Assessing the Effects of Agricultural Practices on Water Quality in the North Carolina Coastal Plain

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Introduction

- NPS pollution is a concern in eastern NC because nutrient over-enrichment has contributed to water-quality problems in the Tar-Pamlico and Neuse River basins, especially the estuaries.
- Agricultural activities, including animal feeding operations, are a leading contributor of NPS nutrients to streams in the Coastal Plain.

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- Excessive inputs of N and P to nutrient-sensitive waters can contribute to eutrophication, excess algal blooms, and fish kills
- NSW management strategies implemented to reduce nutrient loadings to the estuaries

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Background for today's talk

The USGS has conducted various studies with NCDENR, as well as EPA, intended to assist management efforts for protecting and improving water quality throughout eastern NC.

- Factors affecting GW nitrate delivery (Flow Path Study)
- Effects of artificial drainage (Tile Drain Study)
- SW quality associated with CAFOs (CAFO Study)

These studies have helped to increase our understanding of the many factors that affect the occurrence and transport of nutrients in GW and SW in Coastal Plain watersheds.

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Nutrient Transport Considerations

- Different processes influence the fate and transport of nutrient inputs from agricultural fields to receiving streams.
- Primary sources of nutrients applied to fields in Coastal Plain
  - Commercial inorganic fertilizers
  - Animal manures (swine lagoon effluent, poultry litter)
- Offsite transport of nutrients from agricultural fields to streams
  - Groundwater discharge
  - Overland runoff

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Groundwater Transport

- Nutrients applied to fields that percolate through soils to the underlying surficial aquifer can be transported with GW as it discharges to streams
- Nitrate concentrations commonly exceed 10 mg/L in shallow GW
- GW commonly contributes 50 to 60% of the average annual streamflow to streams in the Coastal Plain

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Flow Path Study

- Five flow-path sites located in agricultural fields.
- Site selection
  - Stream order
  - Soil drainage
  - Presence/absence of riparian buffer
  - Fertilizer type

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Study Overview

- Primary goal: Identify those factors that may help control the amount of N transported in GW beneath agricultural fields to SW in receiving streams.
- Monitoring wells and/or piezometers installed along different portions of the flow path at each site
  - Field zone
  - Riparian buffer zone
  - Hyporheic zone – defined as the zone near/under the stream where GW and SW mix
- GW and SW samples analyzed mostly for nutrients, ions, and DOC

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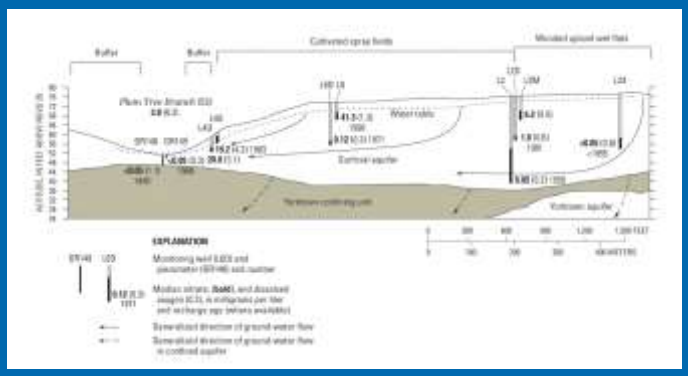
1st order stream, well- to poorly-drained soils with stream buffer



- Nitrate beneath spray fields decreased vertically and laterally toward stream
- Evaluated various factors that helped reduce nitrate along flow paths

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Summary of Findings

- Reduction of nitrate in GW occurred at all sites but the nitrate-reducing processes differed among the field, buffer, and hyporheic zones.
- Most nitrate reduction occurred in the buffer and hyporheic zones, which together can substantially lower the amount of GW nitrate discharged to streams
- A combination of factors appeared to influence GW nitrate concentrations, in association with or independently of denitrification, along the flow paths or at the streams

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Environmental Factors

- Riparian buffers
  Higher reduction of nitrate along the GW flow paths from the fields to the streams when buffers present, less reduction without buffers.
- Soil drainage
  Higher nitrate reduction in GW beneath poorly drained fields than well drained fields, possibly reflecting increased denitrification and vegetative uptake because of slower infiltration rates in the soils.
- Fertilizer use
  GW nitrate higher beneath spray fields (commonly > 20 – 30 mg/L) than conventional fields (commonly < 10 to 15 mg/L)

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Hydrogeologic Factors

- Length of GW flow path and residence times
  Longer residence times increase chance of reduction
- Lithologic properties
  Permeability of aquifer material influences rate of transport
- Tile drainage
  Allows GW to bypass riparian and hyporheic zones

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Geochemical Factors

- Sources and amounts of organic carbon
- Occurrence and distribution of reducing conditions
  Organic-rich sediments and low DO concentrations promote reducing conditions that enable denitrification, especially important in the buffer and hyporheic zones
- Denitrification was the most common factor responsible for decreases in nitrate along the flow paths

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Overland Transport

- Field-drainage ditches and sub-surface tile drains commonly are used in the Coastal Plain for improving drainage in fields with poorly drained soils.
- Water conveyed through the ditches includes:
  - Surface runoff from the fields.
  - Lateral inflows of shallow GW from beneath the fields
  - Tile drainage outflows

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Subsurface tile drains intercept and collect shallow GW at the top of the water table which is discharged directly to the ditches.

