

Nitrogen in the Environment

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Nitrogen in the Environment

- From where?
- With what effects?
- How can adverse effects be addressed?

Nitrogen in the Environment--From where?

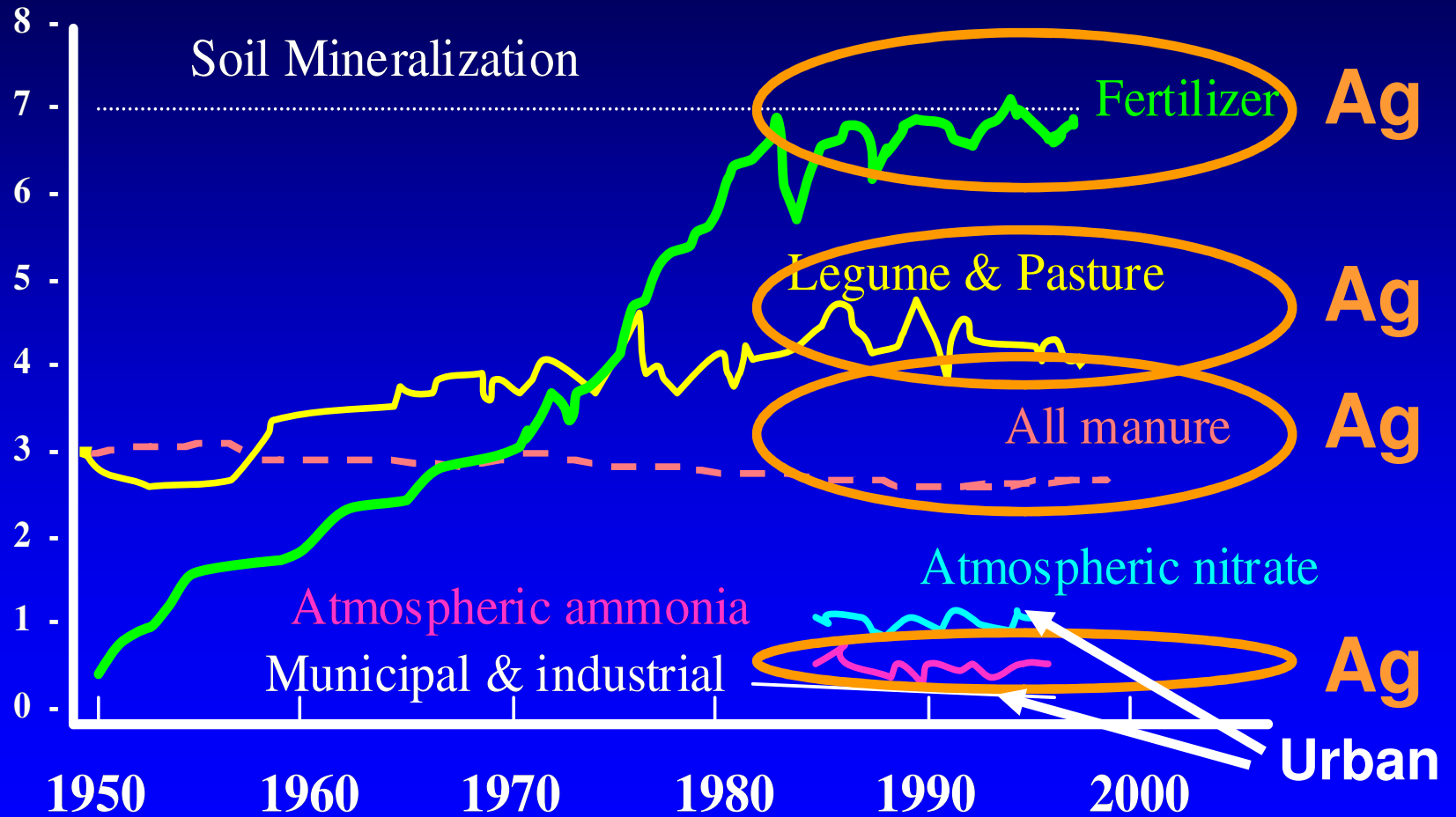
- Recycling of biological N
- Newly-introduced biological N
 - Fertilizer N
 - Leguminous plants
 - Fossil-fuel combustion
 - Lightning

All from N₂ in air

Annual N Inputs to Mississippi Basin

Approximated from Goolsby. USGS. 1999. CENR Report #3

Million metric tons



Agriculture as a nitrogen source

- The bulk of biologically available N is associated with agriculture
- It can be hard to trace the movement of this N to the environment, but most environmental N is probably from ag

Nitrogen: effects on the environment

- Water quality is the main concern
 - Overproduction in coastal waters
 - Nitrate in drinking water
 - No major problems within Missouri
 - DNR is currently setting nutrient standards for water
- Species shifts in low-productivity land ecosystems
 - Deserts
 - Alpine lands

NO TMDLS!

