12 Nutrient Management Module No. 12

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Water Quality Considerations and Regulations

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Introduction

This module is the twelfth in a series of Extension materials designed to provide Extension agents, Certified Crop Advisers (CCAs), consultants, and producers with pertinent information on nutrient management issues. To make the learning 'active,' and to provide credits to CCAs, a quiz accompanies this module. In addition, realizing that there are many other good information sources, including previously developed Extension materials, books, web sites, and professionals in the field, we have provided a list of additional resources and contacts for those wanting more in-depth information about water quality considerations and regulations. This module covers Rocky Mountain CCA Nutrient Management Competency Area II: Nutrient movement in soil and water.

Objectives

After completing this module, the reader should:

1. Recognize nutrient impacts on different water bodies
2. Understand common water quality issues
3. Become familiar with federal and state water quality regulations
4. Identify Best Management Practices (BMPs) for preventing nutrient movement from fields

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Background

Increased awareness and concern about national water quality issues have led to more stringent environmental regulations over the past three decades. Acceptable inputs of potential pollutants (e.g., nitrogen, phosphorus) into water bodies as well as stricter penalties for water quality violations stem from a complex set of environmental regulations. Understanding the effect of these regulations on agriculture as well as identifying Best Management Practices (BMPs) and monitoring strategies should prove useful for effective on-farm and water quality management. Before examining these topics, it is first important to explore water quality problems associated with nutrients as well as the pathways in which nutrients can reach water bodies.

Eutrophication

The U.S. Environmental Protection Agency (EPA) has identified eutrophication as the main cause of impaired surface water quality (USEPA, 1999). Eutrophication is a process characterized by high nutrient concentrations and high aquatic biomass, leading to low dissolved oxygen levels and low water clarity (Pierzynski et al., 2000). The process of eutrophication may negatively impact water use for recreation, industry, fisheries, drinking, and aesthetics, as well as decrease biological diversity. For example, while more productivity may increase numbers of fish, it also increases abundance of less desirable species (e.g., suckers, carp) (Welch, 1980). Unlike cropping systems, where a number of nutrients affect plant growth, nitrogen (N) and phosphorus (P) are the principle nutrients involved in eutrophication.

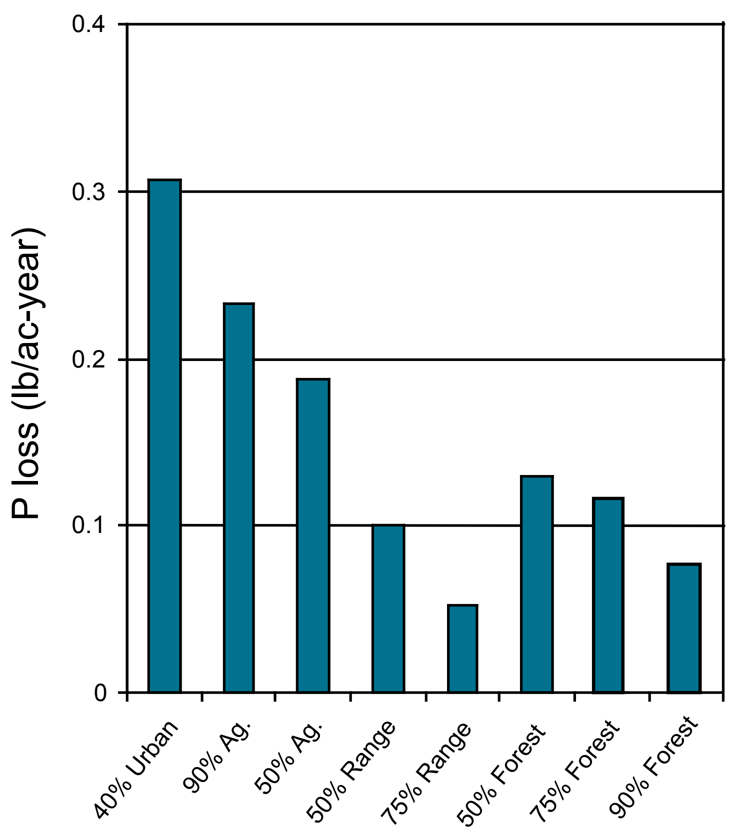

Figure 1. Phosphorus runoff loss as an effect of land use in the United States (Modified from NRCS, 1997).

High N and P concentrations in surface water often lead to eutrophication. However, the process is not caused by N or P independently, but is instead a result of complex interactions between both nutrients, temperature, sunlight, and populations of algal predators such as zooplankton. The type of water body also affects which nutrient is causing eutrophication. Algal growth is generally limited in saltwater and freshwater by N and P, respectively; two exceptions to this are alpine lakes and wetlands, where N generally limits growth. Different land uses also affect the amount of nutrients entering water bodies, and are therefore a consideration when addressing eutrophication. For example, agricultural land has been found to lose more P in runoff than rangeland or forests, but less than urban areas (Figure 1). Although the progression of eutrophication is identified as a natural occurrence in some aquatic systems, 'cultural eutrophication' is a term used to describe humans' influence on the acceleration of this process (Ryding and Rast, 1989).

To understand the interactions related to eutrophication, it is important to first explore the progression of the process, the role that N and P play, the impacts of eutrophication on different water bodies, and the other biological and physical factors involved. Water bodies are often grouped into different 'trophic levels' (fertility measured by degree of growth). A water body's trophic level generally may be classified as 'ultra-oligotrophic' (very low), 'oligotrophic' (low), 'mesotrophic' (medium), 'eutrophic' (high), and 'hypereutrophic' (very high). Figure 2 shows that as eutrophication progresses, 'primary production' (aquatic plant and algae growth) increases and dissolved oxygen and biodiversity decrease. Dissolved oxygen decreases as plant and algal populations die and are decomposed by bacteria (Ryding and Rast, 1989).

