Reducing Nutrient Loss:
Science Shows What Works

Iowa has been working for decades to protect and improve water quality. However, progress measured toward reduction targets at the watershed scale has been challenging, and many complex nutrient-related impacts in Iowa's lakes, reservoirs, and streams remain to be addressed.

The Iowa Nutrient Reduction Strategy is a science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico. It directs efforts to reduce nutrients in surface water from both point and nonpoint sources in a scientific, reasonable, and cost-effective manner.

It was prompted by the 2008 Gulf Hypoxia Action Plan that calls for Iowa and other states along the Mississippi River to develop strategies to reduce nutrient loadings to the Gulf of Mexico. The plan established a goal of at least a 45 percent reduction in total nitrogen and total phosphorus loads.

The Iowa strategy is a coordinated approach for reducing nutrient loads discharged from the state's largest wastewater treatment plants, in combination with targeted practices designed to reduce loads from nonpoint sources such as agriculture.

Success can be achieved using the tools known to work, such as targeted, voluntary conservation measures, in conjunction with research, development, and demonstration of new approaches. The goal is application of proven practices in fields and cities across Iowa.

Science Provides Guidance

The strategy related to farmland is built on a scientific assessment of practices and associated costs to reduce loading of nitrogen (N) and phosphorus (P) to Iowa surface waters.

The College of Agriculture and Life Sciences at Iowa State University and the Iowa Department of Agriculture and Land Stewardship partnered to conduct the scientific assessment. The science team consisted of 23 individuals representing five agencies or organizations.

The objective of the science assessment was to identify and model the effectiveness of specific practices at reducing N and P reaching the Gulf of Mexico.

The assessment involved establishing baseline conditions, reviewing scientific literature, estimating potential load reductions, and estimating implementation costs. The assessment shows that broad implementation of a combination of practices will be needed to reach desired load reductions.

A Closer Look

The need to increase voluntary efforts to reduce nutrient loss is one of the key points related to agriculture in Iowa's Nutrient Reduction Strategy.

The science assessment identified effective nutrient reduction practices in three categories — nitrogen and phosphorus management, land use, and edge-of-field. (See charts on pages 3-4.)

Management practices involve application rate, timing, and method, plus the use of cover crops and reduced tillage.

Land use practices include perennial energy crops, extended rotations, grazed pastures, and land retirement.

Edge-of-field practices involve drainage water management, wetlands, bioreactors, buffers, terraces, and sediment control.

Some practices that have the greatest potential are highlighted here.

Management Practices – Nitrogen

Rate Reduction: Matching N application rates with the Corn Nitrogen Rate Calculator, a university developed online tool, has potential to reduce nitrate-N loss. This tool estimates optimal N rates based on fertilizer and corn prices. (Find the calculator here: http://cnrc.agron.iastate.edu).

Nitrification Inhibitor: Research shows a corn yield increase plus a nitrate-N loss decrease when using a nitrification inhibitor (Nitrapyrin) with fall applied anhydrous ammonia. The only cost associated with this practice is the material. There is a corn yield increase of approximately 6 percent.

Sidedress: Sidedressing N can be done in different ways and with different sources of N, yet the concept of applying fertilizer after corn emergence is consistent. This strategy includes applying N during plant uptake, as well as timing to reduce the risk of loss from leaching events. Sidedressing also allows the N rate to be optimized by either soil sampling or crop canopy sensing.

Management Practices – Phosphorus

Consider Soil-Test P: This practice involves not applying P on fields where the Soil-Test P (STP) values exceed the upper boundary of the optimum level for corn and soybean in Iowa. The practice would continue until the STP level reaches the optimum level.

Cover Crops: Planting a late summer or early fall seeded cover crop can reduce P loss. For example, winter rye offers benefits of easy establishment, seeding aerially or by drilling, growth in cool conditions, initial growth when planted in the fall, and continued growth in the spring. Cover crops also are effective at reducing N loss.

Reduced Tillage: Conservation tillage, where 30% or more of the soil surface is covered with crop residue after planting, or no-till, where 70% or more of the soil surface is covered with crop residue after planting, reduces soil erosion and surface runoff. Reduced erosion and runoff also reduces P transport.

