea, and DAP (18-46-0) should NOT be placed with the seed.
- Apply 20 lbs S/a as sulfate for each canola crop in a preplant application.

Table 6. Grain and silage corn N guidelines based on soil analysis.

CORN - GRAIN		CORN - SILAGE	
Yield Potential (bu/a) *	Available N (lbs/a) **	Yield Potential (t/a) *	Available N (lbs/a) **
50	60	12	108
90	108	15	135
130	156	18	162
170	204	21	189
210	252	24	216
250	300	27	243

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- If starter fertilizer is used, with seed and fertilizer applied together, rates should not exceed 5 to 10 lbs N/a, 10 lbs of P_2O_5/a and 5 lbs of K_2O/a. On sandy soils, such rates may damage germination because these soils are more likely to dry out before the crop is up. If the fertilizer implement places the fertilizer in a band that is to the side and below the seed, you can generally apply the entire recommended rate with the planter.
- Corn is sensitive to inadequate levels of Zn, and deficiency symptoms are occasionally observed in irregular patterns on soils of the Yellowstone Valley, especially where topsoil has been removed by land leveling. Zinc deficiencies may be aggravated by high rates of P.
- Reduce seed placed fertilizer rate by 50%, when soil conditions are dry or sandy, particularly with N as urea, DAP (18-46-0) and ammonium thiosulfate (12-0-0-26).
- Sandy soils may require split N applications.
- Corn is sensitive to Zn and Fe deficiencies. High P can induce Zn deficiencies, even at adequate soil test levels.
- With an Fe soil test below 3.0 ppm, Fe availability is low. With an Fe soil test of 3.0-5.0 ppm, Fe availability is marginal. Direct Fe fertilization usually does not produce an economic return, and as the season warms up and the soil dries out, more Fe may become available to the crop. Incorporation of O.M. and improved drainage can help Fe availability.
- Zn recommendation is based on use of an inorganic product such as zinc sulfate which is broadcast and plowed down. One application should be effective for 2 to 4 years.

Flax

Table 7. Flax N guidelines based on soil analysis.

FLAX	
Yield Potential (bu/a) *	**Available N (lbs/a) ******
20	60
30	90
40	120
50	150

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N

Special Conditions

- $N+K_2O$ applications in contact with the seed should not exceed 10 lbs/a. Nitrogen from urea, and DAP (18-46-0) should NOT be placed with the seed.

Table 8. Grass N guidelines based on soil analysis.

GRASS	
Yield Potential (t/a) *	Available N (lbs/a) **
1	25
2	50
3	75
4	100
5	125

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- Fall N application on sandy soils is not recommended. On all other soils, apply fertilizer in late fall or early spring. Continued application of N in late fall or early spring will favor the growth of cool season grasses at the expense of warm season grasses in native pasture, to enhance or promote the growth of warm season grasses, apply N in early summer.
- With a fluctuating water table (subirrigation), fertilize as though it is irrigated with a higher yield potential; however, be sure to apply P fertilizers in the fall or late winter.
- Hay meadows with reasonably good drainage can be fertilized any time from early winter to early spring. Wet meadows should be fertilized as close to spring as practical. Experiments show less yield increase from fall applications on very wet soils, but they are often profitable, so late winter fertilization may be the best alternative.
- Split N will generally not increase total production. If seeding on summerfallow, O. M. levels of 3% or more may produce enough plant available N to reduce rate of N fertilizer for 2 or 3 years.
- Do not exceed 60 lbs N/a during the seeding year, or within 9 months after a fall seeding date. If ammonium phosphate fertilizer is banded with the seed, for better efficiency of low rates, do not exceed 15 lbs N/a for 14 inch or less row spacings, and do not exceed 10 lbs N/a for rows spaced 18 inches or more. If N is placed with the seed, do not exceed 15 lbs N/a.
- If P is supplied by ammonium phosphate banded below the seed, do not exceed 15 lbs N/a for 14 inch or less row spacings and do not exceed 10 lbs N/a for rows spaced 18 inch or more. Fall application of P may give better first season response than spring application, particularly for low-medium P soils.

Lentil/chickpea/pea

Table 9. Lentil/chickpea/pea N guidelines based on soil analysis.

LENTIL/CHICKPEA/PEA
Generally, no supplemental N is needed. However, under dryland conditions, 15-25 lbs N/a should be present in the top 2 feet of the soil profile. Under irrigated conditions 30-40 lbs N/a should be present in the top 2 feet of the soil profile. Supplemental N may be warranted based on the above criteria. Small amounts of N (<30 lbs N/a) with P fertilization will generally not harm the N-fixing capacity.

Special Conditions

- Legumes without nodules or with ineffective nodules will respond to N applications. Since legumes have the ability to fix N, it is important to inoculate the seed just before planting. This is especially true on fields that have not been recently planted to either crop.
- It is important to use the proper inoculant for pea and lentil, since specific legumes require specific strains of Rhizobia bacteria.
- Starter applications of 10 lbs N/a have been shown to minimize N deficiency during early nodulation particularly on soils low in clay content or with high levels of small grain residues.
- Pea and lentil crops fix from 20% to 80% of their N requirement and obtain the remainder from the soil or fertilizer.
- K application rates when applied with seeding should not exceed 15 lbs K_2O/a due to the potential for seedling damage. If N is applied, the K_2O rate should be decreased by one pound for each pound of nitrogen added with the seed.
- Montana research has shown that the N benefits following pulse crops (chickpea, lentil, pea) averages about 10 lbs/a, but can vary from 0 to 20 lbs N/a depending upon climate and soil conditions. N contributions from green fallowed pulse crops can be substantially higher, but research has not determined actual numbers.

Millet/canary seed/sorghum

Table 10. Millet/canary seed/sorghum N guidelines based on soil analysis.

MILLET/CANARY SEED/SORGHUM	
Yield Potential (lbs/a) *	Available N (lbs/a) **
1500	52
1800	63
2100	74
2400	85
2700	96
3000	107

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- Drill-row applications of N+K_2O should not exceed 10 lbs/a to avoid the possibility of germination damage.

Oat

Table 11. Oat N guidelines based on soil analysis.

OAT	
Yield Potential (bu/a) *	**Available N (lbs/a) ******
60	72
80	96
100	120
120	144
140	168
160	192

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- For oats, N+K_2O fertilizers should be limited to 25 lbs/a when placed in contact with the seed in 6 or 7 inch rows. Reduce these values correspondingly for wider row width. Reduce these amounts by half for dry or coarse textured soils.
- Oats grown for hay should be fertilized with the above N guidelines. If any plant stress (e.g. drought) is present, the hay should be checked for nitrates.

Table 12. Potato N guidelines based on soil analysis.

POTATO	
Yield Potential (cwt/a) *	Available N (lbs/a) **
200	80
300	120
400	160
500	200

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- With an Fe soil test below 3.0 ppm, Fe availability is low. With an Fe soil test of 3.0-5.0 ppm, Fe availability is marginal. Direct Fe fertilization usually does not produce an economic return, and as the season warms up and the soil dries out, more Fe may become available to the crop. Incorporation of O.M. and improved drainage can help Fe availability.
- Zn recommendation is based on use of an inorganic product such as zinc sulfate which is broadcast and plowed down. One application should be effective for 2 to 4 years.

Safflower

Table 13. Safflower N guidelines based on soil analysis.

SAFFLOWER	
Yield Potential (lbs/a) *	Available N (lbs/a) **
750	38
1250	62
1750	88
2250	112
2750	138
3250	162

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- N+K_2O applications in contact with the seed should not exceed 10 lbs/a. Nitrogen from urea, and DAP (18-46-0) should NOT be placed with the seed.
- Drill-row applications of N+K_2O should not exceed 15 lbs/a to avoid the possibility of germination damage.
- Safflower is an excellent N scavenger to depths of 6 feet. Where long-term crop-fallow has been practiced, there is usually sufficient N below 4 feet to supply the majority of N required.

Table 14. Soybean N guidelines based on soil analysis.

SOYBEAN
Additional fertilizer N is generally not needed. The N associated with P fertilizer (18-46-0 and 11-52-0) applications up to 20-30 lbs N/a will generally not adversely impact N fixation.

Special Conditions

- Inoculation with nodule forming N-fixing bacteria is advised for establishment of new legumes or fields not previously used for legumes or combined fields with different cropping histories.
- Soybeans that have been well inoculated are not likely to respond to additional N fertilizer. Inoculation is essential to help meet N demand from N fixation.
- When planted in 30 inch rows, do not apply fertilizer in contact with the seed. When planted in 7 inch rows, limit seed placed N+K_2O to 5 lbs/a, but do not use urea, UAN or DAP (18-46-0) and limit 0-46-0 to 100 lbs/a.

Sugarbeet

Table 15. Sugarbeet N guidelines based on soil analysis.

SUGARBEET	
Yield Potential (t/a) *	Available N (lbs/a) **
16	144
20	180
24	216
28	252
32	288

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- A general guide for spring applied N is to reduce the recommended N rate by 10 pounds for each week that planting is delayed after May 20.
- If the amount of NO_3-N in the 2- to 4-foot depth is more than 30 lbs N/a, the N recommendation should be reduced by 4 pounds for each 5-pound increment above 30 pounds found in the 2- to 4-foot depth.
- 10 to 15 lbs of N/a in the top 6 inches of soil should be adequate to establish the crop.
- Fall applied N fertilizer is not recommended on sandy soils or soils with a high water table.
- Late season release of N from manure can reduce sucrose percentage by stimulating top growth. For this reason, do not apply more than 15 tons of manure/a for a sugarbeets.
- In rotations with sugarbeets, if the tops remain in the field, reduce N requirements by 40 to 50 lbs N/a due to the release of N from this sugarbeet material.
- Sandy soils may require split N applications.
- Ridged beets should have no more than 80 lbs N/a applied preplant broadcast. This is more critical with urea compared to ammonium nitrate.

Table 16. Sunflower N guidelines based on soil analysis.

SUNFLOWER	
Yield Potential (lbs/a) *	Available N (lbs/a) **
1000	50
1300	65
1600	80
1900	95
2200	110
2500	125

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.

Special Conditions

- Some N may be applied in combination with starter fertilizers, but the rate should be less than 10 lbs N/a. Most efficient use can be obtained by applying N just ahead of planting. However, apply all of the fertilizer before heading (bud stage) to maximize yields and N use efficiency.
- Sunflower roots grow quickly into the soil between the rows. Sidedress N fertilizers early in the growing season to avoid root pruning.
- When planted in 30 inch rows, do not apply fertilizer in contact with the seed. When planted in 7 inch rows, limit seed placed N+K_2O to 5 lbs/a, but do not use urea, UAN or DAP(18-46-0) and limit 0-46-0 to 100 lbs/a.
- Sunflower is an excellent N scavenger to depths of 6 feet. Where long-term crop fallow has been practiced, there is usually sufficient N below 4 feet to supply the majority of N required.

Wheat

Table 17. Spring and winter wheat N guidelines based on soil analysis.

WHEAT- SPRING***		WHEAT- WINTER	
Yield Potential (bu/a) *	Available N (lbs/a) **	Yield Potential (bu/a)*	Available N (lbs/a) **
30	99	30	78
40	132	40	104
50	165	50	130
60	198	60	156
70	231	70	182
80	264	80	208
90	297	90	234
100	330		

* Attainable yield with *all* growth factors optimized.
** Fertilizer N = Available N - soil analysis NO_3-N.
***Includes durum and hard red and hard white spring wheat at 13% and 14% protein, respectively.

Special Conditions

- Drill-row applications of N+K_2O should not exceed 20 lbs/a. When using urea as the N source, drill-row application of N+K_2O should not exceed 10 lbs/a with a 6-7 inch row spacing. When using a wider row spacing, do not apply any urea with the seed. With newer drills and openers, the mixture of seed, fertilizer and soil is much greater, so more fertilizer can be placed in the “row” due to the dilution of potential detrimental impacts from salts and ammonia on germination and growth.
- If 14% protein is desired in winter wheat, use spring wheat guidelines.

Table 18. Phosphorus fertilizer guidelines based on soil analysis.

Crop	Olsen P Soil Test Level (ppm)				
	0	4	8	12	16*
	P Fertilizer Rate (lbs P_2O_5/a)				
Alfalfa	140	110	75	40	0
Alfalfa-Grass	55	50	40	25	10
Barley-Feed/Malt	50	40	30	20	10
Bean	30	25	20	15	5
Buckwheat	45	35	30	20	10
Canola	45	40	35	30	25
Corn-Grain	100	80	60	40	20
Corn-Silage	80	65	50	35	25
Flax	35	30	20	15	10
Grass	45	35	30	20	5
Lentil, Chickpea and Pea	35	30	25	20	15
Millet	40	35	25	20	5
Oat	45	35	30	25	20
Potato	170	145	115	75	20
Safflower	50	40	30	20	10
Soybean	60	50	40	25	5
Sugarbeet	85	70	55	40	10
Sunflower	35	30	25	20	15
Wheat-Spring	50	45	35	30	20
Wheat-Winter	55	50	45	40	35

Special Conditions

- With soil analysis levels of greater than 16 ppm, consider using crop removal rates (Table 21) as a P fertilization guideline.

Potassium

Table 19. Potassium fertilizer guidelines based on soil analysis.

Crop	K Soil Test Level (ppm)					
	0	50	100	150	200	250
	K Fertilizer Rate (lbs K_2O/a)					
Alfalfa	240	205	170	140	95	30
Alfalfa-Grass	80	70	60	50	40	25
Barley-Feed	75	65	55	45	30	20
Barley-Malt	90	80	65	50	35	25
Bean	45	40	35	25	15	5
Buckwheat	60	50	40	30	20	5
Canola	45	40	35	30	25	20
Corn-Grain	135	120	100	80	50	20
Corn-Silage	145	125	110	85	60	35
Flax	45	40	35	30	25	20
Grass	80	70	60	45	30	15
Lentil, Chickpea and Pea	45	40	35	30	25	20
Millet	65	55	45	35	20	5
Oat	100	85	70	55	40	25
Potato	300	250	215	165	100	25
Safflower	65	55	45	35	25	15
Soybean	90	75	60	45	30	15
Sugarbeet	120	100	80	60	40	20
Sunflower	55	50	45	40	35	30
Wheat	135	115	90	70	40	10

Table 20. Micronutrient fertilizer guidelines based on soil analysis.