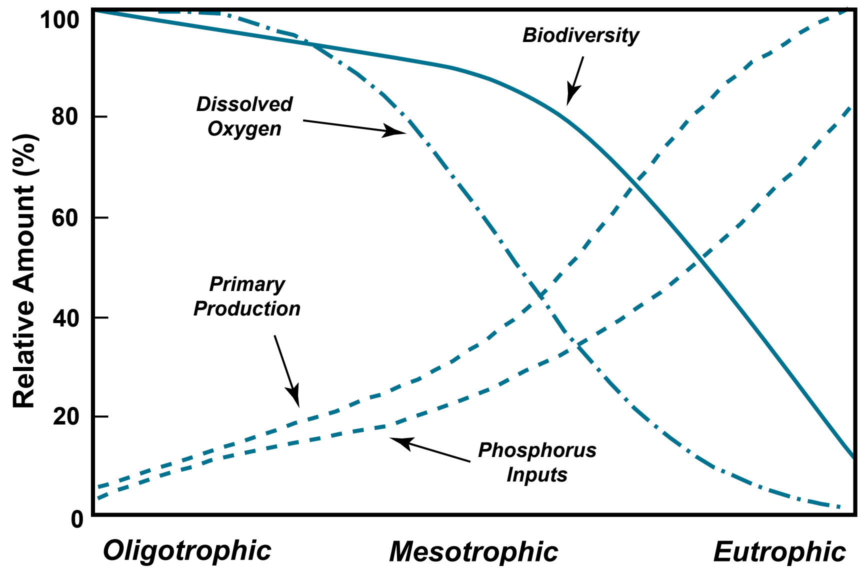

Figure 2. Overview of the changes of freshwater eutrophication (Pierzynski et al., 2000).

Algae, Cyanobacteria and Eutrophication

Algae, including 'dinoflagellates,' 'diatoms' and green algae, as well as 'cyanobacteria' (a photosynthesizing bacteria) occur naturally in surface water, but may lead to water quality problems if they occur at excessive levels. In the late 1980s, the toxic dinoflagellate *Pfiesteria piscicida* was linked to fish kills and human neurological problems on the East Coast, resulting in increased regulations for agricultural operations (Sims and Coale, 2001). Green algae and diatoms contribute to eutrophication and produce green and brown films or sludges respectively, yet pose no health risks. Cyanobacteria (blue-green in color) produce over 70 types of toxins that are dangerous for livestock or domestic animals that drink from waters contaminated with these organisms (www.acnatsci.org). Cyanobacteria can outcompete algae because they have gas vacuoles that allow them to stay close to the surface (and continue photosynthesizing) while algae sometimes naturally settle to lower depths. They also can fix N similar to *Rhizobia* on legumes as discussed in Nutrient Management Module 3 (*NM 3*), so N deficiencies in a water body do not substantially inhibit their growth.

Algae and cyanobacteria are also used as eutrophic indicators. For example, a study of the Yellowstone River used a suite of eutrophic-related species to identify potentially eutrophic river sections. The study found high numbers of eutrophic species between Billings and Forsyth and low numbers near Livingston (Peterson and Porter, 2002).

Nutrient Limitation

Identifying whether N or P is the primary cause of eutrophication is important so producers and watershed managers can focus on decreasing inputs of the 'limiting' nutrient. A N:P ratio is often used to identify the limiting nutrient, because algae need a certain balance of these nutrients in their cells, similar to plants. The N:P ratio is calculated by dividing the mass concentration of total N (i.e., mg/L or ppm) by the mass concentration of total P in the water. If the N:P ratio is greater than 7:1 by concentration, P is likely the limiting factor for algal growth and if the ratio is less than 7:1, N is likely the limiting nutrient. This 'critical' N:P ratio is also often reported as atoms N/atoms P, in which case the ratio is 16:1. There is a vague range around the N:P ratio where either nutrient or both nutrients may be limiting growth, which also often happens in cropping systems. P levels above approximately 35 ppb (parts per billion)

P is the 'threshold', or concentration, at which eutrophication occurs, while the N threshold of 500-1,000 ppb N is much higher (Q&A #1; Table 1). Because the threshold is so low for P, water bodies that have naturally low P concentrations will be very sensitive to P inputs from runoff and erosion (Pierzynski et al., 2000).

Q&A #1

My fish pond has 100 ppb of P and 1,000 ppb of N and an algal bloom recently formed. What nutrient is limiting algal growth and what can I expect to happen to the pond?

P is probably limiting growth because the N:P ratio (10:1) is greater than 7:1. You should therefore identify possible P sources and try to reduce their input into surface water (discussed later). Algal blooms are often a first sign of cultural eutrophication. The following sequence characterizes algal blooms: 1) sunlight cannot penetrate to deeper aquatic plants, which die; 2) decreased dissolved oxygen causes more plants and some fish to die and depletes aerobic bacteria; 3) anaerobic bacteria begin to thrive, causing a "rotten egg" smell; and 4) eventually, the pond will fill with decaying organic matter and essentially will become a non-functioning water body.

Eutrophic Variability

Eutrophication may vary greatly across the surface of a lake or river, with depth, and over time. An example of variability across the surface might involve high eutrophication next to the source of nutrient inputs while the rest of the lake remains unaffected. The effects of eutrophication also vary with depth. Surface plant growth inhibits light penetration to deeper zones, resulting in decreased biodiversity of subsurface vegetation and 'benthic' (bottom-living) organisms. Turbulence caused by high flows, temperature fluctuations, or dredging may also release nutrients several years after their deposition into the system.

Flow changes and contact with more land uses make river and stream eutrophication more variable and often more complex than in lakes. The specific nutrient that limits growth changes among rivers as well as within a single river. For example, the Clark Fork River's atomic N:P ratio ranges from 50:1 just below Deer Lodge to 10:1 just above Missoula. Therefore, P is initially limiting, but as the ratio lowers, N becomes the limiting nutrient (www.deq.state.mt.us).

Regional Eutrophication

Eutrophication in Montana and Wyoming is minimal. In Montana, Lake Mary Ronan, Abbott Lake, Echo Lake, and Rogers Lake are all potentially mesotrophic or eutrophic with elevated levels of chlorophyll *a* and total P (Bonnie Ellis, personal communication). Management efforts can prevent the onset or advancement of eutrophication. For example, Flathead Lake (northwest of

Table 1. Trophic level indicators.