Overproduction in coastal waters

- Nitrogen is the most growth-limiting nutrient in sea water
- Adding N to sea water increases growth of marine plants (same as on land)
- What is “overproduction”, why is it a problem?

Mississippi R. water (high N)

Gulf of Mexico water (high P)

Photo: Nancy Rabalais, Louisiana Universities Marine Consortium

Satellite image of phytoplankton bloom

Mouth of
Mississippi River

A satellite image showing a large, irregularly shaped area of bright green and yellowish-green water, indicating a phytoplankton bloom. The bloom is situated in the Gulf of Mexico, extending from the coast of the United States. A yellow arrow points from the text 'Mouth of Mississippi River' to the northern edge of the bloom, where the river discharges into the ocean. The surrounding ocean water is a deep blue color.

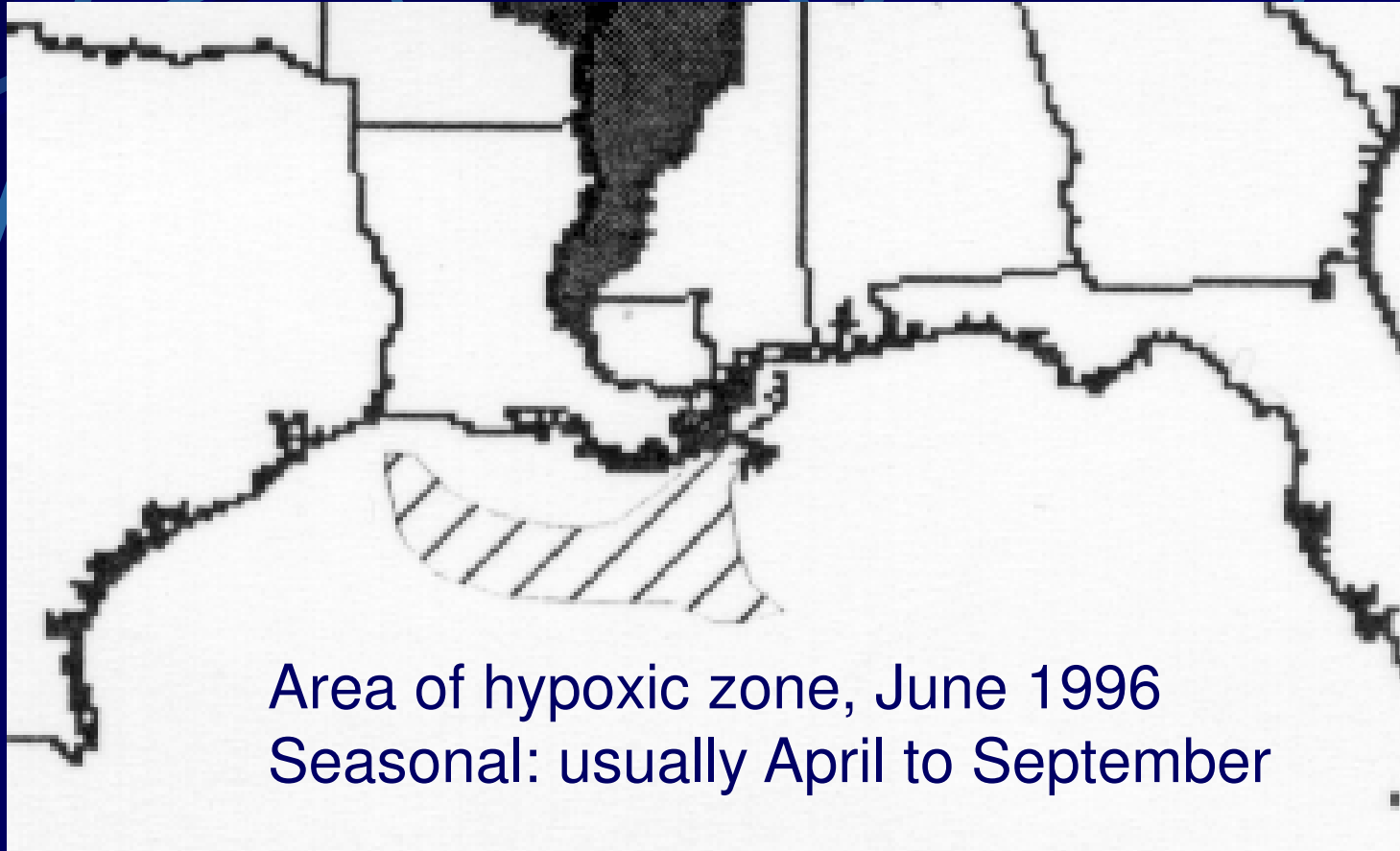
Overproduction in coastal waters

- Excessive productivity of aquatic plants causes:
 - oxygen depletion of water
 - death or migration of oxygen-sensitive species
 - increases in the incidence of toxin-producing blooms
 - loss of submerged aquatic vegetation (habitat) due to increased turbidity

