Michigan Department of AGRICULTURE & Rural Development

Generally Accepted Agricultural and Management Practices for Nutrient Utilization

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Michigan Commission of Agriculture
& Rural Development

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PREFACE

The Michigan legislature passed into law the Michigan Right to Farm Act (Act 93 of 1981), which requires the establishment of Generally Accepted Agricultural and Management Practices (GAAMPs). These practices are written to provide uniform, statewide standards and acceptable management practices based on sound science. These practices can serve producers in the various sectors of the industry to compare or improve their own managerial routines. New scientific discoveries and changing economic conditions may require revision of the GAAMPs during the annual review.

The 2012 GAAMPs that have been developed are the following:

1) 1988-Manure Management and Utilization
2) 1991-Pesticide Utilization and Pest Control
3) 1993-Nutrient Utilization
4) 1995-Care of Farm Animals
5) 1996-Cranberry Production
6) 2000-Site Selection and Odor Control for New and Expanding Livestock Facilities
7) 2003-Irrigation Water Use
8) 2010-Farm Markets

These current GAAMPs were developed with industry, university, and multi-governmental agency input. As agricultural operations continue to change, new practices may be developed to address the concerns of the neighboring community. Agricultural producers who voluntarily follow these practices are provided protection from public or private nuisance litigation under the Right to Farm Act.

This current GAAMP does not apply in municipalities with a population of 100,000 or more in which a zoning ordinance has been enacted to allow for agriculture provided that the ordinance designates existing agricultural operations present prior to the ordinance's adoption as legal non-conforming uses as identified by the Right to Farm Act for purposes of scale and type of agricultural use.

The website for the GAAMPs is http://www.michigan.gov/gaamps.

I. INTRODUCTION

Fertilizer use in Michigan has increased steadily since the 1930's when commercial fertilizers first became available. In 1970 and 1990, nearly 0.9 and 1.3 million tons of commercial fertilizer were used in Michigan to supply 160 and 185 pounds, respectively, of plant nutrients per harvested acre (TVA, 1990). By 2004, total consumption of fertilizers in Michigan had leveled off to slightly more than 1.4 million tons per year (AAPFCO/TFI, 2005). While fertilizer use has been increasing, total farm land has been on the decline. In 1920, Michigan had 19.0 million acres of cropland, but in 1970, 1990, 1999, and 2004 total land in farms had decreased to 12.7, 10.8, 10.4, and 10.1 million acres, respectively (MDARD, 1991, 2005). As a result of modern agricultural practices, Michigan's agricultural system has become one of the most productive in the world.

Many factors are responsible for this increase in productivity. Government policy, farm programs, improved hybrids, new varieties, and many technological advances, including improved and readily-available fertilizer products, at reasonable prices, are some of the major factors responsible for today's modern agricultural practices and increased productivity.

The environmental costs and risks associated with this increased efficiency are not well understood but are rapidly becoming a public concern. The increased fertilizer use on fewer farm acres has caused soil test phosphorus (P) levels to increase dramatically on some soils in recent years. The median soil test level for P in soil samples received by the Michigan State University Soil Testing Laboratory in the 1994-95 season was 106 pounds of Bray P1 per acre (Warncke and Dahl, 1995). More than 50 percent of the corn and soybean fields represented by these samples would not need any more P to be applied, based on current MSU nutrient recommendations (Warncke *et al*., 2004a). Christenson (1989) and Vitosh and Darling (1990) have demonstrated the validity of MSU fertilizer recommendations on corn, soybeans, dry beans, and sugar beets on numerous Michigan farms.

Evidence is increasing that fertilizer nutrients are finding their way into both surface and groundwater. Michigan's 1988 Non-Point Pollution Assessment Report (DNR, 1988) indicates that agricultural fertilizer was <u>perceived</u> as a nonpoint source pollution problem in 71 percent of the 279 watersheds in Michigan. Significant P loading of Michigan's lakes and streams has been documented (DNR, 1985).

Nitrate contamination of groundwater in Michigan has also been well documented (Bartholic, 1985; Ellis, 1988; and Vitosh *et al*., 1989). Cummings *et al*., (1984) reported that nitrates in groundwater in Van Buren County were related to fertilizer use patterns, number of irrigated acres, and the amount of irrigation water applied. Nitrogen (N) fertilizer demonstrations have shown that many corn producers may also be using more N fertilizer than necessary (Vitosh *et al.,* 1991).

Although the use of other fertilizer nutrients has also increased, changes in soil test levels of nutrients such as potassium (K), calcium (Ca), magnesium (Mg), sulfur (S),

and micronutrients have been less dramatic. Currently, these nutrients are not causing any known environmental damage, and there are no concerns for their continued use as long as they benefit the farmer agronomically and economically.

The increasing presence of P in surface water and nitrates in groundwater, and the fact that some farmers are using excess fertilizer, have led to the conclusion that utilization of the Generally Accepted Agricultural and Management Practices (GAAMPs) should be encouraged to prevent degradation of the environment. The purpose of this document is to present acceptable and recommended agricultural practices that will significantly reduce the potential for nitrate movement to groundwater and nonpoint losses of P to surface water.

Adoption of these management practices for nutrient utilization will not totally eliminate nutrient movement into surface water or groundwater, because nutrients are an integral part of the natural hydrologic cycle. However, following these GAAMPs will contribute to environmental protection from nutrient pollution of surface water and groundwater. These GAAMPs are referenced in Michigan's Natural Resources and Environmental Protection Act (NREPA), Public Act 451 of 1994, as amended. NREPA protects the waters of the state from the release of pollutants in quantities and/or concentrations that violate established water quality standards. Discharges are regulated as violations to Part 4 Rules, Water Quality Standards, of Part 31, Water Resources Protection, of the NREPA. Agricultural producers who voluntarily follow these practices are provided protection from public or private nuisance litigation under Public Act 93 of 1981, as amended, the Michigan Right to Farm Act, Michigan Department of Agriculture & Rural Development.

II. ON-FARM FERTILIZER STORAGE AND CONTAINMENT PRACTICES

Fertilizer should be stored in a manner that protects the environment, ensures human and animal safety, and preserves the product and container integrity. Well-water surveys have indicated that improper or defective fertilizer storage and containment facilities can be a source of surface water and groundwater contamination. Before fertilizers are stored on the farm, several concerns should be reviewed and precautions observed.

SECURITY FOR FERTILIZER STORAGE AREAS

1. **Fertilizer storage areas, valves, and containers should be secured when not in use to prevent access by unauthorized personnel, children, or animals.**

Security of the fertilizer storage area should be provided by use of locks, fencing, and/or lighting. Fertilizers should not be stored in the direct presence of fuel products or pesticides due to the increased potential for explosions and significant disposal problems.

FERTILIZER STORAGE FACILITIES

2. Dry fertilizer should be stored inside a structure or device capable of preventing contact with precipitation and/or surface water.

The storage area should be able to handle and contain fertilizer spills properly. The structure or device should consist of a ground cover or base and a cover or roof top. Walls and floors should prevent absorption or loss of fertilizer. Dry fertilizer in an individual quantity of more than 2,000 pounds is considered "bulk fertilizer" and is regulated by Regulation No. 641, "Commercial Fertilizer Bulk Storage." While dry fertilizer is not regulated by Regulation No. 642, "On Farm Fertilizer Bulk Storage," producers are encouraged to follow the guidance provided in Regulation No. 641, when bulk quantities of dry fertilizer are stored on their farm.

Following these regulations is not required for bulk storage of liming materials or for the temporary staging of potash in a field where it is being applied.

3. Liquid fertilizer should be stored in containers approved for and compatible with the fertilizer being stored. Bulk liquid fertilizer should be stored in accordance with Regulation No. 642, "On Farm Fertilizer Bulk Storage," NREPA, Part 85.

All liquid fertilizer storage areas should have secondary containment that will properly handle and contain spills. The floor of the containment area should be constructed to prevent the absorption or loss of fertilizer. Secondary containment areas should not have a working floor drain unless it leads to a collection sump. All liquid fertilizer storage containers should be labeled properly. Containers, valves, gauges, and piping should be made of materials compatible with the products being stored. Backflow protection is recommended when liquid fertilizers are associated with any water supply. The level of the liquid in the containers should be able to be determined readily.

Under Regulation No. 642, "bulk fertilizer" means fluid fertilizer in a single container that has a capacity of more than 2,500 United States gallons, or a combined total capacity for all storage containers or tanks located at a single site or location greater than 7,500 United States gallons. Storage of liquid fertilizers on the farm at these capacities is regulated by Regulation No. 642, so the producer must follow specific requirements in siting and locating new bulk storage facilities. Existing bulk storage facilities will have five years from August 2003 to comply with Regulation No. 642.

4. Fertilizer storage areas should be inspected at least annually by the owner or the person responsible for the fertilizer to ensure safe storage of fertilizers and to minimize mishaps.

Fertilizer storage containers should be inspected prior to use to ensure container integrity. Replace containers as needed to prevent leaks. Regular inspection of bulk fertilizer storage facilities is required by Regulation No. 642.

LOCATION OF BULK FERTILIZER STORAGE AREAS

A site should be selected that minimizes potential for contamination of surface water or groundwater by drainage, runoff, or leaching. Locate the storage site at an adequate distance away from wells, surface water, and other sensitive areas, as herein described. For the purpose of this section, "surface water" means a body of water that has its top surface exposed to the atmosphere and includes lakes, ponds, or water holes that cover an area greater than 0.25 acres, and streams, rivers, or waterways that maintain a flow year-round. "Surface water" does not include waterways with intermittent flow. For bulk liquid fertilizer, reference Regulation No. 642.

5. **Existing bulk fertilizer storage areas shall be located a minimum of 50 feet from any single-family residential water well, a minimum of 200 feet from Type I or Type IIA public water supply wells, and a minimum of 75 feet from Type IIB and Type III public water supply wells.**

Existing bulk fertilizer storage areas are those areas that were used to store or hold bulk liquid fertilizers on a farm before August, 2003. Type III water supplies include farms that hire at least one employee. See MSU Extension Bulletin E-2335 (Wilkinson, 1996) and Regulation No. 642 for information on protection measures for existing storage sites.

6. **New bulk fertilizer storage areas shall be located a minimum of 150 feet from any single-family residential water well, a minimum of 200 feet from surface water, and above a floodplain. The set-back distance from any Type I or Type IIA public water supply well (communities with 25 or more persons and large resorts including municipalities, subdivisions, condominiums, and apartment complexes) is 2,000 feet, if the public water supply does not have a well-head protection program. If there is a well-head protection program, the facility must be located outside the delineated well-head protection area. For Type IIB and Type III public water supply wells, which include noncommunity water supplies such as schools, restaurants, industries, campgrounds, parks, and motels, the set-back is 800 feet.**

To the greatest extent possible, new bulk fertilizer storage areas shall meet these water supply set-back distances. A new bulk fertilizer storage area may be located closer than these distances, upon obtaining a deviation from the well isolation distance through Michigan Department of Environmental Quality (DEQ) or the local health department. Additionally, a new bulk fertilizer storage area that meets the requirements of

Regulation No. 641 or Regulation No. 642 may be located closer than the above water supply set-back distances, but not less than those distances specified in Practice #5.