Trophic Category	TP (ppb)	Maximum Chl *a* (ppb)	Mean Secchi (ft)
Ultra-oligotrophic	<4	<3	>40
Oligotrophic	<10	<8	>20
Mesotrophic	10-35	8-25	<10-20
Eutrophic	35-100	25-75	<5-20
Hypertrophic	>100	>75	<5

Explanation of terms:

TP = mean annual in-lake total phosphorus concentration

Max. Chl *a* = peak annual chlorophyll *a* concentration in surface waters

Mean Secchi = mean annual Secchi depth transparency, indication of clarity

(Adapted from Ryding and Rast, 1989)

Missoula) is classified as oligomesotrophic (between low and medium fertility); therefore, BMPs and monitoring have been implemented to keep the lake from becoming mesotrophic (www.deq.state.mt.us).

Human Health and Aquatic Life Concerns

P is not known to be toxic to humans or fish at concentrations normally observed, but elevated levels of N may cause concern. The primary health risk associated with nitrates (NO_3^-) and nitrites (NO_2^-) is 'methemoglobinemia,' or blue-baby disease (*NM 3*). In the stomach of an infant or young livestock animal, bacteria can convert excess nitrate to nitrite. Any nitrite formed enters the blood and inhibits oxygen carrying capacity by converting hemoglobin to 'methemoglobin,' which cannot transport adequate oxygen. The disease is not a threat to infants older than six months because the stomach begins producing enough acid to kill the bacteria. A NRCS study suggests that nitrate is much less of a health risk if water is from a deep confined or bedrock aquifer because leaching is less of a concern. Conversely, shallow wells in agricultural areas pose a potential risk of nitrate contamination, especially where groundwater is less than 100 feet below the surface and the soil is relatively permeable (NRCS, 1997).

The largest threat to aquatic life is ammonia (NH_3), which is toxic to some organisms in very small amounts. One study showed that the ammonia concentration required to kill 50% of fish species after four days ranged from 0.08 to 1.09 ppm (mg/L) for 'salmonids' (e.g., trout) and 0.14 to 4.60 ppm for nonsalmonids (USDA, 1992). The majority of ammonia salmonid kills are caused by fertilizer or manure spills rather than runoff or leaching (www.thamesriver.org), and may be avoided by implementing BMPs discussed later as well as in *NM 13*.

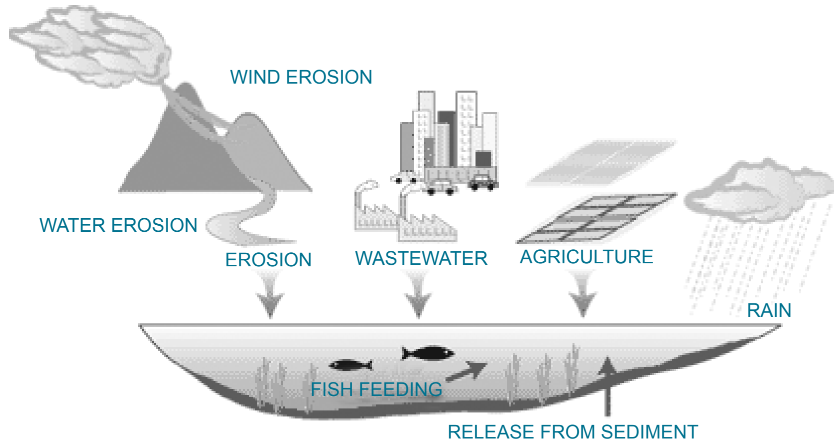

Figure 3. Causes of water quality impairment (From http://deq.state.wy.us/).

Nutrient Transport

Leaching, erosion, and runoff of fertilizers, livestock waste, and land-applied wastes have been linked to nutrient contamination of ground and surface water (NRCS, 1997). However, agriculture is only one of many causes of water quality impairment from nutrients. Golf courses, septic drain fields and natural inputs also contribute to water quality concerns (Figure 3).

Retaining N and P on cropped fields leads to increased crop uptake and yield, more profit, less fertilizer waste, and less environmental impact (Hatch et al., 2002). Nutrients may move through soil and then to the surface water or percolate into ground water (Figure 4, next page), so understanding all possible paths into water bodies is important.

Nitrogen

Nitrogen transport poses a concern when present in excess of plant needs and when water is available to transport it into water bodies. Nitrate and nitrite both are mobile and available, but nitrate is present in soil and water in far larger quantities. Nitrite is the intermediate step in nitrification, and it exists under most soil conditions for only a short amount of time in low concentrations (*NM 3*). Leaching of nitrate and nitrite and potential movement into ground water is most likely with high precipitation,

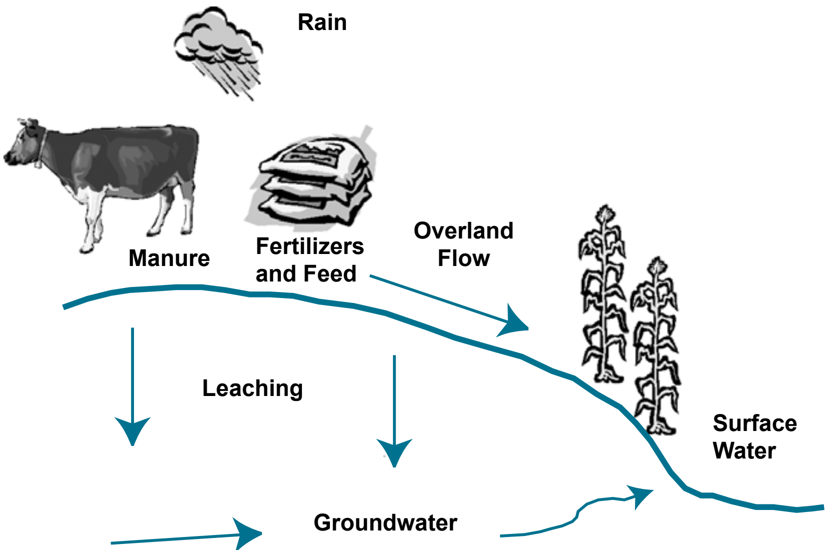

Figure 4. Processes related to nutrient movement in soil and water in agricultural systems.

irrigated soils, and/or coarse-textured, shallow soils (*NM 3*). In many Montana and Wyoming dryland systems, most nitrate and nitrite will not move into ground water because evapotranspiration often exceeds precipitation.