Overproduction in coastal waters

- This type of problem has been seen in:
 - The Gulf of Mexico (“hypoxia”, or, “The Dead Zone”)
 - The Chesapeake Bay
 - Long Island Sound
 - Pamlico Sound
 - The Black Sea
 - The Baltic Sea

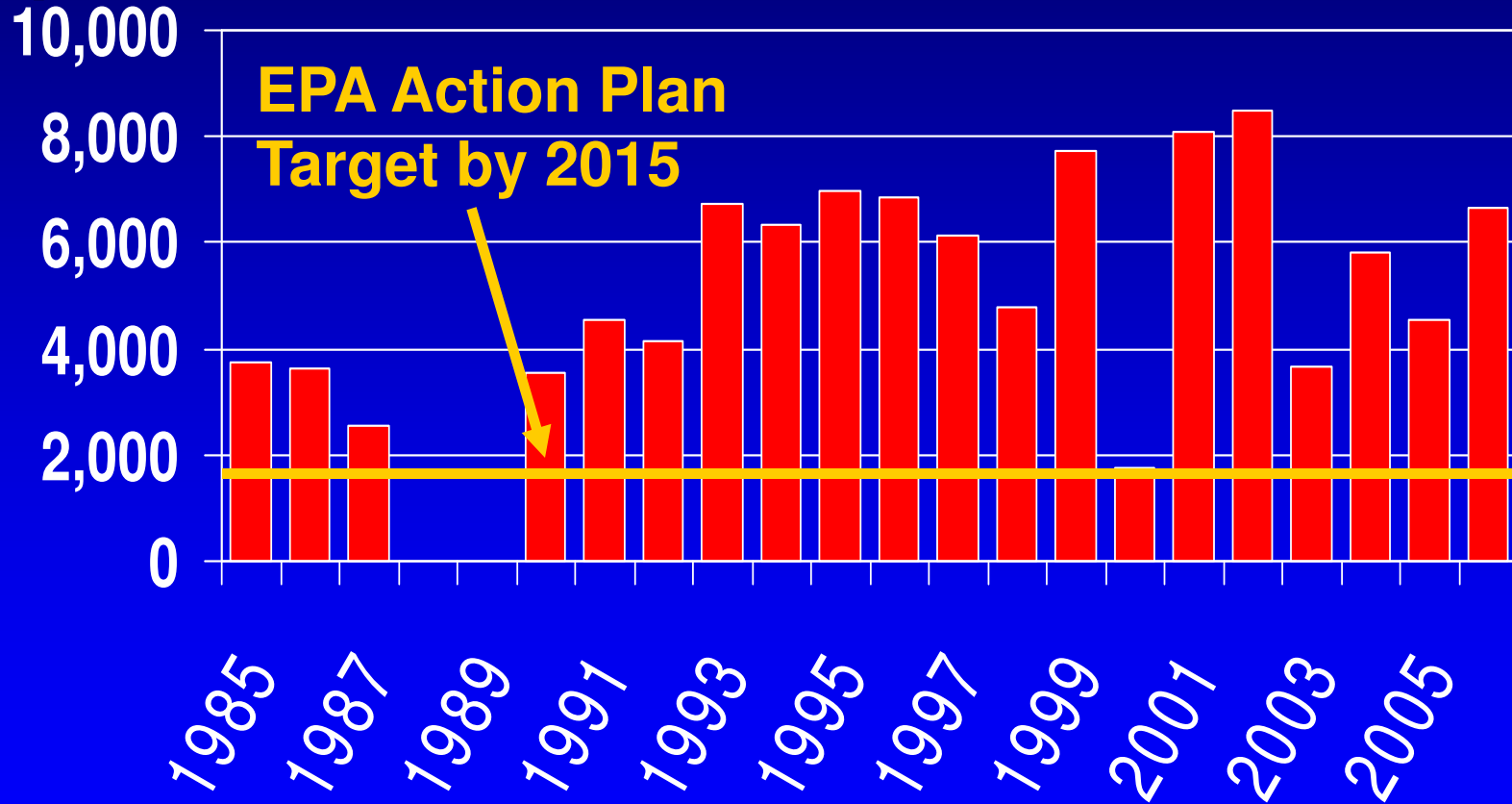
Gulf of Mexico Hypoxia



Mid-Summer hypoxic area in Gulf of Mexico

N. Rabalais, LUMCON

square miles



N fertilizer in the river

- N fertilizer use
 - started after World War II
 - increased until 1980
 - pretty much level since 1980
- Mississippi River N
 - increased from 1950-1980 then leveled off
- Transport from farms to the river is hard to measure, not well understood

Source: USGS. Open File Report 97-230
(Also on the internet)