When planning a new facility, see MSU Extension Bulletin E-2335 (Wilkinson, 1996) and Regulation No. 642 for information on design and construction and for the required set-back distance from drinking water supplies. Additional detailed information on the design or construction of new fertilizer and pesticide containment facilities is available in the MidWest Plan Service Handbook No. 37 (MidWest Plan Service, 1995) or in the United States Department of Agriculture, Natural Resources Conservation Service (NRCS) Agrichemical Containment Facility (702), Michigan Standard (USDA-NRCS). For more information on these set-back distances, reference Public Act 399, the State of Michigan Safe Drinking Water Act of 1976, and Public Act 368, the Michigan Public Health Code of 1978, as amended. These storage set-back distances pertain to bulk fertilizer storage sites and facilities, but do not include staging and application sites. A storage facility is a place for safekeeping of fertilizer. A staging site is an area where fertilizer is temporarily stored, loaded and/or otherwise prepared in a field where it is being applied. An application site is where fertilizers may be appropriately used.

New bulk liquid fertilizer storage areas shall be located above a floodplain, which means any land area that, is subject to a 1 percent or greater chance of flooding, or equivalent to a 100-year flood (as defined in Regulation No. 642). All fertilizer should be stored and handled in a manner which minimizes the potential for drinking water contamination or nutrient losses to surface water.

III. FERTILIZATION PRACTICES FOR LAND APPLICATION

The following management practices are suggested for farmers to help achieve efficient and effective use of fertilizers and to reduce the potential for nutrient contamination of surface water and groundwater.

SOIL FERTILITY TESTING AND TISSUE ANALYSIS

7. All fields used for the production of agricultural crops should have soils sampled and tested on a regular basis before fertilizer nutrients are applied. For small fruit and tree crops, using tissue analysis and/or observing seasonal growth, are better methods to determine their nutrient requirements.

Routine soil testing for pH, P, K, Ca, and Mg is one of the best tools available for determining the availability of nutrients in soil for most crops. One of the keys to a good soil testing program is proper soil sampling. MSU Extension Bulletins E-498 (Warncke, 1998), E-1616 (Meints and Robertson, 1983), and E-498S (Warncke and Gehl, 2006) give instructions on how to obtain a good representative soil sample and how often soils should be re-sampled. Once the capability of the soil to supply nutrients has been assessed, the appropriate amount of supplemental nutrients can be determined. Soil

test results will change with time depending on fertilizer and manure additions, precipitation, runoff, leaching, soil erosion, and nutrient removal by crops. Therefore, soil testing needs to be done on a regular basis within a one to four year time frame, where the appropriate frequency of soil sampling depends on (a) how closely an individual wants to track soil nutrient changes, (b) the crop(s) grown, (c) cropping rotation, (d) soil texture, and (e) the approach used for sampling fields (see Warncke and Gehl, 2006 for more details).

The nutrient requirements of small fruit and tree crops are best monitored by tissue analysis. Tissue samples should be taken every three to five years according to instructions in MSU Extension Bulletin E-2482 (Hanson and Hull, 1994). The nitrogen status of fruit plantings can also be monitored effectively by observing leaf color, shoot growth, and production levels, as described in MSU Extension Bulletin E-852 (Hanson, 1996).

For cranberry production, see the current "Generally Accepted Agricultural and Management Practices for Cranberry Production".

FERTILIZER RECOMMENDATIONS

8. Fertilizer use should follow recommendations consistent with those of Michigan State University and should consider all available sources of nutrients.

Michigan State University fertilizer recommendations for field crops and vegetables are found in Extension Bulletins E-2904 and E-2934 (Warncke *et al*., 2004a, 2004b). Recommendations are based on a soil fertility test, soil texture, crop to be grown, and for most field and vegetable crops, yield goal. Selecting a realistic yield goal for these crops is one of the most important steps in obtaining economic and environmentally-sound recommendations. Excessively high yield goals can lead to loss of income and over-fertilization that may threaten water quality. A yield goal that is both realistic and achievable should be based on the soil potential and the level of crop management utilized. A realistic yield goal is one which is achievable at least 50 percent of the time. If the yield goal is seldom achieved, the entire crop management system should be re-evaluated to identify those factors other than soil fertility that are limiting yields.

Most commercial soil testing laboratories use the same soil test procedures as MSU. These procedures are described in the North Central Regional Research Publication No. 221 (Brown, 1998). Soil tests from these laboratories can be used to determine MSU Extension nutrient recommendations (Warncke *et al*., 2004a, 2004b). Occasionally, fertilizer recommendations vary between MSU and agribusiness. When differences exist, farmers should follow the MSU recommendations because they have been proven to be sound agronomically, economically, and environmentally (Ellis and Olson, 1986).

MSU fertilizer recommendations for fruit crops are found in MSU Extension Bulletins E-852 (Hanson, 1996) and E-2011 (Hanson and Hancock, 1996). Fertilizer recommendations for these crops are often adjusted for each specific planting by tissue testing and observing crop performance (see above bulletins).

Recommended fertilization practices for field-grown perennial woody ornamentals are available from MSU (Fernandez, 2004). Rates of fertilization are based on soil testing, foliar analysis, and growth rates of the crop. Fertilization of annual and perennial field-grown cut flowers is based on similar criteria, but published recommendations are not currently available.

The MSU Soil and Plant Nutrient Laboratory can provide nutrient recommendations for most crops grown in Michigan that include fruit, turfgrass, flowers, shrubbery, and trees. When Michigan State University recommendations are not available for a specific crop or soil type, other land grant university recommendations developed for the region may be used.

Essential plant nutrients from sources other than fertilizer salts may also be used to satisfy the nutrient recommendations for crops. These sources of nutrients can include animal manure and other biological materials, inorganic by-products, irrigation water, and residual nutrients present in the soil from one growing season to the next. Non-fertilizer materials should be tested for their nutrient content, and residual mineralizable N should be estimated (when possible) to determine the appropriate quantities of nutrients that should be credited against the nutrient recommendations.

NUTRIENT CREDITS

9. Take credit for nutrients supplied by organic matter, legumes, and manure or other biological materials.

The contribution of soil organic matter to plant nutrition should be taken into account before determining the final or actual N recommendation. High organic matter soils will need less fertilizer N to obtain the same crop yield because they are capable of mineralizing more N than low organic matter soils. Michigan State University N fertilizer recommendations are based on soils with two to four percent organic matter. See MSU Extension Bulletin WQ-25 (Vitosh and Jacobs, 1996) for suggested N credits for field and vegetable crops grown on soils with higher organic matter levels. Since soil organic matter levels do not change rapidly, routine analysis of organic matter is not necessary. Organic matter content, however, is important in determining proper herbicide rates, so you may want to periodically determine soil organic matter content for this purpose.

Legumes are often grown and plowed under to improve the fertility and tilth of soils in field and vegetable crop rotations. The N supplied by legumes, due to an N fixation process in root nodules, should be credited for subsequent crops in the nutrient management plan. The amount of credit given for legume N fixation depends on the type of legume, how long the legume has been growing, and the density of the legume

stand when it is killed by tillage or applying an herbicide. See MSU Extension Bulletin E-2904 (Warncke *et al.*, 2004a) for suggested legume N credits.

Livestock manure is also a good source of plant nutrients. Manure should be analyzed periodically to determine the appropriate credit for the nutrients supplied. See the current "Generally Accepted Agricultural and Management Practices for Manure Management and Utilization" for recommended management practices when utilizing manure.

Other organic (biological) materials, such as human sewage, food processing by-products, industrial organic by-products, wood, and municipal refuse can potentially be used as a source of plant nutrients. Most of these materials are regulated by DEQ. More information on the use of these organic materials and by-product liming materials can be found in Section VII and Section VIII of these GAAMPs.

NITROGEN MANAGEMENT PRACTICES

10a. To enhance N uptake, match N fertilizer applications to the demand of the crop and the conditions of the soil.

Efficient use of N fertilizer is important economically, agronomically, and environmentally. Greater efficiencies can be achieved by using university recommended rates of N fertilizer, by using sources of N fertilizer compatible with the crop and the environment, and by following good N management practices.

Nitrogen Fertilizer Rate

The amount of N fertilizer applied is crucial for efficient use by plants. Excessive applications can lead to contamination of both surface water and groundwater. The amount of N fertilizer used for field and vegetable crops should be based on a realistic yield goal and the amount of N available from the soil, previous crop, manure, and/or other biological materials. See MSU Extension Bulletins E-2904 and E-2934 (Warncke *et al.*, 2004a, 2004b) for more information on selecting the appropriate rate of N fertilizer. Recommended N rates for fruit crops are given in MSU Extension Bulletins E-852 (Hanson, 1996) and E-2011 (Hanson and Hancock, 1996).

Forms of Nitrogen Fertilizer

Nearly all N fertilizers are soluble in water and are subject to movement in soils as soon as they are applied. However, certain forms of N fertilizers have greater potential for movement out of the root zone. Nitrate N, in calcium nitrate or ammonium nitrate, is readily available for plants but is subject to immediate leaching when added to soil. Under conditions of high leaching potential, nitrate forms of N should not be used unless the plants are actively growing and can utilize the applied nitrate N. Where there is a high potential for leaching, ammonium forms of N, such as urea, ammonium sulfate, or anhydrous ammonia, are preferred sources of N. Ammonium in soil is held on clay and

organic matter and must first be converted to nitrate N before it can be leached or denitrified. This process, known as nitrification, occurs rapidly under warm, moist conditions.

Urea and N solutions containing urea are subject to volatilization loss as gaseous ammonia if surface applied and not incorporated. Conditions which favor this loss are high temperatures, high soil pH, moist soils, and high levels of plant residue on the soil surface. Because the volatilization loss of a urea-based fertilizer is difficult to assess, and since it represents an economic loss to the farmer, urea-containing fertilizers should be incorporated whenever possible. See MSU Extension Bulletin E-896 (Vitosh, 1990) for more information on fertilizer types, uses and characteristics. In fruit plantings and sod production fields where incorporation is not possible, apply urea when conditions are cool and not conducive to volatilization.

Time and Placement of Nitrogen Fertilizer

A small amount of N in a starter fertilizer applied to annual row crops at planting time is often desirable and normally has a beneficial effect on P uptake, particularly under cool, wet conditions. Crops on sandy soils low in organic matter and available N are also likely to respond to starter N fertilizer.

Spring applications of N on corn in Michigan are clearly superior to fall applications (Vitosh, 1991). Fall applications of N for spring or summer-seeded crops are not recommended. Climatic conditions from fall to spring can significantly affect the amount of N movement from the plant root zone. Estimates of N loss from fall applications vary from ten to 20 percent on fine to medium textured soils (clay, clay loams, and loams) and 30 to greater than 50 percent on coarse textured soils (sandy loams, loamy sands, and sands).

For establishment of winter small grains, such as winter wheat or rye, small applications of N fertilizer (20-30 lbs./acre) can be made in the fall at planting time. The remainder of the N requirement for these crops should be applied just prior to green-up in the spring. Avoid applications of N to snow-covered ground and to frozen land with slopes greater than six percent. Nitrogen applications on highly sloping land should be made after the spring thaw.