Other forms of N, such as ammonium (NH_4^+) and ammonia, pose less of a water quality concern. The ammonium cation is generally not a concern because it sorbs relatively strongly to negatively charged soil particles, is relatively immobile, and rapidly nitrifies to nitrate. However, in sandy soils, where sorption is less than in clay soils and pH is generally lower, leaching of ammonium may be significant (Ritter and Bergstrom, 2001).

Ammonia volatilization may be a concern downwind of concentrated organic wastes, such as feedlots. The volatilized ammonia gas may be deposited directly on surface waters or transported first to terrestrial areas and then to water bodies (*NM 3*). Ammonia is toxic to fish and aquatic vegetation when it exists in excessive amounts. It may also react with acidic gases in the atmosphere, forming ammonium salts that impact soil and water when deposited (www.dasc.vt.edu).

Q&A #2

How is water quality characterized?

Water quality can be placed into one of three categories: physical, biological, or chemical. Following are common properties of each category.

Physical: odor, turbidity, color, taste, sediment, and temperature.

Biological: protozoans, viruses, fecal coliform bacteria, macroinvertebrates, fish communities, and algae.

Chemical: gases, salts, nitrates, ammonia, phosphorus, pesticides, metals, fluoride, and dissolved oxygen.

Phosphorus

Phosphorus losses attributed to runoff and erosion are estimated to be as high as 75-90% of total P lost from agricultural systems (NRCS, 1997). Conversely, loss from leaching is relatively low, especially in the dryland systems of Montana and Wyoming (*NM 4*). Factors affecting surface P loss include fertilizer source and chemical form, tillage practice, fertilizer application rate, timing, and placement, slope, Soil Test Phosphorus (STP), and rainfall intensity, duration, and time after application. Montana and Wyoming soils have high amounts of low to medium STP levels (78% in Montana and 58% in Wyoming), indicating that soil P is often a yield-limiting factor in both states (Fixen and Roberts, 2002); therefore, there is also a larger economic incentive to prevent P loss.

Water Quality Regulations Affecting Agriculture

The Clean Water Act (CWA) of 1972 established a program for protecting the nation's waters. The primary objectives of the Act are to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" and provide "fishable and swimmable" waters at a national level (www.epa.gov). To address water quality, a number of methods and parameters are used (Q&A #2). Despite significant improvements in municipal and industrial wastewater treatment, a 2000 national water quality assessment of 699,946 miles found 269,258 miles (39%) of those miles to be impaired (www.epa.gov/305b/2000report).

Drinking Water Standards

The 1974 Safe Drinking Water Act requires EPA to set water quality standards for possible human health risks. The numeric standards range dramatically due to large differences in toxicities among pollutants. For example, the permitted drinking water standards for nickel and sulfate are 0.1 and 500 ppm, respectively (Pierzynski et al., 2000). In 1989, EPA set a standard of 10 ppm for nitrate-N (meaning nitrate expressed *as* N in ppm) and 1 ppm for nitrite-N in drinking water (Fetter, 1988). EPA mandates that municipal water suppliers collect nitrate and nitrite samples, but sampling frequency depends on a number of factors (see Appendix). Monitoring drinking water from private wells is generally done by individuals; the EPA recommends testing for nitrate annually. Materials such as *Montana Farm*A*Syst*, published by the Montana State University Extension Service, can guide individual monitoring and testing plans (see Appendix).

Surface Water Criteria

EPA also has established a number of surface water criteria for aquatic life that Montana and Wyoming have adopted. Both 'numeric' and 'narrative' criteria exist. Numeric criteria have set levels that are not to be exceeded while narrative criteria apply to substances or conditions that lack sufficient information to develop specific numeric criteria. For example, the ammonia chronic criterion is numeric and is dependent on pH, temperature, and the presence or absence of early life stages (ELS) of fish. Nitrate and phosphorus alternatively have narrative standards which prohibit "excessive amounts of which may cause violations of ARM 17.30.6371e" (www.deq.state.mt.us/wqinfo/Circulars/WQB-7.pdf). Identifying variability of contaminants and factors controlling them is complex and EPA is continually revising and evaluating this aspect of the CWA.

Point versus Nonpoint Pollution

The CWA regulates both point and nonpoint source pollution. Regulation of point source pollution is **mandatory**, while nonpoint source control is **voluntary**. Point source pollution is traceable to a specific, discernable location (e.g., sewage treatment plant pipe, canal) where it enters a water body. Concentrated Animal Feeding Operations (CAFOs) fall under point source regulations, while Animal Feeding Operations (AFOs) are nonpoint sources (see *NM 13* to determine the official designation of your operation). Nonpoint pollutants enter water bodies from many diffuse sources. The primary causes of nonpoint pollution are urban, agricultural, and industrial runoff. Nonpoint source pollution accounts for 65-75% of the nation's most polluted waters (Ruhl, 2000). To regulate water pollution, EPA developed the National Pollutant Discharge Elimination System (NPDES) and the TMDL (Total Maximum Daily Load) process.

A NPDES permit is required for all point source dischargers. CAFOs need NPDES permits, which contain limitations and conditions specific to the proposed discharge. Before a NPDES permit is granted, it must undergo a 30-day public review period.

Total Maximum Daily Load (TMDL)

Under Section 303(d) of the CWA, states, territories, and approved tribes must set water quality criteria for water bodies. These may be stricter than EPA standards, but must meet the minimum EPA levels. Establishing standards includes identifying the designated beneficial use of each water body (e.g., aquatic life, irrigation) and establishing water quality standards which protect the designated uses. If a water body does not meet its designated use, then a TMDL must be established and approved by EPA.