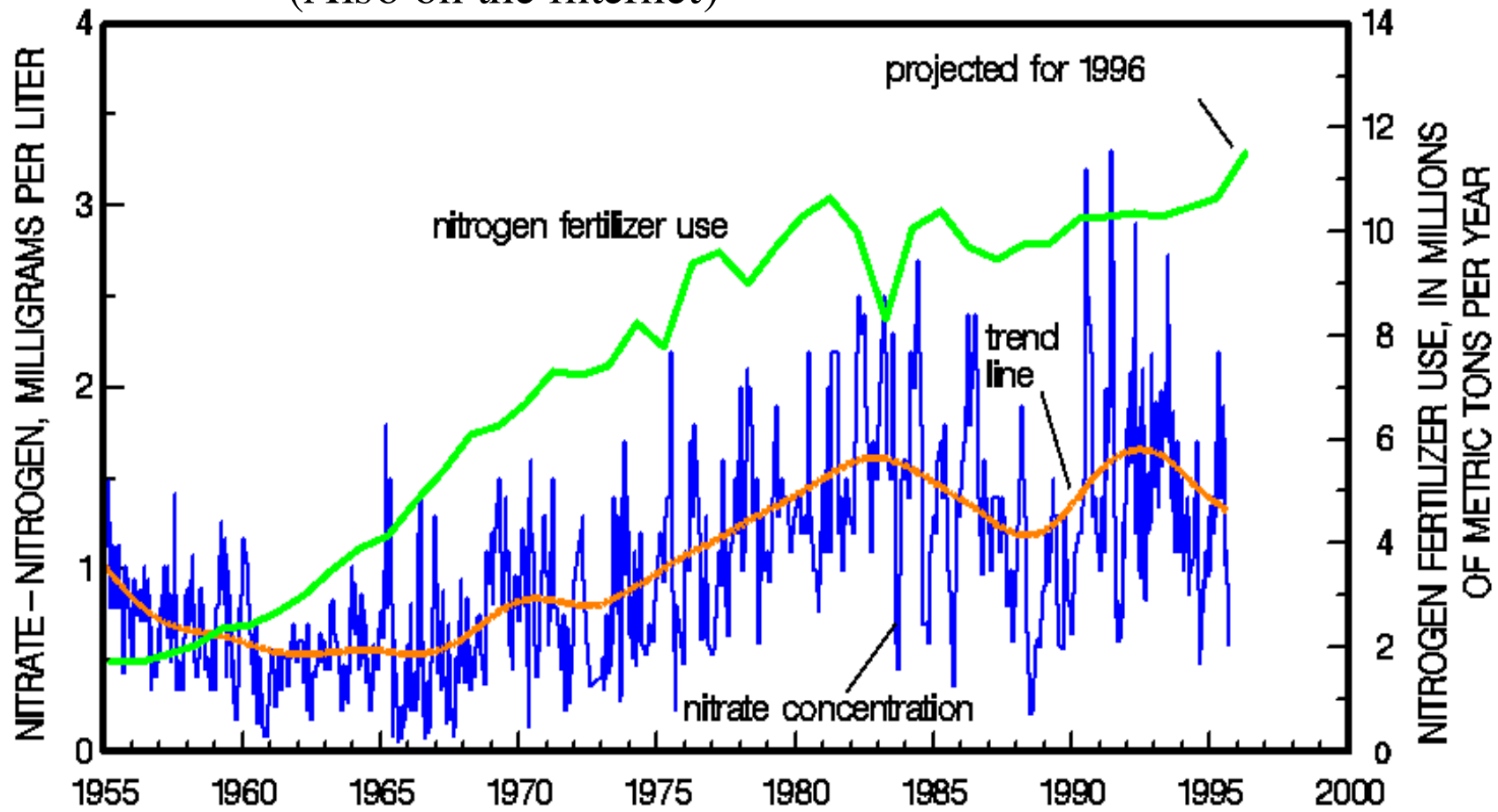


Figure 1. Estimated nitrogen fertilizer use in the United States, and nitrate concentrations in the Mississippi River at St. Francisville, LA., 1955–95.

Hypoxia and N fertilizer

- Hypoxia is associated with an algal bloom
 - Long experience and theory suggests that N input increases the size of the bloom

Hypoxia and N fertilizer

- Is the size of the Gulf hypoxic zone controlled by N use on land?
- We can't really answer this question
 - The size of the hypoxic zone has only been measured since 1985
 - N fertilizer use & Mississippi River nitrate concentration have been nearly level
 - Water flow has mainly controlled the size of the zone 1985 to present

Nitrates in drinking water

- Human health concern
 - 10 ppm nitrate-N limit for drinking water
 - mainly due to threat of blue baby disease
 - extremely rare
 - weakly linked to other health problems

Nitrates in drinking water

- 10 ppm nitrate-N limit for drinking water is exceeded mainly in wells (NE, KS)
- Also exceeded in some rivers used for drinking water
 - Des Moines River in Iowa
 - Illinois?
 - But none in Missouri, except the Des Moines River at the northeast border

Relative nitrate concentrations

- 10 ppm nitrate-N is health advisory limit for human consumption
- Mississippi River water entering the Gulf of Mexico is about 2 ppm
 - enough to cause large hypoxic zone
 - about three times higher than in 1960
 - critical nitrate-N concentration in water is higher for drinking water than for hypoxia

How can the adverse effects of N be addressed?