Split applications of N fertilizer during the growing season on corn and most vegetable crops are frequently beneficial on coarse textured soils (Vitosh, 1986). The benefits of split applications of N on corn grown on fine textured soils are less likely to occur, therefore, total N applications at planting or after emergence are acceptable. Fruit plantings on coarse textured soils may also benefit from split applications of N. Apply part of the N in early spring and part in late spring. Rates in the second application can be adjusted for anticipated yield.

For sod production, a small application of N fertilizer (20-40 lbs./acre) can be made in the fall at seeding time. During the growing season, multiple small applications of N can

be made at four to six week intervals as long as roots are actively growing. This practice will help to maintain turf density and reduce the need for herbicides.

Additional N fertilizer may be used in emergency situations, such as when heavy rains occur early in the growing season causing excessive leaching and/or denitrification. The use of additional N fertilizer in these situations may be necessary to prevent severe yield losses. Adding N fertilizer after heavy rains or flooding late in the season is usually not agronomically or economically effective and should be done only after careful consideration of the benefits and the effect on the environment.

10b. Use special N management practices on sandy soils and in groundwater-sensitive or well-head protection areas.

Many site-specific management practices and tools can be adopted which may improve N recovery and reduce the potential for nitrate contamination of groundwater. Crop rotations, forage crops, cover crops, plant analysis, soil sampling for nitrate, split applications of N, and use of nitrification inhibitors are some of the special N management practices that can be used on sandy soils and other groundwater-sensitive areas to minimize nitrate losses to groundwater. See MSU Extension Bulletin WQ-25 (Vitosh and Jacobs, 1996) for more information on these management practices. The NRCS Field Office Technical Guide (USDA-NRCS) located in each conservation district office contains information for identification of groundwater-sensitive areas.

PHOSPHORUS MANAGEMENT PRACTICES

11a. Apply phosphorus fertilizer based on soil tests or plant tissue analyses using Michigan State University recommended rates and methods of application that will enhance P recovery and uptake.

Michigan State University fertilizer recommendations are found in Extension Bulletins E-2904 (Warncke *et al*., 2004a) E-2934, (Warncke *et al.,* 2004b), E-852 (Hanson, 1996), and E-2011 (Hanson and Hancock, 1996). When soils have a Bray P1 test of 80-100 lbs./acre (40 to 50 ppm), fertilizer recommendations for P_2O_5 will likely be zero for most crops and yields grown in Michigan. So, increasing soil P test levels beyond this range will usually not be beneficial agronomically or economically.

Band application of starter fertilizer to the side and below the seed at planting time is considered to be the most efficient placement of P for field and vegetable crops when grown in rows. Broadcast applications of P are less efficient and normally will result in lower yields than band applications when soil test P levels are low. When broadcast applications are necessary, the P fertilizer should be applied and incorporated prior to establishment of the crop, to improve nutrient utilization by plants and prevent excessive nutrient runoff. For no-till crops, such as soybeans and wheat planted with a narrow row drill, the necessary broadcast application should be made just prior to planting. For established crops, such as grass sod, pastures, legumes, and other forages, where it is

impossible to incorporate the fertilizer, the P fertilizer may be broadcast when soil conditions are favorable for rapid growth, and soil compaction is minimized.

For no-till row crops, all P should be banded at planting time. For perennial crops, P fertilizer should be applied in the spring when soil conditions allow fertilizer applications to be made with minimal soil compaction. The need for P on perennial crops should be determined from plant tissue analyses.

Establish and maintain filter strips between surface waters and fields where fertilizers are applied to prevent any soil erosion and runoff of fertilizer nutrients from reaching surface waters. For more information on filter strips, see the NRCS-FOTG conservation practice Standard No. 393A (USDA-NRCS).

11b. Avoid broadcast applications of phosphorus fertilizers on frozen or snow-covered ground.

Fertilizer applied in the winter is the least desirable from a nutrient utilization and environmental point of view. Frozen soils and snow cover limit nutrient movement into the soil and greatly increase the risk of nutrients being carried to surface waters by runoff and erosion following rain storms or rapid snow melt.

NUTRIENT MANAGEMENT PRACTICES FOR ORGANIC SOILS

12. Manage water table, irrigation, and nutrients to minimize runoff and soil loss.

Organic soils are unique in that they contain 1.0 to 1.7 percent N and may have an annual mineralization rate of 320 to 530 lbs. N per acre. Of this vast amount of mineralized N, nearly 90 percent is denitrified to form gaseous N. While the remaining ten percent is available for plant use, it is also susceptible to movement into surface water and groundwater. Thus, it is important to apply only the amount of N needed by the crop at times when it can be utilized. Nitrogen should not be applied in the fall or winter because leaching could be excessive. Cover crops should be planted after harvest to utilize and hold N in a nonleachable form. For sod production, small N applications (20 to 40 lbs./acre) can be made in the fall as long as turf roots are actively growing.

Mineralization is an aerobic process, which can be reduced by keeping the water table high enough to obtain good crop yields while allowing for the least amount of soil decay. For most cropping situations this depth is 24 to 30 inches.

Nitrate N concentrations in drainage water can be reduced by controlling the level of the water table and by slowing the movement of water in drainage ditches. For more information on this subject see Lucas and Warncke (1988).

RECORDKEEPING

13. Maintain records of soil test reports and quantities of nutrients applied to individual fields.

Good recordkeeping demonstrates good management and will be beneficial for the crop producer, if the producer's management practices are challenged. Annual records should include the following for individual fields:

a. Most recent soil fertility test(s) and/or plant tissue analysis reports;
b. Previous crop grown and yield harvested;
c. Date(s) of nutrient application(s);
d. The nutrient composition of fertilizer or other nutrient-supplying material used (If the nutrient composition, availability or solubility is not provided with the purchase of the nutrient-supplying material, then representative samples of this material should be analyzed to provide nutrient composition information. Grass clippings and non-legume crop residues grown in the field and left to recycle nutrients are not considered to be nutrient additions.);
e. Amount of nutrient-supplying material applied per acre;
f. Method of application and placement of applied nutrients (i.e., broadcast and incorporated, broadcast and not incorporated, subsurface-banded, surface-banded, soil injected, applied through an irrigation system, etc.);
g. The name of the individual responsible for fertilizer applicator calibration, and the dates of calibration (If the equipment is owned by a fertilizer dealer or someone else who is responsible for proper calibration, then the name of the individual and/or business responsible for calibrating fertilizer application equipment should be retained); and
h. Vegetative growth and cropping history of perennial crops.

A recordkeeping system, such as that described in MSU Extension Bulletin E-2340 (Jacobs *et al*., 1992) or available as a computer program like MSU Nutrient Management (Jacobs and Go, 2006), may be helpful in accomplishing this goal.

FERTILIZER APPLICATION EQUIPMENT ADJUSTMENT

14. Check all fertilizer application equipment for proper adjustment so the desired rate of application and placement are achieved.

Fertilizer can be applied in either dry or liquid form. In either case, the application rate should be determined and the equipment adjusted so that the desired rate of application is achieved. Details for the calibration of fertilizer applicators can be found in equipment manufacturers' publications, ASAE Standards (ASAE Standards, 2004), or in Circular Z-138 (Broder, 1982). The equipment owner is responsible for providing instructions for

proper calibration, and users of the equipment are responsible for following the instructions to the best of their ability.

IV. SOIL CONSERVATION PRACTICES

15. Use soil erosion control practices to minimize nutrient runoff and soil loss.

Soil erosion and runoff can result in a loss of soil and nutrients from cropland, which reduce the land's productivity and increase the need for nutrient inputs. Sediment and sediment-borne nutrients are two types of nonpoint source pollution, which can be carried from cropland by runoff causing degradation of surface water. Whenever possible, soil and water conservation practices should be used, both to protect soil productivity and to control and minimize the risk of nonpoint source pollution to surface waters. Examples of such practices are conservation tillage, crop rotations, strip-cropping, contour planting, cover crops, vegetative filter strips between cultivated cropland and adjacent surface waters, and runoff control structures.

When choosing soil and water conservation practices for a particular site, consider factors, such as land slope, surface residue or vegetative conditions, crop rotations, soil texture, and drainage. Local conservation districts and the NRCS can provide technical assistance for producers to plan and implement conservation practices. See the current NRCS-FOTG (USDA-NRCS) for more information on conservation practice standards and specifications.

V. IRRIGATION MANAGEMENT PRACTICES

Careful N management for irrigated crop production also involves careful management of irrigation water. Proper irrigation management can help assure plant growth and crop yields sufficient to remove nutrients that have been applied for realistic yield goals, while minimizing nitrate remaining in the soil that is subject to potential leaching. Excess water from irrigation and/or precipitation can cause nitrates to move below the root zone and eventually to groundwater.

16. Irrigators should use modern irrigation scheduling techniques to avoid applying excess water.

Irrigation scheduling involves keeping track of the amount of water in the soil, or water losses to the atmosphere (evapotranspiration) and irrigating before plants are stressed. After irrigation, some soil water-holding capacity should remain to hold rainfall, should it occur. In most cases, irrigation should occur when 40 to 70 percent of the available soil water is depleted, depending on the soil, crop, and capacity of the irrigation system. Irrigation water should not fill the soil rooting profile to more than 80 percent. Precise

scheduling of irrigation water during the growing season can minimize percolation losses (Vitosh, 1992). See the current "Generally Accepted Agricultural and Management Practices for Irrigation Water Use" for recommended irrigation management practices.

17. Irrigators should use multiple applications of N fertilizer to improve N efficiency and minimize potential loss of nitrate-N to groundwater.

Multiple applications will help to ensure that N is available when plants need it most and to minimize the amount that can be leached. Any combination of application methods can be used, such as starter fertilizers at planting time, side dressing by soil injection, dribbling on the surface, application during cultivation, and/or by injection through the irrigation system.

Nitrogen fertilizer applied through the irrigation system, referred to as fertigation or chemigation, offers several advantages: (1) N can be applied when the crop's demand is greatest, and in trickle-irrigated orchards, where roots are most concentrated; (2) the technique requires little energy for application; and (3) it is well suited to sandy soils where irrigation is needed and leaching may be a problem. Producers who fertigate should test the uniformity of their irrigation system to assure that no extremely high or low zones of water application occur. Careful adjustment of fertilizer injection equipment to obtain the desired rate of application is very important. Irrigation systems used for fertigation must have appropriate backflow-prevention safety devices. (Reference Public Act 368, the Michigan Public Health Code of 1978, as amended, and Public Act 399, the State of Michigan Safe Drinking Water Act of 1976, as amended). See MSU Extension Bulletin E-2099 (Hay *et al.*, 1988) and Northeast Regional Agricultural Engineering Service Bulletin NRAES-4 (NRAES, 1981) for proper and safe use of fertigation equipment.

VI. FERTILIZATION AND IRRIGATION PRACTICES FOR CONTAINER-GROWN PLANTS

Growing plants in greenhouses or outdoor container nurseries requires rapid growth to maintain production schedules and quality. Frequent fertilization and irrigation are needed since common root media lack nutrient and water-holding capacity. However, effective management practices can be adopted to minimize water and fertilizer leaching and/or runoff (Horticultural Water Quality Alliance, 1992).