Micronutrient Soil Test* ppm	Micronutrient Fertilizer Rate lbs/a
Boron	
0 - 0.5	2
0.5 - 1.0	1
>1.0	0
Copper	
0 - 0.5	2
>0.5	0
Iron	
0 - 2.5	4
2.5 - 5.0	2
>5.0	0
Manganese	
0 - 0.50	20
0.50 - 1.0	10
>1.0	0
Zinc	
0 - 0.25	10
0.25 - 0.50	5
>0.50	0

*Based on soil sample from 0-6 inches. Montana research has shown that micronutrient levels may increase with soil depth, regardless of the soil analysis obtained from the top six inches of the profile.

Nutrient uptake

Table 21. Estimated nutrient uptake in harvested portions of crops.*

Crop	Unit	Test Weight lbs/bu	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu	B
			----------lbs----------										
Alfalfa	ton		48	11	53	28	5	5.50	0.38	0.11	0.11	0.02	0.02
Barley-grain	bu	48	0.87	0.36	0.25	0.025	0.05	0.08		0.0015	0.0008	0.0008	0.001
Barley-straw	ton		14	4.10	30	7.6	2	3.8		0.045	0.30	0.01	
Bean	bu	60	3	0.79	0.92	0.18	0.06	0.52	.03	0.004	0.002	0.0015	0.003
Buckwheat	bu	48	0.86	0.16	0.22								
Canola/Mustard/ Rapeseed	bu	50-60	1.94	1.17	0.60			0.34					
Corn - grain	bu	56	0.73	0.60	0.27	0.015	0.05	0.07	0.0055	0.001	0.0006	0.0004	
Corn - straw	ton		19.8	8.8	40	5.8	4.50	3.20		0.067	0.33	0.01	
Flax	bu	56	2.12	0.85	0.75			0.21					
Grass	ton	13-45	25	10	38	7	2.50	2		0.08	0.13	0.01	
Lentil/Chickpea/ Pea	bu	60-68	2.18	0.67	0.87			0.15					
Millet/Canary Seed/Sorghum	bu	40-56	0.83	0.42	0.25	0.07	0.08	0.08		0.007	0.007	0.0002	

Oat - grain	bu	32	0.60	0.24	0.17	0.024	0.04	0.06		0.0006	0.001	0.0004	
Oat - straw	ton		12.2	5.80	33	0.40	4.00	4.60		0.145		0.015	
Potato	bu	50-60	0.20	1.30	0.38	0.009	0.02	0.38	0.16	0.0001	0.0002	0.0001	0.0001
Safflower	lbs	45	0.05	0.0125	0.038								
Soybean	bu	60	1.35	0.30	0.75	0.60	0.27	0.15		0.0002	0.0007	0.006	
Sugarbeet - root	ton		3.60	1.50	5.40	1.75	0.95	0.45			0.05	0.002	
Sugarbeet - top	ton		9.30	6.70	19.6	0.15	1.10	0.40			0.033	0.001	
Sunflower	bu	28	1.06	0.32	0.24		0.10	0.08					
Wheat - grain	bu	60	1.25	0.62	0.38	0.025	0.15	0.08		0.0035	0.002	0.0008	0.001
Wheat - straw	ton		14.5	3.60	25	4.4	2.20	3.7		0.03	0.11	0.007	

*Average of multiple published sources.

Attachment 4: NRCS Code 590 Nutrient Management

Natural Resources Conservation Service
July 2002

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

NUTRIENT MANAGEMENT (ACRE)

CODE 590

DEFINITION

Managing the amount, source, placement, form, and timing of the application of nutrients and soil amendments.

PURPOSE

- To budget and supply nutrients for plant production.
- To properly utilize manure or organic by-products as a plant nutrient source.
- To minimize agricultural nonpoint source pollution of surface and ground water resources.
- 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 **including consideration of organic wastes, commercial fertilizer, legume crops, crop residue, and biosolids.**

CRITERIA

General Criteria Applicable to All Purposes

Plans for nutrient management shall comply with all applicable federal, state, **tribal,** and local laws and regulations.

Plans for nutrient management shall be developed in accordance with policy requirements of the NRCS General Manual Title 450, Part 401.03 (Technical Guides, Policy and Responsibilities) and Title 190, Part 402–Ecological Sciences, Nutrient Management, Policy); **applicable Montana Amendments;** technical requirements of the NRCS Field Office Technical Guide (FOTG); procedures contained in the National Planning Procedures Handbook (NPPH), and the NRCS National Agronomy Manual (NAM), Section 503.

Persons who review or approve plans for nutrient management shall be certified through any certification program acceptable to NRCS within the state. **In Montana nutrient management certification is obtained through job approval authority (JAA) policy and procedures.**

Plans for nutrient management that are elements of a more comprehensive conservation plan shall recognize other requirements of the conservation plan and be compatible with its other requirements, **i.e., FSA compliance plans, waste utilization, pest management.**

A nutrient budget for nitrogen, phosphorus, and potassium shall be developed that considers all potential sources of nutrients including, but not limited to animal manure and organic by-products, waste water, commercial fertilizer, crop residues, legume credits, and irrigation water.

Realistic yield goals shall be established based on soil productivity information, historical yield data, climatic conditions, level of management and/or local research on similar soil, cropping systems, and soil and manure/organic by-products tests. **Yield goals for cereals and safflower may be estimated following the procedures outlined in the Nutrient Management Specification. Where available, Montana State University (MSU) Extension Service approved yield data may be used to calculate realistic yield goals.** For new crops or varieties, industry yield recommendations may be

NRCS, MT
February 2004

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard contact the Natural Resources Conservation Service.

NOTE: This type of font (AaBbCcDdEe 123..) indicates NRCS National Standards.
This type of font (AaBbCcDdEe 123..) indicates Montana Supplement.

used until documented yield information is available.

Plans for nutrient management shall specify the form, source, amount, timing and method of application of nutrients on each field to achieve realistic production goals, while minimizing nitrogen and/or phosphorus movement to surface and/or ground waters and maintaining soil quality.

Erosion, runoff, and water management controls shall be installed, as needed, on fields that receive nutrients. Water erosion prediction estimates must meet soil loss tolerance levels for the design soil during years of nutrient application. Where erosion levels do not meet soil loss tolerance levels, mitigation practices must be installed to ensure protection of surface and ground water resources.

Soil Sampling and Laboratory Analysis (Testing)

Nutrient planning shall be based on current soil test results developed in accordance with Land Grant University guidance or industry practice if recognized by the Land Grant University. Current soil tests are those that are no older than three years.

Soil samples shall be collected and prepared according to the Montana State University guidance or standard industry practice. See MontGuide MT 8602 for proper soil testing techniques. Soil test analyses shall be performed by laboratories that are accepted in one or more of the following programs:

- State Certified Programs,
- The North American Proficiency Testing Program (Soil Science Society of America), or
- Laboratories whose tests are accepted by the Land Grant University in the state in which the tests will be used.

Soil testing shall include analysis for any nutrients for which specific information is needed to develop the nutrient plan. Request analyses pertinent to monitoring or amending the annual nutrient budget, e.g., pH, electrical conductivity (EC), soil organic matter, nitrogen, phosphorus, and potassium.

Plant Tissue Testing

Tissue sampling and testing, where used, shall be done in accordance with MSU standards or recommendations.

Nutrient Application Rates

Soil amendments shall be applied, as needed, to adjust soil pH to the specific range of the crop for optimum availability and utilization of nutrients. For amendments and rates to correct sodium affected soils, see TABLE 10–Gypsum Requirements of Sodium Affected Soils, found in the nutrient management specification.

Recommended nutrient application rates shall be based on recommendations found in Fertilizer Guidelines for Montana, MSU Extension Service, EB 161, and/or industry practice when recognized by the university, that consider current soil test results, realistic yield goals and management capabilities. If MSU guidelines do not provide specific recommendations, application shall be based on realistic yield goals and associated plant nutrient uptake rates.

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, except when manure or other organic by-products are a source of nutrients. When manure or other organic by-products are a source of nutrients, see "ADDITIONAL CRITERIA" below.
- **Phosphorus Application**–Planned phosphorus application rates shall match the recommended rates as closely as possible, except when manure or other organic by-products are a source of nutrients. When manure or other organic by-products are a source of nutrients, see "ADDITIONAL CRITERIA" below.
- **Potassium Application**–Excess potassium shall not be applied in situations in which it causes unacceptable nutrient imbalances in crops or forages. When forage quality is an issue associated with excess potassium application, state standards shall be used to set forage quality guidelines.
- **Other Plant Nutrients**–The planned rates of application of other nutrients shall be consistent with MSU guidance or industry practice if recognized by MSU as plausible.
- **Starter Fertilizers**–Starter fertilizers containing nitrogen, phosphorus and potassium may be applied in accordance

with MSU recommendations, or industry practice, if recognized by MSU. When starter fertilizers are used, they shall be included in the nutrient budget.

Nutrient Application Timing

Timing and method of nutrient application shall correspond as closely as possible with plant nutrient uptake characteristics, while considering cropping system limitations, weather and climatic conditions, and field accessibility.

Nutrient Application Methods

Nutrients shall not be applied to frozen, snow-covered, or saturated soil if the potential risk for runoff exists. **Potential runoff risk will be determined using the Revised Universal Soil Loss Equation (RUSLE) with site specific cropping system data. Potential risk for runoff will be considered negligible if map unit slopes are less than two percent or calculated soil loss prediction from water is less than 5 T/A/Y.**

Nutrient applications associated with **application through** irrigation systems **(fertigation)** shall be applied in accordance with the requirements of **Field Office Technical Guide(FOTG), Section IV–Practice Standards and Specifications, 449–**rrigation Water Management.

Additional Criteria Applicable to Manure or Organic By-Products Applied as a Plant Nutrient Source

Nutrient values of manure and organic by-products (excluding sewage sludge) shall be determined prior to land application based on laboratory analysis, acceptable "book values" recognized by the NRCS **(see Ag. Waste Management Field Manual, Chapter 16)**, and/or the Land Grant University, or historic records for the operation, if they accurately estimate the nutrient content of the material. Book values recognized by NRCS may be found in the Agricultural Waste Management Field Handbook, Chapter 4– Agricultural Waste Characteristics. **Procedures outlined in FOTG, Section IV–Practice Standards and Specifications, 633–Waste Utilization, will be used to estimate nutrient concentrations of manure if manure test analyses are not available.**

Nutrient Application Rates

The application rate (in/hr) for material applied through irrigation shall not exceed the soil intake/infiltration rate. **See Montana irrigation Guide, Appendix A.** The total application shall not exceed the field capacity of the soil.

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

- **Nitrogen Application**–When the plan is being implemented on a phosphorus standard **(or basis)**, manure or other organic by-products **(in consideration of nitrogen contents)** shall be applied at rates consistent with the phosphorus standard. In such situations, an additional nitrogen application, from non-organic sources, may be required to supply the recommended amounts of nitrogen.

  Manure or other organic by-products may be applied on legumes at rates equal to the estimated removal of nitrogen in harvested plant biomass. **See Ag. Waste Field handbook, Chapter 6, TABLE 6-6.**

- **Phosphorus Application**–When manure or other organic by-products are used, the planned rates of phosphorus application shall be consistent with any one of the following options:

  - **Phosphorus Index (PI) Rating.** Nitrogen based manure application on Low or Medium Risk Sites, phosphorus based or no manure application on High and Very High Risk Sites. **See Agronomy Technical Note 80.1, Phosphorus Index Assessment for Montana, and TABLE 8–Phosphorus Application Based on PI.**

  - **Soil Phosphorus Threshold Values.** Nitrogen based manure application on sites on which the soil test phosphorus levels are below the threshold values. Phosphorus based or no manure application on sites on which soil phosphorus levels equal or exceed threshold values–**not applicable in Montana due to lack of research.**

- **Soil Test.** Nitrogen based manure application on sites on, which there is a soil test recommendation to apply phosphorus. Phosphorus based or no manure application on sites on which there is no soil test recommendation to apply phosphorus. **See specification, TABLE 9–Phosphorus Application from Soil Test Results.** Acceptable phosphorus

based manure application rates shall be determined as a function of soil test recommendation or estimated phosphorus removal in harvested plant biomass. **Phosphorus may be applied according to nitrogen requirements of the crop until optimum levels are exceeded. If optimum levels are exceeded, phosphorus will be applied at crop removal rates. No manure will be applied on sites where soil test phosphorus levels are excessive.**

A single application of phosphorus applied as manure 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.
- not be made on sites considered vulnerable to off-site phosphorus transport unless appropriate conservation practices, best management practices, or management activities are used to reduce the vulnerability.

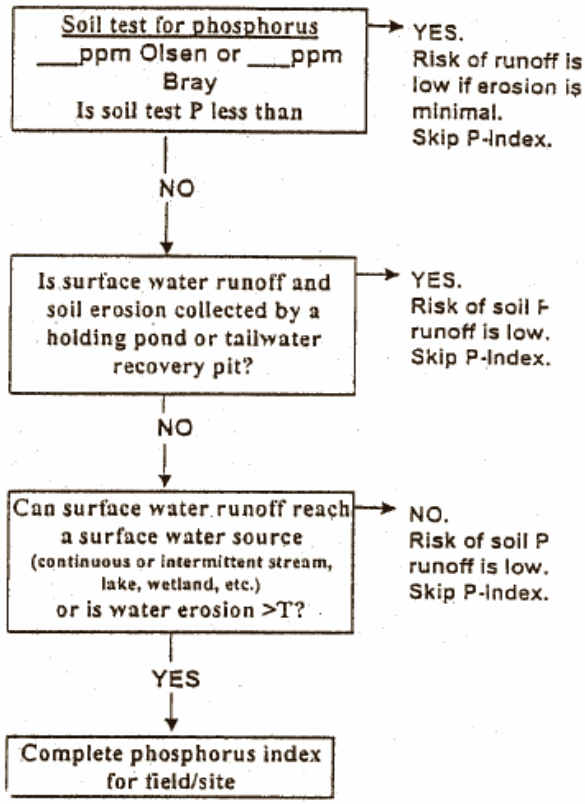
Field Risk Assessment

When animal manures or other organic by-products are applied, a field-specific assessment of the potential for phosphorus transport from the field shall be completed. This assessment may be done using the Phosphorus Index or other recognized assessment tool. In such cases, plans shall include:

- a record of the assessment rating for each field or sub-field, and
- information about conservation practices and management activities that can reduce the potential for phosphorus movement from the site.