- Need to focus on agricultural sources of N
 - Primarily fertilizer N
 - Also N from soil organic matter, manure, legumes
- Taking advantage of easy progress in municipal & industrial N also makes sense

Agricultural N: reducing environmental effects

- Reduce N loss from fields (source reduction)
- Intercept and remove N from water between edge of field and coast
- Remove nitrate from drinking water

Reducing N loss from ag fields

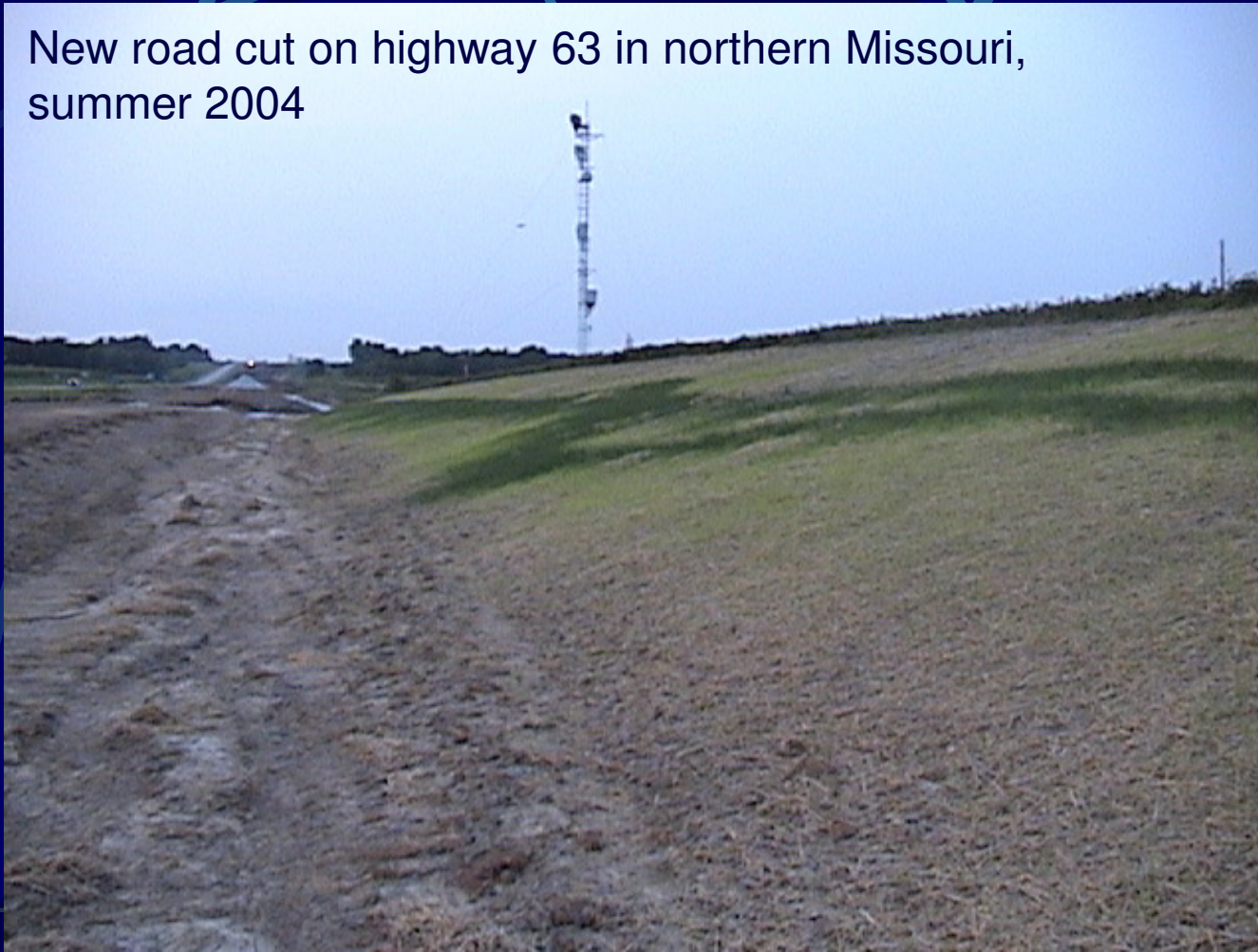
- First: understand transport of N from ag fields to surface water

N transport to water resources

- **Runoff is a minor pathway in most cases**
- **Nitrate leaching is the major pathway**
 - movement with percolating water
 - to groundwater (permanent or transient)
 - substantial groundwater emerges to surface as springs & seeps
 - artificial drains in agricultural fields directly move leached nitrate to surface waters

Nitrate in base flow

New road cut on highway 63 in northern Missouri,
summer 2004



Landscape
slope

Loess cap

Old glacial
till (dense)