RUNOFF PREVENTION

18. Use management practices that prevent or minimize water and fertilizer runoff, such as selecting good quality root media, using slow-release fertilizer, improving irrigation systems, reducing leaching, and scheduling irrigations.

Root Media

Greenhouse root media composed primarily of peat, bark, and other components, such as vermiculite, perlite, or rockwool should be formulated to provide high water-holding capacity, while maintaining adequate drainage and air space. When preparing root media, components, and additives, like wetting agents, which increase the rate of absorption of water, should be incorporated. Commercially prepared root media with high water holding capacity are available for greenhouse use. For outdoor nursery production, root media are composed primarily of bark, peat, and other components and must be porous enough to drain excess water under heavy rainfall conditions.

Fertilization

Essential nutrients should be applied based on plant nutrient requirements, plant growth rate, and root media nutrient availability. Pre-plant incorporation of water soluble nutrients like N and P that will readily leach from the root media should be minimized. Current fertilizer recommendations are based on the concentration of water soluble fertilizer to be applied weekly or at every watering. However, nutrient levels in the root media are a function of both the concentration and volume applied. With reduced leaching, fertilizer concentrations can be decreased (Biernbaum, 1992). Sampling of root media, testing electrical conductivity, and completing an elemental analysis will help determine actual fertilizer requirements. Media analysis for longer term outdoor nursery crops may be conducted less frequently. Test results generated by MSU, other Land Grant Universities, and approved commercial testing laboratories using the testing methodology of the North Central Committee on Soil Testing and Plant Analysis (Chapter 14 of Brown, 1998), can be used for making nutrient recommendations.

Recommended root media nutrient levels and nutrient recommendations are available in MSU Extension Bulletin E-1736 (Warncke and Krauskopf, 1983) for greenhouse crops. Nutrient recommendations for container-grown and field-grown nursery crops can be found in “Management Practices for Michigan Wholesale Nurseries” (Fernandez, 2004). Guidelines for nutrient levels in plant foliar tissue for nursery crops are available (Fernandez, 2004). For greenhouse pots and container-grown nursery crops, water management and use of controlled release fertilizers are important to maintain adequate nutrient levels for optimum plant growth and to minimize leaching and loss of soluble nutrients (Horticultural Water Quality Alliance, 1992; Fernandez, 2004).

Slow release fertilizer, such as sulfur-coated urea or resin-coated fertilizer (RCF), can be incorporated into the root media or surface-applied to reduce water-soluble fertilizer applications and nutrient leaching. With outdoor, overhead irrigation of container-grown nursery stock where heavy rainfall can leach the root medium, RCF can be used to prevent runoff of water-soluble fertilizer. Formulations containing a variety of nutrient levels and release rates are available. Nevertheless, RCF may be an unacceptable alternative for some cropping situations. Problems due to excess nutrient release may occur during the summer when root medium temperatures in the containers become too

high, or during over-wintering of nursery crops when nutrient uptake decreases. Therefore, use proper monitoring to avoid these high soluble salt conditions.

When water-soluble fertilizers are added to irrigation systems, fertilizer injectors or diluters should be checked regularly for proper operation and dilution. Backflow preventers and antisyphon devices must be installed on all water supplies when fertigation or chemigation is used (Reference Public Act 368, the Michigan Public Health Code of 1978, as amended, and Public Act 399, the State of Michigan Safe Drinking Water Act of 1976, as amended).

Irrigation Systems

Overhead sprinklers, traveling booms, and drip systems should be designed to maximize uniformity of application and water absorption by the root media. Overhead fertigation of container-grown nursery plants with water-soluble fertilizers should be avoided unless runoff can be collected and recirculated. Overhead irrigation with sprinklers or traveling booms can be efficient if growing containers are closely spaced, as in the production of bedding plants in flats. Low-volume drip systems can also be designed to be efficient with 90 percent or more of the water available for plant uptake. Subirrigation with water recirculation is very efficient, but is not always practical or affordable (Biernbaum, 1993).

Leaching

In greenhouse production, application of a sufficient quantity of water to facilitate leaching with every irrigation is advised routinely to prevent the accumulation of fertilizer and other salts (Biernbaum, 1992). For container nursery production, rainfall is often sufficient to adequately leach containers. However, during periods of little or no rainfall, container soluble salt levels should be monitored and leaching conducted when necessary (Fernandez, 2004). When the irrigation water contains high levels of boron, chloride, sodium, or other elements, some leaching may be needed. However, when soluble salts in the root zone are a result of over-application of water-soluble fertilizer, the fertilizer concentration should be reduced, or clear water should be applied for several irrigations to bring levels down gradually rather than making heavy applications of water to leach the fertilizer salts. To reduce leaching, water-soluble fertilizer applications with irrigation systems can be made with multiple, short pulses rather than one long application. In some greenhouse situations, plastic trays can be placed under growing containers to catch irrigation water so more of what is applied is available to the plant.

Irrigation Scheduling

Although many peat and bark-based media can be irrigated frequently and heavily without water-logging, growth may be reduced due to excessive leaching of nutrients. Irrigation should be scheduled based on crop water requirements. Measuring water availability and scheduling irrigation of root media in small containers is not practical

with currently available soil moisture monitoring equipment and is generally done based on personal observation and monitoring. When computer equipment is available, water requirements and irrigation schedules can be predicted based on environmental conditions, such as accumulated solar radiation and/or vapor pressure deficit measurements.

RUNOFF COLLECTION

19. When runoff or leaching of fertilizer cannot be controlled, water that contains fertilizer should be collected and reused.

Runoff water and fertilizer solutions can be collected from concrete greenhouse floors, field drains under greenhouses or container nursery areas, and then recycled. Filtering of the water to remove solids or treating the water to control plant pathogens may be needed. Grass gullies or runways and filter strips ahead of the collection pond or reservoir will help remove suspended solids.

Recirculation of water and nutrient solutions can be accomplished in greenhouses without contamination of the nutrient solution when using closed, flood sub-irrigation systems (Biernbaum, 1993). Flood benches, flood floors, or troughs can be used as methods to provide the water and nutrients by subirrigation. After irrigating, the remaining solution is collected in reservoirs and recycled.

RECORDKEEPING

20. Maintain records of fertilizer purchases and irrigation water used.

Recording individual fertilizer applications is difficult since fertilizer may be applied on an almost daily basis. Records of all fertilizer purchases will probably provide the best measure of fertilizer use. Maintaining annual records of irrigation water use or irrigation scheduling to demonstrate water use patterns and conservation is also recommended.

VII. LAND APPLICATION OF ORGANIC (BIOLOGICAL) MATERIALS AND BY-PRODUCT LIMING MATERIALS FOR CROP PRODUCTION

21. The application of organic and by-product liming materials to Michigan soils for crop production is a common and accepted agricultural practice.

The organic material most commonly applied to soils, excluding plant residues, is animal manure. At one time, most farms had livestock, and the manures generated were a primary source of nutrients for crop production. However, with the introduction of commercial fertilizers and the specialization of farming, only about 40 percent of Michigan farms now have livestock that generate manure nutrients. See current "Generally Accepted Agricultural and Management Practices for Manure Management

and Utilization", for recommended management practices, when utilizing manure as a source of plant nutrients. In addition to animal manures, other organic materials are applied to soils in Michigan. From an agricultural point of view, the concept of recycling manure nutrients and organic materials back to cropland is highly desirable. However, the consequences of utilizing some organic wastes from industrialized societies should be addressed to avoid potential negative impacts to animals and humans, the soil-plant system, and the environment.

This section briefly discusses the use of organic materials (i.e., those materials primarily of biological origin) which can be used to supply nutrients for crop production and by-product liming materials used to correct soil acidity and maintain desired soil pH. To provide the reader with a better understanding of the kinds of organic (biological) materials which are produced by our society, the basic categorization used by the U.S. Department of Agriculture (USDA, 1978) was selected. While this USDA report uses the term "organic wastes" to represent the various kinds of organic materials discussed, many of these materials, when used properly, can serve as valuable nutrient resources and organic matter amendments.

The grouping used by the U.S. Department of Agriculture (USDA, 1978) includes most organic materials which might be applied to cropland. The different categories of organic materials and a description of each category follow:

1) Animal manure—feces and urine excreted by bovine cattle, horses, sheep, goats, swine, and poultry, with any accompanying bedding or litter;
2) Crop residues and green manures—stems, leaves, roots, chaff, and any other plant parts remaining after crops are grazed or harvested; also, plant material, which is green and growing to maturity, that is incorporated into the soil;
3) Human wastes—various forms of organic materials containing human feces and urine, such as night soil, septage, sewage wastewater, and sewage sludge (now more commonly called biosolids);
4) Food processing wastes—organic by-products from the fruit, vegetable, seafood, sugar, fats, oils, and dairy food processing industries;
5) Industrial organic wastes—by-products from paper and allied products; fermentation, including pharmaceutical and food additives; soap and detergent; alcoholic fermentation, including distilleries, wineries and malt beverage industries; meat packing and related industries, including those producing pet food, seafood, and poultry products; leather tanning and finishing; organic fiber processing; petroleum refining and related industries; and milling;
6) Logging and wood manufacturing residues—waste debris in forest after logging, such as limbs, leaves, needles, diseased/decayed wood; manufacturing residues, such as chips, bark, sawdust, etc.; and
7) Municipal refuse (also called MSW, municipal solid waste)—the organic portion of collectable solid wastes generated by households, institutions, offices, commercial and industrial premises, and in the streets of urban areas; would also include raw or composted yard wastes and composted MSW.

Potential hazards that may be encountered when organic materials are applied to the soil-plant system for crop production include poor management of nutrients, additions of undesirable trace elements and trace organic chemicals, pathogens, and creation of soil physical problems. The problem most frequently noted is poor management of organic fertilizer nutrients that can pollute water resources, particularly with N and P. Excess nitrate-N can contaminate groundwater. Excess P may accumulate in surface soils increasing the risk of P runoff/erosion losses to surface water. In addition, odors, disease, and vector attraction can occur if the application of these organic materials is not managed properly.

As noted above, the current GAAMPs for Manure Management and Utilization provide recommended management practices for utilization of manure as a source of plant nutrients. Crop residues and green manures produced on cropland are already part of the soil-plant system. The land application of many other organic materials described in the above categories is regulated by DEQ, and these residuals are defined by state and federal environmental regulations as “wastes.” The generator of any waste is responsible for characterizing its waste, determining the waste’s suitability for land application, and obtaining all necessary approvals for a land application program.

For these regulated wastes, DEQ has established guidelines for isolation distances of land application sites from surface water, domestic wells or municipal water supplies, residences and commercial buildings, public roads, and property lines. The DEQ also has requirements for the incorporation of certain organic materials and restrictions on applications to snow-covered or frozen soils. In addition, any approval granted by DEQ to a waste generator for a land application program carries with it the responsibility to prevent adverse environmental effects, including losses from runoff and leaching.

Commercial and industrial generators of organic residuals or by-product liming materials are required to obtain authorization to land apply these materials. Unless a material is declared inert by the DEQ Office of Waste Management and Radiological Protection (OWMRP), such authorizations typically take the form of an Agricultural Use Approval (AUA), which is issued through OWMRP. For more information regarding AUAs, contact OWMRP at PO Box 30241, Lansing, Michigan 48909-7741, or at (517)-284-6593.