When such assessments are done the results of the assessment and recommendations shall be discussed with the producer during the development of the plan.

Use the following preliminary screening tool to determine whether there is potential for phosphorus non-point source pollution:



When sewage sludge 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.

Additional Criteria to Minimize Agricultural Non-point Source Pollution of Surface and Ground Water Resources

In areas with an identified or designated nutrient-related water quality impairment, an assessment shall be completed of the potential for nitrogen and/or phosphorus transport from the field. The Leaching Index (LI) and/or Phosphorus Index (PI), or other recognized assessment tools, may be used to make these assessments. The results of these assessments and recommendations shall be discussed with the producer and included in the plan.

Plans developed to minimize agricultural nonpoint source pollution of surface or ground water resources shall include practices and/or management activities that can reduce the risk of nitrogen or phosphorus movement from the field.

Additional Criteria to Improve the Physical, Chemical, and Biological Condition of the Soil.

Nutrients shall be applied in such a manner as not to degrade the soil's structure, chemical properties, or biological condition. Use of nutrient sources with high salt content will be minimized unless provisions are used to leach salts below the crop root zone. **High salt content sources are those that will produce salinity over time. See FOTG, Section IV–Practice Standards and Specifications, 571–Salinity Management.**

Nutrients shall not be applied to flooded or saturated soils when the potential for soil compaction and creation of ruts is high.

CONSIDERATIONS

Consider induced deficiencies of nutrients due to excessive levels of other nutrients.

Consider additional practices **found in the FOTG, Section IV–Practice Standards and Specifications,** such as 327–Conservation Cover, 412–Grassed Waterway, 332–Contour Buffer Strips, 393–Filter Strips, 449–Irrigation Water Management, 391A–Riparian Forest Buffer, 328–Conservation Crop Rotation, 340–Cover and Green Manure, and Residue Management–329A, 329B, or 329C, and 344–to improve soil nutrient and water storage, infiltration, aeration, tilth, diversity of soil organisms and to protect or improve water quality.

Consider cover crops whenever possible to utilize and recycle residual nitrogen.

Consider application methods and timing that reduce the risk of nutrients being transported to ground and surface waters, or into the atmosphere. Suggestions include:

- split applications of nitrogen to provide nutrients at the times of maximum crop utilization,
- avoiding winter nutrient application for spring seeded crops,
- band applications of phosphorus near the seed row,
- applying nutrient materials uniformly to application areas or as prescribed by precision agricultural techniques,
- immediate incorporation of land applied manures or organic by-products,
- delaying field application of animal manures or other organic by-products if precipitation capable of producing runoff and erosion is forecast within 24 hours of the time of the planned application, and/or
- **applying nutrients as close as possible to time of use to reduce potential for surface and ground water contamination.**

Consider minimum application setback distances from environmentally sensitive areas, such as sinkholes, wells, gullies, ditches, surface inlets, or rapidly permeable soil areas.

Consider the potential problems from odors associated with the land application of animal manures, especially when applied near or upwind of residences.

Consider nitrogen volatilization losses associated with the land application of animal manures. Volatilization losses can become significant, if manure is not immediately incorporated into the soil after application.

Consider the potential to affect National Register listed or eligible cultural resources.

Consider using soil test information no older than one year when developing new plans, particularly if animal manures are to be a nutrient source.

Consider annual reviews to determine if changes in the nutrient budget are desirable, or needed, for the next planned crop.

On sites on which there are special environmental concerns, consider other sampling techniques. For example: Soil profile sampling for nitrogen, Pre-Sidedress Nitrogen Test (PSNT), Pre-Plant Soil Nitrate Test (PPSN) or soil surface sampling for phosphorus accumulation or pH changes.

Consider ways to modify the chemistry of animal manure–including modification of the animal's diet to reduce the manure nutrient content–to enhance the producer's ability to manage manure effectively.

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Consider the negative nutrient interactions and other growth factors that affect soil pH and the availability of nutrients in the soil solution.

Consider utilizing tissue tests, in conjunction with soil tests, to adjust the fertilizer program for crops during the growing season.

PLANS AND SPECIFICATIONS

Plans and specifications shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose(s), using nutrients to achieve production goals and to prevent or minimize water quality impairment.

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

- aerial photograph or map, and a soil map of the site,
- current and/or planned plant production sequence or crop rotation,
- results of soil, plant, water, manure, or organic by-product sample analyses,
- realistic yield goals for the crops in the rotation,
- quantification of all nutrient sources,
- recommended nutrient rates, timing, form, and method of application and incorporation selected by producer,
- location of designated sensitive areas or resources and the associated, nutrient management restriction,
- guidance for implementation, operation, maintenance, record keeping,
- completed Nutrient Budget, Form MT-ECS-590B for nitrogen, phosphorus, and potassium for the rotation or crop sequence,
- completed Field Specific Nutrient Application Plan, Form MT-ECS-590C,
- completed PI worksheet if required, and
- Montana specification.

If increases in soil phosphorus levels are expected, plans shall document:

- the soil phosphorus levels at which it may be desirable to convert to phosphorus based implementation,
- the relationship between soil phosphorus levels and potential for phosphorus transport from the field, and
- the potential for soil phosphorus drawdown from the production and harvesting of crops.

When applicable, plans shall include other practices or management activities as determined by specific regulation, program requirements, or producer goals.

In addition to the requirements described above, plans for nutrient management shall also include:

- discussion with producer about the relationship between nitrogen and phosphorus transport and water quality impairment. The discussion about nitrogen should include information about nitrogen leaching into shallow ground water and potential health impacts. The discussion about phosphorus should include information about phosphorus accumulation in the soil, the increased potential for phosphorus transport in soluble form, and the types of water quality impairment that could result from phosphorus movement into surface water bodies.
- discussion with producer about how the plan is intended to prevent the nutrients (nitrogen and phosphorus) supplied for production purposes from contributing to water quality impairment.
- a statement that the plan was developed based on the requirements of the current standard and any applicable federal, state, tribal, or local regulations or policies; and that changes in any of these requirements may necessitate a revision of the plan.
- The MTagwaste V10.2.XLS has the automated job sheets that can be used rather than hardcopies.

OPERATION AND MAINTENANCE

The owner/client is responsible for safe operation and maintenance of this practice including all equipment. Operation and maintenance addresses the following:

- Periodic plan review to determine if adjustments or modifications to the plan are needed. As a minimum, plans will be reviewed and revised with each soil test cycle.
- Protection of fertilizer and organic by-product storage facilities from weather and accidental leakage or spillage.
- Calibration of application equipment to ensure uniform distribution of material at planned rates.
- Documentation of the actual rate at which nutrients were applied. When the actual rates used differ from or exceed the recommended and planned rates, records will indicate the reasons for the differences.
- Maintaining records to document plan implementation. As applicable, records include:
  - soil test results and recommendations for nutrient application,
  - quantities, analyses and sources of nutrients applied,
  - dates and method of nutrient applications,
  - crops planted, planting and harvest dates, yields, and crop residues removed,
  - results of water, plant, and organic by-product analyses, and
  - dates of review and person performing the review, and recommendations that resulted from the review.

Records should be maintained for five years; or for a period longer than five years if required by other federal, state, tribal, or local ordinances, or program or contract requirements.

Workers should be protected from and avoid unnecessary contact with chemical fertilizers and organic by-products. Protection should include the use of protective clothing when working with plant nutrients. Extra caution must be taken when handling ammonia sources of nutrients, or when dealing with organic wastes stored in unventilated enclosures.

The disposal of material generated by the cleaning nutrient application equipment should be accomplished properly. Excess material should be collected and stored or field applied in an appropriate manner. Excess material should not be applied on areas of high potential risk for runoff and leaching.

The disposal or recycling of nutrient containers should be done according to state and local guidelines or regulations.

REFERENCES

Fertilizer Guidelines for Montana, Montana State University, Extension Service Bulletin EB 104. March 1997.

USDA–Natural Resources Conservation Service, Field Office Technical Guide, Section IV–Practice Standards and Specifications, 328–Conservation Crop Rotation. October 1988.

USDA–Natural Resources Conservation Service, National Engineering Handbook, Agricultural Waste Management Field Handbook, Part 651, Chapter 4, 6, 11, and 16.

USDA–Natural Resources Conservation Service, Field Office Technical Guide, Section I–Maps, Irrigation Climatic Areas for Montana. 1986.

Montana State University Extension Service, Department of Plant, Soil, & Environmental Science, Soil Testing Procedures, Interpretation and Fertilizer Sources, Montguide MT 8704, Bozeman, Montana.

Amber Waves, Washington State University, College of Agriculture and Home Economics Research Center, XB 1025. June 1992.

Montana State University Extension Service, Department of Plant, Soil, & Environmental Science, Soil Sampling, Montguide MT 8602, Bozeman, Montana.

Best Management Practices for Wheat, A Guide to Profitable and Environmentally Sound Production, National Association of Wheat Growers Foundation. 1994.

The National Association of Wheat Growers Foundation. November 1994.

Soil and Plant Analysis Registry, Montana Extension Service Bulletin EB 150. 1998.

Specification MT590-1

NATURAL RESOURCES CONSERVATION SERVICE

NUTRIENT MANAGEMENT (ACRE)

CODE 590

MONTANA CONSERVATION PRACTICE SPECIFICATION

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 soils and plants appropriate nutrients to produce food, forage, fiber, and cover while minimizing environmental degradation. Nutrient management is applicable to all lands where plant nutrients and soil amendments are applied.

Conservation Management Systems–Nutrient management may be a component of a conservation management system. It is used in conjunction with crop rotation, residue management, pest management, conservation buffer practices, and/or other practices needed on a site-specific basis to address natural resource concerns and the producers objectives. The major role of nutrient management is to minimize nutrient losses from fields, thus helping protect surface and ground water supplies.

Nutrient Management Planning–The nutrient management plan is a dynamic tool and must be monitored and adjusted on an annual basis, if appropriate. 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, etc.

Nutrient management components of the conservation plan will include the following information:

- Field map and soil map
- Planned crop rotation or sequence
- Results of soil, water, plant, and organic materials sample analysis
- Realistic expected yield
- Sources of all nutrients to be applied
- Nutrient budget, including credits of nutrients available
- Nutrient rates, form, timing, and application method to meet crop demands and soil quality concerns
- Location of designated sensitive areas
- Guidelines for operation and maintenance

Nutrient management is most effective when used with other agronomic practices, such as cover or green manure crops, residue management, conservation buffers, water management, pest management, and crop rotation.

Expected Yield.

METHOD 1. Yield goals of cereals and safflower can also be calculated using the following procedure:

Refer to Agronomy Technical Note 110.4–Determining Plant Available Moisture for Flex-Crop Systems, to determine (a) plant available soil moisture, and (b) growing season precipitation in inches based on 70 percent probability. Determine consumptive use from Field Office Technical Guide (FOTG), Section I–Maps, Irrigation Climatic Areas for Montana, 1986. Then, using TABLES 1, 2, 3, 4, or 5, estimate potential yield for the specific crop.

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Expected Yield CONTINUED.

METHOD 2. **Average Yield Method:**

Use the producers yield records (i.e., weight slips from the elevator, documented records, etc.) to average the yields obtained over a period of years. Yield estimates will be more accurate with a greater number of years of data. Years of exceptionally poor or exceptionally good yields should be eliminated from the calculation. Then you simply add up all the yields and divide by the number of years crops were produced.

EXAMPLE:

1996 = 35 bu/ac
1997 = 38 bu/ac
1998 = 21 bu/ac (drought)
1999 = 40 bu/ac
2000 = 30 bu/ac
2001 = 33 bu/ac

$$\frac{35 + 38 + 40 + 30 + 33}{5 \text{ yrs}} = 35.2 \text{ bu/ac}$$

35.2 plus 5% = **37 bu/ac expected Yield**

The expected yield can then be calculated by adding 5% onto the average yield. Five percent is added to figure in a little higher yield to cover those years when conditions are favorable and to take into account improved varieties and management techniques.

Soil Tests.

Current soil tests must be used to effectively plan for nutrient application. Current soil tests are those that are no older than three years old. Due to potential annual variability, nitrogen should 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. Application of micro-nutrients should be based on soil tests or plant analysis.

Regular testing of soil nutrient availability is essential for proper nutrient management decision making. Soil tests should be completed as close as possible to the time of seeding for the most accurate results. Organic matter (OM) will mineralize approximately 10-20 pounds of nitrate-nitrogen for every one percent of organic matter if moisture and heat conditions are adequate. For nutrient budgeting purposes, credit OM with

- Dry land 10 pounds NO_3 per acre per 1% OM (maximum 30 pounds).
- Irrigated land 20 pounds NO_3 per acre per 1% OM (maximum 60 pounds).

Where annual precipitation is less than 14 inches, zero pounds of nitrate nitrogen credit for mineralization should be assigned.

To calculate the amount of nitrate nitrogen (NO_3) available for the next crop, use the following calculation:

$$\frac{\text{Soil sample depth (in.)}}{6 \text{ (in.)}} \times 2 \times ___ \text{ ppm} = \text{lbs./acre } NO_3$$

Where two samples are taken and analyzed at different depths–i.e., at 0-12" and at 12-24", calculate pounds of nitrogen using the above formula for each sample depth and add the results.