N transport to water resources

- Missouri MSEA: 15 times more N leached than in runoff
- Iowa MSEA: 16 times more N entering stream via subsurface flow than in runoff
- Georgia: 115 times more N in subsurface flow than in runoff (Jackson et al., 1973)

Major point #1:

Best Management Practices (BMPs) aimed at reducing runoff will have no effect on N movement to ground and surface waters

N transport to water resources

- Grasslands/forages leach very little N
 - Not much water percolation
 - Dense growth, long growing season
 - Little free nitrate, great potential to take up nitrate

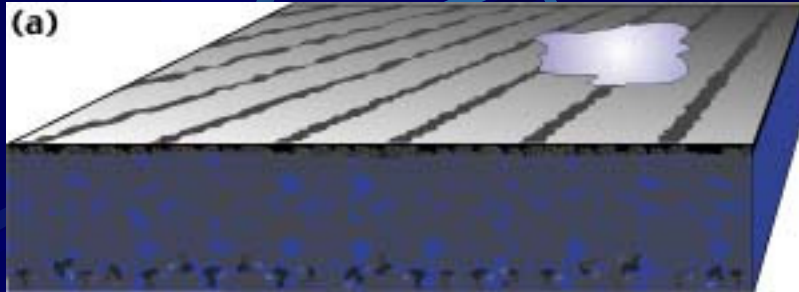
Major point #2:

Very little N is lost from forages to water resources

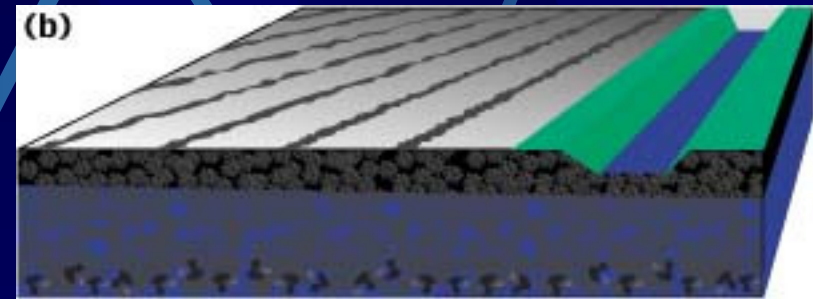
N movement to surface waters via artificial drainage

- Drainage lines are a direct pipeline from the root zone to the river
- Fenelon & Moore (1998): much more nitrate entering river from subsurface drains than from base flow (Indiana)

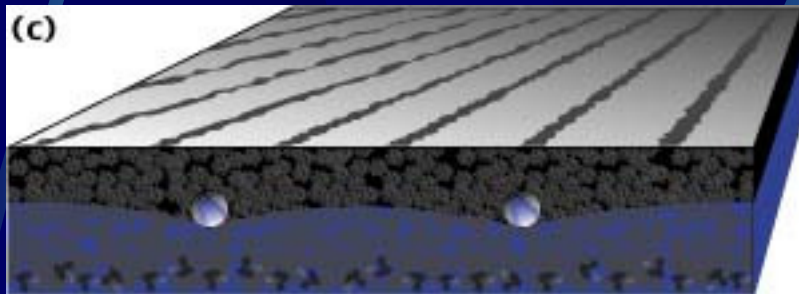
Artificial drainage



Undrained field



Surface-drained field



Subsurface-drained field

Drainage provides a huge grain production and economic benefit

Drainage by geography



Major point #3:

Focusing nitrogen management BMPs in areas with considerable drainage is likely to have maximum impact on N movement to surface waters

Not Missouri!!!