Municipal and privately owned treatment works that treat sewage may obtain authorization to land apply biosolids (wastewater treatment sludges) through the DEQ Water Resources Division (WRD). For more information regarding authorizations to land apply municipal biosolids and/or septage, contact WRD at P.O. Box 30273, Lansing, Michigan 48909-7773, or at (517)-284-5567.

The land application of certain food processing residuals and other non-detrimental materials to agricultural or silvicultural land is authorized by DEQ under the authority of NREPA, Public Act 451 of 1994, as amended, Part 115, Solid Waste Management. The NREPA, Public Act 451, Part 115, Solid Waste Management, Rule 324, Section 11506.(1)(g) conditionally exempts agricultural and silvicultural uses that involve the

land application of certain food processing residuals (from field crops, fruit, vegetable, or aquatic plants), lime from kraft pulping (paper) processes generated prior to bleaching, wood ashes resulting solely from a source that burns only wood that is untreated and inert, aquatic plants, or source separated materials approved by DEQ.

In addition to these residuals, the generation of new by-products is increasing in Michigan and the U.S. from crop-based bioenergy plants producing ethanol from corn and soydiesel blends from soybeans. Two primary by-products are dried distillers grains (DDGs) and wet distillers grains (WDGs). These by-products can be utilized as livestock feed, and DEQ considers these organic by-products as food-processing residuals, which are exempt from regulation as a solid waste and permit requirements, if these by-products are land applied at an agronomic rate consistent with the current GAAMPs specified in Section VIII below.

All of the above non-detrimental materials can be applied to, or composted and applied to, agricultural and silvicultural land without a permit or plan approved by the DEQ, provided these materials are applied at an agronomic rate consistent with current Generally Accepted Agricultural and Management Practices for Nutrient Utilization, hereafter referred to as Practices. The generator of the land applied by-product, along with the applicator and landowner, share responsibility for following the Practices. If the land application of the above referenced by-product(s) is not managed in a manner consistent with these Practices, then the generator of the by-product(s) is required to obtain the necessary permits and approvals from DEQ.

Composting Organic By-Products

Section 11506. (1)(g) of the NREPA also conditionally exempts the land application of composted organic by-products. Composting is a self-heating process carried on by bacteria, actinomycetes, and fungi that decompose organic material in the presence of oxygen. Composting of organic materials prior to land application can result in a rather stable end product that does not support extensive microbial or insect activity, if the process and systems are properly designed and managed. The potential for odors during the composting process depends upon the moisture content of the organic material, the carbon-nitrogen ratio, the presence of adequate nutrients, the absence of toxic levels of materials that can limit microbial growth, and adequate porosity to allow diffusion of oxygen into the organic material for aerobic decomposition of the organic material. Stability of the end product and its potential to produce nuisance odors, and/or to be a breeding area for flies, depends upon the degree of organic material decomposition and the final moisture content. Additional information and guidance about alternatives for composting organic materials are available in the “On-Farm Composting Handbook” (Rynk, 1992) and the National Engineering Handbook (USDA, 2000).

The occurrence of leachate from the composting material can be minimized by controlling the initial moisture content of the composting mixture to less than 70 percent and controlling water additions to the composting material from rainfall. Either a fleece

blanket[1] or a roofed structure can be used as a cover to control rainfall additions and the production of leachate from composting windrows. If the composting process is conducted without a cover, provisions must be made to collect any surface runoff and/or leachate, so it can be either temporarily stored (see Section IV of the current Manure GAAMPs) and applied to land (see Section V of the current Manure GAAMPs), added to the composting material for moisture control during the composting process, or applied to grassed infiltration areas (See Section II of the current Manure GAAMPs). Therefore, depending on how the composting process is conducted, any leachate or runoff generated from composting material and/or from the composting site, must be controlled and/or treated in a manner to protect groundwater and surface water.

Organic by-products generated on a farm, or brought onto a farm, for on-farm composting may be applied to cropland (belonging to that farm operation) as nutrient resources for crop production or as organic matter amendments and is considered an acceptable practice (See GAAMP #21). Composted organic by-products that are land applied should follow the practices specified in Section VIII below.

The "Practices" referred to in the NREPA, Public Act 451 of 1994, as amended, that must be followed to conditionally exempt various organic by-products, composted organic by-products, by-product liming materials, and source separated materials like cull eggs from Solid Waste Management regulations are specified in Section VIII below. Responsibility for determining whether these Practices are being followed to qualify for this conditional exemption is shared by the MDARD and the DEQ, as described in the "Memorandum of Understanding (MOU) between MDARD and DEQ Regarding State Agency Response Actions to Environmental and Nuisance Complaints about Farm Operations" and the "MDARD/DEQ Waste Complaint Response Procedure."

VIII. LAND APPLICATION OF CONDITIONALLY-EXEMPTED ORGANIC BY-PRODUCTS, COMPOSTED ORGANIC BY-PRODUCTS, AND BY-PRODUCT LIMING MATERIALS

As was indicated in Section VII above, various by-products that can supply nutrients for crop production, or correct soil acidity when applied to agricultural or silvicultural land, are conditionally exempt from regulation as a solid waste and permit requirements, if these by-products are applied at an agronomic rate consistent with the current GAAMPs described in this section.

Practices #22-23 apply to all conditionally-exempted organic and inorganic by-products. Management practices #24-33 pertain to organic by-products or composted organic by-products that are used as nutrient sources. Practice #34 discusses wood ashes that have liming value in addition to potash (K_2O) value, and management practice #35

[1] A fleece blanket is a non-woven textile material made from synthetic fibers, such as polypropylene. The non-woven texture of a fleece blanket prevents rainfall from penetrating into the composting material, but allows the necessary exchange of carbon dioxide and oxygen.

discusses by-product liming materials used to correct soil acidity. Management practice #36 discusses the application of soil removed from sugar beets or other root vegetables by mechanical means or by washing with water. The final GAAMP in this section, practice #37, discusses recommended recordkeeping for the application of all by-products to agricultural or silvicultural land.

22. The by-product should be handled in such a manner as to prevent spillage during transport to application sites. Temporary staging or stockpiling of by-product at the field application site prior to land application should be managed in a manner to prevent runoff and/or leaching of nutrients or by-product lime to surface water or groundwater, and to minimize odor impacts upon neighbors. If conditions of the temporary staging or stockpiling site result in adverse environmental effects, the stockpiled by-product should be immediately removed and properly land applied.

23. All fields to which by-products are applied should have soils sampled and tested on a regular basis to determine where by-product nutrients or by-product lime can best be utilized (see Section III, GAAMP #7).

24. Use fertilizer recommendations, consistent with those of Michigan State University, to determine the total nutrient needs for crops to be grown on each field where by-products will be applied (see Section III, GAAMP #8).

25. To determine the nutrient content of a by-product material, analyze it for percent dry matter (solids), ammonium N (NH_4-N), and total N, P, and K.

One goal of a well-managed land application program is to utilize soil testing as a basis for fertilizer (nutrient) recommendations and agricultural lime recommendations. The quantity of nutrients recommended for the crop and yield to be grown will likely need to be supplied by a combination of by-product nutrients and commercial fertilizer nutrients. For soils with low pH's, agricultural lime recommendations to correct soil acidity should be based on soil testing results. By-product liming materials can be substituted for agricultural lime, as discussed in management practices #34 and #35.

In order to effectively manage by-product nutrients for crop production, the nutrient content of the by-product material needs to be known. Because of variation in the nutrient content of by-product materials, a representative sample(s) of the by-product should be obtained and analyzed by a laboratory to determine its nutrient content. To establish "baseline" information about the nutrient content of a by-product material, the by-product should be sampled and tested for at least two years. When there is a change in the kind of material being processed or the process by which the by-product

is produced, additional testing for baseline nutrient composition should be done. MSU Extension and/or MDARD can provide information on collecting representative by-product samples and where to send samples for analysis.

26. The agronomic (fertilizer) rate of N recommended for crops should not be exceeded by the amount of available N added, either from a by-product applied alone or from a by-product plus fertilizer N applied together. For legume crops, the amount of N removed by the legume may be used as the maximum N rate for by-product applications. The available N per ton of by-product material should be determined by using a by-product analysis.

Excessive by-product applications to soils can: (a) result in excess nitrate N not being used by plants or the soil biology that may increase the risk of nitrate N being leached through the soil and into groundwater; (b) cause P to accumulate in the upper soil profile and increase the risk of contaminating surface waters with P where runoff/erosion occurs; and (c) create nutrient imbalances in soils, which may cause poor plant growth or animal nutrition disorders for livestock eating crops grown on by-product-amended soils. The greatest water quality concern from excessive by-product nutrient loadings, where soil erosion and runoff is controlled, is nitrate N losses to groundwater. Therefore, the agronomic fertilizer N recommendation, or crop N removal value for legumes, should never be exceeded.

The availability of N in by-products for plant uptake will not be the same as, highly soluble, fertilizer N. Therefore, total by-product N cannot be substituted for that in fertilizers on a pound-for-pound basis, because a portion of the N is present in by-product organic matter which must be decomposed before mineral (inorganic) forms of N are available for plant uptake.

The rate of decomposition (or mineralization) of by-product organic matter is usually less than 100 percent during the first year, and will vary depending on the type of by-product utilized. In order to estimate the amount of available N that will be provided by each ton of by-product, the total N and NH_4-N content from the by-product analysis can be used with a mineralization factor of 50 percent to calculate this value. This calculation is similar to that used for estimating available N in animal manures. (See Manure Management Sheet #2, MSU Extension Bulletin E-2344 by Jacobs *et al.*, 1993, for more explanation.)

Many of the by-products from fruit, vegetable, or sugar beet processing contain less than one percent N on a fresh weight basis. By-products may be used to meet some or all of the N requirements of the crop, but it may not be practical or wise to apply these by-products as a sole source of N. The rate of application should allow for ease of incorporation when needed and should not adversely affect the permeability of the soil or physically restrict the growth of plants.

27. When the Bray P1 soil test level for P reaches 150 lbs./acre[2] (75 ppm), by-product applications should be reduced to a rate where by-product P added does not exceed the P removed by the harvested crop. (If this by-product rate is impractical due to by-product spreading equipment or crop production management, a quantity of by-product P equal to the amount of P removed by up to four crop years can be applied prior to the first crop year. However, no additional fertilizer or by-product P may be applied for the remaining crop years, and the by-product rate used cannot exceed the N fertilizer recommendation for the first crop grown.)

If the Bray P1 test reaches 300 lbs./acre[2] (150 ppm) or higher, by-product applications should be discontinued until nutrient harvest by crops reduces P test levels to less than 300 lbs./acre. To protect surface water quality against discharges of P, adequate soil and water conservation practices should be used to control runoff and erosion from fields where by-product is applied.

The availability of P and K in by-products is considered to be close to 100 percent for K but considerably less than 100 percent for P. Periodic soil testing can be used to monitor how additions of by-product P and K will affect soil fertility levels. If by-products are applied to supply all the N needs of crops, the P needs of crops will usually be exceeded, and soil test levels for P will increase over time. If the Bray P1 soil test P levels reach 300 lbs./acre (150 ppm)[2], the risk of losing soluble P and sediment-bound P by runoff and erosion (i.e., non-point source pollution) increases. Therefore, adequate soil and water conservation practices to control runoff and erosion should be implemented. In addition, when Bray P1 soil test P levels reach 300 lbs./acre, no more by-product (or fertilizer) P should be added until nutrient harvest by crops reduces P test levels to less than 300 lbs./acre.