Land Use Practices – Nitrogen and Phosphorus

Extended Rotations: Extended rotations reduce the application and the loss of both P and nitrate-N. If a shift to extended rotations is significant, the amount of corn and soybean produced in Iowa would be reduced, along with an increase in alfalfa production that could support increased livestock production for alfalfa feeding. Another benefit would be improved soil quality.

Energy Crops Replacing Row Crops: Although there is not a current large market for perennial biomass crops as a source for energy or transportation fuel production, there are local and regional markets. Replacing row crops with energy crops or integrating energy crops within the rowcrop landscape decreases erosion, surface runoff, and leaching losses in the area implemented; therefore, the loss of both P and nitrate-N is reduced. An added benefit is an increase in wildlife habitat.

Edge-of-Field Practices – Nitrogen and Phosphorus

Wetlands: Wetlands targeted for water quality benefits show great potential for nitrate-N reduction. Wetland costs include design, construction, buffer seeding, maintenance, and land acquisition. In addition to water quality benefits, these wetlands provide other benefits such as improved aesthetics and habitat.

Bioreactors: Subsurface drainage bioreactors also show good potential for nitrate-N reduction. Bioreactor costs include control structures, woodchips, design, construction, seeding, additional tile, management, and maintenance.

Buffers: Edge-of-field technologies such as buffers are designed to settle sediment and sediment-bound N and P, along with retaining nitrate-N and dissolved P. Buffers also provide wildlife habitat, sequester carbon, reduce greenhouse gas emissions, stabilize stream banks, and potentially reduce flood impacts. Costs of buffers can vary greatly depending on width, type of vegetation, and the amount of earthwork required.

Saturated Buffers: Field tile drainage is intercepted in a riparian buffer and a fraction of the flow is diverted as shallow groundwater within the buffer. The nitrate-N contained in the tile drainage water is partially removed by plant uptake, microbial immobilization and denitrification.

Blind Inlet: Also commonly referred to as French drains are an alternative to a tile riser surface inlet for closed depressions. The gravel/aggregate filled trench over the subsurface tile still allows for surface drainage while filtering out debris and sediment and the P attached to the sediment.

Standard Practices‡

The nutrient loss reduction practices presented here and their effectiveness presume that standard recommended practices are applied. Standard nutrient management practices include, but are not limited to:

- calibrating application equipment
- applying fall-applied ammonia products when the soil temperatures are 50°F and trending colder
- accounting all nutrient sources for the crop
- sampling manure and analyzing nutrient content
- basing replacement rates on realistic yield potentials
- not applying nutrients on frozen or snow-covered ground
- avoiding application where the risk of runoff to surface water is high (e.g. surface application near streams and tile inlets), and
- controlling sheet, rill, and ephemeral gully erosion.

More information on Iowa's Nutrient Reduction Strategy is available at www.nutrientstrategy.iastate.edu.

Iowa Strategy to Reduce Nutrient Loss: Nitrogen Practices

This table lists practices with the largest potential impact on nitrate-N concentration reduction (except where noted). Corn yield impacts associated with each practice also are shown as some practices may be detrimental to corn production. If using a combination of practices, the reductions are not additive. Reductions are field level results that may be expected where practice is applicable and implemented.