A TMDL is a calculation of the 'loading capacity' (maximum amount) of a pollutant that a water body can receive

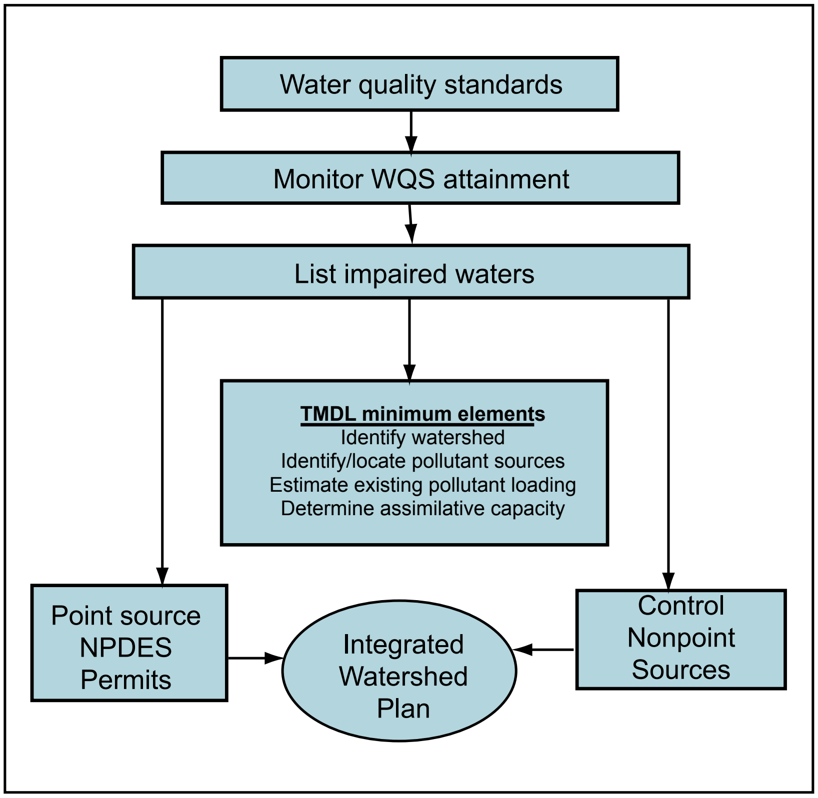

Figure 5. The TMDL process (Adapted from www.asiwpca.org).

Q&A #3

If a TMDL for P is established on my client's property, what happens if they are found to exceed the recommended input levels of P?

The procedure following elevated levels of P depends on whether it is a point or nonpoint source situation. If it is a point source violation, then the NPDES permit may be reevaluated to allow for the higher input level or it may be revoked. If the input is from a nonpoint source, the DEQ (or other agency/organization that is involved) will work with your client to identify BMPs that will effectively lower the input level.

without violating water quality standards. The loading capacity is distributed between point and nonpoint sources, with an allowance for natural inputs and a margin of safety (USEPA 1999, USEPA 2000). Every two years, states, territories, or authorized tribes must submit an updated list that includes priority water bodies as well as those scheduled for TMDL establishment. This list must undergo public review, in which TMDL calculations may be changed. The TMDL process involves a number of steps (Figure 5), with the Integrated Watershed Plan (IWP) as the final part of the process. The IWP provides a flexible framework for controlling pollutant sources and outlines Best Management Practices (BMPs) and monitoring for the impaired water body or watershed. All involved parties, including land owners, management agencies, and environmental organizations hopefully work together to develop the IWP.

Each state is responsible for working with EPA to develop TMDL plans. In Montana, 91 'Hydrologic Units' have been identified for TMDL development, including the Upper and Lower Missouri, Columbia, and Yellowstone watersheds. Wyoming's list of rivers includes parts of the Powder, Green, and Belle Fourche Rivers (see http://deq.state.mt.us/ and http://deq.state.wy.us/).

The TMDL process has been controversial, as standards and guidelines can be confusing and implementation of BMPs is often expensive. For example, if a TMDL for P is required on a stream that drains or runs through an agricultural operation, it is likely that the producer will play a part in load reduction (Q&A #3). Load reduction involves all of the input contributors agreeing upon a fair distribution of reductions as well as implementation of feasible BMPs. BMPs are then paid for by individual contributors or are often cost-shared through the Environmental Quality Incentives Program

(EQIP) or other programs (both public and private).

Water Quality Impairments in Montana and Wyoming

In 2002 there were 1,783 and 109 impairments in Montana and Wyoming, respectively (www.epa.gov/owow/tmdl). Montana and Wyoming have different TMDL listing procedures, which is probably the cause of the large difference in these neighboring states. A Montana water quality study conducted in 2002 assessed 20,099 miles of streams and rivers (current TMDL information for Wyoming was unavailable). Of the 9,667 miles found to be impaired, 29% were attributed to nutrients (Table 2). Ground water contamination is also a concern in Montana and Wyoming. A 1993 study of 3,400 drinking wells in Montana (Figure 6) found nitrate-N concentrations higher than 10 ppm in nearly 6% of tested wells (Bauder et al., 1993). Again, elevated nitrate levels in drinking water pose a potential concern due to risk of blue-baby disease.