To avoid reaching the 300 lbs./acre Bray P1 test level, by-product applications should be reduced to provide the P needs of crops rather than providing all of the N needs of crops and adding excess P. Therefore, when the Bray P1 soil test level for P reaches 150 lbs./acre (75 ppm)[2], by-product applications should be reduced to a rate where by-product P added does not exceed the P removed by the harvested crop. The quantity of by-product P_2O_5[3] that should be added can be estimated by using Crop Nutrient Removal Tables 1 and 2 and a realistic yield goal for the crop to be grown. For example, if a yield of 130 bu/acre for corn grain is anticipated, the amount of by-product P_2O_5 added to this field should be limited to about 48 lbs./acre (130 bu/acre x 0.37 lb. P_2O_5/bu).

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[2] If the Mehlich 3 extractant is utilized for the soil fertility test instead of the Bray P1 extractant, then the following equivalent Mehlich 3 soil test levels can be used for Michigan soils: 150 lbs. P/acre (Bray P1) = 165 lbs. P/acre (Mehlich 3) and 300 lbs. P/acre (Bray P1) = 330 lbs. P/acre (Mehlich 3).

[3] Fertilizer P recommendations are given in, and fertilizer P is sold as, pounds of phosphate (P_2O_5).

If the rate of by-product application based on P removal by the crop is lower than the by-product spreader can physically apply, or is not realistic when planning for crop production management, the rate of by-product application can be increased. The higher rate of by-product application can be equal to the P removal (See Table #1 and 2) for up to four crop years, as long as this rate does not exceed the N fertilizer recommendation for the first crop grown after the by-product is applied. If this higher rate of by-product application is used, no fertilizer or by-product P should be applied during the remaining crop years, or until the accumulative P_2O_5 removed by crop harvest equals the amount of by-product P_2O_5 applied. A good recordkeeping system should be used to track the amounts of P_2O_5 applied and the P_2O_5 removed by harvested crops, when this higher rate of by-product application is used.

28. By-products should be applied to soils in a uniform manner. The amount of by-product applied per acre (tons/acre) should be known, so that by-product nutrients can be managed effectively.

As is true with fertilizers, lime, and pesticides, by-product materials should be spread uniformly for best results in crop production. Also, in order to know the quantity of by-product nutrients applied, the amount of by-product applied must be known. Determining the tons/acre applied by spreading equipment can be accomplished in a variety of ways. One method is to measure the area of land covered by one spreader-load of by-product.

A second method is to record the total number of spreader loads applied to a field of known acreage. With either approach, the capacity of the spreader (in tons) must be known, and some way to vary the rate of application will be needed by adjusting the speed of travel or changing the discharge settings on the spreading equipment. Guidance is available from MSU Extension or the equipment manufacturer to help determine the rates of by-product application that spreading equipment can deliver.

29. By-products should not be applied to soils within 150 feet of surface waters or to areas subject to flooding unless: (a) by-products are injected or surface-applied with immediate incorporation (i.e., within 48 hours after application) and/or (b) conservation practices are used to protect against runoff and erosion losses to surface waters. By-products should be applied in a manner to optimize nutrient utilization and prevent nutrient runoff to surface water.

To reduce the risk of runoff/erosion losses of by-product nutrients, by-product materials should not be applied and left on the soil surface within 150 feet of surface waters. By-products that are surface applied with immediate incorporation can be closer than 150 feet, as long as conservation practices are used to protect against runoff and erosion. A vegetative buffer between the application area and any surface water is a desirable conservation practice. By-products should not be applied to grassed waterways or other areas where there may be a concentration of water flow, unless used to fertilize and/or mulch new seedings during waterway construction. By-products should not be

applied to areas subject to flooding unless immediately incorporated. In all cases, by-products should not be applied to land within 50 feet of surface water, a residence, a single family residential well, or within 200 feet of a public water supply well.

30. As land slopes increase from zero percent, the risk of runoff and erosion also increases. Adequate soil and water conservation practices should be used which will control runoff and erosion for a particular site, taking into consideration such factors as type of by-product to be applied, surface residue or vegetative conditions, soil type, slope, etc.

As land slopes increase, the risk of runoff and erosion losses to drainage ways, and potentially to surface waters, also increases. Soil and water conservation practices should be used to control and minimize the risk of non-point source pollution to surface waters, particularly where by-product materials are applied. Surface application of a by-product should be avoided when the land slope is greater than six percent. However, a number of factors, such as the amount of liquid associated with a by-product(s) application, amount of residues present on the soil surface, soil texture, drainage, etc., can influence the degree of runoff and erosion associated with surface water pollution. Therefore, adequate soil and water conservation practices to control runoff and erosion at any particular site are more critical than the degree of slope itself.

31. Where application of by-product is necessary in the fall, rather than spring or summer, using as many of the following practices as possible will help to minimize potential loss of NO_3-N by leaching: (a) apply to medium or fine rather than to coarse textured soils; (b) delay applications until soil temperatures fall below 50°F; and/or (c) establish cover crops before or after by-product application to help remove nitrate N by plant uptake.

By-product and fertilizer nutrients should be applied as close as possible to, or during, periods of maximum crop nutrient uptake to minimize loss from the soil-plant system. Therefore, spring or early summer application is best for conserving nutrients, whereas fall application generally results in greater nutrient loss, particularly for nitrate N on coarse soils (i.e., sands, loamy sands, sandy loams).

32. Application of a by-product to frozen or snow-covered soils should be avoided, but where necessary, by-product materials should only be applied to areas where slopes are six percent or less. In addition, provisions must be made to control runoff and erosion with soil and water conservation practices, such as vegetative buffer strips between surface waters and soils where the by-product is applied.

Winter application of by-products is the least desirable in terms of nutrient utilization and prevention of nonpoint source pollution. Frozen soils and snow cover will limit nutrient movement into the soil and greatly increase the risk of by-product being lost to

surface waters by runoff and erosion during thaws or early spring rains. When winter application is necessary, appropriately sized buffer strips should be established between surface waters and frozen soils where by-products are applied to minimize any runoff and erosion of by-product materials or nutrients from reaching surface water.

33. By-products should be managed and applied to cropland in a manner to control odors and reduce the potential for complaints concerning excessive odor.

By-products tend to generate odors that are not typical of agricultural operations and may be offensive to neighbors. Therefore, it is important that by-products be applied to land in a manner which reduces the possibility of odor complaints. The following is a list of practices that can be used to reduce odor in the application of by-products to land:

a. Avoid spreading when the wind is blowing toward populated areas.
b. Avoid spreading on weekends/holidays when people are likely to be engaged in nearby outdoor and recreational activities.
c. Spread in the morning when air begins to warm and is rising, rather than in the late afternoon.
d. Use available weather information to best advantage. Turbulent breezes will dissipate and dilute odors, while hot, humid weather tends to concentrate and intensify odors, particularly in the absence of breezes.
e. Take advantage of natural vegetation barriers, such as woodlots or windbreaks, to help filter and dissipate odors.
f. Establish vegetated air filters by planting conifers and shrubs as windbreaks and visual screens between cropland and residential developments.
g. Incorporate by-product materials into the soil as soon as possible after application, e.g. within 48 hours. However, incorporation may not be feasible where by-products are applied to pastures or forage crops, such as alfalfa, or where no-till practices are used. When incorporation of the by-product is not feasible, and the potential exists for an odor complaint, it may be advisable to find a more appropriate site for the application.
h. Open-air stockpiling or storage of by-product materials at field applications sites should be managed in a manner to avoid odor complaints.

34. Wood ashes should be applied at rates based on their potash (K_2O) value and/or their acid-neutralizing value as a substitute for agricultural lime.

The primary value of wood ashes is their potash value and their acid-neutralizing ability. Because of variation in the nutrient content of wood ashes, a representative sample(s) should be obtained and analyzed by a laboratory to determine its K_2O content. The K_2O content per ton of wood ash should then be used to determine the appropriate rate of wood ash to use to meet K_2O fertilizer recommendations.

The wood ash should also be tested to determine its minimum neutralizing value in terms of calcium carbonate equivalent. This information, along with lime recommendations from soil test results, can then be used to determine acceptable wood ash application rates to neutralize soil acidity. Rates applied should be consistent with recommendations of Michigan State University Extension Bulletin E-471 (Christenson *et al*., 1993). When there is no lime requirement recommended, wood ash can still be applied for its potash value, as long as the accompanying liming addition will not interfere with achieving desired crop growth. To avoid potential growth problems from unneeded lime additions, growers should monitor soil test values for pH, P, K, and micronutrients by establishing baseline values prior to applying wood ashes on soils with pH>6.8.

35. By-product liming materials should be applied at rates based on soil pH, lime requirement and neutralizing value of the liming material.

The Michigan Liming Materials Law, Public Act 162 of 1955, as amended, requires that vendors of by-product liming materials determine and present the minimum neutralizing values in terms of calcium carbonate equivalents. This information, along with lime recommendations from soil test results, should be used to determine acceptable by-product lime application rates. By-product liming materials are usually used to neutralize soil acidity and should be applied in amounts consistent with recommendations of Michigan State University Extension Bulletin E-471 (Christenson *et al*., 1993). When there is a desire to apply by-product liming materials on high pH (alkaline) soils, one to two tons per acre of material may be applied to medium and fine-textured soils with a pH above 6.8. Research has shown that this practice will not appreciably change soil pH or soil test values for P and K, and will not harm crop yields. As a management tool, growers should monitor soil test values for pH, P, K, and micronutrients by establishing baseline values prior to application of any liming material.

36. Soil removed from sugar beets or other root vegetables by mechanical means or by washing with water should be applied to cropland at depths that can be physically mixed into the top four to eight inches of the receiving soil.

Dry soil removed from sugar beets or other root vegetables, before processing or use as fresh market produce, can be returned to fields where these crops were harvested without obtaining a permit to do so from DEQ. To accomplish physical mixing of these removed soils into the receiving soil, application depths will depend on the type of tillage equipment used. Suggested depths for applying these soils are one to two inches when a disk or chisel-plow is used and three to four inches when a moldboard plow is used.

Soil removed by commercial processors, by washing with water (from a source as specified in Part 22 Rules, R 323.2211) and collected in some type of storage pond or other facility, can also be air dried and returned to fields without a DEQ permit, if no chemical additives, other than lime, are made to this soil/water slurry. These soil/water slurries can be applied to drying beds or placed in seepage ponds/lagoons and the water allowed to drain into the ground under the following conditions: 1) the discharger must obtain a 2211 (permit by rule with notification) authorization; 2) the volume discharged towards groundwater is <50,000 gallons/day; and 3) DEQ must be notified if the wash water contains an additive. Generators of this type of wash water should refer to the Part 22 Groundwater Quality Administrative Rules for more specific information pertaining to these types of groundwater discharges.