EXAMPLE: Soil was sampled at two different depths to get a better representation of nutrient concentrations. Results were:

SAMPLE 1: 0–12" 32 ppm NO_3
SAMPLE 2: 12–18" 8 ppm NO_3

CALCULATIONS:

SAMPLE 1: $\frac{12"}{6"} \times 2 \times 32 \text{ ppm} = 128 \text{ lbs./ac } NO_3$

SAMPLE 2: $\frac{6"}{6"} \times 2 \times 8 \text{ ppm} = 16 \text{ lbs./ac } NO_3$

128 + 16 = 140 lbs/ac NO_3

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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. When the Phosphorus Index is completed a copy of it will be attached to this specification.

When the phosphorus index (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 TABLE 8)

When the phosphorus index (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 TABLE 9)

When the phosphorus index (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 TABLE 9).

General Nutrient Management Considerations–

- Test soil, plants, water and organic material for nutrient content.
- Set realistic yield goals.
- Apply nutrients according to soil test analysis recommendations.
- Account for nutrient credits from all sources.
- Consider effects of drought or excess moisture on quantities of available nutrients.
- Use a water budget to guide timing of nutrient applications.
- Use cover and green manure crops where possible to recover or retain residual nitrogen and other nutrients between cropping periods.
- Use split applications of nitrogen fertilizer for greater nutrient efficiency.
- Returning crop residue to the soil requires additional nitrogen due to microbial activity "tying up" some nitrogen especially when adding high-carbon organic residues. As a rule, approximately 10 pounds of nitrogen for every 1,000 pounds of residue over 3,000 pounds should be added to the soil to offset this tie-up if nitrogen is in deficit in the nutrient budget.
- If an irrigation water test has been completed, use TABLE 7 Nitrogen Contribution from Irrigation Water, to determine total pounds of nitrogen supplied from water.
- Use TABLE 6, Nitrogen Fixation Estimates for Dryland Conditions, to estimate legume credit of nitrate-nitrogen when a soil test is not available.

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.

The Leaching Index (LI), Nitrogen Leaching and Environmental Analysis Package (NLEAP), the Phosphorus Index (PI), erosion prediction models, water quality monitoring, may all be used to assess risk.

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Evaluate other areas that might have high levels of nutrients, produced or applied, that may contribute to environmental degradation. For example, areas with high livestock concentrations for large areas of high intensity cropping, such as continuous potatoes, corn, or specialty crops, may be contributing heavy nutrient loads to surface or ground water.

Conservation practices and management techniques will be implemented with nutrient management to mitigate any unacceptable risks.

Guidelines for Operation and Maintenance-

- Review the nutrient management component of the conservation plan annually and make adjustments when needed.
- Calibrate application equipment to ensure uniform distribution and accurate application rates.
- Protect nutrient storage areas from weather to minimize runoff and leakage.
- Avoid unnecessary exposure to fertilizer and organic waste, and wear protective clothing when necessary.
- Observe setbacks required for nutrient applications adjacent to water bodies, drainageways, and other sensitive areas.
- Maintain records of nutrient application as required by state and local regulations.
- Clean up residual material from equipment and dispose of properly.

The following jobsheets are attached and are considered part of the specification:

633–Waste Management Specification	☐ YES	☐ NO
MT-ECS-112–Nutrient Budget Jobsheet	☐ YES	☐ NO
MT-ECS-225–Field Specific Nutrient Application Plan	☐ YES	☐ NO
MT-ECS-227–Estimate Manure Nitrogen	☐ YES	☐ NO
MT-ECS-228–Manure Test Nitrogen	☐ YES	☐ NO

Specification MT590-4

Evaluate other areas that might have high levels of nutrients, produced or applied, that may contribute to environmental degradation. For example, areas with high livestock concentrations for large areas of high intensity cropping, such as continuous potatoes, corn, or specialty crops, may be contributing heavy nutrient loads to surface or ground water.

Conservation practices and management techniques will be implemented with nutrient management to mitigate any unacceptable risks.

Guidelines for Operation and Maintenance–

- Review the nutrient management component of the conservation plan annually and make adjustments when needed.
- Calibrate application equipment to ensure uniform distribution and accurate application rates.
- Protect nutrient storage areas from weather to minimize runoff and leakage.
- Avoid unnecessary exposure to fertilizer and organic waste, and wear protective clothing when necessary.
- Observe setbacks required for nutrient applications adjacent to water bodies, drainageways, and other sensitive areas.
- Maintain records of nutrient application as required by state and local regulations.
- Clean up residual material from equipment and dispose of properly.

The following jobsheets are attached and are considered part of the specification:

633–Waste Management Specification	☐ YES	☐ NO
MT-ECS-112–Nutrient Budget Jobsheet	☐ YES	☐ NO
MT-ECS-225–Field Specific Nutrient Application Plan	☐ YES	☐ NO
MT-ECS-227–Estimate Manure Nitrogen	☐ YES	☐ NO
MT-ECS-228–Manure Test Nitrogen	☐ YES	☐ NO

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July 2002

TABLE 1. ESTIMATED SPRING WHEAT YIELDS[a] BASED ON STORED SOIL WATER AND GROWING SEASON PRECIPITATION[a]

CONSUMPTIVE USE AREA	STORED SOIL WATER + GROWING SEASON PRECIPITATION. (IN.) 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	BUSHELS PER ACRE[bc]														
1 High	0	6	10	15	20	24	29	34	39	43	48	53	57	62	67
2 Moderate High	0	6	11	16	21	27	32	37	42	47	52	57	62	67	72
3 Moderate	0	7	13	19	24	30	36	42	48	53	59	65	71	77	82
4 Moderate Low	0	7	13	20	26	32	38	44	50	56	62	68	74	80	87

TABLE 2. ESTIMATED BARLEY YIELDS[a] BASED ON STORED SOIL WATER AND GROWING SEASON PRECIPITATION[a]

CONSUMPTIVE USE AREA	STORED SOIL WATER + GROWING SEASON PRECIPITATION. (IN.) 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	BUSHELS PER ACRE[bc]														
1 High	6	13	20	27	34	41	48	55	62	69	76	83	90	97	104
2 Moderate High	7	14	22	30	37	45	52	60	68	75	83	90	98	106	113
3 Moderate	8	16	25	33	42	50	59	67	76	84	93	101	110	118	127
4 Moderate Low	8	17	26	35	44	53	62	71	80	89	98	107	116	125	134

[a] Estimated yields reflect consumptive use data from Huntley, Havre, Sidney, Conrad, Kalispell, Bozeman, and Moccasin.

[b] Yields may vary from estimates due to climatic conditions, weeds, disease, insects, lodging, or stand density.

[c] When rooting depths are limited by rocks, gravel, or impermeable layers such as shale, yields may vary.

TABLE 3. ESTIMATED WINTER WHEAT YIELDS[a] BASED ON STORED SOIL WATER AND GROWING SEASON PRECIPITATION[a]

CONSUMPTIVE USE AREA	STORED SOIL WATER + GROWING SEASON PRECIPITATION. (IN.) 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	BUSHELS PER ACRE[bc]														
1 High	0	6	11	17	22	28	33	38	44	49	55	60	65	71	76
2 Moderate High	0	6	12	18	24	30	35	41	47	53	59	64	70	76	82
3 Moderate	0	7	14	20	27	34	40	47	53	60	67	73	80	86	93
4 Moderate Low	0	8	15	22	29	36	43	50	57	64	71	78	85	92	99

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TABLE 4. ESTIMATED OAT YIELDS[a] BASED ON STORED SOIL WATER AND GROWING SEASON PRECIPITATION[a]

CONSUMPTIVE USE AREA	STORED SOIL WATER + GROWING SEASON PRECIPITATION. (IN.) 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	BUSHELS PER ACRE[bc]														
1 High	0	2	11	21	30	39	49	58	68	77	86	96	105	115	124
2 Moderate High	0	2	12	23	33	43	54	64	74	84	95	105	115	126	136
3 Moderate	0	2	14	26	37	49	61	72	84	96	108	119	131	143	154
4 Moderate Low	0	2	15	28	40	52	65	78	90	102	115	128	140	152	165

TABLE 5. ESTIMATED SAFFLOWER YIELDS[a] BASED ON STORED SOIL WATER AND GROWING SEASON PRECIPITATION[a]

CONSUMPTIVE USE AREA	STORED SOIL WATER + GROWING SEASON PRECIPITATION. (IN.) 8	9	10	11	12	13	14	15	16	17	18	19	20	21	228
	POUNDS PER ACRE[bc]														
2 Moderate High	115	279	443	607	771	935	1,099	1,263	1,427	1,591	1,755	1,919	2,083	2,247	2.411

[a] Estimated yields reflect consumptive use data from Huntley, Havre, Sidney, Conrad, Kalispell, Bozeman, and Moccasin.

[b] Yields may vary from estimates due to climatic conditions, weeds, disease, insects, lodging, or stand density.

[c] When rooting depths are limited by rocks, gravel, or impermeable layers such as shale, yields may vary.

TABLE 6. NITROGEN FIXATION ESTIMATES FOR DRYLAND CONDITIONS[1]

LEGUME	N FIXATION (LB./ACRE)
Alfalfa (after harvest)	40-80
Alfalfa (green manure)	80-90
Spring Pea	40-90
Winter Pea	70-100
Lentil	30-100
Chickpea	30-90
Fababean	50-125
Lupin	50-55
Hairy Vetch	90-100
Sweetclover (ANNUAL)	15-20
Sweetclover (BIENNIAL)	80-150
Red Clover	50-125
Black Medic	15-25

[1] The large variation in estimates is attributed to different years, climate, management, etc.

NRCS, MT
July 2002

TABLE 7. NITROGEN CONTRIBUTION FROM IRRIGATION WATER

N IN WATER (PPM)	Water Application Rate (ACRE-FEET) 0.5	1.0	1.5	2.0
	LBS N/ACRE)			
2	3	5	8	11
4	5	11	16	22
6	8	16	24	32
8	11	22	32	43
10	13	27	40	54

TABLE 8. PHOSPHORUS APPLICATION BASED ON PI

PHOSPHORUS RISK RATING	PHOSPHORUS APPLICATION
Low	Nitrogen Based
Medium Risk	Nitrogen Based
High Risk	Phosphorus Based (up to crop removal amounts)
Very High Risk	Phosphorus Based or no application

TABLE 9. PHOSPHORUS APPLICATION FROM SOIL TEST RESULTS

SOIL TEST PHOSPHORUS (ppm)	PHOSPHORUS APPLICATION
≤8.0	Nitrogen Based
8.1 – 25.0	Nitrogen Based
25.1 – 100.0	Phosphorus Based
100.1 – 150.0	Phosphorus Based (up to crop removal)
>150.0	No Application

* Estimate; subject to modification based on the development of new research relevant to Montana

TABLE 10. GYPSUM REQUIREMENTS FOR SODIUM AFFECTED SOILS

SAR*	GYPSUM ($CaSO_4 \cdot 2H_2O$) lbs/10,000 ft^2
0 – 12	0
12 – 21	50
21 – 31	100
31 – 40	150

*SAR = Sodium adsorption ratio, 0 – 6 inch sample depth

United States Department of Agriculture
NATURAL RESOURCES CONSERVATION SERVICE
Crop Production
Agronomy Technical Note No. 110.4
September 2001

Determining Plant Available Soil Moisture For Flex-crop Systems

Richard A. Fasching, State Agronomist

BACKGROUND

Historically, many producers in summer fallow areas of Montana followed a strict crop-fallow rotation regardless of soil moisture conditions. By effectively using precipitation and stored soil moisture, producers have the ability to improve their overall production as well as minimizing environmental hazards such as saline seep development, nutrient leaching, and soil erosion.

INTRODUCTION

Flexible cropping can be used in areas of Montana where precipitation is not adequate for or is not predictable enough to allow for annual cropping systems. Flexible cropping or Flex-crop is where the decision to recrop is based on the amount of stored soil moisture and rainfall probabilities that will attain a satisfactory yield. It is designed to accomplish several objectives including (1) increase grain production by using water more efficiently; (2) control saline seeps by cropping as often as possible to use stored soil moisture and precipitation; (3) reduce wind and water erosion by reducing time the land is in a fallow condition. This process is also effective for determining expected yield and associated nutrient applications.

Yield Expectations

Data collected across Montana show that re-crop small grains generally average about 70% of yields attained on fallow acreage. However, considering the two-year total crop production of both systems, flex-cropping produces 130 to 180% of grain production on fallow land. Nonetheless, following a rigid annual cropping system can lead to low uneconomical yields or crop failures in dry years; thus the concept of **"Flexible Cropping".**

Successful use of the flexible cropping system is highly dependent on efficient soil water management, effective weed and volunteer grain control, adequate fertilization, and in general, good soil and crop management. Failure to take care of any of these will often result in lower yields.

Water for the Crop

Approximately 9 inches of available water is needed to produce, at a minimum, a small grain crop. Available water is stored soil moisture plus the growing season precipitation. Neither barley nor spring wheat will produce grain with less than 4 inches of total water use. With more than 5 inches of water use, barley and spring wheat yields will generally increase by 7 and 4 bushels per acre for each extra inch of water, respectively. Grain yields may exceed these estimates in years of favorable climatic conditions but may be lower when there are adverse effects such as weeds, insects, diseases, inadequate fertility, and unfavorable weather.

Determining growing season precipitation needed to produce an acceptable yield is crucial. If the amount of precipitation needed to successfully produce a crop is high and the probability of receiving that amount of precipitation is low, the risk of crop failure is high. With a failure, not only will a producer lose that year's crop but may also risk reduced yields the following year due to excess soil moisture depletion.

Conversely, fallowing land that has adequate soil moisture in spring will aggravate salinity problems in areas that are susceptible.

Water Conservation

The chances of a successful flex-crop system will be improved if fall and winter water conservation measures are incorporated. Fall weed and volunteer grain growth use stored soil moisture that can be saved for the following year's crop. Controlling weeds and green growth will not only save moisture for the next crop but will stop further weed seed production and reduce future weed problems.