N transport to water resources

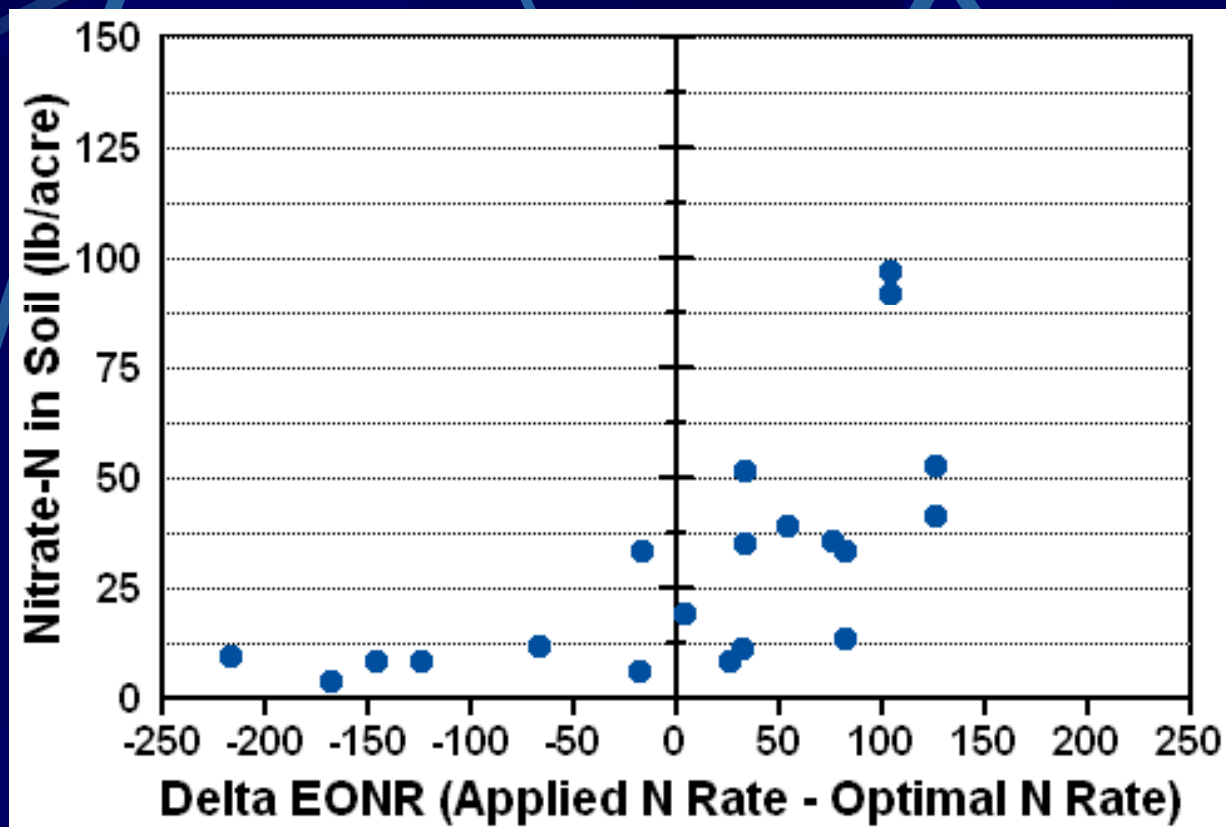
- Nitrate leaching occurs mainly during the “recharge period” when precipitation exceeds evapotranspiration
- In Missouri, this may last from October to May
- Nitrate in the soil from October to May is vulnerable to loss
- Mainly unused N left after harvest

Reducing N loss from ag fields

- First: understand transport of N from ag fields to surface water
- Second: reduce unused N left at harvest

HOW?

Matching N rate to crop need reduces soil N at harvest



Soil nitrate in the top 4 feet after harvest is high only when optimum N fertilizer rate for corn is exceeded.
Centralia, MO, 2000

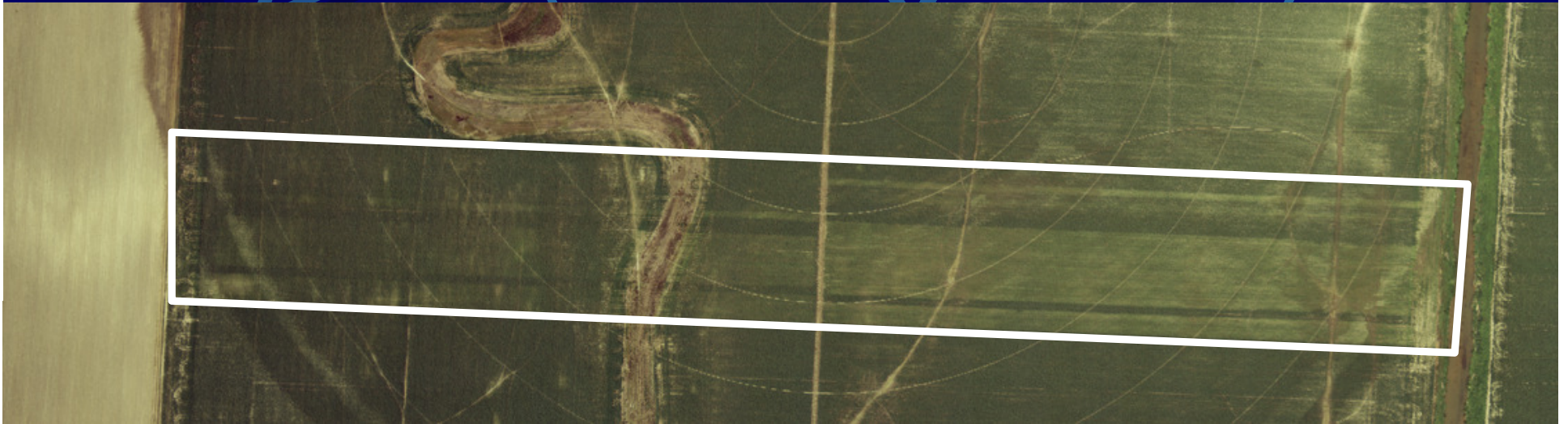
Matching N rate to crop need

- Applying only as much N as the crop needs at any particular place reduces:
 - N remaining in soil at harvest
 - N leached from root zone
 - N in base flow?