The soil slurries collected by commercial processors can also be discharged into a storage pond or facility that does not allow seepage of the water to occur, but additional care is needed (i.e., a permit from DEQ may be required) to properly handle any decant water that is removed or any leachate water lost from slurried soils during handling and other processes used to air dry these soils. Once these soils are air dried, they can be applied to fields per the guidance above.

37. Records should be kept of by-product analyses, soil test reports, and rates of by-product application for individual fields.

Good recordkeeping demonstrates good management and will be beneficial for the crop producer. Records should include by-product analysis reports, rates of by-product applied, and information for individual fields as suggested in Section III under management practice #13.

When planning by-product applications, consider normal weather patterns, the availability of land at different times during the growing season for different crops, and availability of manpower and equipment relative to other activities on the farm. Having adequate storage capacity to temporarily hold by-products can add flexibility to a management plan when unanticipated weather occurs, preventing timely applications. Nevertheless, unusual weather conditions do occur and can create problems for the best of management plans.

Finally, good recordkeeping is the "basis" of a good management plan. Past analysis results for by-product materials should be good predictors of the nutrient content in by-products being produced and applied today. Changes in the P test levels of soils with time due to by-product P additions can be determined from good records, and that information can be helpful in anticipating where by-product rates may need to be reduced and when additional land areas may be needed.

Table 1. Approximate nutrient removal (lb./unit of yield) in the harvested portion of several Michigan field crops.[4]

Crop		Unit	N	P_2O_5	K_2O
			- - - - lb. per unit - - - -		
Alfalfa	Hay	ton	45[5]	13	50
	Haylage	ton	14	4.2	12
Barley	Grain	bushel	0.88	0.38	0.25
	Straw	ton	13	3.2	52
Beans (dry edible)	Grain	cwt	3.6	1.2	1.6
Bromegrass	Hay	ton	33	13	51
Buckwheat	Grain	bushel	1.7	0.25	0.25
Canola	Grain	bushel	1.9	0.91	0.46
	Straw	ton	15	5.3	25
Clover	Hay	ton	40[5]	10	40
Clover-grass	Hay	ton	41	13	39
Corn	Grain	bushel	0.90	0.37	0.27
	Grain[6]	ton	26	12	6.5
	Stover	ton	22	8.2	32
	Silage	ton	9.4	3.3	8.0
Millet	Grain	bushel	1.1	0.25	0.25
Oats	Grain	bushel	0.62	0.25	0.19
	Straw	ton	13	2.8	57
Orchardgrass	Hay	ton	50	17	62
Potatoes	Tubers	cwt	0.33	0.13	0.63
Rye	Grain	bushel	1.1	0.41	0.31
	Straw	ton	8.6	3.7	21
	Silage	ton	3.5	1.5	5.2
Sorghum	Grain	bushel	1.1	0.39	0.39
Sorghum-Sudangrass	Hay	ton	40	15	58
(Sudax)	Haylage	ton	12	4.6	18
Soybeans	Grain	bushel	3.8	0.80	1.4
Spelts	Grain	bushel	1.2	0.38	0.25
Sugar Beets	Roots	ton	4.0	1.3	3.3
Sunflower	Grain	bushel	2.5	1.2	1.6
Timothy	Hay	ton	45	17	62
Trefoil	Hay	ton	48[5]	12	42
Wheat	Grain	bushel	1.2	0.63	0.37
	Straw	ton	13	3.3	23

[4] Source: Nutrient Recommendations for Field Crops in Michigan. (Warncke *et al.*, 2004a)
[5] Legumes get most of their nitrogen from air.
[6] High moisture grain.

Table 2. Approximate nutrient removal (lb./unit of yield) in the harvested portion of several Michigan vegetable crops.[1]

Crop[2]	**N**	**P_2O_5**	**K_2O**
	---- lb./ton[3]----		
Asparagus, crowns new planting, or established	13.4	4.0	10
Beans, snap	24	2.4	11
Beets, red	3.5	2.2	7.8
Broccoli	4.0	1.1	11
Brussels Sprouts	9.4	3.2	9.4
Cabbage, fresh market, processing, or Chinese	7.0	1.6	6.8
Carrots, fresh market or processing	3.4	1.8	6.8
Cauliflower	6.6	2.6	6.6
Celeriac	4.0	2.6	6.6
Celery, fresh market or processing	5.0	2.0	11.6
Cucumbers, pickling (hand or machine harvested)	2.0	1.2	3.6
Cucumber, slicers	2.0	1.2	3.6
Dill	3.5	1.2	3.6
Eggplant	4.5	1.6	5.3
Endive	4.8	1.2	7.5
Escarole	4.8	1.2	7.5
Garden, home	6.5	2.8	5.6
Garlic	5.0	2.8	5.6
Ginseng	4.6	1.2	4.6
Greens, Leafy	4.8	2.0	6.0
Horseradish	3.4	0.8	6.0
Kohlrabi	6.0	2.6	6.6
Leek	4.0	2.6	4.8
Lettuce, Boston, bib	4.8	2.0	9.0
Lettuce, leaf, head, or Romaine	4.8	2.0	9.0
Market Garden	6.5	2.8	5.6
Muskmelon	8.4	2.0	11

Crop[2]	N	P_2O_5	K_2O
	---- lb./ton[3] ----		
Onions, dry bulb or green	5.0	2.6	4.8
Pak Choi	7.0	1.6	6.8
Parsley	4.8	1.8	12.9
Parsnip	3.4	3.2	9.0
Peas	20	4.6	10
Peppers, bell, banana, or hot	4.0	1.4	5.6
Pumpkins	4.0	1.2	6.8
Radish	3.0	0.8	5.6
Rhubarb	3.5	0.6	6.9
Rutabagas	3.4	2.6	8.1
Spinach	10	2.7	12
Squash, hard Squash, summer	4.0 3.6	2.2 2.2	6.6 6.6
Sweet Corn	8.4	2.8	5.6
Sweet Potato	5.3	2.4	12.7
Swiss Chard	3.5	1.2	9.1
Tomatoes, fresh market or processing	4.0	0.8	7.0
Turnip	3.4	1.2	4.6
Watermelon	4.8	0.4	2.4
Zucchini	4.6	1.6	6.6

[1]Source: Nutrient Recommendations for Vegetable Crops in Michigan. (Warncke *et al.*, 2004b)
[2]Values used for some crops are estimates based on information for similar crops.
[3]1 ton = 20 cwt.

APPENDICES ARE PROVIDED FOR INFORMATION PURPOSES

APPENDIX I -- References on State and Federal Laws and Regulations

A person applying, distributing, and storing fertilizer or organic materials in Michigan, must comply with the relevant state and federal laws and regulations promulgated under these statutes, including but not limited to:

1. The Superfund Amendments and Reauthorization Act (SARA) of 1986 Title III: Emergency Planning and Community Right-to-Know. This federal law provides mechanisms to prepare for chemical emergencies. Persons storing anhydrous ammonia above the "Threshold Planning Quantity" of 500 pounds must notify the State Emergency Response Commission within DEQ, the Local Emergency Planning Committee, and the local fire chief that they store this chemical above threshold at some time. The location of the storage facility and name and telephone number of a responsible person must also be reported. If there is a spill or release of anhydrous ammonia above the "reportable quantity" of 100 pounds, the same organizations must be notified. MSU Extension Bulletin E-2575 (Jess *et al*., 2001) contains information to help farmers comply with this law.

2. Public Law 92-500, the Federal Water Pollution Control Act of 1972, as amended. This Act established a central goal to "restore and maintain the chemical, physical and biological integrity of the nation's water". The Water Quality Amendment Act of 1987 added provisions for the management of nonpoint source pollution. As part of Michigan's nonpoint source pollution control management strategy, Best Management Practices (BMPs) for fertilizer use and storage have been developed to meet requirements of the U.S. Clean Water Act.

3. Public Act 451, the Natural Resources and Environmental Protection Act of 1994, as amended. This Michigan law was enacted to protect the environment and natural resources of the state; to codify, revise, consolidate, and classify laws relating to the environment and natural resources of the state; to regulate the discharge of certain substances into the environment; and to regulate the use of certain lands, waters, and other natural resources of the state.

   A. Part 31, (formerly Public Act 245, the Michigan Water Resources Commission Act of 1929, as amended). This part provides a broad substantive basis for protection and conservation of surface water and groundwater resources of the state. Under Part 31, it is unlawful for any person directly or indirectly to discharge into the waters of the state any substances which are or may become injurious to the public health or ecosystem. Violations of Part 31 subject the violator to civil fines up to $25,000 per day and to criminal penalties including two years in prison. Part 31 defines "waters of the state" as the groundwaters, lakes, rivers and streams and all other watercourses and waters within the confines of the state, as well as the Great Lakes bordering the state.

B. Part 55, (formerly Public Act 348, Air Pollution Control Act of 1965, as amended). The Michigan Department of Environmental Quality has statutory authority, powers, duties, functions and responsibilities for rule-making and for issuance of permits and orders to control air pollution. This part provides for control of air pollution which may be in the form of a dust, fume, gas (including anhydrous ammonia), mist, odor, smoke or vapor in quantities which are or can become injurious to human health or welfare, animal life, plant life or to property, or which interfere with the enjoyment of life or property.

C. Part 83, (formerly Public Act 171, Michigan Pesticide Control Act of 1976, as amended). This part regulates registration, distribution, labeling, storage, disposal, and application of pesticides in Michigan.

D. Part 85, (formerly Public Act 198, Fertilizer Act of 1975, as amended). This part regulates the manufacture, distribution, sale, labeling, advertising, and storage of fertilizers, soil conditioners, peat and peat moss, and composted materials. Regulation No. 641, Commercial Fertilizer Bulk Storage. This set of rules regulates the commercial storage of bulk fertilizer. Regulation No. 642, On Farm Fertilizer Bulk Storage. This set of rules regulates the on-farm storage of bulk liquid fertilizer.

E. Part 115, (formerly Public Act 641, the Michigan Solid Waste Management Act of 1978, as amended). This part is to protect the public health and environment; to provide for the regulation and management of solid waste, such as garbage, rubbish, ashes, incinerator ash, incinerator residue, street cleanings, municipal and industrial sludges, food processing wastes, solid commercial and solid industrial wastes, and animal waste other than organic waste generated in the production of livestock and poultry; and to regulate materials that can be placed in licensed solid waste disposal facilities, such as sanitary landfills. A person shall not apply sludges, ashes, or other solid waste to the land without authorization under the Act, unless a plan for managing the wastes as non-detrimental materials appropriate for agricultural or silvicultural use has been approved by the director of the Michigan Department of Environmental Quality.

F. Part 201, (formerly Public Act 307, the Environmental Response Act of 1982, as amended). This part provides for the identification, risk assessment, and priority evaluation of environmental contamination and provides for response activity at certain facilities and sites. This part also provides exemption from liability for farmers if they follow generally accepted agricultural and management practices.

4. Public Act 154, the Michigan Occupational Safety and Health Act (MIOSHA) of 1974, as amended. The Michigan Department of Public Health and Michigan Department of Licensing and Regulatory Affairs jointly enforce this law to protect workers. Employers are required to have available for employees' review Material Safety Data Sheets (MSDS) on all hazardous chemicals that are present in the

work place. Employers must also develop and implement a written employee training program and ensure that all hazardous material containers are properly labeled.