Allowing standing stubble during winter months will trap snow and increase the water content of the soil in spring. Fields with standing stubble may gain 1 to 3 inches more stored soil water during the winter period than fields with tilled stubble. The additional soil water conserved by controlling green growth and weeds in the fall and by trapping snow in the winter will reduce the amount of growing season precipitation required to attain an acceptable yield. "Scalping" maximizes snow catch in stubble. Scalping is the process of cutting grain at various heights at each pass, i.e. first pass grain is cut at 10 inches, 6 inches on the second pass, 12 inches on the third pass, etc.

Fertilization

Fertilization with the necessary plant nutrients at optimum rates is essential for producing good yields and high quality crops. If stored soil water and the probability of growing season precipitation justify a decision to crop, then fertilizer needs should be determined also. Soil samples should be collected and recommendations obtained based on Montana State University Guidelines or industry guidelines (see 590 Nutrient Management standard).

Nitrogen fertility will typically be lower in soils cropped in consecutive years. Soils accumulate nitrate-nitrogen (available to the plant) through microbial conversion of organic nitrogen forms. Annual cropping or recropping allows less time for conversion of organic nitrogen to nitrate than does a crop-fallow. Also, harvesting higher yields because of improved water management will require greater quantities of nitrogen and other nutrients.

Precipitation Probabilities

Table 2 shows the probability (%) of receiving at least the indicated amounts of growing season precipitation for three different time periods at 24 locations in Montana. For locations not coved in Table 2, use the Precipitation Probability Map, Figure 1.

Using the Soil Probe

Using a soil probe (i.e. Brown soil moisture probe) is a convenient tool for determining depth of moist soil. The probe is used by vigorously pushing, without turning, it into the soil. The probe will penetrate moist soil but will stop at dry soil depths. The depth of penetration is the moist soil depth measured in feet (i.e. 1.0, 1.5, 2.5, etc).

Table 1 shows inches of plant available water per foot of moist soil according to textural class. To determine stored soil moisture, multiply depth (in feet) of moist soil X the estimated Average Water holding Capacity (AWC) for the appropriate textural class. Example: 3 feet of

moist soil were probed in spring on a fine sandy loam field. 3 X 1.5+4.5 inches of stored soil water.

To acquire accurate stored soil moisture estimates, each quarter section should be probed at 6 to 10 representative locations or at least once per 20-acre block. Atypical areas such as wet spots, saline seeps, and rock outcrops should be avoided or recorded separately. For each management unit, average the moist soil depth readings, then multiply by the AWC from Table 1.

Determining Plant Available Soil Moisture

1. **Determine the soil texture** in the upper 4 feet of soil profile by field inspection or from a soil survey.

2. **Determine the average depth of stored soil moisture** as close to planting as possible using the soil probe or soil auger. Convert the depth of soil moisture to plant available moisture using Table 1, Plant Available Water Capacities for Textural Classes in Montana. Note that recropping with spring grains is not recommended if stored soil moisture is less than 3 inches.

3. Use Table 2, Growing Season Precipitation Probabilities, to **estimate the probable amount of growing season precipitation.**

4. Determine expected yields based on stored soil moisture plus probable growing season precipitation. Table 3, Estimated Barley Yields; Table 4, Estimated Spring Wheat Yields; or Table 5, Estimated Winter Wheat Yields may be used for estimating yields of small grains.

5. Based on yield estimates, **decide to crop or fallow** (as a general rule, a recrop yield of 60 to 75% of the average yield on fallow should be economical).
   a. Spring Planting Decisions for Flex-Cropping
      - If the available soil moisture plus the estimated growing season precipitation at the 70% probability level is less than 9 inches, do not plant a small grain crop for grain harvest. If calculated available water will be greater than 9 inches, plant a crop (the decision to plant a crop is ultimately the producer's and should be based on economics as well as resource considerations). The decision process is the same for non-small grain crops except water requirements are different.
   b. Fall Planting Decisions for Flex-Cropping.
      - Plant a winter wheat crop when there is 1 inch or more of plant available moisture in the top 1 foot of soil and the average winter-stored soil moisture plus growing season precipitation is equal to 8 inches or more.
      - For winter wheat, growing season precipitation is assumed to equal average precipitation from fall seeding until June 30 with the following adjustments:
        - Under fallow conditions, when the soil profile is at field capacity (4-feet), no additional moisture credit is given for precipitation received from time of planting to April 1.

- Under clean-tilled fallow conditions, with the soil profile at less than field capacity to a 4-foot depth, 12 percent of the average precipitation from date of planting to April 1 is assumed.
- 33% credit is given for winter precipitation when there is standing stubble and 25% for worked stubble.
- Use 48% credit for a herbaceous barrier system.

c. Planting Decision for Summer Fallowed Land for Flex Cropping Rotation
   - Plant a crop on summer fallowed land regardless of stored soil moisture. Tilled double summer fallow is not recommended due to potential for erosion and salinity problems.

d. Planting Decision for Flexible Legume-cereal Rotation.
   - Plant a leguminous crop as early as possible when it is determined that available water makes a small grain (or other grain or root) crop unfeasible.

References:

Soil Water Guidelines and Precipitation Probabilities. Montana State university Extension Service Bulletin 356. Reprinted May 1990

USDA NRCS Field Office Technical Guide, 328 Conservation Crop Rotation

USDA NRCS Field Office Technical Guide, 590 Nutrient Management

Table 1. Plant Available Water Capacities For Textural Classes in Montana[1/and 2/]

		Soil Textural Class	Estimated Average Plant AWC (in/ft)[2/]
Sandy Soils	Course Texture	Sands	0.5
		Loamy sands	1.0
		Loamy fine sands	
		Loamy v. fine sands	1.25
		Fine sands	
		V. fine sands	
Loamy Soils	Moderate Coarse Texture	Sandy loam	1.5
		Fine sandy loam	
	Medium Texture	V. fine sandy loam	
		Loam	2.0
		Silt loam	
		Silt	
	Moderately Fine Texture	Clay loam	
		Sandy clay loam	2.2
		Silty clay loam	
Clayey Soils	Fine Texture	Sandy clay	
		Silty clay	2.0
		Clay	

[1/] Soluble salts and gravel will decrease plant available water capacity. Organic matter and good soil structure will increase it. Capacity increases about 0.1 in/ft for each 1% organic matter. Soils with water restricting layers like compacted subsoil, shallow bedrock or stratification can increase plant available water capacity of the overlying layers. Soils that are deep, medium textured and uniform can have decreased plant available water but allow for deeper rooting.
[2/] Approved by Soils Committee, MSU, Plant and Soil Science Planning Conference, January 31, 1984.

Table 2. Growing Season Precipitation Probabilities (%) of receiving at least the indicated amounts of growing season precipitation at 24 selected locations in Montana.

	Average Precipitation (Inches)	Precipitation - Inches 2	3	4	5	6	7	8
		----------Percent----------						
Big Timber								
Mar 29 - Jun 27	6.48	96.3	94.7	85.3	75.4	60.3	32.7	22.4
Apr 12 - Jul 11	6.42	98.7	94.8	83.4	71.5	55.1	36.7	23.7
May 03 - Aug 01	6.09	>99.0	93.5	81.5	62.9	47.2	30.6	16.4
Bozeman								
Mar 29 - Jun 27	7.06	>99.0	>99.0	95.7	83.1	70.7	49.6	34.3
Apr 12 - Jul 11	6.93	>99.0	98.7	94.8	87.1	68.5	42.6	30.3
May 03 - Aug 01	6.50	>99.0	97.1	85.8	81.1	60.5	41.1	27.9
Cascade								
Mar 29 - Jun 27	6.83	>99.0	96.0	87.4	71.6	63.6	49.8	30.1
Apr 12 - Jul 11	7.01	>99.0	98.6	90.9	73.8	63.0	49.0	33.8
May 03 - Aug 01	6.59	>99.0	93.1	86.6	70.2	56.1	42.7	26.4
Choteau								
Mar 29 - Jun 27	5.60	98.4	90.2	74.1	50.2	34.4	18.2	14.9
Apr 12 - Jul 11	6.05	98.8	93.3	84.1	61.3	39.9	223.2	17.2
May 03 - Aug 01	6.23	97.8	93.7	80.1	63.6	41.7	29.7	22.0
Crow Agency								
Mar 29 - Jun 27	6.39	>99.0	95.0	74.9	63.2	58.3	39.5	25.1
Apr 12 - Jul 11	6.29	>99.0	97.3	78.3	68.0	50.8	33.8	21.1
May 03 - Aug 01	5.67	>99.0	92.7	73.1	57.1	42.4	28.5	15.5
Cut Bank								
Mar 29 - Jun 27	5.27	95.9	93.4	80.9	56.6	27.4	12.4	9.8
Apr 12 - Jul 11	5.76	98.3	93.9	81.6	63.6	40.9	21.5	13.0
May 03 - Aug 01	5.85	98.6	92.4	77.1	64.7	47.1	25.5	12.9
Ekalaka								
Mar 29 - Jun 27	6.77	98.1	94.1	87.0	77.8	58.2	46.0	27.2
Apr 12 - Jul 11	7.26	>99.0	94.4	91.3	81.7	70.8	54.1	40.0
May 03 - Aug 01	7.31	97.9	96.6	90.7	82.4	71.3	60.0	38.6
Flatwillow								
Mar 29 - Jun 27	6.04	98.8	96.4	78.8	63.0	48.2	30.7	28.3
Apr 12 - Jul 11	6.38	>99.0	97.9	85.8	69.1	53.6	37.8	25.2
May 03 - Aug 01	6.49	>99.0	95.0	85.2	77.4	51.9	35.5	25.4
Forks								
Mar 29 - Jun 27	5.33	97.9	88.1	67.9	50.7	36.4	20.5	12.8
Apr 12 - Jul 11	6.06	>99.0	93.0	77.9	64.0	51.0	35.2	22.6
May 03 - Aug 01	6.21	>96.7	91.5	81.0	65.3	43.4	36.2	28.8
Fort Benton								
Mar 29 - Jun 27	6.67	>99.0	>99.0	89.5	76.3	57.9	39.5	21.1
May 01 - Jul 31	6.68	>99.0	97.4	86.8	81.6	57.9	39.5	23.7
Glasgow								
Mar 29 - Jun 27	5.19	>99.0	83.2	69.6	48.3	33.5	20.7	13.4
Apr 12 - Jul 11	5.78	>99.0	87.8	77.7	61.6	37.4	33.3	19.3
May 03 - Aug 01	5.84	>99.0	90.7	77.5	55.7	46.4	29.5	21.7

Glendive								
Mar 29 - Jun 27	6.20	98.4	90.3	84.9	66.8	60.6	33.7	25.7
Apr 12 - Jul 11	6.78	98.8	93.7	88.2	75.4	70.1	52.3	27.2
May 03 - Aug 01	6.87	97.8	96.9	90.9	77.7	63.0	49.1	30.6
Great Falls								
Mar 29 - Jun 27	6.15	>99.0	98.1	88.5	63.9	39.3	29.2	20.3
Apr 12 - Jul 11	6.44	>99.0	97.3	88.5	69.2	44.8	38.9	22.4
May 03 - Aug 01	6.25	>99.0	95.1	80.8	66.0	49.9	35.4	22.9
Havre								
Mar 29 - Jun 27	4.95	98.9	84.8	63.9	48.0	30.0	17.6	8.0
Apr 12 - Jul 11	5.33	>99.0	93.8	73.2	52.4	31.3	24.5	13.9
May 03 - Aug 01	5.43	98.3	89.4	73.0	52.4	36.1	20.9	13.0
Hamilton								
Mar 29 - Jun 27	3.94	96.0	71.7	48.7	27.1	15.8	7.7	3.8
Apr 12 - Jul 11	4.12	94.1	73.4	57.9	31.2	20.0	12.2	4.8
May 03 - Aug 01	4.03	91.0	71.6	50.3	32.4	17.5	6.6	4.1
Helena								
Mar 29 - Jun 27	4.66	98.3	83.2	68.0	40.4	29.0	12.3	3.9
Apr 12 - Jul 11	4.24	>99.0	90.6	71.8	44.1	28.6	16.2	6.6
May 03 - Aug 01	4.78	>98.6	87.3	71.1	40.3	23.5	11.9	5.8
Huntley								
Mar 29 - Jun 27	5.70	96.6	94.4	70.0	58.4	43.7	27.7	17.2
Apr 12 - Jul 11	5.77	96.2	94.0	80.7	60.4	46.5	29.9	22.3
May 03 - Aug 01	5.38	97.1	85.2	76.2	57.1	45.9	22.8	16.2
Jordan								
Mar 29 - Jun 27	5.10	92.7	79.4	62.6	50.1	37.4	21.6	14.2
Apr 12 - Jul 11	5.68	95.5	82.2	68.2	56.0	43.7	31.6	20.7
May 03 - Aug 01	5.56	97.2	88.7	68.3	55.7	46.9	22.0	18.3
Kalispell								
Mar 29 - Jun 27	4.80	100	95.7	73.5	46.0	16.7	7.3	6.3
Apr 12 - Jul 11	5.12	100	97.7	75.9	51.7	24.5	9.4	6.7
May 03 - Aug 01	4.45	100	95.3	71.4	40.4	18.7	7.4	6.7
Malta								
Mar 29 - Jun 27	5.42	98.2	83.1	71.8	54.0	35.0	25.3	16.3
Apr 12 - Jul 11	5.97	98.4	90.7	78.1	62.2	43.6	28.7	21.4
May 03 - Aug 01	6.19	97.0	90.5	82.3	63.0	49.4	32.7	19.9
Medicine Lake								
Mar 29 - Jun 27	5.74	96.5	86.5	69.0	56.9	46.9	26.5	21.8
Apr 12 - Jul 11	6.62	>99.0	92.5	77.5	69.7	60.9	39.0	24.3
May 03 - Aug 01	7.02	>99.0	97.8	84.8	79.2	62.4	38.5	34.3
Mildred								
Mar 29 - Jun 27	5.84	95.9	90.8	76.7	64.6	46.9	32.2	18.1
Apr 12 - Jul 11	6.29	98.4	94.7	80.5	70.6	59.1	37.7	24.2
May 03 - Aug 01	6.23	98.6	93.7	82.7	69.4	56.8	35.3	19.2
Miles City								
Mar 29 - Jun 27	5.74	97.2	92.9	71.3	60.9	45.3	29.3	17.5
Apr 12 - Jul 11	6.06	98.4	93.4	78.7	64.3	49.1	30.7	22.3
May 03 - Aug 01	6.01	>99.0	89.7	79.3	64.8	48.0	32.3	19.3