Both states have point, nonpoint, and natural input impairments. One example of an impairment caused by natural inputs is in the Madison River Valley, where geothermal waters contribute

Table 2. Selected stream and river impairments in Montana

Impairment	Impaired (%)	Impaired Miles
Siltation	38.5	3,723
Nutrients	28.9	2,792
Salinity/TDS/chlorides	6.2	597
Bacteria/pathogens	4.5	434
Suspended solids	3.8	36

Modified from http://nris.state.mt.us

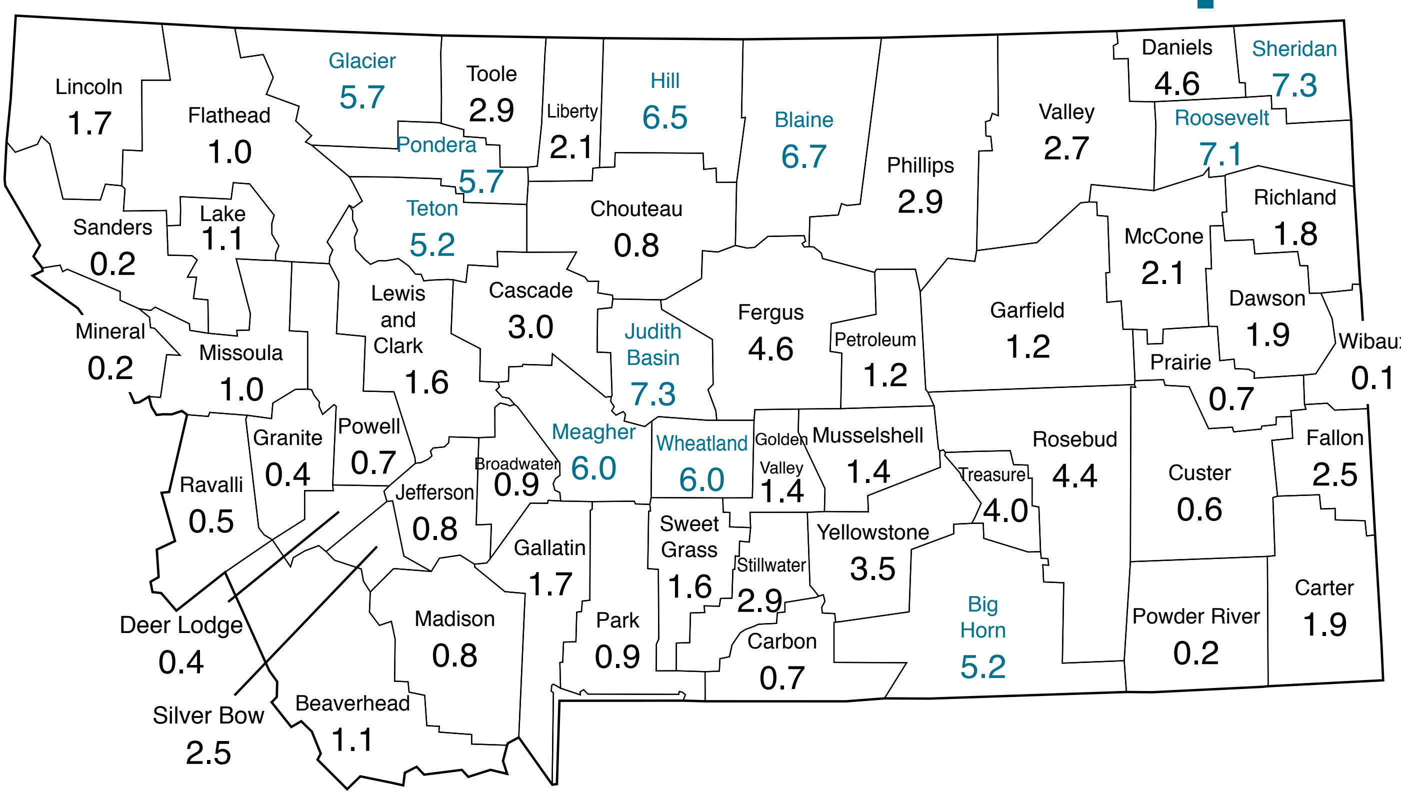

Figure 6. Average nitrate-N well concentrations (mg/L) by county in Montana based on sampling of 3,400 wells. The drinking water standard is 10 mg/L. (Modified from Bauder et al., 1993).

arsenic to the river's headwaters. Ground and surface water in some parts of the watershed naturally exceed the Montana groundwater standard of 18 ppb and the EPA drinking water standard of 50 ppb (a standard of 10 ppb officially went into effect in 2006). In the upper Madison River Valley, arsenic concentrations in irrigation water may reach 88.5 ppb (Tuck, 2001). When natural levels of contaminants are this high, creating a reasonable standard that adequately protects human and aquatic health is challenging. In summary, producers may need to take action to improve water quality, and management agencies or conservation groups can provide guidance and assistance with the process.

Management Practices to Decrease Nutrient Loss

There are a number of management practices that can decrease water contamination and nutrient loss. *NM 13*

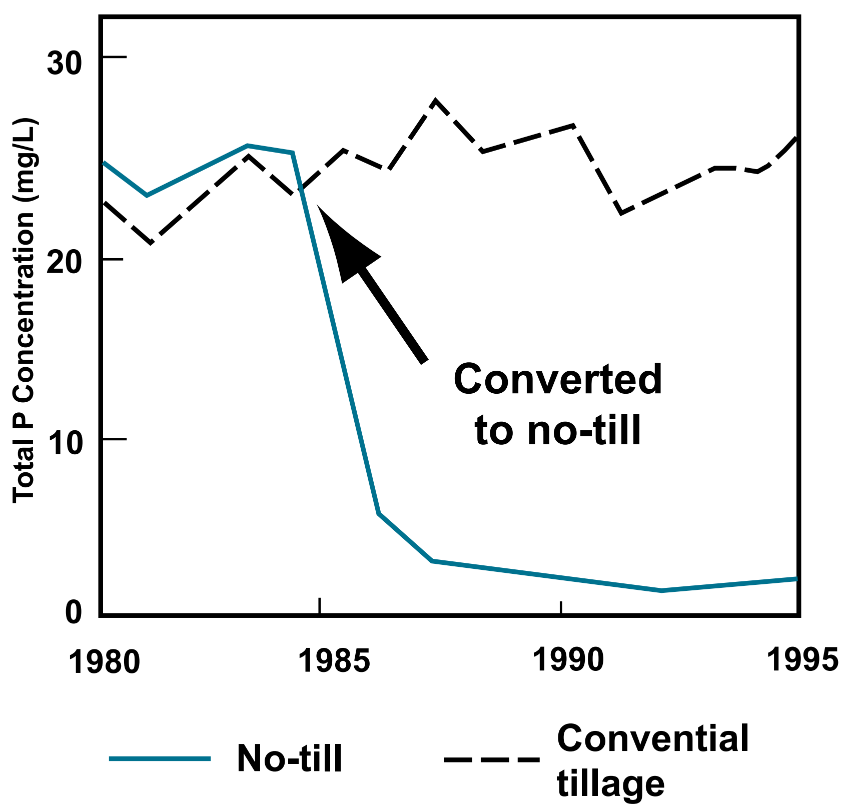

Figure 7. Using no-till in a wheat production system decreases total P concentration in runoff (Modified from Sharpley and Smith, 1994).