	Practice	Comments	% Nitrate-N Reduction*	% Corn Yield Change**
			Average (SD†)	Average (SD†)
Nitrogen Management‡	Timing	Moving from fall to spring pre-plant application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to fall-applied	5 (28)	10 (7)
		Sidedress – Compared to pre-plant application	7 (37)	0 (3)
		Sidedress – Soil test based compared to pre-plant	4 (20)	13 (22)††
	Source	Liquid swine manure compared to spring-applied fertilizer	4 (11)	0 (13)
		Poultry manure compared to spring-applied fertilizer	-3 (20)	-2 (14)
	Nitrogen Application Rate	Nitrogen rate at the MRTN (0.10 N:corn price ratio) compared to current estimated application rate. (ISU Corn Nitrogen Rate Calculator – **http://cnrc.agron.iastate.edu** can be used to estimate MRTN but this would change Nitrate-N concentration reduction)	10	-1
	Nitrification Inhibitor	Nitrapyrin in fall – Compared to fall-applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)	-5 (1)
	Living Mulches	e.g. Kura clover – Nitrate-N reduction from one site	41 (16)	-9 (32)
Land Use	Perennial	Energy Crops – Compared to spring-applied fertilizer	72 (23)	
		Land Retirement (CRP) – Compared to spring-applied fertilizer	85 (9)	
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	42 (12)	7 (7)
	Grazed Pastures	No pertinent information from Iowa – assume similar to CRP	85	
Edge-of-Field	Drainage Water Mgmt.	No impact on concentration	33 (32)	
	Shallow Drainage	No impact on concentration	32 (15)	
	Wetlands	Targeted water quality	52	
	Bioreactors		43 (21)	
	Buffers	Only for water that interacts with the active zone below the buffer. This would only be a fraction of all water that makes it to a stream.	91 (20)	
	Saturated Buffers	Divert fraction of tile drainage into riparian buffer to remove Nitrate-N by denitrification.	50 (13)	
	Multi-purpose Oxbow	Targeted water quality	42 (6)	

* A positive number is nitrate concentration or load reduction and a negative number is an increase.

** A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

† SD = standard deviation. Large SD relative to the average indicates highly variable results.

†† This increase in crop yield should be viewed with caution as the sidedress treatment from one of the main studies had 95 pounds-N/acre for the pre-plant treatment but 110 pounds-N/acre to 200 pounds-N/acre for the sidedress with soil test treatment so the corn yield impact may be due to nitrogen application rate differences.

‡ See Standard Practices (blue box) on page 2 of this publication.

Iowa Strategy to Reduce Nutrient Loss: Phosphorus Practices

Practices below have the largest potential impact on phosphorus load reduction. Corn yield impacts associated with each practice also are shown, since some practices may increase or decrease corn production. If using a combination of practices, the reductions are not additive. Reductions are field level results that may be expected where practice is applicable and implemented.

	Practice	Comments	% P Load Reduction[a]	% Corn Yield Change[b]
			Average (SD[c])	Average (SD[c])
Phosphorus Management‡	Phosphorus Application	Applying P based on crop removal – Assuming optimal STP level and P incorporation	0.6[d]	0
		Soil-Test P – No P applied until STP drops to optimum or, when manure is applied, to levels indicated by the P Index[f]	17[e]	0
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application‡	46 (45)	-1 (13)
		Beef manure compared to commercial fertilizer – Runoff shortly after application‡	46 (96)	
	Placement of Phosphorus	Broadcast incorporated within 1 week compared to no incorporation, same tillage	36 (27)	0
		With seed or knifed bands compared to surface application, no incorporation	24 (46)	0
	Cover Crops	Winter rye	29 (37)	-6 (7)
	Tillage	Conservation till – chisel plowing compared to moldboard plowing	33 (49)	0 (6)
		No till compared to chisel plowing	90 (17)	-6 (8)
Land Use Change	Perennial Vegetation	Energy Crops	34 (34)	
		Land Retirement (CRP)	75	
		Grazed pastures	59 (42)	
Erosion Control and Edge-of-Field	Terraces		77 (19)	
	Buffers		58 (32)	
	Control	Sedimentation basins or ponds	85	
	Blind Inlet	Sediment control	50	

[a] A positive number is P load reduction and a negative number is increased P load.

[b] A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

[c] SD = standard deviation. Large SD relative to the average indicates highly variable results.

[d] Maximum and average estimated by comparing application of 200 and 125 kilogram P_2O_5/hectare, respectively, to 58 kilogram P_2O_5/hectare (corn-soybean rotation requirements) (Mallarino et al., 2002).

[e] Maximum and average estimates based on reducing the average STP (Bray-1) of the two highest counties in Iowa and the statewide average STP (Mallarino et al., 2011a), respectively, to an optimum level of 20 ppm (Mallarino et al., 2002). Minimum value assumes soil is at the optimum level.

[f] ISU Extension and Outreach publication (PM 1688).

‡ See Standard Practices (blue box) on page 2 of this publication.

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