Moccasin								
Mar 29 - Jun 27	6.68	>99.0	97.2	92.4	78.8	58.4	44.5	31.7
Apr 12 - Jul 11	7.11	>99.0	96.7	92.9	81.7	67.0	53.8	41.1
May 03 - Aug 01	7.28	>99.0	98.8	94.5	84.4	68.4	58.9	38.1
Plevna								
Mar 29 - Jun 27	5.99	98.8	91.8	77.0	65.3	52.4	39.6	21.6
Apr 12 - Jul 11	6.42	>99.0	89.7	81.5	69.9	59.7	47.7	27.6
May 03 - Aug 01	6.52	>99.0	95.4	85.3	70.9	62.2	49.7	23.8
Poplar								
Mar 29 - Jun 27	5.52	97.1	87.8	72.8	62.4	40.1	24.6	14.0
Apr 12 - Jul 11	6.49	98.6	91.3	79.7	70.1	60.8	42.4	29.2
May 03 - Aug 01	6.83	>99.0	95.2	84.9	69.1	55.2	44.4	39.3
St. Ignatius								
Mar 29 - Jun 27	5.73	100	96.2	89.7	72.6	41.8	32.6	14.3
Apr 12 - Jul 11	5.95	100	100	89.2	72.9	45.9	27.3	22.9
May 03 - Aug 01	5.11	100	100	89.4	55.2	30.3	21.5	15.6

Table 3. Estimated Barley Yields

Available Soil Water					- Growing Season Precipitation (inches) -							
At Seeding to 4 feet		2	3	4	5	6	7	8	9	10	11	12
Inches					Bushels per Acre							
1	With less than	0	0	5	12	19	26	33	40	47	54	61
2	2"of seasonal	0	5	12	19	26	33	40	47	54	61	68
3	rainfall, barley	5	12	19	26	33	40	47	54	61	68	75
4	will fail in	12	19	26	33	40	47	54	61	68	75	82
5	most years.	19	26	33	40	47	54	61	68	75	82	-
6		26	33	40	47	54	61	68	75	82	-	-
7		33	40	47	54	61	68	75	82	-	-	-
8		40	47	54	61	68	75	82	-	-	-	-

Table 4. Estimated Spring Wheat Yields

Available Soil Water					- Growing Season Precipitation (inches) -							
At Seeding to 4 feet		2	3	4	5	6	7	8	9	10	11	12
Inches					Bushels per Acre							
1	With less than	0	0	9	13	20	22	26	31	35	40	44
2	2"of seasonal	0	8	13	17	22	26	30	35	39	44	48
3	rainfall, spring	8	12	17	21	26	30	34	39	43	48	52
4	wheat will	12	16	21	25	30	34	38	43	47	52	56
5	fail in most	16	20	25	29	34	38	42	47	51	56	60
6	years.	20	24	29	33	38	42	46	51	55	60	64
7		24	28	33	37	42	46	50	55	59	64	-
8		28	32	37	41	46	50	54	59	63	-	-

Table 4. Estimated Winter Wheat Yields

Available Soil Water at Seeding to 4 feet (or early spring)	- Growing Season Precipitation (inches) -																	
	2		3		4		5		6		7		8		9		10	
	A	F	A	F	A	F	A	F	A	F	A	F	A	F	A	F	A	F
Inches	Bushels per Acre																	
1	0	0	0	0	4	7	8	14	12	21	16	28	20	35	24	42	28	49
2	0	0	4	7	8	14	12	21	16	28	20	35	24	42	28	49	32	56
3	4	7	8	14	12	21	16	28	20	35	24	42	28	49	32	56	36	63
4	8	14	12	21	16	28	20	35	24	42	28	49	32	56	36	63	40	70
5	12	21	16	28	20	35	24	42	28	49	32	56	36	63	40	70	44	77
6	16	28	20	35	24	42	28	49	32	56	36	63	40	70	44	77	48	84
7	20	35	24	42	28	49	32	56	36	63	40	70	44	77	48	84	52	91
8	24	42	28	49	32	56	36	63	40	70	44	77	48	84	52	91	56	99
9	28	49	32	56	36	63	40	70	44	77	48	84	52	91	56	98	60	105
10	32	56	36	63	40	70	44	77	48	84	52	91	56	98	60	105	64	112

A - Average condition with some problems such as weeds, disease, fertility, high temperatures and wind.
F - Favorable growing conditions: few weeds, no disease or insect problems, good fertility and climate.

United States Department of Agriculture

NRCS Natural Resources Conservation Service

IRRIGATION CLIMATIC AREAS MONTANA

CONSUMPTIVE USE

- High
- Moderately High
- Moderate
- Moderately Low
- Low
- Mountain Areas

- Field Offices
- County Boundaries

Note: Climatic area boundaries are approximate and are based on interpolation between 85 data points where adequate climatic data were available. Data was compiled using the NRCS Blaney Criddle Procedure.

September 2004

Attachment 5: NRCS Code 633 Waste Utilization

Natural Resources Conservation Service
February 2003

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

WASTE UTILIZATION (ACRE)

CODE 633

MONTANA TECHNICAL GUIDE SECTION IV

DEFINITION

Using agricultural wastes such as manure and wastewater or other organic residues.

PURPOSE

This practice is applied as part of a total resource management system to:

- Protect water quality.
- Provide fertility for crop, forage, fiber production and forest products.
- Provide feedstock for livestock.
- Utilize manure and other organic nutrient sources as a plant amendment or soil conditioner.
- Provide a source of energy.
- Improve or maintain soil structure.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all land where agricultural wastes including animal manure and contaminated water from livestock and poultry operations; solids and wastewater from municipal treatment plants; and agricultural processing residues are generated, and/or utilized including cropland, pastureland, hayland, and rangeland.

CRITERIA

General Criteria Applicable to All Purposes.

Regulations

All federal, state and local laws, rules and regulations governing waste management, pollution abatement, health and safety shall be strictly adhered to. The owner or operator shall be responsible for securing any and all required permits or approvals related to waste utilization. and for operating and maintaining any components in accordance with applicable laws and regulations.

Organic nutrient application to land must comply with the most restrictive of federal, state, or county laws, ordinances and permit conditions. Montana Water Quality Act, Section 75-5-605 (revised 1991) states that "It is unlawful to...cause pollution...of any state waters or to place or cause to be placed any wastes in a location where they are likely to cause pollution of any state waters." Refer to the Montana Supplement of the Agricultural Waste Management Field Handbook, Part 651, Chapter 1, for a listing of pertinent state laws and regulations regarding agricultural wastes.

Rates

A number of factors can affect the annual amount or rate of organic nutrient sources to be applied. Those factors include: nutrients and other elements contained in the source; soil conditions; vegetation; water quality, and limitations of application equipment.

NOTE: This type of font (AaBbCcDdEe 123...)indicates NRCS National Standards.
This type of font (AaBbCcDdEe 123...) indicates Montana Suplement

Organic Nutrient Characteristics

Non-agricultural organic nutrients shall be analyzed for macro and micro nutrient contents. The generator or applier of the sludge is generally responsible for obtaining the analysis.

Use of agricultural wastes shall be based on at least one analysis of the material during the time it is to be used. In the case of daily spreading, the waste shall be sampled and analyzed at least once each year. As a minimum the waste analysis should identify nutrient and specific ion concentrations. Samples should be analyzed for pounds per ton or pounds per 1000 gallons of Tota. Nitrogen (N), Phosphorus (P_2O_5), and Potassium (K_2O). Where the metal content of municipal wastewater, sludge, septage, and other agricultural waste is of a concern, the analysis shall also include determining the concentration of metals in the materials. Sampling techniques must be consistent with Agricultural Waste Management Field Manual, Chapter 16. Contact the Montana Cooperative Extension Service for labs that are certified to test agricultural wastes for nutrients. Uses of on-site analytical kits are permitted if and when endorsed by the Montana Department of Agriculture or Montana State University Extension Service. Waste samples will be gathered and analyzed annually until test results indicate consistent nutrient content over a three year period (results over three years do not deviate from each other by more than 15 percent.) Testing frequency can be reduced to once every three years if consistent nutrient content results are documented.

Organic nutrients tested at different times of the year may vary in nutrient content due to changes in bedding, feed, amounts of water entering a storage facility, or degradation. Initially, conduct multiple within-year analyses if season of application changes or if more than one application will occur within a year.

Use published average nutrient content values only for planning and informational purposes to initially establish total quantity of manure, or to estimate total nutrients in manure for certain time periods. Refer to TABLE 2. Daily Manure Production (as excreted.)

Soil Conditions

Soil salts (specifically salinity) may rise in areas receiving long-term applications of manure due to the inherent salt content naturally present in agricultural wastes. Reduce application rates or rotate field applications prior to soil salinity levels reaching 4 mmhos/cm. Consult the Agricultural Waste Management Field Handbook (AWMFH), Chapters 5, 6, and 11 for additional details concerning salinity hazards.

For additional soil characteristics and limitations for land application of agricultural wastes, refer to AWMFH. TABLE 5-3.

Plant Nutrient Needs

The determination of application rates based on plant nutrient needs is the primary consideration when planning organic nutrient utilization. Criteria found in the Field Office Technical Guide (FOTG), Section IV, Practice Standards and Specificiations, 590–Nutrient Management, will be used to determine plant nutrient needs. Those criteria include soil testing, manure analysis, realistic yield goals, and calculating need for applied nutrients sources by accounting for nutrients already supplied by soil, previous crops, and previous manure applications. Base organic nutrient application rates on nitrogen, phosphorus, or potassium (excessive or deficient) for non-legume crops, grass hayland and grass pasture. Base organic nutrient rates on phosphorus or potassium for planned legumes. In nutrient sensitive areas, base nutrient rates on sensitive N, P, or K.

Vegetation

Insure that timing, quantity and distribution of waste applications do not cause ammonia burn, salt damage, crown damage, or stand suffocation to established crops and forages. Refer to AWMFH, Chapter 6 for additional details concerning vegetation.

Water Quality

The Montana Water Quality Act, Section 75-5-605 of the Act (revised 1991) states that "It is unlawful to cause pollution of any state waters or to place or cause to be placed any wastes in a location where they are likely to cause pollution of any state waters..." See AWMFH, Montana Supplement, Chapter 1. Where wastes are applied within 100 feet of surface waters, subsequent applications of manure shall not occur until the P_2O_5 supplied by the application has been removed by crop(s) when a) the field is not separated from the receiving water by a filter strip (FOTG, Section IV, Practice Standards and Specifications, 393–Filter Strip); and, b) soil P levels are at or over 50ppm. See Crop P removal in definition section for details.

Liquid wastes should be spread in a manner that prevents runoff of the wastes during application. Base the application rate of liquid wastes on soil infiltration rates so as not to exceed the amount of water needed to bring soil moisture content to field capacity within the rooting zone at the time of application. The actual rate shall be adjusted during application to avoid ponding or runoff. Stop applications if runoff or ponding is observed. Procedures for determining inches per hour rates for irrigated liquid manure is found in Chapter 11 of AWMFH.

Application Equipment

Evaluate equipment to determine the capacity to regulate varying application rates. For example, utilizing an applicator that can only be adjusted in units of 1,000 is not appropriate for a design that calls for 3,400 gallons/acre. Do not design a system calling for numerous rates unless and until variable rate manure application equipment is available to producer. Do not design a system for a low application rate that the applicator is not capable of delivering. For example, designing a system calling for a different rate on each of 15 fields would require numerous calibrations, calculations, and documentation.

Records of the use of wastes shall be kept a minimum of three years as discussed in the OPERATION AND MAINTENANCE below.

Location, Incorporation, and Timing

Location

Do not apply organic nutrients:

1. within 25 feet of any state waters.
2. within 50 feet of residences, active or inactive water supply wells, mines, quarries, sinkholes receiving surface runoff, or other direct conduits to ground water.
3. to established grassed waterways, ditches, or other water conveyance system.
4. on fields with predicted water erosion rates greater than 5 T/A/Y (RUSLE).
5. where a minimum separation distance of 15 inches cannot be maintained between injected, incorporated, or unincorporated manure and fractured bedrock.
6. Where agricultural wastes are to be spread on land not owned by the producer, the waste management plan, as a minimum, shall document the amount and concentration of waste to be transferred and who will be responsible for the environmentally acceptable use of the waste.

Incorporation

Incorporation of wastes is encouraged to minimize odor and nutrient and pathogenic organism loss to the environment. The following criteria establish maximum times to incorporation:

1. Inject or incorporate within 24 hours if applied on:
   a) sites within 1000 feet of residential areas;
   b) sites within 300 feet of active or inactive water supply wells, mines, quarries, and sinkholes receiving surface runoff or other direct conduits to groundwater;
   c) soils classified by NRCS as frequently flooded (≥ 50 times in 100 years). Incorporation on frequently or occasionally flooded soils can be delayed for up to 4 days when flooding probability is low.

2. Inject or incorporate within 48 hours if applied on land within:
   a) sites within 1000 feet of residential areas;
   b) 300 feet of surface waters if a filter strip does not separate the field from the receiving water.
3. Inject or incorporate manure within 72 hours on soils classified by NRCS as occasionally flooded (5-50 times in 100 years).

Timing

Fall applications on coarse textured soils (see definition section) are not allowed. Delay fall applications on course textured soils until daily average soil temperatures at a six inch depth are below 50 degrees F.

Inject or incorporate during periods of the year when the water table is greater than 20 inches from the soil surface.

Apply in the morning to minimize odor if applications on warm days are necessary.

Avoid compaction on medium and fine textured soils by applying when soil moisture content is significantly less than field capacity (field is in a good tillable condition).

Additional Criteria For Providing Fertility For Crop, Forage, Fiber Production and Forest Products

Where agricultural wastes are utilized to provide fertility for crop, forage, fiber production, and forest products, the Montana FOTG, Section IV, Practice Standard 590–Nutrient Management shall be followed.