The process of redirecting shallow GW beneath agricultural fields through tile drains and ditches can:

- Increase overland nutrient loads that drain from the fields to adjacent streams
- Allow GW nitrate beneath the fields to bypass the buffer and hyporheic zones that normally help reduce nitrate amounts discharging to the streams

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Tile Drain Study

- 7 sites with a paired tile drain and receiving ditch, 4 individual tile sites

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Study Overview

- Primary goal: To characterize the quality of water transported from tile drains and ditches in agricultural fields with different sources of N fertilizers
- Main focus on fields that received applications of:
  - Commercial inorganic fertilizer (Conventional sites)
  - Swine waste manure from lagoons (Spray sites)

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- Samples were collected monthly for 1 year for analysis of nutrients and ions
- Instantaneous discharge from the tiles and the ditches were measured during sample collections

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Summary of Findings

- Nitrate concentrations and yields through tile drains and ditches were significantly higher at fields with applied swine waste manure than fields with applied commercial fertilizer.

Nitrate at Conventional sites		Nitrate at Spray sites	
Tile drains:	6.8 mg/L	Tile drains:	32.0 mg/L
Field ditches:	2.7 mg/L	Field ditches:	8.2 mg/L

- Regardless of fertilizer type, tile drainage increases nitrate yields through surface drainage ditches which can increase the amount of N ultimately transported through the watershed

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CAFO Study

- 54 stream study sites distributed throughout the Coastal Plain
- Most sites in Neuse and Cape Fear basins where most CAFOs are located

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Study Overview

- Primary goals:
  - Assess water-quality differences among streams draining watersheds with and without land-applied CAFO waste manures
  - Examine relations of environmental variables among watersheds with and without measureable CAFO manure effects
- The 54 streams represented 3 types of agricultural watersheds

1) 18 background watersheds with no CAFOs (BK sites)

2) 18 watersheds with 1 or more swine but no poultry CAFOs (SW sites)

3) 18 watersheds with at least 1 swine and 1 poultry CAFO (SP sites)

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- 6 rounds of bi-monthly samples collected over 1 year
- Nutrients, ions, and stable isotopes

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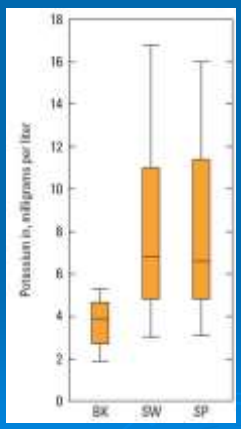
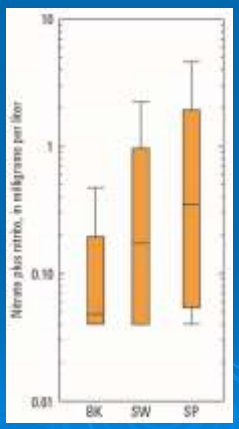
Summary of Findings

- Concentrations for many of the water-quality constituents varied significantly among the BK, SW, and SP site groups

Major ions
Mg
Na
K
Cl



N fractions
NH_4+Org N
NH_4
NO_3+NO_2
Total N



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- The higher median concentrations for the SW and SP site groups relative to the BK site group reflect the influence of:
  - swine-waste manure storage or applications at the SW sites
  - swine- and (or) poultry-waste manure storage or applications at the SP sites

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- In most cases, there were clear chemical distinctions between the results of sites reflecting background agricultural conditions and sites affected by CAFO waste manures
- 10 of the 36 SW and SP sites (28 %) had water quality that was no different than, or similar to, background agricultural conditions
- 21 of the 36 SW and SP sites (58 %) had distinct water-quality differences reflecting swine- and (or) poultry CAFO manure effects

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- CAFO waste-manure effects were most evident in those SW and SP watersheds having either:
  - Lower percentages of wetlands combined with
  - Higher swine barn densities, and (or)
  - Higher total acres available for applying manures at swine CAFOS
- The SW and SP watersheds with water quality similar to background agricultural conditions were associated:
  - Lower swine barn densities combined with
  - Higher percentages of wetlands or
  - Lower total acres available for applying manure at swine CAFOS

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Closing Remarks

- Water-quality protection in the Coastal Plain requires an understanding of the many physical, biological, and environmental variables that affect the occurrence, fate, and transport of nutrients in GW and SW in different agricultural settings.

- Understanding which watersheds are best able to process nitrogen and which are more likely to export nitrogen may allow different nutrient management strategies for controlling nitrogen transport in Coastal Plain streams.

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Questions

Study Reports

- Factors affecting nitrate delivery to streams from shallow ground water in the North Carolina Coastal Plain (SIR 2008-5021)

- Ionic composition and nitrate in drainage water from fields fertilized with different nitrogen sources, Middle Swamp Watershed, NC, August 2000 – August 2001 (SIR 2004-5123)

- Surface-water quality in agricultural watersheds of the NC Coastal Plain associated with CAFOs (SIR 2015-2080)

Link to online reports (http://nc.water.usgs.gov/pubs)

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