Matching N rate to crop need

- It's actually very difficult to predict how much N fertilizer is needed
 - It depends on the amount available from the soil, which is hard to predict and highly variable
- There is no good method in common use by farmers
- N need is highly variable from one field to the next and also within fields

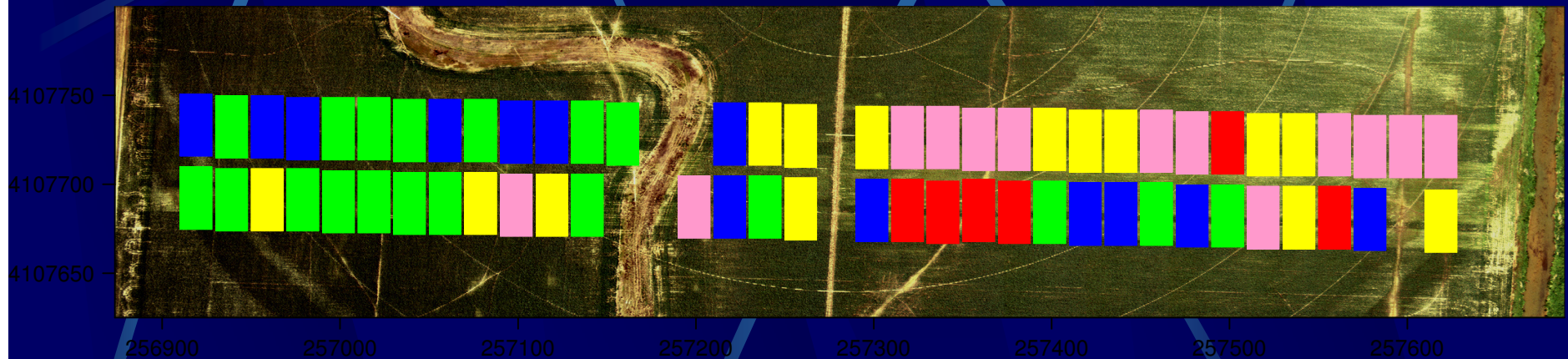
Matching N rate to crop need: an example



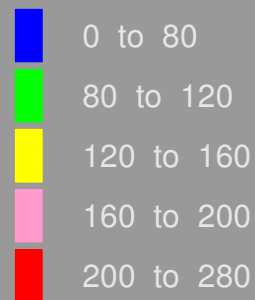
- pivot-irrigated cornfield near Oran, Missouri in 2000
- Nitrogen rates from 0 to 250 lb/acre were applied all across this field, and resulting yields were measured

Crop need for nitrogen varies widely within fields

Oran 2000 Optimal N Rates



Optimal N rates, kg/ha



How do you fertilize this field?

Matching N rate to crop need—how?

- ~~● Soil nitrate test~~
- ~~● Yield goal~~
- ~~● Soil texture~~
- Crop color

Matching N rate to crop need: crop color

- N-deficient plants are much lighter and yellower than plants that have enough N



Matching N rate to crop need: crop color

● Tools

- Chlorophyll meter
- Aerial photographs
- Vehicle-based radiometers

Applicator-mounted sensors

Variable-rate N sidedress based on sensor readings:

- 7 producer-field demos in 2004
- Dark green gets low N rate
- Lighter green or yellow gets high N rate



Matching N rate to crop need: crop color

- Advantage: predictions of N need are much more accurate than those from soil tests or yield goals
 - I believe that ultimately these practices will be widely adopted to allow full crop productivity while minimizing N lost to water resources
- Disadvantage: waiting until crop shows N need to apply fertilizer creates risk and inconvenience
 - Economic incentive from production side alone is not adequate for adoption

Major point #4:

**Matching N rate to crop need,
at times appropriate to
efficient crop uptake, has
great potential to reduce
agricultural N loss to water
resources**

Interception/mitigation

- Once the nitrate-N has leached from the root zone, what kinds of BMPs can reduce movement to water resources?
- To groundwater: effectively no BMPs available
- To surface water:
 - riparian zones
 - natural or artificial wetlands

Riparian zone/wetland functions

- NOT related to runoff (for N)
- Root interception and uptake of groundwater nitrate
 - deep-rooted trees
 - wetland species where groundwater is shallow/emergent
- Denitrification
 - especially in wetlands, favored by high-carbon, low-oxygen conditions

Source reduction vs. interception/mitigation

- Presidential Commission on Gulf of Mexico Hypoxia report:
 - reducing N inputs to the Gulf of Mexico will be much cheaper via source reduction BMPs than via interception/mitigation BMPs

SUMMARY

- Nitrate in drinking water (human health) and N in coastal waters (hypoxia) are the major N/water quality issues
- Most N in water probably originates from agricultural sources
- Reducing N in runoff will not effectively address either issue

SUMMARY (cont'd)

- BMPs will be most effective in reducing N movement to surface waters when used in areas with lots of drainage (Iowa & Illinois)
- Source reduction BMPs (matching rate to crop need, proper timing) will probably be more cost-effective than interception/mitigation BMPs