Application of organic waste containing high amounts of heavy metals can exceed the adsorptive capacity of the soil and increase the potential for ground water or aquifer contamination. Where municipal wastewater and solids are applied to agricultural lands as a nutrient source, the single application or lifetime limits of heavy metals shall not be exceeded. Sandy soils with low organic matter and low pH have a low potential for retention of heavy metals. These soils have the highest potential for heavy metal and trace element contamination of ground water. TABLE 1–Recommended Soil Test Limits of Metals, identifies the recommended cumulative limits for metals of major concern by EPA when wastes are applied to agricultural land. The concentration of salts shall not exceed the level that will impair seed germination or plant growth (4 mmhos).

TABLE 1. Recommended Soil Test Limits of Metals*

	--SOIL CATION EXCHANGE CAPACITY, MEQ/100G --		
	<5	5 to 15	>15
METAL	LB./AC		
Pb	500	1,000	2,000
Zn	250	500	1,000
Ni	125	250	500
Cd	4.4	8.9	17.8

* USEPA 1983, taken from AWMFH, 04/92.

Additional Criteria For Improving or Maintaining Soil Structure

Wastes shall be applied at rates not to exceed the crop nutrient requirements or salt concentrations as stated above, and shall be applied at times the waste material can be incorporated by appropriate means into the soil within 72 hours of application. Manure with high C:N ratio (>30:1) will improve soil structure rapidly.

Additional Criteria For Providing Feedstock For Livestock

Agricultural wastes to be used for feedstock shall be handled in a manner to minimize contamination and preserve its feed value. Chicken litter stored for this purpose shall be covered. A qualified animal nutritionist shall develop rations, which utilize wastes.

Additional Criteria For Providing A Source of Energy

Use of agricultural waste for energy production shall be an integral part of the overall waste management system.

All energy producing components (i.e. digester, generator, power lines) of the system shall be included in the waste management plan and provisions for utilization of residues of energy production identified.

Where the residues of energy production are to be land-applied for crop nutrient use or soil conditioning, the criteria listed above shall apply.

Additional Criteria For Organic Nutrients On Agricultural Land When Vegetation Is Not Harvested

Apply organic nutrients to CRP, USDI–Bureau of Land Management (BLM) or similar land only after obtaining approval from the appropriate agency. Contact USDA–Farm Service Agency for application on CRP land, USDA–Forest Service for application on national forest lands, and USDA–BLM for application on BLM lands.

Apply organic nutrients only in emergency type situations on:

- frozen soils;
- saturated soils;
- snow-covered land.

Plan application rates on the amount needed to supply up to 30-lbs./ac. nitrogen (N) on coarse textured soils and up to 60 lbs./ac. N on other soil types (allow up to 80 lbs./ac. N on other than coarse textured soils for drag hose type applications). For nutrient application rates on Critical Area Treatment land, see FOTG, Section IV, Practice Standard 342–Critical Area Treatment.

Only apply on areas that do not contribute to runoff to receiving waters. Avoid manure applications in a buffer or filter area.

Time application to periods of greatest plant nutrient uptake. Do not apply when the ground is frozen, snow covered, or actively thawing (i.e. during periods of freeze/thaw).

Do not apply organic nutrients on soils defined as frequently flooded, by the National Cooperative Soil Survey (≥ 50 times in 100 years).

Test for soil P and K content once every three years and cease applications when test results indicate P≥ 50 Olsen phosphorus or K≥ 200.

Leave a portion of the total area undisturbed (do not apply wastes) during each application to minimize disruption of nesting activities and temporary destruction of wildlife habitat.

Additional Criteria For Irrigated Lands

Time applications of wastes and water so that runoff to a "state water" does not occur. Considerations should include expected rainfall periods, precipitation, frozen soil, and snow melt periods.

Water application must maximize irrigation water efficiency to negate potential percolation of nutrients and ground water contamination, See FOTG, Section IV, Practice Standards and Specifications, 449–Irrigation Water Management.

Additional Criteria To Protect Water Quality

All agricultural waste shall be utilized in a manner that minimizes the opportunity for contamination of surface and ground water supplies.

Agricultural waste shall not be land-applied on soils that are frequently flooded, as defined by the National Cooperative Soil Survey, during the period when flooding is expected.

When liquid wastes are applied, the application rate shall not exceed the infiltration rate of the soil, and the amount of waste applied shall not exceed the moisture holding capacity of the soil profile at the time of application. Wastes shall not be applied to frozen or snow-covered ground.

CONSIDERATIONS

Waste utilization is an integral part of a waste management system that recycles livestock and other agricultural wastes. The objective is to manage wastes in quantities that benefit plants, limits nutrient or harmful contaminant movement into surface or ground water, does not contaminate crops that are food supply with pathogens or toxic concentrations of metals or other organics, and provides a medium to fix and/or transform nonessential elements and compounds into harmless forms.

Waste utilization must balance the capacity of the soil and plant growth to transform nutrient elements applied in manures with the amount residual in the system. A lack of plant nutrients can create deficiencies and an excess can cause toxicity. Both adversely impact plant growth. Elements that are not retained, transformed, or

utilized by the plants have the potential of leaving the system and becoming a contaminant to surface and/or groundwater.

Nitrogen and phosphorus are the two critical nutrients in addressing water quality issues. Consider nutrient form, methods of application, rates, and timing, to conform to seasonal variation in plant needs.

Plan erosion control measures to minimize soil erosion and runoff that may carry attached and dissolved livestock and other agricultural waste nutrients to surface waters.

Where possible, establish and maintain vegetated buffer areas around sinkholes, surface waters and surface tile inlets.

The effect of Waste Utilization on the water budget should be considered, particularly where a shallow groundwater table is present or in areas prone to runoff. Limit waste application to the volume of liquid that can be stored in the root zone.

Minimize the impact of odors of land-applied wastes by making application at times when temperatures are cool and when wind direction is away from neighbors.

Agricultural wastes may contain pathogens and other disease-causing organisms. Wastes should be utilized in a manner that minimizes their disease potential.

Priority areas for land application of wastes should be on gentle slopes located as far as possible from waterways. When wastes are applied on more sloping land or land adjacent to waterways, other conservation practices should be installed to reduce the potential for offsite transport of waste.

It is preferable to apply wastes on pastures and hayland soon after cutting or grazing before growth has occurred.

Reduce nitrogen volatilization losses associated with the land application of some waste by incorporation within 24 hours.

Minimize environmental impact of land-applied waste by limiting the quantity of waste applied to land using the rates determined using the Montana practice standard 590–Nutrient Management for all waste utilization.

Consider the use of enzyme additives such as phytase to improve animal ability to utilize P in their rations reducing P excreted in feces (applies mostly to swine and poultry).

Consider various uses of organic nutrients when developing a utilization plan (i.e. composted potting medium and feed).

Consider composting to reduce volume of wastes generated or to dispose of deceased animals (poultry, hogs).

PLANS AND SPECIFICATIONS

Plans and specifications for Waste Utilization shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose. The waste management plan is to account for the utilization or other disposal of all animal wastes produced, and all waste application areas shall be clearly indicated on a plan map.

Data shall be recorded on specification sheets and job sheets for nutrient management and Ag waste utilization, including narrative statements in the conservation plan.

An agricultural waste utilization plan shall include the following:

1. Location map - field numbers and a map or sketch of the area to be used.
2. Measured acres.
3. Date practice scheduled and applied.
4. A description of the size and kind of livestock present including quantity or organic materials produced during the planning period.
5. A brief description of the manure storage and handling system including application equipment and labor needed to apply the organic nutrient source.
6. Identification of critical areas where special attention is required when applying organic wastes including areas where nutrients will not be applied (e.g. waterways); areas where immediate incorporation or incorporation within 24-72 hours will be necessary; and areas where wintertime applications should be minimized or eliminated; where soil test P and

K levels are high. Identify sinkholes, wells, high water table soils, frequently flooded soils, and other critical areas.

7. A schedule of application (MT-CPA-225, MT-CPA-226) to include per acre annual rates, frequency of application (if applied more than once in the cropping year to the same field), anticipated month of application(s), time to incorporation after application, and amounts of N, P_2O_5 and K_2O available to plants at the prescribed rate.

8. Calculations and data used to develop the application schedule. This information includes calculations of the operation's organic nutrients available to the crop after application (MT-CPA-223, MT-CPA-224).

9. Montana FOTG Form 590–Nutrient Management, MT-ECS-112, must be used when developing nutrient management plans.

10. Waste disposal including mass and concentration transported from farm.

11. All operation & maintenance activities.

OPERATION AND MAINTENANCE

1. Records shall be kept for a period of five years or longer, and include when appropriate:

- Quantity of manure and other agricultural waste produced and their nutrient content.
- Soil test results, waste nutrient levels.
- Dates and amounts of waste application where land applied, and the dates and amounts of waste removed from the system due to feeding, energy production, or export from the operation.
- Waste application methods.
- Crops grown and yields (both yield goals and measured yields).
- Calibration and inspection of application equipment.
- The operation and maintenance plan shall include the dates of periodic inspections and maintenance of equipment and facilities used in waste utilization. The plan should include what is to be inspected or maintained, and a general time frame for making necessary repairs.

2. Assure that application or spreading pattern is uniform so that the amount specified for a particular area is applied across the entirety of the area.

DEFINITIONS

Coarse Textured Soils—Coarse textured soils apply to the surface soil texture and/or the subsoil texture within three feet of the surface. These textures include sand, loamy sand, loamy coarse sand, fine sand, loamy fine sand, loamy very fine sand, coarse sand, very fine sand, sandy loam, coarse sandy loam, fine sandy loam, and any of the above listed textures with gravely or very gravely modifiers.

Crop Phosphorus Removal Rate—Crop P removal rates for the purposes of this standard is the quantity of P taken up by a specific crop for a specific yield and removed in the harvested portion of that crop. The quantity is independent of the source of the P and can be based on the P need of the current planned crop and following crop(s) provided that no additional applications occur until the planned time period has elapsed. (i.e. do not re-apply until the third crop year after the current year if the planned rate will supply enough phosphorus for the current and following two years' crops). Crop P removal rates will be consistent with Montana State University recommendations. A procedure to calculate removal rates is found in Chapter 6 of the AWMFH.

Filter Strips—Filter strips for purposes of this standard are strips of ungrazed permanent perennial plant species with growth patterns conducive to retarding runoff flow velocities. Tall, upright, sod-forming grasses are recognized as the ideal filter strip vegetation. Strips of permanent vegetation which have much of a field's runoff conveyed through them as concentrated flow, will not filter effectively and should not be considered as filter strips. Strip widths for purposes of this standard shall be consistent with the most current Montana FOTG, Section IV, Practice Standard 393–Filter Strip.

Intermittent Streams—Intermittent streams include off-field drainage channels with definable banks that provide for seasonal water flow to a perennial stream, lake, wetland or water flow during snowmelt or rainfall events.

Surface Waters—Surface waters for purposes of this standard include lakes, perennial streams, Montana regulated wetlands, off-field intermittent streams, off-field drainage ditches, and other water bodies considered locally important.

State Waters—State Waters means "any body of water, irrigation system, or drainage system, either surface or underground" except "irrigation waters where the waters are used up within the irrigation system and the waters are not returned to any other state waters."

Wastes—Wastes include: manure, composted manure or carcasses, bedding, municipal or industrial treatment plant sewage sludge or sewage sludge compost septic tank septage, and materials from agricultural processing plants (i.e. whey).

REFERENCES

USDA–Natural Resources Conservation Service, Field Office Technical Guide, Section IV, Practice Standard 590–Nutrient Management, March 2000.

USDA–Natural Resources Conservation Service, Field Office Technical Guide, Section IV, Practice Standard 393–Filter Strip, April 1999.

Using Whey on Agricultural Land—A disposal Alternative. 1981. University of Wisconsin Extension Publication A3098.

USDA–Natural Resources Conservation Service, Agricultural Waste Management Field Handbook, Part 651. 1992.

Montana's Nondegradation Policy, Montana Department of Agriculture, Water Quality Division, Ground Water Section. 1991.

USDA–Natural Resources Conservation Service, Field Office Technical Guide; Section IV, Practice Standard 449–Irrigation Water management, March 1999.

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Specification MT633-1

NATURAL RESOURCES CONSERVATION SERVICE

WASTE UTILIZATION (ACRE)

CODE 633

MONTANA CONSERVATION PRACTICE SPECIFICATION / JOB SHEET

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

MT-CPA-223
Rev 08/01

MANURE NITROGEN CREDITING

_____ _____
PRODUCER PLANNING DATE

ANIMAL (SPECIES)	_____	_____	_____
FORM (LIQUID OR SOLID)	_____	_____	_____

NITROGEN

TOTAL AVAILABLE NITROGEN IN MANURE
(lbs. N/1,000 gal or lbs. N/ton)
ANALYSIS SOURCE: MT-CPA-227 ___ MT-CPA-228 ___

1ST YEAR AFTER APPLICATION [1]	_____	_____	_____	(a)
2ND YEAR AFTER APPLICATION	_____	_____	_____	(a)
3RD YEAR AFTER APPLICATION	_____	_____	_____	(a)

APPLICATION RATE (1,000 gal/ac. or tons/ac.) [2]

1ST YEAR	_____	_____	_____	(b)
2ND YEAR	_____	_____	_____	(b)
3RD YEAR	_____	_____	_____	(b)

NITROGEN APPLIED (lbs./ac) = (a) x (b)

_____	CROP YEAR (1ST YEAR) [3]	_____	_____	_____
_____	CROP YEAR (2ND YEAR)	_____	_____	_____
_____	CROP YEAR (3RD YEAR)	_____	_____	_____

[1] From Estimating Manure Nitrogen, Form MT-CPA-227, line 8, or Manure Test Nitrogen, Form MT-CPA-227, line 7.

[2] Manure application should be scheduled to meet plant needs using Nutrient Management Specification, Nutrient Checklist, Form MT-ECS-112.