will address using the P index to assess potential loss, reducing off-site inputs of P, effectively storing, applying, and disposing of manure, developing nutrient management plans, and incorporating nitrification inhibitors into manure. Additional management practices that reduce off-site nutrient loss and potentially increase yield and long-term soil and water conservation are discussed below.

Tillage Practices

Conservation tillage involves leaving crop residues on a rough soil surface to reduce erosion (Dept. of Agronomy, Purdue University, 2003). No-till, a type of conservation tillage, lowers rainfall impact on soil, reduces erosion, and may lower dissolved P concentration in runoff, as illustrated in Figure 7. Additional benefits of conservation tillage include increased infiltration, protection from wind erosion, reduction in evaporation losses, increased soil organic matter, improved tilth, and increased habitat for wildlife (Ritter and Shirmohammadi, 2001).

There are a number of other tillage practices that may reduce nutrient loss, including contour farming, strip cropping, planting cover crops, using alternative crops, and conservation crop rotations. Contour farming, or preparing, planting, and cultivating along a contour, provides improved protection against erosion. It also increases infiltration, decreases surface runoff, and increases the amount of soil and fertilizer kept on the field. It is especially effective during moderate to low intensity storms on mild slopes and is less effective with steep slopes. Strip cropping involves planting strips of crops, usually along a contour. Cover crops, or those grown during the time between harvest and planting of the primary crop, provide soil cover, protect against erosion, sequester nutrients over the winter, provide a "green" manure source for the spring, retain moisture, and can provide additional farm revenue. The development of new crop cultivars, such as varieties of perennial wheat and Indian Rice Grass, may also reduce erosion by providing constant soil cover. Perennials continue to grow after harvest, lay dormant in the winter, and then are harvested again the following fall. Conservation crop rotations, or the growing of different crops in a specific sequence on the same field, also reduce erosion. Additional benefits of conservation crop rotations include increased retention of soil organic matter, the opportunity of managing excess and deficient plant nutrients, and reduction in pests when compared to continuous cultivation of one crop (Mostaghimi et al., 2001). These practices may be implemented separately or together to reduce erosion and subsequent transport of nutrients into water bodies.

Constructed Wetlands and Buffer Zones

Constructed wetlands may improve agricultural runoff quality. One primary benefit of wetlands is the oscillation between anaerobic and aerobic environments with the fluctuation of the water level; this situation facilitates processes that make nutrients less available (Figure 8). Specifically, wetland systems will promote denitrification, making less N available for leaching or runoff. Secondly, nutrients (especially P) can be sorbed to suspended sediments in water and settle out before transport into a natural water body. Thirdly, biomass production is often high in wetlands, creating the possibility of nutrient removal through plant uptake and harvest ('phytoextraction'). Wetlands also act as a flow regulator, reducing erosion and nutrient input into water bodies during times of high flow. Lastly, wetlands are a type of buffer zone, where nutrients can be removed before water flows into another water body.

Buffer zones are either preexisting or planted vegetation bands situated between a pollutant source area and a water body. Within buffers, a number of processes, including filtration, plant uptake, and volatilization may occur (NRCS, 1997). An important goal with buffers is to keep flow entering the zones at a low velocity and low nutrient concentration. Low flow velocities are critical to ensure that water remains in the buffer long enough for nutrient removal to occur. Low flows also guard against further erosion from the buffer zones (Ritter and Shirmohammadi, 2001). The proper width of a buffer zone is essential for adequate removal of nutrients from runoff. Runoff decreases as buffer width increases (Figure 9).

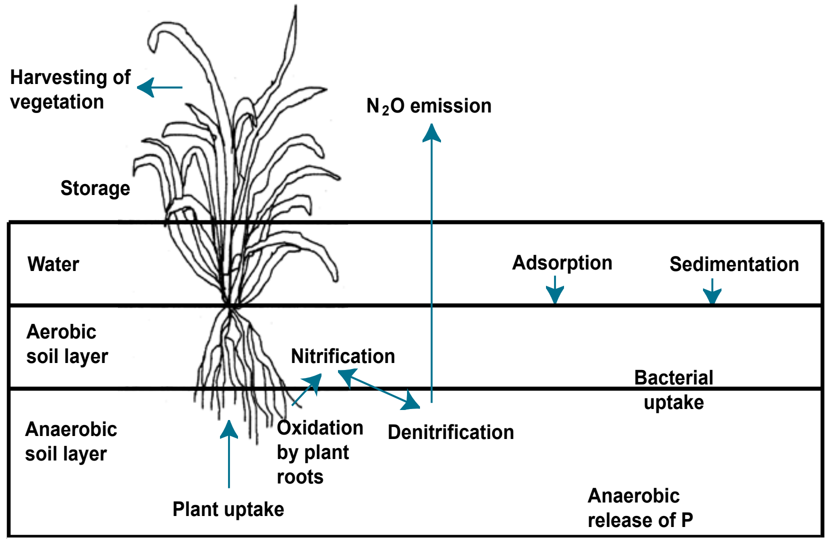

Figure 8. Main wetland processes that contribute to nutrient removal from agricultural runoff (From Blackwell et al., 2002).