5. Public Act 162, Michigan Liming Materials Law of 1955, as amended. This Act provides for the licensing and inspection of agricultural liming materials and regulates the labeling and sale of these products. In addition, this law prescribes penalties for violations. Liming materials, as defined by this Act, include any form of limestone, lime rock, marl, slag, by-product lime, industrial or factory refuse lime, water softener lime, and any other material used to correct soil acidity.

6. Public Act 346, the Commercial Drivers' License Law of 1988, as amended. This Act may require farmers to obtain endorsements on their commercial drivers' licenses for transporting U.S. Department of Transportation classified hazardous materials including anhydrous ammonia. This requirement applies if the total vehicle weight (i.e., towing and trailing vehicles) exceeds 26,000 pounds gross vehicle weight rating (GVWR).

7. Public Act 368, the Michigan Public Health Code of 1978, as amended. An Act to protect and promote the public health; to codify, revise, consolidate, classify, and add to the laws relating to the public health; to provide for the prevention and control of diseases and disabilities; and to provide for the classification, administration, regulation, financing, and maintenance of personal, environmental and other health services and activities.

8. Public Act 399, the State of Michigan Safe Drinking Water Act of 1976, as amended. An Act to protect the public health; to provide for supervision and control over public water supplies; to provide for the classification of public water supplies; and to provide for continuous, adequate operation of privately owned, public water supplies. This Act sets forth standard isolation distances from any existing or potential sources of contamination and also regulates the location of public water supplies with respect to major sources of contamination.

APPENDIX II -- References Cited

AAPFCO/TFI. *Commercial Fertilizers*. 2004. Association of American Plant Food Control Officials and the Fertilizer Institute, Univ. of Kentucky, 2005.

ASAE Standards: ASAE S341.3. *Procedure for Measuring Distribution Uniformity and Calibrating Granular Broadcast Spreaders*. pgs. 198-201. American Society of Agricultural Engineers, 2004.

Bartholic, J.F. Groundwater and Agriculture. pgs. 343-359. *Proceedings of the Plant Nutrient Use and the Environment Symposium*, October 21-23, 1985, Kansas City, MO. The Fertilizer Institute,1985.

Biernbaum, J.A. *Root-zone Management of Greenhouse Container-grown Crops to Control Water and Fertilizer Use*. Hort Technology, Jan/Mar. 2(1):127-132, 1992.

Biernbaum, J.A. *Subirrigation Could Make Environmental and Economical Sense for Your Greenhouse*. Professional Plant Growers Association News, Vol. 24(4): 2-14, 1993.

Broder, M.F. *Best Ways to Calibrate Your Fertilizer Applicator*. Circular Z-138. TVA/OACD-82/19. Tennessee Valley Authority, National Fertilizer Development Center, 1982.

Brown, J.R. *Recommended Chemical Soil Test Procedures for the North Central Region*. North Central Regional Research Publication No. 221, Missouri Ag. Exp. Sta., 1998.

Christenson, D.R. *Phosphorus Demonstration Trial Results*, 1986-1989. Dept. of Crop and Soil Sciences, Mich. State Univ., 1989.

Christenson, D.R., Warncke, D.D., and Leep, R. *Lime for Michigan Soils*. MSU Extension Bulletin No. E-471, Mich. State Univ., 1993.

Cummings, T.R., Twenter, F.R., and Holtschlag, D.J. *Hydrology and Land Use in Van Buren County, Michigan*. U.S. Geological Survey, Water-Resources Investigations Report No. 84-4112, U.S. Geological Survey, 1984.

Ellis, B.G. 1988. *Nitrates in Water Supplies*. pgs. 75-83. Chapter No. 4, Proceedings Water Quality: A Realistic Perspective, Feb. 28, 1988.

Ellis, B.G., and Olson, R.A. Economic, Agronomic and Environmental Implications of Fertilizer Recommendations. North Central Regional Research Publication No. 310, Ag. Exp. Sta., Mich. State Univ., 1986.

Fernandez, T. (ed). *Management Practices for Michigan Wholesale Nurseries*. Dept. of Horticulture, Mich. State Univ., p. 209, 2004.

Hanson, E.J. *Fertilizing Fruit Crops*. MSU Extension Bulletin No. E-852, Mich. State Univ., 1996.

Hanson, E. J. and Hancock, J.A. *Managing the Nutrition of Highbush Blueberries*. MSU Extension Bulletin No. E-2011, Mich. State Univ.,1996.

Hanson, E.J. and Hull, J. *Plant Tissue Sampling for Determining Fertilizer Needs of Fruit Crops*. MSU Extension Bulletin No. E-2482, Mich. State Univ., 1994.

Hay, D.R., Vitzthum, E.F., Witkowski, J.F., and Nelson, E.W. (eds). *Using Chemigation Safely and Effectively*. MSU Extension Bulletin No. E-2099, Mich. State Univ., 1988.

Horticultural Water Quality Alliance. *Water Quality Action Manual for Greenhouse and Nursery Growers*. Society of American Florists, 1992.

Jacobs, L.W., *Recordkeeping System for Crop Production.* MSU Extension Bulletin No. E-2340, Mich. State Univ., 1992.

Jacobs, L.W., Böhm, S.U., and MacKellar, B.A. *Recordkeeping System for Crop Production--Manure Management Sheets*. MSU Extension Bulletin No. E-2344, Mich. State Univ., 1993.

Jacobs, L.W., and Go, A. *Michigan State University Nutrient Management (MSUNM) Microcomputer Program*, Windows Version 2.0. Dept. of Crop and Soil Sciences, Mich. State Univ., 2006.

Krizek, A., and Jess, L. *Emergency Planning for the Farm*. MSU Extension Bulletin No. E-2575, Mich. State Univ., 2005.

Lucas, R.E., and Warncke, D.D. *Managing Organic Soils to Reduce Non-point Pollution*. MSU Extension Bulletin No. WQ-03, Mich. State Univ., 1988.

MCARD. 2014. Right to Farm. *Generally Accepted Agricultural and Management Practices for Cranberry Production*. Michigan Commission of Agriculture & Rural Development.

MCARD. 2014. Right to Farm. *Generally Accepted Agricultural and Management Practices for Irrigation Water Use*. Michigan Commission of Agriculture & Rural Development.

MCARD. 2014. Right to Farm. *Generally Accepted Agricultural and Management Practices for Manure Management and Utilization*. Michigan Commission of Agriculture & Rural Development.

MDARD. 1991. *Michigan Agricultural Statistics*. Michigan Agricultural Statistics Service, Michigan Department of Agriculture& Rural Development, 1991.
MDARD. *Michigan Agricultural Statistics, 2004-2005*. Michigan Agricultural Statistics Service, Michigan Department of Agriculture & Rural Development, 2005. (http://www.nass.usda.gov/mi)

DNR. *State of Michigan Phosphorus Reduction Strategy for the Michigan Portion of Lake Erie and Saginaw Bay*. Michigan Department of Natural Resources, Surface Water Quality Division, 1985. (Available from the Michigan Department of Environmental Quality, Lansing, MI.)

DNR. M*ichigan's 1988 Non-point Pollution Assessment Report*. Michigan Department of Natural Resources, Surface Water Quality Division, 1988. (Available from the Michigan Department of Environmental Quality, Lansing, MI.)

Meints, V.W., and Robertson, L.S. *Soil Sampling for No-Till and Conservation Tillage Crops*. MSU Extension Bulletin No. E-1616, Mich. State Univ., 1983.

MidWest Plan Service. *Designing Facilities for Pesticide and Fertilizer Containment*, Revised 1st Edition. MWPS-37, Iowa State Univ., 1995.

NRAES. *Trickle Irrigation in the Eastern United States*. Publication NRAES-4, Northeast Regional Agricultural Engineering Service, Cornell Univ., 1981.

Rynk, R. *On-Farm Composting Handbook*. NRAES-54, Northeast Regional Agricultural Engineering Service, 1992.

TVA. *Fertilizer Summary Data - 1990*. Tennessee Valley Authority, National Fertilizer and Environmental Research Center, 1990.

USDA. *Improving Soils with Organic Wastes*. p. 157. U.S. Dept. of Agriculture, 1978.

USDA. *National Engineering Handbook, Part 637*, *Environmental Engineering, Chapter 2, Composting*. U.S. Department of Agriculture, Natural Resources Conservation Service, 2000.

USDA-NRCS Field Office Technical Guide. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC. (http://www.nrcs.usda.gov/technical/efotg/)

Vitosh, M.L. *Nitrogen Management Strategies for Potato Producers*. MSU Extension Bulletin No. WQ-09, Mich. State Univ., 1986.

Vitosh, M.L. *N-P-K Fertilizers: Types, Uses and Characteristics*. MSU Extension Bulletin No. E-896, Mich. State Univ., 1990.

Vitosh, M.L. *Nitrogen Management Strategies for Corn Producers*. MSU Extension Bulletin No. WQ-06, Mich. State Univ., 1991.

Vitosh, M.L. *Irrigation Scheduling*. IFS/2-80, Michigan Irrigation Guide, Mich. State Univ., 1992.

Vitosh, M.L. and Darling, B.P. *Starter Fertilizers for Corn - Are They Necessary?* MSU Extension Bulletin No. E-2289, Mich. State Univ., 1990.

Vitosh, M.L., Darling, B.P., and Campbell, D.B. *Nitrate Testing Clinics*. Proceedings of the Nineteenth North Central Extension-Industry Soil Fertility Conference, Potash and Phosphate Institute, 1989.

Vitosh, M.L. and Jacobs, L.W. *Nutrient Management to Protect Water Quality*. MSU Extension Bulletin No. WQ-25, Mich. State Univ., 1996.

Vitosh, M.L., Silva, G.H. and Pruden, T.M. *On-Farm Nitrogen Fertilizer Demonstrations*. Proceedings of the Twenty-First North Central Extension-Industry Soil Fertility Conference, Potash and Phosphate Institute, 1991.

Warncke, D.D. *Sampling Soils for Fertilizer and Lime Recommendations*. MSU Extension Bulletin No. E-498, Mich. State Univ., 1998.

Warncke, D.D. and Dahl, J.G. *Median Soil Test Values for Mineral Soils in Michigan Counties*. Dept. of Crop and Soil Sciences, Mich. State Univ., 1995.

Warncke, D.D., Dahl, J., Jacobs, L., and Laboski, C. *Nutrient Recommendations for Field Crops in Michigan*. MSU Extension Bulletin No. E-2904, Mich. State Univ., 2004a.

Warncke, D.D., Dahl, J., and Zandstra, B. *Nutrient Recommendations for Vegetable Crops in Michigan*. MSU Extension Bulletin No. E-2934, Mich. State Univ., 2004b.

Warncke, D.D. and Gehl, R. *Sampling Soils for Fertilizer and Lime Recommendations: Frequency of Soil Sampling*. MSU Extension Bulletin No. E-498S, Mich. State Univ., 2006.

Warncke, D.D. and Krauskopf, D.M. *Greenhouse Growth Media: Testing and Nutrition Guidelines*. MSU Extension Bulletin No. E-1736, Mich. State Univ., 1983.

Wilkinson, R.H. *On-Farm Agrichemical Storage and Handling*. MSU Extension Bulletin No. E-2335, Mich. State Univ., 1996.

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