[3] Indicate crop year when nutrients will be available. lbs./ac transfers to Nutrient Checklist, Form MT-ECS-112. (Nutrient Management Design and Specification.)

NRCS, MT
August 2001

Specification MT633-2

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

MT-CPA-223
Rev 08/01

MANURE NITROGEN CREDITING continued

TABLE 1. Nitrogen Availability and Loss as Affected by Method of Application

BROADCAST – INCORPORATE[1]			INJECTION		SPRINKLE
<12 hrs.	<4 days	>4 days	Sweep	Knife	
% Total N					
70	60	50	90	95	75

Categories refer to the length of time between manure application and incorporation

PHOSPHORUS and POTASSIUM

Pounds per acre P_2O_5 and K_2O available to crops in the 1st year are found by multiplying P_2O_5 or K_2O in manure (from analysis or TABLE 2) times the selected application rate times 80% and 90%, respectively. No 2nd or 3rd year credits are given.

If a manure analysis was obtained, list total phosphorus and total potassium, as received. (pounds/ton or pounds/1,000 gal.) Attach manure analysis.
Be sure to enter elemental values only from manure analysis, i.e., P and K—not K_2O or P_2O_5.

TOTAL P = [ ] lbs. TOTAL K = [ ] lbs.

FORM: Liquid _____ Solid _____

From manure analysis, calculate lbs./ac. of P_2O_5 and K_2O applied:

[ ] X 2.3 X [ ] X 0.8 = [ ]
P-P_2O_5 Conv. APPLICATION RATE (1,000 GAL./AC. OR TONS/AC.) P_2O_5 (LBS./AC.)

[ ] X 1.2 X [ ] X 0.9 = [ ]
K-K_2O Conv. APPLICATION RATE (1,000 GAL./AC. OR TONS/AC.) K_2O (LBS./AC.)

If manure analysis is not available, determine of P_2O_5 and K_2O produced from TABLE 2 or from:

Has manure been separated? q YES q NO Applied Form? q LIQUID q SOLID

[ ] / [ ] X _____ X 2.3 = [ ] [ ]
P lbs./day Cu. Ft./Day. Cu. Ft./Ton* P-P_2O_5 Conv. P_2O_5 lbs./ton or 1,000 Gallons ADJUSTMENT FOR SEPARATION

[ ] / [ ] X _____ X 1.2 = [ ] [ ]
K lbs./day Cu. Ft./Day. Cu. Ft./Ton* K-K_2O Conv. K_2O lbs./ton or 1,000 Gallons ADJUSTMENT FOR SEPARATION

* Average volumetric weight for all animals.

Calculate lbs./ac. of P_2O_5 and K_2O applied:

[ ] X Application Rate [ ] X 0.8 = [ ]
P_2O_5 Manure (LBS./1,000 GAL. OR LBS./TON) (1,000 GAL./AC. OR TONS/AC.) P_2O_5 (LBS./AC.)

[ ] X Application Rate [ ] X 0.9 = [ ]
K_2O Manure (LBS./1,000 GAL. OR LBS./TON) (1,000 GAL./AC. OR TONS/AC.) K_2O (LBS./AC.)

NRCS, MT
August 2001

Specification MT633-3

NATURAL RESOURCES CONSERVATION SERVICE

WASTE UTILIZATION (ACRE)

CODE 633

MONTANA CONSERVATION PRACTICE SPECIFICATION / JOB SHEET

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

MT-CPA-227
REV 02/2004

ESTIMATING MANURE NITROGEN

1. Is this a beef open feedlot management system? q YES q NO

	N_{excr} =		X		X		=		TOTAL LBS. N
	N_{excr} =		X		X		=		
	N_{excr} =		X		X		=		
ANIMAL TYPE		NO. OF ANIMALS		DAYS		LBS. N/DAY		LBS. N	

Are liquids and solids separated? q YES q NO Manure Form q SOLID q LIQUID

Pounds N based on Separated Manure Forms SOLIDS LIQUIDS

N_{excr} = [ ] X [ ] [ ] LBS. N [ ] LBS. N

2. Estimate portion of nitrogen retained after storage and treatment using TABLE 3. N_{retain} [ ]
Manure Management System: _____

3. Estimate inorganic nitrogen converted from manure nitrogen (mineralization) and becoming available after application using TABLE 4.
N_{conv} 1st year = [ ] N_{conv} 2nd year = [ ] N_{conv} 3rd year = [ ]

4. Estimate portion of nitrogen remaining after denitrification using TABLE 5.
N_{deni} 1st year = [ ] N_{deni} 2nd year = [ ] N_{deni} 3rd year = [ ]

5. Estimate portion of nitrogen remaining due to application of manure using TABLE 1 N_{appl} 1st year = [ ]
(No application reduction is taken second or third years when manure is applied first year only).
Application Method: _____ Time (IF APPLICABLE): _____ HOURS / DAYS

6. Calculate nitrogen (NO_3) available for plant uptake for each year.

N_{excr}	X	N_{retain}	X	N_{conv} 1st yr.	X	N_{deni} 1st yr.	X	N_{appl} 1st yr.	=	N_{avail}	
	X		X		X		X		=		LBS. N 1ST YEAR
	X		X		X		X		=		LBS. N 2ND YEAR
	X		X		X		X		=		LBS. N 3RD YEAR

7. Compute total pounds of manure produced, as excreted. (Use TABLE 2)

Solid Form (USE FOR COMBINED SLURRY/SEMI-SOLID FORMS AND SEPARATED SOLID FORM)

	X		X		/ 32	=		Tons of Manure
	X		X		/ 32	=		Tons of Manure
	X		X		/ 32	=		Tons of Manure
NO. OF ANIMALS		DAYS		CU. FT./DAY	CU. FT./TON*			

Liquid Form (USE FOR SEPARATED LIQUID FORM ONLY)

	X		X		/ 7.48	=		1,000 Gallons of Manure
	X		X		/ 7.48	=		1,000 Gallons of Manure
	X		X		/ 7.48	=		1,000 Gallons of Manure
NO. OF ANIMALS		DAYS		CU. FT./DAY	GAL./CU. FT.*			

* Average volumetric weight for all animals.

8. Calculate total pounds of available nitrogen per ton of manure produced.

[ ]	/	[ ]	=	[ ] Lbs. Available N/ton or N/1,000 Gal.
#AVAIL. N 1ST YR		TONS OR GALS.		
[ ]	/	[ ]	=	[ ] Lbs. Available N/ton or N/1,000 Gal.
#AVAIL. N 2ND YR		TONS OR GALS.		
[ ]	/	[ ]	=	[ ] Lbs. Available N/ton or N/1,000 Gal.
#AVAIL. N 3RD YR		TONS OR GALS		

NRCS, MT
February 2004

Specification MT633-4

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

MT-CPA-227
REV 02/2004

ESTIMATING BEEF FEEDLOT MANURE PRODUCTION

ANIMAL TYPE COW, FEEDER, BULL, CALF, HEIFER	NUMBER OF ANIMALS	AVERAGE WEIGHT	NUMBER OF DAYS IN LOT/YEAR	N LBS/DAY/1,000#	P LBS/DAY/1,000#	K LBS/DAY/1,000#

ANIMAL TYPE COW, FEEDER, BULL, CALF, HEIFER	% MOISTURE OF MANURE	TOTAL N (LBS./YR)	TOTAL P (LBS./YR)	TOTAL K (LBS./YR)	TOTAL SOLIDS (CU. FT./YR.)	TOTAL SOLIDS (TONS/YR.)
TOTAL						

			TONS/AC.				(LBS./AC.)	
[ ]	X	2.3	[ ]	X	0.8	=	[ ]	
LBS P/TON		P–P_2O_5 Conv.	Application Rate				P_2O_5	
			TONS/AC.				(LBS./AC.)	
[ ]	X	1.2	[ ]	X	0.9	=	[ ]	
LBS K/TON		K–K_2O Conv.	Application Rate				K_2O	

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NATURAL RESOURCES CONSERVATION SERVICE

WASTE UTILIZATION (ACRE)

CODE 633

MONTANA CONSERVATION PRACTICE SPECIFICATION / JOB SHEET

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

MT-CPA-228
Rev 01/02

MANURE TEST NITROGEN

DATE: _____

1. From manure analysis, list total nitrogen, as received, (pounds/ton or pounds/1,000 gal.). *Attach manure analysis.*

   q LIQUID q SOLID TOTAL N = [ ] LBS.

2. Estimate inorganic nitrogen converted from manure nitrogen (mineralization) and becoming available after application using TABLE 4.

   N_{conv} 1st year = [ ] N_{conv} 2nd year = [ ] N_{conv} 3rd year = [ ]

3. Estimate portion of nitrogen remaining after denitrification using TABLE 5.

   N_{deni} 1st year = [ ] N_{deni} 2nd year = [ ] N_{deni} 3rd year = [ ]

4. Estimate portion of nitrogen remaining due to application of manure using TABLE 1. N_{appl} 1st year = [ ]
   (No application reduction is taken second or third years when manure is applied first year only).

   Application Method: _____ Time (IF APPLICABLE): _____ HOURS OR DAYS

5. Calculate nitrogen (NO_3) available for plant uptake for each year.

N_{test}	X	N_{conv} 1st yr.	X	N_{deni} 1st yr.	X	N_{appl} 1st yr.	=	N_{avail}	
	X		X		X		=		LBS. N 1ST YEAR
	X		X		X		=		LBS. N 1ST YEAR
	X		X		X		=		LBS. N 1ST YEAR

6. Compute total pounds of manure produced, as excreted. (Use TABLE 2) *Multiple animal types can be entered.*

   Is this a beef open feedlot management system? q YES q NO

   Complete for Solid Form Analysis:

NO. OF ANIMALS		DAYS		CU. FT./DAY		CU. FT./TON*			
	X		X		/	32	=		TONS OF MANURE
	X		X		/	32	=		TONS OF MANURE
	X		X		/	32	=		TONS OF MANURE

   Complete for Liquid Form Analysis:

NO. OF ANIMALS		DAYS		CU. FT./DAY		GAL./CU. FT.*			
	X		X		/	7.48	=		1,000 GALLONS OF MANURE
	X		X		/	7.48	=		1,000 GALLONS OF MANURE
	X		X		/	7.48	=		1,000 GALLONS OF MANURE

7. Calculate total pounds of available nitrogen per ton of manure produced.

#AVAIL. N 1ST YR.	/	TONS OR GALS.	=		LBS. AVAILABLE N/TON OR N/1,000 GALLONS
#AVAIL. N 2ND YR.	/	TONS OR GALS.	=		LBS. AVAILABLE N/TON OR N/1,000 GALLONS
#AVAIL. N 3RD YR.	/	TONS OR GALS.	=		LBS. AVAILABLE N/TON OR N/1,000 GALLONS

* Average volumetric weight for all animals.

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TABLE 2. Daily Manure Production (AS EXCRETED)

ANIMAL	SIZE LBS.	PRODUCTION CU. FT./DAY	PERCENT WATER	NUTRIENT CONTENT N LBS. / DAY	P LBS. / DAY	K LBS. / DAY
Dairy Cow	150	0.190	87	0.060	0.01000	0.04000
	250	0.320	87	0.100	0.02000	0.07000
	500	0.660	87	0.200	0.03600	0.14000
	1000	1.300	87	0.410	0.07300	0.27000
	1400	1.850	87	0.570	0.10200	0.38000
Beef	<750	0.930	88	0.300	0.10000	0.20000
	1000	0.950	88	0.310	0.11000	0.24000
	1250	1.000	88	0.330	0.12000	0.26000
Swine						
Nursey	35	0.038	90	0.016	0.00520	0.01000
Growing	65	0.070	90	0.029	0.00980	0.02000
Finish	150	0.160	90	0.068	0.02200	0.04500
	200	0.220	90	0.090	0.03000	0.05900
Gestate	275	0.150	90	0.062	0.02100	0.04000
Sow & litter	375	0.540	90	0.230	0.07600	0.15000
Boar	350	0.190	90	0.078	0.02600	0.05100
Poultry						
Layers	4	0.0035	75	0.0029	0.00110	0.00120
Broilers	2	00.024	75	0.0024	0.00054	0.00075
Turkey	10	0.0069	75	0.0074	0.00280	0.00280

TABLE 3. Nitrogen Remaining After Storage, Treatment, and Application

MANURE MANAGEMENT SYSTEM	PORTION REMAINING (%)
Oxidation ditch, effluent storage	20 to 30
Anaerobic lagoon or storage pond after 50% dilution	10 to 30
Open lot surface storage	40 to 60
Aerobic lagoon	45 to 55
Roofed storage or manure pack	60 to 75
Shallow, open, manure storage pond	70 to 80
Stacking facility	65 to 75
Deep, open, manure storage pond	70 to 80
Liquid manure tank, covered	80 to 90

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TABLE 4. Organic Waste Decay Rate (MINERALIZATION—SOIL-INCORPORATED "N" CONVERTED TO INORGANIC "N") *

TYPE OF WASTE	1ST YEAR AFTER APPLICATION % AVAILABLE	2ND YEAR AFTER APPLICATION % AVAILABLE	3RD YEAR AFTER APPLICATION % AVAILABLE
Fresh poultry manure	90	2	1
Fresh swine manure	75	4	2
Fresh cattle manure	70	4	2
Fresh sheep and horse manure	60	6	2
Liquid manure, covered tank	65	5	3
Liquid manure, storage pond	35	5	3
Solid manure, stack	60	6	2
Solid manure, open pit	55	5	2
Manure pack, roofed	50	5	2
Manure pack, open feedlot	45	5	3
Storage pond effluent	40	6	3
Oxidation ditch effluent	40	6	3
Aerobic lagoon effluent	40	6	3
Anaerobic lagoon effluent	30	6	3
Digested sewage sludge	35	5	2

* If irrigated, reduce 1st year mineralization by 5%.

TABLE 5. Nitrogen Remaining After Denitrification

SOIL DRAINAGE CLASS	REMAINING INORGANIC "N" %
Excessively or somewhat excessively drained	97
Well drained	90
Moderately well drained	85
Somewhat poorly drained	80
Poorly drained	70
Very poorly drained	60

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