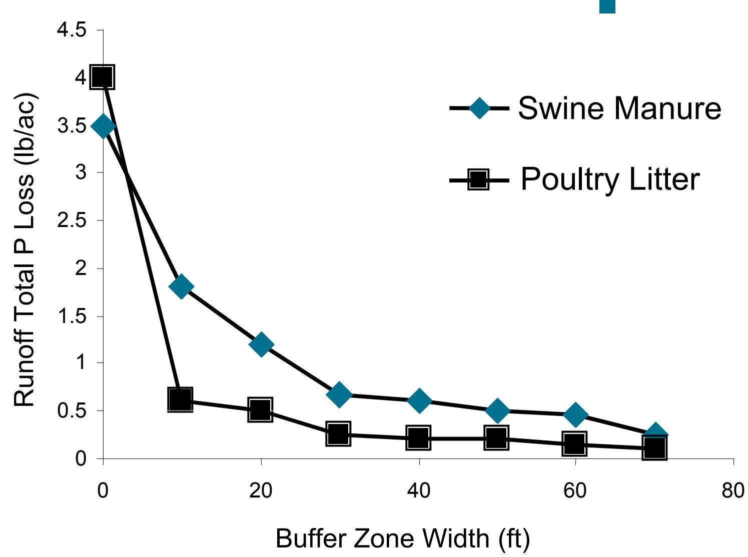

Figure 9. Effects of grass buffer zone width on runoff P loss (Modified from Edwards, 1996).

Monitoring and Testing

Water quality monitoring is the process of observing, collecting, and interpreting water quality data that can then be used to make management decisions. The first step in monitoring is choosing what parameters to measure; this can often be done with help and advice from partner organizations or agencies. The second step is determining study sites that will be repeatedly monitored. Data gathered at a specific location over time will show trends (e.g., upward, stable, downward) that can then be used to indicate changes in water conditions (Keith et al., unpublished data). Again, local water quality districts, state DEQ offices, and water education programs are helpful partners when designing and implementing a water quality monitoring plan (see Appendix).

'Ecological integrity indices' are increasingly being used to interpret monitoring results. Several versions of indices have been developed, but indices using fish or macroinvertebrate species are most common. Typical indices are species abundance, species diversity, presence or absence of specific pollution-sensitive or tolerant species, and stress indicators, such as presence of disease or absence of long-lived species (NRCS, 1997).

Summary

Water quality concerns caused by excess N and P inputs, including eutrophication, blue-baby disease, and degraded aquatic habitat, stem from a number of land uses. Agriculture is one of the contributors to water quality problems, but BMPs such as buffer zones, constructed wetlands, and conservation tillage can greatly reduce nutrient loss to water bodies. These same practices also increase plant uptake of nutrients and soil conservation, resulting in increased yield and nutrient retention. The Montana and Wyoming DEQ offer guidance and clarification of water quality standards and regulations, listings of impaired and threatened water bodies, and oversight of the TMDL process. Conservation and non-profit groups often work cooperatively with farmers and ranchers to reduce water contamination and implement monitoring plans. Modules 13-15 will offer more BMPs and new tools for reducing nutrient loss and sustaining soil and water resources.

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APPENDIX

Books

Agricultural Nonpoint Source Pollution. W.F. Ritter and A. Shirmohammadi, (eds.) 2001. Lewis Publishers, Boca Raton, FL. 342 p. Approximately $100.

Agriculture, Hydrology, and Water Quality. P.M. Haygarth and S.C. Jarvis, (eds.) 2002. CABI Publishing, New York, NY. 502 p. Approximately $150.

From Reclamation to Sustainability: Water, Agriculture, and the Environment in the American West. L.J. MacDonnell and G. Vranesh, (eds.) 1999. University Press of Colorado, Boulder, CO. Approximately $30.

Soils and Environmental Quality. 2nd Ed. G.M. Pierzynski et al. 2000. CRC Press, Boca Raton, FL. 459 p. Approximately $90.

Extension Materials

Conservation Tillage: Drills for Montana Farmers, 2B 1328, 1989. Bozeman, MT: Montana State University Extension. $4.50.

Conservation Tillage: Questions and Answers, EB 8, 1992. Bozeman, MT: Montana State University Extension. $3.

Montana Farm*A*Syst, EB 124, 1994. J.S. Jacobsen and G. Hester. Bozeman, MT: Montana State University Extension. Approximately $5.

Protecting Our Water Resources: Environmental Stewardship Strategies for Fertilizer Facilities, EB 131. 1996. Free.

Water Quality and Agrichemicals in Montana. EB 51, 1993. J.S. Jacobsen and G.D. Johnson. Bozeman, MT: Montana State University Extension. Free.

Nutrient Management Modules (1-15) can be obtained online or at the address below (add $1 for shipping).

MSU Extension Publications
P.O. Box 172040
Bozeman, MT 59717-2040

All are online in PDF format in the category of ag and natural resources, at http://www.msuextension.org/publications.asp

See Web Resources below for online ordering information.

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Web Resources

http://water.montana.edu

A comprehensive Web site that offers resources, educational tools, and recent water quality news.

http://waterquality.montana.edu

A general water quality Web site that provides information on both agricultural and non-agricultural water issues.

http://www.dphhs.mt.gov/PHSD/Lab/environ-lab-index.shtml

DPHHS Environmental Laboratory that does drinking water analysis and other environmental testing.

http://www.deq.state.mt.us and http://deq.state.wy.us/

State Web sites that outline water quality concerns, cite examples, and list water quality resources in Montana and Wyoming.

http://www.epa.gov

National Web site that explains water quality regulations, standards, and provides current water news.

http://www.epa.gov/safewater/pws/pwss.html

Web site shows drinking water standards, provides monitoring suggestions, and has links to state drinking water information.

http://www.msuextension.org/publications.asp

Montana State University Extension Publications ordering information for printed materials.

http://www.mt.nrcs.usda.gov and http://www.wy.nrcs.usda.gov

Web sites that list water quality programs and resources specific to Montana and Wyoming.

http://www.tmdls.net/

A great Web site that gives an overview of the TMDL process and answers related questions.

http://landresources.montana.edu/FertilizerFacts/

Fertilizer Facts summarizing fertilizer findings and recommendations based on field research conducted in Montana by Montana State University personnel.

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